United States Department of the Interior

FISH AND WILDLIFE SERVICE
Washington Fish and Wildlife Office
Central Washington Field Office
215 Melody Lane, Suite 119
Wenatchee, WA 98801

IN REPLY REFER TO:
USFWS Reference: 13410-2010-CPA-0008
Hydrologic Unit Code: 17-02-00-18-07

September 15, 2010

Re: Administrative Record for Prescription of Fishways Pursuant to Section 18 of the Federal Power Act for the Wells Hydroelectric Project, Project No. 2149, Chelan and Douglas Counties, Washington.

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street NE
Washington, D.C. 20426

Dear Ms. Bose:

Enclosed for filing with the Federal Energy Regulatory Commission are the administrative records for the subject licensing proceeding. These Department of the Interior records support the prescription for fishways, pursuant to section 18 of the Federal Power Act.

We will respond promptly and documents will be mailed via first class mail. A written request may be faxed (509) 665-3509, but the original must be mailed to the above address.

Thanks you for your cooperation in filing these documents.

Sincerely,

Jessica L. Gonzales for

Ken S. Berg, Manager
Washington Fish and Wildlife Office

Appendix 1

U.S. Department of Interior
Fish and Wildlife Service
Prescription for Fishways
Wells Hydroelectric Project, Project No. 2149-152

Index to Administrative Record

This is the index for the Administrative Record for the modified Prescriptions for Fishways submitted by the U.S. Department of the Interior, Fish and Wildlife Service on or about October 8, 2010. This Administrative Record supports the Department's Prescription for Fishways made pursuant to Section 18 of the Federal Power Act, and submitted to the Federal Energy Regulatory Commission (Commission) for the Project, located on the mid-Columbia River, Chelan County and Douglas County, Washington.

A. Documents Incorporated by Reference

All public records and documents currently part of the Commission's record for Project No. 2149 including but not limited to:

Beak Consultants, Inc. and Rensel Associates. 1999. Assessment of resident fish in Lake Pateros, Washington. Final Report. Prepared for Public Utility District No. 1 of Douglas County. Beak Consultants, Inc. in cooperation with Rensel Associates. Arlington, Washington.

BioAnalysts, Inc. 2004. Movement of Bull Trout within the mid-Columbia River and tributaries, 2001-2004. Prepared by BioAnalysts, Inc., Eagle Rock, Idaho for Public Utility District No. 1 of Chelan County, Wenatchee, Washington, Public Utility District No. 1 of Douglas County, East Wenatchee, Washington, and Public Utility District No. 2 of Grant County, Ephrata, Washington.

Douglas PUD (Public Utility District No. 1 of Douglas County). 2002. Wells Hydroelectric Project Anadromous Fish Agreement and Habitat Conservation Plan. Public Utility District No. 1 of Douglas County, East Wenatchee, Washington.

Douglas PUD. 2004. Wells Hydroelectric Project Bull Trout Monitoring and Management Plan, 2004-2008. Report prepared by the Public Utility No. 1 of Douglas County for the Federal Energy Regulatory Commission.

Douglas PUD. 2010. Final License Application. Public Utility District No. 1 of Douglas County. May 27, 2010.

Golder Associates Ltd. 2003. Rocky Reach white sturgeon investigations, 2002 study results – final, Rocky Reach Hydroelectric Project No. 2145. Prepared by Golder Associates, Ltd., Castlegar, British Columbia, for Chelan PUD. May 30, 2003. 61 pp.

Jerald, T. 2007. White Sturgeon (*Acipenser transmountanus*) Population and Life History Assessment, Wells Reservoir. A thesis presented to the graduate faculty program, Central Washington University. Ellensburg, Washington.

Johnson, P.N, Le, B., and Murauskas, J.G. 2010. Assessment of Adult Pacific Lamprey Response to Velocity Reductions at Wells Dams Fishway Entrances. Wells Hydroelectric Project, FERC No. 2149. June 2010.

LGL (LGL Limited) and Douglas PUD (Public Utility District No. 1 of Douglas County). 2008*a*. Bull Trout Monitoring and Management Plan 2005-2008. Final Report for Wells Hydroelectric Project (FERC License No. 2149). Report prepared by LGL Environmental Research Associates and Public Utility District No. 1 of Douglas County for Public Utility District No. 1 of Douglas County, East Wenatchee.

LGL and Douglas PUD (Public Utility District No. 1 of Douglas County). 2008b. Adult Pacific Lamprey Passage Evaluation. Wells Hydroelectric Project No. 2149. Prepared by LGL Limited, Ellensburg, WA. Prepared for Public Utility District No.1 of Douglas County, East Wenatchee, WA.

McGee, J. 1979. Fisheries survey of Wells Reservoir. Unpublished report, Douglas County PUD, East Wenatchee, WA, 18 pgs.

Nass, B., C. Sliwinski, and D. Robichaud. 2005. Assessment of Adult Pacific Lamprey Migratory Behavior at Wells Dam Using Radio-telemetry Techniques, 2004. Prepared by LGL Limited Environmental Research Associates for Public Utility District No. 1 of Douglas County, East Wenatchee, Washington.

NMFS (National Marine Fisheries Service). 2002. Anadromous Fish Agreements and Habitat Conservation Plans: Final Environmental Impact Statement for the Wells, Rocky Reach, and Rock Island Hydroelectric Projects. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Region, Portland, Oregon. December 2002.

Robichaud, D., B. Nass, and Douglas PUD. 2009. Adult Pacific lamprey passage and behavior study (adult lamprey passage study). Wells Hydroelectric

Project, FERC No. 2140. Prepared for Public Utility District No. 1 of Douglas County. East Wenatchee, Washington.

USFWS (United States Fish and Wildlife Service). 2004. Biological and Conference Opinion. License amendments to incorporate the Rocky Reach, Rock Island, and Wells Anadromous Fish Agreements and Habitat Conservation Plans. U.S. Fish and Wildlife Service, Central Washington Field Office, Wenatchee, Washington. May 12, 2004. 129p.

USFWS. 2005. Chapter 22, Upper Columbia River Recovery Unit, Washington. *In:* U.S. Fish and Wildlife Service. Bull Trout *(Salvelinus confluentus)* Draft Recovery Plan. Portland, Oregon.

B. Other Documentation Cited, References, Considered, or Relied Upon in Support of the Department's Prescription for Fishways

Beamesderfer, R.C., T.A. Rien, and A.A. Nigro. 1995. Differences in the dynamics and potential production of impounded and unimpounded white sturgeon populations in the Lower Columbia River. Transactions of the American Fisheries Society. 124:857-872.

Beamish, R. 1980. Adult biology of the river lamprey (*Lamprey ayresi*) and the Pacific lamprey (*Lamprey tridentate)* for the Pacific coast of Canada. Canadian Journal of Fisheries and Aquatic Sciences. 37:1906-1923.

Close, D., M. Fitzpatrick, H. Li, B. Parker, D. Hatch, and G. James. 1995. Status report of the Pacific lamprey (*Lampetra tridentate*) in the Columbia River basin. Project No. 94-026, Contract No. 95BI39067, Report to the U.S. Department of Energy, Bonneville Power Administration, Portland, OR.

Daigle, W. R., C. A. Peery, S. R. Lee, and M. L. Moser. 2006. Evaluation of Adult Pacific Lamprey Passage and Behavior in an Experimental Fishway at Bonneville Dam. Report to the U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

Kostow, K. 2002. Oregon Lamprey. Natural history, status and problem analysis. Oregon Department of Fish and Wildlife.

Mesa, M.G., J.M. Bayer and J.G. Seelye. 2003. Swimming performance and physiological responses to exhaustive exercise in radio-tagged and untagged Pacific lampreys. Transactions of the American Fisheries Society 132: 483 - 492.

Moser, M.L. and D.A. Close. 2003. Assessing Pacific lamprey status in the Columbia River Basin. Northwest Science. 77:116-125.

Nez Perce, Umatilla, Yakama, and Warm Spring Tribes. 1995. Wy-Kan-Ush-Mi Wa-Kish-Wit. The Columbia River anadromous fish restoration plan of the Nez Perce, Umatilla, Warm Springs, and Yakama Tribes. Portland, Oregon.

Nez Perce, Umatilla, Yakama, and Warm Springs Tribes. 2008. Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin. Formal Draft. May 2008. 68 pp.

Rieman, B.R., and R.C. Beamesderfer. 1990. White sturgeon in the Lower Columbia River: Is the stock overexploited? North American Journal of Fisheries Management 10:388-396.

Upper Columbia White Sturgeon Recovery Initiative. 2002. Upper Columbia White Sturgeon Recovery Plan. Upper Columbia White Sturgeon Initiative, Revelstoke, BC. 90p. http://www.uppercolumbiasturgeon.org

USFWS (United States Fish and Wildlife Service). 1989. Fisheries USA: the recreational fisheries policy of the U.S. Fish and Wildlife Service. Washington, D.C.

USFWS. 1994. Action Plan for Fishery Resources and Aquatic Ecosystems. 20 pp.

USFWS. 2002a. Conserving America's Fisheries. Fisheries Program Vision for the Future. December. 27 pp.

USFWS. 2002b. Bull Trout (*Salvelinus confluentus*) Draft Recovery Plan. U.S. Fish and Wildlife Service, Portland, Oregon. http://pacific/fws/gov/bulltrout.

USFWS. 2004a. Pacific Region: Fisheries Program Strategic Plan, 2004-2008. 77 pp.

Ward, E.W. and D.L. Ward. 2004. Resident fish in the Columbia River Basin: Restoration, enhancement, and mitigation for losses associated with hydroelectric development and operations. Fisheries. Volume 9. No. 3.

WDFW (Washington Department of Fish and Wildlife). 1997. Policy of Washington Department of Fish and Wildlife and Western Washington Treaty Tribes Concerning Wild Salmonids. Washington Department of Fish and Wildlife. December 1997. Olympia, WA.

Transactions of the American Fisheries Society 124:857–872, 1995

Differences in the Dynamics and Potential Production of Impounded and Unimpounded White Sturgeon Populations in the Lower Columbia River

RAYMOND C. P. BEAMESDERFER, THOMAS A. RIEN, AND ANTHONY A. NIGRO

Oregon Department of Fish and Wildlife
17330 Southeast Evelyn Street, Clackamas, Oregon 97015, USA

Abstract.—White sturgeons *Acipenser transmontanus* were sampled in three lower Columbia River reservoirs from 1987 to 1991 to describe population dynamics, the ability of these stocks to sustain harvest, and differences among reservoir and unimpounded populations. Significant differences were observed among reservoirs in white sturgeon abundance, biomass, size composition, sex ratio, size of females at maturity, growth rate, condition factor, and rate of exploitation. No differences among reservoirs were detected in fecundity, natural mortality rate, or longevity, in part because of sampling difficulties. Recruitment rates and densities in reservoirs were inversely correlated with growth rate, condition factor, and size of females at maturity. Differences in population dynamics resulted in substantial differences in sustainable yields. Maximum yields per recruit were predicted at annual exploitation rates between 5 and 15%. Most characteristics of reservoir populations were less than or equal to optima reported for the unimpounded lower river; as a result, yield per recruit, reproductive potential per recruit, and the number of recruits were less in reservoirs than in the unimpounded river. Comparisons with pristine standing stocks suggest that the unimpounded river may approximate preimpoundment conditions for white sturgeon. We conclude that potential yield from impounded populations has been reduced by dam construction, which restricts populations to river segments that may not include conditions optimal for all life stages. Alternatives for enhancement of reservoir populations might include improved passage at dams, increased spring flow to improve spawning success, transplants from productive populations, hatchery supplementation, and more intensive harvest management.

Despite the value or potential value of sturgeon fisheries worldwide, the population dynamics and factors regulating production in this ancient family are poorly understood. This lack of knowledge is likely a contributor to, and a result of, the depressed or endangered status of sturgeons almost everywhere (Rochard et al. 1990; Birstein 1993). The longevity and delayed maturation of sturgeons appear to render populations incapable of sustaining even moderate exploitation without collapse (Smith 1914; Smith et al. 1984; Threader and Brousseau 1986; Young et al. 1988; Rieman and Beamesderfer 1990; Smith 1990; Boreman, in press). Populations have also been severely affected by changes in their large-river habitats, especially changes related to dam construction (Artyukhin et al. 1979; Votinov and Kas'yanov 1979; Assis 1990; Lane 1991; Markarova et al. 1991).

Construction of hydroelectric dams on the Columbia River from 1938 to 1968 has segregated white sturgeons *Acipenser transmontanus* into a series of functionally discrete populations (North et al. 1993) that have access to different habitats (Parsley and Beckman 1994). Habitat varies in the main-stem Columbia River in relation to the surrounding topography, which includes interior mountains, a semidesert plain, a gorge through the Cascade Range, a drowned coastal valley, and an estuary. The pristine river was characterized by large spring floods and dynamic seasonal changes in habitat and the availability of anadromous prey, including salmonids *Oncorhynchus* spp., eulachon *Thaleichthys pacificus*, and Pacific lamprey *Lampetra tridentata*. Before impoundment, white sturgeons ranged freely (Bajkov 1951), undertaking extensive seasonal migrations among habitats to take advantage of scattered and seasonally favorable resources. Dam construction and operation have reduced white sturgeon access to different habitats, reduced seasonal variation in habitat by controlling annual floods, and reduced habitat diversity by creating a series of homogeneous reservoirs. Habitat changes have favored different prey, predators, and competitors than were historically present.

Habitat differences probably have a complex effect on white sturgeon populations, potentially affecting each life history stage differently. Comparisons of physical habitat availability will not estimate this net effect on white sturgeon because it is unknown where in the life cycle the population is regulated or what combination of habitats optimizes conditions throughout the life cycle. Effects may be difficult to detect with simple comparisons of density or harvest, which are confounded if rates of exploitation vary among populations or years.

The net effect of habitat differences should, however, be reflected in the potential production of the population. We define potential production as the capacity of a population to provide and sustain yield. Potential yield is a useful measure of the benefits we might obtain by exploiting populations under existing environmental conditions. Potential yield and reproductive potential (Prager et al. 1987) can be predicted from rates of reproduction, growth, and mortality by use of population models that allow differences in exploitation rates to be factored out.

We assessed the abundance, dynamics, and sustainability of fisheries for white sturgeon populations in three lower Columbia River reservoirs. We estimated numbers, recruitment, sex ratio, maturity, fecundity, growth, condition, mortality, and longevity, and we used these statistics to predict the potential yield per recruit and reproductive potential per recruit in each population. We also evaluated the effects of habitat differences by comparing characteristics of the impounded populations, the unimpounded population studied by DeVore et al. (1995, this issue), and the pristine population exploited before 1990 (Craig and Hacker 1940).

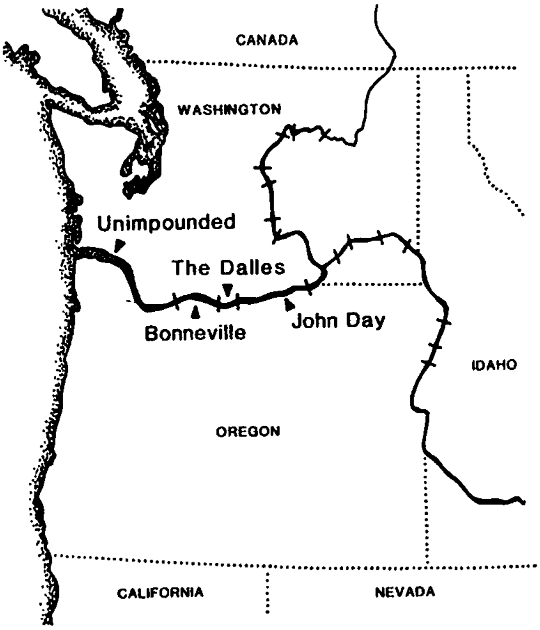


FIGURE 1.—The lower Columbia River basin and reservoirs between Washington and Oregon.

Study Area

John Day, The Dalles, and Bonneville reservoirs are a series of impoundments operated for hydroelectric power generation, navigation, and flood control on the main-stem Columbia River (Figure 1). In all three reservoirs, littoral zones are limited, hydrologic retention times are short (average, 1–5 d), and current is measurable most of the year.

In other respects, the three reservoirs differ. John Day Reservoir is the largest (123 km long; 21,000 ha; average depth, 8.0 m) and most diverse of the three. This reservoir grades from a riverine upper third with gravel and cobble substrate to a shallow transition zone with sand substrate to a more lentic lower section with steep cliff and boulder sides. The Dalles Reservoir is the smallest (38 km long; 4,500 ha; average depth, 7.5 m) and the most riverine, with cobble, gravel, and sand substrates distributed throughout most of its length. Bonneville Reservoir (74 km long; 8,400 ha) is shallow (average depth, 6.7 m) and has a mostly sand substrate, which supports large beds of rooted aquatic macrophytes during summer.

Methods

Data collection.—From April through August 1987–1991, white sturgeons were sampled in the three reservoirs with setlines and gill nets (Elliott and Beamesderfer 1990; North et al. 1993) and by inspecting catches in sport and commercial fisheries (Hale and James 1993). The legal size ranges for catches in the sport and commercial fisheries were 82–166 cm and 110–166 cm fork length (FL), although larger fish were occasionally examined from illegal catches confiscated by authorities. Setline effort was evenly distributed within each reservoir; the reservoirs were completely sampled in four sequential periods of 3 weeks each for The Dalles Reservoir in 1987 and 1988, 4 weeks each for Bonneville Reservoir in 1989, and 5 weeks each for John Day Reservoir in 1990 (North et al. 1993). All reservoirs were sampled during 1991 with a single pass. Gill nets were used in The Dalles Reservoir in 1987 and in all reservoirs in 1991.

Sex and maturity were determined by examining the gonads of fish harvested in fisheries and by surgical biopsy of live fish longer than 170 cm FL. Biopsy involved making a 1–2-cm incision near the midventral line three ventral scutes anterior to the pelvic fin insertion, then using an otoscope to locate and examine the gonad, removing and preserving a 3–5-g sample of ovary, and finally closing the incision with sutures. Gonads of ripe females collected in fisheries and of subsamples removed for egg counts were weighed.

Pectoral-fin sections were removed for age estimation from a subsample of the catch (30 fish/20-cm-FL interval in each reservoir and year, if available). All fish were measured (FL to the nearest centimeter) and weighed (to the nearest 0.1 kg). Fish collected alive and in good condition with setlines were released after tagging them with individually numbered spaghetti or disk tags and removing a barbel or a lateral scute specific to the year of marking (Rien et al. 1994). The minimum size tagged was 70 cm. Tags and marks were noted upon recapture in setlines and fisheries.

Population statistics.—Abundance was estimated in the reservoirs for fish in the 70–166 cm size range with a Schnabel multiple mark–recapture method modified by Overton (1965) to account for removals. Mark–recapture samples were grouped by 3–5-week sampling period. Removals included mortalities during sampling and harvest estimated in sport and commercial fisheries (Hale and James 1993). Fish that lost their tags were identified from secondary marks. The number of size-specific recaptures was too small for reliable mark–recapture abundance estimates; therefore, the length-frequency distribution of the setline catch was used to apportion the mark–recapture population estimate for 70–166-cm fish among size-classes. The mark–recapture estimate was also expanded to a wider size range by means of proportional abundance. The minimum inclusive size (54 cm) was the lower bound of vulnerability to our setline gear.

Length frequencies were adjusted for size selectivity of the gear by dividing by a correction factor based on size-specific recapture rates (Beamesderfer and Rieman 1988). Average recapture to mark-at-large ratios were estimated for fish in 70–81, 82–109, 110–166, and ≥167-cm size-classes for each year. The recapture rate for each size-class was divided by the recapture rate in the most vulnerable size-class for each year to standardize all values relative to one. Recapture rates for years and reservoirs were then averaged for estimates of relative vulnerabilities, which were 0.90 (70–81 cm FL), 0.93 (82–109 cm), 1.00 (110–166 cm), and 0.65 (≥167 cm). Thus, catchability of the ≥167-cm size-group was only 65% of the 110–166 cm size-group; the resulting underrepresentation of large fish in the length-frequency distribution was corrected by dividing number of fish observed that were 167 cm or longer in length by 0.65.

A minimum estimate of the biomass of white sturgeon in the pristine lower Columbia River was based on the total weight of all white sturgeons harvested from 1889, when large-scale fishing for white sturgeon began, until 1899, when populations were depleted and fisheries collapsed. Estimates of biomass per unit area of pristine river were based on the area where most harvest occurred from the estuary to the mouth of the Snake River (Craig and Hacker 1940).

Recruitment to the population, fishery, and protected oversized group in each reservoir were approximately represented as number of fish at ages 1, 10, and 25, respectively. Numbers of 10- and 25-year-old fish were calculated from mark–recapture estimates of abundance by using age distribution in the setline catch. The number of age-1 fish was estimated from the number of age-10 fish by assuming an annual total mortality rate equal to the average for unexploited ages 5–10 fish from Bonneville and The Dalles reservoir gillnet catches.

Sex ratio in each reservoir was estimated from gonad inspections for two size-classes that corresponded to fish within the fishery slot limit (82–166 cm) and fish larger than the maximum size limit (>166 cm). Chi-square contingency tables were used to test for independence of sex frequency between size-classes and among areas (SAS Institute 1988).

Oocytes were classified according to criteria modified slightly from Chapman (1989): immature (previtellogenic, eggs translucent, <1.0 mm average diameter), maturing (vitellogenic, eggs opaque, 1.0–3.0 mm average diameter), mature (eggs black and detached from ovarian tissue, >3.0 mm average diameter), and spent (gonads flaccid with some residual, fully pigmented eggs). Chi-square contingency tables were used to test for independence in proportion of maturing females between size-classes and among areas (SAS Institute 1988).

The relationship between size and female maturity was described in each reservoir with a cumulative normal probability curve fit (Table 1, equation 8); maximum-likelihood methods were used in light of the binomial nature of the data (Welch and Beamesderfer 1993). The fraction of females spawning in each year was estimated as the maturing proportion of all females examined. This spawning fraction estimate included a cor-

TABLE 1.—Equations and definitions of variables and parameters used in a model of the population dynamics of white sturgeon.

Variable or parameter	Definition	Equation number
$N_{x,t}$	Age-specific number of fish in population in any year	
	$= (N_{x-1,t-1})(S_t)$	(1)
x	Age	
t	Year	
x_{max}	Maximum age	
S_x	Age-specific annual rate of survival	
	$= 1 - [m_x + n_x - (m_x)(n_x)]$	(2)
m_x	Exploitation (harvest mortality rate)	
n_x	Conditional natural mortality rate	
L_x	Length at age	
	$= L_\infty\{1 - \exp[-k(x - t_0)]\}$	(3)
L_∞	Von Bertalanffy equation length at infinity	
k	Von Bertalanffy equation parameter	
t_0	Von Bertalanffy equation parameter	
W_x	Weight at age	
	$= (a_w)(L_x)^{b_w}$	(4)
a_w	Length–weight equation coefficient	
b_w	Length–weight equation exponent	
$P_{x,t}$	Reproductive potential of each age-class at or above the age of female maturity	
	$= (N_{x,t})(\mathrm{pf})(\mathrm{ps})(F_x)$	(5)
pf	Proportion of the population that is female	
ps_x	Proportion of the population of females of each age class that spawn in any year	
	$= 1 - [1/(1 + C_\infty\phi)]$ for $L_x \leq \mu$	(6)
	$= 1 - \{1/[1 + C_\infty(1 - \phi)]\}$ for $L_x > \mu$	(7)
C_∞	Maximum proportion of spawning females	
ϕ	Cumulative normal distribution function dependent variable	
	$= \frac{1}{\sqrt{2\pi}}\exp[-(L_x - \mu)^2/2\sigma^2] \cdot \sum_{i=1}^{5} b_i\left(1 + p\left\lvert\frac{L_x - \mu}{\sigma}\right\rvert\right)^{1\,i}$	(8)
μ	Mean length of female sexual maturity	
σ^2	Variance about mean length of females at sexual maturity	
$b_1, \ldots, b_5$	Constants (0.31938153, −0.356563782, 1.781477937, −1.821255978, 1.330274429)	
p	Constant (0.2316419)	
F_x	Age-specific fecundity of females	
	$= (a_f)(L_x)^{b_f}$	(9)
a_f	Length–fecundity equation coefficient	
b_f	Length–fecundity equation exponent	
P_t	Net reproductive potential of all ages in any given year	
	$= \sum P_{x,t}$	(10)
R_t	Number of age-1 recrutis to the population (corresponds to $N_{1,t}$)	
$Y_{x,t}$	Age-specific yield to fisheries by weight in any given year	
	$= (N_{x,t})(m_x)(W_x)$	(11)
Y_t	Net yield of all ages in any given year	
	$= \sum Y_{x,t}$	(12)

rection for apparent reduced catchability of ripe fish on baited setlines during the spawning season (Welch and Beamesderfer 1993). Since white sturgeon vitellogenesis requires 2 years, samples during any time of the year include mature or spent fish that spawn in the current year, maturing fish that will spawn next year, and immature fish that will spawn in subsequent years (Chapman 1989). On average, the number of mature or spent fish should equal the number of maturing fish, but our sampling caught few mature fish during the April–July spawning season. We thus assumed the number of mature females was equal to the number of maturing females in calculating the annual spawning fraction (Welch and Beamesderfer 1993). Comparisons of maturity curves were based on 95% joint confidence regions about paired estimates of size–maturity equation parameters μ and σ (Welch and Beamesderfer 1993). Joint 95% confidence regions that did not include most-likely values for other populations indicated significant differences among populations (Welch and Beamesderfer 1993).

A fecundity–size relationship was estimated from egg counts in subsamples of ovaries expanded by the difference in subsample and total ovary weights. Relationships in a pooled sample of individual fish from all reservoirs and in the unimpounded river (DeVore et al. 1995) were compared with Bonferroni confidence regions for estimates of parameter pairs (Neter et al. 1985). These confidence regions provided a family confidence level of 95% for all populations and parameters; hence, statistically significant differences among populations were identified by comparing confidence region bounds with points representing "best" estimates of parameter pairs for other populations.

Age was estimated by counting marks in thin cross sections of the anterior pectoral fin ray (Rien and Beamesderfer 1994). Von Bertalanffy equations (Table 1, equation 3) that described size at age in each reservoir were fit with a nonlinear regression (SAS Institute 1988). Statistical comparisons among areas were based on Bonferroni 95% confidence regions for the von Bertalanffy parameters L_∞ and k estimated for each population (Kimura 1980; Neter et al. 1985; Moreau 1987). To facilitate comparisons, the von Bertalanffy parameter t_0 was standardized at the mean of values estimated for each of three reservoirs and the unimpounded river (−2.4).

Length (L)–weight (W) equation parameters were estimated for each reservoir with linear regressions on $\log_e$-transformed observations of length and weight. Relationships were compared among areas with Bonferroni 95% confidence regions for estimates of parameter pairs (Neter et al. 1985). Condition factor was also compared among areas with estimates of mean relative weight (W_r) based on the standard weight equation

$$W = 2.735\ \mathrm{E}{-6}{\cdot}L^{3.232}$$

from Beamesderfer (1993). Statistical comparisons of relative weight among areas were based on an analysis of variance (ANOVA), including Tukey's pairwise comparisons (SAS Institute 1988).

Total annual rate of mortality in the reservoirs was estimated by three methods (Ricker 1975). Estimates of instantaneous rates were made from the slope of the descending limb of catch curves from gill nets for fish aged 5–10, and from setlines for those aged 10–15 and 15–25. These age-groups correspond to unexploited sizes, sizes vulnerable only to sport fisheries, and sizes vulnerable to both sport and commercial fisheries. Catch curves were derived from age frequencies based on age–length keys developed for a subsample of the catch in each year and length distributions for that same year. Setline catches were adjusted for size differences in catchability, but comparable data were not available for gill nets.

Total mortality rate in the reservoirs was also estimated by comparing catch rate in setlines of an aged cohort of fish in successive years with the same information used in catch curves.

Finally, estimates were made by comparing catch rate in setlines of a cohort of tagged fish in successive years. Rates were estimated as the quotient of observations when only two observations were available (Ricker 1975). Rates were estimated with a linear least-squares regression of $\log_e$-transformed catch when three or more observations were available. Approximate 95% confidence limits about rate estimates were estimated from regressions as ±2 SE.

Exploitation rate in reservoir populations was estimated as the number of tagged fish observed in the catch of sport and commercial anglers divided by the number of tagged fish at large. Number of tagged fish in the commercial catch was estimated from a subsample examined for marks at commercial fish buyers and fish sale reports required from every fish buyer. Number of tagged fish in the sport catch was estimated from tags returned by anglers corrected for a nonresponse rate based on selected subsamples in interviews of anglers (Hale and James 1993).

Natural mortality rate was estimated with a regression based on growth rate and temperature:

$$M = 10^{[-0.0066\ -\ 0.279\log_{10}(L_\infty)\ +\ 0.6543\log_{10}(k)\ +\ 0.4634\log_{10}(T)]};$$

M = instantaneous rate of annual mortality, k and L_∞ are parameters from the von Bertalanffy equation, and T = mean annual water temperature in degrees Celsius (Pauly 1980). Natural mortality rates based on the difference between total mortality and exploitation rates were also examined.

Observed maximum ages were compared with maximum ages predicted by growth curve parameters ($t_0 + 3/k$; Pauly 1980).

Potential production.—Estimates of population statistics were substituted into the population-modeling software MOCPOP (Beamesderfer 1991) to define an age-structured model and estimate the potential yield and reproduction for each white sturgeon population (Table 1). An equilibrium population was structured for each reservoir population based on constant recruitment (age 1) in each year for the number of years equal to the life span of the white sturgeon. Weight of fish harvested (sizes 82–166 cm FL) and population fecundity in the final year of the simulation were estimated for a range of exploitation rates to identify maxima and corresponding exploitation rates. Yield and reproductive potential were expressed relative to number of age-1 recruits because we lack information on survival between the egg stage and age 1. Area-specific inputs were used except where no significant difference ($P < 0.05$) was detected among areas (Table 2).

Results

Population Statistics

Numbers of white sturgeon (>54 cm) in the reservoirs ranged from 6,300 fish in John Day Reservoir to 51,400 in Bonneville Reservoir (Table 3). Large declines in estimates of abundance in The Dalles Reservoir from 1987 to 1988 correspond to very large harvests by sport and commercial fisheries during those years (almost 8,000 fish in a 2-year period), although the documented harvest was too small to account for observed declines in all size-groups between 1987 and 1988. Densities ranged from 0.30 fish/ha in John Day Reservoir in 1990 to 6.16 fish/ha in The Dalles Reservoir in 1987. Biomasses of white sturgeon ranged from 3.6 kg/ha in John Day Reservoir in

TABLE 2.—Estimates of population statistics used in simulations of white sturgeon populations in three lower Columbia River reservoirs.

Variable or parameter	Ages	Unimpounded river	Reservoir: Bonneville	Reservoir: The Dalles	Reservoir: John Day
n[a]	1–10	0.09[b]	0.213	0.213	0.213
		0.213[b]			
	>10	0.090[c]	0.048	0.046	0.042
L_∞	>0	310	311	340	382
k	>0	0.027	0.022	0.023	0.020
t_0	>0	−2.4	−2.4	−2.4	−2.4
x_{max}	>0	100	100	100	100
a_w	>0	1.04 E−5	3.11 E−6	1.35 E−6	2.40 E−6
b_w	>0	2.96	3.19	3.38	3.26
pf	>0	0.45	0.54	0.46	0.46
μ	>0	160	168	164	194
σ	>0	18	53	26	40
c	>0	0.5	0.5	0.5	0.5
a_f	>0	0.736	3.39 E−4	3.39 E−4	3.39 E−4
b_f	>0	2.94	4.05	4.05	4.05
R	1	1.0 E+4	1.0 E+4	1.0 E+4	1.0 E+4

[a] Conditional rather than instantaneous natural mortality rates were used by modeling program.
[b] Model sensitivity to natural mortality rate for ages 1–10 was examined with separate simulations by using the assumption by DeVore et al. (1995) that rates were similar for all ages and an alternative that mortality of young fish was the same in all populations.

1990 to 81.4 kg/ha in The Dalles Reservoir in 1987. Small fish (54–81 cm) composed a greater proportion of the population in Bonneville Reservoir than in the other two reservoirs (Table 3). Numbers of large fish (>167 cm) ranged from 500 to 1,000 among reservoirs (Table 3).

Reservoir population densities and biomass were much less than in the unimpounded river where DeVore et al. (1995) estimated an abundance of 14.6 fish/ha and a biomass of 87.5 kg/ha. A minimum estimate of historic biomass (77 kg/ha) throughout the area currently including the unimpounded river and the three reservoirs is similar to the current biomass in the unimpounded river.

Among reservoirs, estimated recruitment of age-1 fish varied from 1,200 in The Dalles Reservoir in 1988 to 25,700 in Bonneville Reservoir in 1989 (Table 3). Numbers surviving to the approximate average age of recruitment to fisheries (age 10) in all reservoirs ranged from 140 to 3,020 (Table 3). Annual recruitment was much less than the average in the unimpounded river to age 1 (399,500) and to the fisheries (164,900; DeVore et al. 1995).

TABLE 3.—Abundance of white sturgeons based on mark–recapture estimates ($\hat{N}$ for fish 70–166 cm FL) in three lower Columbia River reservoirs, 1987–1990. Confidence intervals (95%) are in parentheses.

Year	$\hat{N}$	Number of fish by length range (cm, FL)[a]: 54–81	82–109	110–166	≥167	Σ	Age (years): 1[b]	10	25	Number/ha	kg/ha
Bonneville Reservoir											
1989	35,400 (27,500–45,400)	32,900	16,700	1,200	600	51,400	25,700	3,020	340	6.12	30.0
The Dalles Reservoir											
1987	23,600 (15,700–33,600)	7,800	11,000	7,900	1,000	27,700	13,600	1,600	160	6.16	81.4
1988	9,000 (7,300–11,000)	4,200	4,300	2,000	800	11,300	1,200	140	40	2.51	35.5
John Day Reservoir											
1990	3,900 (2,300–6,100)	3,600	1,700	500	500	6,300	3,200	380	60	0.30	3.6

[a] These correspond to total lengths of 24–35, 36–47, 48–72, and ≥73 in.
[b] Refers to abundance back-calculated from age-10 abundance and age-1–10 mortality rate.

TABLE 4.—Sex and stage of female maturity for white sturgeons collected in three lower Columbia River reservoirs, 1987–1991.

Reservoir	Length (cm)	*N*	Unknown	Males	Females		
					Immature	Maturing	Mature and spent
Bonneville	82–166	1,536	1	711	777	35	12
	>166	78	11	24	10	24	9
The Dalles	82–166	1,572	10	854	674	28	6
	>166	62	7	25	13	15	2
John Day	82–166	516	2	283	228	2	1
	>166	42	17	10	7	7	1
All pooled	82–166	3,624	13	1,848	1,679	65	19
	>166	182	35	59	30	46	12

Females were more prevalent in Bonneville Reservoir (54%) than in the The Dalles Reservoir (46%), John Day Reservoir (46%), or the unimpounded river (45%; DeVore et al. 1995). The sex ratio among larger fish was increasingly skewed toward females (Table 4). Differences in sex ratio among reservoirs, and between reservoirs and the unimpounded river were significant for 82–166 cm fish but not for fish larger than 166 cm (Table 5). Differences in sex frequency between fish less than and greater than 166 cm were significant in a pooled reservoir sample, but not in individual reservoir samples (Table 5).

The fraction of females that were mature increased with size (Figure 2; Table 4), and the difference between size-groups in fraction of maturing females was significant in a pooled-reservoir sample (Table 5). More females matured at small sizes in Bonneville Reservoir than in The Dalles Reservoir, John Day Reservoir, or the unimpounded river (Figure 2A). Comparisons of joint confidence regions about paired parameter estimates detected significant differences in maturation among populations (Figure 3), although reservoir differences in proportion of maturing females were not significant when two size-classes were considered separately (Table 5).

Size–fecundity relationships from a pooled-reservoir sample described average fecundities slightly larger than those estimated in the unimpounded river for all sizes of fish (Figure 2B). Differences in size–fecundity relationships were significant (Figure 3).

Fish in Bonneville Reservoir were smaller on average than similar-aged fish in the other two reservoirs or in the unimpounded river (Figure 4), and differences in the von Bertalanffy parameters were significant (Figure 3). In John Day and The

TABLE 5.—Results of chi-square tests for independence of sex or female maturity and size or area.

Variable 1	Variable 2	Observations included	df	χ^2	P[a]
Sex[b]	Size-class[c]	Bonneville Reservoir	1	2.85	0.091
		The Dalles Reservoir	1	1.82	0.177
		John Day Reservoir	1	2.17	0.140
		Reservoirs pooled	1	6.89	0.009
	Reservoir[d]	Fork lengths 82–166 cm	2	25.24	<0.001
		Fork lengths >166 cm	2	1.17	0.558
	Area[e]	Fork lengths 82–166 cm	1	16.99	<0.001
		Fork lengths >166 cm	1	3.47	0.062
Maturity[f]	Size-class[c]	Reservoirs pooled	2	442.81	<0.001
	Reservoir[d]	Fork lengths 82–166 cm	4	8.53	0.074
		Fork lengths >166 cm	4	6.43	0.169
	Area[e]	Fork lengths 82–166 cm	2	6.33	0.042
		Fork lengths >166 cm	2	14.98	<0.001

[a] Considered significant if $P < 0.05$.
[b] Male or female, unknowns excluded.
[c] Fork lengths, 82–166 cm or >166 cm.
[d] Bonneville, The Dalles, and John Day reservoirs.
[e] Reservoirs pooled and the unimpounded river.
[f] Females only: maturing or immature, mature, and spent.

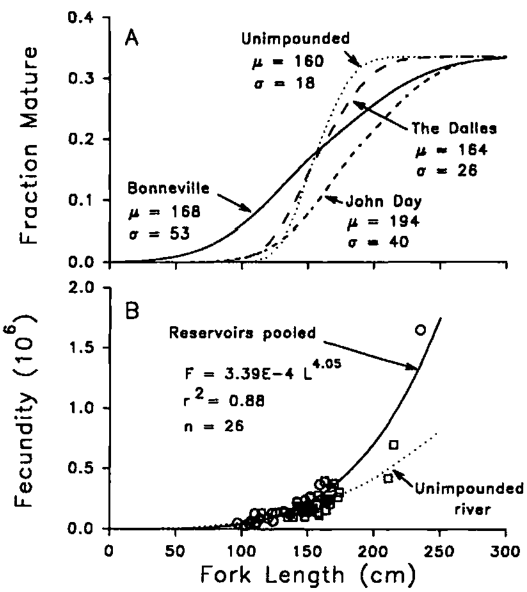


FIGURE 2.—(A) Maturity and (B) fecundity (millions of eggs) versus size of female white sturgeons in three reservoirs and the unimpounded lower Columbia River. Maturity equations are from Welch and Beamesderfer (1993). Data for the unimpounded river is from DeVore et al. (1995).

Dalles reservoirs, mean sizes at age were similar and growth equation parameters were not significantly different. Growth was significantly less for all reservoir populations than for the population in the unimpounded river (Figure 3), although mean length at age in the unimpounded river was only slightly greater than in John Day and The Dalles reservoirs (Figure 4).

A comparison of the relative weight indices (W_r) indicated fish condition was slightly poorer in Bonneville Reservoir (97%) than in The Dalles Reservoir (99%) or John Day Reservoir (100%). Condition in all reservoirs was less than in the unimpounded river (112%; DeVore et al. 1995). Relative weights in Bonneville Reservoir and the unimpounded river were significantly different from relative weight in the other two reservoirs (ANOVA with pairwise multiple comparisons: df = 3, 11,249; $F = 519.0$; $P < 0.001$). Comparisons of confidence regions for joint estimates of parameters in length–weight equations confirm that condition in each area is unique (Figure 3).

Instantaneous total mortality rates estimated for fish aged 5–10 from gill-net catch curves were 0.20 ± 0.33 (95% confidence interval) for The Dalles Reservoir in 1987 and 0.28 ± 0.12 for Bonneville Reservoir in 1991 (Figure 5). Estimates for older fish based on catch curves varied widely among years (Figure 6) and were often less than estimates of fishing mortality for the same periods (Table 6). Estimates based on catch rates of cohorts in successive years also varied, and several were less than or near zero (Table 7).

Annual exploitation rates in combined fisheries were 9–21% in Bonneville Reservoir, 23–42% in The Dalles Reservoir, and less than 10% in John Day Reservoir. Commercial fisheries harvested a majority of the catch in most years when both sport and commercial fisheries were surveyed (Table 6). Harvest and exploitation varied annually (Table 6). Annual exploitation rates in the reservoirs were less than or similar to rates observed in the unimpounded river from 1985–1991 (DeVore et al. 1995).

Instantaneous natural mortality rates estimated with the regression of growth parameters and mean annual water temperature were 0.049 for Bonneville Reservoir, 0.047 for The Dalles Reservoir, 0.043 for John Day Reservoir, and 0.070 for the unimpounded river. These estimates of instantaneous natural mortality rate were somewhat less than the empirical estimate of 0.10 from DeVore et al. (1995) for the unimpounded river but were much less than the 0.20–0.28 estimated for unexploited 5–10-year-old white sturgeons in The Dalles and Bonneville reservoirs. Realistic natural mortality rates could not be calculated from total mortality and exploitation rates because of unreliable estimates of total mortality.

A white sturgeon estimated to be 104 years old was collected in this study, and six other fish from the reservoirs were estimated to be between 50 and 80 years old. Observed maxima were less than the 147 years predicted from von Bertalanffy curve parameters.

Potential Production

Maximum yield per recruit was approximately 25% greater in John Day and The Dalles reservoirs than in Bonneville Reservoir (Figure 7A). Yield per recruit was greatest among reservoir populations at annual exploitation rates between 5 and 15%. Estimates of sustainable annual yield (kg) based on the number of age-1 recruits estimated in each reservoir were 16,000 (1.90/ha) in Bonneville Reservoir, 5,800 (1.29/ha) in The Dalles Reservoir, and 2,600 (0.12/ha) in John Day Reservoir. Potential yields in the reservoirs were substantially less than in the unimpounded river at current levels of recruitment, whether based on instantaneous natural mortality rates of sublegal

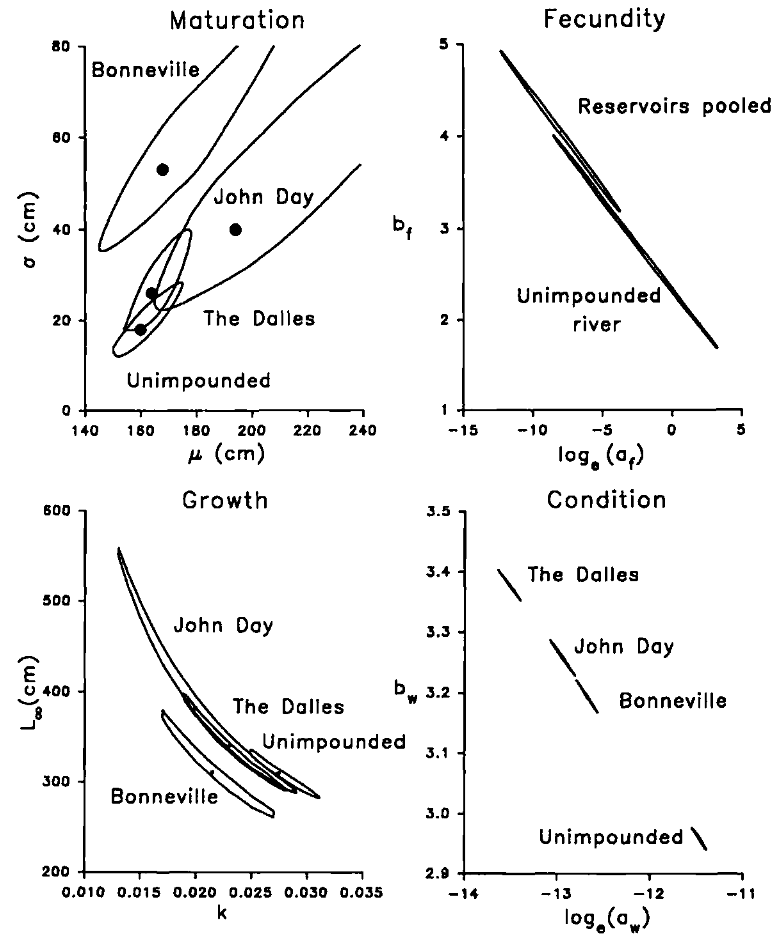


FIGURE 3.—Joint 95% confidence regions for length–female maturity, length–fecundity, von Bertalanffy L_∞ and k (t_0 fixed at −2.4), and length–weight equation parameters for four white sturgeon populations in the lower Columbia River. Parameter pairs are considered significantly different if point estimates are not within the confidence region for another reservoir. (Symbols are defined in Table 1.)

fish similar to the 0.24 estimated in this paper for impounded stocks (295,200 kg or 4.84 kg/ha) or based on the 0.10 used by DeVore et al. (1995) based on fish in the harvestable size range (1,174,500 kg or 19.25 kg/ha: Figure 7A).

Differences in reproductive potential among areas were also substantial (Figure 7B). Reproductive potential per recruit declined exponentially with increasing exploitation and was near zero at rates exceeding 20%. Reproductive potential per recruit in the reservoirs was 13–33% or 57–135% of estimates for the unimpounded river based on different assumptions for natural mortality rate for fish aged 1–10.

Discussion

Characteristics of white sturgeon populations varied significantly among areas. In Bonneville Reservoir, greater numbers of recruits resulted in greater densities, but this population also showed smaller average size, growth rate, condition factor, and size of females at maturity. Recruitment was less in The Dalles Reservoir, but average size, growth rate, condition factor, and size of females at maturity were greater than in Bonneville Reservoir. Growth, condition, and maturation were similar in John Day and The Dalles reservoir, but recruitment and density in John Day were much lower than in the other two reservoirs, and the size composition was skewed to larger, older fish. In the unimpounded river, all population characteristics except fecundity equaled or exceeded maximums observed in any reservoir.

Observed differences in population characteristics result in much less potential yield in the

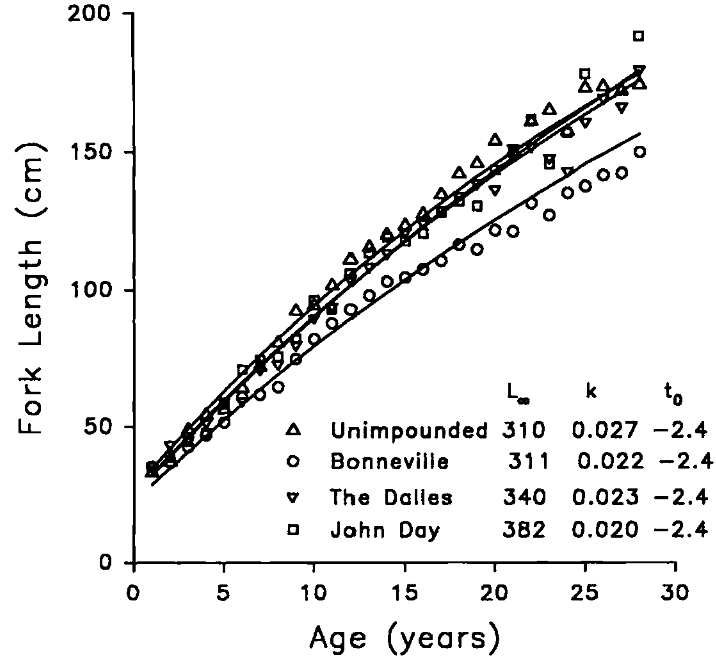


FIGURE 4.—Mean length at age and von Bertalanffy lines for white sturgeons in three reservoirs and the unimpounded lower Columbia River. Data from unimpounded river are from DeVore et al. (1995).

reservoirs than in the unimpounded river and differences in productivity among reservoirs. The unimpounded river provided the best conditions for all life cycle stages, but each reservoir did not. Reductions in yield per recruit, reproductive potential per recruit, and number of recruits all contributed to reduced yield in reservoir populations. Differences in recruitment among the reservoirs mean that Bonneville can sustain the largest net yield and John Day the least, despite the opposite pattern in yield per recruit.

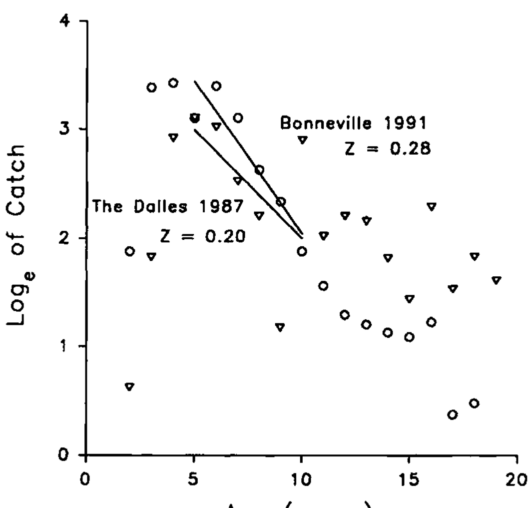


FIGURE 5.—Catch curves for white sturgeons captured in gill nets in Bonneville (O) and The Dalles (∇) reservoirs. Instantaneous rates of total mortality (Z) are indicated for each regression line.

Projected differences in potential yield were based only on differences in population characteristics that we could measure. No differences were detected among reservoirs in fecundity, longevity, or natural mortality rate, in part because of sampling difficulties. Sample sizes for fecundity were very small; fecundity could only be estimated from dead fish; most mature females were larger than those legally harvested in fisheries; catchability of these large fish in our setline sampling was poor; and the rarity and value of these mature fish precluded sacrifice. Many of these large, older fish were also difficult to age (Rien and Beamesderfer 1994); however, we assume that bias in estimates of population statistics is consistent among all populations.

Natural mortality rate was very low, and small differences were impossible to detect from the difference between uncertain estimates of total and fishing mortality rates that rely on complex calculations and assumptions that are rarely met. Therefore, estimates of yield and reproductive po-

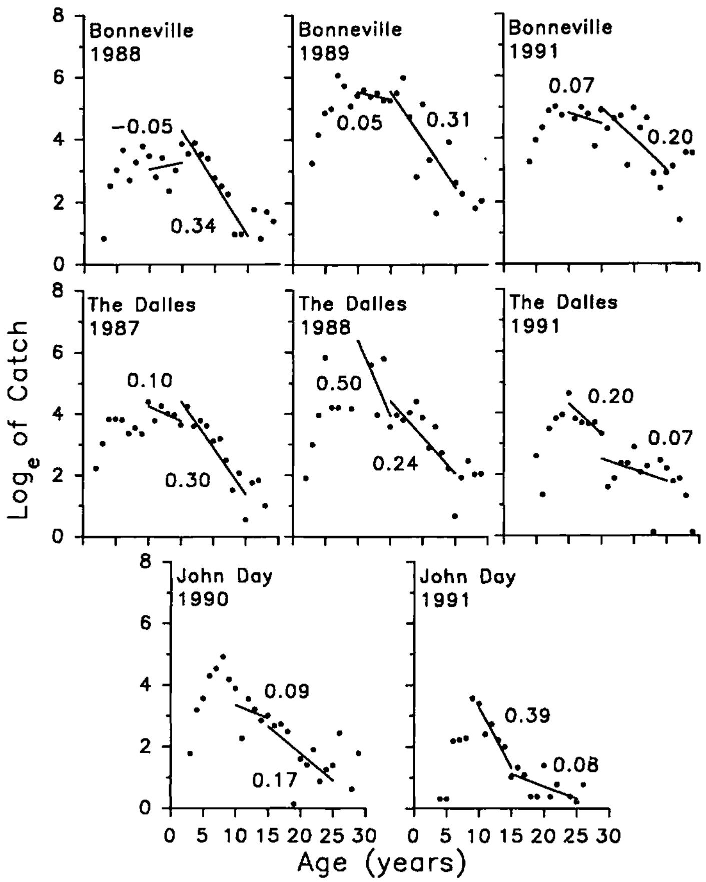


FIGURE 6.—Catch curves for white sturgeons captured in setlines in three Columbia River reservoirs, 1987–1991. Instantaneous rates of total mortality (Z) are indicated for each regression line.

tential were based on natural mortality rates estimated from Pauly's regression to minimize confounding effects of unrelated methods of mortality rate estimation. Rates estimated with Pauly's regressions were consistent with observed maximum ages. For instance, an instantaneous annual mortality rate of 0.05 after age 10 results in only 1% survival to age 100. At greater mortality rates, chances of observing 100-year-old fish are almost zero.

TABLE 6.—Numbers (with percent exploitation in parentheses when it could be calculated) of white sturgeons caught by sport and commercial fisheries in three lower Columbia River reservoirs, 1987–1991.

	Number of white sturgeon caught in:				
Fishery	1987	1988	1989	1990	1991
		Bonneville Reservoir			
Sport		1,530 (3)	2,800 (5)	2,110	
Commercial		2,030 (6)	1,410 (15)	1,890	1,160
		The Dalles Reservoir			
Sport	1,990 (11)	910 (5)	500		
Commercial	3,800 (31)	1,010 (18)	1,930	1,210	340
		John Day Reservoir			
Sport			280	320 (5)	140 (8)
Commercial		1,103	170	410	40

TABLE 7.—Cohort analyses for estimating total annual mortality rate of white sturgeon in three lower Columbia River reservoirs.

Reservoir and year	Ages	Setline days	Sturgeon/ day	Z[a]
Total catch cohort				
Bonneville				
1988	10–24	170	2.0588	
1989	11–25	775	2.8026	
1991	13–28	168	3.3810	−0.155
The Dalles				
1987	10–24	233	2.6137	
1988	11–25	675	1.5733	
1991	14–29	138	0.6957	0.317
John Day				
1990	10–24	327	0.3945	
1991	11–25	96	0.6250	−0.460
Tagged-fish cohorts				
Bonneville[b]				
1989	>9	775	0.0477	
1991	>10	168	0.0476	0.001
The Dalles[c]				
1988	>8	675	0.0904	
1989	>9	70	0.0571	0.459

[a] Estimated as $-\log_e$ (catch rate in year b/catch rate in year a)$^{[1/(b-a)]}$ for samples from 2 years and with a regression on $\log_e$(catch rate) for samples from 3 years.
[b] Fish tagged in 1988.
[c] Fish tagged in 1987.

Our attempts to characterize white sturgeon populations were also confounded by differences in exploitation among areas and years that affected standing stock and size composition, and precluded direct comparisons to evaluate habitat differences. For instance, commercial fisheries were most intense in John Day and The Dalles reservoirs during the 1980s (S. King, Oregon Department of Fish and Wildlife, personal communication) and have likely depressed abundance of white sturgeon in those reservoirs. A decline in abundance in John Day Reservoir is corroborated by declines in harvest per unit effort by anglers from 0.11 white sturgeon per trip in 1983–1986 (Beamesderfer et al. 1990) to 0.04 white sturgeon per trip in 1989–1991 (Hale and James 1993). A trend in increasing harvest from 1979 to 1987 by commercial fisheries in all three reservoirs (ODFW and WDFW 1994) would violate stable age-structure assumptions of catch curve estimates of total mortality rate (Ricker 1975) and would explain total mortality rate estimates which were sometimes less than zero or observed exploitation rates.

Declines in estimated abundance in The Dalles Reservoir from 1987 to 1988 exceed those accounted for by the observed harvest and also include size-classes protected from harvest (<82 cm and >166 cm). It remains unclear whether observed decreases reflect the uncertainty in population estimates or a real decline in abundance

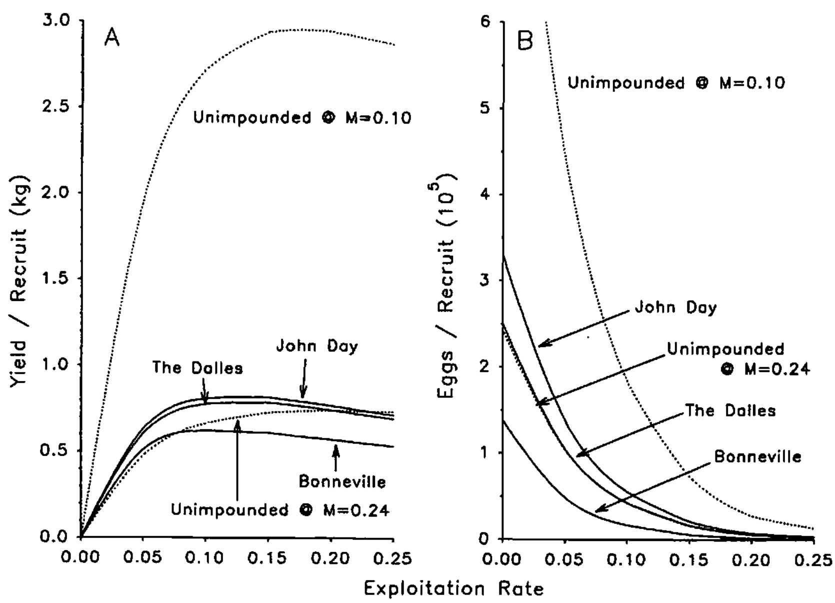


FIGURE 7.—(A) Simulated yield and (B) reproduction per recruit in relation to exploitation rates under a 82–166-cm size window for four white sturgeon populations in the lower Columbia River.

which exceeded documented harvest. If harvest affected abundance in protected size-classes that included age-10 fish, estimates of age-1 abundance back-calculated from the abundance of age-10 fish and annual survival rates would be biased by recent changes in mortality. Hence, the large change in age-1 abundance back-calculated for 1987 and 1988 in The Dalles Reservoir should be interpreted with caution.

The pattern of differences among populations implies environmental or past harvest differences rather than genetic causes. Genetic differences are unlikely because only one or two generations have elapsed since dam construction and existing movement among reservoirs may be adequate to prevent genetic divergence (North et al. 1993). Relatively poorer condition, lower growth rate, and a smaller size of females at maturity in Bonneville Reservoir probably represent a compensatory response to intraspecific competition. Strong recruitment of young fish in Bonneville resulted in densities greater than in The Dalles or John Day reservoirs but less than in the unimpounded river.

Production of impounded white sturgeon populations would likely be greater if dams did not constrain white sturgeon movements. Parsley and Beckman (1994) suggest that large amounts of rearing habitat suitable for white sturgeon occur in all areas but that spawning habitat is limited in The Dalles and John Day reservoirs. Before impoundment, unused rearing habitat now in The Dalles and John Day reservoirs could be fully seeded with white sturgeons spawned in favorable habitat concentrated in Bonneville Reservoir and downstream from Bonneville Dam. White sturgeons spawned in Bonneville Reservoir could have dispersed into rearing habitat upstream or downstream where increased growth and a larger size of females at maturity would increase the potential yield and reproductive potential per recruit.

Estimates from historic harvests confirm that the biomass throughout the impounded lower river was historically greater than currently exists and that the current standing stock in the unimpounded river might be similar to that of the pristine population. The estimate of standing stock in the pristine white sturgeon population is conservative because only fish greater than 20 kg were harvested and because the ocean provided a refuge for a portion of the white sturgeon population. However, we believe this minimum estimate represents a large fraction of the population because large, old fish predominate in unexploited populations of long-lived fish (Power 1978) and because the rapid depletion of the population from 1889 to 1899 could not have been achieved unless the fraction of the population in the ocean was considerably less than the fraction of the population in the river.

Our results suggest several possibilities for improving production of impounded populations of white sturgeon. Improved fish passage at dams is one alternative. Fish ladders might be redesigned to provide upstream access to white sturgeons. White sturgeons occasionally pass ladders and some ladders are used more frequently than others (Warren and Beckman 1993). Fish lifts were examined with some promise at Bonneville Dam from 1938 to 1956 (Warren and Beckman 1993). However, the benefits of improved upstream passage in providing access to underseeded rearing areas in The Dalles and John Day reservoirs may be offset by movement of mature spawners into reservoirs where spawning habitat is poor. Physically collecting and transporting juveniles to underseeded reservoirs might provide harvest benefits similar to improved passage, without the confounding problem of the loss of spawners.

White sturgeon populations in underseeded reservoirs might also be enhanced by operation of the hydropower system to increase river discharge during spawning periods in May and June. Spawning success was positively correlated with river discharge, which affects the amount of habitat suitable for spawning in May and June (Anders and Beckman 1993; Parsley and Beckman 1994). Positive correlations between flow and spawning or recruitment have also been observed for white sturgeon in the Sacramento–San Joaquin system (Stevens and Miller 1970; Kohlhorst et al. 1991) and for other *Acipenser* spp. (Votinov and Kas'yanov 1979; Veshchev 1991; LaHaye et al. 1992). Populations of mature spawners observed in each Columbia River reservoir may be adequate to fully seed available rearing habitat if enhanced discharge provides adequate spawning habitat. Enhanced spring flows currently being pursued to increase survival of juvenile salmonids (Wood 1993) may also be beneficial to impounded white sturgeon populations.

Supplementation of underseeded reservoirs with hatchery-reared fish could be another alternative for enhancement. Hatchery technology that uses wild broodstock has recently been developed for white sturgeon (Conte et al. 1988). However, release of large numbers of offspring from a few parents could pose substantial genetic risk to wild fish. Technology has not yet been applied in a production-level conservation hatchery and many problems (disease, feeding, size and time of release) need investigation. Finally, carrying-capacity limitations and resulting stunting is far more likely for the long-lived, iteroparous, and resident white sturgeon than for anadromous and semelparous salmonids. Similar problems with salmonids have led to a reevaluation of salmon hatcheries and a call for rigorous scrutiny of potential new programs (Hilborn 1992). Transplants of fish would allow investigation of the potential for supplementation without incurring the genetic and disease risks and expenses of a hatchery program.

More intensive regulation of fisheries is another alternative for mitigating effects of dams on white sturgeon productivity. Observed rates of exploitation generally exceeded optimum rates predicted by simulations and, in several cases, exceeded rates where any fish would survive to reproduce and sustain the population. This intensive harvest has collapsed fisheries in The Dalles and John Day reservoirs and would have collapsed populations without the harvest restrictions enacted from 1988 through 1995. Substantial populations of large, mature fish remain in each reservoir and, if protected, could replenish depleted populations within 10–15 years if managed for sustainable harvest.

Optimum rates of exploitation also vary among populations and are dependent on the characteristics of each. For instance, maximum yield per recruit would occur at lesser rates of exploitation in Bonneville Reservoir than in the other two reservoirs (unless population characteristics compensated for differences in exploitation). Management strategies that recognize these differences by means of regulations unique to each population would maximize yield. Different size restrictions may also be appropriate for each population and could be identified with a more detailed series of population simulations.

We conclude that impounded populations of white sturgeon in the lower Columbia River can sustain exploitation but that yield is less than would be expected if populations were not segregated by a series of dams. Several alternatives for mitigating dam effects to enhance production of impounded stocks were identified, but an effective program will require further investigation of habitat constraints and potential compensation in population parameters.

Acknowledgments

We thank Bruce Rieman for contributions to research design, and Lance Beckman, John DeVore, Brad James, Steve King, George McCabe, Mike Parsley, Eric Tinus, and Al Smith for constructive comments on earlier drafts of this manuscript. Our work was funded by the Bonneville Power Administration under contract DE-AI79-86BP63584.

References

Anders, P. J., and L. G. Beckman. 1993. Location and timing of white sturgeon spawning in three Columbia River impoundments. Pages 47–59 *in* R. C. Beamesderfer and A. A. Nigro, editors. Status and habitat requirements of the white sturgeon populations in the Columbia River downstream from McNary Dam, volume 1. Final Report (contract DE-AI79-86BP63584) to Bonneville Power Administration, Portland, Oregon.

Artyukhin, Ye. N., A. D. Sukhoparova, and L. G. Fimukhina. 1979. The gonads of the sturgeon, *Acipenser güldenstädii*, in the zone below the dam of the Volgograd water engineering system. Journal of Ichthyology 18:912–923.

Assis, C. A. 1990. Threats to the survival of anadromous fishes in the River Tagus, Portugal. Journal of Fish Biology 37A:225–226.

Bajkov, A. D. 1951. Migration of white sturgeon (*Acipenser transmontanus*) in the Columbia River. Oregon Fish Commission Research Briefs 3:8–21.

Beamesderfer, R. C. 1991. MOCPOP 2.0: a flexible system for simulation of age-structured populations and stock-related functions. Oregon Department of Fish and Wildlife, Information Report 91-4, Portland.

Beamesderfer, R. C. 1993. A standard weight (W_s) equation for white sturgeon. California Fish and Game 79:63–69.

Beamesderfer, R. C., D. E. Olson, and R. D. Martinson. 1990. Recreational fishery for white sturgeon, walleye, and smallmouth bass in Lake Umatilla (John Day Reservoir), 1983–86. Oregon Department of Fish and Wildlife, Information Report 90-3, Portland.

Beamesderfer, R. C., and B. E. Rieman. 1988. Size selectivity and bias in estimates of population statistics of smallmouth bass, walleye, and northern squawfish in a Columbia River reservoir. North American Journal of Fisheries Management 8:505–510.

Birstein, V. J. 1993. Sturgeons and paddlefishes: threatened fishes in need of conservation. Conservation Biology 7:773–787.

Boreman, J. In press. Sensitivity of North American sturgeon and paddlefish populations to fishing mortality. Environmental Biology of Fishes.

Chapman, F. A. 1989. Sexual maturation and reproductive parameters of wild and domestic stocks of white sturgeon, *Acipenser transmontanus*. Doctoral dissertation. University of California, Davis.

Conte, F. S., S. I. Doroshov, P. B. Lutes, and E. M. Strange. 1988. Hatchery manual for the white sturgeon *Acipenser transmontanus* Richardson with application to other North American Acipenseridae.

University of California, Cooperative Extension Publication 3322, Oakland.
Craig, J. A., and R. L. Hacker. 1940. The history and development of the fisheries of the Columbia River. U.S. Bureau of Fisheries Bulletin 32:133–216.
DeVore, J. D., B. W. James, C. A. Tracy, and D. A. Hale. 1995. Dynamics and potential production of white sturgeon in the unimpounded lower Columbia River. Transactions of the American Fisheries Society 124:845–856.
Elliott, J. C., and R. C. Beamesderfer. 1990. Comparison of efficiency and selectivity of three gears used to sample white sturgeon in a Columbia River reservoir. California Fish and Game 76:174–180.
Hale, D. A., and B. W. James. 1993. Recreational and commercial fisheries in the Columbia River between Bonneville and McNary dams, 1987–91. Pages 287–342 *in* R. C. Beamesderfer and A. A. Nigro, editors. Status and habitat requirements of the white sturgeon populations in the Columbia River downstream from McNary Dam, volume 2. Final Report (Contract DE-AI79-86BP63584) to Bonneville Power Administration, Portland, Oregon.
Hilborn, R. 1992. Hatcheries and the future of salmon in the Northwest. Fisheries 17(1):5–8.
Kimura, D. K. 1980. Likelihood methods for the von Bertalanffy growth curve. U.S. National Marine Fishery Service Fishery Bulletin 77:765–773.
Kohlhorst, D. W., L. W. Botsford, J. S. Brennan, and G. M. Cailliet. 1991. Aspects of the structure and dynamics of an exploited central California population of white sturgeon (*Acipenser transmontanus*). Pages 277–293 *in* P. Williot, editor. Acipenser: actes du premier colloque international sur l'esturgeon. Centre National du Machinisme Agricole du Génie Rural des Eaux et des Forêts, Bordeaux, France.
LaHaye, M., A. Branchaud, M. Gendron, R. Verdon, and R. Fortin. 1992. Reproduction, early life history, and characteristics of the spawning grounds of the lake sturgeon (*Acipenser fulvescens*) in Des Praires and L'Assomption rivers, near Montreal, Quebec. Canadian Journal of Zoology 70:1681–1689.
Lane, E. D. 1991. Status of the white sturgeon, *Acipenser transmontanus*, in Canada. Canadian Field-Naturalist 105:161–168.
Markarova, I. A., A. P. Alekperov, and T. S. Zarbalina. 1991. Present status of the spawning run of sheap sturgeon, *Acipenser nudiventris*, in the Kura River. Journal of Ichthyology 31(5):17–22.
Moreau, J. 1987. Mathematical and biological expression of growth in fishes: recent trends and further developments. Pages 81–113 *in* R. C. Summerfelt and G. E. Hall, editors. Age and growth of fish. Iowa State University Press, Ames.
Neter, J., W. Wasserman, and M. H. Kutner. 1985. Applied linear statistical models, 2nd edition. Irwin, Homewood, Illinois.
North, J. A., R. C. Beamesderfer, and T. A. Rien. 1993. Distribution and movements of white sturgeon in three lower Columbia River reservoirs. Northwest Science 67:105–111.
ODFW (Oregon Department of Fish and Wildlife) and WDFW (Washington Department of Fish and Wildlife). 1994. Status report: Columbia River fish runs and fisheries 1938–93. ODFW Portland, Oregon.
Overton, W. S. 1965. A modification of the Schnabel estimator to account for removal of animals from the population. Journal of Wildlife Management 29: 392–395.
Parsley, M. J., and L. G. Beckman. 1994. White sturgeon spawning and rearing habitat in the lower Columbia River. North American Journal of Fisheries Management 14:812–827.
Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperatures in 175 fish stocks. Journal du Conseil, Conseil International pour l'Exploration de la Mer 39:175–192.
Power, G. 1978. Fish population structure in Arctic lakes. Journal of the Fisheries Research Board of Canada 35:53–59.
Prager, M. H., J. F. O'Brien, and S. B. Saila. 1987. Using lifetime fecundity to compare management strategies: a case history for striped bass. North American Journal of Fisheries Management 7:403–409.
Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191.
Rieman, B. E., and R. C. Beamesderfer. 1990. White sturgeon in the lower Columbia River: is the stock overexploited? North American Journal of Fisheries Management 10:388–396.
Rien, T. A., and R. C. Beamesderfer. 1994. Accuracy and precision of white sturgeon age estimates from pectoral fin rays. Transactions of the American Fisheries Society 123:255–265.
Rien, T. A., R. C. P. Beamesderfer, and C. F. Foster. 1994. Retention, recognition, and effects on survival of several tags and marks on white sturgeon. California Fish and Game 80:161–170.
Rochard, E., G. Castelnaud, and M. Lepage. 1990. Sturgeons (Pisces: Acipenseridae); threats and prospects. Journal of Fish Biology 37A:123–132.
SAS Institute. 1988. SAS/STAT user's guide, release 6.03 edition. SAS Institute, Cary, North Carolina.
Smith, H. M. 1914. Passing of the sturgeon. Report of the U.S. Commissioner of Fisheries for 1913:66–67.
Smith, T. I. J. 1990. Culture of North American sturgeons for fishery enhancement. NOAA (National Oceanic and Atmospheric Administration) Technical Report NMFS (National Marine Fisheries Service) 85:19–27.
Smith, T. I. J., D. E. Marchette, and G. F. Ulrich. 1984. The Atlantic sturgeon fishery in South Carolina. North American Journal of Fisheries Management 4:164–176.
Stevens, D. E., and L. W. Miller. 1970. Distribution of sturgeon larvae in the Sacramento–San Joaquin River system. California Fish and Game 56:80–86.
Threader, R. W., and C. S. Brousseau. 1986. Biology and management of the lake sturgeon in the Moose River, Ontario. North American Journal of Fisheries Management 6:383–390.

Veshchev, P. V. 1991. Effectiveness of natural production in the stellate sturgeon, *Acipenser stellatus*, under conditions of regulated flow in the Volga. Journal of Icthyology 31(5):76–83.

Votinov, N. P., and V. P. Kas'yanov. 1979. The ecology and reproductive efficiency of the Siberian sturgeon, *Acipenser baeri*, in the Ob as affected by hydraulic engineering works. Journal of Icthyology 18(1):20–29.

Warren, J. J., and L. G. Beckman. 1993. Fishway use by white sturgeon to bypass mainstem Columbia River dams. National Oceanic and Atmospheric Administration, Sea Grant Extension Project, Columbia River Series WSG-AG-93-02, Seattle.

Welch, D. W., and R. C. Beamesderfer. 1993. Maturation of female white sturgeon in lower Columbia River impoundments. Pages 89–107 *in* R. C. Beamesderfer and A. A. Nigro, editors. Status and habitat requirements of the white sturgeon populations in the Columbia River downstream from McNary Dam, volume 2. Final Report (contract DE-AI79-86BP63584) to Bonneville Power Administration, Portland, Oregon.

Wood, W. A. 1993. Implementation and evaluation of the water budget. Fisheries 18(11):6–17.

Young, J. R., T. B. Hoff, W. P. Dey, and J. G. Hoff. 1988. Management recommendations for a Hudson River Atlantic sturgeon fishery based on an age-structured population model. Pages 353–366 *in* C. L. Smith, editor. Fisheries Research in the Hudson River. State University of New York Press, Albany.

Received July 22, 1994
Accepted February 7, 1995

Adult Biology of the River Lamprey (*Lampetra ayresi*) and the Pacific Lamprey (*Lampetra tridentata*) from the Pacific Coast of Canada

RICHARD J. BEAMISH

Department of Fisheries and Oceans, Resource Services Branch, Pacific Biological Station, Nanaimo, B.C. V9R 5K6

BEAMISH, R. J. 1980. Adult biology of the river lamprey (*Lampetra ayresi*) and the Pacific lamprey (*Lampetra tridentata*) from the Pacific coast of Canada. Can. J. Fish. Aquat. Sci. 37: 1906–1923.

River lamprey (*Lampetra ayresi*) metamorphose in late July with downstream migration occurring in the following year from May to July. Once adults enter salt water they begin to feed immediately by consuming chunks of flesh primarily from herring and young salmon. From June until September they increase in size by an estimated 11–14 cm and 12–18 g. In 1975, 667 000 lamprey were estimated to be in the Strait of Georgia resulting in the deaths of 60 000-000 juvenile fish. Between September and late winter river lamprey return to freshwater. Spawning occurs in the spring, from April to June and adults die after spawning. The length of adult life from the onset of metamorphosis until death following spawning is 2 yr. Pacific lamprey (*Lampetra tridentata*) begin metamorphosis in July and the known period of entry into salt water is from December until June. Feeding can commence in freshwater or salt water by mid-October. Pacific lamprey move into water deeper than 20–70 m and are present in all major fishing grounds off Canada's west coast. A relatively high incidence of lamprey attacks has been observed on sockeye and pink salmon that are aggregating in preparation to return to freshwater. The smallest mature or maturing pacific lamprey found in this study measured 16 cm and the largest measured 72 cm. Adults may spend 3½ yr in salt water before returning to freshwater from April to June and completing their upstream migrations by late September. Stocks that return in the spring exhibit exceptional migratory instincts often migrating considerable distances in freshwater to the uppermost regions of tributary streams before they spawn from April to July in the following year. After entry into freshwater and prior to spawning, adults shrink in length by approximately 20%. The average life span from the onset of metamorphosis until death following spawning probably is 5 yr. A nonanadromous form that appears to be a new species exists in lakes and attacks a large percentage of resident salmonids.

Key words: Pacific lamprey, river lamprey, life history, fish parasites, Pacific fishes

BEAMISH, R. J. 1980. Adult biology of the river lamprey (*Lampetra ayresi*) and the Pacific lamprey (*Lampetra tridentata*) from the Pacific coast of Canada. Can. J. Fish. Aquat. Sci. 37: 1906–1923.

La métamorphose de la lamproie fluviatile américaine (*Lampetra ayresi*) a lieu fin juillet, la migration en aval se produisant de mai à juillet de l'année suivante. Aussitot arrivés en eau salée, les adultes commencent à se nourrir de morceaux de chair arrachés en grande partie à des harengs et de jeunes saumons. De juin à septembre, les lamproies croissent d'environ 11 à 14 cm et 12 à 18 g. On avait estimé en 1975 qu'il y avait 667 000 lamproies dans le détroit de Géorgie, entraînant la mort de 60 millions de jeunes poissons. Les lamproies fluviatiles américaines retournent en eau douce entre septembre et la fin de l'hiver. La fraie a lieu au printemps, d'avril à juin, après quoi les adultes meurent. La durée de vie adulte, depuis le début de la métamorphose jusqu'à la mort suivant la fraie, est de 2 ans. La lamproie du Pacifique (*Lampetra tridentata*) commence à se métamorphoser en juillet et, en autant qu'on le sache, pénètre en eau salée de décembre à juin. Elle peut commencer à se nourrir en eau douce ou en eau salée vers la mi-octobre. Les lamproies du Pacifique se dirigent vers des eaux de profondeur dépassant 20 à 70 m et sont présentes sur tous les principaux lieux de pêche du large de la côte occidentale canadienne. On a observé une incidence relativement haute d'attaques de lamproies sur des saumons nerka et roses réunis en bancs avant leur retour en eau douce. La plus petite lamproie mature ou en voie de maturation rencontrée dans la présente étude mesurait 16 cm, et la plus grande 72 cm. Les adultes peuvent passer 3½ ans en eau salée avant

[1]This paper forms part of the Proceedings of the Sea Lamprey International Symposium (SLIS) convened at Northern Michigan University, Marquette, Michigan, July 30–August 8, 1979.

Printed in Canada (J5857)
Imprimé au Canada (J5857)

de retourner en eau douce entre avril et juin, cette migration en amont étant terminée fin septembre. Les stocks qui retournent au printemps exhibent des instincts migrateurs exceptionnels, parcourant souvent des distances considérables en eau douce pour atteindre les régions supérieures des cours d'eau tributaires avant de frayer entre avril et juillet de l'année suivante. Après leur entrée en eau douce et avant la fraie, les adultes rapetissent d'environ 20%. La durée de vie moyenne, depuis le début de la métamorphose jusqu'à la mort suivant la fraie, est probablement de 5 ans. Une forme non anadrome, apparemment une espèce nouvelle, existe dans les lacs et attaque un fort pourcentage de salmonidés résidents.

Received November 13, 1979
Accepted May 14, 1980

Reçu le 13 novembre 1979
Accepté le 14 mai 1980

Two species of parasitic lampreys are found off Canada's west coast. Very little is known about the biology of the Pacific lamprey (*Lampetra tridentata*) and almost nothing is known about the biology of the river lamprey (*Lampetra ayresi*). The purpose of this report is to present new information about the adult phase of the life cycle of these two species, including a description of metamorphosis and spawning.

Materials and Methods

Collections were obtained in freshwater using electroshockers, fish weirs that trapped fish moving downstream and occasionally upstream, purse seines, and small midwater trawls. In salt water, samples were obtained using purse seines with small mesh, plankton nets, and large commercial-size midwater trawls with small mesh liners in the codend. Lamprey maintained in the laboratory were held in a variety of tanks ranging in size from 800 to 4250 L. Salt water was obtained directly from the Strait of Georgia and the salinity ranged from 27 to 30‰ annually. Freshwater was dechlorinated city of Nanaimo water. Except for an experiment to induce river lamprey to spawn, no attempt was made to regulate temperature. Lamprey in the laboratory tanks were fed on a variety of species of fishes but primarily Pacific herring (*Clupea harengus pallasi*) and sockeye salmon (*Oncorhynchus nerka*). Ammocoetes were fed 200 mL of dry yeast suspension (200 cm^3 of brewers yeast in 1 L) twice a week (Hanson et al. 1974). Adult river lamprey gut contents were examined in the laboratory by recovering the entire gut content, measuring the volume and examining the contents with a microscope. All weights of live specimens were determined after lampreys were anesthetized in MS-222. All lengths are total lengths and were made using fresh specimens unless indicated. Additional details of most methods are described in Beamish and Williams (1976) and Beamish and Scarsbrook (1979). When appropriate, special comments about methodologies will be included in the descriptions of the life histories.

Identification of Adults

The tooth pattern clearly separates adult Pacific lamprey from the river lamprey and the western brook lamprey (*L. richardsoni*). River lamprey in salt water can also be identified by the lighter color, presence of countershading, and less robust appearance. However, separation of metamorphosing stages of river and western brook lamprey was not possible as recently metamorphosed western brook lamprey have rather prominent cusps and a dentition pattern similar to the parasitic river lamprey. Confirmation of the identity of some western brook lampreys was obtained by holding recently metamorphosed adults over winter in freshwater, and confirming that they matured and in some cases spawned in the early spring of the year following metamorphosis. Characters that will enable the separation of these two species during the macrophthalmia stage have not been identified because up to the present all but two of the recently metamorphosed specimens, captured in the fall and tentatively identified as river lamprey, proved to be western brook lamprey. Therefore, at present, the separation of metamorphosed river and western brook lamprey from samples collected in the fall remains uncertain.

In the spring, immature adult river lamprey in freshwater can be distinguished, in most cases, by the silver color of the body, the prominence and sharpness of teeth, the immature state of the gonads and the advanced state of development of the gut. In the late fall and early spring, river lamprey returning from sea and found in freshwater can be separated from recently transformed western brook lamprey by their advanced stage of maturity and the sharpness of their teeth.

At present, the identification of ammocoetes of river and western brook lamprey are also in doubt. Identifications of ammocoetes were made according to original published descriptions (Pletcher 1963; Vladykov and Follett 1958, 1965); however, not one of the ammocoetes thought to be a river lamprey developed into a river lamprey in the holding tanks.

In some streams adult lamprey were found that possessed characteristics common to both river lamprey and western brook lamprey. These lamprey were silver and possessed a well-defined gut, but the gonad development although more advanced than samples of river lamprey from other streams, was much less advanced than western brook lamprey found in the same stream. Two of these forms died when an attempt was made to acclimate them to salt water. There also was some variation in the morphology of western brook lamprey. Comparative studies of eye diameters, prebranchial lengths, and the number and morphology of velar tentacles confirmed that there are important variations in river and western brook lampreys found in the various rivers.

Results and Discussion

Biology of Adult River Lamprey

Since ammocoetes and recently metamorphosed river lamprey could not be separated from western brook lamprey, it could only be assumed that river lamprey ammocoetes begin metamorphosis in July, at the same time as the other two species. River lamprey have been

TABLE 1. Length frequency of juvenile adult river lamprey caught in downstream traps, in three British Columbia rivers.

Length (cm)	Fraser River[a] June 6–9, 1978	Fraser River[a,b] April 24–June 5, 1979	Morrison Creek[b] May 20–June 11, 1978	Quinsam River[b] April 26, 1978
4	1	—	—	—
5	—	—	—	—
6	—	—	—	—
7	—	—	—	—
8	—	—	—	—
9	3	6	—	—
10	28	23	—	1
11	28	56	4	—
12	15	76	8	—
13	4	31	5	—
14	—	6	—	—
15	—	2	—	—
16	—	1	—	—
17	—	—	—	—
18	—	—	—	—
19	—	1	—	—
Total	79	202	17	1

[a]Samples from 2.5 m^2 small-mesh midwater trawls fished at depths from 0 to 6 m and 3 to 20 km from the mouth of the river. Lengths from samples in 1978 were from previously frozen specimens.
[b]Lengths from preserved samples.

recorded moving downstream from the end of April to mid-June in three rivers in British Columbia. The length of the downstream migrants ranged from 4 to 19 cm with a mean length of 11 cm (Table 1). In 1979, small mesh midwater trawls were fished in the Fraser River starting March 13–16 but river lamprey were not captured until the end of April. Sampling continued until June 5 when the project was terminated because of decreased salmon abundance. While river lamprey occurred in greatest abundance during the last 2 wk of May, they were still present in early June and it is suspected that river lamprey migration into salt water continued throughout June. In 1979, there was no significant difference (t-test, $P > 0.05$) in the mean length of migrants during the main portion of the migration; however, the mean length of the June sample was 0.8 cm smaller than the mean length in the other sampling periods. Most lamprey were found at the 3–6 m depth range in the day samples. Day and night sets were made on May 3 and 17 and while catches were small (9 and 20 river lamprey, respectively), compared to catches during the day, one more river lamprey was captured in the night sets on May 3 and four more in the night sets on May 17 indicating downstream migration continues day and night with a possible preference for the night.

As part of another study, extensive fishing operations using small-mesh surface nets were conducted in the Strait of Georgia in the vicinity of the mouth of the Fraser River from the end of April to mid-July (Robinson et al. 1968a, b; Robinson 1969; Barraclough and Fulton 1967). The earliest recorded catch of river lamprey was on May 4, and catches of river lamprey in the size range of the downstream migrants listed in Table 1 continued to be present in the samples until mid-July, indicating that migration into salt water continued through June and perhaps into early July. A survey of 40 sites among the Gulf Islands in the Strait of Georgia in mid-May 1978 using a small-mesh purse seine (Beamish and Scarsbrook 1979) did not capture any river lamprey. Thus it appears that river lamprey begin to enter salt water late in April or early May and continue moving into salt water possibly as late as early July.

Withler (1955) observed a 162 mm river lamprey feeding on a young coho salmon fingerling in the Skeena River (54°10′N, 130°11′W) in mid-July, 1955. This specimen was larger than most downstream migrants observed in this study and was found in freshwater at about the same time as the maximum abundance of river lamprey was observed in the Strait of Georgia. While migration into salt water may be later for more northern areas, it is possible that the large size and the apparent delayed entry into salt water was related to the initiation of feeding in freshwater.

In June 1976, 50 juvenile sockeye salmon were captured at depths of 190 and 54 m in the northern portion of the Strait of Georgia (Scarsbrook et al. 1980). Seven of these fish had fresh, severe lamprey wounds some of which were identified from the tooth pattern as resulting from river lamprey attacks. The sockeye had an average length of 10 cm and thus had recently entered salt water. Since river lamprey have never been captured in deep water it is probable that

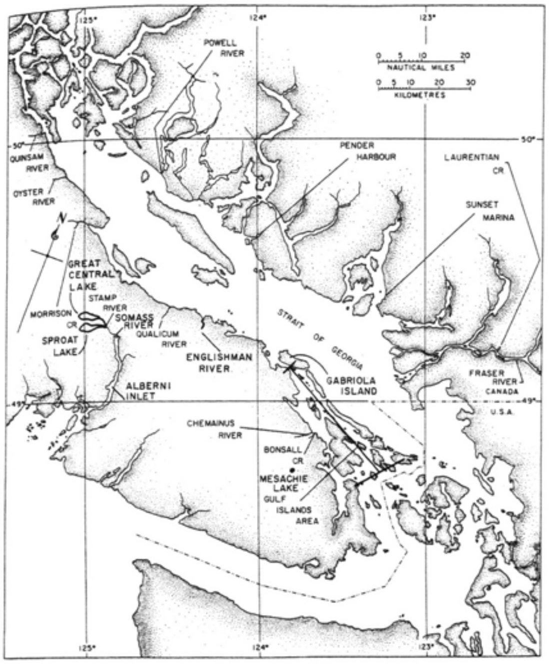


FIG. 1. Strait of Georgia showing areas mentioned in this report.

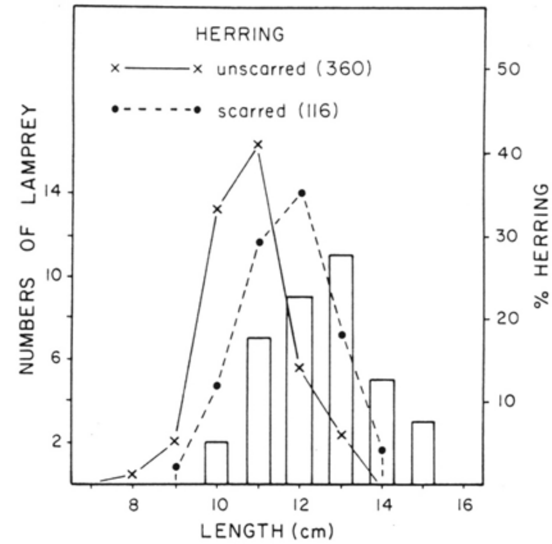


FIG. 2. Length distribution of river lamprey found actively feeding on herring and other fishes in large herring schools in Howe Sound. The length frequency of scarred and unscarred herring is also shown.

the attacks on the young salmon occurred during the downstream migration or in the estuary. These observations and the observations by Withler (1955) indicate that some river lamprey commence feeding in freshwater.

Early Adult Life in Salt Water

In this study the earliest catches of adult river lamprey in salt water were made on May 31 and June 2, 1978 in Sunset Marina in Howe Sound just north of the mouth of the Fraser River (Fig. 1). An entire school of fishes was purse seined and a sample estimated to be about one-third of the total school was removed with dip nets. This subsample contained 18 river lamprey, 1009 Pacific herring, 17 northern anchovy (*Engraulis mordax mordax*), and 5 unidentified salmon. A total of 116 herring (11.5%), 2 northern anchovies (11.8%), and one salmon (20%) were wounded from lamprey attacks. Approximately 75% of the wounds were estimated to be sufficiently severe to cause death. There was a disproportionate number of larger herring that had wounds and fresh scars (Fig. 2). This might be the result of a slightly higher survival rate of the larger fish after an attack rather than a preference for large hosts.

After the subsample was removed, an attempt was made to catch the remaining lamprey. A total of 40 lamprey were obtained and the mean length (Fig. 2) was 1 cm larger than the mean length found for the 1978 Fraser River sample (Table 1) indicating that these lamprey started feeding immediately on entry into salt water. The occurrence of actively feeding river lamprey in schools of Pacific herring is commonly observed for several weeks from several areas in the Strait of Georgia at this time of year. Therefore, it appears that some river lamprey begin their parasitic existence in salt water by associating themselves with schools of Pacific herring and voraciously feeding while remaining part of the school.

Growth and Distribution of Adults in Salt Water

During 1974, purse seine surveys for river lamprey were conducted in the central portion of the Strait of Georgia during July and August. In 1975 the surveys were repeated and extended into September. In 1976, the effort in the main portion of the Strait of Georgia was reduced but a number of standard locations were fished in the Gulf Islands area (Fig. 1) from April through October. In 1974, 1975, and 1976 the range in length of river lamprey from all the samples was 14–23, 12–29, and 9–28 cm, respectively (Fig. 3). In all years there was a wide range in lengths during July and August with little difference observed among the mean lengths (Fig. 3). The September samples did show an increase in mean length although the number of individuals present in the catch was greatly reduced. The Gulf Islands sample in 1976 does indicate that

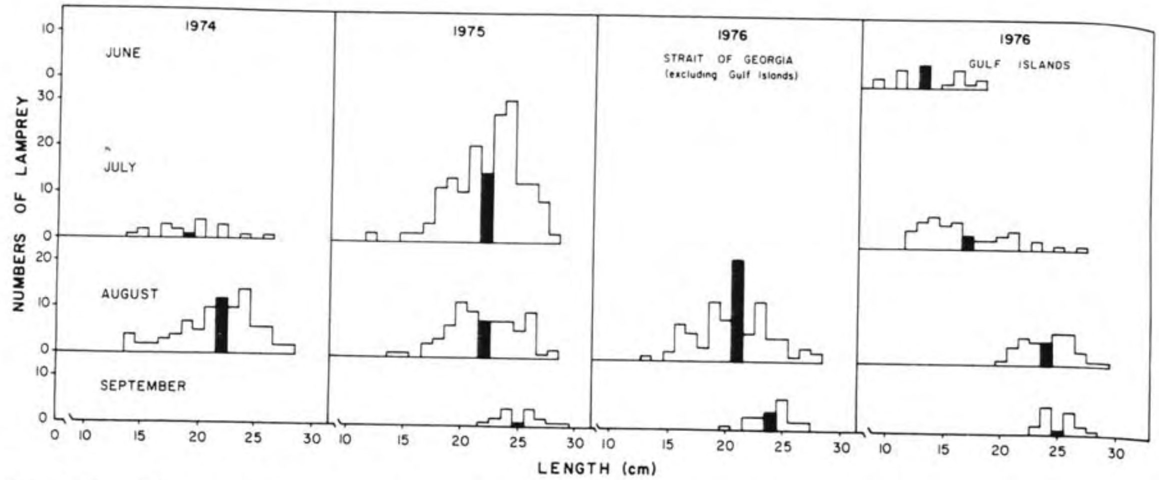


FIG. 3. Length frequency of all river lamprey caught in the Strait of Georgia from 1974 to 1976. In 1976 catches from the Gulf Islands area were separated from the total catch. The shaded bar indicates the mean length of the distribution.

mean length increased from 14 cm in mid-June to 24 cm in mid-August. Increases in length were reduced during late July and August when rapid increases in weight occurred (Fig. 4). The interpretation of growth from length frequencies was complicated by several factors including the time required to complete a survey, the mixing of lamprey from different rivers, and the time of entry into salt water.

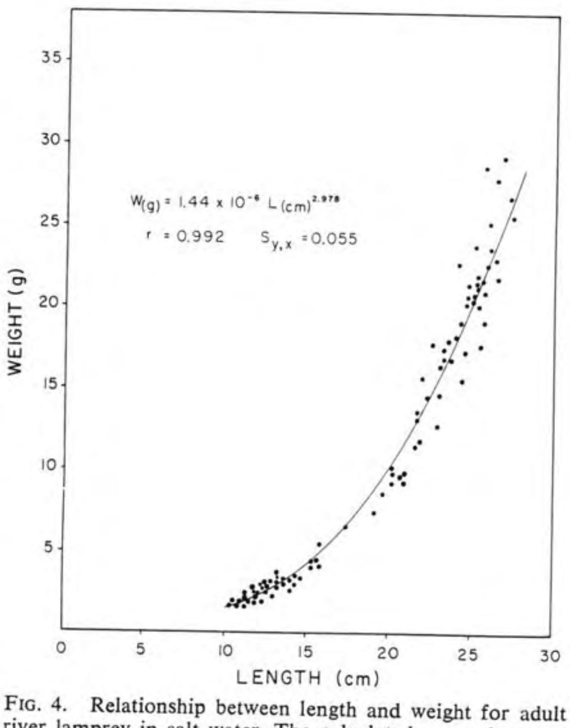


FIG. 4. Relationship between length and weight for adult river lamprey in salt water. The calculated curve does not appear to adequately represent the relationship for length and weight for the largest individuals.

During 1975 and 1976, 229 river lamprey were sexed and sampled for length (Table 2). The mean length of females sampled throughout their salt water residence ranged from being almost identical to being 2.5 cm longer than males. Except for the July 1976 sample there was no significant difference in the mean length of male and female lamprey (t-test, $P > 0.05$).

Sex ratios of adult river lamprey were determined by microscopic examination in 1975 and 1976 when the gut contents were examined. In July 1975 a sample of 50 lamprey consisted of 60% males. In 1976, the sex ratio for the total sample of 182 lamprey examined was 60% females. During July and early August 1976, the ratio of males to females was almost identical. However, in a sample of 59 lamprey collected in late August, there were 64% males and of 17 lamprey found in early September, 74% were females. Thus the adult sex ratios are about equal, but females appear to remain in the surface waters longer.

River lamprey are present in the surface waters from May to September and are most abundant in July. From 1974 to 1979 approximately 500 midwater trawls have been made in the Strait of Georgia at various depths and at various times of the year. While 66 Pacific lamprey were found, only one river lamprey was captured and that was near the surface. (Data are contained in numerous cruise reports, published by the Fisheries and Marine Service, Canada.) Lamprey were most abundant in the surface waters in July and absent after September. No lamprey were found at the surface in the October survey of the Gulf Islands in 1976 or in the 4-day and 4-night purse seine sets made in the Gulf Islands in November 1974. Also a comparison of 20-day and 17-night sets made in the Gulf Islands in

TABLE 2. Mean length (cm) of river lamprey sampled for length and sex in 1975 and 1976. Sample size is in parenthesis.

	1975	1976				
	July 29	June 21–26	July 5–9	Aug. 3–10	Aug. 24–Sept. 2	Sept. 8–15
Male	20.3 (30)	13.9 (6)	15.3 (23)	23.0 (18)	21.8 (21)	24.6 (4)
Female	19.8 (20)	12.0 (12)	17.8 (23)	23.1 (21)	22.7 (38)	25.3 (13)

1976 showed that catches during the day were significantly higher than during the night (t-test, $P < 0.05$, Beamish and Scarsbrook 1979). At night some may move into water deeper than the depth of the purse seine (26–33 m), or move inshore, but they seldom occur at depths greater than 50 m during the day or night. The strong countershading first noted by Kan (1975) is further evidence that this species prefers surface waters.

There seems to be little doubt that a few major rivers such as the Fraser River and its tributaries are a major source of river lamprey in the Strait of Georgia (Fig. 1). By dividing the Strait of Georgia into 7-km squares and plotting the average catch per set for each of these squares (Fig. 5) the areas of concentration were in the vicinity of Pender Harbour, Howe Sound, and the area from the mouth of the Fraser River to Gabriola Island and the Southern Gulf Islands area (Fig. 1).

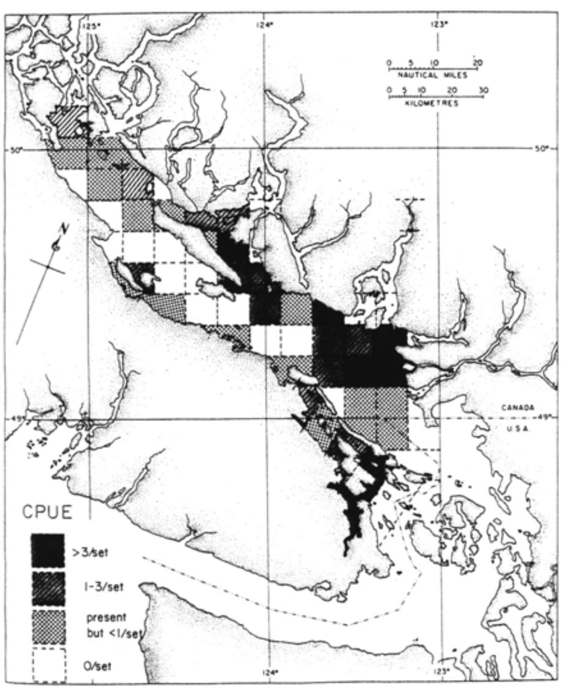


FIG. 5. Catch of river lamprey per unit of effort (CPUE) for all sets made in the Strait of Georgia.

During the summer months the salinity at depths from 10 to 50 m in the Strait of Georgia has an average range of approximately 26–30‰ (Waldichuk 1957). Compared to offshore salinities of approximately 32‰, the salinities in the Strait of Georgia can be considered to be of reduced concentration. The accumulation of river lamprey in the vicinity of major rivers and their distribution throughout the surface waters may indicate a preference for water of reduced salinities.

FEEDING

Gut contents from 182 river lamprey caught in 1976 and from a sample of 50 caught in 1975 were examined in the laboratory. Because river lamprey remove portions of flesh from their hosts (Fig. 6) it was often possible to identify the prey by scales, fin segments, or internal organs such as pyloric caeca. Since much of the gut contents could not be identified, results are expressed as the number of lamprey that contained a particular prey species.

All the identifiable items in each gut were from one prey species. Several guts contained more than one caudal fin or scales from fish of different ages indicating more than one individual had been attacked. Of the 182 guts examined, 38 (22%) were empty and 9 (5%) contained unidentifiable remains. The most frequently occurring species, Pacific herring, was found in 115 (63%) of the guts. Salmon remains were the second most abundant food item occurring in 18 (10%) of the guts. The percent occurrence of salmon remains decreased from 50% in June to 9% in September, while the percent occurrence of herring increased correspondingly. The decrease in the presence of salmon may be related to the movement of young salmon out of the estuaries and the Strait of Georgia. The mean volume of the gut contents was highest in August, averaging 0.8 mL. Because river lamprey often remove pieces of tissue and internal organs, survival of hosts was unlikely. It was estimated from the number of lamprey that contained food, relative to those that were empty, that from June to September each lamprey attacked and fed on 0.8 fish/d.

In laboratory experiments river lamprey fed on a variety of species including Pacific herring, salmonids, shiner perch (*Cymatogaster aggregata*), English sole (*Parophrys vetulus*), on two occasions other river lam-

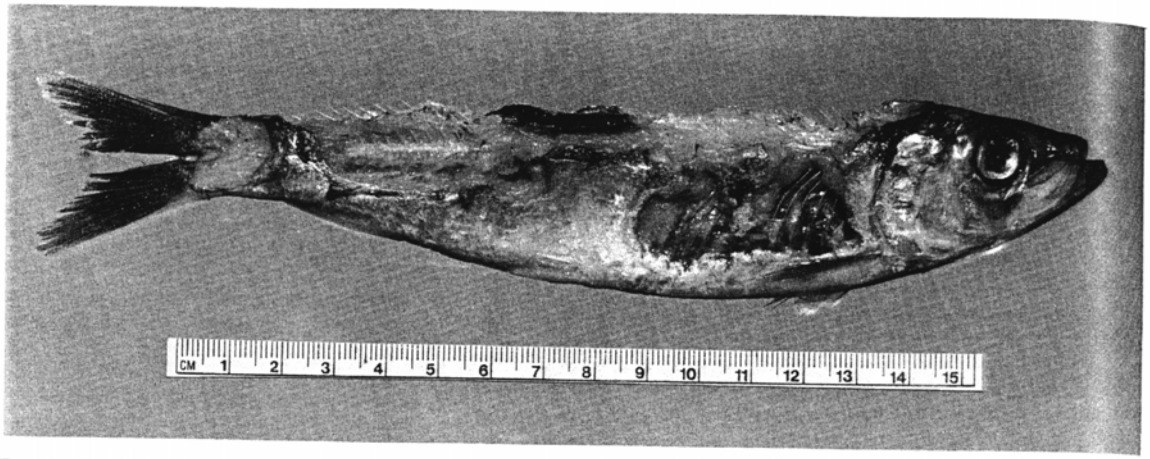


FIG. 6. Pacific herring consumed by river lamprey. The fish was taken from a laboratory feeding experiment and it is apparent from the extensive damage to the body cavity that feeding continued after the death of the host.

prey and one occasion a dead Pacific lamprey. It was not known whether the river lamprey fed on live or dead river lamprey as only a partially consumed carcass was found on the bottom of the tank. On several occasions river lamprey attacked and fed on fish that were already dead. While such attacks were rare, continued feeding on fish that died during an attack was not uncommon. Herring was the preferred species in laboratory experiments and often the addition of fresh herring to a tank would initiate an immediate feeding response. In the laboratory experiments the frequency of feeding was reduced after September. Although river lamprey kept in salt water of the same salinity as the Strait of Georgia started dying in October, those that survived until the following June fed as late as mid-May.

Recreational fishermen have reported that river lamprey attacked their baits and consumed portions of flesh in the length of time it took to retrieve the line. In the laboratory, river lamprey could consume between one-eighth and three-quarters of the body of a small herring (10 cm), exclusive of the head and tail in a single meal of 30–40 min duration. Smaller fish were usually subjected to more general damage with an average of about one-half the trunk tissue being consumed. Larger salmon usually sustained round, deep wounds, often in the anterior dorsal region. Fish smaller than 15 cm seldom survived a lamprey attack for more than a few days or were attacked and killed by another lamprey. During an active 4-wk feeding period in a laboratory experiment, an average of 1.3 fish were killed per lamprey per day (Beamish and Williams 1976). Although it is difficult to relate the results of the number of fish killed in this series of experiments to natural feeding conditions, because lamprey did not feed when first brought into the laboratory, the killing rate of 1.3 fish per lamprey per day is similar to the attacking rate of 0.8 fish per lamprey per day estimated from the analysis of gut contents.

Based on scarring data, Roos et al. (1973) reported that attacks by river lamprey were confined exclusively to the dorsal area. In this study the majority of attacks were dorsal and anterior but some ventral attacks were observed. Ventral attacks probably kill many prey by penetrating the body cavity and would not normally be observed unless large numbers of prey species were examined. There was no question that the majority of attacks observed on fishes in the Strait of Georgia were dorsal, but anterior, posterior, lateral, and ventral attacks were observed in this study. Ventral attacks were more common in laboratory experiments.

At present there is little evidence of predation by other animals on river lamprey. As reported, river lamprey fed on other river lamprey in the laboratory and there is one report of a river lamprey being found in the gullet of a lingcod (Vladykov and Follett 1958). In laboratory experiments in freshwater, salmon fed on small adult western brook lamprey, so predation on river lamprey by other fishes may occur.

ABUNDANCE OF ADULT RIVER LAMPREY IN THE STRAIT OF GEORGIA

As part of the 1975 survey, an approximate estimate of the number of river lamprey in the Strait of Georgia was made by dividing the surface area of the study area in the Strait of Georgia by the total surface area fished in all sets during July to September and multiplying by the total catch of lamprey. From a total survey area estimated to be 4690 km^2, a total area fished of 1.49 km^2, and a catch of 282 river lamprey, it was estimated that 667 000 river lamprey were present in the Canadian portion of the Strait of Georgia (Beamish and Williams 1976). By combining the feed-

TABLE 3. Number of deaths by month for maturing river lamprey held in salt water and freshwater.

	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Total
Salt water												
No. of deaths	4	2	3	1	0	2	1	1	6	2	—	22
(male, female)[a]			(1, 1)			(0, 2)	(1, 0)	(0, 1)	(3, 2)	(2, 0)		
Approximate %	18	9	13	5	0	9	5	5	27	9	—	100
Freshwater												
No. of deaths	—	—	5	9	6	4	3	7	26[b]	6[b]	1[c]	67
(male, female)			(5, 0)	(6, 3)	(4, 2)	(4, 0)	(0, 3)	(1, 1)	(9, 15)	(1, 5)	(0, 1)	
Approximate %	—	—	8	14	9	6	4	10	39	9	1	100

[a]No. of males and females may not add to total as sex was not determined for all fish.
[b]Died after spawning.
[c]Mature female that did not spawn.

ing rate of 0.8 fish per lamprey per day and the killing rate of 1.3 fish per lamprey per day, a killing rate of 1 fish per day per lamprey was assumed. Using this killing rate and assuming that each prey is attacked by only one lamprey it was estimated that 60 000 000 juvenile fish would be killed during the 90-d feeding period from mid-June to mid-September. Since many variables had to be estimated it is obvious that the technique provides only a very approximate estimate of population size. For example, if only the portion of the seine that had a mesh size that could retain lamprey was considered, the effective fishing area would be reduced by 90%. Sets could not always be made in a standard manner in randomly selected locations and it is doubtful that all lamprey remained in the study area during the study period. The estimate does indicate that river lamprey could be an important predator of small fishes particularly herring and salmon.

Return to Freshwater, Spawning, Death

No river lamprey were found in salt water after September, but to date no adult river lamprey have been found in rivers in the fall. Using a small midwater trawl, one maturing 14-cm female river lamprey was caught in Nimpkish Lake on November 30, 1978, indicating that in one river the timing of the upstream migration corresponds with the timing of the disappearance from salt water. Pletcher (1963) recorded the presence of *Lampetra planeri* (now called *L. richardsoni*) in two rivers in British Columbia in February 1957 and May 1942. These lamprey ranged in length from 13 to 20 cm and the largest individuals were larger than any adult western brook lamprey found in this study. It is probable that some of the specimens described by Pletcher were river lamprey and that these were the first recorded observations of maturing river lamprey in British Columbia rivers. Vladykov and Follett (1958) recorded adult river lamprey in San Francisco Bay in the United States in November and February. They also recorded adult river lamprey in Lakes Sammamish and Washington in October and December, respectively. The specimen found in Lake Washington was attached to and possibly feeding on a Kokanee salmon (*Oncorhynchus nerka*). They also reported specimens in spawning condition from the Sacramento River, approximately 240 km from the ocean, in April. From the size of the eggs in these specimens they concluded that the spawning period would be April through May.

In this study, some of the specimens captured in late August and September showed signs of early gonad development. Lamprey held in salt water in the laboratory stopped feeding or fed infrequently after September and died over the period from September to mid-June (Table 3). Individuals that died in November and December were maturing, the gut and eyes were degenerating and there was a noticeable reduction in the postanal length and in the space between the dorsal fins. Such changes are associated with the onset of maturity and onset of upstream migration in other parasitic species (Hardisty and Potter 1971) and suggest that some river lamprey move into freshwater during this time of year. Because a loss of marine osmoregulatory mechanisms occurs with the onset of maturity (Morris 1971), some of the deaths recorded in Table 3 probably are related to changes in osmoregulatory mechanisms. All river lamprey that died in the salt water tanks from February to mid-June were mature. Some river lamprey fed infrequently during this period with the last feeding occurring in mid-May. Although mortalities occurred from September to June, the greatest number occurred in May (Table 3), indicating that some river lamprey can remain in salt water until just before the spawning period. This observation is consistent with that of Vladykov and Follett (1958) who recorded river lamprey in San Francisco Bay at the same time as they were found in some lakes.

In a second experiment, river lamprey were acclimated to freshwater over a period of 6 d in early November and maintained in freshwater. In freshwater,

TABLE 4. Mean length (cm) of Pacific lamprey during metamorphosis and downstream migration (number of fish in sample in parentheses).

	Downstream migrants (trapped)				Metamorphosis adults (electro-shocked)											
	M	A	M	J	J	F	M	A	M	J	J	A	S	O	N	D
Qualicum R. 1977	12 (5)	13 (3)	0	—	—	13 (1)	0	0	0	0	0	—	12 (2)	13 (4)	0	—
Qualicum R. 1978	0	13 (4)	12 (4)	—	—	—	0	0	—	—	—	—	—	—	—	—
Oyster R. 1977	—	—	—	—	—	—	—	—	—	—	—	12 (43)	12 (30)	13 (6)	0	—
Oyster R. 1978	—	—	—	—	—	—	—	—	—	—	—	10 (6)	—	12 (39)	—	—

the pattern of mortalities was similar to that observed for the lamprey held in salt water but by the end of February none of the dead showed advanced signs of maturity and none had fed on any of the salmonids that were kept in the freshwater tanks.

At this time, it can be concluded only that some river lamprey can survive in salt water of approximately 28–30‰ until spawning and that some river lamprey can adapt to freshwater shortly after they disappear from the surface waters in the Strait of Georgia. Separate stocks may exist and some stocks may remain in salt water, possibly in estuaries or below the tide level in rivers during the winter, while others move into lakes and rivers in the fall. Since no spawning occurred in salt water, it appears that a return to freshwater is essential for successful spawning.

River lamprey were acclimated to freshwater in early November 1978, and on April 1, 1979 the water temperature in the tanks was heated to 1–2°C above ambient to correspond with the temperature of rivers known or suspected to contain river lamprey. These lamprey spawned in the holding tanks during May 1979 when the water temperature was 12°C. The nesting and spawning behavior observed in the laboratory was similar to the behavior of most lampreys (Hardisty and Potter 1971). Prior to spawning, lamprey constructed nests approximately 15 cm in diameter in the gravel by lifting rocks out of the nest area with the oral disc and by vigorous digging movements. Just prior to spawning a male would glide up and down the body of the female with his oral disc and eventually attach dorsally behind the head of the female, twisting his tail around the body of the female. The actual release of eggs and sperm was not observed. Males appeared to exert considerable pressure when twisting around the body of females as many spawned females were severely bruised. Most females died within hours of spawning while most males survived for approximately 3 wk.

There was a considerable decrease in length during the period in freshwater from early November until spawning in May. The average length of the 29 spawning lamprey was 18.3 cm. The average length of lamprey in this experiment was 23.8 cm in mid-August and while lengths determined in August were not compared with the length of the same individual measured in May, it is probable that the 21% reduction in length is representative of the amount of shrinkage that occurs during the residence in freshwater prior to spawning. The average length of 14 males was 18.9 cm, about 1 cm longer than the average length of 17.8 cm for 15 females suggesting that females may shrink more than males.

If the temperature at which river lamprey spawned in this study is representative of the temperatures river lamprey initiate spawning in rivers, it can be assumed that most spawning occurs in May and could extend from April to June. Since river lamprey survived only a few weeks after spawning, the average duration of adult life from the onset of metamorphosis in July to death following spawning is 2 yr.

Biology of Adult Pacific Lamprey

Metamorphosis and Movement into Salt Water

Metamorphosing Pacific lamprey were first observed in July. Pletcher (1963) also concluded that metamorphosis started in July. Recently an intensive study of the staging of the metamorphosis of Pacific lamprey in the Chemainus River (Richards 1980) confirmed that metamorphosis begins in July and was complete by October. From August to September in the Qualicum River on Vancouver Island (Fig. 1), metamorphosing Pacific lamprey were observed to move from a mud–silt habitat in lentic waters to silt covered large gravel (1 to 4 cm in diameter) in moderate currents. Movement into the large gravel was complete by early September or Stage 6 (teeth blunt, cusps not present on the tongue, oral fimbriae well developed; Richards 1980; Youson and Potter 1979). A survey of other rivers during September, 1979 showed that Pacific lamprey in an advanced stage of metamorphosis characteristically were found in gravel or boulder substrate where currents were moderate to strong. Metamorphosing Pacific lamprey from a nonanadromous population in Mesachie Lake (Fig. 1) were found in similar substrate along the edge of the lake close to the inlet stream.

The mean size of downstream migrants from the Qualicum River was 12.5 cm (Table 4). The mean size of metamorphosing Pacific lamprey, collected from July through to October in the Qualicum and Oyster rivers was 12.0 cm and was not significantly different from the mean size of the total sample of downstream migrants (t-test, $P > 0.05$). The average size of eight metamorphosed Pacific lamprey from Morrison Creek was 7.8 cm with the smallest metamorphosed lamprey measuring 4.7 cm. Downstream migrating Pacific lamprey captured with small mesh midwater nets in the Fraser River from May 3 to June 5, 1979 ranged in length from 11 to 16 cm with a mean length of 14 cm for the 43 specimens captured. It appears that, while there is some variation among rivers, the average size of Pacific lamprey when they first enter salt water is approximately 13 cm.

Downstream trapping operations from February to June for salmon often capture lamprey, but unfortunately only in recent years have catches of lamprey been preserved and identified. The earliest reported capture of a juvenile adult Pacific lamprey, moving downstream, was in February (Table 4) and the latest capture was in June, both in the Qualicum River. Unpublished downstream trap catches from the Qualicum River indicate that unidentified lamprey were caught as late as August indicating that the period of migration of Pacific lamprey into salt water may extend past June. In the Fraser River in 1979, no metamorphosed Pacific lamprey were captured in March and April, but 43 were captured in May and June. Pacific lamprey adults are thought to be more abundant than river lamprey adults, yet this number of metamorphosed Pacific lamprey was only 21% of the number of river lamprey caught in the same nets. Because of this apparently small catch of Pacific lamprey it was suspected that the main downstream migration occurred earlier than April and that the catches in May and June resulted from the migration of Pacific lamprey from only a few of the tributary rivers of the Fraser River. The capture of a 12-cm adult Pacific lamprey at a depth of 90 m in December (Fig. 7) in the Strait of Georgia, near the mouth of the Fraser River indicates that migration into salt water can occur at least as early as December. Also, the presence of young adults in areas in the stream with moderate to strong currents, during the periods of low water in September and October suggests that some entry into salt water may occur when water levels and current velocities increase in November. Richards (1980) believed Pacific lamprey go to sea in November.

In a laboratory experiment in 1978, metamorphosing Pacific lamprey were acclimated to salt water in late September and started feeding in mid-October (Richards 1980). This experiment was repeated in late September, 1979 using five metamorphosing Pacific lamprey recently captured from each of five rivers. The stage of metamorphosis was noted and lamprey from each river were marked with an injection of colored latex into the dorsal fin fold. Twenty of the 25 lamprey survived the 3-d period of gradually increasing salinity. The five lamprey that did not survive in full strength salt water were from two rivers and either had not reached stage 6 or had just reached the 6th stage of metamorphosis. None of the lamprey in stage 5 sur-

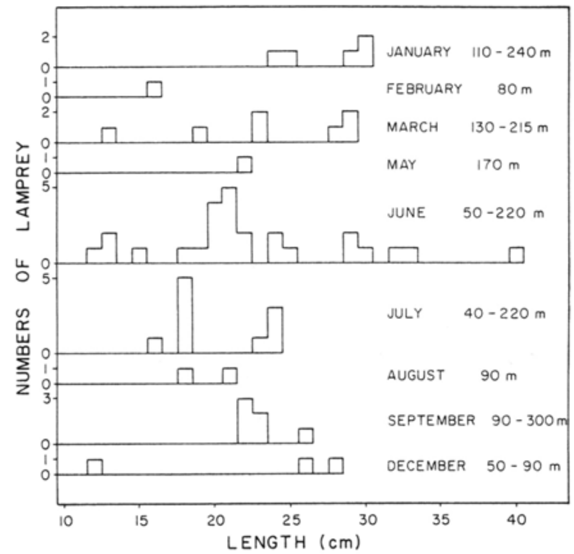


FIG. 7. Length frequency of Pacific lamprey captured in midwater trawls in the Strait of Georgia.

vived in salt water. Live herring (6–10 cm) were added to the tank on October 1 when full strength seawater was achieved. First attachment to a herring was observed in 4 d and the first confirmed feeding on herring occurred in 10 d. By the end of October, 20 herring had been attacked and killed.

In experiments conducted in 1977/78, 1978/79, and 1979/80, metamorphosed Pacific lamprey in freshwater did not survive past mid-July and most perished by the end of January. In the 1978/79 experiments, salmonids were introduced into the tanks in early February; feeding started in late February to early March and lamprey continued feeding until several weeks prior to death. In 1979/80 experiments, salmonids were introduced into tanks in early October. In three separate experiments, each containing 25–35 lamprey, feeding commenced in mid-October, about the same time as the lamprey from the same rivers commenced feeding in salt water. While the frequency of attacks was lower in freshwater (R. J. Beamish unpublished data), it was apparent that feeding can commence in freshwater and salt water at the same time. The cause of death in these experiments was not determined but if it was related to osmoregulatory problems it may indicate that most stocks of Pacific lamprey must enter salt water soon after metamorphosis is complete and no later than July. Thus the known period of migration into salt water is from December to June and the actual period of migration probably is longer.

Hardisty and Potter (1971) have identified the stage in metamorphosis, after the more obvious external changes have taken place, as the macrophthalmia stage. They consider that in a parasitic species this stage ends with the onset of feeding. Since metamorphosis of Pacific lamprey was complete by mid-October and individuals commenced feeding immediately in freshwater or salt water, it appears that Pacific lamprey metamorphose directly into juvenile adults and the macrophthalmia stage is either very short or it does not exist.

In some locations in British Columbia, lamprey do not migrate into salt water but remain and feed in freshwater (Carl 1953). Mesachie Lake (Fig. 1) contains nonanadromous parasitic lamprey as indicated by the freshly wounded fish that were observed throughout the year. The lamprey captured were immature, feeding, and were larger than most downstream migrants from other rivers. Two lamprey captured in June were acclimated to full strength salt water over a period of 3 d. They were kept in salt water of 6 d indicating that the freshwater residence had not impaired their ability to acclimate to salt water. In subsequent studies these lamprey have been maintained in salt water for several months. Since no physical barrier prevents the adult Pacific lamprey in Mesachie Lake from entering salt water, the term "nonanadromous" rather than "landlocked" more accurately describes their confinement to freshwater. These individuals are morphologically different from other Pacific lamprey and may represent a new species. When recently metamorphosed Pacific lamprey from a number of locations were held in freshwater all Pacific lamprey eventually died except those from Mesachie Lake. While these preliminary experiments show that Mesachie Lake lamprey are different from other Pacific lamprey, it remains unknown if the ability to remain in freshwater is the result of genetic differences or is common to other individuals that traditionally migrate into salt water.

When Pacific lamprey enter salt water they do not remain on or near the surface or in shallow water but move to water deeper than 70 m. Robinson and Barraclough (1968a, b) caught only six Pacific lamprey in surface nets in the vicinity of the Fraser River, and in the present study no Pacific lamprey were found in any surface fishing except in the vicinity of the Fraser River. Pacific lamprey slightly larger than the size of the average downstream migrant have been captured at fishing depths of 100–250 m. Pacific hake (*Merluccius productus*) and walleye pollock (*Theragra chalcogramma*) commonly found at these depths were occasionally found with fresh lamprey wounds. Off the west coast of Vancouver Island during the summer of 1979, salmon fishermen reported small lamprey attached to pink salmon (*Oncorhynchus gorbuscha*) caught a few km to 40 km offshore and at fishing depths of 20–90 m in water of depths to 180 m. By mid-September 1979, nine Pacific lamprey, ranging in size from 16 to 42 cm with an average length of 23 cm had been returned by fishermen and 35 fishermen observed lamprey attached to salmon. The length of the smaller lamprey that were captured was very close to the average size of 17 cm, estimated by these 35 fishermen, and is very similar to the size of Pacific lamprey in their first year of salt water residence in laboratory experiments (R. J. Beamish unpublished data). It appears that the small lamprey found in the Strait of Georgia and off the west coast of Vancouver Island are in their first year of salt water residence and are located at depths in the range of 20 to 250 m.

In laboratory experiments, metamorphosed Pacific lamprey that were maintained in freshwater without food until March, and then acclimated to salt water over a 3-d period, initiated feeding within hours of being introduced into a tank containing Pacific herring. Therefore, it appears that juvenile Pacific lamprey leaving freshwater, move directly into deeper water and probably start feeding immediately.

FEEDING

Rarely are Pacific lamprey observed attached to prey, but the scar or wound that remains on fish frequently has impressions of the teeth, clearly indicating that the wound was caused by a Pacific lamprey. A common prey observed in this study was walleye pollock. Pollock were routinely examined for lamprey attacks from all of the major fishing grounds from 1975 to 1979 and of 21 000 fish examined, 124 fish or about 0.6% were found to have wounds or scars caused by lamprey. The highest incidence of attacks on pollock was observed in Dixon Entrance (54°30′N, 132°39′W), where 10% of a sample of 145 pollock were wounded. More scars or wounds have been observed on the left side of pollock but it is difficult to determine if this apparent preference for the left side is real, as lamprey marks on fish are often observed incidentally to some other project and the degree of sampling bias is unknown at this time. Pacific hake were also examined and of the 50 000 examined 51 or 0.01% were wounded. Pacific hake and walleye pollock are midwater fish that often are found in association with layers of plankton (Beamish et al. 1976) and the attacks on these fish may indicate a preference for this plankton layer by young Pacific lamprey.

Scarring on sockeye salmon by Pacific lamprey in the vicinity of the Fraser River was examined by Williams and Gilhousen (1968) and again in this study. Williams and Gilhousen found that approximately 66% of the sockeye and 20% of the pink salmon sampled had marks of lamprey attacks. Six percent of the wounds on sockeye and 2% of the wounds on pink salmon were considered to be severe. They estimated that mortality due to lamprey wounds after fish moved upstream to the spawning grounds was between 1.6 and 1.8% and was of minor significance. In this study a sample of 681 sockeye from a commercial catch was examined in 1978 for wounds and scars and 27% of the fish were found with evidence of lamprey attacks. Sixty-six percent of the attacks penetrated the skin and 2.4% were severe wounds that penetrated deep into the muscle or body cavity. A sample of 140 sockeye

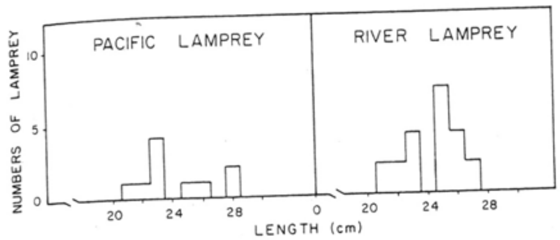


FIG. 8. Length frequency of river lamprey and Pacific lamprey captured in the mouth of the Fraser River Estuary in August–September 1978.

salmon captured during a research cruise, several weeks prior to the examination of the commercial sample contained 17% scarred fish. The higher incidence of scarring in the commercial sample cannot be explained but may be related to the increased time spent in the estuary or may be related to increased attacks on fish that are caught in gill nets. In a combined sample of 821 salmon, 96 attacks were on the right side, 66 were on the left side, 4 were dorsal and 59 were ventral. No explanation for the apparent preference for the right side is possible.

The use of a small mesh purse seine during research cruises in the vicinity of the Fraser River resulted in the capture of Pacific lamprey and river lamprey (Fig. 8) in addition to small and large salmon. On the large sockeye salmon none of the scars in which a tooth pattern could be recognized, appeared to result from river lamprey attacks but many of the smaller salmon had been attacked by river lamprey.

Mason (1974) observed that 61 of 539 coho salmon (14%) returning to Lymn Creek in 1971 had lamprey scars and 137 of 348 in 1972 (45%) had scars. Female coho had significantly more scars than males. Six of 30 sockeye salmon returning to Sproat Lake and 10 of 68 sockeye salmon returning to Great Central Lake had evidence of lamprey attacks. Six fish from the two samples suffered more than one attack and four of the fish had suffered attacks that did not penetrate the skin. Most wounds did penetrate the skin and were approximately 5 mm in diameter, indicating attacks by small, young lamprey. No lamprey were observed on any of the 60 000 sockeye salmon that were counted entering these lakes. Birman (1950) also noted a high percentage (44%) of scars caused by Pacific lamprey on pink salmon in the Amur estuary.

Because the sockeye salmon were returning to spawn and some of the attacks had not penetrated the skin it might appear that the lamprey were also aggregating in preparation to return to freshwater. Soldatov (1934) considered that lampreys gathered in estuaries of larger rivers and attached to salmon that were moving upstream in order to accelerate their own movement into freshwater. However, two of nine Pacific lamprey that were collected in the Fraser River estuary in August in 1976 and measured 20 and 23 cm, were alive in the laboratory in August 1979. The presence of young lamprey in these aggregations, the failure to observe lamprey attached to migrating maturing salmon in freshwater and the observation that maturing Pacific lamprey enter freshwater in the spring, indicates that the aggregations of Pacific lamprey contain younger lamprey and not adults preparing to migrate immediately into freshwater unlike the river lamprey that were captured at the same time.

Pacific lamprey in this study were observed to attack rockfish (*S. aleutianus* and *S. reedi*), Pacific cod (*Gadus macrocephalus*), chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), lingcod (*Ophiodon elongatus*), and sable fish (*Anoplopoma fimbria*). Pike (1950, 1951) recorded lamprey attacks on steelhead trout (*Salmo gairdneri*), Pacific halibut (*Hippoglossus stenolepis*), and whales. In the Bering Sea Pacific lamprey fed on the greenland turbot (*Reinhardtius hippoglossoides*), the arrowtooth flounder (*Atheresthes stomias*), the Kamchatka flounder (*Atheresthes evermanni*), sablefish, Pacific ocean perch (*Sebastes alutus*), and Pacific cod (Novikov 1963; Abakumov 1964). In one study in the Bering Sea, Pacific lamprey attacks were observed on about one-third of all greenland turbot examined (Novikov 1963) and as many as 55% in some hauls had scars or fresh lamprey wounds (Abakumov 1964). The lamprey attacks were almost exclusively on the blind side.

Unlike river lamprey, Pacific lamprey feed in a manner similar to the sea lamprey (Parker and Lennon 1956). Pacific lamprey attacked ventrally and anteriorly leaving 1–3 cm holes in the flesh. A common place of attachment on pollock was just behind the pectoral fin. The anterior ventral area was a common scarring location on sockeye salmon. In the laboratory and in the ocean, multiple attachments occur especially by young metamorphosed lamprey. In the laboratory, lamprey will remain attached to a host for varying periods that last up to several days. Feeding in the laboratory continued throughout the year suggesting feeding in the ocean continues throughout the year.

DISTRIBUTION

From 1975 to mid-1979, 66 Pacific lamprey were captured during fishing operations on research cruises in the Strait of Georgia. In addition, fishermen frequently captured Pacific lamprey attached to sockeye salmon caught in troll and gill nets in the Strait of Georgia. For example, on August 26 to 27, 1979 one fisherman landed 17 Pacific lamprey that ranged in size from 16 to 20 cm. Only nine Pacific lamprey have been obtained from other areas off British Columbia; however, scars or wounds have been observed during research cruises off the west coast of the Queen Charlotte Islands, in Dixon Entrance, Hecate Strait, Queen Charlotte Sound, and off the west coast of Vancouver Island. The relatively large number of lamprey attacks reported in the area off the west coast of Vancouver Island may indicate a relatively high abundance in this area. It is expected that other areas of high relative abundance will be identified in the future because observations of lamprey attacks and collections of lamprey have been solicited from fishermen only in the last few years. Despite the relatively few accounts of lamprey attacks, Pacific lamprey have been observed in all the important commercial fishing areas off Canada's west coast and their number and distribution certainly are greater and more widespread than indicated by current reports.

Predation on Pacific Lamprey

The extent that other animals feed on Pacific lamprey is unknown but various accounts of animals feeding on lamprey indicate that lamprey may be consumed more often than formerly thought. Eighty-two percent of the observed feedings of Steller sea lions (*Eumetopias jubatus*) feeding at the mouth of the Klamath River, California were on Pacific lamprey. Two sea lions that were shot had stomach contents composed entirely of Pacific lamprey (Jameson and Kenyon 1977). One of a group of seals thought to be feeding on sockeye salmon smolts in the Skeena River was shot as part of a program to reduce the nuisance to salmon net fishermen (the program was terminated about 1962). The stomach of the seal contained two lamprey apparently from a group of nearby spawning lamprey (A. Peden, British Columbia, Provincial Museum, personal communication). A fishery officer in the Skeena River area reported that in January he observed a mink (*Mustela vison*) with a live lamprey in its mouth. Pacific lamprey have also been found in the stomach of a sperm whale (*Physeter catodon*) (Pike 1950) and fur seals (Hubbs 1967). In the present study, portions of tails of upstream migrating adult lamprey in freshwater occasionally were missing. In a laboratory experiment, a spiny dogfish (*Squalus scanthias*) bit off the posterior 2–3 cm of the tail of a lamprey and the lamprey survived. As part of another study, spiny dogfish and sablefish fed actively on freshly killed adult Pacific lamprey, consuming about two to three lamprey each in a 15-min period.

Movements and Duration of Saltwater Life

Little evidence is available to indicate whether or not Pacific lamprey from Canadian rivers migrate extensive distances. Larkins (1964) recorded catches of Pacific lamprey during a high seas salmon sampling program suggesting that Pacific lamprey do actually move into the high seas. However, the catches were made 60–150 km south of the Aleutian Islands and possibly were fish from local rivers on the Aleutian Islands. Pacific lamprey have been observed in the central and western regions of the Bering Sea (Novikov 1963) and in rivers in Japan (Hubbs 1971). It is unknown if Pacific lamprey spawn in Asiatic rivers but it is possible that at least some of the observed specimens migrated or were carried into these waters and were endemic to North America. Pletcher (1963) felt that total length might be related to the length of the migratory journey as proposed by Lack (1954) for anadromous fishes. If this is true, then the larger Pacific lamprey that are found in the Fraser, Skeena, and Stamp rivers (40–72 cm range) may range farther than some stocks of smaller Pacific lamprey. It is also possible that size may be related to the duration of feeding, and that lamprey spending longer periods in salt water grow to larger sizes. Certainly Pacific lamprey move offshore and it is probable that some lamprey or some stocks of lamprey migrate considerable distances.

The length of time spent by Pacific lamprey in salt water is unknown and possibly is different for different stocks. Since traditional methods of age determination or tagging could not be used to estimate the time spent in salt water, a simple laboratory holding and feeding experiment was initiated in October 1975 using 15 Pacific lamprey that were captured during midwater trawling operations in June 1975 in the Strait of Georgia (Fig. 7). These lamprey ranged in length from 18 to 40 cm and in weight from 13 to 83 g. They were given salmon and a variety of other species to feed on and were left untouched. By December 1975, 12 lamprey remained alive; in December 1976, 7 remained; in December 1977, 4 remained and in December 1978, 3 were alive. One died and one was lost in January 1979 and the remaining fish died in May 1979. Some lamprey died as a result of culture problems, but most dead fish were mature and presumably ready to spawn. If December can be considered to approximate the time of entry into salt water, the three lamprey alive in December 1978 completed at least 4-yr residence in salt water. Similar experiments were repeated in 1976, 1977, 1978, and 1979 and the results to date are similar.

It is possible that the remaining fish in December 1978 were older than one year in December 1975 and it also can be argued that if these lamprey had been in a natural system they would return to freshwater at an earlier date. River lamprey held in tanks in this study did not survive past the normal spawning time indicating laboratory observations were representative of the natural life cycle. Most landlocked sea lamprey (*Petromyzon marinus*) held in laboratory tanks, matured and showed signs of irreversible physical degeneration (Parker and Lennon 1956) at about the same time as reported for wild fish (Applegate 1950). However, Parker and Lennon (1956) did observe that a few lamprey survived longer than others. Thus it appears that holding in the laboratory may extend the parasitic life of some lamprey. It is also possible that some lamprey do have a longer parasitic period than other individuals of the same species since variation in the duration of saltwater life is known to occur

TABLE 5. Size of maturing Pacific lamprey in freshwater.

Location		Mean length (cm)	Range (cm)	No.
Quinsam River	1978[a,h]	20	18–26	7
Chemainus River	1978[b,h]	27	17–38	131
Bonsall Creek	1978[b,h]	26	13–31	18
Qualicum River	1978[a,h]	19	16–24	6
Kennedy Lake tributary river	1979[a,c,h]	29	23–45	5
Robertson Creek	1978[a,d,j]	28	22–40	11
Babine Lake unnamed creek	1979[a,e,j]	49	42–59	52
	1979[i]	48	41–56	255
	total	48	41–59	307
Babine Lake	1979[b,e,i]	64	55–67	14
Bulkley Falls	1979[b,f,j]	60	55–69	32
	1979[i]	58	48–65	46
	total	59	48–69	78
Moricetown Falls	1979[b,g,i]	64	56–72	9
Stamp River	1979[b,j]	29	23–51	1226

[a]Sampled during spawning period.
[b]Sampled during upstream migration.
[c]49°35′N, 125°30′W.
[d]Robertson Creek is located in the vicinity of Stamp River (Fig. 1).
[e]54°N, 126°W.
[f]54°29′N, 129°16′W.
[g]55°02′N, 127°41′W.
[h]Measured after preservation in 5% formalin.
[i]Measured after freezing.
[j]Measured with no preservation.

for other anadromous fishes such as sockeye and chinook salmon (Hart 1973). If the laboratory observations are representative of a natural life cycle, Pacific lamprey remain and feed in salt water for a period up to 3½ yr if they return to freshwater in the spring.

There is a wide range in the size of adult Pacific lamprey. This difference in size is most obvious when the sizes of returning adults are examined (Table 5). The sizes recorded in freshwater probably underestimate the maximum size because maturing adult lamprey decrease in length as observed in this study and for other species (Beamish 1980; Larsen 1973). While the sample size in Table 5 is small it is apparent that mature Pacific lamprey range in length from 13 to at least 72 cm. Pletcher (1963) also describes a wide range of lengths for Pacific lamprey. The 66 specimens captured in this study in the Strait of Georgia and the 9 specimens found in other areas off the west coast of Canada ranged in size from 12 to 42 cm. It is possible that the very small mature Pacific lamprey found in the Qualicum and Quinsam rivers may not remain in salt water as long as the larger lamprey and some may even remain in freshwater. Until more information is available it might be assumed that the moderate to large lamprey (25–50 cm) spend approximately 3½ yr in salt water.

SEX RATIO

Little information was available concerning the sex ratio of adults captured at sea. Thirty-nine of the 61 specimens captured in the Strait of Georgia were sexed and the ratio was 1.4 males to 1 female. The sex ratios of males to females returning to the Stamp River, Bulkley River, Babine Lake, Chemainus River and Bonsall Creek were 2:1, 0.8:1, 1:1, 1:1, 1:1, respectively. Except for the Stamp River sample, the ratio of males to females was equal, thus it is probable that sex ratios at sea are about equal.

RETURN TO FRESHWATER

Since larger Pacific lamprey are found in only some rivers such as in the Skeena River system, it is probable that at least some lamprey return to their native streams to spawn. However, more information about the size compositions of adults from more rivers is needed before the importance of homing can be assessed.

Pacific lamprey have been reported to return to freshwater from May to September, overwinter in freshwater and spawn April to June and possibly as late as July (Pletcher 1963, Carl et al. 1967, Moffett and Smith 1950). In the Chemainus River, except for a few days, upstream traps were in place close to the mouth of the river from April 20 until June 27. A total of 131 adult lamprey were captured during the period April 23 to May 31 with 94% of the catches occurring between May 5 and 10. Sixty males and 64 females were captured with about equal numbers of males and females in the daily catches. In Bonsall Creek, the upstream trap close to the mouth of the river captured 18 adult Pacific lamprey from May 1 until May 17. The trap was in operation from April 15 until June 1 and equal numbers of males and females were captured.

In the Stamp River, Pacific lamprey were collected in an artifical river bypass or fishway, 14 km from the mouth of the river. The first sample was collected in mid-June, 1979 from an estimated 2500 individuals and at the end of August approximately 300 lamprey were still migrating through the fishway. Observations of movements of tagged lamprey confirmed that the lamprey were actually migrating through the fishway. By the end of September the fishway contained about 250 lamprey. While some lamprey tagged in August were still migrating through the fishway in September it appeared that most lamprey had completed their migration by mid-August. In 1980 no migration was observed until May and since the fishway is approximately 14 km from the ocean it is probable that upstream migrations commenced in April. At a fish counting fence, 400 km from the mouth of the Skeena River and 13 km downstream from Babine Lake, upstream migrating Pacific lamprey were first observed in mid-August at about the same time Pacific lamprey were observed in other tributaries of the Skeena River (Table 5). It was interesting that Pacific lamprey were observed spawning in the Babine Lake area in early July 1979 only 4–6 wk prior to the arrival of next year's spawning individuals. Since these sites are approximately 400 km from the mouth of the Skeena River it is probable that entry into freshwater occurred in April-May as observed in other rivers. Migration into one of the smaller headwater streams of the Skeena River was completed by the end of September 1979. The lamprey apparently remain in the uppermost region of the stream or in a small lake until they spawn in mid-June. Richards (1980) observed young-of-the-year ammocoetes in the uppermost regions of the tributary streams of the Chemainus River indicating adults migrated well upstream prior to spawning. The movement of adult Pacific lamprey into the headwater areas, often through rapids and over waterfalls indicates the species has exceptional migratory instincts. Spawning in the uppermost areas also allows for maximum usage of suitable stream habitats assuming young ammocoetes gradually migrate downstream.

Ovaries from upstream migrating lamprey in the Stamp River in August and the Skeena River in September occupied less than one-third to about two-thirds of the body cavity, respectively. Egg diameters for lamprey from the Stamp and Skeena rivers were approximately 1.0 and 0.7 mm, respectively. The abdomens of all females were not distended and there was no evidence of postanal length reductions or dorsal fin space reductions. Although the females were maturing there was little doubt that they were not close to spawning condition, indicating spawning would not occur until the following spring. Upstream migrants from the Stamp River, held in the laboratory in 1979/80, did not spawn until the spring following entry into freshwater.

It is important that a distinction is made between the time upstream migrations occur in freshwater and the time Pacific lamprey enter freshwater. The observations in this study indicate that entry into freshwater occurs from April to June while most migrations in freshwater streams probably are complete by late September. The statement that the return to freshwater occurs from May to October (Moffett and Smith 1950; Pletcher 1963; Hart 1973) fails to acknowledge that most lamprey enter freshwater early in the spring. This can result in the incorrect assumption mentioned earlier, that Pacific lamprey feeding on maturing salmon in estuaries migrate upstream with the salmon.

Spawning lamprey in June and July in Babine Lake averaged 48 cm in length (Table 5). Lamprey returning to Babine Lake, Bulkley Falls, and Moricetown Falls in August and September, all migrate up the Skeena River and had a similar mean length of 60 cm (Table 5). If average lengths are similar each year, Pacific lamprey in the Skeena River system decrease approximately 12 cm in length from the postmigration period until spawning is complete. This 20% average decrease in length is similar to the 21% decrease previously described for river lamprey, but undoubtedly underestimates the actual amount of shrinkage since the lengths at the time of entry into freshwater were unknown. As reported for other species (Beamish 1980) there was a disproportionate reduction in length of females (23%) compared to males (15%).

Pletcher (1963) observed that April to May was the main spawning period for Pacific lamprey. In this study, Pacific lamprey were observed spawning in a small stream flowing into Babine Lake in early July, 1979 and Pacific lamprey have been observed spawning in the Stamp River in April and in the Englishman River (Fig. 1) in June. Since entry into freshwater occurs from April to June and spawning occurs from April until early July, the average residence of maturing adults in freshwater is about 1 yr. If the period of saltwater residence is about 3½ yr for adults returning to freshwater in the spring, then the period of adult life from the onset of metamorphosis in July to death following spawning is 5 yr.

In smaller rivers, smaller Pacific lamprey were observed to spawn several kilometres from the mouth of the river. It is possible that entry into such rivers occurs in the same year as spawning and the length of saltwater residence may be shorter or longer than 3½ yr.

The spawning and nesting behavior of the Pacific lamprey has been described by Pletcher (1963) and appears to be similar to that of other lamprey. Following spawning, Pacific lamprey have been reported to survive until July (Moffett and Smith 1950). In this study dead, spawned Pacific lamprey were observed in Robertson Creek on Vancouver Island in late April and in Babine Lake in July. A sample of eight live

Pacific lamprey of various sizes that had recently spawned, died when they were reintroduced to full strength salt water in the laboratory over a 3-d period. A sample of six upstream migrating adult lamprey, collected in August 1979 from the fishway at Stamp River also could not be acclimated to salt water over a 3-d period. Thus, after Pacific lamprey enter freshwater in preparation for spawning, they do not return to salt water.

Effect on Commercially Important Fishes in Waters off Canada's West Coast

Very little is known about the size of stocks of Pacific lamprey, however, casual observations at fish counting fences and by commercial fishermen indicate that the numbers of Pacific lamprey may be increasing, at least in some areas. No Pacific lamprey were observed at the fish counting fence near Babine Lake from 1956 to 1962. From 1963 to the present the number of lamprey at the fence has been increasing (F. Jordan, Pacific Biological Station, Nanaimo, B.C., personal communication) and in 1977 I received the first unconfirmed report of a lamprey attacking a fish in Babine Lake. Williams and Gilhousen (1968) reported that fishermen first reported cases of severe lamprey parasitism on Fraser River sockeye in 1967. In 1979 several fishermen reported their first observations of lamprey attacking salmon off the west coast of Vancouver Island, while others reported the incidence of lamprey attacks on salmon was higher than in the past.

The number of streams and rivers that contain Pacific lamprey is unknown. However, Carl et al. (1967) believed Pacific lamprey may be present in all coastal streams and in this study all of the 10–20 streams that have been examined have contained Pacific lamprey. If all or almost all of the coastal streams and rivers contain Pacific lamprey, the numbers of adults may be large, and if Pacific lamprey remain in salt water for 3½ yr they may be an important and overlooked predator of juvenile and adult marine fishes.

Pacific lamprey contribute to the mortality of young salmon but the relative importance of this mortality is unknown. Active predation on juvenile sockeye salmon was observed in this study in the Strait of Georgia and some preliminary unpublished trapping information indicates that in some rivers the movements of Pacific lamprey and juvenile sockeye salmon into salt water are synchronous. Preliminary results from laboratory feeding experiments indicate that one Pacific lamprey in its first year in salt water can kill one salmon of 15–20 cm in length about every 2–4 d. Thus the attacks and in some cases resulting mortalities may be more important than formerly thought. The nonanadromous parasitic lamprey in Mesachie Lake attack a significant number of the resident salmonids. A sample of 221 salmonids contained 122 fish with lamprey attacks and 32 of these attacks (15%) penetrated the body cavity or penetrated deeply into the muscle and probably would result in the death of the fish. Salmonids that were killed by lamprey attacks have been found on the bottom of Mesachie Lake from June until September when observations were terminated. It is apparent that Pacific lamprey are an active predator of marine and sometimes freshwater fishes; however, their role as a predator of commercially important species in relation to other predators is difficult to assess until better estimates of their abundance and food preferences can be determined.

Comparisons and Conclusions

While there is much more to learn about river and Pacific lampreys, it is apparent that the two species differ greatly in many aspects of their adult biology. It is suspected that the date of metamorphosis is similar but it appears that Pacific lamprey enter salt water earlier and perhaps over a longer period. Downstream trapping and fishing in salt water suggested that Pacific lamprey enter salt water in late fall or early winter and continue to enter salt water into the summer. The bulk of river lamprey catches occurred in downstream traps in late May and June and no river lamprey were found in salt water in April or May.

Once in salt water, river lamprey were found in the surface waters and concentrated in the general vicinity of the larger rivers suggesting river lamprey preferred water of reduced salinity. Pacific lamprey were found at greater depths often associated with layers of plankton. Pacific lamprey were more abundant than river lamprey but river lamprey could not be considered to be rare. While Pacific lamprey or evidence of Pacific lamprey attacks were observed on fishes associated with the midwater depths, the evidence of rather substantial predations on greenland turbot from the Bering Sea indicates that this species occurs throughout a wide depth range when at sea. Pacific lamprey or animals attacked by Pacific lamprey were caught well offshore indicating that Pacific lamprey migrated greater distances than river lamprey. River lamprey had a more restrictive diet preferring smaller herring and some smaller salmon. They attacked dorsally and anteriorly and consumed chunks of tissue. Pacific lamprey may feed on herring when first in salt water but generally feed on a variety of fishes and mammals. Pacific lamprey attacked ventrally or laterally apparently preferring body fluids to chunks of flesh.

Adult Pacific lamprey can be much larger than river lamprey, partly as a result of the longer period Pacific lamprey spend in salt water. Pacific lamprey can remain in salt water for 3½ yr while river lamprey may spend only 3–4 mo in salt water. River lamprey may return to freshwater over the period September to May but stocks of Pacific lamprey enter freshwater from April to June. The period of freshwater residence for most maturing Pacific lamprey is about 1 yr but it may be shorter for some other stocks. The period of freshwater residence for maturing river lamprey may be about 8 mo or shorter. Both species decrease in length during the prespawning residence in freshwater and in this study both species decreased in length by approximately 20%. Both species die following spawning.

Predators on adult river lamprey appear rare while Pacific lamprey may be a more common food item of fishes, seals, sea lions, and mammals. It is possible that ammocoetes of both species are consumed by other fishes.

Lampetra ayresi was considered to be conspecific with the European river lamprey *Lampetra fluviatilis* before Vladykov and Follett (1958) reviewed the systematics of those two forms and concluded that they were separate species. Even though these two forms are now considered to be distinct species there are some remarkable similarities in their adult biology. *Lampetra fluviatilis* may prefer water of reduced salinity (Bahr 1952) and feeds on small fish apparently preferring herring species (Bahr 1933; Eglite 1958a, b). When feeding, chunks of muscle, pieces of fins, and internal organs are consumed and attacks frequently occur in the dorsal region (Eglite 1958a). Adults returning to freshwater average 31–34 cm (Berg 1948) but a wide range in sizes of adults has been found. The smaller forms have been described by Berg (1948) as being distinct "praecox" varieties. Berg (1948) noted that some adults return to freshwater in the fall and some in the spring. Hardisty and Potter (1971) consider that from metamorphosis to spawning the duration of adult life of *Lampetra fluviatilis* is about 2½ yr. This is slightly longer than the period of 2 yr observed for *Lampetra ayresi* in this study.

All of the preceding adult characteristics of *Lampetra fluviatilis* were similar to *Lampetra ayresi*. The similarities in form and the biology of the adults of these two species clearly suggest a close relationship at some time in the past.

Acknowledgments

Many people contributed directly or indirectly to this study by sending me their observations on lamprey, saving specimens or simply passing on my requests for assistance. I appreciate their assistance and look forward to their continued cooperation. I particularly wish to thank the many fisheries officers and fishermen that saved specimens or sent information about lamprey. Mr Vince Pullen from Beak Consultants Ltd. kindly provided the lamprey samples from their study of salmon distribution in the lower Fraser River. Jerry Best, Wendy Mitton, Don Myers, John Richards, Ray Scarsbrook, Carl Peterson, Danny Pozar, Stephanie Pullen, Harvey Scott, Mike Smith, Jim Thompson, Keni Weir, Nancy Williams, and Heidi Zeis were particularly helpful with analysis of data, the collection and sorting of samples, and the holding and feeding of live specimens.

ABAKUMOV, V. A. 1964. Some data on the ocean period in the life-cycle of lamprey (*Entosphenus tridentatus* Richardson). Trudy vses. nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 49: 253–256. (In Russian)

APPLEGATE, V. C. 1950. Natural history of the sea lamprey, *Petromyzon marinus* in Michigan. U.S. Fish. Wildl. Serv. Spec. Sci. Rep. Fish. 55: 237 p.

BAHR, K. 1933. Das Flussneunauge (*Lampetra fluviatilis*) als Urheber von Fischverletzungen. Mitt. Dtsch. Seefisch. Ver. 49(1): 3–8.

1952. Beitraege zur Biologie des Flussneunauges, *Petromyzon fluviatilis* L. (Lebensraum und Ernaehrung). Zool. Jahrb. Abt. Syst. Oekol. Geogr. Tiere. 81: 408–436.

BARRACLOUGH, W. E., AND J. D. FULTON. 1967. Data record. Number, size composition and food of larval and juvenile fish caught with a two-boat surface trawl in the Strait of Georgia July 4–8, 1966. Fish. Res. Board Can. MS Rep. 940: 82 p.

BEAMISH, F. W. H. 1980. Biology of the North American anadromous sea lamprey, *Petromyzon marinus*. Can. J. Fish. Aquat. Sci. 37: 1924–1943.

BEAMISH, R. J., AND J. R. SCARSBROOK. 1979. Data for the study of the distribution and feeding habits of lampreys in the surface waters of the Gulf Islands and in the vicinity of the Fraser River, British Columbia. Fish. Mar. Serv. Data Rep. 136: 353 p.

BEAMISH, R. J., M. SMITH, R. SCARSBROOK, AND C. WOOD. 1976. Hake and pollock study, Strait of Georgia cruise G. B. REED, June 16–27, 1975. Fish. Mar. Serv. Data Rec. 1: 174 p.

BEAMISH, R. J., AND N. E. WILLIAMS. 1976. A preliminary report on the effects of river lamprey (*Lampetra ayersii*) predation on salmon and herring stocks. Fish. Mar. Serv. Res. Dev. Tech. Rep. 611: 26 p.

BERG, L. S. 1948. Freshwater fishes of the USSR and adjacent countries. Acad. Sci. USSR. Zool. Inst.: Guide to the Fauna of the USSR, No. 27. (Transl. from Russian for Nat. Sci. Found., Wash., D.C. by the Israel Program for Scientific Translations, Jerusalem, 1962. Vol. 1: 18–52, 494.)

BIRMAN, I. B. 1950. Parasitism of salmon of the genus *Oncorhynchus* by the Pacific lamprey. Vladivostok. Tikhookean. Nauchno-issled. Inst. Rybn. Khoz. Okeanogr. (TINRO) Izv. 32: 158–160. (Transl. from Russian by Fish. Res. Board. Can., Transl. Ser. 290 (1960): 3 p.)

CARL, G. C. 1953. Limnobiology of Cowichan Lake, British Columbia. J. Fish. Res. Board Can. 9: 417–449.

CARL, G. C., W. A. CLEMENS, AND C. C. LINDSEY. 1967. The freshwater fishes of British Columbia. B.C. Prov. Mus., Handbook No. 5: 192 p.

EGLITE, R. 1958a. Feeding habits of *Lampetra fluviatilis* L. in the sea. Zool. Zh. 37(10): 1509–1514.

1958b. The biology of the river lamprey in the Latvian SSR. Gidrobiol. Issled., Tartu 1: 234–269.

HANSON, L. H., E. L. KING JR., J. H. HOWELL, AND A. J. SMITH. 1974. A culture method for sea lamprey larvae. Prog. Fish-Cult. 36(3): 122–128.

HARDISTY, M. W., AND I. C. POTTER [ed.]. 1971. The biology of lampreys. Academic Press. London, New York. Vol. 1: 424 p.

HART, J. L. 1973. Pacific fishes of Canada. Bull. Fish. Res. Board Can. 180: 740 p.

HUBBS, C. L. 1967. Occurrence of the Pacific lamprey, *Entosphenus tridentatus*, off Baja California and in streams of Southern California; with remarks on its nomenclature. Trans. San Diego Soc. Nat. Hist. 14: 301–312.

1971. *Lampetra* (*Entosphenus*) *lethophaga*, new species, the nonparasitic derivative of the Pacific lamprey. Trans. San Diego. Soc. Nat. Hist. 16: 125–164.

JAMESON, R. J., AND K. W. KENYON. 1977. Prey of sea lions in the Rogue River, Oregon. J. Mammal. 58(4): 672.
KAN, T. T. 1975. Systematics, variation, distribution and biology of lampreys of the genus *Lampetra* in Oregon. Ph.D. thesis, Oregon State Univ., Corvallis, OR. 194 p.
LACK, D. 1954. The natural regulation of animal numbers. Clarendon Press, Oxford. 343 p.
LARKINS, H. A. 1964. Some epipelagic fishes of the North Pacific Ocean, Bering Sea, and Gulf of Alaska. Trans. Am. Fish. Soc. 93: 286–290.
LARSEN, L. O. 1973. Development in adult, freshwater river lampreys and its hormonal control. Starvation, sexual maturation and natural death. Copenhagen. 172 p.
MASON, J. C. 1974. Movements of fish populations in Lymn Creek Vancouver Island: a summary from weir operations during 1971 and 1972 including comments on species life histories. Fish. Mar. Serv. Tech. Rep. 483: 35 p.
MOFFETT, J. W., AND S. H. SMITH. 1950. Biological investigations of the fishery resources of Trinity River, California. U.S. Fish. Wildl. Serv. Spec. Sci. Rep. Fish. 12: 70 p.
MORRIS, R. 1971. Osmoregulation, p. 193–239. *In* M. W. Hardisty and I. C. Potter [ed.] The biology of lampreys. Vol. 2. Academic Press, London and New York.
NOVIKOV, N. P. 1963. Attacks of *Entosphenus tridentatus* on halibut and other fish of the Bering Sea. Vopr. Ikhtiol. 3(28): 567–569.
PARKER, P. S., AND R. E. LENNON. 1956. Biology of the sea lamprey in its parasitic phase. U.S. Fish. Wildl. Serv. Res. Rep. 44: 32 p.
PIKE, G. C. 1950. Stomach contents of whales caught off the coast of British Columbia. Fish. Res. Board Can. Prog. Rep. Pac. Coast Stations 83: 27–28.
1951. Lamprey marks on whales. J. Fish. Res. Board Can. 8(4): 275–280.
PLETCHER, F. T. 1963. The life history and distribution of lampreys in the Salmon and certain other rivers in British Columbia, Canada. MSc. thesis, Univ. British Columbia, Vancouver, B.C. 195 p.
RICHARDS, J. E. 1980. Freshwater life history of the anadromous Pacific lamprey *Lampetra tridentata*. M.Sc. thesis, Univ. Guelph, Guelph, Ont., Canada. 99 p.
ROBINSON, D. G. 1969. Data record. Number, size composition, weight and food of larval and juvenile fish caught with a two-boat surface trawl in the Strait of Georgia July 4–6, 1967. Fish. Res. Board Can. MS Rep. 1012: 71 p.
ROBINSON, D. G., W. E. BARRACLOUGH, AND J. D. FULTON. 1968a. Data record. Number, size composition, weight and food of larval and juvenile fish caught with a two-boat surface trawl in the Strait of Georgia May 1–4, 1967. Fish. Res. Board Can. MS Rep. 964: 105 p.
1968b. Data record. Number, size composition, weight and food of larval and juvenile fish caught with a two-boat surface trawl in the Strait of Georgia June 5–9, 1967. Fish. Res. Board Can. MS Rep. 972: 109 p.
ROOS, J. F., P. GILHOUSEN, S. R. KILLICK, AND E. R. ZYBLUT. 1973. Parasitism on juvenile Pacific salmon (*Oncorhynchus*) and Pacific herring (*Clupea harengus pallasi*) in the Strait of Georgia by the river lamprey (*Lampetra ayresi*). J. Fish. Res. Board Can. 30: 565–568.
SCARSBROOK, J. R., R. J. BEAMISH, AND M. S. SMITH. 1980. Hake and pollock study, Strait of Georgia, G. B. REED cruise May 31–June 18, 1976. Can. Data. Rep. Fish. Aquat. Sci. (In press)
SOLDATOV, V. K. 1934. Fishery Ichthyology. Part I. Cited by I. B. Birman. 1950. Fish. Res. Board Can., Transl. Ser. 290: 3 p.
VLADYKOV, V. D., AND W. I. FOLLETT. 1958. Redescription of *Lampetra ayresii* (Günther) of western North America, a species of lamprey (Petromyzontidae) distinct from *Lampetra fluviatilis* (Linnaeus) of Europe. J. Fish. Res. Board Can. 15(1): 47–77.
1965. *Lampetra richardsoni*, a new nonparasitic species of lamprey (Petromyzonidae) from western North America. J. Fish. Res. Board Can. 22: 139–158.
WALDICHUK, M. 1957. Physical oceanography of the Strait of Georgia, British Columbia. J. Fish. Res. Board Can. 14: 321–486.
WILLIAMS, I. V., AND P. GILHOUSEN. 1968. Lamprey parasitism on Fraser River sockeye and pink salmon during 1967. Int. Pac. Salmon. Fish. Comm. Prog. Rep. 18: 22 p.
WITHLER, F. C. 1955. Coho salmon fingerling attacked by young lamprey. Fish. Res. Board Can. Pac. Prog. Rep. 104: p. 15.
YOUSON, J. H., AND I. C. POTTER. 1979. A description of the stages in the metamorphosis of the anadromous sea lamprey, *Petromyzon marinus* L. Can. J. Zool. 57: 1808–1817.

MOVEMENT OF BULL TROUT WITHIN THE MID-COLUMBIA RIVER AND TRIBUTARIES, 2001-2004

Final

ROCKY REACH HYDROELECTRIC PROJECT
FERC Project No. 2145

ROCK ISLAND HYDROELECTRIC PROJECT
FERC Project No. 943

WELLS HYDROELECTRIC PROJECT
FERC Project No. 2149

PRIEST RAPIDS HYDROELECTRIC PROJECT
FERC Project No. 2114

May 26, 2004

Prepared by:
BioAnalysts, Inc.
Eagle, Idaho

Prepared for:
Public Utility District No. 1 of Chelan County
Wenatchee, Washington

Public Utility District No. 1 of Douglas County
East Wenatchee, Washington
&
Public Utility District No. 1 of Grant County
Ephrata, Washington

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SECTION 1: INTRODUCTION

On 10 June 1998, the U.S. Fish and Wildlife Service (Service) listed bull trout (*Salvelinus confluentus*) within the Columbia River basin as threatened under the Endangered Species Act (ESA) (50 CFR 63(111)). Later (1 November 1999), the Service listed bull trout within the coterminous United States as threatened under the ESA (50 CFR 64(210)). The Service identified habitat degradation, fragmentation and alterations associated with dewatering, road construction and maintenance, mining, and grazing; blockage of migratory corridors by dams or other diversion structures; poor water quality; incidental angler harvest; entrainment into diversion channels; and introduced non-native species as major factors affecting the distribution and abundance of bull trout. They noted that dams (and natural barriers) have isolated population segments resulting in a loss of genetic exchange among these segments (50 CFR 63(111):31657). The Service believes many populations are now isolated and disjunct.

In a letter to the Federal Energy Regulatory Commission (FERC), the Service requested consultation under Section 7 of the ESA regarding the effects of hydroelectric project operations on bull trout in the Columbia River (letter from M. Miller, USFWS, to M. Robinson, FERC, dated 10 January 2000). The request for consultation was based on observations of bull trout in the study area. In its reply to the Service, the FERC noted that there was virtually no information on bull trout in the mainstem Columbia River.

Because bull trout within the mid-Columbia River[1] area are listed under the ESA (50 CFR 63(111):31651), and they may be affected by the operation of hydro-projects owned and operated by Chelan, Douglas, and Grant PUDs (Mid-Columbia PUDs), the Mid-Columbia PUDs initiated a multi-year evaluation of the status of bull trout in the project area. Currently, little is known about the life-history characteristics (e.g., movements, distribution, habitat use, etc.) of bull trout in the mid-Columbia River. Therefore, in order to assess the operational effects of hydroelectric projects on adult bull trout within the mid-Columbia, a total of 79 adult bull trout were radio-tagged during the 2001-2003 study period and tracked to describe their movements within the mid-Columbia Basin.

The specific objectives of the study were to: (1) describe the movements and migration of adult bull trout in the mid-Columbia system and (2) assess the effects of hydroelectric operations on the movement and migration patterns of adult bull trout in the mid-Columbia River. This report focuses primarily on the last two years of the study, because the first year of work has already been reported (BioAnalysts, Inc. 2002). However, for comparative purposes, the results for all three years of research have been included into one report. For additional information on the first year of this study, please refer to the publication BioAnalysts, Inc. (2002).

[1] In this document, the mid-Columbia River is defined as the area between the confluence of the Yakima and Columbia rivers and Chief Joseph Dam. NOAA Fisheries refers to this area as the upper-Columbia River.

SECTION 2: PROJECT AREA

The primary geographical area of interest was the mainstem Columbia River from Priest Rapids Dam to Chief Joseph Dam (Figure 1). It is within this area that the effects of Priest Rapids, Wanapum, Rock Island, Rocky Reach, and Wells dams were assessed regarding the movements and migration of adult bull trout. At these dams, fixed-site radio-telemetry systems were installed to monitor the movements of radio-tagged bull trout. The study area also included the four major tributaries to the mid-Columbia River; Wenatchee, Entiat, Methow, and Okanogan systems. Both fixed-site and mobile telemetry surveys monitored the movement of radio-tagged bull trout within each of the major tributary streams.

Columbia River flows in the project area during the period May through October 2001-2003 are shown in Figure 2, Figure 3, Figure 4, Figure 5 and Figure 6. Discharge at the mid-Columbia River projects was a combination of turbine generation and spill generally from the first of May to the end of August. However, minimal spill levels continued at Priest and Wanapum dams until the end of October. Similar spill operations did not occur at Wells, Rocky Reach and Rock Island dams. Migration of bull trout upstream through each of the projects was provided by a fishway ladder system. These ladder systems consist of one or more main entrances located in the tailrace of each project. Some projects (e.g., Priest Rapids, Wanapum, and Rocky Reach dams) also include orifice gates (O.G. gates) that are used to provide additional entrances to the collection channels of the main ladder system. Migration downstream past mid-Columbia River projects likely occurs through powerhouse or spillway passage routes and may also include juvenile bypass collection facilities.

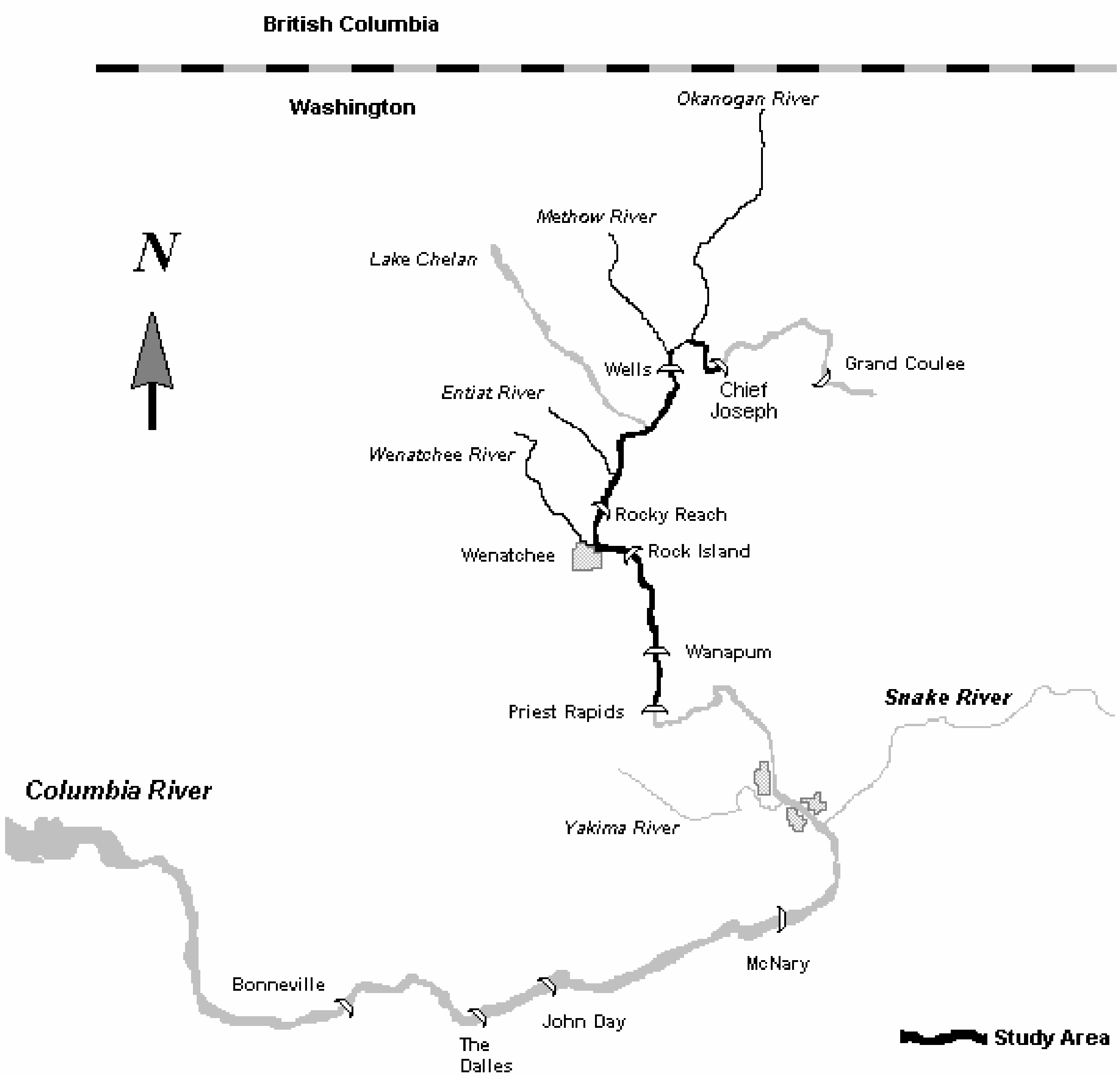


Figure 1: Study area for assessing migration patterns of bull trout in the mid-Columbia River. Fixed radio-telemetry sites monitored the movement of bull trout near Priest Rapids, Wanapum, Rock Island, Rocky Reach, and Wells dams. Fixed sites placed in the Wenatchee, Entiat, Methow, and Okanogan rivers monitored time of entry and exodus of bull trout in large tributaries of the mid-Columbia River.

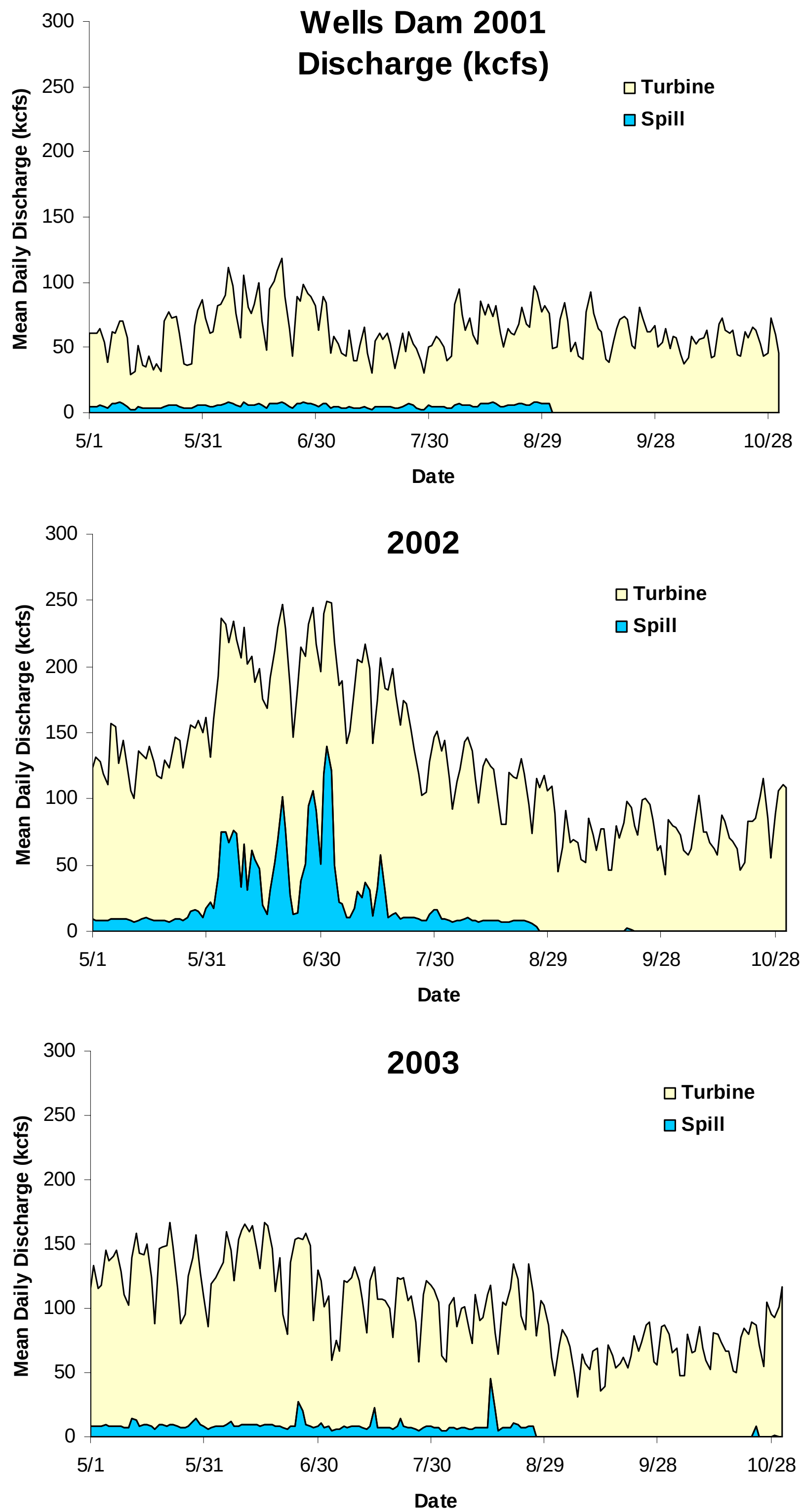


Figure 2: Columbia River flows passing through Wells Dam during the period May through October, 2001-2003.

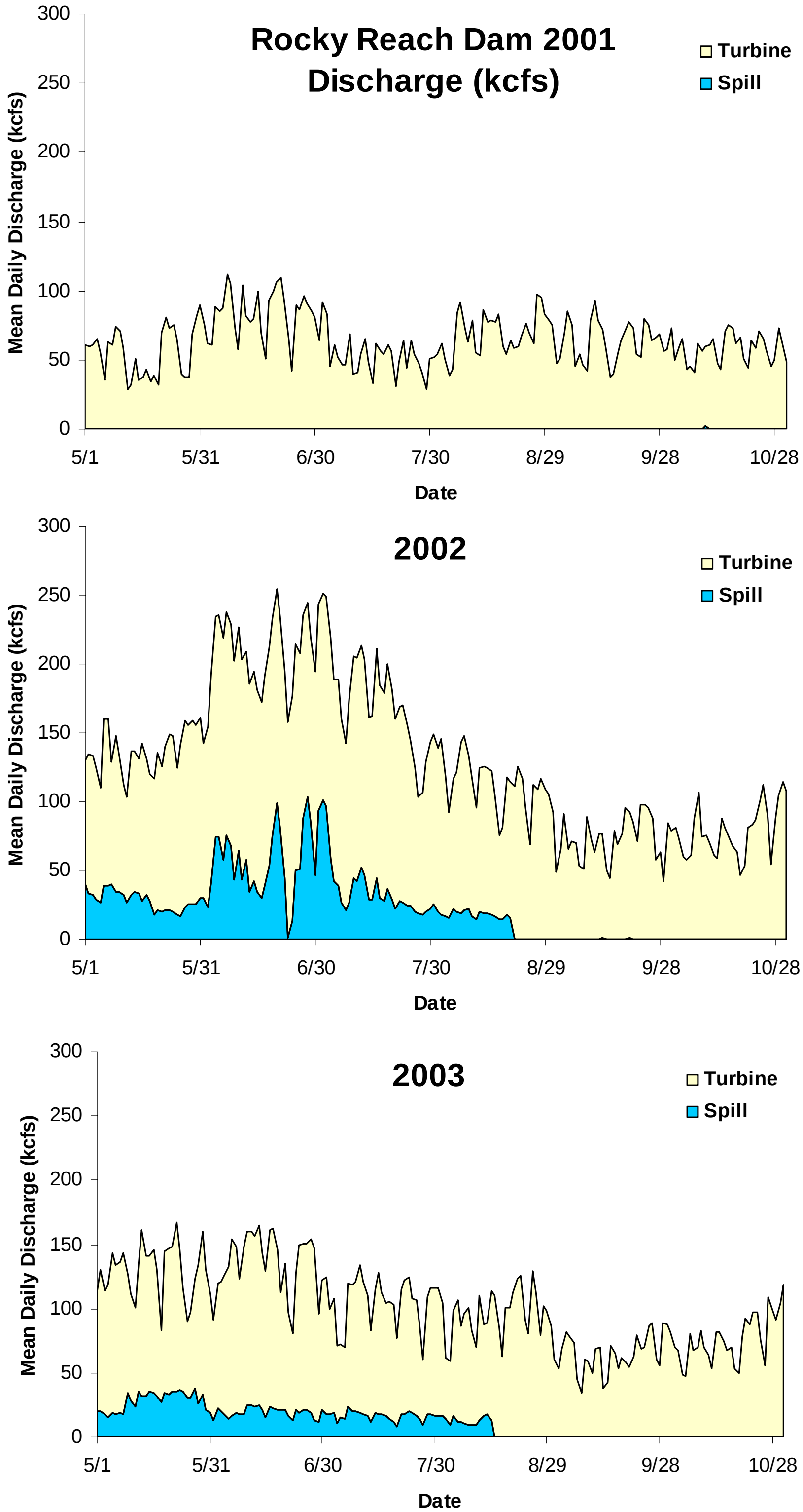


Figure 3: Columbia River flows passing through Rocky Reach dam during the period May through October, 2001-2003.

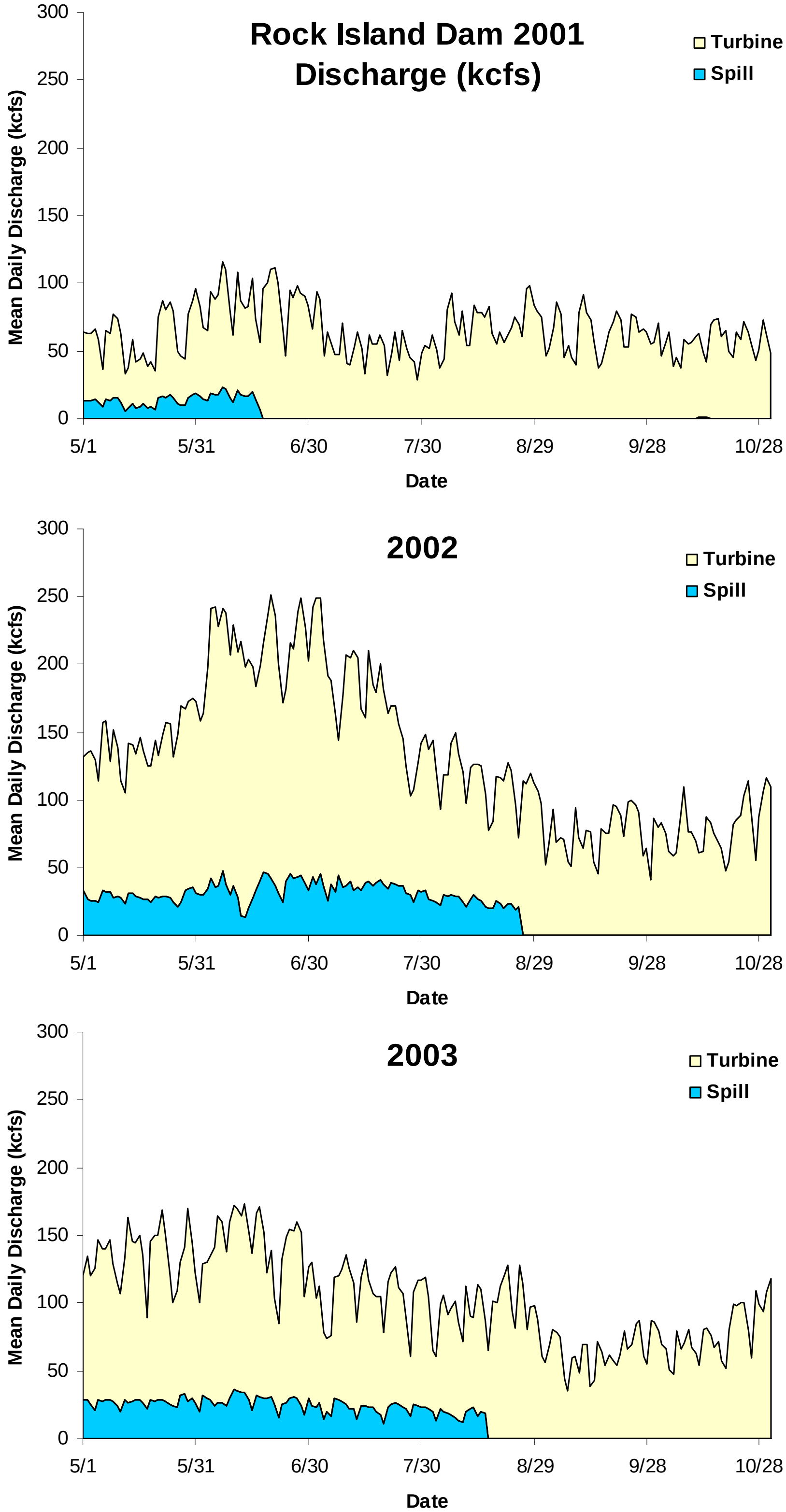


Figure 4: Columbia River flows passing through Rock Island dam during the period May through October, 2001-2003.

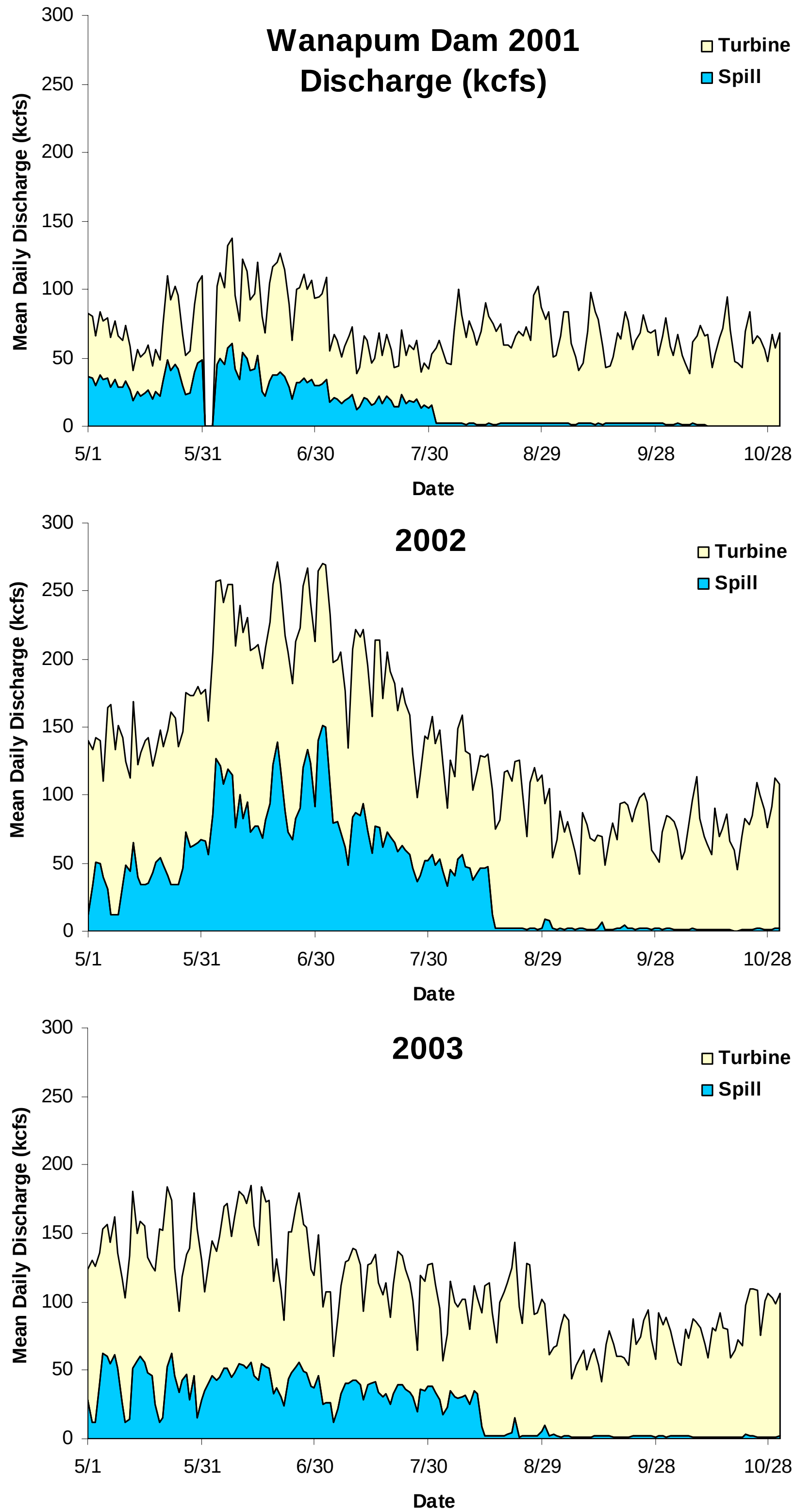


Figure 5: Columbia River flows passing through Wanapum dam during the period May through October, 2001-2003.

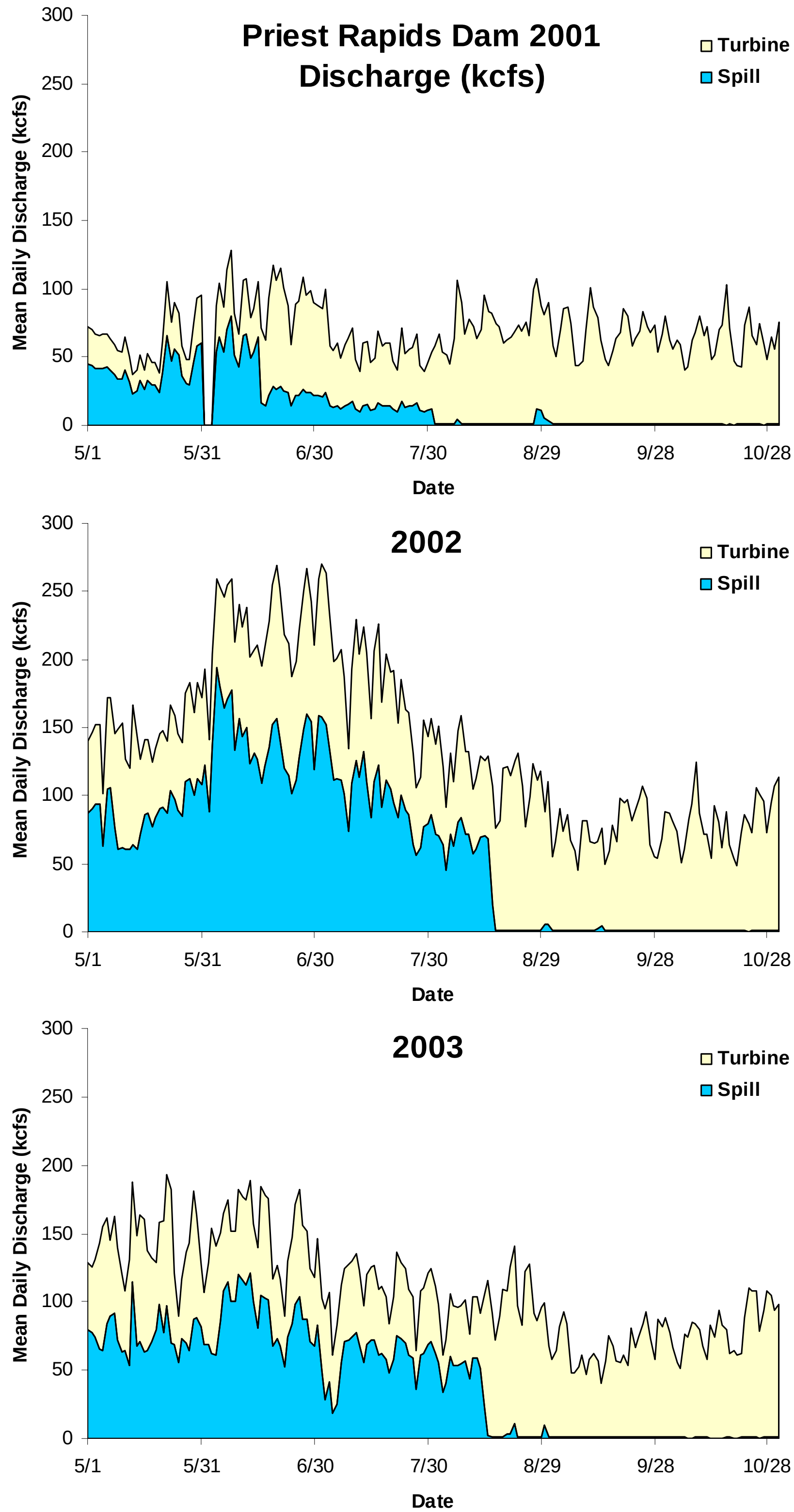


Figure 6: Columbia River flows passing through Priest Rapids dam during the period May through October, 2001-2003.

SECTION 3: METHODS

This study relied on radiotelemetry techniques to monitor the movements and migration patterns of adult bull trout in the mid-Columbia River. Below, is a description of the number of fish tagged in 2002, including the tagging procedures and monitoring systems used in 2002 and 2003. Study methods for the 2001 study period are summarized in BioAnalysts, Inc. (2002). However, it should be noted that all methods and monitoring systems were consistent in all three years of the study.

3.1 Number of Bull Trout Tagged

To assess the movements and migration of adult bull trout, the original proposal was to tag a total of 40 bull trout in the mid-Columbia River in 2002. This number was consistent with tagging efforts in 2001[2] and was based on discussions with the Service. This sample size represented about 20% of all bull trout counted at the dams in previous years. The number of trout to be collected and tagged at each dam was based on the proportion of fish that migrated past those dams in 2000. Because more bull trout pass Rocky Reach Dam than Rock Island or Wells dams, the target was to capture and tag 10 adult bull trout at Rock Island Dam, 20 at Rocky Reach Dam, and 10 at Wells Dam. Bull trout were sampled during mid-May to late-June, which coincides with the period when the most bull trout are observed passing through the three dams (Figure 7, Figure 8 and Figure 9). No attempts were made to tag at Priest or Wanapum dams because very few bull trout are observed moving past those projects.

To avoid a temporal bias in the sampling program, bull trout were collected throughout the spring migration period (20 May to 27 June) at Rocky Reach Dam by establishing weekly tagging targets. These weekly targets were based on the proportion of fish observed at Rocky Reach Dam in 2000 and 2001 (Table 1). That is, bull trout were captured throughout the passage period, but a greater number were collected and tagged during the period of peak passage.

In order to describe passage distribution, the number of bull trout passing Rocky Reach Dam during each week in 2000 and 2001 were compiled. From those data, the proportion of the total run that passed the project during each week was then calculated. The numbers of bull trout captured and tagged at the dam during each week of the 2002 sampling period was estimated from the product of the weekly proportions and total sample size (i.e., 20 fish at Rocky Reach) (Table 1). At most, five fish were to be collected and tagged during a given sampling week (Table 1). Because of the desire to maintain the predetermined tagging schedule, it was decided that if the weekly tagging quotas were not met at the project, the deficit would be carried into the following week.

Diel passage data for adult bull trout at Rocky Reach and Rock Island dams indicated that most bull trout passed the projects between 0800-2300 hours (Figure 10 and Figure 11). Since the upstream release of radio-tagged fish at Rocky Reach Dam required logistical support from Chelan PUD, it was decided to operate the traps between 0800-1700 hours.

---

[2] In 2001, only 39 adult bull trout were captured and tagged. Because of the low number of bull trout that passed Rock Island Dam, only seven fish were collected and tagged there. The deficit was partially made up at Rocky Reach Dam, where 22 adult trout were collected and tagged (two more than the target). The goal of 10 bull trout at Wells Dam in 2001 was met.

No weekly tagging goals were established for the collection of bull trout at Rock Island or Wells dams in 2002. In 2001 at Rock Island, it was difficult to meet tagging quotas near the end of the tagging period. Therefore, the decision was made to collect and tag all fish as they passed the project. At Wells Dam, the overall trap operation time was reduced to minimize the potential for delay and harassment to migrating ESA listed spring Chinook salmon and steelhead. At Wells, collection and tagging began on 21 May and continued through 19 June with trap operation typically Monday through Wednesday between 0900-1400 hours (Figure 12).

Table 1: Weekly adult bull trout tagging schedule for Rocky Reach Dam, 2002. The tagging schedule was based on the proportion observed (counted) during the same period during the 2000 and 2001 migrations.

Week	Beginning	2000 and 2001 Observed Average	Tag
1	13-May	30.5	4
2	20-May	41.5	5
3	27-May	32.5	4
4	03-June	18.0	2
5	10-June	14.5	2
6	17-June	11.5	2
7	24-June	10.0	1
	Totals	**158.5**	**20**

3.2 Trapping Facilities

3.2.1 Rocky Reach and Rock Island Dams

Trap facilities at Rocky Reach and Rock Island dams are integrated with the existing fish-viewing structures within the ladders (Figure 13 and Figure 14). Essentially, the fish-viewing guide wall extends upstream to the exit weir, where a pneumatically-activated gate guides fish into a collection area. On the other side of the pneumatic gate the collection area contains a removable capture vessel. As a bull trout entered the viewing area, a technician activated the pneumatic gate, which blocked passage into the forebay and diverted the bull trout into the collection area. Using an underwater camera, the technician could observe the bull trout enter the collection area, at which time the gate would be closed, trapping the bull trout. Non-target species and small bull trout (<40 cm fork length) were allowed to exit the ladder by simply not activating the pneumatic gate. After a bull trout was contained within the collection area, either an electric or hand-operated winch raised the collection vessel from the collection area up to the work-surface platform. As the vessel emerged from the water, a wooden cover was placed on top of the vessel to reduce stress to the fish and eliminate the possibility of the fish jumping out of the vessel.

The captured bull trout was then transferred from the collection vessel to the surgical facility. To facilitate transfer and reduce handling stress, the bull trout was sedated with tricaine methanesulfonate (MS-222) at a concentration of 80 mg/L while the fish was contained in the collection vessel (see Surgical Techniques for detailed description of sedation). At Rocky Reach Dam, the collection vessel was moved laterally along an I-beam monorail close to the surgical facility located under the roadway of the ladder. The fish was then transferred by hand to the surgical table for processing. At Rock Island Dam, the surgical facility was located within a trailer about 10 m from the collection area. There, the fish was transferred in a rubber bladder filled with anesthetic water to the surgical facility.

3.2.2 Wells Dam

Bull trout at Wells Dam were trapped at the brood-stock collection facility located within the left bank ladder. The brood-stock collection facility is located at pool 40 about half way up the fish ladder. The trap is operated by placing a barrier fence across the entire width of pool. When the trap is in operation, all fish ascending the left bank ladder are blocked by the barrier fence and forced to ascend the off-ladder trap via a steep-pass denil that leads to an upwell enclosure. Once inside the upwell enclosure, fish move down a sorting chute by jets of water introduced near the top of the sorting chute. As the fish slide down the sorting chute, they are identified and either diverted into the holding tank or allowed to pass upstream of the trap. When a bull trout was observed in the chute, a technician activated a pneumatic gate diverting the fish into a 2,270-liter holding tank. Non-target species and small bull trout (<40 cm fork length) were shunted back to the ladder upstream of the trapping barrier. The fish ladder supplied the holding tank with freshwater at a rate of 114 to 151 L/hr to maintain adequate dissolved oxygen and temperature levels. At the time of tagging, bull trout were netted from the holding vessel and transferred to an anesthetic vessel containing an 80 mg/L solution of MS-222. Once anesthetized, fish were transferred to a mobile surgical station for further processing.

3.3 <u>Tagging Procedures</u>

3.3.1 Description of Radio Tags

Adult bull trout were implanted with digitally-encoded transmitters developed by Lotek Engineering. The transmitter, model MCFT-3A, was 16 mm in diameter, 46 mm long, and weighed 6.2 grams in water and 16.0 grams in air. With a 5.0-second burst rate, the estimated life of the transmitter was 761 days.

Winter (1983) identified a criterion of 2% for the ratio of transmitter to body weight (in air) as being acceptable. For transmitters used in this study, that criterion would allow the tagging of trout equal to or greater than 800 grams. However, more recent information suggests that a radio transmitter that is as much as 5-10% of the fish's body weight will not adversely affect fish behavior (Adams et al. 1998). Using the criterion of 5% would allow the tagging of fish as small as 320 grams, and 10% would allow the tagging of fish as small as 160 grams. Taking a conservative approach, a decision was made to only tag fish with a fork length greater than 40 cm (~650 grams). Based on this strategy, at most, the transmitter would amount to 2.5% of the fish's body weight.

3.3.2 Surgical Techniques

The surgical procedures employed are nearly identical to the methods described in Summerfelt and Smith (1990), with some modifications based on consultation with the Service. Bull trout were anesthetized in a pre-operative solution of MS 222 at a concentration of 80 mg/L. Service biologists found that 80 mg/L of MS 222 for initial induction, followed by a concentration of 40 mg/L during surgery was adequate to maintain anesthesia during implantation of transmitters in bull trout (J. De La Vergne, USFWS, personal communication). Before preparation of the pre-operative solution of MS-222, the water was sampled for pH. If the solution was acidic (pH<7.0), it was buffered with sodium bicarbonate to maintain a pH of 7, thereby reducing physiological stress associated with anesthesia (Wedemeyer 1970). After sedation, the fish was weighed, measured, and a genetic sample was taken from the upper lobe of the caudal fin. In addition, several scales were collected for age analysis from all bull trout collected at Rock Island, Rocky Reach, and Wells dams. Scale analysis was performed by the Washington Department of Fish and Wildlife. Genetic samples were preserved and provided to the Service. Genetic characterization was not a task of this study; therefore, genetic results are not presented in this report.

After the fish was sedated, it was placed it on a V-shaped cradle in preparation for surgery. Throughout the procedure, a surgical assistant flushed the gills of the fish with a 40-mg/L solution of MS-222 using a large bulb-type syringe. During this process gill activity was monitored, and if necessary, either freshwater or a stronger solution of MS-222 (80 mg/L) was used to maintain the desired level of anesthesia. Before surgery, all surgical instruments and the radio-transmitter were sterilized in 100% ethyl alcohol, and then rinsed with a 3% solution of sodium chloride to prevent irritation at the incision site.

Before making the incision, the fish's tissue was swabbed with iodine to decrease the likelihood of post-operative infection. An incision about 2-cm long was made lateral to the linea alba and about 2 cm anterior of the pelvic girdle through the musculature of the fish. A 16-gauge cannula sheathed within a Teflon tube (to protect internal organs) was then inserted into the body cavity of the fish. The cannula was positioned at an angle 45 degrees to the medial line of the fish, and distal to the posterior end of the incision. Pressure was then applied to the cannula in order to penetrate the wall of the peritoneal cavity. Once the cannula penetrated the wall of the peritoneal cavity, the Teflon sheath was removed and the transmitter antenna was inserted into the cannula. The cannula was then removed, and the transmitter was inserted into the body cavity of the fish. The body cavity was closed with 3 to 4 internally-knotted absorbable sutures and swabbed with iodine. Veterinary tissue glue was applied to both the incision and the exit site of the transmitter antenna.

After surgery, the fish was transferred to a 49-liter cooler that was supplied with river water, and was held until equilibrium was achieved (typically 10 to 15 minutes). The same vessel was used for post-operative recovery, transport, and release. During the handling procedure, start and completion times were recorded for surgery, recovery, transport, and release. In addition, the water temperature within the recovery/transport vessel was monitored before transport and release.

3.4 Transport and Release

The same general transport procedures were used at the release sites near Rock Island and Wells dams. Typically, after the fish had recovered, the transport vessel containing the fish was loaded into a truck, was supplied with air delivered through an air stone, and was transported quickly to the release site. At the release site, the air stone was removed and the vessel was placed into the river. At the time of release, the water temperature within the vessel and also in the river was then recorded. The vessel was then gently rolled onto its side and the lid was opened allowing the fish to swim free of the vessel. The swimming behavior of the fish was observed and any abnormalities were noted.

The transport procedures described above differed slightly for fish tagged and released at Rocky Reach Dam. Because the surgical station was located under a roadway within the fish ladder, it was not possible to carry the holding vessel to the upper deck for transport to the release site. For fish released into the tailrace of Rocky Reach Dam, the vessel was loaded into a boat and transported the vessel to the boat dock located about 50 m upstream from the dam on the right bank. A truck then transported the vessel from the dock to the release site downstream from the dam. For fish released upstream from the project, the vessel was loaded onto a boat and transported directly to the release site. The remaining release procedures were similar to those described above.

At the request of the Service, at each of the three dams half of the fish were released downstream from the dam and the other half were released upstream from the dam. The purpose of this release strategy was to increase the sample size of fish ascending the ladder systems at each of the projects where fish were collected and tagged. For fish released upstream from the dam, they were released as close to the dam as possible, but outside the influence of the forebay hydraulics (i.e., spill and bypass entrainment flows). Figure 15, Figure 16, and Figure 17 show specific release locations.

3.5 Fish Monitoring Systems

3.5.1 Fixed Telemetry

Multiple-telemetry techniques were used to assess the movement of tagged bull trout within the study area. At Priest Rapids, Wanapum, Rock Island, Rocky Reach, and Wells dams, a combination of aerial and underwater antennas were deployed. The primary purpose for these systems was to document the presence of bull trout at each project, specific to either the forebay or tailrace. In addition to these systems, a number of additional telemetry systems were deployed to address specific questions posed by Chelan and Douglas PUDs. At Rock Island, Rocky Reach, and Wells dams, additional systems were installed to identify tagged bull trout that could enter, ascend, and exit specific gates and fish ladders. At these projects, all possible access points to the adult fish ladders and the exits were monitored individually in 2002, allowing the route of passage to be determined as well as the ability to establish the exact time of entrance and exit from the ladder system. In 2003, however, only the tailrace and ladder exits were monitored at Rock Island and Rocky Reach dams, because of a lack of telemetry receivers. At Wells Dam in 2003, all systems were monitored. English et al. (1998, 2001) provided a detailed description of the telemetry systems at each of the dams and within the tributaries.

To assess movement within tributaries, both fixed-telemetry sites and aerial surveys were used within the Wenatchee, Entiat, Methow, and Okanogan rivers (see English et al. 1998, 2001). In the Wenatchee River basin, a single fixed-telemetry site was deployed at the Wenatchee River County Park (R.K. 12.5). In the Entiat River basin, a single system was deployed at R.K. 4.8. In the Methow basin two telemetry sites were established, one at R.K. 2.4 and the other at R.K. 17.5. In the Okanogan basin, a single system was installed at R.K. 9.0. At each of these locations, two 3- or 4-element Yagi antennas were deployed and monitored separately, with one antenna aimed downstream and the other upstream. This allowed us to assess the presence and direction of travel of bull trout at each site.

3.5.2 Aerial Surveys

Aerial surveys over the Columbia River (between Priest Rapids and Chief Joseph dams) were typically conducted on a monthly basis from April 2002 to the end of March 2003, and a semi-monthly basis from April 2003 to the end of March 2004. In addition, aerial surveys were conducted on the Wenatchee, Entiat, and Methow River systems. Because only two bull trout were detected at the fixed-telemetry site on the Okanogan River (and both later entered the Methow River), no aerial surveys were conducted in that basin. In the other basins, aerial surveys covered the mainstems to natural barriers or to points of safe access for fixed-wing aircraft. In addition, where possible, aerial surveys were conducted on smaller tributaries where bull trout presence was likely.

3.5.3 Boat Surveys

In 2001, boat surveys were used to assess general habitat use by tagged bull trout in the mainstem Columbia River. During that period, bi-weekly boat surveys were conducted in Rock Island and Rocky Reach reservoirs. This task was not repeated during the 2002 and 2003 study periods. Instead, boat surveys were used only to locate tagged fish that had not been detected for some time in the Columbia River and to pinpoint fish (or tags) that had not moved for an extended period of time. As such, only two boat surveys were conducted within Rock Island and Rocky Reach reservoirs in 2002 and three in 2003. Boat survey protocols followed those described in BioAnalysts, Inc. (2002).

During the period of 20 December 2001 to 31 March 2004, a total of 57 boat surveys were conducted within Wanapum and Priest Rapids reservoirs by Grant County PUD and LGL Limited personnel. Of the 57 surveys, 21 were conducted within Priest Rapids Reservoir and 36 within Wanapum Reservoir. Methods varied between surveys, but were typically conducted using either an aerial or underwater dipole antenna or both. These surveys provided detailed information as to the rearing location of tagged bull trout downstream from Rock Island Dam.

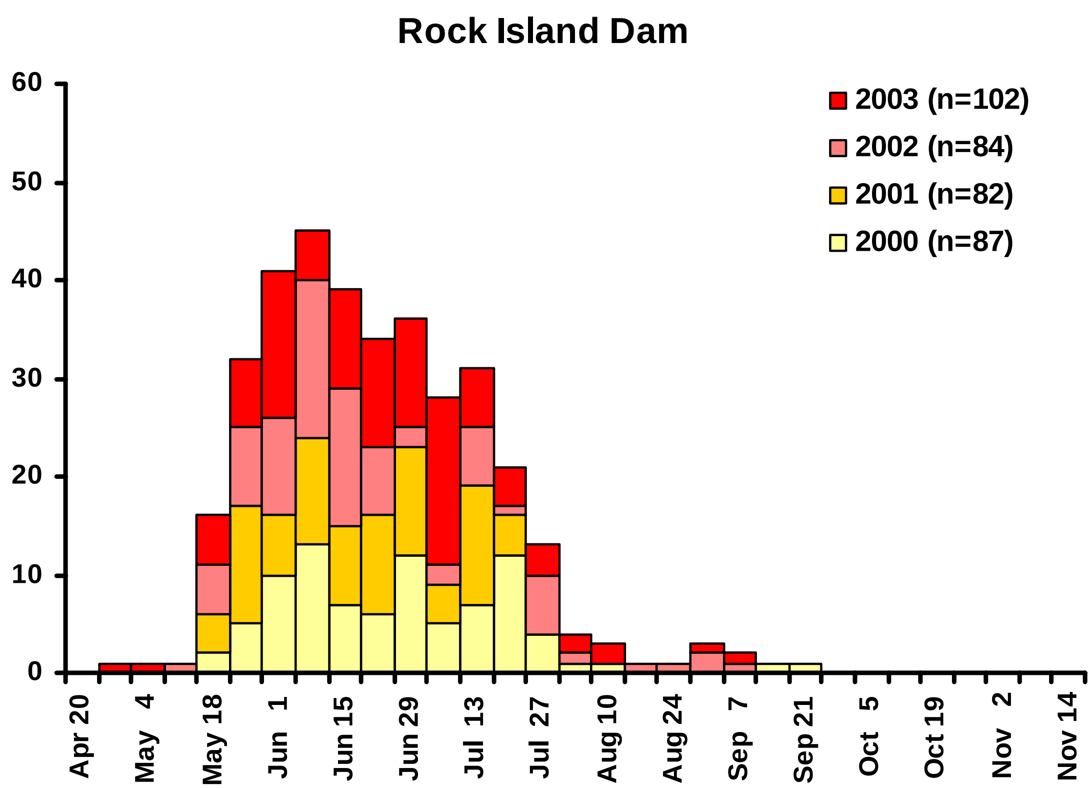


Figure 7: Passage distribution plotted by week for bull trout passing Rock Island Dam from 2000-2003.

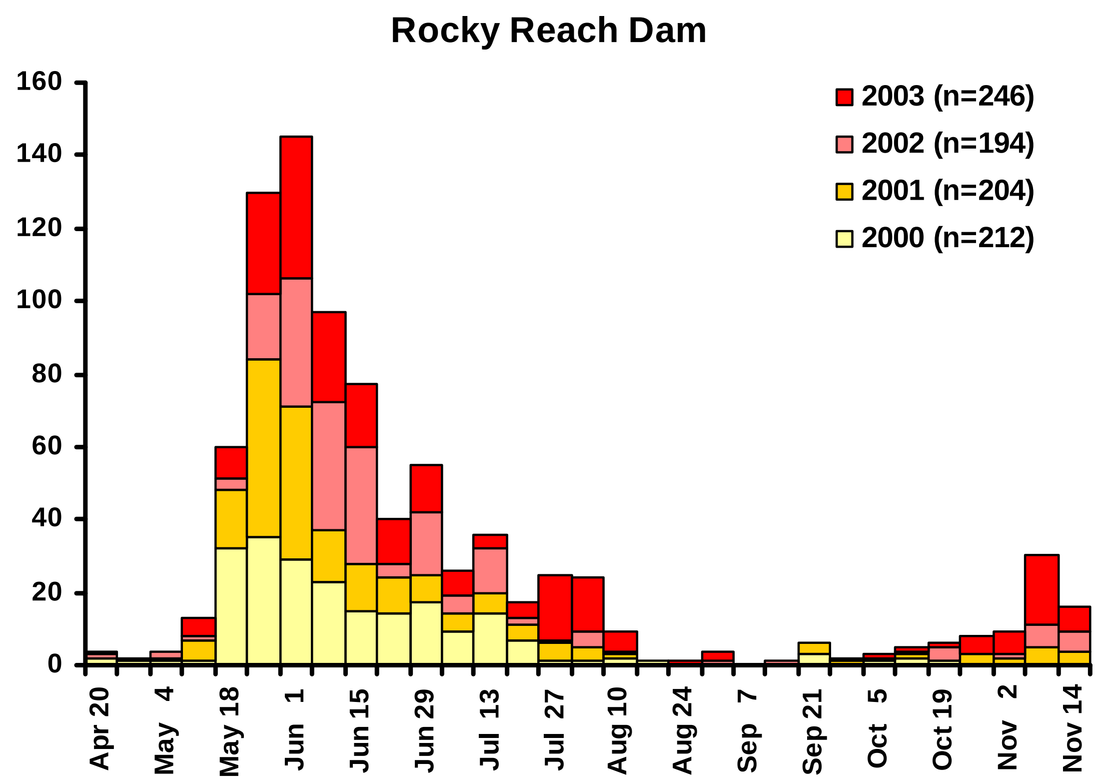


Figure 8: Passage distribution plotted by week for bull trout passing Rocky Reach Dam from 2000-2003.

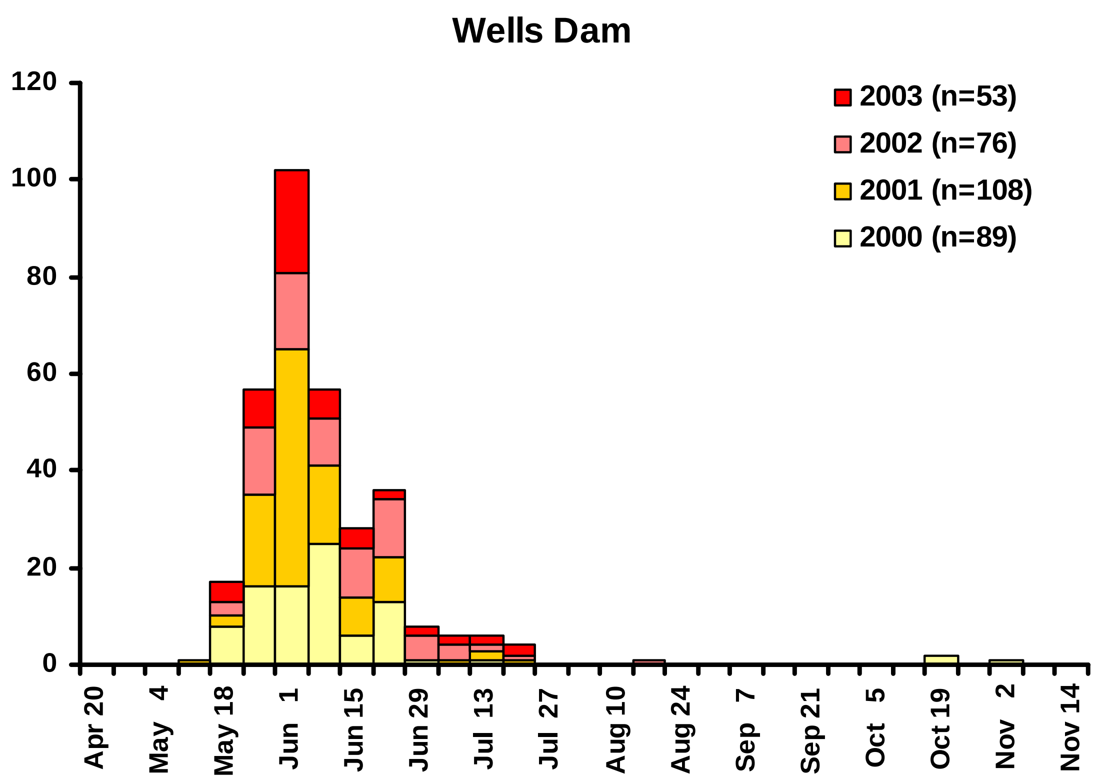


Figure 9: Passage distribution plotted by week for bull trout passing Wells Dam from 2000-2003.

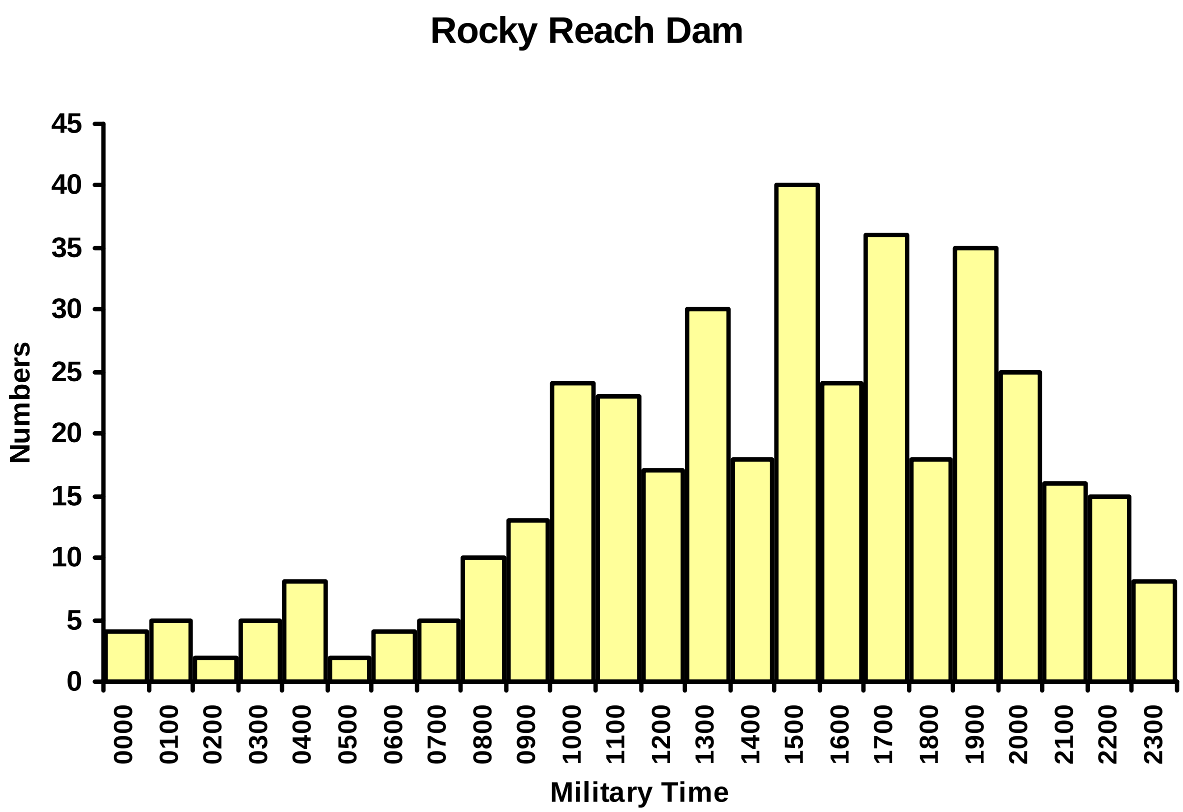


Figure 10: Time of passage for bull trout observed at Rocky Reach Dam ladder from 15 April to 31 November 2000 and 2001.

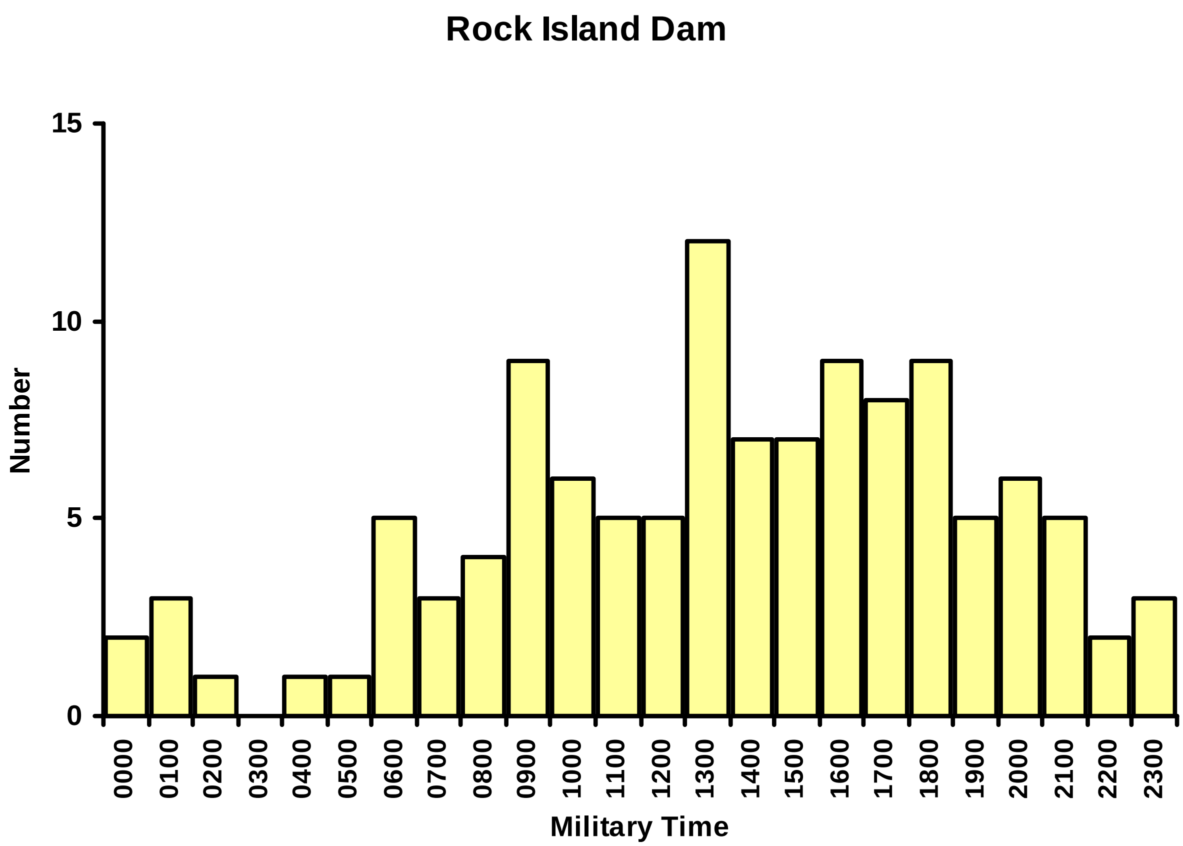


Figure 11: Time of passage for bull trout observed at Rock Island Dam ladders from 15 April to 31 November 2000 and 2001.

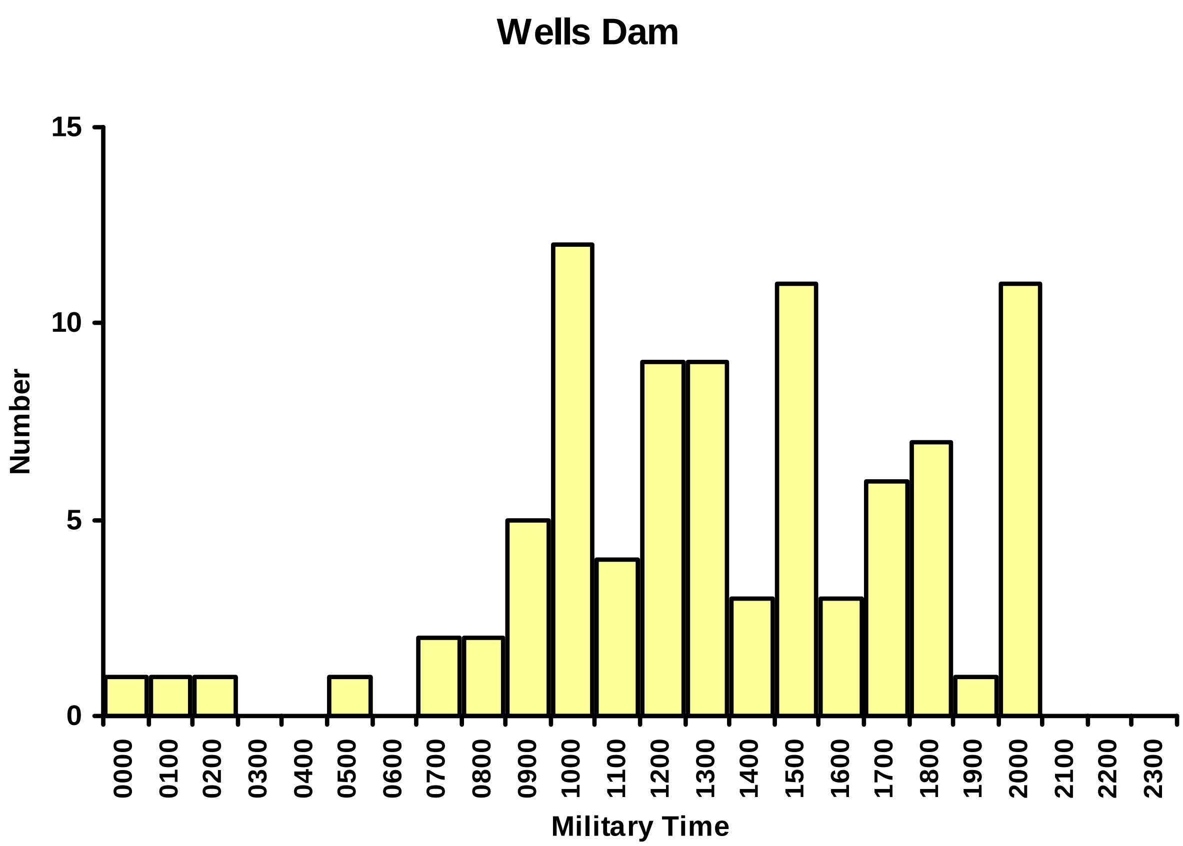


Figure 12: Time of passage for bull trout observed at Wells Dam ladders from 15 April to 31 November 2000.

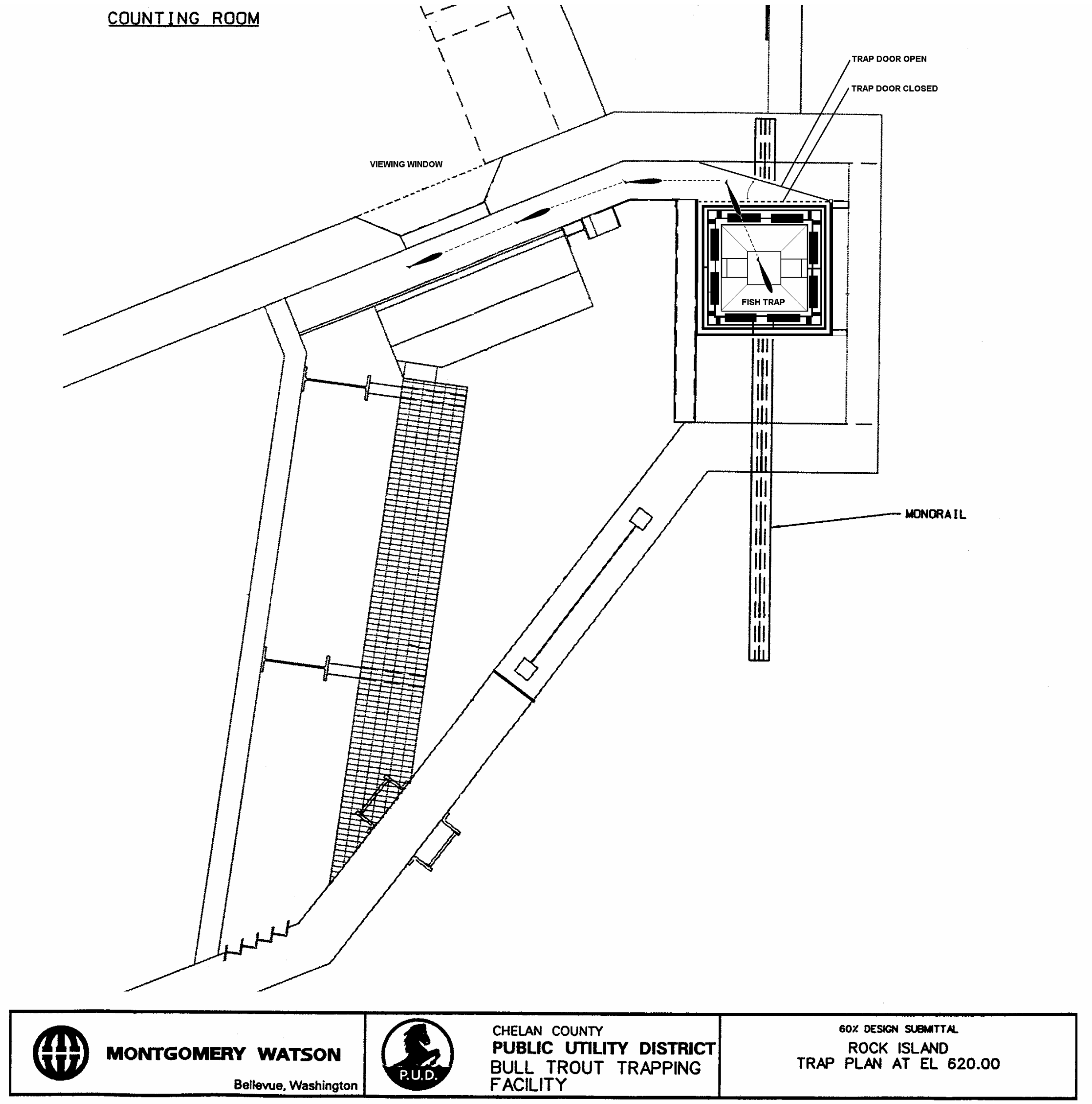


Figure 13: Plan view of Rock Island Dam fish trap showing movement of bull trout past the viewing window and the pneumatic gate open for entry into fish trap.

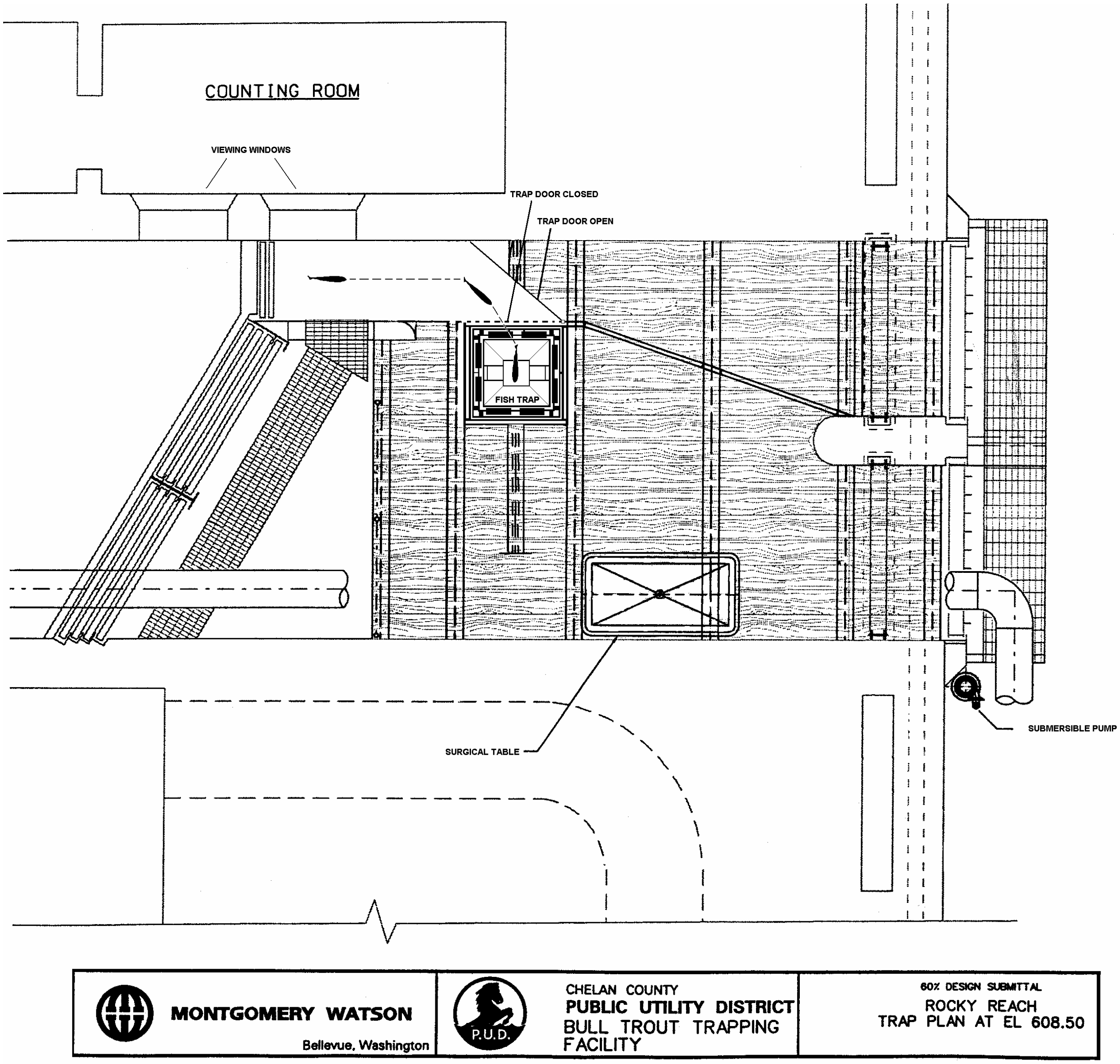


Figure 14: Plan view of Rocky Reach Dam trap showing movement of bull trout past the viewing window and the pneumatic gate open for entry into fish trap.

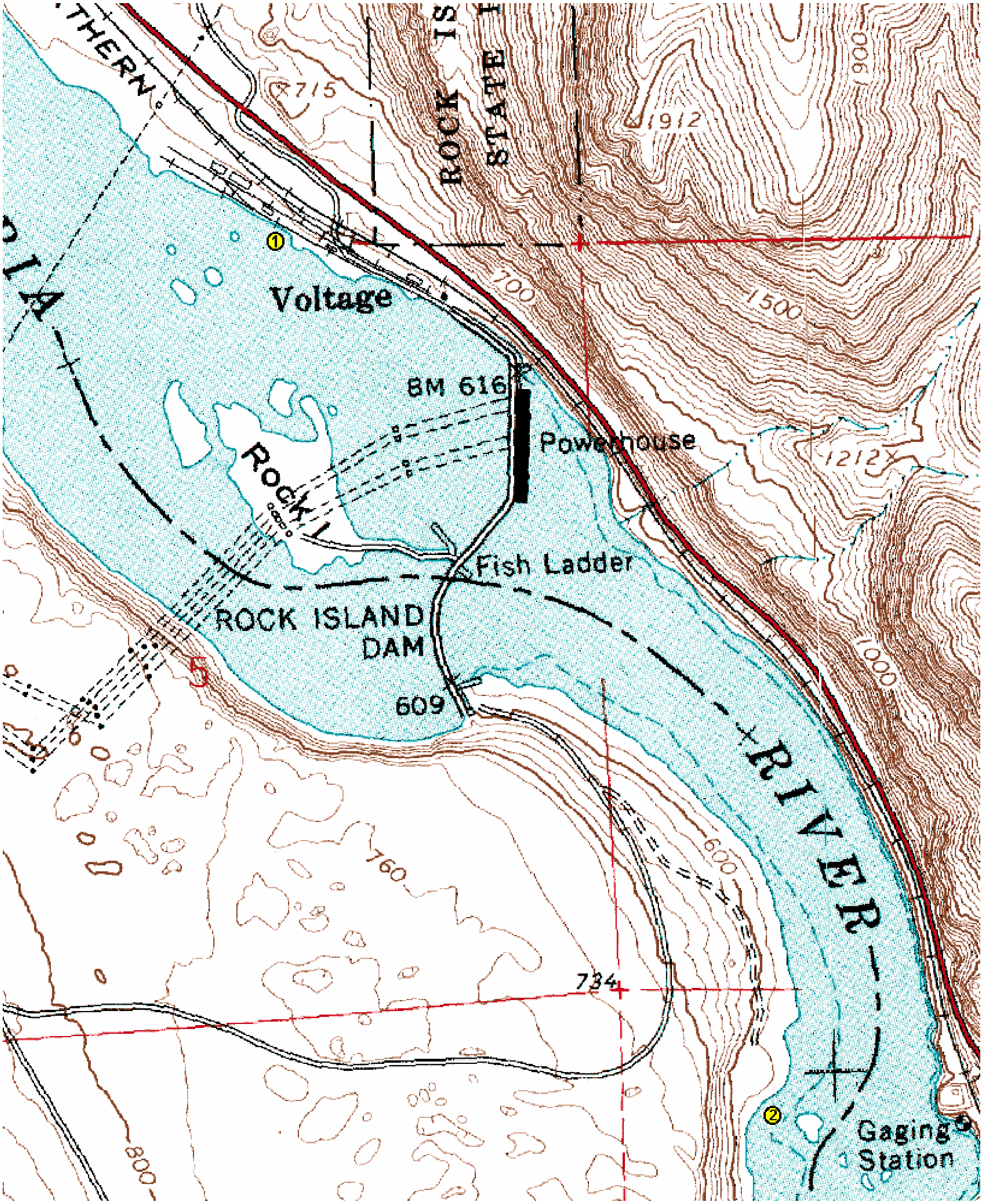


Figure 15: Bull trout release locations upstream (1) and downstream (2) of Rock Island Dam.

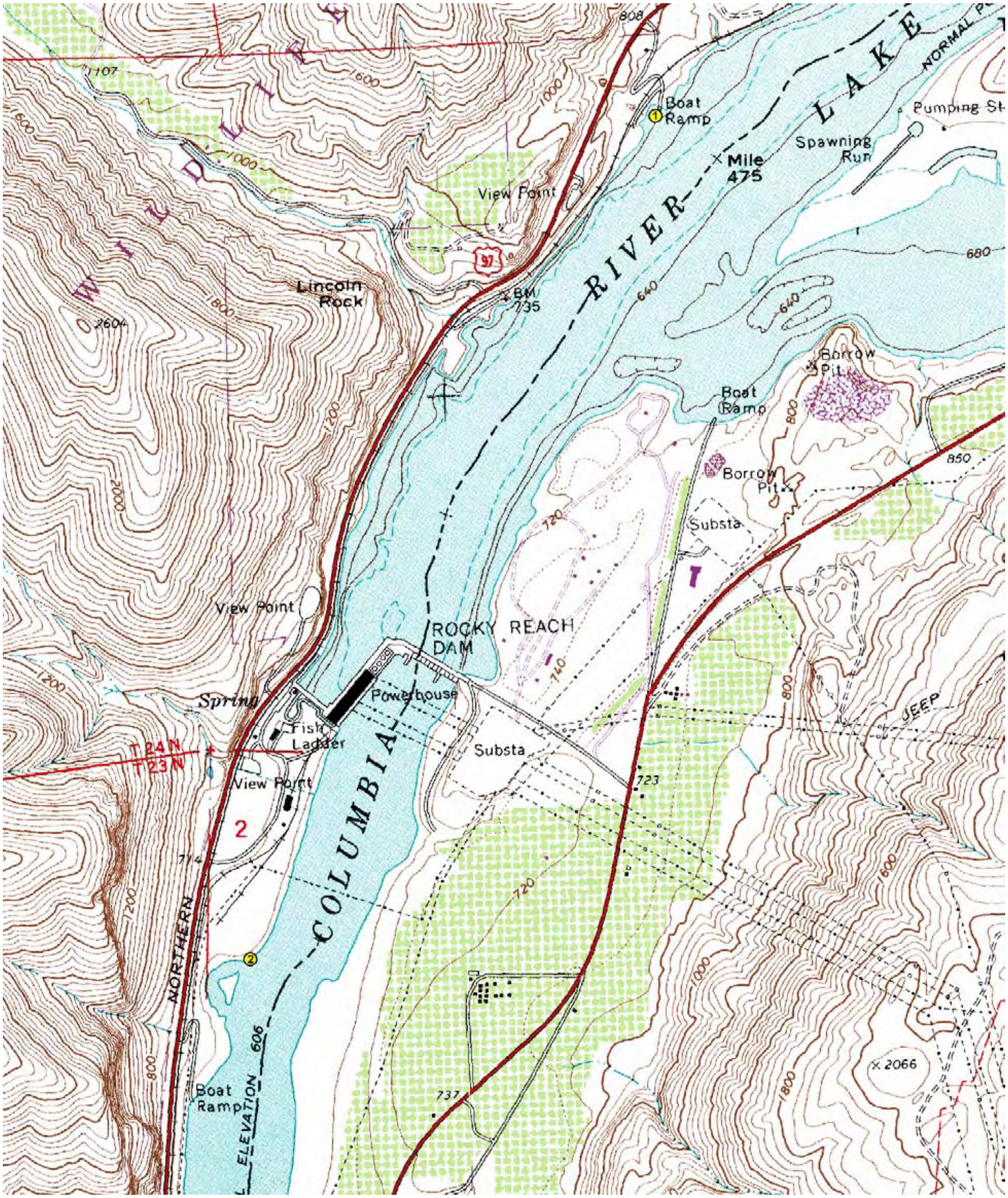


Figure 16: Bull trout release locations upstream (1) and downstream (2) of Rocky Reach Dam.

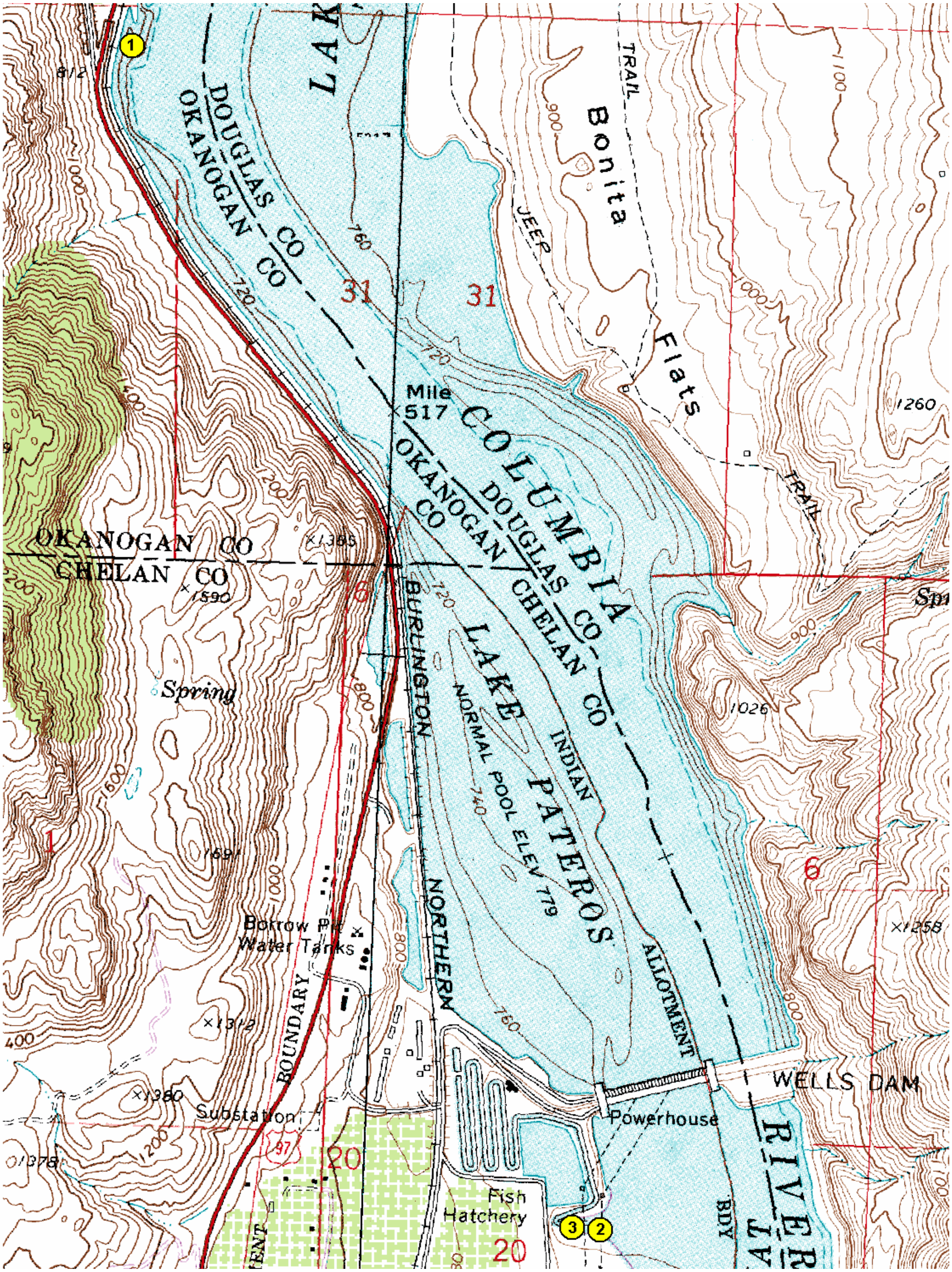


Figure 17: Bull trout release locations upstream (1) and downstream (2) of Wells Dam. Location of hatchery outfall (3) is also identified on the map.

SECTION 4: RESULTS AND DISCUSSION

A total of 79 adult bull trout were radio-tagged at three Columbia River dams during 2001 and 2002, with 39 adult bull trout tagged in 2001 (see results in BioAnalysts, Inc. 2002) and 40 in 2002 (Table 2). In 2002, the goal was to tag 10 fish at both Rock Island and Wells dams and 20 fish at Rocky Reach Dam. At Rock Island Dam in 2002, a total of eight bull trout were captured and tagged, with half released upstream and half downstream from the dam. At Wells Dam, nine adult bull trout were collected and tagged by 12 June, with five released upstream and four downstream from the dam. In an effort to capture and tag a total of 40 adult trout in 2002, the sampling period was extended at Rocky Reach Dam. There, 23 adult bull trout were captured and tagged, with 11 released upstream and 12 downstream from the dam.

The mean size of bull trout captured and tagged in 2002 tended to increase in an upstream direction, with the smallest fish collected at Rock Island Dam and the largest at Wells Dam (Table 2). Bull trout tagged at Rock Island Dam averaged 49.6-cm long (fork length) and weighed 1,325 g. Bull trout at Rocky Reach Dam averaged 55.1-cm long and weighed 1,967 g, while those at Wells averaged 57.3 cm and weighed 2,183 g. In total, the 40 bull trout averaged 54.5-cm long and weighed 1,888 g. Fish size also tended to increase in an upstream direction in 2001, although sizes of fish captured and tagged at Rock Island and Rocky Reach dams were similar (BioAnalysts, Inc. 2002).

The age analysis of fish collected in 2002 varied from the analysis in 2001. In 2002, age was partitioned into two stanzas based on life-history characteristics. For example, an age-5 bull trout could be categorized as a 3/2 fish, which means it spent three years in a cold-water environment (e.g., within a tributary of the mainstem Columbia River) and two years in a relatively warmer-water environment (e.g., the mainstem Columbia River). In 2002, age could be determined for 36 of 40 individuals. Four fish could not be aged because of scale regeneration. Of the 36 fish aged, 12 were 4 years of age (two were classified as 4/0 and ten as 3/1), 19 were 5 years of age (seven were classified as 4/1 and twelve as 3/2), three were 6 years of age (two were classified as 4/2 and one as 3/3), and two were 7 years of age (both were classified as 4/3). Five of the 36 fish had spawned previously on one or more occasion (Table 2). In 2001, only total age was determined for eight bull trout captured at Wells Dam. Of those fish, two were age-5 fish and six were age-6 fish.

For the 40 bull trout captured and tagged at the three collection locations, the mean surgical, recovery, and transport times were 4.7, 11.7, and 11.8 minutes, respectively. The surgical times at the three dams were similar, with the mean times varying by only 0.7 minutes. However, recovery and transport times for the different release sites varied somewhat. The mean recovery time varied between projects by 2.2 minutes, and was likely due to the time necessary to prepare the tagging facility for the next tagging event (this task was completed while the tagged fish recovered). Variability in transport times resulted from road conditions and distance traveled to the various release sites. Nevertheless, the mean overall time from start to finish (surgery, recovery, transport, and release) among tagging locations varied by only 8.3 minutes, with the Rock Island upstream releases requiring only 22.3 minutes and the Rocky Reach downstream releases requiring 30.6 minutes.

Water temperatures within the transport vessel changed little from the time of recovery to the time of release in the river. On only two occasions did the water temperature increase during the time the fish were held in the vessel. On both occasions the temperature increased 0.5°C; however, the increase in temperature during transport probably benefited the fish. That is, for these two fish, the temperature at the release site was higher than the water temperature at the collection site. The increase within the transport vessel served to acclimate fish to the higher temperature at the release location (in both cases, the temperature within the transport vessel at the time of release was the same as at the release site).

Differences in temperatures between the collection site and release site were common. For fish tagged and released at Rock Island and Rocky Reach dams (n = 31), differences in temperatures between the collection and release sites occurred on ten occasions (Table 2), but the difference in temperature never varied by more than 1°C. At Wells Dam, temperatures at the collection and release sites differed during the release of seven trout. Three trout released downstream from Wells Dam experienced temperature differences of 1.0 °C. Trout released upstream from the dam experienced differences that ranged between 0.5 and 3.0°C. While these temperature differences did not appear to affect survival or behavior of the fish exposed to them, it is possible that behavior immediately after release could have been affected. However, no abnormal behavior was observed immediately after release.

Table 2: Description of the 40 adult bull trout tagged in 2002 at Rock Island, Rocky Reach, and Wells dams from 20 May to 27 June 2002. An "s" after the age indicates previous spawning. Water temperatures represent the beginning and end of transport, and at the release site.

Collection		Transmitter		Fish Metrics (cm/g)			Elapsed Time (m)			Water Temp. (°C)			
Date	**Time**	**Chan.**	**Code**	**Fork L.**	**Weight**	**Age**	**Surgery**	**Recovery**	**Transport**	**Begin**	**End**	**Rel.**	**Location**
							Rock Island Dam						
20-May	1555	14	97	53.0	1,700	3/1(s)	6	11	7	11.0	11.0	12.0	Up
23-May	1321	14	90	49.5	1,250	3/2	6	13	11	12.0	12.0	11.5	Down
04-Jun	0845	14	110	60.0	2,400	4/1	5	8	8	12.5	12.5	13.0	Up
04-Jun	1622	14	105	52.0	1,350	3/1	4	10	10	13.0	13.0	13.0	Down
07-Jun	1019	14	109	50.0	1,400	3/1	5	11	7	12.5	12.5	13.0	Up
07-Jun	1640	14	113	43.0	800	4/1	4	10	11	12.5	12.5	12.5	Down
12-Jun	0928	14	119	42.5	700	R	4	10	7	13.0	13.0	14.0	Up
12-Jun	1256	14	115	46.6	1,000	3/1	5	11	11	13.5	13.5	13.0	Down
			Mean:	**49.6**	**1,325**	**---**	**5**	**10**	**10**				
			Minimum:	**42.5**	**700**	**---**	**4**	**8**	**8**				
			Maximum:	**60.0**	**2,400**	**---**	**6**	**13**	**11**				
							Rocky Reach Dam						
20-May	1445	14	88	65.5	3,200	R	6	14	10	11.0	11.0	11.0	Up
21-May	1737	14	89	63.0	2,950	3/2	6	20	11	11.0	11.0	11.0	Down
23-May	1413	14	92	50.5	1,950	3/2	5	16	11	11.0	11.0	11.0	Up
29-May	0858	14	95	57.0	2,100	3/2	6	13	14	12.0	12.0	12.0	Down
30-May	1057	14	98	57.0	1,950	3/2	4	14	10	12.0	12.0	12.0	Up
30-May	1409	14	104	56.0	2,000	3/2	6	13	12	12.0	12.0	12.0	Down
03-Jun	1310	14	108	62.0	2,350	4/1	5	6	13	12.0	12.0	12.0	Up
03-Jun	1416	14	101	55.3	1,950	R	5	6	13	12.0	12.0	12.0	Down
04-Jun	1212	14	100	52.5	1,700	3/2	4	7	11	12.5	12.5	12.5	Up
04-Jun	1427	14	111	56.5	2,200	R	5	17	13	12.0	125	12.5	Down
06-Jun	1017	14	103	61.4	3,300	4/3(s)	5	11	14	12.0	12.0	12.0	Up
06-Jun	1533	14	106	58.5	2,500	3/2(s)	3	16	14	12.0	12.0	12.0	Down
07-Jun	1413	14	121	48.1	1,350	3/1	5	18	11	12.5	12.5	12.5	Up
10-Jun	1200	14	114	54.0	1,700	3/2	4	14	11	12.0	12.0	12.5	Down
10-Jun	1656	14	116	60.8	2,850	4/1	6	17	11	12.0	12.0	12.0	Up
11-Jun	1406	14	118	46.0	950	3/1	4	11	12	12.5	12.5	13.0	Down
12-Jun	1337	14	122	59.7	2,100	3/2	5	10	13	13.0	13.0	13.0	Up
18-Jun	1040	14	126	60.4	2,300	3/3(s)	6	10	13	13.5	13.5	13.5	Down
21-Jun	1136	14	123	57.5	1,750	3/1	4	11	12	14.0	14.0	14.0	Up
24-Jun	1400	14	124	57.0	1,800	3/2	4	13	11	14.5	15.0	15.0	Up
26-Jun	0824	14	125	46.0	1,000	3/1	4	14	12	15.0	15.0	15.0	Down
27-Jun	1226	14	127	41.5	650	4/0	4	14	14	15.0	15.0	15.0	Down
27-Jun	1755	14	120	40.4	650	4/0	4	12	11	15.0	15.0	15.0	Down
			Mean:	**55.1**	**1,967**	**---**	**4**	**12**	**12**				
			Minimum:	**40.4**	**650**	**---**	**4**	**10**	**11**				
			Maximum:	**65.5**	**3,300**	**---**	**6**	**14**	**14**				
							Wells Dam						
23-May	1530	14	91	69.9	4,250	4/3(s)	5	12	21	10.5	10.5	10.5	Up
28-May	1510	14	93	54.5	1,800	4/2	4	9	13	11.5	11.5	12.5	Down
03-Jun	0915	14	107	60.5	2,300	4/1	4	19	12	13.0	13.0	15.0	Up
03-Jun	1425	14	94	51.0	1,400	3/1	4	4	12	13.0	13.0	15.0	Up
03-Jun	1650	14	96	56.0	1,850	4/2	4	7	11	12.0	12.0	13.0	Down
04-Jun	0912	14	102	63.5	2,900	4/1	4	9	11	13.0	13.0	13.0	Down
04-Jun	1325	14	99	46.5	1,150	3/1	3	6	18	13.0	13.0	16.0	Up
11-Jun	1325	14	112	62.1	2,600	3/2	6	10	11	13.0	13.0	14.0	Down
12-Jun	1535	14	117	52.0	1,400	4/1	4	11	14	14.0	14.0	14.5	Up
			Mean:	**57.3**	**2,183**	**---**	**4**	**8**	**12**				
			Minimum:	**46.5**	**1,150**	**---**	**3**	**4**	**11**				
			Maximum:	**69.9**	**4,250**	**---**	**6**	**11**	**13**				

4.1 Mortalities

None of the 40 bull trout tagged in 2002 died during the period from capture to release. All 40 fish appeared to be healthy and exhibited normal behavior upon release. Most migrated to a tributary stream or moved several kilometers from a release area. During the monitoring phase of the study, however, a total of six transmitters were recovered within the study area during the period of April 2002 to March 2003 (2002 Study Period), and eight additional transmitters were recovered during the period of April 2003 to March 2004 (2003 Study Period). For those 14 fish, only one carcass was recovered with a transmitter.

Recovery of a transmitter without a carcass does not necessarily mean that the fish died. For example, a bull trout was captured at Rocky Reach Dam in 2002 that had scarring consistent with a transmitter that had been extruded through the musculature where the transmitter antenna exited the fish. Incision and suture scars were readily apparent on this fish as well as an "asterisk-shaped" scar where the antenna exited the body. It appears that this fish was captured and tagged the previous year, lost its transmitter, and survived. Other researchers have noted similar observations while tagging adult bull trout in the Tucannon and Touche rivers. One fish that was previously tagged, but was missing its transmitter, was recaptured as it entered the Touche River. This fish exhibited the same asterisk-shaped scar that was observed for the fish captured at Rocky Reach Dam (G. Mendel, WDFW, personal communication). Thus, it is possible that some of the recovered transmitters from this study may have been shed from live fish.

During the 2001 study period (May 2001 to March 2002), only one fish was confirmed to have died after release.[3] That fish was released upstream of Rock Island Dam on 3 July 2001 and was detected at Rocky Reach Dam two days later, where it was detected over the course of nine days. Thirteen days after the last detection at Rocky Reach, it was detected in the forebay of Rock Island Dam, where it was detected in the same location over the next 2.5 months. Inspection of the site revealed the skeletal remains and skin of a bull trout. The transmitter was detected about 3 meters from the carcass.

The fate and detailed detection histories of each of the 14 fish tagged in 2002 are presented in Appendix A, and therefore will not be presented in detail here. What follows is only a brief summary on the movements of the 14 fish.

Transmitter Recovery - 2002:

Four of the six transmitters recovered in 2002 were implanted in fish collected at Wells Dam. All four of these fish migrated into the Twisp River (a tributary to the Methow River) and the transmitters were recovered in that tributary upstream from a dewatered section in the fall of 2002. For one of these fish, both the carcass and transmitter were recovered together. The carcass was frozen in an area where there was little water within the stream channel. For another fish, the

[3] Fish tagged in 2001 carried transmitters with a one-year tag life. It is possible that some of these fish died or lost tags after the tag expired and therefore were not detected. Tags used in 2002 had a much longer tag life allowing the opportunity to document mortality or tag loss for a longer period of time.

transmitter was found on shore above the wetted channel. All four fish traveled 98 to 116 km from the release sites at Wells Dam to the Twisp River.

The fifth transmitter was recovered in the upper Entiat River onshore under a boulder. This transmitter was originally implanted into a fish collected at Rocky Reach Dam. This fish traveled 55 km before its transmitter was recovered. The U.S. Fish and Wildlife Service recovered the transmitter and noted that it was in a mink den. The transmitter had identifiable "cut" marks on the antenna resulting from predation or scavenging.

The sixth transmitter recovered in 2002 was implanted in a fish at Rock Island Dam. This fish did not spend any length of time in tributaries, as did other tagged trout. Instead, it moved upstream to Wells Dam, then back downstream to a location downstream from Rock Island Dam. The transmitter was located onshore above the high water mark under debris. This fish traveled about 322 km before its transmitter was recovered.

Transmitter Recovery - 2003:

A total of eight transmitters were recovered in 2003. Three were recovered in the Twisp River, with two originating from Rocky Reach Dam and the third from Wells Dam. One transmitter was recovered downstream of the Poplar Flat Campground, a second near the Scatter Creek Trailhead, and the third near Roads End. Two of the three tags were buried in gravel and the third was on a gravel bar about two feet from the waters edge. No carcasses were recovered with these transmitters.

Two transmitters were recovered in the Mad River (a tributary to the Entiat River), with one fish tagged at Rock Island Dam, the other at Rocky Reach. Both of these transmitters were recovered within 200 meters of each other, and were located about 7 km upstream of the Pine Flat Campground. Both transmitters were found in the water laying on the streambed. No carcasses were found at these sites.

The other three transmitters were recovered in the mainstem Columbia River near the Entiat River confluence. Two of these transmitters were implanted in fish at Rock Island Dam and the other at Rocky Reach. One transmitter was recovered near the east shore about 200 meters upstream of the Entiat River in water about 3.5 m deep. Another was recovered near the west shore at a depth of about 4.5 m, approximately 1.5 km downstream of the Entiat River. The third was recovered about 5 km downstream of the Entiat River near the east shore in 4-m deep water. No carcasses were recovered.

It is likely that five other fish may have died or shed their tags. Two are currently located about 100 m upstream of Box Canyon in the Entiat River, one is in the upper reaches of the Mad River, another is located within the boat restricted zone of Rocky Reach Dam near the east shore, and the fifth was last seen at Priest Rapids Dam. The first four fish have remained in the same location for several months, and the fifth fish has not been detected for some time. Attempts to locate these fish (or their transmitters) have been unsuccessful.

4.2 Migration Time and Downstream Movement

Because of the extensive deployment of telemetry systems at each mainstem dam and near the mouths of major tributaries, it was possible to document the length of time each fish spent within various areas at the dams, the elapsed time between dams, the time required to travel from a dam to the next upstream tributary, and whether bull trout migrated downstream past any of the projects within the study area. For some of the fish tagged in 2001, transmitters were still active as they migrated upstream in 2002. Therefore, these fish were included in the 2002 analysis. For the analysis of the 2003 migration period, only the transmitters for fish tagged in 2002 were active. It should be noted that the number of fish used to estimate the following residence times may be less than the total number of fish passing the dam of interest, or the reach of river upstream from the project. This is because of incomplete detection histories for some fish. For example, if a fish is not detected by the tailrace antenna array, the tailrace and overall dam passage time cannot be estimated.

Over the course of the study, a few modifications in the monitoring systems affected the extent the data could be analyzed. For the 2001 and 2002 migrations, all telemetry systems were operational. However, in 2003 the ladder entrances at Rock Island and Rocky Reach dams were not monitored. Therefore, only overall dam passage time could be ascertained at these projects. This happened because of a concurrent telemetry study conducted by Chelan PUD at the time bull trout were migrating upstream past Rock Island and Rocky Reach dams. As such, the entrance receivers were removed and used in that study. However, the second telemetry study provided telemetry coverage at all spillbays and powerhouse units at Rock Island and Rocky Reach dams. Coverage at these locations allowed detailed analysis of downstream movement through these units by bull trout in 2003.

For clarity, defined are the following terms.

- *Tailrace residence* is the elapsed time between the first detection by the tailrace array and the first detection upon final entrance into the ladder system.
- *Fishway residence* is the elapsed time between the first detection upon final entrance into the ladder system to the last detection at that ladder exit.
- *Elapsed time at the dam* is the sum of the tailrace and fishway times.
- *Elapsed time between dams* is the time from last detection at a ladder exit or from the time it was released to the time of first detection within the tailrace of the next upstream dam.
- *Elapsed time from a dam to an upstream tributary* is the time from last detection at the ladder exit or from the time it was released to the time of entry into an upstream tributary.

For all estimates, only fish that were actively migrating upstream have been included. For example, fish that were detected by the tailrace and ladder systems, but migrated downstream and entered a tributary were not used to calculate tailrace residence time. Downstream migration past a given project was assessed as the detection of a fish downstream from the dam after the fish had recently exited the ladder system.

4.2.1 Rock Island Dam

At Rock Island Dam eight adult bull trout were captured and tagged in 2002. All four of the fish released downstream from the project migrated upstream, with one fish passing the project through the left-bank ladder and the other three through the right-bank ladder. In addition, one fish tagged in 2001 (tag 14-7) passed Rock Island Dam through the right-bank ladder. For these five fish, the median tailrace residence time was 5.66 days, ranging from 0.43-16.43 days (Table 3). The median residence time through the right-bank and left-bank fishways was 0.85 days and 0.18 days, respectively. The median elapsed time at the dam for all five fish was 5.90 days and ranged from 1.21-17.35 days (Table 3). During the 2003 migration, two bull trout migrated upstream past Rock Island Dam. As mentioned previously, the ladder entrances were not monitored, and therefore, only overall dam passage times are available. For these two fish, the median passage time was 5.10 days with a range of 4.03 to 6.17 days (Table 4). In 2001, the median elapsed time at the dam was 2.28 days (Table 5). For the three years of passage at Rock Island Dam, no downstream movement of bull trout was observed after the fish exited the ladder systems.

The migration time for bull trout from Rock Island Dam to Rocky Reach Dam or to an upstream tributary was assessed in 2002 for the eight fish tagged and released at Rock Island Dam in 2002, plus one fish tagged in 2001. Of these nine bull trout, seven were detected in the tailrace of Rocky Reach Dam and the other two migrated into the Wenatchee River. The median time between projects was 2.78 days, ranging from 1.14-5.46 days, and the median elapsed time between detection at Rock Island Dam and the Wenatchee River was 5.99 days, ranging from 4.56 to 7.41 days (Table 3). In 2003, the migration time between Rock Island Dam and the upstream locations was assessed for two fish; with one migrating to Rocky Reach Dam and the other entering the Wenatchee River. For these fish, the elapsed time to Rocky Reach Dam and the Wenatchee River was 1.79 and 1.67 days, respectively (Table 4). In 2001, the median travel time between the two dams was 1.33 days, and the median travel time to the Wenatchee River was 1.39 days (Table 5).

Although elapsed times at Rock Island Dam were greater in 2002 and 2003 than in 2001, no evidence was found that indicated that the longer time periods had a negative impact on successful and timely entry into spawning tributaries.

4.2.2 Rocky Reach Dam

To assess the movement and behavior of bull trout at Rocky Reach Dam in 2002, 11 bull trout were tagged and released upstream and 12 downstream from the project for that year. Analysis of residence and passage times at this project also included fish tagged at Rock Island Dam and bull trout tagged in 2001 that passed the project during the 2002 study period. In sum, 21 tagged bull trout passed Rocky Reach Dam in 2002, eight released in Rocky Reach tailrace, one released in Rocky Reach forebay, six from Rock Island Dam, and six fish tagged in 2001. Two of the fish tagged in 2001 ascended the fishway more than once. One ascended the ladder three times; the other ascended the ladder twice. Unfortunately, during the upstream passage of one bull trout (released downstream from Rocky Reach Dam) the ladder exit receiver did not record the exit time. Therefore, a total of 23 passage events[4] were analyzed at Rocky Reach Dam in 2002.

[4] In this analysis, it is assumed that passage events were independent of each other. This may not be statistically valid because two bull trout ascended the ladder system more than once.

Fish could enter the ladder system at Rocky Reach Dam through a number of entrances or gates. Possible entrances included the right bank entrance, six O.G. gates, the left bank entrance, and the spillway entrance. During the 2002 study period, five tagged fish entered the spillway entrance, nine entered the left-ladder entrance, six entered one of the six O.G. gates, and four entered the right-ladder entrance. In 2001, seven ascended the ladder system through the left-ladder entrance and two entered the right-ladder entrance. In 2002, the median tailrace residence time was 4.44 days, ranging from 0.60-16.25 days (Table 3). The median fishway residence time was 0.28 days (range, 0.13-6.15 days). The median elapsed time at the dam was 4.86 days, ranging from 1.11-16.50 days (Table 3). In contrast, during the 2001 migration, the median time at the dam was 3.79 days, median tailrace time was 1.28 days, and the median fishway time was 1.92 days (Table 5). In general, fish spent more time in the tailrace of Rocky Reach Dam in 2002 than in 2001 (Table 5). In 2003 the ladder entrances were not monitored, and, as such, elapsed times at the dam cannot be partitioned into tailrace and ladder times. However, for the nine fish that passed upstream of Rocky Reach Dam, the overall median elapsed time at the dam was 4.68 days, ranging from 0.66-16.87 days (Table 4).

Further inspection of the data indicated that fish migrating upstream from Rock Island Dam moved through Rocky Reach Dam quicker than fish tagged at Rocky Reach and released into the tailrace. The median time spent in Rocky Reach tailrace for the eleven fish that migrated upstream from Rock Island Dam was 2.97 days, compared to 7.67 days for the eight fish tagged at Rocky Reach and released in the tailrace. A similar trend was observed during the 2001 study period. During that study period, the median tailrace time for fish migrating upstream from Rock Island was 0.85 days compared to 1.79 days for fish tagged at Rocky Reach and released into the tailrace. Once the fish were in the ladder system, little difference in median ladder times was observed between the two groups of fish.

Five downstream passage events were recorded at Rocky Reach Dam in 2002. These events were based on the movements of three bull trout, some of which moved through the project more than once. One fish (14-124) released upstream of Rocky Reach Dam was detected 15 hours later in the tailrace of the project. This fish re-ascended the ladder and entered the Entiat River, where it resided for five days. The following day this fish moved back downstream and passed through the dam a second time. A second fish (14-32) tagged in 2001 moved downstream through the project on two different occasions during an 18-day period. After ascending the ladder system the first time, this fish moved downstream through the powerhouse (unit 6 or 7) and began re-ascending the ladder within three hours. Eleven days after exiting the ladder system, it again moved downstream past Rocky Reach Dam (passage route unknown). It re-ascended the ladder, entered the Entiat River, and seven months later was detected in the tailrace of Wells Dam. Another trout (14-37) tagged in 2001 provided the last downstream event at Rocky Reach Dam in 2002. Within about 24 hours after initially ascending the ladder, this fish moved back downstream through the project (passage route unknown). The fish spent about four days in the tailrace before re-ascending the ladder. This fish was detected in the Entiat River 15 days later.

During the 2003 migration, three bull trout exhibited four downstream passage events at Rocky Reach Dam after exiting the fish ladder. One fish (14-99), resided within the Wenatchee River basin during the fall of 2002. It then moved into Rock Island pool, passed Rocky Reach Dam on 29 May 2003 and within 33 minutes moved back downstream through turbine unit 10. The fish re-ascended the ladder and exited the system on 30 May. On 2 June it was detected at Wells Dam and migrated from there into the Methow River. The second fish (14-101) remained in the Entiat Basin during autumn 2002. It then moved into Rock Island pool, migrated downstream through Rock Island Dam, remained there for some time before moving upstream through the left-bank ladder on 12 June 2003. By 14 June, the fish moved into the Rocky Reach tailrace. It ascended the ladder and exited the system the following day and within 44 minutes the fish entered and passed through turbine unit 1. By 22 June the fish had moved into the Wenatchee River and was stationed near the town of Monitor. This bull trout remained in the Wenatchee system for four months, primarily in Ingalls Creek, a tributary to Peshastin Creek.

The third fish (14-114) exhibited two downstream movement events at Rocky Reach Dam during the 2003 migration. After residing in the Entiat Basin during autumn 2002, the fish moved into Rock Island pool and remained there for the first half of 2003. It then moved to Rocky Reach tailrace (29 May 2003), ascended and exited the ladder on 2 June, and after 27 minutes in the forebay it moved downstream through spillbay 2. By 4 June, the fish re-ascended the ladder and spent 30 minutes in the forebay before moving downstream through spillbay 4. The fish re-ascended and exited the ladder the following day and eventually entered the Entiat River basin where it resided for four months. These observations and those in 2002 indicate that the fish were not significantly harmed during their downstream movements through the dam.

In 2002, migration time was estimated for 30 bull trout from Rocky Reach Dam to either Wells Dam or to an upstream tributary (Entiat River). The 30 fish included eight bull trout released into the tailrace of Rocky Reach Dam, 11 released into the forebay, five tagged at Rock Island Dam, and six from the 2001 study. The median travel time for the 23 bull trout that moved from Rocky Reach to the Entiat River was 11.34 days, range 3.51-26.98 days (Table 3). For the seven fish that traveled to Wells Dam, the median elapsed time between projects was 2.03 days, range 1.09-3.71 days (Table 3). During the 2003 study period, a total of six tagged trout migrated into the Entiat River. For those fish, the median passage time between the dam and the Entiat River was 16.47 days, with a range of 15.18-21.98 days. One other fish migrated upstream to Wells Dam. For that fish, the elapsed time between dams was 1.73 days (Table 4).

Travel times to either the Entiat River or Wells Dam were greater in 2002 and 2003 than in 2001. In 2001, the median travel time between Rocky Reach Dam and the Entiat River was 7.20 days and 1.69 days from Rocky Reach to Wells Dam (Table 5).

4.2.3 Wells Dam

In 2002, nine adult bull trout were tagged and released at Wells Dam to assess movements and migration behavior there. For that year, a total of 11 tagged fish moved through Wells Dam, including five fish from Rocky Reach, the four released into the tailrace of Wells Dam in 2002, and two fish from the 2001 tagging period. One fish re-ascended the ladder twice. Therefore, a total of 12 passage events at Wells Dam were examined, with two bull trout ascending the right-bank ladder and 10 the left ladder. Unfortunately, during the course of the study, the DSP unit monitoring the left-bank ladder entrance malfunctioned, resulting in the detection of only one fish at the left-bank entrance. The absence of detection at this ladder entrance does not affect overall dam passage time (because the left-bank ladder exit monitor worked properly), but precludes estimates of variability of tailrace and ladder residence times.

At Wells Dam in 2002, the median tailrace residence time was 7.84 days, ranging from 1.64-18.35 days (Table 3). The median fishway residence time in the right bank ladder was 0.21 days (range, 0.20-0.23 days) and 0.32 days in the left-bank ladder. The overall elapsed time at the dam for the 12 passage events was 7.60 days and ranged from 1.83-24.87 days (Table 3). During the 2003 migration, only one tagged bull trout migrated upstream through Wells Dam (the left bank ladder). For this fish, the tailrace residence time was 1.0 day and the ladder residence time was 0.16 days. Overall, the elapsed time at Wells Dam was 1.16 days (Table 4).

The median tailrace time in 2002 exceeded those recorded in 2001 by about 6.3 days. However, the median passage times within the ladders as well as the overall dam passage time were less in 2002 than in 2001 (Table 5). For 2003, the tailrace time was similar to 2001, and the ladder time similar to 2002 (Table 5). A possible explanation for these observations is that spill in 2002 was far greater than what was observed in 2001 or 2003.

It is possible to compare elapsed time of fish released at Wells Dam with those released at downstream dams in 2002. The median elapsed time at the dam for the four fish released in the tailrace was 20.09 days, compared to 3.56 days for the seven fish that migrated upstream from downstream dams. A similar trend was observed in 2001 at Wells Dam. In 2001, the median tailrace time was 3.64 days for fish released into the tailrace and 1.04 days for fish that migrated upstream from downstream dams. Similar to observations at Rocky Reach Dam, it appears that releasing recently tagged bull trout immediately downstream from Wells Dam increases tailrace residence time, thereby exaggerating the actual tailrace residence and elapsed time at the dam. It is likely that a recovery period of a few days is needed before fish released in the tailrace behave like fully-recovered fish that migrated from downstream locations.

Of the bull trout that passed Wells Dam, or were released into the forebay of that project in 2002 (n=15), 11 were detected by the fixed-telemetry site near the mouth of the Methow River. Two other fish passed Wells Dam and were detected in the Methow River during aerial surveys, but were not detected at the fixed-telemetry site. The transmitter of another fish apparently died after exiting the left-bank ladder. This transmitter was implanted into a fish in 2001 and was nearly 400 days old, which exceeded the expected 360-day tag life. Finally, another fish (tag 14-108) entered the Okanogan River and shortly thereafter left that river and moved into the Methow River. The travel time between Wells Dam and the Okanogan River site was 3.37 days. For the 11 fish that entered the Methow River, the median travel time between the dam and the river was 2.78 days (range, 0.33-16.42 days; Table 3). In 2003, the single fish that migrated upstream of Wells Dam entered the Methow River, with an elapsed time of 1.09 days between the two sites. The elapsed time between Wells Dam and the Methow River for 2002 and 2003 was longer than in 2001 (0.40 days; Table 5).

Two tagged bull trout were detected as they moved downstream through Wells Dam in 2002. One fish (14-100), released into the forebay of Rocky Reach Dam, migrated upstream and ascended the right-bank ladder at Wells Dam. Within a nine hour period, this fish moved back downstream through the dam. Four days later, the fish had ascended the left-bank ladder and exited the ladder system. This fish eventually ended up in the Methow River. The second fish (14-99) was released upstream of Wells Dam and about five hours later was detected in the tailrace of the project. This fish migrated downstream, passed Rocky Reach Dam, and entered the Wenatchee River. No evidence indicates that these fish were significantly harmed during their downstream passage through the dam. For the 2001 and 2003 migrations, no downstream passage events were observed.

Table 3: Summary of migration time (days) for adult radio-tagged bull trout that traveled between fixed station telemetry sites in 2002. Migration time was only assessed for actively migrating fish.

Location[1]	N	Mean	Median	Minimum	Maximum
Rock Island Dam					
Tailrace (A-B)	5	6.93	5.66	0.43	16.43
Left Fish Ladder (B-C)	1	0.18	0.18	0.18	0.18
Right Fish Ladder (B-C)	4	0.73	0.85	0.25	0.97
Elapsed Time at Dam (A-C)	5	7.55	5.90	1.21	17.35
Dam to Wenatchee River (C-D)	2	5.99	5.99	4.56	7.41
Dam to Rocky Reach Tailrace	7	2.70	2.78	1.14	5.46
Rocky Reach Dam					
Tailrace (A-B)	22	5.82	4.44	0.60	16.25
Fish Ladder (B-C)	23	0.59	0.28	0.13	6.15
Elapsed Time at Dam (A-C)	21	6.51	4.86	1.11	16.50
Dam to Entiat River (C-D)	23	12.26	11.34	3.51	26.98
Dam to Wells Tailrace	7	2.28	2.03	1.09	3.71
Wells Dam					
Tailrace (A-B)	3	9.27	7.84	1.64	18.35
Left Fish Ladder (B-C)	1	0.32	0.32	0.32	0.32
Right Fish Ladder (B-C)	2	0.21	0.21	0.20	0.23
Elapsed Time at Dam (A-C)	12	9.89	7.60	1.83	24.87
Dam to Methow River (C-D)	11	5.83	2.78	0.33	16.42

[1]Locations are defined as:

A First detection by tailrace system (300 meters downstream).

B First detection inside either ladder entrance.

C Last detection at either ladder exit.

D First detection at tributary site.

Table 4: Summary of migration time (days) for adult radio-tagged bull trout that traveled between fixed station telemetry sites in 2003. Migration time was only assessed for actively migrating fish.

Location[1]	N	Mean	Median	Minimum	Maximum
Rock Island Dam					
Tailrace (A-B)	---	---	---	---	---
Left Fish Ladder (B-C)	---	---	---	---	---
Right Fish Ladder (B-C)	---	---	---	---	---
Elapsed Time at Dam (A-C)	2	5.10	5.10	4.03	6.17
Dam to Wenatchee River (C-D)	1	1.67	1.67	1.67	1.67
Dam to Rocky Reach Tailrace	1	1.79	1.79	1.79	1.79
Rocky Reach Dam					
Tailrace (A-B)	---	---	---	---	---
Fish Ladder (B-C)	---	---	---	---	---
Elapsed Time at Dam (A-C)	9	5.46	4.68	0.66	16.87
Dam to Entiat River (C-D)	6	17.19	16.47	15.18	21.98
Dam to Wells Tailrace	1	1.73	1.73	1.73	1.73
Wells Dam					
Tailrace (A-B)	1	1.00	1.00	1.00	1.00
Left Fish Ladder (B-C)	1	0.16	0.16	0.16	0.16
Right Fish Ladder (B-C)	---	---	---	---	---
Elapsed Time at Dam (A-C)	1	1.16	1.16	1.16	1.16
Dam to Methow River (C-D)	1	1.09	1.09	1.09	1.09

[1]Locations are defined as:

- A First detection by tailrace system (300 meters downstream).
- B First detection inside either ladder entrance.
- C Last detection at either ladder exit.
- D First detection at tributary site.

Table 5: Summary of migration time in 2001, 2002, and 2003 (days) for adult radio-tagged bull trout that traveled between fixed station telemetry sites. Migration time was only assessed for actively migrating fish.

	2001		2002		2003	
Location[1]	**N**	**Median**	**N**	**Median**	**N**	**Median**
			Rock Island Dam			
Tailrace (A-B)	---	---	5	5.66	---	---
Left Fish Ladder (B-C)	---	---	1	0.18	---	---
Right Fish Ladder (B-C)	---	---	4	0.85	---	---
Elapsed Time at Dam (A-C)	3	2.28	5	5.90	2	5.10
Dam to Wenatchee River (C-D)	1	1.39	2	5.99	1	1.67
Dam to Rocky Reach Tailrace	4	1.33	7	2.78	1	1.79
			Rocky Reach Dam			
Tailrace (A-B)	9	1.28	22	4.44	---	---
Fish Ladder (B-C)	9	1.92	23	0.28	---	---
Elapsed Time at Dam (A-C)	9	3.79	21	4.86	9	4.68
Dam to Entiat River (C-D)	13	7.20	23	11.34	6	16.47
Dam to Wells Tailrace	6	1.69	7	2.03	1	1.73
			Wells Dam			
Tailrace (A-B)	10	1.53	3	7.84	1	1.00
Left Fish Ladder (B-C)	1	11.63	1	0.32	1	0.16
Right Fish Ladder (B-C)	7	5.45	2	0.21	---	---
Elapsed Time at Dam (A-C)	8	8.87	12	7.60	1	1.16
Dam to Methow River (C-D)	13	0.40	11	2.78	1	1.09

[1]Locations are defined as:
- A First detection by tailrace system (300 meters downstream).
- B First detection inside either ladder entrance.
- C Last detection at either ladder exit.
- D First detection at tributary site.

4.3 Tributary Selection and Residence

In 2001, all surviving adult bull trout tagged at each dam selected a major tributary for fall or fall-winter residence (Table 6). Major tributaries selected included the Wenatchee, Entiat, and Methow systems. One bull trout entered the Okanogan River (detected at the fixed-telemetry site at R.K. 9.0), but shortly thereafter migrated downstream and entered the Methow River. For many of these fish, it is not possible to establish the date of exodus from the tributary of residence. This is likely due to three factors. First, during the period when these fish may have exited the tributaries, the receivers monitoring those sites were also monitoring frequencies associated with other telemetry studies. As such, due to the extended receiver cycle time associated with this activity, fish may not have been detected as they passed the detection site. Second, for some of these fish, the transmitters may have failed by the time the fish exited the various basins. Finally, mobile survey efforts during the period following potential exodus had been reduced due to tagging efforts. However, based on detections within the mainstem at the various dams, five fish without tributary exit dates were confirmed to have exited the basin of residence (Table 6).

Of the 40 bull trout tagged at the three dams in 2002, 37 of them moved into tributaries for fall or fall-winter residence (Table 7). During 2002, the tributary residence of two fish tagged in 2001 was also documented. Other bull trout tagged in 2001 likely entered tributaries in fall 2002, but their transmitters had failed before it was possible to detect them in tributaries. For these 39 fish, their residence times and locations within tributaries have been summarized (Table 7).

Major tributaries selected by these fish included the Wenatchee, Entiat, and Methow River systems (Figure 18, Figure 19, and Figure 20)[5]. Entrance times of fish within the tributaries were based on the first detection at the fixed-sites within each tributary. All fish that entered tributaries were detected at the fixed sites. However, some fish were not detected at the fixed-sites during their exit from tributary streams. Therefore, aerial and boat surveys, as well as fixed-site telemetry data were used to determine tributary exit times for these fish.

Three fish tagged in 2002 did not enter tributaries. One fish (14-110) is likely dead. The transmitter of this fish was discovered downstream from Rock Island Dam on 22 August 2002. Before its transmitter was discovered, the fish had made brief forays into the Wenatchee and Entiat rivers. Another fish (14-124) remained between the Wenatchee River confluence and Rocky Reach Dam, while the third (14-127) resided between the Wenatchee River and Entiat River confluences.

During the fall of 2003, a total of 14 bull trout entered tributaries (Table 8). All of these fish were tagged in 2002. Of these fish, all but two exited tributaries by 23 November 2003, and all were detected by the fixed-sites as they exited the tributaries. The two fish (14-92 and 14-125) that remained in tributaries were last detected on 3 November 2003 during an aerial survey over the Mad River.

[5] These figures represent major tributaries selected, not specific locations within the major tributaries. Appendix B provides the locations where fish were detected during aerial surveys.

There is no indication that the hydro-system prevents bull trout from migrating into tributary streams. However, passage through the hydro-system may delay their entry into tributaries, causing them to miss their window for successful spawning. To address this we compared the timing of bull trout spawning in the basin with times at which tagged bull trout entered tributaries. The assumption is that if bull trout entered tributaries before the onset of spawning, then it is unlikely that the hydro-system prevented them from reaching their spawning areas in time to successfully spawn.

The literature indicates that bull trout spawn from August to November during periods of decreasing water temperatures (reviewed in Chapter 1 in the USFWS 2002 Draft Recovery Plan). In the Entiat Basin, based on over a decade of spawning surveys, median spawning times for bull trout ranged from mid- to late-September (data from P. Archibald, USFS). Our telemetry study indicates that most bull trout entered tributaries by the end of June, and aerial surveys detected tagged bull trout in possible spawning streams well before mid-September (Appendix B). Thus, there is no evidence that the hydro-system delayed the migration of bull trout to spawning areas in tributary streams. The following is a summary of tributary residence.

4.3.1 Wenatchee River

In 2001, of the 38 surviving bull trout, eight (21%) moved into the Wenatchee River basin. Of those fish, two were collected and tagged at Rock Island Dam. One of those came from a downstream release, while the other came from an upstream release. The other six fish that selected the Wenatchee basin were collected and tagged at Rocky Reach Dam and were released downstream from the dam (Table 6).

Aerial surveys were used to describe the location of seven of the eight fish in the Wenatchee system. Four fish remained within the Wenatchee River and did not move into tributaries. One resided about 1 km upstream from the mouth of the river, one near the town of Cashmere, and two in Tumwater Canyon (one near the lower end of the canyon and the other at the upstream end of the canyon). The other three fish resided in tributaries to the Wenatchee River. One fish was found in Peshastin Creek, one in the lower portion of Icicle Creek, and one in the lower portion of the Chiwawa River

In 2002, six tagged bull trout entered the Wenatchee River system (Table 7). These fish originated from releases at all three projects. Two were tagged at Rock Island Dam (Figure 18), three at Rocky Reach Dam (Figure 19), and one at Wells Dam (Figure 20). These fish entered and remained within the mainstem Wenatchee River. Aerial surveys located one near the town of Monitor, another near the town of Dryden, and two near the town of Leavenworth (Appendix B). The other two fish resided near the confluence of the Chiwawa River.

In 2003, three tagged bull trout entered the Wenatchee River system. One was tagged at Rock Island Dam and two at Rocky Reach Dam in 2002 (Table 8). All three of these fish resided within tributaries to the Wenatchee River (Appendix B). One fish resided within Ingalls Creek, which is a tributary to Peshastin Creek, and two resided within the Chiwawa River. The two fish that entered the Chiwawa River in 2003 resided in the Wenatchee basin in 2002 (Table 7 and Table 8; Appendix B). The third fish, which resided within Ingalls Creek in 2003, resided in the Mad River in 2002.

In 2001, bull trout that selected the Wenatchee Basin entered the system at different times. Five of the eight fish entered the Wenatchee River near the end of June 2001. The other three fish entered the Wenatchee River on 16 July, 27 August, and 21 September 2001 (Table 6). The time of egress also varied. As of the end of March 2002, five fish remained in the Wenatchee system, and four did so until their transmitters failed. The fifth fish was detected at Rocky Reach Dam on 22 May 2002. The other three left the system between 2 November and 11 December 2001 (Table 6). Of the three bull trout that left the Wenatchee River, two remained within the Rock Island Pool and did not pass any dams. The other fish moved downstream through Rock Island Dam and later moved back upstream through the dam. It was last detected (1 April) in the forebay of Rock Island Dam.

Bull trout that selected the Wenatchee Basin in 2002 entered and exited the system at different times. Two entered the Wenatchee River by the end of June, three by mid-July, and the last one in early August 2002 (Table 7). The median date of entry was 3 July 2002. The time of tributary egress also varied. Four of the six fish exited the system by the first week of November 2002. The other two exited in mid-December and mid-January, respectively (Table 7). The median date of exodus was 6 November 2002. After leaving the Wenatchee River, four fish resided in the Columbia River between Rock Island Dam and the Wenatchee River confluence, another remained in the Rock Island Pool, and the sixth resided downstream from Rock Island Dam.

For the three fish that resided within the Wenatchee basin in 2003, the date of entry varied by only six days, spanning from 16-22 June. For these fish, the median date of entry was 18 June. The date of tributary egress spanned about five weeks, with the first fish exiting the basin on 17 October. The other two fish exited the Wenatchee basin on 21 and 22 November. For two of these fish, their location of residence after leaving the Wenatchee River was documented during either aerial or boat surveys. One fish migrated downstream of Rock Island Dam, the second is in the Rock Island pool between Rock Island Dam and the Wenatchee River confluence, and the location of the third fish remains unknown.

Tributary selection by bull trout may be influenced by release location. Combining data collected at the three projects during 2001 and 2002 reveals that 28% (11 of 39) of all fish released downstream from projects ended in tributaries downstream from release sites. In contrast, only 3% of the bull trout released upstream from projects ended in tributaries downstream from release sites. This pattern was most apparent at Rocky Reach Dam, where 43% (10 of 23) of the fish released in the tailrace during 2001 and 2002 ended in the Wenatchee River.

4.3.2 Entiat River

For the 2001 period of tributary residence, a total of 15 adult bull trout moved into the Entiat River during the study. Of those, two were tagged at Rock Island Dam (downstream releases), 12 at Rocky Reach (four released downstream and eight upstream), and one at Wells Dam (downstream release; **Table 6**). All fish in the Entiat system resided either in the Mad River (eight fish) or in the mainstem Entiat River (seven fish). Those in the Mad River selected locations upstream from the Pine Flat Campground, while those in the Entiat River resided upstream from the Mad River confluence (BioAnalysts, Inc. 2002).

A total of 21 bull trout entered the Entiat River in 2002. These fish originated from releases at Rock Island (5 fish) and Rocky Reach dams (16 fish) (Table 7; Figure 19). No fish released at Wells Dam ended up in the Entiat Basin (Table 7). All fish in the Entiat system resided in either the Mad River (11 fish) or the mainstem Entiat River (10 fish). Those in the Mad River occupied locations upstream from the Pine Flat Campground (Appendix B). Of the ten fish that resided in the mainstem Entiat River, two were located downstream of the Mad River confluence, one between the confluences of the Mad River and Preston Creek, and seven upstream of Preston Creek (Appendix B).

In 2003, a total of 10 bull trout entered and resided within the Entiat basin (Table 8). Of these, seven occupied locations in the Mad River and three within the mainstem Entiat River (Appendix B). As in previous years, all of the bull trout that entered the Mad River resided upstream of the Pine Flat Campground. For the trout that resided within the mainstem of the Entiat River, all occupied locations upstream of Preston Creek. Of the ten bull trout that resided within the Entiat basin in 2003, seven also resided within that basin in 2002, with six selecting the same general area as the previous year (i.e., mainstem Entiat River or the Mad River). The other three fish in the Entiat basin in 2003 resided in either the mainstem Wenatchee River or in the Columbia River in 2002 (Table 7and Table 8).

All tagged bull trout that entered the Entiat River basin in 2001 did so relatively quickly after being released. The latest date of entry was 18 July, with the majority of the fish entering the system by the end of June (Table 6). The time of egress varied between fish in the Mad River and those in the Entiat River. All tagged fish that left the Entiat River did so by 11 November. Tagged fish in the Mad River remained there through winter and only one left the system by the end of March 2002. Two other fish that resided within the Mad River were detected in the mainstem Columbia River on 22 May and 6 June, 2002. Both of these fish were last detected in the forebay of Rocky Reach Dam. Of the eight adult bull trout that left the Entiat Basin during the study, four moved downstream through Rocky Reach Dam and resided in the Rock Island Pool. Two other bull trout moved downstream through both Rocky Reach and Rock Island dams, but did not pass Wanapum Dam. The remaining two bull trout moved into Rocky Reach Pool and passed no dams.

All tagged bull trout that entered the Entiat River basin in 2002 did so relatively quickly after being released. They entered the Entiat River from 6 June to 13 July with more than half of the fish entering the system by the end of June (Table 7). The median date of entry was 21 June 2002. The time of egress varied between fish in the Entiat River and those in the Mad River, with median tributary exit times of 4 September and 23 October, respectively. Of the 21 tagged fish that entered the Entiat Basin, 15 left the system by 17 December. Of those that remained in the system, three either died or shed their tags (14-88, 14-95 and 14-97), and three others may have died or shed their tags (14-119, 14-122 and 14-123). The 15 bull trout that left the Entiat Basin moved downstream into the Columbia River to reside in Rocky Reach, Rock Island, or Wanapum reservoirs. Ten fish moved into Rocky Reach pool, with seven located between Rocky Reach Dam and the Entiat River confluence and three between the Entiat River confluence and Wells Dam. Four bull trout moved downstream past Rocky Reach Dam and resided between the confluence of the Wenatchee River and Rocky Reach Dam. Finally, one bull trout migrated downstream past Rocky Reach and Rock Island dams and resided in the tailrace of Rock Island Dam.

Entry of bull trout into the Entiat Basin in 2003 spanned a period of ten weeks, with two fish entering that basin on 8 and 20 April and the last fish entering 22 June. However, the majority of the fish entered the Entiat River around mid-June, with a median date of entry of 13 June (Table 8). Of the ten fish that entered the Entiat River, eight exited that basin by the end of the study period (31

March 2004). For those fish, the median date of exodus was 21 October, with the first fish leaving the system on 4 October, and the last on 23 November. After exit from that basin, two fish resided within the Rock Island pool, five in Rocky Reach pool, and one downstream from Rock Island Dam.

4.3.3 Methow River

During the 2001 period of tributary residence, a total of 15 tagged adult bull trout moved into the Methow River. Two of those fish were tagged and released at Rock Island Dam (upstream releases), four at Rocky Reach Dam (one downstream release and three upstream releases), and nine at Wells Dam (four downstream releases and five upstream releases; Table 6). All of the fish entered the Methow basin by 11 June. By the end of March 2002, only four tagged bull trout had left the system. Those four had moved out of the system by 16 December 2001. Of the 11 tagged trout that did not leave the system by the end of the 2001 study period (31 March, 2002), eight remained in the Methow basin until their transmitters failed. For the other three, two were last detected in the tailrace of Wells Dam, and one upstream of that project.

During the 2002 study period, 12 adult bull trout entered the Methow River. These fish originated from releases at Rocky Reach and Wells dams (Table 7). Four bull trout were released at Rocky Reach Dam (Figure 19) and eight at Wells Dam (Figure 20). No fish tagged at Rock Island Dam moved into the Methow River (Table 7). Bull trout in the Methow system selected two primary areas, the mainstem Methow River and the Twisp River (Appendix B). Of the 12 fish that resided within the Methow basin, nine were located within the Twisp River upstream of Buttermilk Creek, and three appear to have resided upstream from the town of Winthrop. For the 2003 migration, only a single bull trout entered the Methow basin. That fish was initially tagged at Wells Dam in 2002, and resided in the mainstem Methow River near the Twisp River confluence (Table 8).

All bull trout that entered the Methow River in 2002 did so during the month of June (between 3 and 27 June). For those fish, their fates can be classified into four categories: 1) fish that exited the basin; 2) those that either died or shed their tags; 3) those that have not exited the basin but appear to be alive; and 4) fish whose fates are unknown.

The first category includes only a single fish (14-112). After entering the Methow River, this fish was not located over a 15 month period. During a routine aerial survey on 23 October 2003, it was located about 2 km downstream from the town of Winthrop and near the confluence of Gold Creek on 3 November. The last detection for this fish was 15 November 2003 at the fixed-telemetry site. As aerial surveys were typically terminated near the town of Winthrop, it is likely that this fish resided upstream of this location for an extended period of time. The second category of fish, those that either died or shed their tags, includes a total of seven fish. The transmitters for all seven fish were recovered in the tributary of residence (Table 7: Tributaries selected by adult bull trout tagged at Rock Island, Rocky Reach, and Wells dams and the dates they entered and left those tributaries, 2002.; Appendix A).

The third category, fish that have not exited the basin but appear to be alive, includes two fish. One fish (14-94) was not detected for 17 months after entering the Methow basin. During an aerial survey conducted by the USFWS on 18 December 2003, this fish was located upstream from the town of Winthrop. Another fish (14-116) has resided in both the mainstem Methow River and the Twisp River, and was most recently detected in Buttermilk Creek on 2 October 2003. This fish has been in the Methow basin for over 16 months. The fate of the last two fish is unknown. One was last detected on 1 July 2002, the other 19 February 2003. For the single fish that entered the Methow basin in 2003, it exited that basin on 28 October 2003 after four and a half months at that location. In 2002, this fish resided within the Wenatchee River basin.

Table 6: Tributaries selected by adult bull trout tagged at Rock Island, Rocky Reach, and Wells dams and the dates they entered and left those tributaries, 2001.

Tagging Information			Tributary Residence			
Release	Code	Date	Entrance	Exit	Subbasin	Location
			Rock Island Dam			
Down	32	21-May-01	04-Jun-01	23-Nov-01	Entiat	Mad River
Down	55	19-Jun-01	28-Jun-01	---	Entiat	Mad River
Down	35	30-May-01	13-Jun-01	---	Wenatchee	Peshastin Creek
Up	48	03-Jul-01	NA	NA	Dead	
Up	4	17-May-01	30-May-01	---	Methow	Twisp River
Up	13	24-May-01	11-Jun-01	---	Methow	Twisp River
Up	36	13-Jun-01	21-Sep-01	02-Nov-01	Wenatchee	Mainstem Wenatchee River
			Rocky Reach Dam			
Down	29[1]	21-May-01	06-Jun-01	---	Entiat	Mad River
Down	18[1]	23-May-01	07-Jun-01	---	Entiat	Mad River
Down	15	25-May-01	06-Jun-01	02-Nov-01	Entiat	Mainstem Entiat River
Down	11	29-May-01	06-Jun-01	02-Nov-01	Entiat	Mainstem Entiat River
Down	54	30-May-01	11-Jun-01	---	Methow	Libby Creek
Down	8	11-Jun-01	30-Jun-01	---	Wenatchee	Chiwawa River
Down	46	18-Jun-01	23-Jun-01	11-Dec-01	Wenatchee	Icicle Creek
Down	5	17-May-01	30-May-01	---	Wenatchee	Mainstem Wenatchee River
Down	9	07-Jun-01	27-Aug-01	16-Nov-01	Wenatchee	Mainstem Wenatchee River
Down	25	25-Jun-01	29-Jun-01	---	Wenatchee	Mainstem Wenatchee River
Down	34[1]	10-Jul-01	16-Jul-01	---	Wenatchee	Mainstem Wenatchee River
Up	45	15-Jun-01	29-Jun-01	---	Entiat	Mad River
Up	47	19-Jun-01	01-Jul-01	---	Entiat	Mad River
Up	3	15-May-01	22-May-01	---	Entiat	Mad River
Up	24	22-May-01	04-Jun-01	---	Entiat	Mad River
Up	6	29-May-01	10-Jun-01	17-Oct-01	Entiat	Mainstem Entiat River
Up	7	04-Jun-01	08-Jun-01	11-Nov-01	Entiat	Mainstem Entiat River
Up	37	06-Jun-01	11-Jun-01	09-Nov-01	Entiat	Mainstem Entiat River
Up	50	13-Jul-01	18-Jul-01	24-Sept-01	Entiat	Mainstem Entiat River
Up	20	21-May-01	30-May-01	16-Dec-01	Methow	Twisp River
Up	12	24-May-01	10-Jun-01	07-Oct-01	Methow	Twisp River
Up	14	25-May-01	02-Jun-01	---	Methow	Twisp River
			Wells Dam			
Down	17	24-May-01	02-Jun-01	10-Aug-01	Entiat	Mainstem Entiat River
Down	22	29-May-01	08-Jun-01	---	Methow	Mainstem Methow River
Down	26	22-May-01	01-Jun-01	16-Dec-01	Methow	Twisp River
Down	19	22-May-01	01-Jun-01	---	Methow	Twisp River
Down	33	22-May-01	08-Jun-01	13-Apr-02	Methow	Twisp River
Up	28	22-May-01	24-May-01	---	Methow	Mainstem Methow River
Up	23[1]	29-May-01	01-Jun-01	---	Methow	Mainstem Methow River
Up	21	22-May-01	24-May-01	02-Nov-01	Methow	Twisp River
Up	31[1]	21-May-01	27-May-01	---	Methow	Buttermilk Creek
Up	16	23-May-01	25-May-01	---	Methow	Buttermilk Creek

[1] Based on detection histories for these fish, it appears that they exited the tributary of residence. However, due to a lack of detections at the fixed telemetry sites on the tributary of residence, a date of exodus can not be established.

Table 7: Tributaries selected by adult bull trout tagged at Rock Island, Rocky Reach, and Wells dams and the dates they entered and left those tributaries, 2002.

Tagging Information			Tributary Residence			
Release	Code	Date	Entrance	Exit	Subbasin	Location
			Rock Island Dam			
Down	105	04-Jun-02	27-Jun-02	17-Dec-02	Wenatchee	Mainstem Wenatchee River
Down	113	07-Jun-02	22-Jun-02	06-Nov-02	Wenatchee	Mainstem Wenatchee River
Down	90[3]	23-May-02	01-Jul-02	04-Sep-02	Entiat	Mainstem Entiat River
Down	115	12-Jun-02	01-Jul-02	04-Sep-02	Entiat	Mainstem Entiat River
Up	110[1]	04-Jun-02	---	---	Columbia River	---
Up	97[2]	20-May-02	19-Jun-02	---	Entiat	Mad River
Up	119[4]	12-Jun-02	29-Jun-02	---	Entiat	Mad River
Up	109[3]	07-Jun-02	20-Jun-02	17-Dec-02	Entiat	Mad River
			Rocky Reach Dam			
Down	127	27-Jun-02	---	---	Columbia River	---
Down	104	30-May-02	01-Jul-02	09-Oct-02	Wenatchee	Mainstem Wenatchee River
Down	125	26-Jun-02	06-Jul-02	06-Nov-02	Wenatchee	Mainstem Wenatchee River
Down	126	18-Jun-02	14-Jul-02	14-Jan-03	Wenatchee	Mainstem Wenatchee River
Down	101	03-Jun-02	25-Jun-02	06-Nov-02	Entiat	Mad River
Down	106	06-Jun-02	27-Jun-02	09-Oct-02	Entiat	Mainstem Entiat River
Down	111	04-Jun-02	18-Jun-02	06-Nov-02	Entiat	Mad River
Down	118	11-Jun-02	01-Jul-02	09-Oct-02	Entiat	Mainstem Entiat River
Down	114	10-Jun-02	01-Jul-02	09-Oct-02	Entiat	Mad River
Down	120	27-Jun-02	13-Jul-02	09-Oct-02	Entiat	Mad River
Down	95[1]	29-May-02	09-Jun-02	---	Entiat	Mainstem Entiat River
Down	89[2]	21-May-02	09-Jun-02	---	Methow	Twisp River
Down	46	18-Jun-01	04-Jul-02	01-Aug-02	Entiat	Mainstem Entiat River
Up	124	24-Jun-02	---	---	Columbia River	---
Up	103	06-Jun-02	21-Jun-02	09-Oct-02	Entiat	Mainstem Entiat River
Up	121	07-Jun-02	20-Jun-02	06-Nov-02	Entiat	Mad River
Up	88[2]	20-May-02	06-Jun-02	---	Entiat	Mad River
Up	92	23-May-02	19-Jun-02	04-Sep-02	Entiat	Mad River
Up	122[4]	12-Jun-02	20-Jun-02	---	Entiat	Mainstem Entiat River
Up	123[4]	21-Jun-02	01-Jul-02	---	Entiat	Mainstem Entiat River
Up	98[3]	30-May-02	12-Jun-02	09-Oct-02	Entiat	Mad River
Up	116	10-Jun-02	24-Jun-02	---	Methow	Twisp River
Up	100	04-Jun-02	27-Jun-02	---	Methow	Twisp River
Up	108[2]	03-Jun-02	23-Jun-02	---	Methow	Twisp River
Up	7	04-Jun-01	11-Jun-02	04-Aug-02	Entiat	Mainstem Entiat River
			Wells Dam			
Down	112	11-Jun-02	19-Jun-02	15-Nov-03	Methow	Mainstem Methow River
Down	93[1]	28-May-02	24-Jun-02	---	Methow	Twisp River
Down	96[1]	03-Jun-02	22-Jun-02	---	Methow	Twisp River
Down	102[2]	04-Jun-02	26-Jun-02	---	Methow	Twisp River
Up	99	04-Jun-02	01-Aug-02	06-Nov-02	Wenatchee	Mainstem Wenatchee River
Up	91	23-May-02	03-Jun-02	---	Methow	Mainstem Methow River
Up	94	03-Jun-02	20-Jun-02	---	Methow	Mainstem Methow River
Up	107[1]	03-Jun-02	09-Jun-02	---	Methow	Twisp River
Up	117[1]	12-Jun-02	21-Jun-02	---	Methow	Twisp River

[1] The transmitters for these fish were recovered at the tributary or location of residence during the 2002 study period.
[2] The transmitters for these fish were recovered at the tributary or location of residence during the 2003 study period.
[3] The transmitters for these fish were recovered after tributary exodus during the 2003 study period in the Columbia River.
[4] These fish are suspected of perishing or shedding their tags in the tributary of residence.

Table 8: Tributaries selected by adult bull trout tagged at Rock Island, Rocky Reach, and Wells dams and the dates they entered and left those tributaries, 2003.

Tagging Information			Tributary Residence			
Release	**Code**	**Date**	**Entrance**	**Exit**	**Subbasin**	**Location**
			Rock Island Dam			
Down	113	07-Jun-02	16-Jun-03	21-Nov-03	Wenatchee	Chiwawa River
			Rocky Reach Dam			
Down	101	03-Jun-02	22-Jun-03	17-Oct-03	Wenatchee	Peshastin Creek
Down	104	30-May-02	01-Jun-03	21-Oct-03	Entiat	Mainstem Entiat River
Down	106	06-Jun-02	20-Apr-03	23-Nov-03	Entiat	Mainstem Entiat River
Down	114	10-Jun-02	22-Jun-03	04-Oct-03	Entiat	Mad River
Down	118	11-Jun-02	08-Apr-03	17-Oct-03	Entiat	Mad River
Down	120	27-Jun-02	18-Jun-03	18-Nov-03	Entiat	Mad River
Down	125	26-Jun-02	18-Jun-03	---	Entiat	Mad River
Down	126	18-Jun-02	18-Jun-03	22-Nov-03	Wenatchee	Chiwawa River
Down	127	27-Jun-02	13-Jun-03	17-Oct-03	Entiat	Mad River
Up	92	23-May-02	14-Jun-03	---	Entiat	Mad River
Up	103	06-Jun-02	13-Jun-03	21-Oct-03	Entiat	Mainstem Entiat River
Up	121	07-Jun-02	08-Jun-03	21-Oct-03	Entiat	Mad River
			Wells Dam			
Up	99	04-Jun-02	03-Jun-03	28-Oct-03	Methow	Mainstem Methow River

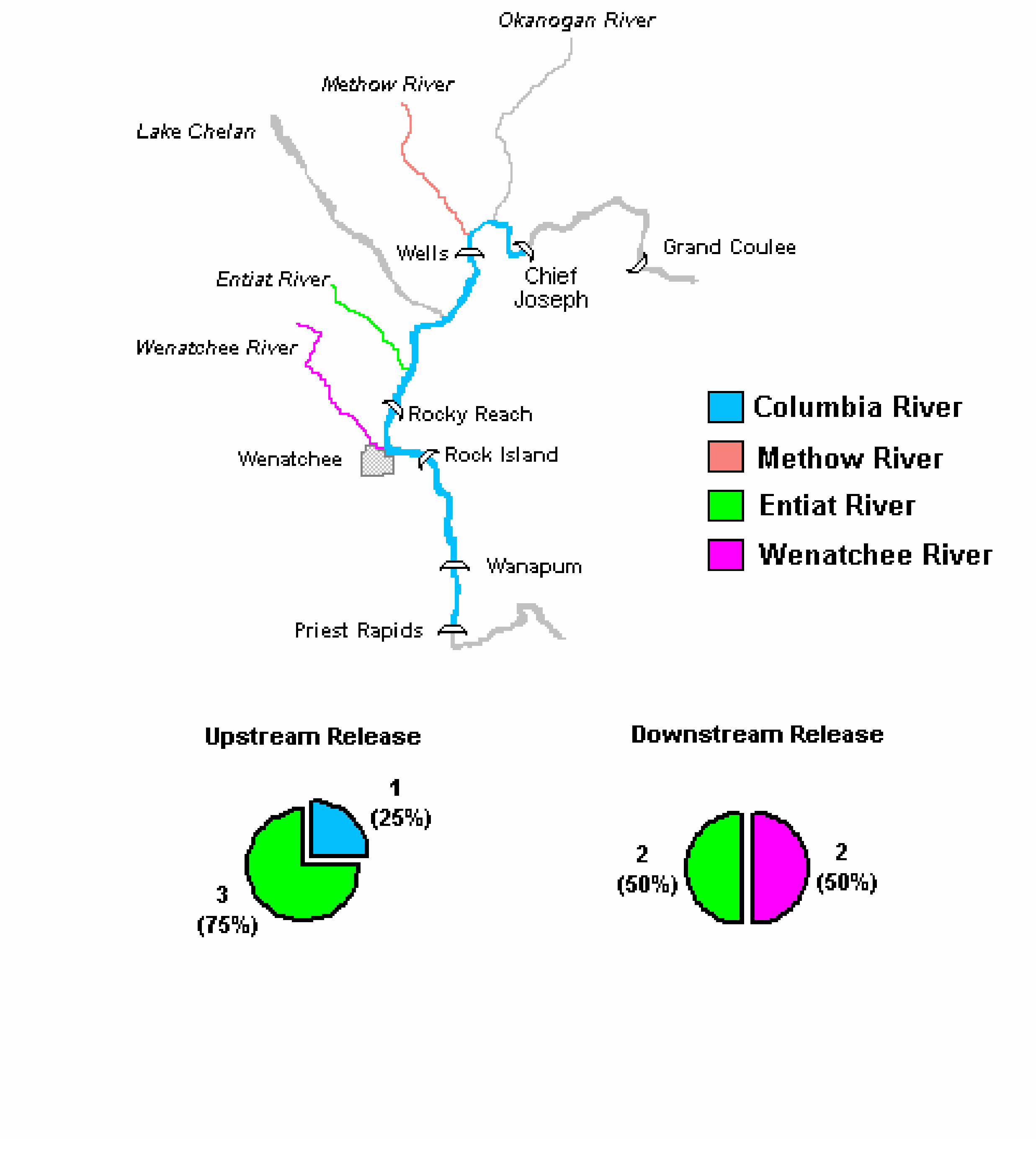


Figure 18: Mid-Columbia River tributaries selected by bull trout after they were released upstream and downstream from Rock Island Dam, 2002. Final destination for radio-tagged bull trout within each tributary is noted in Table 7.

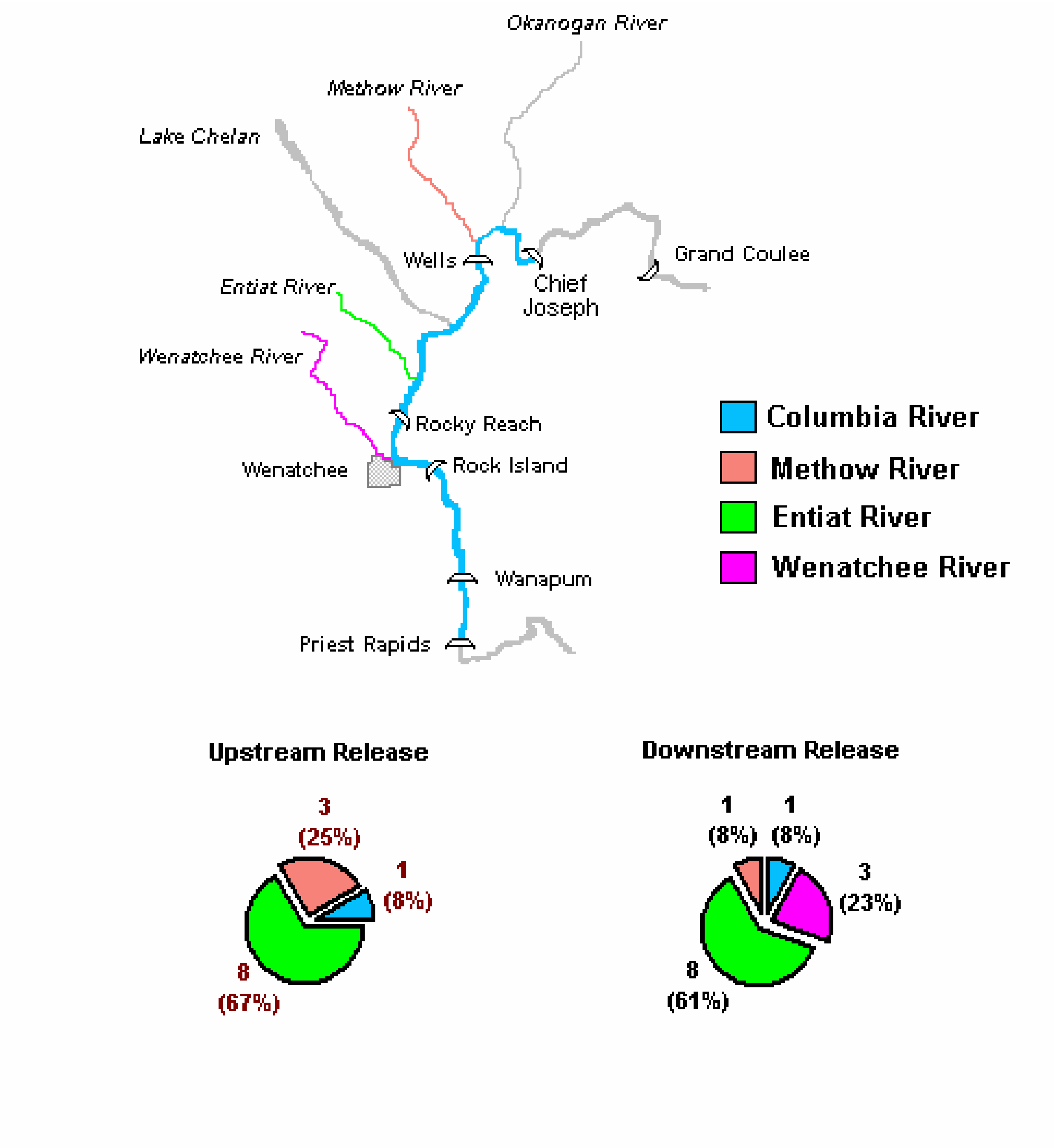


Figure 19: Mid-Columbia River tributaries selected by bull trout after they were released upstream and downstream from Rocky Reach Dam, 2002. Final destination for radio-tagged bull trout within each tributary is noted in Table 7.

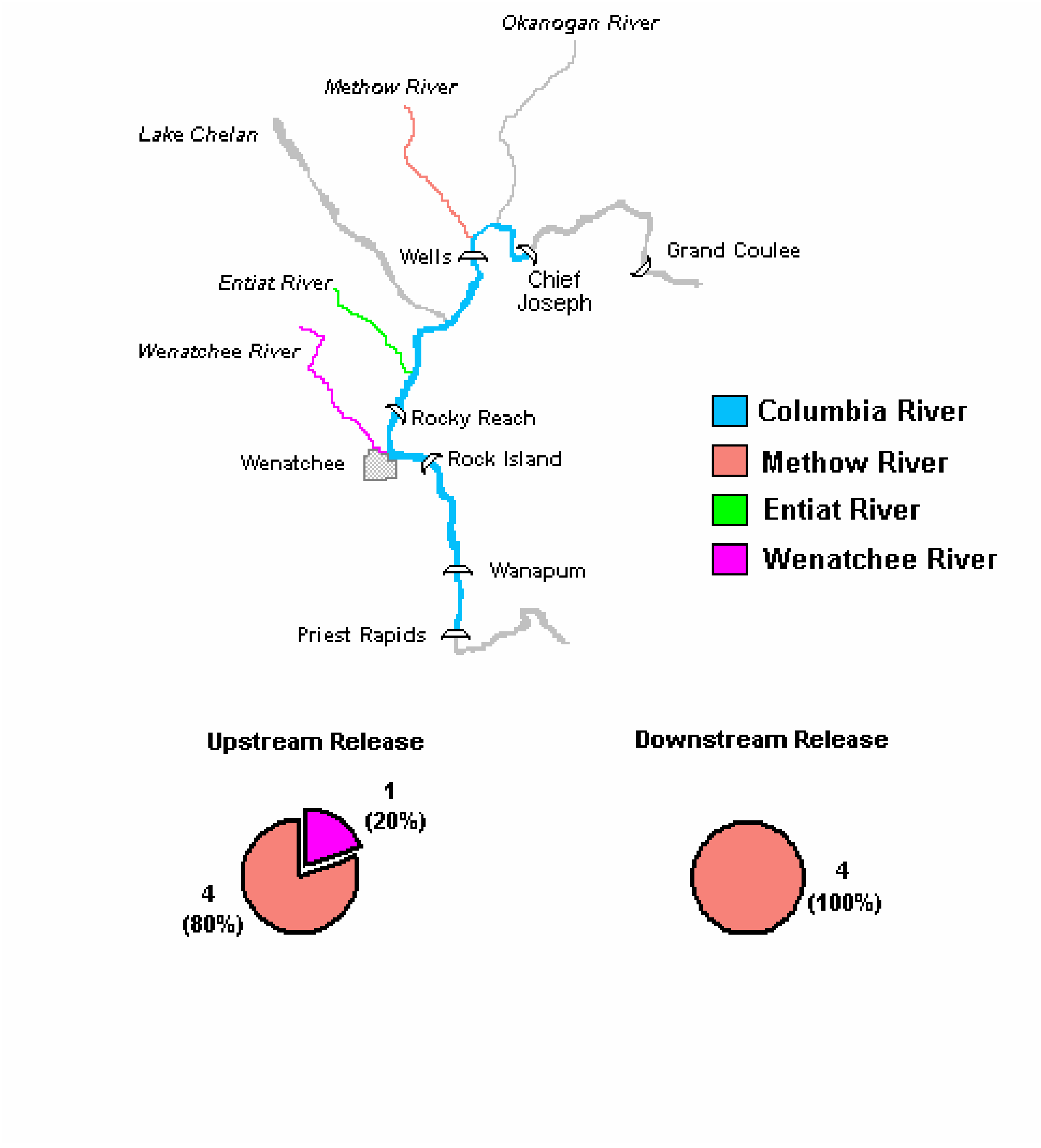


Figure 20: Mid-Columbia River tributaries selected by bull trout after they were released upstream and downstream from Wells Dam, 2002. Final destination for radio-tagged bull trout within each tributary is noted in Table 7.

4.4 Tributary and Mainstem Temperatures

To investigate the relationship between temperature and movement of bull trout in the mid-Columbia River, it is possible to compare temperatures at the time of entry into tributary streams with that of the Columbia River. For this analysis, the mean daily temperature of the Columbia River relative to the various tributaries at the time bull trout entered the Wenatchee, Entiat and Methow rivers have been compared. Where data were available, minimum, mean and maximum daily temperatures within the lower tributaries have been plotted. For fish entering the Wenatchee and Entiat rivers, tributary temperatures were compared to temperatures measured within the Rocky Reach tailrace. For fish entering the Methow River, tailrace temperatures measured at Wells Dam were used. For some fish, there is a history of tributary entrance on more than one occasion. That is, for some fish tagged in 2001, their transmitters were active long enough to document tributary entrance in both 2001 and 2002. Likewise, many fish tagged in 2002 also entered tributaries in 2003.

Temperature data for the various tributaries is in many cases incomplete. Temperature data collected from the Wenatchee, Methow, and Entiat rivers were all collected in the lower 4-kilometers of each stream. For the lower Wenatchee River, daily minimum, mean and maximum temperatures for 2001, and only mean temperatures for 2002 and 2003 were acquired. For the lower Methow River, only daily mean values were available for 2001 and 2003. No temperature data were available in 2002 for the Methow River. Temperature data for the Entiat River were the most complete with daily minimum, mean and maximum values recorded. However, for all three tributaries, data were only available through the latter part of August. However, to better understand mid-Columbia River temperatures and migration of bull trout, the first and last date of entry into each tributary were used, regardless if temperature data were available in the tributaries.

Seventeen bull trout entered the Wenatchee Basin during the spring and summer of a three year study period. There were no temperature data available in the lower Wenatchee River for three of those fish. Bull trout entered the Wenatchee River in June and July when the mean daily temperatures in the Wenatchee River ranged from 10.5 °C to 17.2 °C. In the Columbia River during that time the mean daily temperatures ranged from 11.2 °C to 19.6 °C (Figure 21).

There were forty-six radio-tagged bull trout that entered the Entiat basin from April to mid-July. Bull trout entered the Entiat River when the mean daily temperatures ranged from 7 .5 °C to 15.8 °C (Figure 22). Mean daily temperatures for the Columbia River during the migration period varied from 5.4 °C to 19.6 °C.

Collectively for the 2001-2003 study period 28 radio-tagged bull trout entered the Methow basin in May and June. However, due to sporadic stream temperature monitoring within the lower Methow River, it is only possible to document stream temperatures for six fish at the time of tributary entrance. Six bull trout entered the Methow River when the mean daily temperatures varied from 9.7 °C to 13.5 °C (Figure 23). For all bull trout that entered the Methow basin, mean daily temperatures for the Columbia River during the three year study period ranged from 10.1 °C to 14.9 °C.

For the three years of data regarding tributary entrance into the Wenatchee, Entiat and Methow rivers, a total of 91 tributary entrance events occurred. During the study period bull trout entered mid-Columbia tributaries from April to September but most (94%) entered tributaries during May, June and July. At the time bull trout entered tributary streams the mean daily temperatures in the mainstem Columbia River varied from 5.4 °C to 19.6 °C. Similarly, tributary mean daily temperatures ranged from 7.5 °C to 17.2 °C. Most bull trout (92.3%) entered tributaries before the Columbia River reached a mean temperature of 15 °C. The successful migration of bull trout into the various spawning streams of the Wenatchee, Entiat and Methow suggests that temperatures at the time of migration in the mid-Columbia River did not appear to limit the migration of radio-tagged bull trout.

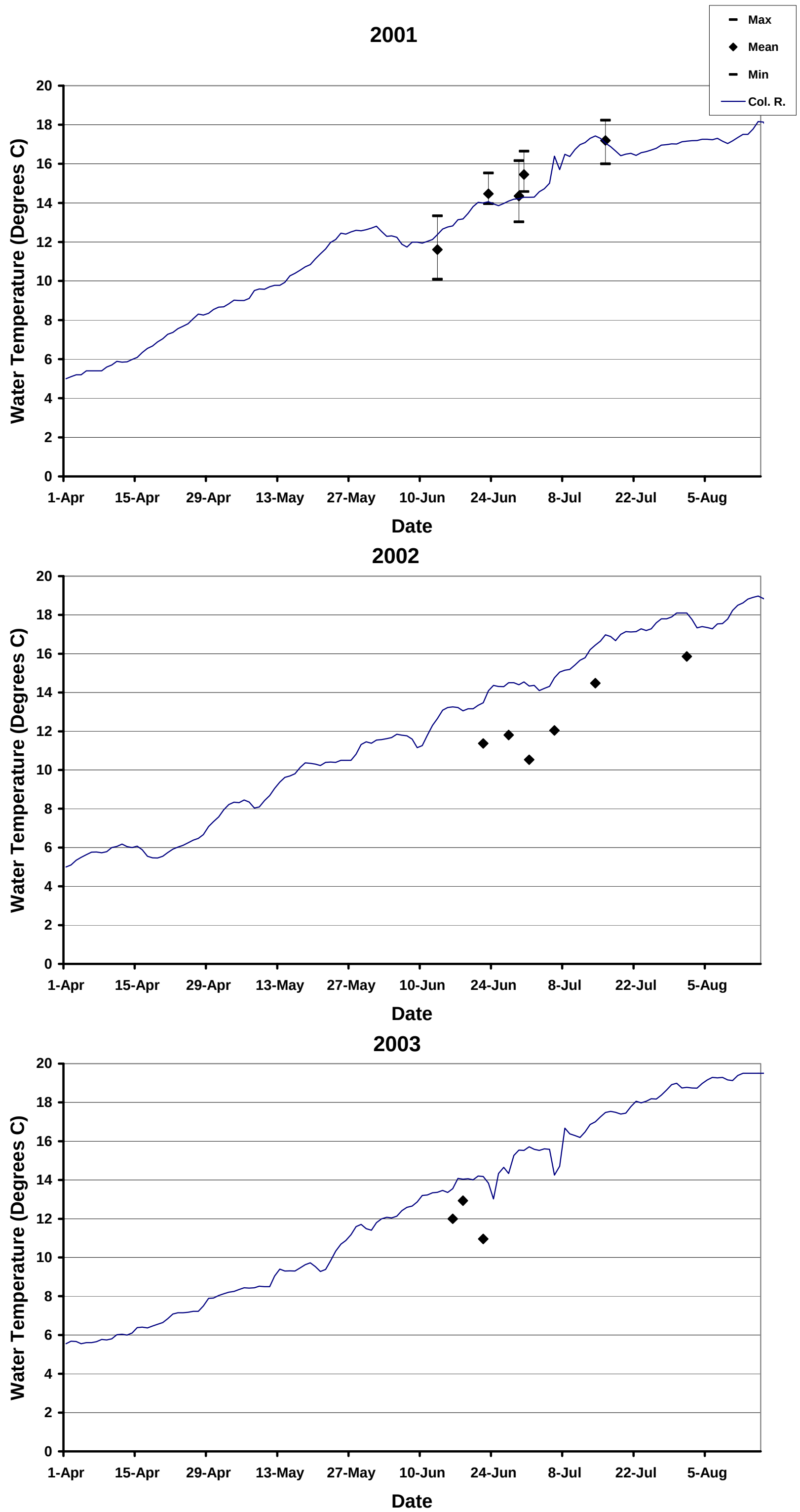


Figure 21: Wenatchee River temperatures at the time of tributary entrance relative to the Columbia River measured downstream of Rocky Reach Dam, 2001-2003. Daily minimum, mean and maximum Wenatchee River temperatures provided where data were available. Each data point represents an individual fish.

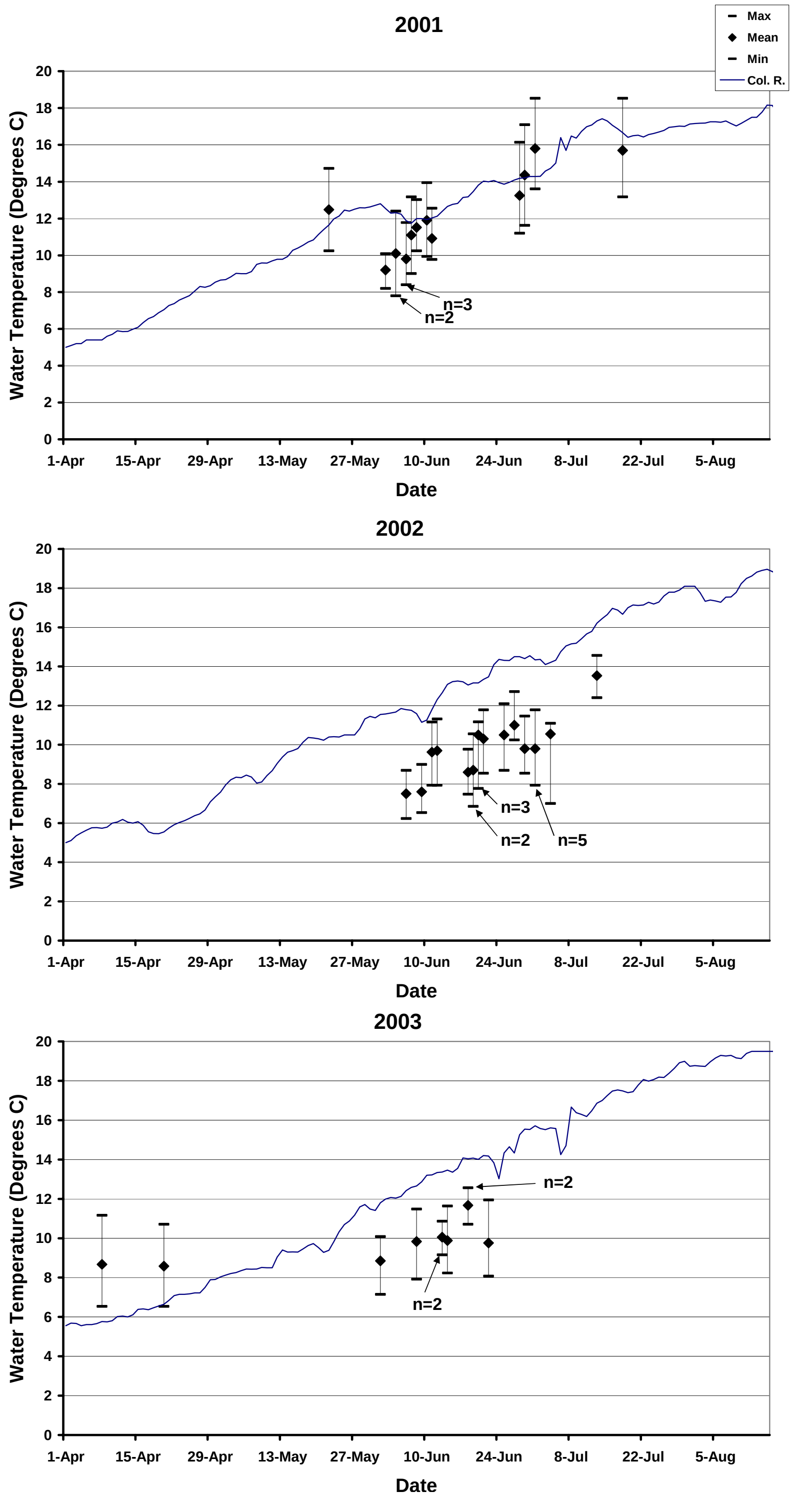
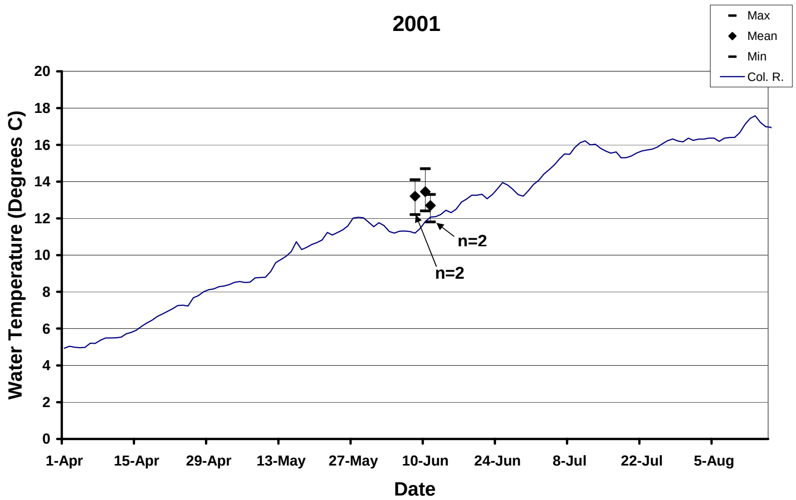


Figure 22: Entiat River temperatures at the time of tributary entrance relative to the Columbia River measured downstream of Rocky Reach Dam, 2001-2003. Daily minimum, mean and maximum Entiat River temperatures provided where data were available. Each data point represents an individual fish except where noted.



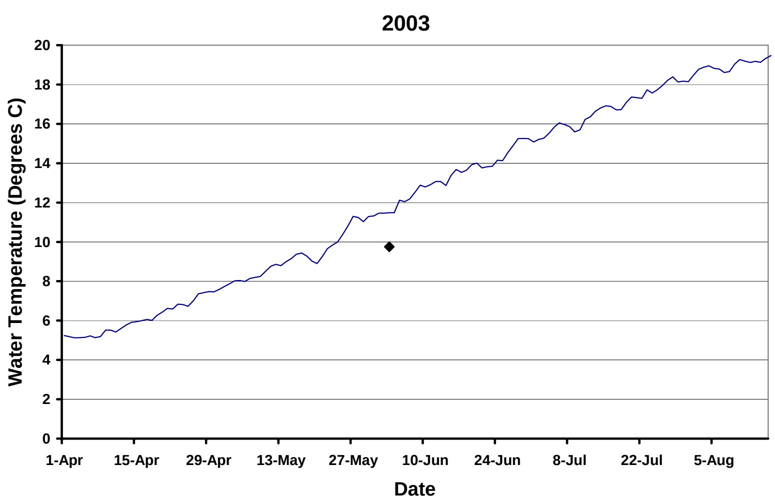


Figure 23: Methow River temperatures at the time of tributary entrance relative to the Columbia River measured downstream of Wells Dam, 2001and 2003. Daily minimum, mean and maximum Methow River temperatures provided where data were available. Each data point represents an individual fish.

4.5 Mainstem Habitat Use

During the 2001 study period, boat surveys were used to describe the general habitats used by tagged adult bull trout as they moved through Rock Island and Rocky Reach reservoirs. Similar surveys were not repeated in 2002 and 2003. For results from those efforts, refer to BioAnalysts, Inc. (2002). However, in addition to the mainstem habitat use assessments conducted by boat in 2001, an effort was also made to examine the extent that radio-tagged bull trout used the Wells Hatchery outfall and the mainstem Columbia River downstream from Rock Island Dam. The purpose of this work was to determine if bull trout used the Wells Hatchery outfall as temperature refugia and to assess the extent that bull trout used Wanapum and Priest Rapids reservoirs. What follows is a summary of those findings.

4.5.1 Wells Hatchery Outfall

To address this issue, an underwater telemetry system was deployed within the outfall channel downstream from the ladder system. In both 2001 and 2002, tagged bull trout were observed in the hatchery outfall. In 2003, a single bull trout was detected in the tailrace of Wells Dam, but it did not use the hatchery outfall. In 2001, of the 39 bull trout that were radio-tagged throughout the mid-Columbia River, a total of 11 (28.2%) were detected within the Wells Hatchery outfall (Table 9). Of the trout that were in the vicinity of Wells Dam and the outfall (12 tagged bull trout), all but one (92%) entered the hatchery outfall. Of those that entered the outfall, two were tagged at Rock Island, four at Rocky Reach, and five at Wells Dam.

The five fish tagged at Wells Dam that entered the outfall were all released downstream from the dam. Thus, their detection in the outfall was not surprising given that they were released about 20 m downstream from the underwater telemetry system. However, all five fish were detected multiple times, and one was detected on 13 separate occasions (Table 9). On average, fish were detected 6.6 times by the outfall underwater telemetry system with a total of 22.3 minutes per detection. The total elapsed time for fish detected at the outfall (i.e., the period of time between the first detection and the last detection for the first and last visits, respectively) averaged 5.6 days, with a range of several minutes to 15.4 days.

In 2002, of the 15 tagged bull trout that were in the vicinity of Wells Dam, ten were tagged in 2002 and five in 2001. Eight of the 15 fish visited the outfall (Table 10). Three were tagged at Rocky Reach and five were tagged at Wells Dam. Four of the five fish tagged at Wells Dam were fish released downstream of the dam in the immediate vicinity of the hatchery outfall, and as with the 2001 observations, it is not surprising that they were detected at the outfall. However, all of these fish were detected multiple times, with one detected on 24 separate occasions (Table 10). On average, fish visited the outfall 9.4 times and averaged 10.2 minutes per visit. The total elapsed time[6] for fish detected at the outfall averaged 6.0 days, ranging from several minutes to 15.5 days.

Bull trout were more likely to use the outfall during daylight hours than at night. Of the 73 detections for the 11 tagged bull trout that occurred in the outfall in 2001, 58 occurred during periods

---

[6] Total elapsed time is defined as the period of time between the first detection and the last detection for the first and last visits, respectively.

of daylight (0500-2100 hours), with an average of 3.6 detections per daylight hour. During periods of darkness, on average 1.9 detections per hour were observed (Figure 24). Similar to observations in 2001, bull trout in 2002 were more likely to use the outfall during daylight hours than at night. Of the 75 detections for the eight tagged bull trout that occurred in the outfall, 56 occurred during daylight, averaging 3.5 detections per daylight hour. During periods of darkness, an average 2.4 detections per hour were observed (n = 19; Figure 25).

There are several possible reasons why adult bull trout frequent the hatchery outflow, including using the area as a temperature refuge, seeking opportunistic feeding opportunities, or simply demonstrating exploratory behavior. With regard to the outflow providing bull trout with a temperature refuge, the hatchery operates June through August primarily on water diverted from the mainstem Columbia River. This water is supplemented with about 4 cfs of well water, which has a fairly constant temperature of 11.1°C. Although the well water may have some moderating effect on water temperature at the hatchery, overall a large difference in temperature between the outfall and the mainstem Columbia River would not be expected. Water temperatures recorded within the mainstem Columbia (recorded at Wells Dam) during the time period when bull trout were detected in the hatchery outfall (3-20 June) ranged between 10.1 and 13.3°C, which are within the thermal optima for adult bull trout (EPA 2001). Therefore, it is doubtful that bull trout used the hatchery outfall as a temperature refuge.

It is possible that the bull trout frequented the outfall in search of prey. Typical operation at the hatchery is to volitionally release yearling chinook smolts between 15 and 30 April, and subyearling chinook smolts in early June. These smolts migrate downstream through the hatchery outfall channel system and then enter the Columbia River. During the 2001 study period, bull trout were observed at the hatchery outfall between 17 May and 27 June. In 2002, detections occurred between 3 June and 20 June. Large numbers of smolts were routinely observed during the period when the bull trout frequented the outflow (Shane Bickford, DPUD, personal communication). Given that bull trout feed opportunistically (Goetz 1989), it is likely that the tagged bull trout were taking advantage of the large concentration of juvenile salmonids within the hatchery outfall system.

Table 9: Number of visits and length of time that eleven bull trout were detected within the Wells Hatchery outfall, 2001. The mean, minimum, maximum and total times are in hours and the elapsed time is in days. The elapsed time is defined as the period of time between the first and last detections at this location.

Release Location	Code	Number of Visits	Time Mean	Min	Max	Total	Elapsed
			Rock Island Dam				
Up	4	1	0:04:35	---	---	0:04:35	0.0
Up	13	15	0:54:34	0:00:12	12:03:18	13:38:25	8.6
			Rocky Reach Dam				
Down	54	6	0:02:45	0:00:31	0:04:58	0:16:31	4.8
Up	12	13	0:09:41	0:01:14	0:22:23	2:05:51	10.3
Up	20	1	0:11:32	---	---	0:11:32	0.0
Up	47	4	0:02:11	0:00:18	0:04:34	0:08:43	2.4
			Wells Dam				
Down	17	2	0:13:39	0:01:02	0:26:15	0:27:17	0.4
Down	19	8	0:29:43	0:00:51	1:59:32	3:57:43	3.6
Down	22	3	1:40:37	0:02:33	4:55:35	5:01:51	8.5
Down	26	13	0:03:21	0:00:30	0:13:47	0:43:38	7.8
Down	33	7	0:04:32	0:00:51	0:13:23	0:31:41	15.4

Table 10: Number of visits and length of time that eight bull trout were detected within the Wells Hatchery outfall, 2002. The mean, minimum, maximum and total times are in hours and the elapsed time is in days. The elapsed time is defined as the period of time between the first and last detections at this location.

Release Location	Code	Number of Visits	Time Mean	Time Min	Time Max	Time Total	Time Elapsed
				Rocky Reach Dam			
Up	100	9	0:06:41	0:00:18	0:32:41	1:00:08	4.16
Up	108	5	0:01:15	0:00:19	0:02:15	0:06:14	4.65
Up	116	7	0:03:08	0:00:15	0:16:59	0:21:59	2.87
				Wells Dam			
Down	93	24	0:16:06	0:00:16	1:04:05	6:26:13	15.50
Down	96	17	0:05:19	0:00:16	1:12:57	1:30:24	14.60
Down	102	3	0:01:51	0:01:35	0:02:03	0:05:32	0.08
Down	112	4	0:04:32	0:00:19	0:07:43	0:18:08	4.74
Up	99	6	0:03:47	0:00:22	0:08:45	0:22:40	1.26

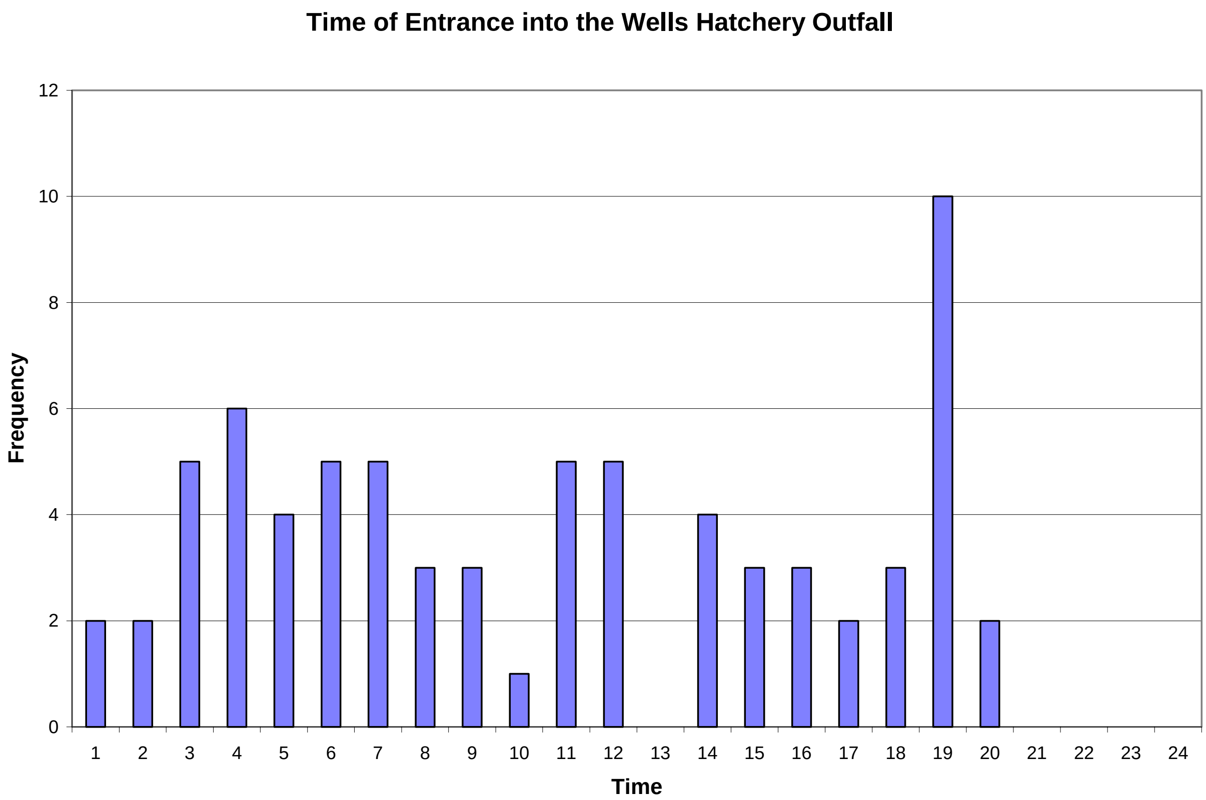


Figure 24: Diel pattern for 11 radio-tagged bull trout detected at the Wells hatchery outfall, 2001. There were 73 visits to the hatchery outfall, but most (58) occurred between 0500-2100 hrs.

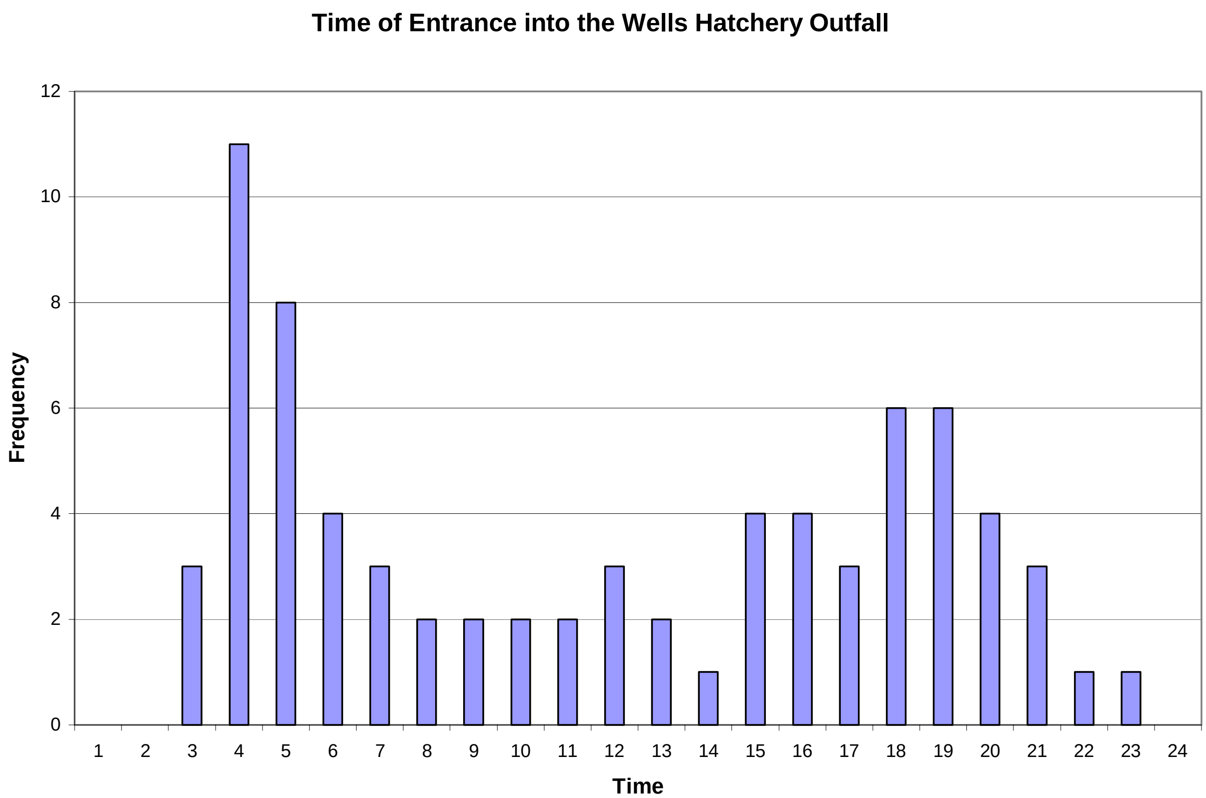


Figure 25: Diel pattern for eight radio-tagged bull trout detected at the Wells Hatchery outfall, 2002. There were 75 visits to the hatchery outfall, but most (56) occurred between 0500-2100 hrs.

4.5.2 Wanapum and Priest Rapids Reservoirs

The extent of movement observed for bull trout that migrated downstream of Rock Island Dam is based primarily on detection histories generated from fixed-site telemetry data collected at Priest Rapids, Wanapum, and Rock Island dams, as well as during mobile surveys. Telemetry data collected at Rocky Reach and Wells dams, as well as the tributary sites, have been integrated to aid in the removal of false records from the database. Collectively, ten radio-tagged bull trout migrated downstream of Rock Island Dam after spending time in tributaries. This represents 12.7% of the tagged population. One fish (14-101) moved downstream on two separate occasions. Only one of the ten fish was detected at Wanapum and Priest Rapids dams. Thus, the other nine remained in the Wanapum Reservoir and did not pass Wanapum or Priest Rapids dams.

In addition to the fixed-site telemetry data, aerial and boat surveys provided relatively accurate information on the location of tagged fish within Wanapum reservoir. During the course of the study, a total of 36 boat and 35 aerial surveys were conducted on Wanapum reservoir. The accuracy of aerial surveys was about 300 m, based on tests conducted by Chelan PUD in the Entiat Basin using ten test transmitters. The accuracy of boat surveys depended on the type of antenna used and the method of tracking. For detections using an underwater antenna, the accuracy was about 10 m. For aerial antennas using triangulation techniques, the accuracy was about 50 m. Simple detection with an aerial antenna was about 200 m.

No bull trout were found in Priest Rapids reservoir during 21 boat and 35 aerial surveys. One bull trout (14-105), however, was detected with fix-site systems at Wanapum and Priest Rapids dams on 26 and 28 May 2003, respectively. These results indicate that bull trout resided primarily in areas upstream of Wanapum Dam. While this observation is limited to only radio-tagged fish included in this study, additional data indicate that bull trout rarely use Priest Rapids Reservoir. Grant County PUD regularly conducts salvage operations of fish collected within gatewells at both Wanapum and Priest Rapids dams during the juvenile migration. For the years of 1997-2003, no bull trout were collected during salvage operations at Priest Rapids Dam. During fish-ladder maintenance at Priest Rapids Dam during 1996-2003, only one bull trout (36-cm long) was found and released alive (left-bank fish ladder; 8 December 2000; T. Dresser, Grant County PUD, personal communication). Additionally, during sampling efforts to document fish assemblages within the Priest Rapids Reservoir in 1999, only a single bull trout was captured, which was 28 cm in length (Pfeifer et al. 2001).

It was possible to document locations of the ten fish residing downstream from Rock Island Dam on several occasions using a variety of methods (i.e., aerial or boat surveys and fixed-telemetry sites). Four fish did not move beyond the tailrace of Rock Island Dam. Another fish (14-101), after moving from tributaries in 2002 and 2003, occupied a station about 2 km upstream of Tarpiscan Creek in both years. Four other fish resided between the I-90 Bridge and about 4 km upstream of Quilomene Island, or about 19 km upstream of Wanapum Dam (Figure 26). The tenth fish was detected at both Wanapum and Priest Rapids dams. What follows is a detailed summary of the detection history for each of the ten fish detected downstream from Rock Island Dam.

Code 6 Bull Trout – This fish was trapped and tagged at Rocky Reach Dam, released upstream of the project on 29 May 2001, and was 56.9-cm long (FL) and weighed 2,000 g. After release, this trout migrated upstream and entered the Entiat River on 10 June 2001, where it resided until 17 October 2001, much of the time near the Silver Falls Campground. After migrating out of the Entiat River, this trout resided within the Columbia River between Rocky Reach Dam and the Entiat River confluence until it passed Rocky Reach Dam on 14 November 2001. During the period of 14 November 2001 to 17 April 2002, this fish was detected within the Rock Island reservoir and Rocky Reach tailrace by both fixed-telemetry sites and mobile surveys. On 3 June 2002, this fish was detected by the aerial array in the tailrace of Rock Island Dam over a seven hour period (Figure 26). This was the last contact with this fish.

Code 7 Bull Trout – This fish was trapped and tagged at Rocky Reach Dam, released upstream of the project on 4 June 2001, and was 48.5-cm long (FL) and weighed 1,150 g. After release, the fish was detected within the Rocky Reach forebay for about 1 day and then was detected at the Entiat River fixed-site (RK 4.8) on 8 June 2001. The fish migrated upstream and resided within the Entiat River upstream of Preston Creek. On 11 November 2001, this fish was again detected by the fixed-site on the lower Entiat River as the fish exited the tributary. The first detection in the tailrace of Rock Island Dam was on 18 November 2001, at which time it migrated downstream of Rock Island Dam to a point about 11 km upstream of Wanapum Dam. The fish remained within this area for about 2 months (28 February to 25 April 2002) (Figure 26). The fish then began an upstream migration and was last detected at the Rock Island and Rocky Reach ladder exits on 20 May and 25 May, respectively, and re-entered the Entiat River on 11 June where it resided between the Mad River confluence and Preston Creek until it exited the Entiat River on 4 August. This fish was last detected on 10 October 2002 between the Wenatchee River confluence and Rocky Reach Dam.

Code 15 Bull Trout – This trout was collected and tagged at Rocky Reach Dam and released into the tailrace of the project. The fish was released on 25 May 2001 and was 56.1-cm long and weighed 1,950 g. After release, this fish spent about 4 days in the tailrace and ladder system at Rocky Reach Dam. After exiting the ladder, it was detected on 6 June 2001 at the Entiat River fixed-telemetry site. From there it migrated upstream and resided upstream of Preston Creek in the Entiat River. During its migration downstream, it was detected in the lower Entiat River again by the fixed-telemetry site on 2 November 2001. On 10 November 2001, the bull trout was detected at Rocky Reach Dam where it resided in the mainstem Columbia River between Rock Island and Rocky Reach dams until 27 March 2002, when it was first detected in the tailrace of Rock Island Dam. This fish was located during four separate aerial surveys within the Rock Island tailrace and by the fixed-telemetry site at that location until 6 August 2002 (Figure 26). This fish was detected on multiple occasions in the tailrace of Wells Dam during the period of 16 December 2002 to 27 February 2003. Subsequent to detections at that location, this fish was detected in the tailrace of Rocky Reach Dam on 17 March 2003.

Code 36 Bull Trout – This bull trout was collected and tagged at Rock Island Dam on 13 June 2001 and released upstream of the project. It was 59.7-cm long and weighed 1,750 g. After release, this fish migrated upstream to Rocky Reach Dam, where it spent about 3 months within the area between the Wenatchee River confluence and the tailrace of Rocky Reach Dam. On 21 September 2001, this fish was detected within the lower 3 to 4 km of the Wenatchee River, where it remained for about 1.5 months. After exiting the Wenatchee River, it was first detected at Rock Island Dam on 1 December 2001 and later in the Rock Island tailrace during the period of 18-24 December 2001 (Figure 26). After exiting the Rock Island ladder, the fish again resided within the Rock Island reservoir until it ascended and exited the Rocky Reach ladder on 2 July 2002. This fish was last detected at Wells Dam on 6 July 2002.

Code 99 Bull Trout – This bull trout was collected and tagged at Wells Dam on 4 June 2002 and released upstream of the project. It was 46.5-cm long and weighed 1,150 g. Five hours after release, this fish was detected in the tailrace of Wells Dam, where it was detected over an eight day period. This trout then migrated downstream and was detected in the tailrace of Rocky Reach Dam on 20 June 2002. The fish then migrated into the Wenatchee River, where it resided for 19 days between the Wenatchee River confluence and the town of Leavenworth. After migrating out of the Wenatchee River, it was detected in the tailrace of Rocky Reach Dam for a period of one day, beginning 11 July 2002, and was subsequently detected in the tailrace of Rock Island Dam on 13 July 2002 until 29 July 2002 (Figure 26). After ascending the Rock Island center fish ladder, this trout was detected in the Wenatchee River, where it resided until 6 November 2002. After migrating out of the Wenatchee River, this fish resided between Rock Island Dam and the Wenatchee River confluence. On 3 June 2003 it entered the Methow River where it remained until 28 October 2003. It then moved into the Entiat River and was last detected there on 3 November 2003 about 1 km upstream of the confluence.

Code 101 Bull Trout – This bull trout was collected and tagged at Rocky Reach Dam on 3 June 2002 and released downstream from the project. It was 55.3-cm long and weighed 1,950 g. After release, this fish ascended the Rocky Reach fish ladder and exited the system on 15 June 2002. Ten days later the fish was detected at the Entiat River fixed-telemetry site and eventually migrated upstream and resided within the Mad River. The fish exited the Entiat basin on 6 November 2002 and was detected in the tailraces of Rocky Reach and Rock Island dams on 15 January 2003 and 16 January 2003, respectively. This fish was later detected about 3 km upstream of Tarpiscan Creek on 18 March 2003 during an aerial survey, and later (28 March 2003) about 2 km upstream of Tarpiscan Creek near the right bank during a boat survey conducted by Grant County PUD (Figure 26). This trout then moved upstream, entered Rock Island Dam tailrace on 6 June 2003, and passed the dam (via the center ladder) on 12 June 2003. It continued upstream, passing Rocky Reach Dam on 15 June 2003. The fish then moved back downstream through the dam and entered the Wenatchee River on 22 June 2003, where it resided in Peshastin Creek for about four months. After leaving the Wenatchee basin, this fish once again moved downstream and passed Rock Island Dam on 20 October 2003, where it remained through the end of the study period (31 March 2004; Figure 26).

Code 105 Bull Trout – This bull trout was collected and tagged at Rock Island Dam on 4 June 2002 and released downstream of the project. It was 52.0-cm long and weighed 1,350 g. After release, this fish was detected over the course of 17 days in the tailrace of Rock Island Dam. On 22 June 2002, it exited the right bank ladder and migrated upstream where it entered the Wenatchee River five days later. Over the course of a five and a half month period of residence within the Wenatchee basin, this fish was only detected on one occasion; an aerial survey conducted shortly after it entered the Wenatchee River (1 July 2002). During that survey, the fish was detected near the town of Monitor, Washington. The location of residence for this fish while within the Wenatchee basin is largely unknown. After exiting the Wenatchee River, this fish resided primarily near the Wenatchee River confluence within the mainstem Columbia River over a period of approximately seven months. During the period of 22-24 May 2003, this fish was again detected at the fixed telemetry site on the Wenatchee River. After detection at this location, it was detected 15 hours later (24 May) in the tailrace of Rock Island Dam. Subsequently, this fish was detected on 26 and 28 May in the forebays of Wanapum and Priest Rapids dams, respectively. These detections were the last contact with this fish. Efforts to locate this fish within the Priest Rapids pool have been unsuccessful, and as such, it is likely that this fish migrated downstream of Priest Rapids Dam. Its fate, whether alive or dead at this point, is unknown.

Code 110 Bull Trout – This bull trout was collected and tagged at Rock Island Dam on 4 June 2002 and is the only fish that may have died downstream from Rock Island Dam (see Section 4.1). The fish was released upstream of the project and was 60.0-cm long and weighed 2,400 g. After release, this fish was detected over a two-day period in the tailrace of Rocky Reach Dam beginning 6 June 2002. Subsequently, this fish migrated downstream and entered the Wenatchee River on 11 June 2002, where it resided between the town of Leavenworth and Tumwater Dam until 10 July. After leaving the Wenatchee River, this trout was detected once again in the tailrace of Rocky Reach Dam beginning 10 July 2002 for a 3-day period. After ascending the fish ladder, the trout was detected in the tailrace of Wells Dam on 14 July 2002 for one day. After migrating downstream, the fish entered the Entiat River on 18 July and remained near the fixed-telemetry site (R.K. 4.8) for two days. On 20 July, this fish was detected in the tailrace of Rocky Reach Dam and on 21 July in the tailrace of Rock Island Dam. The next contact with this fish was between 1 August and 22 August, when its transmitter was recovered (Figure 26).

Code 113 Bull Trout – This trout was captured and tagged at Rock Island Dam and released downstream from the project on 7 June 2002. The fish was 43.0-cm long and weighed 800 g. After release, the fish ascended the left-bank ladder and exited the system on 14 June 2002. Eight days later, this fish was detected at the fixed-telemetry site on the Wenatchee River and subsequently resided within the Wenatchee basin through 6 November 2002, much of that time near the confluence of the Chiwawa River. After leaving the Wenatchee basin, this fish moved downstream, passed Rock Island Dam, and remained near Sunland Bar (downstream from Quilomene Island) during 19 February to 28 March 2003. It then moved to a location about 2 km upstream of Tarpiscan Creek and remained there from 23 May to 3 June 2003 (Figure 26). This fish then migrated upstream, exited the Rock Island right-bank ladder on 14 June 2003, and entered the Wenatchee River on 16 June. It resided within the Wenatchee basin until 21 November, much of the time in Tumwater Canyon and in the Chiwawa River. This fish was last detected on 18 December 2003 in Rock Island reservoir.

Code 118 Bull Trout – This trout was captured and tagged at Rocky Reach Dam and released downstream from the project on 11 June 2002. The fish was 46.0-cm long and weighed 950 g. Twelve days after release, this fish exited Rocky Reach ladder and subsequently entered the Entiat River on 1 July 2002. This trout remained in the mainstem Entiat River downstream from the Mad River confluence until it left the river on 9 October 2002. The fish remained in the Columbia River upstream of Rocky Reach Dam until 8 April 2003, when it re-entered the Entiat River and migrated into the Mad River. After leaving the Entiat basin on 23 October 2003, it was detected in the tailraces of Rocky Reach and Rock Island dams on 5 and 13 November 2003, respectively. This fish has been detected on three occasions over a 3.5 month period downstream of Quilomene Island (Figure 26).

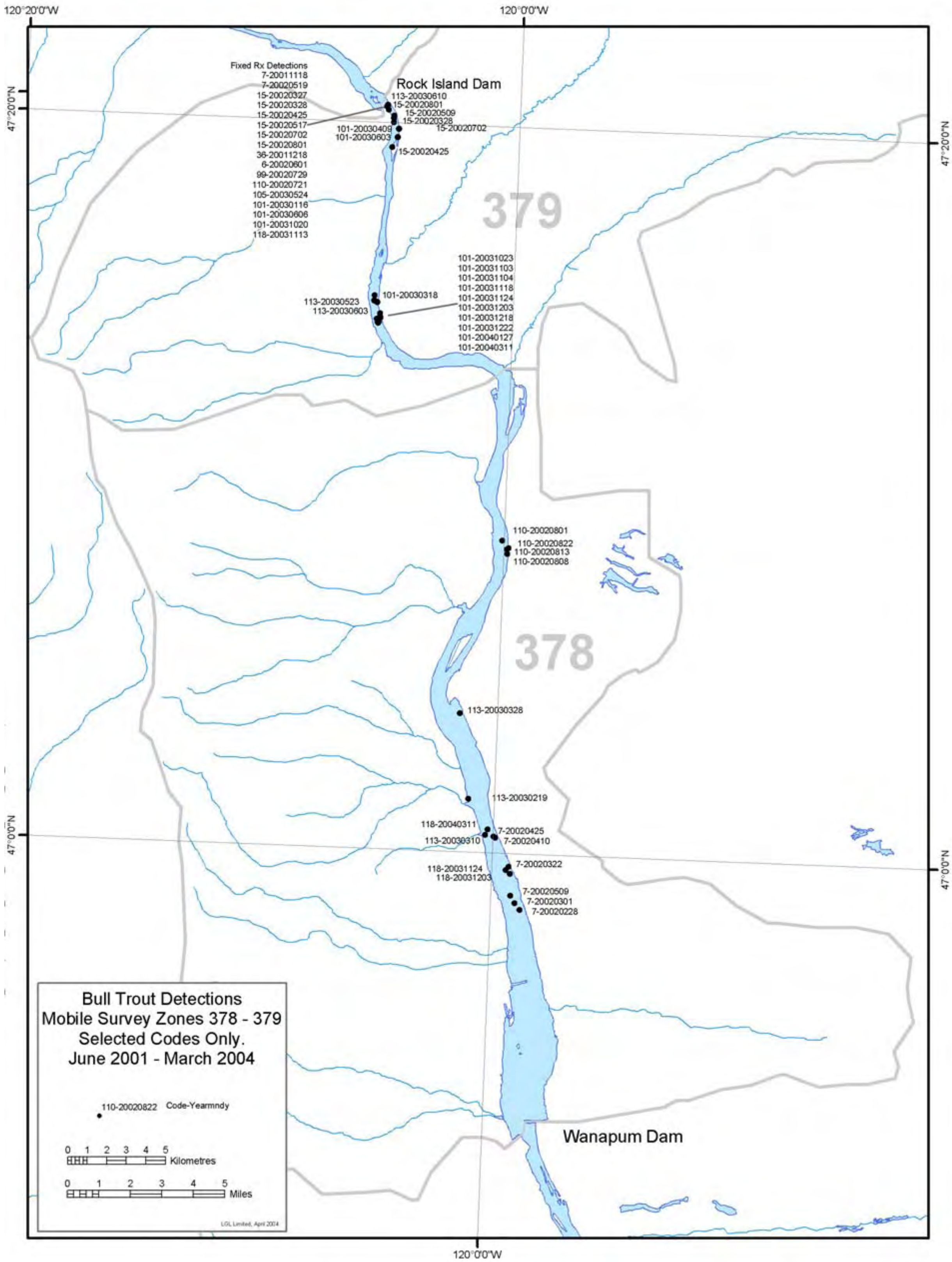


Figure 26: Map of bull trout detected downstream from Rock Island Dam.

SECTION 5: CONCLUSIONS

Based on the results from the 2001-2004 study, we offer the following conclusions.

1. Seventy-nine adult bull trout were successfully tagged with radio tags in 2001 and 2002. Of those, it appears that 15 may have died or shed their tags. However, there is no evidence that any of these potential deaths were the result of hydroelectric projects.
2. Based on data collected in 2001-2004, operations of hydroelectric facilities on the mid-Columbia River did not negatively affect the survival of adult bull trout. That is, no adult bull trout were killed during upstream or downstream passage through the mid-Columbia dams.
3. Although hydroelectric operations did not appear to affect the survival of adult bull trout, the presence of dams may have slowed migration times. On average, it took bull trout longer to pass dams than it did for them to move through reservoirs (i.e., from project to project). One reason for the possible delays is that bull trout found increased foraging opportunities in the tailraces. Additional work is needed to verify this possibility.
4. The overall dam passage time is considerably greater for fish tagged and released into the tailrace of a given project than it is for fish that migrated upstream after being released at downstream projects. The release location of future studies assessing passage rates at dams should be made upstream of the project or far enough downstream to allow adequate recovery following tagging.
5. At Rocky Reach Dam, the location where tagged fish are released appears to influence tributary selection. Of the tagged fish released downstream from the project in 2001, 55% (6 of 11) moved downstream and entered the Wenatchee River. In 2002, 33% (4 of 12) of the fish released downstream from Rocky Reach Dam entered the Wenatchee River. In contrast, only 3% of the fish released upstream from dams move downstream into tributaries.
6. There were nine downstream passage events observed at Rocky Reach Dam (5 in 2002 and 4 in 2003) and two at Wells Dam (2002). Of those, six occurred within 24 hours after exiting the ladder system(s), and two within 15 hours after the fish were released into the forebay (one at Rocky Reach and one at Wells Dam). These two events may be related to releasing the fish too close to the dam. For three fish, after exhibiting downstream movement behavior, two migrated into tributaries downstream of the given project, and one resided within the mainstem Columbia River. Future studies that include forebay releases should consider releasing fish further upstream from the projects to eliminate the effects of handling on downstream movement.
7. Bull trout entered tributaries shortly after release. They selected the Wenatchee, Entiat, and Methow systems. No bull trout selected the Okanogan system, although one entered the Okanogan River, it quickly left and moved into the Methow system. Most entered tributaries by the end of June and were found in possible spawning streams well before the initiation of spawning. Most tagged trout left tributary streams by late November.

8. For the three years of data regarding tributary entrance into the Wenatchee, Entiat and Methow rivers, a total of 91 tributary entrance events occurred. During the study period bull trout entered mid-Columbia tributaries from April to September but most (94%) entered tributaries during May, June and July. At the time bull trout entered tributary streams the mean daily temperatures in the mainstem Columbia River varied from 5.4 °C to 19.6 °C. Similarly, tributary mean daily temperatures ranged from 7.5 °C to 17.2 °C. Most bull trout (92.3%) entered tributaries before the Columbia River reached a mean temperature of 15 °C. The successful migration of bull trout into the various spawning streams of the Wenatchee, Entiat and Methow suggests that temperatures at the time of migration in the mid-Columbia River did not appear to limit the migration of radio-tagged bull trout.
9. Over half (53%) of the bull trout detected within the Wells Dam tailrace entered the hatchery outfall. Four of the five bull trout released downstream of the dam entered the outfall multiple times. Because there was little difference in temperature between the outfall and the mainstem Columbia River, it is unlikely that bull trout used the outfall as a temperature refuge. Instead, they may have used the outfall to increase feeding opportunities.
10. Of the 79 bull trout tagged in 2001 and 2002, ten (12.7%) moved downstream of Rock Island Dam after an extended stay in tributaries. At the conclusion of the study period (31 March 2004), one tagged bull trout had passed Wanapum Dam, and is presumed to have also passed Priest Rapids Dam.

SECTION 6: ACKNOWLEDGMENTS

Chelan, Douglas, and Grant County PUDs funded this study. We thank Scott Kreiter (Chelan PUD), Shane Bickford (Douglas PUD), and Tom Dresser (Grant PUD) for providing valuable assistance in the development and implementation of this study. We especially thank Scott for assuming the role as project coordinator. We thank the Chelan PUD fishway attendants for their assistance in transporting tagged fish and Thad Mosey for his help in securing equipment. Charlie Snow, Washington Department of Fish and Wildlife, coordinated the collection of bull trout at Wells Dam. We appreciate the Douglas PUD operators, who assisted with trapping and tagging activities at Wells Dam, and the Grant PUD fisheries technicians who conducted mobile surveys within Wanapum pool. We thank Karl English, Bryan Nass, and Cezary Sliwinski of LGL Limited for processing telemetry data and LGL field personnel for their assistance in data collection at Priest Rapids, Wanapum, and Wells dams. Finally, we thank Jeff Reeves, Connor Giorgi, and Don Truscott of BioAnalysts for their dedication in trapping and monitoring of bull trout.

SECTION 7: REFERENCES

Adams, N. S., D. W. Rondorf, S. D. Evans, J. E. Kelly, and R. W. Perry. 1998. Effects of surgically and gastrically implanted radio transmitters on swimming performance and predator avoidance of juvenile chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences 55:781-787.

BioAnalysts, Inc. 2002. Movement of bull trout within the mid-Columbia River and tributaries, 2001-2002. BioAnalysts, Inc. Report to Chelan, Douglas, and Grant County Public Utility Districts, Wenatchee, WA.

English, K. K., T. C. Nelson, C. Sliwinski, and J. R. Stevenson. 1998. Assessment of passage facilities for adult sockeye, chinook, and steelhead at Rock Island and Rocky Reach dams on the mid-Columbia River in 1997. Report to Public Utility District No. 1 of Chelan County, Wenatchee, WA.

English, K. K., C. Sliwinski, B. Nass, and J. R. Stevenson. 2001. Assessment of passage facilities for adult steelhead at Priest Rapids, Wanapum, Rock Island, Rocky Reach, and Wells dams on the mid-Columbia River in 1999. Report to Public Utility District No. 1 of Chelan County, Wenatchee, WA.

Environmental Protection Agency (EPA). 2001. Draft EPA Region 10 guidance for state and tribal temperature water quality standards. Public review draft, Seattle, WA.

Goetz, F. 1989. Biology of the bull trout, "*Salvelinus confluentus*," a literature review. Willamette National Forest, Eugene, OR.

Hicks 1998 (Draft). Evaluating standards for protecting aquatic life in Washington's surface water Quatlity standards, Temperature Criteria. Water Quality Program, Watershed Management Section. Washington Dept. of Ecology, Olympia, WA.

Miller, M., J. Stevenson, T. Hillman, and D. Snyder. 2002. Summary of bull trout suspected to have perished in fall, 2002. BioAnalysts, Inc. Report to Chelan, Douglas, and Grant County Public Utility Districts, Wenatchee, WA.

Mullan, J. W., K. R. Williams, G. Rhodus, T. W. Hillman, and J. D. McIntyre. 1992. Production and habitat of salmonids in Mid-Columbia River tributary streams. United States Fish and Wildlife Service, Monograph I.

Rieman, B. E. and J. D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. General Technical Report INT-302. Intermountain Research Station, USDA, Forest Service. Ogden, UT.

Skalski, J. R., J. R. Stevenson, J. Lady, R. Townsend, A. E. Giorgi, M. Miller, and K. English. In prep. An assessment of project, pool, and dam survival for chinook and steelhead smolts at Rocky Reach and Rock Island dams using radiotelemetry and PIT-tag techniques, 2000. Report to Public Utility District No. 1 of Chelan County, Wenatchee, WA.

Stevenson, J. R., J. R. Skalski, J. Lady, R. Townsend, A. E. Giorgi, and R. McDonald. 2000. A pilot study assessing the feasibility of using radiotelemetry and PIT-tag techniques to estimate project, pool and dam survival of steelhead smolts at Rocky Reach and Rock Island dams, 1999. Report to Public Utility District No. 1 of Chelan County, Wenatchee, WA.

Summerfelt, R. C. and L. S. Smith. 1990. Anesthesia, surgery and related techniques. Pages 213-272 *In:* C. B. Shreck and P. B. Moyle, editors. Methods of fish biology. American Fisheries Society Symposium 7, Bethesda, Maryland.

Wedemeyer, G. 1970. Stress of anesthesia with MS 222 and benzocaine in rainbow trout (*Salmon gairdneri*). Journal of the Fisheries Research Board of Canada 27:909-914.

Winter, J. D. 1983. Underwater biotelemetry. Pages 371-395 *In:* L. A. Nielsen and D. L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

APPENDIX A: SUMMARY OF RECOVERED BULL TROUT TAGS

The purpose of this appendix is to provide a detection history for radio tags recovered from bull trout tagged in spring 2002 at Rock Island, Rocky Reach, and Wells dams. Efforts were made in the fall of 2002 and 2003 to recover those tags from bull trout that were suspected to have perished or shed their tags. The detection histories describe the extent of movement after the bull trout were released, but may not explain the circumstances surrounding the loss of the tagged fish.

All the bull trout were captured, tagged, and released in the spring of 2002 at Rock Island, Rocky Reach, or Wells dams. The bull trout were surgically implanted with radio tags and released either upstream or downstream of their respective projects. Fixed-station telemetry receivers at the projects and in the lower tributary rivers along with monthly aerial surveys provided the detection history for these bull trout. A detailed summary of the methods used to tag, release, and track bull trout can be found in BioAnalysts, Inc. (2002). In addition, the U.S. Fish and Wildlife Service provided information on the location for some of the bull trout while the trout resided in tributaries. Their efforts provided valuable information on the recovery of tags and the condition of the tributary streams.

In this summary, the discussion focuses on 14 of 40 (35%) tagged bull trout. For convenience, the bull trout have been separated by tagging location and each bull trout has been identified by the radio transmitter channel and code (e.g., 14-93) with a brief description of their movement after release. For all of these bull trout the tag was recovered but only one carcass was recovered. A map is provided to show the locations where the tags were recovered.

Wells Dam

Tag 14-93--The upstream movement of this bull trout suggests that it made a migration to a known spawning area in the Twisp River of the Methow Basin. A conservative estimate of this bull trout's migration is roughly 109 km (68 miles) from downstream of Wells Dam to the upper Twisp River and then back downstream within the Twisp River (Table A1).

This bull trout was tagged on 28 May at Wells Dam and was released downstream of the project near the west shoreline. Within hours of the release the bull trout had moved back upstream and was detected in the tailrace of Wells Dam. The bull trout was detected for a period of 14 days in the tailrace until it passed the project on 22 June. Two days later, 24 June, the bull trout was detected in the lower Methow River. By 1 July the bull trout was detected just downstream from McFarland Creek on the Methow River. One month later during an aerial survey on 1 August the fish was detected in the Twisp River upstream from the confluence of South Creek. By 4 September, the fish had moved downstream and was detected near the confluence of Reynolds Creek. The next month on 9 October the bull trout was detected even further downstream near the confluence of Scaffold Camp Creek. Finally on 31 October the tag for this fish was recovered near that location on an island gravel bar above the wetted channel and there was no carcass in the area (Figure A1).

Table A1: Summary information on radio tags recovered for bull trout tagged in the spring of 2002.

Tag	Tag Location	Release Location	Detections		Distance Traveled (km)	Tag Recovery	Carcass Recovered
			Basin	Subbasin			
14-093	Wells	Downstream (28-May)	Methow (24-June)	Twisp (1-August)	109	31 October 2002: Twisp R. Tag recovered on an island gravel bar above the wetted channel	No
14-096	Wells	Downstream (3-June)	Methow (22 June)	Twisp (1-August)	98	31 October 2002: Twisp R. Tag recovered mid-channel in a riffle	No
14-102	Wells	Downstream (4-June)	Methow (26-June)	Twisp (1-August)	117	12 September 2003: Twisp R. The tag was recovered on a gravel bar about two feet from waters edge	No
14-107	Wells	Upstream (3-June)	Methow (9-June)	Twisp (1-August)	116	26 November 2002: Twisp R. Tag and bull trout recovered in downstream area with little flow	Yes
14-117	Wells	Upstream (12-June)	Methow (21-June)	Twisp (1-August)	116	22 October 2002: Twisp R. Tag recovered in log jam	No
14-088	Rocky Reach	Upstream (20-May)	Entiat (16-June)	Mad (1-July)	44	16 September 2003: Mad R. The tag was recovered in about 6 inches of water downstream from a log jam	No
14-089	Rocky Reach	Downstream (21-May)	Methow (9-June)	Twisp (1-July)	181	12 September 2003: Twisp R. Tag was buried in six inches of pea gravel below a logjam.	No
14-095	Rocky Reach	Downstream (29-May)	Entiat (9-June)	Up. Entiat (1-August)	55	7 November 2002: Up Entiat R. Tag recovered on shore inside a hole under a boulder. Cut marks were observed on the antenna.	No
14-098	Rocky Reach	Upstream (30-May)	Entiat (12-June)	Mad (1-August)	65	15 September 2003: Columbia R. Tag recovered at a depth of 3 meters in aquatic vegetation	No
14-108	Rocky Reach	Upstream (3-June)	Methow (23-June)	Twisp (1-August)	211	12 September 2003: Twisp R. Tag found by edge of a pool under cobble and gravel	No
14-090	Rock Island	Downstream (23-May)	Entiat (1-July)	Up. Entiat (1-August)	164	15 September 2003: Columbia R. Tag recovered at a depth of 4 meters	No
14-097	Rock Island	Upstream (20-May)	Entiat (19-June)	Mad (Sept.)	81	16 September 2003: Mad R. Tag recovered in stream in about ten inches of water	No
14-109	Rock Island	Upstream (7-June)	Entiat (19-June)	Mad (4 -Sept.)	98	15 September 2003: Columbia R. The tag recovered at a depth of 4 meters on a steeply sloped bank.	No
14-110	Rock Island	Upstream (4-June)	Columbia	Wenatchee Entiat (July)	322	22 August 2002: Columbia R. Tag recovered 10-15 feet from waters edge under a pile of debris	No

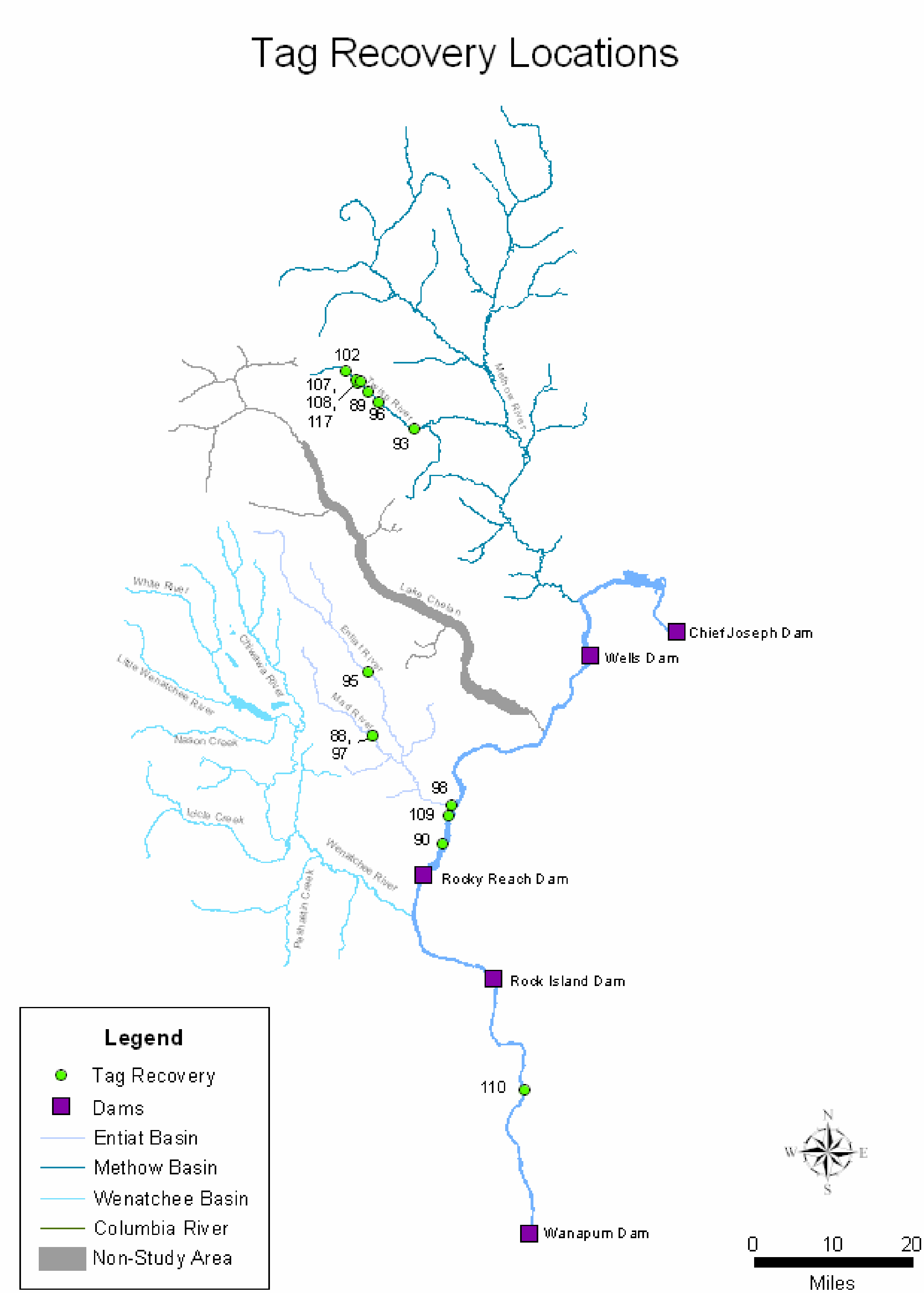


Figure A1: Location and code for radio tags recovered from bull trout tagged at mid-Columbia River projects in spring of 2002.

Tag 14-96--This bull trout migrated to a known spawning area in the Twisp River of the Methow Basin (Figure A1). The bull trout migrated about 98 km (61 miles) from downstream of Wells Dam to the upper Twisp River (Table A1).

The bull trout was tagged on 3 June and was released downstream of Wells Dam near the west shoreline. The bull trout was detected in the tailrace of the project for a period of12 days until it passed on 22 June. Within ten hours after ascending the fish ladder at Wells Dam, the fish was detected in the lower Methow River the same day (22 June). The bull trout was again detected in the lower Methow River on 1 July near Black Canyon Creek. By 1 August, the fish had entered the Twisp River and was detected upstream from the confluence of Williams Creek. The fish was detected at this location on 4 September and again on 9 October. On 31 October, personnel from the US Fish and Wildlife Service recovered the radio tag near this location mid-channel in a riffle (Figure A1). No carcass was found at the location.

Tag 14-102--This bull trout migrated to a known spawning area in the Twisp River of the Methow Basin. The bull trout migrated about 117 km (73 miles) from downstream of Wells Dam to the upper Twisp River (Table A1).

This bull trout was tagged on 4 June 2002 at Wells Dam and was released downstream of the project near the west shoreline. Within hours of the same day the bull trout was detected in the tailrace of Wells Dam and was detected at the project for a period of 12 days until it passed on 26 June. Within ten hours of ascending the fish ladder at Wells Dam, the fish was detected in the lower Methow River the same day (26 June). The bull trout was again detected in the lower Methow River on 1 July during an aerial survey. An aerial survey on 1 August revealed that the fish had migrated to the Twisp River and was upstream from the confluence of South Creek. On 4 September the bull trout was detected further upstream in the Twisp River near Road End Campground. U.S. Fish and Wildlife Service personnel tracked the bull trout to a log jam in the Twisp River near the location it was observed on 9 October. Their last ground survey on 27 November 2002 revealed that the fish had not moved from the location. The tag (no carcass) was recovered on a gravel bar about two feet from waters edge on 12 September 2003 (Figure A1).

Tag 14-107--This bull trout migrated to a known spawning area in the Twisp River of the Methow Basin (Figure A1). The bull trout had traveled about 116 km (72 miles) from upstream of Wells Dam to the upper Twisp River (Table A1).

This bull trout was tagged on 3 June and was released upstream of Wells Dam. The bull trout was detected in the lower Methow River on 9 June. On 1 July the bull trout was detected upstream from Gold Creek on the Methow River. By 1 August the bull trout had migrated to the upper Twisp River upstream from South Creek. In early November flows in the Twisp River came up and portions of the formerly dry channel were now wetted. The bull trout moved downstream during the increased flow. However, the increased flow was not sufficient enough to re-water the entire dry section of the Twisp River. As flow receded the bull trout remained downstream. On 26 November the U. S Fish and Wildlife Service personnel recovered the tagged bull trout carcass (frozen) in this downstream area (Figure A1). Another tagged bull trout (14-116) was captured alive in this area and was transported downstream to where the stream began to flow again.

Tag 14-117--This bull trout migrated to a known spawning area in the Twisp River of the Methow Basin (Figure A1). The bull trout had traveled about 116 km (72 miles) from upstream of Wells Dam to the upper Twisp River (Table A1).

The bull trout was tagged on 6 June at Wells Dam and was released upstream of the project on the west shoreline. The fish then migrated to the Methow River and was detected in the lower river on 21 June. More than a week later on 1 July the fish had ascended the rapids in the lower Methow River and was detected just upstream from French Creek on the Methow River. By 1 August, the bull trout had migrated to the Twisp River and was detected several miles upstream from the confluence of South Creek. U.S. Fish and Wildlife Service personnel observed this fish alive on 25 September in a logjam near a redd. On 9 October the bull trout had moved downstream near the confluence of South Creek. Later, on 22 October the tag but no carcass was recovered in a log jam near that same location (Figure A1).

Rocky Reach Dam

Tag 14-88--This bull trout migrated to a known spawning area in the Mad River of the Entiat Basin. The bull trout migrated approximately 44 km (28 miles) from its release location at Rocky Reach Dam into the Mad River (Table A1).

This bull trout was tagged on 20 May 2002 at Rocky Reach Dam, and was released upstream of the project near the west shoreline. Seventeen days after release, this fish was detected at the fixed-telemetry site on the Entiat River. Upstream movement was documented during a series of aerial surveys; with the fish being detected on 1 July approximately 1.5 km upstream of Pine Flat Campground, on 1 August approximately 1.5 km upstream of Hornet Creek, and on 9 October approximately 1 km downstream from Windy Creek. The fish was detected on four more occasions during the period of December 2002 to March 2003. However, during this period, the transmitter was located at the same location as on 9 October. The transmitter (no carcass) for this fish was recovered on 16 September 2003 at this location in approximately 6 inches of water downstream from a log jam (Figure A1).

Tag 14-089--This bull trout migrated to a known spawning area in the Twisp River of the Methow Basin. A minimum estimate of this bull trout's migration is about 181 km (112 miles) from downstream of Rocky Reach Dam to the upper Twisp River (Table A1).

This bull trout was tagged on 21 May 2002 at Rocky Reach Dam and was released downstream. The next day the bull trout was detected in the tailrace of Rocky Reach Dam. The bull trout passed Rocky Reach Dam 15 days later on 6 June 2002. The next day, 7 June, the fish was detected in the tailrace of Wells Dam. The bull trout passed Wells Dam two days later on 9 June and had moved into the Methow River the same day. On 1 July the bull trout had moved into the Twisp River downstream from the mouth of Buttermilk Creek. Later, on 1 August the fish had moved further upstream in the Twisp River upstream from the confluence of Buttermilk Creek. The fish remained in this area over an extended time until the tag was recovered on 12 September 2003 just downstream of Poplar Flats campground (Figure A1). The tag was buried in approximately six inches of loose pea gravel on the downstream side of a logjam. No carcass was recovered nor were there any obvious signs of predation visible on the radio tag or antenna.

Tag 14-95--This bull trout migrated into the upper Entiat River to a potential spawning area. The bull trout migrated about 55 km (34 miles) from its release location at Rocky Reach Dam to the upper Entiat River (Table A1).

This bull trout was tagged on 29 May at Rocky Reach Dam and was released downstream near the west shoreline. The fish moved back into the tailrace the same day and re-ascended the fish ladder and was last detected at the project four days later exiting the ladder on 4 June. Five days later, on 9 June, the bull trout had migrated to and was detected in the lower Entiat River. The bull trout was detected upstream in the Entiat River between the confluences of Mad and Preston creeks on 1 July. More than a month later (1 August) the bull trout had migrated upstream and was detected upstream from Preston Creek. The bull trout was detected three more times (4 Sept, 9 Oct and 6 Nov) in the same general area on the Entiat River upstream near the confluence of McCrea Creek. Finally on 7 November the tag was recovered by USFWS personnel on the shore inside a hole under a boulder (Figure A1). The tag had obvious scratch marks, and USFWS personnel speculated that the marks were caused by mink (*Mustela vison*) predation or scavaging.

14-098--This bull trout migrated into the Mad River of the Entiat Basin. This fish migrated about 65 km (41 miles) from its release location upstream from Rocky Reach Dam to the Mad River and back downstream into the Columbia River where the tag was found (Table A1).

The bull trout was tagged at Rocky Reach Dam on released upstream of the project on 30 May 2002. The bull trout moved into the Entiat River on 12 June. Later, on 1 July the fish was detected again in the Entiat River from confluence to Mad River. By 1 August the fish had moved into the Mad River. On 9 October 2002 the fish was detected downstream in the Entiat River. By 1 January 2003 the fish had moved downstream and was detected in the Columbia River. The tag but not carcass for this fish was recovered on 15 September 2003 just upstream from the mouth of the Entiat River about 200 meters on west shore (Figure A1). Divers that recovered the tag noted that the tag was found at a depth of about 3 meters in an area of dense aquatic macrophytes with a mud and silt bottom.

Tag 14-108--This bull trout migrated upstream to a spawning area in the Twisp River of the Methow Basin. The fish made a brief excursion to the Okanogan River before heading up the Methow River. This fish traveled about 211 km (131 miles) from upstream of Rocky Reach Dam to the Okanogan River and back down to the Methow River and finally into the headwaters of the Twisp River (Table A1).

The bull trout was tagged on 3 June 2002 at Rocky Reach Dam and was released upstream from the project. The fish then moved upstream and was detected in the tailrace of Wells Dam on 6 June. The bull trout passed Wells Dam on 18 June and was detected in the Okanogan River on 22 June. The next day the bull trout was detected at the mouth of the Methow River on 23 June. The fish was observed again in Methow River between mouth and Libby Creek on 1 July. By 1 August the bull trout had moved into the headwaters of the Twisp River upstream of Buttermilk Creek. The tag for this bull trout was recovered on 12 September 2003 just downstream of the Scatter Creek Trailhead on the edge of a pool under cobble and gravel (Figure A1). There were no obvious signs of predation and no carcass was found.

Rock Island Dam

Tag 14-90--This bull trout migrated to a known spawning area in the Entiat River. The bull trout migrated approximately 164 km (102 miles) from its release location to the spawning area, then back to the Columbia River (Table A1).

This fish was released downstream of Rock Island Dam on 23 May 2002 near the west shore. After release, the fish migrated past the dam through the right bank fish ladder, and exited that system on 8 June. The next day this fish was detected in the tailrace of Rocky Reach Dam, and three days later was detected at the ladder exit at that project. On 1 July, this fish was detected at the fixed-telemetry site on the Entiat River. Subsequently, this fish migrated upstream to a location approximately 1 km downstream from Entiat Falls (1 August 2002), then downstream where it was detected on 4 September approximately 3 km upstream of Preston Creek. The next detection of this fish was in the Columbia River on 17 December 2002, where it was located over the course of approximately 10 months on 11 separate occasions. The transmitter (no carcass) of this fish was recovered on 15 September 2003, and was located approximately 8 km downstream of the Entiat River confluence (Figure A1). The transmitter was in approximately 4 meters of water, and was located near the west shore.

Tag 14-97--This bull trout migrated to a known spawning area in the Mad River of the Entiat Basin. The bull trout migrated approximately 81 km (50 miles) from its release location at Rocky Reach Dam into the Mad River (Table A1).

This fish was tagged on 20 May 2002, and was released upstream of Rock Island Dam near the east shore. Six days after release, this fish was detected in the tailrace of Rocky Reach Dam, and four days later it exited the ladder system at that project. On 19 June 2002, this fish was detected at the fixed-telemetry site located at RK 4.8 of the Entiat River. During the next aerial survey (1 July 2002), it was detected in the lower Entiat River approximately 1 km upstream of the Entiat National Fish Hatchery. During the period of September 2002 to September 2003, this fish was located on nine separate occasions, all during routine aerial surveys. The location of this fish for those surveys was the same, which was approximately 1 km downstream of Windy Creek within the Mad River (Figure A1). The transmitter for this fish was recovered at that location on 16 September 2003 without a carcass.

Tag 14-109--This bull trout migrated into the Mad River of the Entiat Basin. This fish migrated about 98 km (61 miles) from its release location upstream from Rock Island Dam to the Mad River and back downstream into the Columbia River where the tag was found (Table A1).

This bull trout was tagged at Rock Island Dam and released upstream from the project on 7 June 2002. Three days later, 10 June, the fish had moved into the tailrace of Rocky Reach Dam and passed the project on 12 June. The bull trout moved upstream and entered the Entiat River on 19 June. The fish was detected again in the Entiat River on 1 July downstream from confluence of Mad River. The bull trout was detected in the Mad River on 4 September and remained there until 17

December when it was detected back in the Entiat River. The fish moved back downstream into the Columbia River by 14 January 2003 upstream from the confluence of the Entiat River. On 19 February 2003 the fish was detected in the Columbia River back downstream near the confluence of Entiat River. The tag was recovered in the Columbia River on 15 September 2003 about 1.6 kilometers downstream from mouth of Entiat River on the west shore (Figure A1). The radio tag was found in water at a depth of 4 meters on a steeply sloped bank. Divers that recovered the tag noted that the bank was rocky with old trees and lots of fishing line.

Tag 14-110--The movements of this bull trout were mostly within the Columbia River and do not appear to suggest a spawning migration. The bull trout migrated about 322 km (200 miles) from it release location to the tailrace of Rocky Reach, into the Wentachee River, back to the Columbia River and upstream to the tailrace of Wells dam and eventually back downstream of Rock Island Dam (Table A1).

The bull trout was tagged at Rock Island Dam on 4 June and was released upstream of the project. Within two days the fish was detected upstream in the tailrace of Rocky Reach Dam. The fish was detected in the tailrace three consecutive days (6-8 June) until it moved downstream to the Wenatchee River. It moved up the Wenatchee River and was detected near the town of Monitor on 11 June. During an aerial survey on 1 July, this bull trout had migrated upstream in the Wenatchee River and was detected downstream of Tumwater Canyon near the town of Leavenworth. Nine days later on 10 July the fish was detected in the Wenatchee River back downstream near the town of Monitor. That same day, approximately 11 hours later, the fish had moved back into the Columbia River and upstream to the tailrace of Rocky Reach Dam. The bull trout remained in the tailrace four days until it passed the project on 13 July. On 14 July the fish had migrated upstream and was detected in the tailrace of Wells Dam. The fish remained in the tailrace for one day then moved downstream in the Columbia River and was detected in the Entiat River on 18 July. The bull trout then moved further downstream in the Columbia River, passing both Rocky Reach and Rock Island dams on 20 and 21 July, respectively. The bull trout was detected again during an aerial survey on 1 August downstream of Rock Island Dam near Quilomene Island on the Columbia River. Later, the fish was detected upstream 1.5 miles from Quilomene Island in the same location during boat surveys on the Columbia River on 8, 13, 22 August. The tag (no carcass) was found 10-15' from the waters edge under a pile of debris on 22 August (Figure A1).

DISCUSSION

The detection history of most of the bull trout prior to the recovery of the transmitters suggests that they migrated to spawning areas in the Methow and Entiat basins where bull trout are known to spawn (Table A1). The one exception is tag 14-110 that was recovered downstream of Rock Island Dam.

The bull trout reviewed in this summary did not originate from a single tag or release location and were not tagged by a single person, which suggests that these factors did not influence fish survival or tag expulsion. Six of the bull trout were released downstream of mid-Columbia River projects and eight were released upstream. Bull trout released at Wells Dam were detected in the Methow River in June 2002. Those bull trout were later detected in the Twisp River by 1 August 2002. Bull trout released near Rocky Reach Dam entered the Methow and Entiat rivers in June and were detected in the upper Entiat, Mad, and Twisp rivers in July and August. These dates appear to agree with the general migration timing for bull trout (Brown 1994; USFS 2001).

The migration distance for these bull trout from June to September ranged from about 44 km to about 322 km. Assuming that successive detection in different upstream areas means that fish were alive and actively migrating, then most of the fish survived about two months after they were tagged. That length of time between when the fish were tagged to their entry in a tributary stream suggests that the bull trout did not suffer an acute or debilitating injury associated with tagging nor did dam passage have an immediate affect on survival.

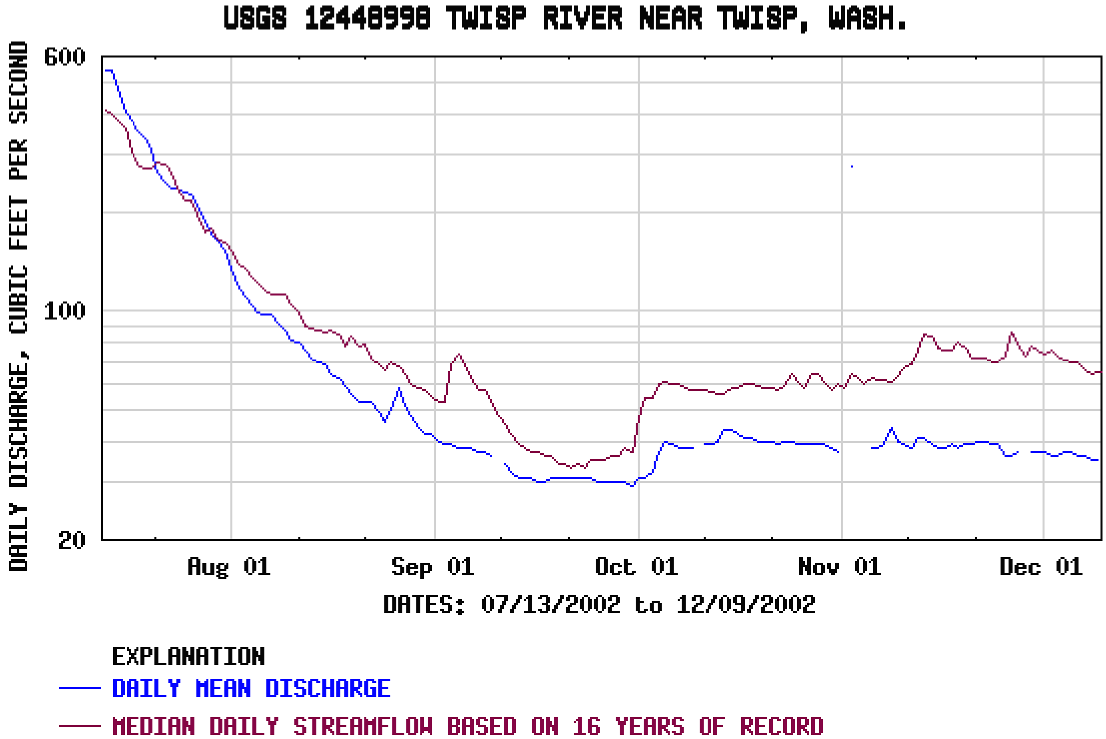
In general, observations made on bull trout tagged by the USFWS and BioAnalysts, Inc. revealed that most of the bull trout only had creases or slight wear marks associated with the external antenna (Per. Comm., Mark Nelson, USFWS). The tags in two bull trout may have shifted internally, resulting in the antenna protruding from the body at a right angle. The one bull trout that was recovered (14-107) in the Twisp River did not have any obvious injuries and the incision healed completely.

The location where four tags were recovered suggests that the fish may have been removed from the water (Table A1). Clearly, tags found above the wetted channel in the tributaries during low flow periods of late summer and fall suggest some method of transport. Some researchers have noted that predation, angling/poaching, and shed tags are the suspected causes of tag loss (Elle 1995; Swanberg 1997; Chandler et al. 2001). The U.S. Fish and Wildlife Service suspect that some of their bull trout tagged in 2002 perished (20% of tagged fish). Some of their tags have been recovered onshore away from the river.

Predation may have played an important role in the disappearance of tagged bull trout. One tag (14-95) had cut marks on the antenna portion of the radio tag (Table A1). Here, the observer noted that the tag was recovered on the shore inside a hole under a boulder perhaps only big enough for a mink. Chandler et al. (2001) and Elle (1995) both noted that mink preyed on their bull trout. The bull trout with tag 14-110 made extensive movement both upstream and downstream in the Columbia River. That tag was finally recovered downstream of Rock Island Dam about 10-15 feet from the waters edge under a pile of debris that had floated in during high water. The observers noted that it was common to see hawks and eagles in this area. Three other tags (14-98, 14-90, and 14-109) were recovered without a carcass in the Columbia River. These fish migrated to spawning areas in the Entiat basin before their tags were found.

Harsh stream conditions in the fall may have contributed to the loss of some bull trout. Both the Twisp and Entiat rivers experienced very low flow conditions in fall 2002 compared to the period of record (Figure A2). Low flows in the Twisp River created a dry stream channel in fall, which prevented adults from migrating downstream, presumably after they had spawned. This condition has been observed in the Twisp River the past two years. Increased flows in late fall, particularly in small tributaries, may be an important cue that triggers downstream movement of adult bull trout. Two bull trout migrated downstream when flows increased in the Twisp River in November 2002. However, the increased flow was not sufficient to provide complete passage downstream to the Methow River. One bull trout died (14-107) after it had moved downstream and became stranded. That bull trout was recovered during a survey conducted by the U.S. Fish and Wildlife Service. Another tagged bull trout (14-116) was rescued and returned downstream along with one untagged bull trout. Swanberg and Burns (1997) observed a similar situation for a bull trout in the upper Blackfoot River. In their study they found a bull trout that became isolated in a large ice-covered pool just upstream of a dry section of Landers Fork. That fish froze seven days later.

Most of the bull trout that were tracked migrated to spawning areas in the Entiat and Methow basins. Although multiple spawning has been reported for bull trout, relatively high mortality (67%) for spawning bull trout has also been noted (Schill et al. 1994). Elle (1998) reported a lower range of mortalities (26% to 36%) for spawning adults. He noted that there was no difference in survival during spawning between radio-tagged and untagged bull trout. This information suggests that the fall spawning period may be a time when adult bull trout are likely to perish. The loss of tagged bull trout, however unfortunate to this study, provides a more complete picture of the life history for bull trout in the mid-Columbia region.



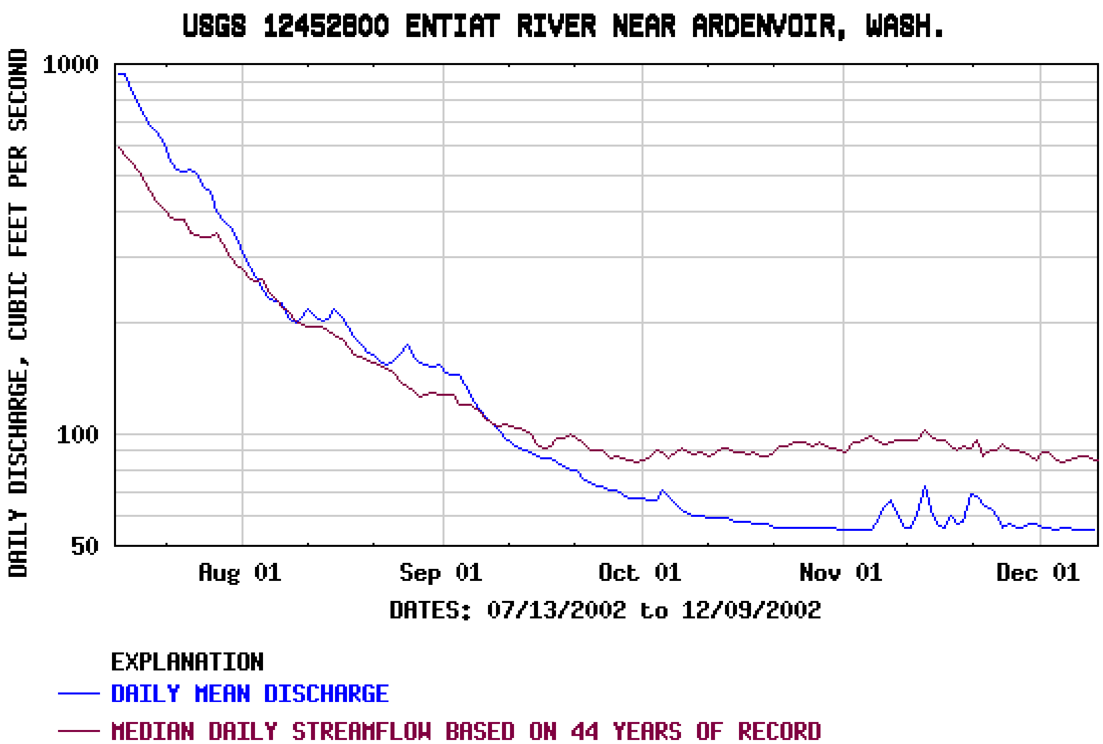


Figure A2: Stream discharge (cfs) in the Twisp and Entiat rivers from August to December, 2002.

REFERENCES

BioAnalysts, Inc. 2002. Movement of bull trout within the mid-Columbia River and tributaries, 2001-2002 -FINAL. Chelan, Douglas, and Grant County Public Utility Districts, Wenatchee, WA.

Brown, L.G., 1994. Zoogeography and Life History of WA Native Char: dolly varden and bull trout. Washington Fish and Wildlife, Report #94-04, Olympia, WA.

Carson, R.J., 2001. Bull trout spawning movements and homing behaviour back to pre-spawning locations in the McLeod River, Alberta. In: Brewin, M.K., A.J. Paul, M. Monita (Eds.), Bull Trout II Conference Proceedings; Ecology and Management of Northwest Salmonids. Trout Unlimited, Canada, Calgary, Alberta, pp. 137-141.

Chandler, J.A., M.A. Fedora, T.R. Walters, 2001. Pre- and Post-spawn movements and spawning observations of resident bull trout in the Pine Creek Watershed, Eastern Oregon. In: Brewin, M.K., A.J. Paul, M. Monita (Eds.), Bull Trout II Conference Proceedings; Ecology and Management of Northwest Salmonids. Trout Unlimited, Canada, Calgary, Alberta, pp. 167-175.

Elle, S., 1995. Annual Performance Report. Project 3; Subproject 1. Wild Trout Regulation Effects on Angler Displacement. Subproject 2. Steelhead Exploitation Studies. Project 6; Subproject 1. Rapid River Bull Trout Movement and Mortality Studies. Subproject 2. Bull Trout Aging Studies. Idaho Fish and Game, Boise, ID.

Elle, S., 1998. Annual Performance Report. Project 3. Wild Trout Investigations, Subproject 1. Whirling Disease Studies, Subproject 2. Evaluations of Salmonid Restricted Harvest Regulations Permitting the Use of Bait, Project 6. Bull Trout Investigations, Subproject 1. Rapid River Bull Trout Movement and Mortality Studies. Project F-73-R-18. Idaho Department of Fish and Game, Coeur d'Alene, ID.

Schill, D., P. Kline, R. Thurow, and S. Elle, 1994. Movement and natural mortality of large fluvial bull trout in Rapid River. Friends of the Bull Trout Conference Proceedings. pgs. 445-446. Calgary, Alberta, Canada, The Bull Trout Task Force c/o Trout Unlimited Canada.

Swanberg, T., Burns, L., 1997. Movement and habitat use of radio-tagged bull trout in the upper Blackfoot River Drainage. Montana Fish, Wildlife and Parks, Helena, MT.

Swanberg, T.R., 1997. Movements of and habitat use by fluvial bull trout in the Blackfoot River, Montana. Transactions of the American Fisheries Society 126, 735-746.

U.S. Forest Service, 2001. 2001 Bull Trout Spawning Survey of Mad River (WDFW Index Reach from Young Cr. to Jimmy Cr.). Unites States Forest Service, Entiat, WA.

APPENDIX B: BULL TROUT DETECTION MAPS

Available Upon Request

July 1995

STATUS REPORT OF THE PACIFIC LAMPREY (LAMPETRA TRZDENTATA) IN THE COLUMBIA RIVER BASIN

Status Report 1995

DOE/BP-

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views of this report are the author's and do r necessarily represent the views of BPA.

This document should be cited as follows:

Close,David A., Martin Fitzpatrick, HiramLi, Oregon Cooperative Fishery Research Unit, Department of Fisheries and Wildlife, Oregon State University, Blaine Parker, Douglas Hatch, Columbia River Inter-Tribal Fish Commission, Gary James, Department of Natural Resources, Fisheries Program, Confederated Tribes of the Umatilla Indian Reservation, U. S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Project Number 94-026, Contract Number 95BI39067, 40 electronic pages (BPA Report DOE/BP-39067-1)

This report and other BPA Fish and Wildlife Publications are available on the Internet at:

http://www.efw.bpa.gov/cgi-bin/efw/FW/publications.cgi

For other information on electronic documents or other printed media, contact or write to:

Bonneville Power Administration
Environment, Fish and Wildlife Division
P.O. Box 3621
905 N.E. 11th Avenue
Portland, OR 97208-3621

STATUS REPORT OF THE PACIFIC LAMPREY *(LAMPETRA TRZDENTATA)* IN THE COLUMBIA RIVER BASIN

Prepared by:

David A. Close
Martin Fitzpatrick
HiramLi

Oregon Cooperative Fishery Research Unit
Department of Fisheries and Wildlife
Oregon State University
Corvallis, O R

and

Blaine Parker
Douglas Hatch

Columbia River Inter-Tribal Fish Commission
Portland, OR

and

Gary James
Department of Natural Resources, Fisheries Program
Confederated Tribes of the Umatilla Indian Reservation
Pendleton, OR

Prepared for:

U. S. Department of Energy
Bonneville Power Administration
Environment, Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-362 1

Project Number 94-026
Contract Number 95BI39067

July 1995

Table of Contents

List of Figures and Tables

I. Cultural Significance. Population Trends, and Life History of the Pacific Lamprey

INTRODUCTION

The widespread decline of Pacific lamprey (Lampetra tridentata) in the Pacific Northwest, especially in the Columbia River system has led to concerns and questions from a number of regional agencies, Native American tribes, and the public. To address these concerns, new research efforts must focus on specific problems associated with this understudied species. The preservation and restoration of this species is critical for a number of reasons, including its importance to the tribes and its importance as an indicator of ecosystem health. Historically lamprey have been labeled a pest species due to the problems associated with the exotic sea lamprey, (Petromyzon marinus), invading the Great Lakes.

The Pacific lamprey is native to the Pacific Northwest and has coexisted with native ichthyofauna for thousands of years. The recovery of the Pacific lamprey may be linked to salmon recovery. In contrast to the sea lamprey, the Pacific lamprey are important fish of cultural, utilitarian, and ecological significance. The following narrative includes a review of the current status of Pacific lamprey in the Pacific Northwest and a list of recommendations for research and management to restore Pacific lamprey.

Cultural Significance: The Pacific lamprey maintains a place of cultural significance in the Columbia and Snake River Basins. Tribal peoples of the Pacific Coast and interior Columbia Basin have harvested these fish for subsistence, ceremonial, and medicinal purposes for many generations (Figure 1).

Figure 1. Umatilla Indians on the Umatilla River, Oregon. Pacific lamprey (eels) drying on rack. Source: Moorehouse Collection 1903.

The tribes use the common name eel when in reference to Pacific lamprey in the Basins. The fish are often harvested at locations where the geology favors capture such as falls or barriers. Two well known places where tribal members historically harvested Pacific lamprey (eels), were at Kasuth near the mouth of the Snake River and at Wallula near the mouth of the Walla Walla River. Eeling is usually done at night when the fish are most active. Active capture methods are used such as a hook on a pole or dip nets. The fish are then prepared traditionally by drying or roasting. Eel oil is used as medicine and is often used as hair grease. Lamprey as part of the Columbia River tribal culture, are important in ceremonies and celebrations similar to many other foods. There are many legends that are associated with the eels, such as the following legend of the eel and the sucker: ,

*"I **have heard it said that long ago, before the people, the animals were preparing themselves for us. The animals could talk to each other during this time. The eel and the sucker liked to gamble so they began to gamble. The wager was their bones. The eel began to lose but he knew he could win. The eel kept betting until he lost everything. That is why the eel has no bones and the sucker has many bones."***

Lamprey are an integral part of Columbia and Snake River tribal cultures and other tribes along the Pacific coast (Anglin et al. 1979; Mattson 1949; Pletcher 1963).

Utilitarian Significance. Lampreys have been valued by other user groups in the Pacific Northwest. Fur trappers seeking coyote, utilized lamprey as bait in the early days (Mattson 1949; pers. comm. Milo Bell, Univ. Washington retired). At the turn of the century, Oregon began developing artificial propagation of salmonids. Fish culturists found that ground raw Pacific lamprey was an ideal feed for young salmon. Adult lamprey were collected at Willamette Falls and then transferred to cold storage to be processed (Figure 2). During the year 1913, twenty seven tons were harvested for this use (Clanton 1913).

In the following years, lamprey became commercially important. From 1941 through 1949 on the Willamette River, a, commercial fishery developed for Pacific lamprey at the Willamette Falls. From 1943 to 1949, a total of 816 tons of lamprey were harvested (Figure 3). The harvest was estimated to be between 10 to 20 percent of the total run. The primary use of the fish was for vitamin oil, protein food for livestock, poultry, and fish meal (Mattson 1949). Presently, Pacific lamprey are important for scientific research as a source for medicinal anticoagulants, for teaching specimens (North Carolina Biological Supply House regularly collects at Willamette Falls), and for food (in 1994, approximately 1800 kg were exported to Europe).

Ecological Signicance: Evidence suggests that. Pacific lamprey was well integrated into the native freshwater fish community and as such had positive effects on the system. It was in all probability, a big contributor to the nutrient supply in oligotrophic streams of the basin as the adults died after spawning (Beamish 1980) Lamprey were an important part of the food chain for many species (Table 1). We suspect that it was an important buffer for upstream migrating adult salmon from predation by marine mammals. From the perspective of a predatory sea mammal it has at least three virtues: (1) it is easier to capture than adult salmon;(2) it is higher

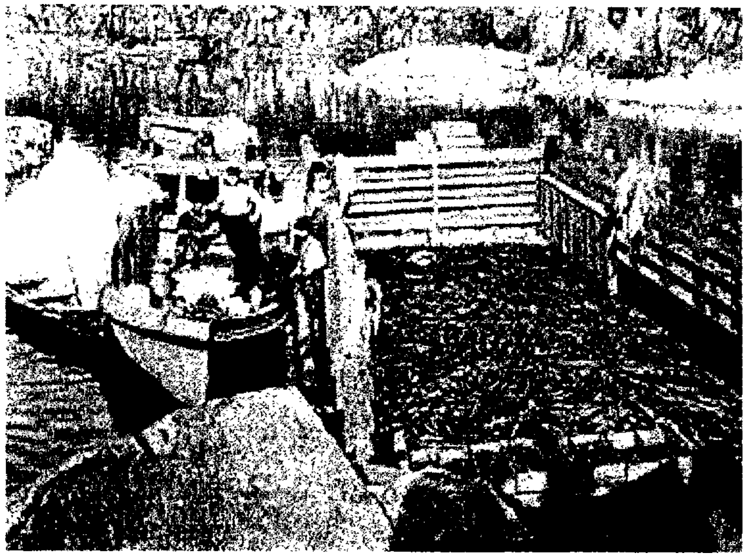


Figure 2. Fifteen tons of Pacific lamprey (eels) aboard a scow for delivery to a cold storage plant to be preserved as food for hatchery salmon fry (Clanton 1913).

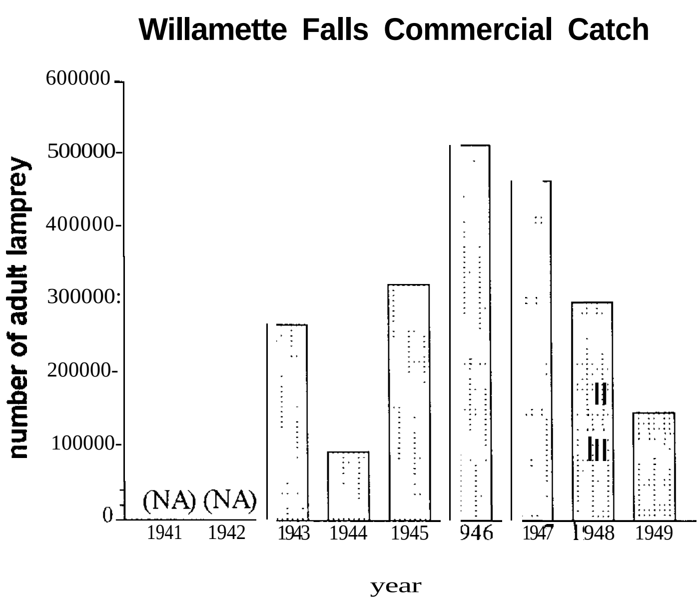


Figure 3. Commercial catch at Willamette Falls on the Willamette River, Oregon. The graph assumes 350 grams per lamprey (as determined from samples of fish captured in 1993 and 1994). The commercial catch data for 1941 and 1942 are not available. Modified after Mattson (1949).

Table 1. Predators of Lampreys

Scientific name	Common name	Comments
Ictalurus punctatus	channel catfish	exotic predator on juveniles
Ascipenser transmontanus	white sturgeon	feeds on all stages
Ptychocheilus oregonensis	northern squawfish	feeds on juveniles
Cyprinidae	minnows	egg and larval predators
Anguillidae	eels	egg and larval predators
Cottidae	sculpins	egg and larval predators
Percidae	logperch	egg and larval predators.
Oncorhynchus mykiss	juvenile rainbow trout	egg and larval predators
Eumetopiasjubatus	Steller sea lion	adult lampreys at mouth of rivers (82%)
Physeter catodon	sperm whale	adult lampreys
Phoca vitulina richardsi	harbor seal	adult lampreys
Zalophus californianus	California Sea lion	adult lampreys
Ardea herodias	great blue heron	adult lampreys
Sterna fosteri	Forster's tern	ammocoetes
Larus occidentalis	Western gull	ammocoetes
Larus californicus	California gull	ammocoetes
Larus delawarensis	ringbill gull	ammocoetes

in caloric value per unit weight than salmonids and (3) they migrate in schools. The' lamprey is extraordinarily rich in fats, much richer than salmon. Caloric values for lamprey ranges from 5.92-6.34 kcal/gm wet weight (Whyte et al. 1993); whereas, salmon average 1.26-2.87 kcal/gm wet weight (Stewart et al. 1983). In addition, Roffe and Mate (1984) revealed that, indeed, the most abundant dietary item in seals and sea lions are Pacific lamprey. As a result, marine mammal predation on salmonids may be more severe because lamprey populations have declined. Larval stages and spawned out carcasses of lampreys were important dietary items for white sturgeon in the Snake and Fraser Rivers (Ken Witty, ODFW retired, personal . communication, Galbreath 1979, Semakula and Larkin 1968).

Juvenile lampreys migrating downstream may have buffered salmonid juveniles from predation by predacious fishes and sea gulls.' Lampreys are found in the diets of northern squawfish ***(Ptychocheilus oregonensis)*** and channel catfish ***(Ictalurus punctatus)*** in the Snake River system (Poe et al. 1991). Merrell (1959) found that lampreys were 71% by volume of the diet of gulls and terns below McNary Dam during early May. Juvenile lampreys may have played and important role in the diets of many freshwater fishes (Table 1). Clanton (1913) reported that ground "eel" (lamprey) was the dietary constituent that lead to the best growth of hatchery salmonid fry. Pfeiffer and Pletcher (1964) found emergent anmiocoetes and lamprey eggs were eaten by salmonid fry. We speculate that wild juvenile salmonids may have found lamprey to be important prey during the spring.

Historical Distribution: Historical distribution of ***L. tridentata*** in the Columbia and Snake Rivers was coincident wherever salmon occurred (Simpson and Wallace 1978). Access to suitable habitat rather than distance from the ocean was suggested to be the important, factor influencing regional distribution (Kan 1975). The overall distribution of Pacific lamprey is from southern California to the Gulf of Alaska and inland to central Idaho (Hammond 1979). Some specimens have been collected off Hokkaido, Japan (Wydoski and Whitney 1979).

Current Distribution The current distribution of Pacific lamprey in the Columbia River and tributaries extends to Chief Joseph Dam and to Hells Canyon Dam in the Snake River (Figure 4). Both dams lack fishways and limit distribution of migrating fish; however, no survey to examine the actual distribution throughout Columbia River drainage has been undertaken. There are only sporadic reports of lamprey because of partial data and/or the lack of survey data. Effort is needed to compile all known information. For example, from fish trapping operations at Threemile, Dam we know that lamprey are no longer. or are very rarely found in the Umatilla River.

Current Status. Data reveal that Pacific lamprey are in precipitous decline in the Columbia and Snake rivers (Figures 5-10). These trends show the same consistent pattern at all dams regardless of the idiosyncratic differences in counting procedures and data processing among different monitoring protocols. Dam counts of lampreys were utilized for determining the status of the Pacific lamprey in the Columbia and Snake River basins. The dam counts should be viewed as trend data and not total counts because there has been little standardized sampling across years and counting was restricted to certain hours. For example, the first fish counters

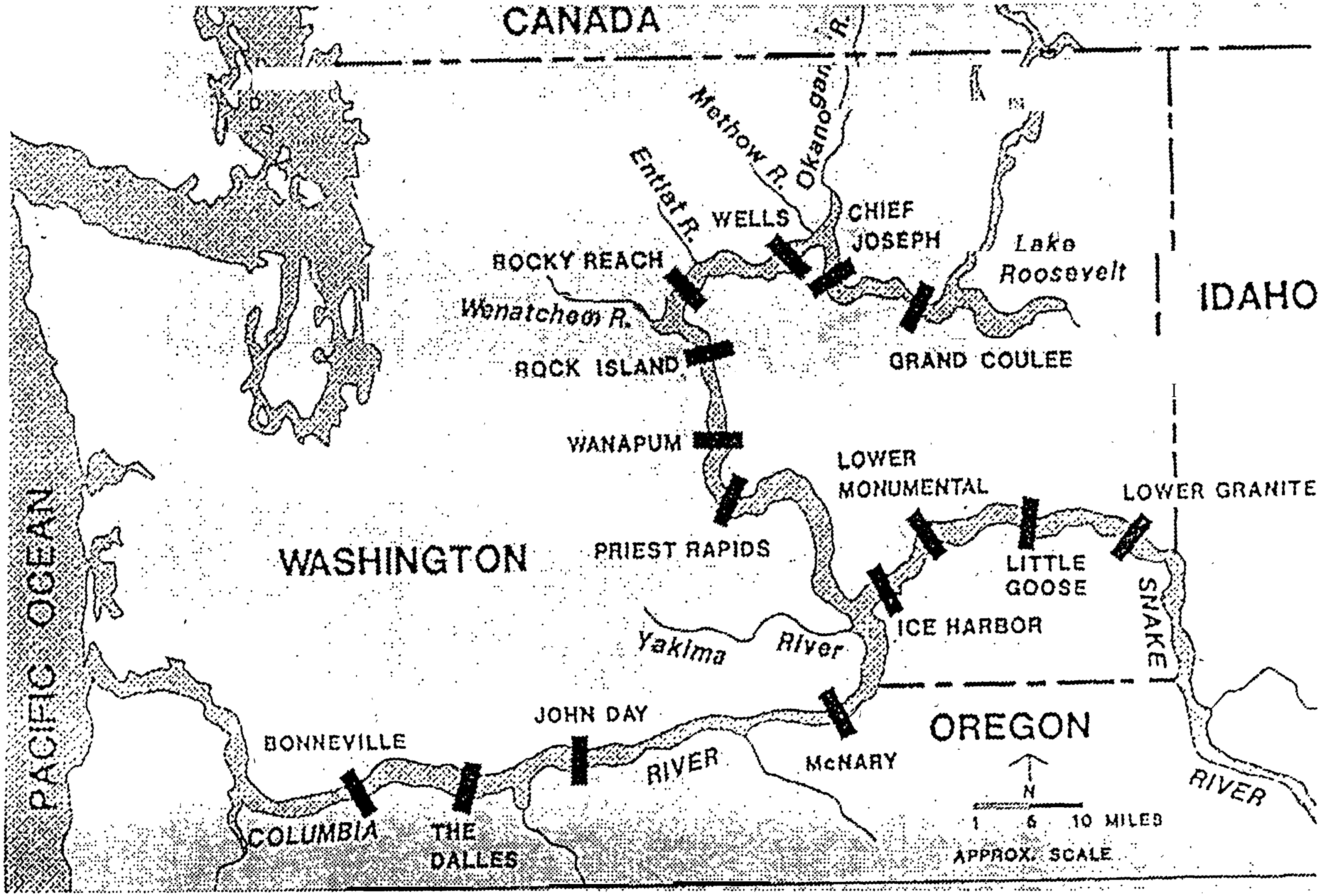


Figure 4. Hydroelectric dams on the Columbia and Snake (mainstem) rivers, Taken from Mullan et al. 1986.

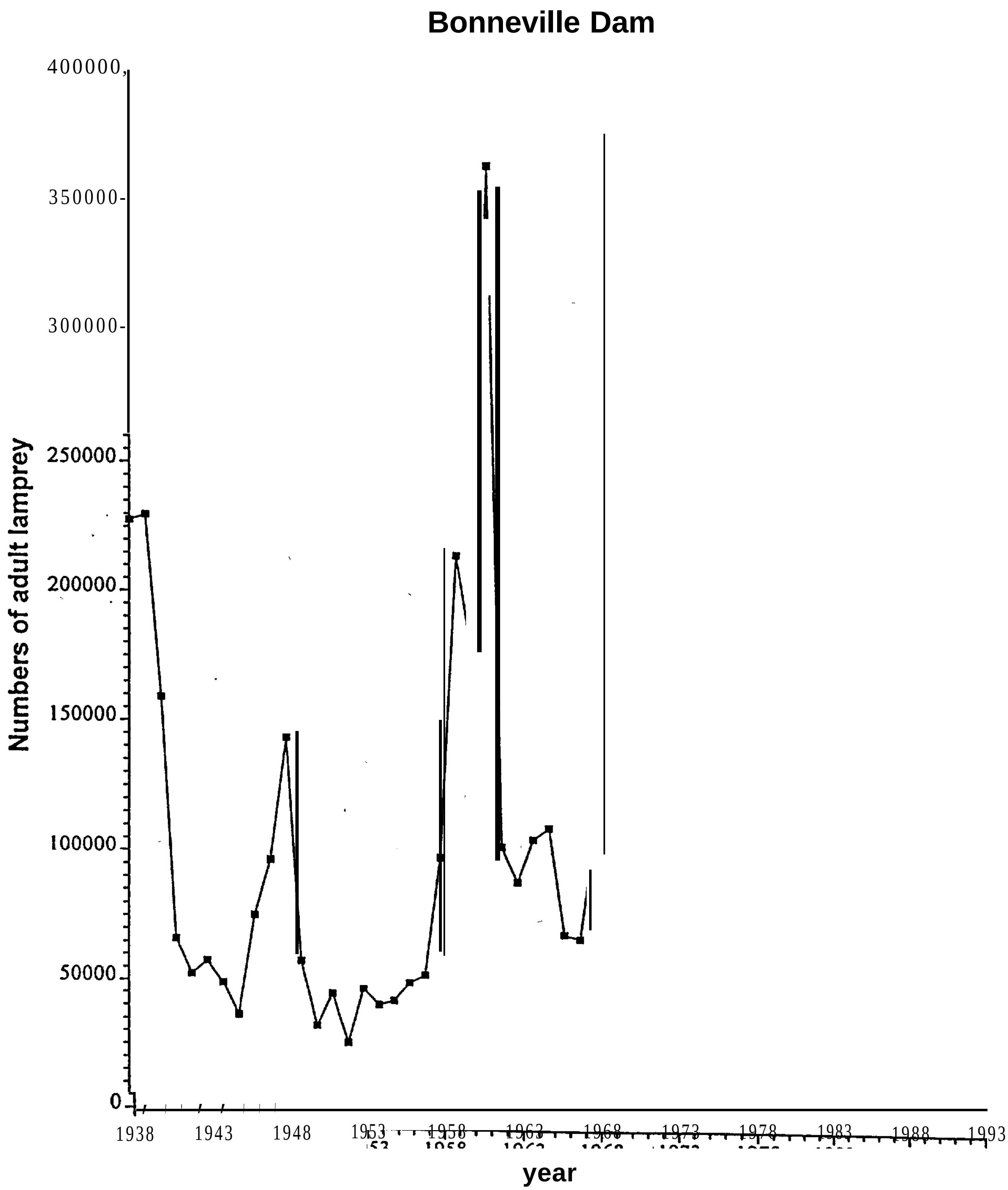


Figure 5 Number of adult lamprey counted at Bonneville Dam Fish Counting Facility (from Corps of Engineers, 1969 Annual Fish Passage Report. Counts for 1993 are based on estimated numbers from Starke and Dalen 1995).

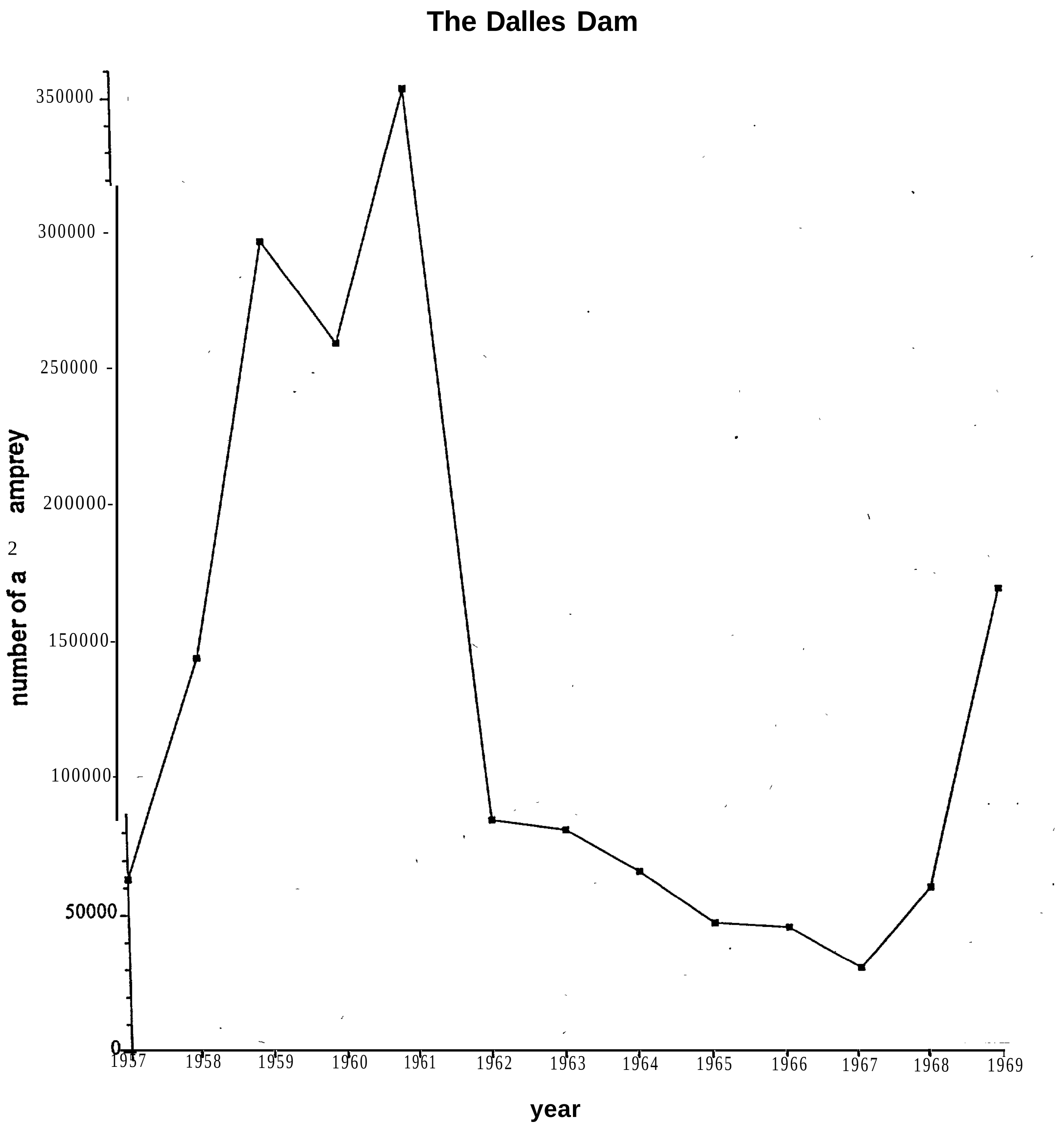


Figure 6. Number of adult lamprey counted at The Dalles Dam Fish Counting Facility (from Corps of Engineers, 1969 Annual Fish Passage Report).

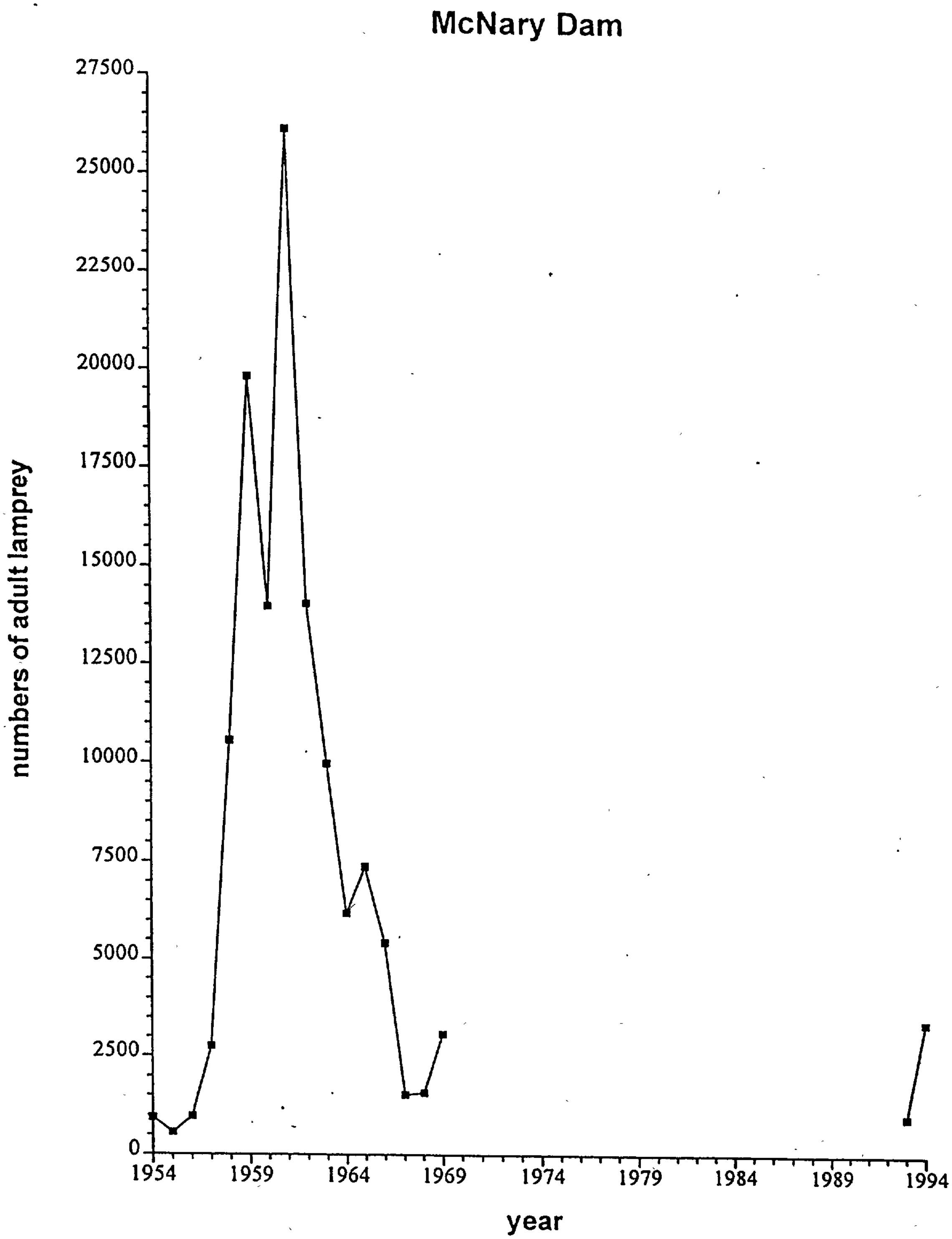


Figure 7. Number of adult lamprey counted at McNary Dam Fish Counting Facility (from the Corps of Engineers, 1969 Annual Fish Passage Report. Counts for 1993 and 1994 are from Washington Department of Fish and Wildlife).

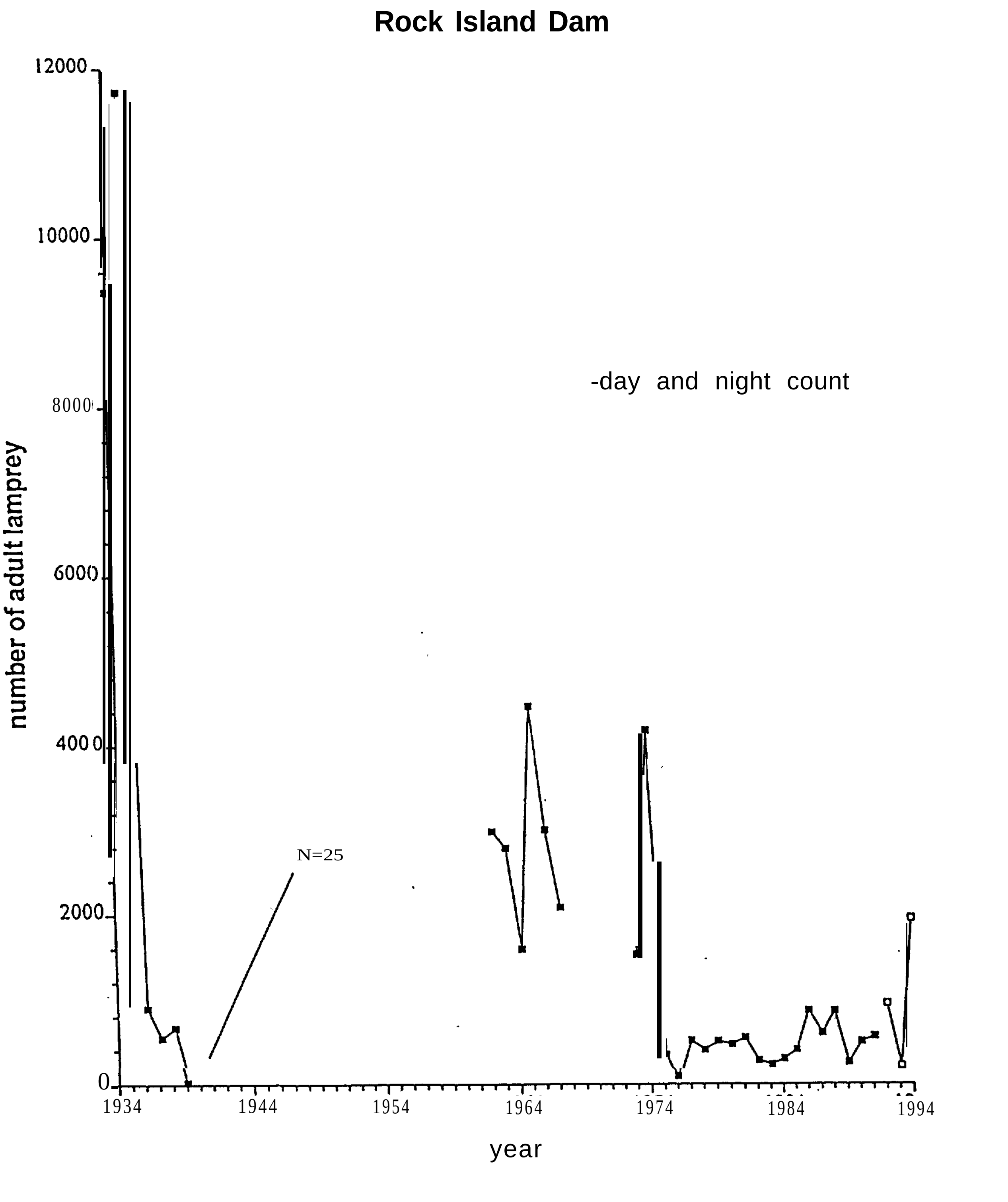


Figure 8. Number of adult lamprey counted at Rock Island Dam Counting Facility (from U.S. Fish and Wildlife Service, Leavenworth, Washington and Chelan County P.U.D.)

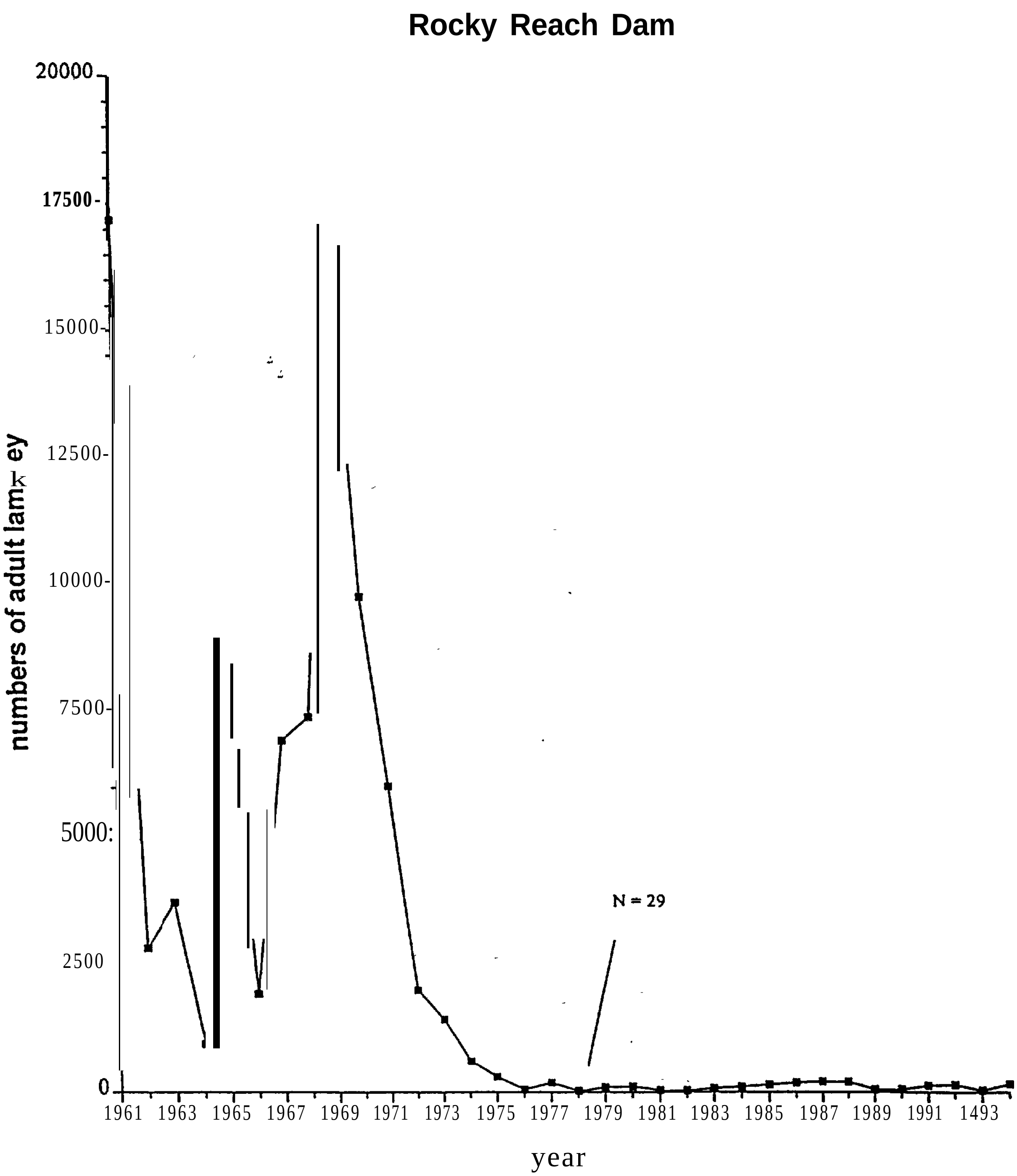


Figure 9. Numbers of adult lamprey counted at Rocky Reach Dam Fish Counting Facility (from U.S. Fish and Wildlife Service, Leavenworth, Washington and Chelan, County P.U.D.)

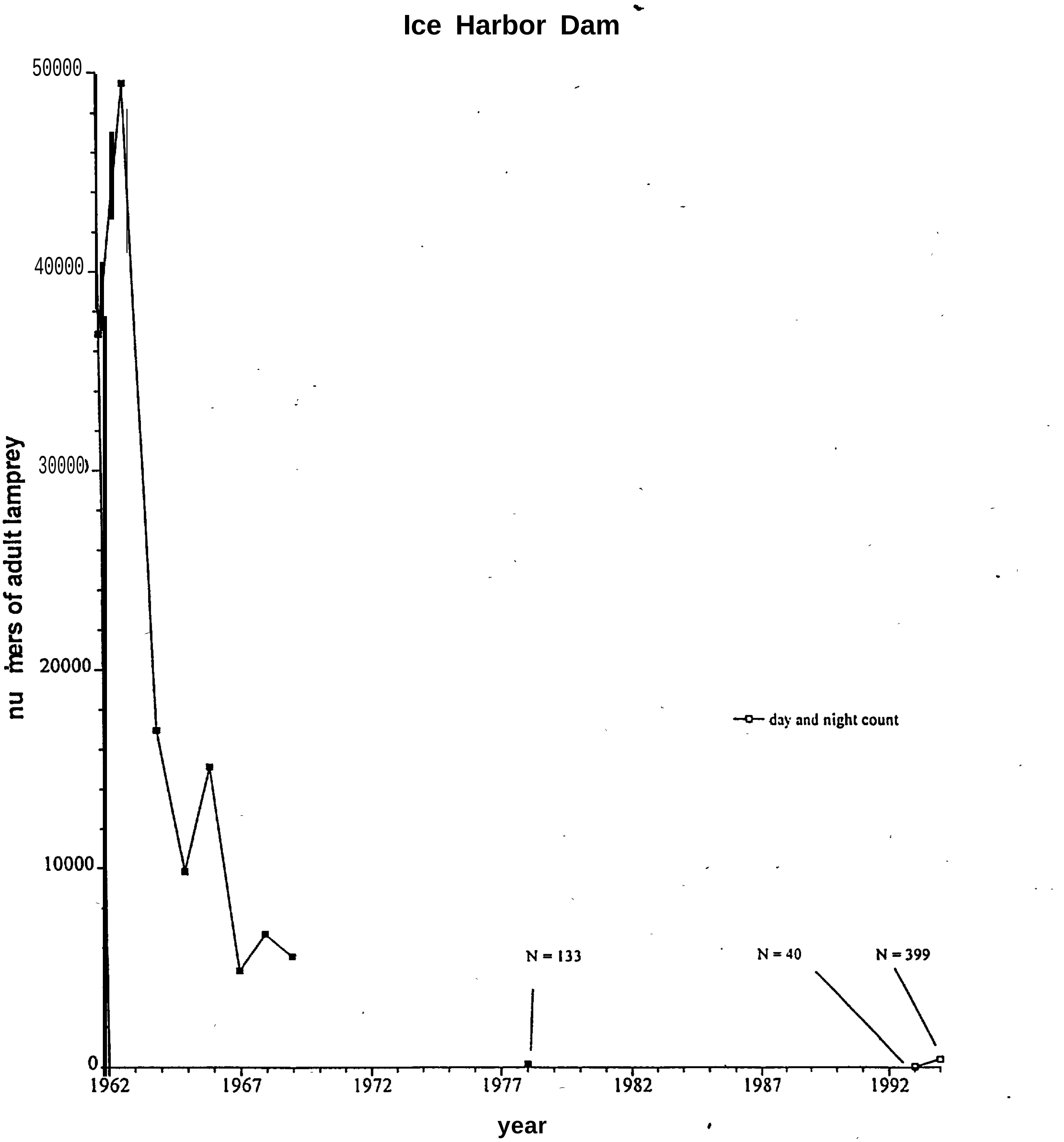


Figure 10. Number of adult lamprey counted at Ice Harbor Dam Fish Counting Facility (from Corps of Engineers, 1969 Annual Fish Passage Report. Count for 1978 from Hammond 1979. Counts for 1993 and 1994 from Washington Department of Fish and Wildlife).

counted fish passing white boards. Today there are windows in the fishway to observe fish passage (Mullan et al. 1986). The fish counters in the past counted for an 8 hour day shift in the beginning and end of the salmon runs and a 16 hour day shift for the main part of the salmon runs (Starke and Dalen 1995). The highest lamprey movement was noted to be at night and therefore lamprey numbers observed during the "salmon counts" should be considered conservative.

Many factors may account for this decline, including (1) passage problems for adult and juvenile lamprey migrating through dams; (2) declining conditions of spawning and rearing habitat in freshwater; (3) decline of the marine prey base including ground fishes, walleye pollock ***(Theragra chalcogramma*)**, Pacific hake **(*Merluccius productus)*,** and salmonids due to fishing and a variety of factors; and (4) chemical "rehabilitation" (i.e., extermination by rotenone) of streams. In order to gain some perspective on the factors leading to the decline of the Pacific lamprey, we provide a synopsis of its life history followed by a discussion of potential factors that may affect the decline of lampreys based on this life history information.

LAMPREY LIFE HISTORY,

Pacific lamprey is one of three species of lamprey that occur in the Columbia River basin. The other two species are the river lamprey ***(L.*** ayresii) and the western brook lamprey (I ***richardsoni*;** Kan 1975). ***L tzidentata*** and L ***ayresii*** are the only two parasitic lamprey in the Columbia River system. L ***richardsoni*** completes its life cycle in freshwater and is nonparasitic.

Spawning Spawning of the Pacific lamprey on the coast of Oregon usually occurs in May with temperatures between **10°C** to 15°C. Pacific lamprey migrating inland in the Columbia River spawn later. Both spawning and pre-spawning fish were collected in the John Day River system in Oregon in July (Kan 1975). Mattson (1949) described spawning activity in the Willamette River during June and July. In the Babine River system in British Columbia, Pacific lamprey were observed spawning from June through the end of July (Farlinger and Beamish 1984).

Spawning Habitat Spawning sites of ***L. tridentata*** generally occur in low gradient stream sections where gravel is deposited (Kan 1975). The nest sites are constructed at the tail areas of the pools and in riffles (Pletcher 1963; Kan 1975;). Pacific lamprey spawning occurs over gravel with a mix of pebbles and sand (Mattson 1949; Kan 1975). Gravel is an important feature for spawning lamprey. Lamprey held in aquaria divided with three inches of sand on one side and gravel substrate on the other, preferred gravel (Pletcher 1963). Therefore, appropriate substrate is a critical habitat feature for ensuring lamprey spawning.

Flow also seems to be an important spawning requirement. Spawning occurs in lotic habitat with velocities ranging from 0.5 to 1.0 meter per second (Pletcher 1963; Kan 1975). The depth that spawning occurs varies but ranges from 0.4 to 1.0 meter (Pletcher 1963; Kan 1975). In the Babine River system, the spawning depths ranged from 30 cm to 4 m, although most occurred at sites of less than 1 m (Farlinger and Beamish 1984). Although rare, it should be noted that ***L. tridentata*** have been observed spawning in lentic habitat in the Babine Lake system in Canada, where depths of the nest sites ranged from 0.5 m to 3 m and lamprey generally oriented towards the creek mouth (Russell et al. 1987). Generally, lampreys prefer flowing water for spawning (Russell et al. 1987; Manion and Hanson 1980).

Spawning Behavior At the beginning of spawning, lamprey generally hide in the substrate or in the shade. However, as spawning proceeds, lamprey are not affected by bright sunlight (Pletcher 1963; Kan 1975). Both sexes begin moving rocks with their buccal funnel to create nests in excavated depressions (Pletcher 1963). Courting consists of a male approaching a female with a gliding motion to stimulate the female (Pletcher 1963). A male attaches his buccal ftmnel to a female's head, and then wraps his body around the female while releasing milt (Pletcher 1963; Russell et al. 1987; Kan 1975). During each spawning act, approximately 100 to 500 eggs are released and covered by sand and pebbles (Pletcher 1963).

Kan (1975) observed spawning of Pacific lamprey in Oregon and found that nests were approximately 30 cm wide, 3 cm in depth, and oval in shape. In the Babine Lake system of British Columbia, nests were 20-30 cm diameter and 4-8 cm deep (Russell et al. 1987). Absolute fecundity for lampreys in Oregon ranged from 98,000 to 238,400 eggs. The relative fecundity was significantly different between lamprey from coastal Oregon, the Molalla and Umpqua rivers, and lamprey from the inland John Day River. Kan (1975) suggested that the lower fecundity in the John Day lampreys may have been due to a higher cost of migration. After spawning, the Pacific lamprey dies within 3 to 36 days (Kan 1975; Mattson 1949; Pletcher 1963).

Larval ***stage:*** Temperature controls, the hatching time of ***L tridentata*** eggs. Pletcher (1963) observed eggs beginning to hatch after 19 days at 15'C. The larvae leave the gravel approximately two or three weeks after hatching and drift downstream usually at night. The larvae settle in slow back water areas such as pools and eddies (Pletcher 1963).

The length of larval life of ***L. tridentata*** is very difficult to estimate due to the inconsistency of length frequency data and the lack of bony structures. The larval stage was estimated to range from four to six years (Richards 1980; Kan 1975; Pletcher 1963) and has been suggested to extend up to seven years (Hammond 1979; Beamish and Northcote 1989). The size of the larvae varies but ranges from 3-5 g and 13-20 cm in length (Mallatt 1983).

During the larval stage, ammocoetes are blind, sedentary, and survive by filtering food particles. Larvae usually feed on detritus, diatoms, and algae suspended above and within the substrate (Moore and Mallatt 1980). Ammocoetes possess a high entrapment efficiency due to mucus secreted by the walls of the pharynx and goblet cells within the gill filaments. The high entrapment efficiency is coupled with low food assimilation. Larvae digested only 30-40% of the food intake while passing large amounts of undigested food (Moore and Mallatt 1980).

Habitat Use: Ammocoetes drift into slow current areas and burrow into the substrate. The slow current allows the larvae to maintain position while burrowing. Under experimental conditions, emergent larvae of size 7-10 mm preferred mud (0.004 cm) over sand (0.005 cm) and gravel (l-O.5 cm) substrate (Pletcher 1963). Current greater than 0.305 m/s prohibited burrowing by emergent larvae in all substrates. When no current was present, larvae of sizes 10-15 mm and 25-30 mm burrowed into the mud faster than larvae of size 40-50 mm. The smallest size group required the most time for burrowing in the sand. With a current of 0.305 m/s, only the 40-50 mm larvae could burrow in the sand, but all groups burrowed into the mud substrate (Pletcher 1963). The current over ammocoete beds in Oregon streams ranges from 0.1 to 0.5 m/s (Kan 1975).

The density of larvae was highest in shallow areas along the banks of the Chemainus River in British Columbia. Ammocoetes <75 mm in length were found in the shallows but only larger larvae >75 mm were found in the deeper middle portion of the river (Richards 1980). Higher densities of ammocoetes are found in the lower sections of rivers with low gradients opposed to sections with steeper gradients (Richards 1980).

Ammocoetes, like other fishes, react to differences in the partial pressure of oxygen. Low oxygen tensions (7-10 mm Hg) caused ammocoetes to emerge and die; whereas higher tensions (18-20 mm Hg) were tolerated at 15.5"C (Potter et al. 1970).

Ammocoetes are usually found in coldwater but have been collected in waters ranging up to 25°C in Idaho (Mallatt 1983). Pacific lamprey ammocoetes held at 14°C and 4°C grew 41% and 11% of body weight per month on a variety of foods in laboratory studies (Mallat 1983). Larval sea lamprey preferred a summer temperature of 20.8" C and ranged from 17.8 to 21.8"C (Holmes and Lin 1994).

Metamophosis Transformation of Pacific lamprey from the larval to juvenile life stages generally occurs during July through October (Richards and Beamish 1981; Hammond 1979). However, Pletcher (1963) observed metamorphosis from July to November in this species from the Chemainus River, British Columbia. During this period, the larvae go through 'morphological and physiological changes to prepare for a parasitic life style, in salt water. External signs of metamorphosis are similar in most species of lampreys. The process occurs in seven stages according to external observations (Yousson and Potter 1979). The changes occur first in the mouth, with the oral hood changing into an oval mouth. The development of the eye and the length of the oral disc increase during stages l-4. Condition factor begins to drop after reaching stage 4 in transforming fish. After four weeks (stage 5) teeth and tongue begin to develop (Richards 1980). The teeth remain soft through stage 6, with cornification occurring near the end of stage 6. When the teeth harden and turn yellow, stage 7 is complete (Richards 1980).

Internal changes such as a development of the foregut during stage 6 coincides with the **ability to osmoregulate in salt water (Richards 1980; Richards and Beamish 1981). Changes in the blood proteins occur during metamorphosis (Richards 1980). The gallbladder and the bile** dud disappear as the fish transforms to a young adult (Bond 1979). The respiratory system changes from a unidirectional system, in which water flows over the gills, moves through the pharynx, and flows out the gill pores, to a tidal flow system, in which water enters and exits the branchiopores (Lewis 1980). The transformation is associated with a new preference of habitat. Transforming fish are associated with larger substrate and move into higher velocity areas (Richards and Beamish 1981; Potter 1980). By stage 6, Pacific lamprey from the Qualicum River in British Columbia moved from mud and silt areas to l-4 cm gravels in faster flows (Beamish 1980).

Young Adult/Doumstream Migration: While waiting to migrate to the ocean, young adults burrow in cobble and boulder substrate (pletcher 1963). , After completing metamorphosis in October and November, young adults migrate to the ocean between late fall and spring. In the Nicola River of British Columbia, 99% of all young adults migrated by April and May (Beamish and Levings 1991). Increased discharge, is associated with migration of young adults and distribution of ammocoetes (Potter 1980; Applegate 1950; Beamish and Levings 1991). In the Fraser River system, 99% of the young adults left the substrate and began migration during the night with increased discharge (Beamish and Levings 1991). Pacific lamprey, like other species of lamprey, rely on currents to be carried downstream (Beamish and Levings 1991). Out- , migrating sea lamprey do not actively swim downstream; instead, they drift downstream tail first (Applegate 1950).

The young adults from some populations can stay in freshwater up to 10 months after metamorphosis, although different populations in British Columbia vary in their ability to survive confinement in freshwater (Beamish 1980). Confined Babine River lamprey did not survive past February, while Chemainus River fish survived until July (Clarke and Beamish 1988) The onset of mortality was associated with decrease in plasma sodium concentration and condition factor (Clarke and Beamish 1988).

Downstream migration of young adult lampreys occurs at night in the Columbia River system (Long 1968). Young adults can be sampled from March to June in collection facilities at John Day and Bonneville dams on the Columbia River (Hawkes et al. 1991; Hawkes et al; 1992; Hawkes et al. 1993). Information on winter emigration of lampreys is lacking because collection facilities do not operate all year. It has been suggested that only 10 % of the migrants use the bypass systems located at the Columbia River dams (pers. comm. Bill Muir, NMFS). Long (1968) found that most migrating lamprey enter turbine intakes near the center and bottom. Therefore, salmonid bypass systems may not be adequate for Pacific lamprey juveniles.

Ocean Life The ocean phase has been estimated to last for periods of up to 3.5 years for Pacific lamprey in the Strait of Georgia in British Columbia (Beamish 1980) Off the coast of Oregon, the duration of the ocean phase was estimated to range from 20 to 40 months (Kan 1975). The ‘timing of entrance into salt water may differ among populations of Pacific lamprey due to environmental conditions (pers. comm., RJ. Beamish, Nanaimo Biological Station, Nanaimo, B.C., Canada). Kan (1975) suggested that coastal populations enter salt water in the late fall, while inland populations enter in the spring. After entrance into salt water, Pacific lamprey move into water greater than 70 m in depth. Young adults have been captured off the Pacific coast of

Canada at depths ranging from 100 to 250 m (Beamish 1980). Pacific lamprey have been collected at distances ranging from 10 to greater than 100 km off the Oregon coast and up to 800 m in depth (Kan 1975) Despite- the occurrence of deep water collections, Pacific lamprey are generally considered to be mid-water fish associated with plankton layers (Beamish 1980).

Feeding: Adult lamprey locate their prey by means of olfaction, electroreception, and vision similar to elasmobranch fishes. Sea lampreys, stimulated by amines from prey fish located in water added to tanks, oriented their bodies towards the source of the smell (Kleerekoper 1958). Lampreys possess electroreceptors on head and trunk regions that may be useful in finding prey (Bodznick and Preston 1983) Farmer (1980) suggested lamprey use vision to locate prey items.

Feeding of lamprey can occur in fresh water and salt water, although freshwater feeding is not common. Freshwater feeding occurred above Dworshak Dam on the North Fork of the Clearwater River in Idaho when migration was cut off in 1969 (Wallace 1978); and above dams in British Columbia that stopped migration of young adults to the ocean (Beamish and Northcote 1989). Wallace (1978) suggested that many of the attachments were unsuccessful in Dworshak reservoir. Eventually, Pacific lampreys became extinct in both drainages.

Pacific lampreys attach to fish ventrally near the pectoral area (Roos et al 1973; Beamish 1980). Lampreys create suction in the buccal funnel by changing the volume in the oral cavity (Hardisty and Potter 1971). The tongue contains dentides that rasp to create tissue damage and buccal glands secrete anticoagulant to assist in feeding of blood (Farmer 1980).

Upstream Migration: Beamish (1980) has suggested that lampreys enter fresh water between April and June, and complete migration into streams by September. In the Chemainus River of British Columbia, lampreys migrated into fresh water beginning in late April and 81% of the catch occurred during two days in May (Richards 1980). It is not clear how flow impacts freshwater immigration. Pacific lampreys are considered weak swimmers compared to other fish Burst swimming speed was calculated to be approximately 2.1 m/sec for lamprey (Bell 1990). On the Fraser River in British Columbia, Pacific lamprey were estimated to migrate 8 km/day (Beamish and Levings 1991). In the Columbia River, the same species was estimated to migrate 4.5 km/day (Kan 1975).

Pacific lamprey overwinter in fresh water and spawn the following spring (Beamish 1980). During the winter, Columbia River dams de-water fishways for maintenance, and it is common for Pacific lamprey to be found and removed at this time (Starke and Dalen 1995). Pacific lamprey generally overwinter in deep pool habitat until spring (RJ. Beamish, personal communication, Dept. of Fisheries & Oceans Nanaimo, British Columbia).

Pacific lamprey do not feed during the spawning migration. The fish utilize carbohydrates, lipids, and proteins for' energy (Read 1968). Beamish (1980) observed 20% shrinkage in body size from the time of freshwater entry to spawning.

POTENTIAL FACTORS AFFECTING LAMPREY DECLINE

Poor Habitat Conditions-The decline of Pacific lamprey may be associated with factors similar to those affecting the decline of anadromous salmonids. Since inland salmon populations were negatively affected by the early 1900's due to agricultural water withdrawals (Lichatowich and Mobrand 1995), it is conceivable that Pacific lamprey were affected as well. It is clear that good water quality is necessary for Pacific lamprey. These fish prefer cold temperatures below 20" C (Mallat 1983). Spawning gravels are needed for reproduction of lamprey as is the case for salmonids. In many parts of eastern Oregon and Washington, stream water is diverted for irrigation which lowers flow and habitat volume, increases' sediment deposition, and elevates stream temperatures - especially in low gradient stream reaches at lower elevations. The highest densities of larval lamprey are found in these stream reaches (Pletcher 1963). Unfortunately, these areas are the most affected by people. Poor grazing practices, and intensive logging are other human activities that can raise stream temperatures and increase the stream's sediment load.

Fish Poisoning Operations-From the late 1940's through the 1980's. the Oregon Fish Commission (ODFW) removed non-game fishes (so-called "rough fish control") by means of rotenone across the state. In 1967 and 1974, approximately 90 and 85 miles of the Umatilla River were chemically treated. The 1967 treatment killed one million fish, which was estimated to be a 95% kill in treated area (ODFW, unpublished). Since larval life of lampreys in the streams can be from 4 to 6 years, these treatments during September may have decimated several age classes of larvae, young adults, as well as adults returning to spawn. The Umatilla River is one example out of many where treatments are suspected to have contributed to the demise 'of lamprey.

Water Pollution-It is unknown how pollution in the Columbia and Snake rivers has affected Pacific lamprey. Extensive mining, refinery, and radioactive waste discharge have created pollution in the form of heavy metals and radionuclides in the Columbia River (Johnson et al. 1994). The industrialization of the Columbia River has caused it to become a sink for heavy metals and radionuclides. Diatoms and organic matter were reported to take up divalent metals (Johnson et al. 1994). Other sources of pollution include agricultural runoff and environmental estrogens from breakdown products of herbicides.

Dam Passage-The hydroelectric dams along the Columbia and Snake rivers (Figure 4) have impacted anadromous fish. In some systems, such as the Umatilla River, inadequate fish passage facilities contributed to the extirpation of anadromous salmonids and perhaps lamprey in the upper reaches of the river. The migration to the ocean may be delayed due to the change in the hydrograph caused by the impoundments. Long (1968) reported lamprey on route to the ocean entrained in the turbines. It is unknown how well young adults survive passage through a turbine unit. Hammond (1979) reported lamprey impinged on traveling screens at the dams used to bypass anadromous fish. Obstructions designed to inhibit passage of adult lamprey were built in the fish ladders of some dams (pers. comm., Milo Bell, Univ. Washington, retired). These obstructions were in the form of grates and velocity barriers that forced lampreys to climb up moist walls of fish ladders using oral suction to the next resting pool. Conceivably, this could increase the rate to exhaustion and decrease migration rate.

Ocean Conditions--The availability of food varies with ocean conditions. Lamprey abundance may track the prey abundance closely. Not only have salmon declined but intense commercial harvest of Pacific hake and walleye pollock may have depleted the prey base for lamprey, sea birds, and sea mammals. The fishery for walleye pollock in the Bering Sea is the largest fishery in the world averaging 15 million tons in the past 15 years (Springer 1992). The U.S. share of the catch rose from 1% to 99% of the world's share since 1980. Springer (1992) argues that walleye pollock is a keystone species in the pelagic food web. Other fisheries are likewise being intensively harvested, and other food web shifts may be occurring that impact lamprey abundance. The rise of sea mammal populations and increased commercial fishing may interact to cause a lack of alternative prey for both sea mammals, lamprey, and other predators, which in turn increases competition for food. In addition, other predators may have increased predation on lamprey during severe food shortages. However, declines in the lamprey in the Umpqua River followed a negative exponential curve from 1967 to present (37,000 lamprey in 1967, 473 fish in 1993; ODFW unpublished data) which does not support the shifting food web hypotheses in this system because the time period spans several years of favorable oceanic conditions off of Oregon as well as times of low upwelling. Despite the Umpqua River example, we know so little about the oceanic ecosystem that poor ocean conditions cannot be excluded as a factor that has contributed to lamprey decline.

II. Recommendations for Immediate Management and Enhancement Actions

1. Immediately begin lamprey abundance monitoring at all dams where counting of other species is already conducted (see Recommendations for Research below).

2. Immediately compile information (e.g., oral histories, historic field data files, existing biological sampling efforts) which would define past and current distribution of lamprey in tributaries (see Recommendations for Research below).

3. All obstructions and/or activities that may still be inhibiting passage of adult lamprey in fish ladders must be immediately removed or halted.

4. Any remaining fish poisoning operations targeted at removing "rough fish" in tributaries must cease immediately.

5. A moratorium must be placed on any existing commercial lamprey harvest (e.g., biological supply companies. fish export). Prohibit gathering of lamprey by sport fishermen.

6. BPA, COE and other responsible parties immediately fund research to address critical uncertainties related to lamprey abundance, distribution, passage impediments, habitat limiting factors, artificial production, and transplantation/supplementation (see Recommendations for Research below).

7. Fund efforts to immediately define implementation actions for lamprey restoration pilot projects in selected tributaries and to identify research needs associated with monitoring the results of these restoration actions (see Recommendations for Research below).

III. **Recommendations for Research and Data Gathering**

Minimal current information on Pacific lamprey in the Columbia Basin suggests that populations are severely depressed or no longer exist in numerous tributaries. Understanding the cause of decline through various data gathering and research efforts will be critical to implementing effective restoration actions. A summary of general research recommendations for Pacific lamprey in the Columbia River Basin follows:

Table 2. Recommended Research and Anticipated Results for Columbia Basin Pacific Lamprey

Recommended Research	Anticipated Results
Determine current abundance	Understanding magnitude of remaining populations
Determine current distribution	Understanding locations of remaining populations
Determine passage limiting factors	Understanding locations and severity of impediments to migration and identification of critical passage improvement needs
Determine other habitat limiting factors	Understanding of suitability of current tributary habitat and identification of critical habitat enhancement needs
Identify potential applications of transplantation	Identification of transplantation actions including methodology, source/donor stocks, target locations, and follow-up monitoring and evaluation needs
Identify potential applications of artificial production	Identification of artificial production actions including techniques, donor stocks, target locations, supplementation options, and monitoring & evaluation needs

The following details goals, anticipated study objectives and study approach for each Pacific lamprey research recommendation identified above:

A. Abundance Studies

Goal: Determine the current abundance and passage trends of adult and juvenile lamprey at mainstem Columbia and Snake River dams.

Objectives: (Adult)

1. Coordinate with organizations currently involved with fish passage/trapping at mainstem Columbia and Snake River dams, and obtain and/or record fish passage video tapes.

2. Review tapes to obtain adult lamprey passage data and determine population abundance above each dam,

3. Estimate diel, seasonal and annual variations in adult lamprey migration at each facility.

4. Estimate adult lamprey length frequencies from video tapes.

Approach: (Adult)

Abundance estimates of adult lamprey will be made at several fish counting stations located at mainstem Columbia and Snake River dams. Much of the adult lamprey migration occurs during periods when on-site counting is not conducted. During much of the year, video tape records of nighttime fish passage are being made at Bonneville, Ice Harbor, Lower Granite, Rock Island and Wells dams. These records are being reviewed and fish ladder passage estimated by the Washington Department of Fish and Wildlife and by Chelan and Douglas County Public Utility Districts.

This study will coordinate with these organizations to obtain video tapes to review for lamprey passage. A stratified random sampling design will be employed to sample video records and estimate lamprey passage at the above mentioned facilities. Length frequency estimates will be made from video records. Length frequency estimates will also be compared both temporally, and spatially. These data will help in determining if different stocks of lamprey exist, and the timing of lamprey passage will be identified. Once this is known, impacts from systems operation will be analyzed.

Objectives: (Juvenile)

1. Coordinate with agencies currently involved with juvenile fish passage facilities at mainstem Columbia and Snake River dams to integrate juvenile lamprey sampling needs with existing operations.

2. Collect data on abundance, passage trends, length frequencies and life phases of juvenile lamprey at the various passage facilities.

3. Collect length frequency information from juvenile lampreys using the standardized subsampling techniques incorporated during smolt sampling.

4. Document life phase and the extent of transformation of juvenile lamprey examined at each facility.

5. Calculate lamprey guidance efficiencies and abundance estimates at the various juvenile passage facilities.

6. Document juvenile lamprey's diel, weekly and seasonal passage trends for each project.

Approach: (Juvenile) Abundance, passage trends and length frequencies will be collected at smolt collection facilities on mainstem Columbia and Snake River dams. Since juvenile lamprey are often collected incidentally with juvenile salmonids, data collections can be conducted with existing personnel and facilities. Passage indices will be calculated for lamprey from existing fish guidance efficiency tests conducted at mainstem Columbia and Snake River dams. These indices in conjunction with sampled juvenile lamprey will be used to calculate abundance estimates for each project. Currently, smolt collection facilities exist at Rock Island, Lower Granite, Little Goose, Lower Monumental, McNary and Bonneville dams. Gatewell collections are periodically conducted at Wanapum, Priest Rapids, and John Day dams. Collections from these facilities are conducted by personnel of Chelan County PUD, Washington Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, Idaho Department of Fish and Game, and the National Marine Fisheries Service. Past information regarding lamprey collections exists for a number of these projects.

B. Distribution Studies

Goal: Document past and determine current presence and distribution of lamprey in Columbia and Snake River tributaries above Bonneville Dam.

Objectives:

1. Conduct literature review regarding historical lamprey presence or absence.

2. Collect information from tribal members, current/past fisheries biologists, and landowners (oral histories and/or survey forms).

3. Collect information from existing efforts (fish screening operations and maintenance or other ongoing research involving fish population sampling).

4. Conduct spot checks (electroshock, seine, etc.) to document presence/absence and relative abundance.

5. Document general tributary habitat conditions relative to lamprey presence/absence information collected above.

Approach: Past and current presence and distribution of lamprey in northeast Oregon tributaries will be documented through a literature search and oral histories. Tribal elders will be interviewed and fisheries management agencies records will be analyzed to establish historical information. Current lamprey presence will be analyzed by review of all existing efforts that involve sampling/counting fisheries populations. If no current lamprey population information is known, field sampling may be conducted to document presence or absence. Lamprey distribution information will be correlated with data from stream habitat studies (discussed later) to see if presence/absence directly relates to specific stream conditions.

C. Passage Studies

Goal: Evaluate adult and juvenile lamprey migration and identify possible passage impediments and improvements at mainstem Columbia and Snake River dams and reservoirs.

Objectives: (Adult)

1. Conduct literature review regarding adult lamprey passage, physiology, migration, and research techniques.

2. Test marking/tagging techniques for monitoring adult lamprey migration in a controlled environment.

3. Develop study plan for evaluating adult lamprey migration and passage in the mainstem Columbia and Snake rivers.

4. Implement adult lamprey passage study plans at various mainstem hydroelectric projects. Study to include tagging lamprey and documenting behavior, timing, and success of movement through the dams and reservoirs.

5. Sample adult lamprey at dams to examine external physical condition and clinical indicators of stress and exhaustion.

6. Identify structural passage impediments and causes of impairment,

7. Compare lamprey migration of a healthy run at Willamette Falls to those experiencing observed impairments at Columbia and Snake River dams and make recommendations for passage improvement.

Approach: (Adult)

An information search (including scientific literature, agency reports and interviews) will be conducted to acquire biological and life history information. Priority will be placed on seeking information relevant to: 1) adult lamprey migration and potential causes of physiological exhaustion impacting upstream passage in the Columbia and Snake rivers; 2). methodology for monitoring behavior and upstream migration of adult lamprey to identify passage impediments.

Application of tools and techniques to examine migration of adult lamprey will be tested in a laboratory setting. Findings from this effort will be applied to develop a passage research plan in the Columbia and Snake rivers. Means of tracking individual fish will be tested through use of various tagging devices. Fish behavior and migration will be evaluated from tracking tagged fish under various facility operating conditions. Passage problems due to structural impediments or particular hydraulic conditions will be identified. Bonneville Dam will likely be evaluated first due to all upriver lamprey having to pass this location. The Willamette River may also be included as a control or comparative river system where more healthy lamprey populations have remained. It is hoped that evaluation of adult lamprey migration at "good" passage locations versus locations with passage impairments will result in identification of specific passage problems and recommendations for improvement.

Obiectives: (Juvenile)

1. Conduct literature review regarding juvenile lamprey passage, physiology, migration, and research techniques.

2. Test marking/tagging techniques for monitoring juvenile lamprey migration in a controlled environment.

3. Capture juvenile lamprey at existing smolt collection facilities.

4. Explore the use of PIT (Passive Integrated Transponder) tags to track the survival of juvenile lamprey through dams. Compare juvenile lamprey survival at dams through release of tagged individuals.

5. Explore the use of underwater video monitors to check for fish impingement on traveling screens.

6. Check condition of lampreys at fish passage facilities for sores and lesions. Examine the potential of comparing the general condition of juvenile lampreys in fish collection facilities at successive dams downstream.

7. Test for lamprey swimming capacity and behavior at various water velocities. Characteristics examined will include attraction/repulsion and ability to swim away from danger.

8. Determine downstream migration patterns through time and space in the river.

<u>Approach:</u> (Juvenile) Literature review and test marking/tagging will be similarly conducted for juveniles as described for adult passage evaluation. Juvenile lamprey will be collected at existing smolt facilities at mainstem Columbia and Snake River dams. Passage indices will be calculated from existing fish guidance efficiency tests utilizing lamprey as discussed under abundance studies. The general approach discussion for tagging and tracking of adults will also apply to juveniles. However, due to the small size of juvenile lamprey these techniques will require extensive testing. Video technology will also be employed to monitor fish bypass effectiveness and impingement on traveling screens.

D Habitat Studies

Goal: Determine habitat factors impacting lamprey production in Columbia and Snake River tributaries above Bonneville Dam.

<u>Objectives:</u>

1. Compile and analyze existing stream habitat data (surveys, temperature, flow records, etc.)

2. If adequate stream habitat information does not exist, examine use of on-the-ground aerial videography methodology to conduct Hankin and Reeves (1988) type of physical habitat surveys.

3. Compare findings from lamprey distribution studies with tributary habitat conditions to better understand relationships between physical and biological data.

4. Identify habitat factors which have and/or are likely still impacting lamprey populations.

5. Identify tributaries which currently have adequate habitat for lamprey reestablishment.

6. Identify tributaries which currently do not have adequate habitat conditions to support lamprey populations and identify habitat enhancement needs.

Approach: Lamprey abundance. distribution, and passage studies will help define where lamprey currently are and are not present. The passage and habitat studies will help answer the “why question” regarding depressed or extirpated lamprey populations. Habitat condition in tributaries are generally known from temperature, flow, and stream survey records. This information will be gathered, summarized, and compared with lamprey presence/absence findings. If general habitat conditions are not available or data is not adequate, aerial videography will be proposed to provide detailed information on stream channel morphology and riparian vegetation characteristics. To quickly target efforts on what habitat “works” and what is “broken”, particular attention on habitat conditions or features will be made where moderate or abundant lamprey populations still exist. Also, from old data, photographs and oral histories, we will define where lamprey were once abundant and examine habitat changes that have occurred since that time. Habitat enhancement recommendations will be made based on these findings.

E. Transplantation

Goal: Utilize transplantation to begin reestablishment or supplementation of lamprey in selected tributaries above Bonneville Dam where populations have been extirpated or are at extremely low levels.

Objectives

1. Conduct literature review regarding lamprey capture. handling. transport, release, and transplantation efforts.

2. Utilize presence/absence and habitat suitability data (discussed earlier) to identify a few ideal tributaries for initial lamprey transplantation projects.

3. Identify available and most appropriate donor population(s).

4. Develop transplantation techniques and an implementation plan for selected tributaries.

5. Develop an evaluation plan to monitor the success of lamprey transplantation projects.

6. Implement plans (capture, transplant, and evaluate).

Approach: Any information on transplantation of lamprey will be sought through an extensive literature review process. Recommended procedures on lamprey capture, handling, transport, and release will be compiled. The location of applying transplantation procedures will depend on the results of lamprey distribution, habitat suitability, and genetics studies. The selection of donor lamprey stocks will be made based upon 1) the remaining population status; 2) the geographic location and life history characteristics of the potential donor stock; 3) baseline genetic information from potential donor stocks; and 4) the availability of potential donor stocks. State of the art techniques will be used for describing genetic variation among different groups of lamprey. An implementation plan will be developed which will include target locations, donor locations and stocks, capture/hauling/release methodologies, and recommendations for follow-up monitoring and evaluation.

Transplantation is a likely method for reestablishment of lamprey populations above Bonneville Dam. It is critical that efforts to define implementation actions for pilot projects are dealt with immediately in order to expedite restoration and allow some research to address on-the-ground project results.

F. Artificial Production

Goal: Utilize artificial production as a part of the lamprey rebuilding effort in Columbia and Snake river tributaries above Bonneville Dam.

Objectives:

1. Conduct literature review of artificial propagation of lamprey.
2. Identify propagation techniques applicable to implementing Pacific lamprey supplementation projects in Columbia and Snake River tributaries.
3. Identify necessary criteria and possible locations for propagation facilities.
4. Identify candidate tributaries to supplement natural lamprey production by means of artificial propagation.
5. Identify available and most appropriate stocks for artificial propagation programs.
6. Utilize above information to compile an implementation plan for selected tributaries.

7. Develop an evaluation plan to monitor the success of lamprey supplementation projects.

8. Implement plan (acquire broodstock, artificially propagate, outplant, and evaluate).

Approach: Artificial propagation of lamprey may be necessary for restoration of natural production, for domestic consumption, and may be an inevitable necessity in order to prevent extinction (Pillay 1990). Due to the greatly different life history compared to commonly cultured fishes, considerable research will be required prior to development and implementation of a lamprey hatchery. Initial research will entail compilation of literature related to artificial holding or propagation of lamprey. Specifics identified will minimally include requirements for lamprey holding, rearing, and spawning, etc. Potential propagation facility sites that meet defined criteria will be defined. Identification of candidate tributaries for supplementation will depend on the results of lamprey distribution, habitat suitability, and genetics studies. The selection of broodstocks will be based on the same factors as described in the "transplantation approach". An implementation plan will be developed which will include facility needs/technologies, potential facility locations, broodstock sources, production goals, target supplementation locations, and recommendations for monitoring and evaluation of artificial propagation and supplementation projects.

Iv. Conflicts with Restoration and Recovery of Columbia River Salmonids

It is unlikely that restoration of the Pacific lamprey will impede the recovery of Columbia River salmonids. There should be little fear that the Pacific lamprey will mimic the role of the sea lamprey, after its invasion into the Laurentian Great Lakes (e.g., Eschmeye 1955, Moffett 1956, Coble et al. 1990). That was a case of an entire community of naive prey being exposed to an exotic predator; whereas, the Pacific lamprey has co-evolved with its community. Beamish (1980) could find no evidence that increased lamprey production in the Skeena River would lead to predation problems on its sockeye salmon. Although Pacific lamprey will prey on salmonids, lamprey prefer to feed on midwater species such as Pacific hake (Merluccius productus) and walleye pollock ***(Theragra chalcogramma)*** in the open ocean (Table 3). The role that intense commercial harvest of Pacific hake and walleye pollock has had on the food chain dynamics of the north Pacific and on Pacific lamprey is likely significant.

Table 3. Lamprey Prey (from Beamish 1980)

Scientific name	Common name	Comment
Oncorhynchus nerka	sockeye salmon	0-66% population scarred
O. kisutch	coho salmon	17-45% population scarred
O. gorbuscha	pink salmon	20-44% population scarred
O. tschawytscha	chinook salmon	+
O. mykiss	steelhead	+
Sebastes aleutianus		+
S. reedi		+
Gadus macrocephalus	Pacific cod	+
Ophiodon elongatus	lingcod	+
Hippoglossus stenolepis	Pacific halibut	+
Rienhardtius hippoglossoides	greenland turbot	+
Anoplopoma fimbria	sable fish	+
Atheresthes stomias	arrowtooth flounder	+
A. evermanni	Kamchatka flounder	+
Sebastes alutus	Pacific ocean perch	+

REFERENCES

Anglin. D.R. W.J. Ambrogetti, and CL Burley. 1979. A preliminary study to determine feasible methods of harvesting adult lamprey in the Columbia River. U.S. Fish and Wildlife Service, Vancouver, Washington. 23 pp.

Applegate, V. C. 1950. Natural history of the sea lamprey, ***Petromyzon marinus,*** in Michigan. U. S. Fish Wildl. Serv. Fish. 55:1-237.

Beamish, RJ. 1980. Adult biology of the river lamprey ***(Lampetra ayersi)*** and the Pacific lamprey ***(Lampetra tridentata)*** from the Pacific coast of Canada. Canadian Journal of Fisheries and Aquatic Sciences 37:1906-1923.

Beamish, RJ., and T.G. Northcote. 1989. Extinction of a population of anadromous parasitic lamprey, Lampetra tridentata, upstream of an impassable dam. Can. J. Fish. Aquat. Sci. ***46:420-425.***

Beamish, RJ., and C.D. Levings. 1991. Abundance and freshwater migrations of the anadromous parasitic lamprey, Lampetra tridentata, in a tributary of the Fraser River, British Columbia. Can. J. Fish. Aquat. Sci. 48:1250-1263.

Bell, M.C 1990. Swimming speeds of adult and juvenile fish. ***in*** Fisheries handbook of engineering requirements and biological criteria. Fish Passage Development and Evaluation Program. Corps of Engineers. North Pacific Division. Portland, Oregon.

Bond, C.L. 1979. Biology of fishes. Saunders, Philadelphia. 514 pp.

Bodznick, D. and D.G. Preston. 1983. Physiological characterization of eletroreceptors in the lampreys Ichthyomyzon Unicuspis and Petromyzon marinus. Journal of Comparitive Physioloby 152: 209-217

Clanton, RE. 1913. Feeding fry in ponds. ***in*** Biennial Report of the Department of Fisheries of the State of Oregon. to the Twenty-seventh Legislative Assembly Regular Session. Salem Oregon, pp. 98-100.

Clarke, W.C.. and RJ. Beamish. 1988. Response of recently metamorphosed anadromous parasitic lamprey ***(Lampetra tridentata)*** to confinement in fresh water. Can. J. Fish. Aquat. Sci. 45:42-47.

Coble. D.W., RE. Bruesewitz. T.W. Fratt, and J.W. Scheirer. 1990. Lake trout, sea lampreys, and overfishing in the upper Great Lakes: a review and reanalysis. Transactions of the American Fisheries Society 119: 985-995.

Eschmeyer, P.H. 1955. The near extinction of lake trout in Lake Michigan. Transactions of the American Fisheries Society 85: 102-119.

Farmer, G.J. 1980. Biology and physiology of feeding in adult lampreys. Can. J. Fish. Aquat. Sci. 37:1751-1761.

Farlinger, S.P., and RJ. Beamish. 1984. Recent colonization of a major salmon-producing lake in British Columbia by the Pacific lamprey ***(Lampetra tridentata).*** Can. J. Fish. Aquat. Sci. 41:278-285.

Galbreath, J. 1979. Columbia river colossus, the white sturgeon. Oregon Wildlife, March:3-8.

Hammond, R-J. 1979. Larval biology of the Pacific lamprey, Entosphenus tridentatus (Gairdner). of the Potlatch River, Idaho. Msc. thesis. University of Idaho, Moscow, Idaho. U.S.A., 44 PP.

Hardisty, M.W., and I.C. Potter. 1971. The general biology of adult lampreys. in The biology of lampreys, vol. 1 (edited by M.W. Hardisty and I.C. Potter)pp. 127-206. London-New York Academic Press.

Hawkes, L.A., R.C. Johnson, W.W. Smith, R.D. Martinson, W.A. Hevlin and RF. Absolon. 1991. Monitoring of downstream salmon and steelhead at federal hydroelectric facilities. Project No. 84-14 prepared for BPA. Portland.

Hawkes. L.A.. RD. Martinson, RF. Absolon. 1993. Monitoring of downstream salmon and steelhead at federal hydroelectric facilities. Annual report to BPA from NMFS, Portland, OR 20 p., plus appendices.

Hawkes. LA., RD. Martinson, W.W. Smith. 1992. Monitoring of downstream salmon and steelhead at federal hydroelectric facilities - 1991. Project No 84-14 prepared for BPA, Portland.

Holmes, J.A., and P. Lin. 1994. Thermal niche of larval sea lamprey, Petromyzon marinus. Can. J. Fish. Aquat. Sci. 51:253-262.

Johnson, V.G. and J.J. Wagner, and N.H. Cutshall. 1994. Sediment quality and ecorisk assessment factors for a major river system. U.S. DOE, Office of Environmental Restoration and Waste Management, P.O. Box 1970, Richland WA 99352.

Kan, T.T. 1975. Systematics, variation, distribution, and biology of lampreys of the genus Lampetra in Oregon. Doctoral Dissertation, Oregon State University, Corvallis, Oregon. 194 p.

Kleerekoper H. 1958, The Localization of Prey by the Sea Lamprey, Petromyzon Marinus L The Anatomical Record, 132 (3):464.

Lewis, S.V. 1980. Respiration of lampreys. Can. J. Fish. Aquat. Sci. 37:1711-1722.

Lichatowich, James A. and Mobrand, Lars E., 1995 Analysis of Chinook Salmon in the Columbia River From An Ecosystem Perspective. U.S. Department of Energy, Bonneville Power Administration, Research Report No. DE-AM-79-92BP25105.

Long, C.W. 1968. Die1 movement and vertical distribution of juvenile anadromous fish in turbine intakes. Fishery Bulletin 66:599-609.

Mallatt, J. 1979. Surface morphology and functions of pharyngeal structures in the larval lamprey, ***Petromyzon marinus.*** Jour. Morph. 162:249-274.

Mallatt, J. 1983. Laboratory growth of larval lampreys ***(Lampetra(entosphenuJ) tridentata*** Richardson) at different food concentrations and animal densities. J. Exp. Bio. 22:293-301.

Manion. P.J., and L.H. Hanson. 1980. Spawning behavior and fecundity of lampreys from the upper three Great Lakes. Can. J. Aquat. Sci. 37:1635-1640.

Mattson, C.R 1949. The lamprey fishery at Willamette Falls, Oregon. ***in*** Fish Commission of Oregon Research Briefs. 2(2):23-27.

Merrell. T.R. 1959. Gull food habits on the Columbia River. Research Briefs, Fish Commission of Oregon 7(1):82.

Moffett, J.W. 1956. Recent changes in the deep-water fish populations of Lake Michigan. Transactions of the American Fisheries Society 86: 393408.

Moore, J.W.. and J.M. Mallatt. 1980. Feeding of larval lamprey. Can. J. Fish. Aquat. Sci. 37:1658-1664.

Mullan, J.W., M.B. Dell, S.G. Hays, and J.A. McGee. 1986. Some factors affecting fish production in the Mid-Columbia River 1934-1983. U.S. Fish and Wildlife Service Report No. FRI/FAO-86-15.

Pfeiffer, W. and T.F. Pletcher. 1964. Club cells and granular cells in the skin of lampreys. J. Fish. Res. Bd. Canada. 21:1083-1088.

Pletcher, T.F. 1963. The life history and distribution of lampreys in the Salmon and certain other rivers in British Columbia, Canada. M.Sc. thesis. University of British Columbia, Vancouver, B.C. 195 p.

Poe, T.P., H.C. Hansel, S. Vigg, D.E. Palmer, and L A. Prendergast. 1991. Feeding of predaceous on out-migrating juvenile salmonids in John Day Reservoir. Columbia River. Transactions of the American Fisheries Society 120405-420.

Potter, I.C., B.J. Hill, and S. Gentleman. 1970. Survival and behavior of ammocoetes at low oxygen tensions. J. Exp. Bio. 53:59-73.

Potter, I.C. 1980. Ecology of larval and metamorphosing lampreys. Can. J. Fish. Aquat. Sci. 37:1641-1657.

Read, L.J. 1968. A study of ammonia and urea production and excretion in the fresh-water-adapted form of the Pacific lamprey, Entosphenus tridentatus. Comp. Biochem. Physiol. 26:455-466.

Richards, J.E. 1980. Freshwater life history of the anadromous Pacific lamprey ***Lampetra tridentata.*** M.Sc. thesis, University of Guelph. Guelph, Ontario, Canada. 99 p.

Richards, J.E., and F.W.H. Beamish. 1981. Initiation of feeding and salinity tolerance in the Pacific lamprey ***Lampetra tridentata.*** Marine Biology. 63:73-77.

Roffe, T.J. and B.R. Mate. 1984. Abundances and feeding habits of pinnipeds in the Rogue River, Oregon. Journal of Wildlife Management. 48(4):1262-1274.

Roos, J.F., P. Gilhousen, S.R Killick and E.R Zyblue. 1973. Parasitism and Juvenile Pacific Salmon (Oncorhynchos) and Pacific Herring (clupea harengus pallasi) in the straight of Georgia by the river lamprey (Lampetra ayresi). J. Fish. Res. Board Can 30: 565-568.

Russell, J.E., F.W.H. Beamish. and RJ. Beamish. 1987. Lentic spawning by the Pacific lamprey, Lampetra tridentata. Can. J. Fish. Aquat. Sci. 44:476-478.

Simpson, J.L. and RL. Wallace. 1978. Fishes of Idaho. University Press of Idaho, Moscow, Idaho. 237 p.

Semakula, S.N., and P.A. Larkin. 1968, Age, Growth. Food, and Yield of the white sturgeon (Acipenser transmontanus) of the Fraser River, British Columbia. J. Fish. Res. Bd. Can.. Vol. 25 (12): 2589-2602.

Springer, A.M. 1992. A review: walleye pollock in the North Pacific-how much difference do they really make? Fisheries Oceanography 1:80-96.

Starke. G.M., and J.T. Dalen. 1995. Pacific lamprey ***(Lampetra Ticidentata)*** passage patterns past Bonneville Dam and incidental observations of lamprey at the Portland district Columbia River Dams in 1993. U.S. Army Corps of Engineers. CENPP-OP-PF. Bonneville Lock and Dam, Cascade Locks. Oregon.

Stewart, D.J., D. Weininger, D.V. Rottiers and T.A. Edsall. 1983. An energetics model for lake trout, ***Salvelinus namaycush:*** application to the Lake Michigan population.

Wallace, RL. 1978. Landlocked parasitic Pacific lamprey in Dworshak Reservoir. Idaho. Copeia. ***1978: (3)545-546.***

Whyte, J.N.C.. RJ. Beamish. N.G. Ginther. and C.-E. Neville. 1993. Nutritional condition of the Pacific lamprey ***(Lampetra tridentata)*** deprived of food for periods of up to two years. Canadian Journal of Fisheries and Aquatic Sciences 50:591-599.

Wydoski, RS. and RR Whitney. 1979. Inland fishes of Washington. University of Washington Press, Seattle, 220 pp.

Youson, J.H.. and I.C. Potter. 1979. A description of the stages in the metamorphosis of the anadromous sea lamprey. ***Petromyzon marinus.*** L Can. J. Zool. 57:1808-1817.

Technical Report 2005-1

IDAHO COOPERATIVE FISH AND WILDLIFE RESEARCH UNIT

EVALUATION OF ADULT PACIFIC LAMPREY PASSAGE AND BEHAVIOR IN AN EXPERIMENTAL FISHWAY AT BONNEVILLE DAM

A Report for Study Codes ADS-P-008 and ADS-P-00-10

by

W.R. Daigle, C.A. Peery, and S.R. Lee
U.S. Geological Survey, Idaho Cooperative Fish and Wildlife Research Unit
University of Idaho, Moscow, ID 83844-1141

and

M. L. Moser
Northwest Fisheries Science Center, NOAA Fisheries
2725 Montlake Blvd. East, Seattle, WA 98112

For

U.S. Army Corps of Engineers
Portland District, Portland OR
And

Bonneville Power Administration
Portland, OR

2005

Technical Report 2005-1

EVALUATION OF ADULT PACIFIC LAMPREY PASSAGE AND BEHAVIOR IN AN EXPERIMENTAL FISHWAY AT BONNEVILLE DAM

A Report for Study Codes ADS-P-008 and ADS-P-00-10

by

W.R. Daigle, C.A. Peery, and S.R. Lee
U.S. Geological Survey, Idaho Cooperative Fish and Wildlife Research Unit
University of Idaho, Moscow, ID 83844-1141

and

M. L. Moser
Northwest Fisheries Science Center, NOAA Fisheries
2725 Montlake Blvd. East, Seattle, WA 98112

For

U.S. Army Corps of Engineers
Portland District, Portland OR

Bonneville Power Administration
Portland, OR

2005

Acknowledgements

Many people provided time and assistance through the course of this study. We would especially like to thank Wade Cavender, Darren Ogden, Jon Book, Dusty Cummings, Rich Piaskowski, Paul Ocker, Rudy Ringe, Eric O’Brien, and Megan Heinrich who helped with field operations and data collection and processing. Thanks to Peter Johnson at BAE Systems for the use of infrared light arrays and power supplies. We would also like to thank Jim Simonson and the crew at NOAA Fisheries field station in Pasco, WA for manufacturing the experimental fishway and providing technical assistance.

Table of Contents

Abstract

Tests were conducted in an experimental fishway at Bonneville Dam in 1999, 2000, and 2002 to evaluate behavior and swimming performance of adult Pacific lamprey *Lampetra tridentata*. These tests were initiated after results from radiotelemetry studies indicated that lamprey did not readily pass dams on the Columbia River. The experimental fishway used for all tests had an 8.2 m long x 1.2 m wide experimental section and was designed with three different configurations: 1) a pool-and-weir with three overflow weirs, each with a 0.5 m square submerged orifice and a 0.6 m wide overflow section, 2) a simulated count window with picketed crowder, and 3) a model entrance with a single 30.5 cm vertical slot weir. Individual trials commenced by placing five to ten lamprey in the downstream end of the fishway. Movements past weirs and other fishway structures were observed at viewports built into the sides of the experimental channel and were recorded using video cameras. Two to eight replicates of each test were performed both during the day and at night.

With the fishway in the pool-and-weir configuration, we ran a total of 120 trials using 625 fish and evaluated the following conditions: time of day, presence of velocity refuges in the orifices, presence of a step at the base of one of the orifices, presence of a diffuser grating upstream from one of the weirs, and surgically implanted radio transmitters.

We found that the fish were generally more active at night than during the day, which was consistent with radiotelemetry data. At the baseline (standard operation) condition, lamprey required a mean of 54.9 min to ascend the three weirs, averaging about 3.0 min to pass through an individual orifice during a 1 to 2 hr test period. The addition of velocity refuges within orifices decreased the mean passage time through the orifice by over 1.0 min ($P < 0.01$) and mean passage through the entire fishway by about 10.0 min, but had little effect on the mean passage success rate ($P = 0.80$); 71 and 66% of lamprey successfully passed all three weirs with and without the refuges in place. The overall passage rate decreased from 69 to 49 % ($P < 0.01$) when we added a 20.3 cm high step downstream from the center orifice to simulate the configuration of the Bradford Island fishway at Bonneville Dam. Lamprey took longer to pass through an orifice ($P < 0.01$) when a diffuser grating was installed just upstream from the orifice, however presence of the diffuser did not significantly affect the percentage of lamprey that successfully passed though the fishway ($P = 0.28$) as more fish passed the modified weir via the overflow section. Passage times through the affected orifice improved ($P = 0.02$) with the installation of a solid plate just upstream from that orifice, which allowed lamprey to attach. Eighty and seventy-three percent of fish with and without surgically implanted radio transmitters passed all three weirs, and these values were not significantly different ($P = 0.65$).

Tests with the simulated count window were conducted with and without count window lights on and a picket lead weir in place. We found that approximately the same proportion of fish passed regardless of whether or not count window lights were on ($P = 0.86$) or the picket lead weir was in place ($P = 0.58$), indicating that the count window lights were not a significant passage obstacle.

Tests with the entrance weir in place were used to evaluate bulkhead shape, head level, time of day, and presence or absence of a lower flow alternative entrance or a

ramp bypass. We again found that lamprey were more active at night than during the day in all trials ($P < 0.01$). Modifying the head level via the weir was the most effective method for increasing passage success. Nighttime passage rates increased from 4% with 45.7 cm of head to 78% with 15.2 cm of head ($P = 0.04$). Bulkhead shape had less effect on passage. Nighttime passage rates were 34% with square bulkheads in place and 41% with round bulkheads ($P = 0.19$). The addition of a second channel with lower flow also had a significant effect on passage. With 45.7 cm of head in the main channel, the passage rate increased from 3% to 44% when a channel with 15.2 cm was available ($P < 0.01$). None of the 400 lamprey used in tests of a bypass ramp opted to use the ramp. Fish would often collect at the base of the ramp, but they made no attempts to ascend during the 1 h tests we conducted. In subsequent ramp experiments performed in 2004, lamprey took longer than 1 hr to approach and start ascending ramps.

Introduction

Pacific lamprey, *Lampetra tridentata*, are a native anadromous species that were historically abundant throughout the Columbia and Snake rivers (Close et al.,1995; Jackson et al.,1997). Lamprey have ecological significance as well as cultural importance to Native Americans who traditionally harvested the fish for sustenance, medicinal, and ceremonial purposes. Current returns of lamprey to the Columbia River are significantly lower than past levels (Kostow,2002). Several factors, including habitat degradation, water pollution, stream impoundment, declining abundance of prey, and direct eradication efforts have contributed to the decline of lamprey in the past half century. To spawn in the upper reaches of the Columbia and Snake River basins, lamprey must successfully negotiate up to 9 hydroelectric dams during their spawning migration. Fishways at these dams were designed for passing adult salmonids with no consideration for physically, physiologically, and behaviorally dissimilar species such as lamprey (Beamish,1980; HardistyPotter,1971; Osborne,1961).

Recent radiotelemetry studies suggest that lamprey have difficulty negotiating fishways designed for salmonid passage (Moser et al.,2002a; Moser et al.,2002b). In studies at Bonneville Dam, the most downstream dam on the Columbia River, less than half of the radio-tagged lamprey that approached the dam successfully passed upstream. Lamprey had difficulty entering fishways and, once inside, were delayed or obstructed in collection channels and transition areas that are influenced by tailwater. The lamprey also showed poor passage success in areas near the top of the ladders. These areas have brightly-lit count window stations, picketed weirs, and serpentine weirs which contribute to a complex environment of artificial lighting, physical barriers, and turbulent, confusing currents.

To date, few researchers have quantified the swimming performance of Pacific lamprey. Bell (1990) found that lamprey could sustain speeds of 0.9 m/s, with burst speeds up to 2.1 m/s when swimming in a flume with steady flow, however it is unclear whether or not lamprey were allowed to attach to the substrate and rest during these trials. Mesa et al. (2003), found that lamprey consistently swam at speeds of less than 1.0 m/s when swimming in a Blazka-type respirometer lined with plastic mesh to prevent them from attaching to the respirometer walls. Beck (1995) found that although lamprey can successful pass through submerged orifices at fishway weirs, they take up to 4.5 minutes (mean) to pass a single orifice and are often observed swimming downstream through the fish ladder. Studies on sea lamprey (HaroKynard,1997) have revealed more fish swimming downstream than upstream at some weirs.

There is still uncertainty about what conditions attract and motivate adult lamprey to move upstream and the mechanisms that are most critical to successful passage in fishways. In the series of tests described here, we evaluated lamprey swimming performance and behavior via the systematic manipulation of an experimental fishway to identify problems and potential solutions associated with passage for adult lamprey both within existing fishways and at fishway entrances.

Methods

Lamprey used in this study were collected in a trap at Bonneville Dam on the lower Columbia River. We captured fish as they ascended the fishway at night during May – August, 1999, 2000, and 2002. Prior to testing, the fish were held at least 12 hours in covered aluminum holding tanks (92 x 152 x 122 cm) that were supplied with flowing Columbia River water. In 1999, we used 313 lamprey with total lengths ranging from 53.5 – 77.0 cm (median = 66.5 cm; Figure 1). In 2000, 412 lamprey with total lengths ranging from 50.0 – 78.5 cm (median = 65.5 cm) were used in these experiments. In 2002, we used 950 fish with lengths of 43.5 – 80.0 cm (median = 67.0 cm).

The experimental fishway where tests were conducted consisted of an 11.6 m long x 1.2 m wide flow-through aluminum tank (Figure 2, Figure 3) with Columbia River water supplied by two 35.6 cm diameter pipes capable of generating flows of 835.3 liters per second. The fishway was comprised of five main sections (listed from the upstream end): 1) a 1.2 m long flow inflow section in which water upwelled through the floor, 2) a 0.6 m long by 2.4 m deep exit section bounded by a perforated plate back and perforated plate formed into fykes to allow lamprey to enter but inhibited exits at the downstream end, 3) an 8.2 m long by 2.4 m deep experimental section on a 1:10 slope, 4) a 0.8 m long by 2.4 m deep acclimation section bounded by a removable perforated plate on the upstream end and a permanent perforated plate on the downstream end, 5) and an outflow section which had an open bottom and contained an adjustable height wall (15.2 cm increments) on the upstream end to control the pool height in the fishway. Viewports set into the sides of the experimental fishway allowed observations of fish behavior during the trials.

Before the start of each trial, 5 to 10 lamprey (typically 10) were placed in the acclimation section of the tank for at least 10 minutes with water flowing at test conditions. Trials were initiated by removing the upstream perforated plate to allow fish access to the experimental section. Tests were run for 2 h in 1999 and for 1 hr in 1999, 2000, and 2002. Tests were shortened from 2 h to 1 h in 1999 after we determined that over 90% of the fish successfully ascended the experimental fishway in the first hour of the trial. During the trials, fish behavior was observed using viewports placed in the sides of the experimental fishway and recorded on video tape to determine modes and times of passage. Infrared lamps were mounted in the fishway at key locations so that observations could be made at night using nightvision goggles and on video cameras that could record under infrared lighting. At the end of each trial period, the fishway was drained and final locations were recorded for each fish. We performed 2 to 8 replicates (typically 4) of each test during both day and night trials. Data collected during these trials included the proportion of fish that successfully ascended the experimental fishway, time to ascend (defined as the time from lifting of the intake screen to fishway exit for each fish), and time to pass the middle weir (defined as the time from fish entry into the camera view until exiting upstream).

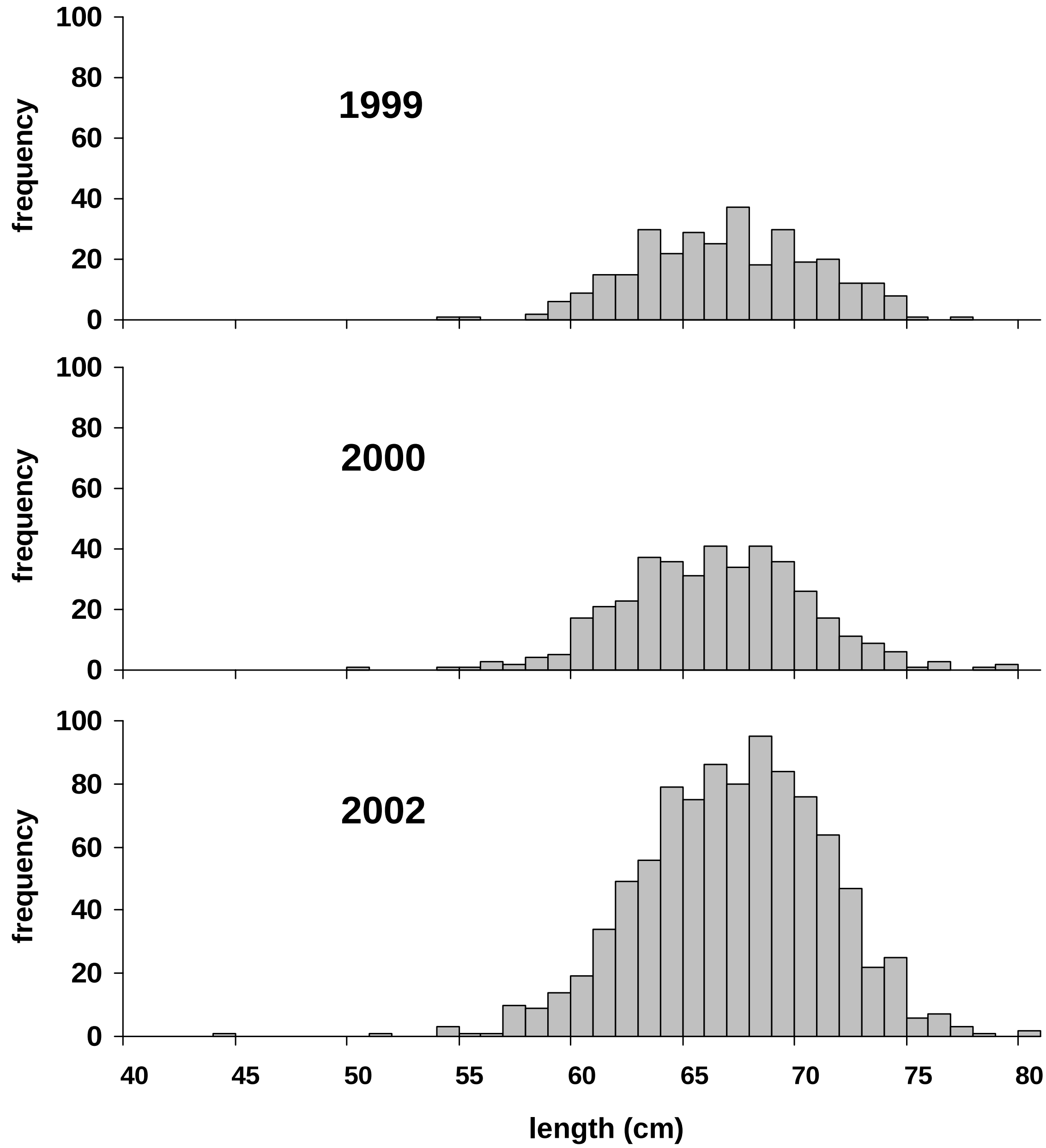


Figure 1. Length frequency distributions for 313, 412, and 950 lamprey used in experiments in 1999, 2000, and 2002.

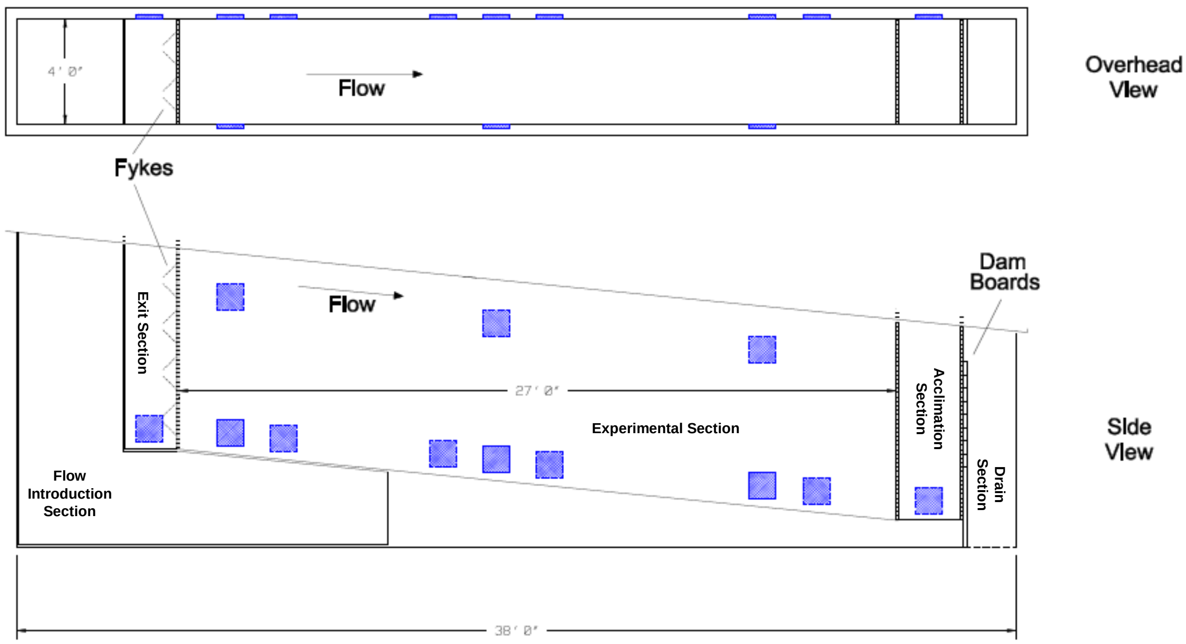


Figure 2. Basic configuration of the experimental fishway set up in the Bonneville Dam Adult Fish Facility (AFF). Squares represent view port locations.

Figure 3. Picture of experimental fishway operating with overflow/orifice weirs in place.

During 1999, we installed three 2.3 m high x 1.2 m wide weirs within the experimental section to simulate conditions in a pool-and-weir type fishway (Figure 3, Figure 4). The weirs were spaced at 3.0 m increments to maintain a head level of 0.3 m at each weir. Each weir had one 0.6 m wide x 0.6 m high overflow section and one 0.5 m wide x 0.5 m high submerged orifice that was positioned flush with the floor of the fishway. All observations were made at the second and third upstream weirs. At the end of a trial, all fish that were upstream of the third weir were considered to have successfully passed through the fishway. Water velocity (m/s) was measured at a variety of depths both upstream and downstream of the weirs using a Marsh McBirney flowmeter[1]. Water velocities ranged from 0.5 to 2.7 m/s at the submerged orifice (Table 1) and from 0.3 to 1.5 m/s at the overflow (Table 2).

Three main sets of tests were carried out in 1999 (Table 3). For the first two sets of tests we varied the depth of water flowing over the top of the weir (0.3 or 0.4 m overflow depth) and presence or absence of velocity refuges within orifices. Each of the four treatments were replicated and each replicate group of fish was tested during both day and night. For each replicate we alternated starting the test during the day and at night, to avoid any potential effects of habituation or learning.

The velocity refuges were created by securing rows of artificial rocks (10.2 cm wide x 10.2 cm high) to the bottom of the fishway upstream from, within, and downstream from the orifice to create zones of low velocities near the floor through which lamprey could swim. Rows of artificial rocks were situated every 35 cm and staggered so there was 70 cm between one rock and the rock directly upstream. Velocity refuge trials ran for one and two hour durations. The initial test trials ran for 2 h each and were conducted under normal fishway conditions with flow over weirs. The second set of trials ran for 1 h each with the water depth lowered in the fishway so that flow was through the submerged orifices only to isolate the impact of the velocity refuges on passage efficiency through orifices. The latter group of tests was run during the day and at night, with and without refuges.

A third set of trials investigated the effect of surgically implanting 7.7 g (<2% of the lamprey body weight) radio transmitters (Lotek MCFT-3BM) into lamprey. Twenty control fish were handled but not implanted and 20 lamprey were implanted with transmitters prior to use in test trials. The fish were anaesthetized and the transmitters were implanted following the methods of Moser et al. (2002a). The fish were allowed to recover from the surgical procedure for at least 12 h. All of these tests took place during the day and with 0.3 m of water flowing over the weir crest. We tested the following independent variables: presence or absence of radio transmitters and presence or absence of velocity refuges. Following experimentation, we removed the radio tags and released the fish upstream from Bonneville Dam.

Initial tests conducted in 2000 used the same pool-and-weir setup as in 1999 to validate previous findings (Table 3). All tests in 2000 were run with 0.3 m of water depth over the tops of weirs and all trials lasted for one hour. For the first set of tests in

---

[1] Does not constitute endorsement by UICFWRU or NOAA Science Center.

2000, we observed passage behavior under three lighting conditions: 1) during the day with ambient light, 2) at night with the room lights (fluorescent) on, and 3) at night with infrared (IR) lights on. IR lights were placed at orifices and overflow sections of the fishway and they permitted observation of fish behavior using night-vision goggles and video cameras capable of recording IR images.

For the second set of tests, we added a 20.3 cm high step, similar to that found in the Bradford Island ladder at Bonneville Dam, just downstream from the middle weir's orifice. Fish behavior with the step was tested during the day and night with IR lighting (i.e., for each replicate the same group of fish were tested during the day and then at night as in 1999). Results from these trials were compared to results from the first set of trials without the step.

For the third set of tests, we removed the step and assessed passage behavior with a 1.2 m wide x 1.5 m long diffuser panel mounted in one of two positions upstream from the middle weir (Figure 4). In a working fishway, diffuser gratings are metal grids that make up the floor of the fishway between some weirs. Water upwells through these grates to supplement flow in the fishway. From radiotelemetry, we learned that areas with diffuser grating can impede lamprey passage, possibly because lamprey are unable to attach to grating material. In the experimental fishway, the diffuser grating was installed in two positions: adjacent to and just upstream from the middle weir, and midway between the second and third upstream weirs. With the gratings positioned adjacent to the middle weir, we also tested the efficiency of three different modifications: 1) no water flowing through the grate, 2) with a 15.2 cm x 30.5 cm mounted over the diffuser grating in the high flow section just upstream from the orifice. The plates provided an attachment area for lamprey moving through the orifice. All tests were replicated and each replicate group of fish was tested during day and night.

The second series of trials for 2000 involved removing the three weirs and installing a simulated count window in the experimental channel (Figure 5). In an operational fishway, fish are crowded into a narrowed, well-lit section of the fishway so that they can be counted at the viewing window. Water is added to the fishway near the count windows through a picketed lead from the auxiliary water channel (AWC). Spacing of the pickets allows lamprey access to the AWC, and once inside, lamprey may have difficulty exiting. Radiotelemetry indicated that lamprey have poor passage efficiency in sections of the Bonneville Dam fishways containing count windows. We hypothesized that lamprey avoided bright lighting at count stations and/or that fish got trapped in the AWC.

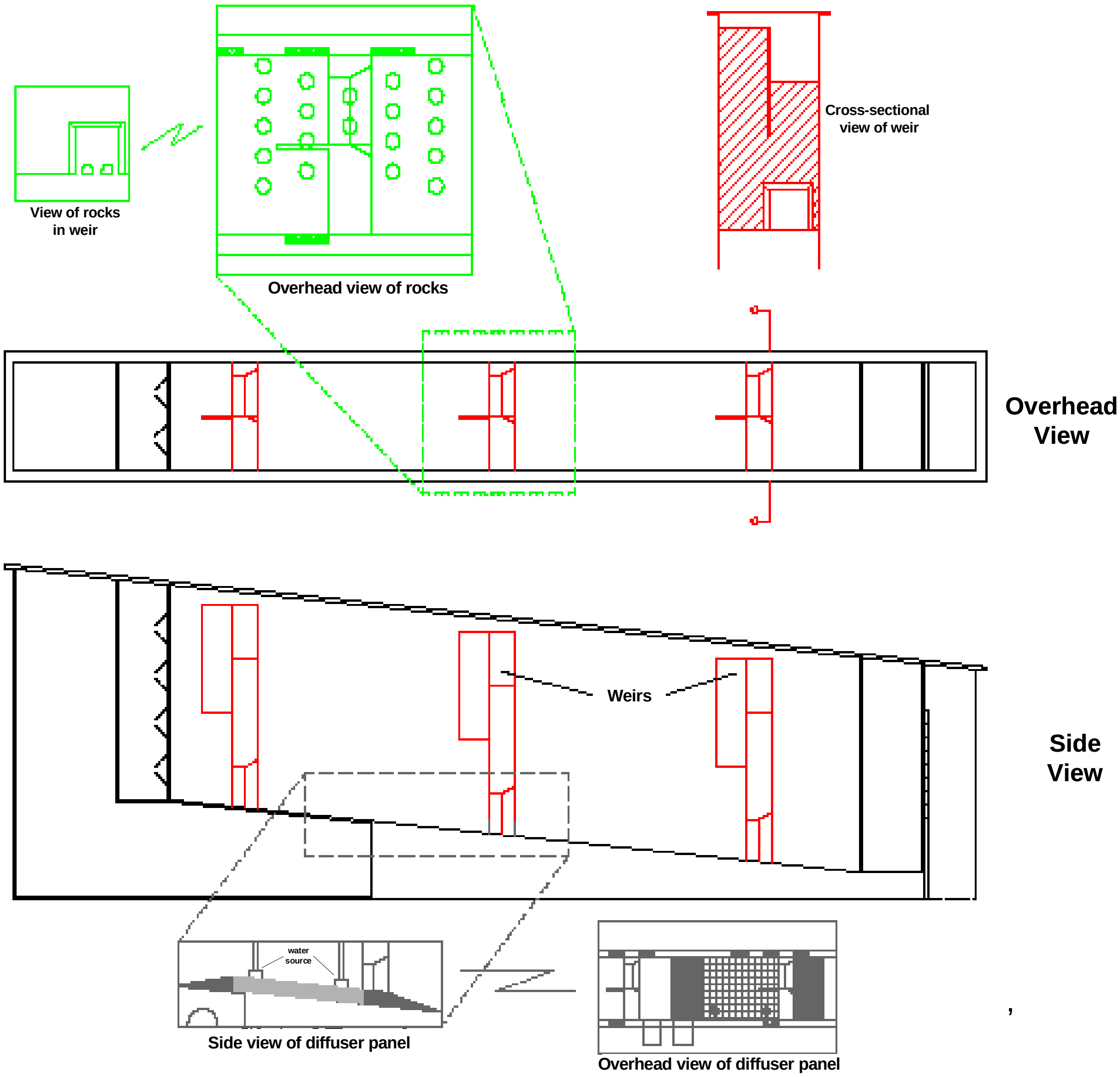


Figure 4. Diagram showing placement and structure of overflow weirs, orifices, a diffuser panel, and velocity refuges.

Table 1. Water velocities measured in the vicinity of the submerged orifice in the experimental pool-and-weir fishway with and without velocity refuges.

Treatment	Flow x cm off the bottom (m/s)				
Location	x = 5	x = 10	x = 23	x = 30	x = 46
Without refuges, 0 cm depth at overflow					
3 cm downstream of weir #1	-	2.35	-	2.19	-
3 cm upstream of weir #1	-	1.52	-	1.31	-
36 cm downstream of weir #2	-	1.83	-	-	-
3 cm downstream of weir #2	-	2.13	-	-	-
3 cm upstream of weir #2	-	1.83	-	1.37	-
With refuges, 0 cm of depth at overflow					
3 cm downstream of weir #1	-	1.07	-	1.92	-
3 cm upstream of weir #1	-	0.85	-	1.46	-
With refuges, 30 cm of depth at overflow					
30 cm downstream of weir #2	0.76	-	1.49	-	0.91
3 cm downstream of weir #2	0.73	-	2.68	-	0.0
3 cm upstream of weir #2	0.46	-	1.92	-	0.91
30 cm upstream of weir #2	0.85	-	2.68	-	0.24

Table 2. Water velocities measured within the vicinity of the overflow section of the experimental pool-and-weir fishway.

Treatment	Flow x cm off the bottom (m/s)				
Location	x = 5	x = 10	x = 15	x = 20	x =30
30 cm of depth at overflow					
46 cm downstream of weir #2	-	-	1.34	-	-
15 cm downstream of weir #2	0.46	1.49	1.07	-	-
center of weir #2	0.58	0.98	1.31	1.43	1.43
15cm upstream of weir #2	0.34	-	0.61	-	0.61

Table 3. Combinations of variables tested in the pool-and-weir experimental fishway at the Bonneville Dam AFF in 1999 and 2000 including diel timing, lighting conditions, trial duration, number of trial replicates, overflow depth, presence or absence of surgically implanted radio transmitters, velocity refuges, a step at one orifice, and a diffuser grating. Treatments with the same analysis group letter were compared statistically.

Time		Duration	# of	Depth			Step	Diffuser			
(D/N)	Lighting	(h)	reps	(m)	Radio	Refuges	(cm)	Position	flowing	plate	Analysis group
						1999					
D	ambient	2	4	0.3	-	no	-	-	-	-	a
N	IR	2	4	0.3	-	no	-	-	-	-	a
D	ambient	2	4	0.3	-	yes	-	-	-	-	a
N	IR	2	4	0.3	-	yes	-	-	-	-	a
D	ambient	2	4	0.4	-	no	-	-	-	-	a
N	IR	2	4	0.4	-	no	-	-	-	-	a
D	ambient	2	4	0.4	-	yes	-	-	-	-	a
N	IR	2	4	0.4	-	yes	-	-	-	-	a
D	ambient	1	4	0	-	no	-	-	-	-	b
N	IR	1	4	0	-	no	-	-	-	-	b
D	ambient	1	4	0	-	yes	-	-	-	-	b
N	IR	1	4	0	-	yes	-	-	-	-	b
D	ambient	1	2	0.3	no	yes	-	-	-	-	c
D	ambient	1	2	0.3	no	no	-	-	-	-	c
D	ambient	1	2	0.3	yes	yes	-	-	-	-	c
D	ambient	1	2	0.3	yes	no	-	-	-	-	c
						2000					
N	IR	1	4	1	-	-	-	-	-	-	d e f
D	ambient	1	8	1	-	-	-	-	-	-	d e f
N	room	1	4	1	-	-	-	-	-	-	d

Table 3. Continued

Time (D/N)	Lighting	Duration (h)	# of reps	Depth (m)	Radio	Refuges	Step (cm)	Diffuser Position	Diffuser flowing	Diffuser plate	Analysis group	
N	IR	1	4	1	-	-	20.3	-	-	-	e	
D	ambient	1	4	1	-	-	20.3	-	-	-	e	
N	IR	1	4	1	-	-	-	weir	yes	none	f	g
D	ambient	1	4	1	-	-	-	weir	yes	none	f	g
N	IR	1	4	1	-	-	-	center	yes	none	f	
D	ambient	1	4	1	-	-	-	center	yes	none	f	
N	IR	1	4	1	-	-	-	weir	no	none		g
D	ambient	1	4	1	-	-	-	weir	no	none		g
N	IR	1	4	1	-	-	-	weir	yes	large		g
D	ambient	1	4	1	-	-	-	weir	yes	large		g
N	IR	1	4	1	-	-	-	weir	yes	small		g
D	ambient	1	4	1	-	-	-	weir	yes	small		g

To simulate a count window area, we divided the upstream half of the experimental section down the middle using a 2.4 m high solid wooden wall. A picketed lead was placed just downstream from and to one side of the divider to direct fish toward the narrowed, count window section (Figure 5). The count window area was lit using a bank of incandescent flood lights to simulate lighting conditions at a working count station. We ran tests with and without the picketed lead in place and with the count window lights on and off to determine the degree to which lamprey enter the AWC and whether or not they avoid the lighted count window (Table 4). Once again, tests were run both during the day and at night.

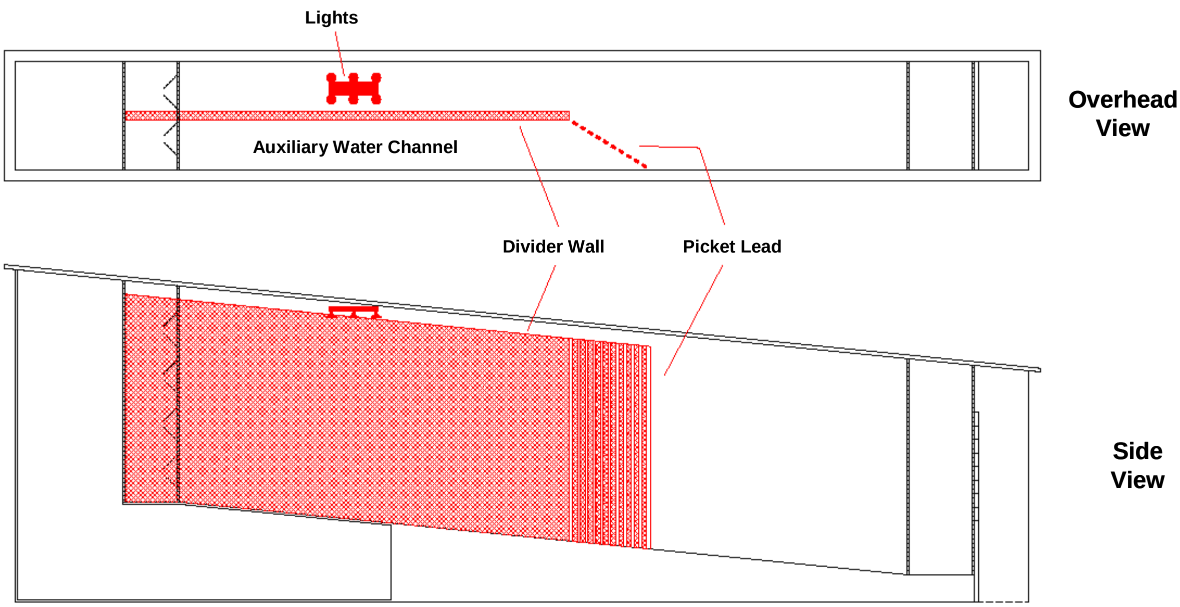


Figure 5. Diagram showing placement of count window lights, a divider, and picket lead weir.

Table 4. Count window tests performed in the experimental fishway at the Bonneville Dam AFF in 2000 including diel timing, trial duration, number of trial replicates, status of count window lights, and presence or absence of a picket lead weir.

Time	Duration (h)	# of Replicates	CW lights (on/off)	Picket Weir (in/out)
Night	1	4	On	In
Day	1	4	On	In
Night	1	3	Off	In
Day	1	3	Off	In
Night	1	4	On	Out
Day	1	4	On	Out

In 2002, we removed the count window structures, and installed a single vertical slot weir in the center of the fishway to simulate conditions at a fishway entrance (Figure 6). The entrance weir was 2.0 m high with a single 0.3 m wide vertical slot. Entrance tests compared efficiency of squared and rounded bulkheads while maintaining a 30.5 cm gap (Table 5). The rounded bulkhead circumscribed a circle with a diameter of 20.5 cm. These two designs were tested with 15.2, 30.5, and 45.7 cm of head differential at the weir. As in previous years, each replicate group of fish was tested during both day and night during these trials. Velocities at the entrance weir ranged from 0.7 – 3.3 m/s (Table 6).

We also tested the efficiency of two potential lamprey bypass options. The first involved the installation of a 0.6 m wide ramp (Figure 7) that led up and over the entrance weir and into an exit chute. Water upwelled from a headbox at the upstream end of the chute and flowed down the chute and ramp. A fyke net placed midway up the chute prevented fish from reentering the lower fishway after ascending the ramp and chute. Four different ramp designs were tested: 1) a steep uncovered ramp (13:2 slope), 2) a steep ramp with a cover situated 5.0 cm over the surface of the ramp, 3) a shallow uncovered ramp (1:1 slope), and 4) a shallow ramp with a cover. Lamprey could access the uncovered ramp at any point throughout the water column. The covered ramp, however, was only accessible via a 0.6 m wide by 5 cm high opening at the base of the ramp flush with the floor of the fishway. All tests were run with 0.5 m of head at the entrance weir and low, medium or high flows (0.3, 0.6, and 1.2 m/s within the exit chute) on the ramp.

These bypass tests involved the installation of a 2.4 m high divider which separated the vertical slot entry, the experimental section upstream from the entrance weir, and the exit section of the fishway (Figure 8). The volume of water available to one side of the fishway was reduced by placing dam boards just upstream from the exit section. Tests were run with 30.5 and 45.7 cm of head on the high flow side of the divider and 7.6 and 15.2 cm of head on the low flow side. We were unable to run tests with the highest flows (45.7 cm of head) on the high flow side and the lowest flows (7.6 cm of head) on the low flow side due to difficulties in maintaining the large flow differential. Once again, we ran tests both during the day and at night for each replicate group of fish.

Video tapes of each trial were used to determine passage times and modes of passage through key sections of the fishway. The entire cross-section of the fishway could not be monitored at any one time and individual fish could not be distinguished, therefore passage times were recorded for all upstream movements regardless of whether or not a single fish fell back and re-ascended. The times reported are the mean passage times for all fish that passed in front of the camera for a given replicate.

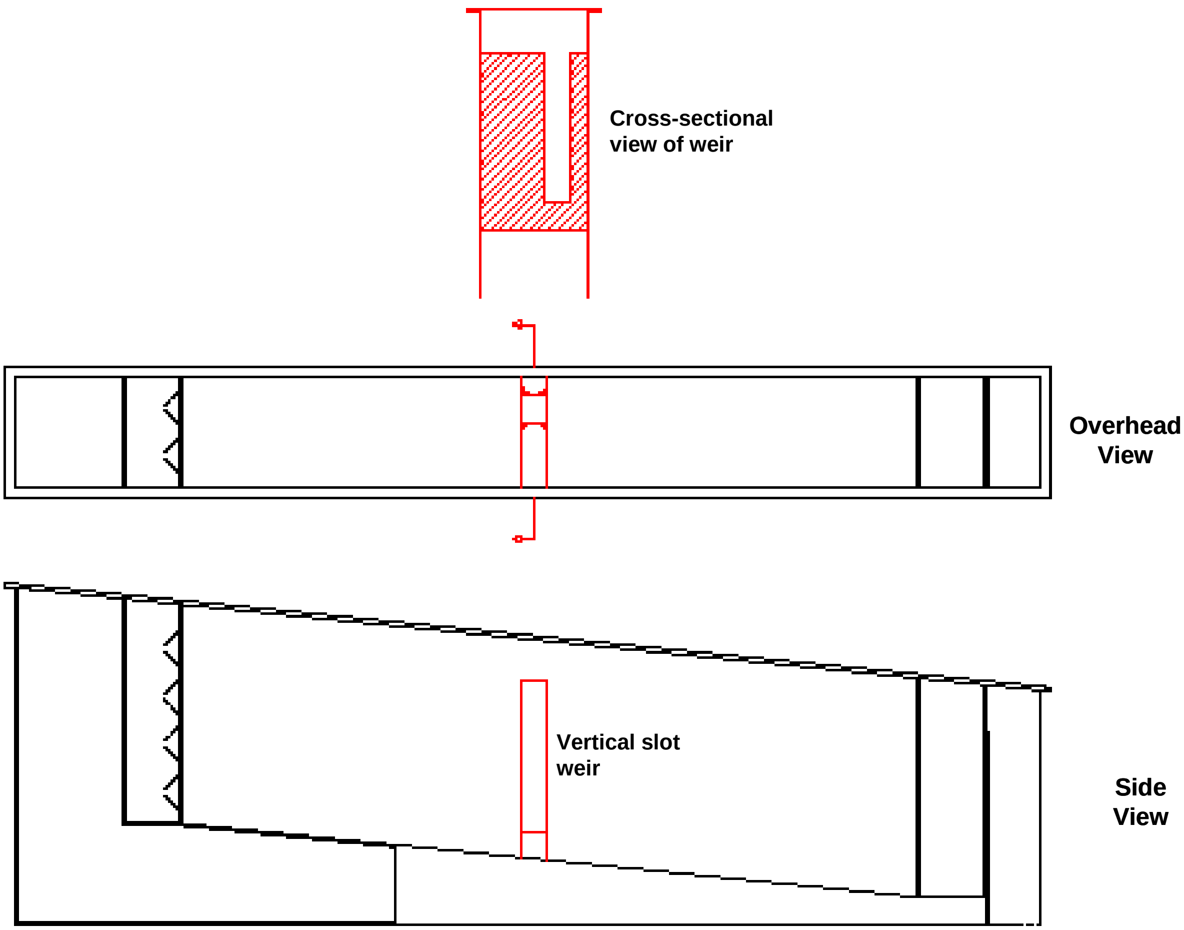


Figure 6. Diagram showing placement of a vertical slot weir with squared or rounded bulkheads.

Table 5. Combination of variables tested in the experimental fishway at the Bonneville Dam AFF in 2002 when an entrance weir was in place including diel timing, number of trial replicates, entrance bulkhead shape, whether or not the entrance was divided, head differential at the entrance, and ramp treatments. For slotted entrance tests, head levels are stated for both sides of the divider. All trials lasted for one hour.

Time	# of	Bulkhead	Divided	Head	Ramp		
(day/night)	reps	shape	Entrance?	(cm)	Type	covered?	flow
Bulkhead Shape Tests							
Day	4	squared	-	45.7	-		-
Night	4	squared	-	45.7	-	-	-
Day	4	squared	-	30.5	-	-	-
Night	4	squared	-	30.5	-	-	-
Day	4	squared	-	15.2	-	-	-
Night	4	squared	-	15.2	-	-	-
Day	4	rounded	-	45.7	-	-	-
Night	4	rounded	-	45.7	-	-	-
Day	4	rounded	-	30.5	-	-	-
Night	4	rounded	-	30.5	-	-	-
Day	4	rounded	-	15.2	-	-	-
Night	4	rounded	-	15.2	-	-	-
Slotted Entrance Test							
Day	4	rounded	Yes	45.7/15.2	-	-	-
Night	4	rounded	Yes	45.7/15.2	-	-	-
Day	4	rounded	Yes	30.5/15.2	-	-	-
Night	4	rounded	Yes	30.5/15.2	-	-	-
Day	4	rounded	Yes	30.5/7.6	-	-	-
Night	4	rounded	Yes	30.5/7.6	-	-	-
Ramp Bypass Tests							
Day	4	rounded	-	45.7	steep	no	low
Night	4	rounded	-	45.7	steep	no	low
Day	4	rounded	-	45.7	steep	no	med
Night	4	rounded	-	45.7	steep	no	med
Day	4	rounded	-	45.7	steep	yes	med
Night	4	rounded	-	45.7	steep	yes	med
Day	4	rounded	-	45.7	shallow	no	med
Night	4	rounded	-	45.7	shallow	no	med
Day	4	rounded	-	45.7	shallow	yes	high
Night	4	rounded	-	45.7	shallow	yes	high

Table 6. Water velocities measured at the simulated fishway entrance.

Treatment / Location	Flow x cm off the bottom (m/s)		Flow at the surface (m/s)
	x=10	x = 40	
Squared Bulkheads, 15.2 cm of head			
2cm upstream of weir	1.22	0.91	0.73
2cm downstream of weir	1.16	1.58	1.55
2.4m downstream of weir	0	0.37	1.19
Squared Bulkheads, 30.5 cm of head			
2cm upstream of weir	1.62	1.55	0.85
2cm downstream of weir	1.92	2.35	2.29
2.4m downstream of weir	0	0.34	1.52
Squared Bulkheads, 45.7 cm of head			
2cm upstream of weir	2.07	1.37	0.76
2cm downstream of weir	2.47	2.99	2.87
2.4m downstream of weir	0	0.79	2.38
Rounded Bulkheads, 15.2 cm of head			
2cm upstream of weir	1.19	0.73	0.91
2cm downstream of weir	2.29	2.07	1.83
2.4m downstream of weir	0	0.33	0.73
Rounded Bulkheads, 30.5 cm of head			
2cm upstream of weir	1.37	1.1	1.04
2cm downstream of weir	2.77	2.1	1.89
2.4m downstream of weir	0	0.58	1.07
Rounded Bulkheads, 45.7 cm of head			
2cm upstream of weir	1.86	1.25	0.55
2cm downstream of weir	3.32	2.8	-
2.4m downstream of weir	0	0.49	0.64

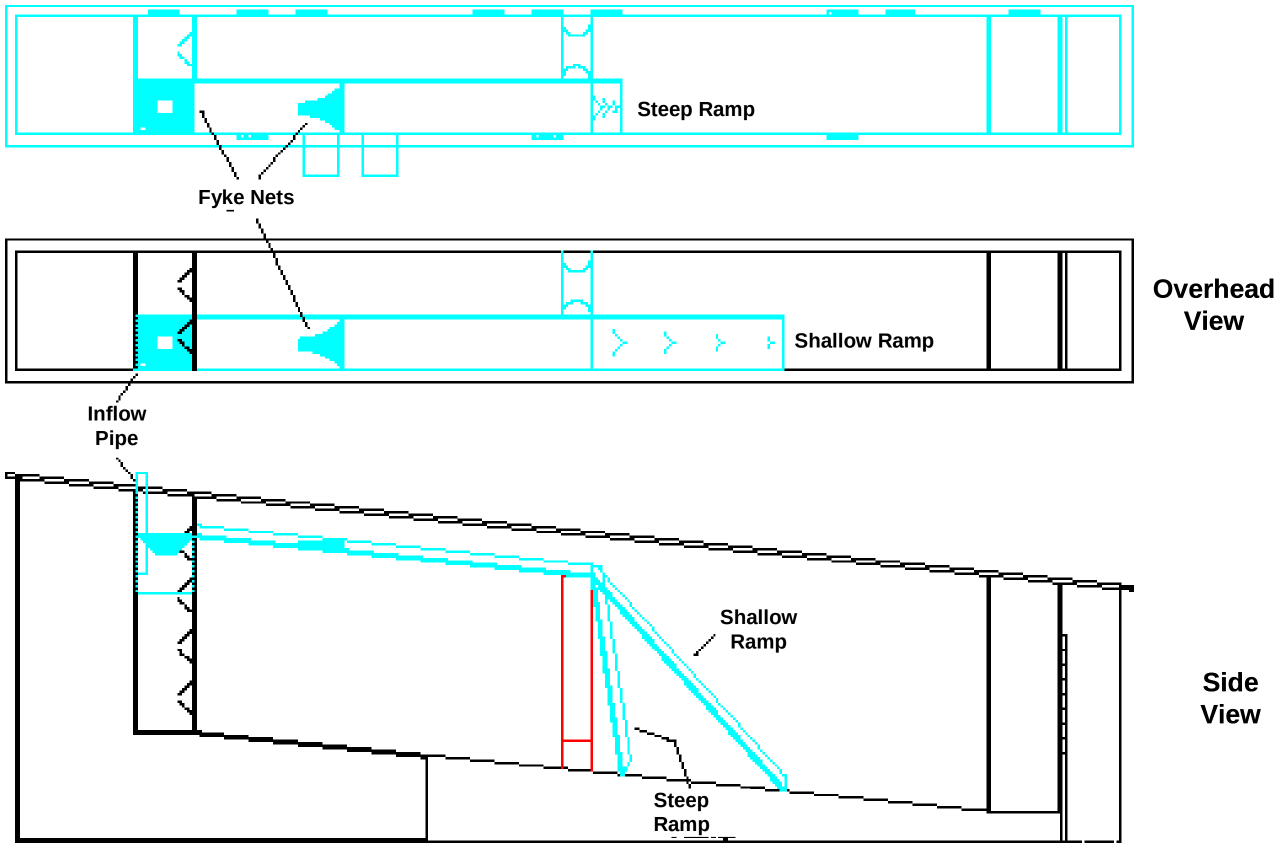


Figure 7. Diagram showing placement and structure of a steep and a shallow bypass ramp.

Data Analysis

We used multiway factorial analysis of variance (ANOVA, Proc GLM, SAS Institute Inc., 2001) to determine the effect of different factors on passage efficiency. Statistically significant factors were then analyzed using a Tukey-type multiple comparison test to reveal specific differences among treatments (Zar,1999). Treatment groups were compared using Kruskal-Wallis nonparametric analysis of variance when the data failed to fit model assumptions. When time of day had a significant interactive effect with other factors being analyzed, the analyses were rerun separately for day and night tests. A separate ANOVA was used to determine differences between groups of naïve fish and those that had been used in previous trials. Use was included in the overall model when it had a significant effect on passage success. Multifactorial analysis of variance (MANOVA) was used to analyze the count window experiments because we were interested in determining whether treatments had a significant effect on the channel selected by individual lamprey. Since fish were used in more than one trial.

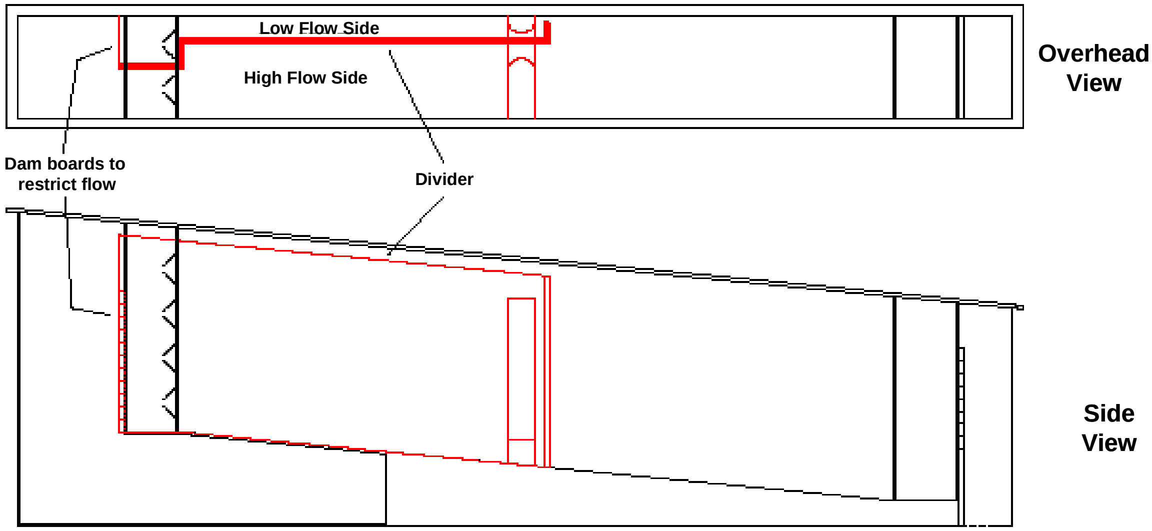


Figure 8. Diagram showing placement of a vertical slot entrance, a divider, and dam boards used to differentially control flow through two portions of the entrance weir.

Results

Pool-and-Weir Fishway Tests

In pool-and-weir tests, we completed 120 trials using 625 total fish. For individual trials, the percentage of fish that successfully passed all three weirs ranged from 0.0 to 100.0% with a mean of 68.9% and a median of 78.9%. Fish passing via the submerged orifice took between 1 s and 43.3 min; those passing over the top of the weir took from 1 s to 8.4 min. Times to pass through the entire fishway ranged from 5.2 to 87.0 min. Sixty-nine percent and 63 % of the naïve fish and those that were used in previous trial successfully passed all three weirs and there was no significant difference between these values ($F_{(1,52)}$ = 1.25, p = 0.2690)

The first set of trials ran for two hours each. Passage efficiencies for seven of the eight treatment groups were at least 90.0%. For the eighth treatment group, during the day with 0.3 m of depth at the overflow and no velocity refuges in place, passage efficiencies ranged from 60.0 to 90.0% (Figure 9). There were no significant differences in passage success among the eight different treatment groups as indicated by the Kruskal-Wallis test, a nonparametric analysis of variance (χ^2 = 10.63, p = 0.1554). Median passage efficiencies were 95.0% during the day and 100% at night. When refuges were absent, 95.0% of lamprey successfully passed all three weirs, whereas 100% of lamprey passed when refuges were in place. Median passage efficiencies were 100% when the depth of water running over the weir crests was 0.3 and 0.4 m. Overall, lamprey took a mean of 46.3 min to pass through the fishway without refuges and 35.7 min to pass through the fishway when refuges were in place (t = 3.37, p = 0.0004; Table 7). During daytime trials with 0.4 m of depth, lamprey took 3.0 min (mean) to pass without refuges in place and 3.7 min to pass when refuges were present (t = -0.97, p = 0.1697; Table 8). Because IR lighting was not used in 1999, very few lamprey were observed passing the weir at night. Of the lamprey that were observed passing during daytime trials, 28.6% passed over the top of the weir when no refuges were present and 13.8% passed over the top of the weir when refuges were in place (χ^2 = 1.84, p = 0.1753).

When we shortened the trial length to one hour and lowered the depth of water within the fishway so that no water flowed over the weirs, overall mean passage efficiencies were 68.4% and there were no significant differences among treatment groups (Figure 10; $F_{(3,12)}$ = 0.33, p = 0.8035). When refuges were absent, 65.5% of lamprey successfully passed all three weirs and 71.3% of lamprey passed when refuges were present. Highly turbid conditions prevented observations during night trials. During day trials, fish passed the submerged orifice in 2.4 min in the absence of refuges and 1.0 min when refuges were present (t = 3.16, p = 0.0014; Table 8). Fish took 39.0 min to pass through the entire fishway when no refuges were present and 34.2 min with refuges at the center weir (t = 1.14, p = 0.1300; Table 7).

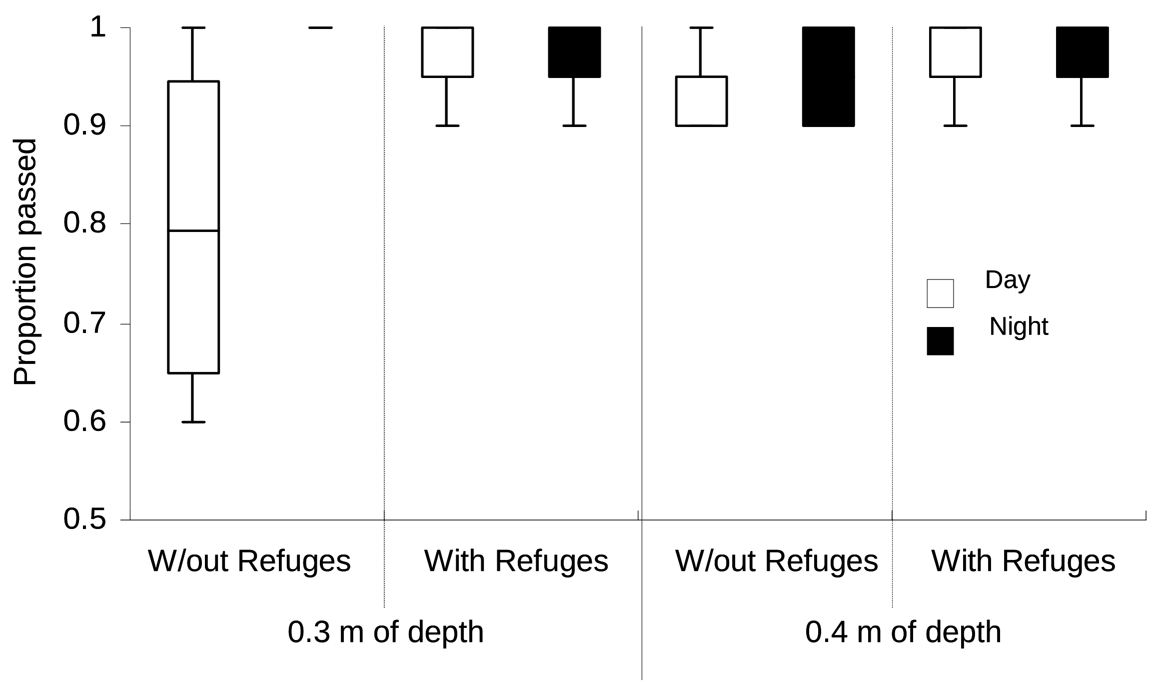


Figure 9. Box plot showing the distribution of passage efficiencies for groups of fish passing through an experimental fishway with and without velocity refuges placed around submerged orifices, during the day and at night with two water levels. The following quartiles are plotted (from bottom to top): minimum, lower quartile, median, upper quartile, and maximum.

Table 7. Mean time to pass through the pool-and-weir fishway from removal of the intake screen until fish passed the third upstream weir in 1999 and 2000.

	Total mean passage time (min)			
	Daytime		Nighttime	
Treatment	n	mean (±sd)	n	mean (±sd)
1999				
30.5 cm of depth, w/o refuges	19	56.7±18.9	4	46.5±3.3
30.8 cm of depth, w/ refuges	35	42.1±19.3	12	33.8±10.4
39.6 cm of depth, w/o refuges	15	47.7±12.5	18	34.2±15.1
39.6 cm of depth, w/ refuges	19	28.4±12.2	3	15.4±2.1
0 cm of depth, w/o refuges	29	39.0±14.8	34	39.7±15.0
0 cm of depth, w/ refuges [1]	21	34.2±14.4	-	-
Untagged	17	32.2±13.9	-	-
Radio tagged	16	32.4±17.1	-	-
2000				
Nighttime w/ IR lights	-	-	19	39.3±9.3
Nighttime w/ room lights	-	-	24	40.7±10.9
Daytime (ambient light)	35	45.1±11.3	-	-
Step @ center weir [2]	-	-	-	-
Diffuser	10	40.5±10.7	16	35.5±14.6
Diffuser (no flow)	2	41.4±18.6	9	49.0±13.0
Diffuser w/ 30.5 cm plate	8	41.5±11.1	24	28.9±10.8
Diffuser w/ 15.2 cm plate	15	37.0±12.0	25	36.4±12.2
Diffuser (centered)	0	-	17	41.4±9.2

1. No observations at night due to turbid water conditions.
2. All observations focused on lip at second upstream weir.

In eight trials where we tested the effect of surgically implanting radio transmitters into lamprey, mean passage efficiencies were 76.3% and there were no significant differences among any of the four treatment groups (Figure 11; $F_{(3,4)} = 0.60$, $p = 0.6503$). Eighty percent of fish with surgically implanted radio transmitters successfully passed all three weirs and 72.5% of fish without transmitters had successful passage. Times to pass a single weir ($t = 0.61$, $p = 0.2739$; Table 8) and time to pass through the fishway ($t = 0.02$, $p = 0.4904$; Table 7) were similar among treatment groups. Untagged lamprey took 3.9 min to pass the second upstream weir and 32.2 min to pass through the fishway and radio-tagged lamprey took 3.5 and 32.4 min.

Manipulating the lighting in the AFF had a significant effect on passage success ($F_{(2,13)} = 5.66$, $p = 0.0171$; Figure 12). During the day, with ambient light conditions, the mean passage rate was 57.8%. This was significantly lower than the passage rate for fish at night using only infrared light (91.8%) according to a post hoc Tukey-type multiple comparison test. During nighttime trials, with the AFF room lights illuminated, 60.0% of fish successfully passed through the fishway. This was not significantly different from daytime trials or nighttime trials with infrared lighting.

Table 8. Mean time to pass a submerged orifice or an overflow weir in 1999 and 2000. All observations occurred at the second upstream weir. Times were calculated from the first time a lamprey came into camera view until it completely passed over the weir or through the orifice.

	Time to pass weir (min)							
	Submerged Orifice				Overflow			
	Daytime		Nighttime		Daytime		Nighttime	
Treatment	n	mean (±sd)	n	Mean (±sd)	N	mean (±sd)	n	mean (±sd)
1999								
30.5 cm of depth, w/o refuges [1]	-	-	-	-	-	-	-	-
30.8 cm of depth, w/ refuges	13	4.8±3.2	7	2.7±1.7	8	1.2±1.7	5	0.2±0.2
39.6 cm of depth, w/o refuges	25	3.0±2.6	5	1.3±1.3	10	0.6±1.0	2	0.2±0.2
39.6 cm of depth, w/ refuges	24	3.7±2.5	0	-	4	0.9±1.4	2	0.2±0.0
0 cm of depth, w/o refuges	24	2.4±1.7	0	-	0	-	0	-
0 cm of depth, w/ refuges	18	1.0±0.9	0	-	0	-	0	-
Untagged	17	3.9±1.6	-	-	4	0.4±0.4	0	-
W/ radio tag	9	3.5±1.7	-	-	5	0.5±0.4	0	-
2000								
Nighttime w/ IR lights	-	-	11	4.1±2.4	-	-	0	-
Nighttime w/ room lights	-	-	27	2.8±1.0	-	-	1	1.5
Daytime (ambient light)	39	3.4±2.0	-	-	4	0.6±0.8	-	-
Step @ center weir	8	3.8±3.1	9	5.1±8.0	3	0.1±0.1	0	-
Diffuser	11	4.7±6.0	17	8.7±8.9	7	1.5±3.1	0	-
Diffuser (no flow)	3	15.9±23.7	12	9.7±10.8	2	0.3±0.2	0	-
Diffuser w/ 30.5 cm plate	7	8.6±11.7	20	3.7±2.5	8	0.3±0.4	0	-
Diffuser w/ 15.2 cm plate	6	3.2±3.0	15	3.4±2.5	5	0.1±0.1	0	-
Diffuser (centered)	-	-	12	4.5±3.6	-	-	0	-

1. Trials were not videotaped.

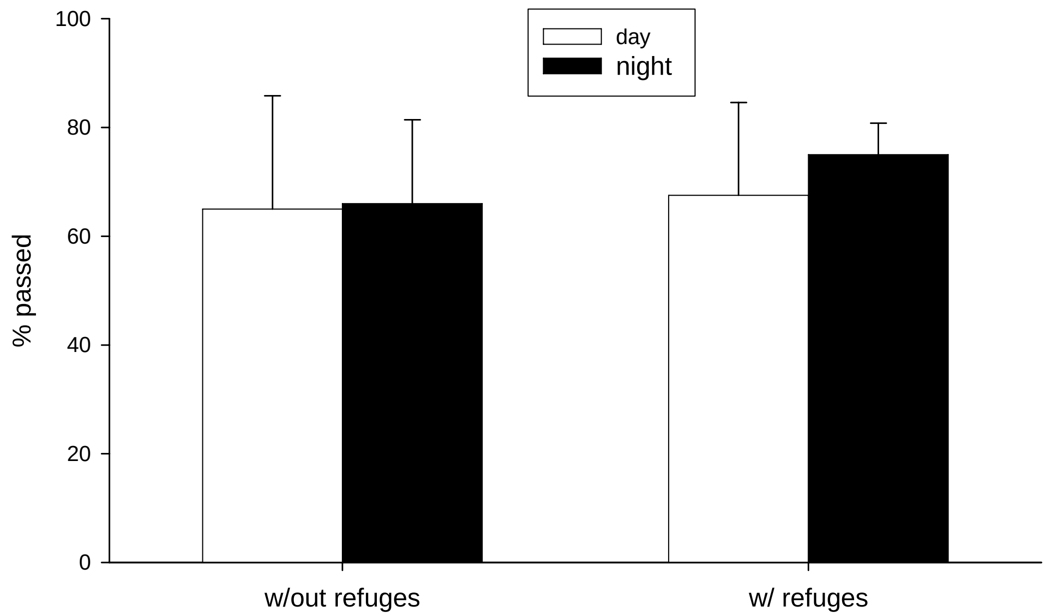


Figure 10. Mean percentage of lamprey that successfully passed a simulated fishway during one-hour long daytime and nighttime trials in 1999 with and without velocity refuges in place at the orifices when no water was flowing over the tops of the weirs.

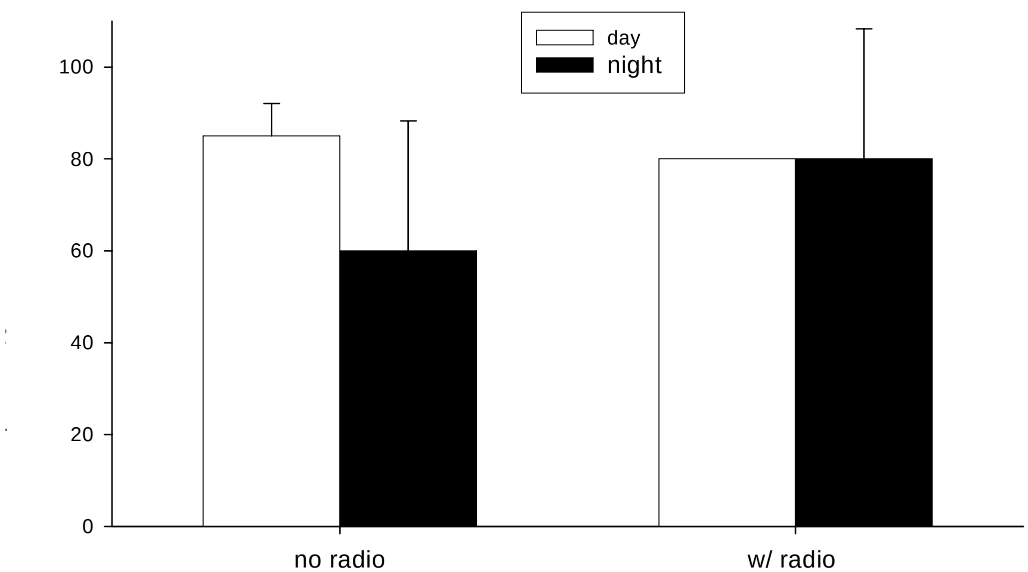


Figure 11. Mean percentage of lamprey that successfully passed a simulated fishway during one-hour trials with and without surgically implanted radio transmitters.

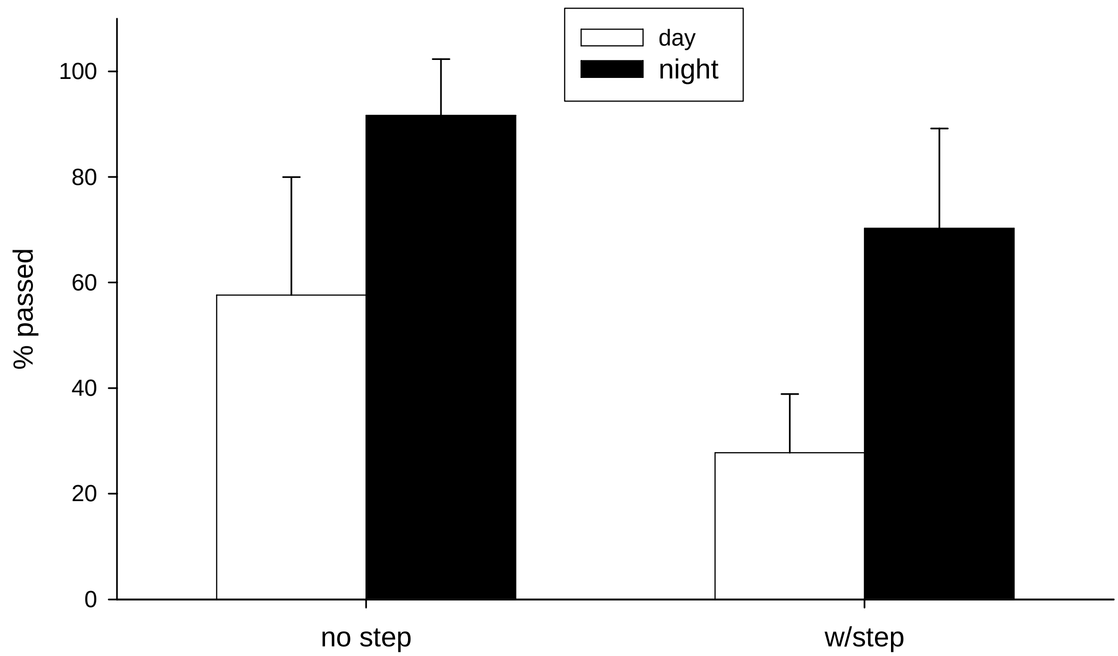


Figure 12. Mean percentage of lamprey that successfully passed a simulated fishway during the day with ambient lighting and at night with fluorescent room lights and with infrared lighting.

During 20 day and night trials to test the effect of adding a step downstream from the middle weir's orifice, there were significant differences among the four treatment groups ($F_{(3,16)}$ = 8.77, p = 0.0011; Figure 13). Mean passage efficiencies were 48.9% when the step was in place and 69.1% when the step was absent ($F_{(1,16)}$ = 9.26, p = 0.0077). Mean times to pass the submerged orifice were 3.6 min in the absence of a step and 4.5 min when the step was present (t = 0.93, p = 0.1779; Table 8).

When the diffuser grating was in place and adjacent to the center weir, the mean passage time through the downstream orifice was 7.1 min as opposed to 3.6 min in the absence of the diffuser (t = 3.79, p = 0.0001; Table 8). During daytime trials, a significantly higher proportion of lamprey were observed passing via the overflow when the diffuser was in place (χ^2 = 7.51, p = 0.0061). Overall passage time through the entire fishway was not significantly longer (t = 0.97, p = 0.1671) with a diffuser present (37.4 min) than when it was absent (43.3 min) (Table7). Time of day had a significant effect on passage rate ($F_{(5,22)}$ = 3.88, p = 0.0113; Figure 14); more fish passed during nighttime trials (83.5%) than daytime trials (49.3 5%; $F_{(1,22)}$ = 13.40, p = 0.0005). The addition of a diffuser grate did not significantly effect passage rates in either of the two positions tested ($F_{(1,22)}$ = 1.34, p = 0.2818); 69.1% of lamprey passed when no grate was in place, 52.5% passed when the diffuser was just upstream of the middle weir, and 67.6% passed when the grate was centered between the second and third upstream weir.

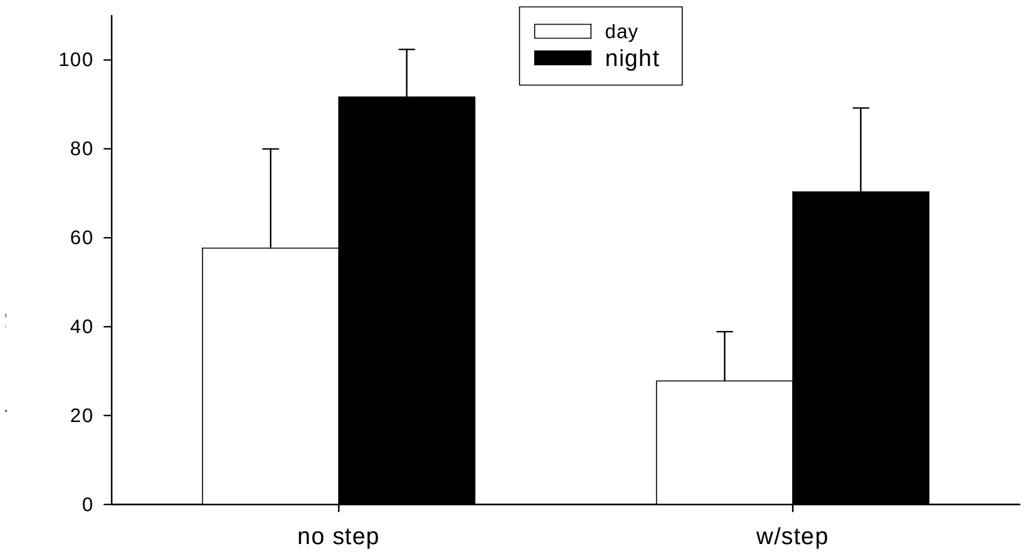


Figure 13. Mean percentage of lamprey that successfully passed a simulated fishway during one-hour day and night trials with and without the presence of a step adjacent to and downstream from one of the orifices.

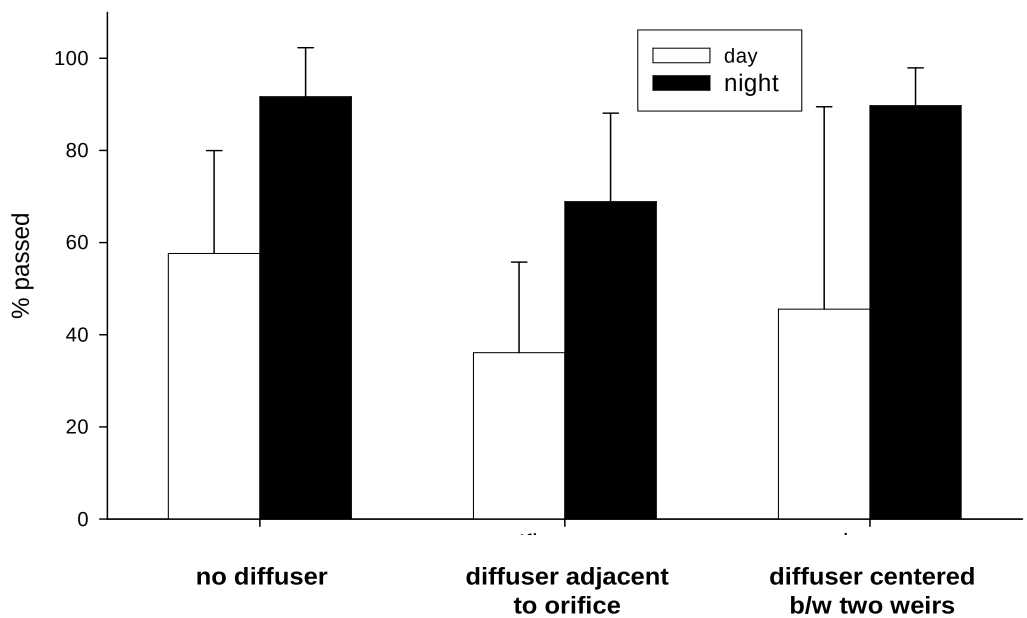


Figure 14. Mean percentage of lamprey that successfully passed through a simulated fishway during one-hour day and night trials with no diffuser grating, with a diffuser placed adjacent to and upstream from the second upstream weir, and with a diffuser centered between the second and third upstream weirs.

Passage times through the downstream orifice decreased from 7.1 min to 3.4 min when a 15.2 cm plate (t = 2.05, p = 0.0231; Table 8) was attached to the diffuser just upstream from the orifice. Passage times were 5.0 min when a 30.5 cm plate (t = 1.08, p = 0.1436; Table 8) was added in this same location. Total passage times through the entire fishway decreased from 37.3 min to 32.1 min with the addition of the 15.2 cm plate (t = 1.61, p = 0.0567; Table 7) and were 36.6 min with the 30.5 cm plate (t = 0.25, p = 0.4015; Table 7).

In 32 day and night trials to test the effects of eliminating flow through the base of the grate or adding solid plates to the grating adjacent to the orifice, there were significant differences in passage efficiency among the eight treatment groups ($F_{(7,24)}$ = 9.48, p < 0.0001; Figure 15). Although there were significant differences among the experimental treatments ($F_{(3,24)}$ = 6.56, p = 0.00210), none of the modifications significantly increased the passage rate. Without modifications, 52.5% of fish passed all three weirs, 57.4% passed when a 15.2 cm long plate was in place, 60.6% passed when a 30.5 cm plate was in place, and 21.3% passed when no water was pumped through the grate. A Tukey-type multiple comparison test revealed that the no flow treatment was the only treatment that produced a significant effect.

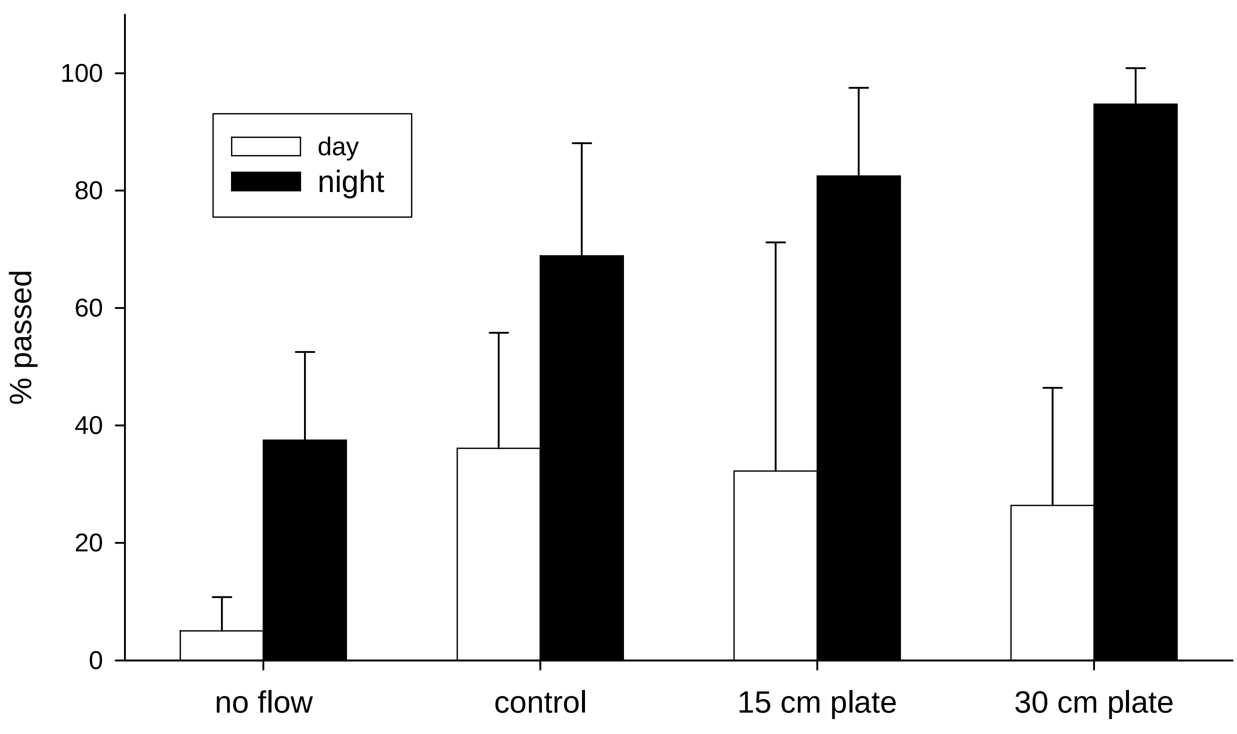


Figure 15. Mean percentage of lamprey to successfully pass through a simulated fishway during one-hour day and night trials with a diffuser grating placed adjacent to and upstream from the second upstream weir (control), with no water flowing through the diffuser, with a 15 cm solid plate attached to the diffuser adjacent to the orifice, and with a 30 cm solid plate attached to the diffuser adjacent to the orifice.

Count Window Tests

Results from a MANOVA test on 22 trials with the count window setup indicated that time of day, presence of count window lights, and a picketed lead had no significant effect on which side of the divider fish chose to swim through (Figure 16). During daytime trials, 35.7% passed on the count window side and 17.4 % passed on the auxiliary side. There was no significant difference ($F_{(1,8)} = 0.20$, $p = 0.6670$) in passage rates between trials with naïve fish and those with fish that had been used in previous trials. At night, 28.2 % passed via the count window and 25.6 % passed via the auxiliary side (*Wilk's* $\Lambda = 0.95$, $F_{(2,15)} = 0.38$, $p = 0.6913$). Thirty percent of the 56.7% of fish that passed did so via the count window side when the count window lights were off, and 32.6% (of 52.1%) when the lights were on (*Wilk's* $\Lambda = 0.98$, $F_{(2,15)} = 0.15$, $p = 0.8589$). When the picketed lead was in place, 33.7% of fish passed on the count window side and 25.2% passed on the auxiliary side. When the lead was removed, 28.8% passed on the count window side and 15.0% passed on the auxiliary side (*Wilk's* $\Lambda = 0.93$, $F_{(2,15)} = 0.57$, $p = 0.5752$).

Entrance Tests

We completed 28 tests evaluating lamprey behavior at simulated fishway entrances, consisting of 112 separate trials that used a total of 879 fish. For individual trials, passage efficiency ranged from 0 to 100%. Fish took from 1 s to greater than 16 min to pass the entrance bulkhead. For the bulkhead shape tests, day and night trials were analyzed separately because there was a significant interaction between time of day and head level ($F_{(2,36)} = 8.04$, $p = 0.0013$). At high head levels (i.e. 45.7 cm), passage efficiencies were low (≤ 10%) regardless of the time of day. Passage rates were significantly higher for trials with naïve fish (mean = 34.2%; $F_{(1,24)} = 7.13$, $p = 0.0130$) than for trials with fish that had been used in previous trials (21.3%).

During nighttime trials, passage success varied among the different treatments ($F_{(11,12)} = 12.14$, $p < 0.0001$; Figure 17). Mean passage rates were 32.5% with squared bulkheads and 50.8% with rounded bulkheads ($F_{(1,12)} = 8.98$, $p = 0.0110$). Sixteen lamprey took a mean of 3.0 min to pass the squared bulkhead, and 32 lamprey took 1.4 min to pass the rounded bulkhead. Water velocity, determined by head differential, significantly affected passage success ($F_{(2,12)} = 49.39$, $p < 0.0001$). Mean passage efficiencies were 78.5%, 42.5%, and 4.0% at night when there was 15.2, 30.5, and 45.7 cm of head at the entrance weir. Each of these were significantly different based on post hoc comparisons using Tukey's HSD test. Twenty-four lamprey passed through the entrance in 0.8 min with 15.2 cm of head (Table 9) and the same number of fish took 3.8 min on average with 30.5 cm of head. No lamprey were recorded passing through the entrance when there was 45.7 cm of head.

During daytime trials, there were no significant overall differences among treatment groups ($F_{(11,12)} = 0.95$, $p = 0.5331$; Figure 17). Mean passage rates were 11.7% when squared bulkheads were in place and 15.8% with rounded bulkheads in place. Eight different lamprey that successfully passed the squared entrance bulkhead did so in an average of 5.2 min, and 13 lamprey passed the rounded bulkhead in 2.8 min. With head levels of 15.2, 30.5, and 45.7 cm, passage efficiencies were 22.5%, 17.5% and 1.3%. Nine lamprey passed the entrance bulkhead in an average of 0.6 min when there was 15.2 cm of head (Table 9). When there was 30.5 cm of head, 12 lamprey passed in 6.6 min. No lamprey were observed passing the bulkhead when there was 45.7 cm of head, so passage time could not be determined for this treatment.

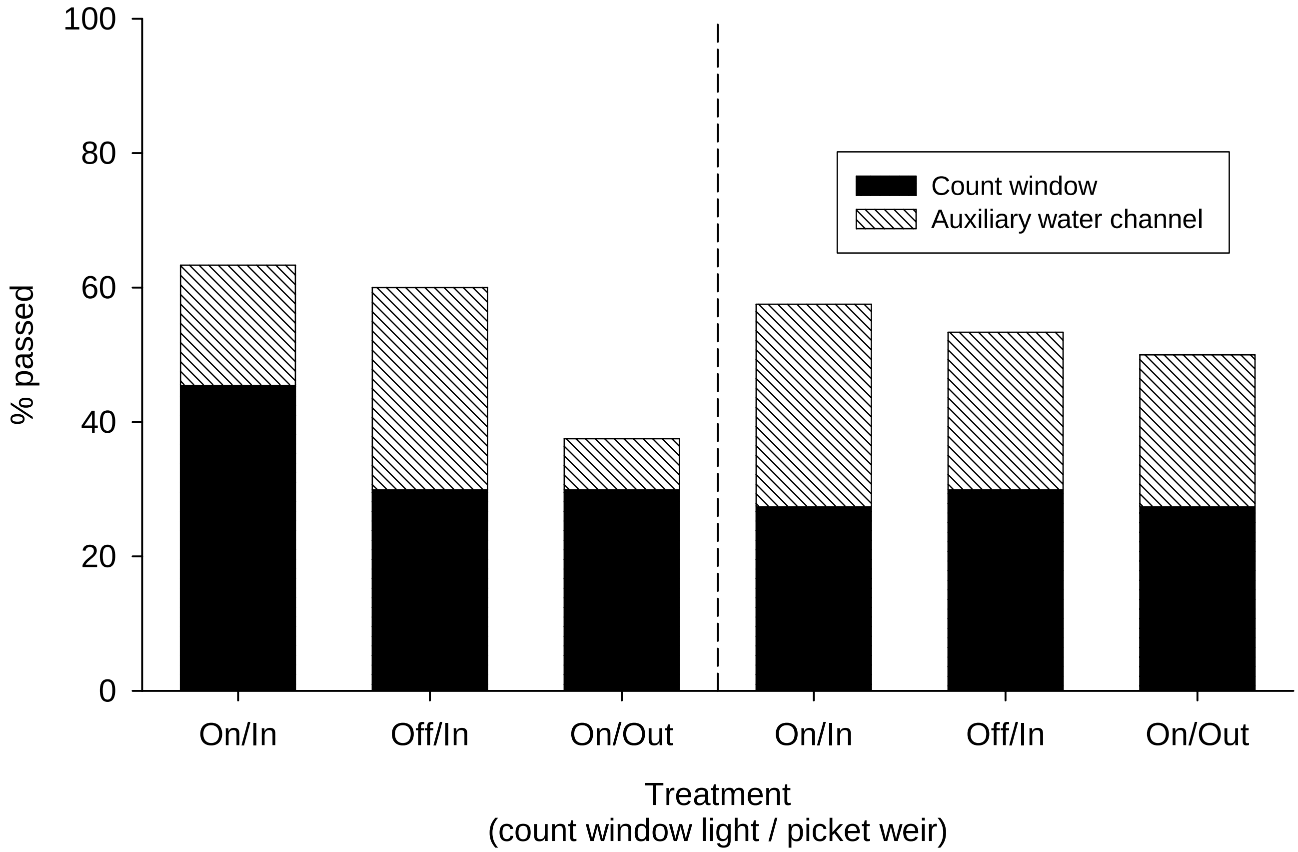


Figure 16. Mean percentage of lamprey that successfully passed through a simulated count window and the proportion of lamprey that passed on each side of divider during one-hour day and night trials with (In) and without (Out) the presence of a picketed lead and with count window lighting on and off.

Table 9. Mean time to pass a simulated entrance weir in 2002. Times were calculated from lamprey entry into the camera view until it completely passed the entrance weir.

	Time to pass entrance weir (min)			
	Day		Night	
Treatment	n	mean (±sd)	n	mean (±sd)
Square, 45.7 cm of head	0	-	0	-
Square, 30.5 cm of head	5	7.1±4.1	5	6.0±6.1
Square, 15.2 cm of head	3	0.8±1.0	11	1.3±1.7
Round, 45.7 cm of head	0	-	0	-
Round, 30.5 cm of head	7	4.9±5.4	19	2.4±2.5
Round, 15.2 cm of head	6	0.3±0.4	13	0.3±0.5
Divided, 45.7/15.2 cm of head	8	0.6±1.4	14	0.6±0.7
Divided, 30.5/15.2 cm of head	12	0.6±0.6	23	0.3±0.4
Divided, 30.5/7.8 cm of head	9	0.9±1.0	25	0.3±0.6

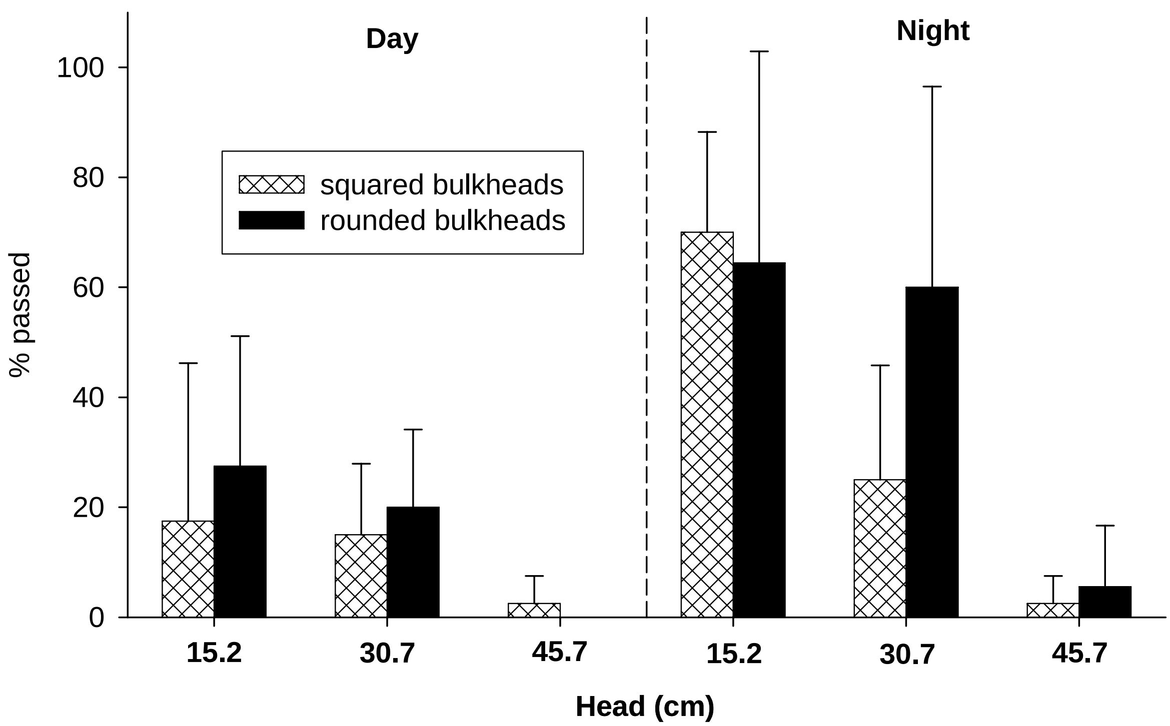


Figure 17. Mean percentage of lamprey that successfully passed a simulated fishway entrance during one-hour day and night trials with squared or rounded bulkheads and 15.2, 30.5, and 45.7 cm of head at the entrance.

The presence of a divider that provided a low flow section on one side of the simulated entrance (15.2 cm versus 30.5 cm of head) significantly increased passage success when compared to trials with rounded bulkheads only ($F_{(1,32)}$ = 17.91, p = 0.0002; Figure 18). Passage efficiencies were 29.0 and 57.1% during day and night trials and these values were significantly different ($F_{(1,32)}$ = 15.30, p = 0.0004). An average of 21.4% of the fish successfully passed the weir when no divider was in place, compared to 57.5% that passed when the divider was in place. Thirty-six lamprey passed the entrance bulkhead in 3.7 min when the divider was absent, and 91 lamprey passed the bulkhead via the low flow side in 0.5 min when the divider was present (Table 9). No attempts were made to observe the fish that passed on the high flow side when the divider was in place.

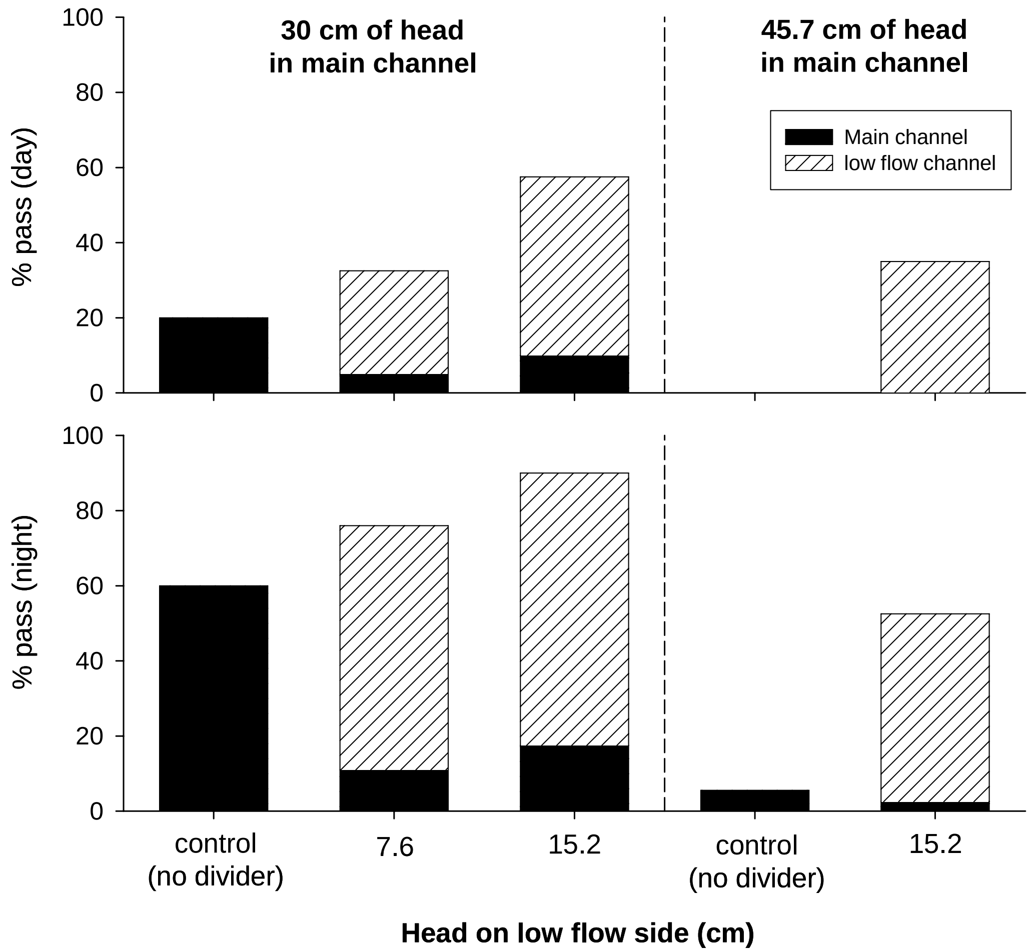


Figure 18. Mean percentage of lamprey that successfully passed a divided fishway entrance and the percentage of fish that passed on each side of the divider during one-hour day and night trials under five different flow treatments: with no divider in place and 30.5 or 45.7 cm of head at the entrance, with 30.5 cm of head on the high flow side and 7.6 or 15.2 cm of head on the low flow side, and with 45.7 cm of head on the high flow side and 15.2 cm of head on the low flow side.

In 23 out of 24 trials in which fish passed the entrance when the divider was present, a significantly higher percentage of fish successfully passed via the low flow side (85.6%; $p < 0.025$, χ^2 test; Figure 18). Overall passage rates were higher during night trials (73.3%) than day trials (41.7%; $F_{(1,18)} = 10.83$, $p = 0.0055$). There were no significant differences in passage efficiency among the three velocity treatments tested ($F_{(2,18)} = 3.31$, $p = 0.0598$); 43.8% of lamprey passed the entrance weir when there was 15.2 cm of head on the low flow side and 45.7 cm of head on the high flow side, 55% passed with 7.6 cm and 30.5 cm of head, and 73.8% passed with 15.2 cm and 45.7 cm of head. Because tests could not be run with 7.6 cm of head on the low flow side and 45.7 cm of head on the high flow side it was not possible to test for interactions between flows on each side of the divider.

In 40 trials with a ramp in place that allowed passage up and over the entrance weir, not a single lamprey used the ramp for passage during the 1 h tests. During preliminary trials we placed lamprey on the ramp and they climbed it without difficulty. However, when water was flowing through the entrance bulkhead, lamprey were not attracted to the base of the ramp. Increasing the amount of water flowing down the ramp provided no additional reaction from the fish within the 1 h duration of these tests

Discussion

General Discussion

We made several critical assumptions throughout this study. We assumed that lamprey used in trials were representative of the general population, although all fish were collected as they passed by an overflow weir. To help account for this, we blocked the corresponding submerged orifice while the trap was in place. We also assumed that both hydraulics and fish behavior were similar in experimental and existing fishways and that fish behavior was unaffected by handling.

Results from this study suggest that lamprey have difficulty passing fishway structures. The single most important factor affecting passage success appeared to be water velocity. Reducing flows at entrances produced the most notable improvement in fish movement. Pacific lamprey have critical swimming speeds of about 0.85 m/s (Mesa et al.,2003). Velocities at fishway entrances approach and exceed 2.0 m/s (Clay,1995), surpassing the swimming abilities of these fish. In these high flow areas, lamprey attach to the substrate with their suctorial disc, surge forward, and then reattach. Consequently, lamprey passage may be difficult in high flow, or turbulent areas that lack suitable attachment points. Having relatively smooth surfaces for attachment in high velocity areas and gradual transitions to high flow are important design considerations for lamprey passage structures. Lamprey are most vulnerable in the time between attachments. Any rapid changes in water velocity or direction can easily change a fish’s trajectory and prevent it from reattaching. Without a quick reattachment, the fish are often swept downstream to areas of low velocities where they can re-orient.

Pool-and-Weir Type Fishways

The addition of velocity refuges within orifices decreased the amount of time that fish took to pass through the orifice and increased the proportion of fish which made use of the orifice. Although overall passage rate was unaffected by the addition of refuges, the passage efficiency was quite high in all of the trials; without refuges in place, 92% of lamprey successfully passed all three weirs in two-hour trials, and 66% of lamprey passed in one-hour trials. Also, the modification was made to one of three weirs in the test ladder. Had all three weirs been modified, a measurable improvement in passage times may have been realized. Adding refuges to the orifices seemed to allow more fish to pass via the orifice. These fish that may have passed over the top of the weir in the absence of refuges. Adding refuges reduced flows at the base of the orifice from about 2 m/s to 1 m/s. As noted above, providing lower velocity avenues for passage appears to be beneficial for adult lamprey. Similar strategies have been used successfully in other fishways. Bunches of plastics bristles affixed to the base of the Isohaara fishway in the Kemijoki River in Northern Finland were used to reduce flows through the vertical slot section (Laine,2001) and aid in the passage of European river lamprey, *L. fluviatilis*. Also, groups of hard plastic bristles or natural or synthetic branches have been used on sloped ramps to aid in upstream migration of catadromous eel (Clay,1995). In these designs, the elvers wormed their way up the ramp in much in the way a snake would climb a slope.

Few lamprey passed a weir using the overflow section, although those that did so passed the weir quicker than those passing via the submerged orifice. Average passage times for fish as they passed over the top of the weir were 38 s, whereas fish passing through the orifice took an average of 3 min 20 s to do so. However, times were only calculated for fish that successfully passed the weir and do not include fish that may have attempted to pass but were pushed downstream and out of view of our cameras. Fish attempting to pass via the overflow rarely made multiple attempts to do so. It appears that fish that did not pass on the first try generally sought other routes to pass. Also, bubbles near the surface made it difficult to view a fish through its entire passage and therefore it was difficult to determine when a fish first arrived at the weir top.

Lamprey passage did not appear to be affected by the presence of surgically implanted radio transmitters. Times to pass a weir were similar for tagged and untagged fish, and more tagged fish successfully passed all three weirs than untagged fish. In studies on swimming performance of tagged and untagged fish by Mesa et al. (2003), lamprey with surgically implanted radio transmitters had significantly lower critical swimming speeds (81.5 ± 7.0 and 86.2 ± 7.5 cm/s respectively), however the difference was minor and may not have produced biologically significant differences in our tests.

Lamprey were reliably more active at night, with highest levels of activity when only the IR lights were in use. This finding is consistent with the nocturnal nature of lamprey behavior (HardistyPotter,1971). Pacific lamprey have also exhibited high levels of nighttime activity in radiotelemetry studies (Moser et al.,2002a).

Passage was inhibited by the presence of a step at the base of orifices. Our observations indicated that lamprey usually approach orifices along the base of the fishway. When they get to a point where they can no longer move forward, they quickly attach to the substrate (generally the fishway floor). When a step is in place, lamprey approaching along the floor must swim up and over a lip and through a large current differential. When attempting to pass over the lip, most of their forward momentum is perpendicular to the flow of water. Lamprey appear to have difficulty redirecting that momentum and re-attaching to the fishway flow before getting pushed downstream. At Bonneville Dam, orifices in the Washington Shore fishway are designed with orifices situated flush against the floor of the floor of the fishway, whereas at the Bradford Island ladder orifices are raised by approximately 20 cm. In our experiments, we placed a step at only one of the three weirs and presence of the step significantly decreased overall passage success. We believe that the cumulative effect of having a step at each and every orifice would have an even greater impact on lamprey passage. Repositioning the orifice or ramping the floor of the fishway downstream from existing orifices may aid lamprey in passing through this section of the Bradford Island ladder. Radiotelemetry studies (Moser et al.,2002a; Moser et al.,2002b; Moser et al.,2005) found little difference between mean annual passage efficiency for lamprey entering the Bradford and Washington shore ladders, however, passage efficiencies were relatively high (>75%) in this portion of the fishway compared to other areas.

Diffuser gratings on the floor of the fishway can be a significant obstacle to lamprey, especially when grates span the entire floor between consecutive weirs. In places with diffusers, lamprey cannot attach to the floor. Although the numbers of lamprey successfully passing through the experimental fishway were similar with and without a diffuser in place, lamprey passed through a single downstream orifice in as little as half the time when the diffuser was absent. With the installation of a 15.2 cm solid plate over the diffuser, passage times through the orifice were similar to those when the diffuser was absent. There may have been a more significant effect on passage rate if the diffuser had spanned the entire space between two consecutive weirs. The diffuser was tested in two positions: adjacent to the downstream, and centered between two weirs. The two main areas of concern are the upstream side of the downstream orifice and the downstream side of the upstream orifice. This experiment tested for the former but not the latter condition.

Count Window Area

We tested two hypotheses regarding lamprey passage at count window areas: 1) lamprey exhibit negative phototaxis and avoid the lighted count window area, and 2) lamprey enter the AWC which is lacking outlet designed for fish passage. Once inside the AWC, fish can exit by swimming back downstream, passing through vents in the wall that separate the auxiliary side from the flow control section of the fish ladder, or by moving directly into the forebay through passage over or under the Tainter gate at the upstream end of the AWC (Moser et al. 2003).

In our tests we determined whether fish were actively avoiding the lighted count window and to what extent fish were gaining access to the AWC though a picketed lead. We found that lamprey were not avoiding the count window lights, as the percentage of fish using each side of the fishway was unrelated to lighting treatment. However, approximately half of the lamprey used in each trial entered the AWC even when the picket lead weir was in place. Lamprey easily passed through the 2 cm spacing between the bars of the picketed lead. In our tests, lamprey appeared to enter whichever side they came to first. These experiments may be underestimating the problem because our count window setup was greatly simplified. In our design, the AWC and the count window channel each accounted for half of the flume's width. At Bonneville Dam, the constricted count window area is about 1 m wide, or 7% of the fishway width at this location. This difference greatly increases a lamprey's likelihood of first coming in contact with the picket lead and directly entering the AWC.

Fishway Entrances

Compared to the other structures we tested, lamprey seem to have the most difficulty at fishway entrances. With conditions similar to those currently found at main fishway entrances at the lower Columbia River dams (approximately 45.7 cm of head and squared bulkheads), no more than 1 out of 10 lamprey successfully passed the entrance weir in any given one hour trial. Radio telemetry has shown higher entrance success at dams, however, fish generally take longer than one hour to enter fishway after first approach (Moser et al.,2005). The extra flow and turbulence found at fishway entrances can be a critical deterrent to lamprey passage. Lamprey congregate outside fishway entrances in large numbers, further suggesting that these entrances block or delay lamprey passage. Flows at these entrances tend to be high – upwards of 2.4 m/s – in order to attract upstream migrating adult salmonids.

In our experiments, head level had a significant effect on lamprey passage. Decreasing the head level at the entrance by 15.2 cm increased nighttime passage rates by 39%. An additional drop in head of 15.2 cm raised the percentage of fish with successful passage by another 36%. Lamprey are largely nocturnal, as opposed to salmonids which tend to be active primarily during the day. Modulating flows during the night could potentially aid lamprey entry without impacting listed salmonids. However, preliminary tests of this idea that were done using radio-tagged lamprey gave no indication that reducing flow at night was effective at the Bonneville Dam spillway entrances (Moser et al. 2002a). Further testing is warranted, as sample sizes for the initial tests were quite low.

An alternate solution may be to provide structural modifications at entrances. In our study, we found that rounding an entrance bulkhead can improve the number of lamprey passing that entrance and lower the time an individual fish takes to pass the weir. Nighttime passage rates increased by 18% when rounded bulkheads were in place. The spillway entrances at Bonneville Dam have already been modified with rounded bulkheads. Radio tracking of adult lamprey at these entrances after the modifications were made further indicated that rounding entrance bulkheads improves lamprey entrance success (Moser et al. 2002a, Moser et al. 2003).

Lamprey Bypasses

Designing a fishway to effectively accommodate both lamprey and salmonids may not be feasible. Rather than completely restructuring the existing fishway to accommodate lamprey passage, a more reasonable option may be to develop a separate fishway to aid lamprey passage. One of the primary questions in developing such a fishway is how to separate lamprey from other species, such as salmon, steelhead, and shad. Lamprey are unique in their ability to squeeze through small spaces, in their willingness and ability to ascend vertical, or near-vertical structures, and in their nocturnal lifestyle. These differences in behavior might be exploited when designing lamprey-specific structures that permit lamprey to enter without negative effects to other species.

We first tested the concept of reducing flows through one portion of the fishway entrance in order to determine whether lamprey would find and use the lower flow channel. Using a solid divider to split the channel within and upstream from the vertical slot weir, we were able to test passage performance under a variety of different flow combinations. In all situations, there were significant improvements in passage as compared to when the divider was not in place. We found that a majority of the lamprey passed via the low velocity side when that option was available. For a system like this to work, it appears as though the actual difference between the flows on each side of the divider is critical. When there were large differences between the velocities, there was a slight drop in overall passage, suggesting that it may have been difficult for lamprey to locate the lower flow channel. We manipulated velocities by restricting the amount of water flowing into the low flow channel. This will be difficult in a full-scale fishway. A reasonable alternative might be to install an extra series of weirs on the low flow side of a divider, thus lowering the head differential and flow velocity at each individual weir.

In this study, lamprey did not use the ramp designed to bypass a fishway entrance. Results from these tests were inconclusive because lamprey were either not attracted to the ramp or that the lamprey required longer than one hour to begin ascending the ramp. In 2004, we tested the use of another ramp design and ran tests overnight for eight hours. Greater than 87% of lamprey used in these trials successfully ascended the ramp, however, on average fish took 1.85 h to begin ascending the ramp and only 25 % of fish did so within one hour. Lamprey can and do climb vertical ramps, but may do so only as a last resort. When placed on the ramp, lamprey ascended without difficulty. Different placements of a ramp-type entrance may prove more successful. Future bypass research should likely focus on determining optimal ramp placement and configuration for effectively attracting lamprey to base of the ramp.

References

Beamish, R. J., 1980. Adult biology of the river lamprey (*Lampetra ayresi*) and the Pacific lamprey (*Lampetra tridentata*) from the Pacific coast of Canada. Canadian Journal of Fisheries and Aquatic Sciences, 37:1906-1923.

Beck, L., 1995. Fish behavior at submerged orifices, overflow weirs, and vertical slots in the fish ladder at Bonneville second powerhouse 1993 - 1994. U.S. Army Corp of Engineers special report. Report number CENPP-OP-SRF. 44 pp.

Bell, M., 1990. Fisheries Handbook of Engineering Requirments and Biological Criteria, 3rd edition. US Army Corps of Engineers, North Pacific Division., Portland, Oregon.

Clay, C. H., 1995. Design of fishways and other fish facilities, 2nd edition. CRC Press, Inc., Boca Raton, Florida.

Close, D. A., M. Fitzpatrick, H. Li, B. Parker, D. Hatch, and G. James, 1995. Status report of the Pacific lamprey (*Lampetra tridentata*) in the Columbia River Basin. 1995 Status Report, Report to Bonneville Power Administration. Report number DOE/BP-39067-1. For Project number 94-026. 40 pp.

Hardisty, M. W., and I. C. Potter, editors, 1971. The biology of lampreys. Academic Press, London, New York.

Haro, A., and B. Kynard, 1997. Video evaluation of passage efficiency of American shad and sea lamprey in a modified Ice Harbor fishway. North American Journal of Fisheries Management, 17:981-987.

Jackson, A. D., D. R. Hatch, B. L. Parker, and D. A. Close, 1997. Pacific lamprey research and restoration. 1997 Annual Report for Bonneville Power Administration. Report number DOE/BP-39067-3. For Project number 1994-026. 97 pp.

Kostow, K., 2002. Oregon lampreys: Natural history status and problem analysis. Report by Oregon Department of Fish and Wildlife. 112 pp.

Laine, A., 2001. Restoring salmonid stock in boreal rivers: Problems of passage at migratory obstructions and land-derived loading in production areas. University of Oulu, Oulu Finland.

Mesa, M. G., J. M. Bayer, and J. G. Seelye, 2003. Swimming performance and physiological responses to exhaustive excercise in radio-tagged and untagged Pacific lamprey. Transaction of the American Fisheries Society, 132:483-492.

Moser, M. L., A. L. Matter, L. C. Stuehrenberg, and T. C. Bjornn, 2002a. Use of an extensive radio reciever network to document Pacific lamprey (Lampetra tridentata) entrance efficiency at fishways in the lower Columbia River, USA. Hydrobiologia, 483:45-53.

Moser, M. L., P. A. Ocker, L. C. Stuehrenberg, and T. C. Bjornn, 2002b. Passage efficiency of adult Pacific lamprey at hydropower dams on the lower Columbia River, USA. Transaction of the American Fisheries Society, 131:956-965.

Moser, M. L., D. A. Ogden, and C. A. Peery, 2005. Migration Behavior of adult Pacific lamprey in the Lower Columbia River and evaluation of Bonneville Dam modifications to improve passage, 2002. Report to the US Army Corps of Engineers, Portland District. 65 pp.

Osborne, M. F. M., 1961. The hydrodynamic performance of migratory salmon. Journal of Experimental Biology, 38:365-390.

Zar, J. H., 1999. Biostatistical Analyses, 4th edition. Prentice-Hall, Inc., Upper Saddle River, New Jersey.

Oregon Lampreys:

Natural History
Status
and Problem Analysis

by
Kathryn Kostow

Oregon Department of Fish and Wildlife
January 24, 2002

TABLE OF CONTENTS

Note: This report was edited on April 21, 2003 by ODFW Conservation and Recovery Program Manager, Charlie Corrarino, to include an acknowledgement (on page 3) and personal communications (on pages 10 and 14) that were inadvertently omitted from the original draft.

Acknowledgements

The Oregon Department of Fish and Wildlife would like to thank Leo Grandmontagne for his contributions to our knowledge of the status of lamprey in the Coquille River Basin and for the use of his photograph shown in Figure 12.

Executive Summary

The jawless lampreys are remnants of the oldest vertebrates in the world. Oregon has somewhere between eight and a dozen species of these primitive fishes. Their taxonomy is obscure because different species tend to look very similar through most of their life cycle, and they have not been well-studied in Oregon. Lampreys occur in the Columbia Basin, including the lower Snake River, along the Oregon coast, in the upper Klamath Basin, and in Goose Lake Basin in southeastern Oregon. They all begin life in fresh water where juveniles burrow into silt and filter feed on algae. As some species approach adulthood they migrate to the ocean or to lakes where they briefly become ecto-parasites, feeding on other live fishes by attaching to them with sucker disc mouths. Other species remain non-parasitic. In addition to some enigmatic species identities, we generally have very little information about the detailed distributions, life histories and basic biology of lampreys.

Lampreys became a conservation concern in the early 1990s when tribal co-managers and some Oregon Department of Fish and Wildlife (ODFW) staff noted that populations of Pacific Lampreys, *Lampetra tridentata*, were apparently declining to perilously low numbers. Pacific Lampreys were listed as an Oregon State sensitive species in 1993 and were given further legal protected status by the state in 1997 (OAR 635-044-0130). Lamprey status is difficult to assess for several reasons: 1) Most observations of lampreys in fresh water are of juveniles and it is difficult to tell the various species apart, even to the extent that the various species are currently clearly designated; 2) Data on lamprey is only collected incidental to monitoring of salmonids. The design and efficiency of the data collection effort is not always adequate for lampreys; and 3) We have very few historic data sets for lampreys. Therefore we often cannot determine how the abundances and distributions we see now compare with those in the past.

The limited data that we have suggests that lampreys have declined through many parts of their ranges. The most precipitous declines appear to be in the upper Columbia and Snake basins where we have some historic data from mainstem dam counts. Pacific Lampreys have declined to only about 200 adults annually passing the Snake River dams. We also have evidence of declines of Pacific Lampreys in the lower Columbia and on the Oregon coast, although our data is quite limited. We have little to no information about any of the other species of lampreys. We are not even sure whether some of the recognized species, like the River Lamprey (*L. ayresi*), is still present in Oregon.

This paper concludes with a Problem Analysis for Oregon lampreys. Our biggest problem is poor information, ranging from not knowing basic species identity to having inefficient or no systematic monitoring of lamprey abundance and distribution. ODFW continued an annual harvest on Pacific Lamprey in the Willamette Basin in 2001, but we lack the necessary information to assess the affects of the harvest on the population. Major habitat problems that affect lampreys include upstream passage over artificial barriers, a need for lamprey-friendly screening of water diversions, and urban and agricultural development of low-gradient flood plain habitats.

Chapter 1

Natural History of Oregon Lampreys

Introduction:

The Superclass Agnatha, the jawless fishes, are an ancient assemblage with origins in the Ordovician Period, about 500 million years ago. Many of the first great advances in the evolution of vertebrates occurred in early agnathans, including the development of bone cells, paired limbs, sensory-line systems, dentine tissue, complex eyes and muscles, and the inner ear. The group radiated into many spectacular forms in the mid-Paleozoic, many of which were characterized by elaborate bony shields and body armor. In all cases the agnathans lacked the jaws that would later characterize all other vertebrates. With the radiation of jawed and, later, bony fishes, most agnathans became extinct. By the end of the Devonian Period (about 350 million years ago) only the hagfishes and the lampreys remained (Long, 1995). Modern agnathans lack body armor and paired fins and have simple, elongated bodies. Still jawless, they include members that are filter feeders, scavengers, and ecto-parasites. The parasitic members feed on other live fishes by attaching themselves with an oral sucker disk, cutting the host's flesh with rasp-like teeth, and feeding on the host's blood. Parasitic lampreys produce an anticoagulant to keep the blood flowing during their meal. The host is left with a round sucker scar.

Lampreys have a colored history with humans. Much of what is known about basic lamprey biology is based on research of the parasitic sea lamprey, *Petromyzon marinus*, that has been conducted as part of extensive effort to eradicate them from the Great Lakes in North America. This species was introduced into the Great Lakes where they contributed to declines of Great Lakes fisheries. Lampreys have been viewed as a threat even where they are native and live in harmony with their own ecosystem (Farlinger and Beamish 1983, Bond and Kan 1973). Some people appear to find the parasitic behavior of some lampreys to be repulsive, a view that is perhaps also sustained by their sliminess and perceived homely appearance. However, lampreys, like all native species, have an intrinsic existence value. Many people find their macabre nature to be fascinating.

Some people also value lampreys for use as food, as a traditional source of medicines and for scientific interest. Fatty and highly nutritious, they are valued as a traditional source of food by Native Americans (Pletcher 1963, Hammond 1979, Downey et al 1993, Close et al. 1995, Downey et al. 1996, Jackson et al 2001). Asian people use them as a source of essential oils for traditional medicines. Pacific lampreys were harvested in large numbers at Willamette Falls during the 1940s to be used as a source of vitamins (Mattson 1949) and they have been used as a source of anticoagulants. They are also a delicacy in some European cuisine. Because of their important position in the evolutionary history of vertebrates, they are common subjects for study and dissection in college science classes.

The nutritious, slow-swimming lampreys are also a valued food for some predator and scavenger species (Close et al. 1995, Hammond 1979). Many other fishes eat lamprey eggs and early emerging larva. Older ammocoetes may be partially protected from predators by an unpalatable skin, residence in burrows, and a tendency to leave their burrows only at night (Pletcher 1963). Adults of anadromous species are eaten in the ocean by marine mammals and larger fish (Beamish 1980). Lampreys appear to be targeted by some mammalian and avian predators during migrations to and from the ocean (Roffe and Mate 1984, Merrell 1959). Adult lampreys die after spawning, feeding scavenger species like sturgeon and contributing rich nutrients to freshwater ecosystems. Observations of lampreys made at Willamette Falls in the 1800s and on the Fraser River in the 1948s indicate that lampreys were historically extremely abundant at some times of the year (McDonald 1894, Pletcher 1963) and possibly their declines have lead to imbalances and disruptions in natural predator-prey systems and nutrition cycles.

Oregon has two familiar lamprey species. The Pacific Lamprey (*Lampetra tridentata*), with a distribution along the coast and inland to the Snake River Basin (Figure 1), is a large, parasitic species and has received the most management and research attention. This species was listed as an Oregon State sensitive species in 1993 due to a perceived serious decline in abundance since the 1950s (Weeks 1993, Close et al. 1995) and was given further legal protected status by the state in 1997 (OAR 635-044-0130). The little, non-parasitic Western Brook Lamprey (*Lampetra richardsoni*), with a coastal distribution and inland in the Columbia Basin to the confluence of the Snake River (Figure 2), is also recognized as a familiar species but has received little attention. Additional species have also been described in Oregon. The 1995 status review of native fish species in Oregon, conducted by Oregon Department of Fish and Wildlife (ODFW), recognized four species of lamprey in the state (*L. tridentata, richardsoni, lethophaga*, and *ayresi*) (Kostow 1995). There are additional enigmatic groups: some are formally described species but may be local variants of other species, others may be new, undescribed species. One species, the little Miller Lake Lamprey (*Lampetra minima*) was declared to be extinct in the 1970s as a result of an intentional eradication program conducted by the state of Oregon (Bond and Kan 1973). The species was rediscovered in the upper Klamath basin in the late 1990s (Lorion et al. 2000).

Species Identification Challenges:

Lamprey taxonomy and field identification has always been difficult. Species are generally identified based on adult characteristics. The most commonly used traits are adult tooth patterns and adult life history traits. The major life history traits that influence taxonomy includes parasitic verses non-parasitic, and anadromous (or adfluvial) verses resident. Spawning adult size may also be an identifying characteristic (Beamish and Neville 1992, Lorion et al. 2000).

But lampreys are adults for a relatively short period of their lives. Some species, such as the River Lamprey *L. ayresi,* are rarely seen in freshwater even if they are abundant (Beamish 1980, Beamish and Youson 1987). Juvenile lampreys, called ammocoetes or larva, are small, worm-like and eyeless, with small filter-feeding mouths, delicate gill slits and narrow fins. On casual observation they are nearly identical across all *Lempetra* species. Field keys for ammocoetes of Pacific Northwest species have been developed (Richards et al 1982) but they are based on subtle variations in color that have been unreliable across the range of the species. Efforts to improve the keys are underway (Bayer et al 2001). Meanwhile, ammocoetes are the most frequent life stage observed during abundance monitoring making status assessment of different species difficult.

Older ammocoetes undergo an extensive metamorphous. In a parasitic species this change leads to a life stage of parasitic feeding. In nonparasitic species the change results in a reproductive adult. The process of change can be very protracted. It begins with a year or more of retarded length growth while lipids are accumulated (Potter 1980). Near the end of that period the lamprey stops feeding and begins an extensive morphological and physiological transformation that may take from two to eight months depending on the species. All species develop eyes and more distinctive fins at this life stage. Their naso-pineal organ, sensitive to light and chemical stimulus, enlarges. The shape of the head, especially the oral disc, enlarges. As appropriate by species, there are changes in the gills, in the gut, in blood chemistry and osmoregulation, and development of the gonads (Pletcher 1963). If the species is parasitic, the rasping teeth begin to develop and at the end of metamorphous the lamprey is parasitic. If the species is adfluvial or anadromous downstream migration occurs late in this period and at the end of metamorphous the anadromous lampreys have physiologically adapted to salt water. During the process of metamorphism, characteristics are changing and can be misleading causing field identification mistakes. Most commonly, some parasitic lampreys species at early states of metamorphism are mistaken for adult brook lamprey because they have eyes but development of their parasitic oral disks is still incomplete. However, lamprey at late stages of metamorphism can be more readily assigned to species.

More difficult, the taxonomy of the genus is unsettled. Within *Lampetra*, closely related species occur in groups called “paired”, “sister” or “satellite” species. Oregon has two lamprey groups that correspond to two subgenera. These can be distinguished by adult tooth pattern and also by conserved molecular genetic markers. Subgenus *Lampetra* includes the Oregon species *L. ayresi* (which is parasitic), *L. richardsoni*, and *L. pacifica* (which are both nonparasitic). All other Oregon species are in the subgenus *Entosphenus* (Docker et al 1999). Species within a subgenus can be very similar during metamorphism until the teeth of the parasitic forms are well developed. Mistakes of identity can even occur between subgenera during early stages of tooth development. Adults within a subgenus that have similar life histories also can be difficult to distinguish and species have been split, grouped and split again in the systematics literature. Species within a complex may be differentiated primarily by adult size at spawning (Lorion et al. 2000). There is a question as to whether parasitism is a clear species characteristic, or whether it may be facultative in some cases (Beamish and Withler 1986, Beamish 1987). *Lampetra tridentata* has been demonstrated to be unable to persist exclusively in freshwater after access to the ocean is blocked (Wallace 1978, Beamish and Northcote 1989) while in other references, freshwater resident *L. tridentata* are described in basins with no access to the ocean (Pletcher 1963, Lorion et al. 2000).

Molecular genetics data and some morphological variation suggests that species within some complexes may interbreed occasionally, or have done so in the recent past, or that some species are polyphyletic (Kan 1975, Lorion et al. 2000). One of ODFW's management actions is to describe conservation groups for management. This is difficult to do when taxonomists cannot even agree on basic species identity.

Life history data that applies specifically to Oregon lamprey, or indeed to the genera and species in the Pacific Northwest, is scant. Most basic life history studies have been of the Sea Lamprey, *Petromyzon marinus,* in the Great Lakes. The following species and life history discussions, based on the literature plus observations by ODFW staff, take a conservative approach with the understanding that further investigations to clarify species identity, population structure within species, basic life history and basic ecology are warranted.

Early Life History

Ammocoetes from different species are difficult to distinguish. Therefore life history descriptions tend to be generalized across all species (Potter 1980, Moore and Mallatt 1980). An exception is the detailed observations of Western Brook Lamprey (*L. richardsoni*), and to a lesser extent Pacific Lamprey, made by Pletcher (1963). The major difference noted between species is the duration of the ammocoete stage. A general description of ammocoete behavior and habitat use is provided here with specifics by species, to the extent they are known, presented below. The following descriptions largely follow Pletcher (1963) and Potter (1980).

Lamprey eggs are sticky and dense and are deposited in redds by spawning adults. Upon completion of a redd the eggs are buried beneath sand and gravel. The length of egg incubation appears to be influenced by temperature, and perhaps varies by species, and lasts between ten and twenty days. Upon hatching early larva spend another week to a month in the redd. They eventually emerge from the natal redd at night and move downstream to areas with fine silt deposits and a mild current where they burrow into the silt. At this age they are about 10 mm long. Successful spawning grounds appear to be those located in riffle/gravel areas close to pools or other silt deposits so that the initial movement into burrows by the tiny larva is successful. The burrow is U-shaped, with the lamprey's mouth at the surface of one end from where it filter feeds.

For the next three to seven years (depending on species and regional variation) lamprey ammocoetes will remain in burrows filter feeding on algae, mostly diatoms. They will move gradually down stream, moving primarily at night, seeking courser sand/silt substrates and deeper water as they grow. Older ammocoetes tend to accumulate in lower basins and flood plains. Growth rate may vary seasonally, influenced by water temperature and food supply. The most rapid increase in length occurs in the first years during which ammocoetes of most species reach about 10 cm in length. Lipid accumulation begins at about that size, and growth rate in length declines, in preparation for the non-feeding period of metamorphism. The age of ammocoetes is very difficult to determine because the species lack bony structures. Statoliths have been used to determine ages by some authors who found no significant differences in the length frequencies of several older age classes of ammocoetes (Beamish and Medland 1988, Beamish and Levings 1991).

Courtship and Spawning

Courtship and spawning behaviors of northwest lampreys have been described for only a few species and in some cases only in captivity. Pletcher (1963) described these behaviors for Western Brook Lamprey, *L. richardsoni*, in both captivity and the wild, and for Pacific Lamprey (*L. tridentata*) mostly in captivity. Beamish (1980) described the behaviors for captive River lamprey (*L. ayresi*). There is enough similarity between these descriptions that a single discussion is provided here.

Courtship occurs on spawning gravels and involves nest-building and mutual displays that are tactile and probably chemical. Solitary males, and perhaps some females, may begin by preparing multiple rudimentary nests. Either gender may initiate courtship by way of a “courtship glide”, where one lamprey slithers along the body of a prospective mate. A receptive mate will accompany the initiator to the rudimentary nest. Initial nests may be communal, occupied by as many as a dozen individuals of both genders. Pletcher (1963) believed that receptive females emitted a chemical stimulus that attracted other lamprey. Communal courtship generally breaks into pairs or smaller groups and disperses to separate nests before actual spawning begins. The female lays in the rudimentary nest and undulates while the male performs most of the nest building. Lamprey will carry smaller rocks to the edge of the nest in their oral disks. Larger rocks may be pushed, and finer substrates may be moved by rapid swimming motions.

When the lampreys are ready to spawn the male grasps the female by the back of her head and twists his tail around her. They vibrate together depositing eggs and burying them. Spawning is mostly done by pairs, but may include additional lamprey. Both polygamous and polyandrous group matings have been observed. A female will deposit about 100 to 500 eggs in each spawning bout. Between bouts, the female rests while the male departs briefly. He resumes nest building upon return, enlarging the nest upstream so that previous egg deposits are undisturbed. Another spawning bout will be followed by another rest. A female probably deposits all her eggs in about 12 hours.

Most authors believe that all lamprey die soon after spawning. The extreme physiological changes, in particular the atrophy of the gut and the filling of the body cavity with gonadal materials, seems to make life after spawning unlikely. Females have been described as living only a few hours to a week after spawning; males perhaps for a few weeks. However one author observed out-migration of several hundred apparently robust lamprey kelts on the Olympic Peninsula and detected a repeat spawning run by two marked individuals the following year (Michael 1980). ODFW staff and volunteers on the south Oregon coast believe they have seen out-migration after spawning by some lamprey.

Pacific Lamprey *Lampetra tridentata*

Pacific lamprey is a member of the subgenus *Entosphenus*. It has the widest world distribution of any lamprey species in Oregon, ranging around the Pacific Rim from Japan and Korea to southern California, and inland in the Columbia Basin to parts of the Snake River Basin (Lee et al 1980) (Figures 1 and 3). It is the largest lamprey, as adults, in Oregon and it is the only species that is harvested. Fisheries target fresh, migrating adults.

Pacific Lamprey is an anadromous, parasitic species with the period of parasitism occurring in the ocean. Ammocoetes live in fresh water where they are burrowing filter feeders. Lampreys undergoing metamorphism and spawning adults do not feed.

A general growth pattern for Pacific lamprey is shown in Figure 4. They emerge from spawning gravels at about 1 cm length. Ammocoetes will grow to 17 or 18 cm, based on measurements taken by ODFW staff in a coastal (Rogue) and a Columbia basin (Umatilla) river (Figure 5). The upper range of ammocoete sizes published in the literature include 17 cm (Beamish and Levings 1991), 16.5 cm (Hammond 1979), and 15.8 cm (Kan 1975). Beamish and Levings (1991) reported that the length of older ammocoetes, aged as 5 or 6 years old by statoliths, did not differ significantly. The age of ammocoetes in Oregon is unknown and may vary regionally with older individuals in colder water or in more inland basins. Hammond (1979) believed that lamprey ammocoetes in Idaho (Clearwater River, Snake Basin) were up to 7 years old.

Metamorphism of Pacific lamprey is reported in the literature as occurring in July through November with out-migration to the ocean occurring November through June, peaking in the spring (Richards 1980, Beamish 1980, all observations in Canada). However, lampreys in apparently early stages of metamorphism have been observed by this author in the lower Columbia River (Scappose River) in early June (enlargement of the oral disc but incomplete eye development). Pletcher (1963) and Kan (1975) were ambiguous about the time of metamorphism in Pacific Lamprey, with occurrence of it observed nearly year-round. Possibly the period of metamorphism is long, or it may vary regionally. Lampreys do not feed during metamorphism since extensive changes in the gut are occurring. Rather they live on lipid reserves, and some individuals may shrink in size. Figure 5 demonstrates the large overlap in size between ammocoetes and eye lamprey. Eyed lamprey on the Rogue ranged from 11 to 17 cm, while on the Umatilla they ranged from 8 to 22 cm. Reports in the literature include ranges of 10 to 12 cm (Beamish and Levings 1991), 10 to 13 cm (Beamish 1980), 8 to 14 cm (Richards 1980), and 10 to 17 cm (Hammond 1979, van de Wetering 1998).

According to the literature, most down-stream movement by lampreys occurs at night (Potter 1980, Beamish and Levings 1991). Timing of migration may be sensitive to temperature cues. Both eyed lamprey and ammocoetes will migrate. Ammocoetes move progressively down stream, eventually accumulating in the lower parts of basins while eyed lampreys are going to the ocean (Richards 1980, Beamish and Levings 1991). Dates of out-migration of both ammocoetes and eyed lamprey, as observed by ODFW staff, are provided in Figure 6. The data is compromised in most examples because trapping did not occur in the fall or winter. The exception is the Umatilla, where monitoring occurred year-round. Out-migration on the Umatilla clearly occurs in winter to early spring, with no observations of eyed lamprey after the end of March (Figure 6a.). Out-migrating juvenile lamprey have been monitored at the John Day Dam juvenile by-pass since 1988. Time of passage is largely in the spring (Figure 6b); however, again no monitoring occurred at John Day in the winter. The Umatilla and John Day Dam monitoring sites are very near each other, since the Umatilla River enters John Day Pool. A comparison of the John Day Dam and Umatilla passage times suggests that perhaps more lamprey are passing John Day earlier in the winter but are undetected (Figure 6c). Lower in the Columbia at Fifteenmile Creek, out-migration, likely of a mix of ammocoetes and eyed lamprey, occurred March through June (Figure 6d.), while on the lower Willamette outmigration peaked in May (Figure 6e), although again in both cases there was no winter monitoring. All of these observations are probably of Pacific Lamprey.

On the Oregon coast, ammocoetes and eyed lamprey were captured well into the summer, as late as August (Figures 6f-g). These samples were likely a mix of lamprey species. One cannot dismiss the possibility that out-migration is also occurring in these basins in the winter or fall. According to van der Wetering (1998) metamorphosed Pacific Lampreys in Tenmile Creek were captured primarily in the fall and winter, peaking in November. Lampreys captured in the upper Rogue were primarily ammocoetes. Some numbers of them were moving downstream throughout the monitoring period, with two big peaks in the spring (Figure 6h.). A small historical data set from the early 1960s is available from the same area in the upper Rogue. Lampreys were present in those years in more substantial numbers well into summer (Figure 6i). The historic traps were not monitored from late fall through early spring and one cannot dismiss the possibility that lamprey were also present during those months. However the current traps were monitored through the summer but detected few lampreys.

Another interesting piece of information from the out-migration timing is the extreme episodic nature of the data. On both the Rouge and on the Umatilla, massive peaks of out-migration of both eyed and ammocoete lamprey occurred over just a few days in particular years. Such striking peaks were not seen every year. The two data sets are quite large and yet are dominated by these few episodes. These events corresponded to years with very high peaks in abundance (see discussion in the status section, below).

Pacific Lamprey enter salt water and become parasitic, feeding on a wide variety of fish and also on whales. In turn marine mammals and larger fish eat them. They move quickly off-shore, into waters up to 70 m deep (Beamish 1980). Specimens have been caught in high seas sampling. The length of time spent in the ocean is not known. Authors have estimated ocean residence could be as short as 6 months and as long as 40 months (Kan 1975, Richards 1980, Beamish 1980). Several authors speculate that Pacific Lamprey adults vary in size as distinct phenotypes and that the larger individuals are ones that move further off shore and spend more time in the ocean (Pletcher 1963, Beamish 1980). Samples of Pacific Lamprey collected in the ocean ranged from 13 to 72 cm (Beamish 1980).

Pacific Lamprey are reported to return to fresh water between April and June in Canada and on the Oregon coast (Kan 1975, Beamish 1980, Richards 1980), but are reported to enter the lower Columbia River as early as February (Kan 1975). Observations by ODFW staff indicate that lamprey peak in numbers at Willamette Falls and at Fifteenmile Creek (Figure 6d) in May and June, while coastal lamprey are present from February into August (Figure 6e-f). Long migrations, such as up the Columbia and into the Snake, can continue as late as September. After entering fresh water and completing part of their migration, Pacific lamprey are thought to over-winter before spawning. Bayer (et. al 2000) observed that adult lampreys in the John Day River, tagged upon their arrival in August, hid under boulders and were sedentary until the following March, when they moved onto spawning grounds.

Pacific Lamprey do not feed after entering fresh water and persist through the winter until spawning by using lipid reserves. Over this period they may shrink up to 20% (Beamish 1980). Therefore measurements of adult size can be variable, depending on when the sample was taken. Measurements of adults in the literature include 39.3 to 62.0 cm (migration) and 33.2 to 54.2 cm (spawning) (Kan 1975), 16.7 to 36.0 cm (Richards 1980), 61.0 to 72.5 cm (migration) (Bayer et al 2000), 13 to 72 cm (Beamish 1980), and 19.3 to 45.0 cm (Pletcher 1963). ODFW staff have measured sizes of adult Pacific Lamprey during spawning on the South Fork Coquille, south Oregon Coast (Figure 7a-b.) and at Willamette Falls during migration (Figure 7c-d.). The spawning Coquille lampreys are somewhat smaller than the migrating Willamette lampreys. Later spawning Coquille lampreys tend to be the smallest in the sample. The sex ratio at Willamette Falls was similar for males and females, and the length/weight distribution of the adults indicated the genders are of about equal size at migration.

Several authors have reported the occurrence of “dwarf races” of Pacific Lamprey in coastal streams in Canada (Pletcher 1963, Beamish 1980). ODFW staff and volunteers (L. Grandmontagne personal communication) have also reported seeing “dwarf” tridentata-like lamprey on the south Oregon coast. These are discussed further in this section under enigmatic species.

Lampreys are observed to spawn in the spring between April and July in Canada (Richards 1980, Beamish 1980), and March through May on the Oregon coast (Kan 1975). ODFW staff on the Oregon coast and in the Willamette Basin note that Pacific Lampreys are spawning at the same time as winter steelhead, from February through May. Lamprey select spawning gravels just upstream of riffles and often near ammocoete habitats (silty pools and banks). They may be attracted to chemical stimuli produced by ammocoetes. Pacific lamprey can be quite fecund, but highly variable. Estimates of fecundities reported in the literature range from 15,500 eggs/female to 240,000 eggs per female (Pletcher 1963, Kan 1975). ODFW staff have not measured lamprey fecundities.

Studies of sea lamprey (*Petromyzon marinus*) in the Great Lakes have indicated that lampreys have essentially no homing behavior (Bergstedt and Seelye 1995). In this study, marked out-migrating lampreys did not favor their own natal streams. Instead, the adults may have been attracted to concentrations of ammocoetes, detected by chemical stimuli. This has led to speculation that Pacific lamprey also have no homing behavior and therefore essentially no population structure. However, several authors have noted patterns of geographic differences in Pacific lamprey. Kan (1975) detected morphological differences between coastal and inland Columbia Basin lampreys. Both Pletcher (1963) and Beamish (1980) speak of "regional differences" among lamprey. Hammond (1979) noted that lamprey in the Snake River, an extreme inland population, may have a longer freshwater residence as juveniles than what is reported for other populations. Certainly there are behavioral differences between lamprey that migrate only a few kilometers up a coastal stream, compared to one that migrates clear to the Snake River. Some of the variation may be environmental. Growth patterns and many behaviors are reported to be sensitive to temperature (Pletcher 1963, Potter 1980). The lampreys that were studied by Bergstedt and Seelye (1995) were exotic to the study area, and lived entirely in freshwater, and of course it was a different genus. It is not clear how the results extrapolate to lamprey in their native Pacific northwest habitats.

Western Brook Lamprey *Lampetra richardsoni*

The non-parasitic Western Brook Lamprey is in the subgenus *Lampetra*. It is recognized as the second most common and widely distributed lamprey in Oregon (Figures 2 and 8). Coast-wide, it's distribution ranges from California to British Columbia (Lee et al 1980), and it is reported inland in the Columbia basin as far as the Yakima. ODFW staff has no information about this species, although some brook lamprey are likely included in samples of ammocoetes and eyed lamprey collected in the lower Columbia River and on the coast. Fortunately, very detailed life history and behavior observations of Western Brook Lamprey were made by Pletcher (1963) on a small tributary of the lower Fraser River in Canada. The following information is entirely based on this work. Many of the behaviors noted are temperature sensitive and dates of occurrence may be somewhat different in Oregon.

Western Brook Lamprey spawn in the spring, producing redds in small gravels upstream of riffles. The hatching of eggs is temperature-sensitive, taking longer in colder temperatures. Hatching under the conditions observed in Canada took 15 to 20 days. Larva remain in the redds an additional 30 days until they are about 7 to 10 mm long. Emergent lampreys are eyeless, but they are very light sensitive due to a well-developed pineal gland. They emerge at night, promptly moving to silty areas to burrow. After they enter their first burrows they develop a protective mucus layer over their skin and their skin becomes very distasteful. These characteristics, plus their tendencies to move at night, provide considerable protection against predators.

Brook lampreys distribute themselves within a creek system according to size. Smaller ammocoetes are further upstream and are in finer silt deposits and in shallower waters. They require gentle currents, but not stagnate water. Larger ones migrated gradually down stream, choose substrates that are more sandy and rich in organic litter, and tend to be in deeper waters. Like all known lamprey ammocoetes, they are filter feeders with a diet that is largely diatoms. Growth is most rapid in the first 1 to 3 years. Older ammocoetes grow much slower. In the year before metamorphous, some may not grow at all or may shrink in length (Figure 9). This growth pattern makes aging ammocoetes very difficult. They likely undergo metamorphism after four to six years.

Western Brook Lampreys in Canada undergo metamorphism between August and November. During this stage they are in burrows in water that is deeper than 1 meter and they do not feed. During this several months of rapid change the lampreys develop their eyes, there is enlargement of the oral disc, changes in the gills, and enlargement of the naso-pineal gland which is used for light and chemical detection. Internally there is a reduction of the gut. Development of the gonads occurs later, closer to spawning.

After this few months of rapid change the Western Brook Lampreys apparently enter deep burrows and become dormant. They remain in these burrows from December to March, or until they are ready to spawn. Readiness to spawn is temperature sensitive and they will remain burrowed until water temperatures rise above 10 degrees C. When they emerge they are sexually mature and range in size from 8 to 17 cm. They may migrate short distances to spawning gravels then promptly begin courtship, nest building and spawning. Spawning occurs from April to July in Canada. Fecundity, measured in the Willamette Basin, ranged from about 2,500 to 5,500 eggs per female (Kan 1975). After spawning the lampreys die. Females die about a week after all their eggs are deposited. Males may live a month after spawning.

Western Brook Lampreys appear to move about very little during their lives. The most notable movement is passive downstream movement when they leave their burrows. Brook lampreys have not been tested for saltwater tolerance, but the anadromous lampreys are only tolerant at the end of their metamorphism when they actually enter the ocean. At the end of metamorphism brook lampreys are ready to spawn and it is likely they are never saltwater tolerant. This combination of low vagility and probable saltwater intolerance is likely to have produced significant population structure among Western Brook Lampreys, especially along coastal areas. Many populations are likely in complete isolation and have been so for thousands of years.

River Lamprey *Lampetra ayresi*

The small parasitic River Lamprey is in the subgenus *Lampetra*, and is the sister-species of the Western Brook Lamprey. The distribution of River Lamprey extends from the Sacramento River to SE Alaska, and inland in the Columbia River to the Columbia Gorge (Figure 10) (Kan 1975, Lee et al 1980). ODFW staff do not believe they have observed this species in many years and have no information about it. This lack of observations may be because the species is very rare, but another factor is likely that the species is very difficult to find in fresh water (Beamish 1980, Beamish and Youson 1987). River Lampreys spend most of their life in fresh water. However, except for the changes that occur during the last six months to one year of life, *ayresi* and *richardsoni* are indistinguishable. This similarity holds even through most of the period of metamorphism. In the spring following metamorphism, Western Brook Lamprey emerge from burrows ready to spawn while the River Lamprey finally complete development of their feeding oral discs and enter the ocean to feed. During the brief periods that River Lamprey are distinctive in fresh water they are not seen, probably because they are in deep water habitats in the mainstems of larger rivers (Beamish and Youson 1987).

The little information that is available about River Lamprey is from observations in the Fraser River and Georgia Straight in Canada (Beamish 1980, Beamish and Youson 1987). No information is available about their early life history, nor is the duration of this period or the habitats in which it occurs known.

Metamorphism occurs over a very long period, from July to April. Their distinctive oral disc is the last feature to develop and is completed just before the lampreys enter the ocean. By that time the lampreys have apparently entered main river channels and are in deep waters, three to six meters deep, just upstream of saltwater influence. At this time they may be caught in freshwater trawls low in river mainstems (Beamish 1980). They are about 12 cm long. They have also been found in samples of dredge spoils from the Fraser River. They are only found in spoils that were taken from sandy substrates high in organic material from the mainstem of the river.

River Lamprey enter salt water between May and July and promptly begin feeding. In the ocean, they are strictly surface-feeders and are not caught in mid-water or deep-water sampling. They remain very close to shore; in Canada they never leave the Georgia Straight and are found mainly near the mouths of the rivers that produced them. Their main diet is of smelt and herring. They may be more predatory than parasitic, consuming large parts of their prey. They also may be scavengers since they readily feed on dead fish. River Lamprey remain in the ocean for only about ten weeks. They leave salt water in September when they are about 25 cm long (Beamish and Youson 1987). It is assumed they spawn the following spring, although adults are almost never seen in freshwater. Kan (1975) reported spring spawning in Oregon and California and provided fecundity measurements ranging from 11,400 to 174,000 eggs per female, taken from the Columbia and the Sacramento.

Beamish (1980) noted that River Lamprey production appears to be concentrated only in particular rivers. They appear to prefer larger rivers, including the Fraser, Columbia and Sacramento (Kan 1975), although samples have also been taken from smaller Oregon coastal streams (Figure 10). Since they do not move far from the estuaries of their natal rivers when they are in the ocean they probably return to those rivers to spawn so that the River Lamprey likely has a considerable degree of population structure.

Enigmatic Lamprey Species on the Oregon Coast and Lower Columbia

A third lamprey species in the subgenus *Lampetra* has been described by Vladkov (1973), the Pacific Brook Lamprey (*Lampetra pacifica*). This species has a described distribution that includes Oregon and northern California (Vladkov 1973, Lee et al 1980).

The species was described based on morphological differences between *pacifica* and *richardsoni*, with particular emphasis of a difference in the number of trunk myomeres between the species (fewer in *pacifica*). Adult Pacific Brook Lamprey were described as ranging in size from 9 to 17 cm (pre-spawning), shrinking to 9 to 14 cm at spawning.

Samples of this species are in the Oregon State University (OSU) fish collection (Figure 11), collected from the Willamette River and Oregon coast. Kan (1975) disagreed with Vladkov (1973) and did not believe *pacifica* was distinctive from *richardsoni*. The American Fisheries Society believes the two species are synonymous based on Kan's argument. However the amount of actual information on this subject in Kan (1975) is very scant and is apparently based on his re-examination of some of the OSU collections. In particular, he did not re-examine any of Vladkov's original collections.

Two other enigmatic lampreys are present on the south Oregon coast. One is an apparently very small non-parasitic lamprey. It has been observed by this author and by other ODFW staff in coastal streams from about the Coquille River south. Observations have been of tight balls of perhaps 15 to 20 small adults less than 10 cm long. These have been disturbed during electroshocking from under stream banks and logs in steep gradient streams – not from expected brook lamprey spawning habitats. There is no mention of such a small lamprey in such habitats or in such large aggregations in the literature.

The second enigmatic "species" is a small parasitic *tridentata*-like lamprey that has been closely observed in the Coquille River. Siletz tribal members also described a second small lamprey on the Oregon coast (Downey et al 1993). The oral discs and dentition of these smaller lamprey are similar to those of Pacific Lamprey. Initially these smaller adults were dismissed as shrunken spawning or post-spawning Pacific Lamprey that appeared "small" in comparison with fresh migrating adults. However, closer observations by ODFW staff and volunteers (L. Grandmontagne personal communication) indicate that both the larger and smaller parasitic adults are spawning in the same season. In these observations, the larger lamprey spawns first and then dies while the smaller one spawns a bit later and then migrates back downstream. A photograph of the two lampreys, both spawners, taken by an ODFW volunteer on the Coquille, is shown in Figure 12. The larger specimen is about 55 cm long while the smaller one is about 37 cm long.

"Dwarf" Pacific Lampreys have been described in Canada as being in the lower portions of coastal streams by both Pletcher (1963) and Beamish (1980). These included even smaller adults, as small as 13 to 20 cm (Pletcher 1963, Richards 1980, Beamish 1980). Beamish further speculated that some of these may spawn the same spring they enter freshwater, which would be a very unique life history. The observation by ODFW staff that the smaller lamprey migrate back to the estuary echoes the observations of Pacific Lamprey kelts described on the Olympic Peninsula by Michael (1980). Different sizes of spawning adults have been identified as a reproductive isolating mechanism between otherwise very similar species (Beamish and Neville 1992, Lorion et al. 2000). The rational is that the spawning behavior, where the male lamprey adheres to the head of the female and wraps his tail around her body, is effective at achieving fertilization only when the male and female are of similar size. Most measurements within a population of *tridentata* have demonstrated similar sizes of males and females (for example, Figure 7d).

This author believes that each of these enigmatic coastal lampreys merit further taxonomic investigation.

Pit-Klamath Brook Lamprey *Lampetra lethophaga*

The nonparasitic Pit-Klamath Brook Lamprey is a member of the subgenus *Entosphenus* and is considered to be the nonparasitic sister species of the Pacific Lamprey. The described distribution of this species is the upper Klamath Basin above Klamath Falls in SE Oregon and the upper Sacramento Basin, including the Pit River in northern California and Goose Lake Basin in SE Oregon (Lee et al 1980). Collection locations from Oregon are shown in Figure 13. Kan (1975) stated that this species might have a polyphyletic origin, although specific reasons for this were not given. Genetics investigations conducted by ODFW, in cooperation with Dr. Margaret Docker, indicate that the populations in Goose Lake Basin and Klamath Basin are likely different species. The Goose Lake lampreys are discussed separately below.

The life history of this species is unknown, beyond being nonparasitic, apparently resident with filter feeding ammocoetes. Kan recorded ammocoetes up to 20 cm. This species appears to have a long period of metamorphism (Kan 1975). It likely spawns in the spring, although Kan described reproductive individuals as being present into October. Fecundity measurements ranged from 900 to 1,100 eggs per female. Adults are described as being 10 to 20 cm in length (Kan 1975).

Klamath River Lamprey *Lampetra similus*

The parasitic Klamath River Lamprey is a member of the subgenus *Entosphenus* and is a sister species of the Pacific Lamprey. The described distribution of this species is the upper Klamath Basin, down river to Copco Dam (Lee et al 1980). Collection locations from Oregon are shown in Figure 14.

Details about the life history of this species are largely unknown. It is parasitic and non-anadromous. It may include resident, riverine individuals as well as those that are adfluvial into lakes, reservoirs and marshes. Kan (1975) (who believed this was a subspecies of *tridentata*) described the ammocoetes and metamorphosing life stages to be very much like *tridentata*. However adults are much smaller, ranging in size from about 16 to 30 cm (Kan 1975, Lorion et al 2000). Kan (1975) believed they metamorphosed in the fall, were parasitic in Klamath Lake for about 12 to 15 months, and spawned in the spring. He measured fecundities ranging from 8,000 to 18,000 eggs per female.

Miller Lake lamprey *Lampetra minima*

The infamous little Miller Lake Lamprey is a member of the subgenus *Entosphenus*. It appears to be most closely related to the nonparasitic *lethophaga.* This species was originally believed to be endemic to the Miller Lake subbasin, a lake/creek system that was isolated from the rest of upper Klamath Basin about 6,600 years ago by the Mount Mazama eruption (Figure 15). The only other fish naturally present in Miller Lake was the Tui chub (*Gila bicolor*), which was the natural host for this small parasitic lamprey (Kan 1975, Lee et al 1980). The species, and it's tui chub host, were intentionally extirpated from Miller Lake by Oregon Department of Fish and Wildlife in 1958 through chemical treatment of Miller Lake with Toxaphene. The reason for the treatment was that the lampreys were scaring hatchery trout that had been planted in the lake, leading to complaints from sports fishers. The species was formally described in 1973 using old collection samples and was declared extinct (Bond and Kan 1973).

The Miller Lake Lamprey in Miller Lake is considered to have been one of the most unique lamprey in the genus. Unlike any other parasitic lamprey, adults were smaller than late-stage larva. At metamorphism the lamprey were about 14 to 15 cm, but by the time they reached spawning they were only about 9 to 11 cm (Bond and Kan 1973, Kan 1975, Lorion et al 2000). This shrinkage during the parasitic phase, a time of extensive growth in all other parasitic lamprey, was thought to occur because the tough, scaly tui chub was difficult prey for the little lamprey. Miller Lake Lampreys were thought to also be scavengers and cannibalistic; basically eating whatever was available. Possibly they were also able to spawn without ever feeding, although they were always capable of feeding unlike a true nonparasitic lamprey. The parasitic phase was very brief, lasting only three or four winter months between a fall metamorphism and spring spawning. Migration either did not occur, or was over a very short distance. Fecundities were low because of their small size, ranging from 500 to 725 eggs per female. They were largely lacustrine, with lentic spawning and ammocoetes rearing in the lake, although adfluvial members also used Miller Creek (Kan 1975).

The Miller Lake Lamprey was rediscovered in the 1990s in several separate incidences by US Forest Service and Oregon State University (OSU) staff. The species was redescribed and declared to be extant with an expanded distribution that includes Miller Lake basin, upper Klamath Marsh and the Klamath River above the marsh, and Sycan Marsh and the Sycan River above the marsh (Lorion et al 2000). It is not known whether all the unique life history characteristics described as occurring in Miller Lake by Kan (1975) are present when the species resides in marshes or riverine habitats.

Enigmatic Lamprey Species in Klamath Basin

There are two other species recognized in the upper Klamath Basin, in addition to *lethophaga, similus* and *minima.* Both are in the subgenus *Entosphenus.*

The first of these is the nonparasitic lamprey *Lampetra folletti,* described by Vladykov and Knott (1976) but not otherwise known. The distribution of this species is described as Lost River and the Klamath Basin around lower Klamath Marsh near Klamath Falls. The interesting morphological features of this species is its large size and an oral disc and dentition that is more highly developed than in most other nonparasitic species. Adult sizes range from about 18 to 23 cm, which is larger than *lethophaga* (Figure 16). Kan (1975) was unaware of this species but did describe several specimens that he thought were deviant from other Klamath lampreys. These were larger than *lethophaga* and because of their more highly developed dentition he thought they might be parasitic, although he was not sure. One of these was collected from Goose Lake Basin.

It is currently not known whether *folletti* is present, or ever was present. OSU does not have any specimens of these in their collections; Vladykov's collections are at the University of Ottawa, Canada. Lost River, an isolated subbasin of Klamath Basin, has been known to have other endemic species such as the Lost River Sucker (*Deltistes luxatus*). It is a highly developed and impacted basin due to agricultural and irrigation development. An investigation into the existence of this species is warrented.

The second enigmatic species is a relatively large parasitic species currently called *Lampetra tridentata* (Lorion et al 2000) but likely a separate species. It is entirely freshwater while true *tridentata* typically will not persist when it is blocked from saltwater migrations (Wallace 1978, Beamish and Northcote 1989, and observations by ODFW staff). This species is the largest lamprey in Klamath Basin, although it is much smaller than the *tridentata* on the Oregon coast or in the Columbia Basin, with adults ranging in size from about 15 to 25 cm. It is parasitic and adfluvial, migrating into Klamath Lake. It seems to be primarily in the lower Sprague River. Other details of its life history are not known.

Genetics evidence from Dr. Margaret Docker indicates that the entire complex of Klamath lampreys are capable of occasional interbreeding, or that hybrid events occurred in the past. The morphological and life history characters of the various species appear to be stable for the most part. However, Kan (1975) thought he detected intermediate forms that suggested to him a polyphyletic origin for at least some of the species and he thought they might be capable of hybridizing. Docker's work discovered that variation at highly conserved gene regions that are typically good species markers were shared across some species and were variable within some populations (also Lorion 2000). In some cases, local populations were remarkably polymorphic at gene regions that otherwise do not vary across entire species.

The Klamath Basin is the most species-diverse basin in Oregon for lamprey, and the species are largely endemics. Further monitoring and investigation of these species is warranted.

Enigmatic Lampreys in Goose Lake Basin

Goose Lake Basin is a land-locked Great Basin in southeastern Oregon that was historically affiliated with the upper Sacramento Basin in California. It is known to contain both parasitic and nonparasitic lampreys in the subgenus *Entosphenus*.

Nonparasitic lampreys are also known from the Pit River (where they are called *lethophaga*), which is south of Goose Lake, but the parasitic form is endemic to Goose Lake Basin. The Goose Lake lampreys have been variably identified as *lethophaga*, *similus*, *tridentata* or some combination of these. Oregon Department of Fish and Wildlife began a taxonomic study of this group in the mid-1990s, working with Dr. Margaret Docker. The results indicate that the Goose Lake lampreys comprise one or two unique species that are not yet named. The Goose Lake lampreys were listed as Oregon State sensitive species in 1993 and given further state protection in 1997 (OAR 635-044-0130).

If the Goose Lake Lampreys were a single species it would uniquely include both parasitic and nonparasitic life histories. Such a condition has been proposed for a Canadian lamprey (Beamish and Withler 1986, Beamish 1987). However the large size differences between parasitic and nonparasitic breeding adults, which is observed in Goose Lake Basin, is generally thought to reproductively isolate such dissimilar groups (Beamish and Neville 1992, Lorion et al. 2000). One proposal is that the parasitic life history is facultative and is expressed only when environmental conditions permit migrations to Goose Lake or basin reservoirs where the lamprey can feed on fish; otherwise the lamprey can spawn without feeding as adults. However, unlike the Miller Lake Lamprey, which may also be able to breed without parasitic feeding, the nonparasitic Goose Lake Lampreys look like and behave like true brook lampreys rather than like distressed parasitic lampreys. Actively feeding parasitic lampreys were observed in streams by ODFW staff during the severe drought of the early 1990s when all access from streams to Goose Lake was lost due to low water, although they were difficult to find and appeared to be rare. Parasitic individuals became much more abundant when Goose Lake refilled and they began accompanying the adfluvial Goose Lake redband trout, a preferred host species, back and forth to Goose Lake from Thomas Creek.

Much of the life history of this (or these) species is largely unknown. Some information has started to become available during investigations in the 1990s to current. Ammocoetes are filter-feeders in the upper tributaries of Goose Lake. Specimens between about 1 cm and 15 cm have been collected by this author from burrows in fine silt lenses along low gradient stream meanders, most often through meadows, in upper Thomas Creek. Lampreys in early stages of metamorphism have been observed in October. Migrations, when they occur, appear to occur in the spring (Figure 19), including both downstream migrations to Goose Lake and upstream migrations of adults. Parasitic adults are able to feed while in streams. Eyed individuals, which may be out-migrating lamprey or adults, are as small as 8 cm. Obviously parasitic adults are about 19 to 21cm (Figure 20). This author has observed spawning by nonparasitic adults in May. Spawning occurred in clean shallow water over small gravels near areas where ammocoetes were rearing.

Completion of the taxonomic investigations and further studies of the life history and ecology of these unique lampreys is warranted.

Other Records of Lamprey in Oregon

Lamprey have been collected in two other locations in Oregon that are outside of the ranges of the species discussed in this report. A nonparasitic lamprey was collected in the 1930s from Chickahominy Reservoir in Silver Creek subbasin in the Malheur Lakes Basin. The collectors considered this lamprey to be a *richardsoni*. The Malheur Lakes Basin is a closed Great Basin with historic connections to the Malheur River in the Snake Basin. The second collection occurred in the 1990s from Thompson Reservoir in the Fort Rock Basin. This lamprey was thought to be a *tridentata*. Fort Rock Basin is a closed Great Basin with unknown historic connections to other basins.

ODFW staff determined that the Thompson Reservoir specimen was likely planted along with a batch of hatchery trout. Lampreys can occasionally enter hatchery raceways through the water intakes. It is likely that the Chickahominy sample came from a similar event. Both reservoirs are artificial water bodies with a history of substantial annual trout stocking. No other lampreys have ever been seen in either basin.

Chapter 2

Status of Oregon Lampreys

Introduction:

The status of Oregon lampreys is very difficult to assess for several reasons. The first reason is that the field identification of lamprey has been difficult so that abundance or distribution data that has been collected is most often generically attributed to "lamprey" and species-specific information is not available. The second reason is that there has been little effort directed at collecting lamprey data. Most data is collected incidental to monitoring salmonids. Therefore the monitoring stations and methods are not designed for the efficient sampling of lamprey, especially of lamprey adults. Also, the locations and timing of monitoring activities are appropriate for salmonids, but not necessarily for lampreys. And finally, there is very little historic data about lamprey. ODFW staff began collecting more data on lamprey in the late 1990s after the state sensitive species listing of Pacific Lamprey, but it is generally impossible to place the current data into any context of an historic trend.

Anecdotal historic observations indicate that lamprey were very abundant, at least periodically. The first observation of lamprey abundance in Oregon was at Willamette Falls in the 1800s. An observer from the United States Fish Commission recorded: "At the falls of the Willamette River, near Oregon City, Oregon, on June 23, the rocks at the particular part of the falls where salmon ascend were at times completely covered with lampreys. In places where the force of the current was least, they were several layers deep, and at a short distance the rocks appeared to be covered with a profuse growth of kelp or other water plants," (McDonald 1894). Likewise on the Fraser River in Canada: "In 1948 it was reported that masses of lampreys formed mats along the walls of Hell's Gate Canyon and Lillooet Rapids to a depth of at least a foot of entangled bodies," (Pletcher 1963). No "masses of lampreys" have been seen anywhere in many decades indicating significant abundance declines.

Most Oregonian's first experience with lamprey occurred in the fish ladder observation window at Bonneville Dam. As recently as the early 1980s, "a lot" of adult Pacific Lamprey, if not "masses" of them, could be seen clinging by their sucker mouths to the windows. Devises were installed in the Columbia River dam fish ladders to keep them away from the counting windows because they were at times thick enough to interfere with counting salmon (Ocker et al 2001). Lampreys are rarely seen at these windows these days, again indicating abundance declines.

The first alarm that something was seriously amiss with lampreys came from tribal members on the Oregon coast and the inland Columbia Basin. Lampreys have been harvested for food by Northwest tribes. Tribal elders recall that lampreys were abundant and easy to catch when they were younger but by the 1990s they had become very rare (Downey et al 1993, Close 1995).

The only attempt at a quantitative estimate of "historic" lamprey abundance was made in Canada in the 1970s. Both Pacific Lampreys and River Lampreys were called "abundant", with an estimate of over half a million feeding adults of each species being produced in Canadian rivers, primarily in the Fraser River (Beamish 1980, Beamish and Youson 1987). Pletcher (1963) found Western Brook Lampreys to be very abundant and easy to find and observe in his study stream, a tributary of the lower Fraser, in the early 1960s. ODFW has a few historic data sets on lamprey abundance, mostly associated with dam counts, harvests, other trapping or fish kills. These sets are discussed below, along with data from the 1990s by region of the state.

One interesting attribute of the scant quantitative data is that it indicates that lamprey abundance can fluctuate wildly from year to year. One study in Canada monitored lamprey abundance in a tributary of the Thompson River in the Fraser Basin and noted that abundance in one of three consecutive years of measurement was over 9 times that seen in other years (Beamish and Levings 1991). ODFW has also noted large variations in abundance, both from year to year and from one location to another. For example, a few tens or hundreds of lampreys may be regularly observed in a network of smolt traps, until suddenly over a couple of days in one year, or in some particular location, several thousands will be observed. The dynamics of lamprey populations, and the distribution of lamprey production appears to be somewhat mysterious, making interpretation of the little quantitative data that is available difficult, especially since most of it has not been systematically collected.

Status of Lampreys in the Inland Columbia Basin (Oregon Subbasins)

SPECIES: PACIFIC LAMPREY (*LAMPETRA TRIDENTATA*) AND WESTERN BROOK LAMPREY (*L. RICHARDSONI*)

Pacific Lampreys were historically present in the inland Columbia Basin well into the Snake River basin while Western Brook Lampreys were historically present up to the confluence with the Snake River. The range of both species in this area appears to have declined.

Lampreys are entirely absent above several major artificial blockages in the inland Columbia Basin. These blockages include the Hells Canyon dam complex on the mainstem Snake, the Pelton/Round Butte dam complex on the Deschutes, and Powerdale Dam on the Hood River, even though there is a fish ladder at Powerdale that successfully passes other fish species. There are no records of historic lamprey in some of these basins but they were likely present since they are known to occur up to the dams. Pacific Lampreys were definitely collected from the Crooked River in the upper Deschutes Basin (Figure 3).

The distribution of lampreys in unblocked basins in the Inland Columbia Basin also appears to have decreased since they are apparently absent in many basins. In 1999, staff from the Umatilla tribes conducted a detailed presence/absence survey of lamprey in the John Day, Umatilla, Walla Walla, Tucannon, and Grande Ronde basins (Close and Bronson 2001). They found Pacific Lampreys throughout the John Day basin, except for several survey stations in the upper South Fork and the very upper North Fork. But Pacific Lampreys were observed only in the lowest reaches surveyed in the Umatilla, Tucannon and Grande Ronde basins, and they were rare in these areas. No Pacific Lampreys were seen in the Walla Walla basin. Western Brook Lampreys were found only in one area in the South Fork Walla Walla, but were not seen in any of the other basins.

Fish inventory surveys by ODFW staff during the 1990s have detected only a few lampreys (species not identified) in the John Day, South Fork Walla Walla and Grande Ronde basins (Figure 21). Lampreys have been regularly observed in smolt traps in the lower Umatilla River and Fifteenmile Creek. However on the Grande Ronde, where smolt traps have been operational since 1997, the only capture of lampreys occurred in 2001 when 13 were observed. Pacific Lamprey adults are observed, and occasionally harvested, at Sherars Falls on the mainstem Deschutes but no lampreys have been captured in smolt traps on Trout Creek in the Deschutes basin. A summary of the apparent remaining distribution of lampreys in the Inland Columbia basin is presented in (Figure 22).

Abundance of adult Pacific Lampreys has been incidentally monitored at Columbia and Snake River mainstem dams, although not throughout the history of fish counts at these sites (Figure 23 a-c). Counts at dams are thought to be an inefficient way to estimate absolute lamprey abundance for several reasons. First, the counts occur during the day while lampreys migrate more often at night. Recently fish counts have included night video taping, but this requires the use of lights in the counting area which seems to disturb the lamrpeys (Ocker 2001). Second, lampreys seem to struggle in the currents of most fish ladders and are often seen floating downstream. Such individuals may be counted multiple times introducing errors. And third, the counting stations were designed for salmon and lamprey can pass them without being detected (Starke and Dalen 1995). However, it is likely that these errors are fairly constant from year to year so that the dam counts data can provide a reasonable index of abundance trends, if not a good measure of absolute abundance. The counts at Bonneville includes one of the best historic data sets available for Oregon lamprey, extending back to 1938.

At Bonneville and The Dalles dams lamprey counts prior to 1970 were regularly at least 50,000 adults, with occasional very high peaks of several hundred thousands (Figure 23a). At McNary Dam, counts prior to 1970 were only in the few tens of thousands (Figure 23b), while the only “historic” count on the Snake was in 1969 at Lower Monumental where about 8,000 lampreys were counted. Thus even prior to 1970, lampreys were less abundant by orders of magnitude at upriver dams than they were at Bonneville or The Dalles dams, which is reasonable given that lamprey move into various subbasins along the way. The historic counts at Bonneville and The Dalles dams also demonstrate the order of magnitude variations in abundance that can occur in lamprey as numbers swung between tens of thousands and hundreds of thousands over just a few years.

Since monitoring resumed in the mid-1990s, lamprey abundance has been lower at all dams compared to the period before 1970, with numbers particularly low at the furthest upstream dams. Only about 25,000 adults are now passing Bonneville Dam annually while less than two hundred lampreys have been observed annually at the upper Snake River dams. These few Snake River lampreys are distributed into potential spawning areas over a large area that includes the Clearwater and Salmon rivers, as well as Oregon subbasins of the Snake. A study in the Clearwater River in the late 1970s indicated that lampreys were already becoming rare in the Snake River basin by that time (Hammond 1979).

Juvenile lampreys have been incidentally caught in the juvenile by-passes at the mainstem dams, and the trend for the John Day by-pass since 1988 is shown in Figure 24. The remarkable increase in juvenile abundance in 1998-2000 may be partly due to improvements in capturing and handling juvenile lamprey at the facility. However, a similar magnitude jump in juvenile abundance occurred on the Umatilla in 2001 (Figure 25). These data may also reflect the episodic nature of lamprey abundance.

Smolt traps are useful tools for capturing juvenile lampreys in smaller basins. Lampreys have been monitored at smolt traps in the lower Umatilla below Threemile Dam since 1995 (Figure 25), and since 1998 in Fifteenmile Creek (Figure 26). The figures show raw counts from the traps because the efficiencies of the traps for capturing lamprey are unknown. An effort to estimate trap efficiency was made for the first time on the Umatilla in 2000 and spring of 2001 by marking the lamprey with a small notch in a fin, then releasing them back upstream with a recovery period along with the salmonid smolts. Trap efficiencies for lampreys in the lower Umatilla ranged from about 0.5% to 5%. This approach is promising and needs to be expanded to other Oregon smolt traps that catch lampreys. Eventually some estimates of juvenile lamprey production by basin may be possible.

Another question is whether the smolt traps, which are installed to monitor salmonids, are operated during the peak of the lamprey out-migration. Monitoring in the Umatilla occurred year-round, and is the only basin in Oregon where this was so. Juvenile lampreys were observed moving out of the Umatilla in their peak numbers during the winter (Figure 6a). On Fifteenmile Creek, and at all other Oregon monitoring stations, the traps are not installed until spring. Heavy winter and early spring freshets in lower Columbia and coastal basins preclude much trapping in the winter and this fact may pose some monitoring complications.

Currently from the available data we can only conclude that similar numbers of juvenile lampreys are typically being caught in the traps in the lower Umatilla River and Fifteenmile Creek, except that the number caught in the lower Umatilla took an apparent magnitude leap in 2001. Lampreys are likely produced throughout the small but generally low-gradient Fifteenmile Creek. Lamprey production in the Umatilla appears to be restricted to the lower few miles of the basin.

The smolt traps also occasionally capture adult lampreys (i.e. Figure 26), but are very inefficient at it. Most adult salmon traps typically cannot contain adult lampreys, which manage to escape through the picket openings in the traps. Lampreys are not seen at the extremely efficient adult salmon traps at Threemile Dam (Umatilla) or Powerdale Dam (Hood); possibly passage up the fish ladders leading to these facilities is not possible for lampreys. Therefore counts of adult lampreys into individual subbasins in the Inland Columbia Basin are not available.

Another source of lamprey abundance information over time is provided as snap-shots by reports of fish kills in basins. Some of the historic fish kills in the John Day and Umatilla basins, were part of intentional fish eradication programs implemented by Oregon Department of Fish and Wildlife. These programs targeted "rough fish" which basically included everything that was not a salmonid, including native species like lamprey. ODFW records of the impact of these treatment projects on fish are often incomplete or unspecific. However, one report of a 1969 rotenone treatment of the North Fork John Day River stated that 33,000 adult Pacific Lampreys were killed. This is a substantial number of adult lampreys compared to contemporary mainstem dam counts. While over 50,000 lampreys were seen at The Dalles Dam in 1969, fewer than 5,000 adult lamprey were counted at McNary Dam, which is the next mainstem dam upstream of the John Day confluence (Figure 23a and b). These comparisons suggest that the John Day Basin may have been an important production area for lampreys in the Inland Columbia Basin at this time – and that a substantial amount of the 1969 breeding population was destroyed in this single rotenone treatment. Another rotenone event on the John Day in 1982 killed thousands of lamprey ammocoetes. Other fish kills have been caused by accidental chemical spills. One such accident in 1999 on the lower Fifteenmile Creek killed thousands of lampreys, mostly ammocoetes.

At this time, conclusions about the status of Inland Columbia Basin and Snake River lampreys are best made from the adult counts at the mainstem dams and from the distribution data. It appears that Pacific Lamprey are at dangerously low numbers in the Snake Basin, with fewer than 200 adults seen annually at Lower Monumental, Little Goose and Lower Granite dams during the 1990s. They are absent above the Hells Canyon dam complex. Pacific Lamprey may be gone from the upper Grande Ronde, Walla Walla and upper Umatilla basins and they are absent from the upper Deschutes and Hood basins. Lamprey distribution seems to be in tact in the John Day basin, but abundance is not known. Abundance monitoring and distribution data is needed in the Deschutes basin below Pelton/Round Butte dams. It appears that basins and reaches not usually considered good habitat for salmonids, such as Fifteenmile Creek and the lower Umatilla and John Day are providing habitat for lampreys and further investigations into similar lower-gradient areas are warranted.

It also appears that the situation for Western Brook Lamprey in the Inland Columbia is precarious. They were completely absent from all areas inventoried, except for a pocket of them in the South Fork Walla Walla. Their historical abundance in these basins is not known; perhaps they were naturally rare and irregularly distributed. There were historic collections made of them from the upper John Day and from Willow Creek, a small subbasin between the John Day and Umatilla Rivers (Figure 8). Their occurrence in the Deschutes and Fifteenmile Creek is unknown.

Status of Lampreys in the Lower Columbia Basin and Willamette

SPECIES: PACIFIC LAMPREY (*LAMPETRA TRIDENTATA*),
WESTERN BROOK LAMPREY (*L. RICHARDSONI*),
RIVER LAMPREY (*L. AYRESI*),
OTHER SPECIES?

Lampreys are more species diverse in the Columbia Basin west of the Columbia Gorge. Most observations of lampreys available from this area are of ammocoetes or of lampreys undergoing metamorphism, and could include a mixture of species. However, River Lamprey, if they are still present, are likely in deeper rivers such as the mainstem Columbia and Willamette where they are not encountered in the incidental surveys currently being conducted. It is highly likely that brook lampreys, at least *richardsoni*, are present in this area along with the Pacific Lampreys. Lampreys have not often been encountered by ODFW inventory crews in the lower Columbia and Willamette (Figure 27) however they are incidentally observed or captured during winter steelhead spawning surveys, and during other trapping, and they have been collected after fish kills. Incidental observations suggest that lampreys are still well distributed through the Willamette Coast Range subbasins, in the Molalla/Pudding system, in the lower Santiam and in the Calapooia. They are also still seen in small numbers passing Leaburg Dam on the McKenzie River.

The distribution of lampreys in the lower Columbia is likely reduced due to passage barriers on the Sandy and Clackamas, and in the North and South Santiam, McKenzie and Middle Fork Willamette (Figure 28). No systematic survey of lamprey distribution has been conducted in this area, nor is the historic distribution known. However, a network of smolt traps in the Clackamas Basin in 2001 demonstrated how lampreys are now restricted to streams below North Fork Dam (Figure 29) in that subbasin. North Fork Dam has a functional fish ladder, unlike the Willamette Basin dams on the Santiam, McKenzie and Middle Fork. The presence of lampreys in the small direct tributaries of the Lower Columbia is generally not known, but many of these streams have small passage barriers like culverts and weirs that may be blockages for lamprey.

The Willamette Basin is probably the most important production area for Pacific Lamprey in the Columbia Basin. This was probably true historically as well as currently, as indicated by a comparison of the number of lamprey taken in the Willamette Falls fishery and the counts of adult lamprey at Bonneville Dam (Figure 30). The Bonneville Dam counts represent essentially the entire population of Pacific Lampreys in the Columbia Basin upstream of that location. During the 1940s the harvest at Willamette Falls was substantially more than the counts at Bonneville Dam in the same years. In the 1990s, the harvest has remained almost equal to the dam counts.

In spite of its importance as a production area and as a location of harvest, the status of Willamette Basin lampreys is poorly understood. The primary data set available to indicate abundance trends is that provided by the harvest itself (Figure 31). Harvest is a poor index of abundance because it is strongly influenced by harvest effort, which was not constant over the time period observed. The high harvests in the 1940s occurred at a time when the harvest effort was very high. Subsequent harvest effort declined. It is difficult to determine how much this change in effort influenced the differences in numbers seen in the 1940s compared to those since 1969. However it is highly unlikely that hundreds of thousands of adult lamprey, the numbers taken in the 1940s harvests, currently pass Willamette Falls.

The only other systematic data set available for Willamette Basin lampreys is a count of adult Pacific Lampreys at Leaburg Dam on the McKenzie River in the upper basin (Figure 32). The numbers are very low; typically less than 50 adults have been counted annually since the early 1980s. Additional incidental observations of lamprey in the Willamette have also been made, mostly in the 1990s (Figure 33). The observations on Pringle Creek were likely a complete count of the lampreys present in the area at that time because these came from an accidental fish kill. The other data are incidental observations made during electroshocking surveys or smolt trapping.

The most interesting observation is the extremely high numbers of juvenile lampreys observed in Clear Creek on the lower Clackamas in 2001, particularly when compared to other lower Clackamas observations using the same sampling method in the same year. This observation suggests that lampreys concentrate in particular areas. Knowledge of where such areas are, and whether abundance in these areas is stable from year to year would be very important for protecting lampreys. If most lampreys are concentrated in only a few areas, a fish kill or other habitat impact in one of those areas could cause a substantial impact on the whole population even if the physical area affected is small.

An historic data set from the lower Columbia collected during the late 1950s-early 60s is available from the Gnat Creek Weir study conducted by ODFW (Willis 1962). Gnat Creek is a relatively small basin in the lower Columbia. Nevertheless, several hundreds to thousands of adult Pacific Lampreys were caught annually, along with thousands of juveniles (Figure 34). The trap at Gnat Creek collected both upstream and downstream migrating lampreys, although the author noted that additional adults were passing upstream around the facility. It is interesting to note that adults also moved downstream; Willis does not report the condition of these. Gnat Creek is now blocked by a hatchery weir.

The Gnat Creek data set can be compared to recent observations at trap facility on Scappose Creek, another lower Columbia Basin tributary. Scappose Creek is a larger basin than Gnat Creek. A comparison of the numbers of lampreys captured in the two basins suggests a substantial decline in lamprey abundance in the lower Columbia since the early 1960s (Figure 35).

The scant data from the Lower Columbia and Willamette indicate that lamprey abundance has declined in this area, yet it remains the most important production area for Pacific Lampreys in the Columbia Basin. The presence and status of the other two major species (Western Brook and River lampreys) is completely unknown. Systematic abundance monitoring needs to be institutionalized on the Willamette, especially if harvest of Pacific Lampreys is going to continue. At this time we are not able to estimate how much of the Willamette Basin lamprey population is being taken in annual harvests.

The issue of homing behavior or lack of homing behavior by Pacific Lampreys is important when assessing the status of Columbia Basin lampreys as a whole. If homing to natal areas does not occur, several factors may work together within a basin like the Columbia to cause major shifts in distribution that interfere with the detection of population declines. Lampreys may be attracted to ammocoete rearing areas by chemical attractants released by the larva. If this is so, a decrease in the juvenile population in a basin, caused for example by a fish kill, may trigger a total extinction in the basin as progressively fewer adults are attracted to it. Difficulties of passage at artificial barriers, even at dams that have fish ladders, may discourage upstream movement and there-by shift population concentrations into other areas below the blockages. The scant data that is available for the Columbia Basin indicates that abundances have seriously declined everywhere, but especially in the upper basin. It is possible that some of the lampreys produced in the upper basin are now electing to return to spawning areas below most of the mainstem dams. If so, the lower basin is an important refuge for the entire system.

The issue of species identity is also a critical one in the Columbia Basin. We cannot differentiate juveniles and the only adults we regularly see are Pacific Lampreys. We currently have no way of knowing for certain whether Western Brook Lampreys and River Lampreys are even still present, although they probably are. Surveys of the lower mainstem Willamette and the mainstem Columbia are likely needed if we want to find River Lamprey. Spring spawning ground surveys in gentle-gradient basins may detect Western Brook Lampreys.

Status of Lampreys on the Oregon Coast

SPECIES: PACIFIC LAMPREY (*LAMPETRA TRIDENTATA*),
WESTERN BROOK LAMPREY (*L. RICHARDSONI*),
RIVER LAMPREY (*L. AYRESI*),
OTHER SPECIES?

Lamprey species diversity on the Oregon Coast is likely similar to that in the lower Columbia, although it is possible that some undescribed species or variants are present on the south coast. Again, most observations of lampreys available from this area are of ammocoetes or of lampreys undergoing metamorphism, and could include a mixture of species. Most of the adult lampreys we see are Pacific Lampreys. Juvenile River Lampreys, if they are present, are likely to be mixed among, and confused with, Western Brook Lampreys in the lower portions of coastal basins.

Although systematic presence/absence surveys targeting lampreys have not been done on most of the Oregon coast they appear to be currently present throughout most Oregon coastal streams. ODFW stream inventory crews have encountered lampreys in most of the areas they have surveyed (Figure 36). Lampreys are also seen in many of the salmonid smolt traps currently operated in coastal basins and during winter steelhead spawning ground surveys. Lampreys were likely never present in some areas such as above Toketee Falls on the North Umpqua River or above Coquille Falls on the South Fork Coquille, and Pacific Lampreys, at least, are likely extinct above Lost Creek and Applegate dams on the upper Rogue River.

A systematic survey for both Pacific and Western Brook Lamprey conducted in the Alsea Basin demonstrated that both species were present and that Pacific Lampreys appeared to be the most common. Lampreys were not found in the most upstream reaches of the basin and both species were often absent above road culverts, which tend to be passage barriers for lampreys. Pacific Lampreys were more often seen in high densities than Western Brook Lampreys; this suggests the brook lampreys could be either more dispersed or more rare (Stan van de Wetering, Siletz Tribes, personal communication).

ODFW counts adult Pacific Lampreys at two dams on the Oregon coast. The count at Winchester Dam on the North Umpqua dates back to 1968. It shows a severe decline in lamprey abundance in the early 1970s and very low numbers since that time (Figure 37a). Only a few tens of lampreys have been seen in some years during the 1990s. The count at Gold Ray Dam on the upper mainstem Rogue River only dates back to 1993. Lampreys at this location have varied from just over 100 to nearly 2,500 annually (Figure 37b).

During the 1990s, lampreys have also been incidentally captured in smolt and adult traps operated on the Oregon coast. Adult lampreys are not commonly captured because the traps, designed to catch either smolts or adult salmonids, are not very efficient for adult lampreys. An historical data set from the early 1960s is available for comparison from several irrigation diversion trap boxes in the upper Rogue Basin. Data from Tenmile and Cummins creeks date back to 1993; otherwise all observations are only from the last several years. The data shown are absolute counts; the efficiencies of these traps for lampreys have not been measured. Smolt trap efficiencies were measured in an independent study in Tenmile Creek on the Oregon Coast, where efficiencies ranged from 3% to 25%. These efficiencies were used to calculate abundances of out-migranting lampreys of 6,569 and 3,592 in 1994 and 1995 from Tenmile Creek (van der Wetering 1998).

Data from ODFW coastal smolt traps again suggest lampreys may concentrate in particular areas, being very abundant in some areas while rare or absent in adjacent areas. An example is provided from the upper Rogue Basin, where several smolt traps have been operated since 1998. Typically a few tens to hundreds of lampreys were seen in the various traps, except for the only year that a trap operated on Bear Creek, where over 6,000 were collected (Figure 38 and 39). Bear Creek, similar to Clear Creek on the Clackamas, appears to be an area of exceptional lamprey concentration, and is also a low gradient stream that is not particularly a high-use tributary for salmonids. The Rogue data indicates that lampreys are being captured in recent smolt traps at similar numbers to what was captured in irrigation diversion trap boxes in the early 1960s (Figure 39).

Cummins and Tenmile creeks on the south Oregon coast have a better record of catching adult lampreys than other traps, perhaps because trapping is more intense in these basins (Figure 40a). More lampreys are consistently seen in Tenmile Creek, including both adults and juveniles (Figure 40a-b), than in Cummins Creek, although both appear to be good locations for lamprey production. Both of these creeks are very small coastal basins; other similarly sized coastal basins are not monitored.

The Cummins and Tenmile creeks data are included with data from other Oregon coastal basins, arranged from the north coast to the south (Figure 41a-c). Although it is difficult to compare the basins from the raw data, production appears to be lower in the Tillamook Bay, Nestucca and Yaquina basins, and highest in parts of the Alsea and in Cummins and Tenmile creeks. The network of traps is operated to monitor salmonids, and possibly the time of operation is late for lamprey, and the locations of the traps are not optimal for lamprey monitoring. However if trap efficiencies are measured, this trap network might, over time, provide a reasonable index of lamprey abundance along the Oregon coast.

Additional information about coastal Pacific Lamprey has been collected incidental to winter steelhead spawning ground surveys (Susac and Jacobs 1999, Jacobs et al 2000). Adult lamprey and redds are observed and have been counted in several basins along the Oregon coast in 1998 and 1999 (Figure 42a-c). Spawning ground counts of redds are probably not a good measure of abundance because lampreys will produce many false redds during courtship. However, the observations are a good indication of the time and location of lamprey spawning behavior and may be used to locate concentrations of spawning activity.

The Winchester Dam counts on the Umpqua demonstrate that Pacific Lampreys in this basin have experienced severe declines since the late 1960s. Similar historic data is not available from elsewhere on the coast to determine whether this trend is coast-wide or unique to the North Fork Umpqua. Lampreys are still observed almost everywhere coast-wide, but generally not in remarkable numbers anywhere. More adult data would be useful and perhaps some of the adult traps used for monitoring salmon can be modified to retain adult lampreys without compromising their primary purpose. However, improvements in our current information will not compensate our lack of historic data and we are likely required to depend on anecdotal recollections from coastal tribal elders, other members of the public and ODFW staff to tell us that coastal lampreys have declined over the last few decades. Better information is also needed on Western Brook Lamprey; we need to determine whether River Lamprey are still present in any basins; and we need to determine whether our observations of enigmatic lampreys really are of unique varieties or species.

Status of Lampreys in Southeastern Oregon

SPECIES: FIVE KLAMATH LAMPREYS
TWO GOOSE LAKE LAMPREYS

The lampreys in Goose Lake and Klamath basins are endemic species or variants that are highly unique with a very limited world distribution. Status of, and protection of, the populations in these basins constitute the condition of entire species. The multiple species are very similar to each other as juveniles, and adults are rarely observed. Therefore, monitoring status of any one species is quite difficult. We are certain that there are four species in the upper Klamath basin. We do not know whether *L. folletti* is actually present. We know that we have both parasitic and non-parasitic lampreys in Goose Lake Basin and are still investigating whether these are one or two species.

At this time, we are only able to observe that lampreys, generically, appear to be well distributed in their two basins (Figure 45), and anecdotal observations by both ODFW staff and USFWS staff suggest that they tend to be at fairly good densities wherever they are present. However, we have started only one systematic data set in Thomas Creek, Goose Lake Basin, incidental to monitoring migratory redband trout (Figure 46). Neither the redband trout nor the lampreys migrated past the location of this trap during the drought of the early 1990s so the current observations, in spite of low numbers, may be taken as a sign of improved status.

ODFW needs to invest significantly more resources into monitoring the lampreys, and other endemic species, in these basins if the agency intends to take its conservation mission seriously. The Klamath Basin, along with other SE Oregon Great Basins, has the highest number of unique and endemic fishes in Oregon, and the highest number of state sensitive species and state and federal ESA-listed species, yet monitoring in these areas remains severely under-invested by the state and is under-staffed. More work is needed to determine the specific distribution of the various lamprey species, to answer the remaining taxonomic questions, and to establish monitoring that can shed some light on the status of individual species.

Because of their endemic nature, the Klamath Basin species likely warrant addition to the state Sensitive Species List as naturally rare species (Puchy and Marshall 1993). The Goose Lake species are already included on the list as *Lampetra tridentata*; they need to be recognized as separate species on the list.

Chapter 3

Problem Analysis

Information Needs

It is not possible to assess the status of species or to take action to correct status problems unless we know something about the species. At a minimum we need to be able to identify individual species and know about their abundance and spatial distribution over time. Knowledge of their basic ecology, life history and habitat needs would let us better address status problems. It is evident that we could allow species to go to extinction through ignorance and negligence, never even knowing what they were. Lamprey species are susceptible to this problem. The Miller Lake Lamprey is an interesting case study of this: it was finally recognized as a unique species nearly twenty years after it allegedly became extinct, then persisted unknown to everyone for another twenty years before it was rediscovered and declared "extant" and even locally abundant. ODFW has a mission statement that says: "It is the policy of the State of Oregon that wildlife shall be managed to prevent serious depletion of any indigenous species and to provide the optimum recreational and aesthetic benefits for present and future generations of the citizens of this state" (ORS 496.012 Wildlife policy) with a goal "To maintain all species of wildlife at optimum levels" (ORS 496.012 (1)). Extinction of species through negligence is contrary to state law. Further, information about status problems for species like lampreys may shed light on some of the reasons for status problems for species that are more popular, like salmon.

ODFW staff began collecting some data about lamprey incidental to salmonid monitoring in the late 1990s. These current efforts, while a considerable improvement over a total lack of information, are not designed for lamprey, are inefficient and are of limited scope. Co-Manager staffs, especially tribal staff in the upper Columbia and mid-Oregon coast, have implemented projects specifically focused on lamprey with much better results. The following actions are recommended for improving ODFW information about lamprey:

1) Minimum Activities:

The following information and monitoring activities are the bare minimum necessary if we wish to assess the status of Oregon lampreys:

a) Species Identification.

i) We need to know what species we have.

It is currently understood that we have Pacific Lamprey (*Lampetra tridentata*) and Western Brook Lamprey (*L. richardsoni*) in the Columbia River and on the Oregon Coast. But it is likely that we have other species in these two regions. Some of these are classified, but we do not know if they are still present, like the River Lamprey (*L. ayresi*). Other enigmatic varieties may be present but their taxonomic identity is uncertain. We also know that the lamprey in the Klamath and Goose Lake basins are different species but for many of them taxonomic identity has not been determined. ODFW has identified a taxonomic survey of Oregon lampreys as an initial priority under new funding for non-game species available through the US Fish and Wildlife Service.

ii) Our staffs need to be able to tell the various species apart in the field.

This problem is extremely difficult for lampreys because field staff most often encounter them as ammocoetes, which are nearly identical across all species. Staff with the US Geological Survey are currently working on an improved key to ammocoetes in the Columbia Basin (Bayer et al, 2001) and ODFW needs to cooperate with their effort.

Some clarity of species identity may be possible based on knowing their spatial distributions and habitat preferences. For example, it is likely that only Pacific Lampreys are present in most of the upper Columbia and Snake basins. Some species, such as the River Lamprey, may occupy unique fresh water habitats, such as lower mainstem channels. Some species may be restricted to specific basins, such as Western Brook Lamprey in the South Fork Walla Walla, or some of the endemic Klamath basin species.

b) Species Distribution.

i) We need to know where the various species are.

Presence/absence surveys that use sampling methods that are efficient for capturing lampreys are needed. Close and Bronson (2001) conducted a good example in Northeastern Oregon basins in 1999. These surveys need to extend into habitats that may be unique to some lamprey species, including low-gradient flood plain habitats and lower mainstem river channels, including the Columbia River. These surveys need to be coupled with accurate species identification. The surveys need to be repeated periodically (but not annually) so that changes in species distribution can be detected.

c) Species Abundance and/or Densities.

i) We need abundance information collected systematically over time.

In order to detect population declines abundance data needs to be collected systematically each year. One of our big problems for assessing lamprey status currently is that we do not have very much historic abundance data for these species: we cannot tell if they have declined since we do not know how many we had in the past. We will never be able to correct this historic problem, but we can initiate abundance monitoring into the future. Several monitoring stations that detect lamprey are already in place in the Columbia Basin, on the Oregon coast, and in Goose Lake basin, although the efficiencies of most of these is currently uncertain. ODFW needs to continue, or support the continuation, of the existing efforts to monitor lamprey abundance, make some improvements, and expand them in some cases.

ii) We need to measure observation and/or capture efficiencies at existing monitoring stations.

The existing network of smolt traps and counting stations at dams successfully capture or observe lampreys in many cases, but we do not know the efficiencies of the sampling. ODFW staff on the Umatilla River have successfully measured smolt trap efficiencies for lampreys using fin mark and release methods similar to what is used for salmon smolts. Smolt trap efficiencies have also been measured in Tenmile Creek (van de Wetering 1998). This effort should be tried in other basins.

We are aware that many dam counts are likely inefficient for lampreys (Starke and Dalen 1995). Some of these inefficiencies might be correctable, for example by including some night counts. It may also be valuable to expand the interval of monitoring, especially for some juvenile facilities, to include winter months (November through March). In other cases we may be able to make efficiency estimates using mark-recapture methods. Even if errors exist, if they are reasonably constant from year to year the dam counts could provide a reasonable index of abundance over time.

iii) We need to modify some existing monitoring facilities to more efficiently capture or observe adult lampreys.

The adult traps that we currently use for salmonids on the Oregon coast and in the Columbia Basin do not efficiently capture adult lampreys because the animals are able to escape thorough pickets in the trap boxes. Slight modifications of some of these traps may permit good, systematic monitoring of adult lampreys.

Moderate improvements of some counting stations in dam ladders may facilitate or improve observations of adult lampreys. Some counting stations at some

Columbia basin dams were specifically equipped with devises to preclude lampreys from the counting windows because they were considered to be a nuisance. Night video counts are now occurring at some mainstem dams but the lights that are necessary to effectively operate the cameras seem to repel the light-sensitive lampreys (Ocker et al 2001). The nature and feasibility of improvements at these facilities will need to be evaluated on a case-by-case basis.

In a few cases, such as at Threemile Dam on the Umatilla and Powerdale Dam on the Hood, access to the traps is difficult or not feasible for adult lampreys and correction of the problem is likely to require a more extensive effort.

iv) We need to add some monitoring stations where none currently exist.

The following three locations should be considered a priority for new monitoring stations:

(1) *The Willamette Basin*. This basin is likely the major production area for Pacific Lamprey in the Columbia Basin, and is also the location of the primary harvest of the species in Oregon. However no systematic monitoring of lamprey occurs currently except for a count at Leaburg Dam on the McKenzie River in the upper basin and the measure of the annual harvest. An adult monitoring station at Willamette Falls is highly recommended. One or more juvenile monitoring station in the basin would also be useful. ODFW staff is currently pursuing Bonneville Power Administration (BPA) funding to initiate some monitoring in this basin.

(2) *The Deschutes Basin***.** This basin is also likely an important production area for Pacific Lamprey in the Columbia Basin. There is also some tribal interest in a harvest in this basin. An adult monitoring station at Sherars Falls is highly recommended.

(3) *Klamath Basin.* Klamath basin is home to four or five endemic species of lampreys, but currently we have no abundance monitoring for any of them. Systematic monitoring of lampreys in this basin will be difficult, particularly since some species are likely not migratory. However at least two species, the Klamath River Lamprey (*Lampetra similus*) and the unnamed *L. tridentata*-like species, are adfluvial between Klamath Lake and its tributaries. Adult monitoring stations for these species should be feasible.

v) We need to add some new monitoring methods that are effective for resident species and species in unusual habitats.

Adfluvial or anadromous species are relatively easy targets of abundance monitoring because they conveniently swim past specific locations during their downstream and/or upstream migrations where they can be intercepted and counted. However resident lampreys may never move very much and we cannot expect to catch them in migrant traps. The most common monitoring method for resident species is a periodic density measurement at selected locations through the species' distribution. This method is relatively labor-intensive, compared to operating a trap, making annual monitoring difficult. Once the spatial distribution of the various resident brook lamprey species is better understood, periodic density measures should be conducted for these species, even if they only occur once every several years.

Monitoring of the anadromous River Lamprey (*L. ayresi*), if indeed it is still present in Oregon, is made difficult because the species, which is in freshwater for all but a few months of its life, is rarely seen in freshwater apparently due to the habitats it uses. Biologists in Canada located River Lamprey and estimated abundance in the Fraser River using several sampling techniques. These included spring freshwater trawls low in the river basins, sampling of dredge spoils from mainstem Fraser River sources, and surface seining in the ocean during the summer near the mouths of the rivers that produce the species (Beamish 1980 Beamish and Youson 1987).

2) Useful Additional Information:

If we wish to understand lampreys better, especially if we need to take actions to improve the status of a particular species, additional information about their ecology, life histories, vulnerabilities, and habitat use is valuable. The following actions would be beneficial to address basic ecology and life history questions. Some additional actions to address some specific harvest and habitat issues are included in later sections.

a) Marking of lampreys.

Marking lampreys as ammocoetes and recapturing them through their life up to adult spawners would provide valuable life history information, such as timing of migrations, durations of various life stages, and adult homing behavior. Lampreys have been successfully marked with coded wire tags (Bergstedt and Seelye 1995). Tags in Oregon lampreys would need to be detectable in live lampreys, for example by using a coded wire tag wand, so that only tagged individuals are affected by reading the tags. PIT tagging would be a viable and non-lethal, although more expensive, alternative. Experimentation is needed to refine marking technology before it can be applied efficiently to lampreys (C. Mallette, personal communication).

b) Basic lamprey ecology and habitat use.

Most of the information on the ecology of the lamprey species that are in Oregon is from graduate theses (i.e. Pletcher 1963, Kan 1975, Hammond 1979, and Richards 1980, van der Wetering 1998). The Bonneville Power Administration (BPA) is currently funding several studies that will improve understanding of lamprey ecology and habitat use in the Columbia Basin. These include studies in the John Day River of Pacific Lamprey (Bayer et al. 2000, Thorgersen and Close 2001), in the Lewis

River in Washington of both Pacific Lamprey and Western Brook Lamprey (Stone et al 2001) and in the Clearwater River in Idaho of Pacific Lamprey (Cochnauer and Claire 2001).

c) Within species biodiversity.

Within species population sub-division may differ greatly from one Oregon lamprey species to another. The anadromous Pacific Lamprey may show little population sub-division if it does not home to natal areas, or sub-division may occur over large areas such as between the coast and the Columbia basin. However, homing behavior and population sub-division in Pacific Lamprey remains to be tested. River Lamprey likely home to natal basins based on the observations made in Canada (Beamish 1980, Beamish and Youson 1987). According to those studies, River Lampreys were found in the ocean only near the mouths of the rivers that produced them; therefore they were unlikely to travel to different rivers to spawn. The resident Western Brook Lampreys are likely not salt water tolerant, therefore they would have significant population sub-division along the Oregon coast. They apparently move very little over their lives and therefore they may be quite sub-divided in the Columbia Basin also. Population sub-division influences species status. The various semi or totally isolated populations in a highly sub-divided species have to be treated as different management units in order to effectively achieve the conservation of the biodiversity contained within the species (Rojas 1992).

Harvest

The only lamprey species that is harvested in Oregon is the Pacific Lamprey. In recent years Pacific Lampreys have been harvested at Savage Rapids Dam on the Rogue River, at Winchester Dam on the Umpqua River, at Willamette Falls on the Willamette River, in Fifteenmile Creek, at Sherars Falls on the Deschutes River, and in the John Day River. Most of the harvest outside of the Willamette Basin has been for personal use by Native Americans. The Willamette Falls harvest has included a commercial, non-tribal component that has come to dominate the harvest since 1997.

In 2001, the Oregon Fish and Wildlife Commission implemented OAR 635-044-0130 which requires that a permit be issued by the Commission before certain native non-game species, including Pacific Lamprey, can be harvested. Permits were issued for Willamette Falls only, a season and regulations were set, and about 15,500 lampreys were harvested, about half of the past ten-year’s average harvest. Details about the 2001 harvest are available in Ward (2001).

At this time we are not able to assess the impact of this harvest because we do not have a measure of lamprey abundance in the Willamette Basin. We are able to compare this harvest to the 2001 Bonneville Dam counts, which represents the entire population of lamprey above the dam (with caveats about potential count error at the dam). The 2001 Bonneville count was 27,947 Pacific Lampreys; therefore, the harvest was about 55% of the dam count. But in order to assess the proportion of the Willamette Basin lamprey population that was taken by the harvest, an independent measure of adult lamprey abundance at Willamette Falls is needed.

It is strongly recommended that an adult abundance monitoring station be installed at Willamette Falls in 2002. Then if the Commission elects to issue permits for harvest in 2002, the proportion of the Willamette Basin population that is taken in the harvest can be measured. ODFW staff is currently seeking BPA funding for this action.

This will still not tell us whether the harvest rate is sustainable since we have no information about lamprey population dynamics or lamprey productivity. It may be very difficult to assess whether a particular lamprey harvest is sustainable for several reasons. First, we have reason to expect, based on the scant data we have on lamprey abundance, that population abundance can be highly variable, varying by orders of magnitude from one year to the next. We do not know why this occurs. Therefore we cannot currently predict a particular year's abundance at the time harvest is set prior to the run. Second, there are information gaps that must be filled before we might be able to develop a method of predicting adult abundance. Monitoring of juvenile lamprey production out of the Willamette Basin may help us predict future abundance and scale harvest to follow fluctuations in abundance. However, at this time we do not know the duration of salt-water residence by Pacific Lamprey. Based on the literature, lampreys leaving the Willamette in any year may return to the basin anywhere from one to four years later. There may be variation in time to return, *if* they return to the basin at all. And, so, third, if there is no homing by the lamprey there may be no relationship between juvenile production in the Willamette Basin and future adult returns to the basin. The only way to determine whether the lamprey produced in the Willamette return to it as adults would be to mark out-migrants with coded wire tags or PIT tags and then recapture them as adults. This study is possible, but some preliminary technology development and testing will be required before it can be developed (C. Mallette, personal communication). ODFW hopes to start some of this testing in 2002.

Sherar's Falls on the Deschutes River is within the usual and accustomed harvest area for the Warm Springs Tribes. If harvest is going to continue to occur there an adult abundance monitoring station should be installed at the falls as soon as possible and we should request annual harvest data from the Warm Springs Tribes.

The only basin in Oregon with a recent lamprey harvest that also currently has an independent measure of adult Pacific Lamprey abundance is the upper Rogue Basin. Lampreys have been harvested at Savage Rapids Dam and adult abundance is counted just upriver at Gold Ray Dam (Figure 38b). Counts at Gold Ray Dam are not very high. So, if, for example, we were to determine that a 15% harvest rate was sustainable for lampreys, we could have an annual harvest of only 50 to 100 lampreys based on these counts. We have no ability at this time to predict abundance in the Rogue before a harvest quota is set so it currently is not possible to track the variation in abundance.

We also have an independent measure of lamprey abundance at Winchester Dam on the Umpqua River, another location where lampreys were harvested in the past. However, fewer than 100 lampreys are seen there annually so harvest is not currently possible there.

Habitat Issues: Provisions for Upstream Passage

Lampreys have a remarkable ability to use their sucker mouths to climb natural barriers and penetrate headwater areas that are not available to other anadromous fish. Therefore it seems surprising that upstream passage barriers would be a problem for lamprey. But lampreys are unable to cope with many artificial barriers. Lampreys are weak swimmers since they lack paired fins, and they have no jumping ability. In order to climb they must find rough surfaces that they can cling to in areas with low or moderate currents so they will not be washed backwards.

The following is a brief description of the types of artificial barriers that impede upstream passage by lampreys:

1) **Dams:** Lampreys are excluded, along with other migratory fish, from passing dams that were not intended to pass fish. This list of dams includes Lost Creek and Applegate dams on the Rogue, the complex of Willamette Basin dams on the Santiam, McKenzie and Middle Fork Willamette, Pelton/Round Butte dams on the Deschutes and Hells Canyon Dam on the Snake.

   Other dams are designed to pass fish upstream and are equipped with fish ladders. However, lampreys are apparently unable to use many of these. Lampreys pass some low-head dams such as Gold Ray and Savage Rapids dams on the Rogue, Winchester Dam on the Umpqua, and Leaburg Dam on the McKenzie in the upper Willamette. They also use the fish ladders at Willamette Falls, although they also cross the falls itself as they did historically (Normandeau Associates 2001). They have not been found above some other small, but higher head dams in Oregon, such as North Fork Dam on the Clackamas, Powerdale Dam on the Hood, or Threemile Dam on the Umatilla.

   Lampreys are seen using the fish ladders in the mainstem Columbia and Snake dams, although with apparent difficulty. They are able to use the fishways, regardless of their length and slope (Slatick and Basham 1985), but some features of the structures seem to pose problems. Studies tracking radio-tagged lampreys through Bonneville, The Dalles and John Day dams have demonstrated that passage efficiency is poor – typically less than half of the lampreys that approached the dams successfully passed above them (Ocker et al 2001). Areas of the fish ladders that seemed most difficult to the lampreys included those areas where lips or gratings had to be crossed, areas where water velocity is higher such as at entry-ways and over diffuser gratings, and areas that were lighted at night. These difficult areas correspond to lamprey biological characters including weak swimming, the need to cling to surfaces to rest and climb, and strong phototaxic behavior expressed as light avoidance. Lampreys, with their slim, snaky bodies, are also able to gain access through small holes into nooks and crannies along fishways that may entrap them (Starke and Dalen 1995).

One modification of fish ladders that may significantly improve lamprey passage without interfering with salmonid passage would be to provide roughened surfaces through the ladders that provide lampreys with areas that they can easily cling to, rest, and climb along.

2) **Road Culverts:** A presence/absence survey conducted by Stan van der Wetering in the Alsea Basin on the Oregon coast demonstrated that lampreys, including both Pacific and Western Brook lampreys, were not found above many road culverts. Most road culverts likely pose severe passage barriers to lamprey caused by at least the following:

    a) Smooth surfaces within the culverts that provide no surfaces for lamprey to cling to;
    b) Velocity barriers within the culverts; and
    c) Hanging culvert entrances. Even an entrance that hangs just a couple of inches cannot be entered by lamprey since they have no ability to jump.

    The provision of rough surfaces through culverts, including along ramps for climbing into the entrances may assist lamprey passage.

3) **Other Barriers to Upstream Passage?** Other artificial features may also be passage barriers to lamprey, such as tide gates, hatchery weirs, or other small barriers and diversion structures. The flashboards installed at the top of Willamette Falls in the summer appear to form a passage barrier (Normandeau Associates 2001). Any barrier that has a sharp lip, a high velocity current, and/or a smooth downstream surface, or a hanging downstream drop more than a few inches high will be a passage problem. These problems should be easily correctable by providing the means for lampreys to climb around these features – it may be as simple as a pile of rocks to one side with a gentle overflow of water.

Habitat Issues: Screening for Downstream Passage

Downstream passage around dams and diversion structures may be the greater hazard for lampreys. Lampreys migrate downstream when they are very small-diameter ammocoetes or recently metamorphosed lampreys. They are not strong swimmers so their movement is at the mercy of the flow velocity. They may pass under fish screens on dams (Long 1985) or go through some bypass screens that have larger openings, making the effort to divert them out of turbines or irrigation canals ineffective. But perhaps the bigger problem is high mortality caused by the fish screens themselves. Anecdotal observations by biologists working on mainstem dams on the Columbia and Snake Rivers during the 1970s and 1980s indicate that juvenile lampreys impinged on the perforated plates that blocked various openings across the forebay faces of the dams and on juvenile bypass screens in huge, but undocumented, numbers. These observations have been documented and tested more recently (Starke and Dalen 1995, Jackson et al 1996, BioAnalysis Inc 2000, Moursund et al 2000, Dauble and Moursund 2000).

The problem of lampreys and fish screens is caused by the small diameter of the juvenile lamprey and their weak or passive movement through the water. The design of the screen mesh is important, but the operation of the screen is also a factor. If flows approaching the screens are high, the lampreys are pressed against the screens eventually impinging from their tail-end as they attempt to swim free. If the flows approaching the screens are too low, the lampreys tend to adhere to the screens with their sucker mouths then rotate with the screens until they are crushed by the gatewells or cleaners (Moursund et al 2001). Research is continuing at the Pacific Northwest National Laboratory in Richland Washington, studying both large bypass screens on mainstem Columbia River dams and smaller screens on irrigation diversions, attempting to discover a screen design and operation that is lamprey-friendly (D. Dauble, personal communication). The ODFW screening program is also interested in supporting or participating in similar studies in an effort to make screens installed on lamprey-bearing streams under ODFW authority adequate to protect lamprey.

Diverting lamprey along with irrigation water into fields is very undesirable. Ironically, however, passing lampreys through turbines may be less harmful to them than the current screens. The shape of lamprey ammocoetes, their lack of a swim bladder, and their cartilaginous skeletons make them less susceptible than salmon to injury due to the changes in pressure and shear conditions during turbine passage (Moursund et al 2001). Earlier studies on mainstem dams indicate that juvenile lampreys tend to be deep in the water column below the reach of many fish screens (Long 1985), although lampreys are certainly being caught in the juvenile bypasses. Also as they travel through the dams, they are able to slither into any little orifice they encounter that is large enough to let them pass, which means any opening larger than about: **O** , and they become entrapped.

Other Habitat Issues:

Our understanding of lamprey is not sufficient to determine all the habitat factors that influence them. We know they need habitats with interspersed small gravel beds (for spawning) and silt lenses (for burrowing). They need organic debris that will produce algae for their food. They need flows that are gentle to moderate. They need passages they can maneuver. Beyond this basic knowledge, our understanding of their needs is poor. The following list includes issues that may pose concerns:

1) Pollution, chemical spills, and other water quality problems

There is some speculation that lampreys are relatively tolerant of poor water quality. Kan (1975) noted that Western Brook Lampreys were present in Willamette Basin streams that were polluted by pulp mills. He speculated they may be attracted to algae that may flourish near the mills under some conditions. They may be able to acclimate to somewhat elevated water temperatures (van de Wetering and Ewing 1999). Researchers in the Great Lakes found the sea lamprey, *Petromyzon marinus*, to be remarkably tolerant of toxins when they were trying to use them to eradicate the species (J. Seelye, personal communication). In Oregon, however, lamprey are a common victim of chemical spills into streams. A 1999 spill in the lower Fifteenmile Creek killed thousands of them – too many to enumerate. They have been found after chemical spills in the Willamette Basin. ODFW demonstrated that Oregon lampreys, including both adults and juveniles, are easily killed using rotenone and toxaphene.

Lamprey juveniles spend their lives buried in silt along stream banks and bottoms. These habitats also are notorious for accumulating toxins. For example, the lower Willamette/Columbia confluence and some of the adjacent sloughs are a federal superfund site due to heavy metals and other toxins built-up to lethal levels in the mud and silt. This same area is lamprey habitat and may house a substantial proportion of the lampreys in the Columbia Basin. Upper Columbia sites used by lampreys, such as the lower Umatilla, have agricultural water pollution. Bear Creek on the Rogue is evidentially important for lamprey production but is heavily polluted. Lampreys may be relatively tolerant to water pollution, in comparison with a cutthroat trout, for example. But high pollution levels, especially when toxins accumulate in the silt that houses lamprey larva, is likely not good for them.

3) Reservoir hydrographs

Anadromous lampreys, like other anadromous fish, undergo extensive physiological changes as they migrate from fresh water into the ocean. Similar to other anadromous fish, they have a specific physiological window during which their transformation occurs. Flows stimulate migratory behavior. The altered hydrograph of the Columbia and Snake rivers, caused by changing the rivers from free flowing into a series of reservoirs has been shown to impact salmonids by substantially slowing their migrations during their out-migration. Lampreys are weak swimmers and juveniles in an unaltered river tend to be carried passively to the ocean during winter and spring freshets. In a series of reservoirs, lampreys may be impacted by delayed out-migrations similarly to salmonids.

3) Dredging

Lampreys, possibly especially the River Lamprey, likely burrow in river bottom sediments all the way down the rivers to the ocean. Beamish and Youson (1987) discovered that one way to find River Lamprey was to sift through dredge spoils from the lower Fraser River. They also discovered that only 3% to 26% of the lampreys passed through a dredge survived the experience.   Dredging goes one continuously in the lower Willamette and Columbia, including up some side-channels and sloughs. It also occurs in some coastal estuary areas. It would be useful to sample dredge spoils to see if lampreys are being taken.

4) Basin scouring

Interspersion of small gravel beds for spawning and fine silt lenses, in lower rivers where natural flows are gentler, are important habitat characteristics for lampreys. Oregon coastal streams were subjected to extensive scouring, especially in lower basin areas, due to the effects of splash-dam logging. Many rivers were scoured to bedrock and lamprey habitat was likely lost. This activity no longer occurs and many impacted areas are recovering.

5) Rapid Water Draw-downs

Water behind some dams may be subjected to periodic rapid water draw-downs. Lamprey ammocoetes are sensitive to changes in water pressure and light and can emerge from their burrows and follow a gradual water draw-down, such as what might occur after a natural flood. However, ODFW staff has seen evidence of lampreys being stranded in their burrows by rapid artificial draw-downs. Such observations have been particularly noted at Savage Rapids Dam on the Rogue River.

6) Vulnerability of high density areas

Our preliminary observations suggest that lampreys may concentrate at extremely high densities in particular locations. In 2001 alone, remarkable concentrations of them were found in Bear Creek in the upper Rogue Basin and Clear Creek in the lower Clackamas, compared to what was observed using similar sampling methods in adjacent tributaries in the same year. It is not yet clear what this distribution pattern is about. However, if substantial portions of the lamprey being produced by a particular basin ten to concentrate in only a few locations a single event, such as a chemical spill, that impacts that location may destroy a substantial amount of the population, even if the event affects only a small area. The extremely high kills of lampreys in Fifteenmile Creek due to a chemical spill in 1999, and due to the rotenone events on the John Day in 1969 and 1982 may have occurred because the lampreys were concentrated in the areas impacted.

7) Development in floodplains and low gradient reaches

Lampreys appear to favor lower basin, low gradient reaches. Pletcher (1963) commented on how lampreys particularly occupied the river reaches in the lower river flood plains. In Oregon, low gradient flood plains tend to be highly developed areas, with primarily industrial, urban and agricultural development. The Willamette Valley, with the state's largest urban area at it's mouth, is the most notable example. The lower rivers and estuaries of most coastal rivers are also highly developed, as is the low gradient, mid-valley areas of the Rogue and Umpqua and the lower tributaries into Klamath Lake, especially the Sprague River. It is not possible to speculate about the potential impacts to lamprey caused by this complex development and habitat alteration but it is likely to have depressed habitat availability and productivity for lampreys.

References

Bayer, J.M., M.H. Meeuwig, and J.G. Seelye. 2001. Identification of larval Pacific Lamprey (*Lampetra tridentata*), River Lampreys (*L. ayresi*), and Western Brook Lampreys (*L. richardsoni*) and thermal requirements of early life history stages of lampreys. Annual Report 2000. Bonneville Power Administration Project Number 2000-029. Portland, Oregon.

Bayer, J.M., T.C. Robinson and J.G. Seelye. 2000. Upstream migration of Pacific Lampreys in the John Day River: Behavior, timing and habitat use. Annual Report 2000. Bonneville Power Administration Project Number 2000-052. Portland, Oregon.

Beamish, R.J. 1980. Adult biology of the River Lamprey (*Lampetra ayresi*) and the Pacific Lamprey (*Lampetra tridentata*) from the Pacific coast of Canada. Can. J. Fish and Aquatic Sci. 37: 1906-1923.

Beamish, R.J. 1987. Evidence that parasitic and nonparasitic life history types are produced by one population of lamprey. Can. J. Fish and Aquatic Sci. 44: 1779-1782.

Beamish, R.J. and J.H. Youson. 1987. Life history and abundance of young adult *Lampretra ayresi* in the Fraser River and their possible impact on salmon and herring stocks in the Strait of Georgia. Can. J. Fish and Aquatic Sci. 44: 525-537.

Beamish, R.J. and T.E. Medland. 1988. Age determination for lampreys. Trans. American Fisheries Soc. 117: 63-71.

Beamish, R.J. and T.G. Northcote. 1989. Extinction of a population of anadromous parasitic lamrpey, *Lampetra tridentata*, upstream of an impassable dam. Can. J. Fish and Aquatic Sci. 46: 420-425.

Beamish, R.J. and C.D. Levings. 1991. Abundance and freshwater migrations of the anadromous parasitic lamprey, *Lampetra tridentata*, in a tributary of the Fraser River, British Columbia. Can. J. Fish and Aquatic Sci. 48: 1250-1263.

Beamish, R.J. and C.E.M. Neville. 1992. The importance of size as an isolating mechanism in lampreys. Copeia 1992(1): 191-196.

Beamish, R.J. and R.E. Withler. 1986. A polymorphic population of lampreys that may produce parasitic and a nonparasitic varieties. Indo-Pacific Fish Biology. Ichthyological Society of Japan, Tokyo, Japan.

Bergstedt, R.A. and J.G. Seelye. 1995. Evidence for lack of homing by sea lampreys. Transactions of the American Fisheries Society. 124:235-239.

BioAnalysis, Inc. 2000. The status of Pacific Lamprey in the Mid-Columbia region. Public Utility District No. 1 of Chelan County. Wenatchee, Wa.

Bond, C.E. and T.T. Kan 1973. *Lampetra* (*Entosphenus*) *minima* n.sp., a dwarfed parasitic lamprey from Oregon. Copeia. 1973(3):568-574.

Close, D.A., M. Fitzpatrick, H. Li, B. Parker, D. Hatch, and G. James. 1995. Status Report of the Pacific Lamprey (*Lampetra tridentata*) in the Columbia Basin. Bonneville Power Administration Project Number 94-026. Portland, Oregon.

Close, D.A. and J.P. Bronson. 2001. Distribution of Larval Pacific Lampreys (*Lampetra tridentata*) in Northeastern Oregon and Southeastern Washington. Confederated Tribes of the Umatilla Indian Reservation. Pendleton, Oregon.

Cochnauer, T. and C. Claire. 2001. Evaluate status of Pacific Lamprey in the Clearwater River Drainage in Idaho. Annual Report 2000. Bonneville Power Administration Project Number 2000-028-00, Portland, Oregon.

Dauble, D.D., and R.A. Moursund. 2000. Effects of extended length bypass screens on juvenile Pacific Lamprey. HydroVision 2000 Technical Paper. HCL Publications Kansas City Mo.

Docker, M.F., J.H. Youson, R.J. Beamish and R.H. Devlin. 1999. Phylogeny of the lamprey genus *Lampetra* inferred from mitochondrial cytochrome *b* and ND3 gene sequences. Can. J. Fish. Aquat. Sci. 56: 2340-2349.

Downey, T., D. Rilatos, A. Sondenaa, and B. Zybach. 1993. The Siletz Eels: Oral History Interviews with Siletz Tribal Elders and Neighboring Residents Regarding the Decline in Siletz River Lamprey Populations. Oregon State University. Corvallis, Oregon.

Downey, T., D. Rilatos, A. Sondenaa, and B. Zybach. 1996. Skwakol: The Decline of the Siletz Lamprey Eel Population during the 20th Century. Oregon State University, Corvallis, Oregon 1996.

Farlinger, S.P. and R.J. Beamish 1983. Recent colonization of a major salmon-producing lake in British Columbia by Pacific Lamprey (*Lampetra tridentata*). Can. J. Fish. Aquat. Sci. 41: 278-285.

Hammond, R.J. 1979. Larval biology of the Pacific Lamprey *Lampetra tridentata* (Gairdner), of the Potlatch River, Idaho. Master of Science Thesis. University of Idaho, Moscow, Idaho. 44p.

Jackson, A.D., P.D. Kissner, D.R. Hatch, B.L. Parker, M.S. Fitzpatrick, D.A. Close, and H. Li. 1996. Pacific Lamprey Research and Restoration. Annual Report 1996. Bonneville Power Administration, Project Number 94-026. Portland, Oregon.

Jackson, A.D., B.P. Connor and D.A. Close. 2001. Traditional ecological knowledge of Pacific Lampreys (*Lampetra tridentata*) in Northeast Oregon and Southwest Washington. Confederated Tribes of the Umatilla Indian Reservation. Pendleton, Oregon.

Jacobs, S., J. Firman, G. Susac, E. Brown, B. Riggers and K. Tempel. 2000. Satus of Oregon coastal stocks of anadromous salmonids. Oregon Plan for Salmon and Watersheds. Oregon Department of Fish and Wildlife, Corvallis, Or.

Kan, T.T. 1975. Systematics, Variation, Distribution and Biology of Lampreys of the genus *Lampetra* in Oregon. Dissertation for the Doctor of Philosophy, Oregon State University, Corvallis, Oregon.

Kostow, K (ed) 1995. Biennial Report on the Status of Wild Fish in Oregon. Oregon Department of Fish and Wildlife, Portland, Oregon.

Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer. 1980. Atlas of North American Freshwater Fishes. Publication #1980-12, Northern Carolina Biological Survey. pp. 24-34.

Long, J.A. 1995. The Rise of Fishes. Johns Hopkins University Press. Baltimore. pp 10-63.

Lorion, C.M., D.F. Markle, S.B. Reid, and M.F. Docker. 2000. Redescription of the presumed-extinct Miller Lake lamprey, *Lampretra minima.* Copeia 2000(4):1019-1028.

McDonald, M. 1894. Notes on Fisheries of the Pacific Coast: Lampreys. Bulletin of the United States Fish Commission, Volume 14. Washington DC. p. 279.

Mattson, C.R. 1949. The Lamprey Fishery at Willamette Falls, Oregon. Fish Commission Research Briefs, Volume 2. Portland, Oregon. pp 23-27.

Merrell, T.R. 1959. Gull food habits on the Columbia River. Fish Commission Research Briefs, Volume 7. Portland, Oregon. p. 82.

Michael, J.H. 1980. Repeat spawning of Pacific Lamprey. California Fish and Game Notes. p. 187.

Moore, J.W. and J.M. Mallatt. 1980. Feeding of larval lamprey. Can. J. Fish. Aquat. Sci. 37: 1658-1664.

Moursund, R.A., D.D. Dauble and M.D. Bletch. 2000. Effects of John Day Dam Bypass Screens and Project Operations on the Behavior and Survival of Juvenile Pacific Lamprey (*Lampetra tridentata*). U.S. Army Corps of Engineers, Portland, Or.

Moursund, R.A., R.P. Mueller, T.M. Degerman, D.D. Dauble. 2001. Effects of Dam Passage on Juvenile Pacific Lamprey (*Lampetra tridentata*). U.S. Army Corps of Engineers, Portland, Or.

Normandeau Associates 2001. Final Report: Assessment of Willamette Falls Project Operational Effects on Upstream Passage of Non-Salmonid Species, in Particular, Pacific Lamprey. Report prepared for PGE, Portland, Or., Blue Heron Paper Co., Oregon City, Or., and Willamette Falls Project Fisheries, Aquatics, and Terrestrial Work Group.

Ocker, P.A., L.C. Stuehrenberg, M.L. Moser, A.L. Matter, J.J. Vella, B.P. Stanford. 2001 Monitoring Adult Pacific Lamprey (*Lampetra tridentata*) Migration Behavior in the Lower Columbia River using Radiotelemetry, 1998-1999. US Army Corps of Engineers, Portland, Oregon.

Pletcher, F.T. 1963. The Life History and Distribution of Lampreys in the Salmon and Certain Other Rivers in British Columbia, Canada. Master of Science Thesis. University of British Columbia, Vancouver B.C. 195 p.

Potter, I.C. 1980. Ecology of larval and metamorphosing lampreys. Can. J. Fish. Aquat. Sci. 37:1641-1657.

Puchy, C.A. and D.B. Marshall. 1993 Oregon Wildlife Diversity Plan. Second Addition. Oregon Department of Fish and Wildlife, Portland, Oregon.

Richards, J.E. 1980. Freshwater biology of the anadromous Pacific lamprey *Lampetra tridentata*. Master of Science, University of Guelph, Ontario, Canada. 99p.

Richards, J.E., R.J. Beamish and F.W. H. Beamish. 1982. Descriptions and keys for ammocoetes of lampreys from British Columbia, Canada. Can. J. Fish. Aquat. Sci. 39: 1484-1495.

Roffe, T.J. and B.R. Mate. 1984. Abundances and feeding habits of pinnipeds in the Rogue River, Oregon. Journal of Wildlife Mangement. 48: 1262-1274.

Rojas, M. 1992. The species problem and conservation: What are we protecting? Conservation Biology. 6: 170-178.

Slatick, E. and L. R. Basham. 1985. The effect of Denil fishway length on passage of some nonsalmonid fishes. Marine Fisheries Review 47:83-85.

Starke, G.M. and J.T. Dalen. 1995. Pacific Lamprey (*Lampetra tridentata*) Passage Patterns Past Bonneville Dam and Incidental Observations of Lamprey at the Portland District Columbia River Dams in 1993. US Army Corps of Engineers, Bonneville Lock and Dam, Cascade Locks, Oregon.

Stone, J., T. Sundlov, S. Barndt and T. Coley. 2001. Evaluate Habitat Use and Population Dynamics of Lampreys in Cedar Creek. Annual Report 2000. Bonneville Power Administration Project Number 2000-014-00. Portland, Oregon.

Susac, G. and S. Jacobs. 1999. Evaluation of spawning ground surveys for indexing the abundance of adult winter steelhead in Oregon coastal basins. Oregon Department of Fish and Wildlife, Corvallis, Oregon.

Torgerson, C.E. and D.A. Close. 2001. Habitat heterogeneity and the spatial distribution of larval Pacific Lamprey (*Lampetra tridentata*) in an Oregon stream. Bonneville Power Administration Project 94-026, Portland, Oregon.

van der Wetering, S.J. 1998. Aspects of Life History Characteristics and Physiological Processes in Smolting Pacific Lamprey (*Lampetra tridentata*) in a Central Oregon Coast Stream. Master of Science Thesis. Oregon State University. Corvallis Oregon.

van der Wetering, S.J. and R. Ewing 1999. Lethal Temperatures for Larval Pacific Lamprey, *Lampetra tridentata.* Confederated Tribes of the Siletz Indians, Siletz Oregon.

Vladykov, V.D. 1973. *Lampetra pacifica*, a new nonparasitic species of lamprey (Petromyzontidae) from Oregon and California. J. Fish. Res. Board Can. 30: 205-213.

Vladykov, V.D. and E. Knott. 1976. A second nonparasitic species of Entosphenus Gill, 1862 (Petromyzonidae) from Klamath River System, California. Can. J. Zool. 54: 974-989.

Wallace, R.L. 1978. Landlocked parasitic Pacific Lamprey in Dworshak Reservior, Idaho. Copeia 1978:545-546.

Ward, D.L. 2001. Lamprey Harvest at Willamette Falls, 2001. Oregon Department of Fish and Wildlife, Clackamas, Oregon.

Weeks, H. 1993. Status of Pacific Lamprey. Status Review for Oregon State Sensitive Species Listing. Oregon Department of Fish and Wildlife. Portland, Or.

Willis, R. 1962. Gnat Creek Weir Studies. Oregon Fish Commission, Portland Oregon.

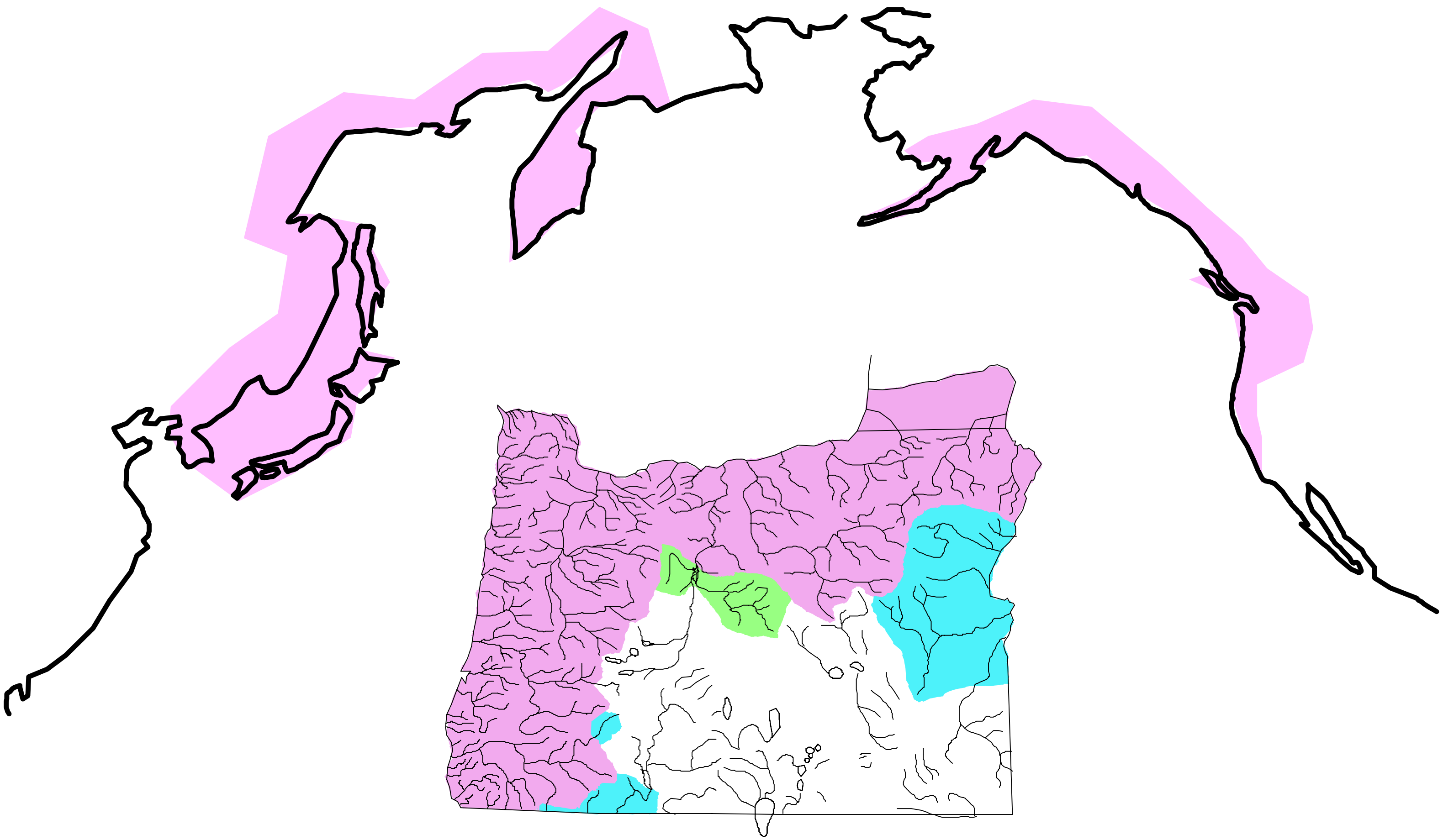


Figure 1. Present and historic distribution of the anadromous Pacific Lamprey (*Lampetra tridentata*) in Oregon and around the Pacific Rim. Present distribution ( ); area of known historic distribution ( ) and areas of suspected historic distribution ( ).

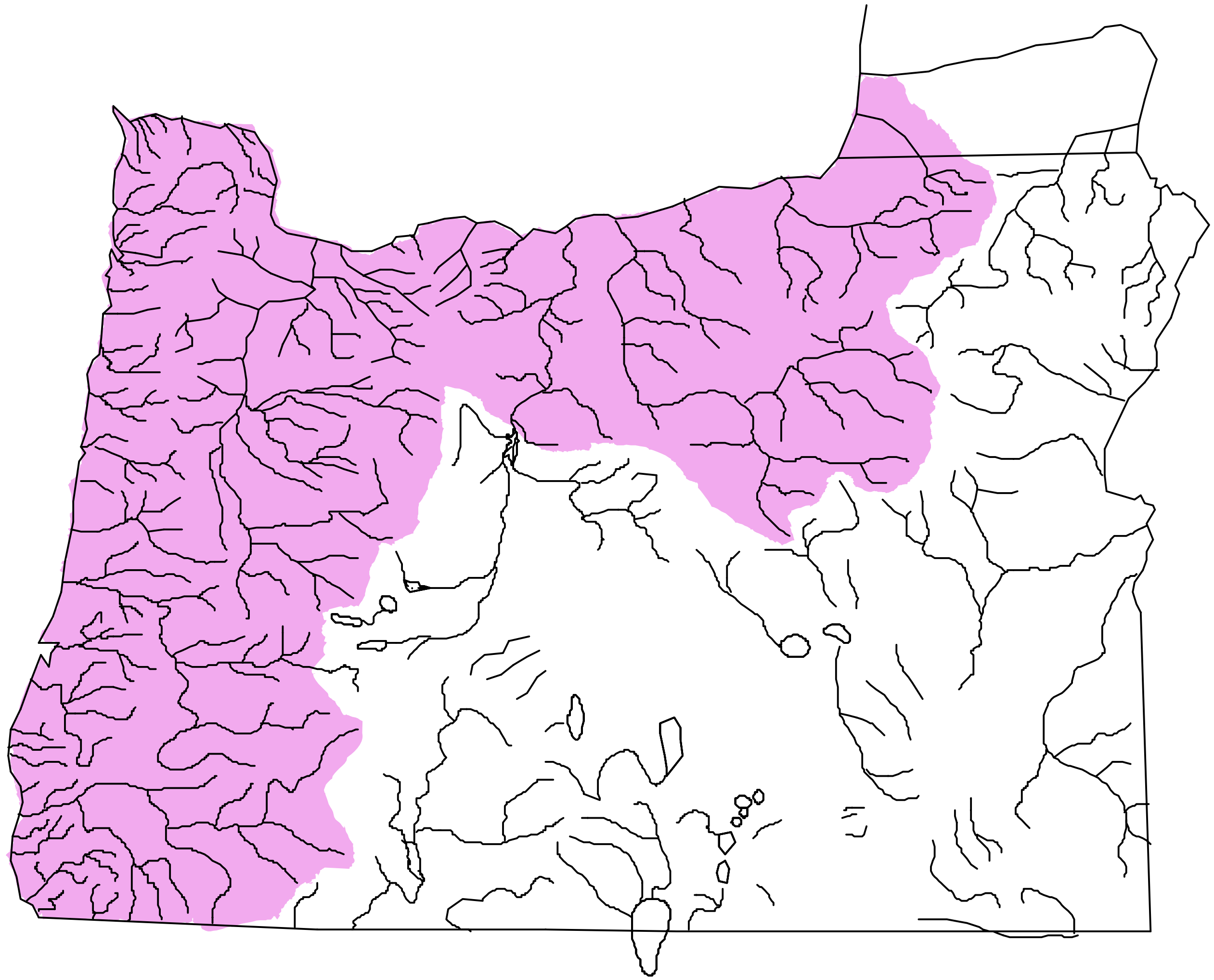


Figure 2. Distribution of the resident Western Brook Lamprey (*Lampetra richardsoni*) in Oregon.

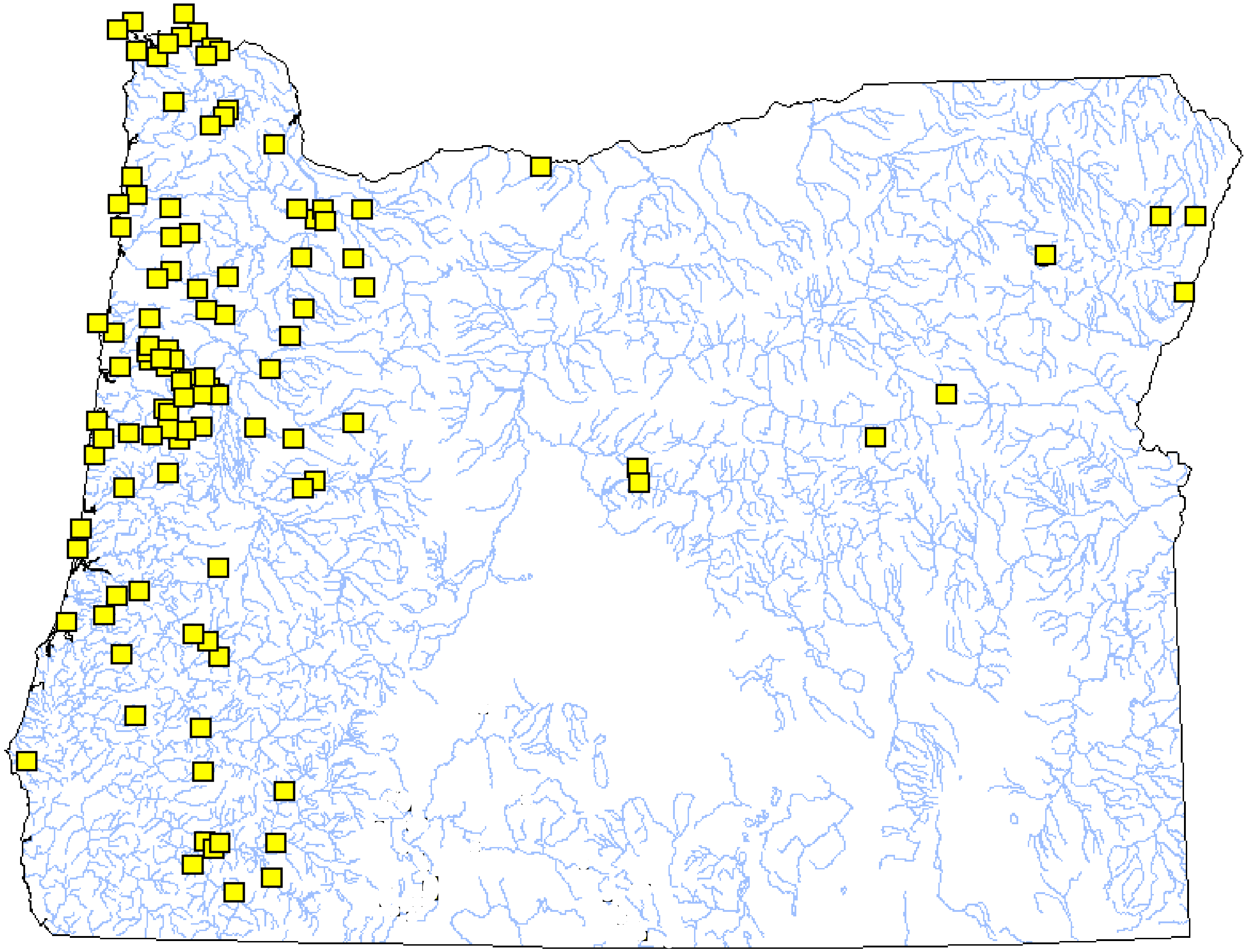


Figure 3. Collection records of anadromous Pacific Lamprey (*Lampetra tridentata*) in Oregon from the Oregon State University museum GIS data base.

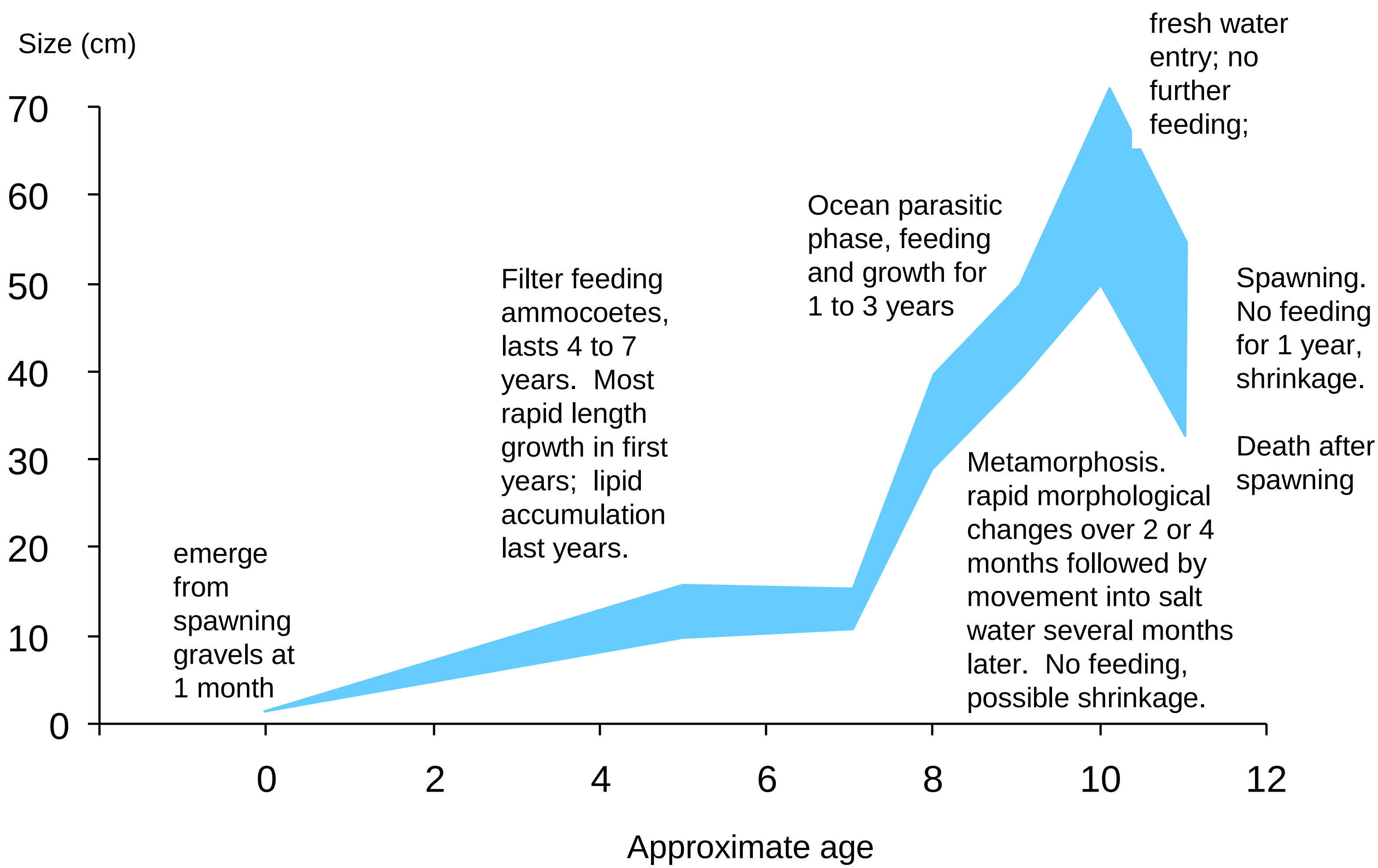


Figure 4. A generalized growth pattern (length) for Pacific Lamprey. Periods of arrested length growth and shrinkage will occur, particularly associated with bouts of no feeding.

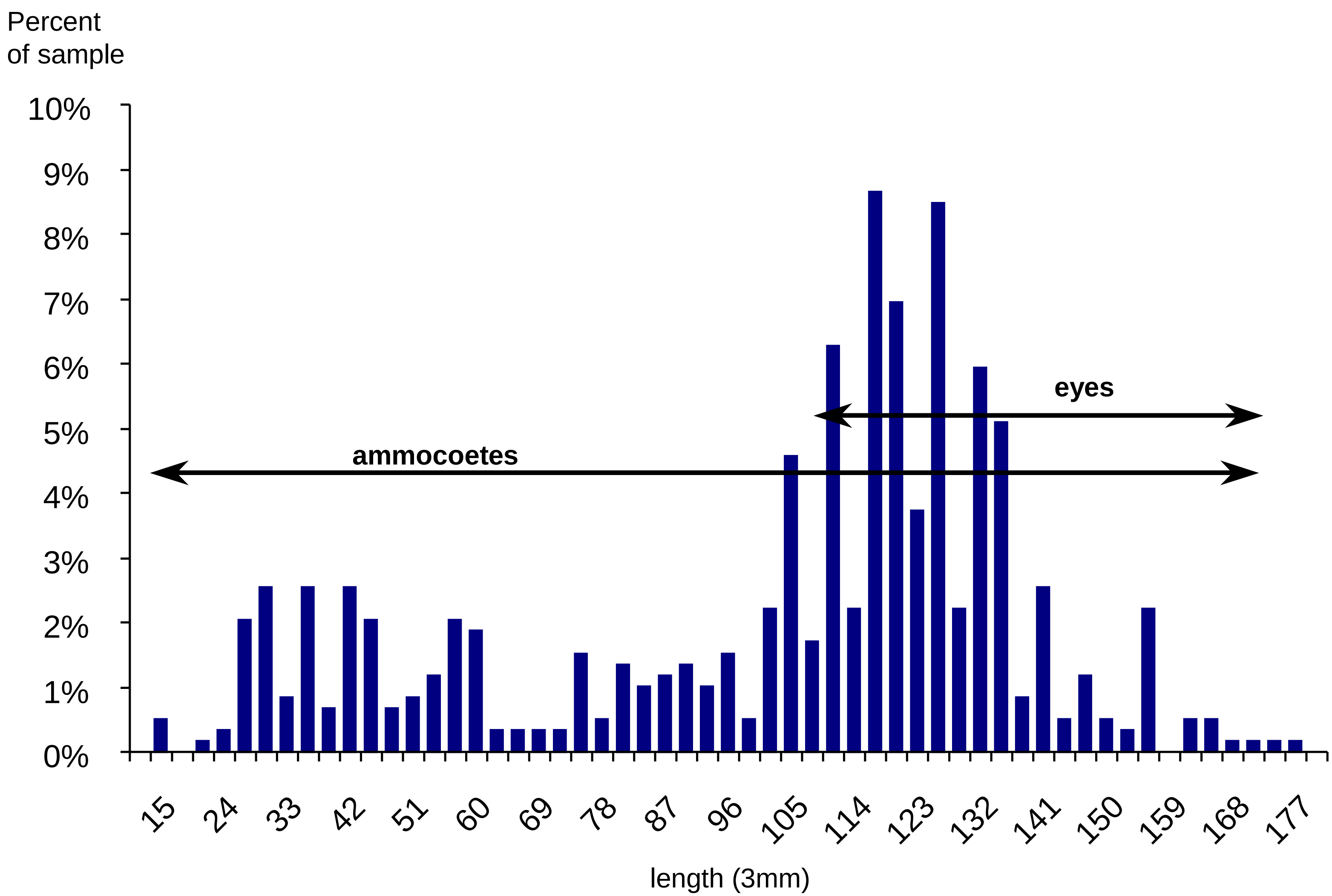


Figure 5a. Size distribution of lamprey captured in smolt traps on the upper Rogue Basin 1998-2001, all traps and years combined. Potentially multiple species present. Eyed individuals are likely undergoing metamorphism although some adult brook lamprey may be included.

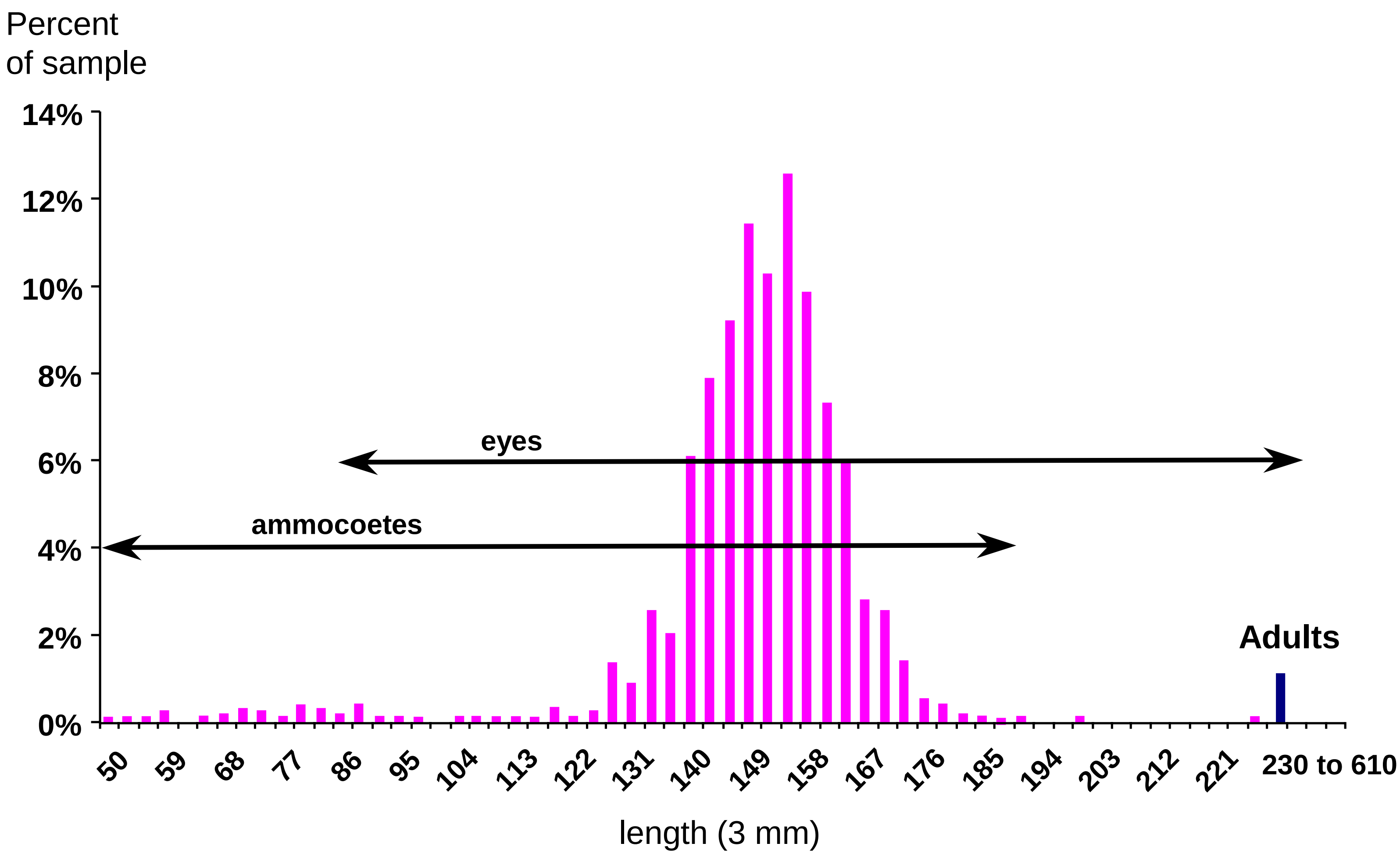


Figure 5b. Size distribution of lamprey captured in smolt traps on the lower Umatilla (RM 1.2 and 3.7), Columbia Basin 1998-2001, all traps and years combined. Only Pacific lamprey are present. Most eyed individuals are undergoing metamorphism although a few larger adults were also observed.

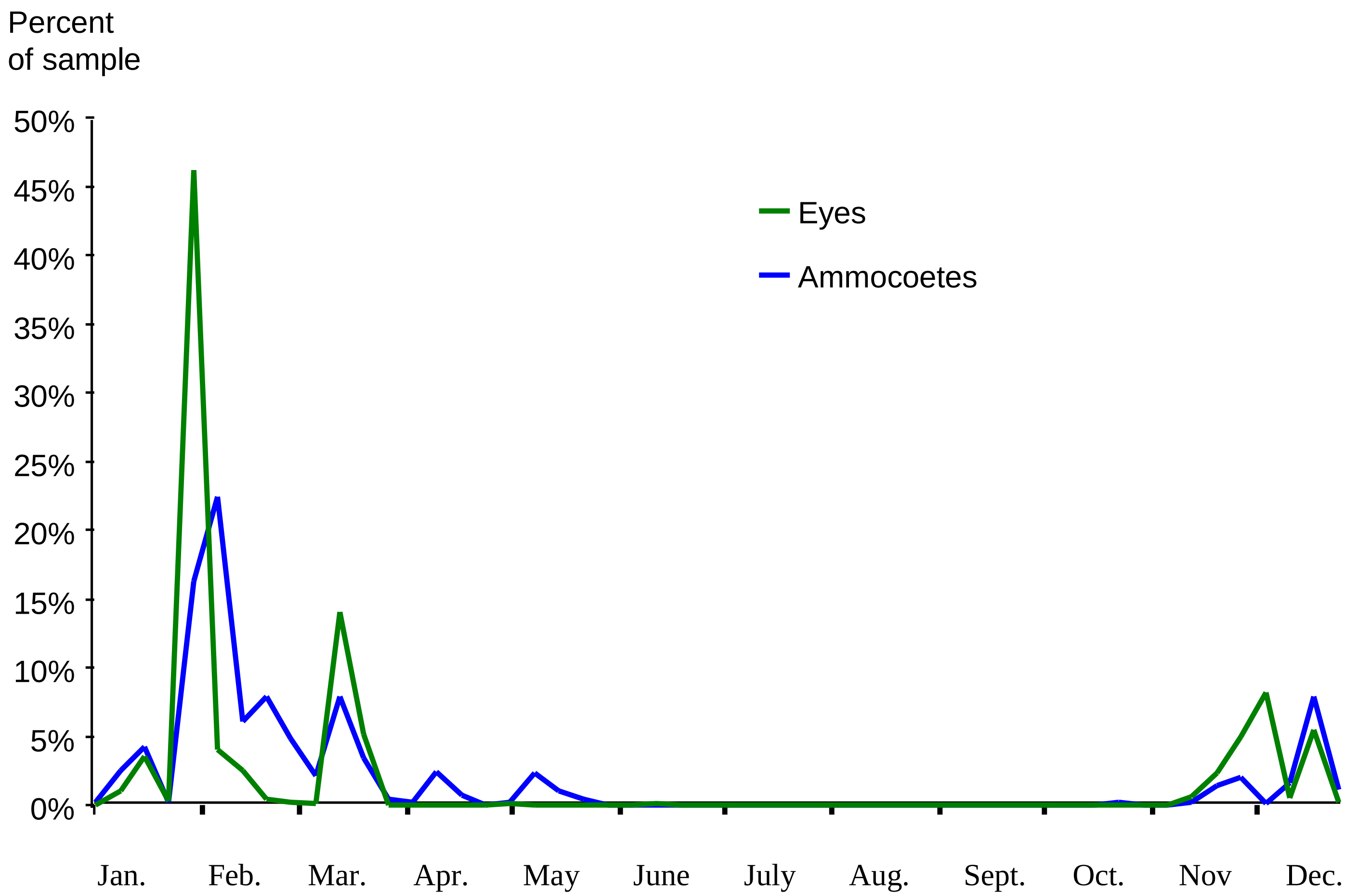


Figure 6a. Date of capture of lamprey in smolt traps in the lower Umatilla, Columbia Basin; weekly counts 1998 - 2001. All years and traps combined. N = 1,162 ammocoetes and N = 914 eyed lamprey. All lamprey observed were likely Pacific Lamprey.

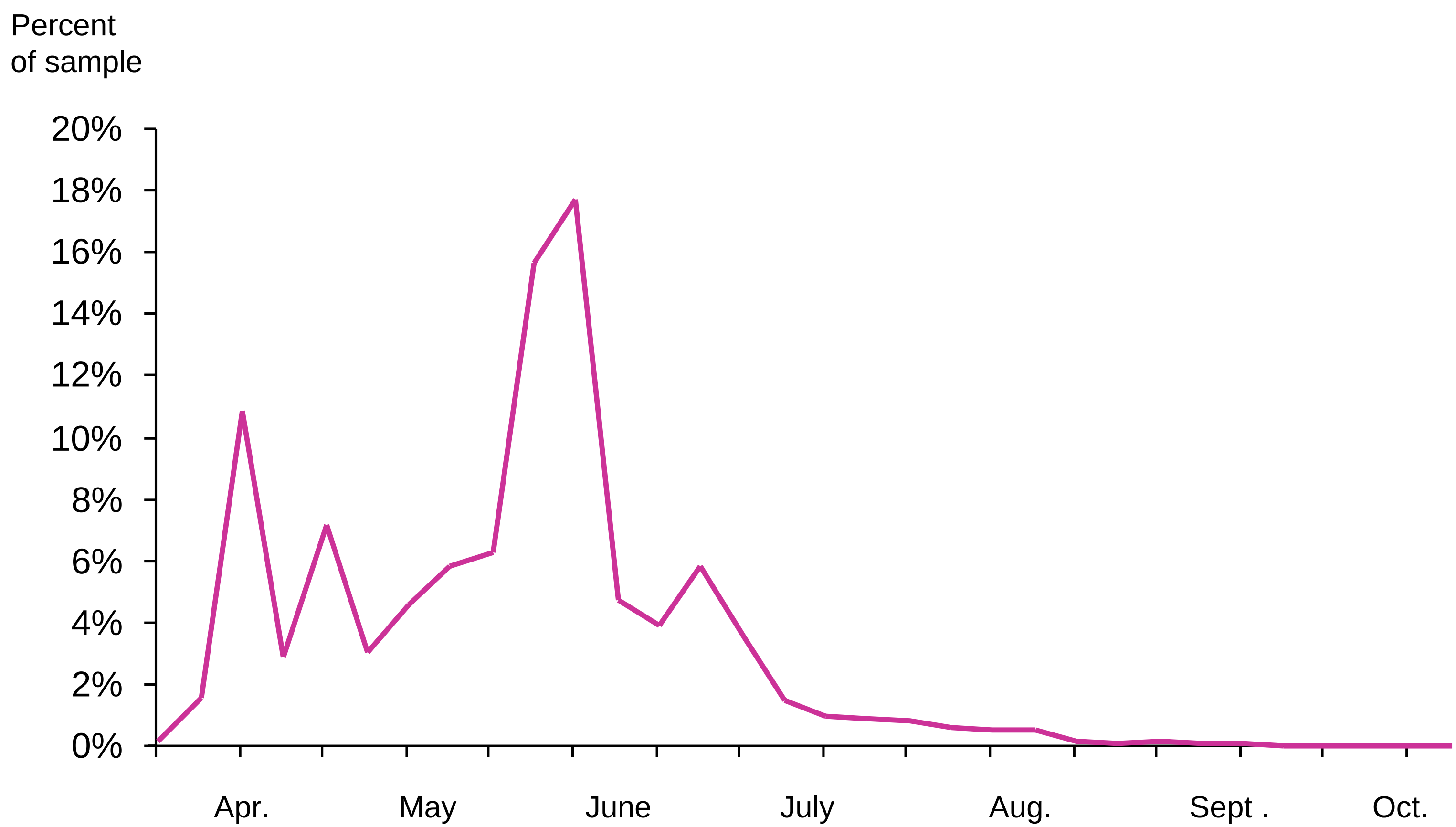


Figure 6b. Date of capture of juvenile lamprey at John Day Dam, mainstem Columbia River, 1988 - 2000 all years combined. N = 479,160. Sampling did not occur from November through mid-March.

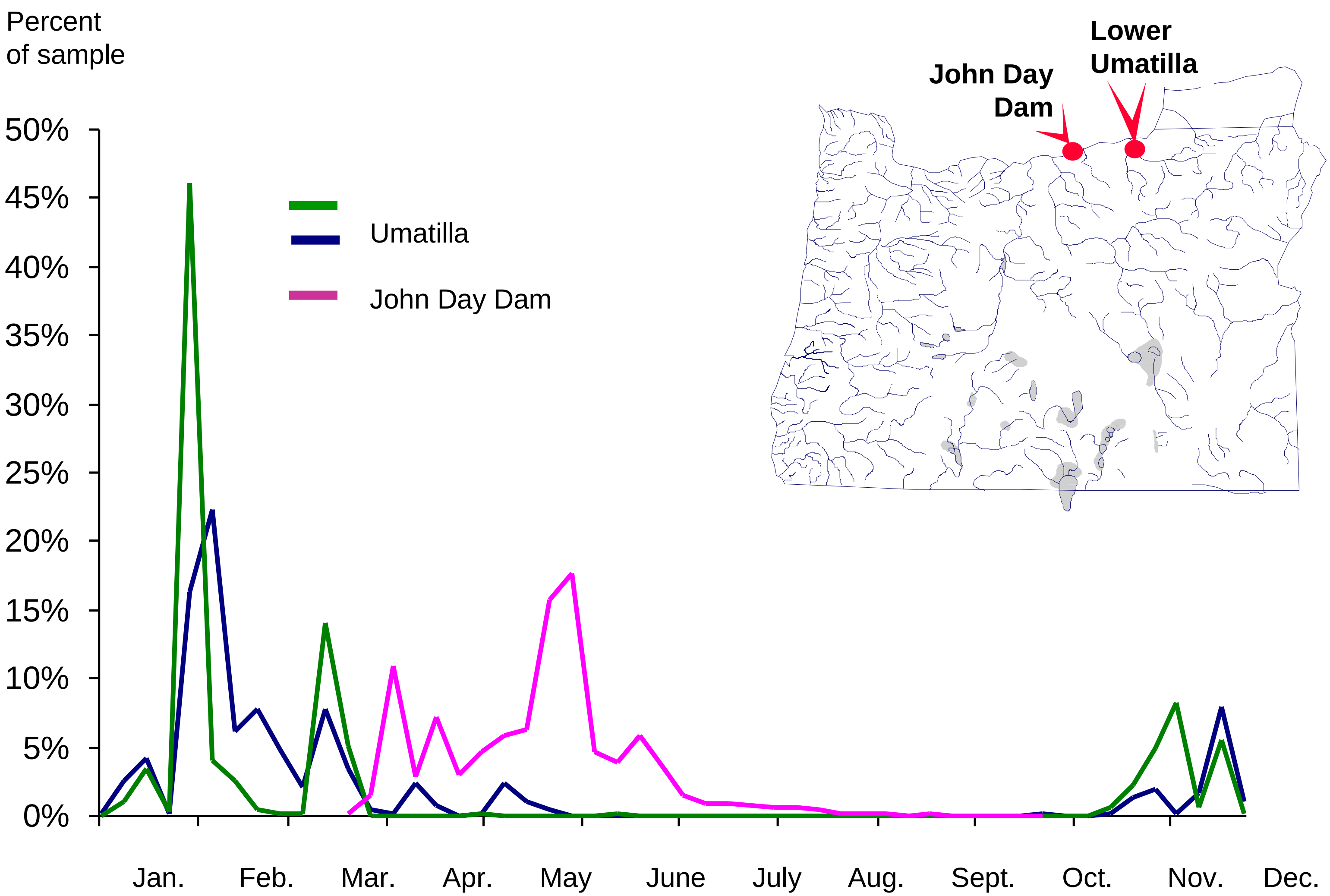


Figure 6c. Comparison of run time measured at John Day Dam (1988 - 2000) and in traps on the lower Umatilla (1998 - 2001). The two monitoring sites are very proximate to each other. Some of the differences in apparent run-time is probably caused by a lack of monitoring during the winter at John Day Dam.

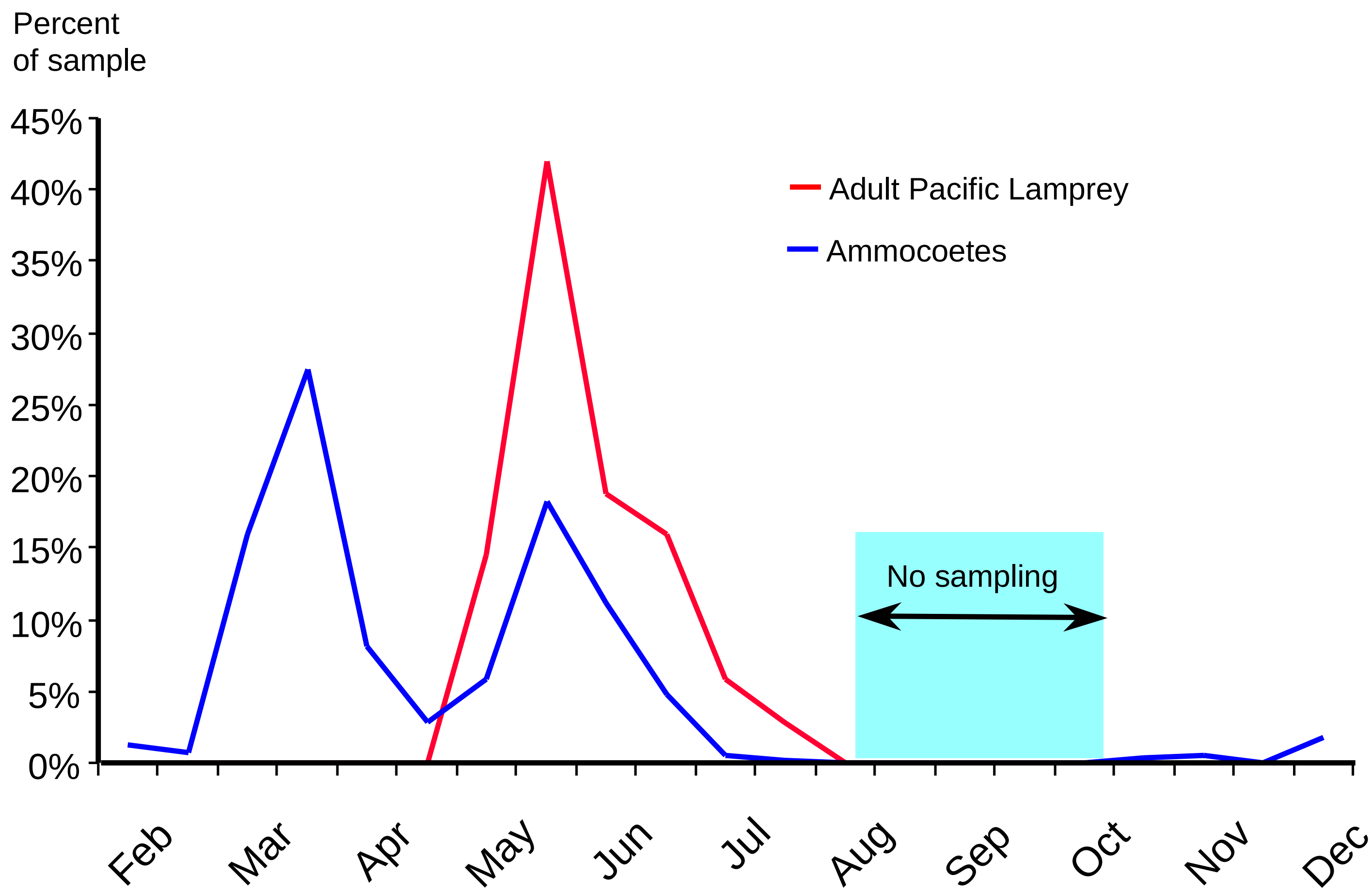


Figure 6d. Date of capture of lamprey in smolt traps on Fifteenmile Creek in the Columbia Basin, weekly counts 1998 - 2000. All years combined. Possibly western brook lamprey are among the ammocoetes. Eyed individuals not specified; uncertain whether any were observed. No sampling occurred between mid-August and mid-October, or between mid-Dec. through January.

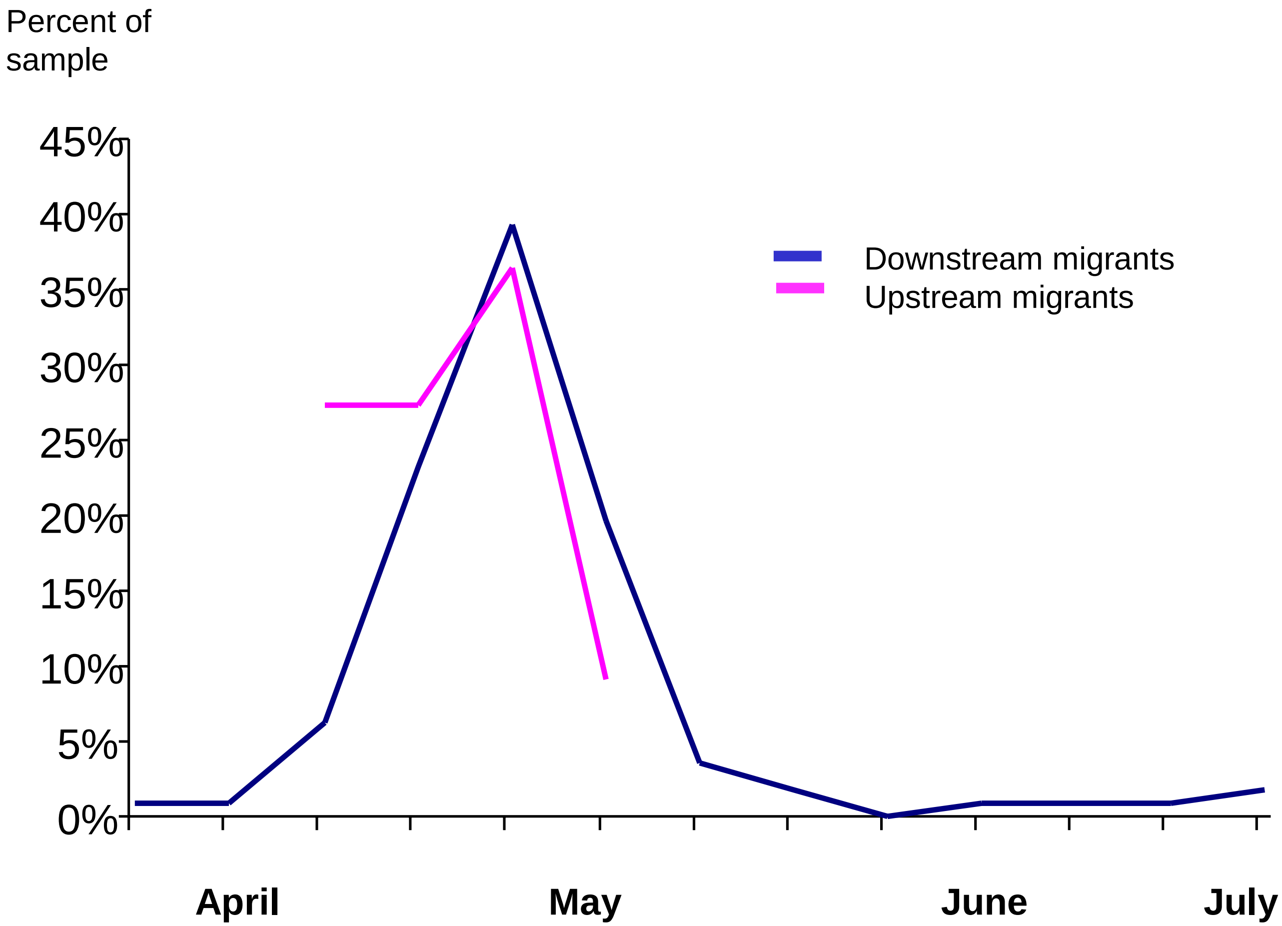


Figure 6e. Date of capture of lamprey at a trap on Mill Creek on the Yamhill River in the Willamette Basin, weekly counts during the spring made in 1976.

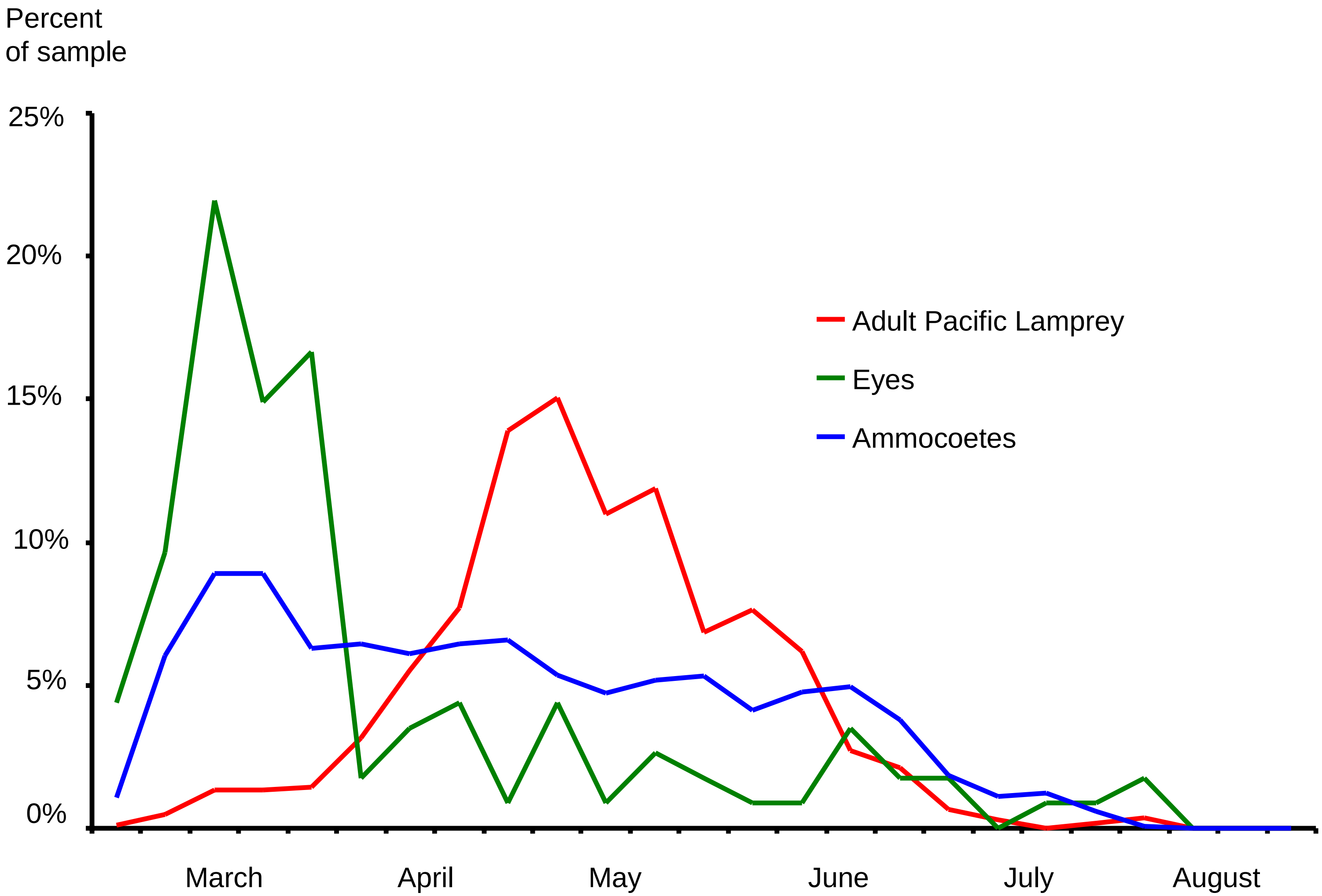


Figure 6f. Date of capture of lamprey in traps in Tenmile and Cummins creeks on the south Oregon coast, weekly counts 1993 - 2001. All traps and years combined. Eyed individuals and ammocoetes may be a mix of species. No monitoring occurred in fall or winter.

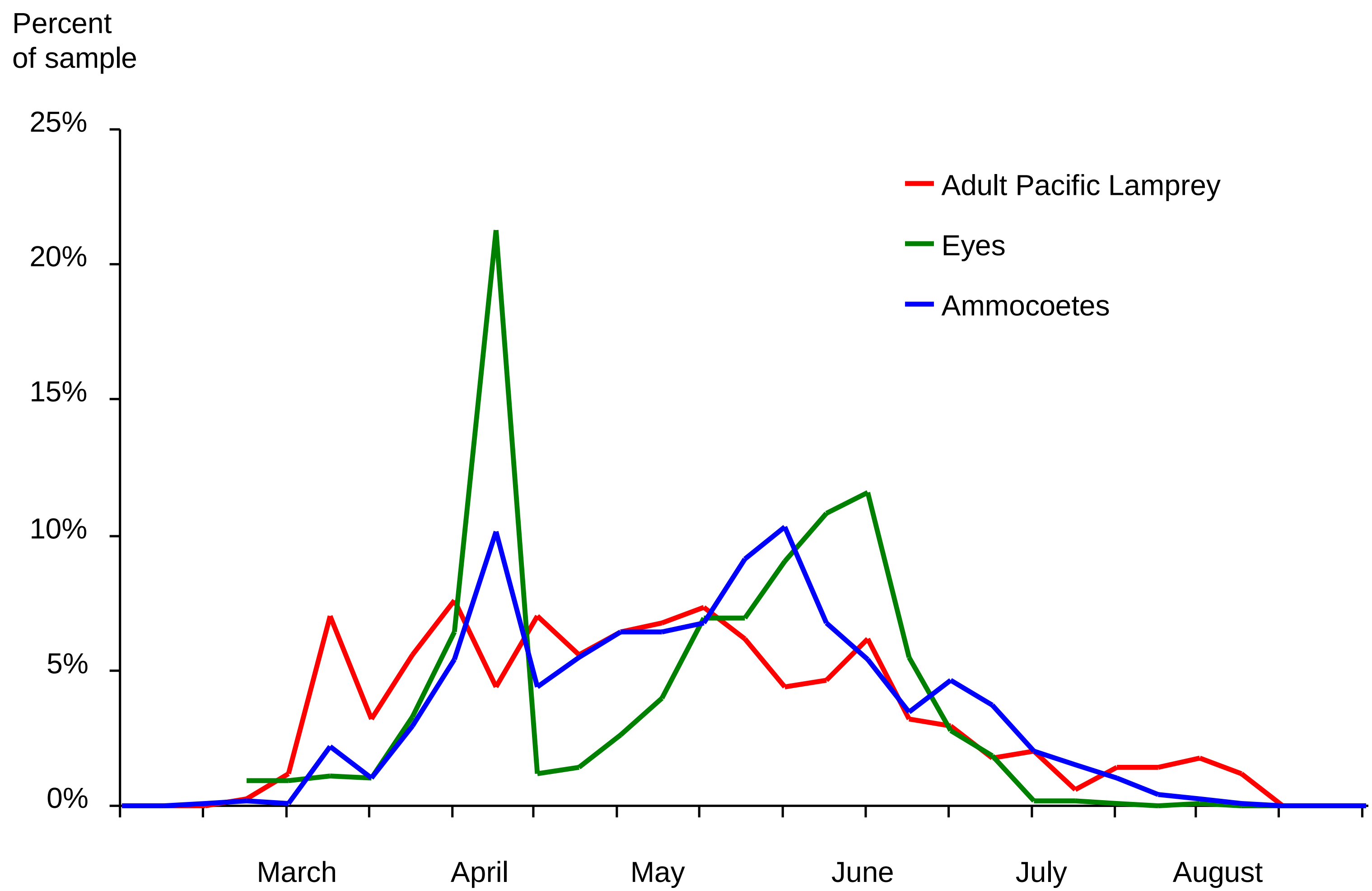


Figure 6g. Date of capture of lamprey in Oregon coastal smolt traps, weekly counts 1998 - 2001. All traps and years combined. Eyed individuals and ammocoetes may be a mix of species. No monitoring occurred in fall or winter.

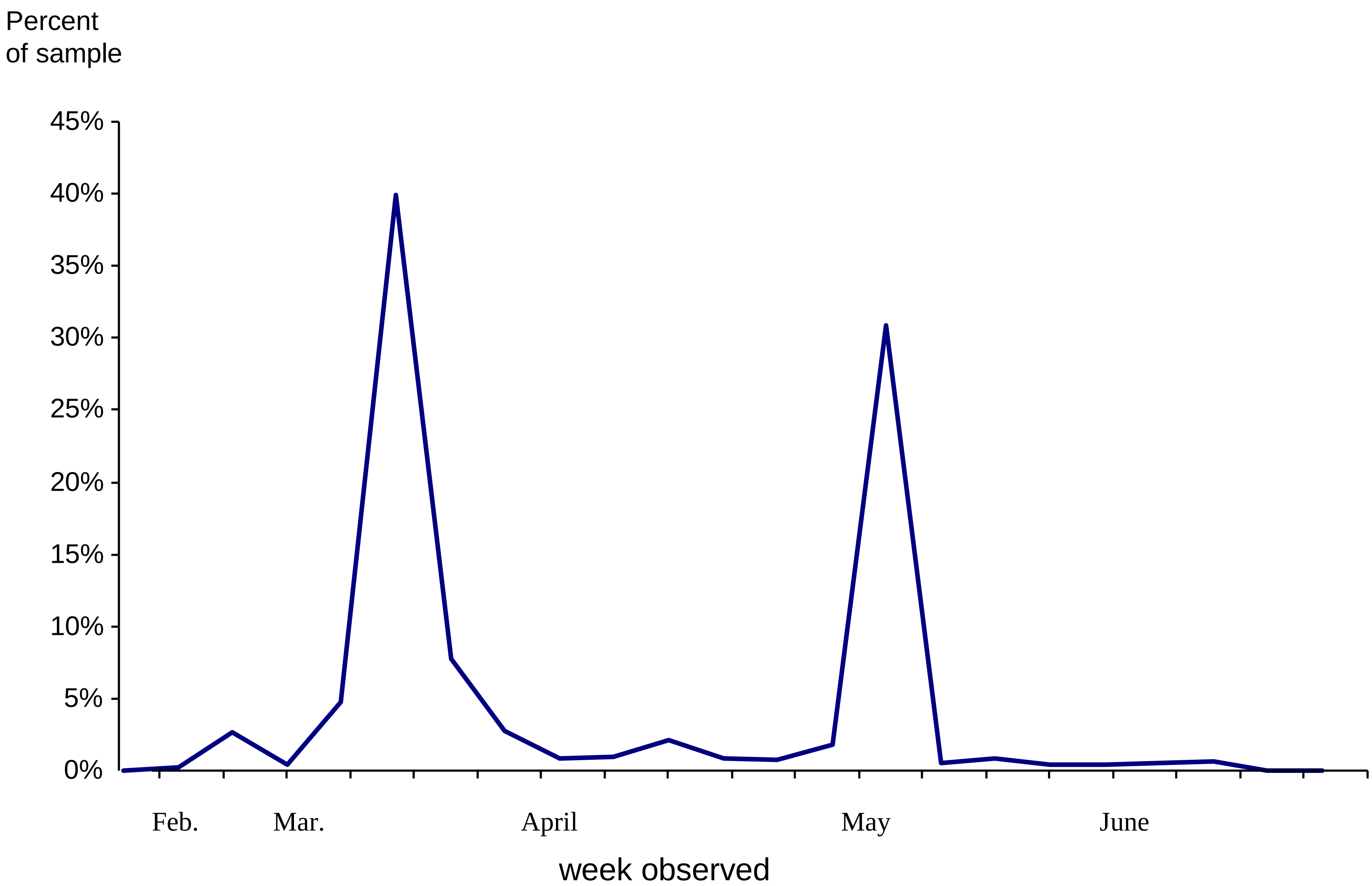


Figure 6h. Time of capture of lamprey in smolt traps in the upper Rogue River Basin; weekly data, 1998-2001. All years and traps combined. N = 7,458. Mostly ammocoetes, possibly a mix of species. A few eyed individuals were seen from late February through April. No monitoring occurred in fall or winter.

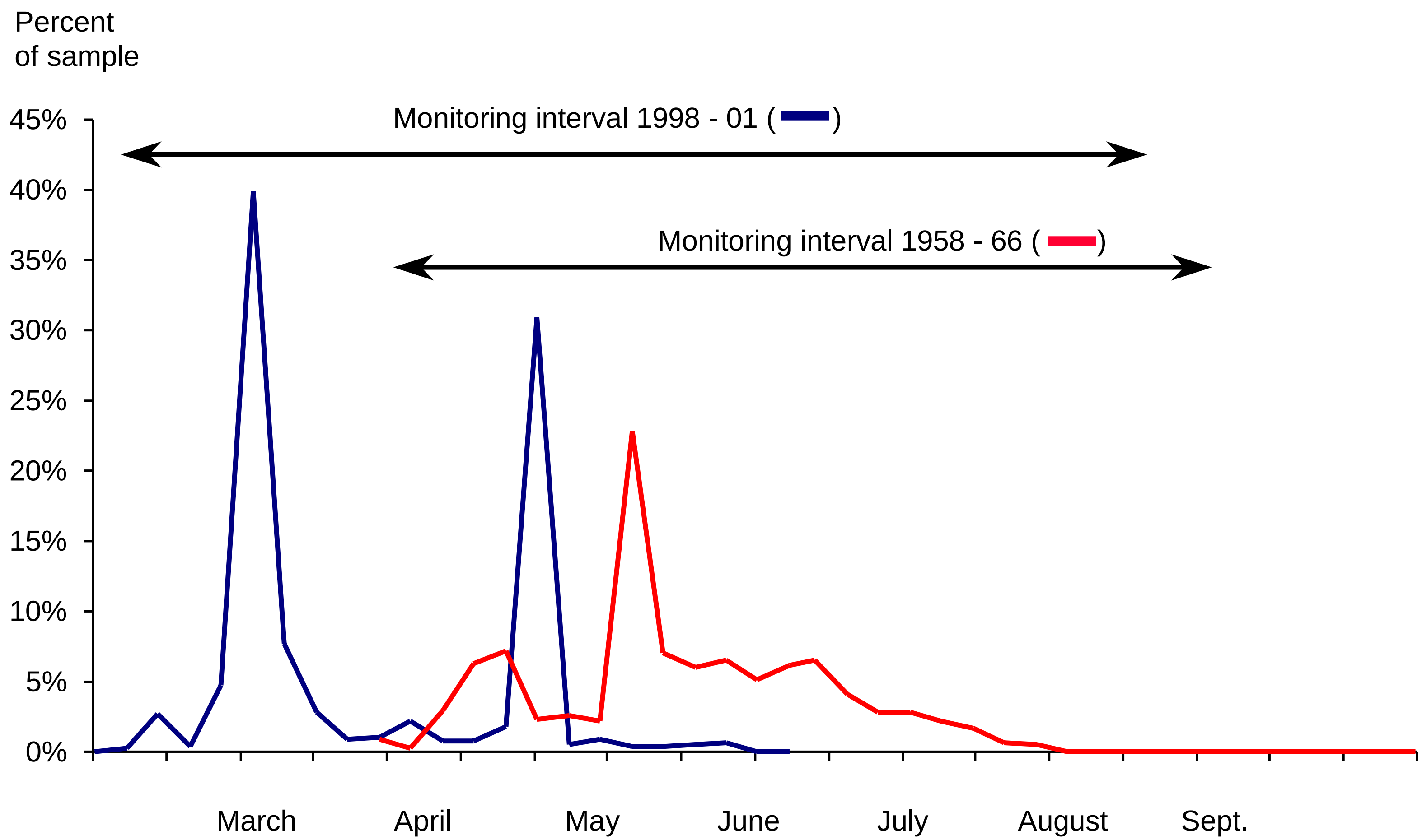


Figure 6i. A comparison of recent (1998 - 2001) and historic (1958- 1966) time of capture of lamprey in traps in the upper Rogue River Basin. All monitoring stations and years combined. The monitoring intervals in the two time periods are shown by arrows. No monitoring occurred in fall or winter.

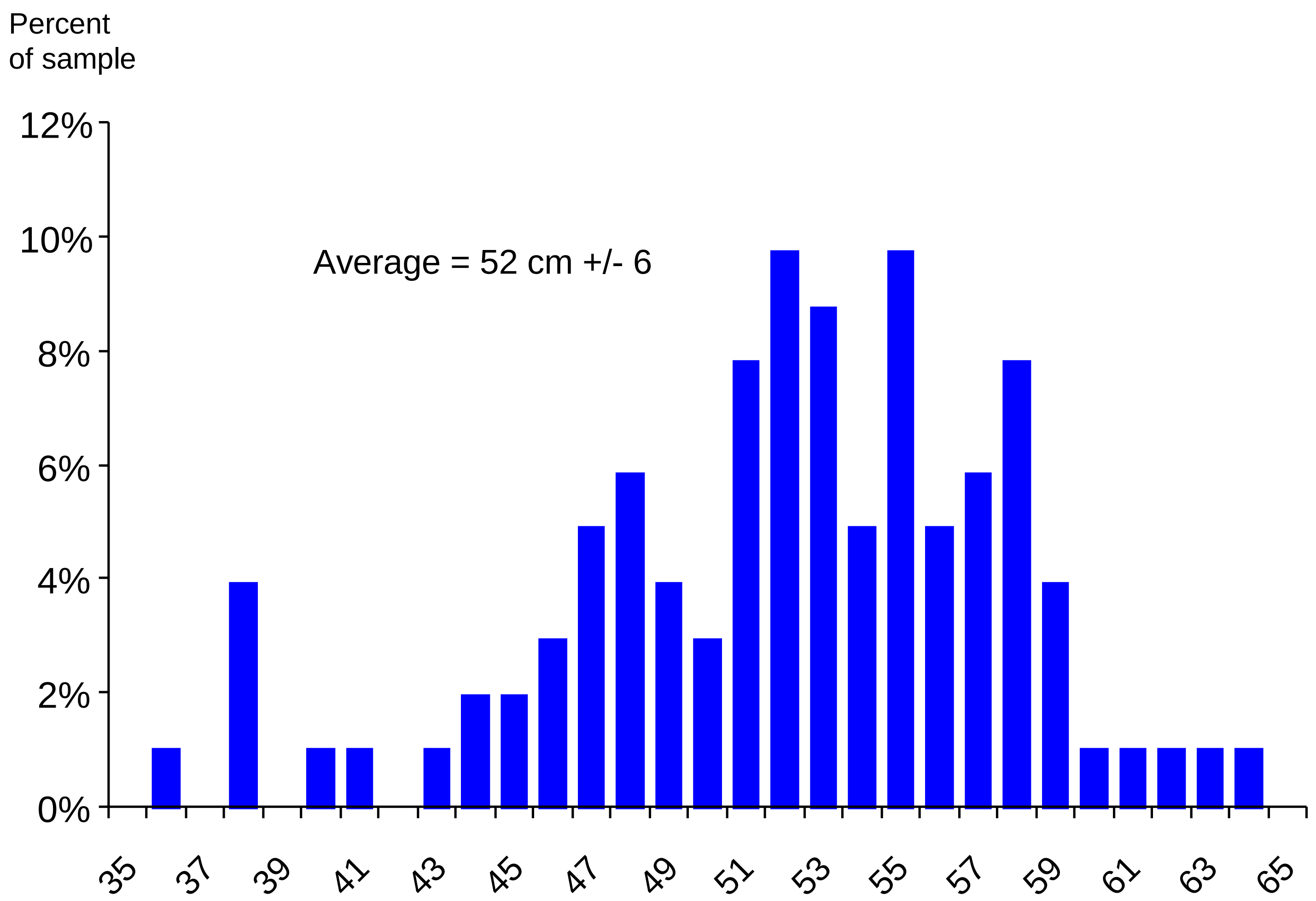


Figure 7a. Sizes of adult Pacific Lamprey collected from spawning grounds on the Coquille, in the spring of 2000; N = 103.

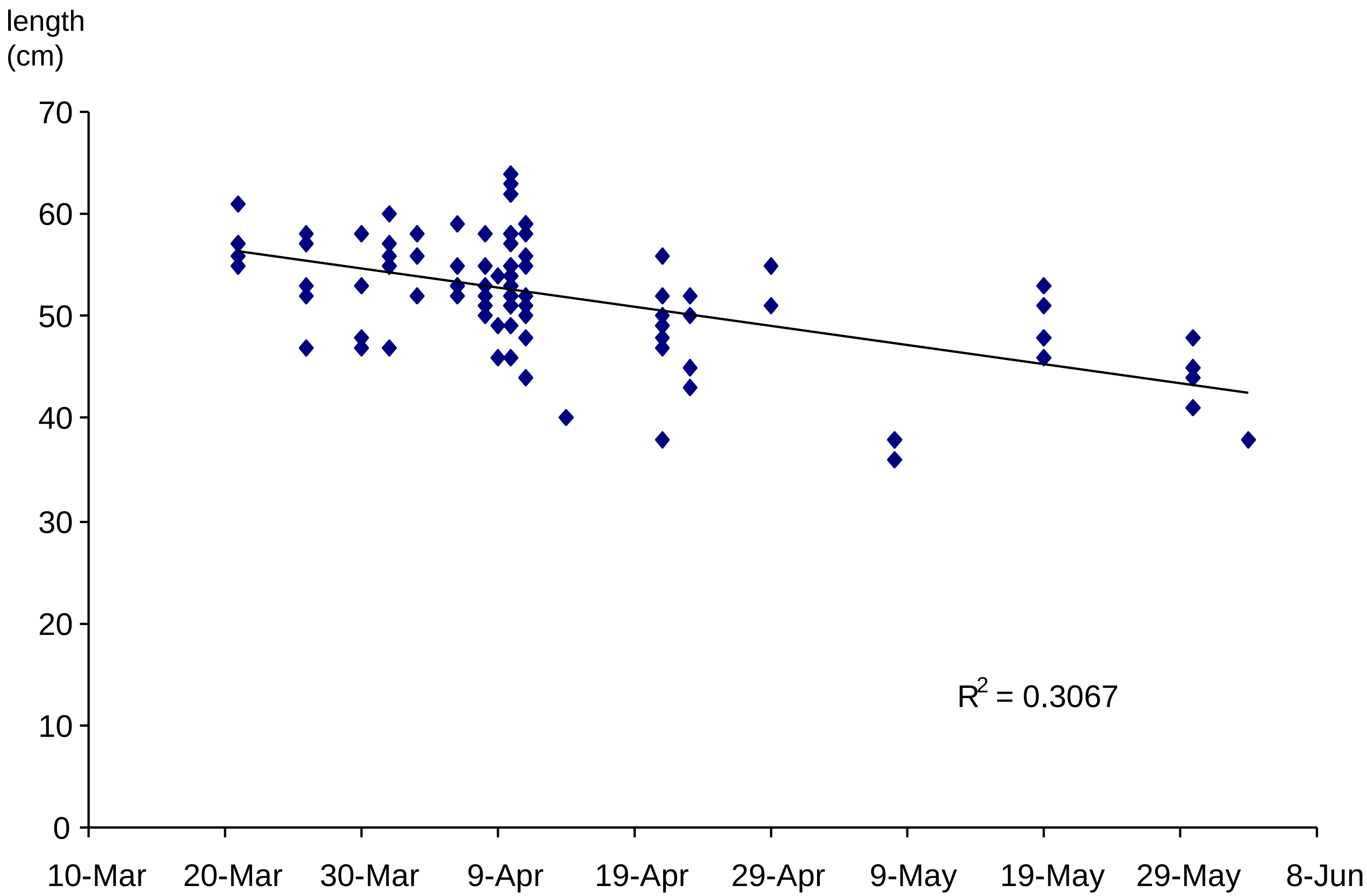


Figure 7b. Relationship between the size of spawning adult lamprey and the date of spawning on the South Fork Coquille, 2000; N = 103. Later spawning individuals tend to be smaller.

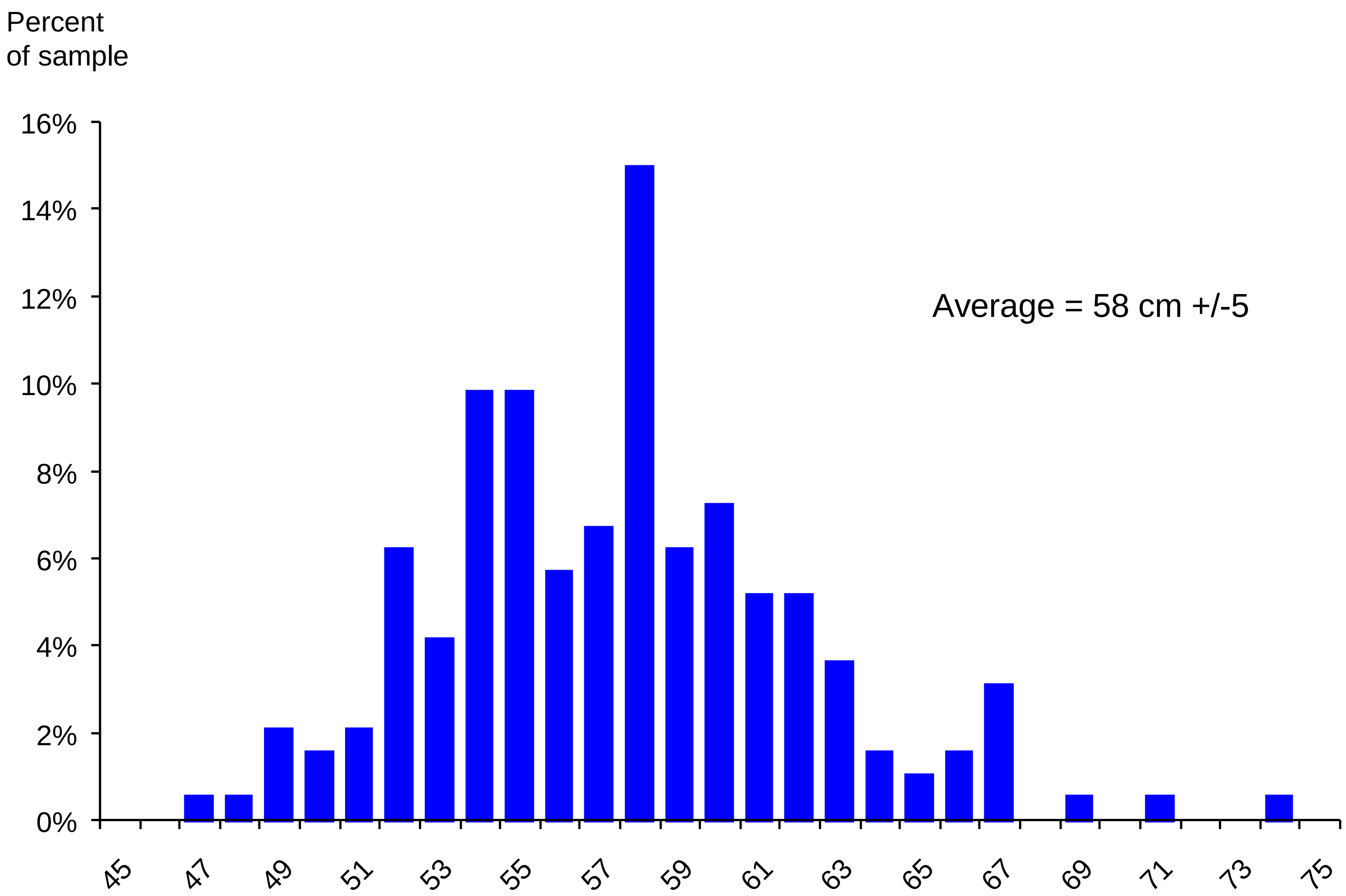


Figure 7c. Length distribution of adult Pacific Lamprey collected on one day in April 1994 at Willamette Falls; N = 194.

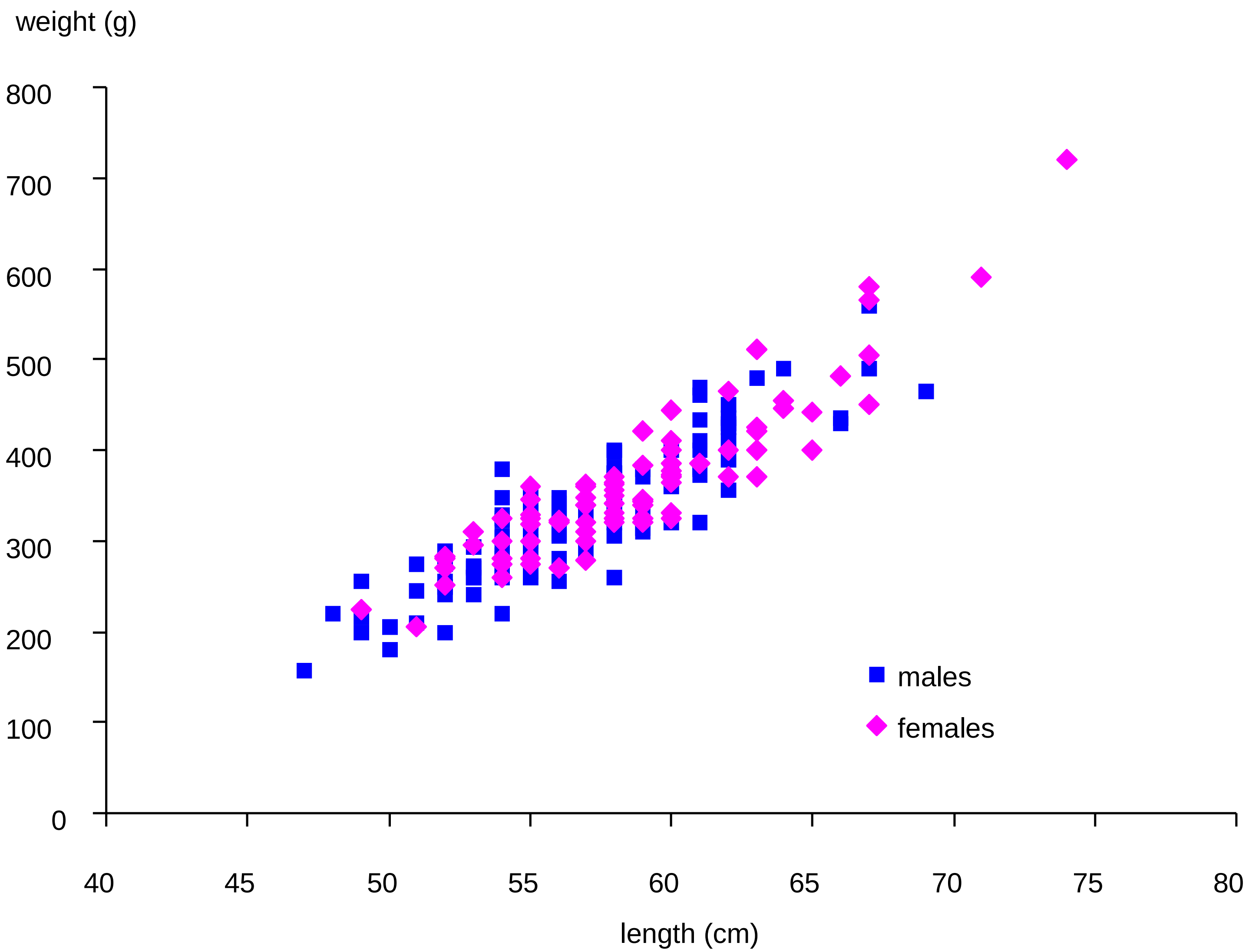


Figure 7d. Weight/length distribution by gender of Pacific Lamprey measured at Willamette Falls.

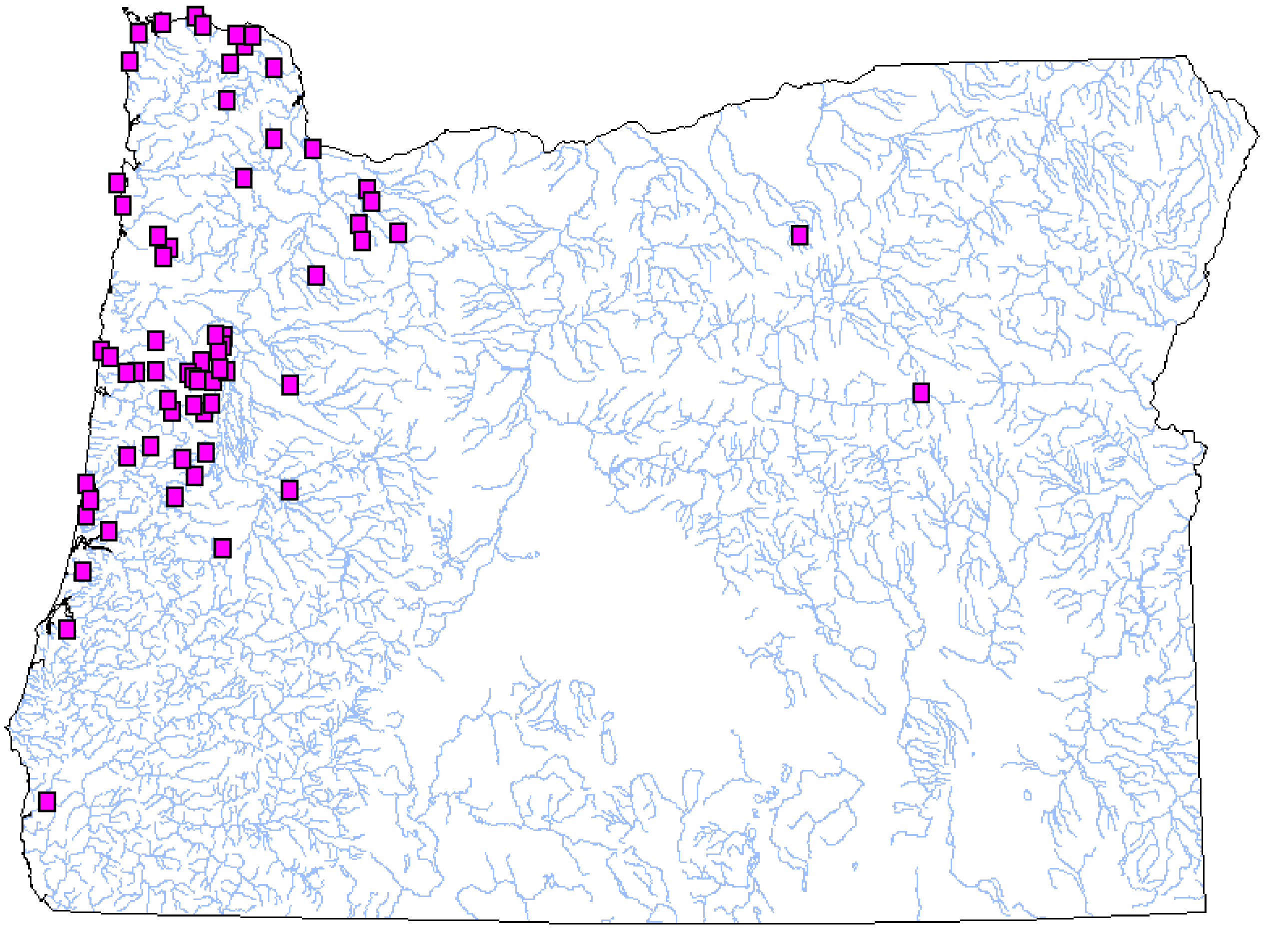


Figure 8. Collection records of the Western Brook Lamprey (*Lampetra richardsoni*) in Oregon from the Oregon State University museum GIS data base.

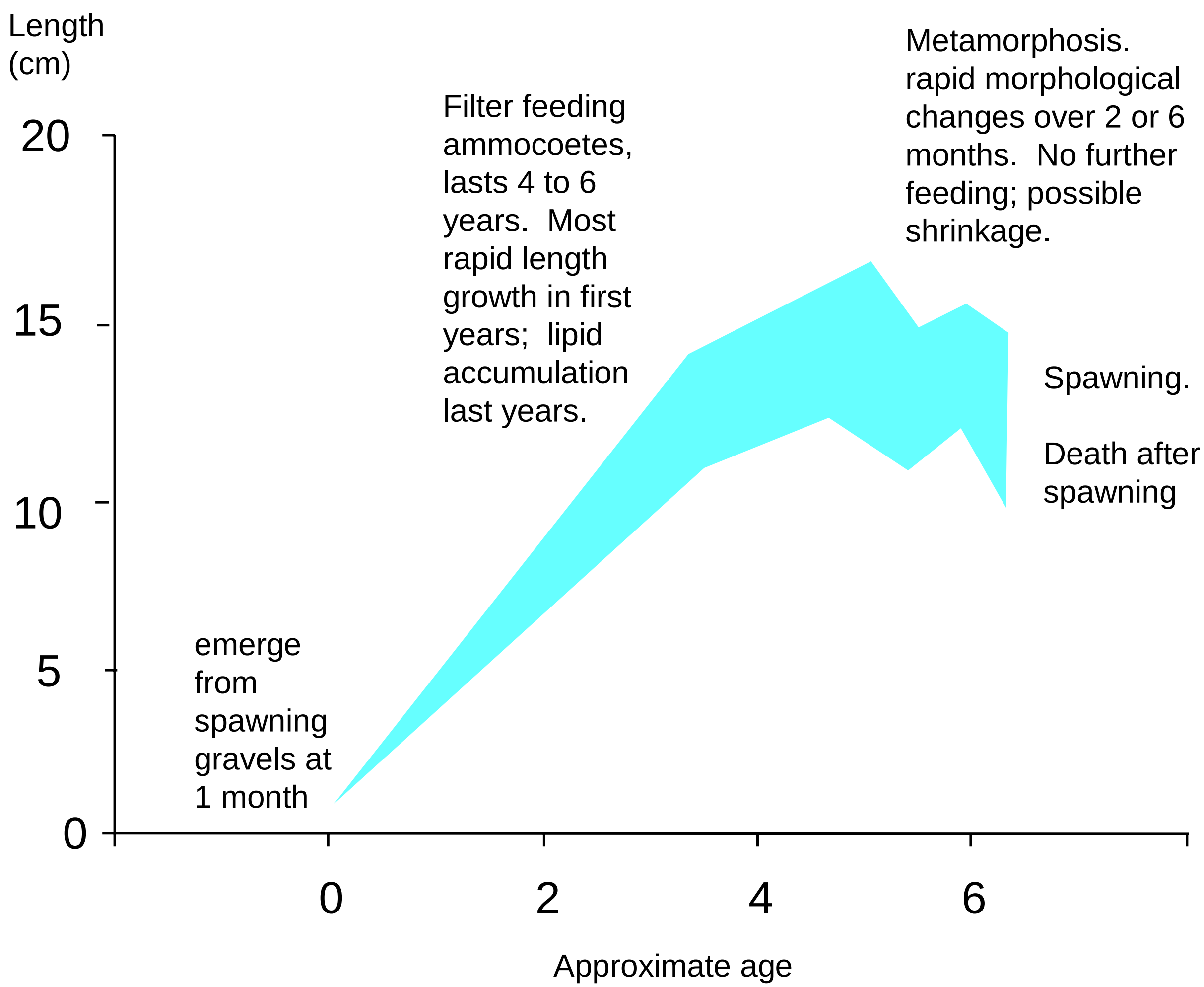


Figure 9. A generalized growth pattern (length) for brook lamprey. Feeding stops at the onset of metamorphism and the lamprey may shrink in size before spawning.

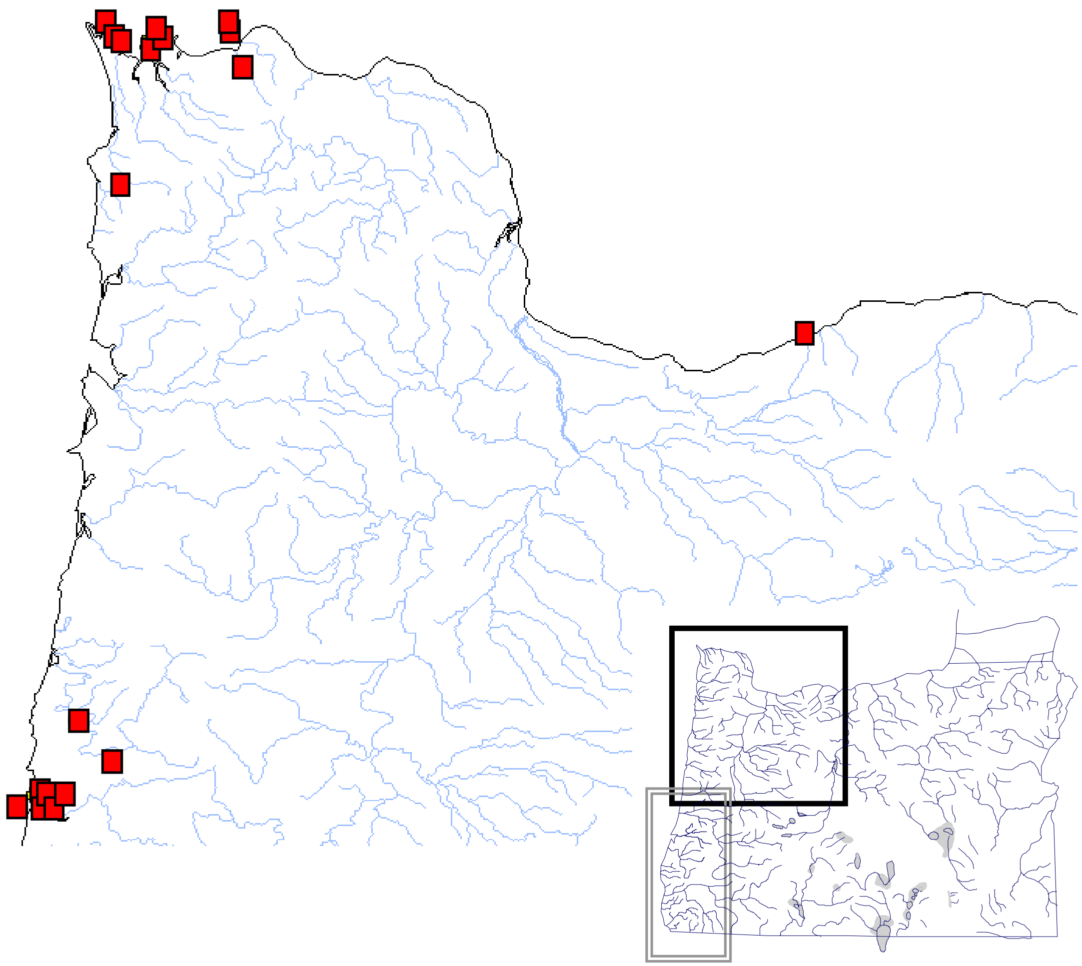


Figure 10. Collection records of the River Lamprey (*Lampetra ayresi*) in Oregon from the Oregon State University museum GIS data base.

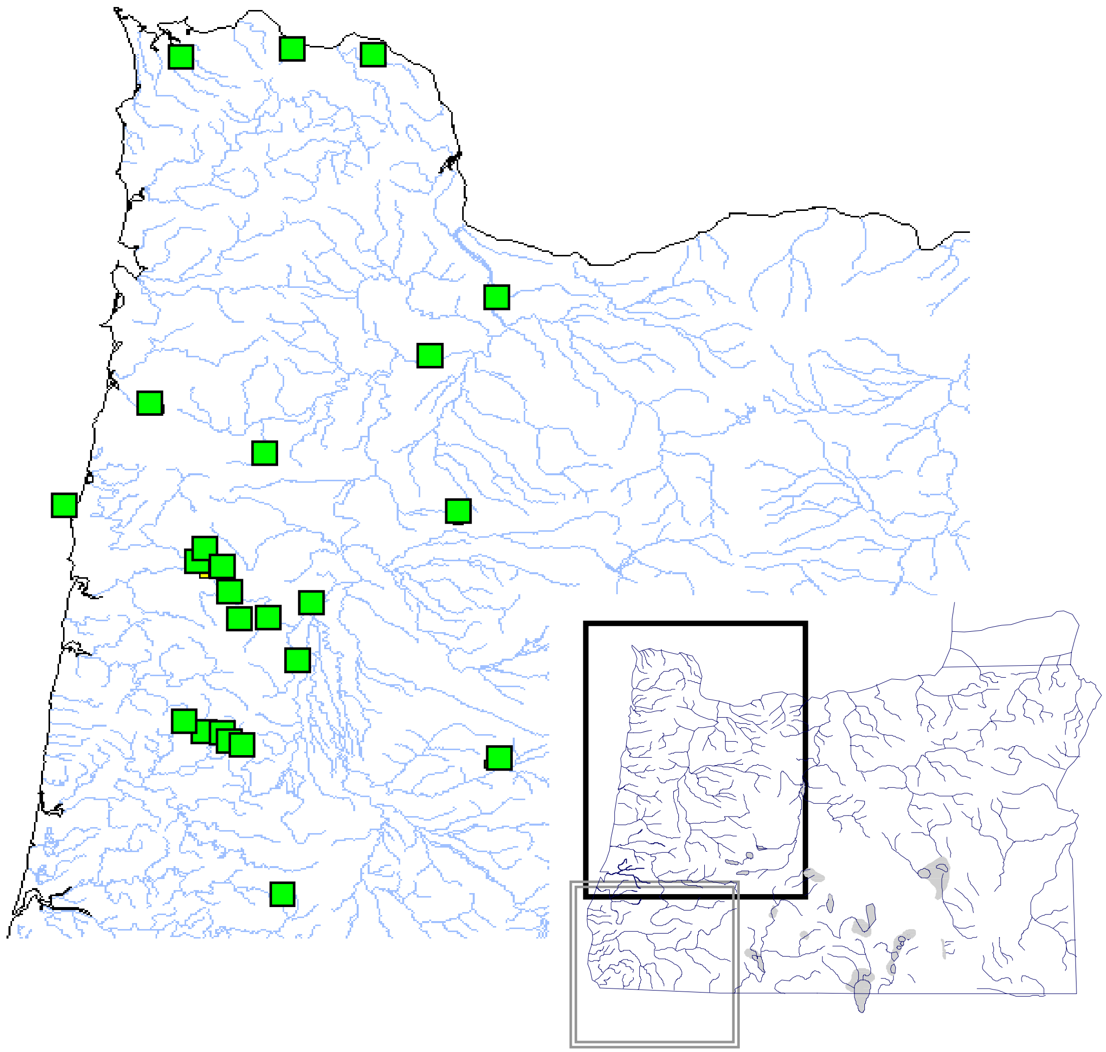


Figure 11. Collection records of the Pacific Brook Lamprey (*Lampetra pacifica*) in Oregon from the Oregon State University museum GIS data base.

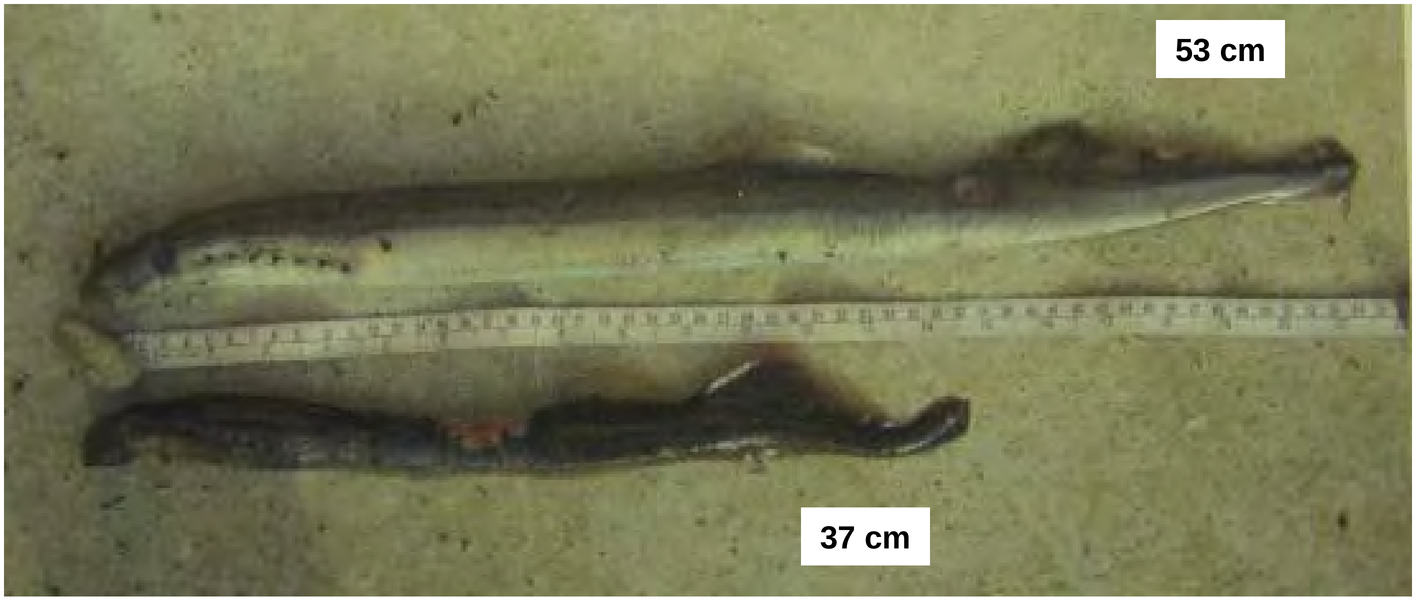


Figure 12. Photograph of Pacific Lamprey and “dwarf” Pacific Lamprey, both taken from spawning grounds, on the Coquille River. Photograph by L. Grandmontagne.

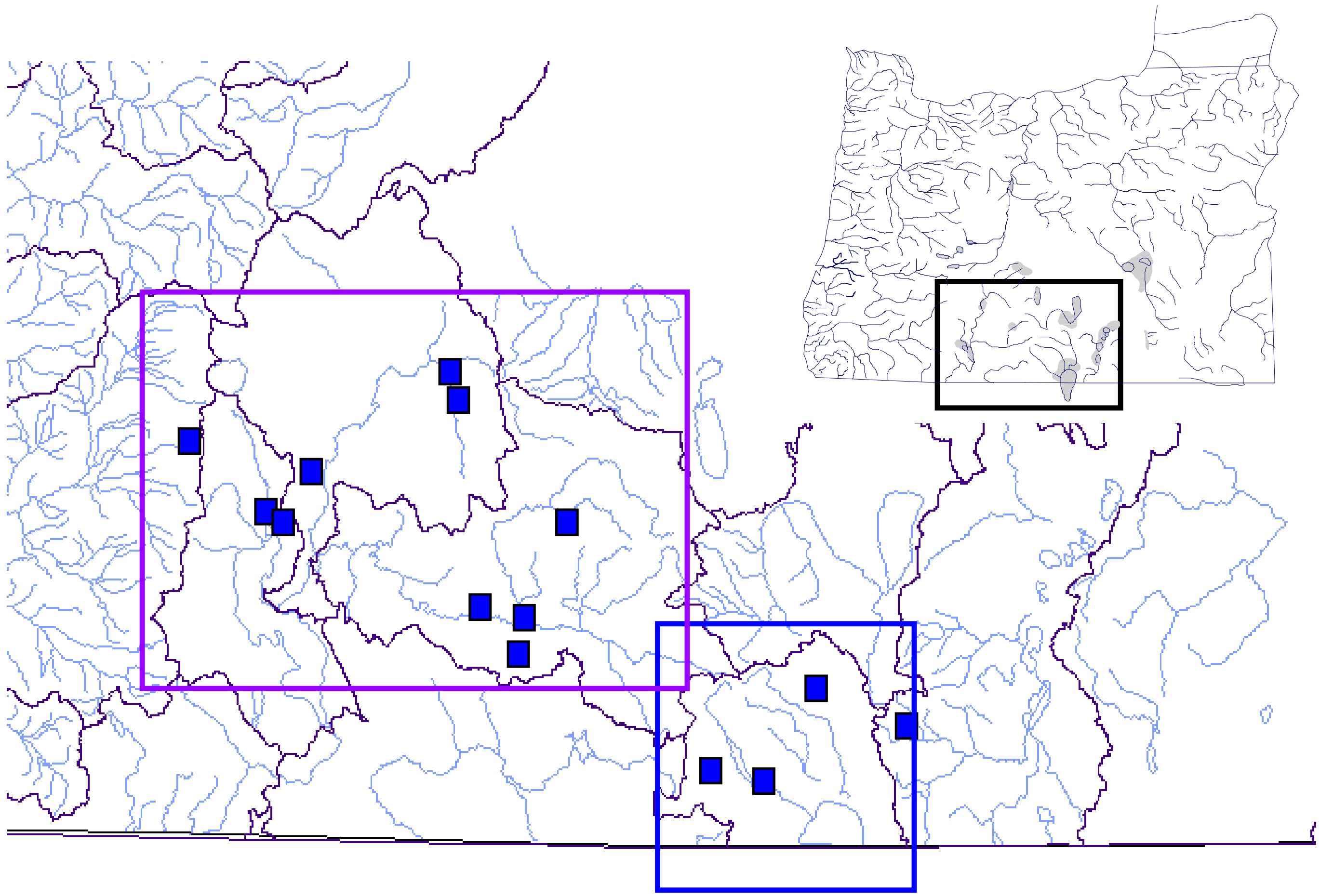


Figure 13. Collection records of the Pit-Klamath Brook Lamprey (*Lampetra lethophaga*) in Oregon from the Oregon State University museum GIS data base. Recent genetics work suggests the Klamath and Goose Lake populations may be different species.

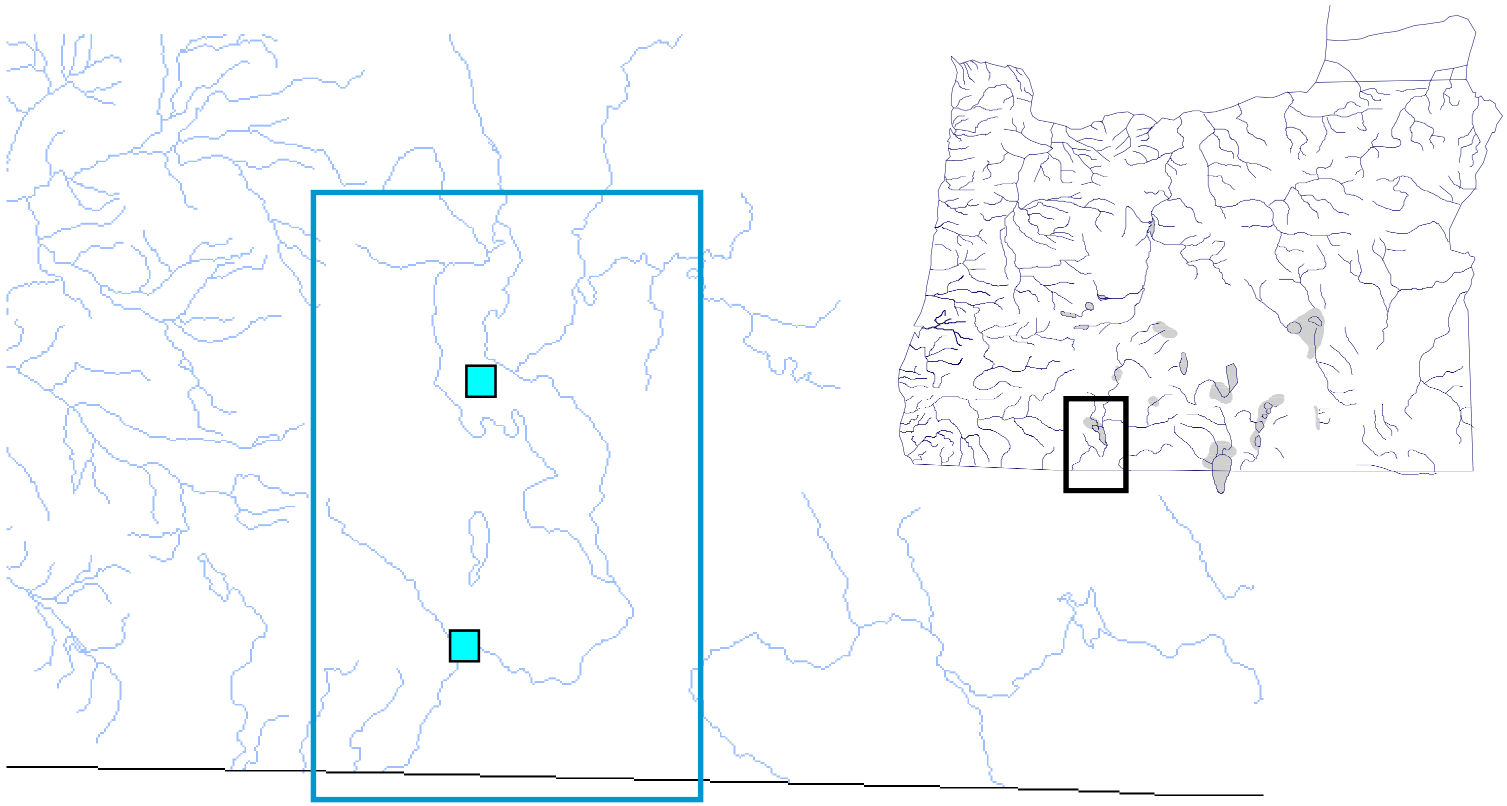


Figure 14. Collection records of the Klamath River Lamprey (*Lampetra similis*) in Oregon from the Oregon State University museum GIS data base.

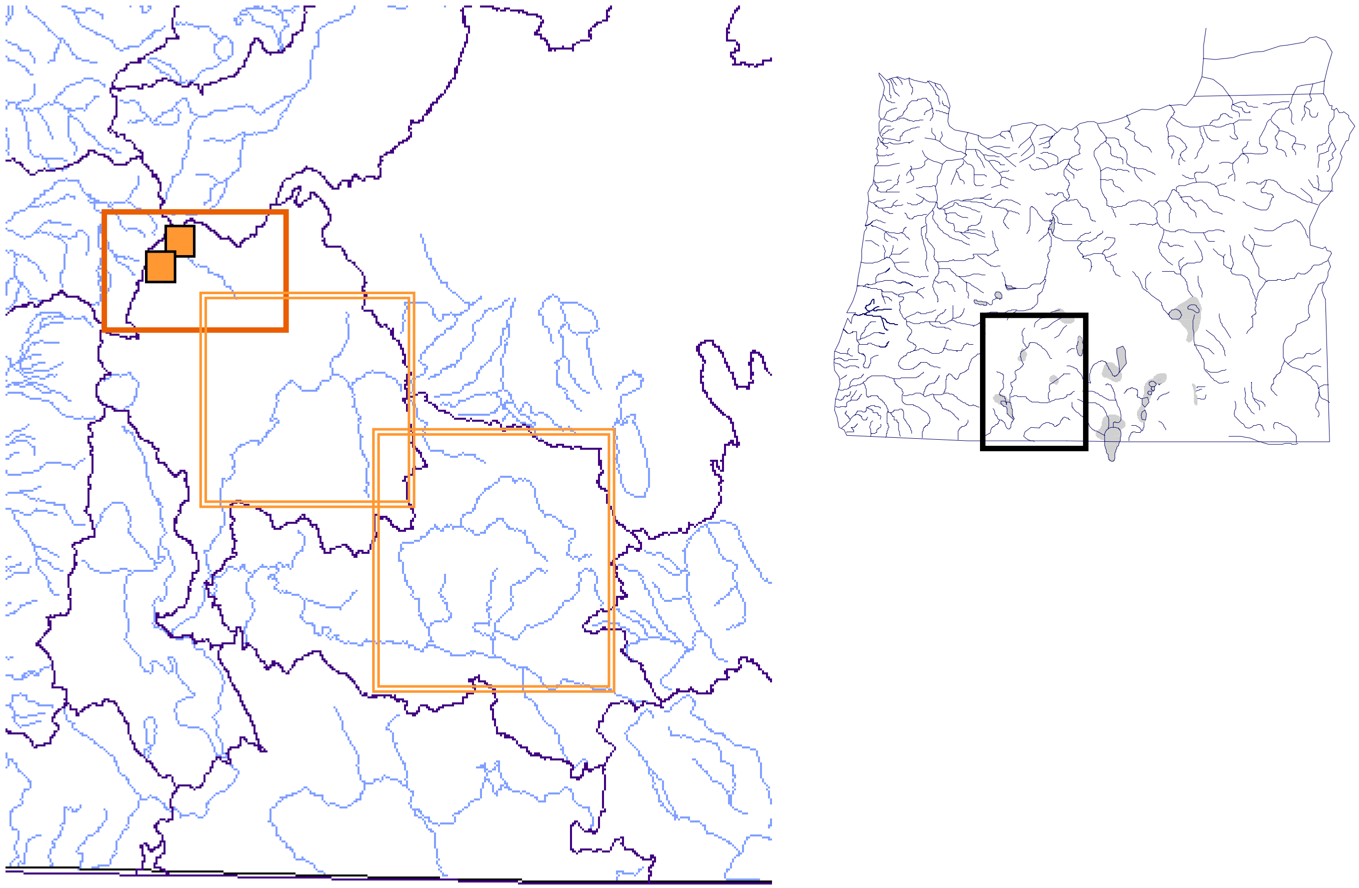


Figure 15. Collection records of the Miller Lake Lamprey (*Lampetra minima*) in Oregon from the Oregon State University museum GIS data base.

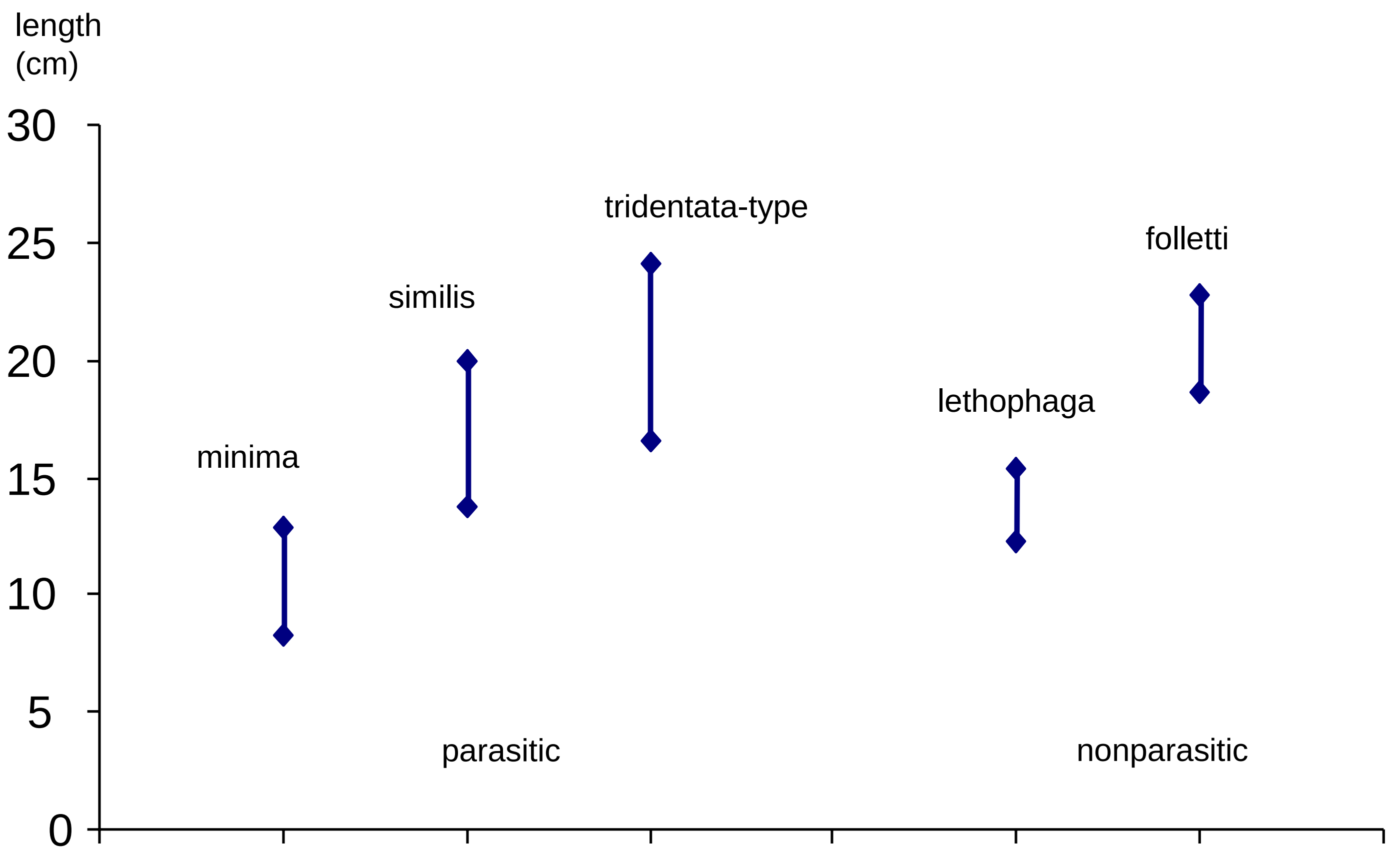


Figure 16. Adult sizes and parasitic/nonparasitic life histories of the Klamath Basin lampreys (data from Lorion et al 2000, Kan 1975, and Vladykov and Knott 1976)..

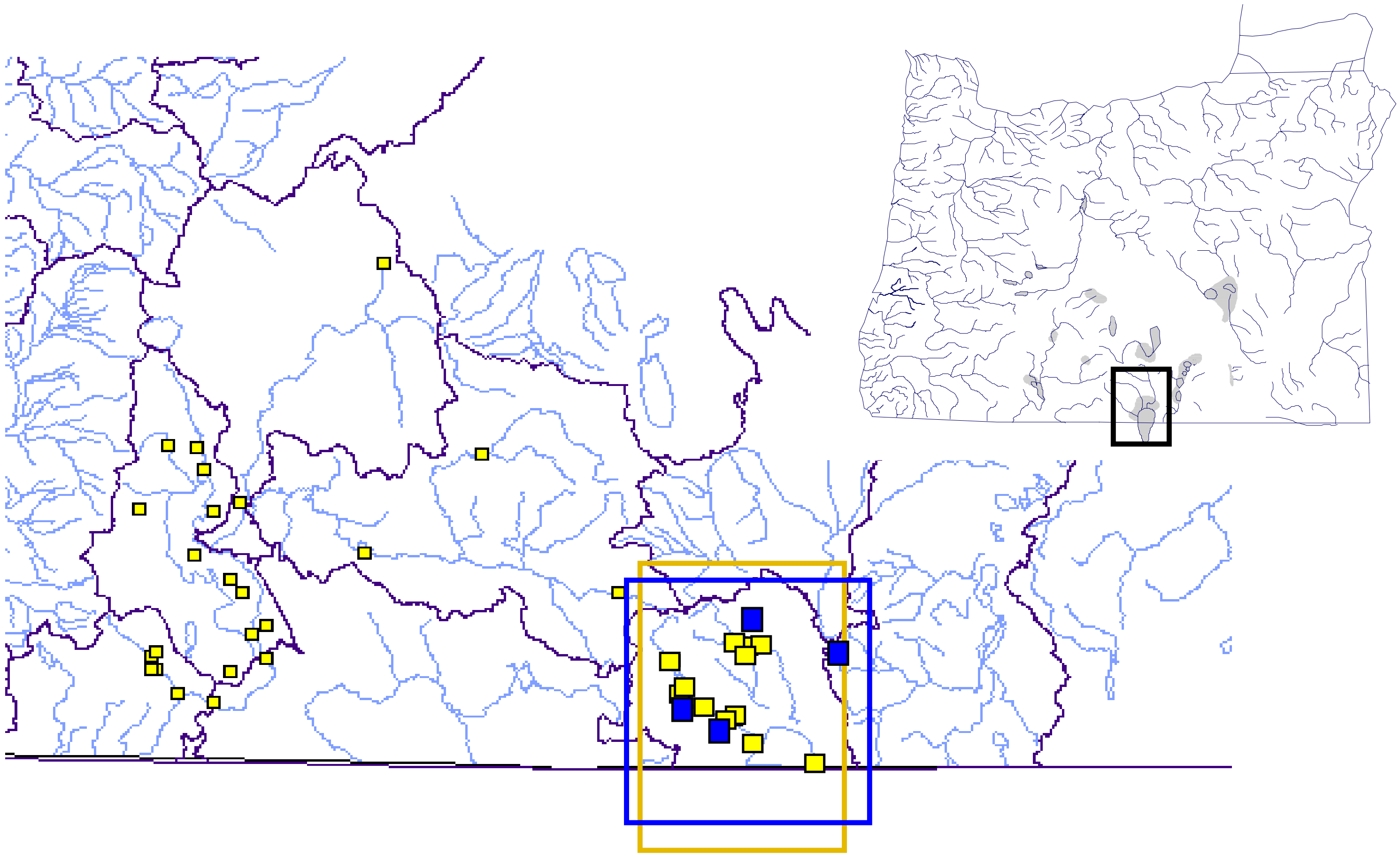


Figure 17. Collection of the Goose Lake Lampreys (*Lampetra sps.*) in Oregon from the Oregon State University museum GIS data base. Specimens include parasitic lamprey ▢ and nonparasitic lamprey ■ .

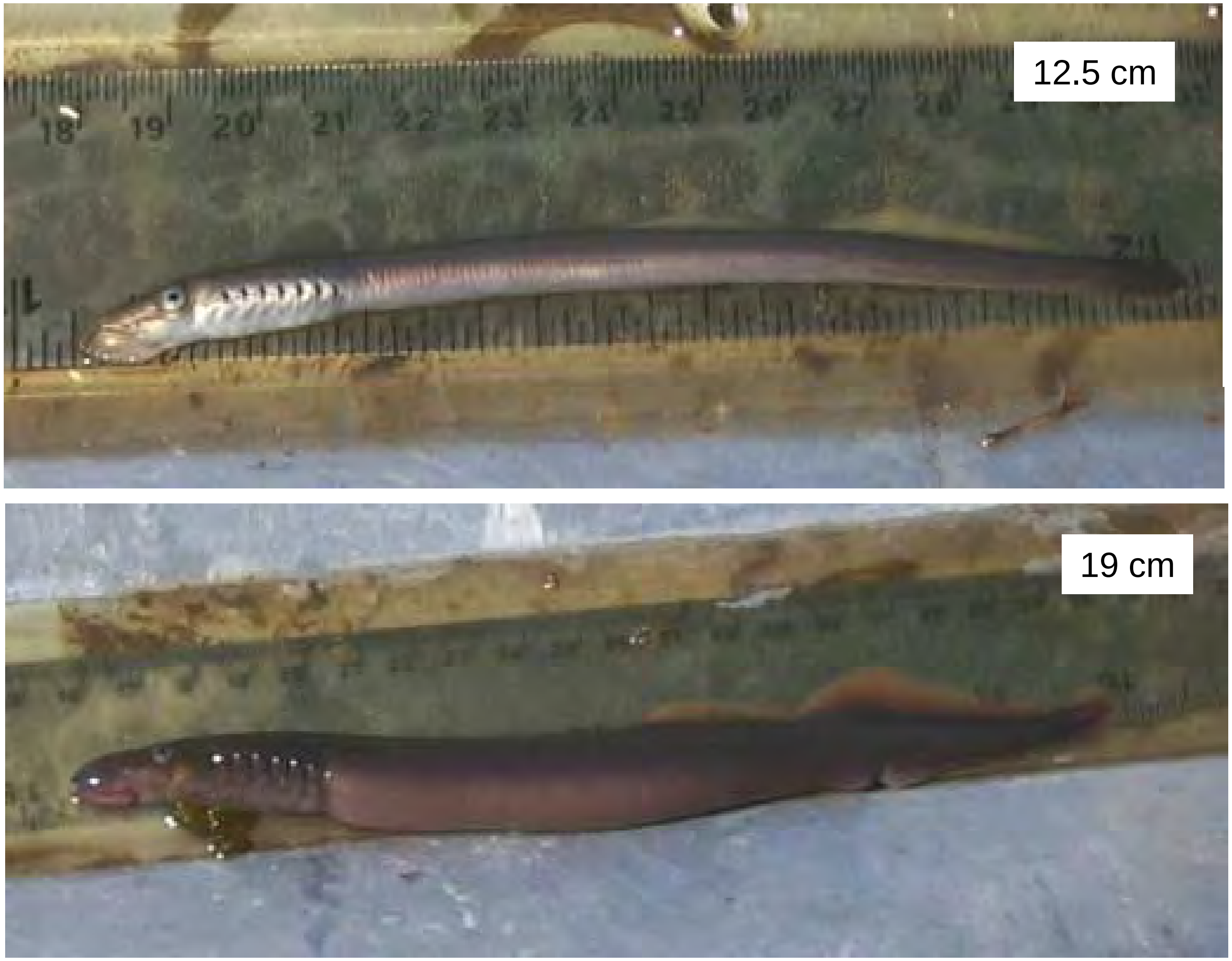


Figure 18. Photographs of Goose Lake Lampreys collected during migrations across Thomas Creek weir. The lamprey in the lower photograph is ready to spawn.

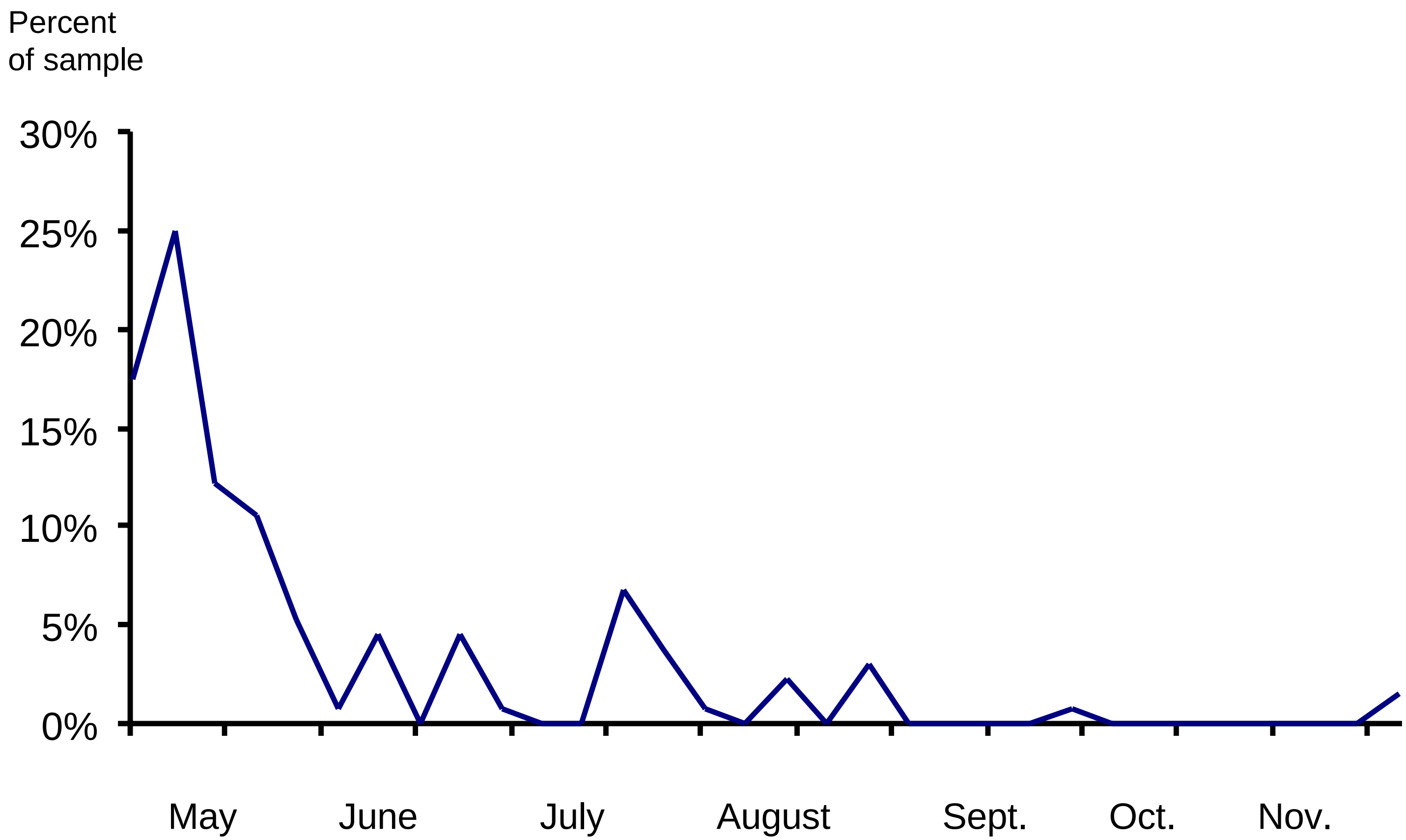


Figure 19. Date of capture of lamprey in the Thomas Creek Trap, Goose Lake Basin. Weekly captures, all data combined from 1999 to 2001 collections. Sampling did not occur between December and March.

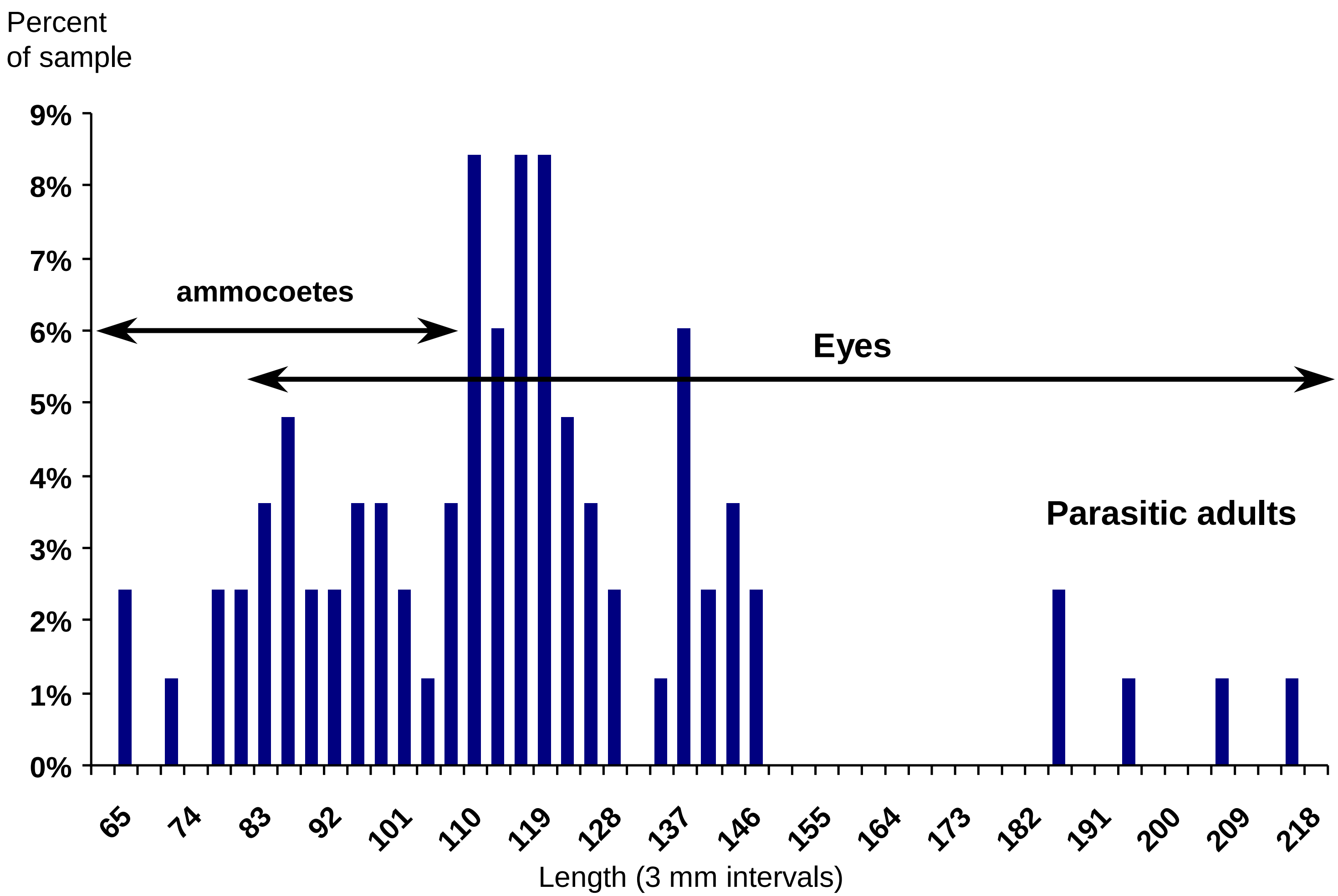


Figure 20. Length frequencies of lampreys caught in the Thomas Creek trap, Goose Lake Basin, 1999 - 2001. The larger specimens were clearly parasitic; the smaller eyed specimens may have included smaller parasitic adults, nonparasitic adults or recently metamorphosed lampreys migrating to Goose Lake.

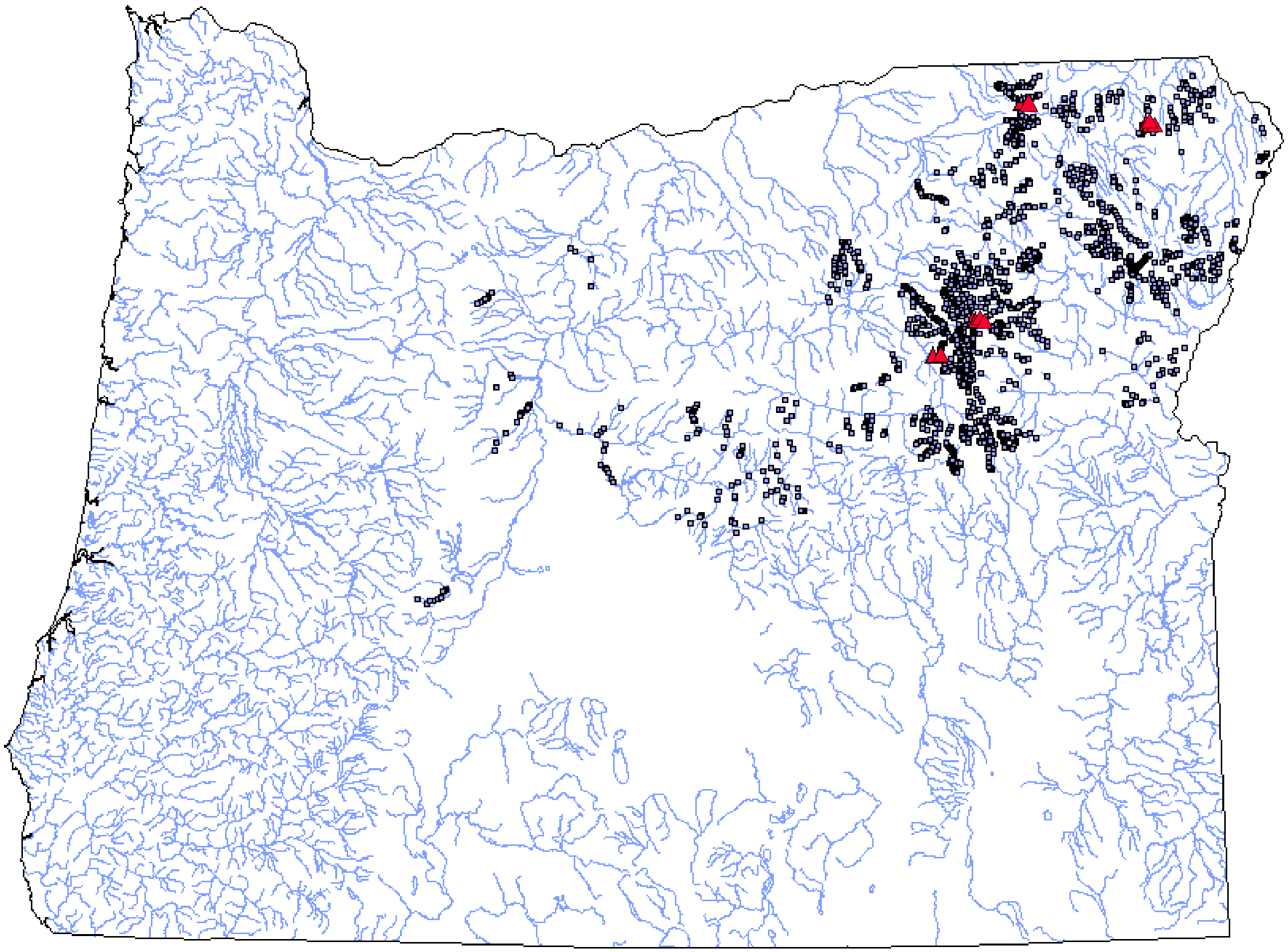


Figure 21. Observation records of lamprey in Northeast Oregon made during ODFW fish inventory surveys. Locations where lampreys were observed ▲. Other locations that were sampled but no lampreys were observed ∎.

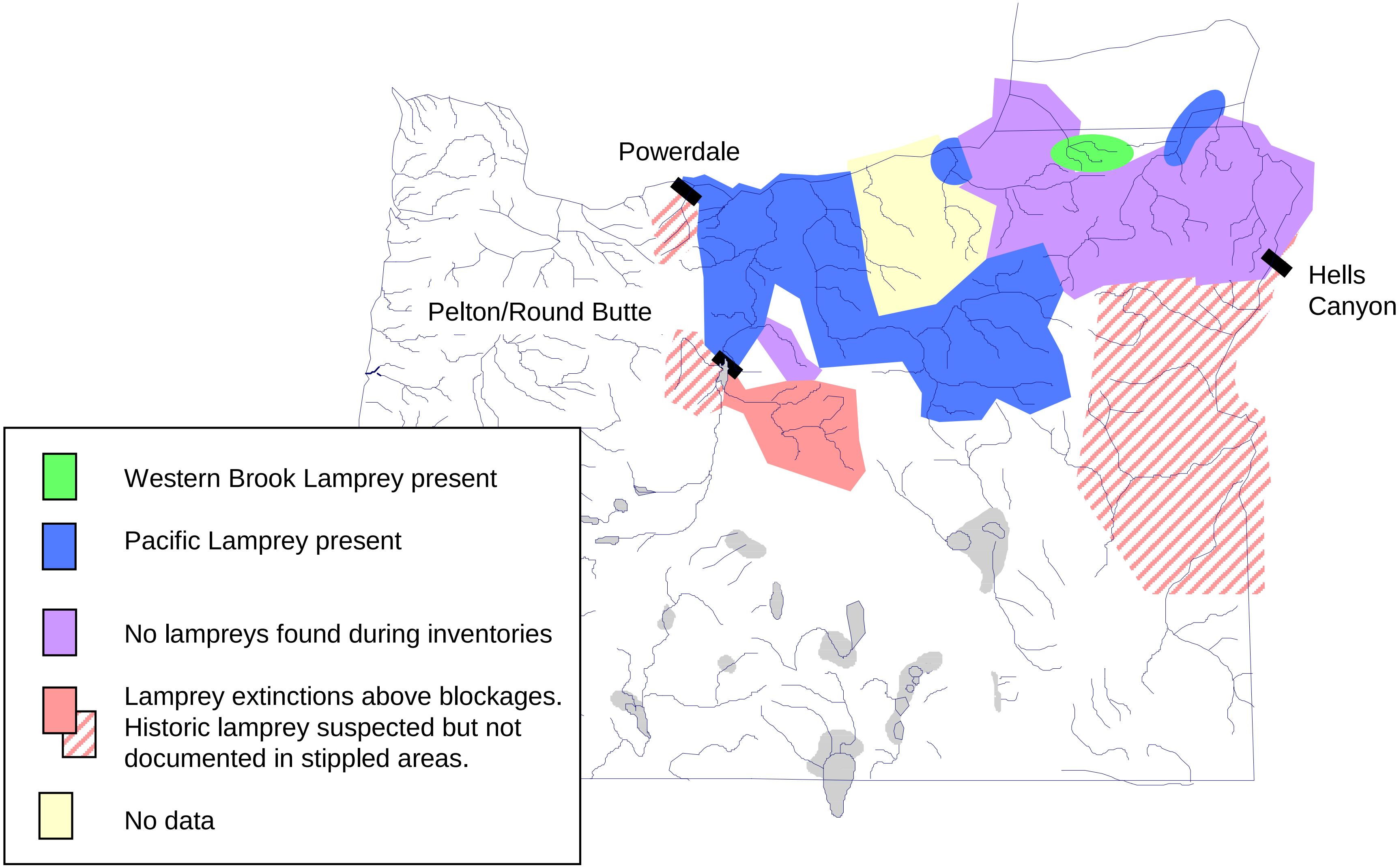


Figure 22. Lamprey distribution information for the Inland Columbia Basin area based on Close and Bronson (2001) and on observations by ODFW staff.

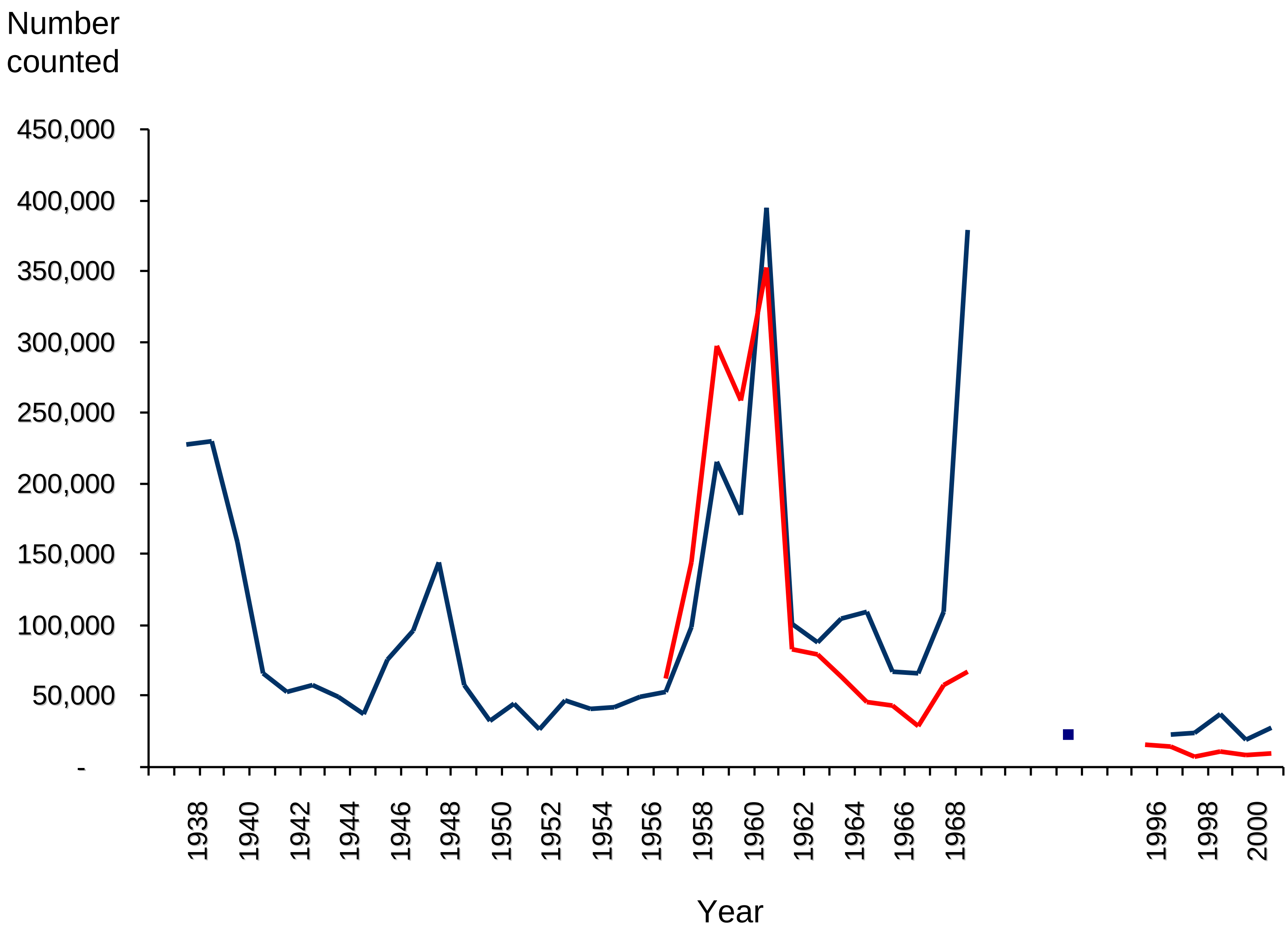


Figure 23a. Annual counts of adult Pacific Lamprey at Bonneville ( ) and The Dalles ( ) dams. Lamprey were not counted from 1970 through the mid-1990s.

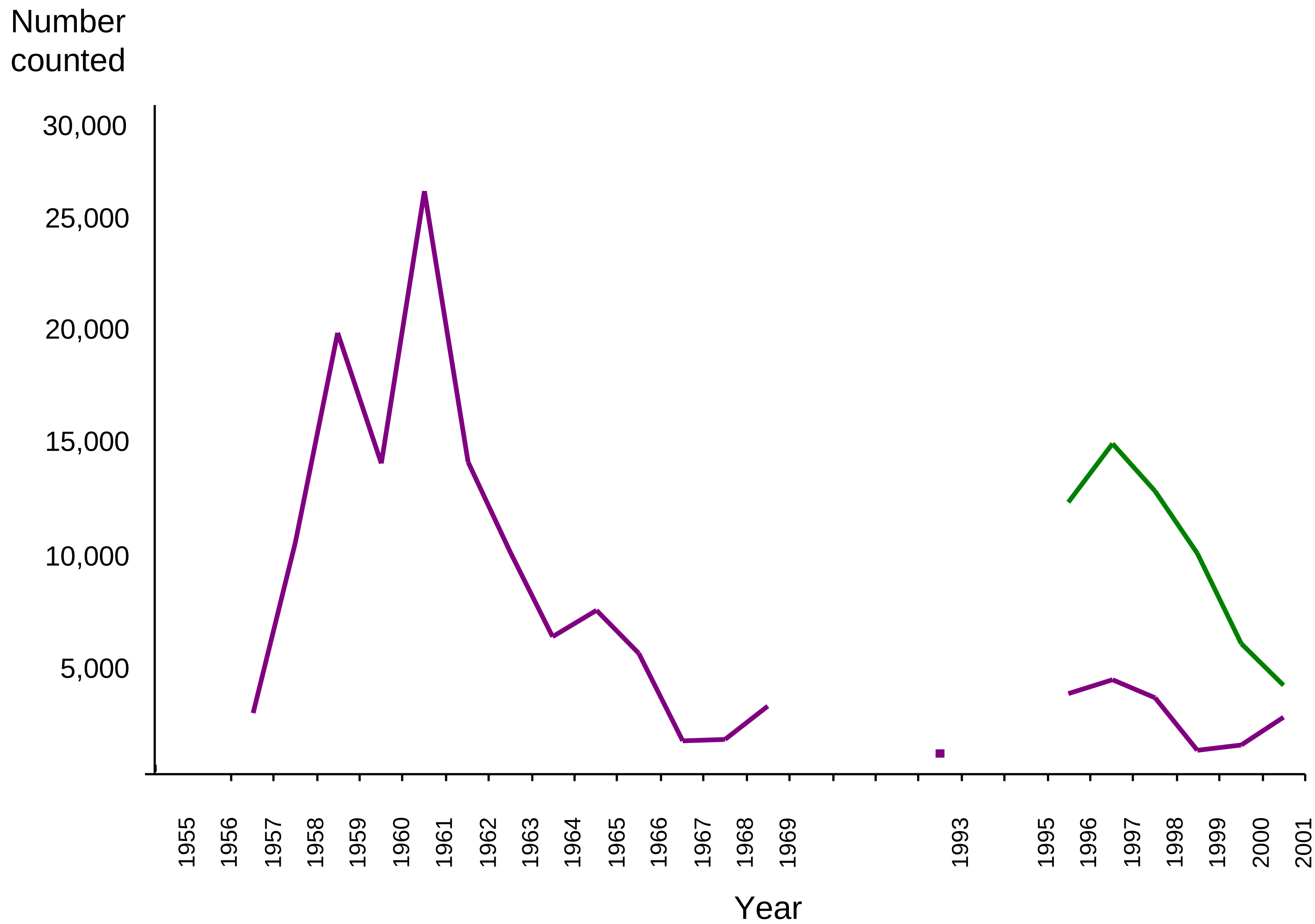


Figure 23b. Annual counts of adult Pacific Lamprey at John Day ( ) and McNary ( )dams. Lamprey were not counted from 1970 through the mid-1990s.

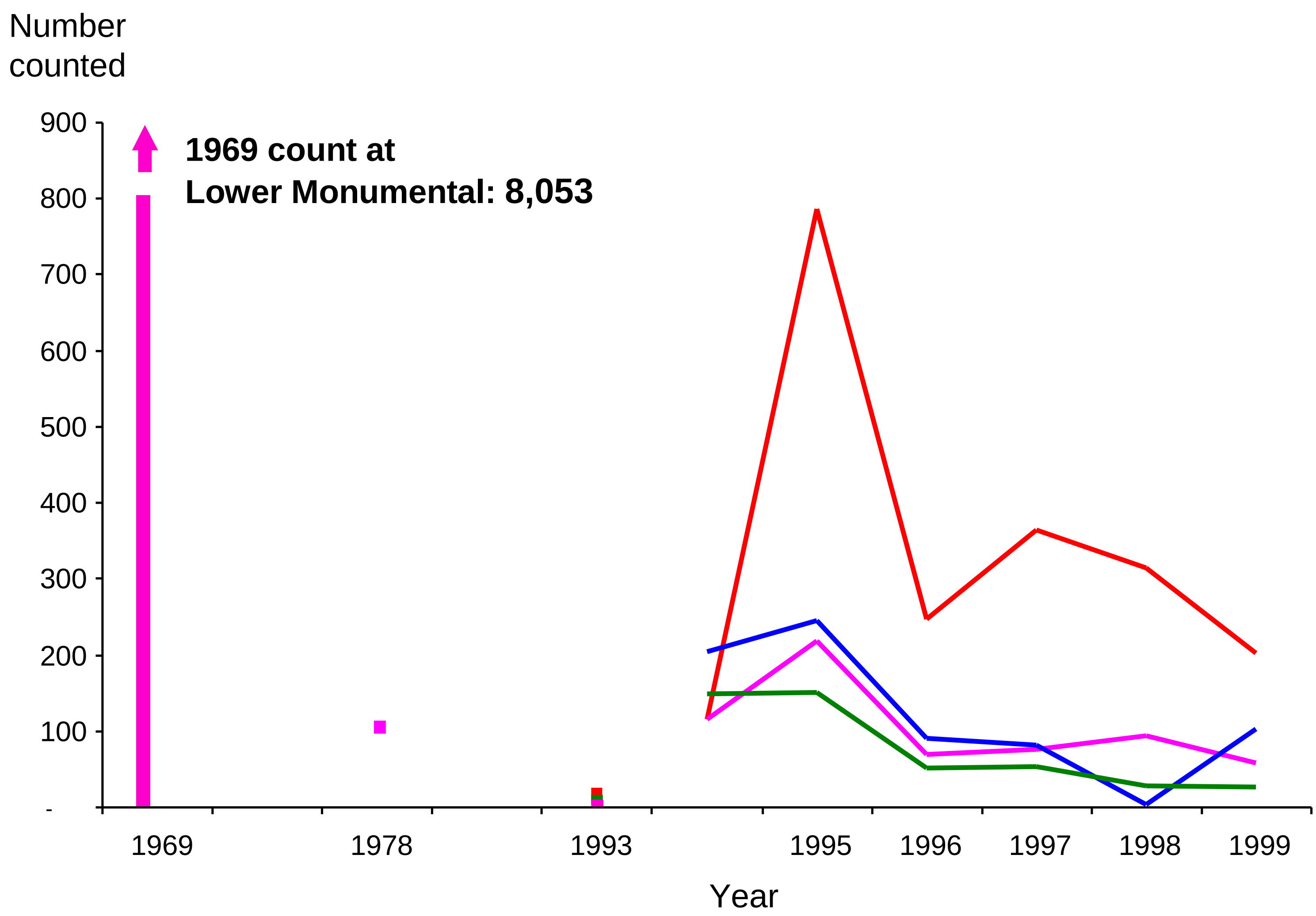


Figure 23c. Annual counts of adult Pacific Lamprey at Ice Harbor ( ), Lower Monumental ( ), Little Goose ( ) and Lower Granite ( ) dams. Lamprey were not counted from 1970 through the mid-1990s.

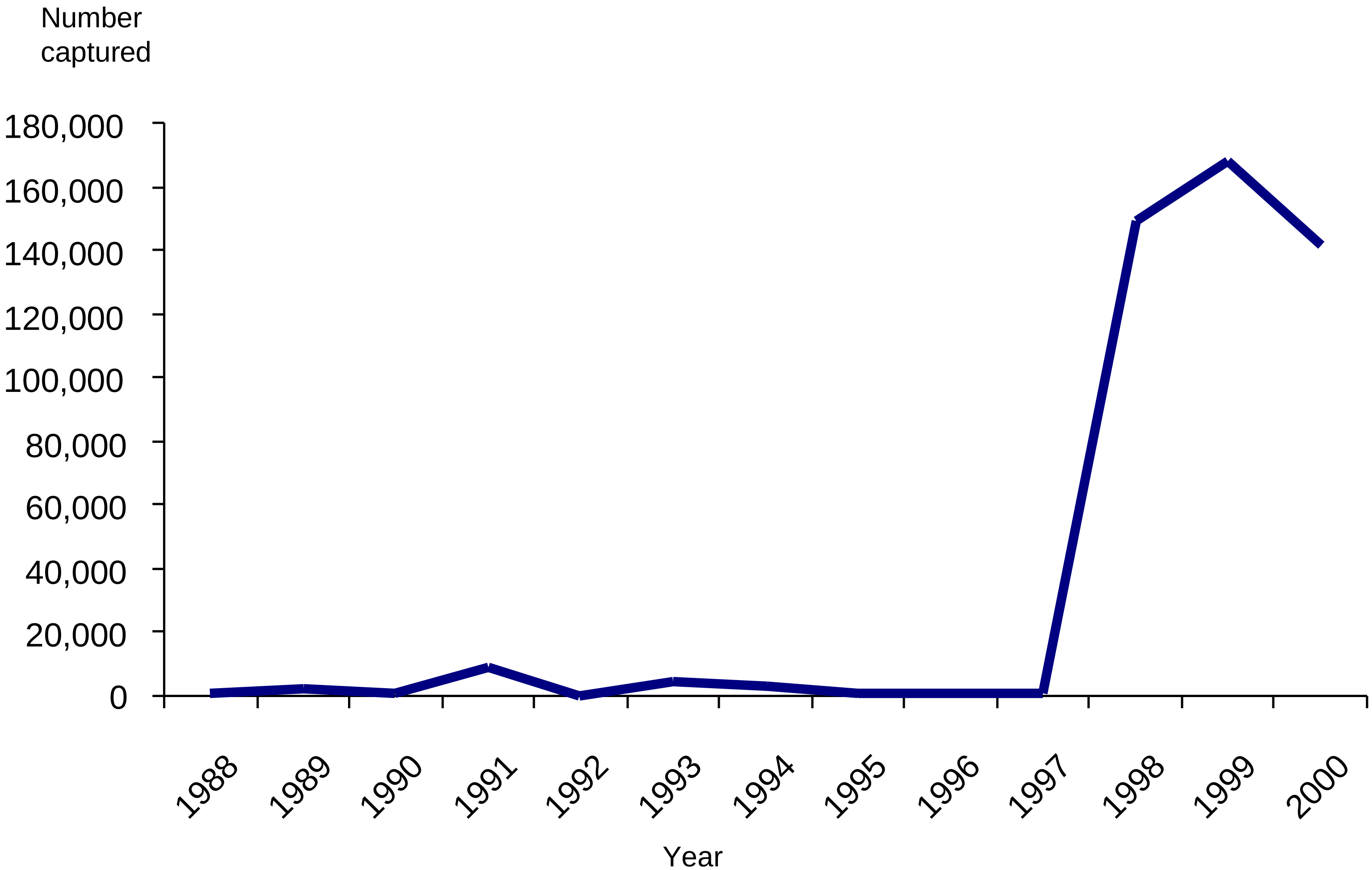


Figure 24. Numbers of juvenile Pacific Lampreys caught in the juvenile by-pass at John Day Dam, 1988 - 2000.

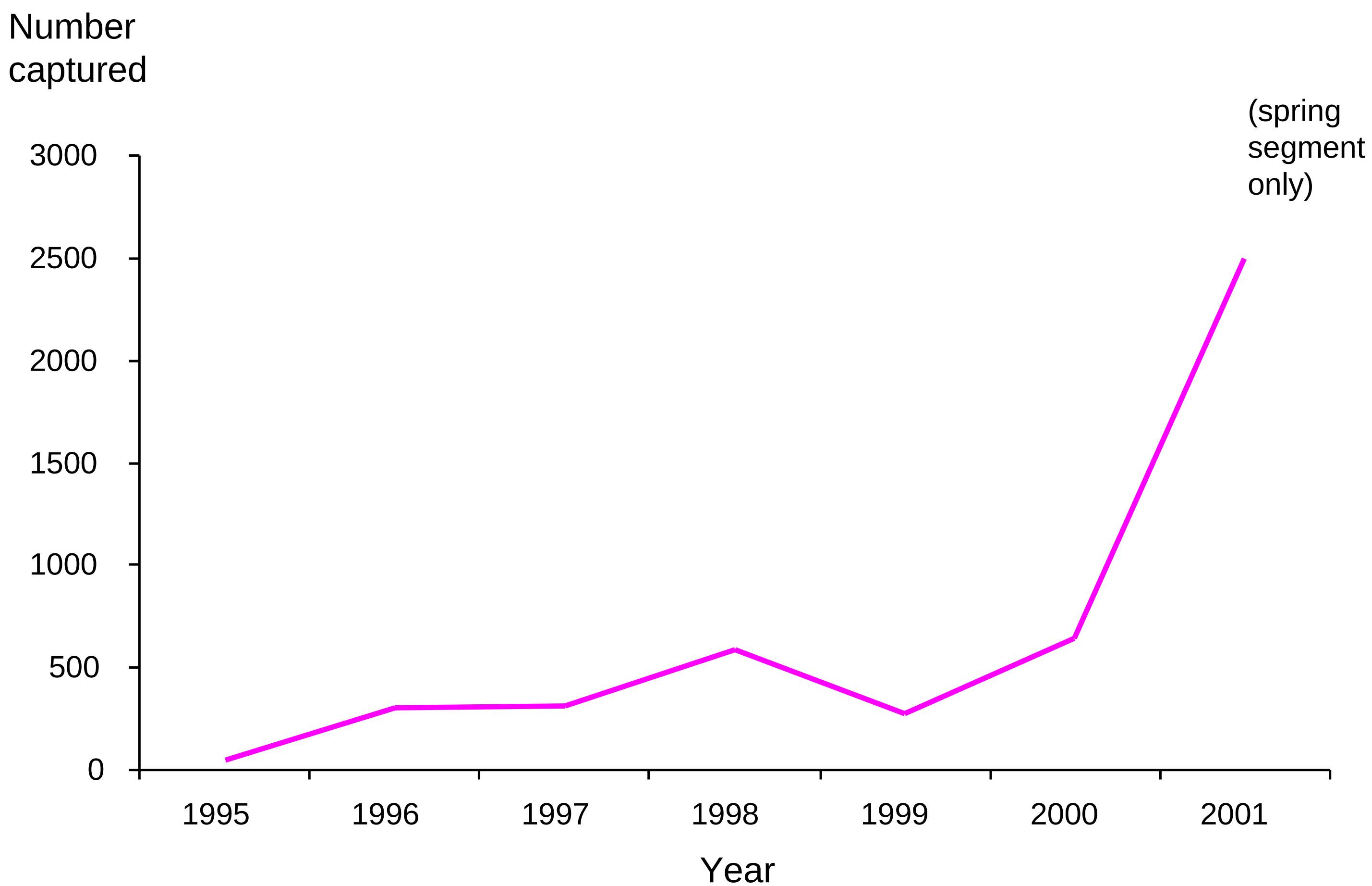


Figure 25. Numbers of juvenile Pacific Lampreys caught in smolt traps on the lower Umatilla, 1995 through spring of 2001.

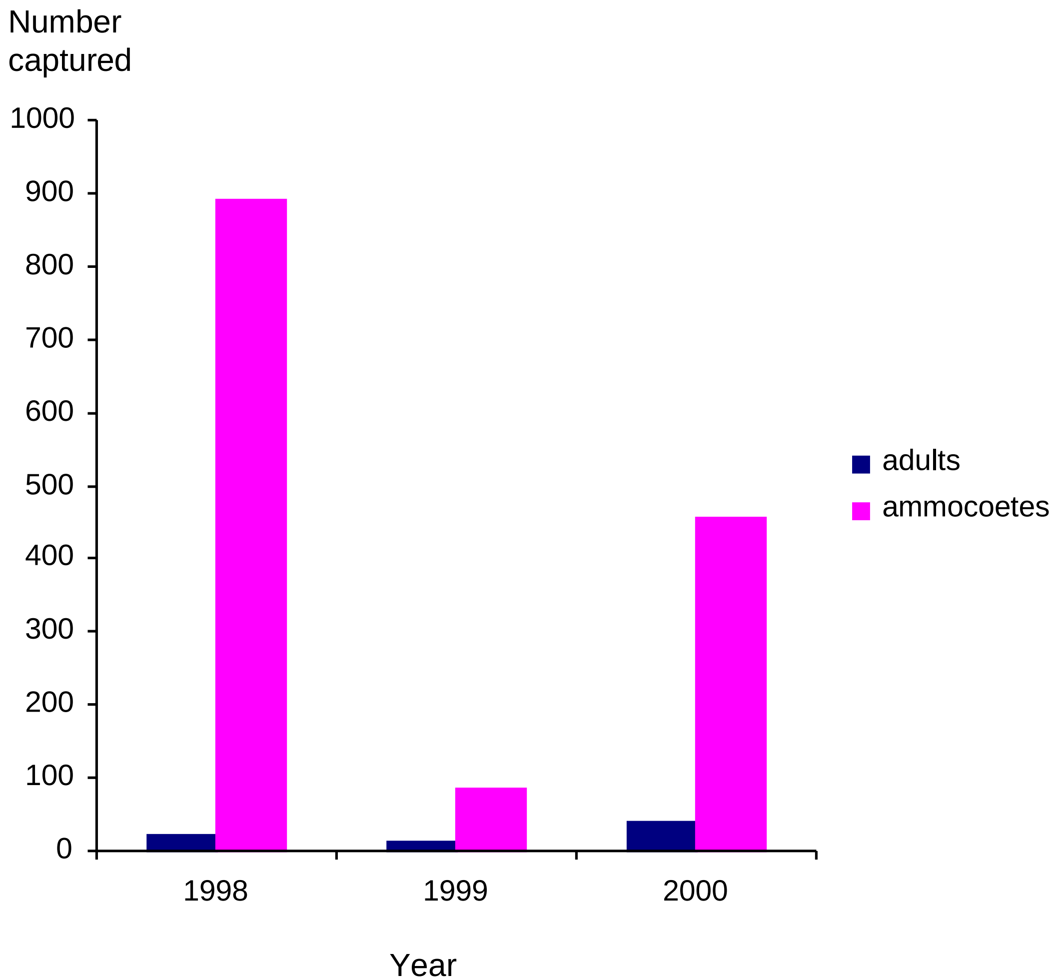


Figure 26. Number of adult and juvenile lampreys captured in a screw trap on Fifteenmile Creek, 1998 - 2000. Some of the ammocoetes may be brook lamprey.

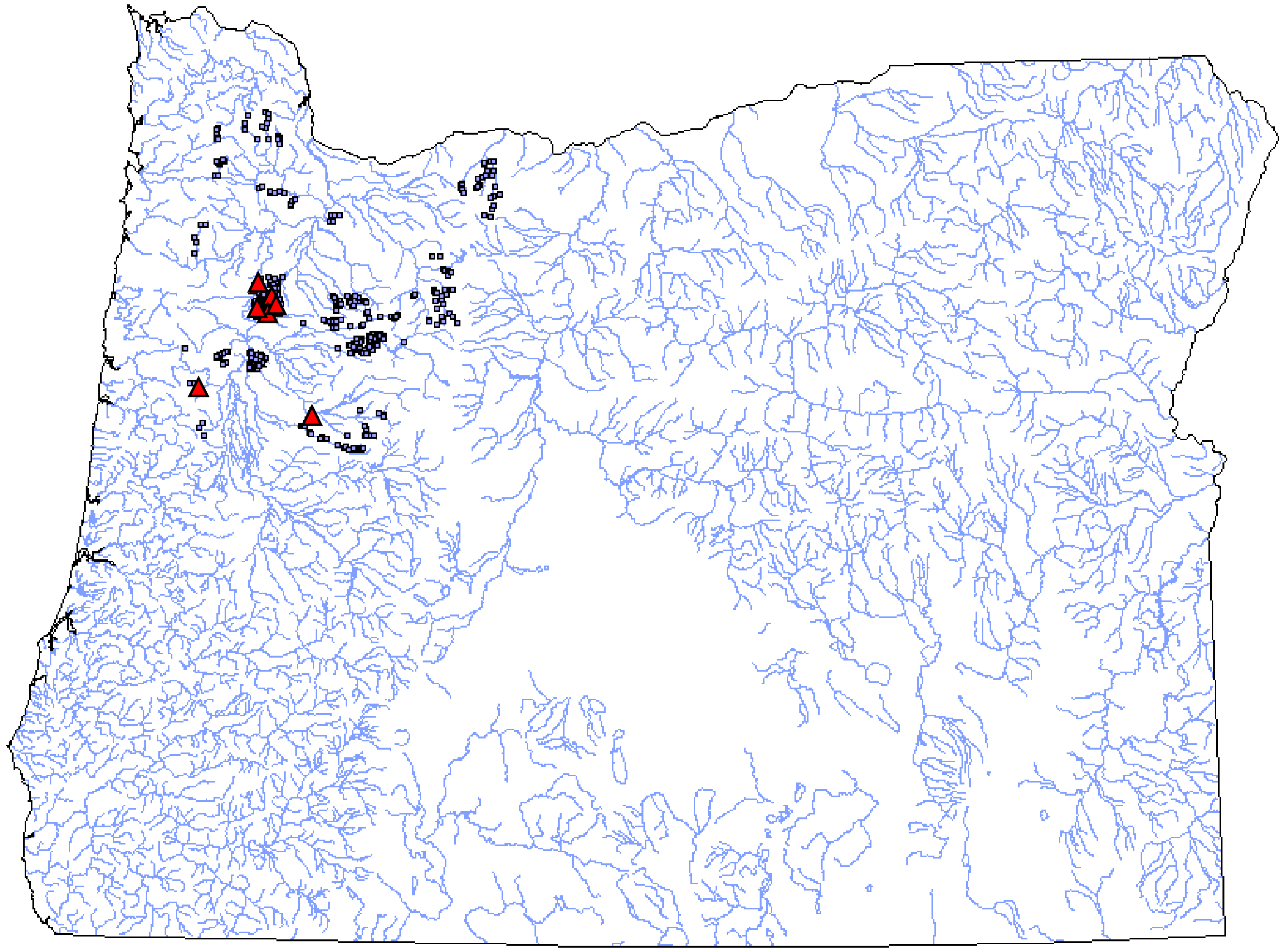


Figure 27. Observation records of lamprey in the lower Columbia and Willamette made during ODFW fish inventory surveys. Locations where lampreys were observed ▲ . Other locations that were sampled but no lampreys were observed ▪ .

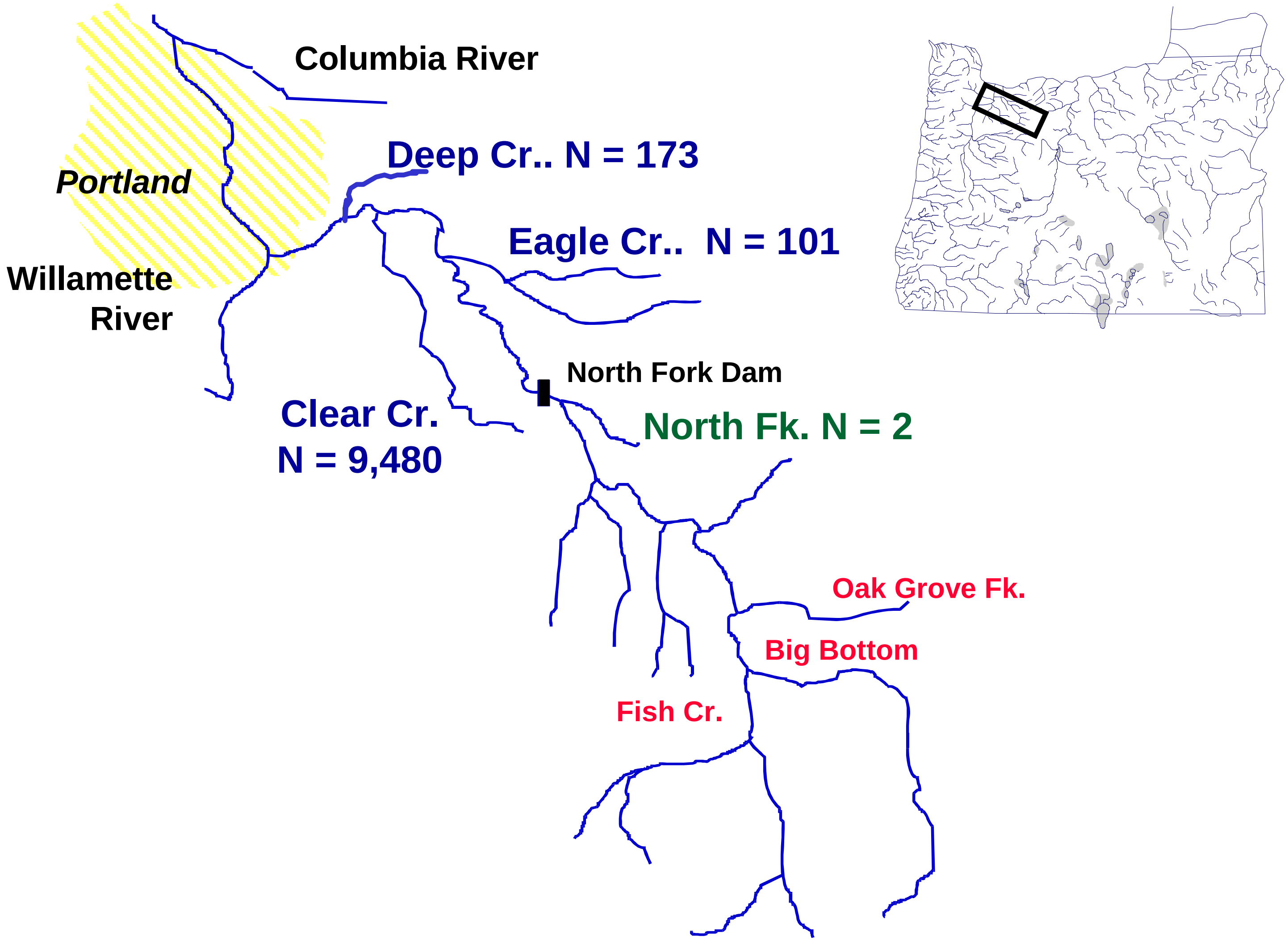
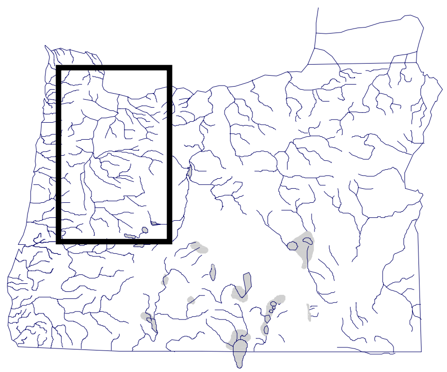


Figure 28. Distribution of lamprey collections in smolt traps on the Clackamas River in 2001. No lamprey were observed in upper basin (red traps). Only brook lamprey were observed in the North Fork trap (green trap). Likely a mix of species was seen in the lower basin (blue traps).



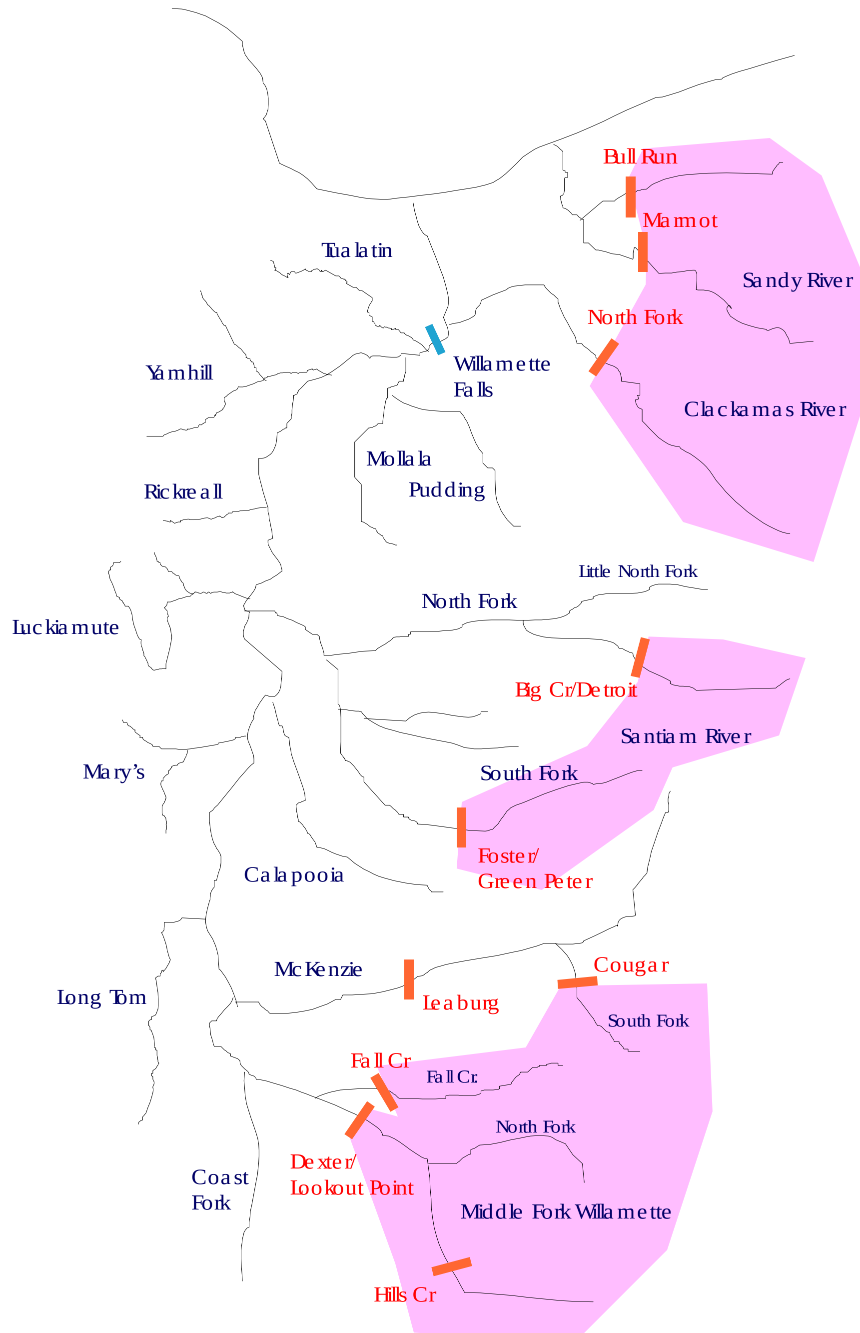


Figure 29. Willamette and Sandy rivers showing areas blocked by dams with no apparent lamprey passage.

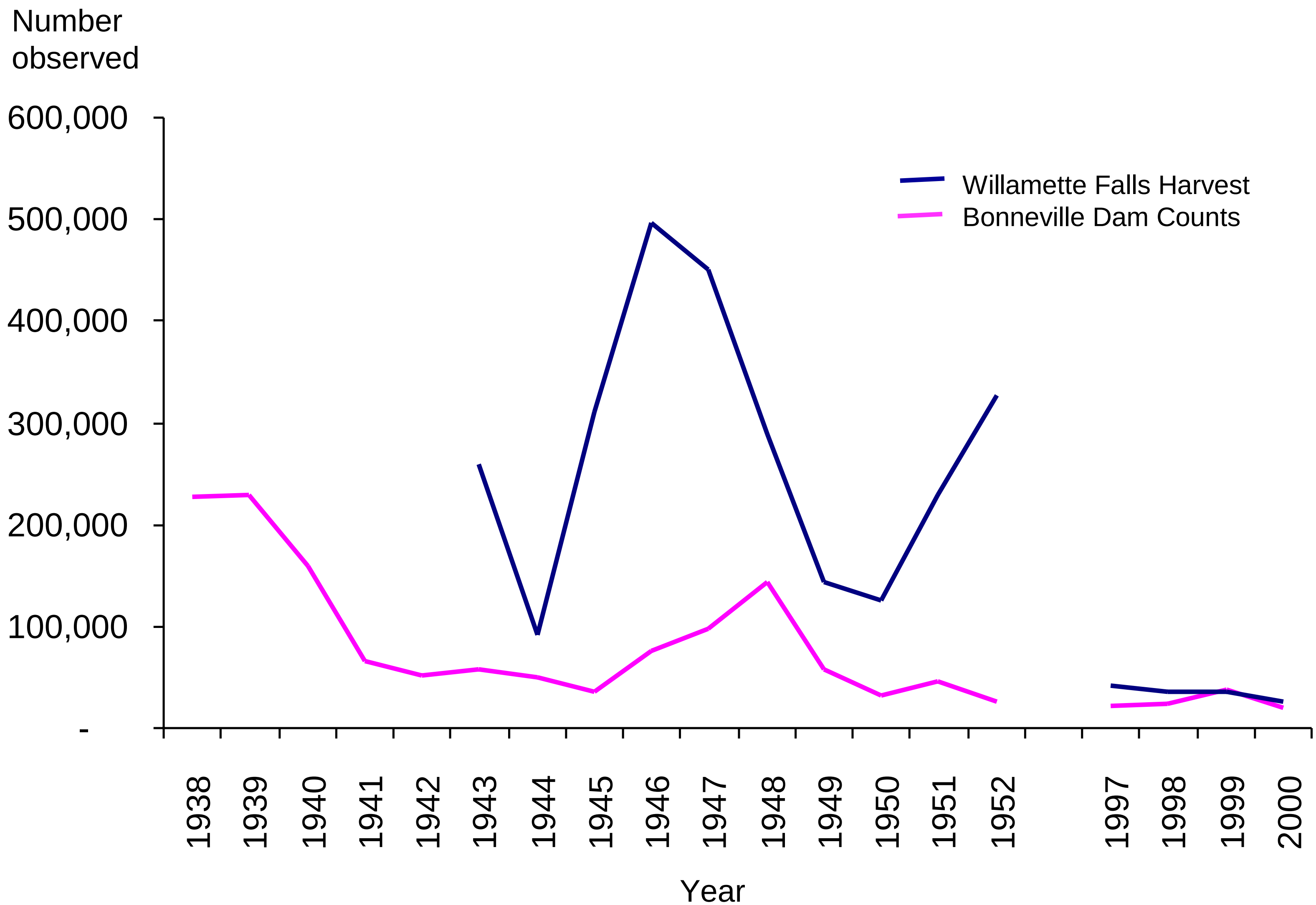


Figure 30. A comparison of the counts of Pacific Lamprey adults at Bonneville Dam to the number of lamprey harvested at Willamette Falls in an historic period (1943-52) and recently (1997-00).

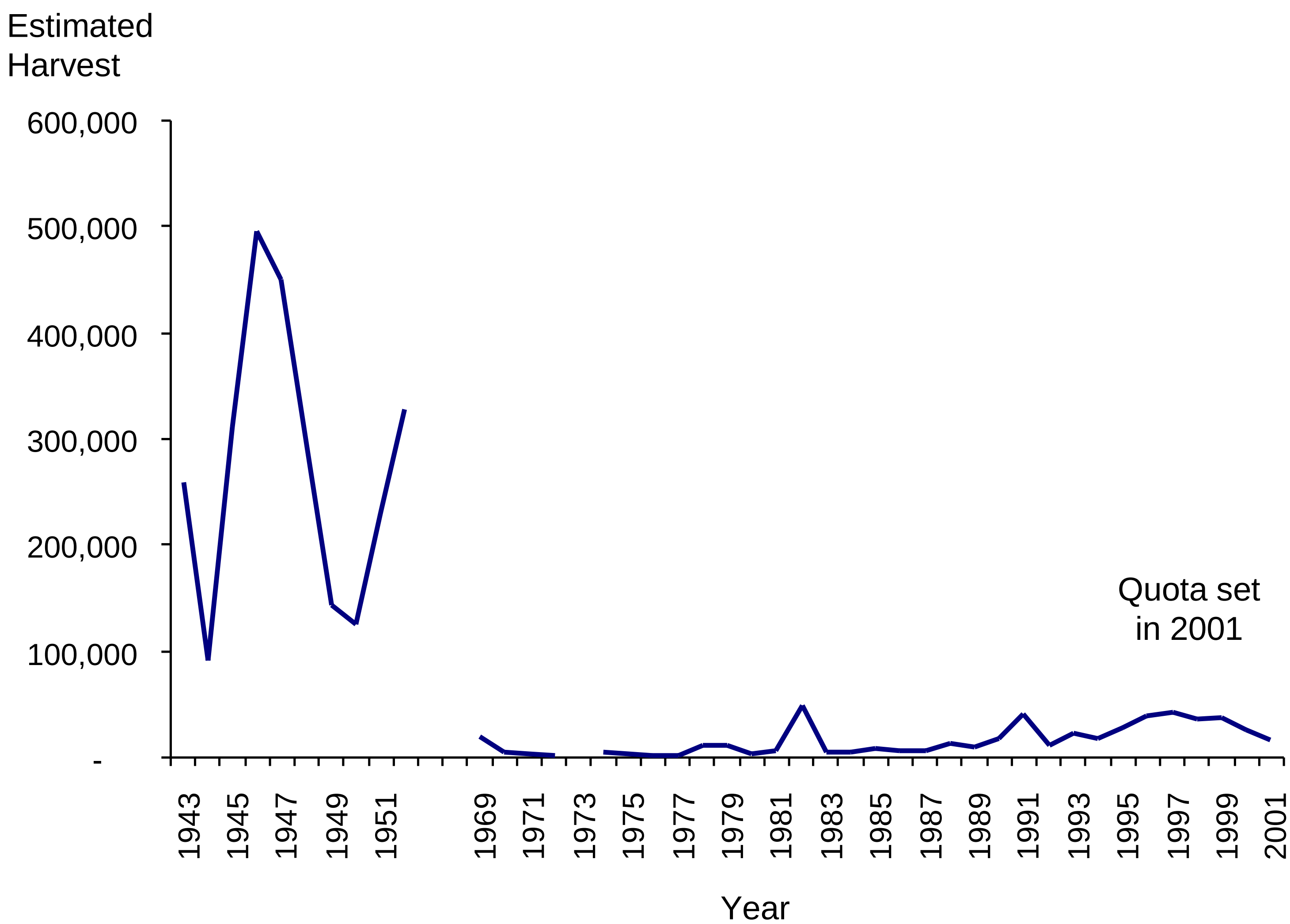


Figure 31. Estimated number of adult Pacific Lamprey harvested at Willamette Falls, 1945 - 01.

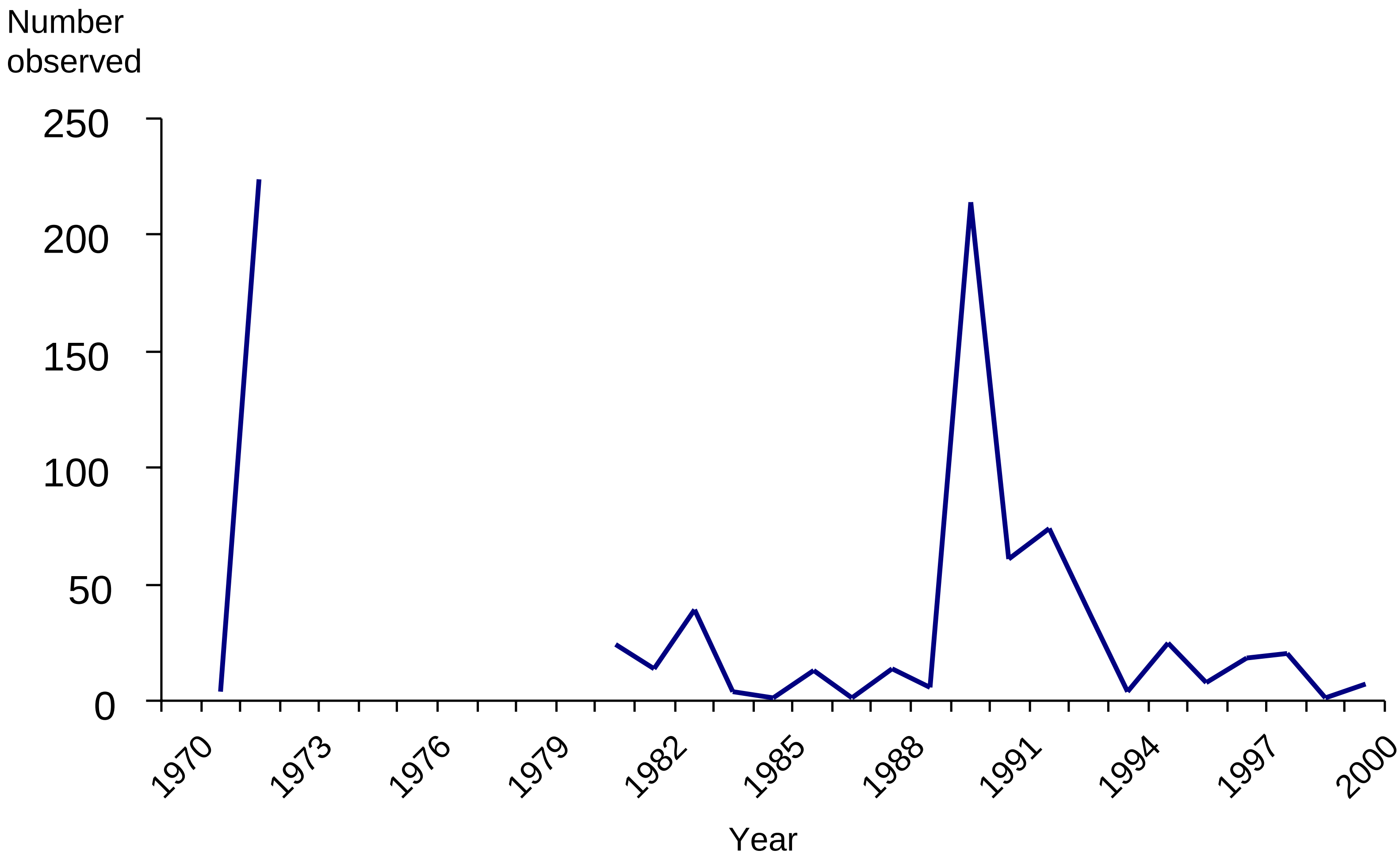


Figure 32. Counts of adult Pacific Lamprey at Leaburg Dam on the McKenzie River, upper Willamette Basin.

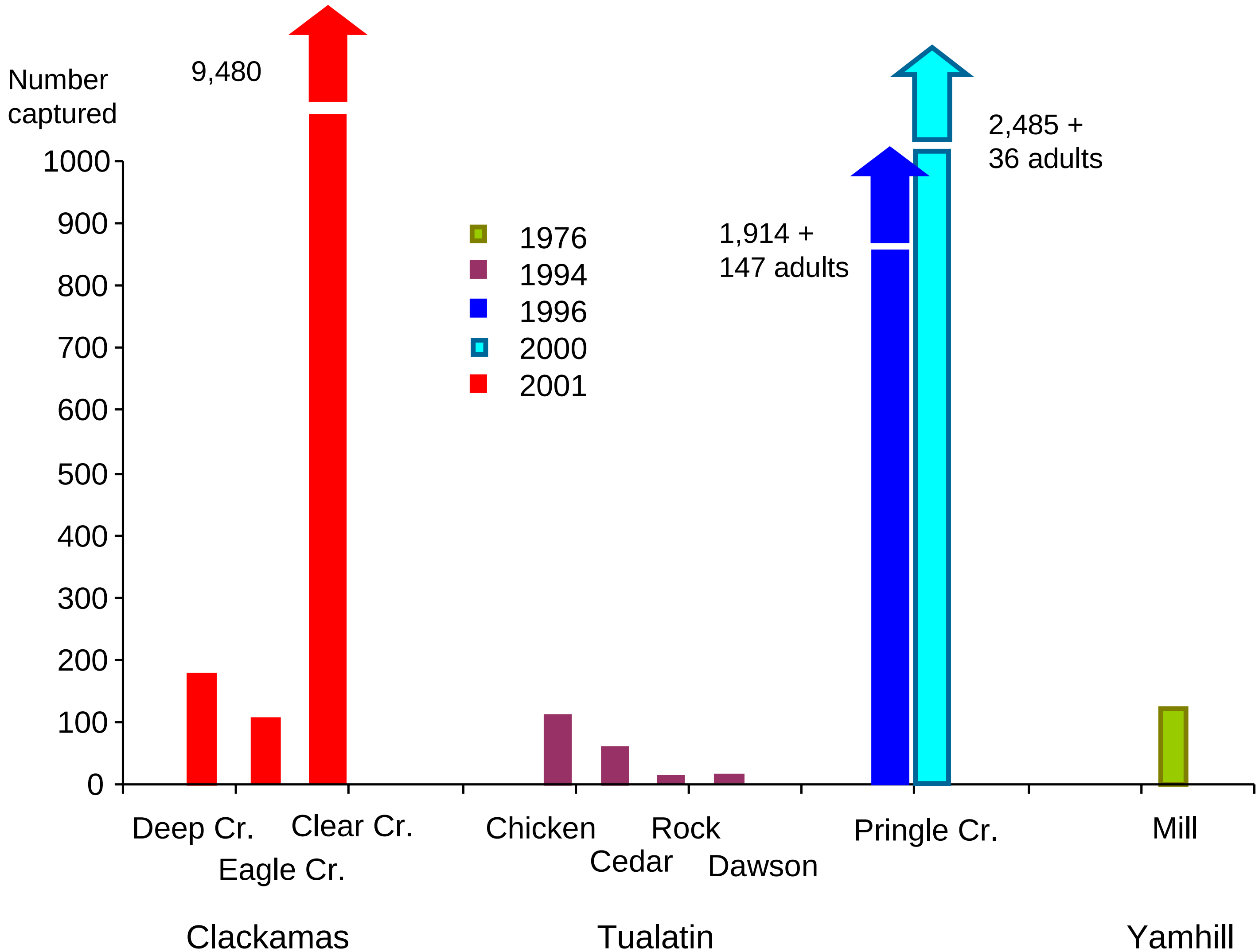


Figure 33. Incidental observations of lamprey, mostly ammocoetes, in the lower Willamette, by various sampling methods (smolt traps, electroshocking, fish kills).

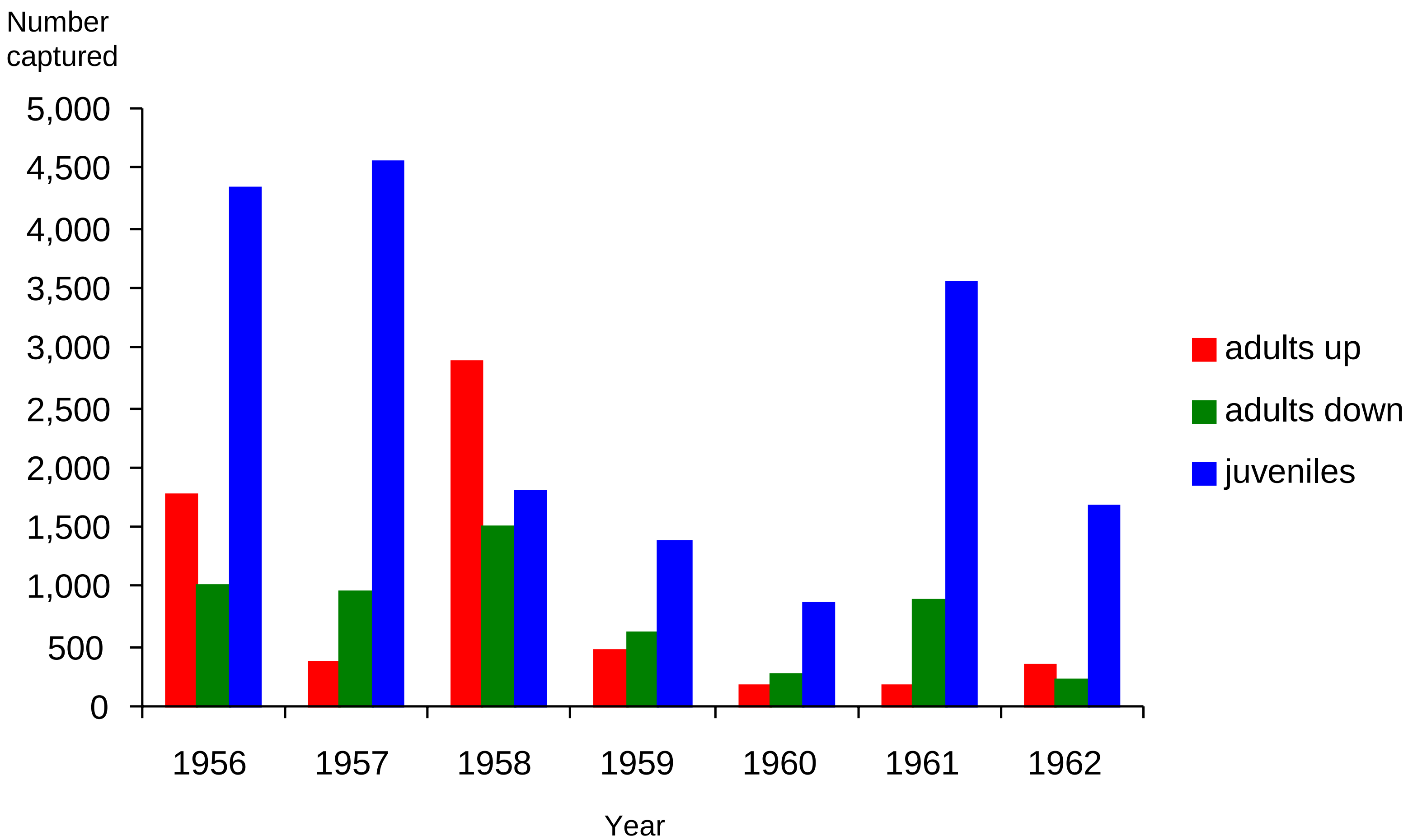


Figure 34. Numbers of lamprey captured during the Gnat Creek weir study, 1956 - 62, (from Willis 1962). All lamprey were identified as Pacific Lamprey. Additional adults were observed passing upstream without entering the trap.

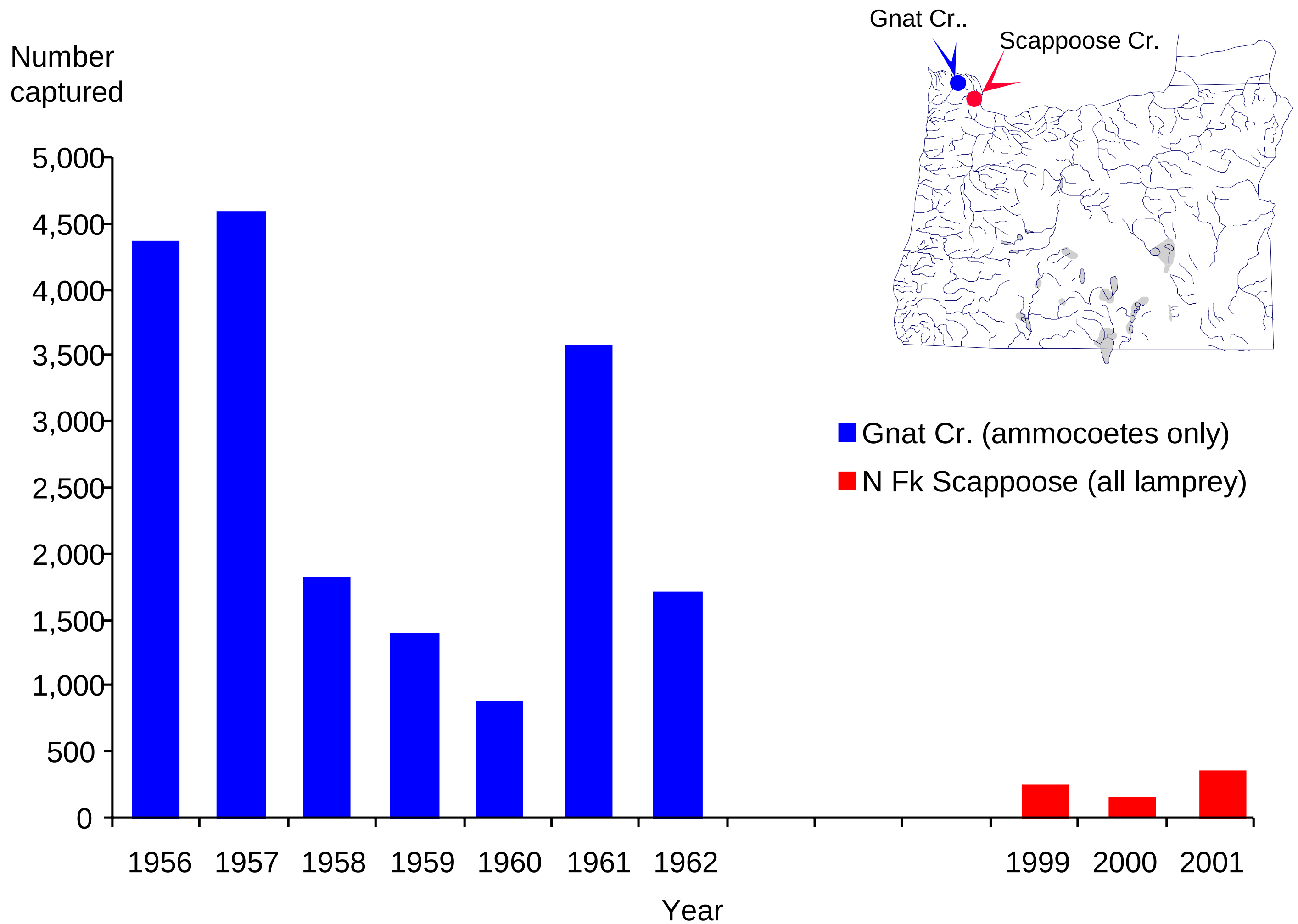


Figure 35. A comparison of the counts of lamprey at traps on Lower Columbia River tributaries, historically (Gnat Cr..) and currently (Scappoose Cr..).

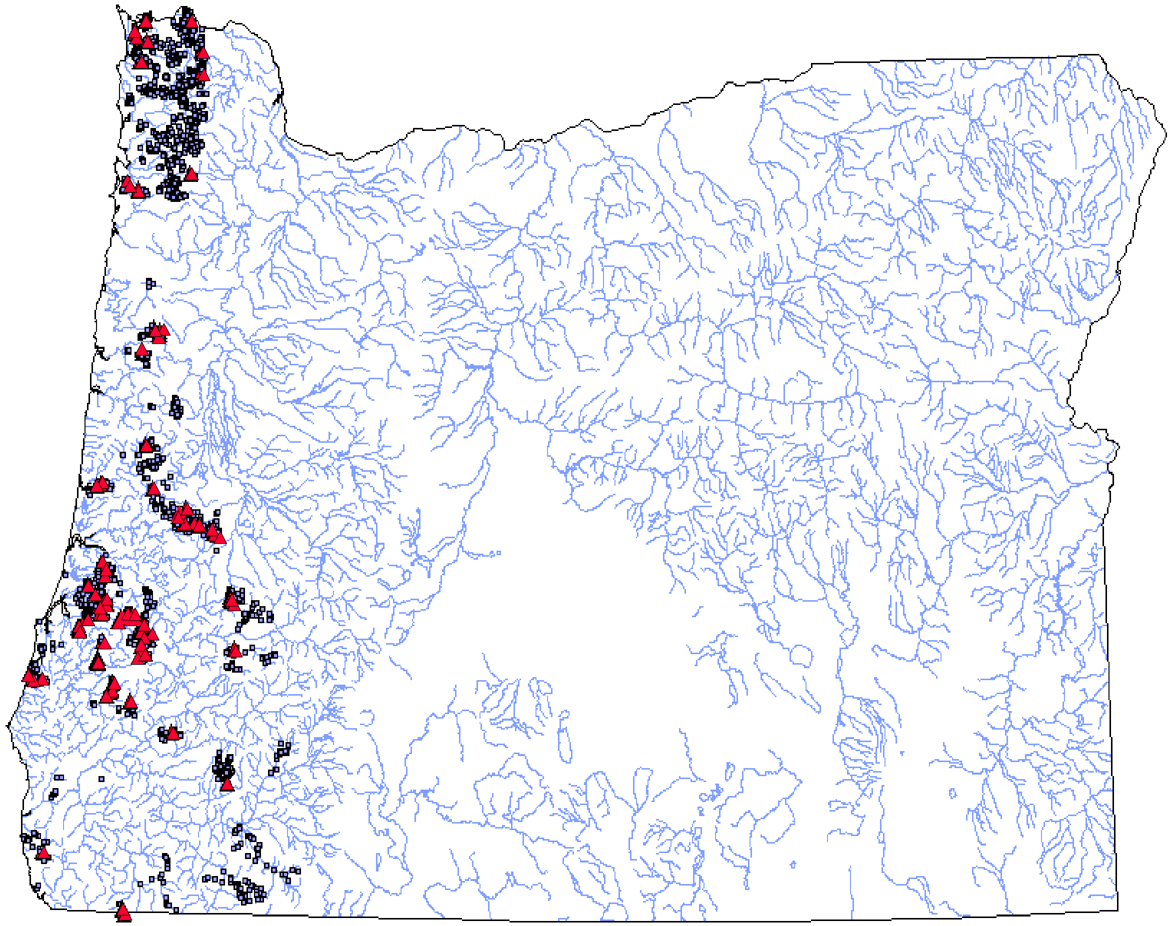


Figure 36. Observation records of lamprey on the Oregon coast made during ODFW fish inventory surveys. Locations where lampreys were observed ▲ . Other locations that were sampled but no lampreys were observed ▪ .

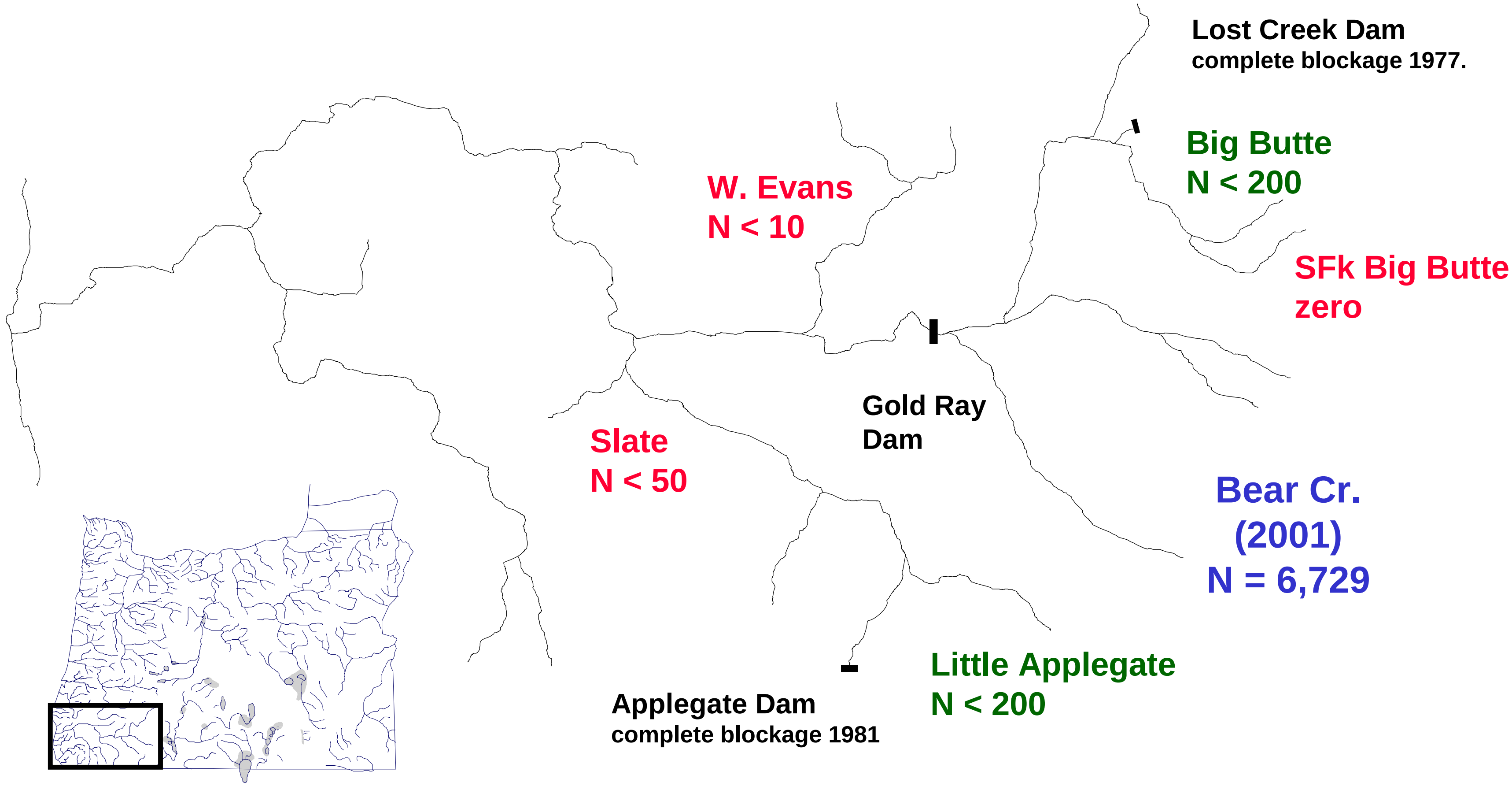


Figure 37. Distribution of recent lamprey observations in smolt traps in the upper Rogue Basin, 1998 - 2001. Counts at the red traps ranged from zero to 100; at the green traps ranged from 100 to 200, and at the blue trap, over 6,000. There is no data from the lower Rogue below the Rogue River Canyon.

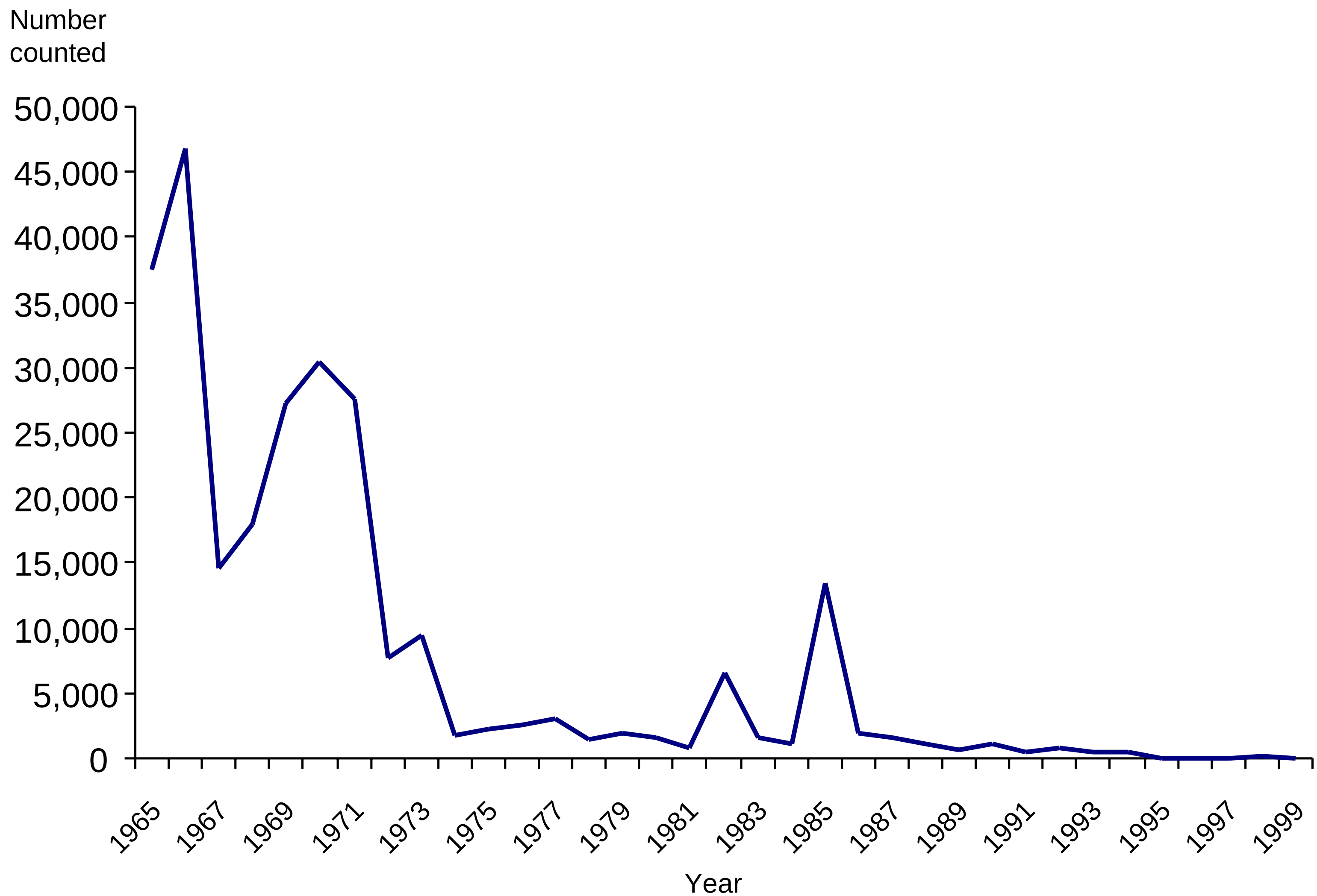


Figure 38a. Annual counts of adult Pacific Lampreys at Winchester Dam on the Umpqua River, Oregon coast, 1965 - 1999.

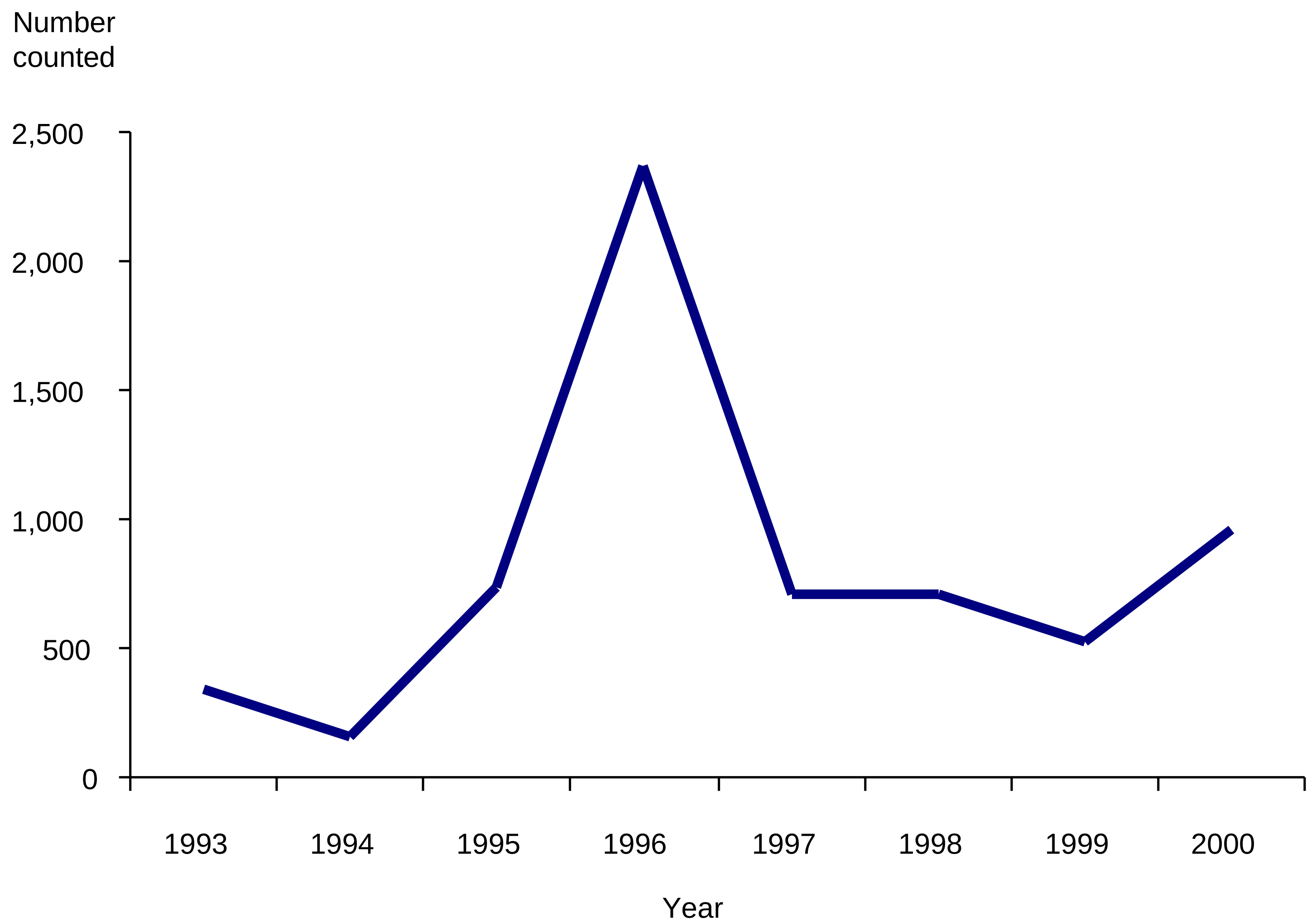


Figure 38b. Annual counts of adult Pacific Lampreys at Gold Ray Dam on the Rogue River, Oregon coast, 1993 - 2000.

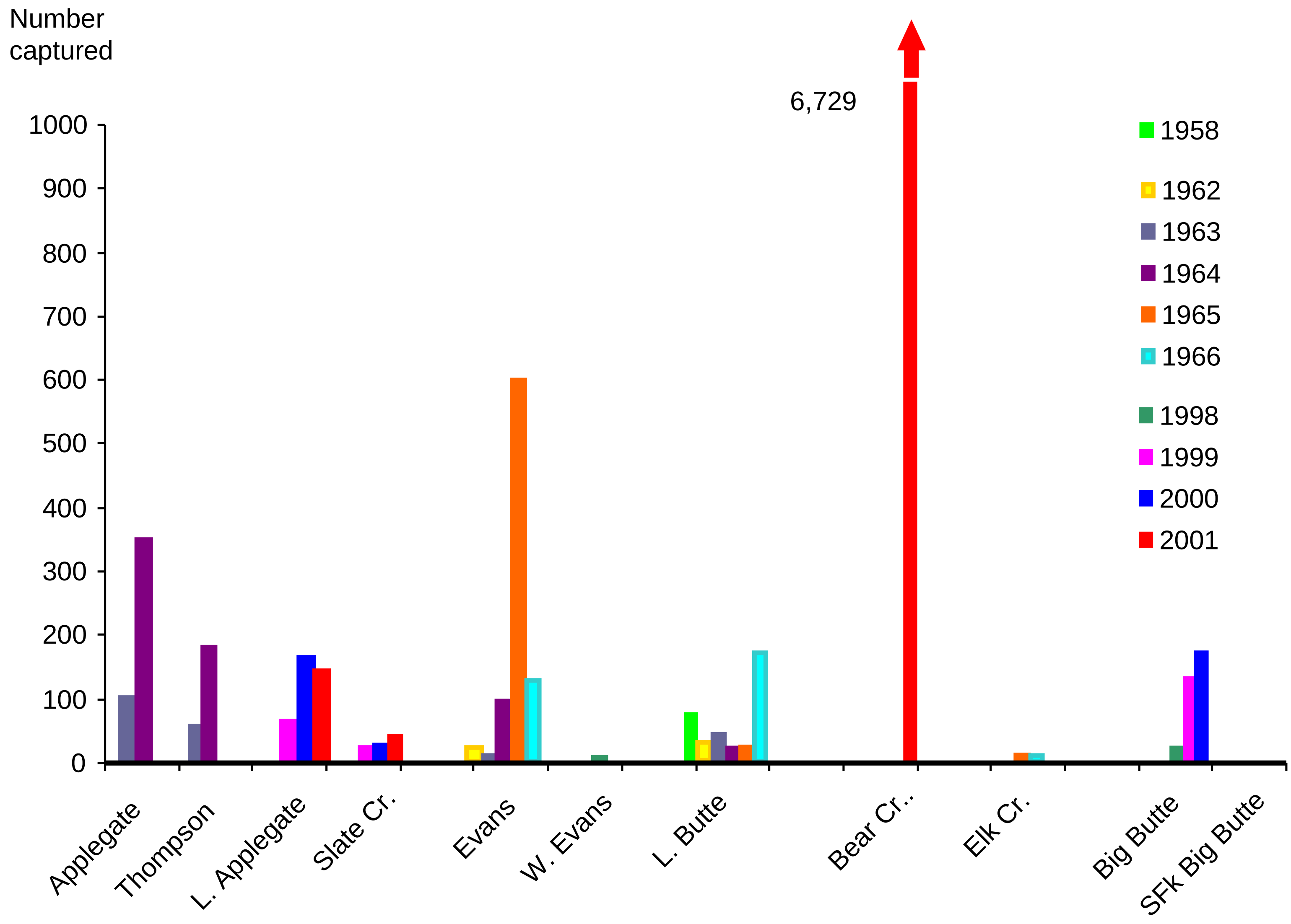


Figure 39. Counts of lampreys captured in traps in the upper Rogue River basin, including some historical observations. Mostly ammocoetes, likely a mix of species.

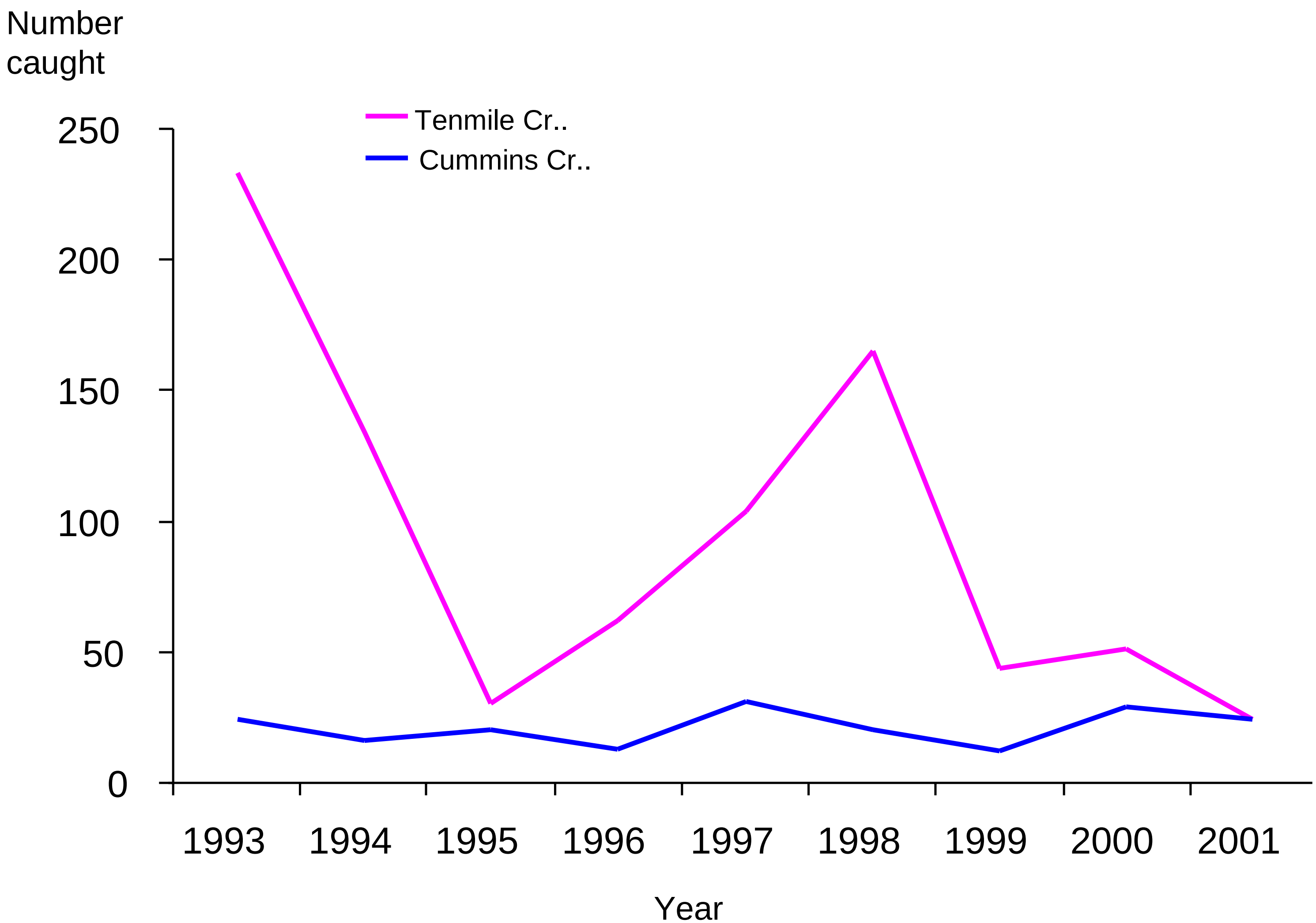


Figure 40a. Number of adult Pacific Lampreys caught annually in smolt traps on Cummins and Tenmile creeks, two small creeks on the south Oregon coast 1993 - 2001.

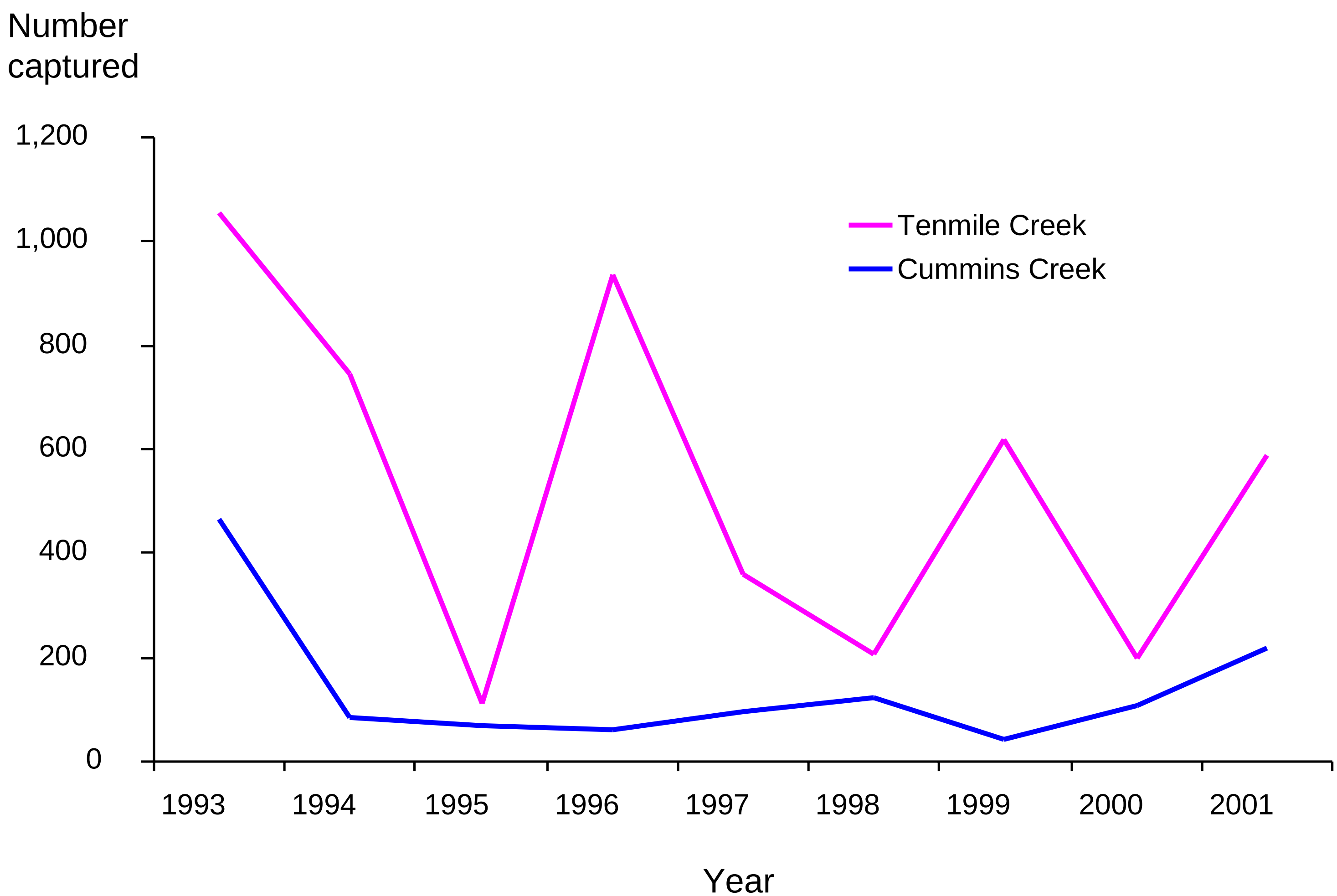


Figure 40b. Number of lamprey ammocoetes caught annually in smolt traps on Cummins and Tenmile creeks, two small creeks on the south Oregon coast 1993 - 2001. A few eyed lampreys were also caught; these may have been brook lampreys or lampreys undergoing metamorphism.

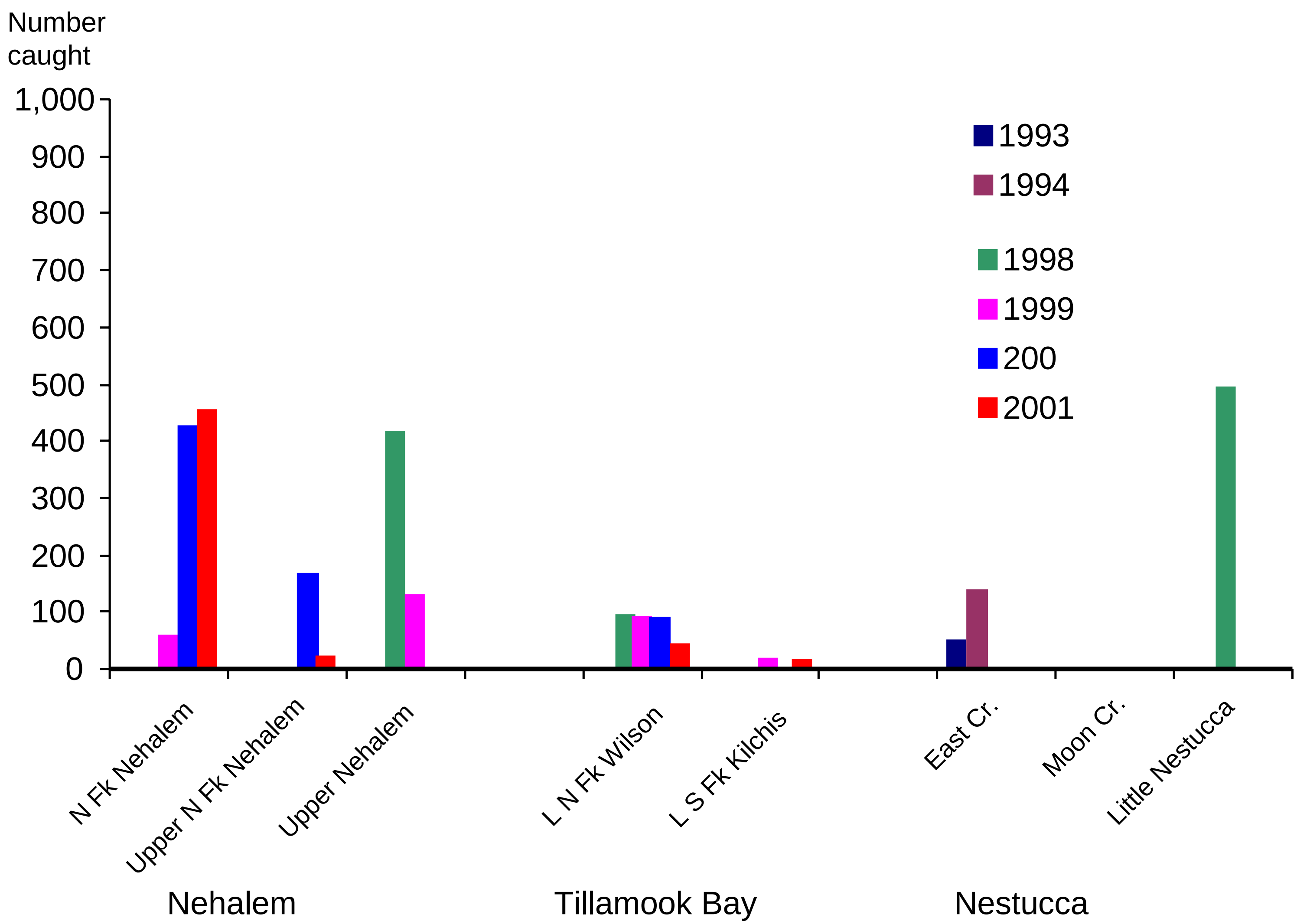


Figure 41a. Lampreys captured in smolt traps on the North Oregon coast. Most lampreys were ammocoetes. Sampling from 1993 - 2001, but not all locations were monitored in all years.

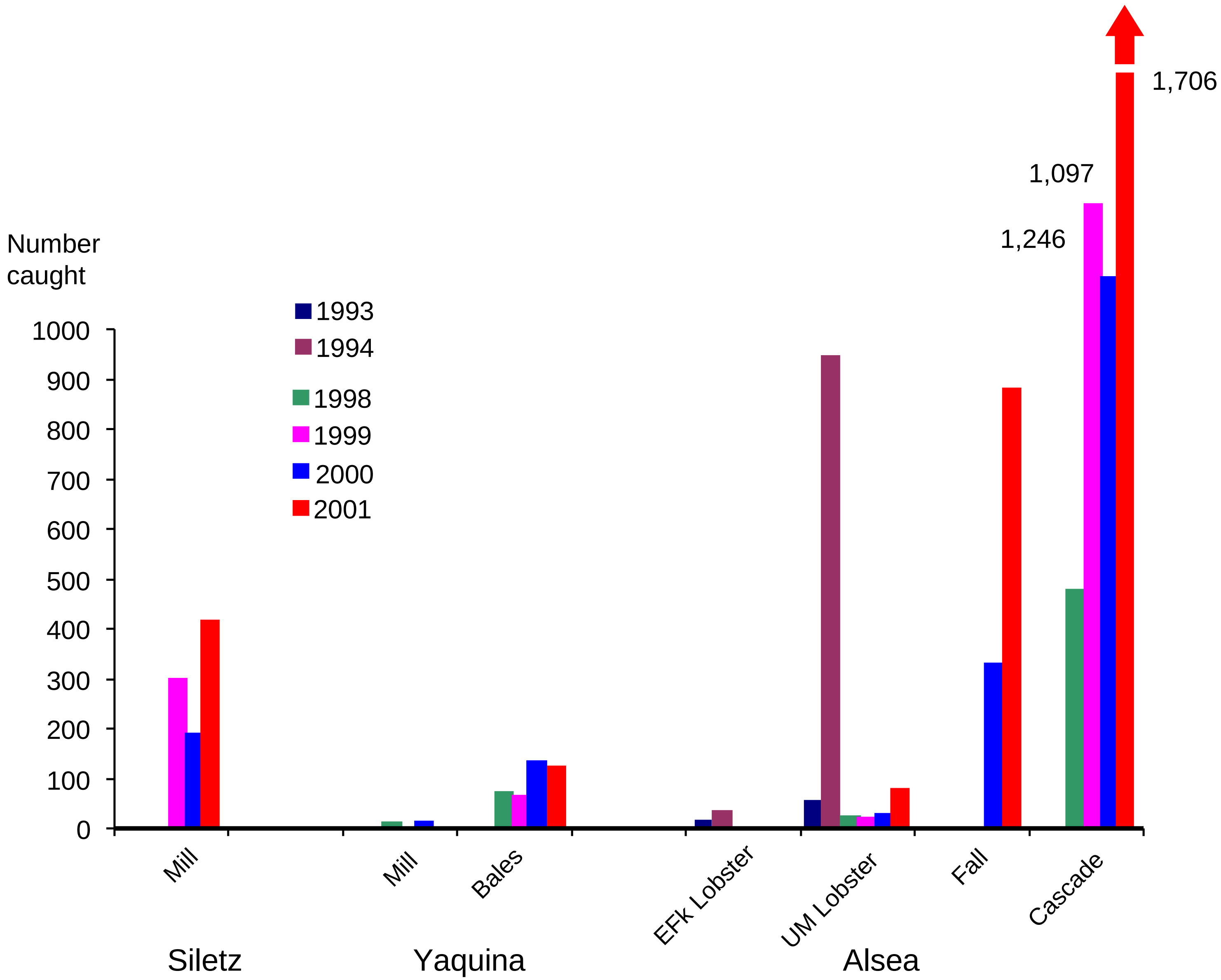


Figure 41b. Lampreys captured in smolt traps on the Mid-Oregon coast. Most lampreys were ammocoetes. Sampling from 1993 - 2001, but not all locations were monitored in all years.

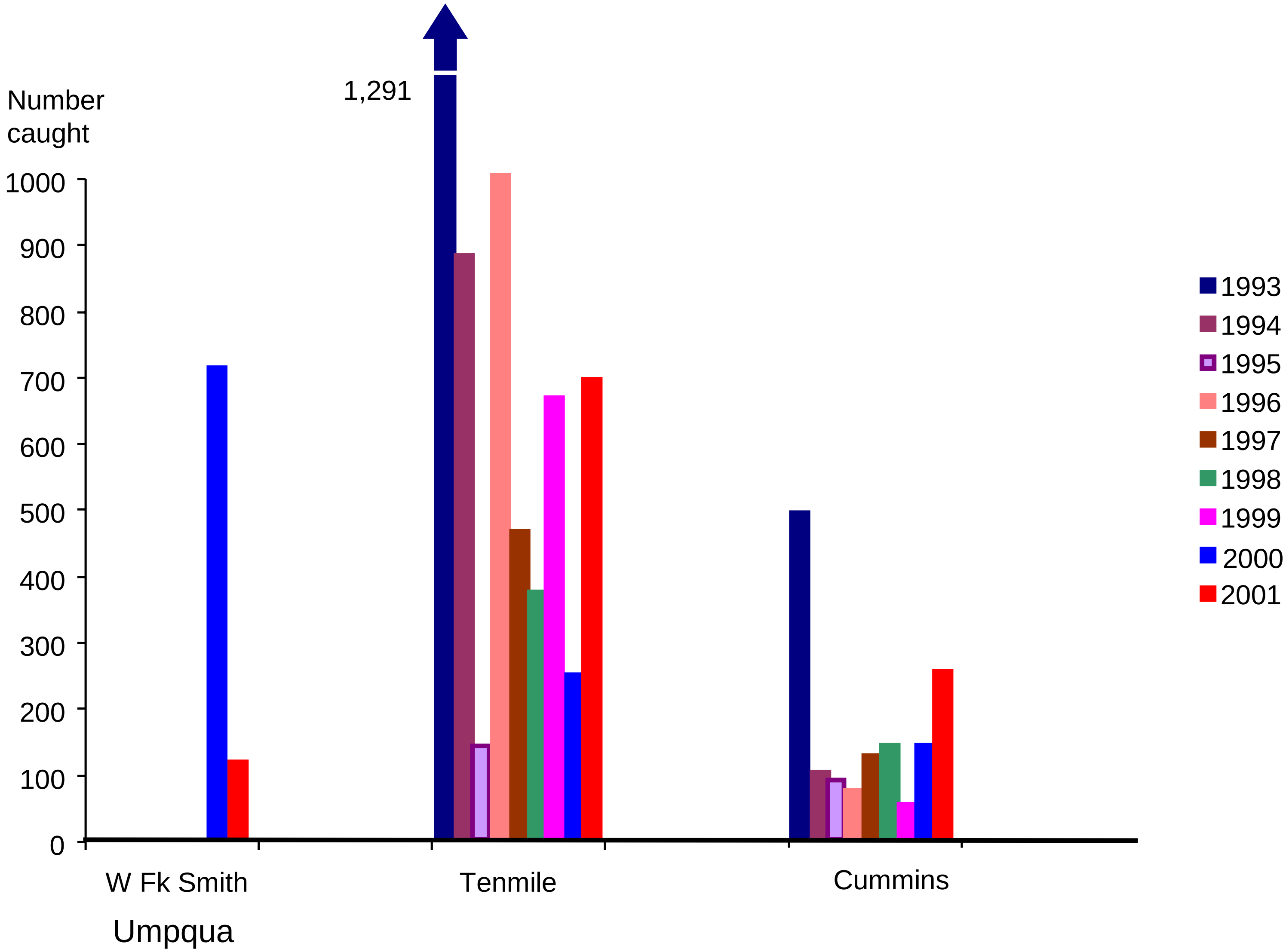


Figure 41c. Lampreys captured in smolt traps on the South Oregon coast. Most lampreys were ammocoetes. Sampling from 1993 - 2001, but not all locations were monitored in all years.

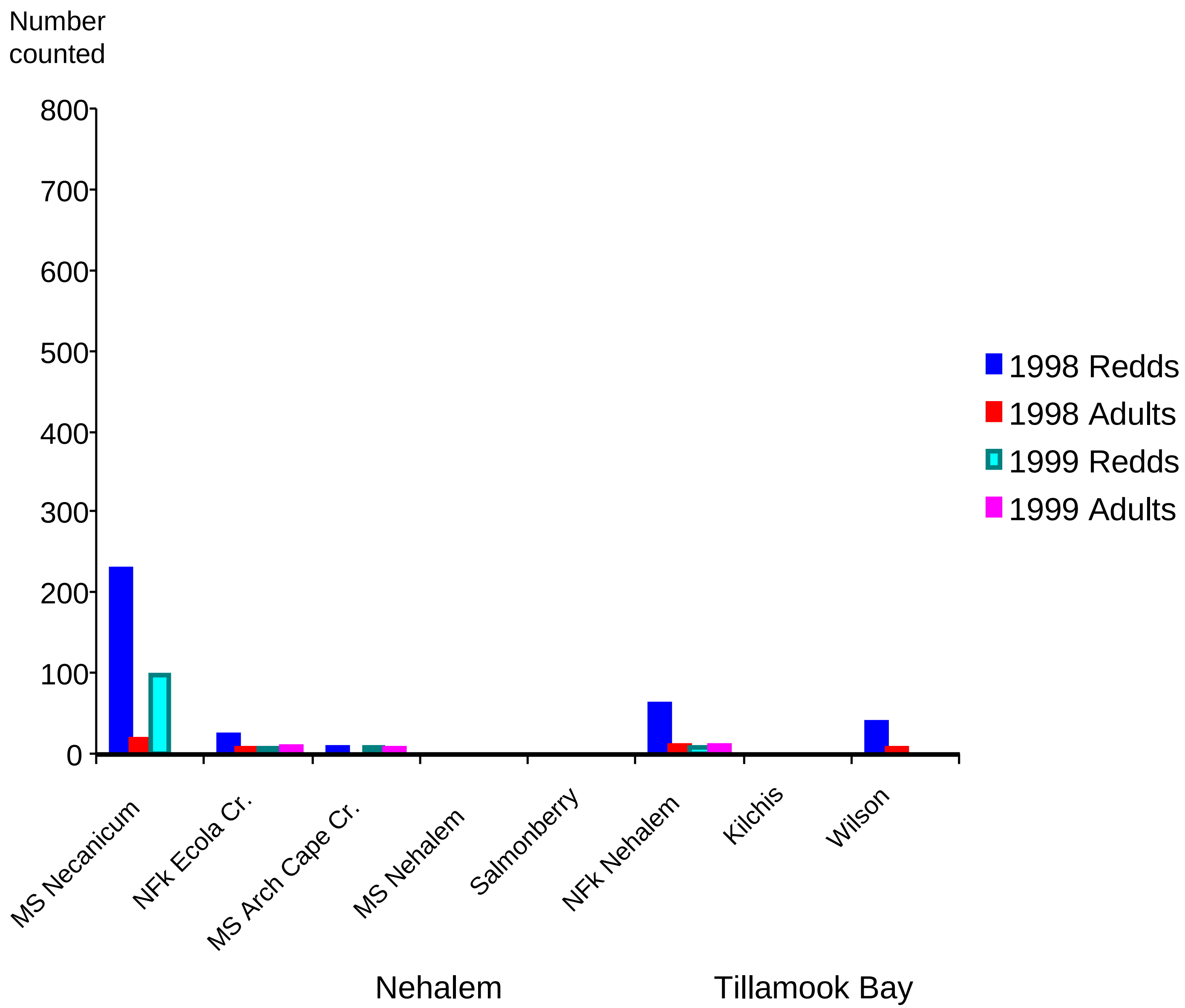


Figure 42a. Pacific Lamprey adults and redds observed during steelhead spawning ground surveys, on the north Oregon coast, 1998 - 1999.

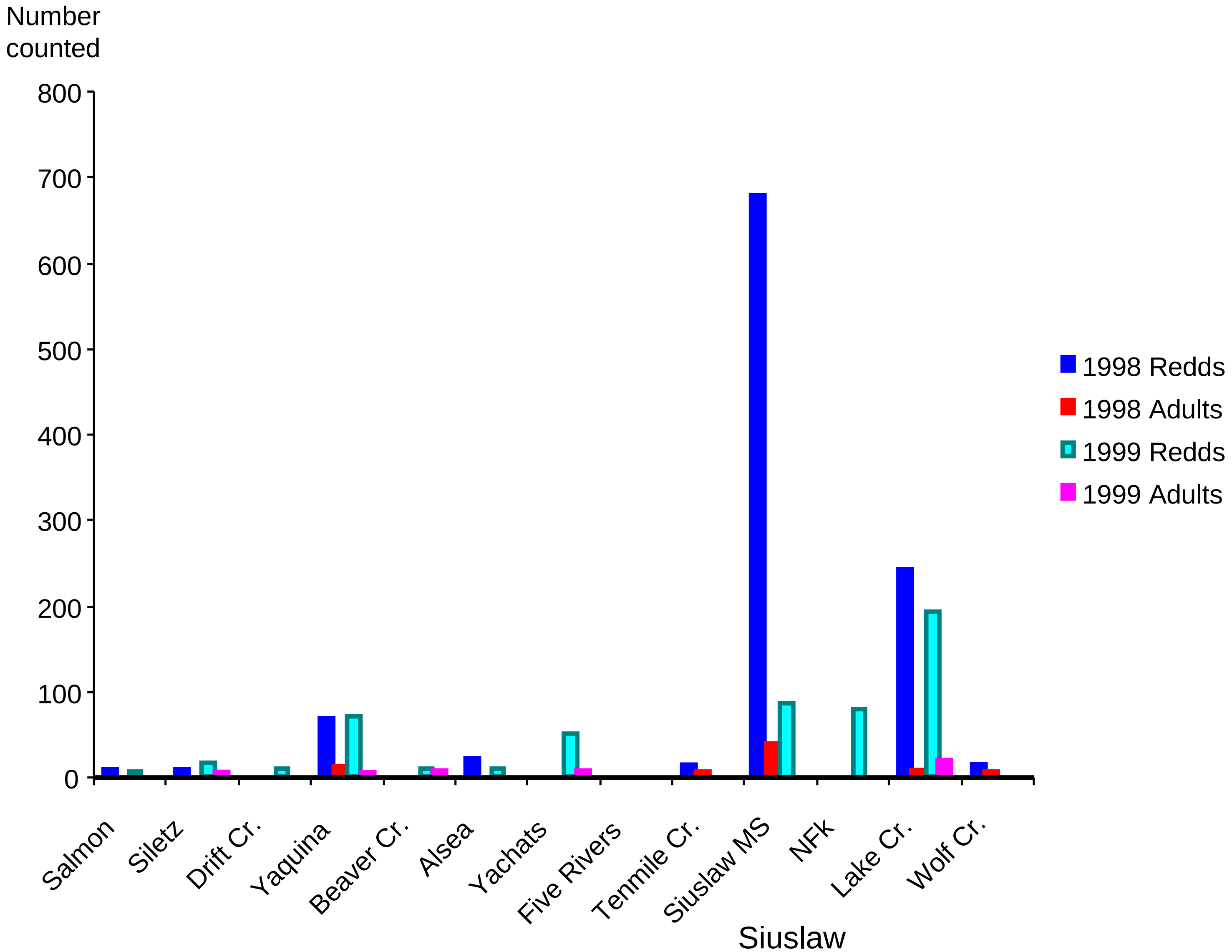


Figure 42b. Pacific Lamprey adults and redds observed during steelhead spawning ground surveys, on the mid-Oregon coast, 1998 - 1999.

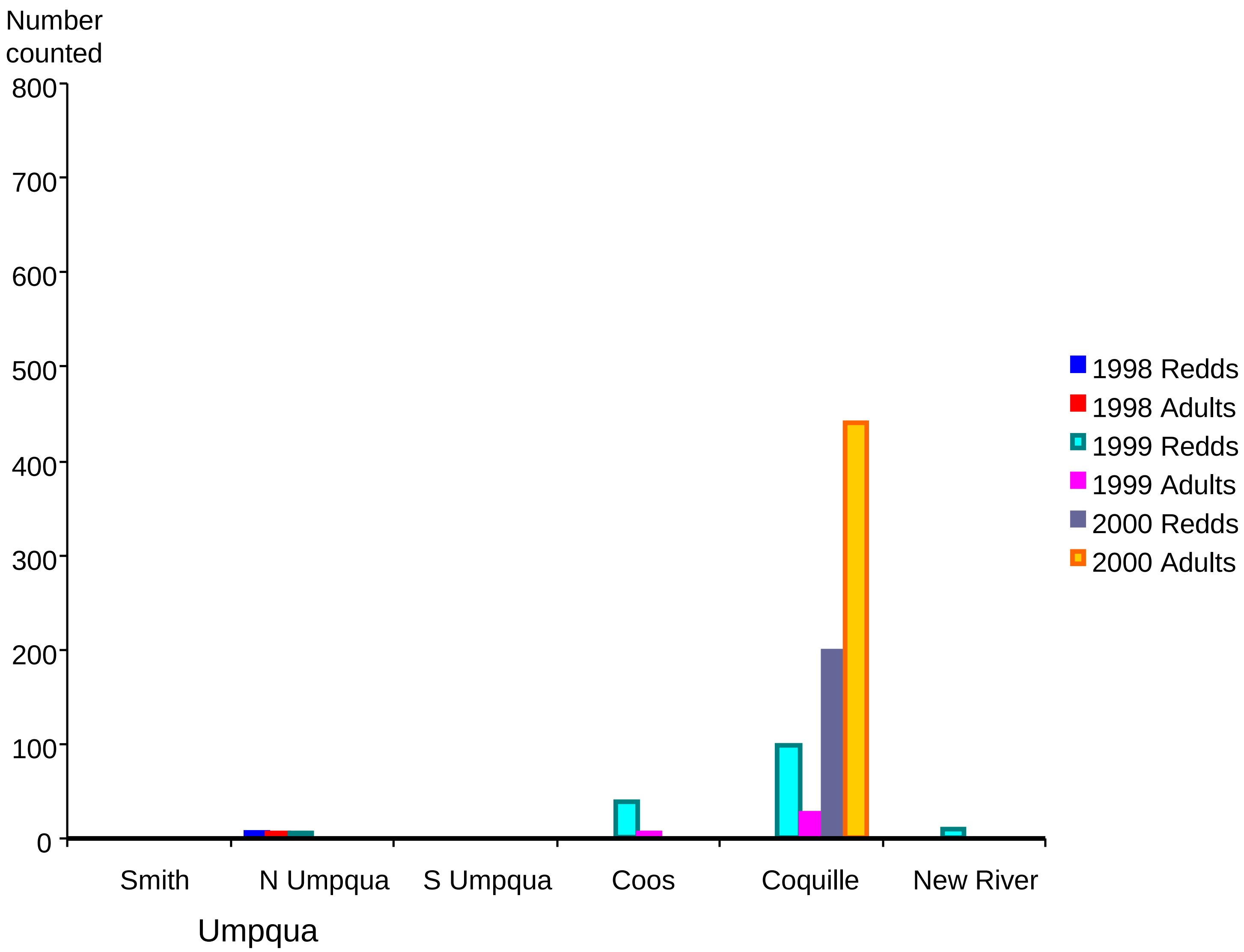


Figure 42c. Pacific Lamprey adults and redds observed during steelhead spawning ground surveys, on the south Oregon coast, 1998 - 2000.

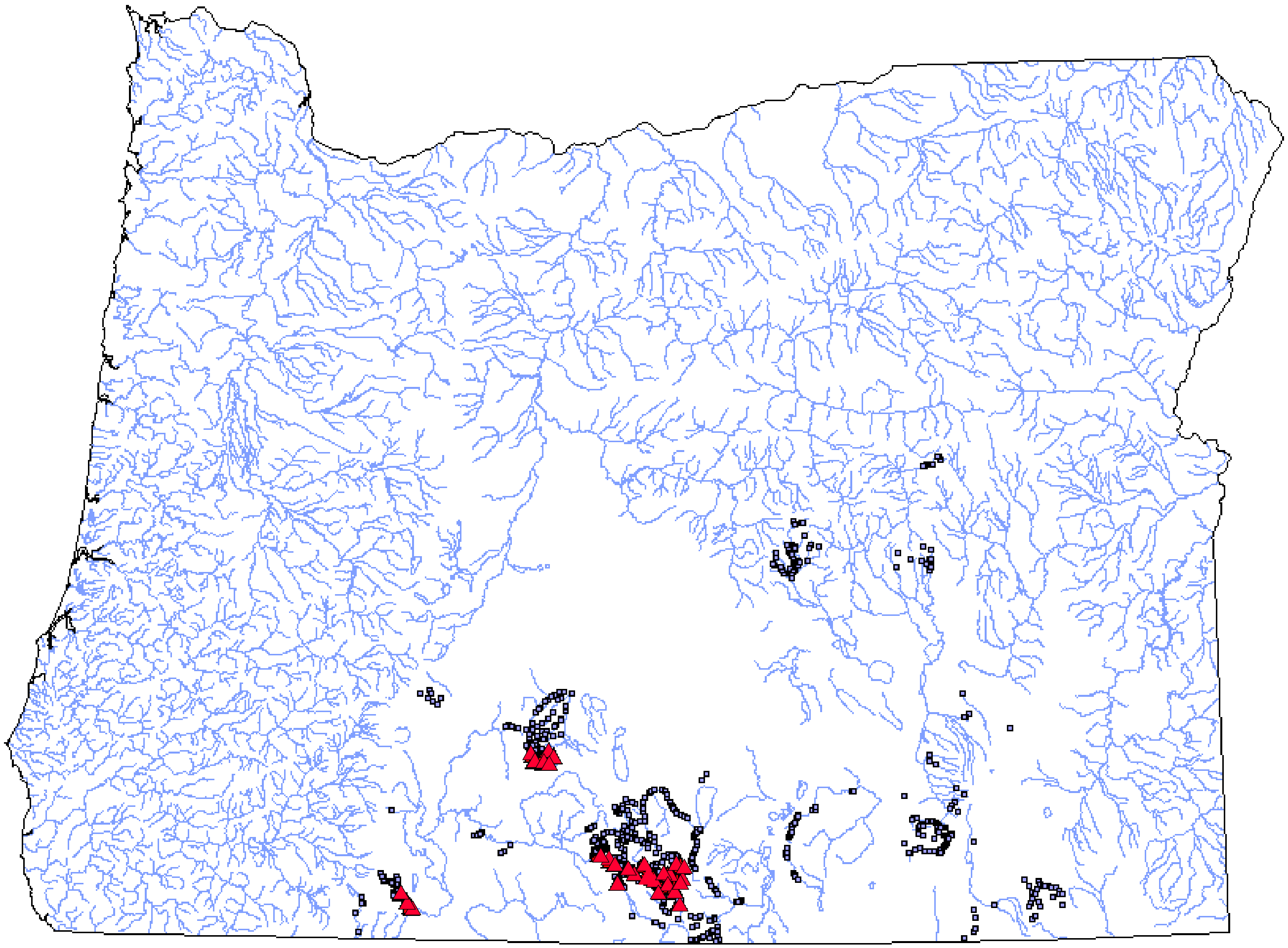


Figure 43. Observation records of lamprey in southeastern Oregon made during ODFW fish inventory surveys. Locations where lampreys were observed ▲ . Other locations that were sampled but no lampreys were observed ▪ .

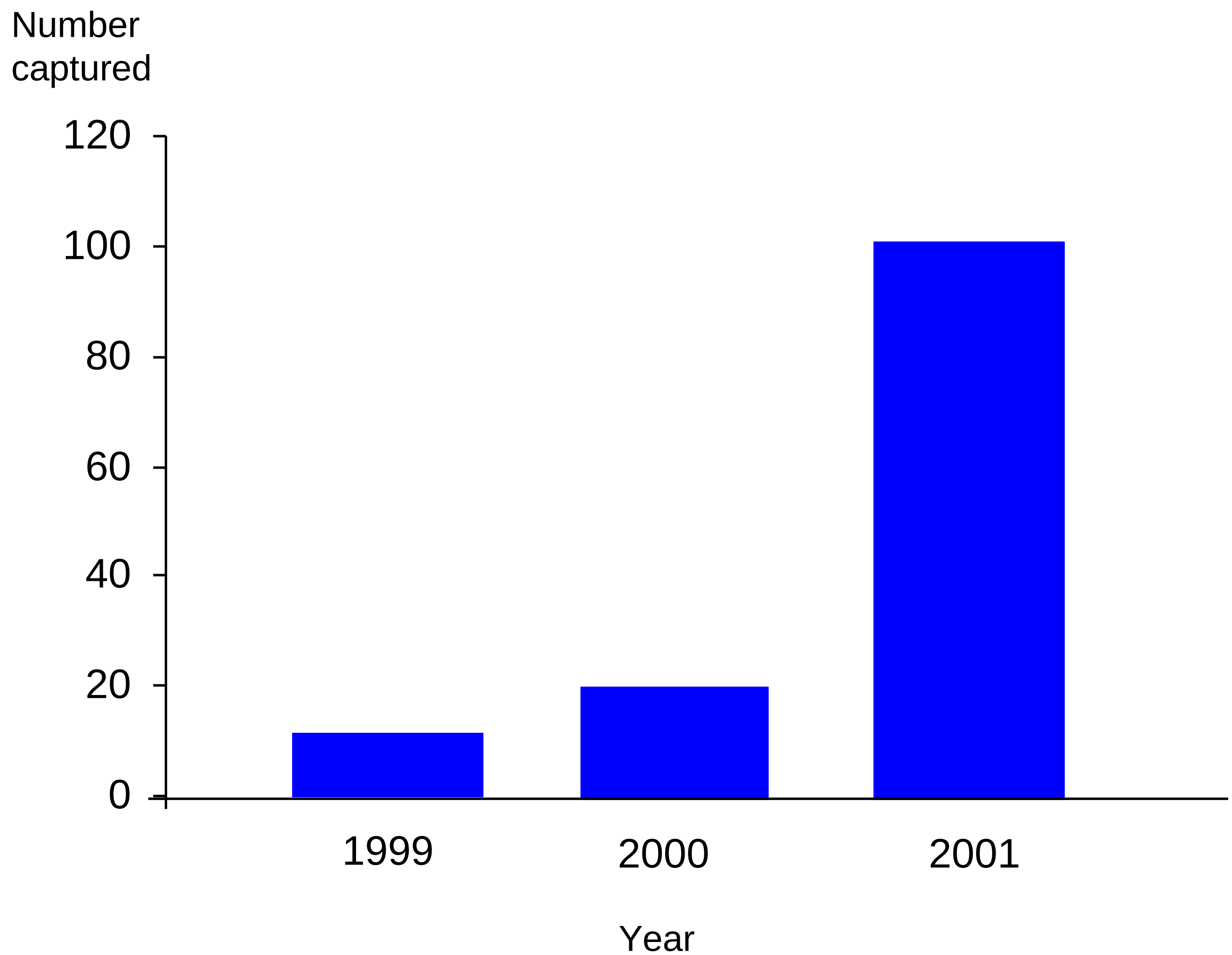
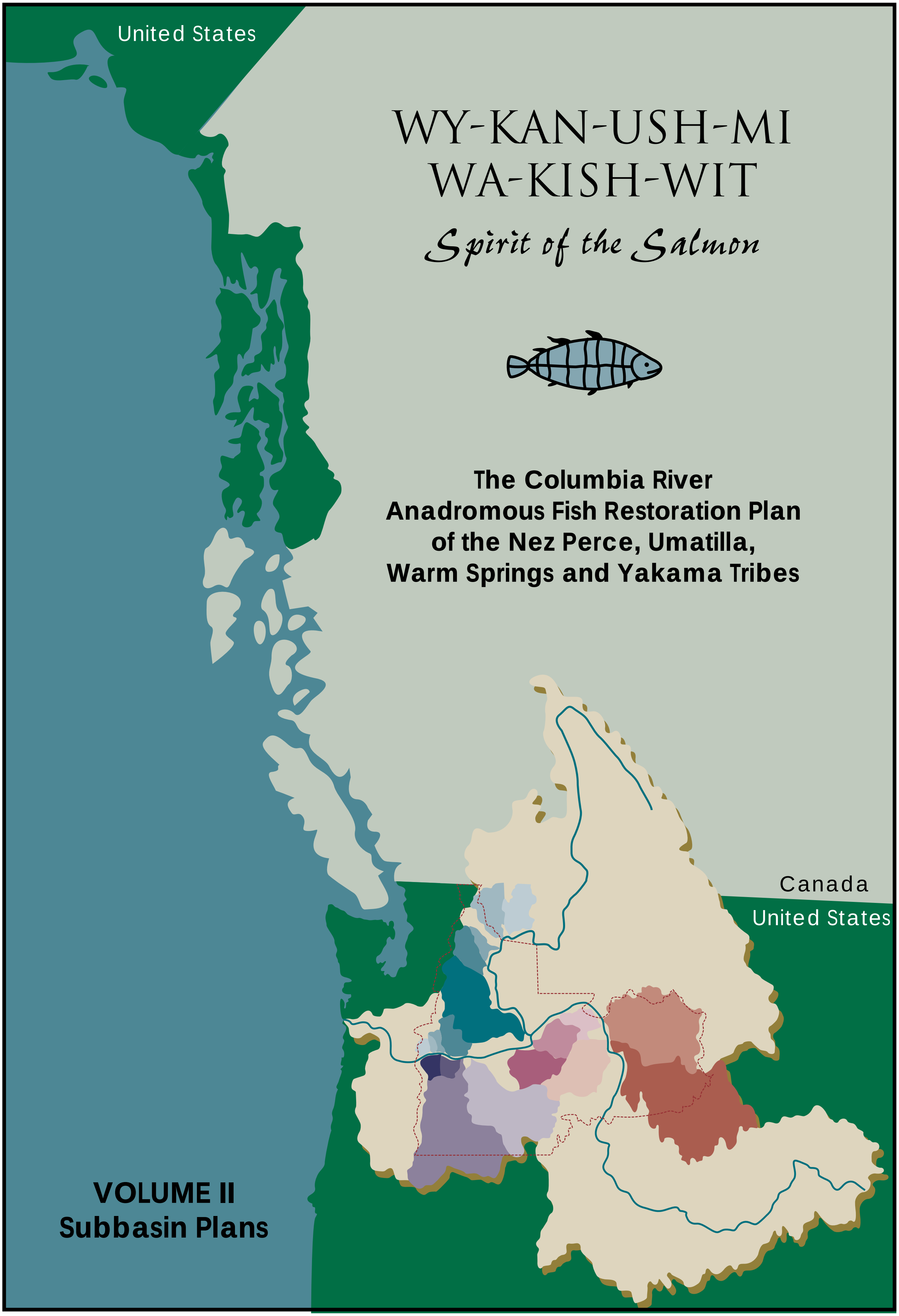


Figure 44. Counts of lampreys at the Thomas Creek trap, tributary of Goose Lake, 1999-2001. Both adults returning from Goose Lake on spawning runs and out-migrants are included.

WY-KAN-USH-MI WA-KISH-WIT

Spirit of the Salmon

The Columbia River Anadromous Fish Restoration Plan of the Nez Perce, Umatilla, Warm Springs and Yakama Tribes



VOLUME II
Subbasin Plans

VOLUME II
SUBBASIN PLANS

TABLE OF CONTENTS

INTRODUCTION

Klickitat, Yakima, Imnaha, Umatilla, Walla Walla—many of the tributaries of the Columbia Basin retain the names of the people who inhabited their banks and fished their waters for no less than ten thousand years. Even those rivers renamed by white settlers remain within the territories where our ancestors, the people of the Umatilla, Nez Perce, Yakama, and Warm Springs tribes lived and died since time immemorial.

Prior to treaty signing in 1855, our Indian people traveled throughout our territories in the Columbia Basin to places where we knew fish and game were available for sustenance and livelihood. In the treaties, which opened the basin to white settlement, we reserved the right to travel to all of these usual and accustomed fishing places to take fish while also reserving the exclusive right to take fish on our reservations. For its part, the United States agreed to secure these rights.

For almost a century following the treaty councils, federal policy generally ignored the treaties by allowing the salmon populations of the basin to decline through over harvest and upper basin development and by misusing mitigation authorities such as the Mitchell Act and the Lower Snake River Compensation Plan in a discriminatory manner. But in 1968, with the initiation of the lawsuit now called *U.S. v. Oregon*, we acted to protect our birthright.

Twenty-seven years later, *U.S. v. Oregon* is still on the federal district court docket and provides a means of dispute resolution when discussion and negotiations fail between our tribes, the United States, and the states of Oregon, Idaho and Washington.

Since 1968, the federal, state and tribal governments created or used other institutions to address the problem of declining salmon stocks. These included the Northwest Power Planning Council (NPPC), the Pacific Salmon Commission, the Columbia River Fish Management Plan adopted by the federal court in *U.S. v. Oregon*, and the consultations conducted by the National Marine Fisheries Service (NMFS) under the Endangered Species Act (ESA).

The NPPC was created under the Northwest Power Act of 1980 to protect, mitigate and enhance salmon in the basin. After determining the magnitude of salmon losses, the NPPC adopted a Fish and Wildlife Program amendment setting forth a program to restore salmon through individual tributary plans (subbasin planning) with implementation slated for 1990.

The Pacific Salmon Commission was created in 1985 under the Pacific Salmon Treaty to rebuild chinook salmon runs and allocate harvests between United States and Canadian fisheries.

The Columbia River Fish Management Plan was approved by the Federal District Court of Oregon in 1988 to address production and harvest issues among the federal, state, and tribal governments. Provisions included the development of subbasin plans to achieve the earliest feasible rebuilding of basin salmon stocks.

In 1991 the National Marine Fisheries Service listed certain Snake River salmon stocks as threatened or endangered, shifting attention to the preservation of fragmented and isolated populations in the Snake River, its tributaries and Redfish Lake. During the Salmon Summit, a series of citizen/industry/government meetings convened in the early 1990s to confront the salmon crisis, key participants rejected the approach that included subbasin restoration programs in favor of a focus on Endangered Species Act listings.

The NMFS listing also restricted the ability of fishery managers to use propagation as a tool for rebuilding by including the "evolutionarily significant unit" (ESU) policy, a severe restriction on the ability of fishery managers to utilize propagation techniques that were included as elements of the subbasin plans and the Columbia River Fish Management Plan.

Regrettably, the ESA designation of Snake River salmon set back efforts to restore the basin's declining salmon populations throughout the basin—efforts that were mandated under *U.S. v. Oregon*, the Pacific Salmon Treaty and the NPPC's Fish and Wildlife Program. However, scientific research indicates now that numerous non-listed populations will be lost unless protection and restoration efforts are begun immediately in every Columbia Basin tributary.

Since the passage of the Northwest Power Act in 1980, the basin's treaty fishing tribes have worked with their neighbors in certain watersheds to restore fisheries for the benefit and enjoyment of all users.

In the Umatilla, the Confederated Tribes of the Umatilla Indian Reservation, in cooperation with the State of Oregon and local irrigators, implemented a program of habitat improvement and outplanting of appropriate stocks that returned chinook salmon and coho to the river for the first time in seventy years.

In the Imnaha, a tributary of the Snake, the Nez Perce Tribe worked with Wallowa County residents to maintain a program for habitat protection and artificial propagation that, in 1992 and 1993, resulted in a ten-fold increase in adult spring chinook returns, then the only increasing trend for spring chinook in the Snake above eight dams.

In the Yakima, the Yakama Indian Nation secured federal legislation to provide enhancement of water quantity as a means to implement an ambitious program of salmon restoration that has been in the NPPC's Fish and Wildlife Program since 1982.

In the Hood River, the Confederated Tribes of the Warm Springs Reservation of Oregon are working closely with the Oregon Department of Fish and Wildlife and with local interests to rebuild spring chinook and steelhead through a program of habitat improvement and supplementation of natural production.

The plans that follow are our tribal proposals to protect or restore salmon populations in each tributary above Bonneville Dam through the implementation of detailed subbasin actions that address both habitat protection and fish production. These subbasin plans are a refinement of the plans completed by the fishery agencies and tribes in 1990—plans that defined watershed habitat and production problems and proposed remedies. They represent the cultural and geographic knowledge of our tribes and, in combination with the life cycle survival framework, scientific hypotheses and recommendations in Volume I of Wy-Kan-Ush-Mi Wa-Kish-Wit, offer the best scientific knowledge available on the use of habitat protection and fish restoration in each watershed. Further, the plans are based upon a thorough technical evaluation of habitat conditions and proper broodstock sources for supplementation where appropriate.

But they are not cast in concrete. Instead the plans that follow are intended to engage our neighbors in the challenge of salmon restoration through cooperative efforts at the watershed and regional level. Such cooperative efforts guiding state and federal government actions are preferable to mandated programs arising from lawsuits and court orders or from state capitals and national offices in Washington, D.C.

Federal, state and tribal governments each have a role to play in Columbia Basin salmon restoration based upon each sovereign's specific authorities and functions. Through the *U.S. v. Oregon* process, the three classes of sovereign governments learned to resolve disputes by defining and answering technical questions in a manner that provided a firm basis on which policy representatives could then find solutions. We believe these same methods can be applied at both the regional and watershed levels so that restoration proceeds on a cooperative basis, thereby avoiding mandated solutions from one government or another.

The watersheds of the basin are both the biological and social neighborhoods in which we live. During the next twelve months, we call upon the stakeholders of each watershed to comment upon these proposals and meet with us in a spirit of neighborly cooperation to address salmon restoration. Institutions such as local governments, municipal and public utility districts, schools and irrigation districts are key players in this effort and their review is especially important.

We call upon state and federal government agencies to assist this effort by supplying technical and financial resources and by constructively participating, along with tribal representatives, in watershed approaches. Certain activities are already under way: Oregon, Idaho and Washington are undertaking various watershed health initiatives under state authorities. In its most recent Fish and Wildlife

Program amendments, the NPPC, whose members are appointed by state governors, called for BPA to fund and fish managers to develop emergency production and habitat actions to protect adult spawners in 1995 and 1996. The four Columbia River tribes and the Shoshone Bannock tribe together with the Earth Conservation Corps and the U.S. Department of Energy are putting young people to work fencing off riparian habitat, restoring streambank vegetation and related projects as a part of Salmon Corps, an AmeriCorps division. The Small Watershed Program, administered by the Natural Resources Conservation Service under P.L 83-566, provides authority for federal technical assistance while, at the same time, directing federal agencies to cooperate with states and local entities to plan ways to minimize erosion, flood and sediment damage. Coordinating these activities on federal lands with local watershed efforts will improve their effectiveness.

On a regional, basinwide level, NMFS and NPPC actions need to be coordinated with one another and with tribal initiatives that reinforce the objectives of the *U.S. v. Oregon* Columbia River Fish Management Plan. Most importantly, coordination requires a means of dispute resolution that recognizes the critical distinction between technical assessments and policy decisions.

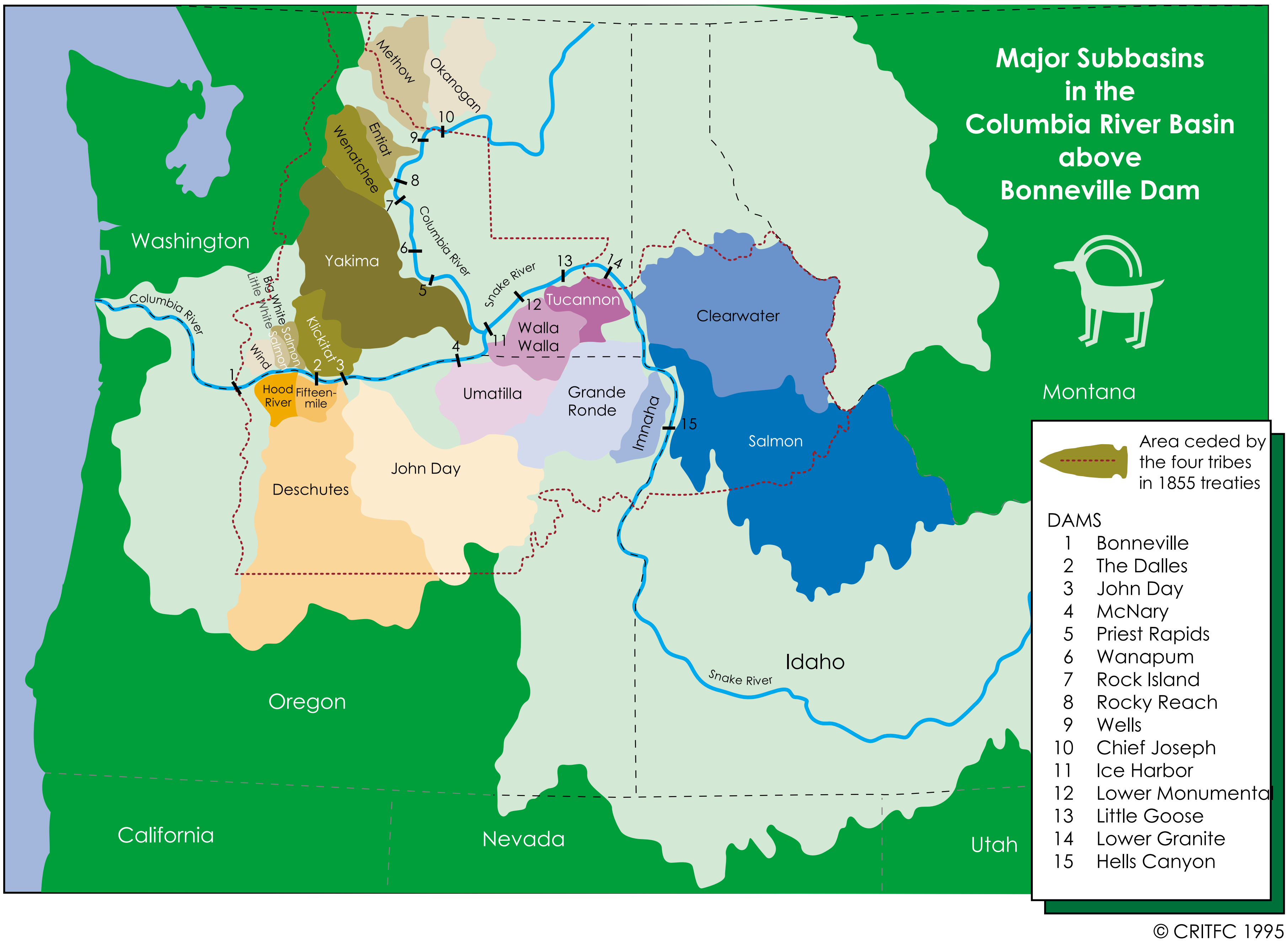
At the basin level, we also call upon the managers of the mainstem Columbia and Snake river projects and the managers of ocean and inriver harvest to recognize their own responsibilities to honestly deal with the impacts they cause to salmon populations both after the salmon leave the watersheds and before they return to spawn. Tribal efforts at developing a life cycle framework for allocating the conservation burden and measuring success are aimed in this direction and have the purpose of providing a scientific context for implementing watershed-based recovery. Without protection of salmon at each stage of its life cycle, the benefits of watershed salmon restoration will be delayed or even eliminated.

On a coastwide level, tribal, state and federal governments need to develop institutional arrangements to support local watershed approaches and coordinate local objectives with regional land use and water development policies. *For the Sake of the Salmon*, a cooperative state, federal, tribal project, is an important coastwide Pacific salmon restoration initiative.

We are calling for a moratorium on salmon posturing and an end to the impasse that has marked salmon restoration since the listing of Snake River stocks in 1991. From the tribal perspective, the progress that marked salmon rebuilding efforts that began in the mid- 1970s was halted as interests suspended constructive dialogue. We believe that most citizens of the Northwest are hopeful that salmon can recover, not only as sustenance for humans and other creatures but also as a cultural symbol of the Columbia River Basin.

Adult return goals for each subbasin and species should be considered interim and will be reviewed periodically as part of the adaptive management process. Habitat-based methods indicate the possibility of achieving larger adult returns over the long term.

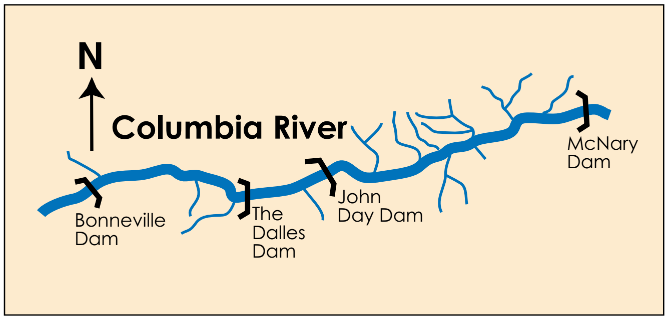
Table 1 provides the annual cost estimates for the tribal restoration programs proposed in the individual subbasin plans.


Major Subbasins in the Columbia River Basin above Bonneville Dam
Washington
Oregon
California
Nevada
Idaho
Montana
Utah
Columbia River
Snake River
Methow
Okanogan
Entiat
Wenatchee
Yakima
Klickitat
Big White Salmon
Little White Salmon
Wind
Hood River
Fifteen-mile
Deschutes
John Day
Umatilla
Walla Walla
Tucannon
Grande Ronde
Imnaha
Clearwater
Salmon
Area ceded by the four tribes in 1855 treaties
DAMS
1 Bonneville
2 The Dalles
3 John Day
4 McNary
5 Priest Rapids
6 Wanapum
7 Rock Island
8 Rocky Reach
9 Wells
10 Chief Joseph
11 Ice Harbor
12 Lower Monumental
13 Little Goose
14 Lower Granite
15 Hells Canyon
© CRITFC 1995

LOWER COLUMBIA RIVER MAINSTEM

(Bonneville to McNary)

Prepared by the Columbia River Inter-Tribal Fish Commission and the Yakama Indian Nation



Introduction

The lower Columbia River mainstem is that section of the river from Bonneville Dam to McNary Dam. This section of the river flows eastward forming the border of Oregon and Washington. The principal tributaries in this section of the river, which have been described individually in these subbasin plans, include the Wind, Little White Salmon, White Salmon, Klickitat rivers in Washington and the Hood, Deschutes, John Day and Umatilla rivers and Fifteenmile Creek in Oregon. In addition to these major rivers, minor tributaries, such as Rock Creek, Eagle Creek, Herman Creek, Mosier Creek, Viento Creek and Willow Creek enter the Columbia River in this stretch of mainstem. (WDF et.al., 1990).

Fish Population Status/Goals

Currently a small number of fall chinook spawn in the minor tributaries of this section of the Columbia River. Those tributaries include Rock Creek (Bonneville Pool), Collins Creek, Eagle Creek, Herman Creek, Linsey Creek and Rock Creek (John Day Pool) (Ibid). Inundation of natural habitat by dam construction significantly affected fall chinook spawning in the mainstem Columbia River.

Minor natural spawning by coho and winter and summer steelhead occurs in the tributaries such as Rock Creek, Eagle Creek, Herman Creek and others (Ibid).

Numerical objectives have not been developed for any of the natural spawning stocks in this section of the Columbia River or the minor tributaries.

Problems Impacting Fish Resources

The major habitat problems in this section of the river continue to be passage and flows at the mainstem dams. In addition, subbasin planners noted that some of the minor tributaries such as Mosier Creek, Willow Creek, Viento Creek and Rock Creek have problems such as natural barriers, agricultural water diversion, culvert blockage and cattle grazing (Ibid). A major loss of habitat also occurred through inundation when the dams were constructed.

Also found in this section of the Columbia River are large irrigation pumps. These pumps, when not properly screened, attract downstream migrants out of the mainstem and into irrigation systems where they die. Table 1 shows the problems impacting the lower Columbia River.

Compensation programs for the losses incurred by the construction of the mainstem dams have been limited, improperly placed or non-existent.

Ongoing Actions In The Lower Mainstem Columbia River

A recently completed study described the extent of mortality associated with improperly screened irrigation pumps and recommended corrective actions. The recommended actions should be taken.

Hatchery production of tule fall chinook in the lower Columbia River typically takes place at Spring Creek National Fish Hatchery (NFH), Oxbow Hatchery, and Bonneville Hatchery. Bright fall chinook production takes place at Bonneville Hatchery. Adult trapping currently occurs at Bonneville and Spring Creek hatcheries. In recent years, tules have also been trapped from the remaining natural runs or shipped downriver from the Spring Creek facility to meet lower river hatchery needs. Additionally, bright fall chinook are provided from Priest Rapids Hatchery as they are needed or become available. Juvenile releases occur at the hatcheries.

Spring Creek National Fish Hatchery is located on the Columbia River near Underwood, Washington. The facility was improved in 1949 as part of the Mitchell Act Program. The facility was modernized in 1972 as part of the John Day Dam mitigation program. Tule fall chinook were then substituted for the bright fall chinook which spawned in that reach of the Columbia River. Broodstock for the Spring Creek program was originally trapped in the Big White Salmon River. The current release program for tule fall chinook is 15,000,000 fish. Releases occur at the hatchery with adults expected to return to the hatchery to provide the needed broodstock. Due to depressed runs in recent years broodstock has also been acquired by trapping adults at Bonneville Dam and transporting them to the hatchery.

With the exception of some of the recent yearly returns, Spring Creek National Fish Hatchery has been considered the most successful fall chinook hatchery on the Columbia River. Not only did it provide for harvest, the facility also routinely provided eggs for Klickitat, Little White Salmon and Abernathy hatcheries.

The success of the station can be further examined by its contribution to other programs during the 1960s. For example in 1965, eggs and fry were sent to Big White Salmon Rearing Pond, Eagle Creek, Entiat, Leavenworth and Carson National Fish hatcheries, the Western Fish Nutrition Laboratory and the Hanford Atomic Energy Laboratory for research, the Klickitat, Washougal and Grays River hatcheries of Washington, the Gnat Creek and Cedar Creek hatcheries of Oregon. In addition, a large number of fry from Spring Creek were released into the John Day River and Willamette River system. Adults were also sent to Little White Salmon Hatchery for their program.

The Bonneville Hatchery was initially improved under the Mitchell Act. The hatchery's bright fall chinook program was further modernized in the mid-1970s when half of the John Day Dam mitigation program was implemented at Bonneville Hatchery. The modernization included the construction of rearing facilities to provide for 95,000 pounds of production at 90 per pound or 8,500,000 subyearlings. Broodstock for the program was acquired by trapping adults at Bonneville Dam and from Priest Rapids Hatchery. Currently the broodstock are acquired from adult returns to the hatchery or from Priest Rapids. Trapping adults at Bonneville Dam no longer occurs. Over the years the hatchery has experimented with different sizes of release.

Recommended Actions For The Lower Mainstem Columbia River

(1) Irrigation pumps that are out of compliance should be immediately screened to conform to the screening criteria of the tribal and state fishery managers. State laws requiring screening should be enforced.

(2) Tributary problems such as those noted in the subbasin plan should be corrected. Riparian areas should be restored and impacts such as grazing be eliminated or restricted.

(3) The following changes are recommended for the release of bright fall chinook from Bonneville Hatchery. The majority of fish are to be released in existing natural production areas for fall chinook. Included in these releases are up to 8,000,000 subyearlings into the Hanford Reach of the Columbia River at Ringold Ponds and Hanford K Ponds, and help ensure the 1,700,000 release programmed for the Yakima River. In addition to the releases into the natural production areas, it is recommended that 500,000 fish be released into Rock Creek utilizing net pens. These releases will all provide additional opportunities for tribal fisheries and if necessary, following mixed stocked fisheries, the tribes could provide a small terminal fisheries in Rock Creek. Broodstock for the program would come from the existing and planned bright fall chinook adult trapping programs in the Hanford area and Yakima River. Releases should occur at the existing final rearing and/or acclimation facilities in the natural production areas.

Because the Spring Creek NFH program plays such an integral part in the harvest management of chinook salmon in the Pacific Northwest major rearing and release changes are not recommended except for the small release to the Wind River.

(4) A program to restore lamprey in the tributaries should be developed by the relevant fishery managers. This program should be under the overall leadership of the tribes.

Table 2 shows the tribal recommended actions needed to restore the fish resources of the lower Columbia River system.

Table 1

Problems Impacting the Lower Columbia River Fish Resources

	Mainstem	Tributaries
Fish Screens	•	
Tributary Problems		•
Inadequate Production Compensation	•	

Table 2

Recommended Actions for the Lower Columbia River System

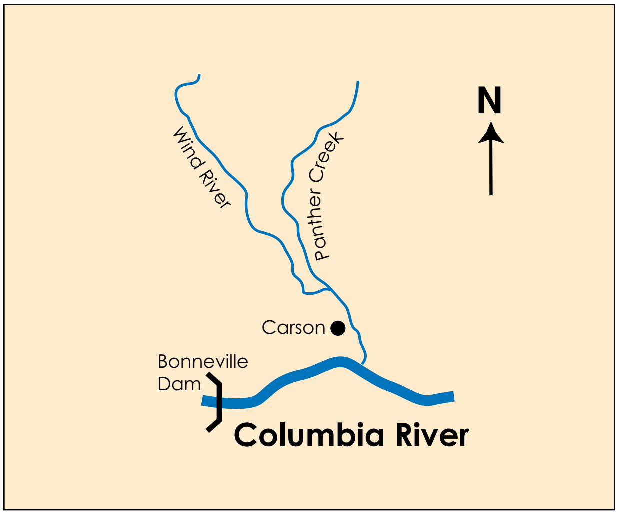
Problem	Recommended Action
Fish Screens	(1) Enforce state and federal screening requirements
Tributary	(2) Evaluate, correct, and restore riparian areas
Inadequate Production Compensation	
Fall chinook	(3) Implement new broodstock programs, release programs, and production programs
Lamprey	(4) Develop and implement programs in tributaries

WIND RIVER

Prepared by the Yakama Indian Nation

Introduction

The Wind River originates in the Gifford Pinchot National Forest in southwestern Washington. It is approximately 30.5 miles long and drains about 225 square miles. The subbasin is in the Cascade Mountains with elevation changes ranging from 3,200 feet at the source to 72 feet at the mouth (WDW, et. al., 1990). It flows southward and enters the Columbia River near Carson, Washington. Principal tributaries include Panther Creek, Trout Creek,Little Wind River, Bear Creek, and Paradise Creek.



Fish Populations Status/Goals

Carson National Fish Hatchery is located about 17 miles from the mouth of the Wind River. As part of the Mitchell Act program, it was constructed by the Corps of Engineers in 1952 and is operated by U.S Fish and Wildlife Service. The facility was designed and constructed to rear 2,600,000 spring chinook to yearling size.

The hatchery also serves as a trapping location for spring chinook. The facility has the unique history of being developed as the station that was to provide spring chinook eggs from upper Columbia River streams for transplanting to the lower Columbia River Mitchell Act hatcheries and tributaries. The program began with the trapping of adults at Bonneville Dam. This program was necessitated after the attempt to trap spring chinook in the upper Salmon River failed in the earlier 1950s.

Natural spawning of spring chinook in the upper Wind River did not occur until passage facilities were built at Shipherd Falls in 1956. As passage was restored and a spring chinook run established at the Carson National Fish Hatchery, natural spawning began in habitats above and below the hatchery. Juvenile chinook have been found in tributaries of the Wind River including Compass, Crater, Planting, Trout, and Trapper creeks. Existing habitat is in relatively good condition in the mainstem Wind River, although some tributaries have been rated fair to poor.

Natural spawning of tule fall chinook in the Wind River occurs in the mainstem below Shipherd Falls. Spawning also may occur in the Little Wind River, but surveys have not been completed for this tributary. Completion of Bonneville Dam inundated some habitats in the lower Wind River. Because tule fall chinook in the Columbia Basin are managed for hatchery production, any contribution from the natural production is minimal. Straying from the Spring Creek National Fish Hatchery is also likely occurring.

Natural spawning of summer and winter steelhead in the Wind River occurs primarily in the mainstem, but spawning also occurs in Trout Creek and Panther Creek. Juvenile steelhead have been found in several tributaries, including Trout, Panther, Bear, Trapper, Dry, and Paradise creeks. Prior to the passage at Shipherd Falls, only steelhead were known to pass the falls successfully. Exact locations and sizes of spawning populations are not well documented. The historic run size was estimated at 2,500 fish, while the present population is approximately 370 fish. Examination of steelhead hatchery release records reveals that steelhead from Beaver Creek, Goldendale, Skamania, and Vancouver hatcheries have been released nearly every year since 1957. Releases were stopped in 1980 when an outbreak of infectious hematapoietic necrosis virus (IHN) at the Skamania Hatchery eliminated the stock. Releases have been and continue to be mostly smolts, even though the naturally spawning steelhead population is otherwise managed as a wild stock. Natural runs probably consist of off-spring from the annual releases and the original stock that inhabited the system.

A small spawning population of coho persists in the Wind River. As in all tributaries except the Umatilla River, no attempt is being made to increase the natural spawning populations of coho in the Wind River. Straying from hatcheries is most likely the primary source of any natural production.

Numerical objectives for natural production of anadromous salmonids was not developed by subbasin planners. The recommended objectives were for tribal and sport subbasin harvests of 2,000 hatchery-released summer steelhead 200 hatchery-released winter steelhead, 5,000 spring chinook, and no subbasin harvest of fall chinook or coho. Table 1 shows the existing fish species, population status, and production goals for the Wind River.

Problems Impacting Fish Resources

Existing salmonid habitats in the Wind River system are in relatively good condition. Problems that were noted in the late 1940's were corrected as part of the Mitchell Act program. Most notable of the habitat improvements was the provision for fish passage at Shipherd Falls in 1956. Habitat problems noted in the subbasin plan are mainly related to timber harvesting practices. Throughout the subbasin there continues to be a need to restore riparian vegetation, reduce sediment delivery to streams, and ensure continuous recruitment of large woody debris into the system.

Management of fish resources for hatchery production has delayed restoration of natural populations. Hatchery production programs for the system were developed following construction of the fish passage device at Shipherd Falls. Spring chinook broodstock for Carson hatchery were trapped at Bonneville Dam. Programs to restore fish to natural habitats have been limited, improperly designed, or non-existent. Losses of some species have not been mitigated in any manner (for example, tule fall chinook and coho). Table 2 shows the problems impacting the Wind River system.

Ongoing Actions In The Wind River System

Progress has been made toward correcting habitat problems and providing improved timber harvest management through the Timber/Fish/Wildlife process (a cooperative natural resource arrangement among tribal, state and private land owners in Washington state).

Hatchery production of spring chinook in the Wind River occurs at Carson National Fish Hatchery. Releases mainly occur at the hatchery and at final rearing ponds on the Big White Salmon River. Broodstock are expected to return and be trapped at the hatchery. Over the years, Carson has been used to provide broodstock throughout the Columbia River system. Due to disease problems in recent years, the transfer of eggs and/or fish has decreased.

Summer run steelhead are currently released into the Wind River system as full-term reared smolts. Hatchery production of steelhead takes place at Skamania Trout Hatchery using Skamania stock. Past releases of steelhead in the Wind River also included releases from Carson National Fish Hatchery.

Recommended Actions For The Wind River System

(1) A diversion on Trout Creek is used to provide water for Wind River Nursery. The diversion dam has created fish passage problems, low water flows, and high water temperatures. The diversion dam should be removed and a well installed.

(2) Riparian vegetation throughout the watershed has been impacted by logging and development. The riparian vegetation should be restored. Logging and development in the riparian areas should be eliminated or restricted to maintain water temperature, bank stability, nutrient delivery, and channel stability.

(3) Large woody debris is removed during logging and clearing of the riparian area. Large woody debris should be retained or restored to help maintain stream integrity.

(4) Sedimentation due to logging occurs throughout the system. Roads, yarding of logs, and mass wasting from timber harvest all contribute to sediment delivery. Other types of streamside development also may introduce substantial amounts of sediment to streams. Logging practices should be made to conform with strict water quality standards or else logging must be prohibited from the watershed.

(5) Runoff from the Wind River Nursery creates water quality problems in Martha Creek. The runoff from the nursery should be treated.

(6) Establish naturally-spawning populations of chinook, coho, and steelhead through supplementation. The existing hatchery program should be changed to begin developing a broodstock source from naturally-spawning populations in the Wind River. Adult holding capabilities at Carson hatchery must be modified to allow separation of adults. The use of the existing hatchery trap should be compatible with maintaining the existing genetic make-up of spring chinook above that location because the naturally spawning fish are derived from hatchery strays. Final rearing and/or acclimation facilities should be constructed in the natural production areas above and below the hatchery.

(7) Reprogram Spring Creek National Fish Hatchery to provide tule fall chinook for release into the natural production area of the lower Wind River. An annual release of up to 1,000,000 smolts should be started. Broodstock should continue to be acquired from the Spring Creek hatchery return.

(8) Reprogram Skamania Trout Hatchery to use Wind River broodstock for supplementation of the naturally spawning summer steelhead population. The hatchery located on the North Fork of the Washougal River near Washougal, Washington, was the first steelhead hatchery constructed as part of the Mitchell Act mitigation program for the Corps of Engineers mainstem dams. The facility is operated by the Washington Department of Fish and Wildlife and currently has the capacity to rear 650,000 smolts. Funding for the operation is provided by National Marine Fisheries Service. The Vancouver Hatchery, located near the I-205 Bridge in Vancouver, Washington, is operated as a satellite for the Skamania facility which allows the National Marine Fisheries Service to also fund that facility. Smolts are released in the Wind River. Broodstock for the program originated mainly from trapping adults in the Washougal River.

The existing broodstock collection does not provide for the use of naturally spawning stocks. To ensure the program is more responsive to the natural runs, new adult traps and final rearing and/or acclimation facilities should be constructed in natural production areas of the Wind River. These facilities could be used in conjunction with the spring chinook program.

(9) Release up to 500,000 juvenile coho from the Willard National Fish Hatchery. This program is to be coordinated with other proposals for Willard coho. Utilize final rearing and/or acclimation facilities for the release program in the natural production areas. Develop adult recapture facilities in the Wind River.

(10) The Carson hatchery water supply should be improved to expand hatchery capacity by 1,800,000 spring chinook yearling smolts.

(11) A program to restore lamprey should be developed by the relevant fishery managers. This program should be under the overall leadership of the tribes.

Table 3 shows the actions needed to restore the fish resources of the Wind River System.

Table 1
Wind River Fish Populations Status and Goals

Species	Current Population (5-year average)	Adult Return Goal
Spring Chinook	350[1]	5,000[2]
Steelhead	1,410[1]	2,000[2] S 200[2] W
Coho	NA	NE
Fall Chinook	1,800[3]	NE
Lamprey	NA	NE

[1] Based on 1985 - 1989 redd counts. Assumes 2.5 fish per redd. Rounded to the nearest tenth.
[2] Sport and tribal harvest
[3] Based on 1982 - 1986 redd counts. Assumes 6 fish per redd.

NA — Information not available
NE — None established

Table 2
Problems Impacting the Wind River Fish Resources

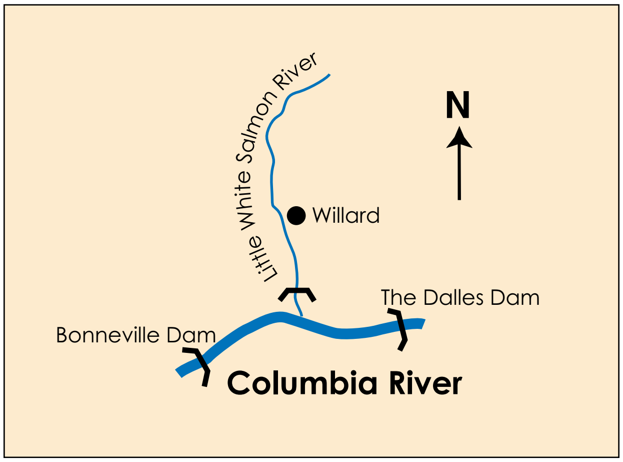
	Basinwide	Trout Creek	Martha Creek
Migration Barrier			•
Irrigation Diversions			•
Riparian Degradation		•	
Lack of Large Woody Debris	•		
Sedimentation	•		
Water Pollution			•
Inadequate Production Compensation		•	

Table 3
Recommended Actions for the Wind River System

Problem	Recommended Action
Migration Barriers	(1) Construct passage facilities
Irrigation Diversions	(2) Change to well system
Riparian Degradation	(3) Restore riparian vegetation
Limited Large Woody Debris	(4) Retain woody debris
Sedimentation	(5) Eliminate or restrict logging, streamside development
Water Pollution	(6) Treat runoff
Inadequate Production Compensation	
Spring chinook, Fall chinook, Steelhead, Coho	(7) Implement new broodstock programs, release programs, production programs
Lamprey	(8) Develop and implement programs

LITTLE WHITE SALMON RIVER

Prepared by the Yakama Indian Nation



Introduction

The Little White Salmon River originates in the Gifford Pinchot National Forest west of Monte Cristo Peak in southcentral Washington (WDW et.al., 1990). It drains approximately 134 square miles and flows south for 19 miles and enters the Columbia River near Cook, Washington.

Fish Populations Status/Goals

Prior to the construction of Bonneville Dam in 1938, a limited amount of natural production by anadromous fish occurred in the Little White Salmon River below a falls located approximately 2 miles above the mouth of the river. That section of the river was inundated by the construction of Bonneville Dam. Historically, fall chinook, spring chinook, coho and steelhead are believed to have utilized the area.

Currently only hatchery reared fish return to the river. Little White Salmon National Fish Hatchery was built in 1898 and is one of the oldest on the Columbia River system. It is operated by the U.S. Fish and Wildlife Service and is located approximately two miles above the mouth of the Little White Salmon River near Cook, Washington. The hatchery was modernized as part of the Mitchell Act Program in 1949.

Current spring chinook program goals provide for on-station releases of 500,000 yearling and 500,000 zero age juveniles. Spring chinook eggs for this program initially came from a variety of sources, including Carson National Fish Hatchery, Eagle Creek National Fish Hatchery, South Santiam Hatchery, and Klickitat Hatchery. The program is currently self-supporting, as broodstock are guided into the hatchery by a barrier dam. In recent years, the hatchery has become an exporter of eggs to other spring chinook stations. Current releases occur at the hatchery.

The fall chinook program at the Little White hatchery provides 1,700,000 pre-smolts for acclimation and release into the Yakima River and 1,800,000 for on-station release. Broodstock for the program are trapped at the hatchery rack. This program also is mostly self-sustaining.

Willard National Fish Hatchery is a Mitchell Act facility located upstream of the barrier falls on the Little White Salmon River at Willard, Washington. The hatchery currently produces 2,800,000 early run coho for direct release into the river. Returning adults are trapped at Little White Salmon hatchery and eggs are transported for incubation, rearing, and release at Willard hatchery.

Subbasin planners did not address natural production objectives for fish resources in the Little White Salmon River. However, salmon habitats in the upper watershed were characterized as good to excellent. Planners recommended sport and tribal harvest objectives of 2,000 spring chinook, and 200 bright fall chinook and coho. Table 1 shows the fish populations, status and goals.

Problems Impacting Fish Resources

Anadromous fish resources are impacted by the continual blockage at the falls and the barrier dam constructed to trap adults. The upper basin continues to be impacted by logging activities which have resulted in passage problems created by improper culvert placement, sedimentation from logging and road building, and harvest of riparian trees.

Production programs have been designed to return fish to the hatchery with no natural production of anadromous salmonids in the system. Table 2 shows the problems impacting the Little White Salmon River.

Ongoing Actions In The Little White Salmon River System

Habitat management is being coordinated through the efforts of the Timber/Fish/ Wildlife process.

There are no efforts at present to introduce natural production of anadromous fish to the watershed above the barrier falls. Salmonid habitats are considered to be extensive and of high quality for spring chinook, steelhead, and coho.

Hatchery production of spring chinook at the Little White Salmon National Fish Hatchery currently supports a moderate sport and tribal harvest opportunity in Drano Lake. Over the years, Little White Salmon hatchery has also provided broodstock to hatcheries throughout the Columbia River system. Adults returning to the hatchery which are in excess of broodstock needs are also provided to the Yakama Indian Nation for subsistence use, particularly by those tribal members who no longer have access to fishing sites.

Hatchery production for coho in the Little White Salmon River takes place at Willard National Fish Hatchery. Fish are released at the hatchery with broodstock trapped at the barrier dam at the Little White Salmon hatchery.

Hatchery production of bright fall chinook also occurs at the Little White Salmon hatchery. Adult trapping currently occurs at the hatchery. In addition, bright fall chinook can be provided from Priest Rapids Hatchery and Bonneville Hatchery if shortfalls occur. Releases occur at the hatchery and Yakima River acclimation facilities.

Recommended Actions For The Little White Salmon River System

(1) Passage into the upper watershed should be provided at the natural falls and hatchery barrier dam for adult spawners. Improperly placed culverts in the upper watershed should be replaced.

(2) Sedimentation due to logging occurs throughout the system. Eliminating or restricting logging activities, including road construction, is necessary.

(3) The loss of the riparian area is occurring due to logging. Logging should be eliminated or restricted in the riparian area to allow the vegetation to recover.

(4) The hatchery spring chinook program should be replaced by a supplementation program to restore natural production to the Little White Salmon River above the barrier falls. The zero-age spring chinook program has not been successful and should be terminated. The available hatchery space should be used to rear additional spring chinook smolts or another species such as fall chinook. Broodstock would be acquired by trapping at the barrier dam.

(5) Coho produced at Willard national hatchery should be used to restore natural coho production in mid-Columbia tributaries and Wind River.

(6) A program to restore lamprey should be developed by the relevant fishery managers. This program should be under the overall leadership of the tribes.

Table 3 shows the tribal recommended actions needed to restore the fish resources of the Little White Salmon River system.

Table 1

Little White Salmon River Fish Populations Status and Goals

Species	Current Population (5-year average)	Adult Return Goal
Spring Chinook	0	2,000[1]
Steelhead	0	NE
Coho	0	200[1]
Fall Chinook	0	200[1]
Lamprey	NA	NE

[1] Sport and tribal harvest

NA — Information not available
NE — None established

Table 2

Problems Impacting the Little White Salmon River Fish Resources

	Basinwide	Upper L. White	Lower L. White
Migration Barrier			•
Sedimentation	•		
Riparian Degradation	•		
Inadequate Production Compensation	•		

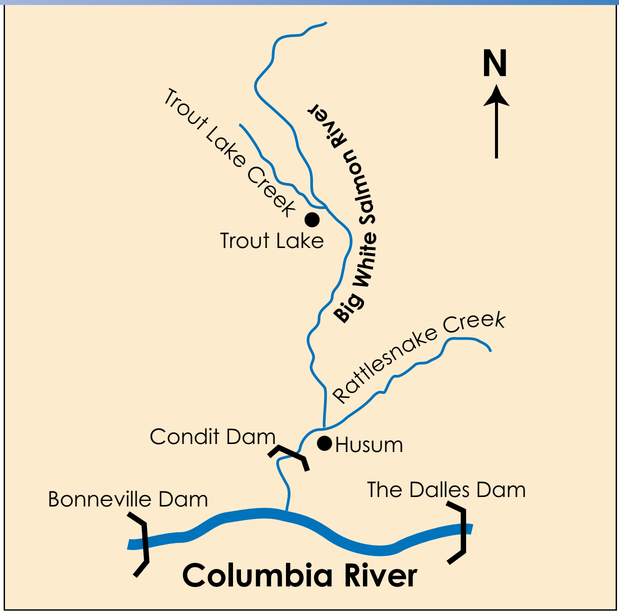
Table 3

Recommended Actions for the Little White Salmon River System

Problem	Recommended Action
Migration Barriers	(1) Construct passage facilities
Sedimentation	(2) Eliminate or restrict logging
Riparian Degradation	(3) Restore riparian vegetation
Inadequate Production Compensation	
Spring chinook, Fall chinook, Coho	(4) Implement new broodstock programs, release programs, production programs
Lamprey	(5) Develop and implement programs

BIG WHITE SALMON RIVER

Prepared by the Yakama Indian Nation



Introduction

The Big White Salmon River originates in the Gifford Pinchot National Forest in south central Washington along the southwest slope of Mount Adams. It drains approximately 386 square miles and flows south for 45 miles and enters the Columbia River at Underwood, Washington. Elevation ranges from the 12,307 foot Mount Adams down to 72 feet at the mouth. Principal tributaries include Trout Lake, Buck and Rattlesnake creeks (WDW, et.al., 1990).

Fish Populations Status/Goals

Natural production of anadromous salmonids in the Big White Salmon River is limited to the lower 3.3 miles downstream of Condit Dam. Condit Hydroelectric Project was constructed in 1913. Efforts to maintain fish ladders failed and the upper watershed was lost to anadromous fish by 1917. Based on oral records provided by longtime residents of the basin, tule fall chinook supported a vigorous tribal fishery at Husum Falls at river mile (RM) 8, and spring chinook, steelhead, coho, and perhaps chum salmon also were seasonally abundant in the upper watershed prior to dam construction.

Spring chinook currently are outplanted and released from U.S. Fish and Wildlife Service (USFWS) rearing ponds near Underwood. These fish are Carson stock taken for this purpose at Carson National Fish Hatchery on the Wind River. Stray adults are often observed in the river up to the splash pool below Condit Dam. Natural production is probably negligible due to lack of spawning habitat.

Prior to the construction of the dam, it is likely that fall chinook used the habitat up to a falls at approximately RM 16. Tule fall chinook natural production now is limited by the absence of suitable spawning and rearing habits below Condit, and by management of tule stocks for hatchery production. Straying from Spring Creek national hatchery probably contributes to some of the natural production.

Currently, there is a small, remnant spawning population of coho in the Big White Salmon River below Condit Dam. Past releases of hatchery fish into the Big White Salmon most likely are the source of any remaining natural production. Historically, coho most likely would have utilized the system above Condit Dam, including the tributaries of Buck Creek and Rattlesnake Creek. Detailed information on the historical distribution of coho in the system, other than the verbal reports cited above, is lacking.

Steelhead are believed to have been found in Trout Lake Creek and the upper Big White Salmon. Principal tributaries above the dam which also could have supported steelhead include Buck Creek, Little Buck Creek, Mill Creek, Spring Creek, Rattlesnake Creek, and Indian Creek. Natural spawning runs of summer and winter steelhead currently are limited to the lower 3.3 miles of river below Condit Dam. Restored passage or removal of Condit Dam would once again open the upper drainage to steelhead.

Harvest objectives established by subbasin planners for sport and tribal fisheries in the White Salmon River were 500 spring chinook, 100 fall chinook, 100 coho, 4,800 summer steelhead, and 800 winter steelhead. However, it is important to note that these objectives were not based on the potential for anadromous fish production in the upper watershed. In addition, note that most summer steelhead harvested in and at the mouth of the White Salmon River are not produced in the basin. Steelhead migrating to upriver tributaries of the Columbia River typically “dip in” to the cooler waters of the White Salmon. Natural spawning objectives were not addressed by the subbasin planners. Table 1 shows the fish populations, status and goals.

Problems Impacting Fish Resources

The major habitat impediment for restoration of the Big White Salmon River anadromous fish continues to be Condit Dam. Aside from being a barrier for anadromous fish passage to upriver habitats, the dam also is a barrier to the natural downstream movement of gravels that create and maintain spawning and rearing habitats in the lower river. Lack of spawning gravels is a major constraint to natural production of fall chinook and steelhead in the lower river. In addition, hydroelectric operations create instream flow fluctuations in the bypass reach of the river between the dam and the powerhouse 1.3 miles downstream that may strand and dewater juvenile salmonids.

In comparison to other subbasins in the upper Columbia, the White Salmon watershed has been characterized as being moderately developed. Subbasin planners identified logging and associated road building, unscreened irrigation diversions, land development, and riparian grazing as constraints to fish production in the upper watershed. These problems have resulted in increased sedimentation, reduced riparian vegetation, loss of large woody debris, reduced instream flow in the upper watershed, and increased summer temperature in the tributaries.

The 8.3-mile section of river above Condit Dam has been included in the federal Wild and Scenic River program. However, this section is mostly narrow canyon and does not suffer the extensive habitat disturbances cited above.

Ongoing Actions In The Big White Salmon River System

There has been virtually no mitigation for losses of fish production and fisheries in the Big White Salmon River. Existing programs call for releases of spring chinook at USFWS Big White Salmon Ponds and steelhead from net pens operated by a local recreational fishing group. These release programs are to provide only for fisheries. There are no programs to actively rebuild natural production of any stock in the basin. Table 2 shows the problems impacting the fish resources of the Big White Salmon River system.

Hatchery spring chinook juveniles are reared and released into the Big White Salmon River at Big White Salmon Ponds. This program is a discretionary use of broodstock from Carson National Fish Hatchery that are in excess of on-station and other identified program needs.

Hatchery steelhead smolts, including both summer and winter runs from Skamania or Vancouver hatcheries, are released on an annual basis in the Big White Salmon River to provide for sport fisheries. In addition, the Washington Department of Fish and Wildlife provides a local sport group with steelhead to be reared in net pens in Northwestern Lake. These fish are then released below Condit Dam. Broodstock for the programs has been acquired from Skamania and Beaver Creek hatchery stocks.

The Condit Hydroelectric Project is currently being reviewed for relicensing by the Federal Energy Regulatory Commission (FERC). A major part of the required consultation between PacifiCorp and the fish and wildlife managers in the relicensing process involves planning for the mitigation of lost fishery resources in the basin. To date, PacifiCorp has proposed no mitigation other than continuation of the status quo, with the exception of increasing the level of spring chinook releases from Big White

Salmon Ponds. The fishery agencies are agreed, however, that restoration of passage for anadromous salmonids into the upper watershed must be a condition of relicensing. The FERC is now preparing an Environmental Impact Statement for the project which should be available in fall of 1994.

Recommended Actions For The Big White Salmon River System

(1) Condit Dam continues to be the most serious habitat problem in the subbasin. Passage should be provided. The most biologically appropriate method is dam removal. Passage facilities should also be constructed at a natural falls located at RM 16.3.

(2) Instream flow levels should be designated, and irrigation diversions should be screened according to the criteria developed by the fishery managers.

(3) Protection of the riparian area is necessary to reduce the introduction of sediments into the river, maintain large woody debris, and restore riparian vegetation. Streams should be fenced to preclude grazing, and logging in the riparian area should be prohibited to allow recovery of large trees and riparian vegetation. Development should be severely restricted within riparian areas.

(4) The Big White Salmon Ponds are operated as a satellite facility of the Carson National Fish Hatchery and are funded by the Mitchell Act. They have the capacity to rear 1,450,000 spring chinook yearlings. Releases from the Big White Salmon Ponds should be terminated and the releases directed to natural production areas in the Big White Salmon River and other natural production areas as determined by the fishery managers. The broodstock for the Big White Salmon Ponds should be acquired from those tributaries that will be supplemented and the progeny separately reared.

Skamania and Vancouver Trout hatcheries have the capacity to rear 650,000 smolts. Funding for the operation is provided by National Marine Fisheries Service. Smolts from these facilities are released into the Big White Salmon River. The existing broodstock collection protocol does not provide for the use of naturally spawning stocks. To ensure the program is more compatible with the natural runs, new adult traps and final rearing and/or acclimation facilities should be constructed in natural production areas of the Big White Salmon River.

(5) A program to restore lamprey should be developed by the relevant fishery managers. This program should be under the overall leadership of the tribes.

Table 3 shows the tribal recommended actions needed to restore the fish resources of the Big White Salmon River system.

Table 1

Big White Salmon River Fish Populations Status and Goals

Species	Current Population (5-year average)	Adult Return Goal
Spring Chinook	NA	500[1]
Steelhead	NA	4,800[1] S 800[1] W
Coho	NA	100[1]
Fall Chinook	NA	100[1]
Lamprey	NA	NE

[1] Sport and tribal harvest

NA — Information not available
NE — None established

Table 2

Problems Impacting the Little White Salmon River Fish Resources

	Basinwide	Upper Big White	Lower Big White	Tributaries
Migration Barrier		•		•
Irrigation Diversions	•		•	
Riparian Degradation		•		
Lack of Large Woody Debris	•			
Sedimentation		•		
Inadequate Production Compensation		•		

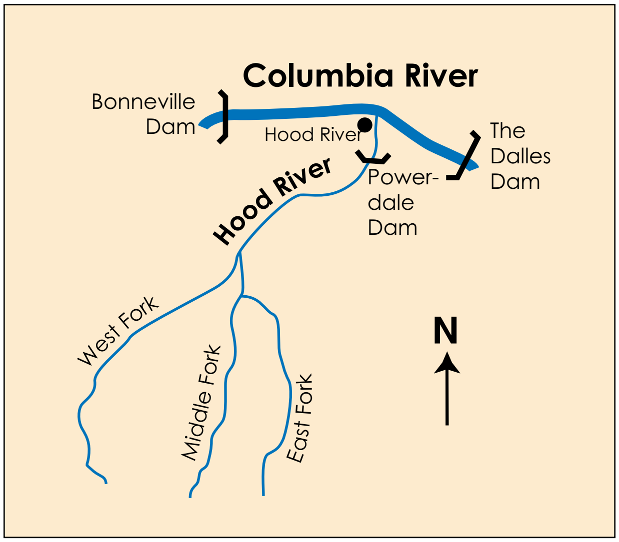
Table 3

Recommended Actions for the Big White Salmon River System

Problem	**Recommended Action**
Migration Barriers	(1) Construct passage facilities, remove Condit Dam
Irrigation Diversions	(2) Screen diversions
Riparian Degradation	(3) Restore riparian vegetation
Limited Large Woody Debris	(4) Retain woody debris
Sedimentation	(5) Eliminate or restrict logging, grazing
Inadequate Production Compensation	
Spring chinook, Fall chinook, Steelhead, Coho	(6) Implement new broodstock programs, release programs, production programs
Lamprey	(7) Develop and implement programs

HOOD RIVER

Prepared by the Confederated Tribes of the Warm Springs Reservation of Oregon



The Hood River, located in north central Oregon, flows in a northeasterly direction to enter the Columbia River at approximately river mile (RM) 169. The subbasin covers 352 square miles, approximately 225,352 acres.

The Hood River subbasin supports naturally producing populations of spring and fall chinook salmon, coho salmon, and summer and winter steelhead. Pacific lamprey were sighted in the river at the time Powerdale Dam was built in 1925. Salmonids must pass one mainstem dam on the Columbia River and one dam 4.0 miles up the Hood River mainstem. The entire Hood River subbasin is located within the ceded lands of the Confederated Tribes of the Warm Springs Indian Reservation of Oregon and thus the fisheries resources are co-managed by the Confederated Tribes of Warm Springs and the Oregon Department of Fish and Wildlife.

Today many of the anadromous species present in the Hood River subbasin are considered to be depressed. This could be due to a combination of watershed problems, water quality, over-harvest and unscreened or poorly screened irrigation diversions.

Land in the Hood River subbasin is owned by the U. S. Forest Service, Hood River county, Pacific Power and Light and other private landowners. Much of the subbasin has been used in the past for timber production and fruit orchard production.

Restoration of the anadromous fish populations in the Hood River subbasin will need to incorporate a combination of improved natural fish production and supplementation with cultured fish. Improved natural production could occur through improvements in the screening of irrigation diversions, habitat restoration and passage restoration. Supplementation with cultured fish will enhance production in areas that are not currently fully seeded.

Restoration Actions

1. Screen the East Fork Irrigation District diversion and improve other screens.

Benefits: Run Size Goals

Species Produced	Naturally Produced	Hatchery	Total
Spring Chinook	400	1,300	1,700
Summer Steelhead	1,200	6,800	8,000
Winter Steelhead	1,200	3,800	5,000

2. Implement the Hood River Production Project (supplementation).
3. Continue collection of data for the Hood River Production Project.
4. Enforce water quality standards.
5. Restore in-stream flows.
6. Acquire in-stream water rights for fish.
7. Continue habitat restoration projects in the subbasin.

Harvest guidelines will be determined by policy decision by the Confederated Tribes of Warm Springs and the Oregon Department of Fish and Wildlife.

Table 1

Recent Escapement to Powerdale Dam (River Mile 4.0)

Run Year	Species	Unmarked	Hatchery	Stray
1992	Spring Chinook	35		411
1993	Spring Chinook	530[1]		156
1992-93	Summer Steelhead	484	1,682	56
1991-92	Winter Steelhead	662	245	32
1992-93	Winter Steelhead	392	185	29
1992	Coho	23	0	80
1993	Coho	0	0	32

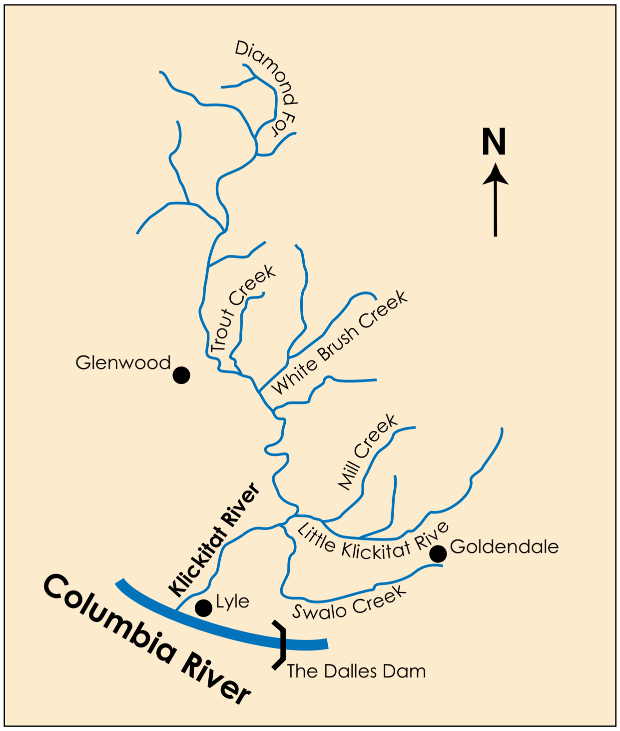
[1] Scale analysis is not complete.

KLICKITAT RIVER

Prepared by the Yakama Indian Nation

Introduction

The Klickitat River originates at 4,400 feet along the east slope of the Cascade Mountains in south central Washington. It bounded on the west by Mount Adams, the north by Goat Rocks and the Simcoe Mountains on the east (YIN, et.al., 1990). It drains an area of 1,350 square miles. It flows generally southward for 95.7 miles and enters the Columbia River near Lyle, Washington. Principal tributaries include the West Fork of the Klickitat, Big Muddy, Summit, and Outlet creeks, and the Little Klickitat River.



Fish Population Status and Goals

Spring chinook spawning has been documented in the mainstem as far upstream as river mile (RM) 84, although little spawning occurs above Castile Falls at RM 64. Tributary spawning by spring chinook is not known to occur, although juveniles have been found in the lower reaches of several tributaries.

Natural production of hatchery-origin fall chinook evidently occurs in the Klickitat River. Since the termination of tule releases from the Klickitat Hatchery in 1987 (see below), slightly over half of this run appears to have been upriver brights.

There is a small spawning population of coho in the Klickitat subbasin, probably derived from hatchery releases. Currently no attempt is being made to increase the natural spawning populations of coho in the Klickitat River. Few efforts have been made to determine the size of the natural run through redd counts or other means. Straying from hatcheries continues to be the primary source of any natural production.

The Klickitat River is one of the major steelhead rivers in this section of the Columbia River. A large spawning population is believed to have been present in the river historically. Escapements today probably average less than 1,000 adults.

Subbasin planners' recommended objectives are to increase the spring chinook run size to 20,000 fish, the fall chinook run by 40,000 fish, coho by 50,000 fish and summer steelhead to 25,000 fish (subsequent plans call for 12,000 steelhead). Table 1 summarizes fish population status and goals.

Problems Impacting Fish Resources

Adult passage improvements in the Klickitat River have not been very effective, particularly at Castile Falls. Spring chinook access to habitat in the upper Klickitat River is also impacted by a barrier dam at the Klickitat Hatchery. In addition, poor design and maintenance of forest road crossings inhibits passage of steelhead and resident salmonids in tributaries.

Castile Falls (RM 64) presents a serious obstacle to upstream migration of spring chinook, despite passage improvements. Irregular fishway maintenance prior to 1988 doubtless contributed to the problem.

In addition to a lack of maintenance, fishway design may be faulty. Adult migrants during summer and fall have no alternative to the tunnel, as a dam was constructed at the uppermost falls to divert water into the tunnel intake.

The deeply incised lower Klickitat River has remained relatively isolated and has few of the problems with diking, channelization, shoreline development or irrigation withdrawals that are common to rivers east of the Cascade crest. The mainstem is affected by intrusion of roads into its narrow floodplain, and its lower tributaries are heavily grazed. Among the lower tributaries, the Little Klickitat drainage is heavily logged and roaded in its upper reaches, and is grazed and diverted further downstream. Nutrients from farming and a sewage treatment outfall cause excessive algal growth in the Little Klickitat. Smaller tributaries share many of the same problems.

Much of the Klickitat subbasin is forested and most of that lies within the Yakama Indian Reservation. On the reservation, logging, construction and use of logging roads, and cattle grazing are the principal activities affecting the Klickitat River and its tributaries. Streams in the forested portion of the subbasin, both on and off the Yakama Indian Reservation, have suffered from past forest practices, including timber harvest and road construction in riparian areas, poor design and maintenance of roads and crossings, skidding on steep slopes and upstream channels, off-season use of wet roads with resulting erosion, and facilitation of overgrazing by providing cattle access over logging roads to riparian areas. In spite of more regulation, most of these problems are continuing to some degree.

The Klickitat River, Diamond Fork and Piscoe Creek contain nearly 30 miles of accessible fish habitat, most of it in the Klickitat River. The Upper Klickitat River flows through McCormick Meadow in the tribally designated Primitive Area, which has been heavily grazed for many years. Aerial photographs reveal that the river channel in this meadow and others nearby has been seriously damaged during 50 years or more of cattle use. In spite of its remoteness, this section of river is now poor habitat for resident or anadromous fish. It can be restored, but not as long as cattle are present. Cattle can be kept out of this steep-sided valley without interfering with tribal hunting, fishing and other cultural uses. In fact, these uses will be enhanced, with benefits to many tribal members, if the valley is protected.

Big Muddy and Little Muddy creeks drain glaciers on the east slope of Mount Adams. During the warmest months, the sediment plume from these tributaries colors the Klickitat River from the West Fork to the Columbia River 63 miles downstream. Glacial melt and landslides in the Big Muddy Creek watershed add significant amounts of fine particles to Klickitat River gravels during the summer when velocities in the river are too low to flush fine particles and when spring chinook are ascending the river to spawn. Table 2 summarizes problems impacting fish resources.

Ongoing Actions In The Klickitat River System

Some passage improvements have been made at natural barriers at Lyle Falls and Castile Falls. Reconstruction is needed at both locations to facilitate fish passage and broodstock collection. Livestock grazing has been eliminated in part of the west half of the subbasin, within the closed area of the Yakama Indian Reservation.

The Klickitat Hatchery was the first facility authorized for construction in 1948 as part of the Mitchell Act Program. Construction funds were provided by the Corps of Engineers as part of their mainstem dam construction. It is operated by the Washington Department of Fish and Wildlife and is located on the Klickitat River near Glenwood, Washington. It currently rears 600,000 spring chinook smolts for release at the hatchery.

The Klickitat Hatchery continues to rear spring chinook, bright fall chinook and early coho, releasing them as smolts at the hatchery. Returns to the facility are the main source of spring chinook eggs, while transfers from other facilities are usually necessary to meet fall chinook and coho egg take requirements.

The original spring chinook program at the Klickitat Hatchery began with eggs from Carson hatchery and adults trapped in the Klickitat River. Adults are diverted into the hatchery by a barrier dam. Some adults are able to pass the barrier dam and spawn in natural production areas above the hatchery site. While field observations indicate crossbreeding between natural-origin and hatchery-origin spring chinook, genetic analysis indicates a degree of separation between the two groups.
Harvest of spring chinook in the Klickitat River is currently managed to provide adequate escapement to Klickitat Hatchery. The fisheries are intended to be conservative because of difficulties in forecasting the run. General non-treaty angling regulations are published annually by the Washington Department of Fish and Wildlife and are subject to in-season emergency action, if necessary.

The dip net fishery in the Lyle Falls reach of the Klickitat River has been an important fishery to Indian people since before the arrival of the first white settlers. This fishery continues to play an important role in meeting the subsistence needs of Yakama Indians, in providing income from fish sales during commercial seasons, and in fulfilling the treaty share of tributary spring chinook harvest in the Columbia Basin. The Klickitat provides one of the few opportunities for spring chinook harvest by tribal members while other Columbia Basin spring chinook stocks remain at low levels of abundance. Enhancement objectives must take into account the need for a significant harvest of spring chinook concurrently with efforts to rebuild the run.

The Klickitat fall chinook program was originally developed to rear tule fall chinook from the Spring Creek hatchery. When the Spring Creek program failed to provide the necessary eggs, the program was changed to bright fall chinook. This program also was intended to provide a better quality fish for the tribal terminal fishery in the lower Klickitat River. The Klickitat program has the capacity to rear 4,000,000 fall chinook smolts for release at the hatchery. Broodstock for the program comes from a variety of sources including Priest Rapids Hatchery, Lyons Ferry Hatchery and Bonneville Hatchery.

The Klickitat Hatchery rears 1,350,000 early-run coho for release from acclimation ponds at the facility. Skamania Salmon Hatchery, located on the Washougal River, also releases late coho into the Klickitat River. The late-run coho releases provide for a late fall terminal fishery, as part of the *U.S. v. Oregon* Columbia River Fish Management Plan.

The current Skamania program calls for rearing 2,500,000 late- run coho for release at RM 26 of the Klickitat River. Broodstock are trapped at the Skamania Hatchery or are provided from other Washington Department of Fish and Wildlife hatcheries. Acclimation facilities for these releases are being developed.

Summer-run steelhead from the Skamania Trout Hatchery and Vancouver Hatchery are currently released directly into the Klickitat River. Broodstock is made up of Skamania Hatchery returns, although founding broodstock for the Skamania stock included adults trapped in the Klickitat River. Like the Wind River, the Klickitat River has had releases from the Skamania Trout and Vancouver hatcheries for over 30 years, averaging about 100,000 smolts per year. Releases were also made from the Beaver Creek Hatchery, Goldendale Hatchery, and Naches Hatchery. Unlike the Wind River where steelhead releases were terminated because of infectious hematopoietic necrosis virus (IHN), releases in the Klickitat were only decreased. Steelhead releases in the Klickitat are mainly to provide for sport fisheries in the river.

The *U.S. v. Oregon* management plan stipulates that steelhead harvest shares be based on the aggregate of mainstem and tributary catches by tribal and recreational fisheries and, further, that neither the treaty share nor the non-treaty share shall exceed 50 percent of the aggregate harvestable steelhead. Within this framework, each season's regulations for the Klickitat River are developed through consultation between the Washington Department of Fish and Wildlife and the Yakama Indian Nation.

Along with Klickitat spring chinook, the Klickitat summer steelhead harvest is important to the subsistence fishing needs of Yakama tribal members. Enhancement objectives must take into account the need for continued treaty harvest while runs are being rebuilt.

Hatchery releases in the Klickitat River have failed to restore natural runs of spring chinook and steelhead. The Yakama Indian Nation initiated planning in 1982 to restore natural runs through supplementation. However, the Klickitat portion of the Yakima/Klickitat Fisheries Project has not proceeded beyond the planning stage.

Recommended Actions for the Klickitat River Subbasin

(1) Implement the Klickitat portion of the Yakima/Klickitat Fisheries Project, retaining the following elements:
(a) use of natural broodstock, (b) final rearing and/or acclimation facilities in natural production areas, (c) supplementation of natural escapement to a level consistent with subbasin carrying capacity, and (d) development and use of excess hatchery production to augment harvest.

(2) Acclimate coho smolts released in the Klickitat River under the U.S. v. Oregon agreement to improve their homing characteristics and survival to terminal fisheries.

(3) Correct problems with fish passage in the Klickitat mainstem. At Castile Falls, this will include increasing attraction flow, adding a sluice gate, and modifying some of the falls. The Lyle Falls fishway must be modified to allow effective broodstock collection under the planned Yakima/Klickitat Fisheries Project.

(4) Improve forest roads and stream crossings. On the Yakama Indian Reservation, a maintenance and rehabilitation program should be funded by commercial users of forest roads.

(5) Improve monitoring of forest practices and their effects on fish habitat. The Bureau of Indian Affairs, in keeping with their trust responsibilities on the Yakama Reservation, must fully implement the environmental protection policies in their 1993 forest management plan.

(6) Change grazing management to allow the restoration of wet meadows and riparian areas. Specifically, close the upper Klickitat River to cattle grazing with a cross fence above the Diamond Fork. Exclude cattle from the trampled meadows at the upper and lower ends of Piscoe Creek. The Bureau of Indian Affairs and the Washington Department of Natural Resources must fund enforcement of range regulations to prevent concentration of cattle in sensitive areas.

(7) Strengthen regulations and their enforcement to deal with point-source and nonpoint-source pollution of lower Klickitat River tributaries.

(8) If shown to be feasible, construct a hydroelectric facility at Big Muddy Creek in conjunction with a sediment removal system to make generation possible and also benefit natural production of chinook.

Table 3 summarizes recommended actions needed to restore fish resources of the Klickitat River system.

Table 1

Klickitat River Fish Populations Status and Goals

Species	Current Population (5-year average)	Adult Return Goal
Spring Chinook	3,736	20,000
Steelhead	NA	25,000
Coho	7,054	50,000[1]
Fall Chinook	3,575	40,000[1]
Lamprey	NA	NE

[1] Goal includes ocean and inriver harvest
NA — Information not available
NE — None established

Table 2

Problems Impacting the Klickitat River Fish Resources

	Basinwide	Upper Klickitat	Lower Klickitat	Tributaries
Depressed Runs			•	
Migration Barriers				•
Forest Practices			•	•
Overgrazing			•	•
Poor Tributary Water Quality			•	
Glacial Sediment			•	

Table 3

Recommended Actions for the Klickitat River System

Problem	**Recommended Action**
Depressed Runs	(1) Implement Klickitat Production Project, acclimate *U.S. v. Oregon* coho
Migration Barriers	(2) Improve Castile Falls and Lyle Falls fishways
Forest Practices	(3) Improve forest roads and stream crossings, monitor forest practices and their effects
Overgrazing	(4) Change grazing management, exclude cattle from sensitive areas
Poor Tributary Water Quality	(5) Strengthen pollution regulations and their enforcement
Glacial Sediment	(6) Investigate tributary hydroelectric plant with sediment removal system

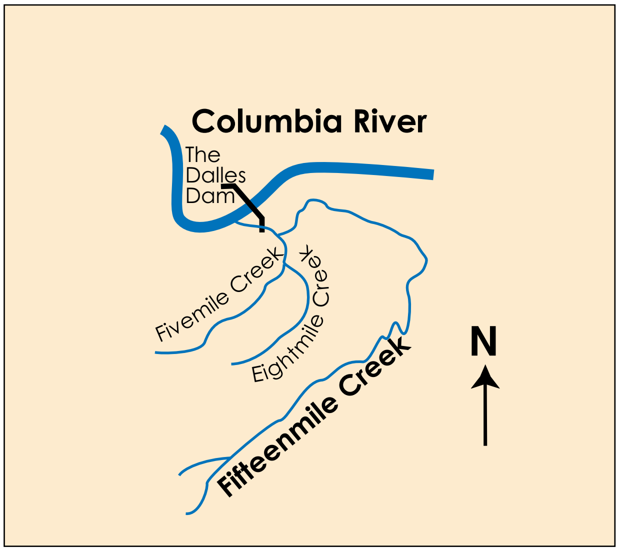
FIFTEENMILE CREEK

Prepared by the Confederated Tribes of the Warms Springs Reservation of Oregon

The Fifteenmile Creek drainage, located in north central Oregon, heads in the Mount Hood National Forest just east of Mount Hood. Fifteenmile Creek flows in a northeasterly direction out of the timbered higher elevations before circling north through the dryland wheat country southeast of The Dalles to enter the Columbia River at approximately river mile (RM) 192. The Fifteenmile Creek drainage is bounded on the west by the Mosier, Mill, Threemile, and Hood River drainages; on the south by the White River drainage; and on the east by the Deschutes River drainage.

The Fifteenmile Creek drainage encompasses approximately 373 square miles. The mainstem of Fifteenmile Creek rises approximately 6,140 feet in the 49 miles from the mouth to its headwaters on Lookout Mountain. Fifteenmile Creek from the mouth to RM 43.6 is a relatively low gradient stream averaging approximately a 0.6 percent grade. From RM 43.6 to its headwaters, located approximately 5.4 miles upstream, the stream gradient increases markedly. The only other tributary streams with any significant year-round flow generally follow a similar pattern. Average stream gradient in the lower 25.5 miles of Eightmile Creek and all of Ramsey and Fivemile creeks is less than or equal to a 2 percent grade. Stream gradient in the upper 3.9 miles of Eightmile Creek and in the North, Middle, and South forks of Fivemile Creek is generally classified as moderate to high, averaging approximately 6.7 percent, 2.2 percent, 2.9 percent,and 3.4 percent, respectively.

The Fifteenmile Creek drainage supports the eastern most population of wild winter steelhead in the Columbia River system. Hatchery winter steelhead have never been released into the drainage. Biologists believe that the existing population is a unique stock of wild fish.



No quantitative and very little qualitative life history information exists on the Fifteenmile Creek stock of wild winter steelhead. It is assumed that the wild run has a life history cycle similar to that of winter steelhead in lower Columbia River subbasins. Winter steelhead return to the Fifteenmile Creek drainage from February through March, primarily as l-salt and 2-salt fish; spawn from March through April; emerge from early June through mid-July; and migrate as smolts during April and May, primarily as age-2+ and age-3+ juveniles. No data is available on age structure, sex ratio, length-weight ratio, fecundity, and egg-to-smolt and smolt-to-adult survival rates.

We assume that the run is presently in fairly good shape, but still at a low level. Based on what limited information is available on the spatial distribution of the population, managers believe that approximately 91 linear miles of suitable spawning habitat and 44 linear miles of suitable rearing habitat are currently available for use by winter steelhead in Fifteenmile Creek; Eightmile and Ramsey creeks, tributaries to Fifteenmile Creek; and Fifteenmile and Fivemile Creek, tributary to Eightmile Creek. The winter steelhead fishery currently harvests only a very limited number of fish. We do not have run size estimates; but the figure is probably 200 to 300 adults.

Production is limited by various land practices in the drainage:

- •Intensive agricultural use and associated soil erosion, low summer flows and elevated water temperatures.

- •Elimination and degradation of riparian zones due to dry land farming and open rangeland.

- •Logging practices that have curtailed the systems ability to store water and regulate runoff.

- •Artificial channelization from two major flood events.

Actions

1. Monitor run size (harvest and escapement).

2. Monitor smolt production.

3. Determine spatial distribution.

4. Gather life history information.

5. Estimate juvenile rearing densities.

6. Protect and enhance aquatic and riparian habitat.

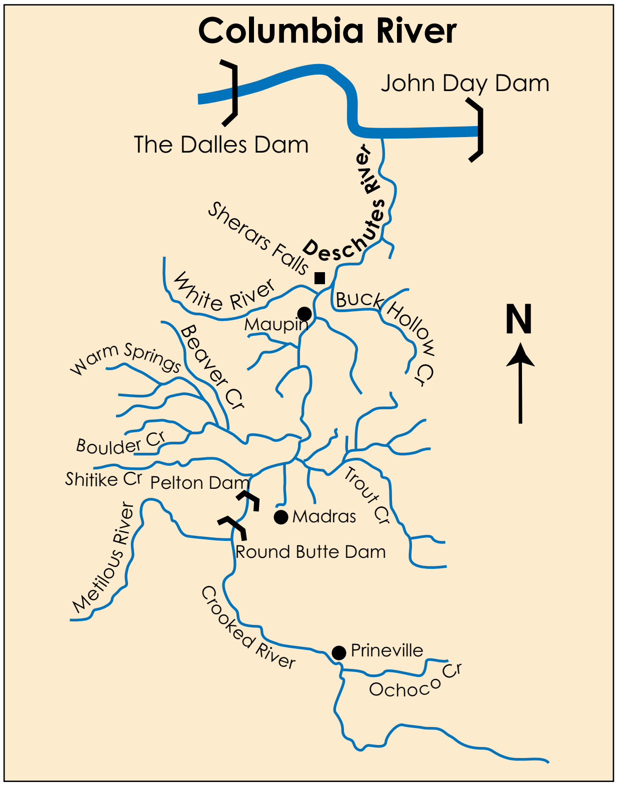
7. Maintain and improve passage.

8. Encourage exceedance of the State Forest Practices Act guidelines.

9. Increase streambank cover, decrease water temperatures during the summer and increase streamflow.

DESCHUTES RIVER

Prepared by the Confederated Tribes of the Warm Springs Reservation of Oregon



The Deschutes River subbasin covers approximately 10,500 square miles in north-central Oregon, and enters the Columbia River 205 miles from the ocean. The Deschutes River supports wild runs of spring and fall chinook salmon, sockeye salmon, summer steelhead, and Pacific lamprey. These species must pass two mainstem dams to enter the basin.

Land ownership in the lower Deschutes River subbasin is primarily private (62%), followed by tribal (21%). Agriculture is a major land use in the basin, and grazing is widespread.

Fish production potential in the subbasin is limited by physical and environmental factors and impacts of land and water uses. Constraints to fish production include low flow and high temperatures in tributaries during summer and fall, sediment in tributaries and the Deschutes River, and loss of fish at unscreened irrigation diversions.

Spring chinook salmon and steelhead spawned historically in the mainstem Deschutes River up to Steelhead Falls at river mile (RM) 128, in Squaw Creek, and in the Metolius River. Steelhead also spawned in the Crooked River. Summer and fall flows may have limited the distribution of fall chinook salmon to the 44 miles of river below Sherars Falls before a fish ladder was built at the falls in the 1940s. Sockeye salmon historically originated in Suttle Lake. Construction of a small power dam and installation of screens at the outlet of Suttle Lake in the 1930s reduced passage of sockeye salmon to and from the lake, but did not eliminate the run in the Deschutes River.

Construction of Pelton and Round Butte Dams at RM 100, completed in 1958 and 1964, respectively, included upstream passage facilities for adult spring chinook salmon and steelhead and downstream facilities for migrating juveniles. Downstream passage facilities at the dams proved insufficient to sustain natural runs above the dams.

Currently, natural production of spring chinook is limited to the Warm Springs River and Shitike Creek, both located on the Warm Springs Indian Reservation. Fall chinook salmon spawn throughout the Deschutes River from the river mouth to Pelton Reregulating Dam. Summer steelhead occur throughout the mainstem Deschutes River below Pelton Reregulating Dam and in most tributaries below the dam. Lake Billy Chinook now has a large population of kokanee. Currently, a small run of sockeye is maintained by incidental passage of smolts through the dam turbines.

The number of salmon and steelhead returning to the Deschutes River has been estimated annually since 1977 by creel surveys of the recreational and tribal fisheries at Sherars Falls and counts at Pelton trap and Warm Springs National Fish Hatchery (WSNFH).

Round Butte Hatchery (RBH) was constructed by Portland General Electric to mitigate for the lost production of salmon and steelhead above the Pelton-Round Butte hydroelectric project. Operation of RBH began in 1972. Smolts reared in Pelton Ladder have helped achieve increased adult returns to the Deschutes River (ODFW, CTWSR, 1991). The U.S. Fish and Wildlife Service operates WSNFH, located on the Warm Springs River nine miles upstream from its confluence with the Deschutes River. Production began in 1978. Since 1980, the return of spring chinook salmon hatchery fish to the Deschutes River has averaged 3,100, with a high return of 6,900 in 1989 and a low return since 1985 of 2,524 in 1993.

The Warm Springs River above Warm Springs National Fish Hatchery and Shitike Creek are currently managed for natural fish only. All fish released from RBH and WSNFH are externally marked to allow escapement of only natural fish above WSNFH. Returns of wild spring chinook salmon have ranged from a high of 3,895 in 1977 to a low of 968 in 1993, and have averaged 1,891. Based on a stock-recruitment model developed by Lindsay et al. (1989), the recommended escapement goal for wild spring chinook salmon above WSNFH is 1,300 adults.

The run size of natural summer steelhead averaged 7,780 through 1987. From 1988 to 1992, the run size of natural summer steelhead averaged 3,698 fish ranging from a low of 910 in 1992 to a high of 4,829. Three of the last five run years have been the lowest recorded since run size estimation began in 1977.

Returns of fall chinook salmon in the lower Deschutes River subbasin are entirely from the wild stock, and from 1977 through 1988 averaged 9,420 fish annually. From 1989 to 1992, the run size averaged 5,730 fish. In 1993, the largest run size of adult fall chinook salmon since 1977, 8,250 fish, returned to the Deschutes River. The return of jacks could not be estimated, but was believed to be very low. Only 13% of the total escapement in 1993 passed above Sherars Falls. From 1980 to 1992, escapement above Sherars Falls averaged 76% of the total escapement. The reason for the change in spawning escapement distribution is unknown.

Through 1988, the number of sockeye salmon returning to the Deschutes River has averaged 127 sockeye, ranging from 29 to 338 fish. Since 1988, the run has averaged only 44 fish. Only seven fish returned to Pelton trap in 1992 and one in 1993.

Very little information is available regarding Pacific lamprey in the Deschutes River subbasin.

Salmon and steelhead provide important fisheries for tribal and recreational fishers. There were no recreational or tribal fisheries for spring chinook salmon in 1981 and 1984. Because of the anticipated record low return of wild spring chinook in 1994, there will be no recreational fishery and the tribal fishery is likely to be severely restricted. Since 1991, recreational and tribal fisheries for fall chinook salmon at Sherars Falls have been severely restricted or closed, because of the low level of escapement above the falls. Retention of wild steelhead is forbidden in recreational fisheries. Tribal ceremonial and subsistence fisheries for sockeye salmon occurred historically in the Deschutes River. Currently, no target fishery for sockeye occurs, although incidental harvest occurs in fisheries at Sherars Falls.

Species	Average Run Size	Annual Harvest
Spring chinook:	8,500-12,000	5,500-8,000
Fall chinook:	10,000-12,000	4,000-5,000
Sockeye:	5,000	1,500
Steelhead:	16,000-22,000	5,000-11,000

Harvest is for both recreational and tribal fisheries combined, and includes adults and jacks.

The following goals were developed by subbasin planners for anadromous stocks in the Deschutes River:

Objectives for the subbasin are:

1. Maximize the protection and enhancement of aquatic and riparian habitat on all land bordering the Deschutes River and its tributaries to result in a net increase in habitat quantity and quality over time.
2. Maintain or improve watershed conditions for the sustained, long-term production of fisheries and high quality water.
3. Maintain or improve flow for fish production in the tributaries of the Deschutes River.

Strategies

1. Support enforcement of existing laws and regulations concerning habitat protection by agencies with enforcement authority.
2. Support implementation of existing land and resource management plans.
3. The Oregon Department of Fish & Wildlife should apply for instream water rights for fish protection.

Actions

Detailed recommended restoration strategies are found in the Deschutes River Subbasin Plan (1990). Below are four important strategies from that plan.

Spring Chinook - Strategy 5 - A combination of natural production enhancement in Shitike Creek and the Warm Springs River, expansion of natural production into the White River drainage above White River Falls, and production increases at Round Butte and Warm Springs hatcheries.

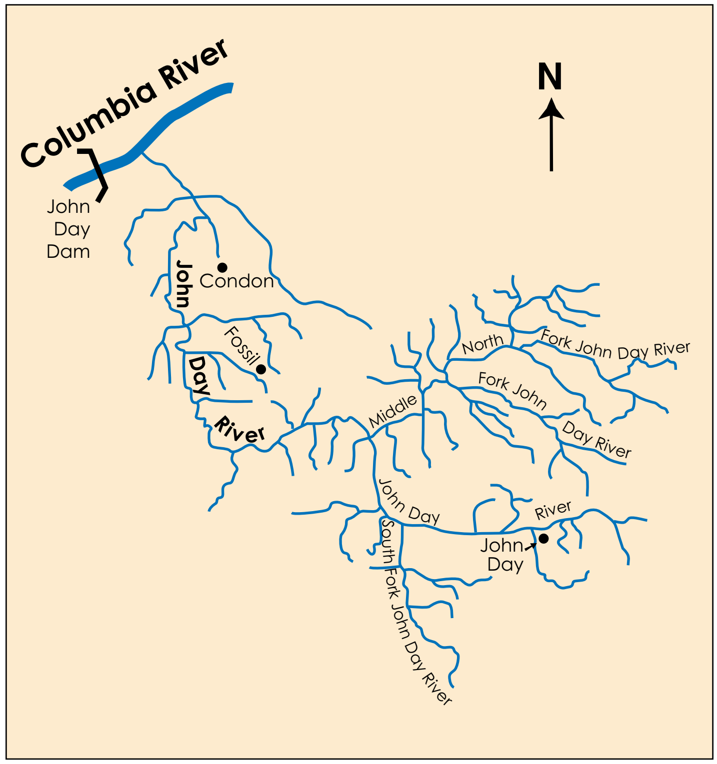
Fall Chinook—Strategy 2—This strategy enhances the riparian areas along the Deschutes River to 60% of the vegetative potential, and enhances the spawning gravel in the upper three miles of the mainstem. Fall chinook salmon will to be managed exclusively for wild fish.

Summer Steelhead - Strategy 3 - Enhance natural production in Trout, Shitike, Bakeoven, and Buck Hollow creeks, the Warm Springs River, and expand natural production into the White River drainage above White River Falls. Current natural production levels would be maintained in all other areas of the subbasin. Current hatchery production levels at Round Butte Hatchery would be maintained.

Sockeye - Recommended that a study be conducted to determine the feasibility of providing passage for sockeye salmon adults and juveniles past the Pelton-Round Butte hydroelectric project.

JOHN DAY RIVER

Prepared by the Confederated Tribes of the Umatilla Indian Reservation and the Confederated Tribes of the Warms Springs Reservation of Oregon



The John Day River drains nearly 8,100 square miles in east-central Oregon, the longest free-flowing river with wild anadromous salmon and steelhead in the Columbia River Basin. The basin covers 11 counties and is bounded by the Columbia River to the north, the Blue Mountains to the east, the Aldrich Mountains and Strawberry Range to the south, and the Ochoco Mountains to the west.

The mainstem John Day River flows 284 miles from its source at an elevation near 9,000 feet in the Strawberry Mountains to its mouth at river mile (RM) 218 on the Columbia River. The lower John Day River from Service Creek (RM 157) downstream to Tumwater Falls (RM 10) is included in the Federal and Oregon Scenic Waterways Systems. Major tributaries in the John Day Basin include the North Fork, Middle Fork and the South Fork. The North Fork, which enters the mainstem John Day River at Kimberly (RM 185) and extends upstream 117 miles to its headwaters in the Blue Mountains at elevations near 8,000 feet, is the largest tributary in the John Day Basin. Fifty-four miles of the North Fork, from Camas Creek upstream, were added to the Federal and State Wild and Scenic Rivers. The Middle Fork John Day River originates immediately south of the North fork and flows roughly parallel to it for 75 miles to its confluence with the North Fork at RM 32, about 31 miles above Kimberly. In 1988, the Middle Fork was added to Oregon's Scenic Waterway system. The South Fork John Day River, tributary to the mainstem near Dayville (RM 212), extends 60 miles to its headwaters in the area south of the Aldrich Mountains. Other major mainstem tributaries include Rock Creek (RM 22) and Canyon Creek (RM 248).

Historically, the John Day River was one of the most significant anadromous fish producing rivers in the Columbia River Basin. The basin continues to support one of the largest remaining runs of wild spring chinook salmon *(Oncorhynchus tshawytscha)* and summer steelhead trout *(Oncorhynchus mykiss)* with populations estimated to range from 3,000 to 4,000 spring chinook salmon and 25,000 to 30,000 summer steelhead. The basin also supports populations of fall chinook, Pacific lamprey (Lampetra tridentata) and other indigenous species. The management policy for the John Day Basin is designed to maintain native, wild stocks of salmon and steelhead, and to preserve the genetic diversity of the native salmon and steelhead stocks for maximum habitat use and fish production (Oregon Department of Fish and Wildlife et al. 1990).

Riparian habitat degradation is the most serious habitat problem in the John Day River Basin with approximately 660 degraded stream miles identified. Degraded fish habitat in the John Day River Basin is a result of low summer flows, high summer and low winter water temperature, high spring flows, depressed beaver populations, accelerated streambank erosion, excessive stream sedimentation and reduced instream cover. The basin's ability to naturally repair itself from riparian habitat degradation and other impacts is slow in the John Day's semiarid environment and some areas are adversely affected by activities which ceased long ago. In other cases, poor management practices continue and problems are escalating. As soil erosion increases, flooding occurs and streambanks erode away, degrading habitat quality. In many tributary streams, excessive water volumes are deepening channels, thus lowering water tables in the immediate proximity (Oregon Water Resources Department 1986). Such loss of habitat quantity and quality, managers believe improved irrigation systems along with restoration of the uplands and riparian systems would provide the greatest long-term natural benefits for fish and improve late season stream flow as well.

Recommended Habitat Enhancement Actions for John Day Subbasin

I. Administrative

A. Laws and Codes, Enforcement & Revision

- State of OR/EPA complete TMDL for stream temps, sediment, other pollutants (Clear Water Act)
- Enforce OR fish screening statutes
- Enforce OR Forest Practices Act to be consistent with Upper Grande Ronde Anadromous Fish Habitat (UGR) Plan
- Upgrade Forest Service Land and Resource Management Plans consistent with UGR Plan to be in compliance with National Forest Management
- Revise mining laws to be consistent with production of high quality water and fish habitat

II. Instream Flow & Passage

A. Instream Flows Enhancement

- Purchase, exchange, lease, or seasonally rent water rights for selected fish habitat during critical low flow periods.
- Implement more efficient irrigation methods and water conservation practices benefitting landowners and instream flows.

B. Passage Needs

III. Watershed Management

A. Watershed Management

- Increase shade cover to reduce stream temperatures (increased downstream extent of temperatures <60°F)
- Reduce sediment from agricultural practices and unimproved roads
- Reduce nitrate, phosphates, bacteria and other contaminants related to agricultural practices

PRIORITIES: Upper South Fork. John Day and tributaries, Middle Fork John Day, upper mainstem John Day, Camas Creek

B. Riparian Restoration Needs

- Implement UGR Plan on State, Federal and Tribal lands
- Implement Best Management Practices, including stream buffers to benefit fish on private lands
- Acquire, lease or implement management agreement to restore natural floodplain habitat and function

PRIORITIES: Upper South Fork John Day and tributaries, Middle Fork John Day, upper mainstem John Day, Camas Creek

C. Range Management

- Revise and implement BMPS to be consistent with UGR Plan Standards and Guidelines (S&G's)
- Restrict/remove livestock in substandard areas
- Acquire, lease, develop projects in priority areas (see above)

D. Forest Management

- Upgrade, monitor, enforce Forest Practices Act consistent with UGR Plan S&G's on private lands
- Implement UGR Plan S&G's on State, Federal, Tribal lands
- Identify and implement active restoration projects

- Institute or continue protection of “good” habitat areas such as North Fork, upper mainstem John Day River tributaries, Vinegar Hill area

E. Mining Impact Reduction Needs

- Mitigate for impacts of mining tailings in North Fork John Day River System

Artificial Production Actions for John Day Subbasin

1. Evaluate historical status of coho and fall chinook salmon production in the subbasin. Determine current production potential in the subbasin for possible establishment of species including the need for adult capture and juvenile acclimation facilities.

2. Discontinue all catchable trout programs in areas where they may affect anadromous salmonid restoration activities.

3. A program to restore lamprey populations utilizing either transplantation or artificial propagation should be developed under the overall leadership of the affected tribes.

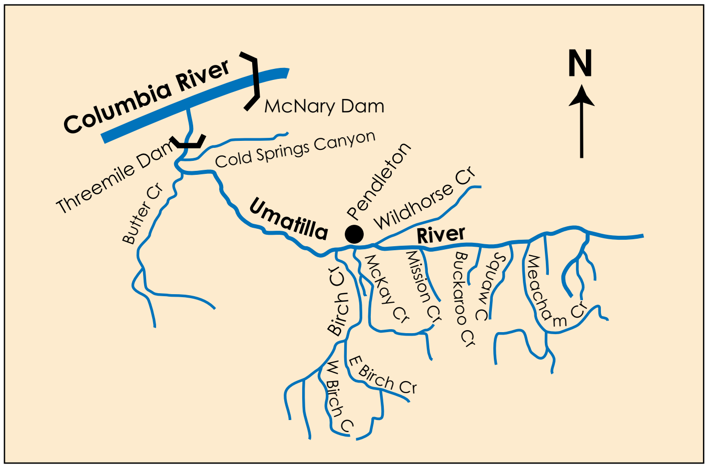
4. Monitor and evaluate all artificial production actions. Use adaptive management to determine whether program changes (i.e. release number, size, time, location, and/or life history) are needed in order to meet restoration objectives.

Benefits

Spring chinook average run size of 7,000 with an estimated harvest of 1,050. Summer steelhead average run size of 45,000 with an estimated harvest of 11,250. Fall Chinook activities to determine stock status. Pacific lamprey activities will also determine the current life history.

UMATILLA RIVER

Prepared by the Confederated Tribes of the Umatilla Indian Reservation



Introduction

The Umatilla River originates on the west slope of the Blue Mountains in the Umatilla National Forest. It flows northwesterly for about 115 miles and enters the Columbia River at river mile (RM) 289 near Irrigon, Oregon. The river drains approximately 2290 square miles with elevations ranging from 3000 feet along the Blue Mountains to 270 feet at the mouth. Its principal tributaries include the North Fork, South Fork, Meacham Creek, Birch Creek, McKay Creek and Butter Creek (CTUIR, et.al., 1990).

Fish Population Status/Goals

From the first decades of this century until 1988, spring chinook did not spawn in the Umatilla River. Then, a program designed to restore the spring chinook to their natural production areas, the Umatilla tribe and Oregon Department of Fish and Wildlife began a program of releasing spring chinook in 1986. Like the restoration of other anadromous runs in the Umatilla River, the restoration of bright fall chinook began with the efforts of the Umatilla tribe to restore salmon to the river. In cooperation with the Oregon Department of Fish and Wildlife, a restoration program began in 1982. Coho restoration is now occurring in the Umatilla River natural habitat. This is the only attempt being made to increase the natural spawning populations of coho in the Columbia River tributaries. Natural production of steelhead occurs throughout the basin and is the only anadromous population that was not extirpated earlier in the century.

The subbasin planners have recommended the return of 11,000 spring chinook to the river with a natural escapement of 1,000 fish and a harvest of 8,800. The recommended return for bright fall chinook is for 21,000 fish with a natural escapement of 11,000 and an inriver harvest of 5,400. The goal for coho is for a return of 6,000 adults to the river. The goal for summer steelhead is an annual adult return of 9,670 and a harvest inbasin of 5,460 fish. Table 1 shows the fish populations, status and goals.

Problems Impacting Fish Resources

Habitat problems in the Umatilla River system are related mainly to irrigation diversions, agricultural practices and timber harvest (Ibid). Many of the passage problems have been corrected under the Northwest Power Planning Council's Fish and Wildlife Program while others are proposed for correction.

Ongoing Actions In The Umatilla River System

Some measures have been implemented in the basin to correct habitat problems and in particular extensive work has been done on the mainstem irrigation diversion dams. Both upstream and downstream facilities have been constructed. Instream flows will be improved with the implementation of the Umatilla Basin Project. This measure will provide for the storage of water in the basin and the exchange of water from the Columbia River.

Hatchery production of spring chinook occurs at Umatilla, Carson and Bonneville hatcheries. In addition to the major hatcheries, final rearing/acclimation ponds have been constructed at Minthorn Springs, Bonifer Springs and on the mainstem near Gibbon and at Thornhollow. Construction of three additional acclimation/release facilities is scheduled in the next two years.

Releases occur at the final rearing/acclimation ponds and release ponds. Broodstock is normally provided from the Carson National Fish Hatchery. Trapping broodstock will occur at the Threemile Dam trapping facility with holding/spawning to occur at a South Fork Walla Walla facility to be completed in 1996.

Bright fall chinook production takes place at Bonneville Hatchery and Umatilla Hatchery. Adult trapping currently occurs at Bonneville Hatchery and Threemile Dam Trapping Facility. Broodstock holding/spawning facilities will be completed at Threemile Dam in 1996. Fall chinook releases will be acclimated at the facilities mentioned above.

Hatchery production for coho takes place at Cascade Hatchery and Lower Herman Creek. Early run coho are reared and direct stream released into the natural production areas. Broodstock for the program is normally provided from trapping at Bonneville Hatchery. In recent years due to a shortage of broodstock, trapping has also occurred at Threemile Dam Adult Trap.

Current hatchery production of steelhead takes place at the Umatilla Hatchery. Umatilla stock summer run steelhead are currently being reared. Broodstock for the hatchery program is acquired by trapping at Threemile Dam Adult Trap. In addition to the hatchery, acclimation and release ponds have been constructed in the Umatilla River system. The existing program releases full-term reared smolts.

Recommended Actions for the Umatilla River System

Habitat Enhancement Actions for Umatilla Subbasin

I. Administrative

A.Laws and Codes, Enforcement & Revision

- •State of Oregon (OR) Environmental Protection Agency complete Total Maximum Daily Load for stream temperatures, sediment, other pollutants (Clear Water Act)
- •Halt water spreading in the lower Umatilla Basin
- •Enforce OR fish screening statutes
- •Upgrade OR Forest Practices Act to be consistent with Upper Grande Ronde (UGR) Anadromous Fish Habitat Plan
- •Upgrade Forest Service Land and Resource Management Plans consistent with UGR Plan to be in compliance with National Forest Management Act
- •Revise Umatilla instream water rights to acknowledge salmon needs
- •Revise mining laws to be consistent with production of high quality water and fish habitat

II. Instream Flow & Passage

A. Instream Flows Enhancement

- •Allocate saved water (from cessation of water spreading) for instream uses
- •Operate Phase I Umatilla Basin Project (UBP) throughout irrigation season
- •Implement Phase II, UBP as soon as possible
- •Develop & implement Phase III, UBP (Westland Irrigation District exchange for increased fish flows from McKay Reservoir)
- •Re-evaluate headwater project storage in upper Umatilla Basin for purpose of enhancing instream flows
- •Revise Umatilla instream water rights to acknowledge salmon requirements
- •Purchase, exchange, lease or seasonally rent water right for selected fish habitat during critical low flow periods

B. Passage Needs

- Continue fish "trap & haul" program in the lower Umatilla River
- Consolidate, eliminate or switch diversions to pumping operations (priorities: Wilson, Holeman, Forth, and Wyss dams)

III. Watershed Management

A. Water Quality Needs

- Increase shade cover to reduce stream temperatures (increased downstream extent of temperatures <60°F)
- Reduce sediment from agricultural practices and unimproved roads
- Reduce nitrate, phosphates, bacteria and other contaminants related to agricultural practices

PRIORITIES: Mainstem Umatilla River, Wildhorse Cr., Meacham Cr., Squaw Cr., McKay Cr., Birch Cr.

B. Riparian Restoration Needs

- Implement UGR Plan on State, Federal and Tribal lands
- Implement Best Management Practices (BMPs) including stream buffers to benefit fish on private lands
- Acquire, lease or implement management agreement to restore natural floodplain habitat and function

PRIORITIES: Wildhorse Cr., Squaw Cr., Meacham Cr., Birch Cr., Mainstem Umatilla River

C. Range Management

- Revise and implement BMPs to be consistent with UGR Plan Standards & Guidelines (S&Gs)
- Restrict/remove livestock in substandard areas
- Acquire, lease, develop projects in priority areas (see above)

D. Forest Management

- Upgrade, monitor, enforce Forest Practices Act consistent with UGR Plan S&G's on private lands
- Implement UGR Plan S&G's on State, Federal, Tribal lands
- Identify and implement active restoration projects
- Institute or continue protection of "good" habitat areas such as North Fork Umatilla and Birch Creek

E. Mining Impact Reduction Needs

No current problems

Artificial Production Actions for Umatilla Subbasin

1. The Umatilla Hatchery Master Plan has already identified production numbers required for restoration and enhancement of salmonid stocks in the Umatilla subbasin. The following action items identified in that plan need to be completed:

   a. Resolve water shortage problem at Umatilla Hatchery so that identified production goals can be met. If the water shortage problem cannot be corrected, production should be relocated or reprogrammed to other Columbia River hatcheries (including the South Fork Walla Walla facility) to meet Umatilla goals.

   b. Complete acclimation/release facilities at Mission, Pendleton, and Barnhart to increase smolt to adult survival rates.

   c. Complete adult holding/spawning facilities for fall chinook (Threemile Dam) and spring chinook (South Fork Walla Walla).

   d. Complete production facilities on the South Fork Walla Walla River as outlined in the Umatilla Hatchery Master Plan supplement for production of and release of 589,000 yearling spring chinook smolts into the Umatilla River. This production was outlined in the original Master Plan as required for meeting identified adult return goals.

2. Maintain summer steelhead program at 150,000. This level is reduced from the original

production level of 210,000 based on density evaluations conducted at Umatilla Hatchery.

3. Increase coho program from 1,000,000 to 1,500,000. Completion of the acclimation facilities identified in 1.b. will allow for acclimation of coho production.

4. Discontinue all catchable trout programs in areas where they may affect anadromous salmonid restoration activities.

5. A program to restore lamprey populations utilizing either transplantation or artificial propagation should be developed under the overall leadership of CTUIR.

6. Continue current monitoring and evaluation of all artificial production actions. Continue to use adaptive management to determine whether program changes (i.e. release number, size, time, location, and/or life history) are needed in order to meet restoration objectives.

Table 1

Species	Current Population	Adult Return Goal (Five-Year Average)
Spring Chinook	1,070[1]	11,000
Fall Chinook	580[1]	21,000
Coho	1,950[1]	6,000
Steelhead	1,990[1]	9,670
Chum	0	NE
Lamprey	NA	NE

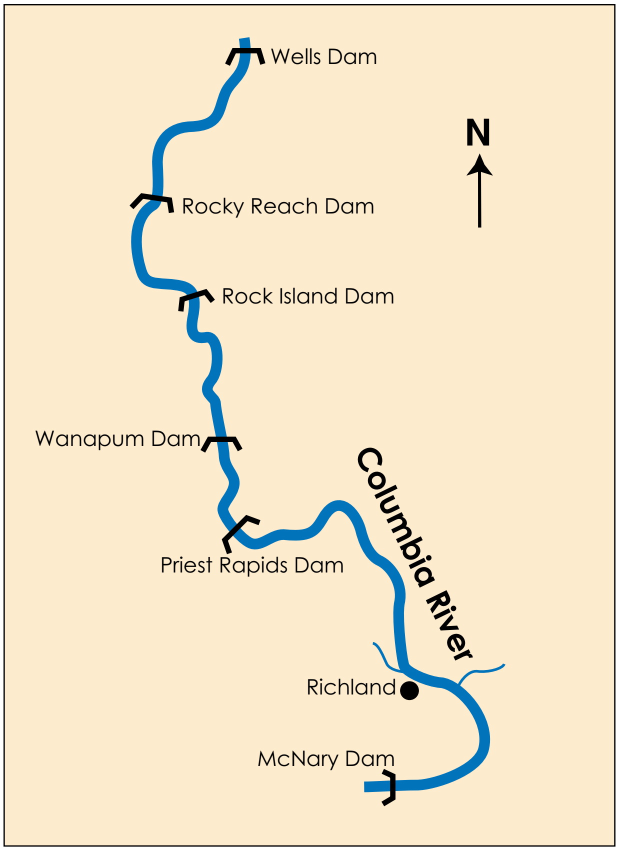
[1] 1989 - 1993 Returns to Umatilla River. Rounded to nearest tenths.
NA — Information not available
NE — None established

MID-COLUMBIA RIVER MAINSTEM

Prepared by the Columbia River Inter-Tribal Fish Commission and the Yakama Indian Nation

Introduction

The mid-Columbia River mainstem is that section of the Columbia River from Chief Joseph Dam downstream to McNary Dam. This section of the river generally flows southward through eastern Washington until it turns westward in the vicinity of Pasco, Washington. The principal tributaries in this section of the river, which have been described individually in these subbasin plans include the Okanogan, Methow, Entiat, Wenatchee, Yakima, Walla Walla and Snake River. In addition to these major rivers, minor tributaries, such as Crab Creek, enter the Columbia River in the Wanapum and Priest Rapids pools.



Fish Population Status/Goals

Currently natural spawning of fall chinook in the mid-Columbia River occurs mainly in the mainstem below Priest Rapids Dam. Small spawning populations also occur above Priest Rapids Dam and in small tributaries to Priest and Wanapum pools. Because of changes in hatchery programs at Wells Dam Hatchery and Turtle Rock Rearing Pond, more fall chinook have been released in the upper mid-Columbia in recent years. Thus, it is very likely that fall chinook are spawning in areas that have typically been identified as summer chinook habitat. This may be specifically occurring in the lower reaches of the Okanogan and Methow rivers due to the previous rearing and release of fall chinook at Wells Hatchery and existing program at Turtle Rock. Inundation of natural habitat by dam construction has significantly affected fall chinook spawning in the mainstem Columbia. Most of the small tributaries have suffered extensive damage from poor land and water management practices, in particular irrigation and grazing.

Natural production of steelhead occurs in the mainstem and other minor tributaries such as Crab Creek. Redd counts for the mainstem and tributaries are nonexistent due partly to their locations, difficulty in surveying, and the lack of manpower to adequately survey the stream. Like the rest of the systems, Crab Creek is impacted by irrigation practices which create passage barriers and water quality problems. Correction of such practices is necessary.

The subbasin planners noted that the objective for fall chinook in this section of the Columbia River is 40,000 adults over McNary Dam. Numerical objectives for the other fish species were not established. Table 1 shows the fish populations, status and goals.

Problems Impacting Fish Resources

The major habitat needs in this section of the river continue to be passage at the mainstem dams. Existing Federal Energy Regulatory Commission

(FERC) settlements between the mid-Columbia Public Utility Districts (PUD) and tribes, state and federal fishery agencies continue to examine the passage options.

Compensation programs for the losses incurred by the construction of the mainstem dams has been limited, improperly placed or non- existent. Table 2 shows the problems impacting the fish resources.

Small tributaries that once supported numerous small populations of salmon are now inaccessible or uninhabitable. Grazing, irrigation withdrawal, and agricultural development have caused extensive riparian loss, sedimentation, channelization, and dewatering in most of these small watersheds.

Ongoing Actions In The Mid-Columbia River Mainstem

Protection of the last remaining free flowing section of the Columbia River is currently being carried out through the Vernita Bar Settlement Agreement between the fishery agencies, treaty tribes, Bonneville Power Administration and mid-Columbia PUDs. The agreement provides guidelines for flows in the Hanford Reach. This agreement should continue to provide the necessary guidelines for the continuing protection of the spawning, incubation and emergence of fall chinook. In addition, the possibility of inclusion in the national Wild and Scenic Rivers program would increase the level of protection for fall chinook in the Hanford Reach.

Priest Rapids Hatchery located below Priest Rapids Dam on the east bank of the Columbia River rears 100,000 pounds of fall chinook for release into the Columbia River. In addition, the facility has reared and released 1,700,000 fall chinook as part of the John Day Dam mitigation. Originally built as a spawning channel, Priest Rapids Hatchery was constructed by Grant County PUD as mitigation for Priest Rapids and Wanapum dams. After several years, the upper portion of the channel was modified to rear the existing poundage at 90 fish/pound. The facility is operated by the Washington Department of Fish and Wildlife. In recent years, they have modified the size of release from 90 fish/pound to 60 fish/pound and most recently to 50 fish/pound. This has reduced production numbers by nearly 50 percent.

The Rocky Reach Hatchery (Turtle Rock Rearing Pond) facility currently rears and releases 500,000 summer/fall chinook smolts at the facility. Eggs for the program are provided from the Priest Rapids Hatchery. Incubation and early rearing occurs at the Rocky Reach Hatchery located on the east bank of the Columbia River immediately below Rocky Reach Dam. Fish are then transferred to the Turtle Rock Rearing Pond facility, above the dam, where they are reared and released into the Columbia River. The practice of releasing fish at the rearing pond has resulted in an increase in straying of fall chinook to other locations in the mid-Columbia.

Adult fall chinook have also been trapped at Wells Dam. As noted above, it is likely they are also seeking out and utilizing summer chinook natural production areas as appears to be the case in the lower Okanogan and Methow rivers.

Additionally, bright fall chinook have been reared at the Little White Salmon Hatchery for release into the Hanford Reach. These rearing programs have all been developed and continue to utilize the mid-Columbia bright fall chinook as broodstock.

Current releases of fall chinook occur at the Priest Rapids Hatchery and Turtle Rock Rearing Pond. Beginning in 1994, fall chinook from Bonneville Hatchery were released into the natural production area of the Hanford Reach by the Yakama Indian Nation using the K-Ponds on the Hanford Reservation and at Ringold Hatchery.
Broodstock for the Priest Rapids program is trapped at the hatchery or as necessary at Priests Rapids Dam. Broodstock collection for the Turtle Rock program is provided from Priest Rapids Hatchery. Broodstock for Bonneville, and Little White Salmon National Fish hatcheries occurs at those facilities or eggs are provided from Priest Rapids Hatchery.

Hatchery production of steelhead takes place at several hatcheries and rearing ponds with most releases occurring off-station in the major tributaries.

Programs have been developed for the release of full-term reared smolts.

The facilities include Wells Hatchery, East Bank Hatchery (Turtle Rock Rearing Pond), Chelan Hatchery, and Ringold Trout Pond. Summer run steelhead are reared in these facilities. Broodstock has been acquired from numerous sources over the years including trapping at Priest Rapids and Wells dams and the use of the Skamania stock from the Skamania Trout Hatchery. An adult trap used to acquire broodstock for summer chinook at Wells Dam is also used for steelhead. Broodstock also return to Ringold Trout Pond and Wells Hatchery.

Recommended Actions For The Mid-Columbia Mainstem

(1) Expedite development of mainstem passage facilities under the FERC settlement agreements for the mainstem dams.

(2) Restore the riparian areas of the tributaries. Adopt and enforce tributary instream flow needs.

(3a) Fall Chinook

Trapping broodstock at Priest Rapids Hatchery should be continued. Trapping at Priest Rapids Dam should be discouraged and only be used if absolutely necessary. Releases should continue at the hatchery adjacent to the natural production areas.

Determine and implement the best option for rearing fall chinook at Turtle Rock (1) terminate the rearing program and improve the facility's water supply to allow the rearing of summer chinook as required in the 1979 interim FERC agreement for Rocky Reach Dam. If the water supply and disease problems are corrected, then additional production of early run coho can occur by utilizing the pond that is now used for fall chinook. (2) Continue to rear fall chinook but require all fish reared to be released into natural production areas below Priest Rapids Dam.

The Bonneville Hatchery should continue to provide bright fall chinook releases into the natural production areas of the mid- Columbia as part of the John Day Dam mitigation program. Programs that began in 1994 include fish for the Hanford K-Ponds and Ringold hatcheries until such time as broodstock programs are developed at those locations. Broodstock should continue to be acquired from the existing mid-Columbia bright fall chinook programs.

The Ringold hatchery facilities should be modified to ensure that this program is compatible with other rearing programs including the ongoing spring chinook and steelhead programs. Broodstock collection facilities should also be developed and integrated with the other bright fall chinook adult collection programs.

The Hanford K-Ponds are located on the Hanford Nuclear Reservation adjacent to the fall chinook natural production areas. With pumping and discharge permit modifications, these ponds have the capability to rear up to 5,000,000 fall chinook and could assist in the rearing programs. In 1994, 500,000 bright fall chinook were reared and released at the facility. Releases in the natural production areas will help increase the natural spawning component of the run. Releases should continue and be increased as broodstock becomes available. Broodstock collection should continue to be at the existing programs and if monitoring finds it to be necessary additional facilities be constructed near the release site.

b) Steelhead

Ringold Trout Pond is located on the Columbia River upstream of the Tri-cities area. It was constructed in 1961 as part of the Mitchell Act program. It was designed to rear and release 180,000 steelhead smolts. All the fish are released on-site to provide sport fishing opportunities for the Tri-cities area. Currently, broodstock is acquired by trapping adults at the adjacent salmon facility. Adults are held at Chelan hatchery where spawning and incubation occurs. Early rearing occurs at the Washington Department of Fish and Wildlife's Columbia Basin Hatchery. In late summer, the fish are transferred to the Ringold pond for final rearing and are released from the pond the following spring. Broodstock for the program originated from the Skamania Hatchery.

Broodstock acquisition and rearing programs should be changed to work in combination with proposed trapping facilities in the mid-Columbia tributaries. Final rearing and/or acclimation facilities should be constructed in the natural production areas including the tributaries such as Crab Creek.

Wells Trout Hatchery should continue to be operated as described in the Okanogan and Methow basin tribal recovery plans.

Chelan Hatchery should continue to be operated as described in the Entiat and Wenatchee basin tribal recovery plans.

East Bank Hatchery should continue to be operated as described in the Entiat and Wenatchee tribal recovery plans.

Turtle Rock Rearing Pond should continue to be operated as described in the Entiat and Wenatchee basin tribal recovery plans.

(4) A program to restore lamprey to the tributaries should be developed by the relevant fishery managers. This program should be under the overall leadership of the tribes.

Table 3 shows the tribal recommended actions needed to restore the fish resources of the Mid-Columbia Mainstem.

Table 1
Mid-Columbia River Fish Populations Status and Goals

Species	Current Population (5-year average)	Adult Return Goal
Fall Chinook	6,740[1]	40,000
Steelhead	NA	NE
Lamprey	NA	NE

[1]1988-1992 redd counts. Number rounded to nearest tenth.

NA — Information not available
NE — None established

Table 2
Problems Impacting the Mid-Columbia River Fish Resources

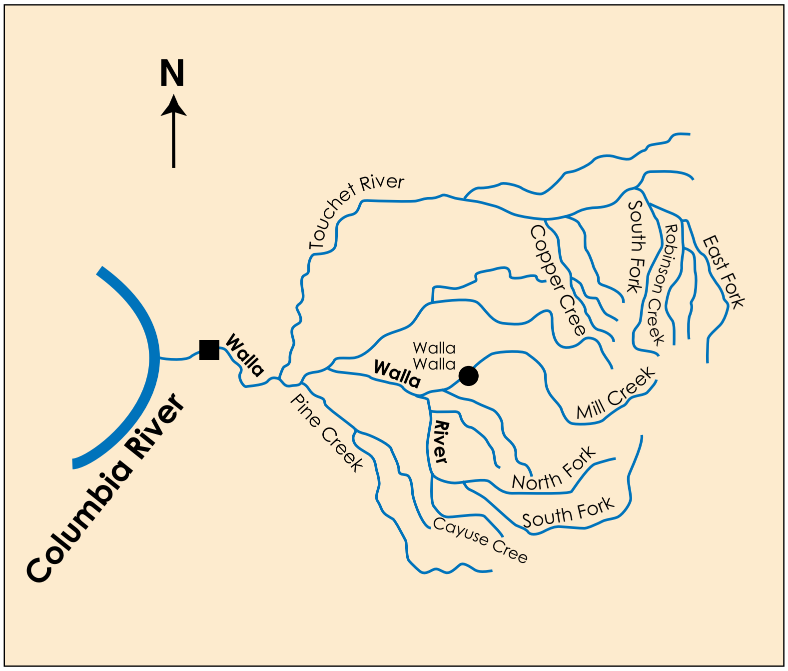
	Mainstem	Tributaries
Passage Facilities		•
Irrigation Diversions	•	
Inadequate Production Compensation	•	

Table 3
Recommended Actions for the Mid-Columbia River System

Problem	Recommended Action
Passage Facilities	(1) Construct passage facilities
Irrigation Diversions	(2) Provide instream flows, restore riparian areas
Inadequate Production Compensation	
Fall chinook, Steelhead Spring chinook, Coho	(3) Implement new broodstock programs, release programs, and production programs
Lamprey	(4) Develop and implement programs

WALLA WALLA RIVER

Prepared by the Confederated Tribes of the Umatilla Indian Reservation



Introduction

The Walla Walla River originates in the Blue Mountains of northeast Oregon. It generally flows west and north and enters the Columbia River at river mile 315 near Wallula, Washington. It drains 1,758 square miles. Elevations range from over 6,000 feet in the Blue Mountains to 270 feet at the mouth. The main tributaries are the North Fork, South Fork, Touchet rivers, and Couse, Birch, Mill, Pine, Dry, Yellow-hawk, and Cottonwood creeks (CTUIR, et. al., 1990).

Fish Population Status/Goals

Currently steelhead are the only anadromous salmonid that spawn in the Walla Walla River system. Natural production of steelhead in the Walla River occurs throughout the system. Historically, spring chinook, coho and chum also utilized the river system. Natural production of spring chinook occurred in the middle and upper mainstem and its major tributaries. Because spring chinook were eliminated from the system in the early 1900s, prior to the collection of detailed records, accurate data on the extent of the natural production is lacking. Information on chum and coho spawning locations and numbers is also lacking.

The subbasin planners recommended objective for spring chinook return is 5,000 adults of which 2,000 would spawn naturally and 2,500 would be for harvest. The summer steelhead objective is for a return of 11,000 of which 3,000 would be naturally produced and 7,680 would be for harvest. Objectives for chum and coho were not established by the subbasin planners.

Problems Impacting Fish Resources

Although problems associated with gravel mining, diking, forest and grazing practices exist, the most significant habitat impacts in the Walla Walla system, as noted in the subbasin plan, are associated with the extensive network of irrigation diversions (Ibid). Numerous passage problems for both adults and juveniles exist throughout the basin. The plan recommends that the passage problems be corrected (Ibid).

In addition to the habitat problems, the Walla Walla basin has received little or no mitigation for the losses incurred. The steelhead program in Washington is more directed at providing harvest opportunities than at restoring natural spawning populations.

Ongoing Actions In The Walla Walla River System

Mostly planning with little implementation is occurring in the basin. This is particularly the case with passage problems. As part of the Lower Snake River Compensation program, a steelhead acclimation and release program exists in the Touchet River, Mill Creek and the mainstem Walla Walla River. The fish are reared at the Lyons Ferry Hatchery located near the mouth of the Palouse River. Hatchery production of spring chinook, coho and chum in the Walla Walla River does not exist. Rearing and release programs for the stocks have not been planned under any of the past mitigation programs, such as the Mitchell Act or Lower Snake River Compensation Plan.

The Confederated Tribes of the Umatilla Indian Reservation have proposed the restoration of spring chinook, coho and chum for the Walla Walla River system. The tribe is currently developing a spring chinook program under Northeast Oregon Hatchery Plan. A spring chinook rearing/adult holding and spawning facility site has been identified on the South fork of the Walla Walla River.

Recommended Actions for the Walla Walla River System

Habitat Enhancement Actions for Walla Walla

I. Administrative

A. Laws and Codes, Enforcement & Revision

- •State of Oregon (OR)/Environmental Protection Agency complete Total Maximum Daily Load for stream temperatures, sediment, other pollutants (Clear Water Act)
- •Enforce OR fish screening statutes
- •Upgrade OR Forest Practices Act to be consistent with Upper Grande Ronde (UGR) Anadromous Fish Habitat Plan
- •Upgrade Forest Service Land and Resource Management Plans consistent with UGR Plan to be in compliance with National Forest Management Act
- •Revise mining laws to be consistent with production of high quality water and fish habitat

II. Instream Flow & Passage

A. Downstream Flow Enhancement

- •Purchase, exchange, lease or seasonally rent water rights for selected fish habitat during critical low flow period
- •Continue evaluation and feasibility of headwater storage in North Fork Walla Walla River for purpose of enhancing instream flows

B. Passage Needs

- •Construct new juvenile screens and smolt traps at the Little Walla Walla diversion (Walla Walla River in Oregon) and Hofer diversions (Touchet River in Washington) to allow safe smolt passage during high flows and to allow trapping & hauling of smolts during low flow periods
- •Construct new or upgrade ladders for improved fish passage at the following irrigation dams: Hofer & Maiden dams (Touchet River) Burlingame, Nursery Bridge, Little Walla Walla dams (Walla Walla River)
- •Remove or partially remove Marie Dorian Dam for improved fish passage

III. Watershed Management

A. Water Quality Needs

- •Increase shade cover to reduce stream temperatures (increased downstream extent of temperatures <60°F)
- •Reduce sediment from agricultural practices and unimproved roads
- •Reduce nitrate, phosphates, bacteria and other contaminants related to agricultural practices

PRIORITIES: Mid to lower mainstem Walla Walla & Touchet Rivers, lower North Fork Walla Walla River

B. Riparian Restoration Needs

- •Implement UGR Plan on State, Federal and Tribal lands
- •Implement Best Management Practices, including stream buffers to benefit fish on private lands
- •Acquire, lease or implement management agreement to restore natural floodplain habitat and function

PRIORITIES: Mid to lower mainstem Walla Walla & Touchet Rivers, lower North Fork Walla Walla River

C. Range Management

- •Revise and implement Best Management Practices to be consistent with UGR Plan Standards & Guidelines (S&Gs)

- •Restrict/remove livestock in substandard areas
- •Acquire, lease, develop projects in priority areas (see above)

D. Forest Management

- •Upgrade, monitor, enforce Forest Practices Act consistent with UGR Plan S&Gs on private lands
- •Implement UGR Plan S&Gs on State, Federal, Tribal lands
- •Identify and implement active restoration projects
- •Institute or continue protection of "good" habitat areas such as upper South & North Forks Walla Walla River, upper Mill Creek watershed

E. Mining Impact Reduction Needs

- •Mitigate for gravel mining impacts in mainstem Walla Walla River

Artificial Production Actions for Walla Walla Subbasin

1. Begin a spring chinook reestablishment program of 600,000 yearling smolts using Carson stock spring chinook to take place in both the South Fork Walla Walla and Touchet rivers. This program was identified in the Northeast Oregon Hatchery Plan (NEOH).
   a. Further expand proposed South Fork Walla Walla hatchery facility to accommodate this production requirement.
   b. Releases into the South Fork Walla Walla River would occur directly from the facility. Develop juvenile acclimation/release facilities in the Touchet River drainage above Dayton.
   c. Develop adult capture facilities in the Walla Walla subbasin to support future broodstock collection. Adults to be held and spawned at the South Fork Walla Walla hatchery facility.
2. Begin a natural brood summer steelhead program of 100,000 yearling smolts into the South Fork Walla Walla River. This program was also identified in the NEOH.
   a. Releases would occur directly from the South Fork Walla Walla hatchery facility.
3. Phase out use of non-native stocks in the existing Washington state summer steelhead program. Replace with natural brood as available through the NEOH program identified in item 2 above.
4. These production actions should proceed concurrently with passage improvement projects identified in the habitat recommendations section.
5. Evaluate coho and chum current production potential in the subbasin for re-establishment of species.
6. Discontinue all catchable trout programs in areas where they may affect anadromous salmonid restoration activities.
7. A program to restore lamprey populations utilizing either transplantation or artificial propagation should be developed under the overall leadership of the affected tribes.
8. Monitor and evaluate all artificial production actions. Use adaptive management to determine whether program changes (i.e., release number, size, time, location, and/or life history) are needed in order to meet restoration objectives.

Table 1

Walla Walla River Fish Populations Status and Goals

Species	Current Population (5-year average)	Adult Return Goal
Spring Chinook	0	5,000
Steelhead	1,090-1,817[1]	11,000
Coho	0	NE
Chum	0	NE
Lamprey	NA	NE

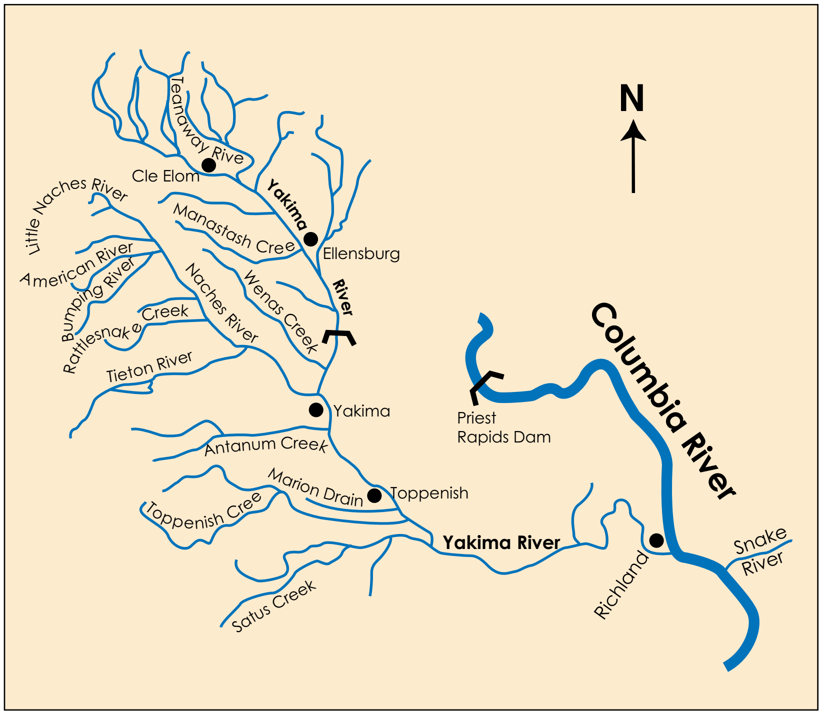
[1]Run years 1977-78 to 1983-84. From (CTUIR, et.al., 1990).
NA — Information not available
NE — None established

YAKIMA RIVER

Prepared by the Yakama Indian Nation

Introduction

The Yakima River originates in the Cascade Mountains at Lake Keechelus at an elevation of 6,900 feet. It is 214 miles long and encompasses an area of 6,155 square miles. The river flows in a southeasterly direction entering the Columbia River at river mile (RM) 335 near Richland, Washington (YIN, et. al., 1990). The major tributaries of the Yakima include the Naches, American, Bumping, Tieton, Little Naches, Cle Elum and Teanaway rivers. Major creeks include Status, Toppenish, Rattlesnake and Nile.



Fish Population Status/Goals

Three stocks of naturally reproducing spring chinook have been identified in the Yakima River. Natural production of one stock of spring chinook (Upper Yakima stock) occurs in the upper Yakima mainstem and the Cle Elum River. A second distinct stock (Naches stock) occurs in the Bumping River, Little Naches River, mainstem Naches River and Rattlesnake Creek. The third stock exists in the American River.

Two stocks of fall chinook occur in the Yakima River. The natural spawning areas for the lower mainstem stock of fall chinook occur in the lower Yakima River principally below Wapato. A second stock exists in Marion Drain.

Summer chinook in the Yakima River system historically occurred in the lower Naches River and mainstem Yakima above Prosser to the mouth of the Naches. Summer chinook are currently listed as an extirpated species of salmon in the Yakima River.

Natural spawning runs of steelhead exist throughout the Yakima River system including all of the major sub-drainage and tributary streams. Current electrophoretic data indicates there may be as many as four stocks of steelhead in the system. These stocks would include naturally reproducing populations located in the Satus Creek, Toppenish Creek, Naches River, and Yakima River subbasins. The largest wild runs are currently found in the two lower river tributaries, Satus and Toppenish creeks.

Coho are also currently listed as extirpated in the Yakima River. Historically, coho spawning occurred throughout the upper mainstem and tributaries of the Yakima River system.

Sockeye are also listed as extirpated in the Yakima system. They historically existed in all of the naturally existing lakes in the headwaters of the system.

The original set of goals and objectives for species of salmon in the Yakima River were listed in the subbasin plan. The objectives for spring chinook have been modified through recent modeling efforts for the Yakima/ Klickitat Fisheries Project (YKFP). The subbasin plan objectives will be listed for all species and the more recent YKFP objectives will also be cited where available.

The subbasin planners recommended objective for spring chinook is 26,303 escapement to the subbasin with a terminal harvest of 15,519 and a spawning escapement of 9,706. The more recent YKFP natural production objectives for all Yakima River spring chinook stocks under the first phase of the YKFP (with only upper Yakima supplementation facilities operating) would include a total return to Yakima of about 11,000 adults: about 9,000 upper Yakima spring chinook, 1,100 Naches, and 700 American River spring chinook. Objectives for natural spawning would include 2,000 spring chinook in the upper Yakima; 640 spring chinook in the Naches; and 390 spring chinook to the American. Harvest objectives would include a Yakima River catch of about 6,000 fish over all spring chinook stocks (5,400 from the upper Yakima, 300 from the Naches, and 200 from the American River stocks), and a total harvest to all fisheries (Yakima River, Columbia River, and ocean) of about 8,800 fish.

Steelhead escapement objective is 29,704 with 16,040 for harvest and 12,298 for spawning escapement. For fall chinook the planners recommended a return objective of 8,410 with a harvest of 4,709 and a spawning escapement of 4,351. The summer chinook objective is 11,956 with a harvest of 7,413 and a spawning escapement of 3,640. The coho objective is 5,025 with a harvest of 2,161. A natural spawning component was not determined. An objective for sockeye was not established. Table 1 shows the fish populations status and goals.

Problems Impacting Fish Resources

Habitat problems identified in the subbasin plan include agricultural practices, grazing, irrigation and fluctuations in stream flows. The need to screen many of the tributary diversions remains (Ibid). Loss of riparian area to residential and recreational home development, channelization and road construction continue to be serious problems throughout the subbasin. In addition to the habitat problems, the compensation programs in the subbasin have been limited or non-existent. Planning for production programs has been occurring since the adoption of the Northwest Power Planning Council's (NPPC) Fish and Wildlife Program resulting in little or no implementation. Table 2 shows the problems impacting the fish resources of the Yakima River system.

Ongoing Actions In The Yakima River System

Pursuant to the Columbia River Basin Fish and Wildlife Program adopted by the NPPC in 1982, a program of constructing new fish passage facilities (fish ladders and fish screens) has been implemented at diversion dams and canals in the Yakima Basin. To date, fish ladders and screens have been constructed at the following major dams and canals: Horn Rapids, Prosser, Sunnyside, Wapato, Roza, and Easton. In addition, fish ladders and screens have been constructed at a number of medium-sized diversion dams and canals, including Toppenish-Satus, Cowiche, Wapatox, Ellensburg Town, and Westside.

Construction of fish ladders and screens at over 60 smaller diversions is in progress, pursuant to the 1987 revised Columbia River Basin Fish and Wildlife Program (Phase II). These should be completed by the end of the decade.

There are two ongoing enhancement programs for fall chinook and coho salmon in the Yakima River. The fall chinook program includes the production and release into the Yakima of 1.7 million smolts from the Little White Salmon National Hatchery. This project is one component of the John Day mitigation program. Adults for the Little White Salmon Hatchery rearing program are currently trapped at the hatchery. Prior to 1994 the smolts were transported and directly released into the Yakima River. The Yakama Indian Nation, with funds provided under the Mitchell Act program, has developed acclimation facilities in the vicinity of Prosser Dam for final rearing and release of these fall chinook smolts.

The *US vs. Oregon* mandated coho program provides 700,000 early run coho for release to the Yakima River. These coho are produced at the Cascade Hatchery located near Bonneville Dam on the Oregon shore. This program is part of a larger effort to release coho in upper Columbia tributaries rather than in the lower Columbia. In 1994, these coho were also acclimated as part of the Yakama Indian Nation program to improve their post release survival.

Steelhead releases have occurred in the Yakima Basin over the past decade as a combined effort of the Washington Department of Fish and Wildlife and the local Trout Unlimited/Steelhead club. Originally these steelhead were imported as presmolts from out of basin hatcheries. The fish were generally of Skamania stock.

In recent years, local broodstock was acquired from the adult trapping facility located at Prosser Dam. The hatchery production of the local summer run steelhead occurred at the Yakima and Naches Hatcheries. This program has been reduced in recent years from 200,000 to 30,000 smolts. Over the last several years these smolts were used as experimental fish in the species interaction studies conducted on the Teanaway River. The last releases of steelhead in the Yakima occurred in 1994.

Recommended Actions For The Yakima River System

(1) Thermal pollution in the lower Yakima River is a serious problem. Tempera-tures often exceed the lethal threshold for salmonids during the smolt outmigration period, causing both immediate and delayed mortality. Thermal pollution is caused primarily by the diversion of nearly the entire flow of the river for irrigation upstream of Sunnyside Dam, irrigation return flows with elevated temperatures entering the river, downstream of Sunnyside Dam, and the removal of riparian vegetation.

Decreasing the thermal pollution in the lower Yakima River will require a broad program of increasing instream flows below Sunnyside Dam, reduction of return flows entering the Yakima River below Sunnyside Dam, and the restoration of riparian vegetation along the river. Such a program will require the involvement and cooperation of the state and federal resource agencies, irrigation districts, and landowners.

(2) Construction of large storage reservoirs in the upper drainage has drastically altered the natural hydrograph of the Yakima River. As a consequence, necessary flows are often not optimal to provide rearing habitat or flushing flows for smolt outmigration. Therefore, flows need to be revised for summer and winter rearing habitat, as well as flushing flows for smolts during the outmigration period.

(3) Much of the riparian vegetation in the Yakima Basin has been removed. This has resulted in drastic reduction in the recruitment of large woody debris to the streams. Large woody debris (living and dead large trees) should be retained in the riparian zone, and where necessary, large woody debris should be placed in the streams to provide urgently needed rearing habitat.

(4) Residential and shoreline development in the floodplain, agricultural development, road construction, and diking have resulted in the loss of side channels, reduction of floodplain function, channelization, and habitat simplification. Riparian and floodplain activities should be restricted by strict application of appropriate state and federal regulations (Growth Management Act, Shoreline Management Act). In addition, side channels should be reconnected to the river, overflow channels breached where appropriate, and riparian vegetation should be restored.

(5) Overgrazing in riparian areas and wet meadows, construction of recreational and residential homes, and the drainage from forest roads continues to cause sedimentation problems in streams, elevated water temperatures, and reduced instream flows. These impacts are especially noticeable on many tributary streams. Grazing in riparian areas and wet meadows should be properly managed, forest road management plans should be developed and implemented, and home construction in riparian areas should be regulated in a manner to prevent impacts to fisheries habitat.

(6) Virtually all of the fish passage problems on the mainstem Yakima and Naches River have been corrected. However, even after the construction of the Phase II fish passage facilities referred to above, a number of fish passage problems will remain on the tributaries. These should be immediately incorporated into the existing Phase II effort, and the entire Phase II effort should be accelerated.

(7) In addition to the serious thermal pollution problems referred to, irrigation return flows also contain heavy silt loads and high concentrations of agricultural pesticides. An aggressive water conservation program needs to be implemented in order to reduce silt loads entering the Yakima River, particularly below Sunnyside Dam. Water conservation will help reduce the introduction of agricultural chemicals into the Yakima River, as well as help reduce water temperatures.

(8) Water diversions for the generation of electrical energy occurs at Wapatox, Roza, and Prosser diversion dams. These diversions create low instream flows at three critical reaches in the Yakima River Basin. To solve these low instream flow problems, diversion of water for power production should be subordinated in order to provide proper instream flows.

(9a) Spring chinook

The Yakima/Klickitat Fisheries Project is the main production program measure planned for the Yakima River system as part of the NPPC Fish and Wildlife Program. The project managers, the Washington Department of Fish and Wildlife and the Yakama Indian Nation (as lead agency) have proposed to supplement all of the stocks of anadromous salmonids in the Yakima system. The program will be phased in over a number of years. The Environmental Impact Statement for the first phase will be released in 1995. The first phase will include the upper Yakima spring chinook stock (850,000 smolts) and the 700,000 coho smolts from the *US vs. OREGON* program that is currently operating in the Yakima. The other stocks will be implemented on a priority basis in subsequent phases of the program.

The spring chinook portion of the program calls for the construction of a main facility in the Yakima Basin near Cle Elum.

There will also be satellite final rearing and/or acclimation facilities in the spring chinook natural production areas. Broodstock acquisition will occur at a recently constructed adult trap at Roza Dam.

b) Fall chinook

The Yakima/Klickitat Fisheries Project is being designed to produce 2,600,000 juvenile fall chinook. Half of these juveniles will be of the lower mainstem stock and half of the Marion Drain stock. Broodstock will be trapped from returning adults in the lower Yakima (Horn Rapids Dam) and at facilities on Marion Drain. For the lower river stock there will be six final rearing and/or acclimation facilities near Horn Rapids Dam. Three final rearing and/or acclimation facilities will be developed in the Marion Drain and three acclimation facilities near Wapato for the Marion Drain stock.

c) Summer chinook

The Yakima/Klickitat Fisheries Project is being designed to rear 200,000 summer chinook smolts for release into the lower Naches River. Since there are currently no summer chinook left in the Yakima River system, the program will utilize the Wenatchee River summer chinook to provide broodstock to start the run. Once reestablished, the broodstock will be acquired from locally adapted adults returning to the Yakima system.

d) Coho

The Yakima/Klickitat Fisheries Project is being designed to produce 2,000,000 early run coho for release into the Yakima River system. Acclimation and release facilities should be developed. Broodstock acquisition could utilize the adult trapping facilities being developed for the other stocks.

e) Sockeye

In an attempt to restore sockeye to the Yakima River system, the National Marine Fisheries Service completed a study in 1992 designed to determine the feasibility of passing sockeye above Cle Elum Dam. No adult or juvenile fish passage facilities were constructed on any of the Yakima storage reservoir dams when they were constructed in the early 1900's. A final study report is due out soon. If successful, the program will be expanded and production facilities developed as part of the YKPP. Broodstock for the research has come from trapping at Tumwater Dam on the Wenatchee River. The study should be evaluated and if determined feasible, a full scale sockeye restoration program should be implemented.

f) Steelhead

The Yakima/Klickitat Fisheries Project is currently being designed to rear and release 400,000 steelhead smolts. The broodstock will be acquired from natural spawning populations and releases will occur in the natural production areas using 12 acclimation ponds in the Naches Basin and Toppenish Creek and potentially 15 acclimation ponds above Roza Dam. The final stream to be supplemented will be Satus Creek.

The Naches Hatchery is located on the Naches River near the confluence with the Yakima River. It is a Washington Department of Fish and Wildlife facility. Currently, Naches Hatchery is in poor condition and needs major renovation. The Naches steelhead program has reared approximately 100,000 fish to fingerling size for transfer to the Nelson Springs Raceway for final rearing and release. During recent years, the program was funded by the Bonneville Power Administration and operated by the Washington Depart-ment of Fish and Wildlife. The Nelson Springs Raceway is operated by the Yakima Chapter of Trout Unlimited. Broodstock for the program was trapped by the Yakama Indian Nation at Prosser Dam. Currently, this program rears 33,000 fish per year for use in research above Roza Dam. The research is expected to continue until 1995. At that time, a determination for supplementation of steelhead above Roza Dam will be made.

The Yakima Hatchery is located in the Yakima Basin near the Yakima Airport. The Yakima steelhead program was very similar to the Naches Hatchery program. Like the Naches Hatchery, the Yakima Hatchery is also in very poor condition and the water supply inadequate. The Yakima program consisted of rearing 100,000 smolts for release into the Naches River. Broodstock was also acquired from trapping at Prosser Dam. The Yakima steelhead rearing program has now been terminated. The Naches Hatchery steelhead program, with the exception of the research described above, has also been terminated.

(10) A program to restore lamprey should be developed by the relevant fishery managers. This program should be under the overall leadership of the tribes.

Table 3 shows the tribal recommended actions needed to restore the fish resources of the Yakima River system.

Table 1

Yakima River Fish Populations Status and Goals

Species	Current Population (5-year average)	Adult Return Goal
Spring Chinook	4,270[1]	26,300[2]
Summer Chinook	0	12,000[2]
Fall Chinook	450[3]	4,700[2]
Steelhead	2,150[4]	29,700[2]
Coho	NA	5,000[2]
Lamprey	NA	NE

[1] Based on 1986-1990 redd counts. Assumes 2.5 fish per redd. Number rounded to nearest ten.
[2] Rounded to nearest hundred.
[3] Based on 1984-1988 redd counts. Assumes 7 fish per redd. Number rounded to nearest ten.
[4] Based on years 1985-1989 (YIN, et.al., 1990). Rounded to nearest ten.
NA — Information not available
NE — None established

Table 2

Problems Impacting the Klickitat River Fish Resources

	Basinwide	Upper Yakima	Lower Yakima	Tributaries
Thermal Pollution			•	
Unnatural Hydrograph			•	•
Lack of Large Woody Debris	•			
Riparian Degradation	•			
Sedimentation	•			
Passage Barriers				•
Inadequate Production Compensation	•			

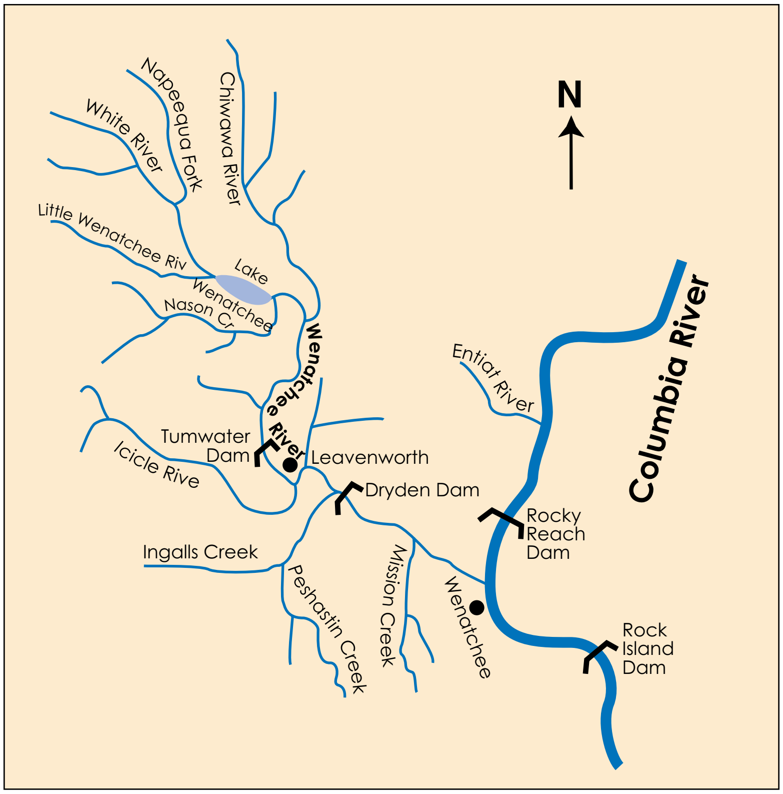
Table 3

Recommended Actions for the Yakima River System

Problem	**Recommended Action**
Thermal Pollution	(1) Restore riparian areas
Unnatural Hydrograph	(2) Provide smolt flushing flows, summer and winter rearing flows through storage releases
Limited Large Woody Debris	(3) Retain woody debris
Riparian Degradation	(4) Restore riparian vegetation
Sedimentation	(5) Eliminate or restrict logging, grazing, riparian development
Passage Barriers	(6) Construct passage facilities on tributary irrigation diversions
Water Quality	(7) Water conservation program to reduce silt and pesticides
Water Diversions	(8) Provide for instream flows
Inadequate Production Compensation	
Spring Chinook, Fall Chinook Summer Chinook, Coho Steelhead	(9) Implement new broodstock programs, release programs, production programs
Lamprey	(10)Develop and implement programs

WENATCHEE RIVER

Prepared by the Yakama Indian Nation



Introduction

The Wenatchee watershed drains a portion of the east Cascade Mountains in north central Washington within Chelan County. The watershed encompasses approximately 1,327 square miles, with 230 miles of major streams and rivers. The watershed originates in high mountainous regions of the Cascade Crest, with numerous tributaries draining sub-alpine regions within the Alpine Lakes and Glaciers Peak Wilderness areas. The Little Wenatchee and White rivers flow into Lake Wenatchee, the source of the Wenatchee River. From the lake outlet the river descends rapidly through Tumwater Canyon, dropping into a lower gradient section in the region of Leavenworth, where Icicle Creek joins the main-stem. Other tributaries include Peshastin Creek, Chiwawa River and Nason Creek (WDF et al. 1990).

Fish Population Status/Goals

Natural spawning runs of spring chinook occur in the Chiwawa, White, and Little Wenatchee rivers, and Peshastin, Nason, and Icicle creeks. The main natural production area for summer chinook in the mid-Columbia tributaries is the Wenatchee River mainstem. Like the rest of the runs in the mid-Columbia tributaries, the Wenatchee run was reestablished by the translocation of upper Columbia runs during the Grand Coulee Dam mitigation period. Natural spawning of sockeye occurs in the Wenatchee River system above Lake Wenatchee in the White River, Napeequa River (a tributary of the White River) and the Little Wenatchee River. Natural spawning of steelhead occurs throughout the Wenatchee River system. A large natural spawning run of coho historically occurred in the mid-Columbia River tributaries including the Wenatchee River. That population is believed to be functionally extirpated.

The subbasin planners' recommended objective for spring chinook is 21,000 adults of which 12,000 are natural stock and 9,000 hatchery; summer chinook objective is 10,000 adult natural fish; sockeye objective is 35,000 adult natural fish; summer steelhead objective is 12,218 adults of which 4,718 are natural fish and 7,500 hatchery fish for harvest. Objectives have not been established for fall chinook or coho. Table 1 shows the fish population status and goals.

Problems Impacting Fish Resources

Existing habitat conditions in the Wenatchee system varies widely. Problems have been noted with inadequate irrigation diversion screens and low flows later in the season (WDF, et. al., 1990). Some problems at the mainstem Dryden diversion still causes entrainment of adults and juveniles. Riparian areas in the mid and lower watershed have been significantly damaged. Losses are likely to continue given Chelan County's non-compliance with the Growth Management Act requirements and the County's general indifference to environmental issues. The subbasin is under intense recreational and residential development pressure.

Forest practices impacts range from low (Chiwawa River) to extreme (Mission Creek) but should decrease over time in much of the subbasin if the requirements of the Clinton Forest Plan are followed. The U.S. Forest Service is the major timber land owner in the watershed but the state Department of Natural Resources and a large timber company own a substantial portion of commercial timber land as well. The fate of watersheds with significant non-federal ownership is less certain.

Irrigation withdrawals significantly reduce habitat quality on the mainstem and render several tributaries, notably Peshastin Creek, nearly unusable for anadromous fish. Icicle Creek is over-appropriated such that summer water temperatures approach lethal levels.

Highway construction and attendant channel realignment, bank hardening, and loss of riparian vegetation have severely limited rearing habitat downstream of Lake Wenatchee.

Maintenance of existing habitat must be a high priority. The subbasin plan recommends the identification of diversions with improper screening and the repair and replacement of those screens as necessary (Ibid).

Limited compensation programs for some stocks is occurring in the basin; while other compensation, such as for coho and lamprey, is non- existent. Restoration of natural spawning fish is limited to only a few stocks and is also limited in overall numbers of fish. Until all programs are modified to restore the runs to the rivers and streams, the natural spawning populations will not recover. Table 2 shows problems impacting the fish resources of the Wenatchee River system.

Ongoing Actions In The Wenatchee River System

Some habitat improvements including fish ladders and screens have been constructed in the Wenatchee River system. Instream flow studies have been conducted on the mainstem, Nason Creek, and the Chiwawa River but flows identified by the study have not been adopted. Minimum flows have been established for the mainstem but not for tributaries. However, minimum flows are not adequate to realize the spawning potential of the existing habitat.

Watershed analysis is being conducted on Nason Creek, which should lead to better management of federal and private timber lands in that watershed.

A large group of concerned citizens and irrigators has formed to seek mutually beneficial solutions to environmental and agriculture problems. This group has to date focused on problem definition and education, but is currently trying to find funds to develop better water management strategies for the subbasin.

Hatchery production of spring chinook occurs at Leavenworth National Fish Hatchery (NFH) and Eastbank Hatchery. An adult trap has been constructed in the Chiwawa River. Eastbank Hatchery is assisting in restoring the natural run in the Chiwawa River. The program includes trapping broodstock from the Chiwawa River and releasing the smolts back into the river.

The Leavenworth NFH was constructed as part of the Grand Coulee Dam mitigation. It is located on Icicle Creek near Leavenworth, Washington. It was built during the late 1930s and early 1940s and modernized in the mid-1970s. It is designed to rear approximately 3,000,000 spring chinook smolts.

Currently, the program entails the trapping, rearing and releasing of spring chinook at the hatchery. The original program at the Leavenworth Hatchery began with fish being trapped at Rock Island Dam. Like the other Grand Coulee programs, the intent was to use the hatchery to assist in translocating the runs destined for above Grand Coulee Dam to the mid-Columbia tributaries. Also, like the other programs, eggs from other sources such as Carson, Cowlitz, Eagle Creek, Little White and Marion Forks hatcheries have been used at Leavenworth over the years. Leavenworth Hatchery is the primary back-up station for the Entiat and Winthrop hatcheries. Recently the Yakama Indian Nation and the state have developed terminal spring chinook fisheries in Icicle Creek.

Hatchery production of summer chinook takes place at the Eastbank Hatchery. Releases occur in the Wenatchee River just below Dryden Dam. The Eastbank Hatchery program began by trapping adults at Dryden and Tumwater dams on the Wenatchee River and transporting them to the Eastbank Hatchery for holding until spawning.

Hatchery production of sockeye occurs at the Eastbank Hatchery. Through the Federal Energy Regulatory Commission (FERC) intervention process, the Chelan County Public Utility District (PUD) is developing the sockeye program. Chelan PUD is using net pens for rearing in Lake Wenatchee. Broodstock for the program comes from trapping in the Wenatchee River at Tumwater Dam.

Following the construction of Grand Coulee Dam, there was an extensive hatchery supplementation program for reintroducing sockeye to Lake Wenatchee. The original program principally used stock trapped at Rock Island Dam that were destined for the Arrow Lakes region of British Columbia. The program was terminated in the 1950's primarily because the commercial fisheries in the lower Columbia below Bonneville Dam were unable to harvest enough fish to show a favorable benefit/cost ratio. During this period, lower river sockeye fisheries were restricted because of the impact on the summer chinook run. Not until the tribes became involved in the mid-Columbia FERC interventions was sockeye considered a priority species for restoration.

Hatchery production of steelhead takes place at Eastbank Hatchery, Chelan Hatchery, and Leavenworth Hatchery. Summer run steelhead are reared in these facilities. Broodstock has been acquired from numerous sources over the years including from traps at Priest Rapids and Wells dams, and from the use of the Skamania stock from the Skamania Trout Hatchery and Ringold Trout Pond.

Following the construction of Grand Coulee Dam, coho were released in the Wenatchee River. This coho program was discontinued in the 1960's and replaced with the lower Columbia River coho program in the area below Bonneville Dam. The Rocky Reach Hatchery (Turtle Rock Rearing Pond) coho program was terminated in 1992.

Recommended Actions For The Wenatchee River System

(1) No new permits for off-stream consumptive water use should be issued. New IFIM-based (Instream Flow Incremental Methodology) instream flow protection levels should be adopted for the mainstem and tributaries. Additional stream gauges should be placed in tributaries to better regulate interruptible water rights. The exemption from permitting extended to wells which use less than 5,000 gallons per day should be removed. Regional Water Planning should be conducted, and the state water code must be rigorously enforced.

(2) Chelan County must adopt and enforce an adequate Critical Areas Ordinance pursuant to the Growth Management Act.

(3) The Washington Forest Practices Act should be amended to include scientifically credible Riparian Management Zone requirements.

(4) The Dryden screens should be improved if still causing loss of juveniles and the entrainment of adults.

(5) To improve holding/resting and juvenile rearing habitat, provide in-channel habitat features (rock structures) in river reaches where the channel has been confined and the banks hardened. Re-open side channels cut-off by highway and railroad construction.

(6) Purchase undeveloped riparian areas in the White River, Nason Creek, and Chiwawa River drainages.

(7) Eliminate or severely restrict ground disturbing

activities that do not meet proposed fine sediment standards, such as road construction, logging and grazing .

(8) Purchase or lease water rights and fund improvements in irrigation efficiency.

(9a) Spring chinook
The existing Leavenworth Hatchery program should be changed by acquiring broodstock from the Wenatchee River natural production areas. Trapping in the Wenatchee River system should occur at Tumwater Dam or an appropriate tributary if stock identification data indicates significant genotypic or phenotypic differences among the various populations above Tumwater Dam. In recognition of the terminal fisheries in Icicle Creek and lack of adult capture/acclimation facilities in the upper tributaries, the program should be phased in over a period of time. This will enable the relevant fishery managers an opportunity to establish fisheries in the mainstem and tributaries above Tumwater Dam as well as construction of adequate release facilities in the White and Little Wenatchee rivers and Nason Creek. As the program is implemented, it will be necessary to modify the holding facilities at Leavenworth Hatchery to keep individual stocks separate.

Release programs should utilize final rearing and/or acclimation facilities in natural production areas. These should include Nason Creek, White River, and the Little Wenatchee River. Additional facilities should be constructed in the other natural production areas as necessary. The Chiwawa program will continue as part of the Rock Island Dam Settlement Agreement.

The Eastbank Hatchery was constructed in 1989 as part of the Rock Island Dam Settlement Agreement and is operated by the Washington Department of Fish and Wildlife. The program has the capacity to rear 672,000 smolts. The main hatchery is located just east of Rocky Reach Dam. A satellite facility for adult trapping and final rearing and release is located on the Chiwawa River. Broodstock for the program is acquired from the Chiwawa River. The main hatchery was constructed without a ladder or adult trapping capabilities to ensure that the program does not simply create another hatchery run. Broodstock for the program originally came from snagging adults off the natural spawning grounds in the Chiwawa River when a floating picket weir was ineffective. Monitoring and annual modifications are continuing at the Chiwawa trapping facility.

This program should be integrated with the Leavenworth Hatchery program to assist the natural spawning populations of the Wenatchee River system.

b) Summer chinook
The Eastbank Hatchery summer chinook program is designed to rear 1,816,000 yearling smolts, of which 840,000 are to be released into the Wenatchee River. Current releases occur in the natural production area. This program should continue.

c) Sockeye
The Chelan County PUD's Rock Island Dam Settlement Agreement calls for the rearing and release of 250,000 sockeye at 25 fish/pound into Lake Wenatchee. Broodstock are trapped at Dryden Dam or Tumwater Dam with adult holding, incubation, and early rearing in the Eastbank Hatchery. Due to the failure of the Dryden Dam trap, it is necessary to utilize the Tumwater Dam trap to acquire broodstock. Once feeding begins, fish are transferred to net pens in Lake Wenatchee where they are reared to 25 fish/pound and then released in late fall. The Chelan County PUD program should continue.

d) Steelhead
The Chelan Hatchery was constructed as part of Chelan County PUD's mitigation for Rocky Reach Dam. It is located on the Columbia River near the town of Chelan Falls. The facility rears 195,000 smolts for release into the Entiat and Wenatchee rivers. Prior to the Eastbank Hatchery coming on line, the facility also provided incubation and early rearing for 200,000 steelhead for the Turtle Rock Rearing Pond. The facility is funded by the Chelan County PUD and operated by the Washington Department of Fish and Wildlife. Broodstock for the program is acquired by bringing in eggs or adults from other facilities. Wells Dam pro-

vides most of the eggs for the current program. Eggs for the Turtle Rock program were provided from the Skamania Hatchery and, most recently, the Ringold Trout Pond.

Operation of the Chelan Hatchery should be integrated with operation of Eastbank Hatchery. Broodstock acquisition, final rearing and/or acclimation facilities should be developed in the Wenatchee River system. Additional releases should occur in the natural production area.

Eastbank Hatchery steelhead program is designed to rear 200,000 steelhead. Releases occur in the Entiat and Wenatchee River. The Eastbank program should continue to assist the natural spawning population in the Wenatchee River and its tributaries. Broodstock for the program should be acquired from the natural spawning populations and the use of other stocks terminated. Adult trapping and final rearing and/or acclimation facilities should be constructed and integrated with the other programs.

From the early 1950s to the mid 1970s, Leavenworth Hatchery reared resident trout in addition to salmon. The resident trout program was terminated in the mid 1970's when the hatchery was modernized and reprogrammed for spring chinook production. At the same time, Leavenworth began rearing 100,000 steelhead annually as compensation for the termination of the resident trout programs. Broodstock was acquired from the Washington Department of Fish and Wildlife's program at Wells Dam. Currently, the steelhead are reared to smolt size and released at the hatchery. If available, broodstock are also acquired at the hatchery. This program should be integrated with the recommended Eastbank and Chelan hatchery programs.

e) Coho

Opportunities for reintroducing coho into the Wenatchee River must come from reprogramming existing hatcheries. Willard National Fish Hatchery in the Bonneville Pool offers immediate opportunities. Currently, Willard NFH rears and releases early run coho which is the preferred stock for the Wenatchee River. As its name implies, the early run stock enters the Columbia earlier than the late run stock. Using the early run stock will allow coho to reach the up-river habitat while still in good condition. Willard National Fish Hatchery has the capability of rearing 2,500,000 early run coho smolts. The smolts are currently released at the Little White Salmon Hatchery at the mouth of the river. The program should be modified to release up to 500,000 coho into the natural production areas of the Wenatchee River. Future broodstock needs would be met by trapping in the natural production areas once the runs have been reestablished. Adult trapping facilities used for the summer chinook program can be used to acquire the broodstock. Final rearing and/or acclimation facilities should be constructed in the natural production areas.

(10) A program to restore lamprey should be developed by the relevant fishery managers. The overall restoration of lamprey should be under the leadership of the tribes.

Table 3 shows the tribal recommended actions needed to restore the fish resources to the Wenatchee River system.

Table 1

Wenatchee River Fish Populations Status and Goals

Species	Current Population (5-year average)	Adult Return Goal
Spring Chinook	1,280[1]	21,000
Summer Chinook	6,900[1]	10,000
Steelhead	6,410[2]	12,218
Sockeye	NA	35,000
Coho	NA	NE
Fall Chinook	NA	NE
Lamprey	NA	NE

[1] Based on 1989-1993 redd counts. Assumes 2.5 fish per redd. Number rounded to nearest tenth.

[2] Based on years 1983-1987. Includes both hatchery and natural runs. Rounded to nearest tenth.

NA — Information not available

NE — None established

Table 2
Problems Impacting the Wenatchee River Fish Resources

	Basinwide	Upper Wenatchee	Lower Yakima	Tributaries
Low Flows			•	•
Reduced Low Velocity Habitat			•	•
Lost Riparion Area	•			
Irrigation Diversions			•	•
Channelization			•	•
Loss of Side Habitat			•	•
Degraded Water Quality			•	•
Inadequate Production Compensation	•			

Table 3
Recommended Actions for the Yakima River System

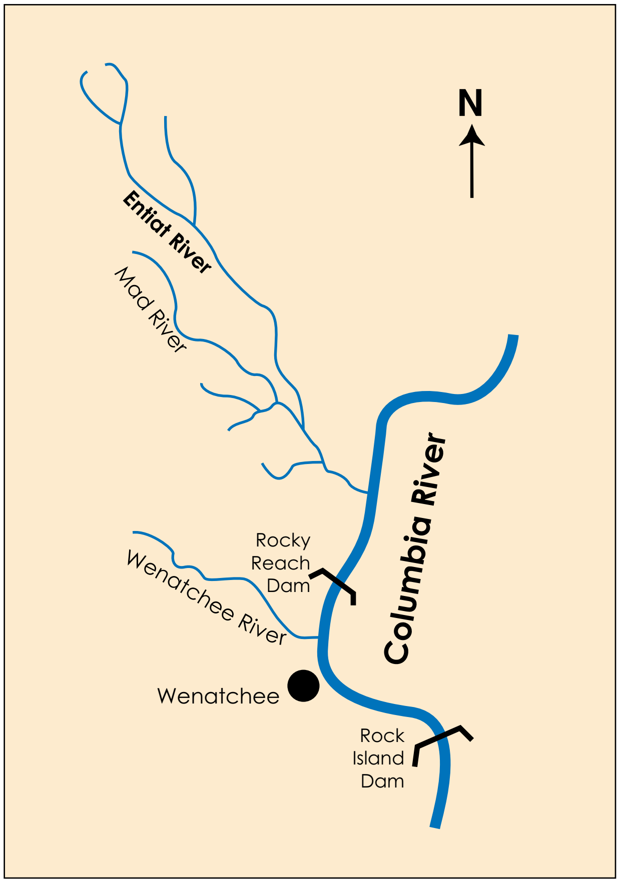
Problem	Recommended Action
Low Flows	(1) Adopt instream flows, cease over-appropriations, conduct regional water planning
Reduced Low Velocity Habitat	(2) Restore shoreline habitat, utilize Canadian-style bank stabilization
Riparian Degradation	(3) Restore riparian vegetation, adopt and enforce appropriate riparian protection regulations
Irrigation Diversions	(4) Improve passage facilities, enforce design criteria
Loss of Side Habitat	(5) Restore channel configurations, adopt instream flows
Degraded Water Quality	(6) Reduce sedimentation, increase instream flows
Inadequate Production Compensation	
Spring Chinook, Sockeye Summer Chinook, Coho Steelhead	(7) Implement new broodstock programs, release programs, production programs
Lamprey	(8) Develop and implement programs

ENTIAT RIVER

Prepared by the Yakama Indian Nation

Introduction

The Entiat River Basin is located in north central Washington, within Chelan County. The Entiat River originates at an elevation of over 9,000 feet in the Cascade Mountains. From its headwaters, the Entiat River flows southeasterly for approximately 42 miles before entering the Columbia River at river mile (RM) 483.7. Two major tributaries drain into the Entiat River, the North Fork Entiat and the Mad River, which enters into the Entiat at RM 10.5. Total drainage area of the subbasin is 419 square miles. (WDF et al. 1990).



Fish Population Status/Goals

A natural spawning run of spring chinook exists in the upper mainstem. A remnant natural spawning run of summer chinook exists in the Entiat River from the mouth to at least River Mile 28. Fall chinook may also now be spawning in the river. Straying from Turtle Rock releases may be occurring. There is little information available on the condition of the natural run of steelhead in the Entiat River. Natural production occurs in the mainstem Entiat and some of its major tributaries. Sockeye have also been reported spawning in the river near Brief. The origin of those fish has not been determined, but they are probably strays from the Wenatchee and/or Okanogan river systems.

A large natural spawning run of coho historically occurred in the mid-Columbia River tributaries. Natural spawning runs were recorded in the Okanogan, Methow, Entiat and Wenatchee. Currently, there is no attempt to count redds or determine if a small run still exists in the Entiat or any of the other tributaries.

The subbasin planners' recommended objective for summer steelhead is 4,471, of which 1,471 are natural and 3,000 are hatchery fish for harvest. The recommended spring chinook return is for a two-level approach for harvest. The first is for a run of 200-500 for harvest and the second objective for a run of 500-1,000 fish for harvest. The planners did not provide any numerical natural spawning objectives for spring chinook, coho, or fall chinook. Table 1 shows the fish population status and goals.

Problems Impacting Fish Resources

The habitat in the Entiat system has been affected by a host of land and water management activities. The Entiat River subbasin plan, completed under the Northwest Power Planning Council Fish and Wildlife Program, identified a few of these including irrigation diversions and associated low flows, inadequate fish screens as well as riparian vegetation removal. Additionally, the subbasin has been significantly affected by forest practices, bank hardening, and residential shoreline development.

Much of the subbasin was burned by major forest fires over the past 25 years. The Dinkleman Fire, 1988, burned approximately 50,000 acres and led to a major landslide that filled the lower four miles of the river with sediment. The Tyee Fire of 1994 burned much of the riparian areas within the watershed. In the aftermath of these fires, mass failures and rehabilitation activities will likely produce substantial sediment delivery to the streams. The fires have resulted from both natural and anthropogenic sources, but in all cases, forest management (notably roads) has significantly amplified the impact of fire to fish habitat. Absent fire, forest roads would be the most significant source of fine sediment, and they are in the un-burned portions of the watershed.

The steep topography of the subbasin largely limits residential development to floodplain and alluvial fan features. Accordingly, development has significantly affected fish habitat quality. Pressure to develop the remaining suitable building sites is extreme. Chelan County is more than two years behind schedule relative to the requirements of the Growth Management Act, and has proposed inadequate shoreline and wetland protection measures, the consequences of additional development will likely be severe.

The Entiat River is not as heavily appropriated as other Columbia subbasins, but the impact of water withdrawals is significant particularly during the late summer. New water rights are being issued subject to minimum instream flows. From August through the end of the irrigation season in most years instream flows are below minimums. Unfortunately, the Department of Ecology does not have adequate enforcement staff to ensure that interruptible diversions cease when low-flow thresholds are reached. Further, an Instream Flow Incremental Methodology (IFIM) study conducted in 1992 showed that the adopted flows are much lower than necessary to maintain habitat productivity.

Much of the riparian habitat within the subbasin has been altered, mostly by orchard owners who believe that riparian vegetation serves as alternative housing for orchard pests. Significant additional riparian vegetation has been removed or diminished by road construction, timber harvest, and fire damage in riparian areas.

Problems associated with irrigation diversions and screens, low flows, and modification of riparian areas also occur in the Entiat River system. All irrigation diversion structures should be inventoried and evaluated. New and improved fish screening systems should be installed (Ibid).

In addition to the habitat problems, past and present mitigation programs were not developed to return the fish to the natural environment. In some instances, species that have been lost or seriously diminished have not been restored either to the basin or the habitat. Table 2 shows the problems impacting the Entiat River system.

Ongoing Actions In The Entiat River System

Planning for habitat improvement projects has taken place, but implementation has not. A watershed coalition of local landowners and interested individuals was formed in 1993. They have intimated an interest in improving land and water management to improve conditions for fish but have yet to develop a substantive approach for doing so. The U.S. Forest Service (USFS) requirements under the Clinton Forest Plan should lead to better management of their ownership in the subbasin. Mitigation programs include those established as part of the Grand Coulee mitigation program and the Chelan County Public Utility District (PUD) mitigation for their mainstem dams.

Hatchery production of spring chinook in the Entiat River exists at the Entiat National Fish Hatchery (NFH). The Entiat Hatchery is operated as a satellite facility for Leavenworth complex. In addition to the hatchery, a spawning channel has been constructed on the upper end of the Entiat River natural production area.

Hatchery production of steelhead for release into the Entiat River exists at Eastbank Hatchery and Chelan Hatchery. Summer run steelhead are reared in these facilities. Broodstock has been acquired from numerous sources over the years including trapping at Priest Rapids and Wells dams and the use of the Skamania stock from the Skamania Trout Hatchery.

There currently are no releases of summer chinook or coho into the Entiat River.

Recommended Actions For The Entiat River System

(1) The DOE should stop issuing consumptive water rights, and replace the inadequate existing instream flow flows with more appropriate IFIM-based flows.

(2) Cease road construction and begin to close roads and return system to more natural condition. Systems roads that cannot be closed should be retro-fitted with crossing structures that can withstand the increased peak flows that invariably follow fires.

(3) Loss of the riparian vegetation throughout the system must be stopped and a program of riparian restoration implemented. Chelan County must adopt and enforce an adequate Critical Areas Ordinance pursuant to the Growth Management Act.

(4) Issuances of hydraulic permits by the state for channel control has led to bank hardening. The issuances of hydraulic permits should be strictly controlled to ensure there is no additional loss of the riparian vegetation.

(5) Logging and grazing in the watershed have created degraded water quality due to sediment entering the system. A USFS report indicates that fine sediment levels exceed forest plan standards in the middle/lower reaches of the watershed. This condition will be exacerbated by the 1994 Tyee Fire. Watershed activities such as logging and grazing which continue to cause sedimentation should be eliminated or severely restricted until the system recovers.

(6) Conduct Regional Water Planning to improve water management to the betterment of fish habitat. After Regional Planning is completed create a water conservation trust fund to pay for conservation improvements that will return saved water to instream flows.

(7) Reconnect the river to blocked side channels and/or create new side channels to improve rearing habitat conditions.

(8a) Spring chinook
Entiat NFH was constructed as part of the Grand Coulee Dam mitigation. The facility reared approximately 800,000 smolts before switching to well water. Capacity has been reduced by roughly one half, and the hatchery now releases about 400,000 subyearlings and 400,000 yearling smolts. Broodstock acquisition occurs by trapping at the hatchery or egg transfers from Leavenworth NFH. Current releases occur at the hatchery. The Entiat Hatchery should begin a program to acquire broodstock from the existing natural run. Final rearing and/or acclimation facilities should be provided in the natural production areas. The spawning channel located in the upper end of the natural production area should be examined for possible modification to a semi-natural rearing pond for summer rearing and late fall release.

b) Summer chinook
The Eastbank Hatchery program for summer chinook should be changed to provide release of some of the existing production into the Entiat River natural production area. Final rearing and/or acclimation facilities should be constructed.

c) Steelhead
The Chelan Hatchery steelhead program for the Entiat River should be integrated with operation of Eastbank Hatchery. Releases should be acclimated and adult trapping facilities developed. These may be integrated with the other release and adult capture programs.

d) Coho
Eastbank Hatchery is designed to rear 200,000 steelhead for releases in the Entiat and Wenatchee River. The Eastbank program should continue to assist the natural spawning

populations in the Entiat River and its tributaries and be integrated with the Chelan Hatchery program.

The Turtle Rock Rearing Pond produced 500,000 coho smolts for release at the facility until 1992. With the termination of the steelhead program at Turtle Rock, coho production may be possible providing the disease problems are corrected. Evaluate the use of the facility for rearing coho with the release to occur in the Entiat River natural production areas.

Willard National Fish Hatchery has the capability of rearing 2,500,000 early run coho smolts. The smolts are currently released at the Little White Salmon Hatchery at the mouth of the river. The program should be modified to begin a release program of up to 500,000 coho into the natural production areas of the Entiat River.

Since there are no adult trapping programs in the Entiat River for summer chinook, coho or steelhead, the existing adult traps on the Wenatchee River will be used to trap broodstock for the Entiat River. Once restored, broodstock for the Entiat River would be acquired from the restored runs.

(9) A program to restore lamprey should be developed by the relevant fishery managers. The overall restoration to the Columbia River lamprey should be under the leadership of the tribes.

Table 3 shows the tribal recommended actions needed to restore the fish resources of the Entiat River System

Table 1

Entiat River Fish Populations Status and Goals

Species	Current Population (5-year average)	Adult Return Goal
Spring Chinook	190[1]	200-500[2] 500-1,000[2]
Summer Chinook	NA	NE
Steelhead	NA	3,000[2] 1,471[3]
Coho	NA	NE
Fall Chinook	NA	NE
Lamprey	NA	NE

[1] Based on 1986-1990 redd counts. Assumes 2.5 fish per redd. Number rounded to nearest tenth.
[2] Harvest goal only. Natural production goal not established for spring chinook.
[3] Natural production goal.
NA — Information not available
NE — None established

Table 2

Problems Impacting the Entiat River Fish Resources

	Basinwide	Upper Entiat	Lower Entiat	Tributaries
Irrigation Diversions	•			
Roads	•			
Riparian Degradation	•			
Bank Hardening	•			
Degraded Water Quality	•			
Inadequate Production Compensation	•			
Recent Fire History	•			

Table 3

Recommended Actions for the Entiat River System

Problem	**Recommended Action**
Irrigation Diversions	(1) Implement conservation programs, cease over-appropriations, provide adequate instream flows
Road Construction	(2) Stop road construction
Riparian Degradation	(3) Restore riparian vegetation
Bank Hardening	(4) Stop issuances of hydraulic permits
Poor Water Quality	(5) Eliminate or severely reduce logging, grazing
Degraded Water Quality	(6) Reduce sedimentation, increase instream flows
Inadequate Production Compensation	
Spring Chinook, Steelhead Summer Chinook, Coho	(7) Implement new broodstock programs, release programs, production programs
Lamprey	(8) Develop and implement programs

METHOW RIVER

Prepared by the Yakama Indian Nation

Introduction

The Methow River is located in north central Washington with its source on the eastern slopes of the Cascade Mountains, and flows southeasterly to enter the Columbia River at river mile (RM) 524 near the town of Pateros. The Methow subbasin encompasses about 1,800 square miles. The Methow and Okanogan subbasins represent the upper limit of anadromous salmonid distribution in the Columbia River Basin. The Methow River enters the Columbia between Wells and Chief Joseph dams (WDF et al. 1992).

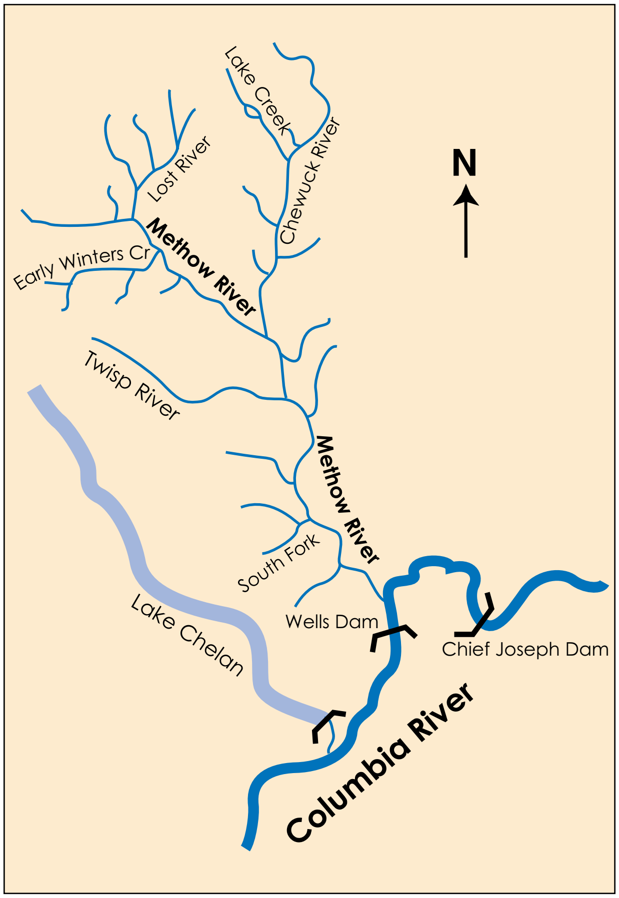
Fish Population Status/Goals

Spring chinook spawn naturally in the Twisp, Chewuck, and upper Methow rivers and some minor tributaries. A natural run of summer chinook exists in the mainstem from Winthrop downstream to the mouth of the river. Steelhead natural production occurs throughout the basin. A minor population of coho may still spawn in the system.

The National Marine Fisheries Service is presently considering the mid-Columbia (Methow, Okanogan, Entiat, and Wenatchee rivers) summer chinook as a candidate for protection under the Endangered Species Act.

The subbasin planners did not provide natural production objectives for the various stocks. Rather they recommended harvest return objectives of 2,000 spring chinook, 3,000 summer chinook and 10,000 hatchery reared steelhead. They did not provide harvest or natural production objectives for coho.

Table 1 lists fish population status and goals.



Problems Impacting Fish Resources

Habitat quality has been significantly reduced by a range of activities including forest practices, flood control, mining, dredging, grazing and shoreline development. The most significant impact, however, is probably irrigated agriculture. Flows in all mainstem reaches downstream of Winthrop and the lower reaches of all major tributaries are significantly reduced by irrigation withdrawals. Further, during the late summer, most of the Methow's minor tributaries are completely diverted for irrigation. Minimum instream flows were established in 1977 for several mainstem reaches and for a few larger tributaries. Unfortunately, the adopted flows did not reflect actual fish habitat requirements but instead represented but a portion of the hydrograph that remained after more than eighty years of appropriation. A subsequent Instream Flow Incremental

Methodology (IFIM) study revealed that the adopted flows are generally less than 50% of optimal flows for salmonids, and are frequently less than 20% of optimal.

The impacts of such diversions include reduced habitat area, juvenile stranding, adult passage barriers, redd de-watering, elevated water temperatures, and increased vulnerability to predation. Additionally, many of the irrigation diversions are poorly screened or not screened at all.

Most of the irrigation systems in the subbasin are terribly inefficient by modern standards. The largest system in the valley, the Methow Valley Irrigation District, diverts approximately thirty acre feet of water for every acre of land served. The Skyline Ditch, which diverts water from the Chewuch River, a large Methow River tributary, diverts more than 50 acre feet per acre served. Ironically, on-farm efficiencies were recently judged by the U.S. Bureau of Reclamation to be fair to good. Poor delivery systems are responsible for most the inefficiencies of Methow subbasin irrigation systems. Commonly, water is delivered via simple earth canals cut into porous glacial till.

Flood control efforts have not been as extensive in the sub- basin as they have been elsewhere primarily because the river south of the Carlton is deeply incised. However, several side channels in the vicinity of the town of Twisp have been disconnected from the river by flood control projects. Additionally, gravel and large wood were dredged from the mainstem and Chewuck rivers following the 1948 and 1972 floods in an effort to increase channel capacity. Persistent effects of that action include loss of habitat complexity and low in-channel wood volume. There are no flood control dams in the subbasin.

Along the mainstem, development encroachment into the shoreline has been similarly mitigated relative to other subbasins by the river's deep incision. Natural topography, highway construction, and other development (agricultural, residential, and municipal) along the few sites below the confluence of the Methow and Chewuck rivers, which historically supported riparian vegetation have conspired to limit habitat productivity in this reach. Residential, commercial, and agricultural development, and dispersed camping have significantly affected many tributary shoreline areas. Grazing impacts are generally low to moderate subbasin wide but are locally severe (particularly on tributaries) on mostly private lands.

The U.S. Forest Service (USFS) is the major forest land owner in the subbasin. Much of the federal land is protected by inclusion in the wilderness system, but most of the anadromous fish habitat is within the portion available for timber harvest. Many forest roads, particularly those in the Chewuck drainage, are in poor condition. Riparian vegetation is in generally good shape along the mainstems within the forest and varies from excellent to poor in tributary watersheds. The Washington State Department of Natural Resources and several private interests own the remainder of the commercial forest ground in the subbasin.

Ongoing Actions In The Methow River System

The recently completed *Draft Methow River Basin Plan* (January, 1994) developed cooperatively by state, tribal, and local governments, and environmental, fishing, recreation, business, and agricultural interests calls for an end to the further diminution of instream flows. The group convened to resolve the water allocation impasse that has existed in the basin for the past 17 years. The plan recommends that any new out-of-stream uses be satisfied by savings from existing uses and that 90% or more of saved water be returned to the stream to benefit aquatic resources. The group also suggested a number of approaches for implementing conservation.

Hatchery production of spring chinook occurs at Winthrop National Fish Hatchery (NFH) and the Methow Valley Spring Chinook Hatchery. Adult traps have been constructed on the Twisp and Chewuck rivers. Releases occur from acclimation facilities at all three of the sites. Broodstock holding occurs at the Methow and Winthrop hatcheries.

Winthrop NFH is located in the upper Methow near the town of Winthrop, Washington. As part of the

Grand Coulee Dam mitigation, it was constructed in the early 1940's by the Bureau of Reclamation and is operated by the U.S. Fish and Wildlife Service. Since its construction, the facility has been modernized (most recently in the mid-1970s) and currently has the capacity to rear approximately 1,000,000 spring chinook to smolt size. The hatchery also serves as a trapping location for spring chinook. A proposal to expand the Winthrop Hatchery to assist in the restoration of spring chinook into the Similkameen River above Enloe Dam was originally put forth in the 1973 Oroville-Tonasket Project Report. But due to continuing political problems since that time, the project has not been implemented.

The Methow Valley Spring Chinook Hatchery was constructed as part of the Wells Dam Settlement Agreement. The facility is designed to rear and release 738,000 smolts. The main facility is operated in conjunction with two satellite final rearing/acclimation facilities on the Twisp and Chewuck rivers. Adult traps have been constructed on these rivers to acquire broodstock for the rearing program.

Hatchery production of summer chinook takes place at Wells Hatchery and the Eastbank Hatchery. Broodstock for the Wells Dam program is acquired from trapping at Wells Dam. The facility was designed and constructed to rear 4,400,000 summer chinook to subyearling smolt size. The program was modified in 1984 to require the release of 400,000 fish into the natural production area of the Methow River. Currently, releases from Wells Hatchery occur at the hatchery. Only one release has been made from the facility into the Methow River.

The Eastbank Hatchery summer chinook program for the Methow River was started by trapping adults at Wells Dam and Wells Hatchery for release in the Methow River. The hatchery is designed to rear 1,816,000 yearling smolts, of which 400,000 are released into the Methow River. The Methow River releases are the responsibility of the Chelan County Public Utility District (PUD) and are coordinated with the Douglas County PUD's Wells Dam program.

Releases from Rock Island Hatchery occur in the Methow River near Twisp. The run at Wells Hatchery was developed by trapping adults at Wells Dam. The Rock Island Hatchery program began by trapping adults and hatchery volunteers at Wells Dam and at Wells Hatchery and then transporting them to the Rock Island Hatchery for holding until spawning.

The Wells Hatchery steelhead program for the Methow River system originated from adult trapping facility at Priest Rapids Dam. Broodstock collection was moved to the Wells Dam ladder in the early 1980s. This allows naturally spawned and hatchery returns destined for the streams above Wells Dam to be used as broodstock on an annual basis.

Although the existing broodstock collection provides for the use of some naturally spawning stocks, it does not provide for separation of the stocks above Wells Dam.

Currently there are no releases of coho into the Methow River system.

Recommended Actions For The Methow River System

(1) Irrigation diversions in combination with natural low flow occurrences and channel realignment in the basin create dewatering problems and upstream passage problems and significantly reduce available habitat. Instream flows will be significantly improved by implementing the recommendations of the *Draft Methow Basin Plan*. The Department of Ecology, in concert with the U. S. Forest Service on its lands, should enforce the state water code to stop illegal diversions. A relatively modest funding program ($2-3 million per year for 10 years) for water conservation projects would swiftly and significantly improve in-basin productivity for all anadromous stocks.

(2) Spring chinook rearing and over-wintering habitat could be significantly increased by reconnecting cut-off side channels and oxbows and by creating new off-channel habitats such as percolation channels. In the upper-Methow and Lost rivers, flows often disappear in late summer apparently as a result of natural phenomena. Percolation channels designed to take advantage of this circumstance would provide ideal year-round rearing environments.

(3) Riparian degradation throughout the basin should be stopped. Incentives for private landowner cooperation in programs to restore the riparian vegetation should be implemented. Programs for public education, development of riparian easements and enforcement of regulations should also be implemented.

(4) To ensure adequate large woody debris recruitment over time, Okanogan County must enforce its "Critical Areas" ordinance under the Growth Management Act and incorporate appropriate language into its Flood Management Plan. Washington State Forest Practices Act must be changed to require scientifically credible riparian buffer widths, and the U.S. Forest Service must adhere to the riparian reserve prescriptions in the Clinton Forest Plan. Additionally, the U.S.Forest Service should explore the possibility of adding large wood (whole tree scatter planting) to wood-deficient streams and stream reaches.

(5a) Spring chinook
Broodstock for the Winthrop rearing program should be changed to acquire broodstock from the Methow River system natural spawning population. Due to the depressed run, broodstock acquisition will by necessity be done over an extended period of time. This program should be implemented in a coordinated manner with the Methow Valley Spring Chinook program. The need for a new adult trap to be constructed in the natural production area of the Lost River should be evaluated. Release facilities, some of which are already developed as features of the PUD settlement agreements, are needed in natural production areas. Adult traps and release facilities exist on the Chewuck and Twisp rivers. Adult holding capabilities at Winthrop Hatchery must be modified to ensure proper separation of adults.

b) Summer chinook
Summer chinook adult traps and final rearing and/or acclimation facilities should be constructed in natural production areas. Adult holding capabilities at Wells Hatchery should be modified to ensure separation of adults.

c) Steelhead
Steelhead adult traps and release facilities should be constructed in natural production areas. Many of these facilities could be used in conjunction with the current spring and summer chinook programs of the Methow River basin. Adult holding capabilities at Wells Trout Hatchery may need modification to ensure separation of the adults.

d) Coho
The Winthrop National Fish Hatchery has previously been used to rear coho for release into the Methow River system. The program was highly successful, but was terminated when the decision by the fishery agencies was to move the coho program to the lower Columbia River hatcheries. Until the Turtle Rock facility is modified, and the spring chinook program is fully on line, it may be possible to utilize part of the production capability at Winthrop to rear coho for release in the Methow River.

The Rocky Reach Hatchery coho program produced 500,000 late run coho for release at the facility until 1992. Because of disease problems, adult production from this station was essentially non-existent. Providing a quality smolt can be reared at Turtle Rock, the facility could be modified to rear 500,000 coho smolts for release into the Methow River. Final rearing and/or acclimation facilities should be developed on the Methow River. Adult trapping facilities can utilize the existing trapping facilities at Wells Dam and those developed for summer chinook.

e) Fall chinook
The Rocky Reach Hatchery fall chinook program currently rears 500,000 smolts for release at the facility. Incubation and early rearing occurs at the Rocky Reach Hatchery facility located on the east bank of the Columbia River immediately below Rocky Reach Dam. Fish are then transferred to the Turtle Rock Rearing Pond facility, above the dam, where they are reared and released into the Columbia River.
The practice of releasing fish at the rearing pond has resulted in an increase in straying of fall chinook to other locations in the mid-Columbia. Adult fall chinook have also been

trapped at Wells Dam. As noted earlier fall chinook have only been recorded spawning in the Methow River. These fish are in all probability the result of straying past Priest Rapids Dam and past the rearing program at Wells Hatchery. This program should be terminated and a program of rearing summer chinook or coho reevaluated.

If the fall chinook is not terminated, broodstock should be acquired from Priest Rapids. Releases should occur below Priest Rapids Dam using final rearing and/or acclimation facilities in the natural production area.

(6) A program to restore lamprey should be developed by the relevant fishery managers. This program should be under the overall leadership of the tribes.

Table 3 shows the tribal recommended actions needed to restore the fish resources of the Methow River system.

Table 1

Methow River Fish Populations Status and Goals

Species	Current Population (5-year average)	Adult Return Goal
Spring Chinook	620[1]	2,000[2]
Summer Chinook	510[3]	3,000[2]
Steelhead	13,100[4]	10,000[2]
Coho	NA	NE
Fall Chinook	NA	NE
Lamprey	NA	NE

[1] Based on 1989-1993 redd counts. Assumes 2.5 fish per redd. Number rounded to nearest tenth.
[2] Harvest goal only. Natural production goal not established.
[3] Based on 1989-1993 redd counts. Assumes 2.5 fish per redd. Number rounded to nearest tenth.
[4] Based on years 1982-1986 from Wells Dam counts. Rounded to nearest tenth.
NA — Information not available
NE — None established

Table 2

Problems Impacting the Methow River Fish Resources

	Basinwide	Upper Methow	Lower Methow	Tributaries
Migration Barrier		•		
Irrigation Diversions	•			
Riparian Degradation	•			
Lack of Large Woody Debris	•			
Inadequate Production Compensation	•			

Table 3

Recommended Actions for the Methow River System

Problem	Recommended Action
Migration Barriers	(1) Construct passage facilities
Irrigation Diversions	(2) Line facilities, change to pump system, implement conservation programs, cease over-appropriation, implement plan
Riparian Degradation	(3) Restore riparian vegetation
Limited Large Woody Debris	(4) Retain woody debris
Inadequate Production Compensation	
Spring chinook, Steelhead Summer chinook, Coho	(5) Implement new broodstock programs, release programs, production programs
Lamprey	(6) Develop and implement programs

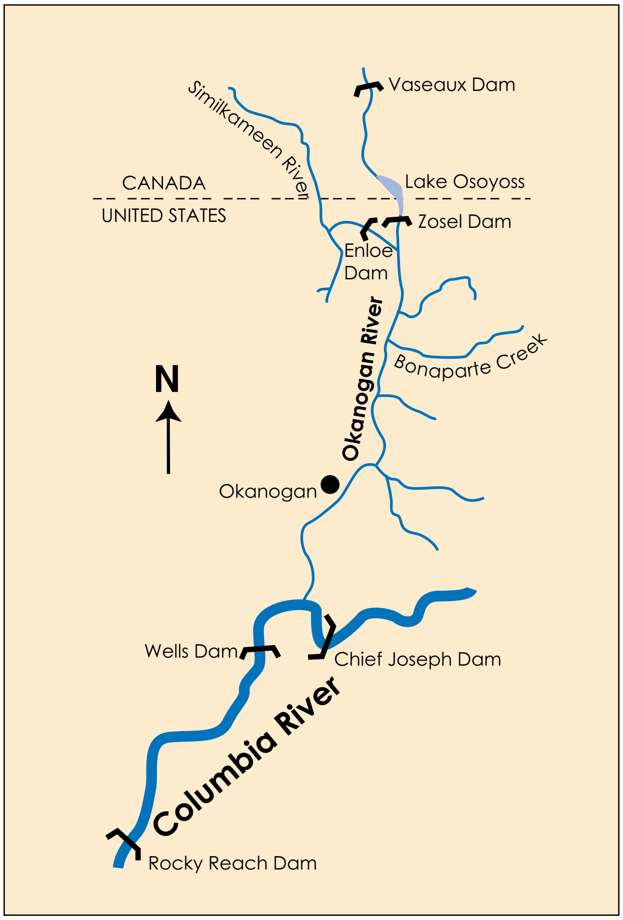
OKANOGAN RIVER

Prepared by the Yakama Indian Nation

Introduction

The Okanogan subbasin represents the upper limit of anadromous salmonids in the Columbia River Basin and enters the Columbia between Wells and Chief Joseph dams. The Okanogan subbasin straddles British Columbia and Washington, begins near Armstrong, British Columbia, and flows south through a chain of lakes. The first and largest of these is Lake Okanogan, followed by Lakes Skaha, Vaseaux and Osoyoos. The U.S. -Canadian border divides Lake Osoyoos into two, nearly equal parts. From Lake Osoyoos, the Okanogan River flows about 80 miles south where it enters the Columbia River near Brewster at river mile (RM) 533 (WDF et al. 1992).

The Similkameen River enters the Okanogan River from the northwest approximately 75 miles above the mouth. It is the main tributary to the Okanogan. The subbasin encompasses approximately 8,200 square miles.



Fish Population Status/Goals

A natural spawning run of summer chinook exists in the mainstem and the Similkameen River. Natural spawning of sockeye occurs in the Okanogan River (downstream of Vaseaux Dam) above Lake Osoyoos as well as a limited amount of lake spawning. Coho have been occasionally observed spawning in the mainstem. Steelhead natural production occurs throughout the basin. Spring chinook are believed to be extinct in the Okanogan subbasin.

The subbasin planners did not provide for specific run sizes to the Okanogan River. Their objective was to provide returns for harvest rather than natural production. Their recommended harvest objectives were 1,000 spring chinook, 2,000 summer chinook, 15,000 sockeye, and 10,000 hatchery reared steelhead. Table 1 shows the fish population status and goals.

Problems Impacting Fish Resources

Land and water resource management have significantly reduced habitat quality and quantity for all salmonid species and life stages. The Okanogan River mainstem suffers from extreme summer temperature, fine sediment, and low flow problems. These problems are further exacerbated by ubiquitous bank erosion and the attendant increase in channel width-to-depth ratio. Agricultural activities, including uncontrolled grazing, water diversions, and riparian vegetation removal, are the principal causes of the basin's habitat problems.

Tributary habitats have also been significantly affected by agriculture and additionally by forest practices and anthropogenic barriers. Salmon

Creek, as the name implies, once supported a spring chinook population, but is now entirely diverted into an irrigation delivery system. Enloe Dam blocks access to more than 95% of the anadromous habitat in the Similkameen River, the Okanogan's largest tributary. Additional thermal and or structural barriers exist on most tributaries within the subbasin.

Sockeye habitat in the Okanogan has been affected by loss of the riparian vegetation and channelization for flood control. There are additional problems, most notably dam blockage of the upper reaches of the Okanogan system. Correction of these passage problems could ultimately provide for full utilization of the spawning and rearing habitat. Low flows and high temperatures also affect sockeye migration in the Okanogan River during late summer and early fall. Sockeye rearing habitat in the system occurs in Lake Osoyoos. Water quality in Lake Osoyoos, the principal rearing area for Okanogan sockeye, may be a significant factor limiting smolt production. Warm summer water confines rearing juveniles to a relatively small portion of the lake's deeper upper basin. Instream flows are also a significant problem for sockeye. Flows in the Canadian portion of the subbasin are dropped approximately by half at the end of the irrigation season, resulting is redd exposure and occasionally total desiccation. Spring flows have also been inadequate to flush sockeye smolts from the system, leaving them vulnerable to predation by the river's considerable big mouth minnow population.

The Oroville-Tonasket Irrigation District has proposed a dam on Palmer Lake which would increase water temperatures in the Similka-meen River. Any temperature increase in this heavily stressed system could spell disaster.

Compensation programs for some stocks have been lacking and those that are being developed have either been to small or in some instances have not been implemented with the objective of restoring the natural runs. Table 2 shows the problems impacting the fish resources of the Okanogan River system.

Ongoing Actions In The Okanogan River System

Some measures have been implemented in the Okanogan River system as part of compensation programs for the mid-Columbia Public Utility District (PUD) projects. Previous mitigation attempts such as the mitigation for Grand Coulee Dam, were minor. Plan for correcting habitat problems have been completed, but little has been done to carry out the plans.

Hatchery production of summer chinook for the Okanogan River takes place at Wells Hatchery and the East Bank Hatchery. Broodstock for the programs is acquired from trapping at Wells Dam. Currently, releases from East Bank Hatchery occur in the Similkameen River near Oroville. The East Bank Hatchery program began by trapping adults at Wells Dam and transporting them to the East Bank Hatchery for holding until spawning.

Hatchery production of steelhead in the Okanogan River takes place at Wells Trout Hatchery. Releases occur in mainstem and the Similkameen River. The adult trap used to acquire broodstock for summer chinook at Wells Dam is also used for steelhead.

Sockeye production has been experimental as part of the Douglas County PUD Wells Dam settlement. The early rearing program is being developed on the lower Okanogan at Cashmere Springs by the Colville Tribe. The fish are then transported, placed in net pens and released in Lake Osoyoos.

Currently, there are no releases of coho or fall chinook into the Okanogan River system.
An advisory group of state, tribal, and federal fish managers, the Department of Ecology, and interested local irrigators has met with Canadian authorities in each of the past two years to recommend flow management operation schedules for the basin. The group meets each spring to decide how the limited available, unappropriated flow can be configured for fish.

The subbasin is closed to further water appropriation during the irrigation season.

Recommended Actions For The Okanogan River System

(1) The United States/Canada Boundary Waters Treaty should be amended to include flow agreements which better protect anadromous fish. Within the United States, the water code must be rigorously enforced, and opportunities to acquire water rights for instream flows for the mainstem and all tributaries should be aggressively pursued.

(2) Passage should be provided at Enloe Dam (dam removal is the best option) to the lakes located above Lake Osoyoos, Salmon Creek and the natural falls on Omak Creek. Due to the large sediment load, barriers have developed in the mainstem. The riparian area should be restored and bio-engineered erosion control measures implemented. Such approaches will reduce width-to-depth ratio and make limited water more useable as fish habitat.

(3) Grazing and agricultural practices should be improved to prevent sedimentation of spawning and rearing habitat. Funding to develop additional Coordinated Resource Management Programs which feature riparian protection/recovery should be made available.

(4) Okanogan County must strictly enforce its Critical Areas Ordinance and further ensure that all remaining riparian areas are protected.

(5) Lumber mill effluent on Omak Creek should be treated before being released into the system. Standards of the Clean Water Act or state standards should be investigated and enforced.

(6) Wetland and riparian restoration projects should be implemented on all tributaries and on the mainstem.

(7) The Washington Forest Practices Act should be amended to include scientifically credible Riparian Management Zone prescriptions.

(8a) Summer chinook
Wells Hatchery is located on the west bank of the Columbia River below Wells Dam. It is part of Douglas County PUD's mitigation for Wells Dam and is operated by Washington Department of Fish and Wildlife. The facility was designed and constructed to rear 4,400,000 summer chinook to subyearling smolt size. The program was modified in 1984 to require the release of 400,000 fish into the natural production area of the Methow River. Releases have also been proposed for the Okanogan River. An adult trap and final rearing and/or acclimation facility should be constructed in natural production area of the mainstem. Adult holding capabilities at Wells Hatchery should be modified to ensure separation of adults.

The Eastbank Hatchery program for the Okanogan River was started by trapping adults at Wells Dam for release in the Similkameen River. The hatchery is designed to rear 1,816,000 yearling smolts, of which 576,000 are released into the Similkameen River. The Okanogan River releases are the responsibility of the Chelan County PUD and should be coordinated with the Douglas County PUD's Wells Dam program to ensure compatibility.

b) Steelhead
Wells Trout Hatchery is located on the west bank of the Columbia River immediately below Wells Dam. It was constructed in 1967 as mitigation for Wells Dam. The facility was improved in the mid 1980s by the Bureau of Reclamation as part of the Oroville-Tonasket Project and currently has the capacity to rear 450,000 smolts. Current funding for the operation is provided by Douglas County. The facility is operated by the Washington Department of Fish and Wildlife. Currently, the facility rears summer run steelhead some of which are released into the Okanogan and Similkameen rivers. Broodstock for the program originated mainly from adults trapped at Priest Rapids Dam. Broodstock collection was moved to the Wells Dam ladder in the early 1980s. This allows naturally spawned and hatchery returns destined for the streams above Wells Dam to be used as broodstock on an annual basis.

Although the existing broodstock collection provides for the use of some naturally spawning stocks, it does not provide for separation of the stocks above Wells Dam. To ensure the program is more responsive to the natural runs, new adult traps and final rearing and/or acclimation facilities should be constructed in natural production areas. Many of these facilities could be used in conjunction with the summer chinook program.

Adult holding capabilities at Wells Trout Hatchery may need modification to ensure separation of the adults.

c) Sockeye

Douglas County PUD's Wells Dam Settlement Agreement calls for the rearing and release of 200,000 sockeye at 25 fish/pound into Lake Osoyoos. Broodstock is acquired at the Wells Dam trap, with incubation occurring at Cashmere Springs located on the lower Okanogan River. The program is funded by the PUD and operated by the Colville Tribe. Fish are put in net pens for partial rearing released as pre-smolts to complete their final rearing in the lake environment. Providing the program is successful, it will be increased to 375,000 at 25 fish/pound for release into Lake Osoyoos.

d) Coho

Turtle Rock hatchery water supply should be improved so that it can begin a coho release program for the Okanogan River. The facility could be modified to rear 500,000 coho smolts in place of the existing fall chinook program. Final rearing and/or acclimation and release facilities should be developed on the Okanogan River. Adult trapping facilities can utilize the existing trapping facilities at Wells Dam and those developed for summer chinook once the runs have been reestablished. It must be stressed that this program can only be achieved if the disease problems at Turtle Rock facility are corrected.

e) Fall chinook

Rocky Reach Hatchery (Turtle Rock Rearing Pond) currently rears and releases 500,000 subyearling fall chinook at Turtle Rock. Incubation and early rearing occurs at the Rocky Reach Hatchery facility located on the east bank of the Columbia River immediately below Rocky Reach Dam.

The practice of releasing fish at the rearing pond has resulted in an increase in the straying of fall chinook to other mid-Columbia locations. Adult fall chinook have also been trapped at Wells Dam. Sporadic spawning of fall chinook has been documented in the Okanogan River. These fish are in all probability the result of straying past Priest Rapids Dam, the past rearing program at Wells Hatchery and most recently the rearing and release of bright fall chinook at Turtle Rock. This program should be terminated and the facilities reevaluated for rearing summer chinook or coho.

Adult trapping facilities should be developed for all of the stocks including summer chinook and steelhead. Since there is only one stock of sockeye located above Wells Dam, the adult trapping at the dam should continue.

Additional final rearing and/or acclimation facilities should be developed for all species throughout the natural production areas. The facilities could consist of ponds, raceways, net pens or other such structures.

(9) A program to restore lamprey should be developed by the relevant fishery managers. This program should be under the overall leadership of the tribes.

Table 3 shows the tribal recommended actions needed to restore the fish resources of the Okanogan River system.

Table 1

Okanogan River Fish Populations Status and Goals

Species	**Current Population (5-year average)**	**Adult Return Goal**
Summer Chinook	860[1]	2,000[2]
Sockeye	47,300[3]	15,000[2]
Steelhead	1,750[4]	10,000[2]
Spring Chinook	0	1,000[2]
Coho	NA	NE
Fall Chinook	NA	0
Lamprey	NA	NE

[1] Based on 1986-1990 redd counts. Assumes 2.5 fish per redd. Number rounded to nearest ten.
[2] Harvest goal only. Natural production goal not established.
[3] Based on Wells Dam counts 1983-87.
[4] Based on years 1984-88.
NA — Information not available
NE — None established

Table 2

Problems Impacting the Okanogan River Fish Resources

	Basinwide	Upper Okanogan	Lower Okanogan	Tributaries
Thermal Barrier		•	•	•
Passage Barriers		•	•	•
Sedimentation	•			
Low Stream Flows	•			
Poor Water Quality	•			
Inadequate Production Compensation	•			

Table 3

Recommended Actions for the Okanogan River System

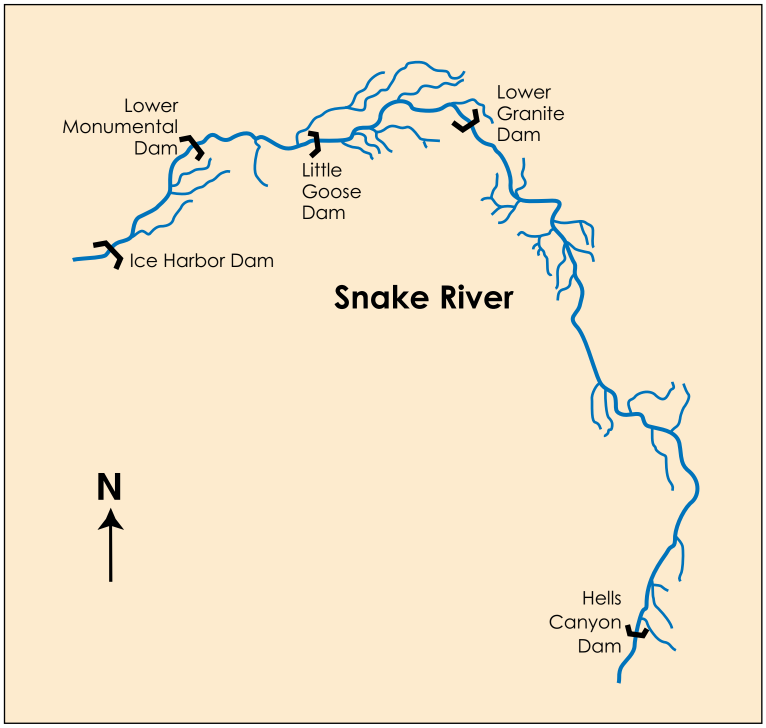
Problem	Recommended Action
Thermal Barrier	(1) Secure instream flows, renegotiate boundary water treaty, restore riparian vegetation
Passage Barrier	(2) Provide passage
Sedimentation	(3) Eliminate or reduce grazing, provide gravel flushing flows
Low Stream Flows	(4) Provide instream flows, cease over-appropriations
Poor Water Quality	(5) Enforce Clean Water Act, process effluent
Inadequate Production Compensation	
Spring chinook, Steelhead Summer chinook, Coho	(6) Implement new broodstock programs, release programs, production programs
Lamprey	(7) Develop and implement programs

SNAKE RIVER MAINSTEM

Prepared by the Columbia River Inter-Tribal Fish Commission, the Nez Perce Tribe and the Confederated Tribes of the Umatilla Indian Reservation

Introduction

The Snake River mainstem is that section of the river from Hells Canyon Dam downstream to the Columbia River. This section of the river generally flows northward forming the border of Idaho and Oregon and Washington until it turns westward at Lewiston, Idaho. The Snake River Basin is the largest drainage system that enters the Columbia River. The drainage area for the basin is approximately 34,100 square miles (WDF, Et al., 1990). The principal tributaries in this section of the river, which are described individually in these subbasin plans include the Salmon, Clearwater, Imnaha, Grande Ronde, and Tucannon rivers. In addition to these major rivers, minor tributaries, such as Asotin Creek, enter the Snake River.



Fish Populations Status/Goals

Currently natural spawning of fall chinook in the Snake River occurs mainly in the mainstem below Hells Canyon Dam. Small populations also appear to spawn below the lower Snake River mainstem dams. Inundation of habitat by dam construction has significantly affected fall chinook spawning in the mainstem Snake.

Natural production of spring chinook occurs in Asotin Creek. Natural production of steelhead occurs in the mainstem and other minor tributaries such as Asotin Creek.

The recommended goal for mainstem Snake River fall chinook is 18,300. Numerical objectives were not developed for spring chinook or steelhead. Table 1 shows the populations, status and goals.

Problems Impacting Fish Resources

The major habitat needs in this section of the river continue to be passage at mainstem dams and flows below the Hells Canyon Dam. An existing Federal Energy Regulatory Commis-sion (FERC) settlement between the Idaho Power Company (IPC) and fishery agencies requires IPC to provide flows for downstream migration should the fishery agencies require IPC to release fall chinook (FERC Settlement Agreement, 1980). This part of the settlement agreement has not been implemented.

Also found in this section of the river are large irrigation pumps. These pumps, when not properly screened, attract downstream migrants out of the mainstem and into the irrigation systems where they are lost.

Compensation programs for the losses incurred by the construction of the mainstem dams have been limited, improperly placed or non-existent.

Ongoing Actions In The Snake River Mainstem

A study recently determined the extent of the mortality associated with irrigation pumps and recommended corrective actions that should be taken.

Hatchery production of spring chinook for the mainstem Snake River occurs at Rapid River Hatchery. In 1994, spring chinook were also released below Hells Canyon Dam from Lookingglass Hatchery. An adult trap has also been constructed below Hells Canyon Dam to acquire broodstock. Direct stream releases occur at the adult trap. Since these fish are part of the Rapid River stock, the National Marine Fisheries Service (NMFS) does not consider them as listed Snake River spring chinook even though these Rapid River fish represent the only major stock currently being reared that originated from the Snake River system.

The Northeast Oregon Hatchery is currently being planned as a measure in the Northwest Power Planning Council (NPPC) Fish and Wildlife Program. It is expected that the facilities) will provide some fish for release in Snake River tributaries in Northeast Oregon and Southwest Washington.

Hatchery production of fall chinook in the mainstem Snake River takes place at Lyons Ferry Hatchery. Adult trapping currently occurs at Lyons Ferry Hatchery and Lower Granite Dam. Releases from the facility currently occur at the hatchery. Previous releases also occurred below Ice Harbor Dam with broodstock expected to return and be trapped at the hatchery or Ice Harbor Dam adult trap. NMFS has not included these fish in the listing of Snake River fall chinook, although beginning in 1996 they will allow the use of Lyons Ferry stock to supplement natural production above Lower Granite Dam.

Oxbow Hatchery is an Idaho Power Company facility that is currently used to hold steelhead and spring chinook. Although the facility is on-line, it currently does not produce fall chinook.

The Nez Perce Hatchery being studied under the NPPC Fish and Wildlife Program may include a fall chinook component. Currently, the Nez Perce Hatchery program is being designed to consist of a central incubation, rearing and release facility. Broodstock will be acquired from trapping at Lower Granite Dam.

Hatchery production of steelhead for the mainstem Snake River takes place at Lyons Ferry Hatchery. In addition and as noted in the individual basin recovery plans, final rearing ponds have been constructed in the Tucannon and Grande Ronde river systems. Two final rearing ponds have also been constructed outside the Snake basin in the Walla Walla River system. Broodstock is expected to return mainly to the hatchery.

Releases of full-term reared smolts occur at the hatchery and ponds. Past broodstock has included eggs from Wells and Skamania stocks.

Recommended Actions For The Snake River Mainstem

Artificial Production Actions for Mainstem Snake Subbasin

1. Begin a fall chinook supplementation program using Lyons Ferry stock. For the interim, produce yearlings (up to 900,000) and subyearlings (after full yearling production is met).

   a. Reduce releases at Lyons Ferry Hatchery to a level which (on average) will result in adult rack returns adequate to meet no more than broodstock needs. Outplant remaining juveniles above Lower Granite Dam.

   b. Maintain adult capture capabilities at Lower Granite Dam to capture broodstock as necessary.

   c. Develop adult capture and juvenile acclimation/release facilities in the Asotin Creek and Pittsburg Landing areas on the Snake River and selected tributaries to support future broodstock collection and smolt outplanting activities. Until final facilities are developed, direct stream releases should occur immediately.

2. Any returning adults not required to meet the above two objectives should be released above Lower Granite Dam into the natural production area.

3. Continue the summer steelhead program at Lyons Ferry Hatchery using Lyons Ferry stock.

4. Begin a natural broodstock summer steelhead program in Asotin Creek. The program should be phased in with releases occurring as production becomes available.

5. Develop adult capture and juvenile acclimation/ release facilities in Asotin Creek to support future broodstock collection and smolt outplanting activities. Until final facilities are developed, direct stream releases should occur.

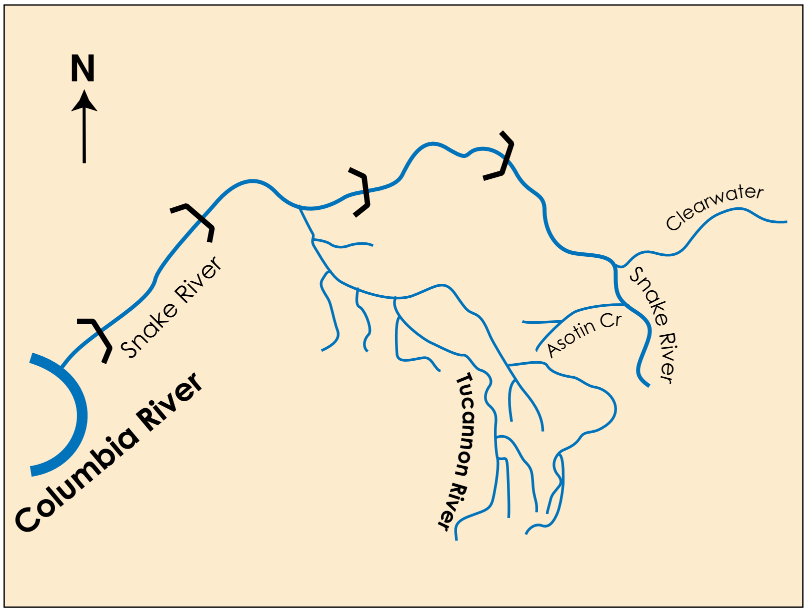
6. Discontinue all catchable trout programs in areas where they may affect anadromous salmonid restoration activities.

7. A program to restore lamprey populations utilizing either transplantation or artificial propagation should be developed under the overall leadership of the affected tribes.

8. Monitor and evaluate all artificial production actions. Use adaptive management to determine whether program changes (i.e., release number, size, time, location, and/or life history) are needed in order to meet restoration objectives.

TUCANNON RIVER

Prepared by the Confederated Tribes of the Umatilla Indian Reservation and the Nez Perce Tribe



Introduction

The Tucannon River originates in the Blue Mountains of the Umatilla National Forest at an elevation of 6,387 feet. It drains approximately 550 square miles flows north for 50 miles through Washington state and enters the Snake River near Starbuck, Washington at 500 feet elevation (WDF, et. al., 1990). The principal tributary is Pataha Creek.

Fish Population Status/Goals

Natural production of spring chinook occurs in the Tucannon River. Recent returns have averaged about 400 adults per year, until 1994 when only about 100 fish returned. Natural production of fall chinook in the Tucannon River has been observed at small levels since the construction of Lyons Ferry Hatchery. These fish are believed to be strays from the hatchery release program. The National Marine Fisheries Service (NMFS) has listed the spring and fall chinook as threatened under the Endangered Species Act. Natural production of group A steelhead occurs in the Tucannon River.

The tribes recommended adult return goals are 3,000 for spring chinook and 2,000 for fall chinook. The recommended objective for summer steelhead is 2,200 fish with a natural escapement of 1,500 and a harvest of 700 fish. Table 1 shows the fish populations, status and goals.

Problems Impacting Fish Resources

Problems in the basin include those related to both habitat and production. Habitat problems noted by the subbasin planners include high temperatures, irrigation, sedimentation, loss of riparian vegetation and passage (Ibid). Inadequate production programs and failure to mitigate for lost species also occur in the Tucannon River system.

Ongoing Actions In The Tucannon River System

Hatchery production of spring chinook for the Tucannon River occurs at Lyons Ferry Hatchery. An adult trap and release facility are located on the Tucannon River at the existing Tucannon Hatchery.

Hatchery production of fall chinook takes place at Lyons Ferry Hatchery. It is believed that some of the returns have strayed to the Tucannon River.

Hatchery production for steelhead in the Tucannon River takes place at Lyons Ferry Hatchery. Broodstock sources for steelhead released into the Tucannon River have included Skamania, Wells, Priest Rapids and Lyons Ferry Hatchery. In addition to the hatchery, a final rearing and release pond has been constructed in the Tucannon River. Releases of full-term reared smolts occurs at the pond.

Broodstock is acquired from the returns to Lyons Ferry Hatchery. When broodstock does not arrive, eggs are exchanged between stations. As noted, Wells, Priest Rapids and Skamania stocks have been used in the Tucannon River.

Some measures have been implemented to correct habitat problems.

Recommended Actions For The Tucannon River System

Habitat Enhancement Actions for Tucannon

I. Administrative

A. Laws and Codes, Enforcement & Revision

- State of Oregon (OR)/Environmental Protection Agency complete Total Maximum Daily Load for stream temperatures, sediment, other pollutants (Clear Water Act)
- Enforce Oregon fish screening statutes
- Upgrade Oregon Forest Practices Act to be consistent with Upper Grande Ronde (UGR) Anadromous Fish Habitat Plan
- Upgrade Forest Service Land and Resource Management Plans consistent with UGR Plan to be in compliance with National Forest Management
- Revise mining laws to be consistent with production of high quality water and fish habitat

II. Instream Flow & Passage

A. Instream Flow Enhancement

- Purchase, exchange, lease or seasonally rent water rights for selected fish habitat during critical low flow periods
- Implement more efficient irrigation methods and water conservation practices benefitting landowners and instream flows

III. Watershed Management

A. Water Quality Needs

- Increase shade cover to reduce stream temperatures (increased downstream extent of temperatures <60°F)
- Reduce sediment from agricultural practices and unimproved roads
- Reduce nitrate, phosphates, bacteria and other contaminants related to agricultural practices
- Manage ponds and lakes that are located in close proximity to the mainstem Tucannon in a manner that will minimize contribution of elevated water temperatures

PRIORITIES: Mainstem Tucannon River, Pataha Creek

B. Riparian Restoration Needs

- Implement UGR Plan on state, federal and tribal lands
- Implement Best Management Practices (BMPs), including stream buffers to benefit fish on private lands
- Acquire, lease or implement management agreement to restore natural floodplain habitat and function
- De-emphasize recreational use along upper mainstem Tucannon River by relocating existing use

PRIORITIES: Mainstem Tucannon River, Pataha Creek

C. Range Management

- Revise and implement BMPs to be consistent with UGR Plan Standards & Guidelines (S&Gs)
- Restrict/remove livestock in substandard areas
- Acquire, lease, develop projects in priority areas (see above)

D. Forest Management

- Upgrade, monitor, enforce Forest Practices Act consistent with UGR Plan S&Gs on private lands
- Implement UGR Plan Standards & Guidelines on state, federal, tribal lands
- Identify and implement active restoration projects
- Institute or continue protection of “good” habitat areas such as upper Tucannon drainage within wilderness area and upper mainstem Tucannon River below wilderness area

E. Mining Impact Reduction Needs
No current problems

Artificial Production Actions for Tucannon Subbasin

1. Maintain the Tucannon stock spring chinook program of 132,000 yearling smolts.

   a. Use no more than 50% of the returning adults for program broodstock requirements. Release all other returning adults upstream into the primary natural production area.

   b. Change release location to a site upstream of the hatchery weir to encourage more escapement above the weir into the best spawning/rearing habitat area. Immediately develop acclimation facilities in the primary natural production area. In the interim, acclimate and release spring chinook from the Curl Lake acclimation pond.

2. Discontinue use of non-native stocks in the existing summer steelhead program. Develop a new broodstock population from natural Tucannon returns.

   a. Reduce program to 120,000 yearling smolts.

   b. Continue the existing steelhead release program from Curl Lake in a manner which would not interfere with spring chinook acclimation.

3. Begin acclimation/release program of 500,000 subyearling fall chinook. Lyons Ferry stock should be used as the founder population for this program.

   a. Develop adult capture and juvenile acclimation/release facilities in the Starbuck Dam area to support future broodstock collection and smolt outplanting activities. Until final facilities are developed, direct stream releases should occur.

4. Evaluate historical status of coho populations and current production potential in the subbasin for reestablishment of species.

5. Discontinue all catchable trout programs in areas where they may affect anadromous salmonid restoration activities.

6. A program to restore lamprey populations utilizing either transplantation or artificial propagation should be developed under the overall leadership of the affected tribes.

7. Monitor and evaluate all artificial production actions. Use adaptive management to determine whether program changes (i.e., release number, size, time, location, and/or life history) are needed in order to meet restoration objectives.

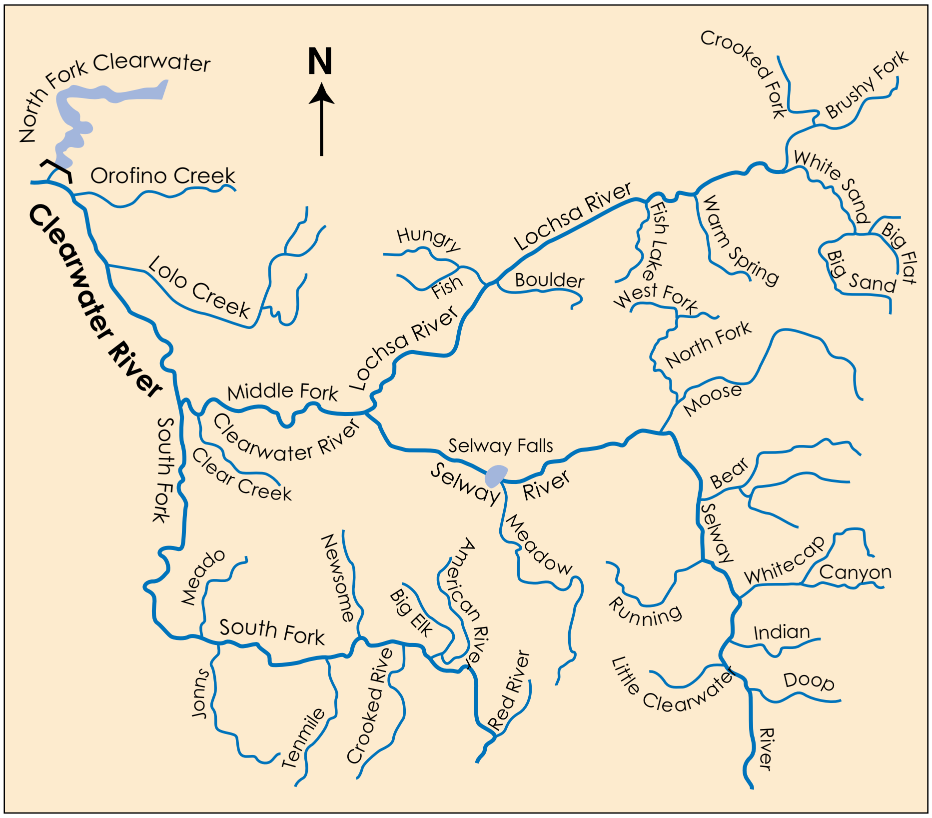
Table 1
Tucannon River Fish Populations Status and Goals

Species	Current Population (5-year average)	Adult Return Goal
Spring Chinook	400	3,000
Steelhead	NA	2,200
Fall Chinook	NA	2,000
Lamprey	NA	NE

NA — Information not available
NE — None established

CLEARWATER RIVER

Prepared by the Nez Perce Tribe



Introduction

The Clearwater River is located in north central Idaho and drains approximately 9,645 square miles. The subbasin extends from the Washington and Idaho border in the west to the eastern headwaters along the west slope of the Bitterroot Moun-tains along the border of Idaho and Montana. It elevations range from 9,000 feet at the headwaters to 700 feet at the mouth where it enters the Snake River at Lewiston, Idaho. The main tributaries include the Locsha, Selway, South Fork and North Fork rivers (NPT, et al., 1990). Other tributaries include the Red River, Lolo, Orofino, Newsome, Brushy Fork and Lapwai creeks.

Fish Populations Status/Goals

Natural spawning runs of spring chinook in the Clearwater River system were severely impacted by Lewiston Dam. Its removal in 1972 opened up major habitat which has led to re-establishment of natural spawning in all of the major subdrainage and tributary streams. These actions demonstrate the ability of fish runs to be re-established with dam removal and supplementation. The streams include Newsome, Meadow, and Johns creeks and the Crooked, American, and Red rivers in the South Fork drainage; Crooked Fork, Brushy Fork, Boulder Creek, and White Sands Creek in the Lochsa drainage; Selway River and Bear, Meadow, Running, Whitecap and Moose creeks in the Selway drainage; and Lolo Creek and Eldorado Creek in the Lolo Creek drainage. These natural runs have not been listed under the Endangered Species Act.

A remnant natural spawning run of summer chinook may exist in the Clearwater River system as a result of past hatchery releases. Existence of natural spawning summer chinook should be confirmed.

A natural spawning run of fall chinook occurs in the Clearwater River. These fish have been designated as endangered by the (NMFS).

Historical information regarding locations of natural spawning runs of coho in the Clearwater River system is not recorded. Attempts to restore coho runs in the South Fork and its tributaries occurred in the 1960s using egg incubation channels and fry plants. The Integrated System Plan recognized

Orofino Creek as having potential for reintroduction of coho through supplementation. Nez Perce tribal members have also noted that coho were found in such streams as Fish Creek and Clear Creek.

Natural spawning runs of both group A and group B steelhead exist in the Clearwater River system. Group A are found in the lower river tributaries. Natural spawning in the Clearwater system occurs in all of the major subdrainage and tributary streams. These include: Newsome, Meadow, and Johns creeks and the Crooked, American, and Red rivers in the South Fork drainage; Crooked Fork, Brushy Fork, Boulder Creek, and White Sands Creek in the Lochsa drainage; the Selway River and Bear, Meadow, Running, Whitecap, and Moose creeks in the Selway drainage; and Lolo Creek and Eldorado Creek in the Lolo Creek drainage.

The subbasin planners recommended a long- term objective of 60,000 spring chinook to the basin with a natural spawning component of 10,000 fish and a harvest component of 45,000 fish. The recommended long-term minimum objective for summer chinook is 50,000 fish. The long-term objective run size for fall chinook is 50,000 fish. The recommended objective for coho is 14,000 fish. The recommended long-term objective for B-run steelhead is 91,000 fish with a natural spawning component of 12,000 fish and a harvestable component of 74,000 fish. For the A-run component the objective is for 2,000 fish with an escapement of 1,000 and harvest of 1,000. Table 1 shows the fish populations, status and goals.

Problems Impacting Fish Resources

Existing habitat condition in the Clearwater system varies widely. Problems noted in the subbasin plan include logging, road building, grazing, mining, barriers and others (Ibid). The subbasin planners noted specific major habitat constraints in 45 spring chinook streams and 63 steelhead streams (Ibid). These constraints include sedimentation, low flows, water quality (temperatures), migration barriers, rearing and spawning habitat, riparian degradation and channel/bank instability (Ibid). Habitat programs are not coordinated on a watershed basis thus limiting their effectiveness to restore the habitat.

Compensation programs for the Clearwater River system have been limited or non-existent. Programs have not been developed and/or implemented with the objective of restoring the natural spawning populations. Off-station release programs for the most part occur to provide fisheries rather than to increase the natural spawning runs. Tribal production planning has been occurring since 1982 with little or no program implementation even though the programs are intended to increase the natural populations. As terminal fisheries and production programs develop on hatchery returns, the ability to modify the release to the habitat becomes more difficult. Releases of fall chinook and coho do not occur in the subbasin at this time. In 1993, returns of fall chinook to the Dworshak Hatchery were destroyed rather than used to help restore natural spawning populations. Table 2 shows the problems impacting the Clearwater River system.

Ongoing Actions In The Clearwater River System

Some habitat improvements have occurred in the basin under the Northwest Power Planning Council's (NPPC)Fish and Wildlife Program. These include improvements on Meadow Creek, Crooked River, and Red River in the South Fork; Brushy Fork and White Sands Creek in the Lochsa; and Lolo Creek and Eldorado Creek in the Lolo Creek drainage.

Hatchery production of spring chinook in the Clearwater River occurs at several major hatcheries and rearing ponds. Hatcheries constructed include Dworshak, Kooskia, and Clearwater Anadromous Hatchery. In addition to the major hatcheries, rearing ponds have been constructed at Red River, Powell, and Crooked River. Facilities being studied under the Fish and Wildlife Program include the Nez Perce Tribal Hatchery. Adult traps have been constructed at the hatcheries and rearing ponds.

Releases occur at the hatcheries or adult traps, with broodstock expected to return and be trapped at those locations. When broodstock does not arrive, eggs are acquired from other stations. Over the years, Carson, Leavenworth, Little White Salmon, and Cowlitz hatcheries have been used to provide broodstock. The primary back-up station in recent years has been the Rapid River Hatchery.

To begin a program of tributary releases and to begin restoring natural production, the Nez Perce Tribe has utilized the Sweetwater Springs incubation and early rearing facility to rear and release spring chinook into Meadow Creek a tributary of the Selway. The program began by utilizing Rapid River broodstock. The fish are released as Time Released Fed Fry (TRFF) utilizing a helicopter to distribute the fish throughout the stream. The spring chinook reared in the Clearwater River system have not been designated by the NMFS under the Endangered Species Act.

Hatchery production of steelhead in the Clearwater River takes place at Dworshak Hatchery and the Clearwater Anadromous Hatchery. Releases of full-term reared smolts at Dworshak Hatchery occur mainly at the hatchery. Broodstock is expected to return and be trapped at the hatchery. The Clearwater Anadromous Hatchery releases occur throughout the Clearwater system. The broodstock for the program is trapped at Dworshak Hatchery.

Recommended Actions For The Clearwater River System

(1) Logging, road building and the loss of the riparian vegetation has created high cobble embededness. To eliminate or reverse this problem, those practices should be stopped or severely restricted until the streams can recover.

(2) The loss of the riparian area is occurring throughout the watershed. Practices such as mining, logging and development in the riparian area must be halted and the riparian vegetation be allowed to recover.

(3) Sedimentation due to logging is occurring throughout the watershed. In addition, mining and road building also continue to create sedimentation problems. The watershed must be left to recover by eliminating or severely restricting these practices. Riparian restoration must be carried out.

(4) High water temperatures like the other problems are mainly due to logging, road building and grazing. Establish-ment, adoption and enforcement of standards under the Clean Water Act are necessary. As noted, eliminating or severely restricting logging, grazing and road building are needed.

(5) In lower river tributaries where agricultural diversions exists, high water temperatures and low stream flows are a problem. The adoption and enforcement of instream flows are needed.

(6) Land use practices in highly erodible streams such as Deadman and Canyon creeks must be controlled and limited to ensure that little to no erosion occurs.

(7) Practices such as logging which removes large woody debris from the riparian areas must be terminated. Large woody debris must be maintained to help ensure the stream integrity.

(8a) Spring chinook

The Dworshak Hatchery spring chinook program is part of the Lower Snake River Compensation Plan. Dworshak Hatchery is located on the North Fork of the Clearwater River approximately one mile below Dworshak Dam. It has been constructed to rear 1,200,000. Although the program calls for off-station releases, most of the smolts have been released at the hatchery site to ensure broodstock needs are met. The release of fingerlings excess to program needs have occurred off-station. Additionally, smolts have been released at the Powell Adult Trap site. Fingerlings are also provided to Red River Pond, Crooked River Pond and Powell Pond. Returns will be used as broodstock in the Clearwater Anadromous Hatchery program.

Development of the Dworshak run has utilized numerous hatchery runs including Carson, Leavenworth, Little White Salmon and Rapid River. The Dworshak program is very representative of the Clearwater River spring chinook programs in that a variety of spring chinook runs have been used to develop the program. Currently, there are adult trapping facilities on the upper Lochsa at the Powell Adult Trap and the upper South Fork at the Red River and Crooked River adult traps.

Clearwater Anadromous Hatchery was constructed as part of the Lower Snake River Compensation Plan. It has been designed to rear and release 1,369,500 spring chinook smolts. Additionally, the facility will provide 1,050,000 fry for rearing and release at three satellite facilities in tributaries of the Clearwater. The facility should provide the fry for the satellite rearing facilities. In conjunction with other rearing programs, the smolts should be released to the natural production areas of the Clearwater River system. Broodstock acquisition should use, to the extent possible, the currently constructed traps. Construction of additional traps will be necessary in other natural production areas. Final rearing and/or acclimation facilities should be constructed in the natural production areas.

Red River Rearing Pond was originally constructed in the early 1970s. It was incorporated as a program of the Pacific Northwest Regional Commission, composed of the governors of Washington, Oregon, and Idaho. The Red River Program is unique in that it rears spring chinook under semi-natural rearing conditions. The fish are introduced into the pond in early summer as fed fry and allowed to leave the pond in late fall as fingerlings to over-winter in the natural environment of the Clearwater River system. Most of the fish have been acquired from Rapid River Hatchery.

Recently, the facility has been upgraded and adult trapping capabilities installed as part of the Lower Snake River Compensation Plan. Broodstock is now taken from the returning adults. The program should continue and the unique nature of the past rearing and release program maintained. The program had been very successful in returning adults. A significant increase in the natural spawning population had been demonstrated. In recent years the program has taken too many adults. The tribal recommended broodstock trapping protocol that does not adversely affect the natural production is needed.

Crooked River Pond, located on the South Fork, and Powell Pond, located on the upper Lochsa, are operated in a manner similar to Red River. As with Red River, a broodstock trapping protocol is needed at the facilities. All three are considered part of the Clear-water Anadromous Hatchery program.

Kooskia Hatchery is a federally constructed enhancement hatchery constructed on the Nez Perce Indian Reservation and is capable of rearing 800,000 spring or summer chinook smolts. It is located near the mouth of Clear Creek, a tributary of the Middle Fork. Over the years, the hatchery has used numerous upriver broodstocks for its program. Like the other programs in the Clearwater system, its current primary backup station is Rapid River Hatchery. In recent years the hatchery has been operated in conjunction with Dworshak Hatchery. Releases have been mainly at the hatchery.

Releases from this facility should include off-station releases in tributaries of the Clearwater. Although the Clearwater system has had numerous releases of non-indigenous stocks, the primary option for broodstock acquisition should be trapping at release sites. Secondary programs could include any of the other trapping facilities on the Clearwater system. Releases should be done utilizing final rearing and/or acclimation facilities. Because of the wilderness designation, construction of facilities for releases into Selway River, even temporary ones, may not be allowed. In such a case, direct stream releases should occur. Helicopter releases may be necessary.

The Nez Perce Tribal Hatchery has been planned under the NPPC Fish and Wildlife Program since 1982. The spring chinook program has been designed to consist of a central incubation and early rearing facility. Fish will then be moved to eleven tributary facilities. Fish will be reared at the tributary satellite facilities during the summer months and will be released in late fall to over-winter in the natural environment. Once reestablished and adult trapping facilities constructed, broodstock will be acquired in tributaries where fish will be released.

(b) Summer chinook
Kooskia Hatchery is capable of rearing 800,000 spring or summer chinook smolts. Although it is currently rearing spring chinook, future rearing at this facility may be converted to summer chinook to begin a program for that stock in the Clearwater River basin. Broodstock for the program would originally be acquired from the South Fork Salmon River. Releases would all be off-station in tributaries of the Selway. Future broodstock could be acquired by trapping at Selway Falls if feasible.

The Clearwater Anadromous Hatchery should provide 400,000 smolts to assist in the restoration of summer chinook in the Clearwater River system.

Besides the facilities currently on-line, additional facilities proposed under the Integrated System Plan would provide up to an additional 500,000 summer chinook smolts for the Selway River.

c) Fall chinook
Lyons Ferry Hatchery, which is located in Lower Monumental Pool, was designed to rear 9,100,000 fall chinook smolts for release into the Snake River. Broodstock for the program has been developed by trapping adults at the hatchery and Ice Harbor Dam. Smolts are released in the Snake River at the hatchery. Past releases have also occurred below Ice Harbor Dam. Trapping broodstock at the hatchery and Ice Harbor Dam should be terminated and a trapping program begun at Lower Granite Dam. Releases at the hatchery and below Ice Harbor Dam should be terminated and all releases should occur above Lower Granite Dam in natural production areas. Up to one-half of the production should be considered for release annually into the Clearwater River.

The Nez Perce Hatchery being studied under the Fish and Wildlife Program may include a fall chinook component. Currently, the Nez Perce Hatchery program is being designed to consist of a central incubation, rearing, and release facility. Broodstock will be acquired from trapping at Lower Granite Dam.

d) Coho
The Sandy River Hatchery is part of the Mitchell Act program. It is located on the Sandy River near the town of Sandy, Oregon. It currently rears 1 million early run coho for release at the hatchery. To begin a program in the Clearwater River system, current operations would be modified by releasing smolts into Orofino Creek and Fish Creek. Final rearing and/or acclimation and release facilities should be developed on Orofino Creek.

e) Steelhead
The Dworshak Hatchery steelhead program is mitigation for the construction of Dworshak Dam on the North Fork of the Clearwater. Dworshak Hatchery is located on the North Fork of the Clearwater River approximately one mile below Dworshak Dam. It rears 1,300,000 to 2,500,000 group B steelhead smolts. Most of the smolts are released at the hatchery site to ensure broodstock needs are met. Off-station releases of smolts are made mainly to provide harvest. The release of fry, fingerlings, and adults in excess to program needs have occurred off-station. In recent years Kooskia Hatchery, has been used as an early rearing station for Dworshak Hatchery.

Broodstock development has occurred by trapping fish from the North Fork. The broodstock has been manipulated over the years to provide for sport fishing needs. These stocks should no longer be used as a predominate source for release to the natural production areas. New broodstock acquisition programs should be undertaken to acquire broodstock from the tributaries of the Clearwater. This program should be done in conjunction with the Clearwater Anadromous Hatchery.

Clearwater Anadromous Hatchery has been designed to rear and release 2,500,000 steelhead smolts. All the fish are to be released off-station to provide additional fishing opportunities and supplement natural production. Currently no broodstock source other than Dworshak Hatchery has been identified for the program.

Broodstock acquisition should be changed to work in combination with the spring chinook trapping facilities. Final rearing and/or acclimation facilities should be constructed in the natural production areas.

(9) A program to restore lamprey should be developed by the relevant fishery managers. This program should be under the overall leadership of the tribes.

Table 3 shows the tribal recommended actions needed to restore the fish resources of the Clearwater River system.

Table 1

Clearwater River Fish Populations Status and Goals

Species	Current Population (5-year average)	Adult Return Goal
Spring Chinook	270[1]	60,000
Summer Chinook	NA	50,000
Fall Chinook	NA	50,000
Steelhead	NA	91,100 B 2,000 A
Coho	NA	14,000
Lamprey	NA	NE

[1] Based on 1989-1993 redd counts. Assumes 2.5 fish per redd. Number rounded to nearest ten.
NA — Information not available
NE — None established

Table 2

Problems Impacting the Clearwater River Fish Resources

	Basinwide	South Fork Clearwater	Middle Fork Clearwater	Tributaries
High Cobble Embededness				•
Loss of Riparian Area	•			
Sedimentation	•			
High Water Temperatures		•	•	•
Poor Water Quality		•	•	
Irrigation Diversions				•
Severe Erosion				•
Lack of Large Woody Debris				•
Inadequate Production Compensation	•			

Table 3

Recommended Actions for the Clearwater River System

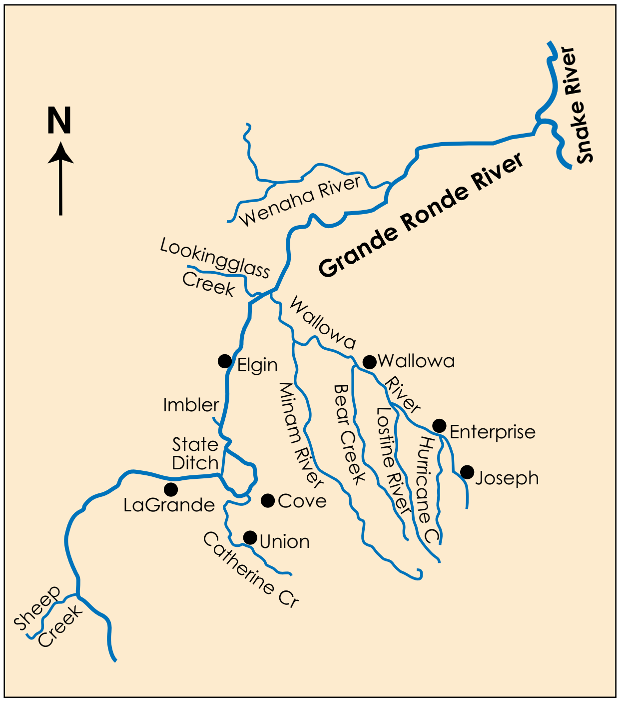
Problem	Recommended Action
High Cobble Embededness	(1) Eliminate or severely restrict logging, road building, restore riparian area
Loss of Riparian Area	(2) Restore riparian vegetation, reduce or eliminate mining
Sedimentation	(3) Eliminate or severely restrict loggng and grazing, restore riparian area
High Water Temperature	(4) Enforce Clean Water Act, reduce diversions, reduce or eliminate grazing, reduce roads
Irrigation Diversions	(5) Reduce diversions, provide instream flows
Severe Erosion	(6) Control land use in highly erodible areas
Limited Large Woody Debris	(7) Retain large woody debris
Inadequate Production Compensation	
Spring chinook, Steelhead Summer chinook, Coho	(5) Implement new broodstock programs, release programs, production programs
Lamprey	(6) Develop and implement programs

GRANDE RONDE RIVER

Prepared by Confederated Tribes of the Umatilla Indian Reservation and the Nez Perce Tribe

Introduction

The Grande Ronde River originates in the Blue Mountains of northeastern Oregon. It is bounded by the Blue Mountains to the west and northwest and the Wallowa Mountains in the southeast. It drains an area of approximately 3,950 square miles and flows 212 miles from its headwaters enters the Snake River in the Hells Canyon reach at river mile (RM) 168.7 (ODFW, et.al., 1990). Its principal tributaries are the Wenaha, Wallowa and Minam rivers, and Catherine and Lookingglass creeks. Smaller tributaries include Bear, Hurricane, Sheep and Indian creeks.



Fish Population Status/Goals

Natural spawning of spring chinook occurs in the Wenaha, Wallowa, Minam, Lostine, and upper Grande Ronde rivers, and Bear, Hurricane, Lookingglass, and Catherine creeks. The Washington Department of Fish and Wildlife has recently documented fall chinook natural spawning in the lower Grande Ronde River (WDF, 1993). Natural spawning of group A steelhead occurs throughout the Grande Ronde River system. Historically, sockeye spawning occurred in the tributaries of Wallowa Lake. Natural spawning runs of coho historically occurred in the Grande Ronde River system. Natural spawning runs were recorded in the Wenaha, Wallowa, Minam, and Lostine rivers and Catherine, Prairie, and Spring creeks.

The National Marine Fisheries Service (NMFS) has listed the natural component of the Grande Ronde spring chinook as part of the Snake River spring/summer chinook and has listed them as endangered under the Endangered Species Act. They have also listed the fall chinook as endangered.

The subbasin goals call for an annual return of 16,000 spring chinook with a natural escapement of 12,400 and a harvest of 4,000 fish. The recommended return of fall chinook is for 10,000 of which 2,500 would be for harvest. The recommended goal for summer steelhead is a 27,500 return of which 18,450 were for natural production and 9,050 for harvest. The recommended goal for sockeye is a return of 2,500 fish with a harvest of 625 fish. The recommended coho return is for 3,500 fish with a natural escapement of 1,000 and a harvest of 300. Table 1 shows the fish populations, status and goals.

Problems Impacting Fish Resources

Problems noted in the subbasin plan include those related to logging, road building, irrigation, grazing and stream channelization (Ibid). Some habitat improvement has occurred in Wallowa River and the upper Grande Ronde River. In addition to the habitat problems, the compensation programs for the basin are either inadequate or lacking. Many species are not being replaced, particularly not in the natural habitat.

Ongoing Actions In The Grande Ronde River System

Some measures have been implemented in the basin to correct habitat problems or partially mitigate losses. An extensive planning process has been completed in the basin leading to the development of the Upper Grande Ronde Plan. Implementation of the measures outlined in the plan has been lacking.

Hatchery production of spring chinook in the Grande Ronde River occurs at Lookingglass Hatchery. A new facility, Northeast Oregon Hatchery, has also been studied under the Northwest Power Planning Council (NPPC) Fish and Wildlife Program. Past releases from Lookingglass Hatchery have occurred throughout the basin. Since the listing of the natural run component and the failure to list the hatchery reared component, the NMFS has attempted to modify the release program from Lookingglass Hatchery. This has resulted in a decrease in the numbers released into the basin and a decrease in the run. The releases now occur at the hatchery with broodstock expected to return and be trapped at the hatchery. In addition, the state and federal fishery agencies propose to trap adults at Lower Granite Dam and prevent them from entering the Grande Ronde River. Over the years, Carson, Rapid River and Marion Forks hatcheries have been used to provide broodstock. The primary back-up station in recent years has been the Rapid River Hatchery.

Hatchery production of steelhead for the Grande Ronde River takes place at Irrigon Hatchery and Lyons Ferry Hatchery. In addition to the hatcheries, final rearing ponds have been constructed in the Grande Ronde River systems. Broodstock are acquired by trapping the fish at Wallowa Hatchery and adult traps. Broodstock used in the Grande Ronde system have included Pahsimeroi, Snake River, Wallowa, Wells, and Skamania.

Releases of full-term reared smolts occur at Wallowa Hatchery at the final rearing/acclimation facilities and through direct stream releases. When broodstock does not arrive, eggs are exchanged between stations.

Currently, there is no hatchery production of coho or fall chinook in the Grande Ronde River. Opportunities for reintroducing coho and increasing fall chinook production in the Grande Ronde come from reprogramming existing hatcheries.

Recommended Actions For The Grande Ronde River System

Habitat Enhancement Actions for Grande Ronde

I. Administrative

A. Laws and Codes, Enforcement & Revision

- State of Oregon (OR)/Environmental Protection Agency complete Total Maximum Daily Loads for stream temperatures, sediment, other pollutants (Clear Water Act)
- Enforce Oregon fish screening statutes
- Upgrade Oregon Forest Practices Act to be consistent with Upper Grande Ronde (UGR) Anadromous Fish Habitat Plan
- Upgrade Forest Service Land and Resource Management Plans consistent with UGR Plan to be in compliance with National Forest Management
- Revise mining laws to be consistent with production of high quality water and fish habitat

II. Instream Flow & Passage

A. Instream Flow Enhancement

- Purchase, exchange, lease or seasonally rent water rights for selected fish habitat during critical low flow periods
- Implement more efficient irrigation methods and water conservation practices benefitting landowners and instream flows
- Reinvestigate Prairie Creek pipeline project which would conserve irrigation water and make it available for enhancement of instream flows in the Wallowa River below Wallowa Lake

B. Passage Needs

- Ladder Wallowa Lake Dam to allow upstream passage for sockeye salmon

III. Watershed Management

A. Water Quality Needs

- Increase shade cover to reduce stream temperatures (increased downstream extent of temperatures <60°F)
- Reduce sediment from agricultural practices and unimproved roads
- Reduce nitrate, phosphates, bacteria and other contaminants related to agricultural practices

PRIORITIES: Upper Grande Ronde and tributaries, mainstem Grande Ronde River, Catherine Creek & tributaries, Joseph Creek & tributaries, Wallowa River & tributaries outside wilderness area

B. Riparian Restoration Needs

- Implement UGR Plan on state, federal and tribal lands
- Implement Best Management Practices, including stream buffers to benefit fish on private lands
- Acquire, lease or implement management agreement to restore natural floodplain habitat and function

PRIORITIES: Upper Grande Ronde & tributaries mainstem Grande Ronde River, Catherine Creek & tributaries, Joseph Creek & tributaries, Wallowa River & tributaries outside wilderness area

C. Range Management

- Revise and implement Best Manage-ment Practices to be consistent with UGR Plan Standards & Guidelines
- Restrict/remove livestock in substandard areas
- Acquire, lease, develop projects in priority areas (see above)

D. Forest Management

- Upgrade, monitor, enforce Forest Practices Act consistent with UGR Plan Standards & Guidelines private lands
- Implement UGR Plan Standards & Guidelines on State, Federal, Tribal lands
- Identify and implement active restoration projects
- Institute or continue protection of "good" habitat areas such as upper Grande Ronde River and tributaries above Vey Meadows (east Fork Grande Ronde, Lookout Cr., East Fork Sheep Cr., Chicken Cr. upper Limber Jim Cr. Weneha, Minam River, Upper Lostine, Bear, Hurricane, Five Points, Beaver and Lookingglass)

E. Mining Impact Reduction Needs

- Mitigate for impacts of mining tailings in the upper Grande Ronde system

Artificial Production Actions for Grande Ronde Subbasin

1. Continue the Rapid River stock spring chinook production program (at Lookingglass Hatchery) up to 900,000 yearling smolt level to provide for supplementation in Lookingglass Creek, Catherine Creek (CC) and the upper Grande Ronde River (UGRR). The Rapid River program would be reduced only when, or if, naturalized brood programs are developed or Imnaha program requirements increase.

   a. Release all Rapid River stock spring chinook smolts at Lookingglass Hatchery except for releases designated in 1 b.

   b. Supplement Catherine Creek and the upper Grande Ronde River with 250,000 Rapid River spring chinook smolts each. Adult not utilized for Lookingglass Hatchery brood and Lookingglass Creek outplanting should also be released into these habitats.

2. Develop adult capture and juvenile acclimation/release facilities in both CC and UGRR to support future broodstock collection and smolt outplanting activities. Until final facilities are

developed, direct stream releases should occur.

3. Continue to outplant adult Rapid River stock spring chinook in Lookingglass Creek at a level of 200 adults per year to re-establish a natural spawning population.

   a. Implement water treatment modifications to the Lookingglass Hatchery water intake system so that adult escapement in Lookingglass Creek above the hatchery can be increased to near production potential (about 500).

4. Adult spring chinook trapping and removal at Lower Granite Dam should be discontinued.

5. Immediately begin a Lostine River spring chinook captive broodstock program to provide up to 250,000 yearling smolts for supplementation of Wallowa River tributaries. Switch to conventional smolt supplementation programs using naturally produced broodstock when returns reach levels that would support adult broodstock collection.

   a. Develop adult capture and juvenile acclimation/release facilities in the Lostine River to support future broodstock collection and smolt outplanting activities. Until final facilities are developed, direct stream releases should occur.

   b. Modifications may be required at Lookingglass or another hatchery facility to implement the captive broodstock rearing programs.

   c. Modification of adult holding facilities at Lookingglass Hatchery may be necessary to keep stocks separate.

6. No hatchery supplementation of spring chinook should occur at this time in the Minam and Wenaha Rivers (pristine habitats located in wilderness areas) but population monitoring should continue for evaluation of future supplementation needs.

7. Utilize the Cottonwood Creek acclimation facility on the lower Grande Ronde River to acclimate and release fall chinook (from Lyons Ferry Hatchery). Continue the existing steelhead release program in a manner which would not interfere with the fall chinook acclimation program.

8. Discontinue use of non-native stocks in the existing summer steelhead programs. Develop new broodstock populations from Grande Ronde natural runs. Summer steelhead broodstock collection in the Grande Ronde system should occur in conjunction with spring chinook collections near natural productions areas. Release programs should utilize final rearing/acclimation facilities sited in natural production areas. Necessary facilities should be developed immediately. Until final facilities are developed, continue steelhead releases from existing facilities and/or direct stream releases.

9. Coho reprogramming of lower Columbia River hatcheries should occur to provide 2 million early run coho (Tanner Creek stock) for release into the Grande Ronde River system. Release programs should utilize several final rearing/acclimation facilities, including Big Canyon, located in natural production areas. Historical coho production areas in the Grande Ronde Basin include the Wallowa River and tributaries, Catherine Creek, and the upper Grande Ronde River. Spring chinook and steelhead acclimation facilities may also be utilized for coho. Broodstock should be acquired from existing early run returns of Tanner Creek stock coho to lower Columbia River facilities until such time as runs are reestablished in Snake River tributaries. At that time, broodstock collection would occur at Lower Grande Dam and/or at adult collection facilities located in natural production areas.

10. A program to reestablish sockeye salmon returning to Wallowa Lake should be initiated. Requirements for such a program have been already been investigated and are outlined by S.P. Cramer and Associates. Mid-Columbia sockeye stocks should be examined as potential founder populations for reestablishment in Wallowa Lake.

11. Discontinue all catchable trout programs in areas where they may affect anadromous salmonid restoration activities.

12. A program to restore lamprey populations utilizing either transplantation or artificial propagation should be developed under the overall leadership of the affected tribes.

13. Monitor and evaluate all artificial production actions. Use adaptive management to determine whether program changes (i.e., release number, size, time, location, and/or life history) are needed in order to meet restoration objectives.

Table 1

Grande Ronde River Fish Populations Status and Goals

Species	Current Population (5-year average)	Adult Return Goal
Spring Chinook	900[1]	16,000
Fall Chinook	NA	10,000
Steelhead	NA	27,500
Sockeye	0	2,500
Coho	0	3,500
Lamprey	NA	NE

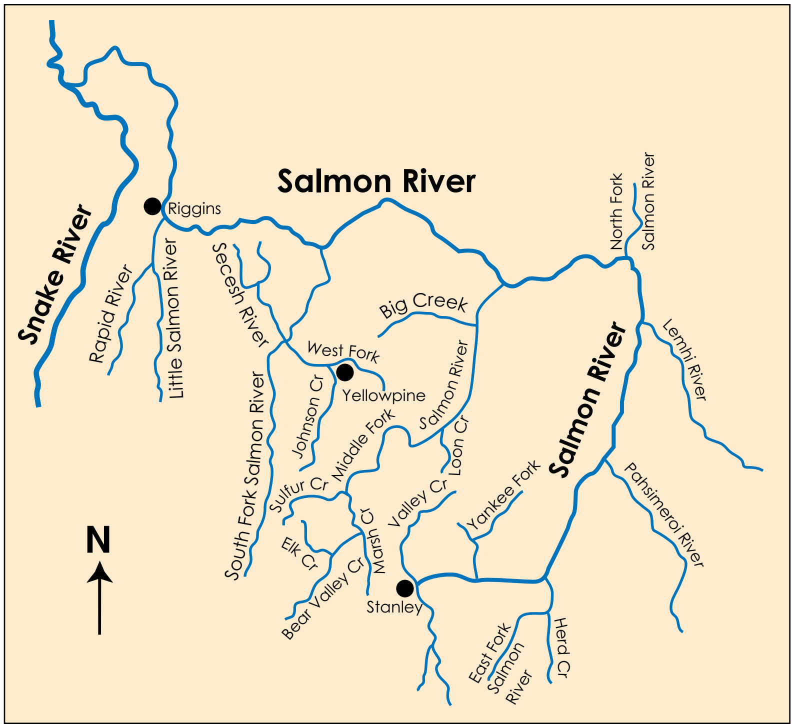
[1] Based on 1986-1990 redd counts. Assumes 2.5 fish per redd.

NA — Information not available

NE — None established

SALMON RIVER

Prepared by the Nez Perce Tribe



Introduction

The Salmon River originates in the Sawtooth Mountains of central Idaho near the 12,662 feet high Mount Borah. The river flows 410 miles north and west. After flowing west through the River of No Return Wilderness, it enters the Snake River in the Hells Canyon Reach. The Salmon River subbasin is the largest in the Columbia Rives system, excluding the Snake River and is just over 14,000 square miles. The major tributaries include the East Fork, Pahsimeroi, Lemhi, North Fork, Middle Fork, South Fork and Little Salmon rivers (IDFG, et. al., 1990). Many other tributaries flow into the Salmon River including Valley, Yankee Fork, Panther, Chamberlain, Slate and Allison creeks.

Fish Populations Status/Goals

Natural spawning of spring chinook in the upper Salmon River occurs in upper Valley Creek, upper Yankee Fork, Herd Creek, upper East Fork, Alturas Lake Creek, and the upper Salmon River. Spring chinook also spawn in the Lemhi River, North Fork of the Salmon River and the Middle Fork of the Salmon River in upper Big Creek, Sulfur, Elk, Marsh, and Bear Valley creeks and other mainstem Salmon River tributaries.

Natural spawning of summer chinook in the upper Salmon River occurs in lower Valley Creek, lower East Fork, and the mainstem Salmon River. Summer chinook also spawn in the Middle Fork of the Salmon River in lower Big Creek and Loon Creek. The South Fork of the Salmon and its tributaries Johnson Creek and Secesh River/Lake Creek are the principal summer chinook spawning areas in the lower Salmon River system.

The spring chinook and summer chinook have been designated by the National Marine Fisheries Service (NMFS) as endangered under the Endangered Species Act.

Natural spawning of sockeye occurred in the upper Salmon River in the Stanley lakes area. This area included Alturas, Petit, Yellow Belly, Redfish, and Stanley lakes. Due to a variety of factors such as irrigation, dams, harvest, poisoning and migration barriers to create resident sport fisheries, and lack of mitigation, the run has disappeared. Because much of the existing spawning and rearing habitat is in fair to good condition, the opportunity exists to restore fish to the natural habitat. Although most existing habitat is in fair to good condition, problems should be corrected to provide for full utilization of the habitat. The lakes historically used by sockeye in the upper Salmon River system included Stanley, Redfish, Yellowbelly, Petit and Alturas lakes.

Natural spawning of group A steelhead in the upper Salmon River is believed to occur in most of the drainage that is accessible to the run. Exact locations and size of spawning populations have not been fully documented. Examination of the Pahsimeroi Hatchery release records reveals that group A steelhead have been released into nearly every drainage from the mouth of the Middle Fork to the upper reaches of the Salmon River. Group B steelhead that were introduced from the Clearwater River have also been released in numerous tributaries in this section of the Salmon River system. Success of the past releases is not known. Most of the fish were released as fry. Smolt releases have occurred mainly at hatcheries and adult traps or in streams near population centers for sport fisheries.

In the lower Salmon River, natural spawning runs of steelhead exist throughout this section of the Salmon River from the mouth of the Middle Fork to the Snake River. Like the upper reaches, very little is known of the size and location of spawning populations. Hatchery releases have occurred in this area, but they have been less frequent than in the upper Salmon. With the exception of the Middle Fork of the Salmon and its tributaries, all other major drainages have received hatchery releases. Both group A and group B steelhead have been released in this section of the river.

During the subbasin planning process, numerical objectives were not developed for the various species. Table 1 shows the fish populations, status and goals.

Problems Impacting Fish Resources

Existing habitat condition in the Salmon system varies from pristine habitat to very badly damaged. Problems identified in the subbasin plan include among others, mining, grazing, irrigation, road building and logging. High sedimentation is clearly the biggest problem in the Salmon River subbasin due to the highly erodible terrain. Past studies clearly indicate that the degradation has contributed significantly to fish declines. Most streams out of wilderness are terribly degraded by sedimentation as indicated by the documented pool losses, which range from 30 to 70 percent.

Compensation programs for the Salmon River have been limited or non-existent. With the exception of steelhead, very few releases are made in the natural environment. Steelhead releases, for the most part, are intended to provide either for fisheries or the continuation of the hatchery programs. Because attempts were made to eliminate sockeye from the system very few remain. Rather than beginning an aggressive restoration program for sockeye, attempts are being made to develop a very questionable captive broodstock program.

Table 2 shows the problems impacting the Salmon River system.

Ongoing Actions In The Salmon River System

Streams that have received improvements through the Northwest Power Planning Council (NPPC) Fish and Wildlife Program include the Middle Fork tributaries, Valley Creek, Yankee Fork, and upper mainstem of the Salmon River. Feasibility studies on other needed improvements have been completed on a number of streams including Panther Creek, Lemhi River, Herd Creek and East Fork of the Salmon. The subbasin planners' recommended strategies for habitat include habitat enhancement, screening, and barrier removal (Ibid). Without significant changes in grazing and logging practices, it is unlikely the habitat measures alone will lead to recovery of the streams.

Hatchery production of spring chinook occurs at Sawtooth and Rapid River hatcheries. In addition to the major hatcheries, a rearing pond has been constructed on Yankee Fork and an adult trap has been constructed on the East Fork of the Salmon River. Releases mainly occur at the hatcheries or adult trap, with broodstock expected to return and be trapped at the hatchery or adult trap. Rapid River serves as the primary back-up station for egg distribution in the Snake River system. Sawtooth has been attempting to develop a run by trapping at the hatchery and the East Fork Trap. The NMFS has listed the Sawtooth Hatchery component as threatened but did not list the Rapid River component under the Endangered Species Act.

Currently, the Nez Perce Tribal Hatchery program is being designed to consist of a central incubation and early rearing facility. Broodstock will be acquired in tributaries where fish will be released including Slate Creek a tributary of the lower Salmon River. Fish will be reared at satellite facilities during the summer months and released in late fall to over-winter in the natural environment.

Hatchery production of summer chinook takes place at McCall and Pahsimeroi hatcheries. Facilities are being proposed under the Integrated System Plan (ISP) to produce an additional five million smolts. However, the ISP does not disclose what broodstock will be used to produce these additional smolts. One adult trap has been constructed in the South Fork of the Salmon. Adults are also trapped at Pahsimeroi Hatchery. The NMFS listed the McCall Hatchery run component, but did not list the Pahsimeroi Hatchery component of the summer chinook.

Releases from Pahsimeroi Hatchery occur at the hatchery. Releases from McCall Hatchery occur approximately one mile above the adult trap on the South Fork of the Salmon, with broodstock expected to return and be trapped at the hatchery or adult trap. The run at Pahsimeroi Hatchery was begun by acquiring eggs from the South Fork trapping program.

With the exception of the captive broodstock program at Eagle Hatchery, artificial production of sockeye does not exist. Past programs have been very limited and the last program attempted to use broodstock from British Columbia. No mitigation program was planned under the Lower Snake River Compensation Plan. Currently, the Nez Perce Tribe is proposing the construction of an artificial production program for the Snake including the Salmon River system. Details of this program such as size and location have not yet been determined. The NMFS has listed sockeye as endangered.

Hatchery production for steelhead takes place at several major hatcheries. Both group A and group B steelhead are reared in the facilities. The group A hatchery includes Niagara Springs. Both group A and group B are reared at Hagerman National Fish Hatchery and Magic Valley Hatchery. Releases of full-term reared smolts occur mainly at the hatcheries or adult traps, with broodstock expected to return and be trapped at the hatchery or adult trap. Adult traps used to acquire broodstock for spring and summer chinook are also used for steelhead. Additionally, releases are made near population centers to provide for sport fisheries.

Recommended Actions For The Salmon River System

(1) Barriers that have been constructed on the sockeye lakes should be removed. Culverts that have been improperly installed should be replaced. Natural migration barriers on streams should be removed or passage provided.

(2) Streams that have excess irrigation diversions must have instream flows adopted and enforced. Diversions should be reduced and the continual practices of over-appropriation of water stopped.

(3) The loss of the riparian area is occurring throughout the watershed. Logging, mining and grazing in the riparian area must be stopped and the riparian vegetation be allowed to recover.

(4) The removal of large woody debris from the riparian area should be terminated. Large woody debris is necessary to help ensure stream integrity.

(5) Sedimentation due to logging including road building, grazing, and mining is occurring throughout the watershed. These practices must be eliminated or severely restricted in highly erodible areas to allow the watershed to recover. Riparian restoration should also be carried out.

(6) Water quality problems such as high temperatures and chemical pollution are caused mainly by irrigation diversions and mining. Adoption and enforcement of water quality standards under the Clean Water Act are necessary. The elimination or severe restriction of mining and irrigation, particularly the over-appropriation of water, are needed.

(7a) Spring chinook

Sawtooth Hatchery is located in the upper Salmon River near the town of Stanley, Idaho. As part of the Lower Snake River Compensation Plan, it was constructed by the Corps of Engineers and is operated by Idaho Department Fish and Game. The facility was designed and constructed to rear 2,300,000 spring chinook to smolt size. It also serves as a trapping location for spring chinook. Steelhead for the Hagerman National Fish Hatchery and Magic Valley Hatchery are also trapped at Sawtooth Hatchery.

A satellite facility on the East Fork of the Salmon River is also operated in conjunction with Sawtooth Hatchery. It is used to trap spring chinook for Sawtooth Hatchery and also steelhead for the Hagerman and Magic Valley steelhead hatcheries. In addition, the East Fork site is used as a release location.

Besides releases at the hatchery and East Fork satellite, smolts have been released into the natural production areas of upper Yankee Fork and upper Valley Creek. The construction of rearing ponds on Yankee Fork have the capability of rearing 200,000 fingerlings for fall release.

Numerous options exist for acquiring broodstock for the Sawtooth rearing program. The first option would continue the current program of trapping and holding spring chinook at Sawtooth Hatchery, East Fork Trap, and at upper Yankee Fork, upper Valley Creek, and at other tributaries in the region. The stocks trapped at these locations are compatible with the current genetic make-up of the chinook stocks above the traps because fish from this stock have been captured and used since the hatchery was constructed in the mid-1980s. The second option, construction of new adult traps and final rearing and/or acclimation facilities, should be constructed in other natural production areas, including in natural production areas above Sawtooth Hatchery. These options are compatible with the Endangered Species Act listing of Snake River spring chinook.

To begin the program immediately, construct temporary adult traps in the tributaries (except on the East Fork). Adult holding capabilities at Sawtooth Hatchery must be modified to ensure separation of adults.

Release locations should be modified to ensure the natural runs are being assisted by the supplementation program. The use of the Yankee Fork Rearing Ponds should be incorporated in future release strategies for Sawtooth Hatchery. Additional release programs on the tributaries should be done using final rearing and/or acclimation facilities as described previously. The practice of marking all releases must be terminated. In all instances, the practice of removing any fins, other than the adipose for evaluation purposes, must be terminated.

Rapid River Hatchery was started by trapping adults at Hells Canyon Dam in 1964. The trapping was terminated after three years. The hatchery is designed to rear three million smolts. Broodstock acquisition occurs by trapping approximately one mile below the hatchery and below Hells Canyon Dam. Current releases occur at the hatchery and below Hells Canyon Dam. Fish for the Hells Canyon release should originate from the broodstock trapped below the dam.

This program should continue. In addition, the Rapid River stock should be designated as appropriate for use in restoration of naturally spawning Snake River spring chinook stocks. The program should also be incorporated in a tributary release program in concert with the proposed Nez Perce facility.

(b) Summer chinook

The Pahsimeroi Hatchery is located in the upper Salmon River near the town of Challis, Idaho. It is part of Idaho Power Company's mitigation for its Hells Canyon Dam complex and is operated by Idaho Department of Fish and Game. The facility was designed and constructed to rear 1,000,000 spring chinook to smolt size. However, following an initial program for spring chinook, it was converted to a summer chinook program in the late 1980s. It also serves as a trapping location for summer

chinook. Steelhead for the Niagara Springs Hatchery are also trapped at the site.
Adult traps and final rearing and/or facilities should be constructed in natural production areas, and the use of the South Fork Salmon River summer chinook should be terminated. This will ensure that the stock used in the facilities is appropriate for release into natural production areas. The facilities are needed in the natural production areas of the mainstem Salmon and lower East Fork. Adult holding capabilities at Pahsimeroi Hatchery should be modified to ensure separation of adults. Release locations should be modified to include the natural production areas of the Salmon River and the lower East Fork.

McCall Hatchery was started by trapping summer chinook adults at Lower Granite Dam in the late 1970s. Trapping continued for three years, until the trap was completed on the South Fork of the Salmon. Trapping was then terminated at Lower Granite Dam. The hatchery is designed to rear one million smolts. Current releases occur in the South Fork approximately one mile above the trap. A final rearing and/or acclimation facility should be constructed in the natural production area above the trap and the current direct stream release program phased out.

This recommended action should be expanded to begin additional releases in the natural habitat, including in Johnson Creek where adult trapping and smolt acclimation facilities will have to be constructed.

(c) Steelhead
Hagerman National Fish Hatchery is located in the Thousand Springs area near the town of Hagerman, Idaho. It is part of the Lower Snake River Compensation Plan. It was constructed by the Corps of Engineers and is operated by the U.S. Fish and Wildlife Service. The facility was designed and constructed to rear 2,400,000 steelhead to smolt size. Currently, the facility rears both group A and group B steelhead. The group A steelhead are primarily released at Pahsimeroi and Sawtooth hatcheries and the group B are primarily released at the East Fork Trap. Group A broodstock for the program originated from Hells Canyon trapping and group B from the Dworshak Hatchery. Group A steelhead for the Hagerman National Fish Hatchery are currently trapped at Pahsimeroi and Sawtooth hatcheries. Group B steelhead are acquired from either the East Fork Salmon River Trap or Dworshak Hatchery.

New adult traps and final rearing and/or acclimation facilities should be constructed in the natural production areas including the North Fork and Lemhi rivers. These facilities may be used in conjunction with the spring chinook program as that program is also expanded.

Adult holding capabilities at Sawtooth and Pahsimeroi hatcheries should be modified to ensure separation of the adults. Additional release programs on the tributaries should be implemented using final rearing and/or acclimation facilities.

The Magic Valley Hatchery was constructed as part of the Lower Snake River Compensation Plan. It is located in the Thousand Springs area near Filer, Idaho. It was designed to rear two million smolts. Currently, the program rears one million group A steelhead and one million group B steelhead. Group A steelhead are primarily released at Pahsimeroi and Sawtooth hatcheries and group B are released at the East Fork Trap. Broodstock acquisition is similar to that for the Hagerman National Fish Hatchery.

Operation of the Magic Valley Hatchery should be in conjunction with operation of Hagerman hatchery. Broodstock acquisition, final rearing and/or acclimation facilities would be compatible.

Niagara Springs Hatchery is part of Idaho Power Company's mitigation for the Hells Canyon Dam complex. It is located in the Thousand Springs area near Buhl, Idaho. It rears 1,600,000 group A steelhead. Releases occur primarily at Pahsimeroi Hatchery and below Hells Canyon Dam. Broodstock was originally acquired by trapping steelhead below Hells Canyon Dam and transferring them to the Pahsimeroi Hatchery for rearing and release. Pahsimeroi Hatchery continues to be the primary trapping facility for upper Salmon River group A steelhead.

The Niagara program should be used to assist the natural spawning populations in the lower Salmon River tributaries. Adult trapping and final rearing and/or acclimation facilities should be constructed on the tributaries.

d) Sockeye
The current captive rearing program for sockeye occurs at the Eagle Hatchery near Eagle, Idaho. This program was developed following the listing of sockeye as endangered. The few fish that have returned to Redfish Lake have been trapped for this program. Out-migrants, including kokanee, have also been trapped at the Redfish Lake outlet. Because of this broodstock acquisition program, there is no evidence that the fish being reared are actually sockeye.

An additional sockeye program should be started for the Salmon River system's other historical sockeye lakes. This proposed new restoration program would not affect the existing captive broodstock project. Since the captive fish are marked by means of fin removal, the new program would not remove any fins so that the stocks could be differentiated. To start the program, broodstock should be acquired from the existing run of sockeye destined for mid-Columbia tributaries. Trapping can occur at the existing Tumwater Dam trap or the Wells Dam trap. Trapped adults can be held in the vicinity of these existing traps until spawned or they could be trucked to and held in the Idaho lakes until spawned.

The eggs could be used in reprogrammed public hatcheries or private hatcheries for rearing and release back into Petit, Stanley, Yellowbelly and Alturas lakes. The trapped adults could also be allowed to spawn naturally in existing spawning habitat above these lakes. The dams constructed at the outlets of sockeye lakes (in a successful past effort to eliminate the sockeye in favor of sport fishing stocks) should be removed or fish ladders installed to allow passage.

Juvenile release programs should be developed on each lake using final rearing and/or acclimation facilities. These facilities could consist of net pens which would allow the fish to adjust to natural lake conditions. If final rearing is to occur, net pens will be a necessary component of the artificial rearing facility. Until these facilities have been acquired it will be necessary to directly release the fish into the lakes. Lake water should be mixed with tanker water to minimize extreme temperature variations between the truck water and the lake.

The Nez Perce Tribe is currently examining the feasibility of a sockeye rearing facility. The size, location, broodstock requirements, and rearing and release locations have not yet been determined.

(8) A program to restore lamprey should be developed by the relevant fishery managers. This program should be under the overall leadership of the tribes.

Table 3 shows the tribal recommended actions needed to restore the fish resources of the Salmon River system.

Table 1
Salmon River Fish Populations Status and Goals

Species	Current Population (5-year average)	Adult Return Goal
Spring Chinook	900[1]	128,000
Summer Chinook	1,750[1]	60,200
Steelhead	NA	192,900
Sockeye	<10	44,500
Lamprey	NA	NE

[1] Based on 1989-1993 redd counts. Assumes 2.5 fish per redd. Number rounded to nearest ten.
NA — Information not available
NE — None established

Table 2

Problems Impacting the Salmon River Fish Resources

	Basinwide	Upper Salmon	Lower Salmon	Tributaries
Migration Barrier			•	
Irrigation Diversion		•		•
Riparian Degradation	•			
Lack of Large Woody Debris	•			
Sedimentation	•			
Poor Water Quality		•		•
Inadequate Production Compensation	•			

Table 3

Recommended Actions for the Salmon River System

Problem	Recommended Action
Migration Barriers	(1) Construct passage facilities
Irrigation Diversions	(2) Provide for instream flows. Stop over-appropriation
Riparian Degradation	(3) Restore riparian vegetation
Limited Large Woody Debris	(4) Retain woody debris
Sedimentation	(5) Eliminate or severely restrict grazing, logging, mining, road construction
Poor Water Quality	(6) Enforce Clean Water Act, rstrict mining, reduce irrigation diversion
Inadequate Production Compensation	
Spring chinook, Steelhead Summer chinook, Sockeye	(7) Implement new broodstock programs, release programs, production programs
Lamprey	(8) Develop and implement programs

IMNAHA RIVER

Prepared by the Nez Perce Tribe and the Confederated Tribes of the Umatilla Indian Reservation

Introduction

The Imnaha River originates in the Wallowa/Whitman National Forest in Northeast Oregon at an elevation of approximately 10,000 feet. It drains 980 square miles
and from its juncture of the North and South forks it flows northerly for 63.5 miles and enters the Snake River in the Hells Canyon reach at an elevation of 975 feet (NPT, et. al., 1990). Its principal tributary is Big Creek.

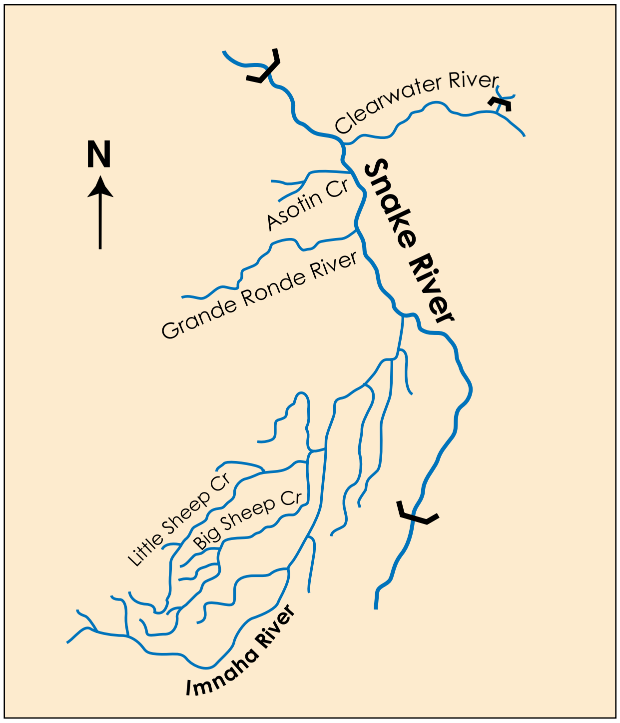
Fish Population Status/Goals

Spring chinook spawning occurs in the Imnaha River, Big Sheep Creek, and Lick Creek. Summer chinook spawning may occur in the Imnaha River. Fall chinook spawning occurs in the lower reaches of the Imnaha River which was verified by the Washington Department of Fish and Wildlife in 1992 (WDF, 1993). The chinook stocks in the Imnaha have been listed by the National Marine Fisheries Service (NMFS) as endangered. The NMFS also designated the spring chinook and summer chinook as one stock under their spring/summer chinook classification. Natural spawning of group A steelhead occurs throughout the Imnaha River system.

The goal for the spring chinook return to the basin is for 5,740 fish of which 3,800 are for natural production and 700 for harvest. The goal for fall chinook is for a return of 3,000 adults. The goal for steelhead is 4,315 of which 2,100 are for natural escapement and 2,000 for harvest (Ibid). Table 1 shows the fish populations, status and goals.

Problems Impacting Fish Resources

Problems noted in the subbasin plan include logging, road building, mining, farming and ranching practices (Ibid). These are not thought to be major limiting factors on fish production. Habitat improvement has occurred in Big Sheep Creek. Table 2 shows the problems impacting the fish resources in the Imnaha River system.



Ongoing Actions In The Imnaha River System

Hatchery production of spring chinook for the Imnaha occurs at Lookingglass Hatchery which is located in the Grande Ronde River Basin. An adult trap and release facility has been constructed on the Imnaha River. Releases mainly occur at the adult trap and other locations by direct stream releases. Broodstock are trapped at the adult trap. Additional facilities being studied under the Northwest Power Planning Council (NPPC) Fish and Wildlife Program include Northeast Oregon Hatchery.

Hatchery production of steelhead for the Imnaha River reach of the basin takes place at the Irrigon Hatchery. A smolt release facility and adult trap have been constructed on Little Sheep Creek. The program rears group A steelhead.

Habitat projects to date have been ineffective in restoring the Imnaha River natural habitat. Habitat must be improved through a coordinated watershed approach.

Recommended Actions For The Imnaha River System

(1) The Wallowa Valley Improvement Canal Diversion diverts water from the Imnaha River system to the Grande Ronde River system. This practice should be terminated and instream flows provided.

(2) Logging and grazing throughout the basin should be eliminated or reduced significantly to reverse the sedimentation problem.

(3) The Forest Service salvage logging should be terminated to allow from the retention of large woody debris.

(4) Riparian destruction throughout the watershed should be stopped. Programs to restore the riparian vegetation should be implemented.

(5) Logging should be severely curtailed or eliminated.

(6) Stream channelization due to road construction should be eliminated. Where possible streams should be allowed to follow their natural course.

(7) Grazing should be severely curtailed or eliminated.

(8) Currently, the spring chinook program entails trapping and release of spring chinook in the mainstem Imnaha River facility with rearing at Lookingglass Hatchery.. The current program at Lookingglass Hatchery for the Imnaha River utilizes eggs from the Imnaha River.

Release programs should utilize final rearing and/or acclimation facilities in natural production areas. An additional facility should be constructed on Big Sheep Creek. Until the new facility is constructed, direct stream releases should occur.

The steelhead program calls for the trapping of broodstock in Little Sheep Creek. Releases occur at the trapping facility. This program should be expanded to acquire broodstock from streams throughout the system. Releases should also occur throughout the system through the use of final rearing and/or acclimation facilities.

The Northeast Oregon Hatchery is currently being planned as a measure in the NPPC Fish and Wildlife Program. It is expected that the facilities will provide fish for release in the Imnaha River system. The broodstock and smolt release facilities currently developed or recommended under the Lookingglass program could also be used for this program.

(9) Programs to restore fall chinook, coho and lamprey have not yet occurred. Development of restoration plans by the relevant fishery managers is recommended.

The tribally recommended action needed to restore Imnaha River fish resources is shown in Table 3.

Table 1
Imnaha River Fish Populations Status and Goals

Species	Current Population (5-year average)	Adult Return Goal
Spring Chinook	340[1]	5,740
Summer Chinook	NA	NE
Fall Chinook	NA	3,000
Steelhead	NA	4,315
Lamprey	NA	NE

[1] Based on 1984-1988 redd counts. Assumes 2.5 fish per redd.
NA — Information not available
NE — None established

Table 2

Problems Impacting the Imnaha River Fish Resources

	Basinwide	Upper Imnaha	Lower Imnaha	Sheep/Lick
Irrigation Diversion		•	•	
Sedimentation	•			
Limited Large Woody Debris	•			
Loss of Riparian Area			•	
Logging		•		•
Road Construction	•			
Grazing	•			
Inadequate Production Compensation		•		

Table 3

Recommended Actions for the Imnaha River System

Problem	Recommended Action
Irrigation Diversion	(1) Provide instream flows
Sedimentation	(2) Restrict logging, grazing
Limited Large Woody Debris	(3) Retain woody debris
Loss of Riparian Area	(4) Cease stram channelization, grazing, fencing
Logging	(5) Eliminate or reduce reduce logging
Road Construction	(6) Reduce road construction
Grazing	(7) Eliminate or reduce grazing
Inadequate Production Compensation	
Spring chinook, Steelhead	(8) Proper broodstock acquisition, release programs, additional production
Fall chinook, Coho, Lamprey	(9) Develop programs

ACRONYMS

BIA	Bureau of Indian Affairs
BCF	Bureau of Commercial Fisheries
BLM	Bureau of Land Management
BPA	Bonneville Power Administration
CBFWA	Columbia Basin Fish and Wildlife Authority
CCT	Confederated Colville Tribes
CFF	Commission of Fish and Fisheries
COE	U.S. Army Corps of Engineers
CRITFC	Columbia River Inter-Tribal Fish Commission
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CTWSIR	Confederated Tribes of the Warm Springs Indian Reservation
DOE	Department of Energy
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ICFRU	Idaho Cooperative Fish and Wildlife Research Unit
IDFG	Idaho Department of Fish and Game
ISP	Integrated System Plan
MCPUD	Mid-Columbia Public Utilities District
NMFS	National Marine Fisheries Service
NPT	Nez Perce Tribe
ODFW	Oregon Department of Fish and Wildlife
PNL	Pacific Northwest Laboratories
PUD	Public Utilities District
SBT	Shoshone-Bannock Tribes of Fort Hall
USFWS	U.S. Fish and Wildlife Service
WDF	Washington Department of Fisheries
WDW	Washington Department of Fish and Wildlife
YIN	Yakama Indian Nation

anadromous fish: Fish, such as salmon and lamprey, that hatch in freshwater, migrate to the ocean, where they grow, and then return to freshwater as mature fish to spawn.

anthropogenic: Produced or caused by humans.

artificial propagation: Using a human-controlled system to spawn, incubate, hatch and/or raise fish.

basin: See **watershed**.

Best Management Practices (BMPs): An action or combination of actions that are the most effective and practical (including technological, economic, and institutional considerations) means of preventing or reducing non-specific sources of water pollution.

Bonneville Power Administration: Created in 1937, the agency markets and distributes power generated by the Federal Columbia River Hydroelectric System and provides funding for salmon recovery projects under the Northwest Power Act.

broodstock: Adult fish that produce the next generation of fish.

Clean Water Act: A federal statute with the primary goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters. The act delegates the authority to develop and implement water quality standards to the U.S. Environmental Protection Agency (EPA). The EPA also acts to ensure that each state's water quality standards and pollution control programs are consistent with the act's purposes.

Columbia River Fish Management Plan (CRFMP): A consent decree approved by and entered as an order of the district court in *United States v. Oregon*, in which the parties to *United States v. Oregon* may exercise their sovereign power in a coordinated and systematic manner to protect and rebuild upper Columbia River fish runs and allocate their harvest between Indian and non-Indian fisheries.

Columbia River Inter-Tribal Fish Commission (CRITFC): A coordinating fisheries agency, founded in 1977 by the Nez Perce, Umatilla, Warm Springs, and Yakama tribes — the four Columbia River tribes that reserved fishing rights in 1855 treaties with the United States government. CRITFC, through its staff of biologists, policy analysts, law enforcement officers, and other specialists, strives to protect the tribes' fishing rights and works to restore the fish resources upon which tribal religion, culture and livelihood depend.

desiccation: The process of making dry or being dried.

downstream migration: The journey of young salmon or lamprey from streams and rivers to the ocean.

Endangered Species Act (ESA): A federal statute with a primary goal of protecting threatened and endangered species and the ecosystems on which they depend. Under the act, the U.S. Fish and Wildlife Service (USFWS) has the authority to designate species for protection and the responsibility to develop recovery plans. The National Marine Fisheries Service, under an agreement with the USFWS, administers the ESA for Pacific salmon.

escapement: The number of salmon surviving to return to a specified point of measurement. Spawning escapement consists of those fish that survive to spawn.

fish ladder (also known as **fishway**): A series of ascending pools of water, constructed to enable salmon or other fish to swim upstream around or over a dam. Resembles a stairway.

fish screen: A meshlike structure placed across a water intake, pipe or passageway to divert fish from the intake.

flow: The rate at which water passes a given point on a stream or river; often expressed as cubic feet per second (cfs).

genetics: The study of heredity and variation in organisms of the same or related kinds.

genotypic: Pertaining to the genetic make-up of an organism.

habitat: The place where a plant or animal lives and grows.

hydrograph: A representation of water levels over time.

infectious hematapoietic necrosis (IHN): A virus that can kill salmonids including chinook, sockeye and steelhead; the most severe outbreaks occur when fish are young (i.e. fry or fingerlings).

instream flow incremental methodology (IFIM): Analytic tool to estimate quantity and quality of water in rivers and streams to determine whether and where fish habitat is available.

juvenile: Young fish, usually two years of age or less.

mainstem: The main channel of a river as opposed to tributary streams and smaller rivers that feed into it.

Mitchell Act: A federal statute passed in 1938 to mitigate for fishery damage caused by Bonneville Dam and subsequent federal water projects; and implemented by state and federal agencies primarily through hatchery programs which resulted in the taking of upper Columbia and Snake river salmon as brood-stock for downriver hatcheries.

mitigation: Actions taken to help compensate for damage, such as human-caused damage to fish and wildlife resources. Mitigation for fish losses often takes the form of hatchery production.

mortality: The death of fish from natural or human causes.

natural production: Fish that are raised and return to spawn in streams, either by natural spawning or by outplanting hatchery fish.

Northwest Power Act: The Pacific Northwest Electric Power Planning and Conservation Act of 1980 (also known as the Regional Power Act), which authorized the Northwest Power Planning Council and called for the development of a Columbia Basin fish and wildlife mitigation program to be funded by the Bonneville Power Administration. See Northwest Power Planning Council.

Northwest Power Planning Council (NPPC): The NPPC, authorized by the Northwest Power Act, consists of eight members appointed by the governors of Idaho, Montana, Oregon and Washington. Under the federal act, NPPC is charged with the development of a fish and wildlife program to protect, mitigate, and restore Columbia Basin fish and wildlife (including related spawning grounds and habitat) harmed by hydroelectric dams.

outplanting: See **supplementation**.

passage: The movement of migratory fish through a river system.

phenotypic: Pertaining to the visible or otherwise measurable physical characteristics of an organism.

population: A group of organisms of a species living in a certain area.

rearing: The juvenile life stage of anadromous fish that is spent in freshwater rivers, streams, and lakes before migrating to the ocean.

recruit: A fish of sufficient size to be subject to harvest and/or a mature fish arriving at a spawning area.

redd: A spawning nest dug into gravel in a stream bed by an adult salmon.

riparian areas: The region adjacent to bodies of water, such as streams, springs, rivers, ponds, and lakes.

run: A population of fish of the same species consisting of one or more stocks migrating at a discrete time.

salmonid: A fish of the Salmonidae family, which includes salmon and trout.

sedimentation: The settling of silt or any matter in bodies of water.

smolt: A juvenile salmon migrating to the ocean and undergoing physiological changes (smoltification) to adapt its body from a freshwater to a saltwater environment.

spawner: A mature fish that produces eggs or sperm.

species: Basic category of biological classification. In sexually reproducing organisms, a group of interbreeding individuals not normally able to interbreed with other groups. Under the ESA, a species can be either a biological species, biological sub-species, or distinct population segment of a biological species.

stock: A group of fish that spawn together in a particular stream during a particular season that generally do not interbreed with any other group of their species that spawns at a different time.

straying: The tendency of some anadromous fish to return and spawn in streams other than those in which they were born.

subbasin: A designated watershed with a single entry river into either the Snake or Columbia River basin.

supplementation: The act of releasing young, artificially propagated fish into natural spawning and rearing habitat. As adults, these fish will return to spawn naturally in the stream where they were released rather than returning to the propagation facility. (Also called outplanting.)

total maximum daily load (TMDL): Under the Clean Water Act, the total amounts of different pollutants allowable for a particular watershed.

tributary: A stream of lower order than the stream or river it joins. For example, the Clearwater River is a tributary of the Snake River which is a tributary of the Columbia River.

United States v. Oregon: The federal court case that upheld the treaty fishing rights of the Columbia River treaty tribes in a 1969 decision. The case remains under the court's jurisdiction. In 1983 the court ordered tribes, states, and the federal government to develop a management plan which the court then approved in 1988. See **Columbia River Fish Management Plan**.

United States-Canada Salmon Treaty (also called the **Pacific Salmon Treaty**): Signed in 1985, the United States-Canada Pacific Salmon Interception Treaty limits each country's interception of the other's salmon to promote the ability of stocks to rebuild in both nations.

upstream migration: The return of adult salmon from the ocean to inriver areas where they were born and where they will spawn the next generation.

watershed: The drainage area contributing water, organic matter, dissolved nutrients and sediments to a river or lake. Used interchangeably with basin or subbasin.

Definitions are provided for additional clarification; they have no legal significance.

REFERENCES

Allard, D. 1994. Annual Coded Wire Tag Program, Missing Production Groups. U.S. Fish and Wildlife Service. 47 pages.

Beeman, J.W. and J.F. Novotny. 1994. Pen Rearing and Imprinting of Fall Chinook Salmon. National Biological Survey. 27 pages.

Blankenship, L.H. and G.W. Mendel. 1993. Upstream Passage, Spawning, and Stock Identification of Fall Chinook Salmon in the Snake River. 1992. Washington Department of Fisheries. 73 pages.

BCF. 1958. Fishery Development Program of the Columbia River. Progress Report Through Fiscal Year 1958. Bureau of Commercial Fisheries. 120 pages.

BCF. 1959. Columbia River Fishery Development Program. Hatchery Production and Distribution Data Through Fiscal Year 1959. Bureau of Commercial Fisheries. 84 pages.

BCF. 1960. Columbia River Fishery Development Program. Review Report, Volume I. Bureau of Commercial Fisheries. 33 pages.

BOR. 1975. Oroville-Tonasket Unit Extension Okanogan-Similkameen Division Chief Joseph Dam Project Washington, Feasibility Report. Bureau of Reclamation. 121 pages.

CBFWA. 1990. Integrated System Plan. Columbia Basin Fish and Wildlife Authority. 449 pages.

Chapman, D., et al. 1994. Status of Summer/Fall Chinook Salmon in the Mid-Columbia Region. Appendix A-G. 412 pages.

Christianson, C. 1992. Integrated Hatchery Operations Team Operation Plans for Anadromous Fish Production Facilities in the Columbia River Basin, Volume III, Annual Report 1992. Oregon Department of Fish and Wildlife. 324 pages.

Cochnauer, T. 1990 Fish Hatchery Evaluations-Idaho. Idaho Department of Fish and Game. 52 pages.

COE. 1975. Special Report Lower Snake River Fish and Wildlife Compensation Plan. U.S. Army Corps of Engineers. 95 pages.

CRITFC, CTWSR, CTUIR, NPT, YIN. 1991. Draft Integrated Tribal Production Plan, Volume II Production Proposal for Recovery of Mid-Columbia Stocks. Columbia River Inter-Tribal Fish Commission. 114 pages.

CRITFC, CTWSR, CTUIR, NPT, YIN. 1992. Draft Integrated Tribal Production Plan, Volume III Production Proposal for Recovery of Lower Columbia Stocks. Columbia River Inter-Tribal Fish Commission, et al. 120 pages.

CRITFC, CTWSR, CTUIR, NPT, YIN. 1990. Integrated Tribal Production Plan, Volume I Production Proposal for Recovery of Snake River Stocks. Columbia River Inter-Tribal Fish Commission. 143 pages.

CRITFC. 1981. The Mitchell Act An Analysis. Columbia River Inter- Tribal Fish Commission. 12 pages.

CRITFC. 1982. Mitigation of Anadromous Fish Losses—Efforts Related to Columbia and Snake River Dams and a Plan for Reprogramming Hatcheries. Columbia River Inter-Tribal Fish Commission. 42 pages.

CTWSR, ODFW. 1990. Deschutes River Subbasin Salmon and Steelhead Plan. Northwest Power Planning Council. 133 pages.

CTWSR, ODFW. 1990. Fifteenmile Creek Subbasin Salmon and Steelhead Plan. Northwest Power Planning Council. 65 pages.

CTWSR, ODFW. 1990. Hood River Subbasin Salmon and Steelhead Plan. Northwest Power Planning Council. 203 pages.

CTWSR, CTUIR, ODFW. 1990. John Day River Subbasin Salmon and Steelhead Plan. Northwest Power Planning Council. 116 pages.

CTWSR, CTUIR, IDFG, NMFS, NPT, ODFW, SBT, WDF, WDW, USFWS, YIN. 1988. Columbia River Fish Management Plan. CTWSR, CTUIR, IDFG, NMFS, NPT, ODFW, SBT, WDF, WDW, USFWS, YIN. 74 pages.

CTUIR, NPT, WDW, WDF, ODFW. 1990. Grande Ronde River Subbasin Salmon and Steelhead Plan. Northwest Power Planning Council. 161 pages.

CTUIR, NPT, ODFW. 1990. Imnaha River Subbasin Salmon and Steelhead Plan. Northwest Power Planning Council. 89 pages.

CTUIR, ODFW. 1990. Umatilla River Subbasin Salmon and Steelhead Plan. Northwest Power Planning Council. 166 pages.

CTUIR, ODFW, WDF, WDW. 1990. Walla Walla River Subbasin Salmon and Steelhead Plan. Northwest Power Planning Council. 98 pages.

Cuenco, C.L., T.H. Backman and P.R. Mundy. 1993. The Use of Supplementation to Aid in Natural Stock Restoration. Columbia River Inter-Tribal Fish Commission. 25 pages.

Dauble, D. D. 1990. Letter Regarding 1989 Hanford Reach Redd Counts. Pacific Northwest Laboratories. 2 pages.

Dauble, D. D. 1992. Letter Regarding 1990 and 1991 Hanford Reach Redd Counts. Pacific Northwest Laboratories. 4 pages.

Dauble, D. D. 1993. Letter Regarding 1992 Hanford Reach Redd Counts. Pacific Northwest Laboratories. 2 pages.

Dauble, D. D. and D.G. Watson. 1990. Spawning and Abundance of Fall Chinook Salmon (Oncorhynchus tshawytscha) in the Hanford Reach of the Columbia River, 1948-1988. Pacific Northwest Laboratories. 50 pages.

Davidson, F.A. 1966. Population Trends in the Blueback and Upper Columbia River Fall Chinook Salmon. Grant Public Utility District. 36 pages.

DeLarm, M.R. and R.Z. Smith. 1990. Assessment of Present Anadromous Fish Production Facilities in the Columbia River Basin, Volume 1: U.S. Fish and Wildlife Service Hatcheries. National Marine Fisheries Service. 106 pages.

DeLarm, M.R. and R.Z. Smith. 1990. Assessment of Present Anadromous Fish Production Facilities in the Columbia River Basin, Volume 4: Washington Department of Fish Hatcheries. National Marine Fisheries Service. 130 pages.

DeLarm, M.R. and R.Z. Smith. 1990. Assessment of Present Anadromous Fish Production Facilities in the Columbia River Basin, Volume 5: Washington Department of Wildlife Hatcheries. National Marine Fisheries Service. 122 pages.

DeLarm, M.R. and R.Z. Smith. 1988. Columbia River Fisheries Development Program Annual Report for 1987. National Marine Fisheries Service. 78 pages.

Fish, F. F. and M. Hanavan. 1948. A Report Upon the Grand Coulee Fish-Maintenance Project 1939-1947. U.S. Fish and Wildlife Service. 63 pages.

French, R.R. and R.J. Wahle. 1960. Salmon Runs - Upper Columbia River, 1956-57. U.S. Bureau of Commercial Fisheries. 15 pages.

French, R.R. and R.J. Wahle. 1965. Salmon Escapements above Rock Island Dam, 1954-60. U.S. Bureau of Commercial Fisheries. 18 pages.

Fulton, L. A. 1968. Spawning Areas and Abundance of Chinook Salmon (*Oncorhynchus tshawytscha*) in the Columbia River Basin — Past and Present. U.S. Bureau of Commercial Fisheries. 26 pages.

Fulton, L. A. 1970. Spawning Areas and Abundance of Steelhead Trout and Coho, Sockeye, and Chum Salmon in the Columbia River Basin — Past and Present. National Marine Fisheries Service. 37 pages.

Fuss, H. J. et al. 1994. Annual Coded Wire Tag Program (Washington) Missing Production Groups. Washington Department of Fisheries. 81 pages.

Garrison, R. L. et al. 1994. Annual Coded Wire Tag Program (Oregon) Missing Production Groups. Oregon Department of Fish and Game. 77 pages.

Horner, N. and T.C. Bjornn. 1981. Status of Upper Columbia and Snake River Coho Salmon In Relation to the Endangered Species Act. Idaho Cooperative Fish and Wildlife Research Unit. 45 pages.

Horner, N. and T.C. Bjornn. 1981. Status of Upper Columbia and Snake River Spring Chinook Salmon In Relation to the Endangered Species Act. Idaho Cooperative Fish and Wildlife Research Unit. 63 pages.

Horner, N. and T.C. Bjornn. 1981. Status of Upper Columbia and Snake River Summer Chinook Salmon In Relation to the Endangered Species Act. Idaho Cooperative Fish and Wildlife Research Unit. 58 pages.

IDFG. 1979. Columbia Basin Upriver Salmon and Steelhead Stocks Status Information Relative to Consideration Under the Endangered Species Act. Idaho Department of Fish and Game. 25 pages.

IDFG. 1993. Operations Plans for Anadromous Fish Production Facilities in the Columbia River Basin Volume II. Idaho Department of Fish and Game. 92 pages.

Irving, J.S. and T.C. Bjornn. 1981. Status of Snake River Fall Chinook Salmon In Relation to the Endangered Species Act. Idaho Cooperative Fish and Wildlife Research Unit. 52 pages.

Kiefer, S. 1994. Idaho Redd Counts, Personnel Communication.

Kohn, M. S. 1987. Spring and Summer Chinook Spawning Ground Surveys Methow and Okanogan River Basins 1987. Yakama Indian Nation. 53 pages.

Kohn, M. S. 1988. Spring and Summer Chinook Spawning Ground Surveys Methow and Okanogan River Basins 1988. Yakama Indian Nation. 44 pages.

Kohn, M. S. 1989. Spring and Summer Chinook Spawning Ground Surveys Wenatchee, Methow and Okanogan River Basins 1989. Yakama Indian Nation. 43 pages.

Larson, R. E. and L. Mobrand. 1992. Nez Perce Tribal Hatchery Master Plan and Appendices. Nez Perce Tribe and Mobrand, Inc. 128 pages.

MCPUD. 1993. Comments Concerning the Petition to List Summer Chinook from the mid-Columbia River as Threatened or Endangered Under the Endangered. Mid-Columbia Public Utility District. 25 pages.

Meekin, T. K. 1967. Report on the 1966 Wells Dam Chinook Tagging Study. Washington Department of Fisheries. 40 pages.

Mullen, J. W. 1983. Overview of Artificial and Natural propagation of Coho Salmon (*Onchorhynchus kisutch*) on the Mid- Columbia River. U.S. Fish and Wildlife Service. 37 pages.

Neuberger, R. L. 1941. The Great Salmon Mystery. <u>Saturday Evening Post</u>. 6 pages.

NMFS. 1992. Designated Critical Habitat; Snake River Sockeye Salmon, Snake River Spring/Summer Chinook Salmon, and Snake River Fall Chinook Salmon. <u>Federal Register</u>. 6 pages.

NMFS. 1992. Endangered and Threatened Species; Threatened Status for Snake River Spring/Summer Chinook Salmon, Threatened Status for Snake River Fall Chinook Salmon. Final Rule. National Marine Fisheries Service. 26 pages.

NMFS, ODFW, IDFG, WDF, IPC. 1980. Idaho Power Company Settlement Agreement. Federal Energy Regulatory Commission. 17 pages.

NPT, IDFG. 1990. Clearwater River Subbasin Salmon and Steelhead Plan. 238 pages.

NPT, CTUIR, WDF, WDW. 1990. Tucannon River Salmon and Steelhead Plan. Northwest Power Planning Council. 98 pages.

NPT, SBT, IDFG. 1990. Salmon River Subbasin Salmon and Steelhead Plan. Northwest Power Planning Council. 383 pages.

NPT, CTUIR, SBT, IDFG, ODFW, WDF, WDW. 1990. Snake River Subbasin (Mainstem from Mouth to Hells Canyon Dam) Salmon and Steelhead Plan. Northwest Power Planning Council. 81 pages.

ODFW, CTWSR. 1991. Pelton Ladder Master Plan. Bonneville Power Administration. 67 pages.

ODFW, WDF, WDW. 1990. Mid-Columbia River Subbasin (Bonneville Dam to Priest Rapids Dam) Salmon and Steelhead Plan. Northwest Power Planning Council. 87 pages.

Olsen, E.A., R.A. French. and J.A. Newton. 1993. Hood River and Pelton Ladder Evaluation Studies. CTWSR, Oregon Department of Fish and Wildlife. 45 pages.

Olsen, E.A., et.al. 1994. Salmon and Steelhead Stock Summaries for the Grande Ronde River Basin. Oregon Department of Fish and Wildlife. 132 pages.

Olsen, E.A., et.al. 1994. Salmon and Steelhead Stock Summaries for the Imnaha River Basin. Oregon Department of Fish and Wildlife. 93 pages.

Pevan, Charles M. 1994. Comments Concerning the Petition to List Summer-run Steelhead from the mid-Columbia River As Threatened or Endangered Under the Endangered Species Act of 1973. Mid-Columbia Public Utility District. 21 pages.

Pevan, Charles M. 1994. Spring and Summer Chinook Spawning Ground Surveys on the Wenatchee River Basin, 1993. Chelan Public Utility District. 29 pages.

Production Advisory Committee. 1992. Brood Year Reports for 1991. CTWSR, CTUIR, NPT, YIN, ODFW, WDF, WDW, IDFG, SBT, USFWS, NMFS. 77 pages.

Rhodes, J., et al. 1994. Overview: Coarse Screening Process. Columbia River Inter-Tribal Fish Commission. 27 pages.

Schwartzberg, M., and P.B. Roger. 1986. An Annotated Compendium of Spawning Ground Surveys in the Columbia River Basin Above Bonneville Dam. Columbia River Inter-Tribal Fish Commission. 110 pages.

Scribner, T., et al. 1993. Spring Chinook Spawning Ground Surveys of the Methow River Basin 1993. Yakama Indian Nation. 34 pages.

Smith, M. 1991. Pelton Ladder Master Plan. Oregon Department of Fish and Wildlife, Confederated Tribes of the Warm Springs Indian Reservation. 67 pages.

Smith, R.Z. and R.J. Wahle. 1981. Releases of Anadromous Salmon and Trout From U.S. and Canadian Pacific Coast Rearing Facilities, 1960-1976. National Marine Fisheries Service. 411 pages.

Spaulding, S. 1993. Snake River Sockeye Salmon (*Oncorhynchus nerka*) Habitat/Limnologic Research Annual Report 1992. Shoshone Bannock Tribes of Fort Hall. 78 pages.

Stone, L. 1885. Explorations of the Columbia River from the Head of Clarke's Fork to the Pacific Ocean, Made in the Summer of 1883. Commission of Fish and Fisheries. 22 pages.

Strong, T. 1993. Letter to M. Tuttle regarding status of mid- Columbia summer chinook. Columbia River Inter-Tribal Fish Commission. 26 pages.

Wahle, R.J. and R.E. Pearson. History of Artificial Propagation of Coho Salmon, Oncorhynchus kisutch, in the Mid-Columbia River System. Marine Fisheries Review. National Marine Fisheries Service. 10 pages.

Watson, D.G. 1970. Fall Chinook Salmon Spawning in the Columbia River Near Hanford 1947-1969. Pacific Northwest Laboratories. 46 pages.

Watson, D.G. 1976. Temperoral and Spatial Fall Chinook Salmon Redd Distribution Near Hanford 1967-1976. Pacific Northwest Laboratories. 6 pages.

WDF. 1938. Report of the Preliminary Investigations Into the Possible Methods of Preserving the Columbia River Salmon and Steelhead at the Grand Coulee Dam. Bureau of Reclamation. 121 pages.

YIN, WDF, WDW, CCT. 1990. Entiat River Subbasin Salmon and Steelhead Plan. Northwest Power Planning Council. 74 pages.

YIN, WDF, WDW. 1990. Klickitat River Subbasin Salmon and Steelhead Plan. Northwest Power Planning Council. 108 pages.

YIN, WDF, WDW. 1990. Little White Salmon River Subbasin Salmon and Steelhead Plan. Northwest Power Planning Council. 52 pages.

YIN, WDF, WDW, CCT. 1990. Methow and Okanogan Rivers Subbasin Salmon and Steelhead Plan. Northwest Power Planning Council. 159 pages.

YIN, WDF, WDW, CCT. 1990. Wenatchee River Subbasin Salmon and Steelhead Plan. Northwest Power Planning Council. 122 pages.

YIN, WDF, WDW. 1990. White Salmon River Subbasin Salmon and Steelhead Plan. Northwest Power Planning Council. 81 pages.

YIN, WDF, WDW. 1990. Wind River Subbasin Salmon and Steelhead Plan. Northwest Power Planning Council. 91 pages.

YIN, WDF, WDW. 1990. Yakima River Subbasin Salmon and Steelhead Plan. Northwest Power Planning Council. 282 pages.

YIN, WDF, WDW. 1990. Yakima River Subbasin Salmon and Steelhead Plan, Supplement 1. Northwest Power Planning Council. 88 pages.

YIN, WDF, WDW. 1990. Yakima River Subbasin Salmon and Steelhead Plan, Supplement 2. Northwest Power Planning Council. 27 pages.

Tribal Pacific Lamprey Restoration Plan for the Columbia River Basin

Formal Draft
May 15, 2008

Nez Perce, Umatilla, Yakama and Warm Springs Tribes

TRIBAL PACIFIC LAMPREY *(Lampetra tridentata)*
COLUMBIA BASIN RESTORATION PlAN

Executive Summary

Pacific Lamprey (*Lampetra tridentata*) abundance and distribution in the Columbia River Basin is declining precipitously, bringing the species dangerously close to regional extinction. Lamprey continue to decline despite, or in part because of, measures taken to protect and restore salmonid species. The plight of the Pacific Lamprey has garnered some attention, but little effective action.

For over 10,000 years the people of the Nez Perce, Umatilla, Yakama and Warm Springs tribes depended on lamprey (eels), salmon, and roots and berries. The tribal people used the eel for food and medicine and through the years many stories and legends surrounding the eel were passed down from generation to generation. Before The Dalles Dam, the river at Celilo Falls was black with eels and tribal members took just what their families needed for a year. Eels were plentiful in the Walla Walla River, Asotin Creek, Lolo Creek, the south fork of the Salmon River, Swan Falls, the upper portions of the Yakama River, and the tributaries of the upper Columbia.

Now these great rivers have no eels, or at best remnant numbers. The eel has vanished from the tribal longhouse tables. As eels disappear, younger tribal members are losing their collective memory for the species and the culture that it surrounds.

The tribes propose this plan for restoration of the species to numbers adequate for tribal use and ecological health of the region. The tribes believe action must be taken now, despite a general paucity of information about the life history and population dynamics of the species.

Achieving improvements in dam passage efficiencies and survival is of primary importance. Only about 50% of adult lamprey successfully pass a single dam. Improving dam passage will require a set of operational and structural modifications to the existing dams. These modifications are possible, practical, and should be undertaken immediately. They include the use of 24 hour video counting, installation of lamprey passage systems, altering existing fishway structures to prevent trapping, reducing velocity barriers, reducing/eliminating juvenile impingement on screens and reducing fishway flows at night.

Improving tributary and mainstem habitat for lamprey ammocoetes and macrophalmia is also important. This draft plan contains detailed subbasin plans by each tribe for achieving these goals. We also recommend the development of effective tagging technology and installation of devices preventing entrainment of juveniles into irrigation canals and tributary water diversion.

Lamprey supplementation using translocated adults has been tried and found effective as an emergency, interim action. Supplementation is recommended as a consideration for all subbasins, particularly those with no or low populations of juvenile lamprey. This is particularly crucial given evidence that suggests adult lamprey select spawning streams by following pheromones emitted by ammocoetes.

There must be a basinwide, coordinated effort to continue to fund and perform research, monitoring and evaluation and to collect and make widely available and accessible all pertinent data.

Finally, implementation of the plan cannot succeed without a consistent, coordinated public education and outreach programs to communicate: 1) the plight of the eel, 2) the need for public infrastructure investments at all government levels for restoration actions, and 3) the consequences of failing to act.

There is no time to waste. The Pacific lamprey has been neglected and ignored for too long.

Introduction

The Pacific lamprey (*Lampetra tridentata)* or "eel" is an ancient, anadromous, native species that has suffered widespread decline throughout the Columbia Basin and the Northwest coast from California to Alaska. One of three lamprey species in the Columbia River Basin, they are the most important the tribes (Close et al. 2002). In addition, Pacific lamprey are a key indicator of the ecological health of the Columbia Basin and appear to be a choice food for avian, marine mammal and fish predators, and at times may be preferred over salmon smolts (Close 1995; Stansell 2006).

Once abundant with Pacific lamprey, most Columbia Basin rivers now have few or none. Like other lamprey throughout the world, the Pacific lamprey's decline in abundance is due primarily to human factors, including dams for hydropower and flood control facilities, irrigation and municipal water diversions, lost habitat, poor water quality, excessive mammal, avian and fish predation and the application of fish eradication chemicals. Besides these direct effects on mortality, reproductive success has also been impacted. Lamprey access to much of the historic spawning and freshwater rearing habitat has been blocked by mainstem and tributary dams and other obstacles.

The species decline has not gone unnoticed. For example, in 1993, the State of Oregon listed Pacific lamprey as a state sensitive species and in 1997 lamprey were given further legal protection (OAR 635-044-0130; Kostow 2002). In Washington State, lamprey are placed in a monitoring status, the lowest threat level of the state's "species of concern" list. In 1994 , after a precipitous decline in population numbers over 20 years, the United States Fish and Wildlife Service (USFWS) designated the species for listing as a Candidate 2 under the Endangered Species Act. In their 1994 Fish and Wildlife Program, the Northwest Power Planning Council noted the lamprey decline in the Columbia Basin and called for a status report (Close et al. 1995). The Oregon Natural Resources Council petitioned the USFWS to list the species under the Endangered Species Act (ESA) in 2002.[1] The USFWS denied consideration of the petition in 2004, finding that the petition did not present substantial scientific or commercial information to indicate the listing was warranted. Repeatedly the USFWS has noted the lack of information regarding the status and distribution of Pacific lamprey.

Nonetheless, the USFWS has remained open to submission of new information concerning the status of, or threats to, the species, stating that this information would help them monitor and encourage conservation of the species. Recently, the USFWS presented a "Coast wide Conservation Initiative" intended to bring focus on lamprey restoration. Since this Initiative's goals and objectives are very broad, the tribes have responded with this restoration plan which focuses on the Columbia Basin.

---

[1] ONRC (Oregon Natural Resource Council). January 28, 2002. Petition for rules to list four Pacific lamprey species as Threatened and Endangered under the Endangered Species Act.

Lamprey are of great importance to Native American tribes for cultural, spiritual, ceremonial, medicinal, subsistence and ecological values. From a tribal perspective, the decline of lamprey continues to have at least three negative effects: (1) loss of cultural heritage, (2) loss of fishing opportunities in traditional fishing areas, and (3) necessity to travel large distances to lower Columbia River tributaries, such as the Willamette River, for ever-decreasing lamprey harvest opportunities. As a consequence of declining or elimination of harvest in interior Columbia River tributaries, many young tribal members have not learned how to harvest and prepare lamprey for drying. In addition, young tribal members are losing historically important legends associated with lamprey.

In part due to the image of sea lamprey as a nuisance species in the Great Lakes region, and a fundamental lack of education of the ecological and cultural importance of Pacific lamprey in the Columbia Basin, they have suffered a negative image among non-tribal peoples. Yet they are every bit as important as salmon and steelhead. The Columbia River Inter-Tribal Fish Commission's (CRITFC) member tribes recognize and stress that Pacific lamprey are an important part of the ecosystem, contributing to food web dynamics, acting as a buffer for salmon from predators, and contributing important marine nutrients to inherently nutrient-poor watersheds.

In 1855, CRITFC's member tribes relinquished many millions of acres of Columbia Basin lands in treaties to the United States but retained their rights to fish at "usual and accustomed places" on both their reservations and their ceded lands (Figure 1). Fish were not limited to salmon and steelhead, but include lamprey, sturgeon and other species. The U.S. Supreme Court recognized the importance of fish to the tribes early in the development of the treaty interpretation:

> *The right to resort to… fishing places…was a part of larger rights possessed by the Indians upon exercise of which there was not a shadow of impediment and which were not much less necessary to the existence of the Indians than the atmosphere that they breathed."*

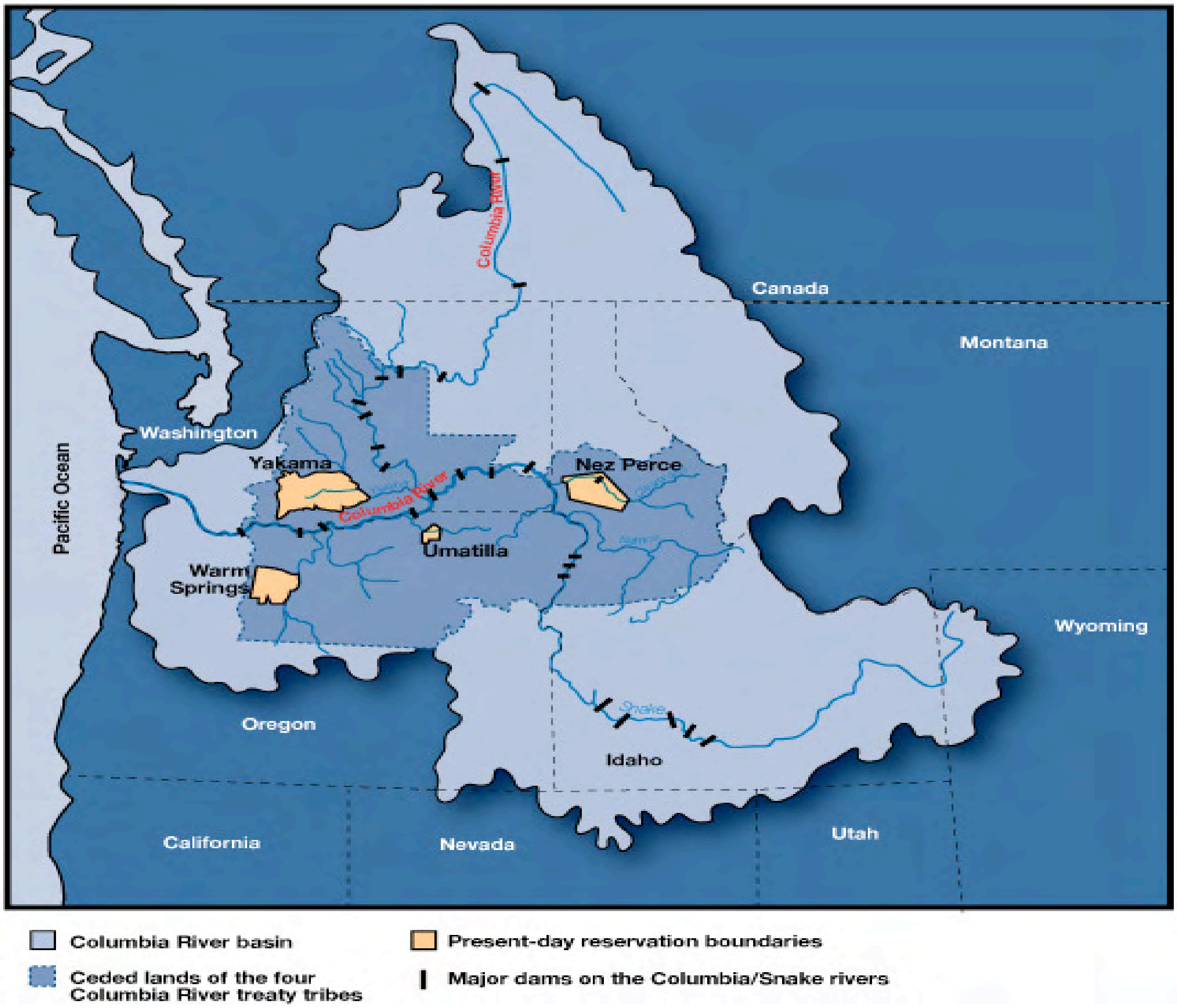


Figure 1. Map of Columbia Basin showing historical tribal ceded lands, current reservation boundaries and major federal and FERC licensed dams that affect Pacific Lamprey.

To the Columbia River Treaty Tribes, restoration of lamprey populations is as necessary to the restoration of the ecological health of basin watersheds as are salmon and other native fish populations. In the Columbia River treaty tribes' anadromous fish restoration plan, *Wy-Kan-Ush-Mi Wa-Kish-Wit* (Nez Perce et al. 1995), the tribes' objectives were to to halt the declining trends in salmon, sturgeon, and lamprey populations originating upstream of Bonneville Dam in 7 years, and to increase Pacific lamprey populations to naturally sustainable levels that also support tribal harvest opportunities within 25 years.

Firm substantive commitments to restore Pacific lamprey are crucial. In 2004, the member tribes of the Columbia River Inter-Tribal Fish Commission (CRITFC) sponsored a regional "Lamprey Summit" to focus on the severe decline of lamprey and to identify factors and critical uncertainties contributing to their decline. Tribal elders and researchers briefed representatives of federal and state agencies as to the importance and status of lamprey. The result was a consensus to take actions to restore lamprey. However, earlier priorities focused regional attention on restoring ESA listed salmon stocks, with the result that lamprey populations continued their serious decline. Currently only a few dozen adults manage to migrate past the uppermost passable dams on the Columbia and Snake Rivers where forty years ago, before the series of dams were completed on the Snake and Upper Columbia reaches, hundreds of thousands migrated to these areas. Unless effective action is taken immediately, the risk of local extirpation of lamprey from vast traditional tribal fishing areas is extremely high.

Although relatively few restoration actions have been implemented in the Columbia River Basin since the 2004 Lamprey Summit, there have been two important initiatives. First, the 2008 Columbia Basin Fish and Wildlife Authority's (CBFWA) submission to the Northwest Power and Planning Commission Amendment Process recognizes the severe downward trends in the Columbia River lamprey populations and recommends nine specific strategies, detailing numerous measures for implementation. These recent CBFWA recommendations are a product of the regional fishery managers collaborating to address this serious problem. The CBFWA's Lamprey Technical Working Group (CBLTWG) listed a number of important critical uncertainties in addressing lamprey passage, limiting factor analysis, population delineations and population dynamics. Second, the 2008 US Fish and Wildlife Service "Conservation Initiative" aims to "*facilitate communication and coordination relative to the conservation of Pacific lampreys throughout their range.*"

The tribes applaud these and other efforts and are committed to their success. However, the tribes also recognize that the lamprey's current dilemma demands a heightened level of political will, a change in institutional priorities and more technical innovation to realize a cost-effective and timely implementation of critical actions.

The tribes believe making necessary improvements at basin mainstem hydroprojects, resolving biological uncertainties, and improving lamprey productivity throughout the Columbia Basin will require a regionally coordinated effort from tribes, federal and state fishery agencies and closely coordinated funding contributions from federal and private/public hydroprojects licensed under the Federal Energy Regulatory Commission (FERC).

The Tribal Restoration Plan is a call to action. The rapid declines in lamprey populations challenge resource managers to accelerate coordination and collaboration, both in terms of establishing priorities and in acquiring necessary funding. While regional initiatives are being developed and adopted, substantive actions based on current knowledge must be implemented immediately to prevent the impending loss of Pacific lamprey across vast portions of its remaining range within the Columbia Basin.

The emphasis of this Tribal Restoration Plan is to provide an explicit and timely path, including specific actions that can be implemented in the next ten years for both the mainstem Columbia/Snake Rivers and associated tributary streams. The ultimate goal is restoration of Pacific lamprey to levels supportive of their unique cultural and ecosystem values. Our primary objectives include 1) improving mainstem passage and survival, 2) improving tributary habitat conditions, 3) implementing translocation/re-introduction actions and 4) continuing research to improve our understanding of their life history and biology.

While the plan's time line spans ten years, actions should be immediately taken. As one tribal fisheries manager put it, "For some of us our "ten years" was up ten years ago."

The Nez Perce, the Umatilla, the Warm Springs and the Yakama tribes' Pacific Lamprey Restoration Plan contains the key elements to achieve the stated goal and associated objectives. The need is even more crucial considering the increasing impacts of climate change and human population growth in the Columbia Basin (ISAB 2007a; ISAB 2007b; WGA 2008; NRDC 2008).

The Tribes strongly encourage the region to actively and collaboratively engage in further development and implementation of this Pacific Lamprey Tribal Restoration Plan.

***Clearly, the time to act is now*.**

Cultural Context

All lamprey are and have been of great importance to Native American tribes (Close et al. 1995; Close et al. 2001). Indigenous peoples from the coast to the interior Columbia and Snake rivers harvested lampreys for subsistence, religious, medicinal, spiritual and cultural purposes for many generations (Close et al. 1995). Today, these peoples have dwindling opportunities to harvest lamprey, with these opportunities restricted to the lower portions of the Columbia Basin (Close et al. 2002).

Historically, tribal people of the CRITFC's member tribes harvested adult lampreys in the mainstem tributaries of the Columbia and Snake rivers. Tribal members typically harvested enough lamprey at Celilo[2] and Willamette Falls to last families for a year. The lamprey were collected at night in areas where they accumulated at the falls, and were used for sustenance and trading for other food and clothing. Tribal members continue to refer to lamprey as "eels" Pre-treaty traditional fishing areas of the Umatilla, Walla Walla, and Cayuse tribes, for example, included the John Day, Umatilla, Walla Walla, Tucannon, Grande Ronde, and Powder rivers.

In the 1970s, tribal members began noticing declines in the numbers of lampreys migrating into the interior Columbia River basin. Two types of lampreys were harvested from spring through fall: the short brown type and the long dark type, which may have represented different species or subspecies of lamprey. Lamprey spawning distributions stretched from the mouth to the headwaters in the Umatilla,Yakima, Deschutes, Salmon and Clearwater rivers. Tribal members observed larval lampreys in the mud and sand areas of these rivers. Tribal members identified declines in lamprey from declining habitat conditions, fish poisoning operations and dams (Close et al. 2004).

When the few opportunities for harvest occur, younger tribal members, with training from adult tribal members, often collect eels for tribal elders. Without lamprey to catch and prepare and preserve, younger tribal members will lose the opportunity to gain associated technical knowledge and cultural experiences, including important connections with elders. The loss of traditional tribal fishing areas leads to the loss of how to catch and prepare lamprey. This, and the loss of other traditional knowledge surrounding eel myths and stories threatens loss of tribal culture (Close et al. 2002). One tribal elder stated:

The eels was part of the July feast.. because along with the salmon… this is what our older people tell us… that when the time began the foods were created. The foods were here before us…and they said that the foods made a promise on how they would take care of us as Indians and the eels was one of those who made a promise to take care of us. (Close and Jackson 2001).

A tribal story states:

I have heard it said that long ago, before the people, the animals were preparing themselves for us. The animals could talk to each other during this time. The eel and the sucker liked to gamble, so they began to gamble. The wager was their bones. The eel began to lose but he knew he could win. The eel kept betting until he lost everything. That is why the eel has no bones and the sucker has many bones (Close et al. 1995).

[2] Celilo Falls was probably the most significant tribal cultural site in North America for more than 10,000 years and was inundated by the backwaters of The Dalles Dam in 1957. It was the primary site for tribal lamprey and salmon harvest in the Columbia Basin.

Institutional Context

Changes in institutional priorities are needed. The region needs to acknowledge policy and institutional barriers that are independent from scientific and economic issues that prevent federal, state and local agencies from taking action to restore lamprey. Current institutions and policies fail to foster timely actions. Among other things, these agencies need to work with the tribes to educate the general public about the importance of lamprey as a vital part of the Columbia River ecosystem.

Conservation of Pacific lamprey within the Columbia Basin has not been a fisheries management priority. Instead, Pacific lamprey have often been lumped into a multispecies context—it has been assumed that measures taken to restore salmon species would carry along the less charismatic species. Although these primitive fish share many of the same habitats as anadromous and resident salmonids listed under the Endangered Species Act and are an integral part of ecosystems on which these fish depend, the Pacific lamprey have been little more than add-ons to species preservation plans. Unfortunately, the efforts to help salmon and other native fish have not resulted in flourishing lamprey populations and in fact, some bioengineering measures for salmon have proven detrimental to lamprey (Bleich and Moursund 2006).

Wy-Kan-Ush-Mi Wa-Kish-Wit (Nez Perce et al. 1995) recognized that lamprey restoration "*…depends on institutional structures that efficiently coordinate the actions and resources of relevant government agencies and enlist the support and energy of individuals and non-government agencies*". Redirection of funding and personnel by sovereign entities as well as local governments is needed in order to implement goals, objectives, actions, monitoring and evaluation in an active adaptive management framework (Walters 1986; Walters and Holling 1990;Hilborn 1987). When policy makers, technical experts or implementers differ on restoration approaches and actions, dispute resolution processes must be timely so that progress is not stalled.

Existing Columbia Basin management forums and processes established for salmon restoration must be expanded to include actions for Pacific lamprey. This includes but is not limited to the Northwest Power and Conservation Council's Fish and Wildlife Program, state programs for species of concern, license conditions issued by the Federal Energy Regulatory Commission, requirements for permits issued under the Clean Water Act, the Fish and Wildlife Coordination Act, the National Environmental Policy Act and the Corps of Engineers' Columbia River Fish Mitigation Program. The recent memorandums of agreements between three of CRITFC's member tribes and three federal agencies provide a good start toward working partnerships and actions to restore Pacific lamprey, but in themselves will not be enough to reverse the ongoing decline.

The inconsistency of conditioning dam passage goals and actions by the USFWS in FERC licensing is a particular problem that needs to be remedied. As the federal agency responsible for Pacific lamprey restoration, the USFWS should use their Section 18 authorities to condition FERC licenses to expedite structural and operational passage improvement at project dams and reservoirs. These authorities become mandatory license conditions and are much more defined and enforceable than Section 401 water quality certificates issued by the state water quality agencies.

As a first step toward making institutional reforms for lamprey recovery, we recommend that all federal and state agencies and FERC license holders establish specific funding streams and other resources to implement lamprey actions. Among other things, this includes expedited establishment of at least one full time scientist/manager who focuses entirely on lamprey restoration and who coordinates with tribes, other agencies and other basin forums such as CBFWA's Columbia Basin Technical Lamprey Working Group.

As is evident by the drastic reduction of eels observed in the upper portions of the Snake and Columbia rivers, the general state of our Pacific lamprey management can be characterized as simply watching these once strong populations dwindle to functional extinction. This must change—it is past time the lamprey received priority attention.

Life History of Pacific Lamprey

Due to the lack of information, the life history of Pacific lamprey is not as clear as salmon life history (Figure 2). There appears to be between and within-basin variation in time of spawning, metamorphosis, outmigration, ocean residency, and upstream migration. Fossil records indicate that lamprey existed 450 million years ago (Schawb and Collin 2005 and Bond 1996 in Cummings 2007). This compares to salmon that have a history of 40 million years in existence (Wilson and Williams 1992 in Cummings 2007).

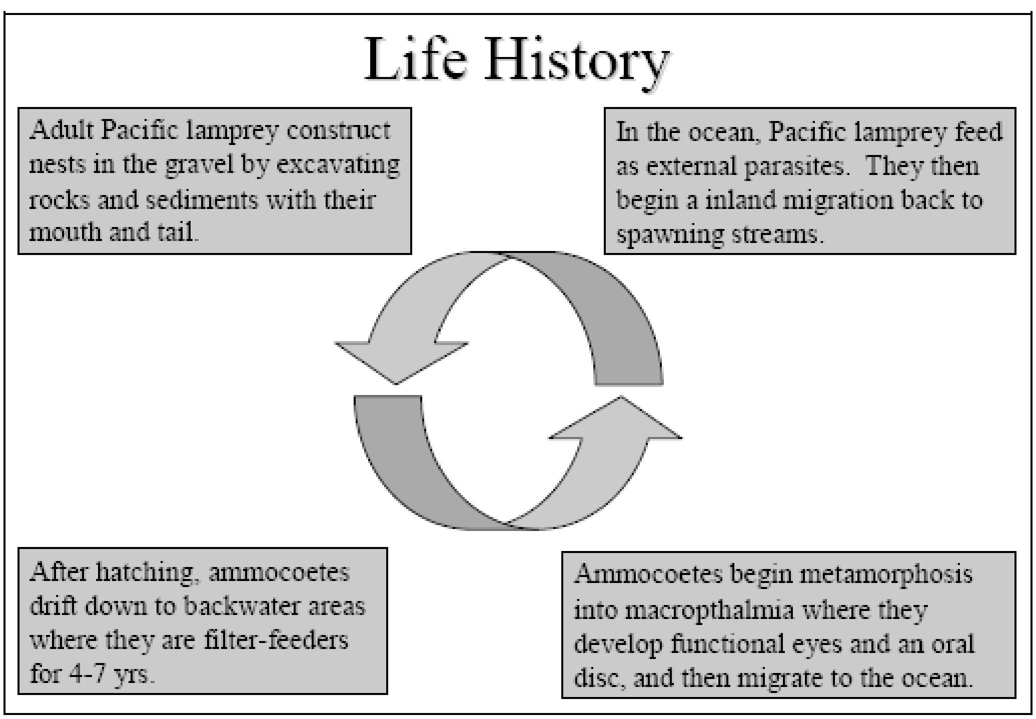


Figure 2. Generalized life history of Pacific lamprey (from Cummings 2007).

After feeding and growing in saltwater for about one year, Pacific lamprey migrate into freshwater to spawn (Cummings 2007). In the Columbia River adults migrating upstream have been observed entering freshwater as early as February (Kan 1975) and as late as September (Beamish 1980). Counts at Bonneville and The Dalles dams peak during June - August (Fish Passage Center 2008). Adult Pacific lamprey spend a winter prior to spawning becoming sexually mature in deep river pools with cover (i.e., boulders, organic debris) (Beamish 1980; Bayer et al. 2000). After over-wintering, adult lamprey have been observed spawning between March and July when the water temperature is between 10 and 15°C (Beamish 1980; Beamish and Levings 1991; Close et al. 2003; Brumo 2006). Males and females cooperate to build redds by using their buccal funnel to remove and stack gravel substrate (Pletcher 1963). Spawning activity is not affected by light (Pletcher 1963; Kan 1975). Absolute fecundity varies between 98,000 – 238,400 eggs per female (Kan 1975). Unlike salmon, eggs are released in a series of short spawning events, with generally 100 – 500 eggs per event. During copulation eggs are fertilized by the male and then covered with fine substrate before another spawning event is initiated (Pletcher 1963). Adult lamprey die within 3-36 days after spawning (USFWS 2006).

Age at time of spawning is difficult to estimate due to life history plasticity, difficulties in aging ammocoetes, and lack of information on ocean residency time and migration behavior. For these reasons it is difficult to track individual year-classes throughout their life cycle, and thus modeling population dynamics is challenging. A literature search did not yield techniques to age adult lamprey. Some adult river migrants may be as old as ten or eleven years, as they can be seven years old when out-migrating to the ocean. There is also evidence that age at time of maturation varies depending upon geographic location in the basin (i.e.where they reared as ammocoetes and macropthalmia; Kostow 2002).

Depending on water temperature, eggs hatch after approximately 15 days and spend another 15 days in redd gravels until they emerge and drift downstream to suitable rearing habitats (Pletcher 1963, Brumo 2006). Dispersion from redds to suitable burrowing habitat is dependent upon flow and stream gradient (Potter 1980). Ammocoetes move downstream during high flow and scouring events, generally observed during the spring and winter (Graham and Brun 2006).

In general, ammocoete habitat occurs in low velocity, low gradient areas containing soft substrate and organic materials (Pirtle et al. 2003; Graham and Brun 2006). Ammocoetes will remain burrowed in soft substrates for up to 7 years (Close et al. 1995). While burrowed, ammocoetes are blind and sedentary. They filter feed on diatoms and other organic material suspended in the water column (Moore and Mallatt 1980). In filter feeding, ammocoetes produce mucus from the pharynx that entraps food particles that flow over rearing beds (Moore and Mallatt 1980).

Similar to salmonids, lamprey ammocoetes go through a "smolting" process where they undergo morphological and physiological changes to prepare for ocean life and the predatory phase of their life history (Close et al. 1995). Ammocoetes develop eyes, an oval mouth, functional teeth and a tongue, and the size of their oral disc increases (Yousson and Potter 1979). Internal changes include foregut development for osmoregulation (Richards 1980; Richards and Beamish 1981), blood protein changes (Richards 1980), disappearance of the bile duct and gallbladder (Bond 1979), and development of a unidirectional respiratory system (Lewis 1980). Metamorphosis generally occurs between July and October (Richards and Beamish 1981; Hammond 1979). Once metamorphosis is complete, ammocoetes are considered macropthalmia or juvenile lamprey. Before outmigration, macropthalmia appear to change their habitat preference to larger cobble sized substrate and faster water (Beamish 1980).

After metamorphosis macropthalmia migrate to the Pacific Ocean between fall and spring, taking advantage of periods of high river discharge (Richards and Beamish 1981; Beamish and Levings 1991; van de Wetering 1998; Graham and Brun 2006; Bleich and Moursund 2006). Pacific lamprey are thought to remain in the ocean, feeding parasitically on a variety of fish, for approximately 18–40 months before returning to freshwater as immature adults (Kan 1975; Beamish 1980). Pacific lamprey use olfactory perception, vision, and electroreception to choose their prey (Close et al. 1995). Feeding occurs when an adult lamprey attaches itself on prey using its oral disc, rasps through prey tissue, injects anticoagulant, and feeds upon removed blood and fluids. Beamish (1980) found walleye pollock (*Theragra chalcrogramma*) and Pacific hake (*Merluccius productus*) were the majority prey of Pacific lamprey. Lamprey have also been observed feeding on marine mammals (Scott and Crossman 1973).

It is uncertain how or even if lamprey home back to their natal streams. While there is some research in this area, more needs to be done (Lin et al. 2007). Researchers at Michigan State and Humboldt State universities are investigating stream attractants perhaps driven by genes or pheromones, that determine lamprey spawning locations. Adult Pacific lamprey, like sea lamprey appear to be attracted to spawning sites by pheromones released by ammocoetes based upon their production of bile acids (Bergstedt and Seelye 1995 *in* Lin et al. 2007).

Goodman (2006) analyzed 81 tissue samples from lamprey along the Pacific Ocean coastline and found no evidence of genetic variability among drainages. Lin et al. (2007) analyzed muscle and fin tissue from seven different Northwest rivers including four in the Columbia Basin for genetic DNA differences. While they, like Goodman (2006), found no statistically significant differences between the Columbia and Klamath basins, they found statistically significant differences among samples within those basins. They concluded that Pacific lamprey showed a geographical divergence pattern across the range of Northwest samples but there was no clear pattern of geographical structure within the Northwest, based upon the samples. They hypothesized that lamprey from different rivers disperse and mix in aggregations at sea and could be carried for hundreds of miles by prey and ocean currents. That and the absence of natal homing could lead to temporal unstable genetic differences between spawners. They concluded that more genetic, physiological and demographic studies of lamprey migration will be able to better resolve genetic and geographical separation hypotheses.

Ecological Significance

Evidence suggests that Pacific lamprey integrated well into the native freshwater fish community and had positive effects on the system. In all probability they were and continue to be a significant contributor to the nutrient supply in oligotrophic streams of the basin as adults die after spawning (Beamish 1980). Lamprey were and continue to be an important part of the food chain for many species such as sturgeon, northern pike minnow, trout, sea lions, whales, gulls and terns (Close et al. 1995). Close et al. 1995 suggested that lamprey were and are an important buffer for upstream migrating adult salmon from predation by marine mammals. From the perspective of a predatory sea mammal it has at least three virtues: (1) they are easier to capture than adult salmon; (2) they are higher in caloric value per unit weight than salmonids and (3) they migrate in schools. The lamprey is extraordinarily rich in fats, much richer than salmon. Caloric values for lamprey ranges from 5.92-6.34 kcal/gm wet weight (Whyte et al. 1993); whereas, salmon average 1.26-2.87 kcal/gm wet weight (Stewart et al. 1983).

Further, Roffe and Mate (1984) revealed that the most abundant dietary item in seals and sea lions are Pacific lamprey. As a result of dwindling lamprey stocks, marine mammal predation on salmonids may be more severe. Larval stages and spawned out carcasses of lampreys were important dietary items for white sturgeon in the Snake and Fraser Rivers (Ken Witty, ODFW retired, personal communication, Galbreath 1979; Semkula and Larsen 1968). Juvenile lampreys migrating downstream may have buffered salmonid juveniles from predation by predacious fishes and sea gulls (Merrell 1959).

Lampreys are found in the diets of northern pike minnow *(Ptychocheilus oregonensis)* and channel catfish *(Ictalurus punctatus)* in the Snake River system (Poe et al. 1991). Merrell (1959) found that lampreys were 71% by volume of the diet of gulls and terns below McNary Dam during early May. Close et al. 1995 suggests that juvenile lampreys may have played an important role in the diets of many freshwater fishes. Clanton (1913) reported that ground up “eel” (lamprey) was the dietary constituent that led to the best growth of hatchery salmonid fry. Pfeiffer and Pletcher (1964) found emergent ammocoetes and lamprey eggs were eaten by salmonid fry. Close et al. 1995 speculated that wild juvenile salmonids may have found lamprey to be important prey during the spring.

Historical Abundance and Status

Over the last 30 years abundant lamprey populations have dramatically declined concurrent with the construction and operation of mainstem and tributary dams, irrigation and agricultural projects, urban development, and habitat loss (Close et al. 1995; Moser and Close 2003; Kostow 2002).

Investigators have used oral histories of Pacific lamprey from tribal elders to gauge the relative decline of lamprey populations (Close and Jackson 2001). These oral histories provide a baseline to measure lamprey decline that predates other methods. Oral histories have documented consistent historical lamprey distribution and abundance throughout the basin.

In the 1840's, harvests of 40 – 185 tons (i.e.100,000-500,000 adults; E. Crow, 2007 pers. com) were documented for commercial eel fisheries at Willamette Falls. During the late 1800's Pacific lamprey were described as completely covering Willamette Falls, Oregon (ONRC 2002). There is documentation at Willamette Falls of collection of lamprey for processing for non-tribal use of 27 tons in 1913 (E. Crow. 2007 pers. com.). Records of adult lamprey passage began at Bonneville Dam in 1938. Counts ranged between about 50,000 to about 400,000 between 1938 and 1969 (Close et al. 1995). The Corps of Engineers (Corps) did not count adult lamprey at their dams between 1969 and 1993 (Close et al. 1995). Close et al. (2002) documented that in the early 1960's adult counts reached 300,000-350,000 at The Dalles Dam, 25,000 at McNary Dam and 17,500 at Rocky Reach Dam.

Typically, lamprey numbers decrease significantly as the run moves upstream. For example, Jackson et al. (1997) found a 65% reduction in numbers from Bonneville to The Dalles, a 72% reduction between John Day and McNary dams and a 40% reduction between Rock Island and Rocky Reach dams. The main causes of the declines are believed to be mortality and turnoff into tributaries. In some instances, lamprey counts at upstream dams have been greater than downstream dams, perhaps indicating that lamprey pass some dams undetected. For example, Jackson et al. (1996 in Bioanalysts 2000) reported 593 adults passing Rocky Reach Dam compared to 979 adults passing Wells Dam in 1996.

Although historical adult abundance estimates are incomplete and not rigorous, it is hard to deny that adult lamprey counts at mainstem dams have been in serious decline, with Snake River and Upper Columbia estimates at only a few dozen individuals (FPC 2006). These meager counts indicate that in recent times only very small numbers of adult lamprey pass the upper most dams in the Lower Snake and Upper Columbia. For example, in 2006 only 21 adult lamprey were counted passing Wells Dam in the upper Columbia and only 35 adults were counted passing Lower Granite Dam in the Snake River (Figure1 and Table 1; FPC 2007).

Cummings (2007) noted that based upon the current trajectory, Pacific lamprey will soon reach unsustainable levels through much of the Columbia Basin. The tribes believe that this is already the case. For example, of 38,941 adults counted at Bonneville Dam in 2007, only 35 passed Lower Granite Dam in the Lower Snake River, seven dams above Bonneville and only 32 passed Wells Dam in the upper Columbia River, eight dams above Bonneville.

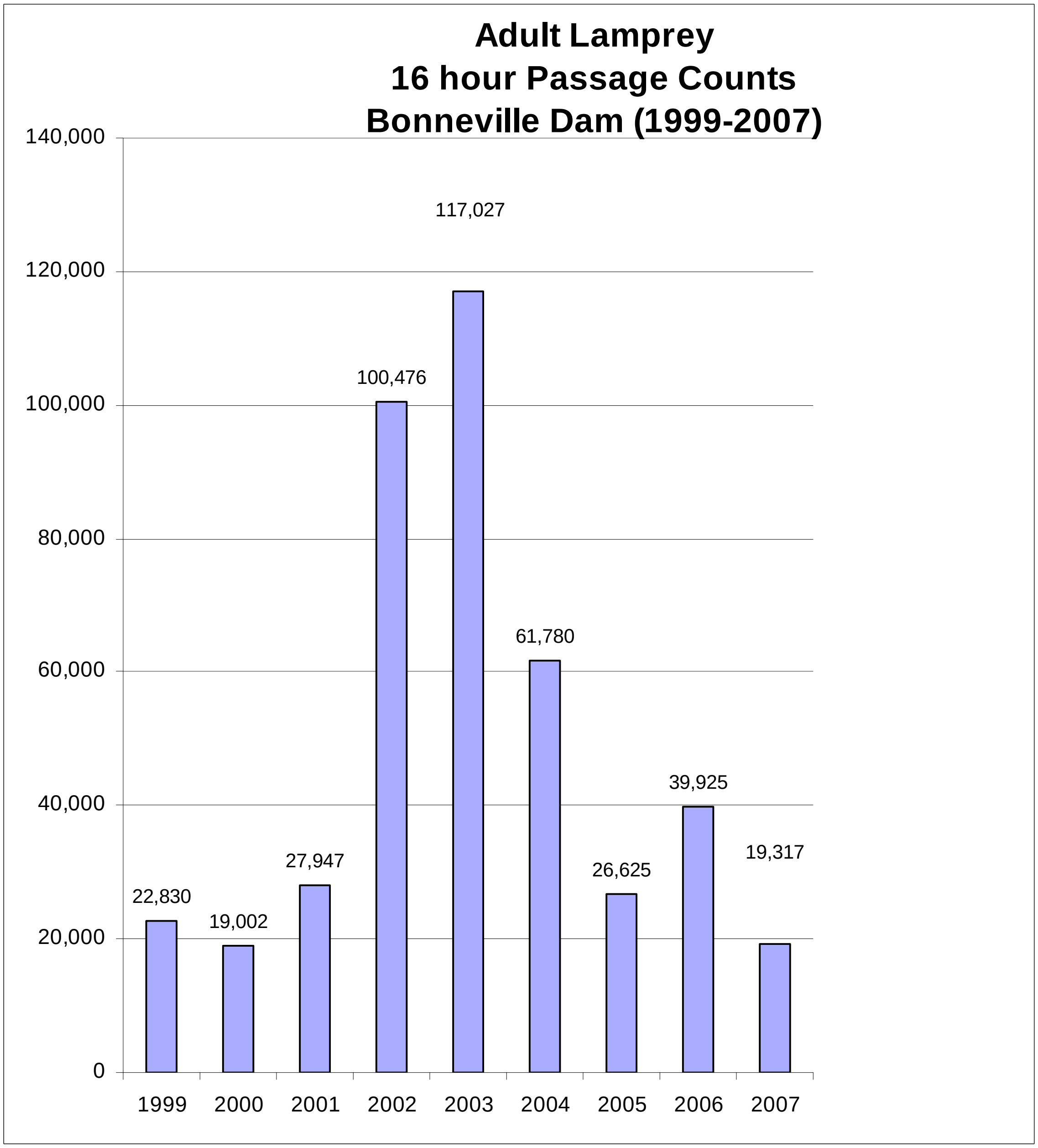


Figure 3. Recent adult lamprey 16 hour counts (daytime) at Bonneville Dam. Data from Fish Passage Center.

Table 1. Recent adult lamprey counts at Corps and Mid-Columbia PUD dams

Year	McNary	Priest Rapids	Ice Harbor	Wells	Lower Granite
2000	1,281	1,468	315	NA	28
2001	2,539	1,624	203	261	27
2002	11,282	4,007	1,127	338	128
2003	13,325	4,339	1,702	1,408	282
2004	5,888	2,647	805	291	117
2005	4,158	2,598	461	212	40
2006	2,139	3,273	255	21	35
2007	3,389	3,419	288	32	34

.

With respect to juvenile lamprey declining abundance, little is known except for gross observed declines, particularly in the Snake River Basin. Tribal and non-tribal accounts documented plentiful juvenile abundance and widespread distribution in the 1970's (E.Crow pers.com. 2007; S. Petitt, pers. com. 2000). There have been a few studies of juvenile lamprey abundance in the Snake River Basin, the Umatilla Basin, the Deschutes River Basin and the Willamette River Basin.

Plan Vision: *Pacific lamprey are widely distributed within the Columbia River Basin in numbers that fully provide for ecological, tribal cultural and harvest utilization values.*

Plan Goal: *Immediately halt population declines and reestablish lamprey as a fundamental component of the ecosystem by 2018. Restore Pacific lamprey to sustainable, harvestable levels throughout the historical range and in all tribal usual and accustomed areas.*

Objective 1: Improve mainstem lamprey passage efficiency, survival and habitat

Considering dam count data and adult tagging studies, the tribes believe that passage is the most urgent problem facing lamprey in the Columbia River Basin. As has been found in other river systems such as the Great Lakes (Haro and Kynard 1997) and in Europe (Laine et al. 1998), passage impediments throughout the basin considerably impact upstream production. In its report on critical uncertainties for lamprey, the Columbia Basin Lamprey Technical Working Group (CBLTWG 2005) prioritized passage improvements as a second rank critical uncertainty in the overall effort to restore lamprey.

Millions of dollars have been spent on dam fishways, juvenile passage systems and irrigation screening systems that were designed and constructed for adult and juvenile salmon.. Unfortunately, the biological and swimming capacities of lamprey were never considered. In general, all of the existing research and literature indicate that lamprey as aguilliform type swimmers are not as efficient as teleost-type swimmers such as salmon (CBLTWG 2004).

As research and evaluation provides information on dam impacts to lamprey, this paradigm is slowly changing. In their 1999 review of the Corps of Engineers Columbia River Fish Mitigation Program, the Independent Scientific Advisory Board of the Northwest Power Planning Council (ISAB) advocated for creating a "biodiversity standard" of which passage fixes for all fish should be considered. They recommended passage standards and targets, passage designs and evaluations that focus on protecting biodiversity and that best fit natural behavior patterns and river processes (ISAB 1999). Among other things, the ISAB recommended against installation of extended length, fixed (not rotating) bar turbine screens at John Day Dam because of the demonstrated impacts of the screens on juvenile lamprey. Unfortunately, these recommendations have not been acted upon and passage structures, especially for juvenile fish migrants, continue to be focused on salmon.

Specific Passage Metrics

There are key metrics that are used to evaluate dam passage success. Lamprey passage efficiency is defined as the number of lamprey that successfully pass a dam to upstream areas divided by the number of lamprey that approached the dam (Moser et al. 2002). Passage timing is another important metric of passage success and refers to the time it takes an individual animal to pass a dam (Mesa et al. 2007). Reduction of passage timing is important with respect to conservation of limited bioenergetic reserves. Laboratory bioenergetics studies corroborated radio telemetry studies and concluded that lamprey must use significant energy reserves to successfully negotiate such fish ladders (Mesa et al. 1999; Mesa et al. 2003). Loss of energy reserves could ultimately affect spawning success. Adult lamprey are not known to feed during their freshwater migration, which can last for up to a year (Kostow 2002).

It is important that passage methods that have proven successful at mitigating impacts to lamprey at certain dams be immediately implemented, monitored and evaluated at upstream dams in an active adaptive management context (Walters and Holling 1990; Hilborn 1992). For example, reducing nighttime fishway flows at Bonneville Dam appears to facilitate adult lamprey passage, without affecting adult salmon, which don't pass fishways at night. This action should be expedited at other upstream dams.

The overarching goal of this objective is to achieve the same rate of juvenile and adult passage survival through the hydrosystem area without delayed passage impacts as if the hydrosystem was not present.

Sub-objective: A   Adult Passage and Habitat

Determine adult passage rates for each route of passage at each mainstem dam

It is important to secure accurate adult lamprey counts at mainstem dams to provide an index of population abundance over time. Multiple studies and existing video counting records indicate that most adult lamprey pass dams during night time hours (Moser et al. 2002a; Moser et al. 2002b). However, currently most lamprey passage counts at dams only occur during the day (Moser et al. 2000; Moser and Close 2003; Moser et al. 2006). Adult lamprey counts at most mainstem Columbia and Snake River dams are only performed on a 16 hour basis, from 0400-2000 hours. An exception is at Lower Granite, where 24 hour counts are required for ESA listed Snake River sockeye.

The night time passage of adult lamprey was discovered using radio telemetry studies and PIT-Tag monitoring of adults at Bonneville Dam. Results showed that 67% of tagged adults passed between 2200 and 0600 hours (Close and Moser 2003). The daytime/nighttime passage counts at Lower Granite in 2007 confirmed this approximate distribution; 55 adults passed during nighttime hours while only 34 passed during daytime hours. Based upon preliminary review of videotapes of fish count windows at Bonneville Dam, the total 24 hour count increased over the daytime count by 28% in May and by 67% in June 2007 (Clabough et al. 2007).

CRITFC begin video counting investigations in 1995 and 1996 at several Corps dams using a stratified systematic sampling design to improve counting accuracy (Hatch and Parker 1997). During these years, the Umatilla Tribes counted lamprey at Bonneville Dam using these techniques (Hatch and Parker 1997). Unfortunately, funding was not provided to continue and refine these efforts. In 2007, the Corps sent CRITFC 24 hour fish recording tapes for McNary Dam which are presently being manually counted. There is an opportunity to use video counting technology developed by CRITFC to facilitate more timely and less labor intensive counts.

Obtaining accurate counts at Lower Columbia River dams, particularly at Willamette Falls and Bonneville Dam where the largest remaining lamprey populations still pass, have proven problematic due to the following, described by Fryer (2007) and Clabough et al. (2008).

- High shad passage during nighttime hours in June and July clogs fishways and makes counting difficult.
- Lamprey passage is highest during night time hours during some periods in the summer.
- Lamprey tend to hang in the viewing window for hours making them difficult to count.
- Count inaccuracies can occur when a portion of lamprey pass the counting station out of the field of view on the other side of the window crowder.
- Lamprey tend to move along the bottom of the ladder below the window, which, when complicated by poor lighting, adds to the difficulty in counting.

These problems need to be addressed on a counting station by counting station basis. Many of these problems are not significant issues because of low numbers of adults at upstream dams. The use of half duplex PIT-tag and radio telemetry techniques can be incorporated with dam counts to provide more assessment of lamprey dam passage accurate counts (Peery 2007).

Currently there has been few adjustments in counting or monitoring practices to consider the lamprey. Thus, there is an immediate need to establish and maintain, as a very high priority, 24 hour counts for adult lamprey at all mainstem dams. The Corps, Mid-Columbia PUDs and ODFW [3] need to commit to obtaining these counts.

Determine individual and cumulative impacts of mainstem hydroprojects (dams and reservoirs) on lamprey

Over the last decade basic passage research has been conducted at several Columbia Basin dams. Radio-telemetry and half duplex PIT- tag techniques have been utilized to track adult lamprey passage thorough the Lower Columbia River dams since 1997. Most of these studies found that upon release below a dam, most of the adults did not stray but immediately sought passage routes in dam tailraces (Mesa et al. 2007; Moser et al. (2002). Vella et al. (2001) noted that of 130 adults detected at the Bonneville Dam tailrace, only 29 were detected at The Dalles. Other radio-tagging studies conducted at fish ladders at Corps' Lower Columbia River dams found only 38% to 82% passage efficiency for adult lamprey (Moser et al. 2002), and passage times ranged from 4-5 days. Only 3% of adults tagged at Bonneville Dam reached areas above John Day Dam (Moser et al. 2002a). Cummings et al. (2006) found that 43% of radio-telemetry and half duplex PIT-tagged lamprey released below McNary Dam were able to ascend the dam, while 63% of tagged adults below Ice Harbor were able to pass that dam.

The use of PIT-tags has been coupled with radio tags and adult counts to better quantify passage blockage areas and overall passage success through fishways and river reaches. Recent developments have included the use of half duplex PIT-tags that are surgically implanted in adult lamprey (Figure 4). These tags are larger than full duplex tags used for tagging juvenile salmon, so they allow for separate detections in fishways and other sites.

[3] ODFW owns and operates the fish ladder and provides fish counts at the Willamette Falls Hydroelectric Project. To date, no attempt has been made to institutionalize lamprey counts at the fish ladder.

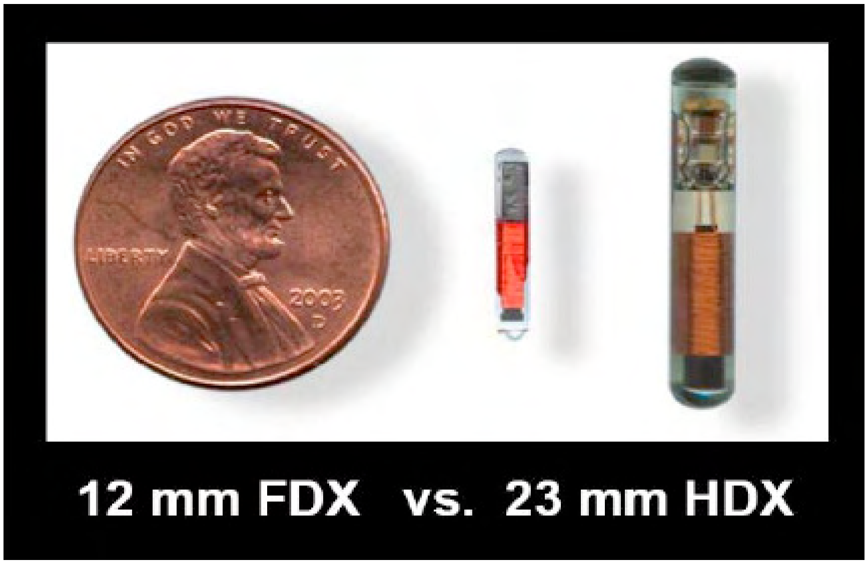


Figure 4. Full duplex (left) and half- duplex PIT-tags (Cummings 2007).

A few studies have assessed passage efficiency and rates at FERC licensed public utility dams in the Mid-Columbia. Nass et al. (2003) concluded that there was no consistency of passage efficiencies between years for specific fishways at Priest and Wanapum dams, as measured efficiencies ranged between 46-100%. However, studied samples sizes were small, limiting between year comparisons, and a large proportion of the total sample did not make it to the fishway entrance. Bioanalysts (2005) found that 55% of radio-tagged adult lamprey released below the dam exited the fishway at Rocky Reach Dam but the fallback rate over the dam for lamprey was 12.7%, higher than rates observed at Corps' lower Columbia dams and Priest and Wanapum dams.

Tracking adult lamprey passage and migration can be a complex and challenging task (Figure 5). At the Willamette Falls Hydroelectric Project, Mesa et al. (2007a) found 35% and 23% of adults passed the dam in 2005 and 2006, respectively. No adults were found to have passed the falls, even during periods when flashboards were not installed. Median passage times through the Project fishways ranged from 4-74 hours.

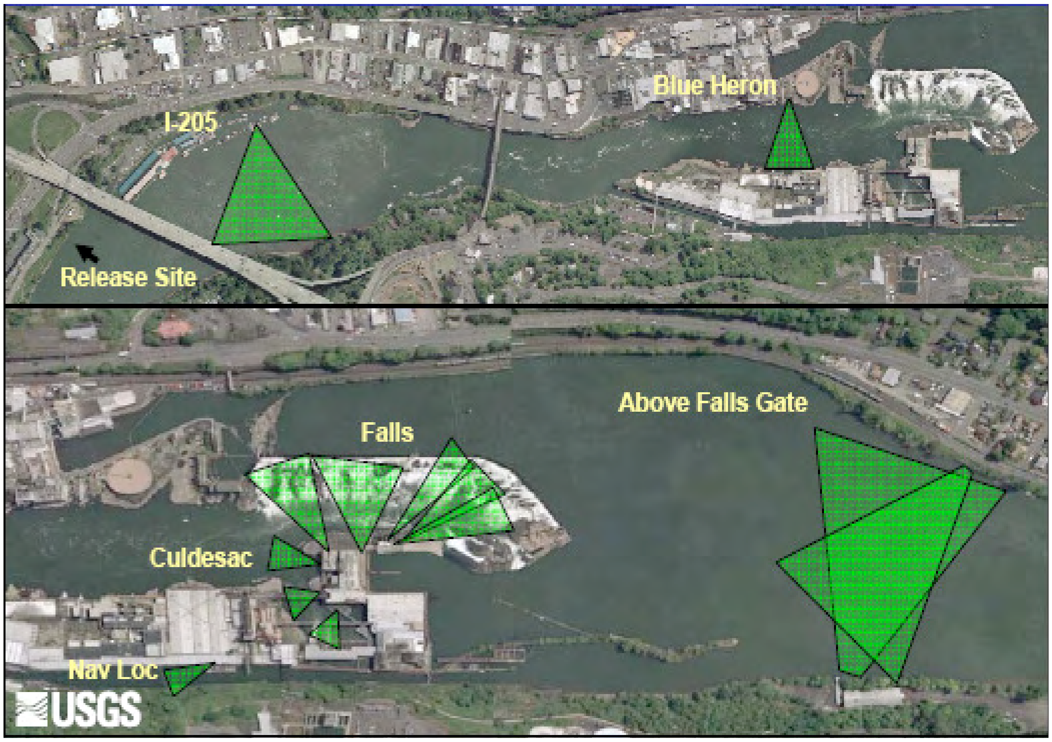


Figure 5. Radio telemetry arrays for the USGS adult lamprey study at the Willamette Falls Hydroelectric Project (USGS 2006).

These studies identified several features common to most fishways that appeared to hinder lamprey passage. While lamprey have sufficient burst speeds, they need access to surfaces which are conducive for oral disc attachment in order to rest (CBFWA 2004). Negotiating 90 degree turns in fishways appears difficult for lampreys. Other problem areas include diffuser gratings, junction pools, fish counting windows,[4] areas around picketed leads, vertical slots in fishway entrances, blind cul-de-sacs and cracks in the fishways themselves (Figure 6). High velocity sections, such as fishway entrances, gate slots upstream of fishway entrances, submerged orifaces and serpentine weirs have been identified as key problem areas (Figure 7).[5] Also, adult lamprey can slip through too-large gratings to become trapped below floor diffusers during fishway dewatering. (Figure 8). This occurred in November 2002, when over 5,000 lamprey were trapped at John Day; of these about 1,140 were lost due to human error (CTUIR 2003).

These studies are supplying a wealth of information important to the preservation of Pacific lamprey. It is important they be continued and expanded to all dams and

[4] In the past, counters at windows actively used jets and brushes to remove lamprey from counting windows because they restricted visibility necessary for counting adult salmon.
[5] While lamprey can obtain burst speeds up to 3.9 m/s for a few seconds, they cannot maintain this effort for long enough to successfully pass high velocity areas such as ladder entrances, submerged orifaces and serpentine weir sections, unless they are able to attach to surfaces to provide a sequential passage route (Moser et al. 2002; Moser pers com. 2007).

reservoirs in the basin. To date little to no passage studies have been conducted at dams at the upper ends of the basin (i.e. Wells and Lower Granite). Further, to date, little if any research has been conducted combining adult dam passage studies and evaluating the effects of passage on spawning success into tributaries. These remain key research needs.

Figure 6. Counting station at the John Day Dam fishway. Note the picketed lead on the right side of the picture below the netting (Richards 2007).

Figure 7. Serpentine weir section at Bonneville Oregon Shore fishway (Moser et al. 2004).

Figure 8. Floor diffuser grating and submerged orifice at the dewatered John Day Dam fishway (Richards 2007).

Identify and apply scheduled structural and operational improvements to achieve volitional adult passage standards approximating the best known achievable rates at mainstem dams and reservoirs (i.e. 80% passage efficiency at The Dalles)

The region lacks specific, consistent qualitative and quantitative performance standards for upstream and downstream (fallback) adult lamprey passage among mainstem hydroelectric project, due in part to information deficits. During several recent FERC relicensing proceedings, these standards were identified as key areas for the USFWS to pursue, but little has occurred to date to rectify these deficiencies. Instead, in several recent FERC settlement agreements (that have subsequently been incorporated into FERC licenses), the parties have adopted a placeholder phrase: "safe, timely and effective qualitative goal without serious injury or mortality" (see the 2004 Willamette Falls Hydroelectric Project Settlement Agreement).

In general, FERC staff and the FERC Commission have generally ignored or discounted lamprey restoration actions in environmental impact statements and license conditions. This is especially problematic given the dire state of lamprey and the fact that licenses are awarded for a 30-50 year time period. Passage goals and objectives in the 401 Water Quality Certifications for the new licenses are often more rigorous than FERC staff mandated conditions, largely due to tribal pressure on state water quality agencies. For example, the overall goal established for the Rocky Reach Hydroelectric Project is a "no net impact"[6] goal with an adult passage objective to achieve passage rates at that project similar to that the best known achievable rates at other mainstem dams in 7 years after issuance of a new license. However, 401 water quality conditions are not consistent among FERC licensed hydroprojects. For example, the 401 certificate for the Priest Rapids license does not establish an explicit goal of meeting adult passage rates similar to the best known achievable rates at other mainstem dams. As mentioned in the above institutional context section of this plan, the inconsistency of conditioning dam passage goals and actions by the USFWS in FERC licensing is a particular problem that needs to be remedied.

A small subgroup of the CBFWA Lamprey Technical Working Group was charged to develop passage objectives and related performance standards (CBLTWG 2007). Preliminary objectives included:

- The range of system passage and survival should be similar to that of steelhead (although there was a question about strong natal fidelity of lamprey to make them comparable to steelhead)
- Passage at each dam should be at least equal to that of the dam with the best current passage

Complicating these objectives was the lack of knowledge regarding the proportion of adult lamprey passing a dam that actually intend to spawn, since most lamprey likely over winter before spawning. The group recommended that a workshop be conducted to

[6] "No net impact" refers to a condition in which passage impacts are minimized to the extent possible and all unavoidable losses are mitigated through off site projects.

develop interim passage objectives and develop a list of passage needs. This workshop has yet to occur but remains a key priority.

Identify and apply scheduled improvements to individual and system operations to facilitate adult lamprey migration

From 2001-2007 the Corps of Engineers funded adult lamprey passage research and implemented some structural modifications as efforts to identify structural remedies for fishway problem areas. The Corps' Portland District created draft passage management plans, focusing on the Portland District dams (Clugston 2004; Corps 2007). Stansell (2002), Moser et al. (2002a) and Daigle et al. (2006), and Moser (2006) devised structural alterations in the Oregon and Washington shore fishways at Bonneville Dam to facilitate passage.

These changes included installation of ramps, plates over diffuser areas, modifying head differentials over weirs, rounding sharp corners, and more recently installing long, fabricated, metal boxes (Lamprey passage systems or LPS) that allow lamprey passage access over difficult passage areas such as serpentine weirs in fish ladders and wall dividers (Moser et al. 2006; Moser et al. 2007; Figure 9). Lamprey passage through the LPS systems is significant and has ranged from 7,365 adults at Bradford Island (Oregon shore) fishway (4% of tagged all tagged fish passing the dam) to 2152 adults at the Washington shore fishway (7% of all tagged fish passing the dam). This compares to 38,941 lamprey counted at Bonneville Dam fishway stations over 16 hours in 2006. Based on experiments at Bonneville Dam, reduction in diffuser gratings from 1 inch to ¾ inch has resulted in virtually eliminating trapping of adults below main fishway channels (Moser et al. 2007b). This structural modification has been successfully applied at the John Day north shore fishway counting station and needs to be duplicated at other dam fishways. To date no specific passage plans have been established at the Walla Walla District dams. This remains a critical area needing immediate attention.

Figure 9. LPS structure at the Bonneville Dam Oregon Shore fishway. A lamprey passing upstream can be seen at the upper portion of the bottom of the structure (Moser et al. 2004).

In 2007, in conjunction with FERC relicensing, Portland General Electric completely rebuilt the fishway at the River Mill Dam (the lowest dam on the Clackamas River) incorporating features, such as rounded weir corners, that were demonstrated at other dams to be beneficial for adult lamprey passage. At the Willamette Falls Hydroelectric Project, experimental lamprey ramps have been installed after flashboard installation. To date, no passage over these structures has been observed (Figure 9), however, a new ramp design will be evaluated in 2008.

Figure 10. Lamprey passage ramps installed at Willamette Falls after flashboard installation (CRITFC 2004).

In 2006, Grant County Public Utility District installed a slotted “key hole” fishway entrance at Priest Rapids Dam (Figure 11). This structure effectively modifies fishway entrance velocities over a range of dam tailwater elevations. The Corps of Engineers proposes to install a similar entrance at John Day and other Corps dams as warranted in the near future.

Figure 11. Slotted “key hole” fish ladder entrance installed at
Priest Rapids Dam (Lauver 2006).

Fishway operational changes are being evaluated as ways to improve passage efficiency and reduce passage times. At the Bonneville Dam Washington shore fishway, flows at night were reduced to 4 feet per second and head differentials were reduced to 0.5 feet. Johnson et al. (2007) found that the fishway entrance efficiencies increased with the reduced flows (29% for reduced flows vs. 2% at normal flows). However, at other fishway entrances improvements in entrance efficiencies, while still increased under the reduced flow condition, were of a lesser magnitude. Because few if any salmon are known to pass fishways at night, this operation was considered to have little, if any negative impact on salmon passage.

Implement flow regimes to benefit adult lamprey passage and survival

Similar to adult salmon, adult lamprey returning from sea may fix on freshwater cues in the Columbia River estuary plume intensified by the spring freshet. Peak passage periods coincide with the peak hydrograph. Thus, managing flows to a peaking hydrograph will not only benefit salmon, but will also benefit adult lamprey. Flow augmentation, reducing water withdrawals, reservoir draw down, and achieving upper rule curves at storage reservoirs before the spring freshet are all potential tools to increase flows and establish a peaking hydrograph (CRITFC 2008). The additional stressor of climate destabilization will likely require consideration of modifying flood control rule curves through improved forecasting methods to create additional storage for spring and summer flow augmentation (WGA 2008).

Determine water quality impacts of hydroprojects on lamprey and implement actions to reduce these impacts.

Water temperature changes determine timing and adult migration and spawning (CBTLWG 2004). Adult migration data indicate that as temperatures increase during the summer, adult migration rates also increase, peaking around July 24 at Bonneville Dam. However, as with adult salmon, high temperatures can act as a thermal block for adult lamprey migration. Ocker et al. (2000, cited in CBTLWG 2004) noted that fewer adult lamprey successfully passed Bonneville Dam when temperatures exceeded 19.5 C. More research is needed in this area.

Many of the water quality improvements recommended for adult salmon will likely benefit adult lamprey. For example cool water releases from storage dams, fishway temperature controls, gas abatement structures, and reductions of oil in dam seep holes are actions that should be taken to improve water quality for adult lamprey (CRITFC 2008).

Little is know about effects of total dissolved gas and toxic inorganic and organic pollutants on adult lamprey from agricultural and industrial sources. More research is needed in this arena.

Assess and address impacts of irrigation water withdrawal structures on adult lamprey. Assess and address irrigation related water quality impacts on adult lamprey.

Millions of dollars have been spent in the Columbia Basin to keep juvenile salmon out of irrigation canals. Primarily, drum screen structures are implemented to address this need, however, the true impacts of these screens have not been well documented. While some monitoring work has occurred in California, none has been conducted in the Columbia Basin. The Bureau of Reclamation (BOR) staff proposed to inventory and create a database of BOR project impacts on lamprey dedicating $100,000 and four years to the project. The elements of the proposal include:

The first objective of this research is to inventory Reclamation facilities where the lamprey species exist. This will involve gathering background information of western river basins where lamprey are known and determine what lamprey species may inhabit the basin. Site specific background information will be included (if available) demonstrating the known or recorded occurrence of lamprey, e.g. lamprey passing through adult salmonid fish counting stations. As a key part of this research, a list of Reclamation facilities within the basins will be compiled and a determination made if there are any possible lamprey issues related to the operation of these facilities. Specific information, if available, will be cited as to exactly how the Reclamation facility affects the lamprey (i.e. inhibits adult upstream migration, inhibits juvenile outmigration, loss of habitat, thermal pollution, etc.) (Bark 2008).

Once this work is in progress, the tribes recommend prompt implementation and evaluation of mitigation efforts. In particular, additional emphasis should be placed on the passage impacts at irrigation withdrawal projects to monitor impacts and to facilitate technological (and other) advances to protect lamprey at these sites.

Inventory and protect spawning habitat in reservoirs

Little is know about adult spawning in Columbia Basin hydrosystem reservoirs. Determining the extent of spawning and developing measures to protect habitat in these areas is an important sub-objective.

Implement actions to address excessive hydro-related avian, piscivorous and marine mammal predation.

Over the last few years the Corps of Engineers has documented accelerating predation of adult lamprey by California and Stellar sea lions below Bonneville Dam (Figure 12). Recently, under an amendment of the 1972 Marine Mammal Protection Act and court orders, the States of Washington and Oregon have gained authority to capture and kill, if necessary, limited numbers of particularly problem animals that prey upon salmon, sturgeon and lamprey in the Bonneville Dam tailrace. It is important that this effort be maintained and perhaps even expanded to areas above and below Bonneville Dam.

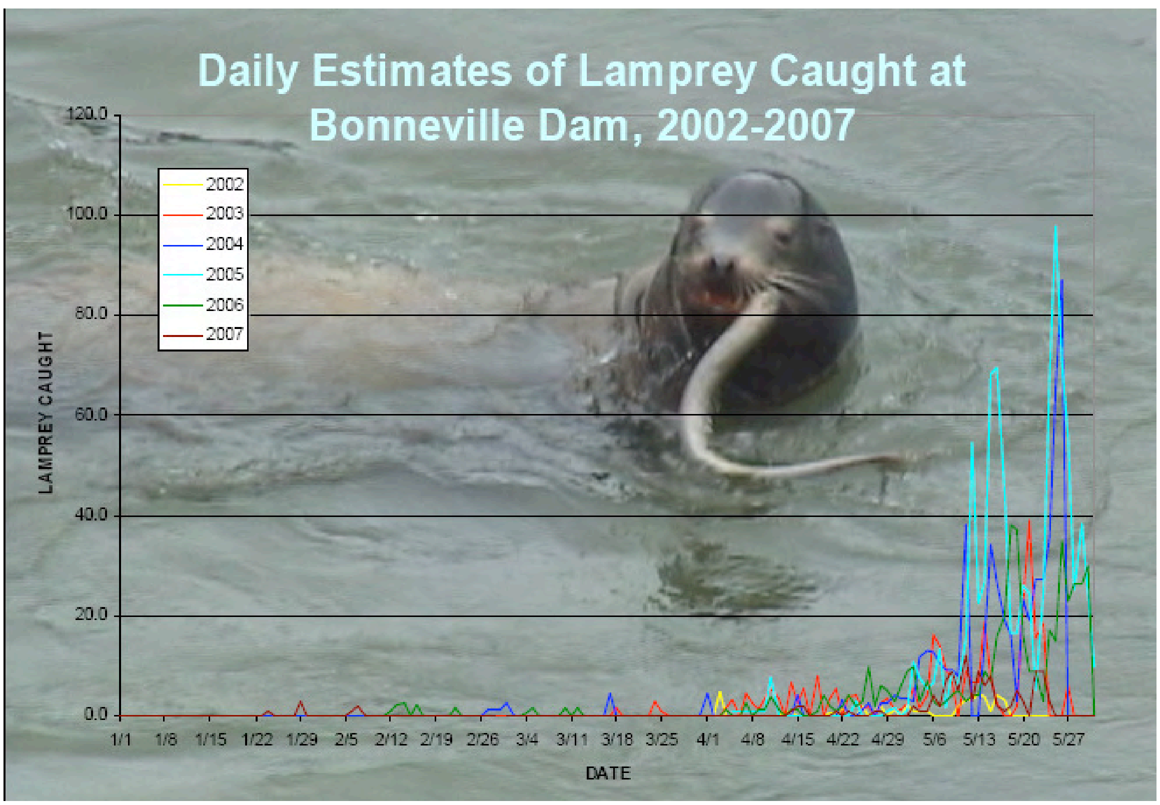


Figure 12. Lamprey predation estimates from Corps of Engineers observations at Bonneville Dam (Stansell 2006).

Figure 13. Avian predation on juvenile lamprey on Cresent Island in the Mid-Columbia River (A. Evans 2008).

Avian predation on lampreys has been observed near dams, but to date there has been no quantification of the impact. There appears to be little data obtained a bird colonies with respect to lamprey predation, but there is evidence that it occurs (Figure 13). This remains a critical uncertainty that should be addressed at all mainstem and tributary dams.

Adult Passage Structural and Operational Improvements-
General and Specific Actions

The tribes have identified improvement of passage efficiency and reducing the time and energy expenditure spent in passage as the first priority for lamprey restoration . To determine effective methods for accomplishing this, we've examined the dams with the highest existing passage efficiencies and compared these dams to all others in the Columbia Basin. From this analysis, the following are the specific steps recommended for all dams. Specific actions and schedules for implementation at FERC licensed dams should be developed and reflect coordination of license holders, tribal, state and federal agencies. These actions and schedules should be consistent with those found in Table 2 as appropriate. All of the following actions should be reflected in the Corps of Engineers Annual Fish Passage Plans and annual operations plans of FERC licensed hydroprojects. Adult passage at The Dalles Dam appears the best from current information. An investigation should occur to determine what structures or operations facilitate passage at

The Dalles to see if it can be transferred to other dams. Table 2 gives the recommended schedule for the implementation of the recommendations for each dam. Much of the schedule and priority for actions will be modified as knowledge about specific dam and fishway passage impediments are obtained.

1. Fishway surveys

All fishways should be surveyed and inventoried for structural improvements such as rounded corners, plates covering diffusers, closures of blind end fishway areas, cracks, counting stations, transition pools and picketed leads. All fishways should be evaluated for installation of lamprey passage systems (LPS) and appropriate modifications to fishway entrances. The dam operators should be solicited for information including anecdotal, qualitative or quantitative. Information from pass salvaging efforts should be sought and documented. Detailed passage reports should be written and submitted to peer-review. The results should be improved passage success, reduced injuries, shortened passage times and reduced energy expenditures which should lead to increased reproductive success.

2. Inspections

Protocols should be established at all dams for formal inspection and annual lamprey passage reporting. The reports and recommendations should be reviewed by regional peers.

3. Prioritization

There should be standardized and peer reviewed protocols for prioritizing needed actions. There should be standardized methods for evaluating the results of instituted changes.

4. Grating replacement

All 1 inch gap diffuser gratings should be replaced with ¾ inch gap grating. Of highest priority is the replacement of grating in fish counting areas and auxiliary water systems (AWS). This will reduce lamprey stranding and mortality, especially during ladder de-watering and in blind areas such as auxillary water system (AWS) channels.

5. Counting

Twenty-four hour video counting for lampreys should be initiated. All count stations should be examined and modified as necessary to ensure accurate counting. This will provide information to create an index of adult lamprey abundance and a means for tracking sub-basin stock productivity over time.

6. Night time fishway flow rates

Implement and evaluate decreased nighttime fishway flows. Make these changes permanent if appropriate. This will likely result in improved lamprey passage efficiency by increasing passage success, decreasing passage times and decreasing energy expenditures during passage.

7. Corners

Blunt or round off all corners at slots and orifices. This will allow for shortened passage times and allow lamprey to attach and rest in high velocity areas.

8. Plates

Install plates over diffusers along the bases of walls and weirs and evaluate for any benefit. Make permanent if appropriate; it is not known, but these modifications are suggested for improving passage success and to reduce passage times.

9. Ramps

Install ramps at sills and lips and evaluate. Make permanent if appropriate. It is suggested that ramps may allow for more attachment sites in high velocity areas. This would improve passage success.

10. Ladder dewatering

Ladder dewatering procedures should be evaluated and improved with an eye toward protecting lamprey. Weir blocking devices should be evaluated and flushing maintained. Provisions should be made for salvage tanks and enough skilled personnel to make sure trapped lamprey are salvaged for translocation up river. These modifications should work to protect trapped lamprey from injury and mortality. If modifications do not prevent entrapment, entrapped lamprey can be translocated to reestablish upriver populations.

11. Fishway entrances and transition pools

Entrances and transition pools should be modified to improve lamprey passage. Keyhole entrances should be assessed and implemented if practical and effective. All altered fishway entrances should be monitored and passage rates quantified. The lowered head of keyhole entrances reduces passage fallout, shortens passage times and promotes success at entry.

Table 2. Specific Actions and Schedules for Adult Lamprey at Federal Dams

ACTIONS AND SCHEDULE FOR FEDERAL DAM IMPROVEMENTS	BONN DAM	THE DALLES DAM	JOHN DAY DAM	MCNARY DAM	ICE HARBOR DAM	LOWER MONUMENTAL DAM	LITTLE GOOSE DAM	LOWER GRANITE DAM
Survey Fishways	2009	2009	2009	2009	2009	2009	2009	2009
Peer-reviewed reports	2009-2018	2009-2018	2009-2018	2009-2018	2009-2018	2009-2018	2009-2018	2009-2018
Annual Inspection Protocols/Reports	2009-2018	2009-2018	2009-2018	2009-2018	2009-2018	2009-2018	2009	2009
Prioritization	2009-2018	2010	2009-2018	2009-2018	2009-2018	2009-2018	2009-2018	2009-18
Grating Replacement	2009-2012	2012	2010	2011	2012	2012	2012	2012
24 hour Video Counting	2008-2018	2008-2018	2008-2018	2008-2018	2009-2018	2009-2018	2009-18	2018
Reduce Fishway Night Flows	2009-2018	2018	2009-2018	2009-2018	2009-2018	2009-2018	2009-18	2009-18
Rounding Corners	2009-2012	2012	2011	2011	2012	2012	2012	2012
Plate installations	2009-2010	2012	2010	2010	2012	2010	2010	2010
Ramp Installations	2012	2012	2012	2012	2012	2012	2012	2012
Ladder Dewatering Improvements	2009-2018	2009-2018	2009-2018	2009-2018	2009-2018	2009-2018	2009-2018	2009-2018
Fishway Entrance Improvements	2009-2012	2012	2010	2011-2013	2011-2013	2011-2013	2011-13	2011-2013
LPS installations and evaluations	2009-2011	2012	2010	2011	2012	2013	2013	2013

Sub-objective: B   Juvenile Passage and Habitat

Determine discrete and cumulative impacts of hydro projects (dams and reservoirs) on lamprey populations.

On their seaward journey, juvenile lamprey migrate past dams and reservoirs in two life history forms, ammocetes and macrothalmia,. There is considerable variation in passage rates and run timing through dams but available data indicates that, as with juvenile salmon, peak passage rates coincide with the late spring/early summer freshet (Figures 14 and 15. Compared to juvenile salmon, juvenile lamprey are relatively weak swimmers. Laboratory trials indicate that average juvenile burst speed is 2/3 ft/sec or 5.2 body lengths/second (Moursund et al. 2000). Lamprey take advantage of stream power for migration, a strategy that reserves energy for physiological transition to saltwater

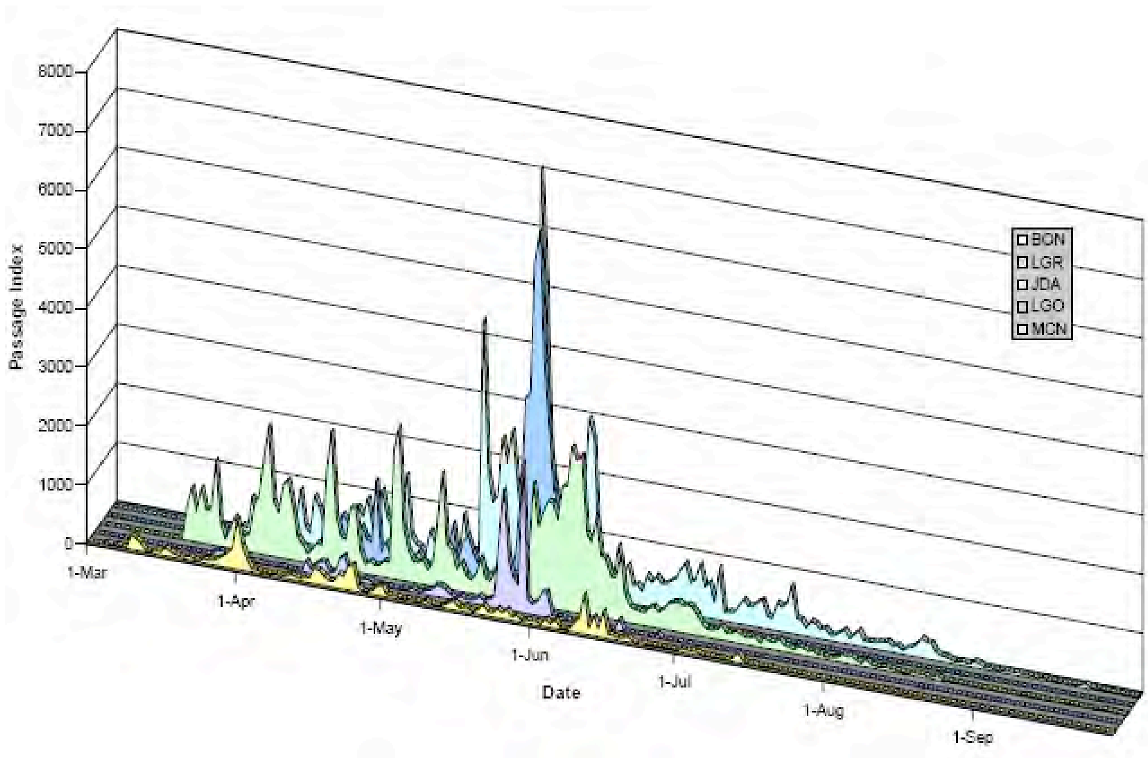


Figure 14. 1998-2002 average juvenile lamprey run timing at five Lower Snake and Lower Columbia dams (Bleich and Moursund 2006).

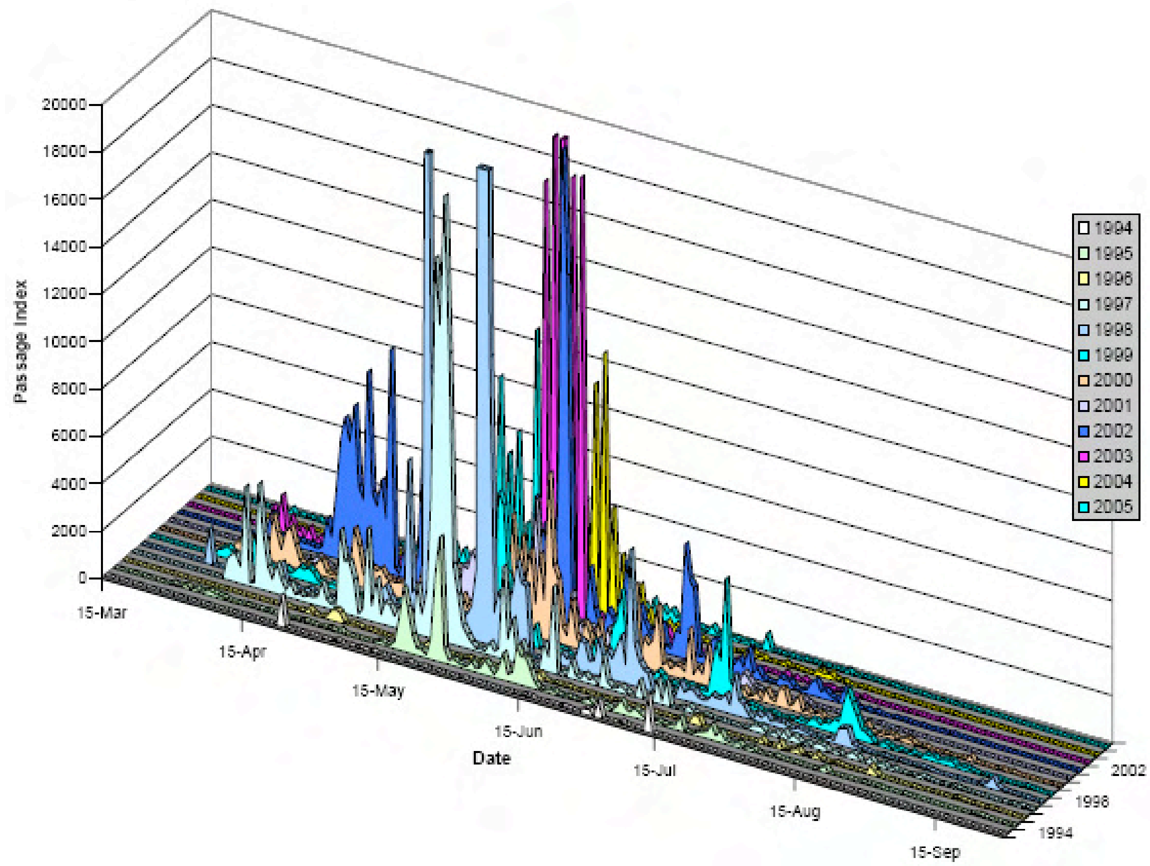


Figure 15. Juvenile lamprey run timing at McNary Dam from 1994-2005 (Bleich and Moursund 2006).

Little research has been funded for juvenile lamprey, but some specific migration data exists. For example, using PIT-tag technology, Bleich and Moursund (2006) found evidence that the travel time of juvenile lamprey of 5-16 days from McNary Dam to John Day Dam was similar to that of subyearling Chinook. They also observed that in the very low flow year of 2001 juvenile lamprey and subyearling Chinook migration times were much longer, lasting 10-28 days. This indicates that juvenile lamprey likely have a water particle/fish travel time relationship similar to that for juvenile salmon (Schaller et al. 2007; Connor et al. 2003a; Connor et al.2003b).

Thus, improving flow regimes appears to be a good restoration strategy to speed juvenile lamprey to saltwater. Additionally, greater flow rates probably contribute to juvenile lamprey survival by increasing water turbidity, helping to conceal the juveniles from predation as well as decreasing duration of exposure to predators, disease and increasing water temperatures.

Regarding dam passage efficiency and survival specifically, current information is limited to fyke net observations, PIT-tags, samples in salmon screen bypass systems and underwater and surface observations (Figure 16).

Figure 16. Fyke net removed from a turbine gatewell at John Day Dam (Moursund et al. 2003).

For many years the common assumption was that most juvenile lamprey travel along the bottom of the river during their approach to dams and pass through turbine intakes under turbine intake screens (Figure 17). Among other things, this conclusion arose from the fact that juvenile lamprey lack a swim bladder, in contrast to juvenile salmon. However, in several cases, data from lamprey trapped on fyke nets placed in turbines behind turbine intake screens and on the screens themselves indicate that they travel higher in the vertical water column than previously believed. For example, fyke net tests at Priest Rapids Dam indicate that juvenile lamprey were found nearly equally distributed from the top to the bottom of the turbine gatewell slot (Carlson 1995 unpublished data). Moursund et al. (2003) found that 86% of juvenile lamprey found on the John Day Dam extended length turbine screens were within the top 10% and bottom 10% of the screen face (Figure 18). They also documented 91% of PIT-tagged lamprey and 14% of run-of-river lamprey were captured at fyke net levels 1-4 behind the turbine intake screen.

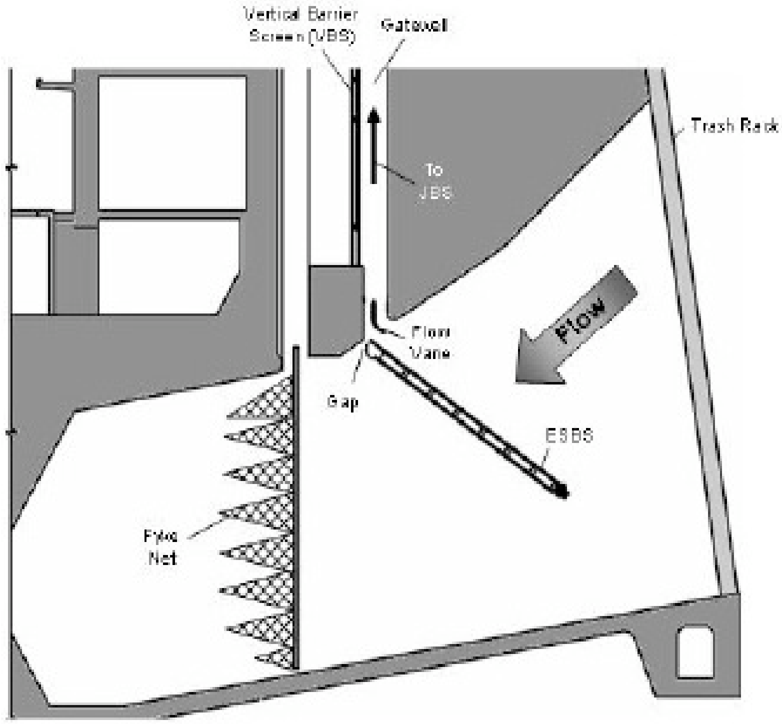


Figure 17. Sectional diagram of turbine unit, with location of extended length bar screen, gatewell, vertical barrier screen and trash rack (Moursund et al 2003).

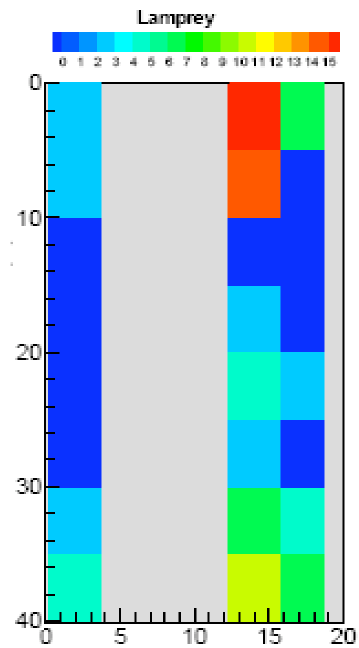


Figure 18. Juvenile lamprey vertical and horizontal distribution on a turbine screen. Units in feet. (Moursund et al. 2003).

Significant impingement of juvenile lamprey on turbine and gatewell screens designed for juvenile salmon passage was first observed in the mid 1990's. Starke and Dalen (1995) first noted and then in 1998 photographed the impingement on 40 foot extended length bars screens at John Day Dam (Figure 19). Juvenile lamprey swimming ability is too limited to avoid contact with the screens. The impingement was not restricted to the lower portion of the screen but was vertically distributed equally over the screen face. A conservative estimate from the photographs was that 200 lamprey were impacted (Lorz 1998). Brushes on the screen designed to scrape debris from the face also scraped off the juvenile lamprey, routing them to the turbines. Since the observation was made in February, a time of low juvenile migrants, it is likely that the impact would be much greater during the peak migration times.

Figure 19. Impingement of juvenile lamprey on John Day extended length bar screen (Starke and Dalen 1998).

In response to this observed impact, the Corps conducted underwater camera observations of extended length screens at McNary Dam and conducted impingement studies at John Day. Initially, problems with the camera prevented an accounting of the impact. Subsequently, the Corps funded studies at McNary and John Day to further address the issue (Moursund et al. 2000; Moursund et al. 2002; Moursund et al. 2003;

Bleich and Moursund 2006). Research indicated that 98% of lamprey were unable to free themselves from screen impingement at typical screen face velocities (Moursund et al. 2000). As evidence of impingement persisted, recommendations were made to mitigate these impacts by reducing screen gap size from 3.175 mm to 1.75 mm (Bleich and Moursund 2006). Due to several issues, the 40 foot extended length screens were never installed at John Day Dam, but had already been installed at McNary, Lower Granite and Little Goose dams with the smaller gaps that cause impingement. The tribes requested that the Corps remove the screens during the peak of the juvenile migration as an interim measure before the screens could be replaced. Replacing the existing turbine intake screens with larger gaps turbine intake screens could cost tens of millions of dollars. At this point, the screens remain and are likely a limiting factor for lamprey restoration.

In laboratory studies, Moursund et al. (2000) and Moursund et al. (2001) concluded that juvenile lamprey were not affected by simulated turbine sheer or pressure changes. However, turbine blade strike and cumulative effects were not examined. To date, no studies have been conducted regarding juvenile lamprey survival through actual dam turbines or spill.

It appears that juvenile lamprey that survive passing into collection channels of bypass systems will pass in high numbers through the rest of the system (Bleich and Moursund 2006). The inadvertent transportation of juvenile lamprey with juvenile salmon downstream in trucks or barges has an unknown impact on lamprey. Moser et al. (2008) attempted to use light to segregate lamprey juveniles out of the collection channel facilities, and found that macrothalmia were stimulated by bright light, but only for short periods. They concluded that vertically oriented stainless steel mesh screens may function best to separate juvenile lamprey in bypass raceways. Juvenile lamprey are often observed *en mass* at downstream screens of transportation raceways. Corps biologists have concentrated on finding methods for routing these lamprey safely into tailrace areas. More work is needed in these areas.

Aggressively pursue development of juvenile lamprey tag technology. Determine juvenile passage and survival rates via each route of passage at each dam.

As stated above, for juvenile lamprey, there are no current estimates for general and route specific dam passage rates and survival. These deficiencies can be attributed primarily on gaps in tagging technology, which in turn can be attributed to the fact that juvenile lamprey have the body diameter of a pencil or less, Schreck et al. (2000) conducted a review of tags that might be appropriate for juvenile lamprey. They conducted laboratory studies with both internal and external tags including radio tags, PIT-tags and even harmonic radar (Figure 20). They found that battery size was a limiting factor for internal radio tags; PIT-Tags could not be detected with current systems over large expanses such as turbines or spillways, lamprey were able to wriggle out of external tags and, finally, the physical properties of water prevented transmission ranges needed to track juvenile lamprey.

Figure 20. Inserting a PIT-tag into a juvenile lamprey for passage studies (Bleich and Moursund 2006).

For the near term, CRITFC has suggested rigging a combination of inflatable Hi-Z turbine tags with external radio tags to obtain passage and survival estimates. These combinations are used routinely to obtain juvenile salmon passage and survival estimates through turbines and spillways. While there would be obvious behavior effects on lamprey, the tests take only 10-15 minutes to perform and recapture efficiency is very high.

More funding emphasizing expedited lamprey tag development is a critical need. Over the longer term, ongoing development of the JSATS acoustic tags for small juvenile salmon by Corps'contractors holds promise for juvenile lamprey studies. Another alternative is to expand the range of half duplex PIT-tag transceivers to detect lamprey through large areas such as turbines or spillways.

Implement flow regimes to benefit juvenile lamprey passage and survival.

Given that juvenile lamprey travel time is related to water particle travel time, increases in freshet flows will likely reduce lamprey travel time. Thus, managing flows to a peaking hydrograph will benefit juvenile lamprey as well as juvenile salmon. Flow augmentation, reducing water withdrawals, reservoir draw down, and achieving upper rule curves at storage reservoirs before the spring freshet are all potential tools to increase flows and establish a peaking hydrograph (ISG 1996; ISAB 2001; Bunn and Arthington 2002). A future consideration is climate destabilization, as it may complicate efforts to augment flow rates to improve passage efficiency. It will probably be necessary to modify flood control rule curves through obtaining better runoff forecasting to create additional storage for spring and summer flow needs (ISG 1996; ISAB 2001; ISAB 2007).

Develop structures and project operations at each dam and reservoir to facilitate juvenile lamprey passage and survival and reduce migration delays. Establish juvenile passage standards.

The apparent first priority for increasing juvenile lamprey survival is to immediately modify or remove dam structures demonstrated to impact lamprey, such as turbine intake and vertical barrier screens.

The lack of knowledge of the route specific passage and survival rates for juvenile lamprey does not preclude taking steps immediately to modify or remove dam structures known to impact lamprey, such as turbine intake and vertical barrier screens. The need to establish those rates is critical, and should be expedited by using current technology and developing effective tags as fast as possible. In the meantime, some basin hydro projects have established passage survival goals for salmon fry as high as 98%. There is no reason not to expect the same for juvenile lamprey and adopt this rate as a goal and standard.

Determine water quality impacts of hydro projects on juvenile lamprey populations.

Many of the water quality impacts on juvenile salmon are likely to negatively affect juvenile lamprey. Efforts to mitigate the elevated temperatures found in reservoirs and fish bypass systems would likely benefit juvenile lamprey. Examples of these efforts include the installation of temperature control structures or modified operations at Grand Coulee and Brownlee dams (BOR 2003a; NPT 2008).

Assess impacts of irrigation water withdrawal structures and correct defective structures.

Drum and other screens in basin irrigation facilities have been installed over the last decade or more to reduce juvenile salmon entrainment into irrigation conveyance structures, such as ditches and canals, small hydroelectric facilities and other small diversion structures (Figure 21). Unfortunately, the exclusionary devices were not designed to protect juvenile lamprey. Ostrand (2004) conducted laboratory tests on lamprey macrothalmia on screens that met salmon criteria and found that lamprey tended to adhere to the screens and were likely to be crushed by cleaning devices used to clear the screens of debris. At the low water velocities tested, the screen velocity criteria seemed appropriate for juvenile lamprey, however; even then, lamprey did tend to group in areas where attachment was facilitated.

Again, the lack of information determining real damage and impact to juvenile lamprey passage and survival is no reason not to act. Inventories of these impacts are slated to begin in summer 2008, in the meantime tribal biologists have observed that many juvenile lamprey are already lost in the current operations as is. Suggested modifications include spray or bubble devices that would cause lamprey to detach from the screens.

Figure 21. Drum Screen at irrigation diversion (BOR 2003b).

Belt screens may provide better protection for juvenile lamprey (Howerton pers com. 2008). They have a steeper angle making it more difficult for lamprey to travel over the structure to end up in irrigation facilities or fields (Figure 22). In any case, much effort and funding should be expedited to examine and mitigate impacts of screen diversions throughout the Columbia River Basin.

Figure 22. Traveling belt screen (BOR 2003b).

Inventory and protect rearing habitat in reservoirs.

To date, little work has been conducted in hydro system reservoirs to inventory juvenile lamprey. Juvenile lamprey have been captured in Mid-Columbia reservoirs during seining work for sturgeon (B. Parker pers. com. 2007), so it is likely that lamprey are using main stem reservoirs for rearing. More research effort is need in this area.

Implement actions to address excessive hydro-related avian, piscivorous and marine mammal predation on juvenile lamprey.

Little is known about predation rates on juvenile lamprey. Because of their fat content, lamprey are highly desirable as prey items. Moursund et al. (2006) found that two PIT-Tags from 679 lamprey that were tagged in the McNary Dam screened bypass collection channel were detected in the two McNary Dam fishways less than 24 hours later—the speed that tags traveled in the fishway indicated they were taken by fish that had preyed upon the lamprey. Roby (pers com. 2007) using guano analysis reported evidence of bird predation on juvenile lamprey in the Columbia River Estuary. It is likely that predation measures established for salmon, such as reductions of pikeminnow, bass and walleye and of tern and cormorant populations will benefit juvenile lamprey.

Table 3. Summary of Juvenile Passage and Mainstem Habitat Actions

Action	Schedule	Benefit
Expedite development of juvenile lamprey tagging technology and support regional research	2008-2012	Enable acquisition of baseline and post action data to gauge impacts and monitor and evaluate mitigation actions
Use existing tagging technology and other tools to determine dam impacts on juvenile lamprey	2008-2010	Establish baseline data for impacts in near term
Survey reservoirs for juveniles and rearing habitat	2009-2012	Determine presence and absence of juveniles
Implement improved flow regimes	2009-2018	Reduce fish travel time and increase survival
Develop route specific dam passage and survival estimates	2009-2018	Establish baseline information for improvements
Remove or modify turbine intake screens that cause impingement	McNary 2009; Snake River dams 2010	Reduce juvenile direct mortality
Assess impacts of irrigation screens and tributary blockages and make improvements	2009-2018	Reduce juvenile mortality
Determine water quality impacts and seek improvements	2009-2018	Reduce juvenile mortality
Create annual peer-reviewed progress reports	2009-2018	Reduce juvenile mortality

Objective 2: Protect and restore tributary habitat and passage

(Note: Actions are summarized for the tribal basin-wide ceded areas in the Tributary Actions Plans Appendix)

Sub-objective A: Tributary Passage

Identify priority tributary passage needs.

Develop, implement and evaluate specific tributary passage actions

Sub-objective B: Tributary Habitat

Identify priority tributary spawning and rearing habitats

Develop, implement and evaluate specific tributary habitat restoration and protection actions.

Objective 3: Supplement lamprey by reintroduction and translocation in areas where they are severely depressed or extirpated (Note: Actions are summarized for the tribal basin-wide ceded areas in the Tributary Action Plans Appendix)

Implement and monitor translocation or supplementation programs from mainstem dams to upstream watersheds

As discussed previously under Objective 1, the tribes believe that the most urgent problem lamprey face is surviving upstream and downstream passage. It is essential that fishway modifications that have proven successful at certain dams be immediately implemented and evaluated at upstream dams in an active adaptive management context (see discussion under Objective 1).

According to CBFWA (2008), available indices indicate severely declining numbers and precarious status. This is especially true for the interior Columbia River Basin, such as the Snake River Basin in Idaho and the Umatilla and Walla Walla rivers. As noted in the above objectives, information on adult Pacific lamprey passage efficiencies past main stem dams indicates successful passage rates through the hydro system are low and that passage success is poorer for smaller lamprey. For example, Cochnaer and Clarie (2002) found only 541 ammocetes in sampling 70 sites in five major tributaries of the Lower Snake River.

Nez Perce Tribe Translocation Program

To enter the expansive spawning areas in the Snake River Basin adult lamprey must successfully pass eight main stem dams on the Columbia and Snake rivers. The cumulative impact of successive poor dam passage efficiencies results in very few adult lamprey annually migrating into the Snake Basin to spawn. Recent surveys by IDFG failed to detect the presence of ammocoetes in many Clearwater River tributaries known to have supported traditional lamprey fisheries (Claire 2004). Absence of smaller size ammocoetes in Clearwater River tributaries streams still containing lamprey indicate little or no recent spawning recruitment. These data, together with the drastically low annual counts of adult lamprey passing Lower Granite Dam suggest a serious threat of local extirpation (Claire 2004).

Current data on the presence, densities and age structure of ammocoetes support concerns that they are in serious decline. Presence-absence survey findings in 2000-2005 indicate that Pacific lamprey ammocoetes and macropthalmia are not numerous or widely distributed in Idaho river basins. Historically, Pacific lamprey distribution was confined to the lower reaches of Red River below rkm 8.0, the S. F. Clearwater River, Lochsa River (Weir Creek to mouth), Selway River (Bear Creek to mouth), M. F. Clearwater River, the Clearwater River (downstream to Potlatch River), M.F. Salmon River and the main stem Salmon River downstream of the N.F. Salmon River (Cochnauer et al. 2005). Currently, Pacific lamprey populations persist in the Selway and Lochsa River subbasins where the instream rearing habitat is largely considered good to excellent; however, excellent habitat quality in spawning and rearing streams is considered incapable of adequately compensating for the limited number of returning adult Pacific lamprey passing Lower Granite Dam (Cochnauer et al. 2005). Cochnauer et al. (2005) could not speculate whether populations of Pacific lamprey throughout the Clearwater River drainage are approaching a critical unrecoverable threshold. Nonetheless, they did report that over the 300 presence-absence/trend monitoring samples taken and numerous stream reaches sampled, only a few produced Pacific lamprey.

Purpose and rationale

In view of the depressed status of the lamprey in those Idaho streams still accessible to anadromous fish, Cochnauer et al. (2005) proposed that translocation of pre-spawn adults from downstream Columbia River locations as well as supplementation with hatchery spawned ammocoetes into suitable habitat is a recovery strategy that should be reserved as is necessary. This proposal was made prior to the record low count of 35 adults passing Lower Granite Dam in 2006 that portends an imminent crisis stage for Snake River lamprey.

Compounding the concern for the fate of lamprey in the Snake River Basin, in view of this drastically low adult return, is that the migration of adult lamprey to tributary spawning locations is likely influenced by pheromones. Adult lamprey do not select their natal streams for reproduction (Bergstedt and Seelye 1995), but instead prefer streams that contain higher densities of larval lampreys that produce higher concentrations of the migratory pheromone attractant (Moore and Schleen 1980). The downward spiral of adults returning to the Snake River basin to spawn translates to severely reduced presence of juvenile lamprey available to emit attractants that draw adults into the spawning tributaries. Thus, cues that guide adult lamprey to the Snake River tributaries to spawn will be lost.

The above suggests an immediate need to translocate lamprey adults to selected Snake River tributaries to bolster ammocoete production and to preserve the pheromone attractant mechanism that guides adults to spawning habitat. Cummings (2007) found that trapping and translocating adult lamprey did not appear to affect their migration success. She suggested that the absence of negative translocation impacts was evidence that lamprey, unlike salmon, may not home to natal areas but instead may use other environmental cues to find appropriate spawning habitat. Moser et al. (2007a) suggested that such cues include temperature, discharge, photoperiod and olfactory markers.

Disease could be a concern in translocating adults. However, Cummings (2007) found that of 20 adult lamprey collected at Bonneville and McNary dams during the early summer migration season, only two bacterial pathogens were found and only one was identified (*A. hydrophila).* No viral pathogens or parasites were found on these lamprey. Disease could be a concern if water temperatures were beyond lamprey upper tolerance levels; however, most adults from dam fishways for tribal translocation programs are removed during winter dewatering periods.

By implementing the translocation effort, tribes will at least preserve the potential for harvestable returns of adult lamprey to the remaining accessible areas traditional fished by the Nez Perce and Umatilla tribes. This is the goal at the heart of this endeavor. The uncertainties and risks associated with lack of knowledge on mechanisms guiding adult lamprey to suitable spawning locations only emphasizes the need to act now to avoid local extirpation in poorly recruited portions of its range, such as the Snake River Basin and the Umatilla River subbasin.

In response to this critical immediate need in the late 1990s the Umatilla Tribes and in 2006 the Nez Perce Tribe initiated Pacific lamprey translocation programs as a safety-net measure to maintain some level of lamprey production in target spawning streams. Continuance of these translocation initiatives on an annual basis is included as an integral piece of Pacific Lamprey Restoration Plan. Adult translocation will be needed until improvements to main stem passage increases the recruitment of spawning adults into the Middle Columbia subbasins and the Snake Basin, the threat of local extirpation is addressed, and restoration objectives are achieved.

Tasks to implement the Nez Perce translocation initiative include:

- Coordinate with US Army Corps of Engineers main stem dam fishway dewatering activities for the salvage and collection of adult lamprey. Establish a tribal-Corps technical team with both the Portland and Walla Walla District biologists and dam operators.

- Establish adult collection facilities at select main stem projects to facilitate translocation efforts.

- Target 500 adult Pacific lamprey to be translocated from main stem dams to Snake River tributaries annually.

- Hold transported adults for over wintering at the Nez Perce Tribal Hatchery within the Nez Perce Reservation.

- Release over-wintered adults in the spring into target spawning streams. A subset of the target streams will be stocked on an annual, ongoing basis. Use radio-telemetry methods to monitor and evaluate passage and, where possible, spawning success for a sample of these individuals.

- Collect ammocoete data to evaluate effectiveness of the translocation efforts.

<u>Umatilla Tribes Translocation Program</u>

In 1995, a status report was completed for Pacific lamprey by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) as directed by the Northwest Power and Conservation Council (NWPCC). The status report identified measures that needed immediate implementation for reintroduction of lamprey along with recommendations for research and data gathering.

In 1998, a juvenile electrofishing survey in NE Oregon and SE Washington was conducted to document current abundance and distribution in the CTUIR ceded lands. The Umatilla, Walla Walla, Tucannon and Grande Ronde rivers had negligible lamprey presence suggesting extremely low or extirpated lamprey populations for those basins. The John Day River had the best lamprey production of NE Oregon/SE Washington rivers sampled, with juvenile lamprey documented throughout the basin.

In 1999, a restoration plan for Pacific lamprey in the Umatilla River was developed and peer-reviewed as directed by the NPCC. The CTUIR detailed a plan to reintroduce lamprey into the Umatilla River where they were once an integral part of the basin. This plan called for: 1) locating an appropriate donor stock for translocation, 2) identifying suitable and sustainable habitat within the basin for spawning and rearing, 3) outplanting up to 500 adult lampreys annually, and 4) long-term monitoring of spawning success, juvenile growth, juvenile density increases, juvenile outmigration, and adult returns. In 2000, CTUIR began implementing the restoration plan. The Umatilla River was chosen primarily for reintroduction because it once supported an abundant population of lamprey and a traditional lamprey fishery, and donor stocks where geographically close for translocation. In addition, numerous habitat improvements had been completed for salmonids.

Tasks to implement the Umatilla translocation plan include:

- Coordinating with US Army Corps of Engineers mainstem dam fishway dewatering activities for the salvage and collection of adult lamprey

- Establishing adult collection facilities at select mainstem projects to facilitate translocation effort

- Targeting 500 adult Pacific lamprey to be translocated from mainstem dams to the Umatilla River and tributaries annually.

- Holding transported adults for overwintering at the South Fork Walla Walla River Adult Lamprey Holding facility and Minthorn Springs Adult Lamprey Holding facility

- Releasing over-wintered adults in the spring into the Umatilla River Basin

- Long-term monitoring of translocation success

Objective 4: Status monitoring and research
(Note: Actions are summarized for the tribal basin-wide ceded areas in the Tributary Action Plans Appendix)

It will be important to reestablish the CBFWA Lamprey Technical Working Group and expand the focus to dam passage, mainstem habitat, genetic work and consideration of an aquaculture facility. Consistent participation of regional lamprey expert scientists in this forum and specific passage forums such as the Corps Anadromous Fish Evaluation Program is very important.

Sub-objective A: Status Monitoring

Monitor lamprey population status and trends

No effort to restore a species can be complete without attention to evaluating and monitoring effectiveness. This plan aims for an adaptive management framework. Adaptive management cannot be done without measuring both the progress and effect of plan actions. Each step described previously included recommendations for monitoring after implementation, but a larger more global effort is needed. Similarly, a more global effort is needed to integrate this plan as seamlessly as possible with others initiated by other agencies and institutions.

In the 2007-2009 Northwest Power Conservation Council's Fish and Wildlife Program solicitation of new projects, Mesa et al. (2007b) submitted a comprehensive proposal to study the relative abundance, distribution, and population structure of lamprey in the Columbia River Basin (CRB). This research directly addresses the highest ranking critical uncertainties for anadromous and resident lamprey in the CRB, as described in the 2005 report of the Lamprey Technical Work Group (LTWG) entitled "*Critical* *uncertainties for lamprey in the Columbia River Basin: results from a strategic planning retreat of the Columbia River Lamprey Technical Workgroup".* This group, a subcommittee of the Anadromous Fish Committee of the CBFWA, was created to provide technical review, guidance, and recommendations for activities related to lamprey conservation and restoration. The LTWG has been charged with identifying critical uncertainties regarding lamprey conservation, establishing lamprey research, monitoring, and evaluation needs, prioritizing research, reviewing new proposals and existing projects, and disseminating technical information. This work should be funded.

Establish regional data protocols for collection, storage and analysis.
Develop means to widely access and share information.

<u>Data Management Plan (Schmidt 2008)</u>

The Lamprey Management Plan envisions adopting the following approaches to collecting and managing the data that will be utilized to assess and monitor the health, abundance and distribution of lamprey populations. The intent is to make all key data compatible regardless of origin. These steps will be taken collaboratively with all cooperating tribes and agencies:

1. Identify and agree on the specific key metrics needed to measure lamprey abundance and distribution.
2. Identify and agree on the specific sampling methodologies that will be employed by all cooperating tribes and agencies to measure the various key metrics.
3. Develop a common list of data definitions and codes for use in recording and managing the data related to the key metrics.
4. Develop a data management plan that outlines the approaches to managing the resulting data, including:
    a. Where the data will reside
    b. How to consolidate data for wide scale analysis
    c. What data quality assurance procedures will be employed
    d. How the data will be maintained and updated (process used) and who will be responsible
    e. What formats and platforms will be used
    f. How the data will be shared and with whom, and whether there are any limitations on dissemination of the data.
    g. Procedures for summarization and analysis of the data
5. Develop metadata (information describing the data) for each data set related to the key metrics.
6. Develop standard data recording forms for use by all samplers for each key metric. Develop a standard data entry template for data collected in the field, and explore the feasibility of using mobile tools for direct data entry in the field.
7. Explore the feasibility of developing a common database system to house the data resulting from these sampling efforts. Features to consider include: the ability for data originators to directly enter, review and manage their data;

The data management approach developed under this plan is intended to serve as a platform for range-wide work with all lamprey species, so the program will be developed collaboratively with the direct partners and with input from other interested agencies and parties in the Pacific Northwest, including USFWS, WDFW, IDFG and ODFW, FERC license holders and other appropriate parties if they wish to participate.

<u>Sub-objective B: Research</u>

Expand existing knowledge on limiting factors and critical uncertainties

Every recommendation of this plan is made with the understanding that there is a severe deficit of definitive knowledge of the status, ecology and biology of the species. This plan does not ignore this fact; instead it attempts to rectify the deficit while recognizing the very real need for immediate action. Integrated with every step of this plan are recommendations for concurrent investigations designed to address the deficiencies.

Determine genetic structure and maintain genetic integrity

The plan recognizes and calls for research into the genetic makeup of the species and particularly the genetics of the remaining populations with a goal of maintaining genetic integrity of those populations.

Evaluate the need for a lamprey aquaculture facility based upon a limiting factor analysis

An additional specific research focus is to evaluate the need and practicality for the establishment of a lamprey aquaculture facility. Currently many researchers obtain juvenile lamprey for research from the John Day Dam salmon juvenile bypass system. The tribes are concerned about the impact of these actions on remaining juvenile lamprey from the John Day River and other lower Columbia nursery areas. Creation of an aquaculture facility would enable culture of juvenile lamprey for basin research without impacting remaining wild populations.

Objective 5: Establish, coordinated public education and other outreach programs to communicate and establish: 1) an awareness of the importance of Pacific lamprey and their current status and, 2) the need to implement actions in this plan to restore them throughout the Columbia River Basin, 3) the consequences of failing to act.

Unlike salmon, there is a general public lack of awareness and appreciation for Pacific lamprey. This is a key barrier that must be overcome if actions in this restoration plan are to be successful. The following are key objectives for a coordinated public education and outreach program:

- The importance and status of lamprey must be consistently communicated to the public, elected officials and public servants in agencies in the context of restoring the Columbia River ecosystem (ISG 1996). As one agency representative recently stated, "salmon restoration will not happen without lamprey restoration." This will involve increasing public understanding of lamprey science and cultural significance of lamprey to tribal peoples.

- Bring people and constituencies together to foster learning networks; create credibility for lamprey restoration through sound science and constituencies relating on-the-ground experiences for federal, state and private lands; explain any uncertainty about restoration actions particularly in the face of additional impacts of climate change and population growth. Explain the risk to species, ecosystem services, economies, cultural values, and social values as a consequence of failing to act.

- Make institutional and investment commitments to collaborate on developing a scientific understanding of lamprey responses to restoration actions at the scale of the entire Columbia Basin.

Summary and Conclusion

The take home message from this draft plan is that ***action is needed now***. Pacific lamprey are teetering on the brink of extinction. While the Pacific lamprey may lack the charisma of salmon, they remain an important entity in the Columbia River Basin in their own right. For the tribes who value the species as essential to their culture, losing lamprey is "not an option". Lamprey feed whole streams with their degrading carcasses and they act as a buffer for predators that prey on fish that many value more. In short, all members of the Columbia River Basin community, not just tribes, will be hurt if lamprey are lost—the species has played a vital part in the ecosystem for hundreds of millions of years. If history is any guide, we and future generations will miss them much more than we currently expect.

This draft Pacific lamprey restoration plan is a unique document that contains a high level of detail describing specific objectives and actions. No plan like this has ever been developed before. There are five objectives, of which the first- improving mainstem passage- is of primary and urgent importance. The actions to achieve passage improvements must be implemented immediately. Next, and of high priority, is to protect and supplement existing juvenile lamprey groups in the mid and upper portion of the basin with translocated adults from the lower basin. These immature forms are obviously important for recruitment, and may also be essential to attracting adults to upstream spawning sites. Research and monitoring directed toward understanding the lamprey abundance, distribution and life history of the species has been sorely neglected and is also a vital objective of this draft plan. Effective systems of communication and data acquisition, management and sharing must be developed and implemented. Finally, but most important, public education outreach and communication programs addressing lamprey status, importance and the consequences of failing to expediently take restoration actions must be developed and implemented. Despite existing uncertainties and lack of knowledge it bears repeating that action on all objectives must be initiated as soon as possible to halt the present decline.

The tribes recognize that this plan is a work in progress, with potential for modification as our knowledge base increases. As we actively strive to restore this humble, yet essential, species, we welcome and expect support from the entire Columbia River community. Finalizing and implementing this draft plan must be a collaboration—it lives only if the tribes can gain the participation, cooperation and coordination of federal and state agencies, the public, NGOs and FERC license holders. After all, the test of any community is how it regards and considers all of its members—even those least revered such as lamprey.

It is in this spirit of inclusiveness that the tribes offer this draft plan.

References

Bayer, J. M., T. C. Robinson, and J. G. Seelye. 2000. Upstream migration of Pacific lampreys in the John Day River: Behavior, timing and habitat use. Annual report to Bonneville Power Administration, Project Number 2000052.

Bark, R. 2008. **-** Inventory of Reclamation facilities where lamprey species exist, issues confronting lamprey, and how to aid fishways for passage and monitoring**.** Bureau of Reclamation. Denver, Colorado.

Beamish, F. W. H. 1974. Swimming performance of adult sea lamprey, *Petromyzon marinus*, in relation to weight and temperature. Transactions of the American Fisheries Society. 103:355-358.

Beamish, R. J. 1980. Adult biology of the river lamprey (*Lampetra ayresi*) and the Pacific lamprey (*Lampetra tridentata*) from the Pacific coast of Canada. Canadian Journal of Fisheries and Aquatic Sciences. 37: 1906-1923.

Beamish, R.J. and T.G. Northcote. 1989. Extinction of a population of anadromous parasitic lamprey *Lampetra tridentate* upstream of an impassable dam. Canadian Journal of Fisheries and Aquatic Sciences 46:420-425.

Beamish, R. J. and C. D. Levings. 1991. Abundance and freshwater migration of the anadromous parasitic lamprey, *Lampetra tridentata*, in a tributary of the Fraser River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences. 48:1250-1263.

Bergstedt, R.A., and J.G. Seelye. 1995. Evidence for lack of homing by sea lampreys. Transactions of the American Fisheries Society. 124:235-239.

Bergstedt, R. A., D. V. Rottiers, and N. R. Foster. 1981. Laboratory determination of maximum swimming speed of migrating sea lampreys: a feasibility study. U. S. Fish and Wildlife Service Administration Report No. 81-3.

Bleich, M.D., and R.A. Moursund. 2006. The use of pit-tags to evaluate the passage of juvenile Pacific lamprey *(Lamptera tridentata)* at the McNary Dam juvenile bypass system, 2005. Contract DACW68-02-D-0001 to Corps of Engineers. By Batelle NW Pacific Laboratories. Richland, WA.

BioAnalysts, Inc. 2000. A status of Pacific lamprey in the mid-Columbia Region. Rocky Reach Hydroelectric Project FERC Project No. 2145. Prepared for Public Utility District No. 1, Chelan County, Wentachee, Washington.

BioAnalysts, Inc. 2005. Evaluation of adult Pacific lamprey passage at Rocky Reach Dam using radiotelemetry techniques, 2004. For Public Utility District No. 1 of Chelan County. BioAnalysts, Redmond, Washington.

BOR (Bureau of Reclamation). 2003a. Initial review of three strategies to manage water temperatures at Grand Coulee Dam. Discussion Paper-draft. Prepared for Grand Coulee Power Office. USDOI, BOR. Boise, Idaho.

BOR. 2003b. Programmatic environmental assessment. Mid-Columbia River Steelhead ESU- Action 149 Implementation. Boise, Idaho.

Bond, C.L. 1979. Biology of fishes. Saunders, Philadelphia. 514 pp.

Brumo, A. and D. F. Markle. 2004. Spawning, larval drift, early mortality, and ecological role of Pacific lamprey in the South Fork Coquille River. Annual report to Oregon Department of Fish and Wildlife and US Fish and Wildlife Service.

Bunn, S.E., and A.H. Arthington. 2002. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Enviromental Management. V. 30 (4), pp. 492-507.

Carlson, C. 1995. Fyke net testing data from Priest Rapids Dam. Unpublished data. Public Utility District No. 2 of Grant County. Ephrata, Washington.

CBLTWG (Columbia Basin Fish and Wildlife Authority Lamprey Technical Workgroup). 2007. Development of lamprey passage standards. Passage standards Ad-hoc subgroup. September 28, 2007 memorandum from D. Ward to CBFWA Anadromous Fish Advisory Committee. Columbia Basin Fish and Wildlife Authority. Portland, OR.

CBLTWG 2005. Critical uncertainties for lamprey in the Columbia River Basin: Results from a strategic planning retreat of the Columbia River Lamprey Technical Workgroup. Columbia Basin Fish and Wildlife Authority. Portland, OR.

CBLTWG. 2004. Passage considerations for Pacific lamprey. Columbia Basin Fish and Wildlife Authority. Portland, Oregon.

CBLTWG. 2002. Columbia River Lamprey Program Summary. Prepared for the Northwest Power Planning Council. Columbia Basin Fish and Wildlife Authority. Portland, Oregon.

CBLTWG. 1999. Planning of the Columbia Basin Pacific lamprey projects and needs. Report to Northwest Power Planning Council and Bonneville Power Administration. Columbia Basin Fish and Wildlife Authority. Portland, Oregon.

Clabough, T.S., E.L. Johnson, D.C. Joosten and C. Peery. 2007. Nighttime lamprey counts at Bonneville and The Dalles Dam. Abstract and presentation at Corps of Engineers Annual Research Review. December 2007. Walla Walla, Washington.

Clabough, T., E. Johnson, D. Joosten, and C. Peery. 2008. Evaluating adult Pacific lamprey dam passage counting methodology at Bonneville and The Dalles dams-2007- A preliminary letter report for Bradford Island Fishway. Report to Corps of Engineers, Portland District. Department of Fish and Wildlife Resources. University of Idaho. Moscow, Idaho.

Claire, C.W. 2004. Pacific lamprey larvae life history, habitat utilization and distribution in the South Fork Clearwater River drainage, Idaho. MS Thesis. Department of Fish and Wildlife. University of Idaho. Moscow, Idaho.

Clanton, RE. 1913. Feeding fry in ponds. ***in*** Biennial Report of the Department of Fisheries of the State of Oregon. to the Twenty-seventh Legislative Assembly Regular Session. Salem,Oregon, pp. 98-100.

Clugston, D. 2003. Draft lamprey passage plan for Portland District Corps of Engineers. Portland, Oregon.

Close, D. A., M. Fitzpatrick, H. Li, B. Parker, D. Hatch, and G. James. 1995. Status report of the Pacific lamprey (*Lampetra tridentata*) in the Columbia River Basin. Technical Report to Bonneville Power Administration DOE/BP-39067-1

Close, D. A., M. Fitzpatrick, Martin, C. M. Lorion, W. H. Li, and C. B. Schreck. 2003b. Effects of intraperitoneally implanted radio transmitters on the swimming performance and physiology of Pacific lamprey. North American Journal of Fisheries Management. 23:1184–1192.

Close, D.A., M. Fitzpatrick, H. Li., B.L. Parker, D.R. Hatch, and G. James. 1995. Status report of the Pacific lamprey (Lampetra tridentata) in the Columbia basin. Bonneville Power Administration Report, Project Number 94-026, Portland, OR.

Close, D. A. 2000. Pacific lamprey research and restoration project. 1998 Annual Report to Bonneville Power Administration, Contract No. 00000248-1, Project No. 199402600

Close, D.A., M.S. Fitzpatrick and H.W. Li. 2002. The ecological and cultural importance of a species at risk of extinction, Pacific Lamprey. Fisheries. Vol 27. No. 7. Pg. 19-25.

Close, D.A, and A. Jackson. 2001. Pacific Lamprey research and restoration project. Annual Report 1999. Project Number 94-026. Contract No. 95BI39067 to Bonneville Power Administration. By Confederated Tribes of the Umatilla Indian Reservation. Department of Natural Resources. Pendleton, OR. 171 pages.

Close, D.A., M. Fitzpatrick, H. Li, B. Parker, D. Hatch and G. James. 2005. Status report of the Pacific lamprey *(Lampetra tridentata)* in the Columbia River Basin. Project No. 94-026. Contract No. 95BI39067. To Bonneville Power Administration. By Oregon State Cooperative Fishery Research Unit, Columbia River Inter-Tribal Fish Commission and Confederated Tribes of the Umatilla Indian Reservation. Department of Natural Resources. Pendleton, OR. 35 pages.

Cochnauer, T. and C. Claire. 2001. Evaluate status of Pacific lamprey in the Clearwater River drainage, Idaho. Annual Report 2002. Prepared for BPA. Idaho Department of Fish and Game. Lewiston, Idaho.

Connor,W.P., R.K. Steinhorst and H.L. Burge. 2003a. Migratory behavior and seaward movement of wild subyearing chinook in the Snake River. North American Journal of Fisheries Management. 23:414-430.

Connor, W.P. H.L. Burge, J.R. Yearsley and T.C. Bjornn. 2003b. Influence of flow and temperature on survival of wild subyearling fall chinook salmon in the Snake River. North American Journal of Fisheries Management. 23:362-375.

Corps of Engineers. 2004. Water temperatures in adult fishways at mainstem dams on the Snake and Columbia Rivers: Phase I-Physical Characterization (2000 FCRPS BiOp RPA Action 114). Walla Walla District. Walla Walla. Washington.

CRITFC. 2008. January 8, 2008 Comments on the draft 2008 Biological Opinion on the Operation of the Federal Columbia River Power System. Columbia River Inter-Tribal Fish Commission. Portland, Oregon.

CTUIR (Confederated Tribes of the Umatilla Indian Reservation). 2003. May 13, 2003 letter from J. Mithorn, Board of Trustees to BG D. Fastabend and Lt. Colonel R. Hobernicht regarding adult lamprey mortality at John Day Dam during fishway dewatering. Pendleton, Oregon.

Cummings, D. 2007. Direct and Indirect Barriers to Migrations- Pacific lamprey at McNary and Ice Harbor Dams in the Columbia River Basin. MS Thesis. College of Natural Resources. University of Idaho. Moscow, Idaho.

Cummings. D. , C. Peery and M. Moser. 2006. 2006 Evaluation of adult Pacific lampey passage success at McNary and Ice Harbor dams. Abstract and presentation at Corps of Engineers Annual AFEP Review. Portland, Oregon.

Daigle, W., C. Peery and M.L. Moser. Adult Pacific lamprey passage efficiency in the lower Columbia River and lamprey bypass structure development. November 16, 2006 Abstract and presentation at Corps of Engineers'Anadromous Fish Evaluation Program Annual Research Review. Portland, OR.

Daigle, W. R., C. A. Peery, S. R. Lee, and M. L. Moser. 2005. Evaluation of adult Pacific lamprey passage and behavior in an experimental fishway at Bonneville Dam, Technical Report to the US Army Corp of Engineers and Bonneville Power Administration, Study No. ADS-P-008 and ADS-P-00-10

FPC (Fish Passage Center). 2006. Historical adult lamprey counts. http://www.google.com/search?hl=en&q=fish+passage+center&btnG=Search

FPC (Fish Passage Center). 2007. Historical adult lamprey counts. http://www.google.com/search?hl=en&q=fish+passage+center&btnG=Search

Fryer, J. 2007. Feasibility of using a computerized video fish counting system to estimate night time passage of salmon and lamprey at the Washington Shore Bonneville Dam fish counting station. Unpublished report. CRITFC. Portland, Oregon.

Galbreath, J. 1979. Columbia river colossus, the white sturgeon. Oregon Wildlife, March:3-8.

Goodman, D., S. Reid, and M. Docker. 2006. A phylogenetic analysis of the Pacific lamprey Estosphenus tridentatus, Final Report to United States Fish and Wildlife Service No. 10181-4-M465.

Hammonds, R. J. 1979. Larval biology of the Pacific lamprey, *Entosphenus tridentatus* (Gairdner), of the Potlatch River, Idaho. M.S. thesis, University of Idaho, Moscow, Idaho.

Hanson, L. H. 1980. Study to determine the burst swimming speed of spawning-run sea lampreys

Haro, A. and B. Kynard. 1997. Video evaluation of passage efficiency of American shad and sea lamprey in a modified Ice Harbor fishway. North American Journal of Fisheries Management. 17:981-987.

Hatch, D.R. and B.L. Parker. 1997. Lamprey research and restoration project. Report to the Confederated Tribes of the Umatilla Indian Reservation. CRITFC. Portland, Oregon

Hilborn, R. 1987. Living with uncertainty in resource management. North American Journal of Fisheries Management. Volume 1. Pages 1-5.

Howerton, B.J. Bureau of Indian Affairs biologist. March, 2008. Personal communication.

ISAB (Independent Scientific Advisory Board). 2007a. Climate change impacts on Columbia River Basin Fish and Wildlife. Report 2007-2. Northwest Power and Conservation Council. Portland, OR

ISAB. 2007b. Human Population Impacts on Columbia River Basin Fish and Wildlife. Report 2007-3. Northwest Power and Conservation Council. Portland, OR

ISAB. 2001. A review of salmon recovery strategies for the Columbia River Basin. Report 2001-7 to the Northwest Power Planning Council. Portland, OR.

ISAB. 1999. Report and Recommendations to the Northwest Power Planning Council upon Review of the Corps of Engineers' Columbia River Fish Mitigation Program. Report 99-5. Northwest Power and Conservation Council. Portland, OR.

ISG (Independent Scientific Group). 1996. Return to the River. Restoration of salmonid fishes in the Columbia River ecosystem. Northwest Power and Conservation Council. Portland, OR.

Jackson, A. D, P. D. Kissner, D. R. Hatch, B. L. Parker, D. A. Close, M. S. Fitzpatrick, and H. Li. 1996. Pacific lamprey research and restoration. Annual report to Bonneville Power Administration, Project No. 94026.

Jackson, A. D., D. R. Hatch, B. L. Parker, D. A. Close, M. S. Fitzpatrick, and H. Li. 1997. Pacific lamprey research and restoration. Annual report to Bonneville Power Administration, Project Number 94026.

Johnson, M. Tribal biologist. Yakama Nation. May 7, 2008. Personal communication.

Johnson, E, C. Peery and M. Moser. 2007. Effects of reduced nighttime entrance velocities on lamprey entrance use at Bonneville Dam. Abstract and presentation at Corps of Engineers Annual AFEP Research Review. December 3-7, 2007. Walla Walla, Washington.

Kan T. T. 1975. Systematics, variation, distribution, and biology of lampreys of the genus Lampetra in Oregon. PhD. Dissertation, Oregon State University, Corvallis, Oregon.

Karr, M.H, J.K. Fryer and P.R. Mundy. 1998. Snake River water temperature control project. Phase II. Methods for managing and monitoring water temperatures in relation to salmon in the lower Snake River. CRITFC. Portland, Oregon.

Kostow, K. 2002. Oregon lampreys: Natural history status and problem analysis. Oregon Department of Fish and Wildlife. Salem, OR.

Laine, A., R.Kamula and J. Hoodli. 1998. Fish and lamprey passage in a combined denil and vertical slot fishway. Fisheries Management and Ecology. 5:31-44.

Lauver, E. 2006. Priest Rapids Project. Adult Fishway Improvements. Annual Report. Public Utility District of Grant County. Ephrata, Washington.

Lin, B. and 6 co-authors. 2007. AFLP assessment of genetic diversity of Pacific lamprey. *In review.*

Long, C. W. 1968. Diel movement and vertical distribution of juvenile anadromous fish in turbine intakes. Fishery Bulletin 66:599-609.

Lorz, T. 1998. Memorandum to Fish Management Section. Lamprey impingement problems at John Day extended bar screens. CRITFC. Portland, Oregon.

Luzier, C. and G. Silver. 2005. Evaluate habitat use and population dynamics of lampreys in Cedar Creek. 2004 Annual Report to Bonneville Power Administration Project No. 200001400

Mattson, C. R. 1949. The lamprey fishery at Willamette Falls, Oregon. Fish Commission Research Briefs, Volume 2. Portland, Oregon. pp 23-27.

Meeuwig, M. H., J. M. Bayer, and J. G. Seelye. 2005. Effects of temperature on survival and development of early lifestage Pacific and western brook lampreys. Transactions of the American Fisheries Society, 134: 19-27.

Merrell. T.R. 1959. Gull food habits on the Columbia River. Research Briefs, Fish Commission of Oregon 7(1):82.

Mesa, M, J. Bayer, J. Seelye, and L. Weiland. 1999. Swimming performance and exhaustive stress in Pacific lamprey (*Lampetra tridentata*): implications for upstream migrations past dams. U.S. Geological Survey. Draft annual report to the U.S. Army Corps of Engineers, Portland District.

Mesa, M. G., J. M. Bayer, and J. G. Seelye, 2003. Swimming performance and physiological responses to exhaustive exercise in radio-tagged and untagged Pacific lamprey. Transaction of the American Fisheries Society, 132:483-492.

Mesa, M.G., R.J. Magie and E.S. Copeland. 2007a. Passage and behavior of radio-tagged adult Pacific lamprey at Willamette Falls, Oregon. Draft report to Portland General Electric. USGS. Columbia River Research Laboratory. Cook, Washington.

Mesa, M.G.,C. Luzier and D. Hatch. 2007b. Relative abundance, distribution, and population structure of lampreys in the Columbia River Basin. Project ID 200716500. Proposal submitted to the Northwest Power and Conservation Council, 2007-2009 Solicitiation. Portland, Oregon.

Moore, J. W., and J. M. Mallatt. 1980. Feeding of larval lamprey. Canadian Journal of Fisheries and Aquatic Sciences. 37: 1658-1664.

Moser, M.L., P.A. Ocker, L.C. Stuehrenberg and T.C. Bjornn. 2002a. Passage efficiency of adult Pacific Lampreys at hydropower dams on the Lower Columbia River, USA. Trans. Amer. Fish. Soc. 131:956-965.

Moser, M. L., A. L. Matter, L. C. Stuehrenberg, T. C. Bjornn. 2002b. Use of an extensive radio receiver network to document Pacific lamprey *(Lampetra tridentata*) entrance efficiency at fishways in the Lower Columbia River, USA. Hydrobiologia 483: 45-53.

Moser, M.L. and D.A. Close. 2003. Assessing Pacific Lamprey status in the Columbia River Basin. Northwest Science. Vol 77. No. 2.

Moser, M.L., H. Pennington, J. Ross and W. Daigle. Development and evaluation of aids to adult Pacific lamprey passage at Bonneville Dam. November 16, 2006 Abstract and presentation at Corps of Engineers' Anadromous Fish Evaluation Program Annual Research Review. Portland, OR.

Moser, M.L., D.A. Ogden, D.L. Cummings and C.A. Peery. 2006. Development and evaluation of a lamprey passage structure in the Bradford Island Auxiliary Water Supply Channel, Bonneville Dam, 2004. Report to Portland District Corps of Engineers. Contract E96950021. NOAA Fisheries Science Center. Seattle, WA.

Moser, M.L., J.M Butzerin and D.D. Dey. 2007a. Capture and collection of lampreys:the state of the science. Rev Fish Biol Fisheries 17:45-56

Moser, M.L., H.T. Pennigtonand J.M Roos. 2007b. Grating size needed to protect adult Pacific lamprey in the Columbia River Basin. Contract E96950021 to Corps of Engineers. NOAA Fish Ecology Division. Seattle, Washington.

Moser, M.L., I.J. Russon and M.H. Gessel. 2007c. Developing a separator for juvenile lamprey. Abstract and presentation at Corps of Engineers Annual Research Review. December, 2007. Walla Walla Washington.

Mousund,R.A., D.D. Dauble and M.D. Bleich. 2000. Effects of John Day Dam bypass screens and project operations on the behavior and survival of juvenile Pacific lamprey (*Lampetra tridentata).* For Corps of Engineers, Portland District. By Pacific Northwest Laboratory, Richland, Washington.

Moursund, R.A., R.P. Mueller, T.M. Degerman, and D.D. Dauble. 2001. Effects of dam passage on juvenile Pacific lamprey *Lampetra tridentata*. Final Report. Prepared for U.S. Army Corps of Engineers, Portland District.

Moursund, R.A., M.K. Bleich, K.D. Ham, R.P. Mueller. 2002. Evaluation of the effects of extended length submerged bar screens on migrating juvenile Pacific lamprey (*Lampetra tridentata*) at John Day Dam in 2002. Prepared for the U.S. Army Corps of Engineers, Project No. DE-AC06-76RL01830.

Moursund, R. A, M. D. Bleich, K. D. Ham, and R. P. Mueller. 2003. Evaluation of the effects of extended length submerged bar screens on migrating juvenile Pacific lamprey at John Day Dam in 2002. Final Report of Research, U. S. Army Corps of Engineers.

Nass, B. C. Sliwinski, K.K., English, L. Porto and L. Hildebrand. 2003. Assessment of adult lamprey migratory behavior at Wanapum and Priest Rapids dams using radio-telemetry techniques, 2001-2002. Report for Grant County PUD. By LGL Limited. Sidney, B.C.

NPT (Nez Perce Tribe) 2008. Comments on the Final Environmental Impact Statement for the relicensing of the Hells Canyon Hydroproject (FERC No. 1971). Lapwai, Idaho.

Nez Perce et al. 1995. Wy-Kan-Ush-Mi Wa-Kish-Wit. The Columbia River anadromous fish restoration plan of the Nez Perce, Umatilla, Warm Springs, and Yakama Tribes. Portland, Oregon.

NRDC (National Resources Defense Council) and Rocky Mountain Climate Organization. 2008. Hotter and Drier. The West's Changed Climate. New York. N.Y.

Ocker, P. A., L. W. Stuehrenberg, M. L. Moser, A. L. Matter, J. J. Vella, B. P. Sanford, T. C. Bjornn, and K. R. Tolotti. 2001. Monitoring adult Pacific lamprey (*Lampetra tridentata*) migration behavior in the lower Columbia River using radiotelemetry, 1998-1999. Annual Report of Research to the U.S. Army Corp of Engineers, Portland District.

Ostrand, K.G. 2004. Validation of existing screening criteria for lamprey macrothalmia. Abernathy Fishery Technical Center. Longview, Washington.

Peery, C. 2007. Evaluating methods to estimate true escapement of adult Pacific lamprey migrants at Bonneville and The Dalles Dam,-2008. Continuing research preliminary proposal. Study code: ADS-P-00-8. To Corps of Engineers AFEP program. By Department of Fish and Wildlife Resources. University of Idaho. Moscow, Idaho.

Pfeiffer, W. and T.F. Pletcher. 1964. Club cells and granular cells in the skin of lampreys. J. Fish. Res. Bd. Canada. 21:1083-1088.

Pirtle. J, J. Stone, and S. Barndt. 2003. Evaluate habitat use and population dynamics of lampreys in Cedar Creek. 2002 Annual Report to Bonneville Power Administration Project, Project No. 200001400.

Pletcher T. F. 1963. The life history and distribution of lampreys in the Salmon and certain other rivers in British Columbia, Canada. M.Sc. thesis, University of British Columbia, Vancouver, British Columbia.

Potter, I.C. 1980. Ecology of larval and metamorphosing lampreys. Canadian. Journal of Fisheries and Aquatic Sciences 37:1641- 1657.

Potter, I. C., B. J. Hill, and S. Gentleman. 1970. Survival and behavior of ammocoetes at low oxygen tensions. Journal of Experimental Biologist. 53: 59-73.

Potter, I. C., R. W. Hilliard, J. S. Bradley, and R. J. McKay. 1986. The influence of environmental variables on the density of larval lampreys in different seasons. Oikos 70: 433-440.

Poe, T.P., H.C. Hansel, S. Vigg, D.E. Palmer, and L A. Prendergast. 1991. Feeding of predaceous on out-migrating juvenile salmonids in John Day Reservoir. Columbia River. Transactions of the American Fisheries Society 120405-420.

Torgersen, C.E. and D.A. Close. 2004. Influence of habitat heterogeneity on the distribution of larval Pacific lamprey (*Lampetra tridentate*) at two spatial scales. Freshwater Biology. 49:614-630.

Richards, J. E. 1980. Freshwater life history of the anadromous Pacific lamprey *Lampetra tridentata*. M.S. thesis, University of Guelph, Guelph, Ontario.

Richards, J. E., and F. W. H. Beamish. 1981. Initiation of feeding and salinity tolerance in the Pacific lamprey *Lampetra tridentata*. Marine Biology 63:73-77.

Richards, N. John Day Dam fishway improvements. February 9, 2007 power point. Portland District. Corps of Engineers, Portland, Oregon.

Roby, D.D. Avian predation researcher. Corp of Engineers research proposal meeting. December 2007 personal communication.

Roffe, T.J. and B.R. Mate. 1984. Abundances and feeding habits of pinnipeds in the Rogue River, Oregon. Journal of Wildlife Management. 48(4):1262-1274.

Schaller, H. and 13 co-authors. 2007. Comparative survival study of PIT-Tagged spring/summer Chinook and steelhead in the Columbia River Basin. Ten-year retrospective summary report. Project #1996-020-00. Multi-agency Comparative Survival Study Oversight Committee and Fish Passage Center, Portland, Oregon.

Schmidt, B. 2008. Protocols for data management and distribution. Pacific States Marine Fisheries Council.

Schreck, C. S. Heppell and D. Lerner. 2000. Determination of passage of juvenile lamprey:Development of a tagging protocol. BPS-P-0015-b. Report to Corps of Engineers. Oregon Cooperative Fish and Wildlife Research Unit. Biological Resources Division, USGS. Oregon State University. Corvallis, Oregon.

Scott, W. B. and E. J. Crossman. 1973. Freshwater fishes of Canada. Canadian Government Publishing Centre, Ottawa, Canada.

Semakula, S.N., and P.A. Larkin. 1968. Age, growth, food and yield of the white sturgeon (*Acipenser transmontanus)* of the Fraser River, British Columbia. Journal of the Fisheries Research Board of Canada. Vol 25(12):2589-2602.

Sit, V. and B. Taylor (eds). 1998. Statistical methods for adaptive management studies. Research Board British Columbia Ministry of Forestry Research Branch. Victoria, B.C. Land Management Handbook No. 42.

Southeastern Washington from Indigenous Peoples of the Confederated Tribes of the Umatilla Indian Reservation. Journal of Northwest Anthropology, Fall 2004, Vol 38, No.2, pp 141-160.

Stansell, R. Sea lion predation and deterrence measures at Bonneville Dam. November 16, 2006 Abstract and presentation at Corps of Engineers' Anadromous Fish Evaluation Program Annual Research Review. Portland, OR.

Starke, G.M. and J.T. Dalen. 1998. Photographs of juvenile lamprey impingement on turbine intake screens at John Day Dam, Rufus, Oregon.

Starke, G.M. and J.T. Dalen. 1995. Pacific lamprey (*Lamptera tridentate*) passage patterns past Bonneville Dam and incidental observations of lamprey at Portland District Columbia River dams in 1993. Unpublished report on file at U.S. Army Corps of Engineers, Bonneville Lock and Dam, Fish Field Unit. Cascade Locks, OR.

Stewart, D.J., D.Weininger, D.V. Rottiers and T.A. Edsall. 1983. An energetics model for lake trout (*Salvelinus namaycush)*:application to the Lake Michigan population.

USFWS (United States Fish and Wildlife Service). 2006. Life history of Pacific lamprey. Chart for distribution. Vancouver, Washington.

USGS. (United States Geological Survey). 2006. Adult lamprey passage study at Willamette Falls Hydroelectric Project. Power point presentation. Cook, Washington.

van de Wetering, S. J. 1998. Aspects of life history characteristics and physiological processes in smolting Pacific lamprey, *Lampetra tridentata*, in a central Oregon stream. M.S. theses, Oregon State University, Corvallis, Oregon.

Vella, J., L. Steuhrenberg, and T. C. Bjornn. 1999. Migration patterns of Pacific lamprey (*Lampetra tridentata*) in the lower Columbia River, 1996. Annual Report of Research to the U.S. Army Corp of Engineers, Portland District.

Vella, J., L. Steuhrenberg, and T. C. Bjornn. 2001. Migration patterns of Pacific lamprey (*Lampetra tridentata*) in the lower Columbia River, 1997. Annual Report of Research to the U.S. Army Corp of Engineers, Portland District.

Walters, C.J. and C.S. Holling. 1990. Large-scale management experiments and learning by doing. Ecology 71:2060-8.

Walters, C.J. 1986. Adaptive management of renewable resources. MacGraw –Hill. New York, NY.

WGA (Western Governors Association). 2008. Wildlife Corridors Initiative. Climate Change Working Group. Draft Report. April 2, 2008. Denver, Colorado.

Whyte, J.N.C., R.J. Beamish, N.G.Ginther, and C.E. Neville. 1993. Nutritional condition of the Pacific lamprey *(Lampetra tridentata)* deprived of food for periods of up to two years. Canadian Journal of Fisheries and Aquatic Sciences. 50:591-599.

Wydoski, R. S. and R. R. Whitney. 1979. Inland Fishes of Washington. University of Washington Press. Seattle and London.

Youson, J.H., and I.C. Potter. 1979. A description of the stages in the metamorphosis of the anadromous sea lamprey (*Petromyzon marinus)*. Canadian Journal of Zoology. 57:1808-1817.

North American Journal of Fisheries Management 10:388-396, 1990

White Sturgeon in the Lower Columbia River: Is the Stock Overexploited?

BRUCE E. RIEMAN[1] AND RAYMOND C. BEAMESDERFER

Oregon Department of Fish and Wildlife
17330 S.E. Evelyn Street, Clackamas, Oregon 97015, USA

Abstract.—We used computer simulation to examine potential yields and sustainable exploitation rates for white sturgeon *Acipenser transmontanus* in the lower Columbia River. Simulated yields varied with assumptions used for mortality, growth, and stock-recruitment relationship, and with size restrictions imposed on harvest. The stock-recruitment function had the greatest influence on our results. Maximum yields (sustained or at 100 years) ranged from 0.2 to 2.9% of unexploited biomass. Maximum yields were produced with exploitation rates ranging from 0.02 to 0.20, and yields declined or collapsed at higher rates. Size restrictions (sport and commercial harvest of fish only between 92 and 183 cm or 122 and 183 cm, respectively) resulted in higher yields and higher supportable exploitation than no size restrictions. However, size windows did not prevent collapse of the fishery under higher exploitation rates when a stock-dependent recruitment function was used. The fishery on the Columbia River has expanded dramatically in recent time. Most recent yields were about 30% of the peak yield realized when the stock was overfished before 1890, and were at least three times the sustained yields expected from our most optimistic simulations. Cultural development of the river could have reduced the productivity of the stock and made it vulnerable to overexploitation. The present fishery appears to be overexpanded. Current yields probably cannot be sustained, and current harvest risks eventual collapse of the fishery.

Overexploitation of long-lived, relatively slow-growing fishes is a well-known problem (Ricker 1963; Adams 1980; Francis 1986). Expanding fisheries typically produce increasing yields in a "fishing-up" process (Ricker 1975) that cannot be sustained. Yields can decline dramatically, often to levels that represent a small fraction of the peak (Francis 1986). If the fishery expands beyond the effort producing maximum sustained yield (MSY), stocks can be quickly and seriously overfished. Recovery to a level supporting MSY can take many years (Adams 1980; Francis 1986). The fishery for white sturgeon *Acipenser transmontanus* in the Columbia River is susceptible to each of these problems. White sturgeon may live to 100 years or more (Scott and Crossman 1979); Columbia River white sturgeon commonly exceed 30 years in age (Hess 1984). Although white sturgeon can reach tremendous sizes (reports from the Columbia River exceed 450 kg), documented growth is relatively slow (Hess 1984). Increase in weight from age 5 to age 30 averages less than 20% per year.

A commercial fishery for white sturgeon started on the Columbia River in the 1880s. The fishery expanded to a peak yield of nearly 2.5 million kg (80,000 fish) in 1892 and then declined to less than 45,400 kg by 1899 (Figure 1). Yield from the fishery fluctuated between about 45,400 and 227,000 kg from 1899 to the late 1960s.

Following the decline in catch, management agencies enacted new regulations. From 1897 to 1899, the states of Oregon and Washington adopted a 122-cm minimum-length restriction for commercial catches. Managers added a maximum-size restriction of 183 cm for sport and commercial catches and a 92-cm minimum-length limit for the sport fishery in the 1950s. In 1989 the minimum size for sport harvest was increased to 102 cm. Yields have increased since 1970 (Figure 1). Managers attribute some of the increase to the stock rebuilding under protective regulations (Galbreath 1985), but effort has increased in the same period (Figure 2). Both the sport fishery below Bonneville Dam and a native-American treaty fishery above Bonneville Dam increased substantially since the 1970s (Figure 2). The dominant part of the catch in recent years was taken in the 92-183-cm size window by sport fishermen.

Galbreath (1985) suggested that current regulations provide adequate protection from overexploitation. However, stock-recruitment and yield characteristics for Columbia River white sturgeon are unknown, so sustainable exploitation and yield under any management regime have not been estimated.

The Columbia River has also been developed.

[1] Present address: Idaho Department of Fish and Game, 1798 Trout Road, Eagle, Idaho 83616, USA.

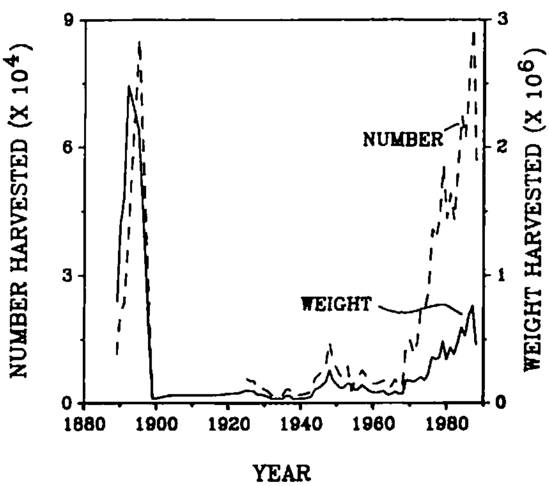


FIGURE 1.—Annual combined sport, commercial, and treaty harvests of white sturgeon from the lower Columbia River, 1889–1988. Data are from Cleaver (1951), FCO and WDF (1971), ODFW and WDF (1988), and Hess and King (1989).

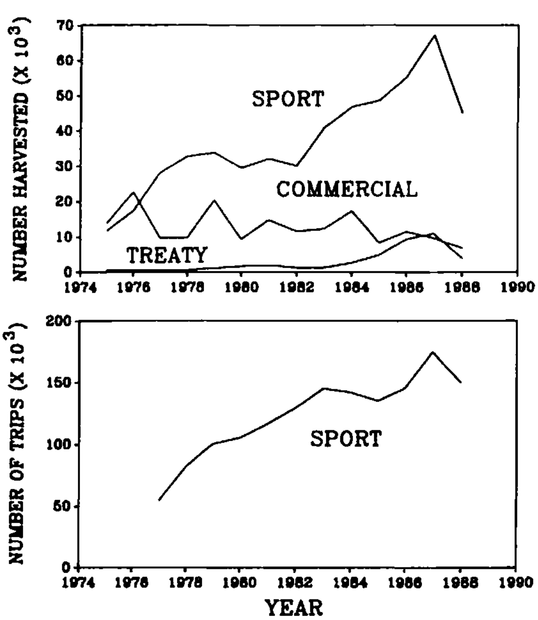


FIGURE 2.—Recent trends in annual harvest of white sturgeon from the lower Columbia River by sport, commercial, and treaty fisheries and in effort by sport anglers. Data are from ODFW and WDF (1988) and Hess and King (1989).

Hydropower dams, the first constructed in the 1930s, have inundated sections of the once free-flowing river. A white sturgeon population that once moved freely within the river and between the river and the ocean is now restricted to a single free-flowing segment with access to the ocean and several smaller segments (reservoirs) blocked by the dams (Figure 3). White sturgeon do move between reservoirs, but the extent of movements relative to historic patterns is unknown and is thought to be very limited. Habitat throughout the river has been altered by flow regulation, channel modification, diking, and dredging. Habitat alterations have been associated with declines in other sturgeons (Artyukhin et al. 1978; Votinov and Kas'yanov 1978; Deacon et al. 1979). Reproduction and recruitment seem to be particularly vulnerable to the environmental changes caused by dams. Development of the Columbia River might well have resulted in a white sturgeon stock or a collection of stocks that are less productive than the one present in 1885.

To better understand the potential yield of the Columbia River white sturgeon fishery, we used population simulations to examine possible responses of white sturgeon populations to exploitation. We used a range of values for population parameters to represent productive as well as unproductive stocks. We describe potential peak and sustained yields simulated with harvest regulations like those used on the Columbia River. We use our results to examine the range of exploitation rates that should produce maximum sustained yields based on our assumptions. Our results will be useful for interpretation of future estimates of exploitation rates. We also use our results to compare theoretical sustained yields and peak yields with those observed for the fishery. We reasoned that the ratios of sustainable yields to peak yields from our models are a useful index of fishery potential. We assumed that a ratio of present yield to the historic peak that is substantially higher than our model predictions would be evidence of an overexpanded fishery.

For the sake of simplicity in our analysis, we have considered the fisheries below Bonneville Dam and those in three reservoirs above Bonneville Dam as one. We believe comparison of yields from these pooled fisheries to that taken from the historic free-ranging stock to be a liberal approach (i.e., it is more likely that development of the river has reduced the total productivity of white sturgeon rather than enhanced it). Our prediction of yield ratios should therefore be optimistic.

Methods

Simulations.—We used a life history model of a white sturgeon population to estimate the range over which maximum yield and the exploitation

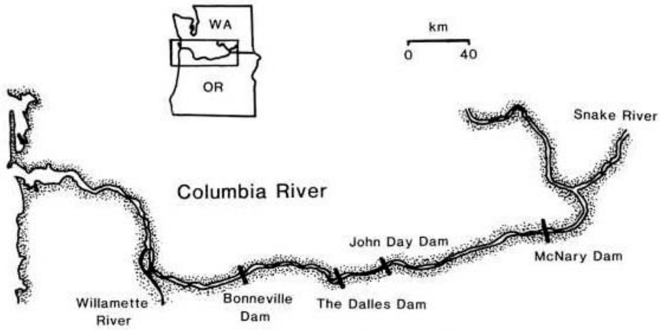


FIGURE 3.—The lower Columbia River between Oregon and Washington.

rate (proportion of the population removed annually) maximizing yield might be expected to vary given the predominant size restriction (92–183-cm window) regulating harvest during recent years. Our model incorporated recruitment, mortality, and growth to predict yield. We used a series of simulations with all combinations of low and high values for recruitment, mortality, and growth. We believe that the values used represent the realistic ranges of these values. Each simulation was run until the population stabilized or for 100 years, whichever occurred first. We ran all simulations with exploitation varied from 0.01 to 0.50. We use the term collapse to represent the condition when yield or the population number approached zero (less than 0.05% of the unexploited biomass or number) within 100 years.

To standardize results, we present yield as a percentage of total biomass in an unexploited population at equilibrium. We identified maximum yield from plots of yield versus exploitation. Because we do not know current numbers in the real populations, our simulations were based on arbitrary population sizes. Yields were compared among alternative exploitation and regulation scenarios on the basis of relative and not absolute differences.

We compared the effects of different size restrictions (none, 92–183 cm, 122–183 cm) on maximum yield with a second series of simulations in which rates of natural mortality and growth were held constant at intermediate values. We simulated the effects of regulation under high and low recruitment scenarios.

We used a third set of simulations to estimate peak yields associated with the fishing-up process, with and without size restrictions. We again used intermediate values for mortality and growth. The recruitment function was unimportant to the estimate of peak yield because yields peaked before changes in the adult stock could feed back to recruitment. We compared cases in which exploitation increased geometrically (doubled each year) and more slowly (increments of 0.05/year). Simulations were run 1 year at a time until yield began to decline.

We used a final set of simulations to demonstrate the time lags possible in population and yield responses. We used an exploitation scenario that should be similar to recent changes in the Columbia River fishery. We used a model population with intermediate values for the growth and mortality parameters and the low stock–recruitment parameter. We imposed a 92–183-cm size window and exploited the population for 20 years at half the rate producing maximum sustained yield, then increased exploitation by 20% per year (roughly the rate of sport-harvest increase from 1974 to 1986) until the yield declined for 3 years. After the 3-year decline, we used three alternative responses in harvest: (1) exploitation was reduced to the rate producing maximum yield (0.05); (2) exploitation was held constant at the level in the third year of decline, but a 122–183-cm size restriction was imposed; and (3) exploitation was held constant at the level in the third year of decline. We then continued simulations for 50 years with no further changes in exploitation.

Population model.—We used an age-structured population model (Beamesderfer 1988) similar to that described by Taylor (1981) except that recruitment was either a Beverton–Holt-type function of adult egg production or constant. Numbers of sturgeon in each age-class (N_x) after the first year of simulation were calculated as

$$N_{x+1,t+1} = (N_{x,t})(S_x); \quad (1)$$

S_x = age-specific annual survival rate, and t = year. Age-specific annual survival was calculated as

$$S_x = 1 - [m_x + n - (m_x)(n)]; \quad (2)$$

m_x = age-specific harvest mortality (exploitation), and n = conditional natural mortality rate (Ricker 1975).

Density dependence in the model operated only through the stock-dependent recruitment function. The initial population in each simulation was assumed to be at equilibrium with no exploitation. Equilibrium egg production was calculated for the population with a stable age distribution at an arbitrarily selected recruitment to age 1. Mortality from age 0 to age 1 was calculated to produce the selected recruitment at equilibrium.

A density-dependent relationship between egg production and number of age-0 fish was represented by a Beverton–Holt recruitment function of the form

$$R = P/\{1 - A[1 - (P/P_r)]\}; \quad (3)$$

R = number of age-0 fish or recruitment; P = egg production; P_r = egg production at replacement; and A = a parameter with value 0–1 that completely describes the shape of the curve. Egg production was calculated as

$$P = \sum_x (N_x)(p_f)(p_s)(F_x); \quad (4)$$

p_f = proportion of population that is female; p_s = proportion of females that spawn in any year after the age of first maturity (M); and F_x = age-specific fecundity of females.

Age-specific fecundity was estimated as

$$F_x = a\,L_x^{\,b}; \quad (5)$$

L_x = age-specific length (cm), and a and b = parameters in the length–fecundity equation. Age-specific lengths were calculated with a von Bertalanffy model:

$$L_x = L_\infty(1 - e^{-k(x-t_0)}) \quad (6)$$

L_∞ = length (cm) at infinity, k = the growth coefficient, and t_0 = theoretical age at length 0.

Yield (Y; weight of white sturgeon harvested) was calculated as

$$Y = \sum_x (N_x)(m_x)(W_x); \quad (7)$$

W_x = age-specific weight (kg). Age-specific weight was calculated as

$$W_x = cL_x^{\,d}; \quad (8)$$

c and d = length–weight equation parameters.

Parameter estimation.—We estimated fecundity, age at first maturity, and proportion of females spawning each year (Table 1) from data on white sturgeon in the Columbia River below Bonneville dam (S. King, Oregon Department of Fish and Wildlife, personal communication). We fit a length–fecundity relationship with a least-squares regression (Figure 4). Although estimates of these recruitment parameters are useful for realism of results under stock-dependent recruitment, they had relatively minor influence in our simulations. The stock–recruitment function was by far the dominant feature in simulated population responses. We therefore did not vary estimates of these parameters in our simulations.

We did vary parameter estimates for recruitment, mortality, and growth. We selected 0.5 for the parameter A in the stock–recruitment function to describe a reasonable lower bound in the shape of the curve and used constant recruitment to represent the upper bound (Figure 5). In the latter case, our model was equivalent to the Ricker equi-

TABLE 1.—Parameter estimates used in simulations of a white sturgeon population.

Parameter[a]	Estimate: Intermediate	Minimum	Maximum
A (3)		0.5	1.0
a (5)	0.00013		
b (5)	4.13		
c (8)	0.00000065		
d (8)	3.43		
k (6)	0.045		
L_∞ (6)	285	229	340
M	15		
n (2)	0.075	0.05	0.10
pf (4)	0.5		
ps (4)	0.143		
t_0 (6)	0		

[a] Numbers in parentheses indicate text equations for which parameters are defined.

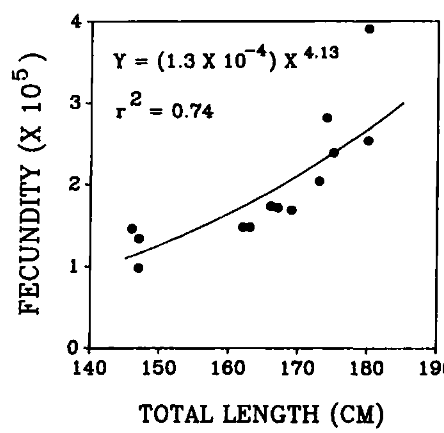


FIGURE 4.—Fecundity versus total length of white sturgeon from the lower Columbia River.

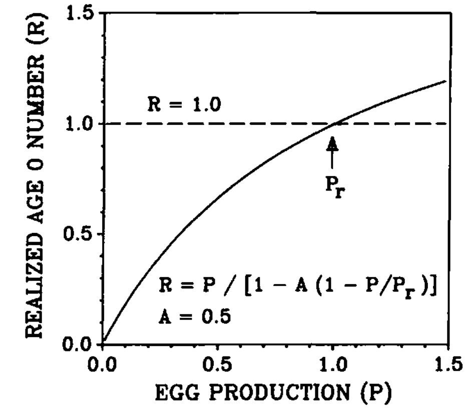


FIGURE 5.—Recruitment models used to simulate white sturgeon populations and fisheries in the lower Columbia River. The stock-dependent model is a Beverton–Holt function (Ricker 1975). R = number of age-0 fish or recruitment; P = egg production; P_r = egg production at replacement; A is a parameter from 0 to 1 that describes the shape of the curve.

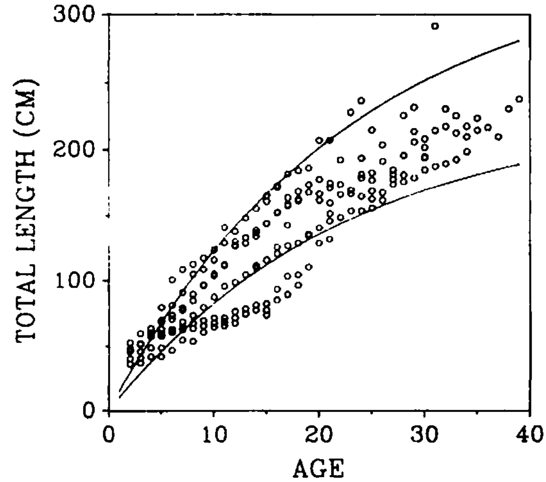


FIGURE 6.—Growth models (lines) used to simulate white sturgeon populations and fisheries in the lower Columbia River. Data are from the Columbia (Malm 1979; Hess 1984), Snake (Cochnauer 1983; Lukens 1985; Coon et al. 1977), Sacramento (Pycha 1956; Kohlhorst et al. 1980), and Fraser (Semakula and Larkin 1968) rivers.

librium yield model (Ricker 1975). The upper bound represents an exceptionally productive population, whereas the lower bound represents a population in which productivity is reduced but not unreasonably low (Kimura et al. 1984; Francis 1986).

We estimated the range of natural mortality (n; Table 1) based on data presented by other authors (Table 2). We assumed that white sturgeon reached a maximum age of 75 years (though older fish are reported) because fish older than 75 years contributed little to total stock biomass, even under the lowest mortality rates.

We described growth with the von Bertalanffy model (Ricker 1975). We described upper and lower limits by using maximum and minimum values for L_∞ and k that gave curves tracing observed limits of age–length data for white sturgeon reported by other authors (Figure 6). We arbitrarily set t_0 equal to 0. Parameters for the length–weight equation were from Lukens (1985).

Results

The simulated response of yield to exploitation (under a 92–183-cm size restriction) varied substantially depending upon our assumed values for growth, mortality, and the recruitment function (Figure 7). Maximum yields ranged from about 0.2 to 2.9% of unexploited biomass. Exploitation rate producing maximum yield ranged from about 0.02 to 0.20 (Figure 7). Selection of the recruitment response had the most important influence on our results. Simulations with stock-dependent recruitment produced the lowest yields and supported the lowest exploitation rate. Populations with stock-dependent recruitment collapsed under the same exploitation levels producing maximum yields with constant recruitment (Figure 7).

Simulations with estimates of growth and mortality intermediate between extremes showed that the size limits may provide a benefit in yield at higher exploitation rates (Figure 8). When we used stock-dependent recruitment, a population simulated with no size restriction collapsed with exploitation of 0.10. A 92–183-cm window and 122–183-cm window resulted in collapse at exploitation rates of about 0.20 and 0.30, respectively. The

TABLE 2.—Estimates of annual rate of natural mortality (n) reported for white sturgeon populations.

Location	n	Ages	Reference
Fraser River	0.05	>10	Semakula and Larkin (1968)
Sacramento River	0.05–0.10	10–20	Kohlhorst (1980)
Snake River, Upper	0.06	16–30	Cochnauer (1983)
Snake River, Hell's Canyon	0.12	6–25	Lukens (1985)

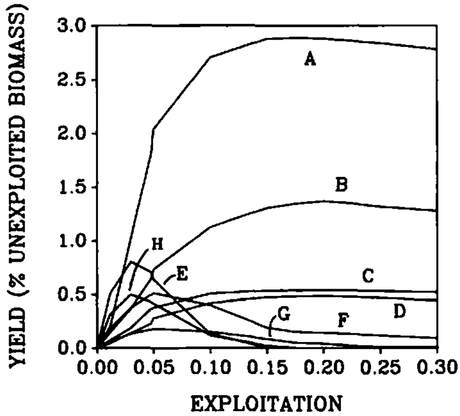


FIGURE 7.—Simulated yields in relation to exploitation rates under a 92–183-cm size window for white sturgeon populations. Curves represent simulations with different combinations of stable (*S*) and stock-dependent (*D*) recruitment, and high (*H*) and low (*L*) values for natural mortality and growth parameters, respectively, as follows: A = *S, H, L*; B = *S, H, H*; C = *S, L, L*; D = *S, L, H*; E = *D, H, L*; F = *D, H, H*; G = *D, L, H*; H = *D, L, L*.

size windows also produced substantially better yields than no limit when exploitation ranged from 0.05 to 0.20, but did not produce a higher maximum yield. When we used stable recruitment, a 92–183-cm size window produced lower yields than no size restriction with exploitation under about 0.15 (Figure 8) and similar yields at higher levels of exploitation. The 122–183-cm size window produced the highest yields of all simulations with exploitation higher than about 0.11.

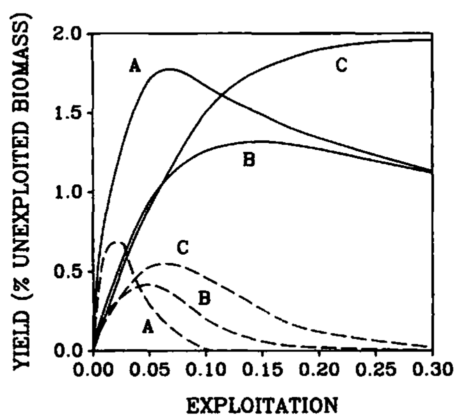


FIGURE 8.—Simulated yields of white sturgeon in relation to exploitation under three sets of size windows (A = none; B = 92–183 cm; C = 122–183 cm) with stable (solid lines) and with stock-dependent (dashed lines) recruitment. Models used intermediate values for natural mortality and growth parameters.

TABLE 3.—Peak and sustained or 100-year yields (percent of unexploited biomass) from simulated "fishing up" (Ricker 1975) and sustained exploitation of white sturgeon.

Simulation	Regulation: No size window	Regulation: 92–183-cm window
Peak yield		
Fishing up, exploitation increased 0.05/year	14	9
Fishing up, exploitation doubled each year	29	40
Sustained yield		
Stock-dependent recruitment	0.5	0.4
Stable recruitment	1.7	1.3

Peak yield varied from 9 to 40% of unexploited biomass with the rate of fishing up and with the imposition of a size window (Table 3). Sustained yields with no size restriction were 2–12% of peak yield under the same regulation. Sustained yields with a size window were 1–14% of peak yields. We could expect sustained yields when most of the catch was taken in a 92–183-cm window to be 1–9% of the 1885 peak yield (i.e., under no size restriction).

In the final simulations with initial exploitation at half the rate producing the maximum 100-year yield, yield declined slowly for 20 years (Figure 9). We fished that population up to a peak yield of about 2.7% of unexploited biomass before yields began to decline again. Exploitation was 0.32 at

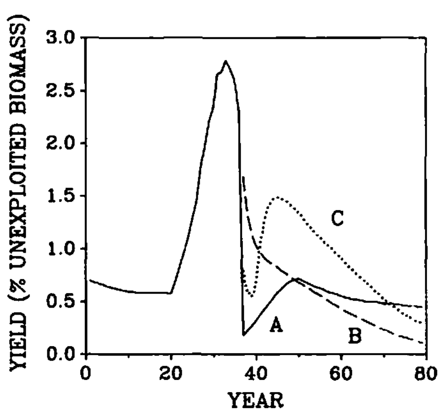


FIGURE 9.—Simulated yields from a white sturgeon population under three scenarios for exploitation following a peak and decline from fishing up. Exploitation rate under a 92–183-cm size window was constant at 0.025 for 20 years and then increased at 120% per year. After 3 years of declining yield, exploitation was (A) reduced to 0.05; (B) held at a maximum rate; or (C) held at the maximum rate with a 122–183-cm size restriction.

the peak and 0.46 by the third year of decline. In all of the alternative simulations following the peak, yields declined dramatically. When exploitation was reduced, yields recovered to the sustainable level in about 7 years. Exploitation sustained at the postpeak high resulted in decline toward collapse over a prolonged period. The most restrictive size limit produced a secondary peak in yield and delayed the long-term decline in yield.

Discussion

Results of our simulations were strongly dependent upon the recruitment functions we used. If recruitment for Columbia River white sturgeon is stock-dependent and not highly productive, maximum yields should occur with relatively low exploitation (<0.15). Exploitation rates higher than 0.15 could eventually collapse the fishery. If recruitment is stronger, sustained yield and supportable exploitation should be higher, but exploitation rates producing maximum yields should still be less than 0.25.

In unaltered environments, white sturgeon recruitment might conceivably be independent of adult stock, at least at higher population numbers. The population could more than fully seed the available habitat for prerecruited life stages. Expansion of the Columbia River sturgeon fishery in the late 19th century was not followed by extinction, but by a fishery and yields that were sustained at 2–5% of the peak. A similar response was observed following expansion of the white sturgeon fishery in the Fraser River, British Columbia (Semakula and Larkin 1968). The available data suggest that historic white sturgeon in the Columbia and Fraser rivers were resilient to exploitation. Production of young fish was sustained even though much of the adult stock was removed in a short period.

Other sturgeon species have declined dramatically following habitat alteration and destruction. Sturgeon populations in Idaho rivers altered by dams appear incapable of supporting any exploitation (Cochnauer and Lukens 1984; Cochnauer et al. 1985). With development, habitat is lost, perhaps reducing rearing capacity and the number of recruits, but not necessarily creating a stock-dependent relationship. Declines in fecundity, growth, spawning frequency, spawning success, and egg quality, however, might also be associated with environmental change (Artyukhin et al. 1978; Votinov and Kas'yanov 1978). These changes may reduce reproductive potential and push a stock below the full seeding level. In effect, such changes could make a stock less productive: a stock with a stock–recruitment function moved toward or below the lower bound in our simulations.

Construction of dams on the lower Columbia River has restricted migration, altered flows, and eliminated some habitats. Similar development reduced spawning success and reproductive potential of sturgeons (*Acipenser baeri, A. gueldenstaedti*) in the Soviet Union (Artyukhin et al. 1978; Votinov and Kas'yanov 1978). We believe it reasonable to assume that Columbia River white sturgeon are less productive than in 1885. Changes in the river may well have influenced spawning success and the nature of the stock–recruitment relationship. Even if recruitment was once very strong, it is probably less so now.

Kimura et al. (1984) suggested that most fish stocks have recruitment functions lying between the two extremes we used in our simulations. We believe that our models provide useful bounds for consideration of white sturgeon management, but not necessarily the limits of possibility. We suggest that alteration of the Columbia River system may have pushed the actual relationship toward or even beyond our lower bound. The stock-dependent simulations may not represent the most conservative interpretation of the effects of exploitation on Columbia River white sturgeon.

Our results suggested that white sturgeon cannot support heavy exploitation even with size restrictions on the harvest. If recruitment is stock dependent, exploitation higher than 0.05 could result in a substantial loss of yield. Exploitation greater than 0.10 may risk collapse of the fishery. We have no precise estimates of recruitment or exploitation for the Columbia River white sturgeon fisheries. We cannot conclude that the stock is seriously overexploited. We do believe, however, that the current yields are well above what can be sustained, and overexploitation is a good possibility. From 1930 to 1969, commercial harvest averaged about 91,000 kg, or about 4% of the 1885 peak (Figure 1). Our simulations suggested that sustained yield (with a 92–183-cm size restriction) could be near that level (1–9% of the historic peak). After 1970, sport and commercial fisheries expanded. Total yield in 1987 was about 800,000 kg, or about 35% of the 1885 peak. The 1987 yield was more than three times the relative sustained yield in even our most optimistic simulations (those with stable recruitment). Unless the post-1885 decline was the result of a dramatic decline in effort and not in the exploitable stock, or unless the current stock is more productive than in the past, recent exploitation must have increased beyond that producing maximum sustainable yield.

Based on our results, we believe that current yields of white sturgeon from the Columbia River will decline dramatically. Although length restrictions on the fisheries probably provide a significant benefit, they will not necessarily prevent overexploitation. More seriously, overexploitation might risk stock collapse. Hydropower and other development of the Columbia River may well have resulted in a less-productive stock and a population more vulnerable to overharvest. Our last set of simulations suggested that decline and collapse of the fishery could take many years, even with very high exploitation. Our simulations were dependent on the recruitment function we used and thus represent only one possibility. The recruitment responses for white sturgeon in the Columbia River could be even less productive than that in our simulations, particularly for fish isolated in river segments between dams. Current research suggests that reproductive success in isolated reservoirs may be sporadic, and recruitment failures may not be uncommon (L. Beckman, U.S. Fish and Wildlife Service, personal communication). Until we have better information, more conservative management is warranted. Effort should be reduced; further expansion of the fishery is dangerous.

Acknowledgments

We thank D. H. Bennett, M. Buckman, T. G. Cochnauer, A. McGie, A. A. Nigro, S. Vigg, E. Wagner, and three anonymous reviewers for comments on early drafts of this paper.

References

Adams, P. B. 1980. Life history patterns in marine fishes and their consequences for fisheries management. U.S. National Marine Fisheries Service Fishery Bulletin 78:1–12.

Artyukhin, Y. K., A. D. Sukhoparova, and L. G. Fimukhira. 1978. The gonads of sturgeon, *Acipenser güldenstädti*, in the zone below the dam of the Volgrad water engineering system. Journal of Ichthyology 18:912–923.

Beamesderfer, R. C. 1988. MOCPOP: a flexible simulator for analysis of age-structured populations and stock-related functions. Oregon Department of Fish and Wildlife, Information Report 88-3, Portland.

Cleaver, F. C., editor. 1951. Fisheries statistics of Oregon. Oregon Fish Commission Contribution 16.

Cochnauer, T. G. 1983. Abundance, distribution, growth and management of white sturgeon (*Acipenser transmontanus*) in the middle Snake River, Idaho. Doctoral dissertation. University of Idaho, Moscow.

Cochnauer, T. G., and J. R. Lukens. 1984. Where have all the sturgeon gone? *Acipenser transmontanus* throne is shaky. Idaho Wildlife (May–June):4–6.

Cochnauer, T. G., J. R. Lukens, and F. E. Partridge. 1985. Status of white sturgeon, *Acipenser transmontanus*, in Idaho. Pages 127–133 *in* F. P. Binkowski and S. I. Doroshov, editors. North American sturgeons: biology and aquaculture potential. Dr. W. Junk, Dordrecht, The Netherlands.

Coon, J. C., R. R. Ringe, and T. C. Bjornn. 1977. Abundance, growth, distribution and movements of white sturgeon in the mid-Snake River. Report to U.S. Department of the Interior, Office of Water Research and Technology, Washington, D.C.

Deacon, J. E., G. Kobetich, J. D. Williams, and S. Contreras-Balderas. 1979. Fishes of North America endangered, threatened, or of special concern: 1979. Fisheries (Bethesda) 4(2):29–31, 42–44.

FCO (Fish Commission of Oregon) and WDF (Washington Department of Fisheries). 1971. Status report: Columbia River fish runs and commercial fisheries, 1938–70. FCO, Portland.

Francis, R. C. 1986. Two fisheries biology problems in west coast groundfish management. North American Journal of Fisheries Management 6:453–462.

Galbreath, J. L. 1985. Status, life history, and management of Columbia River white sturgeon, *Acipenser transmontanus*. Pages 119–125 *in* F. P. Binkowski and S. I. Doroshov, editors. North American sturgeons: biology and aquaculture potential. Dr. W. Junk, Dordrecht, The Netherlands.

Hess, S. S. 1984. Age and growth of white sturgeon in the lower Columbia River, 1980–83. Oregon Department of Fish and Wildlife, Portland.

Hess, S. S., and S. D. King. 1989. The 1988 lower Columbia River and buoy 10 recreational fisheries. Oregon Department of Fish and Wildlife, Portland.

Kimura, D. K., J. W. Balsiger, and D. W. Ito. 1984. Generalized stock reduction analysis. Canadian Journal of Fisheries and Aquatic Sciences 41:1325–1333.

Kohlhorst, D. W. 1980. Recent trends in the white sturgeon population in California's Sacramento–San Joaquin estuary. California Fish and Game 66:210–219.

Kohlhorst, D. W., L. W. Miller, and J. J. Orsi. 1980. Age and growth of white sturgeon collected in the Sacramento–San Joaquin estuary, California: 1965–1970 and 1973–1976. California Fish and Game 66: 83–95.

Lukens, J. R. 1985. Hells Canyon white sturgeon investigations. Idaho Department of Fish and Game, Federal Aid in Fish Restoration, F-73-R, Study 7, Final Report, Boise.

Malm, G. W. 1979. White sturgeon (*Acipenser transmontanus*) population characteristics in the Bonneville Reservoir of the Columbia River (1976–1978). U.S. Fish and Wildlife Service, Vancouver, Washington.

ODFW (Oregon Department of Fish and Wildlife) and WDF (Washington Department of Fisheries). 1988. Status report: Columbia River fish runs and fisheries, 1960–88. ODFW, Portland.

Pycha, R. L. 1956. Progress report on white sturgeon studies. California Fish and Game 42:23–35.

Ricker, W. E. 1963. Big effects from small causes: two examples from fish population dynamics. Journal of the Fisheries Research Board of Canada 20:257–264.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191.

Scott, W. B., and E. J. Crossman. 1979. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184.

Semakula, S. N., and P. A. Larkin. 1968. Age, growth, food, and yield of the white sturgeon (*Acipenser transmontanus*) of the Fraser River, British Columbia. Journal of the Fisheries Research Board of Canada 25:2589–2602.

Taylor, M. W. 1981. A generalized inland fishery simulator for management biologists. North American Journal of Fisheries Management 1:60–72.

Votinov, N. P., and V. P. Kas'yanov. 1978. The ecology and reproductive efficiency of the Siberian sturgeon, *Acipenser baeri* in the Ob as affected by hydraulic engineering works. Journal of Ichthyology 18:20–29.

United States Department of the Interior

FISH AND WILDLIFE SERVICE
WASHINGTON, D.C. 20240

RECREATIONAL FISHERIES POLICY
of the
U.S. Department of the Interior
Fish and Wildlife Service

Date: Dec 5, '84

DIRECTOR

FISHERIES - USA

The Recreational Fisheries Policy

of the

U.S. Fish and Wildlife Service

PREFACE

The heritage of the U.S. Fish and Wildlife Service's (Service) recreational fisheries management program began with the founding of the U.S. Fish Commission in 1871. Over the years, organizational and philosophical changes have altered the course of the Federal fisheries management effort, but throughout this history the Service has maintained a leadership role in scientifically based fishery resource management. Motivated by tradition and the desire to elevate the stature and substance of this Nation's recreational fisheries, the Service initiated a multilateral effort to establish a National Recreational Fisheries Policy (National Policy). This National Policy, adopted in 1988, was structured to serve as a rallying point for agencies, organizations, and individuals across the Nation to enhance the vitality of recreational fisheries at the local, State, and National levels.

Under the auspices of the National Policy, the Service has identified its responsibilities and role. FISHERIES - USA, was selected as the title of the Service Recreational Fisheries Policy (Service Policy), because:

> The Service's fisheries program is active within every State of the Union. Thus, the Service's recreational fisheries program is truly national in scope.
>
> The letters U.S.A. are the first letters of three words that describe what the Service Policy is committed to accomplish.

Usability: The Service is committed to optimize the opportunities for people to enjoy the Nation's recreational fisheries.

Sustainability: The Service is committed to ensure the future quality and quantity of the Nation's recreational fisheries.

Action: The Service is committed to work in partnership with other Federal governmental agencies, States, Tribes, conservation organizations, and the public to effectively manage the Nation's recreational fisheries.

INTRODUCTION

As a signatory to the National Policy, the Service endorses its guiding principles, goals, and objectives. The Service recognizes that conservation and enhancement of the Nation's fishery resources will result if the conceptual framework of ideas, principles, and strategies in the National Policy are supported, advanced, and implemented.

The number of recreational anglers in the United States has more than doubled during the past 30 years. During 1985, 60 million anglers engaged in recreational fishing in the United States. Their collective activity generated $30 billion and 1.2 million jobs for the Nation's economy. These statistics clearly demonstrate the social and economic importance of recreational fishing in this Nation today.

As a leader in recreational fisheries since 1871, the Service directs fisheries management, law enforcement, and research through 8 Regional Offices; 75 National Fish Hatcheries and 4 Technology Centers; 12 National Fishery Research Centers/Laboratories; 41 Cooperative Fishery Units and other satellite research stations; 128 Law Enforcement Offices; the National Fisheries Academy; many of the 452 National Wildlife Refuges; 44 Fish and Wildlife Assistance Offices; and 64 Fish and Wildlife Enhancement Field Offices, and with an annual budget exceeding $500 million. The Service also administers $181 million (Fiscal Year 1989) through Federal grants.

During daily activities, the Service enhances fish populations and their habitats that support recreational fishing and provides information and services through functions such as technical assistance, fish production, research, technology development, public education, professional training, coordination, and professional reviews of programs and publications.

Fish and Wildlife Assistance Offices provide technical assistance both internally and outside of the Service in the scientific management and utilization of fish stocks. Fish and Wildlife Enhancement Offices provide technical evaluation and planning recommendations to other Federal agencies, States, and the public regarding environmental impacts on fishery resources and habitats resulting from land and water development projects that are sponsored, licensed, or assisted by the Federal Government. Environmental contaminant specialists carry out investigations to determine the potential impact of contaminants on fishery and habitat resources, and recommend remedial action. Federal Aid offices provide technical assistance and guidance to the States and administer apportionments that are derived through the Sport Fish Restoration Act and the Anadromous Fish Conservation Act.

The Service operates National Fish Hatcheries that produce and distribute a variety of fish species for recovery, mitigation, restoration, and/or recreational fishing, and conducts a national broodstock program. Fishery research laboratories and technology centers provide the Service with a strong research and development capability that supports progressive management of recreational fisheries. Law Enforcement curbs illegal activities and exploitation of fish stocks.

There are approximately 14 million acres of water on National Wildlife Refuges that support or may have the potential to support quality recreational fishery resources. Recreational fishing opportunities currently are available on 216 refuges (48% of the total number).

The Service has mandated Federal stewardship authority to protect, restore, and enhance fishery resources and habitats that support aquatic life. This authority is provided by various Federal laws including the Fish and Wildlife Act, Fish and Wildlife Coordination Act, Clean Water Act, Anadromous Fish Conservation Act, National Wildlife Refuge System Administration Act, Refuge Recreation Act, Water Resources Development Act, Endangered Species Act, National Environmental Policy Act, Alaska National Interest Lands Conservation Act, Salmon and Steelhead Conservation Act, Great Lakes Fishery Act, Pacific Northwest Electric Power Planning and Conservation Act, Connecticut River Atlantic Salmon Compact, Estuary Protection Act, Atlantic Striped Bass Conservation Act, the Klamath River Basin Fishery Restoration Act, Sikes Act, Columbia River Basin Fishery Development Act (Mitchell Act), Indian Self Determination Act, Wild and Scenic Rivers Act, and the Russian River Basin Restoration Act.

Fisheries - USA serves to reaffirm the Service's commitment to the Nation's fisheries resource. The goals and strategies described in this Service Policy will be accomplished by using available resources and by expanding capabilities through new budget initiatives in areas where further opportunities are identified. The new budget and partnership initiatives will be developed in the Policy's implementation plan.

SERVICE RECREATIONAL FISHERIES POLICY

This Policy defines the Service's stewardship role in the management of the Nation's recreational fishery resources. The Service believes that the preservation, maintenance, mitigation, and enhancement of aquatic ecosystems is one of the most important roles the Federal government can undertake to ensure high-quality recreational fisheries. In defining its role, the Service recognizes and respects the rights of other jurisdictional entities, and desires to work in partnership with them for effective management of these resources. The Service acknowledges that most existing management areas (including National Wildlife Refuges) were established for specific purposes, and that actions taken under this Policy that involves those areas must be compatible with the legislated purposes. For the purpose of this Policy, the definition of recreational fishing encompasses related recreational activities such as fish photography and fish watching.

Current estimates indicate that the demand for recreational fishing may increase as much as 40% by the year 2030. This increased demand must be met through a diversity of ways, including:

- ensuring that recreational fisheries are given full consideration in future water resource projects,
- identifying and remediating the affects of contaminants on fisheries,
- developing access to waters previously unavailable for fishing,
- restoring or enhancing depleted or declining fisheries,
- optimizing productivity of existing fisheries through habitat and water quality improvement, and
- utilizing angler education programs to adjust expectations of what constitutes a successful fishing experience.

The Service is committed to promote and enhance freshwater, anadromous, and coastal fishery resources for maximum long-term public benefit. Therefore, the Service's Policy is to:

1. Preserve, restore, and enhance fish populations and their habitats.
2. Promote recreational fishing on Service and other lands to provide the public with a high quality recreational experience.
3. Ensure that recommendations concerning recreational fisheries

potentials and opportunities are included as part of appropriate field studies and management assistance efforts performed by the Service on non-Service waters.

4. Serve as an active partner with other Federal governmental agencies, States, Tribes, conservation organizations, and the public in developing recreational fisheries programs.

5. Promote the conservation and enhancement of the Nation's recreational fisheries through the Service's grant in aid programs.

6. Improve and expand quantifiable economic valuations of the Nation's recreational fisheries to demonstrate the importance of this resource to the health and welfare of our society and to the Nation's economy.

The accomplishment of this Service Policy is the shared responsibility of all Service managers and employees. Current Service programs already provide and/or support recreational fishing. Opportunities exist, however, to enhance the Service's performance in the recreational fisheries arena by clearly identifying responsibilities for developing and managing recreational fisheries and delegating those responsibilities to the appropriate field managers. All Service employees are encouraged to explore innovative approaches to implement the intent of this Policy, and supervisors are directed to encourage, recognize, and reward contributions.

GOALS AND STRATEGIES

Collectively, the following goals and strategies provide internal guidance for program development emphasis. Additionally, they describe ways through which the Service will work in partnership with other Federal governmental agencies, States, Tribes, conservation organizations, and the public. While the strategies address ongoing and new activities, most of the ongoing activities do not have sufficient resources to adequately meet present program support needs. Consequently, new initiatives are needed to support the new activities, and to address adequately, the capabilities of many ongoing activities.

GOAL A. EFFECT THE PRESERVATION AND/OR INCREASED PRODUCTIVITY OF FISHERY RESOURCES

The Service recognizes that many fish populations and the quality of their habitats continue to decline while the numbers of anglers and angling effort are increasing. Providing adequate fishery resources for the enjoyment of future anglers and others will require coordinated, concerted, and diligent efforts by State and Federal agencies, and Tribes to maintain, restore, and increase the productivity of existing fish populations and their habitats.

Strategy 1. The Service will utilize its resources and encourage other entities to conserve and enhance the Nation's recreational fishery resource by:

a. Ensuring that management policies on Service-managed waters promote the conservation and enhancement of existing and potential recreational fisheries and their habitats.

b. Providing technical assistance to Federal agencies such as Department of Defense, Forest Service, National Park Service, Bureau of Land Management, Bureau of Reclamation, Federal Energy Regulatory Commission, Bureau of Indian Affairs, and Tribal and State agencies for the management of recreational fisheries and aquatic habitats.

c. Assisting with the identification and inventory of significant interjurisdictional recreational fish stocks and habitat, while continuing to support State interjurisdictional coalitions.

d. Seeking opportunities to identify and manage unique and/or threatened recreational fisheries to ensure that they are restored and/or maintained, and continue to be managed as recreational fisheries.

e. Promoting recovery, restoration, and enhancement of recreational fishery resources by propagation and stocking of fish as appropriate.

f. Assisting in accomplishing the goals and objectives of the Service's "No Net Loss" Wetlands Policy, including quantity and quality of wetlands as they relate to fisheries initiatives.

g. Providing consultation on potential adverse impacts to endangered, threatened, or candidate fish species or their habitats through Section 7 consultation under the Endangered Species Act, in recognition that this effort frequently yields positive benefit to recreational fisheries.

h. Assisting in the restoration or recovery of seriously depleted, endangered, or threatened fish such as the Atlantic salmon, Apache trout, shortnose sturgeon, or greenback cutthroat trout with the expectation that such species could eventually contribute to recreational fishing.

i. Ensuring that protection, mitigation, enhancement, and evaluation of recreational fisheries are addressed in Fish and Wildlife Coordination Act reports, Section 10 and Section 404 permit comments, and Service comments on Federal Energy Regulatory Commission hydroelectric licensing proposals.

j. Conducting technical reviews of Environmental Assessments and Environmental Impact Statements developed under the National Environmental Policy Act on proposed Federal water development projects to enhance, or minimize adverse impacts on, recreational fisheries.

k. Actively participating in the development and review of State Water Quality Standards and Certifications and other water quality issues, such as NPDES permits and non-point source control to ensure that highest protection is given to fishery habitat.

l. Identifying recreational fishing opportunities that are limited by water quality or habitat degradation, and promoting restoration of such situations to support healthy recreational fisheries.

m. Providing highly professional fisheries training opportunities to Service employees, other Federal and State employees, Tribes, and the private sector.

n. Providing law enforcement assistance in accordance with appropriate authorities where illegal activities negatively impact fishery resources.

o. Maintaining and improving, where possible, water quality and quantity on Service-managed lands in support of healthy recreational fisheries.

Strategy 2. The Service will promote, support, and conduct research and development that will support fisheries management by:

a. Providing needed information on fish and their habitats including biological and/or ecological requirements that will have practical application to management and fish husbandry.

b. Providing required genetics information for use in the management of recreational fisheries.

c. Facilitating the registration of drugs, chemicals, and biological control methods required for fishery management and fish culture with careful consideration of the possible effects of discharge of such chemicals on wild stocks and the environment.

d. Directing research efforts concerning the co-management of migratory bird populations and other plant and animal communities, and recreational fisheries on Service-managed lands.

e. Developing and maintaining biological data bases on recreational fish species and their ecological requirements for use by managers in planning and managing recreational fisheries.

f. Providing a technology transfer system through which recreational fisheries information is made available.

GOAL B. ENSURE AND ENHANCE THE QUALITY, QUANTITY, AND DIVERSITY OF RECREATIONAL FISHING OPPORTUNITIES

The Service has the opportunity to increase the quality of recreational fishing on Service managed waters. These opportunities include, but are not limited to, providing additional accesses to fisheries, designating additional waters on Service lands as recreational fisheries, developing new fisheries, increasing the productivity of existing fisheries, and restoring depleted or declining fisheries and habitat through intensive management.

Strategy 1. The Service will provide for the development, enhancement, and diversification of recreational fishing opportunities by:

a. Inventorying all Service-managed waters to determine fish species and habitats present, and assessing existing and potential recreational fishing opportunities.

b. Developing and implementing management plans for fisheries on Service-managed lands with recreational fisheries potential, and revising existing plans as necessary.

c. Developing training programs for Service biologists concerned with the innovative co-management of wetlands for both migratory bird populations and recreational fisheries.

d. Establishing new recreational fishing opportunities through habitat and/or species management and through the propagation and stocking of fish, when appropriate, on Service-managed waters. Put-and-take fishing projects (stocking catchable fish) will be considered on a case by case basis.

e. Increasing access to recreational fishing sites on Service-managed waters and to off-site recreational fisheries when access across Service land is required.

f. Taking action to avoid, minimize, or remediate pollution problems leading to contamination of fish and their habitats and advising the public of any advisories, restrictions, or warnings related to taking or consuming fish from Service facilities.

g. Increasing program emphasis in promoting cooperative initiatives for the management of large reservoirs, tailwaters, large rivers, estuaries, and coastal areas.

h. Providing enhanced capabilities to assist in the coordination of multijurisdictional fisheries.

Strategy 2. The Service will develop and maintain social and economic data bases on recreational fisheries by:

a. Conducting studies as needed to obtain information on angler preferences, opinions, and satisfaction.

b. Conducting the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation to ensure that adequate information is obtained on the use and value of recreational fisheries.

GOAL C. DEVELOP AND ENHANCE PARTNERSHIPS BETWEEN GOVERNMENTS AND THE PRIVATE SECTOR FOR CONSERVING AND MANAGING RECREATIONAL FISHERIES

The Service will participate in coordinating, coöperating, and forming partnerships with other Federal governmental agencies, States, Tribes, conservation organizations, and the public to determine recreational fishing needs, and to maintain, enhance, or develop effective recreational fisheries management programs.

Strategy 1. The Service will develop specific forums for exchange of information and program coordination by:

a. Consulting with constituency organizations to obtain their assistance in scoping, planning, and reviewing Service initiatives to maintain, enhance, and develop recreational fisheries.

b. Developing and implementing forums, workshops, and symposia for the exchange of information on effective management methods and program coordination.

c. Making Service scientific and technical resources available to further the development of aquaculture in the United States to include technical fish health assistance and disease certification services to State agencies and private aquaculture.

d. Assisting, when requested, with the inventory, assessment, management plan preparation, implementation, facility design, and management of fish populations and habitats on waters owned and/or controlled by non-Service entities.

Strategy 2. The Service will develop and promote mechanisms for the private sector to participate in recreational fisheries programs by:

a. Encouraging challenge grant opportunities for private sector partnerships in managing and developing recreational fisheries on Service-managed waters.

b. Encouraging representatives from constituency organizations to participate in Service recreational fisheries programs.

c. Creating opportunities that will encourage volunteer participation in activities, such as those that take place under the Take Pride in America Program, that support recreational fishing and enhancement of aquatic habitat.

d. Developing regional outreach programs to provide Service technical assistance to angler constituency groups in support of their efforts in recreational fisheries conservation and restoration.

Strategy 3. The Service will support a major aquatic resource education/information program to encourage public participation in recreational programs, to promote ethical use of fishery resources, and to emphasize the importance of conserving and restoring healthy aquatic habitats by:

a. Enhancing information endeavors that will increase public awareness and understanding of fishery management practices and problems.

b. Providing information through the media, technical publications, informational pamphlets, and other sources, to anglers and the public on how their activities related to fishing, waste disposal, land use, etc., impact fisheries conservation and management.

c. Identifying and publishing the effects of environmental contaminants on fish populations, habitats and assisting the angling community in finding solutions to habitat contamination problems.

d. Promoting recreational fisheries as re-usable resources by encouraging non-harvest (i.e., catch-and-release fishing) where appropriate.

e. Promoting improved outdoor ethical behavior among recreational anglers and encouraging the development and acceptance of a national code of angler ethics.

Strategy 4. The Service will administer effective and efficient grant programs to enhance the ability of States, territories, and Tribes to manage sport fish resources and conduct aquatic educational programs by:

a. Assisting the States desiring to participate, to maintain their eligibility.

b. Working with the Treasury Department to ensure that funds are promptly and accurately apportioned to the States.

c. Documenting that Service research projects funded with with administrative or reverted funds, and State projects, provide recreational fishery resource and user benefits.

d. Maintaining records of costs, assets, and accomplishments, and provide such information to the public.

e. Disseminating information and plans generated by the States and the Service to facilitate effective and cooperative management of fishery resources.

f. Continuing to provide technical support and guidance to Tribal recreational fisheries programs.

GOAL D. COOPERATE TO MAINTAIN A HEALTHY RECREATIONAL FISHERIES INDUSTRY

The recreational fisheries industry is uniquely dependent on healthy aquatic habitats capable of supporting an abundant supply and variety of fish. Therefore, fostering sound aquatic conservation endeavors is in the industries best interest to ensure the potential for future recreational fisheries. Effective management of existing and judicious development of new fisheries are critical to maintain a prosperous recreational fisheries industry.

Strategy: To ensure that sound management percepts are available to the industry, the Service will work toward maintaining a healthy recreational fisheries industry by:

a. Developing cooperative projects, such as habitat improvement projects, with the recreational fisheries industry for the mutual benefit of recreational fishery resources.

b. Working cooperatively with the recreational fisheries industry, such as through the promotion of National Fishing Week, to promote enhancement of recreational fisheries.

c. Promoting the use of the sport fish restoration logo on fishing tackle and equipment, and at the site of field projects, to emphasize that the fishing public is contributing to sport fish restoration through the Federal Aid program.

Conserving America's Fisheries

U.S. Fish and Wildlife Service
Department of the Interior

Fisheries Program
Vision for the Future

December 2002

United States Department of the Interior

FISH AND WILDLIFE SERVICE

A Message from the Director

The U.S. Fish and Wildlife Service has a proud record of more than 130 years in fisheries and aquatic resource conservation. As Director, I am keenly aware of the need for a renewed commitment from the Service in conserving these valuable resources. Despite our proud heritage, we have become increasingly convinced of the need for greater support and resources if we are to be successful in meeting the challenges of our critical role in fisheries and aquatic resource management and conservation.

The Service is currently undertaking the task of describing the future role of its Fisheries Program in conserving this Nation’s aquatic resources. I realize that the Service has undertaken planning exercises in the past. What is fundamentally different about this current effort is the development of a collaborative strategy with the Sportfishing and Boating Partnership Council and its Fisheries Steering Committee. This Steering Committee represents perspectives from a wide range of fisheries and aquatic conservation interests. This is an effective and powerful partnership that has worked well over a number of years, and I look forward to building on it as the Service strengthens and revitalizes its Fisheries Program.

The pride and passion of our Fisheries Program employees are clearly evident. They have carried us to where we are, in spite of difficult times. The Service has much to be proud of in our leadership in fisheries and aquatic resource conservation. Resolving real and perceived issues and revitalizing the Fisheries Program are among my highest priorities.

Steven A. Williams

Executive Summary

The Fisheries Program of the U.S. Fish and Wildlife Service (Service) has played a vital role in conserving and managing fish and other aquatic resources since 1871. Today, the Fisheries Program is a critical partner with States, Tribes, other governments, other Service programs, private organizations, public institutions, and interested citizens in a larger effort to conserve these important resources. The Nation's fish and other aquatic resources are among the richest and most diverse in the world. These resources have helped support the Nation's growth by providing enormous ecological, social and economic benefits. Despite efforts by the Service and others to conserve aquatic resources, a growing number are declining at alarming rates. Loss of habitat and invasive species are the two most significant threats to the diversity of aquatic systems. One-third of the Nation's freshwater fish species are threatened or endangered, 72 percent of freshwater mussels are imperiled, and the number of threatened and endangered species has tripled in the last 20 years. Clearly, there is increasing urgency to identify and implement actions that will reverse these alarming trends before it is too late.

In order to better conserve and manage fish and other aquatic resources in the face of increasing threats, the Service worked with partners to refocus its Fisheries Program and develop a vision. The vision of the Service and its Fisheries Program is working with partners to restore and maintain fish and other aquatic resources at self-sustaining levels and to support Federal mitigation programs for the benefit of the American public. To achieve this vision, the Fisheries Program will work with its partners to:

- *Protect* the health of aquatic habitats.
- *Restore* fish and other aquatic resources.
- Provide opportunities to *enjoy* the benefits of healthy aquatic resources.

In July, 2001, the Sport Fishing and Boating Partnership Council (SFBPC) was charged by the Service to convene a steering committee representing perspectives from a broad array of stakeholders in fish and aquatic resource conservation to work with the Fisheries Program during the development of a new blueprint for the future. This provided partners with a unique opportunity to be engaged before the strategic vision was drafted. It was also unique because the Fisheries Steering Committee included representatives from the Service, along with partners and stakeholders.

In January, 2002, the SFBPC Fisheries Steering Committee provided the Service with a set of consensus recommendations on the Fisheries Program's role in the partnership effort to conserve the Nation's fish and other aquatic resources. This report, entitled "A Partnership Agenda for Fisheries Conservation," along with the earlier SFBPC hatchery report, "Saving a System in Peril," were keystone elements in developing the Fisheries Program's strategic vision. Using these two reports and working collaboratively with partners, the Service has better defined its role in conserving and managing aquatic resources across the country. This strategic vision discusses where the Fisheries Program is today, where it needs to go in the future, and why it is important to get there. To move forward and be successful in this role, the Fisheries Program must be solidly supported, backed by sound science, and grounded in dynamic partnerships.

The Fisheries Program consists of almost 800 employees nationwide, located in 64 Fishery Resource Offices, including a Conservation Genetics Laboratory, 69 National Fish Hatcheries, 9 Fish Health Centers, 7 Fish Technology Centers and a Historic National Fish Hatchery. Together, these employees and facilities provide a network that is unique among Federal agencies, State and Tribal governments, and private organizations in its broad on-the-ground geographic coverage, its array of technical and managerial capabilities, and its ability to work across political boundaries and take a national perspective. It also brings to the aquatic conservation table the only Federal hatchery system, with extensive experience culturing more than one hundred different aquatic species.

The Fisheries Program and its partners recognize that they need to continue working together to identify actions that need to be initiated or expanded to achieve shared management goals, and then to address these needs or "gaps." The Fisheries Program and its partners also recognize that responsibilities for managing and conserving fish and other aquatic resources are shared, and success is usually contingent on partnerships that cut across jurisdictions and link all stakeholders and partners. Resource objectives and Federal, State and Tribal roles have also shifted over time. Where once the Service focused primarily on restoring and managing game species, its conservation mission has expanded, and today includes non-game and endangered species. Just as important, the Service and its partners know that the opportunities, challenges, and needs facing aquatic resources exceed budgetary resources, as well as Federal authorities and responsibilities. Consequently, the Fisheries Program will use five criteria in deciding what activities, opportunities, and issues to address for each of the seven priority areas set out in this strategic vision. Current and potential actions will be evaluated against the following criteria, and partners will be consulted as key decisions are made that affect the direction of the Fisheries Program. The Service will weigh potential actions by:

- The strength of Federal authority and responsibility;
- The extent to which our efforts will complement others in the fisheries and aquatic resource conservation community;
- The likelihood that our efforts will produce measurable resource results;
- The likelihood that our efforts will produce significant economic or social benefits; and
- The extent of partner support.

The Service will also ensure that actions taken by the Fisheries Program will be consistent with strategic plans being developed by the Department of the Interior and the Service as a whole, and that Fisheries Program actions will help achieve performance targets laid out in those plans. The Fisheries Program's strategic planning effort is proceeding parallel to the strategic planning efforts being conducted by the Department and the Service. These planning efforts have been closely coordinated to ensure agreement and consistency among the three levels of management.

The Service is re-committing to its role as a partner in conserving America's fish and other aquatic resources. In some cases, the Fisheries Program will lead; in others, it will facilitate or follow. In all cases, the Fisheries Program will focus its efforts and activities on what it is best positioned to contribute based on its unique resources and capabilities, recognizing that sound science and solid partnerships will continue to be the key to aquatic resource stewardship. Working with its partners, the Fisheries Program has identified seven areas of emphasis with associated goals, objectives, and actions to focus on in the future. In some cases, these actions reflect a reaffirmation of current activities; in other cases, they reflect some change in those activities. In a few cases, the actions reflect a new activity for the Fisheries Program. Many of its current activities support these goals and objectives, and there will be some opportunities to refocus and change within existing resources. However, the scope and speed with which this blueprint for the future becomes reality will depend on the level of support and resources that are available to the Fisheries Program. The seven focus areas that the Fisheries Program will take actions to emphasize are:

- Partnerships and Accountability;
- Aquatic Species Conservation and Management;
- Public Use;
- Cooperation with Native Americans;
- Leadership in Science and Technology;
- Aquatic Habitat Conservation and Management; and
- Workforce Management.

Introduction

Since 1871, the Fisheries Program of the U.S. Fish and Wildlife Service (Service) has played a vital role in conserving and managing this Nation's aquatic resources. Over the years, the Service has been a leader in almost every aspect of fisheries management, fish health and fish culture. Today, the Fisheries Program is a critical partner with other Service programs, States, Tribes, other governments, private organizations, public institutions, and interested citizens in a larger effort to conserve fish and other aquatic resources. The Service asked a broad array of these partners to help identify the most critical needs for aquatic resources and to reach consensus on the most appropriate role for the Fisheries Program. The new vision for the Fisheries Program was developed with their help.

Vision

The vision of the Service and its Fisheries Program is working with partners to restore and maintain fish and other aquatic resources at self-sustaining levels and to support Federal mitigation programs for the benefit of the American public.

Implementing this vision will help the Fisheries Program do more for aquatic resources and the people who value and depend on them through enhanced partnerships, scientific integrity, and a balanced approach to conservation.

Status of the Nation's Fish And Other Aquatic Resources

The Nation's fish and other aquatic resources are among the richest and most diverse in the world. These resources, and the recreational, commercial, and subsistence opportunities they provide, have helped support the Nation's growth by providing enormous ecological, social and economic benefits. Preliminary surveys conducted by the Service show that recreational fishing contributed more than $35 billion annually to the American economy in 2001 alone. An economic analysis conducted independently by the American Sportfishing Association in 1996 showed that recreational fishing's overall economic impact to the economy was $108.4 billion, including 1.2 million jobs and $28.3 billion in personal income (ASA 1996). Fish and aquatic resources are particularly important to our Nation's Native American communities which rely upon healthy, sustainable natural resources to meet subsistence, economic, ceremonial, religious, and medicinal needs.

Despite efforts by the Service and others to conserve fish and other aquatic resources, a growing number are declining at alarming rates. Almost 400 aquatic species either have, or need, special protection in some part of their natural or historic range (Williams et al. 1989; Moyle and Leidy 1992). The number of species listed as threatened or endangered under the *Endangered Species Act* in 2002 has increased to 19 amphibian species, 21 crustacean species, 70 mussel species, and

115 fish species. Several threatened and endangered species of fish are important recreational, subsistence, and commercially species, including several species or populations of salmon, sturgeon, and trout. Of the 297 species of freshwater mussels in the U.S., 213 (72 percent) are threatened, endangered, or of special concern (Williams et al. 1993). None of these aquatic species or populations have ever been removed from the *Endangered Species Act* list, although a few are close to being de-listed or down-listed from endangered to threatened.

The reasons for these declines are linked largely to habitat loss or alteration (including flow changes, watershed modifications, sedimentation and pollution) and the impacts of harmful exotic or transplanted species. Healthy stream and riparian habitats are critical to the sustainability of all aquatic resources. Approximately 53 percent of the Nation's 221 million acres of wetlands have disappeared (Dahl 1990). Today, 185 species of fish and 88 species of mollusks are found in the U.S. that have been introduced from every continent except Antarctica (Fuller et al. 1999; OTA 1993). While some of these species create significant economic benefits, others, such as zebra mussels, Asian clams, and Asian carps cause significant harm to native fish and other aquatic resources. Native fish and other aquatic resources are especially threatened by these invaders because of their rapid spread through connected waterways. Since the unintentional introduction of zebra mussels into the Great Lakes, the number of native mussel species in the east channel of the Mississippi River near Prairie du Chien, Wisconsin, decreased from more than 30 to only 7 species during a 4-year period (Miller and Payne 2001). Clearly, the Nation is at risk of losing its diverse aquatic resources and the critically important benefits they provide.

Biological and social scientists, government agencies, conservation groups, and the American public are becoming increasingly concerned about the decline of fish and other aquatic resources and the economic impact of those declines. They point with increasing urgency to actions that must be taken to reverse these alarming trends. Management and conservation actions for virtually all fish and other aquatic resources are a shared responsibility. Success in reversing the trend will rely on continuing partnerships and forging new partnerships that cut across jurisdictions and link stakeholders and partners.

Over time, resource objectives and Federal, State and Tribal roles have shifted. Where the Service once focused primarily on restoring and managing game species, the conservation mission has changed and today, includes non-game and endangered species. These new realities led the Service to re-examine its Fisheries Program's existing obligations and to explore the appropriate balance between State, Tribal and Federal responsibilities. Working collaboratively with its partners, the Service has better defined its role in conserving and managing aquatic resources across the country. To move forward, the Service and its Fisheries Program must be solidly supported, backed by sound science, and grounded in dynamic partnerships.

How This Effort Is Different

In July, 2001, the Sport Fishing and Boating Partnership Council (SFBPC) was charged by the Service to convene a steering committee representing perspectives from a broad array of stakeholders in fish and aquatic resource conservation to work with the Fisheries Program during the development of a new blueprint for the future. This provided partners with a unique opportunity to be engaged before the strategic vision was drafted. It was also unique because the Fisheries Steering Committee included representatives from the Service, along with partners and stakeholders.

In January, 2002, the SFBPC Fisheries Steering Committee provided the Service with a set of consensus recommendations on the Fisheries Program's role in the partnership effort to conserve the Nation's fish and other aquatic resources. This report, entitled "A Partnership Agenda for Fisheries Conservation," along with the earlier SFBPC hatchery report, "Saving a System in Peril," were keystone elements in developing the Fisheries Program's strategic vision. The Service also used GAO reports, ongoing interactions with the SFBPC Fisheries Steering Committee, Service employees, and the Service work group efforts to address the 24 hatchery-related directives from the Department of the Interior and the Office of Management and Budget to better defined its role in conserving and managing aquatic resources across the country.

The Service is re-committing to its role as a partner in conserving America's fish and other aquatic resources. In some cases the Service will lead; in others, it will facilitate or follow. In all cases, the Service will focus its efforts and activities on what it is best positioned to contribute based on its unique resources and capabilities, recognizing that sound science and solid partnerships will continue to be the key to aquatic resource stewardship. The Service will work closely with its partners on an ongoing basis to refine and adapt its Fisheries Program activities within this framework to effectively respond to priority needs and issues.

The Service's Fisheries Program

The Service's Fisheries Program consists of almost 800 employees nationwide, located in 64 Fishery Resources Offices, including a Conservation Genetics Laboratory, 69 National Fish Hatcheries, 9 Fish Health Centers, 7 Fish Technology Centers and a Historic National Fish Hatchery. Together, these employees and these facilities provide a network that is unique among Federal agencies, State and Tribal governments, and private organizations in its broad on-the-ground geographic coverage, its array of technical and managerial capabilities, and its ability to work across political boundaries and take a National perspective.

This network stands out, but it does not stand alone. Its main strength is its ability to work collaboratively with partners on almost any issue, problem or opportunity to conserve or restore the Nation's fish and other aquatic resources. Another strength is its ability to bring unique capabilities that individual States and Tribes often lack because of their narrower authorities and jurisdictions. For example, the Fisheries Program's National Fish Hatchery System, the only Federal fish hatchery system that exists, has extensive experience culturing more than one hundred aquatic species, including fish, mussels, plants, amphibians and invertebrates. By sharing capabilities at National Fish Hatcheries, Fish Technology Centers, and Fish Health Centers, Service fisheries biologists can lead or participate in cooperative programs related to fish health, nutrition, and water use technology. Similarly, field biologists in Fishery Resources Offices serve a vital role in restoring, managing, and conserving the health of nationally significant fish and other aquatic resources and the habitats they depend on. Biologists develop scientifically sound data and information to improve the health of populations and their habitats, diagnose problems, prescribe solutions, and coordinate diverse efforts. The broad geographic responsibilities of these biologists often enable them to reach across State and Tribal boundaries, as well as agency jurisdictions, to craft coalitions, partnerships and solutions.

Our Commitment

The vision of the Service and its Fisheries Program is working with partners to restore and maintain fish and other aquatic resources at self-sustaining levels and support Federal mitigation programs for the benefit of the American public. To achieve that dream, the Fisheries Program is committed to working with our partners to:

- *Protect* the health of aquatic habitats.
- *Restore* fish and other aquatic resources.
- Provide opportunities to *enjoy* the many benefits of healthy aquatic resources.

Making Decisions and Setting Priorities

The crisis facing the Nation's fish and aquatic resources demands the attention of Federal, State, and Tribal resource management agencies, conservation and environmental organizations, and the American public. The Fisheries Program embraces a balanced approach toward aquatic resource stewardship that recognizes the need to conserve and manage self-sustaining populations and their habitats, and at the same time, provide quality opportunities for responsible fishing and other related outdoor activities.

Opportunities, challenges, and needs facing aquatic resources exceed budgetary resources, as well as Federal authorities and responsibilities. With the help of partners, the Service and its Fisheries Program has identified seven priority areas where it can and should make a difference. These priority areas are listed below, and include goals, objectives, and actions which include reaffirming some current activities, refocusing others, and starting new ones. This strategic vision document is intended to focus and direct Fisheries Program activities over the next 10 years.

The Fisheries Program will use five criteria in deciding what fishery activities, opportunities, and issues to address for each of the seven priority areas, and partners will be consulted as key decisions are made that affect the direction of the Fisheries Program. The criteria are based on the identification of a Federal role and a determination of whether or not the Service is the most appropriate Federal agency. The Service will weigh proposed and potential activities by:

- The strength of Federal authority and responsibility;
- The extent to which our efforts will complement others in the fisheries and aquatic resource conservation community;
- The likelihood that our efforts will produce measurable resource results;
- The likelihood that our efforts will produce significant economic or social benefits; and
- The extent of partner support.

Implementation Actions

The implementation actions included in this strategic vision document focus on the key actions the Fisheries Program believes it needs to take to attain the vision. They also focus on actions that will make the Fisheries Program more effective in conserving aquatic resources, meeting the needs of American citizens and establishing partnerships. Each objective in this strategic vision is supported by one or more implementation actions. These actions were chosen and described to be specific, measurable, accountable, and results-oriented. Their order does not indicate an order of importance. The scope and speed with which these actions can be taken will depend on the support and resources available to the Fisheries Program.

Determining the Service's success in implementing this strategic vision will be based on monitoring and evaluating accomplishments. Equally important is communicating successes and failures to our partners, stakeholders, Congress, and the Administration. Meetings will be held each year to communicate progress and accomplishments. A report to Congress will be written biennially. This strategic vision with its implementation actions serves as a general contract between the Service and its partners. It identifies key actions the Service and its Fisheries Program will take in the interest of conserving America's fish and other aquatic resources and in sustaining the benefits those resources provide.

The implementation actions included in this report draw on a number of sources, most significantly the two SFBPC reports, ongoing interaction with the SFBPC Fisheries Steering Committee, Service employees, and the Service work group efforts to address the 24 hatchery-related directives from the Department of the Interior and the Office of Management and Budget. Some of the work group responses to the hatchery directives are still in development and will be added as appropriate when they are finalized. The implementation actions also draw on twelve issue papers that were exchanged between the Service and the Steering Committee during development of the two SFBPC reports, and that proved invaluable in identifying actions that should be undertaken or expanded to help fill in gaps in the collective capabilities of the Service and its partners.

Success in implementing this strategic vision for the Fisheries Program hinges on developing step-down actions that are specific to each of the seven geographic regions of the Service and its Fisheries Program headquarter's office. These 5 year step-down plans will identify specific activities that will contribute to the strategic vision and identify annual targets that link back to Departmental and Service strategic plans developed under the *Government Performance and Results Act* (GPRA). The regional Fisheries Program step-down plans will establish accountability for each activity by identifying responsible parties, due dates and end products or outcomes. Linkages among activities will also be identified, as will factors and prerequisites that might be especially important to successfully completing those activities. The plan for the Fisheries Program headquarters office will dovetail with the seven regional step-down plans and facilitate successful implementation of activities in those plans. Where two or more regions have common issues, they will coordinate the development of activities. All eight step-down plans will be assembled as a compendium, made available broadly on the Internet, and used in planning and operations to set direction and promote communication, understanding, accountability and partnerships. All eight plans and the Strategic Plan for the Fisheries Program will include components to ensure and promote financial accountability.

The Fisheries Program's strategic planning effort is proceeding parallel to the strategic planning efforts being conducted by the Department and the Service. These planning efforts have been closely coordinated to ensure agreement and consistency among the three levels of management. Tasks conducted under the Fisheries Program's Strategic Plan will support four goals under the Department's major goal areas:

RESOURCE PROTECTION
- Goal #1: Watersheds, Landscapes, and Marine Resources
- Goal #2: Biological Communities

RECREATION
- Goal #2: Ensure Quality Experience and Enjoyment of Natural and Cultural Resources on DOI Managed and Partnered Lands and Waters

SERVING COMMUNITIES
- Goal #3: Fulfill Indian Trust Responsibilities

Performance measures and performance targets will be developed as the strategic plan for each management level is stepped down into outcomes, actions, and tasks. Core performance measures will be the same under the strategic plans for all three levels of management. Furthermore, a small number of additional performance measures specific to the Service or to the Fisheries Program may be developed during the Regional step-down planning process. The Regional step-down plans will be rolled back up and assembled into the Strategic Plan for the Service's Fisheries Program. The common, core performance measures will link the Fisheries Strategic Plan to the Service's Strategic Plan, and then to the Department's Strategic Plan.

Goals, Objectives, and Actions

The Service will strengthen and revitalize its Fisheries Program and re-commit itself to partnership efforts to conserve the Nation's fish and other aquatic resources, focusing on seven priority areas: Partnerships and Accountability, Aquatic Species Conservation and Management, Public Use, Cooperation with Native Americans, Leadership in Science and Technology, Aquatic Habitat Conservation and Management, and Workforce Management. The order of these priority areas is not intended to imply a relative priority. Goals, objectives, and actions have been identified for each of the seven priority areas.

1. Partnerships and Accountability

Partnerships are essential for effective fisheries conservation. Many agencies, organizations, and private individuals are involved in fisheries conservation and management, but no one can do it alone. Together, these stakeholders combine efforts and expertise to tackle challenges facing fisheries conservation. The success of these partnerships will depend on strong, two-way communications and accountability. Goals, objectives, and actions were developed to direct Fisheries Program efforts for working with partners and being accountable.

Partnership Goal: Open, interactive communication between the Fisheries Program and its partners. The Fisheries Program will develop and improve relationships with partners, focusing on the following areas:

Objective 1.1: Develop and improve long-term partnerships with States, Tribes, other federal agencies, non-governmental organizations (NGOs), and other Service Programs to develop collaborative conservation strategies for aquatic resources.

> *Action 1.1.1:* Facilitate annual meetings in each Region with State Fish and Wildlife Agencies, Tribal representatives, NGOs, other federal agencies, and Service counterparts to identify and resolve aquatic resource management problems, explore new management opportunities, and maintain productive working relationships.
>
> *Action 1.1.2:* Explore new opportunities to improve government-to-government relationships with Tribal governments.
>
> *Action 1.1.3:* Establish new "Friends Groups" to support the goals and purposes of the associated hatchery or other Fisheries facility with annual objectives established on regional and national levels.
>
> *Action 1.1.4:* Work with other Service Programs to leverage available funding and expertise, and maximize the attainment of aquatic resource conservation goals.

<u>Accountability Goal:</u> Effective measuring and reporting of the Fisheries Program's progress toward meeting short-term and long-term fish and other aquatic resource conservation goals and objectives. The Fisheries Program will develop effective accountability measurements and reporting, focusing on the following areas:

<u>Objective 1.2:</u> Develop and implement performance measures to determine the efficiency and effectiveness of Fisheries Program resource activities and financial accountability.

> *<u>Action 1.2.1:</u>* Develop and implement regional and headquarters step-down plans, tiered from the Service's Fisheries Program strategic vision within 6 months after the finalization of this strategic vision.
>
> *<u>Action 1.2.2:</u>* Annually monitor and evaluate Regional and National progress toward meeting specified performance measures, including *Government Performance Results Act* (GPRA) performance measures, and report on its related accomplishments.
>
> *<u>Action 1.2.3:</u>* Develop performance measures to evaluate the effectiveness and efficiency of its activities relative to the strategic vision, starting in FY04, using both internal evaluations and input from States, Tribes, NGOs, and other federal agencies to measure progress toward meeting expectations.
>
> *<u>Action 1.2.4:</u>* Manage Fisheries Program funding to maximize Program performance and to allocate and spend Program funds in a timely and responsible manner.

2. Aquatic Species Conservation and Management[1]

The Fisheries Program maintains and implements a comprehensive set of tools and activities to conserve and manage self-sustaining populations of native fish and other aquatic resources. These tools and activities are linked to management and recovery plans that help achieve restoration and recovery goals, provide recreational benefits, and address Federal trust responsibilities. Sound science, effective partnerships, and careful planning and evaluation are integral to conservation and management efforts. Goals, objectives, and actions were developed to direct Fisheries Program efforts for Native Species, Aquatic Nuisance Species, and Interjurisdictional Fisheries.

Native Species

Habitat degradation and the spread of aquatic nuisance species are causing many native species populations to decline. One hundred fifteen species of fish, 19 species of amphibians, 70 species of mussels, and 21 species of crustaceans are listed as threatened or endangered under the *Endangered Species Act*. Many other unlisted species are also in decline.

[1] For activities related to introduced and naturalized species, please see the Public Use section.

Native Species Goal: Self-sustaining populations of native fish and other aquatic resources that maintain species diversity, provide recreational opportunities for the American public, and meet the needs of tribal communities. The Fisheries Program will conserve native fish and other aquatic resources, focusing on the following areas:

Objective 2.1: **Recover fish and other aquatic resource populations protected under the *Endangered Species Act*.** The Fisheries Program will increase efforts in planning and implementing actions with partners to help recover threatened and endangered aquatic species, such as developing rearing technologies and providing refugia, while restoring aquatic habitats.

> *Action 2.1.1:* Provide increased expertise to the Endangered Species Program to conduct status reviews for fish and other aquatic resources populations.
>
> *Action 2.1.2:* Identify threatened and endangered fish and other aquatic species that do not currently have recovery plans and update the list on an annual basis, in coordination with the Endangered Species Program.
>
> *Action 2.1.3:* Take the lead in working with Endangered Species Program staff and partners to develop recovery plans for those threatened and endangered species identified in Action 2.1.2.
>
> *Action 2.1.4:* Increase implementation of appropriate actions identified in recovery plans.

Objective 2.2: **Restore declining fish and other aquatic resource populations before they require listing under the *Endangered Species Act*.** The Fisheries Program will increase its support and assistance in stopping and reversing declines of native fish and other aquatic resources, including restoring fish passage and rebuilding populations.

> *Action 2.2.1:* Work with States, Tribes, the Endangered Species Program, and other key partners to identify declining fish and other aquatic resource populations and the associated threats.
>
> *Action 2.2.2:* Work with States, Tribes, and other partners to identify and prioritize actions that will be most effective and efficient in achieving desired resource goals and outcomes.
>
> *Action 2.2.3:* Work with States, Tribes, and other partners to begin implementing identified priority actions to eliminate or reduce the threats causing the declines.

Objective 2.3: **Maintain diverse, self-sustaining fish and other aquatic resource populations.** The Fisheries Program will increase its participation in collaborative efforts to ensure that habitats and native biological communities remain intact and at self-sustaining levels.

Action 2.3.1: Work with States, Tribes, and other federal agencies to monitor the status of self-sustaining native fish and other aquatic resource populations and to identify the biggest threats to those populations.

Action 2.3.2: Work with States, Tribes, and other federal agencies to identify and implement priority actions that need to be taken to reduce and monitor the biggest threats.

Aquatic Nuisance Species

Aquatic nuisance species threaten the diversity or abundance of native species or the ecological stability of infested waters, or commercial, agricultural, aquacultural or recreational activities dependent on those waters. More than 20 Federal agencies are involved with preventing and controlling aquatic nuisance species, in cooperation with States, Tribes, private industry, and others.

Aquatic Nuisance Species Goal: **Risks of aquatic nuisance species invasions are substantially reduced, and their economic, ecological, and human health impacts are minimized.** The Fisheries Program will seek to prevent and reduce the establishment and spread of aquatic nuisance species, focusing on the following areas:

Objective 2.4: **Prevent new introductions of aquatic nuisance species.** The Fisheries Program will increase its leadership role in collaborative efforts to implement activities and programs that prevent the establishment of aquatic nuisance species.

Action 2.4.1: Increase efforts to work with the Aquatic Nuisance Species Task Force, the National Invasive Species Council, and others to identify and monitor high-risk pathways for the introduction of Aquatic nuisance species and to participate in preventative actions to reduce the likelihood of the introduction of new aquatic nuisance species associated with those pathways.

Action 2.4.2: Facilitate the prevention and control of aquatic nuisance species through the development and support of State management plans, regional panels and other mechanisms.

Action 2.4.3: Coordinate the Service's efforts in the re-authorization of the National Invasive Species Act.

Action 2.4.4: Increase education and outreach activities to raise public awareness of aquatic nuisance species problems and how the public can help.

Action 2.4.5: Implement Hazard Analysis and Critical Control Points (HACCP) or similar control planning processes in the National Fish Hatchery System and other Fisheries Program activities to prevent the unintentional release or spread of aquatic nuisance species.

Objective 2.5: **Minimize range expansion and population growth of established aquatic nuisance species.** The Fisheries Program will expand its role in partnership efforts by developing methods and conducting programs designed to prevent the spread of aquatic nuisance species to new locations and limit growth of established populations.

> *Action 2.5.1:* Increase efforts to work with States, Tribes, and other partners by coordinating surveys and monitoring efforts to detect and control aquatic nuisance species.
>
> *Action 2.5.2:* Work with the National Wildlife Refuge System, States, Tribes, other federal agencies, and NGOs to increase rapid response and other capabilities to control aquatic nuisance species populations and prevent their expansion.

Interjurisdictional Fisheries

Responsibility for managing native, interjurisdictional fisheries in the United States is assigned by many laws, treaties, and court orders, but follows no single model. By definition, interjurisdictional fisheries management is a collaborative process involving State, Tribal and Federal governments.

Interjurisdictional Fisheries Goal: Interjurisdictional fish populations are managed at self-sustaining levels. The Fisheries Program will support, facilitate and/or lead collaborative approaches to conserve, and where necessary restore, sustainable interjurisdictional fish populations, focusing on the following areas:

Objective 2.7: **Co-manage interjurisdictional fisheries.** The Fisheries Program will increase its participation and assistance with other Federal, State, and Tribal interjurisdictional fishery management efforts, including commercial and subsistence fisheries in freshwater, coastal, and marine ecosystems.

> *Action 2.7.1:* Lead the development of a Memorandum of Understanding to clarify the roles and responsibilities of the Service and the National Marine Fisheries Service in managing interjurisdictional fisheries.
>
> *Action 2.7.2:* Increase participation in interstate fishery management councils, commissions, and other associations.
>
> *Action 2.7.2:* Provide Federal leadership to implement the Federal subsistence fisheries program in Alaska, pursuant to mandates of the Alaska National Interest Lands Conservation Act.

Objective 2.8: **Support, facilitate, and/or lead collaborative approaches to manage interjurisdictional fisheries.** The Fisheries Program will increase its involvement in collaborative efforts, including the development of fishery and watershed management plans, collect and share scientific information and data, and provide fish required under fishery management plans.

> *Action 2.8.1:* Work with States, Tribes, and other federal agencies to identify the biggest threats to maintaining self-sustaining, interjurisdictional fish populations in freshwater, coastal, Great Lakes and marine ecosystems.
>
> *Action 2.8.2:* Work with States, Tribes, and other federal agencies to identify and implement priority actions to eliminate or reduce those threats.

3. Public Use

As the population in the United States continues to grow, the potential for adverse impacts on aquatic resources, including habitat will increase. At the same time, demands for responsible, quality recreational fishing experiences will also increase. The Service has a long tradition of providing opportunities for public enjoyment of aquatic resources through recreational fishing, habitat restoration, and education programs and through mitigating impacts of Federal water projects.

The Service also recognizes that some aquatic habitats have been irreversibly altered by human activity (i.e. - dam building). To compensate for these significant changes in habitat and lost fishing opportunities, managers often introduce non-native species when native species can no longer survive in the altered habitat. This aspect was considered in the development of the Public Use section. Goals, objectives and actions for Fisheries Program activities related to Recreational Fishing and Mitigation Fisheries were developed.

Recreational Fishing

Fishing continues to be a favorite pastime in the United States. The Service's 2001 preliminary National Survey of Fishing, Hunting, and Wildlife-Associated Recreation reported that 34 million anglers (16 % of the U.S. population) 16 years old and older, spent more than $35 billion annually on trips, equipment, licenses, and other items to support their fishing activities. The average annual expenditure was $1,046 per angler.

Providing recreational fishing opportunities is a cooperative effort between the Service, other Federal agencies, States, Tribes, NGOs and the sportfishing community. The Service provides various recreational fishing opportunities on lands it manages. At least 268 out of 538 National Wildlife Refuges provided recreational fishing and hosted 6.4 million fishing visits in 2000. The Service also works with the Department of Defense to provide fishing opportunities on military lands.

Recreational Fishing Goal: Quality opportunities for responsible fishing and other related recreational enjoyment of aquatic resources on Service lands, on Tribal and military lands,

and on other waters where the Service has a role. The Fisheries Program will focus its efforts to achieve this goal on the following areas:

Objective 3.1: **Enhance recreational fishing opportunities on Service and Department of Defense lands.** The Fisheries Program will increase its work with National Wildlife Refuges, National Fish Hatcheries, and the Department of Defense to enhance fishing opportunities for the public on Service and military lands. Activities will focus on maintaining and restoring aquatic habitats, developing and implementing fishery management plans, and increasing access for recreational fishing opportunities.

> *Action 3.1.1:* Provide increased expertise and assistance to help develop fish and other aquatic resource conservation elements in Refuge Comprehensive Conservation Plans (CCP's).
>
> *Action 3.1.2:* Provide increased expertise and assistance to help develop and implement fish and other aquatic resource management plans on National Wildlife Refuges.
>
> *Action 3.1.3:* Work with the National Wildlife Refuge System to identify and implement ways to increase recreational fishing use on Refuges, where compatible, through actions, such as creating additional access, new habitat, and promotion and outreach.
>
> *Action 3.1.4:* Advocate for the appropriate involvement of Tribes and State Fish and Wildlife Agencies in activities that involve recreational fisheries, on an ongoing basis.
>
> *Action 3.1.5:* Provide technical assistance and recommendations for conserving and rehabilitating recreational fisheries on military installations.

Objective 3.2: **Provide support to States, Tribes, and other partners to identify and meet shared or complementary recreational fishing and aquatic education and outreach objectives.** The Fisheries Program will continue to provide hatchery fish and technical assistance in support of recreational fishing and aquatic outreach activities.

> *Action 3.2.1:* Work with States, Tribes, and other partners to provide technical assistance and, under certain conditions, provide hatchery fish to meet recreational fishing objectives (i.e., for mitigation, restoration and recovery of recreationally valuable species, treaty-reserved or statutorily defined Tribal trust natural resources, using conservation exchanges and cost-recovery to optimize fish production, and aquatic outreach and education activities).
>
> *Action 3.2.2:* Continue to support National Fishing and Boating Week events, scouting jamborees, and similar events with technical assistance and hatchery fish, on an ongoing basis.

Objective 3.3: **Recognize and promote the value and importance of recreational fishery objectives in implementation of other Service responsibilities.** The Fisheries Program will continue its efforts to balance the conservation of native fish and other aquatic resources and providing quality recreational fishing opportunities.

> *Action 3.3.1:* Work with other Service programs to ensure that actions, decisions, policies, and programs consider the recreational fisheries roles and objectives of the Service, on an ongoing basis.
>
> *Action 3.3.2:* Work with partners to identify and implement outreach and education activities regarding the concept, value, and importance of responsible recreational fishing to the American public.
>
> *Action 3.3.3:* Conduct a national economic analysis of its contributions to recreational and commercial fishing.

Mitigation Fisheries

When Federal locks and dams were constructed, Congress and the Federal government committed to mitigate impacts on recreational, commercial, and tribal fisheries. Mitigation activities include habitat improvement, native species recovery, and stocking native and non-native fish. Over the years, Congress provided funds and directed the Service to construct and operate hatcheries to provide fish to help mitigate fishery losses. These mitigation hatchery programs are a legitimate use of the National Fish Hatchery System. In some cases, Congress provided funds to others to construct mitigation hatcheries operated by the Service and certain states. Today, the current challenge is to delineate agency mitigation responsibilities and related funding mechanisms.

Mitigation Fisheries Goal: The Federal government meets its responsibilities to mitigate for the impacts of Federal water projects, including restoring habitat and/or providing fish and associated technical support to compensate for lost fishing opportunities. The Service will work with other Federal agencies, States, and Tribes to meet mitigation responsibilities, with a focus on the following areas:

Objective 3.4: **Identify the mitigation responsibilities of Federal agencies for Federal water projects.** The Fisheries Program will work with the Administration and Congress to identify and clarify federal agency mitigation responsibilities for federally-funded water projects.

> *Action 3.4.1:* Determine the Service's mitigation responsibilities for federally-funded water projects.
>
> *Action 3.4.2:* Work with other federal agencies to determine their mitigation responsibility for federally-funded water projects.

<u>Objective 3.5:</u> **Meet the Service's responsibilities for mitigating fisheries at federally-funded water projects.**

> *<u>Action 3.5.1:</u>* Provide fish to meet its determined mitigation responsibilities.
>
> *<u>Action 3.5.2:</u>* Develop legislative strategies to clarify and authorize mitigation responsibilities for federally-funded water projects.

<u>Objective 3.6</u>: **Recover 100 percent of costs for mitigation activities associated with hatchery production and stocking from the water project sponsor.** The Fisheries Program will identify the full cost of its mitigation activities and increase efforts to pursue cost recovery from the appropriate Federal agencies, involving the Administration and Congress in these efforts. Where full cost recovery is not obtainable, the Service will work with the appropriate entities to identify other means of maintaining the mitigation activities.

> *<u>Action 3.6.1:</u>* Identify the full costs of Service mitigation activities.
>
> *<u>Action 3.6.2:</u>* Pursue full cost-recovery from other federal agencies for their mitigation responsibilities associated with federally-funded water projects.

<u>4. Cooperation with Native Americans</u>

Conserving this Nation's fish and other aquatic resources cannot be successful without the partnership of Tribes; they manage or influence some of the most important aquatic habitats both on and off reservations. In addition, the Federal government and the Service have distinct and unique obligations toward Tribes based on trust responsibility, treaty provisions, and statutory mandates. The Fisheries Program plays an important role in providing help and support to Tribes as they exercise their sovereignty in the management of their fish and wildlife resources on more than 55 million acres of Federal Indian trust land and in treaty reserved areas.

<u>Native American Assistance Goal</u>: Assistance is provided to Tribes that results in the management, protection, and conservation of their treaty-reserved or statutorily defined trust natural resources which helps Tribes develop their own capabilities. The Fisheries Program will focus its efforts on the following areas:

<u>Objective 4.1</u>: **Provide technical assistance to Tribes.** The Fisheries Program will continue to provide technical assistance to Tribes, as requested and to the extent possible, for Tribal natural resource management activities.

> *<u>Action 4.1.1:</u>* Provide technical assistance to Tribes that supports Tribal natural resource management goals, such as training, developing management plans, maintaining healthy hatchery fish, and developing hatchery operating procedures, on an ongoing basis.

Action 4.1.2: Explore the use of cooperative agreements and Intergovernmental Personnel Act Agreements (IPAs) to advance technical assistance to Tribes and develop Tribal technical expertise in fish and wildlife management.

Objective 4.2: **Identify sources of funds to enhance Tribal resource management.** The Fisheries Program will increase its efforts to work with Tribes and other stakeholders to identify sources of funds that can be used to enhance Tribal resource management infrastructures or for particular partnerships or initiatives involving Tribes.

Action 4.2.1: Work with Tribes to identify potential funds for tribal resource management.

Objective 4.3: **Provide fish for Tribal resource management.** The Fisheries Program will continue to provide fish as part of recovery plans for listed species, in support of sustainable fisheries management, and for trust species and ongoing programs to enhance outdoor recreation on Tribal lands.

Action 4.3.1: Work with Tribes to identify shared or complementary fisheries conservation management objectives.

Action 4.3.2: Provide fish to implement fishery management plans.

Action 4.3.3: Provide fish as agreed to under conservation exchanges or other special arrangements.

Objective 4.4: **Recognize and promote the Service's distinct obligations toward Tribes within the Fisheries Program.** The Fisheries Program will continue to be vigilant that its actions, programs, and other partnerships do not infringe upon tribal rights.

Action 4.4.1: Consult with and integrate Tribes into decisions affecting them to ensure that actions, decisions, and policies consider and integrate tribal roles and responsibilities.

5. Leadership in Science and Technology

Science and technology form the foundation of successful fish and aquatic resource conservation and are used to structure and implement monitoring and evaluation programs that are critical to determine the success of management actions. The Service is committed to following established principles of sound science.

Science and Technology Goal: Science developed and used by Service employees for aquatic resource restoration and management is state-of-the-art, scientifically sound and legally defensible, and technological advances in fisheries science developed by Service employees are available to partners. The Fisheries Program will develop, apply, and disseminate state-of-the-art science and technology to conserve and manage aquatic resources, focusing on the following areas:

Objective 5.1: **Utilize appropriate scientific and technologic tools in formulating and executing fishery management plans and policies.** The Fisheries Program will increase its efforts to identify, revise, and update aquatic science tools as necessary to support the management and conservation of sustainable fisheries.

> *Action 5.1.1:* Work with partners to ensure that all fish and other aquatic resource conservation plans are based on scientifically valid information.
>
> *Action 5.1.2:* Adhere to the highest scientific standards and ethics in all its activities.

Objective 5.2: **Develop and share applied aquatic scientific and technologic tools with partners.** The Fisheries Program will continue to develop science and technology at its Fish Technology Centers, Fish Health Centers, and Fishery Resources Offices, including its Conservation Genetics Laboratory, and share those capabilities in order to provide a platform for cooperative programs that are beyond the scope of individual States and Tribes.

> *Action 5.2.1:* Work with partners to determine the highest priority needs for scientific, management, and technology tools.
>
> *Action 5.2.2:* Expand science and technology development to meet priority needs.
>
> *Action 5.2.3:* Identify, revise, and update aquatic science and technology tools used by the Service and its partners on an ongoing basis.
>
> *Action 5.2.4:* Increase facilitation for the approval of new and expanded use of aquatic animal chemicals and therapeutic drugs.
>
> *Action 5.2.5:* The Service Director will work with the Director of the U.S. Geological Survey (USGS) to increase USGS participation in aquatic-related research within the Science Support Partnerships Program and develop more effective mechanisms for Service aquatic resource conservation research needs and priorities to be incorporated into USGS/BRD research activities.

6. Aquatic Habitat Conservation and Management

Loss and alteration of aquatic habitats are principal factors in the decline of native fish and other aquatic resources and the loss of biodiversity. Seventy percent of the Nation's rivers have altered flows, and 50 percent of waterways fail to meet minimum biological criteria.

Aquatic Habitat Goal: America's streams, lakes, estuaries, and wetlands are functional ecosystems that support self-sustaining communities of fish and other aquatic resources. The Fisheries Program will collaborate with partners to conserve and restore habitats for fish and other aquatic resource populations, focusing on the following areas:

Objective 6.1: **Facilitate management of aquatic habitats on national and regional scales.** The Fisheries Program will start work with Federal, State, Tribal, and other partners to identify aquatic habitat restoration needs and implement priority actions.

> *Action 6.1.1:* Identify and implement significant watershed management programs with partners to ensure that habitat conservation and restoration is an integral component of management actions.

> *Action 6.1.2:* Work with Federal, State, Tribal, and other partners to explore the benefits of a National Aquatic Habitat Plan and the appropriate Service role in its development and implementation.

Objective 6.2: **Expand the use of Fisheries Program expertise to avoid, minimize or mitigate impacts of habitat alteration on fish and other aquatic species.** The Fisheries Program will increase the involvement of its employees in Service activities to address issues and threats related to hydropower re-licensing and development of wetlands.

> *Action 6.2.1:* Increase Fisheries Program involvement in existing and new Service habitat conservation programs and activities (e.g., HCPs, Partners for Fish and Wildlife, environmental contaminants, FERC relicensing, Refuge planning, and others) to ensure that priority aquatic habitat issues are addressed.

> *Action 6.2.2:* Work with partners to identify and provide access beyond barriers to fish migration.

Objective 6.3: **Increase the quantity and improve the quality of aquatic and riparian habitat on Service lands.** The Fisheries Program will expand the involvement of its employees, in coordination with the National Wildlife Refuge System, to identify and implement opportunities for increasing the quantity and improving the quality of aquatic and riparian habitats on Service lands.

> *Action 6.3.1:* Work with the National Wildlife Refuge System to develop and implement strategies for increased or new aquatic habitat conservation programs on Service lands.

> *Action 6.3.2:* Work with the National Wildlife Refuge System to re-evaluate the Fisheries and Aquatic Resource component of the Land Acquisition Priority System.

Action 6.3.3: Work with the National Wildlife Refuge System to identify opportunities for land protection proposals benefitting fish and other aquatic resources.

7. Workforce Management

The Fisheries Program relies on a broad range of professionals to accomplish its mission: biologists, managers, administrators, clerks, animal caretakers, and maintenance workers. Without their skills and dedication, the Fisheries Program cannot succeed. Employees must be trained, equipped and supported in order to perform their jobs safely, often under demanding environmental conditions, and to keep current with the constantly expanding science of fish and aquatic resource management and conservation.

Workforce Management Goal: Maintain and support an adequately-sized, strategically positioned workforce with state-of-the-art training, equipment, and technologies in their career fields. The Fisheries Program will recruit, support, and position an effective and motivated workforce capable of meeting the expectations of employees and partners in fish and other aquatic resource conservation, focusing on the following areas:

Objective 7.1: **Staff Fisheries Program field stations at levels adequate to effectively meet the Service's goals and objectives in fish and other aquatic resource conservation.** The Fisheries Program will analyze positions and organizational structures at all Fisheries Field Stations, identify the critical staff and functions needed to support various types and sizes of hatcheries and Fishery Resources Offices, and fill critical vacancies or gaps in the workforce with well-qualified individuals.

Action 7.1.1: Develop a 5-year plan to guide human capital management decisions.

Action 7.1 2: Develop and adhere to annual operational work plans for each station.

Objective 7.2: **Provide employees with opportunities to maintain competencies in the expanding knowledge and technologies needed to improve opportunities for professional achievement, advancement and recognition.** The Fisheries Program will identify training and developmental learning opportunities both inside and outside the Service for all skills utilized, as well as preparing staff for future leadership positions.

Action 7.2.1: Identify core competencies required for its employees.

Action 7.2.2: Work with the National Conservation Training Center to develop training opportunities for employees to meet competency levels.

Objective 7.3: **Provide employees with access to facilities and equipment needed to effectively, efficiently and safely perform their jobs.** The Fisheries Program will provide its employees with state-of-the-art biotechnology, computers, and maintenance and safety equipment.

Action 7.3.1: Identify and start implementing operational, structural and geographic changes that would help maximize effectiveness and efficiency at field stations.

Definitions

Aquatic nuisance species - introduced, exotic, or transplanted species, including viruses, bacteria, protozoans, and parasites, that threaten the diversity or abundance of native species or the ecological stability of infested waters, or commercial, agricultural, aquacultural or recreational activities dependent on those waters.

Conservation - management, restoration, and protection of self-sustaining and imperiled species populations.

Exotic species - any species introduced from a foreign country (Shafland and Lewis 1984).

Imperiled species - any species listed as threatened or endangered under the authority of the *Endangered Species Act*, considered a candidate for listing, or its population is in a steep decline.

Interjurisdictional fisheries - freshwater, coastal, or marine fish populations managed by two or more states, nations, or tribal governments because of their geographic distribution or migratory patterns.

Introduced species - any species moved from one place to another by human activity (Shafland and Lewis 1984).

Invasive Species - any non-native species whose introduction does or is likely to cause economic or environmental harm or harm to human health (Executive Order 13112, 1999).

Native species - any species within historic range, the area occupied at the time of European colonization of North America (Horak 1995).

Naturalized species - any non-native species that has adapted and grows or multiplies as if native (Horak 1995).

Non-native species - any species that occupies an ecosystem beyond its historic range (Horak 1995).

Responsible fishing - the act of fishing while 1) abiding to all fishing regulations and laws; 2) preventing the spread of aquatic nuisance species, and; 3) respecting private property and the rights of other anglers.

Self-sustaining - capable of maintaining itself independently (*Webster's New World Dictionary*, Third College Edition, s.v. "self-sustaining").

Transplanted species - any species moved outside of its native range but within a country where it occurs naturally (Shafland and Lewis 1984).

Literature Cited

ASA (American Sportfishing Association). 1996. The Economic Importance of Sport Fishing. 10 pp. American Sportfishing Association. Alexandria, VA.

Dahl, T.E. 1990. Wetland losses in the U.S. 1970's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington D.C. 21 pp.

Executive Order 13112. 1999. Invasive Species.

Fuller, P.L., L.G. Nico, and J.D. Williams. 1999. Nonindigenous fishes introduced into inland waters of the United States. American Fisheries Society, Special Publication 27, Bethesda, Maryland.

Horak, D. 1995. Native and Non-native Fish Species Used in State Fisheries Management Programs in the United States. American Fisheries Society Symposium 15:61-67.

Miller, A. and B. Payne. 2001. Effects of zebra mussels (*Dreissena polymorpha*) and essential habitat for *Lampsilis higginsi* in the Upper Mississippi River System, 2000. Aquatic Ecology Branch, Engineering Research and Development Center, U.S. Army Corps of Engineers, Vicksburg, MS. 28pp.

Moyle, P.B. and R.A. Leidy. 1992. Loss of biodiversity in aquatic ecosystems: Evidence from fish faunas. In: Fielder, P.L. and S.K. Jans, eds. Conservation Biology: The Theory and Practice of Nature, Conservation Preservation and Management. Chapman and Hall, NY.

OTA, Office of Technology Assessment. 1993. Harmful Non-Indigenous Species in the United States. Washington (DC): Office of Technology Assessment, US Congress.

Shafland, P.L. and W.M. Lewis. 1984. Adapted from: Terminology Associated with Introduced Organisms. Fisheries 9(4):17-18.

Webster's New World Dictionary, Third College Edition. 1988. Simon and Schuster, Inc. New York, New York.

Williams, J.D., M.L. Warren, K.S. Cummings, J.L. Harris, and R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18(9):6-22.

Williams, J.E., J.E. Johnson, D.A. Hendrickson, S. Contreras-Balderas, J.D. Williams, M. Navarro-Mendoza, D.E. McAllister, and J.E. Deacon. 1989. Fishes of North America endangered, threatened, or of special concern: 1989. Fisheries 14(6):2-20.

Chapter: 22

State(s): Washington

Recovery Unit Name: Upper Columbia

Region 1
U.S. Fish and Wildlife Service
Portland, Oregon

DISCLAIMER

Recovery plans delineate reasonable actions that are believed to be necessary to recover and protect listed species. Recovery plans are prepared by the U.S. Fish and Wildlife Service, and in this case with the assistance of recovery unit teams, State and Tribal agencies, and others. Objectives will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not necessarily represent the views, the official positions or approval of any individuals or agencies involved in plan formulation, other than the U.S. Fish and Wildlife Service. Recovery plans represent the official position of the U.S. Fish and Wildlife Service *only* after they have been signed by the Director or Regional Director as *approved*. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

Literature Citation: U.S. Fish and Wildlife Service. 2002. Chapter 22, Upper Columbia Recovery Unit, Washington. 113 p. *In*: U.S. Fish and Wildlife Service. Bull Trout (*Salvelinus confluentus*) Draft Recovery Plan. Portland, Oregon.

ACKNOWLEDGMENTS

Members of the Upper Columbia Recovery Unit that contributed to the development of this chapter include:

Ken MacDonald, U.S. Forest Service, Okanogan-Wenatchee National Forest
Heather Bartlett, Washington Department of Fish and Wildlife
Barbara Kelly-Ringel, U.S. Fish and Wildlife Service
Judy De La Vergne, U.S. Fish and Wildlife Service
Bill Baer U.S. Forest Service, Okanogan-Wenatchee National Forest
Tim Cummings, U.S. Fish and Wildlife Service

Additional review and comments were provided by:

Nancy Wells, U.S. Forest Service, Okanogan-Wenatchee National Forest
Jim Uehara, Washington Department of Fish and Wildlife
Terry Jackson, Washington Department of Fish and Wildlife
Bao Le, U.S. Fish and Wildlife Service

UPPER COLUMBIA RECOVERY UNIT
CHAPTER OF THE BULL TROUT RECOVERY PLAN

EXECUTIVE SUMMARY

CURRENT SPECIES STATUS

The Fish and Wildlife Service issued a final rule listing the Columbia River and Klamath River populations of bull trout (*Salvelinus confluentus*) as threatened species under the Endangered Species Act on June 10, 1998 (63 FR 31647). The Columbia River Distinct Population Segment is threatened by habitat degradation and fragmentation, blockage of migratory corridors, poor water quality, and past fisheries management practices such as the introduction of nonnative species.

As required by the Endangered Species Act, the U.S. Fish and Wildlife Service has developed a plan which when implemented will lead to the recovery and ultimate delisting of the Columbia River Distinct Population Segment. An overall recovery team with membership from the States of Washington, Oregon, Idaho, Montana, and Native American Tribes was established to develop a framework for the recovery plan, provide guidance on technical issues, and ensure consistency through the recovery planning process. Within the Columbia River Distinct Population Segment, the recovery team has identified 22 recovery units. Recovery unit teams were established to develop specific reasons for decline and actions necessary to recover bull trout.

Recovery units were identified based on three factors: 1) recognition of jurisdictional boundaries, 2) biological and genetic factors common to bull trout within a specific geographic area, and 3) logistical concerns for coordination, development, and implementation of the recovery plan. In Washington, to facilitate the recovery planning process and avoid duplication of effort, the recovery team has adopted the logistical framework proposed in the 1999 draft Statewide strategy to recover salmon, “Extinction Is Not An Option.” Based on this draft strategy, bull trout recovery units overlap the State’s salmon recovery regions. The identification of Lower Columbia, Middle Columbia, Upper Columbia, Snake, and Northeast Washington recovery units will allow for better coordination during both salmon and bull trout recovery planning and implementation.

The U.S. Fish and Wildlife Service, in cooperation with the Washington Department of Fish and Wildlife, solicited participation with the Upper Columbia Recovery Unit Team from individuals having bull trout expertise or other technical expertise applicable to bull trout recovery planning. The team had representation from the U.S. Forest Service, Washington Department of Fish and Wildlife, and the U.S. Fish and Wildlife Service. The Upper Columbia Recovery Unit Team believes that coordination with the National Marine Fisheries Service salmon recovery efforts is essential for the recovery of bull trout in the Upper Columbia Recovery Unit.

The Upper Columbia Recovery Unit Team identified three core areas including the mainstem and tributaries of the Wenatchee, Entiat, and Methow Rivers. Based on survey data and professional judgement, the Upper Columbia Recovery Unit Team also identified local populations of bull trout within each core area. Currently there are six local populations in the Wenatchee Core Area, two in the Entiat Core Area, and eight in the Methow Core Area. Additional local populations may be added to this total as additional information is gathered in areas outside the currently designated core areas for this recovery unit.

Recent information on migration and use of the mainstem Columbia River by bull trout has been verified. Tagging studies conducted by the Chelan County Public Utilities District have monitored movements of bull trout tagged and released at Rock Island, Rocky Reach, and Wells dams. In addition, studies conducted by the U.S. Fish and Wildlife Service have verified the movement of adult bull trout into the lower Wenatchee River. Most likely, these tagged fish entered the mainstem Columbia River to overwinter and feed. The mainstem Columbia River contains core habitat elements for bull trout that are important for migration, feeding, overwintering, and eventual recovery. The Upper Columbia Recovery Team believes that further research on migrational patterns and genetic similarities is needed to better understand the role that the mainstem Columbia River will play in recovery.

The Lake Chelan basin is historic bull trout habitat, but their presence has not been documented since the late 1950's, and they may have been extirpated from the basin. However, complete surveys in remote tributary reaches of the Lake Chelan basin have not been conducted and further investigation is needed. While there are anecdotal reports on bull trout occurrence in the Okanogan River, the current distribution within the Okanogan basin is unknown. The Upper Columbia Recovery Unit Team recommends that expanded surveys be conducted in each basin to verify status and distribution.

HABITAT REQUIREMENTS AND LIMITING FACTORS

A detailed discussion of bull trout biology and habitat requirements is provided in Chapter 1 of this recovery plan. The limiting factors discussed here are specific to the Upper Columbia Recovery Unit Chapter.

Within the Upper Columbia Recovery Unit, historic and current land use activities have impacted bull trout local populations. Some of the historic activities, especially water diversions, hydropower development, forestry, and agriculture within the core areas, may have significantly reduced important fluvial populations. Lasting effects from some, but not all, of these early land and water developments still act to limit bull trout production in core areas. Threats from current activities are also present in all core areas of the Upper Columbia Recovery Unit.

RECOVERY GOALS AND OBJECTIVES

The goal of the bull trout recovery plan is to **ensure the long-term persistence of self-sustaining, complex interacting groups of bull trout distributed across the species' native range, so that the species can be delisted.** To achieve this goal the following objectives have been identified for bull trout in the Upper Columbia Recovery Unit:

- Maintain current distribution of bull trout and restore distribution in previously occupied areas within the Upper Columbia Recovery Unit.

- Maintain stable or increasing trends in abundance of bull trout.

- Restore and maintain suitable habitat conditions for all bull trout life history stages and strategies.

- Conserve genetic diversity and provide opportunity for genetic exchange.

RECOVERY CRITERIA

Recovery criteria for the Upper Columbia Recovery Unit are established to assess whether actions are resulting in the recovery of bull trout in the basin. The criteria developed for bull trout recovery address quantitative measurements of bull trout distribution and population characteristics on a recovery unit basis.

1. **Distribution criteria will be met when bull trout are distributed among at least 16 local populations in the Upper Columbia Recovery Unit.** The 16 identified local populations are currently distributed within the Wenatchee (6), Entiat (2) and Methow (8) core areas and are comprised of the migratory life-history form. For recovery to occur, the distribution of these migratory local populations should be maintained, while abundance is increased. Designation of local populations is based on survey data and the professional judgement of Upper Columbia Recovery Unit Team members. Further genetic studies are needed in order to more accurately delineate local populations, quantify spawning site fidelity, and determine straying rates. The complete distribution of resident local populations in the recovery unit is unknown. The Upper Columbia Recovery Unit Team recommends that further studies be conducted in the Wenatchee, Entiat, and Methow core areas to elucidate the current and recovered distribution of resident bull trout in the recovery unit. Geographic distribution of resident local populations should be identified within 3 years and actions needed to implement re-introduction efforts will be incorporated into review of the Upper Columbia Recovery Unit plan. Additional local populations may be added to this total as additional information is gathered in areas outside the currently designated core areas for this recovery unit.

2. **Abundance criteria will be met when the estimated abundance of bull trout among all local populations in the Upper Columbia Recovery Unit (Wenatchee, Entiat, and Methow core areas) is between 6,322 and 10,426 migratory fish.** Recovered abundance ranges for the Wenatchee (1,876 to 3,176), Entiat (836 to 1,364), and Methow (3,610 to 5,886) core areas were derived using the professional judgement of the Team and estimation of productive capacity of identified local populations. Resident life history forms are not included in this estimate, but are considered a research need. As more data is collected, recovered population estimates will be revised to more accurately reflect both the migratory and resident life history components.

3. **Trend criteria will be met when adult bull trout exhibit a stable or increasing trend for at least two generations at or above the recovered abundance level within the Wenatchee, Entiat, and Methow core areas.** The development of a standardized monitoring and evaluation program that would accurately describe trends in bull trout abundance is identified as a priority research need. As part of the overall recovery effort, the U.S. Fish and Wildlife Service will take the lead in addressing this research need by forming a multi-agency technical team to develop protocols necessary to evaluate trends in bull trout populations.

4. **Connectivity criteria will be met when specific barriers to bull trout migration in the Upper Columbia Recovery Unit have been addressed.** The Upper Columbia Recovery Unit Team recommends that to adequately address habitat problems in the Methow core area (*e.g.*, low instream flows, grazing, culverts, and diversion dam barriers), and to recover bull trout, basin-wide conservation efforts (*e.g.*, Habitat Conservation Plans) must be developed and implemented. The U.S. Fish and Wildlife Service working with Federal, State, and private entities, and in coordination with local governments, needs to secure quality habitat conditions for bull trout. These efforts should be coordinated with ongoing National Marine Fisheries Service salmon recovery actions to avoid duplication in planning and implementation.

The Upper Columbia Recovery Unit Team expects that the recovery process will be dynamic and will be refined as more information becomes available. Future adaptive management will play a major role in recovery implementation and refinement of recovery criteria. While removal of bull trout as a species under the Act (*i.e.,* delisting) can only occur for the entity that was listed (Columbia River Distinct Population Segment), the recovery unit criteria listed above will be used to determine when the Upper Columbia Recovery Unit is fully contributing to recovery of the population segment.

ACTIONS NEEDED

Recovery for bull trout will entail reducing threats to the long-term persistence of populations and their habitats, ensuring the security of multiple interacting groups of bull trout, and providing habitat and access to conditions that allow for the expression of various life history forms. The seven categories of actions needed are discussed in Chapter 1; tasks specific to this recovery unit are provided in this chapter.

ESTIMATED COST OF RECOVERY

Total estimated cost of bull trout recovery in the Upper Columbia Recovery Unit is $15 million. Total costs include estimates of expenditures by local, Tribal, State, and Federal governments and private business and individuals. The estimate includes recovery actions associated with the Wenatchee, Entiat, and Methow core areas as well as identified research needs (*e.g.,* Columbia River). These costs are attributed to bull trout conservation, but other aquatic species will also benefit. Cost estimates are not provided for tasks which are normal agency responsibilities under existing authorities.

ESTIMATED DATE OF RECOVERY

The time required to achieve recovery depends on bull trout status, factors affecting bull trout, implementation and effectiveness of recovery tasks, and responses to recovery tasks. A tremendous amount of work will be required to restore impaired habitat, reconnect habitat, and eliminate threats from nonnative species. Three to five bull trout generations (15 to 25 years), or possibly longer, may be necessary before identified threats to the species can be significantly reduced and bull trout can be considered eligible for delisting.

Degradation and fragmentation of bull trout habitat in the Upper Columbia Recovery Unit have resulted in populations that are at high risk. Ultimately, these threats must be addressed in the near future if recovery is to be achieved. If identified actions are implemented, the Upper Columbia Recovery Unit Team anticipates that recovery could occur within 25 to 50 years.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

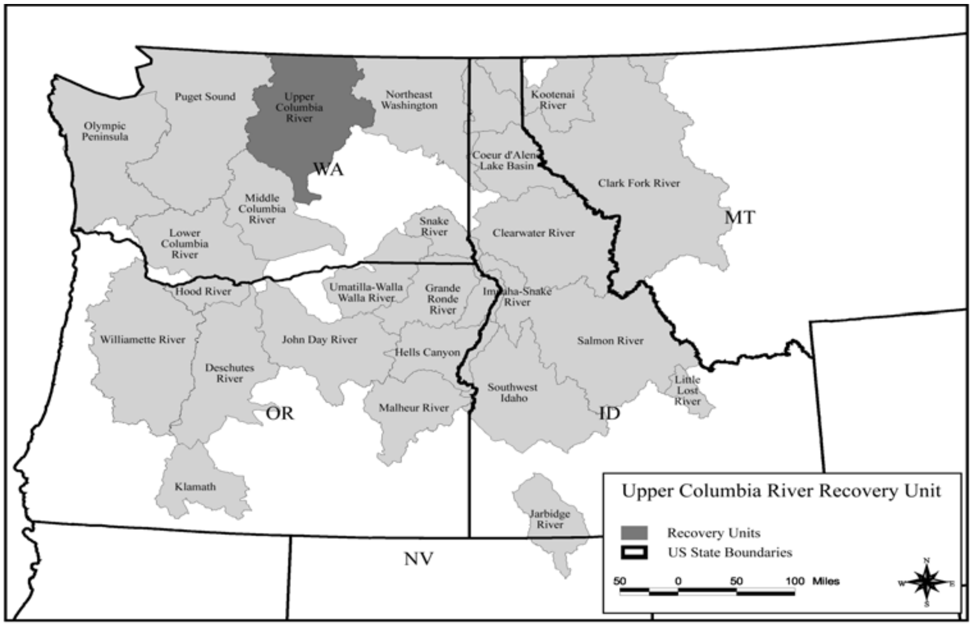
Recovery Unit Designation

The Fish and Wildlife Service issued a final rule listing the Columbia River and Klamath River populations of bull trout (*Salvelinus confluentus*) as a threatened species under the Endangered Species Act on June 10, 1998 (63 FR 31647). The Jarbidge River population was listed as threatened on April 8, 1999 (64 FR 17110). The Coastal-Puget Sound and St. Mary-Belly River populations were listed as threatened on November 1, 1999 (64 FR 58910), which resulted in all bull trout in the coterminous United States being listed as threatened (Figure 1). The five populations discussed above are listed as distinct population segments, *i.e.*, the U.S. Fish and Wildlife Service has concluded that they meet the joint policy with the National Marine Fisheries Service regarding the recognition of distinct vertebrate populations (61 FR 4722).

An overall recovery team with membership from the states of Washington, Oregon, Idaho, Montana, and Native American Tribes was established to develop a framework for the recovery plan, provide guidance on technical issues, and ensure consistency in the recovery planning process. Within the Columbia River Distinct Population Segment, the recovery team has identified 22 recovery units. Recovery unit teams were established to develop specific reasons for decline and actions necessary to recover bull trout.

Recovery units were identified based on three factors: 1) recognition of jurisdictional boundaries, 2) biological and genetic factors common to bull trout within a specific geographic area, and 3) logistical concerns for coordination, development, and implementation of the recovery plan. In Washington, to facilitate the recovery planning process and avoid duplication of effort, the recovery team has adopted the logistical framework proposed in the 1999 draft Statewide strategy to recover salmon entitled "Extinction Is Not An Option" (WGSRO 1999). Based on this draft strategy, bull trout recovery units overlap the State's salmon recovery regions. The identification of Lower Columbia,

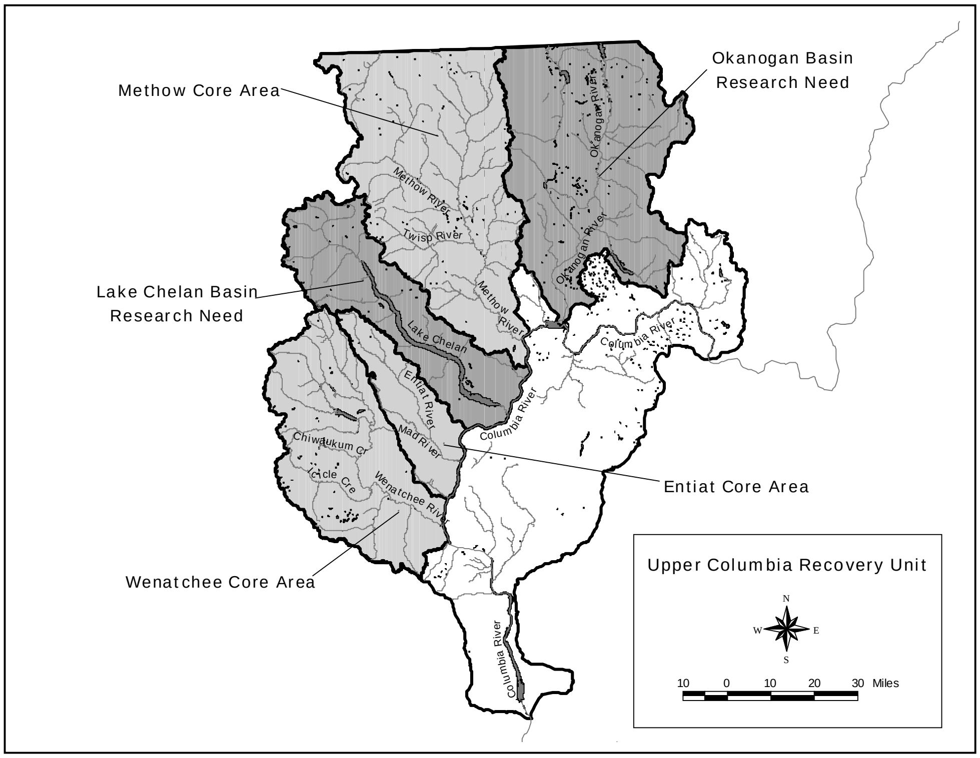
Figure 1. Bull trout recovery units in the United States. The Upper Columbia Recovery Unit is highlighted.



Middle Columbia, Upper Columbia, Snake, and Northeast Washington recovery units will allow for better coordination during both salmon and bull trout recovery planning and implementation.

The Upper Columbia Recovery Unit encompasses the geographic area from the Yakima River upstream to Chief Joseph Dam. The recovery unit includes the Entiat, Wenatchee, Methow, Chelan, and Okanogan basins and the mainstem Columbia River (Figure 2). Historically, these basins have been an important area for anadromous salmon, steelhead (*Oncorhynchus mykiss*), and bull trout production. Based on survey data and professional judgement**,** the Upper Columbia Recovery Unit Team identified three core areas (Wenatchee, Entiat, and Methow Rivers) in the recovery unit. The Upper Columbia Recovery Unit Team has identified the mainstem Columbia River as containing core habitat elements (*e.g.*, foraging and overwintering habitat) considered important for bull trout recovery.

Figure 2. Upper Columbia Recovery Unit.



Within the Wenatchee, Entiat, and Methow core areas 16 local populations supporting migratory bull trout were identified. The Upper Columbia Recovery Unit borders reservations lands of the Colville Tribe and geographically overlaps ceded lands established by Executive Order along portions of the Okanogan River. In addition, the Upper Columbia Recovery Unit overlaps ceded lands (Wenatchee, Entiat, and Methow Rivers) of the Yakama Nation. When the Upper Columbia Recovery Unit has achieved its goal, the Washington Department of Fish and Wildlife, Colville Tribe, and Yakama Nation will determine the location and level of bull trout harvest that can be sustained while maintaining healthy populations.

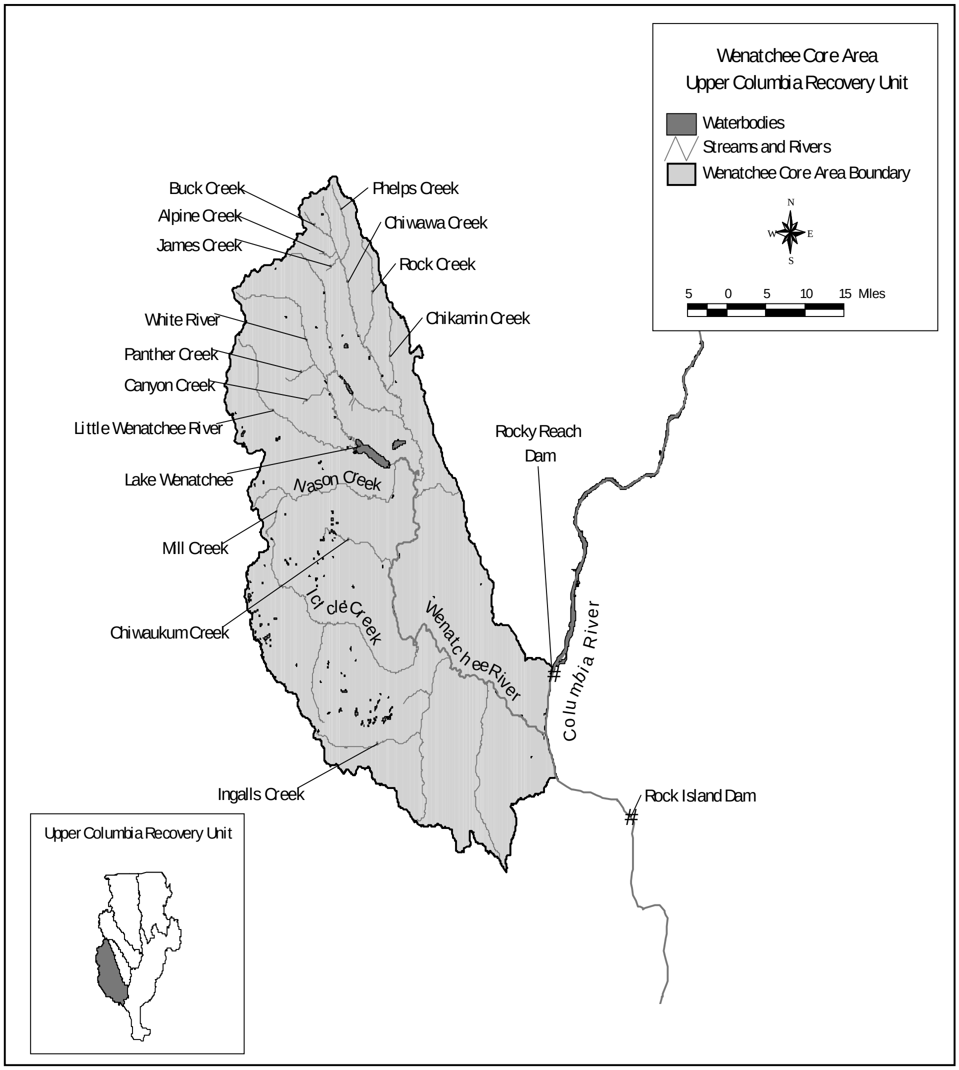
Geographic Description

Wenatchee Core Area. The Wenatchee basin encompasses approximately 3,551 square kilometers (1,371 square miles) in central Washington (NPPC 2001a; USFS 1999a; 1999b; WSCC 2001). The watershed heads at the Cascade crest and flows east towards the Columbia Plateau (Figure 3). The Wenatchee River drains into the Columbia River at the town of Wenatchee. Major tributaries are the White and Little Wenatchee Rivers, which drain into Lake Wenatchee (source of the Wenatchee River), Chiwawa River, and Nason Creek. Additional tributaries to the Wenatchee River include Icicle Creek, Peshastin Creek, and Mission Creek.

Higher elevations within the Wenatchee River basin are characterized by heavy precipitation with accumulations close to 385 centimeters (150 inches) annually (WSCC 2001). Lower portions of the basin receive less than 22 centimeters (8.5 inches) of precipitation annually. Average monthly discharge in the basin varies from a low of 24 cubic meters per second (836 cubic feet per second) in September to 258 cubic meters per second (9,043 cubic feet per second) in June (Parametrix, Inc. 2000). Mean annual discharge is approximately 96 cubic meters per second (3,390 cubic feet per second).

As described by the U.S. Forest Service, two major subsections, the Wenatchee Highlands and Swauk Sandstone Hills, dominate the basin geology (USFS 1999a). Prevalent land types include glacial cirque headwaters, glacial trough, and floodplains. Water rapidly runs off the cirques, due to the shallow soils and near surface rock, and into the till material where it moves slowly downslope into stream channels. The regulating capacity of the troughs provides relatively well-regulated summer flows with relatively low summer stream temperatures, especially in tributaries. In contrast, stream temperatures during low summer flows in the mainstem rivers can approach the upper limits of the preferred temperature range for salmonids. However, these high temperatures are usually short in duration.

Figure 3. Wenatchee Core Area and selected tributaries.



The Peshastin, Mission and Chumstick watersheds lie within the Wenatchee Swauk Sandstone Hills Subsection (USFS 1999a). The Swauk Sandstone and Chumstick Sandstone geologic formations dominate this subsection. The geomorphology is characterized by confined “v-shaped” valleys. Surface erosion is the predominant erosion process with occasional mass wasting of weaker slopes. These land forms lie within the rain shadow of the crest of the Cascade Mountains, and with the exception of some headwaters areas, are relatively dry landscapes.

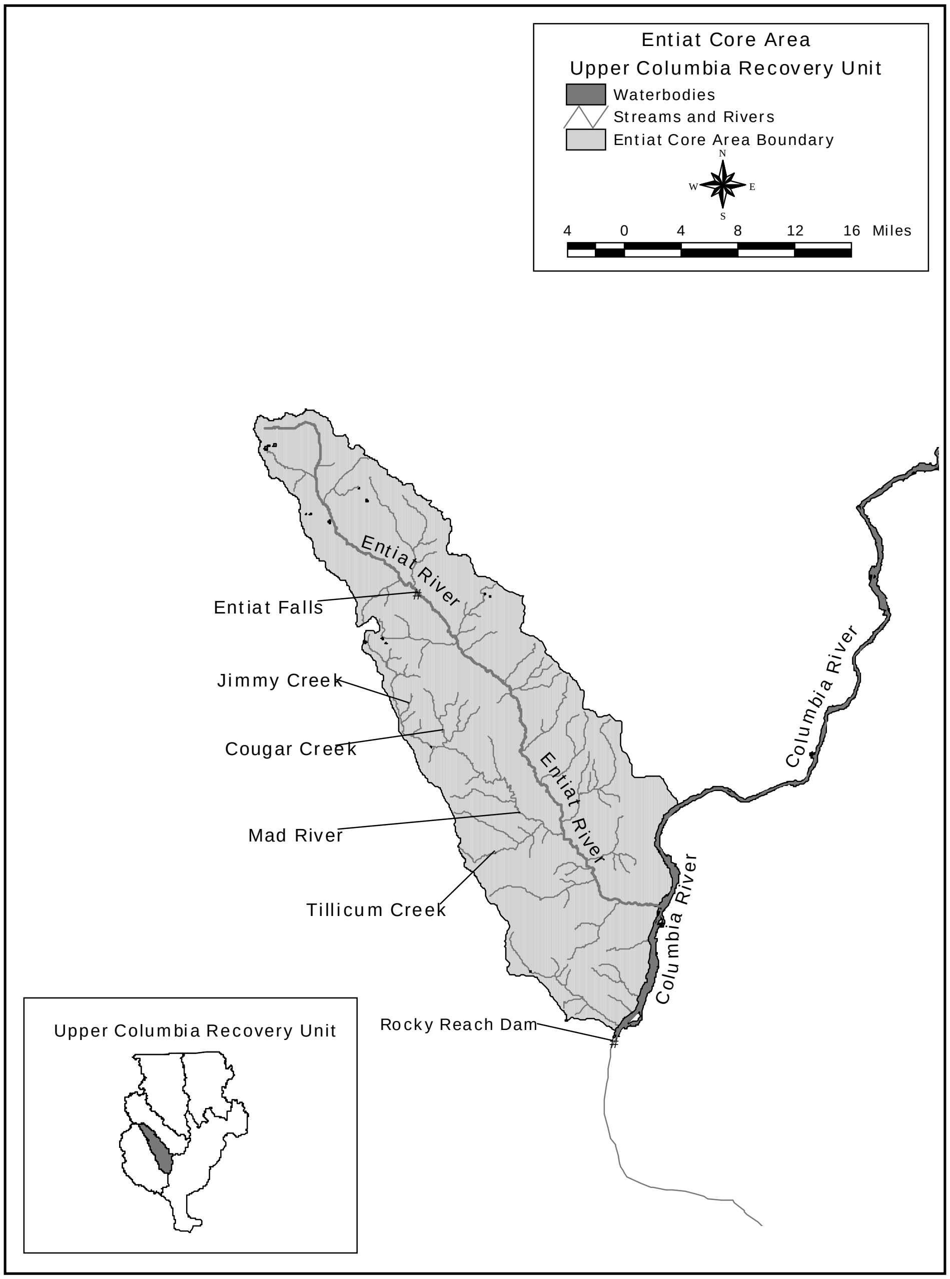
Historically, much of the lower Wenatchee Swauk Sandstone Hills experienced a natural high frequency of low-intensity fires (USFS 1999a). Management actions such as fire suppression and selective timber harvesting have changed much of the area to an unnatural high-intensity fire regime. Now when fires occur, followed by high-intensity precipitation, an accelerated rate of erosion may occur.

Entiat Core Area. The Entiat River drains an area of approximately 1,085 square kilometers (419 square miles) (NPPC 2001b; WSCC 1999). The headwaters of the Entiat River are in glaciated basins near the Cascade Crest. Flowing southeasterly the Entiat River enters the Columbia River near the town of Entiat, approximately 32 kilometers (20 miles) upstream from Wenatchee (Figure 4). Approximately 90,720 hectares (224,000 acres) of the 108,540-hectare (268,000 acre) drainage area are in public ownership, primarily U.S. Forest Service lands, with lesser amounts of land administered by the Bureau of Land Management and Washington Department of Fish and Wildlife (USFS 1996a). Agriculture is an important land use in the lower portion of the valley that includes 527 hectares (1,300 acres) of orchards. About one-half of the Entiat River flows through the Wenatchee National Forest. The two major tributaries are the North Fork Entiat River and the Mad River.

Precipitation ranges from about 25.4 centimeters (10 inches) at the mouth of the Columbia River to 228 centimeters (90 inches) in the headwaters (WSCC 1999).

Summer thunderstorms can produce flash floods in narrow tributary channels. The steep topography, pinnate drainage pattern, relatively low drainage density

Figure 4. Entiat Core Area and selected tributaries.



and short drainage length is conducive to rapid mainstem flow response time and can result in a "flashy" flow regime. Mean annual peak flow is approximately 99 cubic meters per second (3,500 cubic feet per second) and mean annual base flow is around 2.3 cubic meters per second (80 cubic feet per second).

As described by the U.S. Forest Service, the Entiat River watershed can be divided into three broad geomorphic settings, the Transportation, Transition, and Deposition Zones (USFS 1996a). The Transportation Zone extends from the headwaters of the Entiat River down to Entiat Falls, and lies within the Wenatchee Highlands Subsection (USFS 1996a). It consists of strongly-glaciated land types, and has high subsurface water storage capacity. Woody debris and sediment are recruited from stream banks and a naturally high occurrence of debris flows. The Transition Zone extends from Entiat Falls downstream to near the National Forest boundary. The Transition Zone is an area of glacially-influenced mountain slopes without the strong expression of glacial troughs (USFS 1996a). The primary bull trout spawning and rearing in the Mad and Entiat Rivers occurs in the Transition Zone. The lower Entiat is in the Deposition Zone where sediment deposition is the dominant process. Flooding and debris flows are significant transport processes for both sediment and organic input (USFS 1996a). Alluvial fans are present at the mouths of most tributary drainages.

The U.S. Forest Service indicates that fire is an important natural disturbance in the Entiat basin (USFS 1996a). High-intensity, stand replacing fires with 50 to 100 year recurrence intervals are a dominant process in the upper elevations. In the lower elevations, the historic fire regime is characterized by low-intensity fires with a recurrence interval of 5 to 10 years.

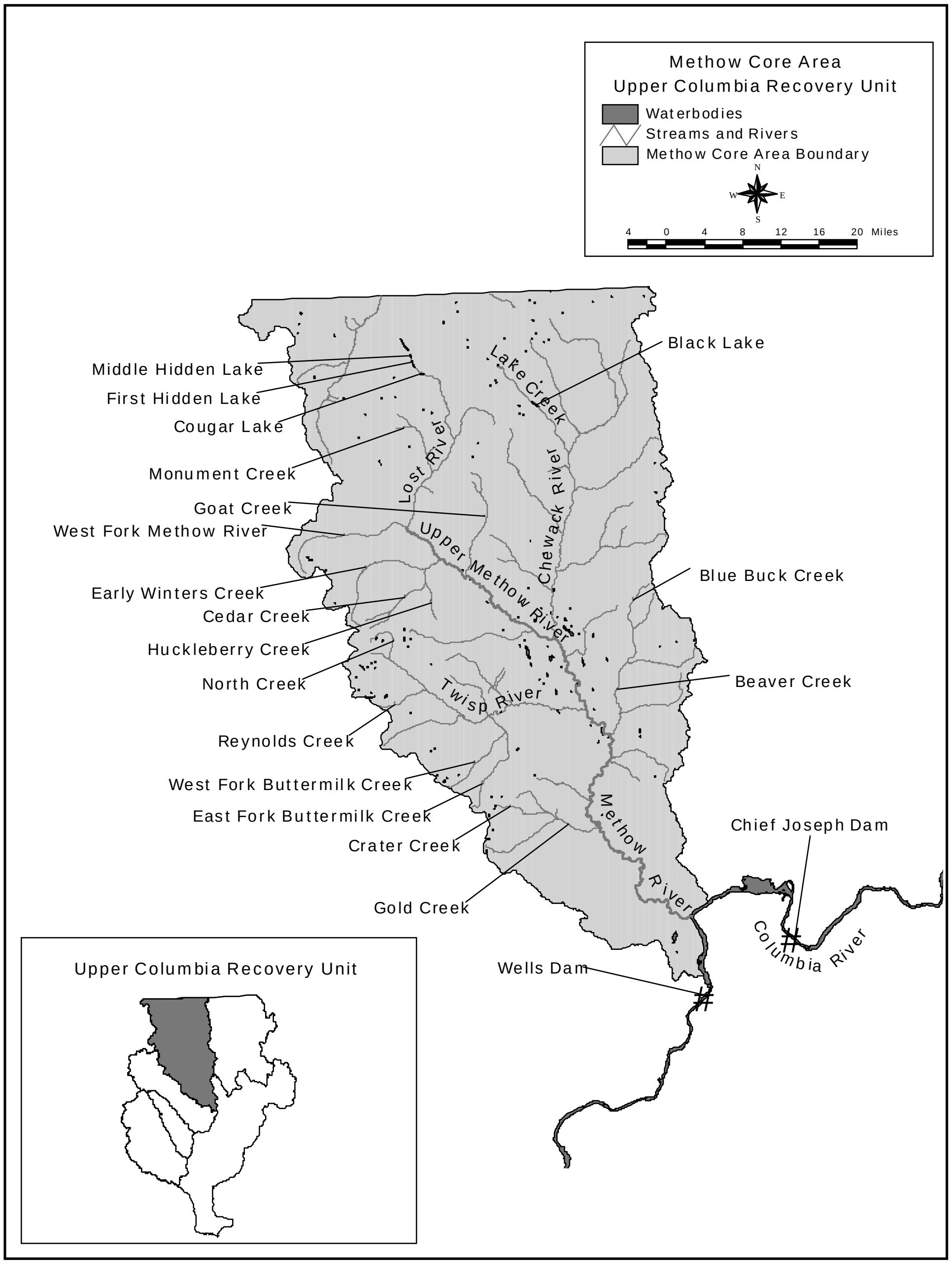
Methow Core Area. The Methow Core Area drains an area of approximately 4,895 square kilometers (1,890 square miles) (NPPC 2001c). The Middle Methow watershed contains approximately 86,670 hectares (214,000 acres), of which about 52,893 hectares (130,600 acres) are U.S. Forest Service lands, 33,615 hectares (83,000 acres) are privately owned, and the remaining 162 hectares (400 acres) are managed by the Washington State Department of

Wildlife. The watershed drains in a northwest to southeast direction and major tributaries include Early Winters Creek, Twisp River, Chewuch River, and the Lost River (Figure 5).

Over 60 percent of the annual precipitation within the Methow River basin occurs between October and March (NPPC 2001c; Parametrix, Inc. 2000). Precipitation is primarily in the form of snow with summer thunderstorms contributing minor amounts. The upper reaches of the basin along the Cascade Crest receive as much as 203.2 centimeters (80 inches) of precipitation annually. The amount of precipitation drops with elevation, with only about 25.4 centimeters (10 inches) occurring in the lower elevations each year. Average monthly flows within the lower Methow River range from 12 cubic meters per second (424 cubic feet per second) in January and February, to 170 cubic meters per second (5,963 cubic feet per second) in June (Parametrix, Inc. 2000).

Most of the land in the lower watershed has been heavily modified by a combination of farming, irrigation, or residential and recreational development (WSCC 2001). Upslope of the private lands are U.S. Forest Service lands, and a majority of these are used for timber management. There is a small section of the Lake Chelan-Sawtooth Wilderness located in the western portion of the watershed. There is also a small section of the Pasayten Wilderness located in the northern portion of the watershed.

Figure 5. Methow Core Area and selected tributaries.



DISTRIBUTION AND ABUNDANCE

Status of Bull Trout at the Time of Listing

In the final listing rule (63 FR 31647), the U.S. Fish and Wildlife Service identified eight bull trout subpopulations in the Entiat, Wenatchee, and Methow River basins (USFWS 1998). The U.S. Fish Wildlife Service identified eight subpopulations within this recovery unit: Lake Wenatchee, Ingalls Creek, Icicle Creek, Entiat system, Methow River, Goat Creek, Early Winters Creek, and Lost River. The Service considered half of these to be “at risk of stochastic extirpation” due to: a) their inability to be refounded, b) presence of a single life-history form, c) limited spawning areas, and c) relatively low abundance. Although subpopulations were an appropriate unit upon which to base the 1998 listing decision, the recovery plan has revised the biological terminology to better reflect the current understanding of bull trout life history and conservation biology theory. Therefore, subpopulation terms will not be used in this chapter.

Current Distribution and Abundance

The Wenatchee River has bull trout dispersed throughout the basin, with the strongest populations centered around Lake Wenatchee and the Chiwawa River (WDFW 1998). Bull trout are found in the Entiat River up to Entiat Falls, with the primary known spawning areas occurring in the middle reaches of the Mad River. Migratory bull trout persist in the Methow River; the largest populations occurr in the Twisp River, Wolf Creek, West Fork Methow River, and the Lost River. The overall status and distribution of resident bull trout within the Methow River basin is unknown. Bull trout have recently been found using the mainstem Columbia River, most likely for feeding, overwintering, and migration.

The Lake Chelan basin is historic bull trout habitat, but their presence has not been documented since the late 1950's, and they may have been extirpated from the basin (WDFW 1992; WDG 1984). Complete surveys in remote tributary reaches of the Lake Chelan basin have not been conducted, however, and further investigation is needed. Bull trout are known to occur in the Okanogan River in British Columbia (McPhail and Carveth 1992). While there are anecdotal reports on bull trout occurrence in the Okanogan River (United States portion), the current distribution within the Okanogan basin is unknown (Wells, N. pers. comm., 2000). The Upper Columbia Recovery Unit Team recommends that expanded surveys be conducted in each basin to verify status and distribution.

Based on survey data and professional judgement, the Upper Columbia Recovery Unit Team identified three core areas (Wenatchee, Entiat, and Methow Rivers) within the recovery unit. Genetic information for distinguishing local populations was lacking for the Upper Columbia Recovery Unit. Tributaries that comprise migratory local populations were grouped based on professional judgement and geographic proximity. Future genetic studies may revise the current classification. Currently there are six local populations in the Wenatchee Core Area, two in the Entiat Core Area, and eight in the Methow Core Area.

Wenatchee Core Area. The Upper Columbia Recovery Unit Team has identified six migratory local populations within the Wenatchee River including the Chiwawa River (including Chikamin, Phelps, Rock, Alpine, Buck and James creeks), White River (including Canyon and Panther creeks), Little Wenatchee River (below the falls), Nason Creek (including Mill Creek), Chiwaukum Creek, and Peshastin Creek (including Ingalls Creek). Adfluvial, fluvial, and resident forms of bull trout currently exist in the Wenatchee River Core Area (WDFW 1998). The majority of the spawning and fry rearing habitat are within U.S. Forest Service lands, including the Glacier Peak and Alpine Lake Wilderness areas. Resident bull trout occur in Icicle Creek above the barrier falls, and migratory bull trout are known to frequent the area below the falls, most likely while foraging. It is unclear whether migratory bull trout can pass the falls, and more information is needed in order to determine if Icicle Creek could support a local population of migratory bull trout. The distribution and status of resident bull trout in Icicle Creek is unknown and the role of Icicle Creek in bull trout recovery is considered a research need.

Chiwawa River

The Chiwawa River local population complex is the strong-hold for bull trout in the upper Wenatchee (WDFW 1998). Spawning has been documented in Rock Creek, Chikamin Creek, and Phelps Creek (Table 1). Spawning has also been documented in the mainstem Chiwawa River and in Buck Creek (J. DeLaVergne, U.S. Fish and Wildlife Service, pers. comm., 2001). A minor amount of spawning has been documented in Alpine and James Creeks (WDFW 1992). Spawning surveys have been conducted by the U.S. Forest Service in cooperation with Washington Department of Fish and Wildlife and the U.S. Fish and Wildlife Service in Rock, Chikamin, and Phelps Creeks since 1989. A change in fishing regulations in 1992 has apparently helped stabilize the Chiwawa local population of bull trout. Rock Creek represents the strongest population in the basin, and since 1995, annual surveys have documented between 151 and 355 redds. Habitat in Phelps Creek is in good condition and bull trout surveys have documented between 22 and 33 redds since 1995. While both Rock and Phelps Creeks contain similar high quality habitat features, production in Phelps Creek is limited by an impassable barrier falls located approximately 1 mile upstream from the confluence with the Chiwawa River (K. MacDonald, U.S. Forest Service, pers. comm., 2001).

Juvenile bull trout and redds have been observed in the upper reaches of the Chiwawa River (Hillman and Miller 1993; 1994; 1995). The majority of the juveniles have been found between Rock Creek and the old mining site at Trinity, which corresponds with where spawning has been observed in the mainstem. Adult bull trout 46 to 61 centimeters (18 to 24 inches) in length have been found throughout the river. While these are definitely migratory fish, whether they are fluvial (from the mainstem Chiwawa River, Wenatchee River, or possibly the Columbia River), or adfluvial fish from Lake Wenatchee, or a combination is not known. Smaller, possibly resident bull trout have also been observed during the surveys.

Table 1. Bull trout redd survey data in the Wenatchee River 1989 to 2001. (Incomplete survey indicated by asterisks. Data provided by the U.S. Forest Service, Wenatchee, WA.)

Local Population	Stream	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Chiwawa River	Rock Creek	114	64	239	205	179	169	313	258	271	220	355	298	151
	Chikamin Creek	39	22	71	16	19	19	66	67	52	99	59	29	24
	Phelps Creek	23	7	22	34	32	19	26	33	1*	28	22	22	33
	Chiwawa River											26	48	38
	Buck Creek												3	---
White River	Panther Creek	33	7*	37	26	45	48	26	29	18	35	11	19	11
	White River											30*	43	10
Nason Creek	Nason Creek									0	6	5	10	1
	Mill Creek								3	1	3	10	5	2
Little Wenatchee River	Below Falls											3	3	1

White River

The White River local population is a major tributary to Lake Wenatchee and is an important spawning stream for sockeye salmon (*O. nerka*), spring chinook salmon (*O. tshawytcha*), steelhead, and bull trout (WDFW 1998). Bull trout have access to the system up to an impassable barrier at White River Falls. Recently, bull trout spawning in the mainstem White River has been documented at least down to the Napeequa River (WDFW 1992; MacDonald, pers. comm., 2001)(Table 1). Bull trout have been observed in the smaller tributaries of Canyon and Sears creeks. Canyon Creek is a very flashy system moving large amounts of bedload, which may make it marginally suitable. Presently the mouth of Canyon Creek flows subsurface in late summer and fall due to deposition of coarse substrate at the mouth.

The Napeequa River is a major tributary to the White River and approximately 2 miles of this glacier-fed stream is potentially available before a potential barrier falls. In 1999, 5 to10 large migratory bull trout were observed in the Napeequa River (DeLaVergne, pers. comm., 2001). Whether or not these bull trout spawned in the Napeequa River is unknown. Rough terrain and glacial flour limit the ability to effectively conduct spawning ground surveys in this tributary.

Panther Creek is a known spawning stream for bull trout and consistent redd surveys have been conducted since 1989 (Table 1). Bull trout spawn in the lower reach, approximately 1 mile before a barrier falls. While spawning counts have fluctuated, Panther Creek represents an important spawning tributary in the White River system (USFWS 1999a; MacDonald, pers. comm., 2001).

Little Wenatchee River

The Little Wenatchee River local population is the other major tributary to Lake Wenatchee. Like the White River, the Little Wenatchee is used by sockeye salmon, spring chinook salmon, and steelhead. In the past, redd surveys for bull trout have been very difficult due to the combination of spring chinook redds and sockeye redds. Migratory bull trout have access to the Little Wenatchee up to Little Wenatchee Falls at river kilometer 11 (river mile 6.8). A few redds were identified during recent surveys in the mainstem Little Wenatchee and further survey work is needed (Table 1). There are anecdotal accounts of migratory spawners below the falls but no adults have been observed recently. Resident bull and brook trout (*S. fontinalis*) have been observed below the falls and some hybridization may have occurred (WDFW 1992; Hillman and Miller 1995). Limited snorkel survey data indicates that resident bull trout may exist above the falls in Rainy Creek (MacDonald, pers. comm., 2001). More intensive survey work is needed above the falls in order to characterize the status and distribution of bull trout.

Nason Creek

Nason Creek originates at Steven's Pass and flows into the Wenatchee River just below the outlet of Lake Wenatchee. Limited redd surveys indicated that spawning for this local population of bull trout occurs in Nason Creek and Mill Creek (Table 1). Large migratory fish have been observed in lower Nason Creek. Nason Creek is sparsely populated by adult and juvenile bull trout throughout but are primarily found in the upstream reaches (WDFW 1992; USFS 1996c). Resident bull trout exist in Mill Creek up to a barrier falls about a mile from the confluence with Nason Creek. Bull trout redd counts are low in Mill and Nason Creeks and both resident and migratory bull trout are believed to spawn in the system (USFWS 1999a). Bull trout redds were identified during spot surveys near the Whitepine campground in 2000, by the U.S. Fish and Wildlife Service, and adult bull trout were observed in the vicinity of Nason Creek campground (De La Vergne, pers. comm., 2001).

Chiwaukum Creek

Chiwaukum Creek joins the Wenatchee River at the head of Tumwater Canyon. There is a potential barrier falls approximately 4 miles upstream from the mouth. Brown (1992) reports anecdotal accounts of a localized fishery for adult bull trout in the late summer and fall. There have been no recent intense surveys of potential bull trout habitat in Chiwaukum Creek. Two approximately

25 to 30 centimeter (10 to 12 inch) bull trout were identified during U.S. Forest Service snorkel surveys in 1997 (MacDonald, pers. comm., 2001). A subsequent foot survey was conducted for approximately 1 mile upstream, but no redds were observed. In 2001, intensive snorkel surveys were conducted and 27 juvenile, 12 migratory-size fish, and 29 redds were observed (USFWS, *in litt.* 2002). The status and distribution of bull trout in Chiwaukum Creek is unknown and expanded surveys are needed.

Peshastin Creek

Peshastin Creek serves as a bull trout migrational corridor to Ingalls Creek. Ingalls Creek is the only tributary within the Peshastin Creek watershed known to support bull trout. Brown (1992) indicated that in the 1950's, Peshastin Creek had a large run of bull trout in the late summer. Bull trout migration into Ingalls Creek was documented through angler interviews. Bull trout were still present during recent surveys by the U.S. Fish and Wildlife Service in Ingalls Creek (USFWS 1997). However, bull trout were not found during the same surveys in Peshastin Creek (USFWS 1997). More recently, three bull trout were observed in lower Peshastin Creek, and one radio-tagged bull trout was located in Peshastin Creek during the winter of 2001-2002 (USFWS *in litt.* 1998a; Kreiter 2002).

Icicle Creek

Large migratory fish have been observed in Icicle Creek below the dam at Leavenworth National Fish Hatchery, however, it is unclear whether successful spawning has occurred (WDFW 1992; USFWS 1999b). Resident bull trout are known to occur upstream of the dam in low densities (USFWS 1997). Bull trout have also been observed in French Creek (USFWS 1999c). The status and distribution of these resident bull trout is unknown.

Snorkel surveys conducted below the spillway dam resulted in documentation of 8 bull trout in 1996; 6 in 1997; 40 in 1998; 7 in 1999; and 40 in 2000 (USFWS 2002). Four dead bull trout were removed from the hatchery’s water diversion at river mile 4.5 (B. Kelly-Ringel, U.S. Fish and Wildlife, pers. comm., 2001). Bull trout radio-tagged in the spillway pool have been documented moving downstream past Dryden Dam. One bull trout radio-tagged in the Columbia River moved into Icicle Creek in 2001. Potential use of Icicle Creek by migratory bull trout, and the status and interaction with the upstream resident component, is considered a research need.

Entiat Core Area. Currently two local populations of bull trout are found in the Entiat Core Area (mainstem Entiat River, and Mad River). The two local populations are thought to be isolated from each other due to a natural thermal barrier (USFS 1996a). Bull trout in the Entiat River are believed to be primarily fluvial. The Washington Department of Fish and Wildlife has classified the status of bull trout in the mainstem Entiat River as “Unknown,” while bull trout in the Mad River have been classified as “Healthy,” based on the trends in available abundance data (WDFW 1998). However, the U.S. Forest Service expressed concern for the long-term persistence of bull trout in the Entiat Core Area due to the low number of spawning fish, restricted spawning distribution, and limited opportunities for refounding (USFS 1996a).

Mainstem Entiat

Bull trout have been found in small numbers throughout the mainstem Entiat River up to Entiat Falls (WDFW 1992). Bull trout in the mainstem Entiat are considered to be fluvial, rearing there, or possibly the Columbia River. A very small amount of spawning has been observed below the falls, but no spawning aggregations have been found (USFS 1996a). Habitat may be a potentially limiting factor for bull trout in tributaries to the Entiat (USFS 1996a). The tributaries are either low in the drainage where thermal regimes are not believed to be suitable for bull trout, or the streams are blocked by natural falls. Incomplete spawning ground surveys have been conducted in the Entiat since 1995. These surveys indicate that the local population abundance is very low (Table 2). Additional tributary surveys are needed to identify potential spawning areas.

Table 2. Bull trout redd counts in the Mad River Index Reach 1989 to 2001, and Entiat River 1994 to 2001. Surveys in the Entiat River are incomplete. (Data provided by the U.S. Forest Service, Wenatchee, WA)

Local Population	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Mad River	15	17	21	16	10	17	16	23	23	43	30	45	34
Entiat River						3	3	0	0	0	6	0	3

Mad River

The majority of the known bull trout spawning and rearing in the Entiat River occurs in its 40 kilometer (25 mile) tributary, the Mad River (WDFW 1998). The Mad River flows into the mainstem Entiat at the town of Ardenvoir. Most bull trout spawning occurs over a 12.4 kilometer (7.7 mile) reach between Young Creek and Jimmy Creek (USFS 1996a). A barrier falls upstream of Jimmy Creek prevents further access. Bull trout spawning surveys have been conducted annually on the Young Creek to Jimmy Creek index reach since 1989 (Table 2). Redd counts have varied from a high of 45 in 2000, to a low of 10 in 1993. Bull trout in the Mad River may be a combination of fluvial and resident fish (WDFW 1992). Bull trout may also spawn in Tillicum Creek (a tributary to the lower Mad River) (WDFW 1998). Additional survey information is needed to characterize the current use and potential importance of Tillicum Creek within the Mad River.

Methow Core Area. Bull trout are known to occur in Gold Creek, Twisp River, Chewuch River, Wolf Creek, Early Winters Creek, Upper Methow River, Lost River, and Goat Creek. The Washington Department of Fish and Wildlife classifies the status of bull trout in the Lost River as “Healthy,” but the remaining bull trout in the Methow River are classified as “Unknown” (WDFW 1998). Within the Methow River, adfluvial, fluvial and resident life history forms are present. The resident form is usually found in portions above passage barriers and the distribution and abundance of the resident form is a research need. Sporadic and incomplete redd surveys have been conducted in selected areas of the Methow River basin since 1992.

Gold Creek

The lower Methow River (below the town of Carlton) is an important spawning area for summer chinook and steelhead as well as for bull trout (WSCC 2000). Bull trout most likely use the lower Methow River as a migratory corridor, moving in and out of the Columbia River (DeLaVergne, pers. comm., 2001). Crater Creek, a tributary to Gold Creek, has the only documented fluvial spawning population within the Gold Creek watershed (Table 3) (USFS 1996b). During a 1998 spawning survey, a 15 centimeter (6 inch) dead bull trout was found in Gold Creek (DeLaVergne, pers.comm., 2001). A radio-tagged bull trout was tracked into Libby Creek in 2001, but limited snorkel surveys by the U.S. Forest Service did not result in any bull trout. Additional survey work in the lower Methow River is needed to accurately understand current and potential bull trout distribution.

Beaver Creek

Bull trout in the South Fork Beaver Creek and Eightmile Creek in the Methow system may have been extirpated due to brook trout introgression (WDFW 1998; USFS 1993). However, there may be a few bull trout remaining in Bluebuck Creek and the mainstem of Beaver Creek (USFS *in litt.* 1992; USFS 1993; Proebstel *et al.* 1998).

Twisp River

Bull trout in the Twisp River local population are comprised of migratory and resident forms in mainstem Twisp River, Buttermilk Creek, Bridge Creek, Reynolds Creek, and North Creek. Redd count surveys for migratory adults have been conducted in the mainstem Twisp River since 1992 (Table 3). While older surveys are incomplete, more recent sampling indicates that the mainstem is an important spawning area. Bull trout are known to spawn and rear in the upper reaches of the Twisp River (USFS 1995a). The Twisp River is also an important spring chinook spawning and steelhead spawning and rearing stream. There is considerable spatial and temporal overlap of bull trout, salmon, and steelhead spawning areas in the Twisp River, and consequently some observational error may occur.

Table 3. Bull trout redd survey data in the Methow River 1992 to 2001. Incomplete surveys indicated by asterisk.. (Data provided by the U.S. Forest Service, Wenatchee, WA.)

Local Population	Stream	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Gold Creek	Crater Creek					2*	1	1	0		
Twisp River	Mainstem	3*	5*	4*	18	10*	3	67	38	72	53
	E.F. Buttermilk				4*	0*	0	0	0	0	3
	Reynolds	1*				0*					
	North							19	63	33	0
Chewuch River	Lake Creek				22	13*	9	9	0	12	23
Wolf Creek	Mainstem					7	3	27	29	15	20
Early Winters	Mainstem					9*	0*	2	0	3	5
	Cedar Creek					1	2*		0		
Upper Methow River	West Fork				27	10	13*	11*	1	2	19
Goat Creek	Mainstem				0					11	
Lost River	Mainstem	5*		0				0			
	Monument Creek	2*	0								

Buttermilk Creek may be an important spawning and rearing stream for bull trout. Bull trout are found throughout the mainstem to at least river kilometer 8 (river mile 5). Bull trout also inhabit the first 11 kilometers (6.8 miles) of the East Fork and 7.9 kilometers (4.9 miles) of the West Fork (DeLaVergne, pers. comm., 2001). Both fluvial and resident bull trout have been located in the Buttermilk Creek drainage (WDFW 1998). Four redds were found during surveys on the West Fork in 1995 (DeLaVergne, pers. comm., 2001). Additional survey information is needed to delineate bull trout distribution within Buttermilk Creek.

Reynolds Creek is used by both resident and fluvial fish, with the distribution of fluvial fish limited below a barrier falls at river kilometer 1.1 (river mile 0.7) (WDFW 1998). Spawning occurs between the falls and U.S. Forest Service Road number 4430, with a single redd observed in 1990 and 1992 (DeLaVergne, pers. comm., 2001; WDFW 1998). Resident-sized bull trout have also been located in North Creek, but their distribution and status is unknown (WDFW 1998).

Wolf Creek

The Wolf Creek local population is an important spawning and rearing stream for migratory bull trout. Distribution within the watershed extends up to approximately river kilometer 18 (river mile 11 mile) where a natural rock and log barrier blocks upstream passage. Only westslope cutthroat (*O. Clarki lewisi*) have been found above the rock barrier (USFS 1995b). Redd counts have been conducted in the mainstem since 1996 and the population appears to be highly variable (Table 3). From 1999 to 2001, adfluvial sized bull trout were seen at the base of these falls and within the surveyed spawning reach (DeLaVergne, pers. comm., 2001). Resident bull trout have also been located in Wolf Creek (WDFW 1998).

Chewuck River

The Chewuck River local population currently consists of bull trout in Lake Creek. Bull trout in Lake Creek (Upper Chewuck River) are thought to be an adfluvial population inhabiting Black Lake (DeLaVergne, pers. comm., 2001). Redd surveys conducted since 1995 are low and highly variable (Table 3). Above Black Lake, bull trout have been observed in Lake Creek up to Three Prong Creek (USFS 1995c). Additional surveys are needed to determine distribution upstream of Three Prong Creek. Bull trout have also been observed in Black Lake during a survey conducted by the U.S. Forest Service (USFS 1994). A few bull trout (possibly of fluvial origin) have been caught in the lower and middle reaches of the Chewuck River, and occasionally show up in the Methow Salmon Hatchery fish trap (WDFW 1998; DeLaVergne, pers. comm., 2001). In 2001, bull trout redds were seen in the Chewuch River near Thirty Mile Creek (De La Vergne, pers. comm., 2002). Historically, Eightmile and Boulder Creeks may have supported bull trout (USFS 1994).

Upper Methow River

The Upper Methow River local population includes the West Fork of the Methow River, Trout Creek, Robinson Creek, and Rattlesnake Creek. There are resident and fluvial life-history forms present in the Upper Methow River local population. Redd surveys in the West Fork Methow have been conducted since 1995 (Table 3). The redd counts are highly variable ranging from 1 redd in 1999 to 27 redds in 1995. Surveys have been inconsistent and the available information indicates that the West Fork Methow is not in a secure condition (USFS 1998a). A few bull trout have been observed spawning in the lower portions of Trout Creek (WDFW 1998). While bull trout have not been documented in Robinson or Rattlesnake Creeks, the lower portions of these systems are accessible to bull trout and may provide additional spawning habitat (DeLaVergne, pers. comm., 2001).

Goat Creek

Little survey work has been conducted in the Goat Creek local population, however, 11 migratory bull trout redds were found during surveys in 2000, and this may be an important spawning area (DeLaVergne, pers. comm., 2001). The watershed contains both resident and fluvial fish, but the status of each life-history form is unknown (USFS 1995d). The resident bull trout component was determined through size at maturity of females (WDFW 1998).

Early Winters Creek

Bull trout in the Early Winters Creek local population apparently continue to exist in very low numbers (Table 3). The Early Winters Creek local population includes the mainstem, Cedar Creek, and Huckleberry Creek. Incomplete redd surveys in the mainstem have been conducted since 1995, with a high redd count of nine occurring in the same year. Redd surveys are conducted from Klipchuck Campground up to the falls at river kilometer 13 (river mile 8.0) near the crossing of Highway 20. The falls are thought to be a barrier to chinook salmon and steelhead. Migratory-sized bull trout were found above the falls during recent electrofishing surveys by the U.S. Fish and Wildlife Service (DeLaVergne, pers. comm., 2001). Resident bull trout are known to be above these falls and are thought to spawn in the upper reaches (WDFW 1998).

Cedar and Huckleberry creeks are tributaries to Early Winters in the lower reaches of stream. Two and one bull trout redds were found during incomplete redd surveys in Cedar Creek during 1996 and 1997, respectively (USFS 1998a). In 1988, the Washington Department of Fish and Wildlife estimated the population to be 4 fish per 100 square meters (WDFW 1998). The location of spawning is thought to occur below a falls on Cedar Creek at about river kilometer 4 (river mile 2.4) (WDFW 1998). While bull trout have access to Huckleberry Creek, it is unknown if bull trout use this area for spawning, and additional survey information is needed.

Lost River

The Lost River local population may be represented by resident, fluvial, and adfluvial forms (USFS 1999c). In 1993, the Washington Department of Fish and Wildlife estimated the bull trout population size in the Lost River to be 1,092 fish (WDFW 1998). This estimate did not distinguish between resident and migratory life-history forms and was based on a catch per unit effort of 210 fish per mile. Timing and distribution of bull trout migration in the Lost River is unknown. Many holding areas in the upper Lost River and near the outlet of Cougar Lake were identified during snorkel surveys conducted by U.S. Fish and Wildlife Service and U.S. Forest Service (DeLaVergne, pers. comm., 2001). Other information indicates that the current population of bull trout in the Lost River is most likely greater than 500 adults (DeLaVergne, pers. comm., 2001). This number includes the populations in Cougar Lake, First Hidden Lake, and Middle Hidden Lake, as well as fish downstream of the gorge. Migratory bull trout redd surveys in the Lost River are incomplete and surveys are complicated due to the inaccessibility of stream reaches and rough terrain (Table 3).

Intermittent connectivity exists between headwater lakes during spring runoff and early summer. Downstream connectivity is also intermittent between the lakes and the mainstem Lost River. The Lost River periodically goes subsurface near the downstream end of the gorge above Monument Creek. Currently in the Lost River, spawning seems to be occurring upstream of the gorge and in Monument Creek (WDFW 1998; DeLaVergne, pers. comm., 2001).

Mainstem Columbia River. In 2001, Chelan County Public Utility District began a radio telemetry study of 39 bull trout captured at Rock Island (7 fish), Rocky Reach (22 fish), and Wells (10 fish) Dams (Kreiter 2001). Fish were released upstream and downstream at each facility. All bull trout released downstream moved back upstream, and those released upstream continued moving upstream. Tagged bull trout have been located in the Wenatchee River mainstem (4), Icicle Creek (1), Peshastin Creek (1), Chiwawa River (1), Entiat River mainstem (6), Mad River (7), Methow River mainstem (3), and Methow River tributaries Libby Creek (1), Twisp River (10) , and Twisp River tributary Buttermilk Creek (1). Some bull trout were tracked moving up more than one of the mainstem dams. One of the tagged bull trout ventured into the Okanogan River, but left shortly after detection, and immigrated into the Methow River. In 2002, one bull trout was detected near the I-90 Highway bridge near Vantage, Washington (DeLaVergne, pers. comm., 2002)

In 2000, during a U.S. Fish and Wildlife Service bull trout radio telemetry study in the Wenatchee River, movements of two bull trout were monitored in the Chiwawa River and Rock Creek during the spawning migration (USFWS 2000a; 2001). After spawning, the tagged fish moved downstream and overwintered most likely in the mainstem Columbia River. In 2001, these bull trout migrated back to the Chiwawa River and Rock Creek. Further mainstem and tributary studies are needed to elucidate movements and habitat requirements of adult and subadult bull trout in the recovery unit.

REASONS FOR DECLINE

Within the Upper Columbia Recovery Unit, historic and current land use activities have impacted bull trout local populations. Some of the historic activities, especially water diversions, hydropower development, forestry, and agriculture within the core areas, may have significantly reduced important fluvial populations. Lasting effects from some, but not all, of these early land and water developments still act to limit bull trout production in core areas. Threats from current activities are also present in all core areas of the Upper Columbia Recovery Unit. Below, we discuss the historic and current human-induced limiting factors to bull trout.

Dams

Mainstem Columbia River dams (Rock Island, Rocky Reach, and Wells) have significantly altered historic habitat conditions within the recovery unit. Dams on the Columbia River can effect salmonids by delaying or impeding migration of adults and by injuring or killing juveniles that pass downstream. In 2000, the U.S. Fish and Wildlife Service issued a Biological Opinion on the Effects to Listed Species from Operations of the Federal Columbia River Power System (USFWS 2000b). Effects of the Federal Columbia River Power System included: 1) fish passage barriers and entrainment, 2) inundation of fish spawning and rearing habitat, 3) modification of the streamflow and water temperature regime, 4) dewatering of shallow water zones during power operations, 5) reduced productivity in reservoirs, 6) gas supersaturation of waters downstream of dams, 7) loss of native riparian habitats, 8) water level fluctuations interfering with establishment of riparian vegetation along reaches affected by power peaking operations, and 9) establishment of non-native riparian vegetation along affected reaches. Similar effects most likely occur with the operation of Rock Island, Rocky Reach, and Wells Dams within the Upper Columbia Recovery Unit. Recent information indicates that adult bull trout do use the mainstem Columbia River for foraging, overwintering, and as a migrational corridor. The operation of each facility, and potential impacts to bull trout, need additional investigation.

Historically, dams on the major tributaries in the Upper Columbia Recovery Unit probably contributed to the decline in bull trout by blocking migratory corridors, and restricting connectivity to upstream spawning areas and downstream overwintering areas. Large dams for generating power and dams for irrigation water were located on the mainstem Wenatchee, Entiat, and Methow Rivers (Bryant and Parkhurst 1950). Fish movements were blocked for several years in the late 1800's and early 1900's in each of these major tributaries. Migrations to and from the Columbia River would have been blocked, and long-term effects to life-history patterns is unknown.

Within the Wenatchee River system, Dryden Dam at river kilometer 28.3 (river mile 17.6) was constructed in 1908. Originally designed for power production, the facility is currently used as a water diversion structure to provide water to the Wenatchee Reclamation District Canal and to the Washington Department of Fish and Wildlife for fish rearing. Tumwater Dam at river kilometer 51.5 (river mile 32) was constructed in 1909. Both Dryden and Tumwater dams were reladdered with vertical slot fishways in 1986 and 1987. Two radio-tagged bull in the Chiwawa River have been tracked moving downstream past the dams in 2000 and 2001, and returning upstream in 2001 (USFWS 2000a; 2001). Some concern exists regarding the operation of each facility and the possible delaying of bull trout migration.

The Leavenworth National Fish Hatchery has blocked upstream fish passage in Icicle Creek at river kilometer 4.5 (river mile 2.8) since 1941. As part of the “Icicle Creek Restoration Project” the U.S. Fish and Wildlife Service has proposed to improve fish passage through Icicle Creek, and to improve habitat conditions adjacent to the hatchery (USFWS 2002). A natural boulder barrier exists upstream of the hatchery at river kilometer 8.9 (river mile 5.5) and it is unknown whether fish can negotiate upstream passage.

In 2001, the Washington Legislature approved a $250,000 grant to undertake a water storage feasibility study on Lake Wenatchee in the Wenatchee River basin (Partridge, *in litt*., 2001). The Legislature acted upon recommendations of the State's Water Storage Task Force to study the issue of water storage across the State. If a project is implemented, it would involve construction of a dam on the Wenatchee River downstream of Lake Wenatchee. The project would flood the lower parts of the Little Wenatchee and White Rivers, and possibly Nason Creek, depending on the location of the dam. Project effects to the lake ecosystem, including lake productivity, predator and prey population dynamics, and habitat suitability are unknown. The majority of the bull trout in the Wenatchee basin migrate between Lake Wenatchee and the Chiwawa River for spawning. Juveniles moving into the lake for rearing, and spawning adults, would need to migrate over the dam and up its ladder. Construction of a new dam in important bull trout spawning, rearing, and migratory habitat is a significant concern. Evaluation of the proposed dam, and potential negative impacts to bull trout, will be reviewed by the U.S. Fish and Wildlife Service under section 7 of the Endangered Species Act.

Summary of Dam Effects

Continued research into the operation of mainstem Columbia River dams and their effect on bull trout is needed in the Upper Columbia Recovery Unit. Studies should address concerns and potential limiting factors similar to those identified by the U.S. Fish and Wildlife Service in the "Biological Opinion on the Effects to Listed Species from Operations of the Federal Columbia River Power System." Passage and habitat improvement measures recommended in the Final Environmental Impact Statement on the "Icicle Creek Restoration Project" need to be implemented to address concerns at Leavenworth National Fish Hatchery. In addition, the potential use of Icicle Creek by migratory bull trout is considered a research need. Research on the continued operation of Tumwater and Dryden Dams is needed to ensure that these facilities do not inhibit bull trout passage. The proposed construction of a water storage facility on Lake Wenatchee should be scrutinized through section 7 consultation to ensure consistency with goals, objectives, and recovery criteria identified in the Upper Columbia Recovery Unit Plan.

<u>Forest Management Practices</u>

Both direct and indirect impacts from timber harvest have altered habitat conditions in portions of the Upper Columbia Recovery Unit. Impacts from timber harvest management included the removal of large woody debris, reduction in riparian areas, increases in water temperatures, increased erosion, and simplification of stream channels (Quigley and Arbelbide 1997). Past timber harvest practices include the use of heavy equipment in channels, skidding logs across hillslopes, splash damming to transport logs downstream to mills, and road construction. Today the legacy of these activities still persists where roads, channel changes, and compaction of hill slopes remain.

The aquatic assessment portion of the Interior Columbia Basin Ecosystem Management Project provided a detailed analysis of the relationship between road densities and bull trout status and distribution (Quigley and Arbelbide 1997). The assessment found that bull trout are less likely to use streams for spawning and rearing in highly roaded areas, and were typically absent at mean road densities above 1.1 kilometer per square kilometer (1.7 miles per square mile). Road construction and maintenance can effect bull trout habitat when sedimentation, channel connectivity, high erosion and slope hazards, culvert sizes, and access are not addressed concurrently with land management proposals. Roads can promote simplification and channelization, which reduce the connectivity of surface and ground waters.

Wenatchee Core Area. In the Wenatchee River, natural channel complexity and riparian conditions have been altered over time by past timber-related activities (WSCC 2001). These activities have resulted in reduced riparian and wetland connectivity, reduced high flow refuge habitat, reduced sinuosity and side channel development, increased bank erosion, reduced large woody debris, and reduced pool frequency. Road construction associated with timber harvest adjacent to streams or rivers has resulted in the straightening of stream channels, alteration of stream gradients, decreased gradients, and an overall change in habitat type (USFS 1999a).

High road densities within certain portions of U.S. Forest Service lands in the Wenatchee River basin may contribute to habitat degradation (USFS *in litt.* 2002). Areas of special concern, where road densities need to be reduced, include: Lower Chiwawa River, Middle Chiwawa River, Lake Wenatchee, Lower White River, Lower Little Wenatchee, Upper Little Wenatchee, Lower Nason Creek, Upper Nason Creek, the headwaters of Nason Creek, Wenatchee River (Upper, Middle, and Lower portions), Lower Icicle Creek drainage, and Peshastin Creek.

Entiat Core Area. Fish habitat in the lower Entiat River (Deposition Zone) has been impacted by human activity. Channelization, bank stabilization, and wood removal has resulted in a wider than natural, simplified channel with a loss of pool habitat, large pools, cover, and off-channel habitat (WSCC 1999). Large pool habitat has declined by 88 percent between surveys in 1935 - 1937, and in 1990, 1994, and 1995 (USFS 1998b). Agricultural development precludes future wood recruitment and development of off-channel habitat. Juvenile bull trout are often positively associated with cover; lack of suitable rearing habitat negatively impacts bull trout (Hillman and Miller 1993; 1994; 1995; Reiman and McIntyre 1993). Water temperatures in the Deposition Zone are higher than generally accepted for bull trout rearing habitat. The degree to which artificial widening and channelization have contributed to elevated temperatures is not known. Much of the Deposition Zone of the Entiat River may never have had temperatures conducive to juvenile rearing. The habitat simplification may have had a greater effect on adult bull trout given the preference of adult fish for pool habitat.

The Transition Zone of the Entiat River has not been impacted to the degree as the Deposition Zone. Bull trout spawning has been documented in the Transition Zone. The river has not been channelized, but salvage logging and stream clean-out after the 1970 fires has removed in-channel wood and diminished the potential for future wood recruitment. A comparison of 1935 to 1937 surveys with 1990 to 1994 surveys in the Entiat River shows large pool habitat has decreased by 31 to 60 percent (USFS 1996a).

Loss of pools in the lower Mad River and mainstem Entiat River may have had an adverse effect on adult bull trout. Habitat diversity is provided by plunge pools and pocket pools in riffles that are formed by boulders and wood (USFS 1996a). There has been a history of wood removal in the 1970's in the Mad River, and during the 1994 Tyee Fire, wood in the channel was "bucked" during suppression. Bucking the in-channel wood destabilized some known spawning gravel. Most management activity (*e.g.*, timber harvest) in the Mad River has occurred in the headwaters of tributary streams.

High road densities within portions of U.S. Forest Service lands in the Entiat River basin may contribute to habitat degradation (USFS *in litt.* 2002). Areas of special concern, where road densities need to be reduced, include: Lower Entiat River, Middle Entiat River, Lower Mad River, Middle Mad River, and the Upper Mad River.

Methow Core Area. In the Methow River area, roads that accessed timbered lands are located in the narrow floodplains, with extensive networks in the Twisp watershed including sensitive bull trout tributaries (*e.g.*, Little Bridge and Buttermilk Creeks). A similar situation exists in Lake Creek in the Chewuch watershed (WSCC 2000). This road location practice can result in multiple impacts. Ground-based skidding is still a common practice on the private lands in these watersheds and can be a significant source of sediment.

High road densities within portions of U.S. Forest Service lands in the Methow River Core Area may contribute to habitat degradation (USFS 2002; 2001a; 2001b). Areas of special concern, where road densities need to be reduced, include: Lower Methow River, Chewuch River, and Goat Creek.

Summary of Forest Management Practices Effects

A detailed analysis of road impacts, including elevated sediment delivery and instream habitat alteration, needs to be developed for the Upper Columbia Recovery Unit. Recommendations for road repair or decommissioning should be prioritized based on the location of sensitive bull trout local populations. Areas within the Upper Columbia Recovery Unit that support strong bull trout populations and are currently in a low road density or "unroaded" condition should be maintained. Road densities in bull trout watersheds that exceed 1.1 kilometer per square kilometer (1.7 miles per square mile) should be reduced. Restoration activities should be initiated to increase the quality of spawning and rearing habitat in bull trout local populations.

The Upper Columbia Recovery Unit Team recommends the development and implementation of guidelines for bull trout that would provide for high quality habitat conditions. These guidelines would also provide for consistency in identifying areas for restoration throughout the recovery unit. Current forest practice regulations should be evaluated to determine effectiveness in key habitat areas. Establishment of new forest practices rules should include detailed monitoring and enforcement components.

Road management on non-Federal forested lands falls under State forest and fish regulations when associated with timber management. Efforts should be made to encourage Habitat Conservation Plan development in areas where effects to bull trout may occur from land management activities. In the Upper Columbia Recovery Unit, areas in the Wenatchee River (*e.g.,* White River, Nason Creek, and Peshastin Creek), Entiat (lower Mad and Entiat rivers), and in the Methow River (*e.g.,* lower portions of Gold Creek, Wolf Creek, Early Winters Creek, lower Chewuch River, and lower Twisp River) should be considered the highest priority areas for Habitat Conservation Plan development, conservation agreements, and land exchanges.

Livestock Grazing

Historically, grazing of cattle, horses, and sheep has occurred throughout the Upper Columbia Recovery Unit (USFS 1999a; 1998c; 1996a; and WSCC 1999; 2000; 2001). Annual operating plans are usually drawn up for each allotment, and continued monitoring of these allotments is necessary to ensure compliance with the Endangered Species Act and Forest Plan Standards and Guidelines. Concerns associated with grazing include water withdrawals, loss of riparian vegetation, and redd trampling.

Methow Core Area. Over 60 percent of the private bottom lands in the Methow River area have erosion problems related to grazing (USFWS 1992). Cattle have access to the main channels and eroded stream banks (and associated sediment inputs) are an existing problem. Of specific concern are riparian areas adjacent to the Twisp River, lower Wolf Creek, Upper Methow River, Chewuch River, Buttermilk Creek, Gold Creek, and Goat Creek (USFWS *in litt.* 1998b). Impacts from grazing need to be evaluated in these and other areas, and where appropriate, corrective measures should be instituted. Future livestock grazing plans should include actions to reduce impacts (*e.g.,* riparian fencing) and should adaptively manage allotments to ensure quality habitat conditions. The development of these plans should be coordinated with conservation districts, counties, and private landowners.

Agricultural Practices

Irrigation Diversions

Irrigation diversions can result in passage barriers by creating structural blockages, reducing or dewatering stream flows, and increasing water temperatures. Decreased stream flow and high temperatures can create barriers to upstream habitat and poor habitat conditions. High temperatures can result in negative effects to foraging and migrational patterns. Historically, there were many irrigation diversions in the Upper Columbia Recovery Unit that may have totally or partially blocked migrating fish (USFWS 1992). Other irrigation diversions, although not located in bull trout spawning streams, remove instream flow and may impact important foraging and high water refuge habitat. Future watershed studies should address potential impacts to bull trout from reduced instream flows and changes in downstream habitats.

Wenatchee Core Area. The Peshastin Irrigation District operates an irrigation diversion dam that presents a barrier to summer and fall migration, partially blocking migrating spring chinook salmon and migrating bull trout. In low water years, the stream directly downstream of the diversion is dewatered for 100 feet during late summer, completely blocking all fish passage (USFS 1998d). In October 2001, several large salmonids, including a large adult bull trout and a large rainbow/steelhead, were found dead at the screening structure by a Washington Department of Fish and Wildlife biologist (DeLaVergne, pers. comm., 2001). An assessment of the structure needs to occur to determine how effective it is at reducing impacts to bull trout.

The Tandy irrigation ditch is located upstream of the Peshastin Irrigation Ditch diversion about one-half mile. The ditch is screened; however, the effects to bull trout from water diversion and instream flow manipulation of the ditch channel are unknown. Similarly, Mill Creek (tributary to Peshastin Creek) has multiple irrigation diversions and the impact to bull trout is also unknown. Numerous unnamed intermittent tributaries exist in Lower Peshastin Creek that have irrigation diversions, and effects of these on bull trout are unknown. Diversion dams can limit the potential to transport wood, sediment, water, and nutrients during spring run-off and winter and summer storm events (USFS 1999d). Diversion dams may also limit high flow refuge habitat for rearing subadult or adult bull trout during certain times of the year.

In Icicle Creek, the water diversion dam for the Leavenworth National Fish Hatchery and the Cascade Orchards Irrigation District intake, blocks fish passage at low flows and is improperly screened (USFWS 2002). During drought years, the stream is dewatered from the diversion downstream to the fish hatchery. Upstream, the Icicle/Peshastin Irrigation District water diversion also has an instream structure that may impact bull trout migration. The screens at the Icicle/Peshastin Irrigation District diversion do not currently meet National Marine Fisheries Service and U.S. Fish and Wildlife Service criteria, and need to be updated. Within Icicle Creek, diversions for irrigation, hatchery operations, and municipal use remove significant portions of water during August, September, and October (USFWS 1992). Low flows in the lower reach are the result of natural conditions compounded by public water supply needs, irrigation diversions, and the fish hatchery diversions (Hindes 1994).

Within the upper Wenatchee River, there are several water diversions and a diversion dam located on Chiwaukum Creek (USFS 1999b). It unknown whether these diversions meet National Marine Fisheries Service and U.S. Fish and Wildlife Service screening criteria. The Chiwawa Irrigation District water diversion is located at river kilometer 5.8 (river mile 3.6) on the Chiwawa River and can divert up to 0.94 cubic meters per second (33.3 cubic feet per second), but more commonly diverts 0.3 to 0.4 cubic meters per second (12 to 16 cubic feet per second) (USFS 1999b). The diversion is screened (updated in the mid 1990's), but it is unclear if the screen meets the National Marine Fisheries Service and U.S. Fish and Wildlife Service fish screen criteria, or how the altered flow regime may effect rearing or subadult fish. The U.S. Forest Service and the Chiwawa Irrigation District currently monitor flows and temperatures above and below the diversion to determine impacts to aquatic habitat.

A diversion in the upper Chiwawa River in Phelps Creek is located within spawning and rearing habitat (USFS 1999b). The Trinity water diversion is located approximately 1.2 kilometers (0.75 miles) upstream of the 2.4 meter (8 foot) natural falls at river kilometer 0.6 (river mile 1.0), which blocks upstream fish passage. Bull trout have not been found in the area of the diversion headgate structure, but have been located spawning within the return channel from the settling ponds and in Phelps Creek below the falls. The Trinity diversion is currently being relicensed under Federal Energy Regulatory Commission. It is unknown how the changes in instream flows affect rearing and spawning bull trout downstream in Phelps Creek.

Entiat Core Area. Currently, there are no identified passage barriers for bull trout in the Entiat Core Area. The McKenzie Irrigation Diversion was modified in 1994 to be fully passable at all flows. However, the Entiat River has been listed on the 303d list for instream flow deficiencies, high stream temperatures, and exceeding pH standards (USFS 1996a). Natural low summer flows in the Entiat River may be exacerbated by irrigation withdrawals, and plans should be developed to minimize potential impacts to the migratory corridor.

Methow Core Area. In the Twisp watershed, the mainstem Methow River, Little Bridge Creek, and East Fork Buttermilk Creek have full or partial barriers. There is a diversion dam across the Twisp River on non-Federal land at approximately river kilometer 8 (river mile 5) and is used by the Twisp Power

Irrigation Ditch and the Washington Department of Fish and Wildlife for adult chinook brood stock collection (WSCC 2000). It is assumed that this dam does not impede passage, but further investigation of the diversions operation is needed to verify suitable passage conditions.

Prior to 1999, two irrigation dams on Little Bridge Creek were partial passage barriers to bull trout. Both structures have been improved in an attempt to pass fish, but current effects of the diversion dams need to be evaluated. Bull trout have been observed in the lower 2 miles of Little Bridge Creek between the lower and upper diversions (WSCC 2000). No bull trout have been seen above the upper irrigation dam barrier which may still impede adult bull trout migration during the spawning season. Other irrigation withdrawal points that may impact bull trout as passage barriers or by contributing to low instream flow problems include:

1. The Eightmile Ranch Ditch is owned by the U.S. Forest Service and irrigates pasture for horse and mule stock (WSCC 2000).

2. The Lucille Mason Ditch located on the opposite bank from the Eightmile Ranch Ditch is adequately screened but contributes to low flow conditions in the Lower Chewuch River (WSCC 2000).

3. Irrigation withdrawal by three diversions (Wolf Creek Reclamation District Irrigation Ditch) operated in the Wolf Creek watershed (including use of Patterson Lake for irrigation storage) may be adversely impacting bull trout (WSCC 2000). The Wolf Creek diversion is one of the largest irrigation ditches in the Methow Valley and has been in operation since 1921.

Dewatering of channels as a result from irrigation or water withdrawals may act as a barrier to bull trout passage. In the Methow basin, the Lost River and the mainstem upper Methow River typically go subsurface. Ground water and irrigation withdrawals may have a compounding effect on maintaining perennial flows. Where subsurface flows are natural, the condition may be exasperated by instream and aquifer withdrawals. Specific areas of concern include: Lower Early Winters Creek, Methow River from Robinson Creek to Weeman Bride, Lost River, Wolf Creek, Twisp River, and Gold Creek.

Summary of Agricultural Practices Effects

Irrigation withdrawal in the Wenatchee River may have localized effects on local populations within the core area. A basin-wide study in the Wenatchee Core Area is needed to determine impacts to bull trout migration, spawning, rearing, and foraging habitat. The Upper Columbia Recovery Unit Team also recommends that instream flow assessments be conducted in areas where irrigation withdrawals could potentially impact bull trout. As part of the final Environmental Impact Statement for the "Icicle Creek Restoration Project," the preferred alternative for correcting passage problems should be implemented (USFWS 2002).

The current pattern of irrigation withdrawal within the Methow Core Area represents an impediment to bull trout recovery, and the development of a coordinated basin-wide approach to water management is needed. A specific limiting-factors analysis is needed to identify barriers that prevent passage or entrain bull trout. Overall, the Upper Columbia Recovery Unit Team recommends that Habitat Conservation Plans be developed in the Methow Core Area to address bull trout instream flow, passage, and entrainment issues. This effort should be coordinated with salmon and steelhead planning processes to limit overlap and development costs.

Mining

Mining can degrade aquatic habitats used by bull trout by altering water chemistry (*e.g.*, pH); altering stream morphology and flow; and causing sediment, fuel, and heavy metals to enter streams (Martin and Platts 1981; Spence *et al.* 1996; Harvey *et al.* 1995). Mining activities within Washington State are guided by published rules entitled "Rules and Regulations for Mineral Prospecting and Placer Mining in Washington State" (also known as the "Gold and Fish" pamphlet) (WDFW 1999b). The pamphlet describes streams, timeframes, and equipment that are permitted for small scale prospecting and mining. Currently, small scale recreation gold mining occurs within the Wenatchee River (*e.g.,* Peshastin Creek and Chiwawa River) (USFS 1999a). Cumulative impacts from these operations on water quality should be monitored and evaluated.

The U.S. Forest Service has issued a special use permit in the upper Chikamin Creek drainage for an exploratory mining operation. Bull trout spawn just downstream in Chikamin Creek and hold within the Chiwawa River for most of the year. Given the importance of bull trout in this system, rigorous monitoring of this operation should occur, and potential impacts to this high quality habitat should be evaluated. In addition, the potential for establishing a gold mine in the Twisp River (North Creek) is being considered (DeLaVergne, pers. comm., 2001). The Twisp River is an important local population of bull trout in the Methow River. Future development of this, and other mining operations, should be evaluated relative to possible effects on bull trout populations.

Residential Development and Urbanization

Residential Development

Numerous areas within the Upper Columbia Recovery Unit are experiencing a socio-economic shift from a natural resource based economy reliant on agriculture, forestry, and mining to an economy more dependent on industries associated with tourism, recreation, and general goods and services. Population growth in Chelan and Okanogan Counties have been 27.5 percent and 18.6 percent in the 1990's, respectively (WSOFM 2000). Concern over impacts to bull trout center around the degradation of water quality, instream habitat, and riparian habitat in migratory corridors within the Wenatchee and Methow Rivers (WSCC 2000; 2001; Parametrix, Inc 2000).

Areas of concern in the Wenatchee Core Area include:

1. The Wenatchee River downstream of Leavenworth (loss of side channels, bank revetment, and floodplain development).

2. Wenatchee River through communities of Plain and Ponderosa (degraded water quality due to improperly functioning septic systems).

3. Peshastin Creek (below Ingalls Creek confluence, the natural channel and floodplain function has been disturbed due to channel constriction and confinement).

4. Icicle Creek (lower portion of the river has been impacted from loss of riparian vegetation, bank hardening, and residential development).

5. Nason Creek (lower Nason Creek impacts include channel confinement, removal of riparian vegetation, and reduction in large woody debris recruitment).

6. White River (below Panther Creek impacts due to loss of riparian and large woody debris recruitment).

7. Lake Wenatchee (shoreline development and associated loss of riparian vegetation, increased nutrient loading, and inadequate sewage treatment).

Areas of concern in the Methow Core Area basin include:

1. Early Winters Creek (riprap and diking of the lower 0.5 miles).

2. Mainstem Methow River (bank erosion and loss of vegetation from the Early Winters Creek confluence downstream to Mazama).

3. Mainstem Methow River (Wolf Creek confluence bank erosion and loss of vegetation).

Cumulative effects from development within the basin are the greatest concern. Areas identified within this chapter as important habitat (*e.g.*, spawning sites and migrational corridors) for bull trout in the Wenatchee and Methow rivers should be incorporated in Chelan and Okanogan County planning efforts to minimize impacts to bull trout.

Recreational Development

Campgrounds, trails, and other recreational development in the Upper Columbia Recovery Unit frequently overlap areas of bull trout spawning, juvenile rearing, and adult migration (USFS 1999a; 1999b; 1996a). Impacts of these recreational developments can include reduction in large woody debris and its recruitment, loss of riparian vegetation, and diking or bank hardening to protect campgrounds. These developments can also increase stream access, which can lead to poaching of bull trout. In many cases, the U.S. Forest Service is beginning to take action to move campgrounds away from streams. Studies to evaluate impacts and recommend corrective actions where necessary need to be initiated, and should focus on sensitive bull trout areas including: Tumwater Campground at the confluence of Chiwaukum Creek and the Wenatchee River, Nason Creek Campground, Riverside Campground on the Little Wenatchee River, dispersed sites on the Little Wenatchee River, Pine Flat Campground on the Mad River, Roads End Campground on the Twisp River, and dispersed camping sites on the Chiwawa River.

<u>Fisheries Management</u>

Nonnative species

Problems with non-native species in the Upper Columbia Recovery Unit focus primarily on brook trout (WSCC 1999; 2000; 2001). Brook trout are well established above Entiat Falls, and have been observed at lower levels below the falls (WDFW 1998; USFS 1996a; WSCC 1999). The presence of this strong brook trout population directly upstream of the primary bull trout habitat in the Entiat River is a concern.

In the Wenatchee River, a major concern is presence of brook trout in the Chiwawa River including Chikamin and Big Meadow creeks (USFS 1999b). The introduction of brook trout into Schaefer Lake in the 1940's was most likely the source population. Efforts to eradicate brook trout from Schaefer Lake have been unsuccessful. Given the importance of the Chiwawa River system to bull trout, the potential for brook trout to invade additional areas is a concern.

Brook trout are widespread within the Methow River and the potential for introgression with bull trout is a concern (NPPC 2001c). Brook trout are well established in Beaver and Eightmile Creeks and are thought to have resulted in the loss of bull trout from these systems (WDFW 1998). Brook trout are also known to inhabit portions of the Twisp River (NPPC 2001c). Additional survey work is needed to verify the distribution of brook trout within the basin, assess potential impacts, and recommend corrective actions.

Harvest

Currently, the harvest of bull trout is prohibited on all stocks in the Upper Columbia Recovery Unit with the exception of the Lost River in the Methow drainage. Fishing may have been a factor leading to the decline of bull trout in the Upper Columbia Recovery Unit. Certain areas within the recovery unit (*e.g.*, Lake Wenatchee) were targeted bull trout fisheries, and large numbers of bull trout were harvested (WDFW 1992). Bull trout were rarely targeted in the mainstem Entiat but may have been harvested incidentally in trout fisheries, especially when hatchery rainbows were planted. Hatchery trout have not been stocked since 1996. With the cessation of stocking in the Entiat, selective fishery regulations, and the closure of steelhead fishing, incidental harvest should be reduced. However, bait fishing is legal in some areas, and may result in incidental hooking mortality. It is suspected that a few anglers (and poachers) may still target bull trout in certain areas of the Mad and Methow Rivers (DeLaVergne, pers. comm., 2001).

The Lost River above Drake Creek is the only area within the recovery unit open to bull trout harvest (WDFW 1998). The abundance of bull trout in this area (210 catchable-sized fish per mile) was thought to be sufficient to allow retention of bull trout as part of a two fish catch limit. Fishery rules include a bait prohibition and a 36 centimeter (14 inch) minimum size intended to permit most females to spawn at least once. Angling is minimized by the lack of direct access to the lower end of this reach. The canyon reach is accessible only in late summer when stream flows recede enough for fording. Almost no fishing occurs in this reach. Some fishing occurs below Cougar Lake, in the vicinity of the horsecamp around Diamond Creek, and in the area just above the mouth of Drake Creek. Due to the importance of bull trout in the Lost River, the fishery should be intensively monitored to gage its impact on bull trout.

Although fishing regulations for bull trout have been restricted, there are still some current regulations that may cause incidental take of bull trout. Incidental catch of bull trout during otherwise lawful fishing seasons has been raised as a concern in Lake Wenatchee, the Lost River, and portions of the Chiwawa River (DeLaVergne, pers. comm., 2001). Incidental catch during open seasons for mountain whitefish (*Prosopium williamsoni*) has also been implicated as a possible source of bull trout mortality in the Wenatchee, Entiat, and Methow Rivers. In addition, harvest of bull trout may occur within their range due to misidentification. Schmetterling and Long (1999) found that only 44 percent of anglers correctly identified bull trout, and anglers frequently confused related species. Resource managers should cooperatively analyze available information on incidental take, misidentification of bull trout, and instream disturbance and suggest corrective measures when warranted (*e.g.,* selective gear restrictions and modifying timing of fishing seasons).

Eggs and alevins in redds are vulnerable to wading-related mortality during the incubation period. Under Statewide regulations most streams are open June 1 through October 31. Most bull trout in this recovery unit spawn during September and October. Egg mortality of up to 46 percent can occur from a single wading event (Roberts and White 1992).

Forage (Prey) Base

Throughout the Upper Columbia Recovery Unit there have been declines in the numbers of native salmonids. Both spring chinook salmon and steelhead are listed under the Endangered Species Act in this area, and with few exceptions, continue to exhibit low abundances. In addition to decreasing the forage base for bull trout, the decline of salmon and steelhead has reduced a historic energy source coming into the basin through the dying and recycling of nutrients from adult carcasses, eggs, and juveniles. Coordination and support of spring chinook and steelhead restoration efforts is important for the success of bull trout recovery in the Upper Columbia Recovery Unit.

Spring Chinook Egg Collection and Captive Broodstock Collection

The collection of Upper Columbia River spring chinook salmon eggs and juveniles occurs in the supplementation and captive broodstock program by the Department of Washington State Fish and Wildlife (WDFW 1999a). This program is in response to projects that were developed as part of the Mid-Columbia River Habitat Conservation Plan with the Chelan and Douglas County Public Utility Districts. In the Wenatchee River, eggs and juveniles are collected in Nason Creek and the White River. Bull trout temporally and spatially overlap spring chinook spawning areas in both of these Wenatchee River tributaries. Future plans have identified possible collection sites in the Methow River. Misidentification of redds may occur in these overlaping spawning areas, resulting in direct bull trout mortality. The possible impact to bull trout needs to be evaluated.

Summary of Fisheries Management Effects

Introduced nonnative brook trout present a definite threat to bull trout in the Upper Columbia Recovery Unit. Impacts to current bull trout local populations need to be evaluated, and where appropriate, management actions should be initiated to reduce brook trout distribution and abundance. Illegal harvest of bull trout is a problem in certain areas within the recovery unit, and increased enforcement of current regulations should be initiated in sensitive bull trout spawning areas. In areas where harvest of bull trout is legal (*i.e.,* Lost River), or where incidental catch of bull trout occurs, impacts to bull trout should be evaluated. If warranted, regulation changes should be enacted to protect sensitive local populations of bull trout. The Upper Columbia Recovery Unit Team recommends coordination and support of salmon and steelhead recovery efforts in order to restore the historic forage base within the recovery unit. Impacts to bull trout from the Spring Chinook Egg Collection program should be evaluated.

Isolation and Habitat Fragmentation

Dikes

In the Methow Core Area, lotic habitats have been fragmented, resulting in loss of floodplain and off-channel habitats that could provide important rearing areas for bull trout (WSCC 2000). Existing dikes in the Methow River that contribute to habitat fragmentation are the McKinney Mountain Dike, People Mover Dike, and the dike on the Lost River. Alteration of habitat from channel modification (*e.g.*, bank revetment and riparian alterations) have disconnected floodplains and impacted normal stream function. Specific areas of concern include: Goat Creek, lower Early Winters Creek, and the Twisp River. A complete review of existing dikes, and the associated deleterious modifications to instream habitat need to be identified, and corrective actions prioritized and implemented.

Road Culverts

Road culverts in watersheds with bull trout can block or impede upstream passage (WSCC 1999; 2000; 2001; NPPC 2001a; 2001b; 2001c). Culverts may preclude bull trout from entering a drainage during spawning migrations, outmigration of juveniles, and foraging activities, and may also limit access to refuge habitat needed to escape high flows, sediment, or higher temperatures. Culverts have been identified as a limiting factor for salmonids in the Methow River basin (NPPC 2001c; WSCC 2000). There is a need for a specific limiting-factors analysis throughout the Upper Columbia Recovery Unit to identify culverts that would impact bull trout recovery. Culverts that have already been identified as possible passage barriers include: Peshastin and Nason Creeks (Wenatchee River); Twisp River, Beaver Creek, Gold Creek, Little Bridge Creek, and East Fork Buttermilk Creek (Methow River).

ONGOING RECOVERY UNIT CONSERVATION MEASURES

The Entiat and Mad Rivers are classified as a “key watersheds” under the Record of Decision for the Northwest Forest Plan. Road restoration work has been on-going in the watershed, particularly in the mainstem and headwaters of Mad River tributaries. As noted previously, the Mad River has been closed to all angling within the range of bull trout, and the Entiat River within the range of bull trout is under selective fishery regulations with no harvest of bull trout allowed. Stocking of hatchery trout has stopped in the mainstem Wenatchee and Entiat Rivers. Specifically, there is no longer an active stocking program for brook trout within the basin.

Currently, timber management on U.S. Forest Service lands is guided by several land management plans. The Northwest Forest Plan is implemented in the Wenatchee River, Entiat River, and the west half of the Methow River (USFS and BLM 1994). Land management activities relative to bull trout in the eastern half of the Methow River are guided by standards contained in INFISH (USFS 1995e). These strategies are overlaid with on-site forest management plans that, when implemented, are designed to reduce impacts to aquatic species, riparian areas, and listed fish.

RELATIONSHIP TO OTHER CONSERVATION EFFORTS

Subbasin Planning

As part of the Pacific Northwest Electric Power Planning and Conservation Act of 1980, the Bonneville Power Administration has the responsibility to protect, mitigate and enhance fish and wildlife resources affected by operation of Federal hydroelectric projects in the Columbia River and its tributaries. The Northwest Power Planning Council develops and implements the Columbia River Basin Fish and Wildlife Program, which is also implemented by the Bonneville Power Administration, U.S. Army Corps of Engineers, and the Federal Energy Regulatory Commission. Coordination of Bonneville Power Administration's responsibilities for protection, enhancement, and mitigation, and incorporation of recommendations by Northwest Power Planning Council, is done in part through the development of subbasin summaries that identify the status of fish and wildlife resources, limiting factors, and recommended actions.

The draft Wenatchee, Entiat, and Methow subbasin summarys were completed in October 2001, and overlap with the Upper Columbia Recovery Unit for bull trout (NPPC 2001a; 2001b; 2001c). Each subbasin summary goal emphasizes the need to maintain, protect, or restore the ecological functions necessary to maintain habitat, increase productivity, and maintain diversity for fish and wildlife resources. Each draft subbasin summary identifies objectives and strategies to deal with degraded habitat and water quality conditions, loss of connectivity due to dams and irrigation withdrawal, introduction of nonnative species, and disruption of normal hydrologic processes that have contributed to the decline of native salmonids. Overall, the identified objectives and strategies dealing with salmonids in the subbasin summarys are consistent with actions identified in the Upper Columbia Recovery Unit Chapter. The Upper Columbia Recovery Unit Team will continue to coordinate with these planning efforts through the development of subbasin plans.

Salmon Recovery Efforts

The National Marine Fisheries Service listed spring chinook and steelhead in 1997 and 1999, respectively, in the upper-Columbia Evolutionarily Significant Units as endangered under the Endangered Species Act. These Evolutionary Significant Units overlap with the Upper Columbia Recovery Unit for bull trout. As part of the recovery planning process for chinook and steelhead, the National Marine Fisheries Service has issued guidance for the technical development of recovery plans (NMFS, *in litt.*, 2001). The framework for steelhead and salmon recovery plan development is divided into distinct geographic areas, or domains that may contain multiple Evolutionarily Significant Units. Recovery plans for listed salmon and steelhead will contain the same basic elements as mandated by the Endangered Species Act, and include: 1) objective measurable criteria, 2) description of site-specific management actions necessary to achieve recovery, and 3) estimates of cost and time to carry out recovery actions. Timeframes for recovery plan development for Upper Columbia River spring chinook and steelhead have not been finalized, but the Upper Columbia Recovery Unit Team will coordinate the implementation of bull trout recovery actions with salmon and steelhead measures to avoid duplication and maximize the use of available resources.

State of Washington

Salmon Recovery Act

The Governor's Office in Washington State has developed a Statewide strategy (WGSRO 1999) that describes how State agencies and local governments will work together to address habitat, harvest, hatcheries, and hydropower as they relate to recovery of listed species. The Salmon Recovery Act, passed in 1998, provides the structure for salmonid protection and recovery at the local level (counties, cities, and watershed groups).

The Salmon Recovery Planning Act of 1998 directs the Washington State Conservation Commission, in consultation with local government and treaty Tribes, to invite private, Federal, State, Tribal, and local government personnel with appropriate expertise to convene as a Technical Advisory Group. The purpose of the Technical Advisory Group is to identify habitat-limiting factors for salmonids. Limiting factors are defined as "conditions that limit the ability of habitat to fully sustain populations of salmon, including all species of the family Salmonidae." The bill further clarifies the definition by stating, "These factors are primarily fish passage barriers and degraded estuarine areas, riparian corridors, stream channels, and wetlands." It is important to note that the responsibilities given to the Conservation Commission in Eng Substitute House Bill 2496 do not constitute a full limiting-factors analysis. This report is based on a combination of existing watershed studies and knowledge of the Technical Advisory Group participants.

Upper Columbia Salmon Recovery Board

The Upper Columbia Salmon Recovery Board is a broad-based partnership group that includes Chelan, Douglas, and Okanogan Counties, the Colville Confederated Tribes, and the Yakima Nation (UCSRB 2001). The Upper Columbia Salmon Recovery Board works in cooperation with local, State, and Federal partners to develop strategies to protect and restore salmonid habitat. The mission of the Upper Columbia Recovery Board is to restore viable and sustainable populations of salmon, steelhead, and other at-risk-species through the collaborative efforts, combined resources, and wise resource management of the Upper Columbia Region. The Upper Columbia Region overlaps with the Upper Columbia Recovery Unit for bull trout, and encompasses the mainstem Columbia River from Rock Island Dam upstream to Chief Joseph Dam, including major tributaries in the geographic area.

Released in July 2001, a discussion draft entitled "A Strategy to Protect and Restore Salmonid Habitat in the Upper Columbia Region" (UCSRB 2001) categorizes watershed habitat conditions and species status within the Upper Columbia Region. The report identifies priority areas in species distribution, needed habitat activities, and identifies general interim goals for each basin. As part of an overall effort, a compilation of limiting habitat factors for salmon, steelhead, and bull trout is being prepared in seven Water Resource Inventory Areas. The limiting habitat factors analysis for the Wenatchee, Entiat, and Methow Rivers is a valuable source of information for the Upper Columbia

Recovery Unit. Coordination with the Upper Columbia River Recovery Board in implementing bull trout recovery actions will be essential in the future.

Washington State Bull Trout Management Plan

The Washington Department of Fish and Wildlife has developed a bull trout management plan that addresses both bull trout and Dolly Varden (*S. malma*) (WDFW 2000). The Washington Department of Fish and Wildlife no longer stocks brook trout in streams or lakes connected to bull trout waters. Fishing regulations prohibit harvest of bull trout, except in a few areas where stocks are considered "healthy" within the State of Washington. The Washington Department of Fish and Wildlife is also currently involved in a mapping effort to update bull trout distribution data within the State of Washington, including all known occurrences, spawning and rearing areas, and potential habitats. The salmon and steelhead inventory and assessment program is currently updating their database to include the entire state; an inventory of stream reaches and associated habitat parameters important for the recovery of salmonid species and bull trout.

Forest Practices

In January 2000, the Washington Forest Practices Board adopted new emergency forest practice rules based on the Forest and Fish Report (WFPB 2000). These rules address riparian areas, roads, steep slopes, and other elements of forest practices on non-Federal lands. Although some provisions of forest practice rules represent improvements over previous regulations, the plan relies on an adaptive management program for assurance that the new rules will meet the conservation needs of bull trout. Research and monitoring being conducted to address areas of uncertainty for bull trout include protocols for detection of bull trout, habitat suitability, forestry effects on groundwater, field methods or models to identify areas influenced by groundwater, and forest practices influencing cold water temperatures. The Forest and Fish Report development process relied on broad stakeholder involvement, and included State agencies, counties, Tribes, forest industry and environmental groups. A similar process is being used for agricultural communities in Washington, and is known as "Agriculture, Fish, and

Water." The Service is considering the possible impacts and potential benefits from both of these State processes relative to bull trout recovery.

Biological Opinion on the Federal Columbia River Power System

On December 20, 2000, the Service issued a biological opinion on the "Effects to Listed Species from Operation of the Federal Columbia River Power System" (USFWS 2000b). The opinion identifies the need for continued research into distribution of bull trout within the mainstem Columbia River. The Biological Opinion recognizes that as recovery actions are implemented, bull trout will likely increase their use of the mainstem Columbia. Reasonable and prudent measures in the Biological Opinion are consistent with primary research needs identified by the Upper Columbia Recovery Unit Team. As recovery proceeds, the need for research to investigate problems associated with fish ladder use, entrainment, spill, flow attraction, and water quality will need to be addressed through the formal consultation process.

Habitat Conservation Plans

The U.S. Fish and Wildlife Service and National Marine Fisheries Service are in the process of preparing an environmental assessment or environmental impact statement related to the proposed approval of a Habitat Conservation Plan and the issuance of an incidental take permit in accordance with section 10(a) of the Endangered Species Act. The permit applicant is Chewuch Basin Council, which is comprised of the three irrigation companies operating in the Chewuch Basin (Chewuch Canal Company, Fulton Ditch Company, and the Skyline Ditch Company). These companies own and operate independent diversion structures, fish screens, irrigation ditches, pipes, canals, and reservoirs, and appurtenant structures located on and adjacent to the Chewuch River in the vicinity of Winthrop, Washington. The application is related to water withdrawals from the Chewuch River located in southern Okanogan County, Washington. The ditch companies intend to request a permit for chinook salmon, steelhead trout, and bull trout. In accordance with the Endangered Species Act, the Chewuch Basin Council will prepare a plan to minimize and mitigate for future watershed management activities within the irrigation reach.

STRATEGY FOR RECOVERY

A core area represents the closest approximation of a biologically functioning unit for bull trout. The combination of core habitat (*i.e.*, habitat that could supply all the necessary elements for the long-term security of bull trout, including for both spawning and rearing, foraging, migrating, and overwintering) and a core population (*i.e.*, bull trout inhabiting a core habitat) constitutes the basic core area upon which to gauge recovery within a recovery unit. Within a core area, many local populations may exist.

For purposes of recovery, the Upper Columbia Recovery Unit has three core areas, including the Wenatchee, Entiat, and Methow Rivers. Although we know bull trout in the Upper Columbia migrate to the Columbia River and back, we do not clearly understand the extent of their use and distribution in the Columbia River mainstem. Factors considered when identifying core areas included: the extent of historic and current migratory connectivity, existence natural barriers, survey and movement data, and genetic information where available. Except where supported by biological or geographic evidence, core areas are considered to be distinct, and their boundaries do not overlap. Additional genetic information within the Upper Columbia Recovery Unit may help refine the current classification.

Within each core area, many local populations may exist. A local population is defined as a group of bull trout that spawn within a particular stream or portion of a stream system. A local population is assumed to be the smallest group of fish that is known to represent an interacting reproductive unit. For most waters where specific information is lacking, a local population may be represented by a single headwater tributary or complex of headwater tributaries. Based on survey data and professional judgement, the Upper Columbia Recovery Team identified 16 local populations in the Wenatchee (6), Entiat (2) and Methow (8) core areas.

Recovery Goals and Objectives

The goal of the bull trout recovery plan is to ensure the long-term persistence of self-sustaining, complex, interacting groups of bull trout distributed across the native range of the species, so that it can be delisted. To achieve this goal, the following objectives have been identified for bull trout in the Upper Columbia Recovery Unit:

- Maintain the current distribution of bull trout and restore distribution in previously occupied areas within the Upper Columbia Recovery Unit.
- Maintain stable or increasing trends in abundance of bull trout.
- Restore and maintain suitable habitat conditions for all bull trout life history stages and strategies.
- Conserve genetic diversity and provide opportunities for genetic exchange.

Rieman and McIntyre (1993) and Rieman and Allendorf (2001) evaluated the bull trout population numbers and habitat thresholds necessary for long-term viability of the species. They identified four elements, and the characteristics of those elements, to consider when evaluating the viability of bull trout populations. These four elements are: 1) number of local populations; 2) adult abundance (defined as the number of spawning fish present in a core area in a given year); 3) productivity, or the reproductive rate of the population (as measured by population trend and variability); and 4) connectivity (as represented by the migratory life history form and functional habitat). For each element, the Upper Columbia Recovery Unit Team classified bull trout into relative risk categories based on the best available data and the professional judgment of the team.

The Upper Columbia Recovery Unit Team also evaluated each element under a potential recovered condition to produce recovery criteria. Evaluation of these elements under a recovered condition assumed that actions identified within this chapter had been implemented. Recovery criteria for the Upper Columbia Recovery Unit reflect: 1) the stated objectives for the recovery unit, 2) evaluation of each population element in both current and recovered conditions, and 3) consideration of current and recovered habitat characteristics within the recovery unit. Recovery criteria will probably be revised in the future as more detailed information on bull trout population dynamics becomes available. Given the limited information on bull trout, both the level of adult abundance and the number of local populations needed to lessen the risk of extinction should be viewed as a best estimate.

In this approach to developing recovery criteria, the status of populations in some core areas may fall short of ideals described by conservation biology theory. Some core areas may be limited by natural attributes or by patch size, and may always remain at a relatively high risk of extinction. Because of limited data within the Upper Columbia Recovery Unit, the recovery unit team relied heavily on the professional judgment of its members.

Local Populations

Metapopulation theory is important to consider in bull trout recovery. A metapopulation is an interacting network of local populations with varying frequencies of migration and gene flow among them (see Chapter 1). Multiple local populations distributed and interconnected throughout a watershed provide a mechanism for spreading risk from stochastic events. In part, distribution of local populations in such a manner is an indicator of a functioning core area. Based in part on guidance from Rieman and McIntyre (1993), bull trout core areas with fewer than 5 local populations are at increased risk, core areas with between 5 and 10 local populations are at intermediate risk, and core areas with more than 10 interconnected local populations are at diminished risk.

Currently, local populations of migratory bull trout in the Wenatchee Core Area include: Chiwaukum Creek, Chiwawa River (including Chikamin, Rock, Phelps, Alpine, Buck, and James Creeks), White River (including Canyon and Panther Creeks), Little Wenatchee (below the falls), Peshastin Creek (including

Ingalls Creek), and Nason Creek (including Mill Creek). Migratory local populations in the Entiat Core Area include the mainstem Entiat and Mad Rivers. The Methow Core Area has migratory bull trout local populations in Gold Creek (including Crater Creek), Twisp River (including North and Reynolds Creeks and mainstem, East and West Fork Buttermilk Creeks), Wolf Creek, Chewuch River, Goat Creek, Early Winters Creek (including Cedar and Huckleberry Creeks), Lost River (including Cougar Lake, First Hidden Lake, Middle Hidden Lake and Monument Creek), and Upper Methow River. Bull trout in the Wenatchee and Methow Core Areas are considered at a intermediate risk, while bull trout in the Entiat Core Area are at an increased risk. Resident bull trout are known to occur in each core area within the recovery unit. However, an accurate description of their current distribution is unknown, and the identification of resident local populations is considered a research need.

Adult Abundance

The recovered abundance levels in the Upper Columbia Recovery Unit were determined by considering theoretical estimates of effective population size, historical census information, and the professional judgment of recovery team members. In general, effective population size is a theoretical concept that allows us to predict potential future losses of genetic variation within a population due to small population sizes and genetic drift (see Chapter 1). For the purpose of recovery planning, effective population size is the number of adult bull trout that successfully spawn annually. Based on standardized theoretical equations (Crow and Kimura 1970), guidelines have been established for maintaining minimum effective population sizes for conservation purposes. Effective population sizes of greater than 50 adults are necessary to prevent inbreeding depression and a potential decrease in viability or reproductive fitness of a population (Franklin 1980). To minimize the loss of genetic variation due to genetic drift and to maintain constant genetic variance within a population, an effective population size of at least 500 is recommended (Franklin 1980; Soule 1980; Lande 1988). Effective population sizes required to maintain long-term genetic variation that can serve as a reservoir for future adaptations in response to natural selection and changing environmental conditions are discussed in Chapter 1 of the recovery plan.

For bull trout, Rieman and Allendorf (2001) estimated that a minimum number of 50 to 100 spawners per year is needed to minimize potential inbreeding effects within local populations. In addition, a population size of between 500 and 1,000 adults in a core area is needed to minimize the deleterious effects of genetic variation from drift.

For the purposes of bull trout recovery planning, abundance levels were conservatively evaluated at the local population and core area levels. Local populations containing fewer than 100 spawning adults per year were classified as at risk from inbreeding depression. Bull trout core areas containing fewer than 1,000 spawning adults per year were classified as at risk of genetic drift.

Overall, bull trout in the Wenatchee, Entiat, and Methow core areas persist at low abundance. The strongest population in the Wenatchee Core Area is the Chiwawa River. Since 1999, the Chiwawa River has ranged between 246 and 462 redds annually. Conservative estimates (2 fish per redds) would result in an estimate of 492 to 924 spawning adults in the Chiwawa local population. Based on the aforementioned guidance, the Chiwawa River local population is not at risk of inbreeding depression. All other local populations in the Wenatchee Core Area persist at low abundance levels, and are considered at risk of inbreeding depression. Accurate abundance estimates for the Wenatchee Core Area are not available. However, results from the 2001 redd surveys in the Wenatchee Core Area indicate that the annual spawning population is probably less than 1,000 individuals, and should be considered at risk of genetic drift. Both local populations in the mainstem Entiat and Mad rivers persist at low abundance levels (less than 100 individuals), and are considered at risk of inbreeding depression. The low abundance in the Entiat Core Area places it at risk of genetic drift. Seven of the local populations in the Methow Core Area are mostly under 100 adults annually and are at risk of inbreeding depression. The most recent 4-year average for adult abundance (174) in the Twisp River indicates that this local population may not be at risk of inbreeding depression. However, the high variability in redd counts in the Twip River is a source of concern, and the genetic risk for this local population should continue to be monitored. Based on available information, adult spawning abundance in the Methow Core Area is probably less than 1,000 adults and therefore is at risk of the deleterious effects of genetic drift.

Productivity

A stable or increasing population is a key criterion for recovery under the requirements of the Endangered Species Act. Measures of the trend of a population (the tendency to increase, decrease, or remain stable) include population growth rate or productivity. Estimates of population growth rate (*i.e.*, productivity over the entire life cycle) that indicate a population is consistently failing to replace itself also indicate an increased risk of extinction. Therefore, the reproductive rate should indicate that the population is replacing itself, or growing.

Since estimates of the total population size are rarely available, the productivity or population growth rate is usually estimated from temporal trends in indices of abundance at a particular life stage. For example, redd counts are often used as an index of a spawning adult population. The direction and magnitude of a trend in the index can be used as a surrogate for the growth rate of the entire population. For instance, a downward trend in an abundance indicator may signal the need for increased protection, regardless of the actual size of the population. A population that is below recovered abundance levels, but that is moving toward recovery, would be expected to exhibit an increasing trend in the indicator.

The population growth rate is an indicator of probability of extinction. This probability cannot be measured directly, but it can be estimated as the consequence of the population growth rate and the variability in that rate. For a population to be considered viable, its natural productivity should be sufficient for the population to replace itself from generation to generation. Evaluations of population status will also have to take into account uncertainty in estimates of population growth rate or productivity. For a population to contribute to recovery, its growth rate must indicate that the population is stable or increasing for a period of time.

In the Upper Columbia Recovery Unit, bull trout were classified as having an increased risk due to either the short duration of population census information, or the incomplete record of the redd count surveys within each core area.

Connectivity

The presence of the migratory life history form within the Upper Columbia Recovery Unit was used as an indicator of the functional connectivity of the recovery unit. If the migratory life form was absent, or if the migratory form was present but local populations lacked connectivity, the core area was considered to be at increased risk. If the migratory life form was persisting in at least some local populations, with partial ability to connect with other local populations, the core area was judged to be at intermediate risk. If the migratory life form was present in all or nearly all local populations, and had the ability to connect with other local populations, the core area was considered to be at diminished risk.

Within the Wenatchee and Entiat Core Areas, the migratory life history form is predominant within the existing local populations, and both areas were considered at a diminished risk. While localized habitat problems currently exist that may impede connectivity, there are no large scale man-made migration barriers within either system. Conversely, habitat degradation within the Methow Core Area has fragmented bull trout populations within the basin. Reduction in habitat quality resulting from irrigation water withdrawals, diversion dams, grazing, and passage barriers associated with culverts have collectively contributed to the decline of bull trout in the basin. Bull trout in the Methow Core Area were considered to be at an increased risk.

Recovery Criteria

Recovery criteria for bull trout in the Upper Columbia Recovery Unit are as follows:

1. **Distribution criteria will be met when bull trout are distributed among at least 16 local populations in the Upper Columbia Recovery Unit.** The 16 identified local populations are currently distributed within the Wenatchee (6), Entiat (2) and Methow (8) core areas and are comprised of the migratory life history form. For recovery to occur, the distribution of these migratory local populations should be maintained while abundance is increased. The recovered distribution places the Wenatchee and Methow Core Areas at an intermediate risk from stochastic events. The Entiat Core Area, under a recovered condition, would remain at an increased risk from stochastic events. The Upper Columbia Recovery Unit Team recognizes that natural habitat features within the Wenatchee, Entiat, and Methow Rivers may limit the expansion of bull trout distribution. Designation of local populations is based on survey data and the professional judgement of Upper Columbia Recovery Unit Team members. Further genetic studies are needed in order to more accurately delineate local populations, and quantify spawning site fidelity and straying rates. The complete distribution of resident local populations in the recovery unit is unknown. The Upper Columbia Recovery Unit Team recommends that further studies be conducted in the Wenatchee, Entiat, and Methow Core Areas to elucidate the current and recovered distribution of resident bull trout in the recovery unit. Geographic distribution of resident local populations should be identified within 3 years, and actions needed to implement reintroduction efforts should be incorporated into review of the Upper Columbia Recovery Unit plan. Additional local populations may be added to this total as additional information is gathered in areas outside the currently designated core areas for this recovery unit.

2. **Abundance criteria will be met when the estimated abundance of adult bull trout among all local populations in the Upper Columbia Recovery Unit (Wenatchee, Entiat, and Methow Core Areas) is between 6,322 to 10,426 migratory fish (see Appendix 2).** Recovered abundance ranges for the Wenatchee (1,876 to 3,176), Entiat (836 to 1,364), and Methow (3,610 to 5,886) Core Areas were derived using the

professional judgement of the team and estimation of productive capacity of identified local populations. Resident life history forms are not included in this estimate, but are considered a research need. As more data is collected, recovered population estimates will be revised to more accurately reflect both the migratory and resident life history components. The established recovered abundance levels assume that threats (including fragmentation of local populations) have been addressed and that each core area is a functioning metapopulation. While the recovered abundance for each core area falls short of long-term idealized estimates for effective population size (see Chapter 1), the Upper Columbia Recovery Team feels that the estimated ranges accurately reflect achievable recovered abundance levels. In the Wenatchee and Methow core areas, the identified recovered abundance levels should prevent inbreeding depression and minimize the loss of genetic variation due to genetic drift. The natural productive capacity of the Entiat Core Area may keep it below 1,000 spawning adults annually, and at risk of genetic drift. The U.S. Fish and Wildlife Service will evaluate the identified abundance levels relative to the maintenance of long-term genetic variation that would provide the population the ability to adapt to natural selection and changing environmental conditions.

3. **Trend criteria will be met when adult bull trout exhibit a stable or increasing trend for at least two generations at or above the recovered abundance level within the Wenatchee, Entiat, and Methow Core Areas.** The development of a standardized monitoring and evaluation program that would accurately describe trends in bull trout abundance is identified as a priority research need. As part of the overall recovery effort, the U.S. Fish and Wildlife Service will take the lead in addressing this research need by forming a multi-agency technical team to develop protocols to evaluate trends in bull trout populations.

4. **Connectivity criteria will be met when specific barriers to bull trout migration in the Upper Columbia Recovery Unit have been addressed.** The Upper Columbia Recovery Unit Team recommends that

to adequately address habitat problems in the Methow Core Area (*e.g.*, low instream flows, grazing, culverts, and diversion dam barriers), and to recover bull trout, basin-wide Habitat Conservation Plans must be developed. The U.S. Fish and Wildlife Service, working with Federal, State, and private entities, and in coordination with local governments, need to secure quality habitat conditions for bull trout. These efforts should be coordinated with ongoing National Marine Fisheries Service salmon recovery actions to avoid duplication in planning and implementation.

Recovery criteria for the Upper Columbia Recovery Unit were established to assess whether recovery actions are resulting in the recovery of bull trout. The Upper Columbia Recovery Unit Team expects that the recovery process will be dynamic and will be refined as more information becomes available. While removal of bull trout as a species listed under the Endangered Species Act (*i.e.*, delisting) can only occur for the entity that was listed (Columbia River Distinct Population Segment), the criteria listed above will be used to determine when the Upper Columbia Recovery Unit is fully contributing to recovery of the population segment.

Research Needs

Based on the best scientific information available, the Upper Columbia Recovery Unit Team has identified recovery criteria and actions necessary for recovery of bull trout within the recovery unit. However, the recovery unit team recognizes that many uncertainties exist regarding bull trout population abundance, distribution, and actions needed. The recovery team feels that if effective management and recovery are to occur, the recovery plan for the Upper Columbia Recovery Unit must be viewed as a “living” document that will be updated as new information becomes available. As part of this adaptive management approach, the recovery unit team has identified research needs that are essential within the recovery unit. Research needs apply to areas where the recovery unit team feels more information is needed in order to accurately determine full recovery in this recovery unit and to implement effective recovery actions.

Columbia River and Tributaries

Recent information on migration and use of the mainstem Columbia River has been verified. Movements of bull trout tagged and released at Rock Island, Rocky Reach, and Wells Dams have been monitored through tagging studies conducted by the Chelan County Public Utilities District (Kreiter 2001; 2002). In addition, studies conducted by the U.S. Fish and Wildlife Service have verified the movement of adult bull trout into the lower Wenatchee River, and most likely the mainstem Columbia River. The mainstem Columbia River contains core habitat elements for bull trout that are important for migration, feeding, overwintering, and eventual recovery.

The Upper Columbia Recovery Team recommends that current studies on migration and use of the mainstem Columbia River be expanded and coordinated with genetic investigations in order to better understand the role that the Columbia River can play in recovery. Increased knowledge of the use of the mainstem Columbia River may revise core area descriptions and could have management and operational implications for mainstem Columbia River hydropower facilities. Research needs identified in the U.S. Fish and Wildlife Service's Biological Opinion on the "Effects to Listed Species from Operation of the Federal Columbia River Power System" are applicable to mainstem facilities in the Upper Columbia Recovery Unit (USFWS 2000b). Reasonable and prudent measures in the Biological Opinion are consistent with information data gaps identified in the Upper Columbia Recovery Unit. Research designed to investigate problems associated with fish ladder use, entrainment, spill, flow attraction, and water quality should be initiated.

The Upper Columbia Recovery Unit Team also considers the Lake Chelan basin and the Okanogan River basin to be research needs. The Lake Chelan basin historically supported adfluvial bull trout. The Upper Columbia Recovery Team feels that the application of a rigorous methodology to determine presence within tributaries to Lake Chelan is necessary to validate the current status. If bull trout are not found in the basin, the Upper Columbia Recovery Team recommends that a study to assess the feasibility of reintroducing bull trout into the basin be conducted. Recent investigations (Kreiter 2001) indicated that radio-tagged bull trout temporarily moved into the lower portions of the Okanogan River. Historic evidence of local populations of bull trout in the Okanogan River is limited (N. Wells, U.S. Forest Service, pers. comm., 2001). The Upper Columbia Recovery Unit Team recommends that the potential use of the Okanogan River by bull trout be investigated.

Monitoring and Evaluation

The Upper Columbia Recovery Unit Team realizes that recovery criteria will most likely be revised as recovery actions are implemented and bull trout populations begin to respond. In addition, the Upper Columbia Recovery Unit Team will rely on adaptive management to better refine both abundance and distribution criteria. Adaptive management is a continuing process of planning, monitoring, evaluating management actions, and research. This approach will involve a broad spectrum of user groups and will lay the framework for decision making relative to recovery implementation and ultimately, the possible revision of recovery criteria in this recovery unit.

This recovery unit chapter is the first step in the planning process for bull trout recovery in Upper Columbia Recovery Unit. Monitoring and evaluation of population levels and distribution will be an important component of any adaptive management approach. The U.S. Fish and Wildlife Service will take the lead in developing a comprehensive monitoring approach that will provide guidance and consistency in evaluating bull trout populations. Development and application of models that assess extinction risk relative to abundance and distribution parameters are critical in refining recovery criteria as the recovery process proceeds. Application of agreed upon methods for evaluating recovery would benefit the scientific community and user groups alike.

Genetic Studies

The Upper Columbia Recovery Unit Team recommends that studies be initiated to describe the genetic makeup of bull trout in the mainstem Columbia, Wenatchee, Entiat, and Methow Rivers. This information would be essential for a more complete understanding of bull trout interactions and population dynamics. In addition, a recovery unit-wide evaluation of the current and potential threat of bull trout hybridization with brook trout is needed. The ability to evaluate the potential harm to specific local populations could be used in prioritizing management actions. Genetic baseline information would also be a necessity in the implementation of any artificial propagation program.

The Role of Artificial Propagation and Transplantation

The Upper Columbia Recovery Unit Team has determined that reaching a recovered condition within the Wenatchee, Entiat, and Methow Core Areas within 25 years could require the use of artificial propagation. Artificial propagation could involve the transfer of bull trout into unoccupied habitat within the historic range (ODFW 1997). In addition, artificial propagation could involve the use of Federal or State hatcheries to assist in recovery efforts (MBTSG 1996). The Upper Columbia Recovery Team recommends that studies be initiated to determine the effectiveness and feasibility of using artificial propagation in bull trout recovery.

Any artificial propagation program instituted in the Upper Columbia Recovery Unit must follow the joint policy of the U.S. Fish and Wildlife Service and the National Marine Fisheries Service regarding controlled propagation of listed species (65 FR 56916). The overall guidance of the policy is that every effort should be made to recover a species in the wild before implementing a controlled propagation program. If necessary, an appropriate plan would need to be approved that considers the effects of transplantation on other species as well as the donor bull trout populations. Transplanting listed species must be authorized by the U.S. Fish and Wildlife Service and meet applicable State fish-handling and disease policies.

While artificial propagation has played an important role in the recovery of other listed fish species, where possible, the overall recovery strategy for bull trout in the Upper Columbia Recovery Unit should emphasize the removal of threats and habitat restoration. Recovery should emphasize identifying and correcting threats affecting bull trout and their habitats. Artificial propagation programs should not be implemented unless reasons for decline have been addressed.

ACTIONS NEEDED

Recovery Measures Narrative

In this chapter and all other chapters of the bull trout recovery plan, the recovery measures narrative consists of a hierarchical listing of actions that follows a standard template. The first-tier entries are identical in all chapters and represent general recovery tasks under which specific (*e.g.*, third-tier) tasks appear when appropriate. Second-tier entries also represent general recovery tasks under which specific tasks appear. Second-tier tasks that do not include specific third-tier actions are usually programmatic activities that are applicable across the range of the species; they appear in *italic type*. These tasks may have third-tier tasks associated with them (see Chapter 1 for more explanation). Some second-tier tasks may not be sufficiently developed to apply to the recovery unit at this time; they appear in *a shaded italic type*. These tasks are included to preserve consistency in numbering tasks among recovery unit chapters and are intended to assist in generating information during the comment period for the draft recovery plan, a period when additional tasks may be developed. Third-tier entries are tasks specific to the Upper Columbia Recovery Unit. They appear in the implementation schedule that follows this section and are identified by three numerals separated by periods.

The Upper Columbia Recovery Unit chapter should be updated or revised as recovery tasks are accomplished, environmental conditions change, monitoring results become available, or other new information becomes available. Revisions to the Upper Columbia Recovery Unit chapter will likely focus on priority streams or stream segments within core areas where restoration activities occurred, and habitat or bull trout populations have shown a positive response. The Upper Columbia Recovery Unit Team should meet annually to review annual monitoring reports and summaries, and make recommendations to the U.S. Fish and Wildlife Service for revision of the Upper Columbia Recovery Unit chapter.

1. Protect, restore, and maintain suitable habitat conditions for bull trout.

1.1 Maintain or improve water quality in bull trout core areas or potential core habitat.

1.1.1 Investigate alternatives to improve low flow conditions. Investigate alternatives to improve low flow conditions, evaluate ground water/surface water interactions, and evaluate human-induced changes. Specific areas to address include: lower Early Winters Creek, the two diversions at River Miles 1.4 and 0.6, the Methow River from Robinson Creek to Weeman Bride at River Mile 6 below Mazama Bridge, Lost River, Twisp River, Gold Creek near water diversions at River Miles 0.2 and 1.3, Peshastin Creek, Chiwaukum Creek, Chiwawa River, and Icicle Creek in the Wenatchee River.

1.2 Identify barriers or sites of entrainment for bull trout and implement tasks to provide passage and eliminate entrainment.

1.2.1 Reconnect floodplains. Reconnect floodplains and off-channel habitats that provide important spawning and rearing areas. In the Methow basin, the McKinney Mountain and People Mover Dikes should be considered for removal. Support restoration efforts planned for Goat Creek (a channel function restoration project in the lower 1.5 channelized miles and a stream restoration project between River Miles 6.5 and 9.5). Support projects that propose alternatives to maintaining the dike on Lost River. Support projects that propose to restore the lower 2 miles of Early Winters Creek, which has been riprapped and diked, had side-channels cut off, and had trees removed from riparian areas. Restore access to the floodplain and reconnect side channels in the lower 15 miles of the Twisp River.

1.2.2 Correct irrigation passage barriers. Develop a comprehensive list of irrigation diversion passage barriers in the Upper Columbia Recovery Unit that impact bull trout and their habitat. Correct identified barriers to allow fish passage, and correct or minimize impacts they have on bull trout habitat.

1.2.3 Screen diversions and irrigation ditches. Screen known water diversion and irrigation ditches to meet State, U.S. Fish and Wildlife Service, and the National Marine Fisheries Service screening criteria.

1.2.4 Assess impacts from proposed Lake Wenatchee Dam. Assess direct and indirect effects to bull trout of the proposed damming of Lake Wenatchee, including impacts to current populations and habitat.

1.3 Identify impaired stream channel and riparian areas and implement tasks to restore their appropriate functions.

1.3.1 Minimize further shoreline and floodplain development. Reduce current impacts from shoreline and floodplain development along the mainstem Methow, Entiat, and Wenatchee rivers. Minimize further development that will constrict or constrain the channel, degrade riparian areas, negatively impact ground water and surface water interactions, or in any other way degrade stream channel functions.

1.3.2 Develop road management strategy. Develop a road management strategy in coordination with U.S. Forest Service Road Analysis to enhance bull trout connectivity and restore habitat.

1.3.3 Develop and coordinate access and travel management plans. Coordinate public and private land owner development of access and travel management plans that will minimize effects of roads in bull trout watersheds.

1.3.4 Identify and repair, remove, or relocate culverts. Identify and repair, remove, or relocate culverts that are barriers for fish migration, restrict connectivity, or inhibit downstream transport of substrate and woody debris. Areas of concern include: Peshastin and Nason Creeks (Wenatchee River), Twisp River, Beaver Creek, Gold Creek, Little Bridge Creek, and East Fork Buttermilk Creek (Methow River).

1.3.5 Identify and repair, remove, or relocate roads. Identify and repair, remove, or relocate roads that are barriers for fish migration, restrict connectivity, increase sediment delivery, intercept ground water and surface water, detrimentally effect riparian and floodplain function, or alter normal hydraulic processes.

1.3.6 Avoid placement of new roads in riparian areas.

1.3.7 Assess forest practice regulations. Assess the effectiveness of current forest practice regulations to protect bull trout habitat.

1.3.8 Reduce road density and road-related sediment delivery. Reduce road density and road-related sediment delivery in bull trout core areas. In the Methow Core Area, priority watersheds include: Goat Creek, Beaver Creek, Chewuch River, Wolf Creek and tributary Gate Creek, Early Winters Creek, lower Methow River, Twisp River and tributaries Little Bridge Creek and Buttermilk Creek. In the Wenatchee Core Area, priority watersheds include: lower

Chiwawa River, middle Chiwawa River, Lake Wenatchee, lower White River, lower Little Wenatchee, upper Little Wenatchee, lower Nason Creek, upper Nason Creek, the headwaters of Nason Creek, Wenatchee River (upper, middle, and lower portions), lower Icicle Creek drainage, and Peshastin Creek. In the Entiat Core Area, priority watersheds include: lower Entiat River, middle Entiat River, lower Mad River, middle Mad River, and the upper Mad River.

1.3.9 <u>Develop and implement habitat restoration and protection guidelines</u>. Develop and implement habitat restoration and protection guidelines for bull trout that restore or maintain habitat elements (*e.g.*, sediment delivery, water temperature, normative hydrologic function) to provide for recovery.

1.3.10 <u>Ensure enforcement of mineral prospecting and placer mining regulations</u>. Ensure mineral prospecting and placer mining activities comply with the Washington State Hydraulic Code (Gold-N-Fish pamphlet).

1.3.11 <u>Maintain unroaded portions of bull trout watersheds in current roadless condition</u>.

1.3.12 <u>Address access road impacts</u>. Identify and close, or provide law enforcement for, roads that increase risk of poaching and fishing pressure, especially in bull trout spawning and staging areas.

1.3.13 <u>Monitor mining activities</u>. Monitor mining activities for compliance with the Gold Pamphlet and recovery actions to determine the effectiveness of regulations and recovery actions in providing desired habitat and water quality conditions.

1.3.14 Ensure that bull trout are considered in all planning phases of new gold mining operations. Ensure that bull trout are considered in all planning phases of new gold mining operations in the North Creek drainage in the Twisp River and Chikamin Creek.

1.3.15 Implement and monitor stream nutrient enhancement projects. Implement projects to distribute salmon and steelhead carcasses in streams to increase stream nutrients and aid in the restoration of historic nutrient flows. Monitor their effectiveness.

1.3.16 Quantify grazing impacts. Identify and investigate grazing impacts and quantify impacts to bull trout habitat in the Upper Columbia Recovery Unit (*e.g.*, Rainy, Wolf, Goat, Buttermilk, Gold, and Libby Creeks). Focus on impacts to riparian areas and stream channel condition.

1.3.17 Develop and implement livestock grazing plans. Develop, implement, and adaptively manage livestock grazing plans that include actions (*e.g.*, riparian fencing), performance standards, and targets for floodplains, riparian vegetation, stream banks and channels, and wetlands that protect bull trout habitat and water quality.

1.3.18 Exclude grazing from sensitive habitat areas. Exclude grazing from sensitive bull trout habitat areas (*e.g.*, spawning grounds, early rearing habitats) during spawning and the incubation period (*e.g.*, September-April).

1.3.19 Identify and mitigate habitat impacts from highways and railroads. Identify reaches in the Wenatchee and Methow where highways and railroads have altered bull trout habitat (*e.g.,* Wenatchee River, Nason Creek, Peshastin Creek, Early Winters Creek, and the upper Methow River) and recommend mitigative actions.

1.3.20 Coordinate with grazing interests to minimize grazing disturbance. Coordinate, work with, and support conservation districts, counties, and private landowners to evaluate grazing disturbances and implement corrective actions in bull trout habitat.

1.3.21 Reduce sediment loading to streams. Reduce sediment loading from irrigation return flow and non-point source runoff (*e.g.,* Wolf Creek irrigation ditch).

1.3.22 Identify and, where feasible, correct man-made barriers to fish passage in foraging and refugia habitats. Identify and, where feasible, correct man-made barriers to fish passage in non-local population streams that provide foraging and high water refuge habitat.

1.3.23 Restore and protect habitat that is impacted by recreational campgrounds. Take corrective actions to restore and protect habitat that is impacted by recreational campgrounds. Priority areas include: Tumwater Campground at the confluence of Chiwaukum Creek and the Wenatchee River, Nason Creek Campground and dispersed sites on Nason Creek, Riverside Campground on the Little Wenatchee River and dispersed sites on the Little Wenatchee River, Pine Flat Campground on the Mad River, Roads End Campground on the Twisp River, and dispersed camping sites on the Chiwawa River.

1.4 Operate dams to minimize negative effects on bull trout in reservoirs and downstream.

1.4.1 Evaluate bull trout passage at Wells, Rock Island, and Rocky Reach Dams, and initiate passage studies at Wanapum Dam. Continue evaluation of bull trout passage at Wells, Rock Island, and Rocky Reach dams. Focus on level of use and adequacy of current passage facilities. Initiate bull trout passage studies at Wanapum Dam.

1.4.2 Assess feasibility of providing fish passage at Leavenworth National Fish Hatchery. Improve fish passage at Leavenworth National Fish Hatchery if feasible.

1.4.3 Evaluate downstream passage at Tumwater and Dryden Dams. Evaluate downstream passage at Tumwater and Dryden Dams, and if warranted investigate methods necessary to improve downstream passage.

1.5 *Identify upland conditions negatively affecting bull trout habitats and implement tasks to restore appropriate functions.*

2. Prevent and reduce negative effects of nonnative fishes and other nonnative taxa on bull trout.

2.1 *Develop, implement, and enforce public and private fish stocking policies to reduce stocking of nonnative fishes that affect bull trout.*

2.2 *Enforce policies for preventing illegal transport and introduction of nonnative fishes.*

2.3 *Provide information to the public about ecosystem concerns of illegal introductions of nonnative fishes.*

2.4 *Evaluate biological, economic, and social effects of control of nonnative fishes.*

2.5 Implement control of nonnative fishes where found to be feasible and appropriate.

2.5.1 Evaluate opportunities for experimental removal of brook trout or other competing nonnative fish species. Evaluate opportunities for experimental removal of brook trout or other competing nonnative fish species from selected streams. Initial priority areas include Twisp River, Chikamin and Minnow Creeks and Shaefer Lake on the Chiwawa River.

2.6 Develop tasks to reduce negative effects of nonnative taxa on bull trout.

2.6.1 Evaluate impacts of nonnative fish species on bull trout. Evaluate impacts of nonnative fish species on bull trout, especially when present in local populations. Evaluate predation, hybridization, and competition impacts to all life stages.

3. Establish fisheries management goals and objectives compatible with bull trout recovery, and implement practices to achieve goals.

3.1 *Develop and implement State and Tribal native fish management plans, and integrate adaptive research.*

3.2 Evaluate and prevent overharvest and incidental angling mortality of bull trout.

3.2.1 Ensure compliance with harvest regulations. Ensure compliance with harvest regulations and policies, and target bull trout spawning and staging areas for enforcement in the Upper Columbia Recovery Unit. Priority areas include Mad River, Panther Creek, Rock Creek, Chiwawa River, Twisp River, and Lake Wenatchee based on past observations of poaching.

3.2.2 Reduce angler pressure. Reduce angler pressure in areas where incidental mortality continues to be detrimental to recovery. Utilize innovative techniques such as seasonal or permanent road closures, and establishment of conservative regulations or fisheries management policies.

3.2.3 Provide educational opportunities and materials to anglers. Provide anglers with information about bull trout identification, special regulations, and how to reduce hooking mortality of bull trout caught incidentally in recreational fisheries.

3.2.4 Develop and implement a bull trout fishery management plan. Develop and implement a bull trout fishery management plan for the Upper Columbia Recovery Unit to assess harvest and incidental take during other fisheries (*e.g.*, whitefish season).

3.2.5 Increase natural forage (prey) base. Implement restoration actions that increase natural production of salmon, steelhead, and other native species thereby improving the natural forage base for bull trout.

3.2.6 Evaluate impacts to bull trout from the general fishing season in the Lost River. Monitor effects of the current harvest regulations for the Lost River and evaluate their adequacy to protect bull trout spawner abundance in this important local population.

3.2.7 Monitor scientific collection. Monitor scientific collection and regulate collection methods (techniques, intensity, timing). Specifically, address possible take of bull trout during spring chinook egg collection and recommend corrective actions if necessary.

3.3 Evaluate potential effects of introduced fishes and associated sport fisheries on bull trout recovery and implement tasks to minimize negative effects on bull trout.

3.3.1 Discontinue stocking of brook trout. Discontinue stocking of brook trout in areas where impacts to bull trout may occur. Review stocking plans for lakes that are in bull trout watersheds and recommend changes that would benefit bull trout.

3.4 Evaluate effects of existing and proposed sport fishing regulations on bull trout.

3.4.1 Evaluate and implement harvest regulations that reduce nonnative fish populations impacting bull trout. Evaluate and implement harvest regulations that reduce nonnative fish populations where bull trout will benefit. Ensure that the liberalized limits targeting nonnatives do not increase incidental catch of bull trout.

4. Characterize, conserve, and monitor genetic diversity and gene flow among local populations of bull trout.

4.1 *Incorporate conservation of genetic and phenotypic attributes of bull trout into recovery and management plans.*

4.2 *Maintain existing opportunities for gene flow among bull trout populations.*

4.3 Develop genetic management plans and guidelines for appropriate use of transplantation and artificial propagation.

4.3.1 Establish genetic reserve protocols. Establish genetic reserve protocols and standards for initiating, conducting, and evaluating artificial propagation programs.

4.3.2 Establish genetic baselines. Genetic baseline descriptions of bull trout in the Columbia, Wenatchee, Entiat, and Methow Rivers is essential for a complete understanding of bull trout interactions and population dynamics.

4.3.3 Evaluate hybridization with brook trout. Recovery Unit wide evaluation of the current and potential threat of bull trout hybridization with brook trout is needed. The ability to evaluate the potential harm to specific local populations can be used in prioritizing management actions.

4.3.4 Determine feasibility and appropriateness of artificial propagation. Reestablishment of local populations within the Upper Columbia Recovery Unit may require the use of artificial propagation. Initiate studies to determine the effectiveness and feasibility of using fish transfers and hatcheries to assist in future reintroduction efforts.

5. Conduct research and monitoring to implement and evaluate bull trout recovery activities, consistent with an adaptive management approach using feedback from implemented, site-specific recovery tasks.

5.1 *Design and implement a standardized monitoring program to assess the effectiveness of recovery efforts affecting bull trout and their habitats.*

5.2 Conduct research evaluating relationships among bull trout distribution and abundance, bull trout habitat, and recovery tasks.

5.2.1 Develop and implement a monitoring program. Develop a monitoring program to assess the contribution of the resident life history form to overall population abundance.

5.3 *Conduct evaluations of the adequacy and effectiveness of current and past Best Management Practices in maintaining or achieving habitat conditions conducive to bull trout recovery.*

5.4 *Evaluate effects of diseases and parasites on bull trout, and develop and implement strategies to minimize negative effects.*

5.5 Develop and conduct research and monitoring studies to improve information concerning the distribution and status of bull trout.

5.5.1 Evaluate the current and potential bull trout use of the Columbia River and lower mainstem portions of the Methow, Entiat, and Wenatchee Rivers. Determine habitat use, foraging requirements, and migrational patterns within these mainstem areas.

5.5.2 Investigate the potential and feasibility for re-introducing bull trout to the Chelan basin.

5.5.3 Investigate potential use of the Okanogan River by bull trout, and investigate habitat suitability.

5.5.4 Conduct problem assessments for bull trout and identify site-specific threats that may be limiting recovery efforts. Coordinate with Water Resource Inventory Areas and the Northwest Power Planning Council’s Subbasin Planning process to fill data gaps related to the identification of site-specific threats that may be limiting recovery efforts.

5.5.5 Conduct population surveys. Conduct intensive population surveys to determine presence of bull trout and to fully describe the distribution of juvenile, sub-adult, and adults in the Upper Columbia Recovery Unit.

5.5.6 Assess the feasibility for using Patterson Lake bull trout to reestablish Methow River local populations.

5.6 *Identify evaluations needed to improve understanding of relationships among genetic characteristics, phenotypic traits, and local populations of bull trout.*

6. Use all available conservation programs and regulations to protect and conserve bull trout and bull trout habitats.

6.1 Use partnerships and collaborative processes to protect, maintain, and restore functioning core areas for bull trout.

6.1.1 Protect high quality habitats. Protect existing high quality habitats in the Upper Columbia Recovery Unit and provide for long-term habitat protection through purchase from willing sellers, conservation easements, and management plans (*e.g.,* Entiat River, Peshastin Creek, White River, Chiwawa River, and mainstem Wenatchee and Methow Rivers). A conservation easement to secure riparian buffers should be pursued on the upper Methow River between Goat Creek and Mazama where accelerated erosion is occurring in areas impacted by agriculture and residential development.

6.1.2 Develop basin-wide habitat conservation efforts. Work with conservation districts, counties, State agencies, and private landowners to develop basin-wide habitat conservation efforts (*e.g.,* Habitat Conservation Plans) to protect bull trout and their habitat in the Upper Columbia Recovery Unit (priority is the Methow River).

6.1.3 Work with watershed groups and landowners. Work with and support local watershed groups and private landowners to assess bull trout status, actions needed, and implementation of recovery.

6.2 Use existing Federal authorities to conserve and restore bull trout.

6.2.1 Assess impacts to bull trout during hydropower relicensing. Continue bull trout monitoring in the mainstem Columbia to gather necessary information to describe the effects of project operations at Wells, Rocky Reach, and Rock Island Dams. This information will be necessary to complete section 7 consultation for bull trout during the upcoming Federal Energy Regulatory Commission relicensing process.

6.3 Enforce existing Federal and State habitat protection standards and regulations and evaluate their effectiveness for bull trout conservation.

6.3.1 Ensure implementation of Washington State habitat protection laws.

6.3.2 Ensure full compliance monitoring of Forest and Fish Report standards. Ensure full compliance monitoring associated with Forest and Fish Report standards and modify rules through adaptive management when indicated by effectiveness monitoring.

6.3.3 Implement Federal land management plans that protect fish habitat (*e.g.*, INFISH).

6.3.4 Develop, implement, and enforce water quality standards for surface water in the State of Washington. Develop, implement, and enforce water quality standards specific for bull trout.

6.3.5 Increase monitoring and enforcement of Hydraulic Permit Applications in the State of Washington.

6.3.6 Develop and implement county and local habitat protection laws and ordinances.

7. Assess the implementation of bull trout recovery by recovery units, and revise recovery unit plans based on evaluations.

7.1 *Convene annual meetings of each recovery unit team to generate progress reports on implementation of the recovery plan for the U.S. Fish and Wildlife Service.*

7.2 *Develop and implement a standardized monitoring program to evaluate the effectiveness of recovery efforts (coordinate with 5.1).*

7.3 Revise the scope of recovery as suggested by new information.

7.3.1 Periodically review progress toward recovery goals and assess recovery task priorities. Annually review progress toward population and adult abundance criteria and recommend changes, as needed, to the Upper Columbia Recovery Unit chapter. In addition, review tasks, task priorities, completed tasks, budget, timeframes, particular successes, and feasibility within the Upper Columbia Recovery Unit.

IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows describes recovery task priorities, task numbers, task descriptions, duration of tasks, potential or participating responsible parties, total cost estimate, estimates for the next 5 years, if available, and comments. These tasks, when accomplished, are expected to lead to recovery of bull trout in the Upper Columbia Recovery Unit. Costs estimates are not provided for tasks that are normal agency responsibility under existing authorities. The total estimated cost of recovery actions is $15.5 million.

Parties with authority, responsibility, or expressed interest in implementing a specific recovery task are identified in the Implementation Schedule. Listing a responsible party does not imply that prior approval has been given, or require that party to participate, or expend any funds. However, willing participants may be able to increase their funding opportunities by demonstrating that their budget submission or funding request is for a recovery task identified in an approved recovery plan, and is therefore part of a coordinated effort to recover bull trout. In addition, section 7(a)(1) of the Endangered Species Act directs all Federal agencies to use their authorities to further the purposes of the Endangered Species Act by implementing programs for the conservation of threatened or endangered species.

The following are definitions to column headings in the Implementation Schedule:

Priority Number: All priority 1 tasks are listed first, followed by priority 2 and priority 3 tasks.

> Priority 1: All actions that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.
>
> Priority 2: All actions that must be taken to prevent a significant decline in species population or habitat quality, or to prevent some other significant negative effect short of extinction.

Priority 3: All other actions necessary to provide for full recovery (or reclassification) of the species.

Task Number and Task Description: Recovery tasks as numbered in the recovery outline. Refer to the action narrative for task descriptions.

Task Duration: Expected number of years to complete the corresponding task. Study designs can incorporate more than one task, which when combined may reduce the time needed for task completion.

Responsible or Participating Party: The following organizations are those with responsibility or capability to fund, authorize, or carry out the corresponding recovery task. **Bolded type** indicates agency or agencies that have the lead role for task implementation and coordination, though not necessarily sole responsibility.

BPA	Bonneville Power Administration
CC	Chelan County
CCPUD	Chelan County Public Utilities District
CD's	Conservation Districts
CT	Colville Tribe
DCPUD	Douglas County Public Utilities District
EPA	Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
GCPUD	Grant County Public Utilities District
NRCS	Natural Resources Conservation Service
OC	Okanogan County
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WDOE	Washington Department of Ecology
WDOT	Washington Department of Transportation
YN	Yakama Nation

Cost Estimates: Cost estimates are rough approximations and provided only for general guidance. Total costs are estimated for the duration of the task, are itemized annually for the next five years, and includes estimates of expenditures by local, Tribal, State, and Federal governments and by private business and individuals.

An asterisk (*) in the total cost column indicates ongoing tasks that are currently being implemented as part of normal agency responsibilities under existing authorities. Because these tasks are not being done specifically or solely for bull trout conservation, they are not included in the cost estimates. Some of these efforts may be occurring at reduced funding levels and/or in only a small portion of the watershed.

Double asterisk (**) in the total cost column indicates that estimated costs for these tasks are not determinable at this time. Input is requested to help develop reasonable cost estimates for these tasks.

Triple asterisk (***) indicates costs are combined with or embedded within other related tasks.

IMPLEMENTATION SCHEDULE FOR BULL TROUT RECOVERY PLAN: UPPER COLUMBIA												
Priority number	Task number	Task description	Task duration (years)	Responsible parties	Cost estimates ($1,000)						Comments
					Total cost	Year 1	Year 2	Year 3	Year 4	Year 5	
1	1.1.1	**Investigate alternatives to improve low flow conditions**.	4	**WDNR, USFS**, **NRCS**, WDFW, OC, CC	200	50	50	50	50		
1	1.2.2	**Correct irrigation passage barriers.**	5	**USFS, OC, CC, CD's, WDNR**, **NRCS**	250	50	50	50	50	50	
1	1.2.3	**Screen diversions and irrigation ditches.**	4	**USFS, WDNR, NRCS**, OC, CC, USFWS, WDFW	500	300	50	50	100		
1	1.3.4	**Identify and repair, remove, or relocate culverts.**	10	**USFS, WDNR,** CD's, OC, CC	1000	100	100	100	100	100	

IMPLEMENTATION SCHEDULE FOR BULL TROUT RECOVERY PLAN: UPPER COLUMBIA												
Priority number	Task number	Task description	Task duration (years)	Responsible parties	Cost estimates ($1,000)						Comments
					Total cost	Year 1	Year 2	Year 3	Year 4	Year 5	
1	1.4.1	**Evaluate bull trout passage at Wells, Rock Island, and Rocky Reach dams, and initiate passage studies at Wanapum Dam.**	5	**CCPUD, DCPUD, GCPUD, BPA,** WDFW, USFWS	500	100	100	100	100	100	
1	3.3.1	**Discontinue stocking of brook trout.**	25	**WDFW**	*						
1	4.3.2	**Establish genetic baselines.**	3	**WDFW**, USFWS	180	70	100	10			
1	5.5.1	**Evaluate the current and potential use of the Columbia River and lower mainstem portions of the Methow, Entiat, and Wenatchee Rivers.**	5	**WDFW, USFWS, BPA,** CCPUD	250	50	50	50	50	50	

IMPLEMENTATION SCHEDULE FOR BULL TROUT RECOVERY PLAN: UPPER COLUMBIA

Priority number	Task number	Task description	Task duration (years)	Responsible parties	Cost estimates ($1,000)						Comments
					Total cost	Year 1	Year 2	Year 3	Year 4	Year 5	
1	5.5.4	**Conduct problem assessments for bull trout and identify site-specific threats that may be limiting recovery efforts.**	3	**WDFW, USFS**, USFWS	90	30	30	30			
1	6.1.1	**Protect high quality habitats.**	10	**WDNR**, WDFW, USFWS, OC, CC	5000	500	500	500	500	500	
1	6.1.2	**Develop basin-wide habitat conservation efforts (*e.g.*, Habitat Conservation Plans).**	10	**CD's OC, CC, WDNR**, USFWS	1000	100	100	100	100	100	
1	6.2.1	**Assess impacts to bull trout during hydropower relicensing.**	10	**CCPUD, DCPUD**, **GCPUD,** FERC, USFWS	*						

IMPLEMENTATION SCHEDULE FOR BULL TROUT RECOVERY PLAN: UPPER COLUMBIA

Priority number	Task number	Task description	Task duration (years)	Responsible parties	Cost estimates ($1,000)						Comments
					Total cost	Year 1	Year 2	Year 3	Year 4	Year 5	
2	1.2.1	**Reconnect floodplains.**	5	**USFS, WDNR**, WDFW	500	100	100	100	100	100	
2	1.2.4	**Assess impacts from proposed Lake Wenatchee Dam.**	3	**USFS, WDNR**, WDFW, USFWS, CC	75	25	25	25			
2	1.3.2	**Develop road management strategy.**	3	**USFS, WDNR, OC, CC**	*						
2	1.3.5	**Identify and repair, remove, or relocate roads.**	10	**USFS, WDNR,** NRCS, WDOT, CC, OC	2,000	200	200	200	200	200	
2	1.3.6	**Avoid placement of new roads in riparian areas.**	25	**USFS, WDNR**, **WDOT**	*						
2	1.3.7	**Assess forest practice regulations.**	5	**USFS, FWS, WDNR,** WDFW	*						Target areas adjacent to bull trout watersheds.

IMPLEMENTATION SCHEDULE FOR BULL TROUT RECOVERY PLAN: UPPER COLUMBIA												
Priority number	Task number	Task description	Task duration (years)	Responsible parties	Cost estimates ($1,000)						Comments
					Total cost	Year 1	Year 2	Year 3	Year 4	Year 5	
2	1.3.8	**Reduce road density and road-related sediment delivery.**	10	**USFS, WDNR**	500	50	50	50	50	50	
2	1.3.9	**Develop and implement habitat restoration and protection guidelines.**	3	**USFS, USFWS**, WDNR	*						
2	1.3.10	**Ensure enforcement of mineral prospecting and placer mining regulations.**	25	**USFS, WDNR, WDFW**	*						
2	1.3.12	**Address access road impacts.**	25	**USFS, WDFW**, USFWS	*						
2	1.3.13	**Monitor mining activities.**	25	**USFS, WDNR**, WDFW	*						

IMPLEMENTATION SCHEDULE FOR BULL TROUT RECOVERY PLAN: UPPER COLUMBIA											
Priority number	Task number	Task description	Task duration (years)	Responsible parties	Cost estimates ($1,000)						Comments
					Total cost	Year 1	Year 2	Year 3	Year 4	Year 5	
2	1.3.14	**Ensure that bull trout are considered in all planning phases of new gold mining operations.**	25	**USFS**, USFWS	*						
2	1.3.15	**Implement and monitor stream nutrient enhancement projects.**	10	**USFS, WDFW**, **YN**, NMFS, USFWS	100	10	10	10	10	10	
2	1.3.16	**Quantify grazing impacts.**	4	**WDFW, USFS**, USFWS, NRCS	400	100	100	100	100		
2	1.3.17	**Develop and implement livestock grazing plans.**	25	**WDNR, USFS**, USFWS, NMFS, CD's, NRCS	*						

IMPLEMENTATION SCHEDULE FOR BULL TROUT RECOVERY PLAN: UPPER COLUMBIA											
Priority number	Task number	Task description	Task duration (years)	Responsible parties	Cost estimates ($1,000)						Comments
					Total cost	Year 1	Year 2	Year 3	Year 4	Year 5	
2	1.3.20	**Coordinate with grazing interests to minimize grazing disturbance.**	3	**CD's, OC, CC,** USFWS, WDNR, USFS, NRCS	75	25	25	25			
2	1.4.2	**Assess feasibility of providing fish passage at Leavenworth National Fish Hatchery.**	2	**USFWS**	50	25	25				
2	2.5.1	**Evaluate opportunities for experimental removal of brook trout and other competing nonnative fish species.**	2	**WDFW, USFS**, USFWS	30	15	15				
2	2.6.1	**Evaluate impacts of nonnative fish species on bull trout.**	5	**WDFW**, USFWS, USFS	250	50	50	50	50	50	

IMPLEMENTATION SCHEDULE FOR BULL TROUT RECOVERY PLAN: UPPER COLUMBIA												
Priority number	Task number	Task description	Task duration (years)	Responsible parties	Cost estimates ($1,000)						Comments
					Total cost	Year 1	Year 2	Year 3	Year 4	Year 5	
2	3.2.1	**Ensure compliance with harvest regulations**.	25	**USFS, WDNR, WDFW**, NRCS	*						
2	3.2.2	**Reduce angler pressure.**	5	**WDFW**, USFS	*						
2	3.2.3	**Provide information to anglers.**	3	**WDFW**, USFS	45	15	15	15			
2	3.2.4	**Develop and implement a bull trout fishery management plan.**	3	**WDFW, YN**, USFWS	60	20	20	20			
2	3.2.5	**Increase natural forage (prey) base.**	3	**WDFW**, USFWS, CCPUD	300	100	100	100			
2	3.2.6	**Evaluate impacts to bull trout from the general fishing season in the Lost River.**	3	**WDFW**, USFWS, USFS	*						

IMPLEMENTATION SCHEDULE FOR BULL TROUT RECOVERY PLAN: UPPER COLUMBIA											
Priority number	Task number	Task description	Task duration (years)	Responsible parties	Cost estimates ($1,000)						Comments
					Total cost	Year 1	Year 2	Year 3	Year 4	Year 5	
2	3.2.7	**Monitor scientific collection.**	25	**USFWS,** WDFW	*						
2	3.4.1	**Evaluate and implement harvest regulations that reduce nonnative fish populations impacting bull trout.**	5	**WDFW, YN**	*						
2	4.3.4	**Determine feasibility and appropriateness of artificial propagation.**	3	**USFWS,** WDFW, YN	30	10	20	10			
2	5.5.5	**Conduct population surveys.**	5	**WDFW, USFS**, USFWS	500	100	100	100	100	100	
2	6.1.3	**Work with watershed groups and landowners.**	25	**CD's, OC CC, USFWS**	*						

IMPLEMENTATION SCHEDULE FOR BULL TROUT RECOVERY PLAN: UPPER COLUMBIA												
Priority number	Task number	Task description	Task duration (years)	Responsible parties	Cost estimates ($1,000)						Comments
					Total cost	Year 1	Year 2	Year 3	Year 4	Year 5	
2	6.3.1	**Ensure implementation of Washington State habitat protection laws.**	25	**WDNR, WDFW, WDOE**	*						
2	6.3.2	**Ensure full compliance monitoring of Forest and Fish Report standards.**	25	**WDNR, WDFW,**	*						
2	6.3.3	**Implement Federal land management plans that protect fish habitat (*e.g.*, INFISH).**	25	**USFS**	*						
2	6.3.4	**Develop, implement, and enforce water quality standards for surface water in the State of Washington.**	25	**WDOE, EPA,** USFWS, WDFW	*						
2	6.3.5	**Increase monitoring and enforcement of Hydraulic Permit Applications in the State of Washington.**	25	**WDNR**, WDFW	*						

IMPLEMENTATION SCHEDULE FOR BULL TROUT RECOVERY PLAN: UPPER COLUMBIA											
Priority number	Task number	Task description	Task duration (years)	Responsible parties	Cost estimates ($1,000)						Comments
					Total cost	Year 1	Year 2	Year 3	Year 4	Year 5	
2	6.3.6	**Develop and implement local habitat protection laws and ordinances.**	25	**Local Governments**, OC, CC	*						
3	1.3.1	**Minimize further shoreline and floodplain development.**	10	**USFS, OC, CC, WDNR**, USFWS	500	50	50	50	50	50	
3	1.3.3	**Develop and coordinate access and travel management plans.**	25	**USFS, WDFW**, **OC, CC**, USFWS	*						
3	1.3.11	**Maintain unroaded portions of bull trout watersheds in current roadless condition.**	25	**USFS, WDNR**	*						

IMPLEMENTATION SCHEDULE FOR BULL TROUT RECOVERY PLAN: UPPER COLUMBIA											
Priority number	Task number	Task description	Task duration (years)	Responsible parties	Cost estimates ($1,000)						Comments
					Total cost	Year 1	Year 2	Year 3	Year 4	Year 5	
3	1.3.18	**Exclude grazing from sensitive habitat areas.**	25	**USFS, WDNR**	*						
3	1.3.19	**Identify and mitigate habitat impacts from highways and railroads.**	2	**WDOT,** WDOE. WDNR	50	25	25				
3	1.3.21	**Reduce sediment loading to streams.**		**USFS, OC, WDNR**, USFWS, NMFS	130	30	100				
3	1.3.22	**Identify and, where feasible, correct man-made barriers to fish passage in foraging and refugia habitats.**	3	**USFS,** WDFW, USFWS	150	50	50	50			
3	1.3.23	**Restore and protect habitat that is impacted by recreational campgrounds.**	5	**USFS**	250	50	50	50	50	50	

IMPLEMENTATION SCHEDULE FOR BULL TROUT RECOVERY PLAN: UPPER COLUMBIA												
Priority number	Task number	Task description	Task duration (years)	Responsible parties	Cost estimates ($1,000)						Comments
					Total cost	Year 1	Year 2	Year 3	Year 4	Year 5	
3	1.4.3	**Evaluate downstream passage at Tumwater and Dryden dams.**	3	**WDFW, USFS** USFWS	150	50	50	50			
3	4.3.1	**Establish genetic reserve protocols.**	3	**USFWS,** WDFW, YN	*						
3	4.3.3	**Evaluate hybridization with brook trout.**	3	**WDFW**, **USFS** USFWS,	*						
3	5.2.1	**Develop and implement a monitoring program.**	3	**USFWS**, USFS, WDFW	*						
3	5.5.2	**Investigate potential and feasibility for reintroducing bull trout to the Chelan Basin.**	3	**WDFW**, USFS, USFWS	150	50	50	50			
3	5.5.3	**Investigate potential use of the Okanogan River by bull trout, and investigate habitat suitability.**	3	**WDFW, CT, USFS**	150	50	50	50			

IMPLEMENTATION SCHEDULE FOR BULL TROUT RECOVERY PLAN: UPPER COLUMBIA											
Priority number	Task number	Task description	Task duration (years)	Responsible parties	Cost estimates ($1,000)						Comments
					Total cost	Year 1	Year 2	Year 3	Year 4	Year 5	
3	5.5.6	**Assess feasibility for using Patterson Lake bull trout to reestablish Methow River local populations.**	3	**USFS, WDFW**, OC, USFWS	75	25	25	25			
3	7.3.1	**Periodically review progress toward recovery goals and assess recovery task priorities.**	25	**USFWS, NMFS**	*						

REFERENCES CITED

Brown, L.G. 1992. Draft management guide for the bull trout *Salvelinus confluentus* (Suckley) on the Wenatchee National Forest. Washington Department of Wildlife. Wenatchee, Washington.

Bryant, F.G., and Z.E. Parkhurst. 1950. Survey of the Columbia River and its tributaries; area III, Washington streams from the Klickitat and Snake Rivers to Grand Coulee Dam, with notes on the Columbia and its tributaries above Grand Coulee Dam. USFWS, Special Scientific Report 37, 108 pp.

Crow, J. F. and M. Kimura. 1970. An introduction to population genetics theory. Harper and Row, New York.

Franklin, I. R. 1980. Evolutionary changes in small populations. Pages 135-149 in M. E. Soule and B. A. Wilcox, editors. Conservation biology: An evolutionary-ecological perspective. Sinauer Associates, Sunderland, Massachusetts.

Harvey, B. C., T. E. Lisle, T. Vallier, D.C. Fredley. 1995. Effects of suction dredging on streams: a review and evaluation strategy. Report to Gray Reynolds, deputy chief National Forest System, USDA Forest Service. September 29, 1995.

Hillman, T. W. and M. D. Miller. 1993. Estimated abundance and total numbers of chinook salmon and trout in the Chiwawa River, Washington 1992. Report to Chelan County Public Utility District, Washington. Don Chapman Consultants inc. Boise, Idaho.

Hillman, T. W. and M. D. Miller. 1994. Estimated abundance and total numbers of chinook salmon and trout in the Chiwawa River Basin, Washington

1993. Report to Chelan County Public Utility District, Washington. Don Chapman Consultants inc. Boise, Idaho.

Hillman, T. W. and M. D. Miller. 1995. Abundance and total numbers of chinook salmon and trout in the Chiwawa River Basin, Washington 1994. Report to Chelan County Public Utility District, Washington. Don Chapman Consultants inc. Boise, Idaho.

Hindes, R. 1994. Wenatchee River Watershed Ranking Project. Chelan County Conservation District, Wenatchee, WA.

Kreiter, S. 2001. Bull trout study updates. Chelan PUD, Wenatchee, Washington.

Kreiter, S. 2002. Bull trout study updates. Chelan PUD, Wenatchee, Washington.

Lande, R. 1988. Genetics and demography in biological conservation. Science 241: 1455-1460.

Martin, S.B. and W.S. Platts. 1981. Influence of forest and rangeland management on anadromous fish habitat in western North America, effects of mining. U.S. Forest Service General Technical Report PNW - 119.

McPhail J. D. and R. Carveth. 1992. A foundation for conservation: the nature and origin of the freshwater fish fauna of British Columbia. Fish Museum, Department of Zoology, University of British Columbia. Vancouver, B.C., Canada.

(MBTSG) Montana Bull Trout Scientific Group. 1996. The role of stocking in bull trout recovery. Montana Bull Trout Restoration Team. Helena, Montana.

(NPPC) Northwest Power Planning Council. 2001a. Draft Wenatchee Subbasin Summary. Prepared by L. Berg and D. Lowman.

(NPPC) Northwest Power Planning Council. 2001b. Draft Entiat Subbasin Summary. Prepared by L. Berg and S. Matthews.

(NPPC) Northwest Power Planning Council. 2001c. Draft Methow Subbasin Summary. Prepared by J. Foster.

(ODFW) Oregon Department of Fish and Wildlife. 1997. Status of Oregon's Bull Trout. Prepared by D. Buchanan, M. Hanson, and R. Hooton. Portland, Oregon.

Parametrix, Inc. 2000. Anadromous Fish Agreements and Habitat Conservation Plans for the Wells, Rocky Reach, and Rock Island Hydroelectric Projects. Draft Environmental Impact Statement prepared for the National Marine Fisheries Service in cooperation with Public Utility District No. 1 of Douglas County, Public Utility District No. 1 of Chelan County, and Federal Energy Regulatory Commission. November 2000.

Proebstel, D.S., R.J. Behnke, and S.M. Noble. 1998. Identification of salmonid fishes from tributary streams and lakes of the mid-Columbia basin. Joint publication by U.S. Fish and Wildlife Service and World Salmonid Research Institute, Colorado State University.

Quigley, T.M., and S.J. Arbelbide, tech. eds. 1997. An assessment of ecosystem components in the Interior Columbia Basin and portions of the Klamath and Great Basins: volume III. Gen. Tech. Rep. PNW-GTR-405. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 4 vol.

Rieman, B. E. and J. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. Gen. Tech. Rep. INT-302. Ogden, UT: U. S. Department of Agriculture, Forest Service, Intermountain Research Station. 38p.

Rieman, B.E., and F.W. Allendorf. 2001. Effective populations size and genetic conservation criteria for bull trout. North American Journal of Fisheries Management 21: 756-764.

Roberts, B.C, and R.G. White. 1992. Effects of angler wading on survival of trout eggs and pre-emergent fry. North American Journal of Fisheries Management 12:450-459.

Schmetterling, D.A. and M.H. Long. 1999. Montana Anglers' Inability to Identify Bull Trout and Other Salmonids. Fisheries 24(7):24–27.

Soule, M. E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pages 151-170 in M. E. Soule and B. A. Wilcox, editors. Conservation biology: An evolutionary-ecological perspective. Sinauer and Associates, Sunderland, Massachusetts.

Spence, B.C., G.A. Lomincky, R.M. Hughes, and R.P. Novitzki. 1996. An ecosystem approach to salmonid conservation. National Marine Fisheries Service, U.S. Fish and Wildlife Service, Environmental Protection Agency. TR-4501-96-6057.

(USFS) U.S. Forest Service. 1993. Beaver Creek Stream Survey Report. Okanogan National Forest, Methow Valley Ranger District, Winthrop, WA.

(USFS) U.S. Forest Service. 1994. Chewuch River Watershed Analysis. Okanogan National Forest, Methow Valley Ranger District, Winthrop, WA.

(USFS) U.S. Forest Service. 1995a. Twisp River Watershed Analysis. Okanogan National Forest, Methow Valley Ranger District, Winthrop, WA.

(USFS) U.S. Forest Service. 1995b. Wolf Creek Stream Survey Report. Okanogan National Forest, Methow Valley Ranger District, Winthrop, WA.

(USFS) U.S. Forest Service. 1995c. Lake Creek Stream Survey Report. Okanogan National Forest, Methow Valley Ranger District, Winthrop, WA.

(USFS) U.S. Forest Service. 1995d. Goat Creek Watershed Analysis and Interim Late Successional Reserve Assessment. Okanogan National Forest, Methow Valley Ranger District, Winthrop, WA.

(USFS) U.S. Forest Service. 1995e. Inland Native Fish Strategy Environmental Assessment. Forest Service; Intermountain, Northern, and Pacific Northwest Regions.

(USFS) U.S. Forest Service. 1996a. Watershed Assessment Entiat Analysis Area. Wenatchee National Forest. Wenatchee, WA.

(USFS) U.S. Forest Service. 1996b. Gold Creek Stream Survey. Wenatchee National Forest, Wenatchee, WA.

(USFS) U.S. Forest Service. 1996c. Nason Creek Watershed Analysis Environmental Assessment. Wenatchee National Forest, Wenatchee, WA.

(USFS) U.S. Forest Service. 1998a. Upper Methow Watershed Analysis. Okanogan National Forest, Methow Valley Ranger District, Winthrop, WA.

(USFS) U.S. Forest Service. 1998b. Biological assessment for steelhead, spring chinook, bull trout and cutthroat trout for the proposed actions of the Mud-Potato road relocation project on the Entiat Ranger District of the Wenatchee National Forest Chelan County, Washington. Wenatchee National Forest, Entiat, WA. Prepared by P. Archibald.

(USFS) U.S. Forest Service. 1998c. Biological assessment for steelhead, spring chinook, bull trout, and cutthroat trout for the proposed actions of livestock grazing on the Entiat Ranger District of the Wenatchee National Forest, Wenatchee, WA.

(USFS) U.S. Forest Service. 1998d. Peshastin Stream Survey. Wenatchee National Forest, Wenatchee, WA.

(USFS) U.S. Forest Service. 1999a. Mainstem Wenatchee River Watershed Assessment. Wenatchee National Forest, Wenatchee, WA.

(USFS) U.S. Forest Service. 1999b. Wenatchee National Forest Aquatic Consultation Package for Wenatchee River Subbasin: Biological assessments for upper Columbia River spring chinook, steelhead, bull trout and westslope cutthroat in watersheds of the Wenatchee River basin. Wenatchee National Forest, Wenatchee, WA.

(USFS) U.S. Forest Service. 1999c. Lost River and Robinson Creek Watershed Analysis. Okanogan National Forest, Methow Valley Ranger District, Winthrop, WA.

(USFS) U.S. Forest Service. 1999d. Peshastin Creek Watershed Assessment. Leavenworth Ranger District. Wenatchee National Forest, Wenatchee, WA.

(USFS) U.S. Forest Service. 2001a. Upper Methow Watershed Aquatic Species Biological Assessment. Okanogan-Wenatchee National Forests. Prepared by J. Haskins and D. Hopkins.

(USFS) U.S. Forest Service. 2001b. Lower Methow Watershed Biological Assessment. Okanogan-Wenatchee National Forests. Prepared by B. Baer and J. Molesworth.

(USFS) U.S. Forest Service. 2002. Chewuch Watershed Aquatic Species Biological Assessment. Okanogan-Wenatchee National Forests. Edited by J. Molesworth.

(USFS) U.S. Forest Service and (BLM) Bureau of Land Management. 1994. Record of Decision of Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl; Standards and Guidelines for Management of Habitat for Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern Spotted owl.

(USFWS) U.S. Fish and Wildlife Service. 1992. Production and Habitat of Salmonids in Mid-Columbia River Tributary Streams: USFWS, Monograph I, 1992. Mid-Columbia River Fish Resource Office, Leavenworth, WA.

(USFWS) U.S. Fish and Wildlife Service. 1997. An analysis of fish populations in Icicle Creek, Trout Creek, Jack Creek, Peshastin Creek, Ingalls Creek, and Negro Creek, Washington, 1994 and 1995. Mid-Columbia River

Fishery Resource Office, Leavenworth, WA. Prepared by B. Kelly-Ringel.

(USFWS) U.S. Fish and Wildlife Service. 1998. Klamath River and Columbia River bull trout population segments: status summary. Prepared by the Service's bull trout listing team. Boise, Idaho.

(USFWS) U.S. Fish and Wildlife Service. 1999a. Bull trout spawning ground surveys of Panther, Mill and Nason Creeks, Washington, 1998. Mid-Columbia River Fishery Resource Office, Leavenworth, Washington. Prepared by B. Kelly-Ringel.

(USFWS) U.S. Fish and Wildlife Service. 1999b. Summary of snorkel surveys in Icicle Creek in the large pool adjacent to the Leavenworth National Fish Hatchery. Mid-Columbia River Fishery Resource Office, Leavenworth, Washington. Prepared by b. Kelly-Ringel.

(USFWS) U.S. Fish and Wildlife Service. 1999c. Survey of fish populations in French Creek, Washington. Mid-Columbia River Fishery Resource Office, Leavenworth, Washington. Prepared by B. Kelly-Ringel and L. Murphy.

(USFWS) U.S. Fish and Wildlife Service. 2000a. Wenatchee basin bull trout radio telemetry study updates. Mid-Columbia River Fishery Resource Office, Leavenworth, Washington. Prepared by B. Kelly-Ringel and J. De La Vergne.

(USFWS) U.S. Fish and Wildlife Service. 2000b. Biological Opinion. Effects to listed species from Operations of the Federal Columbia River Power System. U.S. Fish and Wildlife Service Regions 1 and 6, Portland, Oregon and Denver, Colorado.

(USFWS) U.S. Fish and Wildlife Service. 2001. Wenatchee basin bull trout radio telemetry study updates. Mid-Columbia River Fishery Resource Office, Leavenworth, Washington. Prepared by B. Kelly-Ringel and J. De La Vergne.

(USFWS) U.S. Fish and Wildlife Service. 2002. Icicle Creek Restoration Project, Final Environmental Impact Statement.

(UCSRB) Upper Columbia Salmon Recovery Board. 2001. A Strategy to protect and restore salmonid habitat in the upper Columbia region.

(WDFW) Washington Department of Fish and Wildlife. 1992. Draft management guide for the bull trout Salvelinus confluentus (Suckley) on the Wenatchee National Forest. Washington Department of Wildlife. Wenatchee, Washington. Prepared by L. Brown.

(WDFW) Washington Department of Fish and Wildlife. 1998. Washington salmonid stock inventory. Appendix: bull trout and Dolly Varden. Washington Department of Fish and Wildlife. Olympia, WA.

(WDFW) Washington Department of Fish and Wildlife. 1999a. Collection of Spring Chinook Salmon *Oncorhynchus tshawytscha* Eggs from Nason Creek and White River During 1999. Prepared by K. Peterson and B.Dymowska. WDFW, Olympia, WA.

(WDFW) Washington Department of Fish and Wildlife. 1999b. Gold and Fish: Rules and Regulations for Mineral Prospecting and Placer Mining in Washington State.

(WDFW) Washington Department of Fish and Wildlife. 2000. Bull trout and Dolly Varden management Plan. Washington Department of Fish and

Wildlife, Fish Management Division, Fish Program, Olympia, Washington. September 2000.

(WDG) Washington Department of Game. 1984. Lake Chelan fisheries investigations in cooperation with Chelan County Public Utility District, Chelan County WA. Prepared by L. Brown.

(WFPB) Washington Forest Practices Board. 2000. Washington forest practices: rules–WAC 222 (including emergency rules), board manual (watershed manual not included), Forest Practices Act, RCW 76.09. Washington Forest Practices Board, Olympia, Washington.

(WGSRO) Washington Governor's Salmon Recovery Office. 1999. Draft statewide strategy to recovery salmon, extinction is not an option. Olympia, Washington. January 1999.

(WSCC) Washington State Conservation Commission. 1999. Salmon and Steelhead Habitat Limiting Factors Report for the Entiat Watershed (Water Resource Inventory Area 46). Prepared by C. Andonaegui.

(WSCC) Washington State Conservation Commission. 2000. Salmon and Steelhead Habitat Limiting Factors (Water Resource Inventory Area 48 - Methow Watershed). Prepared by C. Andonaegui.

(WSCC) Washington State Conservation Commission. 2001. Salmon and Steelhead Habitat Limiting Factors Report for the Wenatchee Basin (Water Resource Inventory Area 47). Prepared by C. Andonaegui.

(WSOFM) Washington State Office of Financial Management. 2000. Washington State Census. www.ofm.wa.gov/census2000.

In Literature (In Litt.)

(NMFS) National Marine Fisheries Service. 2001. Northwest Salmon Recovery Planning.

Partridge, M. 2001. Article in the Wenatchee World. Staff writer.

(USFS) U.S. Forest Service. 1992. Beaver Creek Stream Surveys Report.

(USFS) U.S. Forest Service. 2002. Road densities in the Wenatchee, Entiat, and Methow Basins.

(USFWS) U.S. Fish and Wildlife Service. 1998a. Peshastin Creek stream survey report, 1997. Leavenworth, WA. Prepared by M. Cappellini.

(USFWS) U.S. Fish and Wildlife Service. 1998b. Informal Consultation Letter (1-3-98-I-394 through 398) for livestock Grazing in Five Watersheds in the Methow: Wolf Creek, Twisp River, Chewuck River, Upper Methow River, Lower Methow River within the Northwest Forest Plan Area. USFWS, Wenatchee Office, Wenatchee, WA.

(USFWS) U.S. Fish and Wildlife Service. 2002. Survey of fish populations in Chiwaukum Creek, 2001. Leavenworth, WA. Prepared by B. Kelly-Ringel.

Personal Communication (Pers. Comm.)

De La Vergne, J. U.S. Fish and Wildlife Service, Wenatchee, Washington. 2001.

De La Vergne, J. U.S. Fish and Wildlife Service, Wenatchee, Washington. 2002.

Kelly-Ringel, B. U.S, Fish and Wildlife Service, Leavenworth, Washington. 2001.

MacDonald, K. U.S. Forest Service, Wenatchee, Washington. 2001.

Wells, N. U.S. Forest Service, Okanagon, Washington. 2000.

Appendix A - Recovered Abundance Estimates

The recovered abundance levels for migratory bull trout in the Upper Columbia Recovery Unit were derived by combining redd density values and estimates of potential spawning and rearing habitat in local populations under a recovered condition (Table B1). Redd counts have been conducted in selected areas within the Wenatchee River since 1989. Fishing for bull trout has been prohibited since 1992. Redd counts from 1995 to present were selected to represent census data that excluded the influence of fishing mortality. Since 1995, the Chiwawa River local population complex (including Rock Creek, Chikamin Creek, Phelps Creek, and most recently the mainstem Chiwawa River and Buck Creek) has varied from 492 to 924 adults (246 and 462 redds). Redd density estimates from two areas within the Chiwawa River complex (Rock and Phelps creeks) were selected to develop an achievable recovered abundance range within the recovery unit. Habitat within Rock and Phelps creeks is considered to be in good condition and these populations are generally considered among the most secure in the Wenatchee Core Area. Redd densities in Rock Creek and Phelps Creek are 44 redds per mile and 27 redds per mile, respectively. While the habitat quality in Rock and Phelps creeks is similar, the total amount of available spawning area in Phelps Creek is restricted due to a barrier falls approximately 1 mile upstream from the confluence with the Chiwawa River. The Upper Columbia Recovery Unit Team believes that differences in redd density estimates between these local populations reflects natural variation in these relatively undisturbed stream reaches. These redd density values were then multiplied by the estimated number of available miles of spawning and rearing habitat in each local population to arrive at redd abundance. Finally, a range of recovered adult abundance for each local population was generated using a conservative estimate of two fish per redd.

Extrapolation of redd density estimates from Rock Creek to other local populations within the recovery unit would represent the "best case" scenario for a recovered abundance. Estimates from Phelps Creek would represent a "satisfactory" abundance level. The Upper Columbia Recovery Unit Team recognizes that under a recovered condition, some local populations may not reach these estimated levels, even after recovery actions have been implemented. The Upper Columbia Recovery Unit Team acknowledges that this approach contains a number of inherent assumptions relative to the productivity of individual local populations. Variation in habitat characteristics in local populations including temperature regimes, instream habitat, as well as other factors will result in variation in recovered abundance estimates. Site specific studies need to be initiated to better refine the productive potential in each local population and recovered abundance estimates in the Upper Columbia Recovery Unit.

Recovered abundance estimates are only for the migratory life-history form. Abundance estimates for the Wenatchee Core Area do not include Icicle Creek. It is unknown whether or not bull trout could pass over the barrier falls on Icicle Creek. After evaluation of the possible passage barrier above the hatchery, recovered abundance estimates may be generated for migratory bull trout in Icicle Creek. Resident bull trout are known to exist in Icicle Creek above the falls. Abundance estimates for resident bull trout in Icicle Creek, and other tributaries, are considered a research need. Local population in the Methow are represented by complexes of spawning tributaries and encompass: Gold Creek (including Crater Creek), Twisp River (including North, West Fork Buttermilk, East Fork Buttermilk, Reynolds, Little Bridge, and War creeks), Beaver Creek (only Bluebuck Creek), Wolf Creek, Goat Creek, Lost River (including Monument Creek and Eureka Lake), Upper Methow River (including Trout, Robinson, and Rattlesnake creeks), Chewuch River (including Lake and Eightmile creeks), and Early Winters Creek (including Huckleberry and Cedar creeks).

Table 4. Recovered Abundance estimates for migratory bull trout in Wenatchee, Entiat, and Methow core areas.

Core Area	Local Population	Stream Miles	Number of Redds (Density-27 per mile)	Number of Redds (Density-44 per mile)	Recovered Abundance Range (2 fish per redd)	
Wenatchee	White River	2.8	76	123	152	246
	Nason Creek	5	135	220	270	440
	Chiwaukum Creek	5	135	220	270	440
	Ingalls Creek	6	162	264	324	528
	Little Wenatchee	6.8	184	299	368	598
	Chiwawa River	---	---	---	492	924
Wenatchee Core Area Total					**1,876**	**3,176**
Entiat	Mainstem Entiat	8	216	352	432	704
	Mad River	7.5	202	330	404	660
Entiat Core Area Total					**836**	**1,364**
Methow	Gold Creek	3.5	94	154	188	308
	Twisp River	18	486	792	972	1,584
	Beaver Creek	0.5	14	22	28	44
	Wolf Creek	3.5	94	154	188	308
	Goat Creek	4	108	176	216	352
	Lost River	7.3	197	321	394	642
	Upper Methow	7.5	202	330	404	660
	Chewuch River	18	486	792	972	1,584
	Early Winters Creek	4.6	124	202	248	404
Methow Core Area Total					**3,610**	**5,886**
Total in Recovery Unit					**6,322**	**10,426**

Appendix B - List of Chapters

U.S. Fish & Wildlife Service

Pacific Region: Fisheries Program Strategic Plan

2009-2013

CONSERVING AMERICA'S *Fisheries*

A MESSAGE FROM THE REGIONAL DIRECTOR

In 2002, the U.S. Fish and Wildlife Service (Service) and the Sport Fishing and Boating Partnership Council's Fisheries Steering Committee worked together to develop a plan for the Fisheries Program titled, *Conserving America's Fisheries, U.S. Fish and Wildlife Service Fisheries Program Vision for the Future* (*Fisheries Vision*). The *Fisheries Vision* provided national level goals, objectives, and action items and identified the need for the geographic regions of the Service to develop regional step-down plans. This effort culminated in the development of a Strategic Plan for the Pacific Region Fisheries Program in 2004. For the past year, the Fisheries Program has dedicated its staff to reviewing and updating that plan to guide its program for the next five years.

I want to share my appreciation to all who contributed to the development of our Regional Plan for 2009 through 2013. It contains a vast array of objectives, all of which are critical to the Service's effectiveness in helping fish populations to achieve and maintain self-sustainable levels and contribute to public enjoyment. We will constantly evaluate our progress to document our success in meeting the challenges of protecting and conserving fisheries resources in the Pacific Region.

Our Regional Plan was built in partnership with employees, individuals, and organizations, across the Pacific Region. Continued communication, cooperation, and collaborative partnerships will be critical to the successful implementation of our Regional Plan, and fulfillment of the Fisheries Program resource responsibilities and obligations.

I look forward to the Fisheries Program building on the partnerships that are inherent in our Regional Plan. The Service does not have the funds and staffing to solely meet the challenges we face with the declining abundance of fish populations and quality of habitats on which they depend. Through more and stronger partnerships, the Service can be more successful in meeting these challenges.

Robyn Thorson

Robyn Thorson

Table of Contents

Executive Summary

In 2002, the Service and the Sport Fishing and Boating Partnership Council's Fisheries Steering Committee worked together to develop a plan for the Fisheries Program titled, *Conserving America's Fisheries, U.S. Fish and Wildlife Service Fisheries Program Vision for the Future* (*Fisheries Vision*). The *Fisheries Vision* provided national level goals, objectives, and action items and identified the need for the geographic regions of the Service to develop regional step-down plans. This effort culminated in the development of a Strategic Plan for the Pacific Region Fisheries Program for 2004 through 2008.

This Strategic Plan for 2009 through 2013 builds on our last plan but differs in two ways. First, the new Plan does not identify specific tasks for each Regional Objective, as was done in the earlier plan. Details on task level of activities can be obtained by contacting the Regional Office or a field station in your area (Appendix A). Second, for each of the Focus Areas we have added a narrative that describes the challenges and opportunities we have identified for achieving our Regional Objectives, which directly support goals articulated in the national Fisheries Strategic Plan. Regional Objectives have also been renumbered to reflect their sequence of occurrence in this Plan. Those Focus Areas and Regional Objectives are summarized as follows:

Partnership and Accountability

- Develop working relationships with additional stakeholders.
- Enhance relationships with our working partners in the Pacific Region.
- Implement a means of providing feedback to support the long-term success of partnerships.

Aquatic Habitat Conservation and Management

- Work with Tribes, States, partners, and other stakeholders to facilitate management of aquatic habitats on national and regional scales.
- Develop and expand our expertise to help avoid, minimize, or mitigate impacts of habitat alteration on aquatic species and monitor implemented projects.
- Work with other Service programs in the Pacific Region and adjacent Service regions to expand opportunities to increase the quantity and improve the quality of aquatic and riparian habitats.
- Expand opportunities to connect people with nature and engage citizen scientists and volunteers, and employ America's youth within aquatic habitat conservation programs.

Aquatic Species Conservation and Management

- Collaborate with the Service's Division of Ecological Services, NOAA Fisheries and others to recover fish and other aquatic resource populations protected under the Endangered Species Act (ESA).
- Collaborate with others to maintain healthy, diverse, self-sustaining populations of fish and other aquatic resources.
- Use Service facilities such as National Fish Hatcheries to support the research and aquaculture needed to prevent listing or recover and minimize impacts to native species listed or proposed for listing under the ESA.

- Coordinate with other Service programs, other Federal agencies, States, Tribes, and other partners to reduce the risk of aquatic invasive species (AIS) introductions, measure and track the existing range and impacts of AIS, and develop programs designed to control and manage existing populations.

Public Use

- Work jointly with States, Tribes, and NOAA Fisheries to assist in the management of inter-jurisdictional fisheries and conduct scientifically based hatchery programs to meet mutually agreed-upon fishery management objectives.
- Guide our mitigation programs by and maintain compliance with approved Fishery Mitigation Plans, Fishery Management Plans, and associated Biological Opinions.
- Work with others to identify appropriate mitigation hatchery production goals and Federal agency funding responsibilities, and meet our own responsibilities for mitigating fisheries affected by federally funded water development projects.
- Work with others to enhance recreational fishing opportunities for priority fish species, promote the value of recreational fishing, use our facilities to connect people with nature, and identify and implement shared or complementary aquatic education objectives.

Cooperation with Native American Tribes

- Provide technical assistance to Tribes as requested and to the extent possible, in tribal natural resource management activities.
- Provide fish from the Service's National Fish Hatcheries, where appropriate, to support tribal fish culture programs, subsistence programs, ceremonies, and resource management activities.
- Recognize and promote the Service's responsibilities toward Tribes.

Leadership in Science and Technology

- Develop and share state-of-the-art, scientifically sound, and legally defensible tools with other Service programs and in conjunction with our partners.
- Use state-of-the-art, scientifically sound, and legally defensible tools in formulating and executing fishery related plans and policies.

Workforce Management

- Identify the critical staff and functions needed to support various types and sizes of Pacific Region's Fisheries Program offices.
- Train and develop employees for the most effective use of their skills and positions.
- Ensure our employees are equipped with the technology, tools, and equipment to effectively, efficiently, and safely conduct their jobs.

Many objectives identified in this plan can be addressed with existing resources and authority; others cannot. The individual Fisheries Program offices will continue to assess their expertise, priorities, and resources to determine which of the objectives and tasks they can accomplish and implement. Each office will emphasize the overall direction and spirit of the Fisheries Program while seeking additional resources and cooperation with partners to expand their capabilities.

Compliance with Strategic Plan objectives will be evaluated in cooperation with Tribes, States, partners, and other stakeholders by maintaining an ongoing dialog to identify any necessary revisions to the Strategic Plan.

This *Strategic Plan* is consistent with the Department of Interior's (DOI) Strategic Plan. Appendix B contains the DOI performance output measures and the Fisheries Program's projected accomplishment targets.

Introduction

The Fisheries Program of the U.S. Fish and Wildlife Service (Service) has played a vital role in conserving and managing fish and other aquatic resources since 1871, when Congress established the position of Commissioner of Fish and Fisheries in response to concern regarding the decline in natural food fish supplies. The Service has a proud history of leading Federal fishery conservation efforts along the West Coast since the first Federal salmon hatcheries were established more than 100 years ago. Throughout this century-plus, the Service has taken a holistic approach to fishery conservation, focusing on a broad array of scientific fishery management and conservation efforts. Today, the Fisheries Program is an important partner with States, Native American Tribes (Tribes), other governments, other Service programs, private organizations, public institutions, and stakeholders in a larger effort to conserve these important resources. In 2002, the Service, working with its many partners in aquatic conservation through the Sport Fishing and Boating Partnership Council's Fisheries Steering Committee, completed its document: "Conserving America's Fisheries, Service Fisheries Program Vision for the Future" (*Fisheries Vision*). The *Fisheries Vision* included goals, objectives, and action items on a national programmatic scale.

The *Fisheries Vision* identified the need for the Service to develop five-year step-down plans with specific activities that will contribute to the *Fisheries Vision*. The Pacific Region developed its first five-year *Fisheries Program Strategic Plan* (*Strategic Plan*) to cover the period between 2004 through 2008. This document provides the Pacific Region's step-down plan for the period 2009 through 2013 and describes how we will implement the goals identified in the *Fisheries Vision.*

The Fisheries Program recognizes that many responsibilities for managing and conserving fish and other aquatic resources are shared, and success is often contingent upon the combined knowledge, resources, and commitment of each party. As a result, the Pacific Region views this *Strategic Plan* as an understanding between the Fisheries Program and its partners and stakeholders.

Vision

The Fisheries Program vision is to protect, restore, and enhance fish and other aquatic resources to self-sustaining levels and to support Federal mitigation programs in cooperation with States, Tribes, and other partners for the continuing benefit of the American public. To achieve that vision, the Fisheries Program is committed to working with our partners to:

- Protect the health of aquatic habitats.
- Recover and restore fish and other aquatic resources.
- Provide opportunities to enjoy the many benefits of healthy aquatic resources.

Challenges and Opportunities Summary

Hatchery Reform:

To assist in the recovery of ESA-listed fish and to compensate for lost fishery resources from Federal water resource development, the Fisheries Program will be working with our partners to reform and improve all National Fish Hatchery programs in the Pacific Region. Implementation of "hatchery reform" may include clarifying specific biological goals and objectives, improving our ability to adaptively manage our facilities though improved science, improving rearing and release protocols, changing broodstock, and adjusting production levels where appropriate. We will work closely with our partners to prioritize and coordinate implementation activities to ensure our fish hatchery programs help recover ESA-listed species while also meeting our Federal mitigation and treaty trust obligations.

Adaptive Management and Strategic Habitat Conservation Framework:

The Service has developed an adaptive management framework for all our conservation activities. We call this framework "Strategic Habitat Conservation". We have been developing Strategic Habitat Conservation as a guide for setting and achieving fish and wildlife conservation at multiple scales (landscape to site-specific). Over the next several years, we will be emphasizing cooperative conservation at the landscape scale. This will involve developing spatially explicit biological objectives, designing effective conservation programs that achieve our biological objectives, implementing on-the-ground conservation actions, and monitoring our activities to shape future planning and project development. Each of these steps will be done in cooperation with our partners.

Global Climate Change:

The Service recognizes the significant challenges that fish and wildlife resources are facing as a result of global climate change. We are actively developing a strategic plan and a 5-year action plan to help us begin to address the effects of climate change on fish, wildlife, plants, and their habitats. We are already working with partners and available resources to address climate change effects on fish and wildlife across our country. Accelerating climate change will amplify many of the conservation challenges we are dealing with today.

However, we cannot meet these challenges alone. Over the next 5 years, we will seek to acquire additional resources and build our agency's capacity to address the impacts of climate change on ecosystems and fish and wildlife resources. We will also be forming new partnerships and developing new scientific information that will help us predict and respond to the effects of future climate change.

Connecting People with Nature:

With the increasing movement of people to urban areas and towards indoor recreational pursuits, many of America's youth are losing their connection to the outdoors and are experiencing a gap in their knowledge of fish, wildlife, and their habitats, and the need for natural resource conservation. In addition, demographic changes will also necessitate greater emphasis on engaging non-traditional groups and under-represented groups (urban populations, minorities, and women) to experience nature.

Fortunately, research also shows that it is never too late to develop a connection with nature that will lead to caring and positive behaviors toward fish, wildlife, and their habitats. Recognizing this opportunity, the Service has adopted a program to "Connect People with Nature" to help ensure the future of conservation. Our Connecting People with Nature program is one of our highest priorities. While our other priorities emphasize our scientific and natural resource management work, we recognize that if we do not find ways to connect the American people with nature, thereby creating tomorrow's conservationists, much of our work could be in vain. We believe this program can result in all individuals and communities gaining a greater connection with nature, sense of place, respect for their environment, and a lifelong interest in and participation in the conservation, protection, and enhancement of fish, wildlife, plants, and their habitats.

Status of the Pacific Region's Fisheries Resources

The West Coast of the United States possesses rich and diverse natural resources. Unique among these are Pacific salmon and steelhead. Salmon and steelhead are more than an icon of the Pacific Region; they are a national treasure and are seriously depleted. Western rivers were once among the most productive in the world. The Columbia River had runs of five species of Pacific salmon, steelhead, and other anadromous fish totaling as many as 10 to 16 million fish that supported both tribal and commercial fisheries. The Pacific Region has reached a point where many other migratory fish species (e.g., sturgeon, coastal cutthroat, bull trout, and Pacific lamprey) and resident fish stocks (e.g., bull trout, westslope cutthroat, white sturgeon, river lamprey, burbot, chub, and those of the Pacific Islands) are either listed or being considered for listing under the ESA.

In short, genetic diversity and geographic distribution of these fish are shrinking markedly. The causes of these declines not only reflect the health of the Pacific Ocean, inland waters, and watersheds, but the immense human demand for water, energy, and land. Many demands are national and international in scope and complex, with legal implications to Federal responsibilities under both international and tribal treaties.

The Pacific Region Fisheries Program

The Fisheries Program is a network of 25 Field Stations and a Regional Office under the direction of the Assistant Regional Director (ARD) Fisheries in Portland. Field stations are located in the states of Washington, Oregon, Idaho, and Hawaii (Figure 1).

National Fish Hatcheries: Fifteen National Fish Hatcheries (NFH) produce more than 60 million fish annually in the Pacific Region. These NFHs, along with other Fishery Program offices, are important components of an integrated approach to the management and restoration of aquatic species and their environments. Most NFHs are operated to mitigate for adverse impacts from Federal water development projects and have an important role in supporting recreational, commercial, and international fisheries, and meeting tribal trust responsibilities. However, with the decline of many native species, Pacific Region NFHs

Figure 1.—Map of U. S. Fish and Wildlife Service, Pacific Region Fisheries Program, field offices and facilities.

now play an increasing role in supporting the recovery of species listed under the ESA. Salmon and steelhead remain the focus of most NFH efforts in the Pacific Region, though we also work with other anadromous and resident species as well. Comprehensive hatchery management planning will, with the help of Tribes, States, partners, and other stakeholders, ensure our NFHs and the fish they produce will help, not harm, our native species and the environments they depend upon and thus continue a legacy of fish and fishing for all to enjoy.

Lower Snake River Compensation Plan Office: The Lower Snake River Fish and Wildlife Compensation Plan (LSRCP) is a nationally unique program that compensates for lost fish and wildlife resources in Oregon, Washington, and Idaho caused by the construction and operation of four lower Snake River dams. The LSRCP Office is located in Boise, Idaho, and administers the LSRCP's hatchery program with the goal of rearing and releasing sufficient salmon, steelhead, and resident trout to compensate for reduced adult fish returns to the Snake River basin and lost fishing opportunities. The LSRCP provides funding to three States, three Tribes, and three Service offices to operate 26 fish hatchery facilities, fish health facilities and research labs in Oregon, Washington, and Idaho and to carry out programs to evaluate the success of the program.

Fish Health Centers: Three Fish Health Centers (FHC) provide long-term pathogen surveys and monitoring of fish at NFHs and selected wild fish populations as well as disease diagnostics and investigational studies. The FHCs are the lead offices in fish pathogen containment, emergency disease diagnostic control, and epidemiological assistance to fishery managers. They provide training, policy, and biological guidance for fish disease and fish health management. They assist a wide range of cooperators including Tribes, States, partners, and other stakeholders with fish health technical and training services. Their expertise includes aquatic animal health, veterinary medicine, physiology, pathology, and microbiology.

Fishery Resource Offices: Three Fishery Resource Offices (FRO) assist in the collection, evaluation, coordination, and dissemination of fisheries information to help restore declining fish species, recover species listed under the ESA, reduce the need for future listings of new species, and provide science-based management of aquatic resources. They provide long-term monitoring, evaluation, and technical support to assess the status of wild fish and aquatic species populations. Evaluation of stocks released from the Service's NFHs is a major function of the FROs. They provide technical assistance to agencies with the authority to set fish management regulations. They also provide technical assistance to many landowners (e.g., Federal, State, tribal, and private) to prevent the loss of fish habitat and implement best management practices for the long-term benefit of fish and their habitats. FROs further promote interagency coordination by serving on technical and policy workgroups (committees, councils, commissions, etc.) in the areas of hydropower operations, harvest, hatchery, and habitat management.

Fish and Wildlife Offices: Two Fish and Wildlife Offices (FWO) include Fisheries Program operations (Western Washington and Pacific Islands). These offices are distinct in that they include both Fisheries and Habitat Conservation and Ecological Services functions of the Service. The fisheries functions include the same responsibilities as those carried out by FROs.

Fish Technology Center: The Abernathy Fish Technology Center (Center) provides leadership in the scientifically based management of national fishery resources through development of new concepts and techniques to solve specific problems in aquatic restoration and recovery activities. The Center is the Pacific Region Fisheries Program's applied research facility and one of only eight such USFWS facilities nationwide. Staff research activities are concentrated in Washington, Oregon, and Idaho working on Pacific salmon, steelhead/rainbow trout, cutthroat trout, bull trout, Pacific lamprey, white sturgeon, Arctic grayling, and other species native to North America. The Center maintains Applied Research Programs in the fields of Nutrition, Conservation Genetics, Ecological Physiology, and Hatchery Reform. Applied research activities and information are shared with other Service offices (National Fish Hatcheries, Fish Health Centers, Fishery Resource Offices, Fish and Wildlife Offices, Ecological Services Field Offices, National Wildlife Refuges), Federal, State, and Tribal agencies, industry, and recreational groups. The information provided is critical to the restoration and recovery of declining, threatened, and endangered fish populations.

Focus Areas:

Partnerships and Accountability

Forming and maintaining strong partnerships with Federal agencies, States, Tribes, non-government organizations and individuals who are interested in the conservation and management of fisheries resources is essential to achieving mutual goals of healthy and abundant fish populations that have access to quality habitat and provide significant opportunities for harvest in the Pacific Region.

Accountability is a critical element of ensuring the successful implementation of this Strategic Plan. This is accomplished by implementing principles of sound science in accordance with Service policies and guidelines that stand up to peer review; making data and reports easily accessible; using financial and staff resources efficiently and wisely; reporting activities and accomplishments in a timely and accurate manner; involving partners; and fulfilling commitments.

***National Goal*: Open, interactive communication between the Fisheries Program and its partners.**

> ***Regional Objective 1.1.* Develop and maintain relationships with partners throughout the Pacific Region.**
>
> ***Regional Objective 1.2.* Implement a means of providing feedback to ensure the long-term success of partnerships.**
>
> ***Regional Objective 1.3.* Improve data collection and management and internal and external reporting to reduce redundancy and improve access and usefulness for ourselves and our partners.**

Challenges and Opportunities:

Partnerships

The partners the Pacific Region Fisheries Program works with have a broad array of interests, differing levels of resources, and varying tactics for addressing the wide scope of Service mandates and aquatic resource conservation issues we address. To effectively communicate information of interest to such a diverse constituency of partners, the Fisheries Program will:

- Engage our working partners to learn which Service activities or programs are most important to them or their constituents, and focus communications and information exchange on those topics.
- Keep personnel informed as to current operations and issues that may impact partners.
- Implement the Department of the Interior's 21st Century Youth Conservation Corps initiative and the Service's Connecting People with Nature.
- Network with partners to leverage limited resources.
- Use emerging technology to improve and diversify outreach efforts.

Measuring Success

There are many ways to measure success when working with partners, but most important is clarifying mutual obligations and expectations. To better address accountability, the Fisheries Program will:

- Maintain and develop Memorandums of Understanding and Memorandums of Agreement to better define expectations and enhance accountability.
- Improve opportunities for our partners to meet with regional and field staff to provide direct feedback on our progress in meeting plan objectives.
- Improve data management and reporting.

Focus Area:

Aquatic Habitat Conservation and Management

Because fish and wildlife resources inhabit landscapes that cross geographic boundaries, our efforts to conserve and restore aquatic habitat are done in cooperation with other Federal agencies, States, Tribes, nongovernmental organizations (NGOs), and private parties. Many of our aquatic habitat conservation and management efforts to date have been opportunistic, or based on actions called for within species-specific management or recovery plans. A growing consensus for habitat conservation at a landscape level has been building in the face of resource challenges such as global climate change. This has led to the beginning of a national collaborative framework to identify and conserve key watersheds and aquatic "strongholds," and address the root causes of declines in aquatic habitat quality and quantity.

While the needs for aquatic habitat protection and restoration are many, there is a major void in the monitoring and evaluation of completed habitat improvement projects. To take a landscape approach to ecosystem restoration, research and monitoring are needed to determine the effectiveness of habitat restoration efforts. The Fisheries Program is positioned to fill this void since our employees have extensive experience with monitoring and evaluating hatchery programs, fish populations, and their habitats.

***National Goal*: America's streams, lakes, estuaries, and wetlands are functional ecosystems that support self-sustaining communities of fish and other aquatic resources.**

***Regional Objective 2.1.* Facilitate management of aquatic habitats on national and regional scales by working with Tribes, States, partners, and other stakeholders.**

***Regional Objective 2.2.* Develop and expand the use of its expertise to help avoid, minimize or mitigate impacts of habitat alteration on aquatic species and monitor and evaluate completed projects.**

***Regional Objective 2.3.* Coordinate with Service NWRs and NFHs to identify and implement opportunities for increasing the quantity and improving the quality of aquatic and riparian habitat.**

***Regional Objective 2.4.* Expand opportunities to connect people with nature, engage citizen scientists and volunteers, and temporarily employ youth in the aquatic habitat conservation and monitoring programs and activities we lead or support.**

Challenges and Opportunities:

Strategic Habitat Conservation Framework

Strategic Habitat Conservation (SHC) allows for prioritizing the delivery of conservation actions. When using a strategic approach the Fisheries Program will:

- Use biological planning, conservation design, conservation delivery, and outcome-based monitoring to ensure that habitat requirements for aquatic trust species are included for projects undertaken with partners.
- Work with the Service's Divisions of Ecological Services and Refuges to align policies, goals, and objectives to conserve and restore aquatic habitats identified in Regional Focal Areas.
- Collaboratively develop the best scientific data and analysis for decision makers.
- Provide expertise to our partners, when possible, to assess, model, and develop opportunities to improve mainstem river habitat, fish passage, and emigration survival for aquatic trust species.
- Prioritize Service analysis and modeling capabilities toward measuring responses of wide-ranging Service trust species (e.g., bull trout, cutthroat trout, Pacific lamprey) to climatological effects on habitat, such as changes to temperature regimes.

National Fish Habitat Action Plan (NFHAP)

The National Fish Habitat Action Plan has increased the influence of its national network of partners to implement science-based, non-regulatory restoration, enhancement, and protection of fish habitat in key watersheds. Expectations and opportunities for the Service to further develop the NFHAP will further increase over the next 5 years. To address the challenges and opportunities the Fisheries Program will:

- Participate, support, and help develop NFHAP Partnerships.
- Work with our partners to ensure that habitat requirements and data needs for Service trust aquatic species are addressed in the Science and Data Management framework adopted by the National Fish Habitat Action Plan Board.
- Work with NFHAP Partnerships to develop funding proposals in the Fisheries Operating Needs System to support trust species.

Climate Change

Global climate change is expected to alter the quantity, seasonal availability, and quality (e.g., temperature regime) of water needed to support aquatic organisms in ways that are not fully understood or predictable. This unpredictability leads to debate and uncertainty regarding priorities for the best use of limited resources to study and implement broad scale management of aquatic habitats. However, the recent national and international attention that climate change is receiving provides the Service with the opportunity to focus our technical expertise in a collaborative environment to seek solutions. To address the challenge of global climate change, the Pacific Region Fisheries Program will support the Service's new strategic plan for addressing climate change "Rising to the Challenge," by focusing on our Program strength in population analysis, habitat conservation, and monitoring and evaluation.

- Partner with the USGS and others to conduct the basic research needed to predict impacts of changing water quality, quantity, and seasonal availability on the viability of trust species.
- Apply our expertise where needed in Region 1 Landscape Conservation Cooperatives (LCC)[1].
- Develop educational materials for Service staff to foster a better understanding of the technical and policy issues we face.

Effective Partnering

Aquatic resource conservation issues that involve multiple partners and their interests are challenging to resolve. To more effectively address resource challenges, the Pacific Region Fisheries Program will:

[1] Landscape Conservation Cooperatives (LCC) are a Service concept for building a core scientific capacity under cooperative partner oversight that assists resource managers direct science toward conservation priorities areas defined landscape units. LCC's are part of Secretary Salazar's September 14, 2009, Secretarial Order No. 3289 "Addressing the Impact of Climate Change on America's Water, Land, and other Natural and Cultural Resources."

- Support and participate in collaborative workshops (utilizing cross-program expertise) to inform partners and discuss the merits of the scientific approaches, tools, and results that address complex aquatic resource management issues.
- Train staff in conflict resolution, partnership building, decision making, etc.
- Increase internal communications by holding cross-program meetings.

Focus Areas:

Aquatic Species Conservation and Management

Native Species

In the Pacific Region, the primary focus of the Fisheries Program is addressing the problems affecting native aquatic species listed under the ESA and other aquatic species of concern. Activities conducted by the Fisheries Program to promote native species conservation include assessing populations and habitats; developing conservation, management and recovery plans; providing technical assistance to Tribes, States, partners, and other stakeholders; planning, monitoring and evaluating habitat restoration projects; and implementing various aspects of recovery plans. We will continue to work with our partners to collaboratively identify, prioritize and address the complex issues facing native aquatic species.

National Goal: ***Self-sustaining populations of native fish and other aquatic resources that maintain species diversity, provide recreational opportunities for the American public, and meet the needs of tribal communities***.

> ***Regional Objective 3.1.*** ***Collaborate with Ecological Services (ES) Program, National Oceanographic and Atmospheric Administration Fisheries (NOAA Fisheries) and others, to recover fish and other aquatic resource populations protected under the ESA.***
>
> ***Regional Objective 3.2.*** ***Maintain healthy, diverse, self-sustaining populations of fish and other aquatic resources.***
>
> ***Regional Objective 3.3.*** ***Support the research and fish culture needed to prevent listing or to recover native species listed or proposed for listing under ESA.***

Challenges and Opportunities:

Climate Change

To address the uncertain impacts of climate change on aquatic resources and their habitats in a strategic way, the Fisheries program will:

- Work with partners to learn from each other on projected global climate impacts.
- Collaborate to identify potentially resilient watersheds with a goal of preserving and restoring habitat connectivity to assist species ability to adapt to future climate conditions.
- Consider the use of artificial propagation to help offset impacts of climate change.

- Investigate opportunities to create research programs and assessment tools for "sentinel species" (e.g., bull trout, Oregon chub) that highlight the effects of climate change.

Hatchery Reform:

The Service has conducted or participated in various hatchery reform processes in the region including our own Hatchery Review Team (HRT) and NOAA Fisheries' Hatchery and Scientific Review Group (HSRG). These reviews provide scientific recommendations to Federal, Tribal, and State co-managers regarding how hatchery operations can be enhanced and modified to better protect wild and native species and meet defined fish production and harvest management objectives. In general, hatchery reform seeks to minimize harmful genetic, biological, or demographic effects on native and wild fish stocks and support recovery of ESA listed species, while pursuing pre-defined fishery management objectives. Important fishery management objectives include support of treaty trust and mitigation obligations. It is likely that hatchery reform recommendations will play a significant role in any modifications to existing fish production programs. In some cases, these changes could affect ongoing production and harvest activities of State and Tribal cooperators. Therefore, hatchery reform recommendations and associated changes will require collaborative co-manager input, review, and decision-making. As the Region 1 Fisheries Program pursues hatchery reform objectives, the Region 1 Fisheries Program will seek to:

- Recommend modifications of hatchery operations utilizing the best available scientific information from regional hatchery reform reviews such as the HRT and HSRG processes, scientific information available from the literature, and other Tribal, State, and Federal hatchery evaluation studies.
- Coordinate any proposed changes in fish production programs through appropriate policy review and decision processes, such as U.S. v. Oregon and ESA consultations.
- Prioritize hatchery implementation and funding of hatchery reform projects to meet mutual State, Tribal, and Federal fishery management objectives and ESA recovery priorities.
- Secure funding from appropriate sources to make the necessary hatchery facility modifications.

Aquatic Invasive Species

Introductions of aquatic invasive species (AIS) have caused significant economic and ecological problems throughout North America. After habitat loss, invasive species are considered the second most significant threat to native species. The National Invasive Species Act of 1996 established the following initiatives: 1) prevention, monitoring, and control of AIS; 2) research, technical assistance, and education on the AIS issue; 3) ballast water regulation; 4) the establishment of the Aquatic Nuisance Species (ANS) Task Force to act as a national coordinating body; 5) the establishment of regional coordinating bodies that support the ANS Task Force; 6) the funding of state or interstate invasive species management plans; 7) the establishment of a brown tree snake control program.

Although AIS populations have been surveyed in some locations, data are generally incomplete regarding distribution and impacts in the Pacific Region. There are many examples of existing problems, ranging from infestations of New Zealand mudsnails in Idaho hatcheries and native trout streams to nonnative marine algae overgrowing coral reefs in Hawaii. In addition, damaging invaders like quagga and zebra mussels continue to pose a high risk of invading the Pacific Region, bringing with them a history of environmental and economic impacts. AIS efforts by the Fisheries Program will emphasize prevention, early detection, and rapid elimination of new introductions and support efforts to control existing plant and animal AIS in freshwater and marine habitats.

***National Goal*: Risks of aquatic invasive species invasions are substantially reduced, and their economic, ecological, and human health impacts are minimized.**

> ***Regional Objective 4.1.* Coordinate work with other programs within the Service, other Federal agencies, States, Tribes, Interstate Commissions, and other partners to reduce the risk of AIS introductions, including early detection and rapid response.**
>
> ***Regional Objective 4.2.* Coordinate work with other programs within the Service, other Federal agencies, States, Tribes, Interstate Commissions, and other partners to measure and track the existing range and impacts of AIS.**
>
> ***Regional Objective 4.3.* Coordinate work with other programs within the Service, other Federal agencies, States, Tribes, Interstate Commissions, and other partners to develop programs designed to control and manage existing populations.**

Challenges and Opportunities:

Limiting Introductions of AIS

The Pacific Region faces several challenges to limit introductions of AIS including the growing potential for an invasion by zebra and quagga mussels, insufficient early detection capabilities, and major gaps in a regional rapid response infrastructure. To address these challenges, the Fisheries Program will:

- Continue collaborating with 100th Meridian Initiative program partners to enhance prevention, early detection, and rapid response preparedness for zebra and quagga mussels and other AIS.
- Expand our use of the Hazard Analysis and Critical Control Point (HACCP) planning.
- Continue to support implementation of State AIS management plans.
- Coordinate with State, regional, and national AIS organizations, including the ANS Task Force and its Western Regional Panel.
- Collaborate to better understand the pathways for spreading AIS.

Incomplete Information Regarding Current Distribution and Abundance

We have insufficient understanding of the current distribution and abundance of AIS, limited integration of AIS monitoring into other aquatic ecosystem monitoring and research programs, and fragmented management of AIS data. To address these challenges, the Fisheries Program will:

- Continue to work with USGS, the Pacific Northwest Aquatic Monitoring Partnership, States, Tribes, universities and other partners to enhance the monitoring of AIS populations and better manage the data.
- Support ongoing surveys of biological communities in aquatic systems in the region to enhance understanding of the biological characteristics and ecological conditions so that AIS invasions can be prevented or managed.

Controlling and Managing Existing AIS Populations

There are insufficient decision-support and population-control tools available to ensure effective long-term mitigation of AIS impacts, and inconsistent management strategies at the regional and national scale. To address these challenges, the Fisheries Program will:

- Continue implementing national AIS control plans (e.g., New Zealand mudsnails) and assist in developing new plans for species like nutria.
- Work with USGS and other partners to develop and enhance management decision tools.

Climate Change and Population Growth

Global climate change and further habitat degradation associated with population growth will likely change the potential range of AIS and risk of new introductions. To address these challenges, the Fisheries Program will:

- Support collaborative research, monitoring, and evaluation to better understand the factors contributing to the establishment and expansion of AIS related to climate change, and ensure that AIS concerns are adequately reflected in regional climate change initiatives.
- Promote other aquatic habitat conservation tactics within this plan, and ensure that AIS prevention, control, monitoring, and education are incorporated into Service activities under Strategic Habitat Conservation, the National Fish Habitat Action Plan, and other related efforts.

Better Integration of AIS into Service Programs

There is a need to better integrate AIS into all Service programs, including related efforts targeted at terrestrial invasive species. To address this challenge the Fisheries Program will:

- Explore creation of a Region 1 cross-program invasive species team to identify collaboration opportunities, mutual policy issues, and other areas of overlap.
- Expand integration of AIS activities into relevant Service field offices, including local implementation of outreach programs, on-site capacity for HACCP technical assistance, early detection monitoring, and development of local partnerships.
- Coordinate with other partners, including executive level discussions, to develop integrated proposals to expand funding for AIS management at the regional level, including special focus on the Pacific Islands, and to prioritize AIS concerns and activities relative to currently available resources.

Awareness and Understanding

There is a need to educate the Service and external audiences about scope, severity, and relevance of the AIS problem. To address this challenge the Fisheries Program will:

- Implement outreach and education programs, such as use of national campaigns like Stop Aquatic Hitchhikers and 100th Meridian Initiative.
- Integrate AIS into the Connecting People with Nature program.

Interjurisdictional Fisheries

Interjurisdictional fisheries management is a collaborative process involving two or more states, nations, or tribal governments with direct management authority. Responsibility for managing interjurisdictional fisheries is determined by many laws, treaties, and court orders and as such, follows no single implementation model. Many Pacific Region fisheries are interjurisdictional in nature. Management of interjurisdictional fisheries in the Pacific Region has become greatly influenced by the requirement for adequate protection and recovery of species listed under the ESA. To meet the Service's Federal tribal trust, resource protection, hatchery mitigation, and public benefit responsibilities, the Fisheries Program plays an integral role in the development of fishery management plans, development of new fishery management strategies and evaluation tools, conduct of applied research, and monitoring of harvest allocation and fishery impact limitation compliance.

While the challenges and opportunities for engagement in interjurisdictional fisheries management are broad-based, the Fisheries Program in the Pacific Region has a long history of providing hatchery fish production for harvest, monitoring and evaluation of hatchery production programs, and technical assistance to our State, Tribal, and Federal co-manager partners in stock assessment and fishery impact analysis. The Fisheries Program is well positioned to continue these efforts.

***National Goal*: Interjurisdictional fish populations are managed at self-sustaining levels.**

> ***Regional Objective 5.1*. When directed by statute, court order, or other legal or interagency agreement, the Fisheries Program will work jointly with States, Tribes, and NOAA Fisheries to assist in the management of interjurisdictional fisheries.**
>
> ***Regional Objective 5.2.* The Fisheries Program will conduct scientifically-based hatchery programs to meet mutually agreed upon interjurisdictional fishery management objectives for harvest, native stock conservation, ESA compliance, and Tribal trust, with full assessment of the benefits and risks of production.**

Challenges and Opportunities:

Maintaining Commitments

To maintain the Service's commitment to interjurisdictional fisheries management, the Fisheries Program will:

- Provide leadership in scientific analysis and ensure that the best scientific data is available for decision makers.
- Represent the Service on the Pacific Salmon Commission, Pacific Fisheries Management Council, and *U.S. vs. Oregon* fisheries forums, assisting them with implementation of scientifically based fish marking, stock assessment, and coast-wide harvest management programs.
- Work with our partners and co-managers to revise Hatchery Genetic Management Plans (HGMPs) for Service funded or operated programs.

Developing Consensuses on Hatchery Programs

Implementation of Hatchery Scientific Review Group (HSRG) and Hatchery Review Team (HRT) recommendations for Fisheries programs to assist in management of interjurisdictional fisheries will be complicated due to the multiple perspectives of stakeholders and co-managers. To address this challenge the Fisheries Program will:

- Continue to provide policy and technical support and guidance to co-managers and other stakeholders to seek consensus resolution of conflicting objectives and priorities while addressing recommendations of the HRT.

Climate Change

Anticipated changes in freshwater and ocean conditions may lead to shifts in anadromous salmon life-history timing, survival, and oceanic distribution. Such changes may require Pacific Salmon Treaty parties to renegotiate conservation and harvest sharing agreements. To address this challenge the Fisheries Program will:

- Work collaboratively with our partners to document and evaluate changes if they occur to provide the data needed to develop sustainable fisheries objectives.

Focus Areas:

Public Use

Mitigation Fisheries

When Federal water development projects (e.g., locks and dams) were constructed, Congress and the Federal government committed to mitigating for impacts on recreational, commercial, and tribal fisheries. Fisheries mitigation programs in the Pacific Region have generally involved stocking Pacific salmon, steelhead, and trout. Approximately half of the Pacific Region's hatchery programs are funded by the Corps of Engineers, Bureau of Reclamation, NOAA Fisheries, and the Bonneville Power Administration.

***National Goal*: The Federal government meets its responsibilities to mitigate for the impacts of Federal water projects, including restoring habitat and/or providing fish and associated technical support to compensate for lost fishing opportunities.**

Regional Objective 6.1. ***Work with Federal agencies, Tribes, State agencies, and others to identify the appropriate adult production hatchery mitigation goals for water development projects and funding responsibilities of the respective Federal agencies.***

Regional Objective 6.2. ***Ensure the Pacific Region's mitigation programs are guided by and in compliance with approved Fishery Mitigation Plans, Fishery Management Plans and associated Biological Opinions.***

Regional Objective 6.3. ***Meet the Service's responsibilities to implement mitigation programs for Federal action agencies responsible for mitigating fisheries affected by federally funded water development projects.***

Regional Objective 6.4. ***Pursue recovery of all direct and indirect costs for mitigation activities associated with hatchery production and stocking, marking and tagging, and monitoring and evaluation from the Federal agency on whose behalf the mitigation program is conducted.***

Challenges and Opportunities:

Obtaining Full Cost Reimbursement

Securing full funding for hatchery operations, maintenance, evaluation, and environmental compliance is an ongoing challenge for some of the mitigation programs operated by the Fisheries Program. To address this challenge the Fisheries Program will:

- Work collaboratively with the States, Tribes, and Federal partners to craft appropriate budgets to ensure full cost of the program, including hatchery operations and maintenance, capital improvement, marking and monitoring, evaluation, and environmental compliance.

Quantifying Mitigation Goals

Some hatchery mitigation programs in the Columbia Basin do not have defined adult production goals. Lack of clear goals makes evaluation of program success difficult. To address this challenge the Fisheries Program will:

- Work with our State, Tribal, and Federal partners to define appropriate mitigation goals for hatchery programs that do not have adult production goals or whose goals are under review (e.g., Mitchell Act, Grand Coulee, and John Day mitigation goals).

Implementation of Scientifically Sound Hatchery Evaluation and Adaptive Management Practices

Sound hatchery programs require scientific evaluation of the cost and benefits of those activities and feedback loops into management decision-making. Hatchery Review Team (HRT) recommendations identify infrastructure, operational, and management alternatives to improve hatchery operations. To address this challenge, the Fisheries Program will:

- Work with our staff and partners to fill as many gaps in program adequacy as can be done within existing budgets.
- Work with NOAA Fisheries and our partners to identify Best Management Practices (BMPs) for hatchery evaluation and to include the BMPs in new Hatchery and Genetic Management Plans (HGMPs) and seek funding to fill identified needs.

Facility Management and Technology

Aging facilities and evolving propagation programs require new infrastructure and technology to protect hatchery fish while on-station and to conserve native fish and habitat in the local watershed. Improved effluent treatment facilities are also needed to meet more stringent environmental compliance. To address these facility needs, the Fisheries Program will:

- Conduct annual assessments of the condition of all Service-owned hatchery facilities and develop a prioritized list of needed infrastructure repairs and improvements.
- Work with our funding partners to explain our methods for assessing needs and our priorities and the importance of those priorities.
- Prioritize facility improvements to meet Clean Water Act compliance through infrastructure improvement and fish culture operational changes.
- Provide recurring water quality and regulatory training for employees.
- Improve fish culture practices, water quality, station security, and energy efficiency through use of new or improved technologies and facilities.
- Work with NOAA Fisheries and within the Service as part of the section 7 consultation process under the ESA to identify and prioritize infrastructure needs necessary for protection and recovery of listed species.

Mitigation and ESA Recovery

The Fisheries program is committed to carrying out its mitigation programs in a way that supports ESA recovery criteria and actions. Meeting ESA compliance may require program adjustments such as choice of broodstock, production levels, release strategies, or other changes to achieve fishery mitigation goals and objectives. To address this challenge the Fisheries Program will:

- Work with our partners and co-managers to develop revised Hatchery and Genetic Management Plans (HGMPs) for Service operated mitigation programs.
- Provide technical assistance and guidance to regional hatchery planning activities to implement HRT and HSRG recommendations at Service funded hatcheries.

Healthy Fish

To maximize the survival of propagated fish and to minimize the impact of hatchery fish as a disease vector affecting native fish populations, the Fisheries Program will:

- Provide fish health advice and technical assistance to Service facilities and to our partners and customers on a reimbursable basis.

Recreational Fishing

The Fisheries Program has a long history of providing funding, hatchery fish, and scientific information in support of recreational fisheries on Service lands, tribal lands, military lands, and other waters where there is a Service nexus. In the Pacific Region, recreational harvest occurs on fish produced at Service hatcheries mitigating for impacts and loss of habitat due to the development of Federal water projects. The Fisheries Program also supports recreational fishing by connecting people with nature at fishing events held at our facilities.

***National Goal*: Provide quality opportunities/or responsible fishing and other related recreational enjoyment of aquatic resources on Service lands, on tribal and military lands, and on other waters where the Service has a role.**

> ***Regional Objective 7.1.* Work cooperatively to enhance recreational fishing opportunities for priority fish species and promote the value of recreational fishing as one of their priority responsibilities while implementing all national and regional activities.**
>
> ***Regional Objective 7.2.* Identify and meet shared or complementary aquatic education or other outreach objectives at local and regional levels.**

Challenges and Opportunities:

Providing Opportunities to Fish

Our challenge will be to continue providing quality recreational fishing opportunities for current and future generations. To address these challenges the Fisheries Program will:

- Work with Partners to monitor and evaluate the implementation of recreational fishing and help document successful recreational opportunities through websites and other media.
- Implement mass marking programs at federally funded facilities to facilitate selective recreational fisheries while minimizing impacts to wild populations, and maintaining consistency of the programs with tribal treaty rights.
- Continue to provide technical and policy support for the implementation of fish mitigation responsibilities and associated programs.
- Continue to meet our obligations for mitigating for the impacts of water development projects in the region.
- Develop sound data for assessing the economic value of recreational fishing in order to guide policy decisions on resource allocation.

Reconnecting People with Fishing

Urbanization of the Pacific Region has lessened opportunities for many of the region's residents to experience the region's rich natural heritage. To address this issue the Fisheries Program will:

- Help develop and sponsor events promoting recreational fishing with special focus on youth, the disabled, and urban fishing opportunities.

- Increase the number and quality of outreach and environmental education programs with an emphasis on our Connecting People with Nature Program.
- Maintain and provide opportunities for people to view fish in the wild.

Focus Area:

Cooperation with Native American Tribes

The Fisheries Program has a long history of cooperation with Tribes and support of tribal natural resource management. We understand that we play an important role in protecting the fish and wildlife resources that form the subsistence and cultural base of many Tribes of the Pacific Region. The trust relationship of the Federal government has evolved from treaties, statutes, court decisions, and the United States Constitution. The Service recognizes tribal treaty and other rights, interacts with Tribes on a government to government basis, and strives to conduct its programs and actions in a manner that protects tribal trust resources, including fish and wildlife resources and their associated habitat.

National Goal: ***Assistance is provided to Tribes that results in the management, protection, and conservation of their treaty-reserved or statutorily defined trust natural resources, which help Tribes develop their own capabilities.***

> ***Regional Objective 8.1.*** ***Recognize and promote the Service's distinct obligations toward Tribes.***
>
> ***Regional Objective 8.2.*** ***Provide technical assistance to Tribes in tribal natural resource management activities as requested and as funding is available.***
>
> ***Regional Objective 8.3.*** ***Ensure Service fish production and harvest management activities are consistent with legally mandated (e.g., U.S. v. OR) or other cooperatively developed fish management plans.***

Challenges and Opportunities:

Recognizing Tribal Co-Manager Authorities and Responsibilities

Over the last decade many tribal resource management agencies have developed new capabilities and capacity to participate in collaborative management. Tribes throughout the Pacific Northwest are active and legally recognized co-managers of many lands, waters, and aquatic resources within their ceded areas and marine environments. In recognition of tribal natural resource management authorities and capabilities, the Fisheries Program will:

- Formally consult with Tribes on Service programs affecting tribal interests.
- Work cooperatively to leverage resources towards programs of shared resource management concern.
- Coordinate Fishery Program activities within and between Tribes in concert with our trust responsibilities.

Managing Surplus Fish and Eggs from National Fish Hatcheries

In many years, adult salmon and steelhead return to Service-funded or operated hatcheries that are surplus to broodstock needs. Likewise, in some years more eggs are taken than can be reared in facilities because survival is higher than expected. Determining what is best to do with excess fish can be controversial because of logistical issues, differences in scientific views, or cultural beliefs. To address this issue the Fisheries Program will:

- As a matter of policy, and consistent with best fishery management practices, give high priority for the use of surplus fish and eggs from National Fish Hatcheries to tribal fish culture, subsistence, ceremonial, and resource management programs.
- Ensure timely communication coordination with tribal natural resources staffs to avoid creating "crisis management" decision environments for our respective policy makers.
- Engage with the Tribes to better understand tribal culture, history, and governmental structure.
- Actively communicate with tribal organizations and membership to explain and discuss fish production abilities and limitations.
- Develop MOUs and MOAs to enhance tribal relationships and accountability.
- Communicate with Tribes through the tools they prefer.
- Make available and promote emerging technologies as requested and to the extent possible to improve communication.

Implementing Federal Trust Responsibilities

To effectively carry out trust responsibilities, staff throughout the Fisheries program need to understand the special relationship we have with Tribes and our responsibilities for conserving trust resources. To address this opportunity the Fisheries Program will:

- Continue to implement the Secretary of the Interior and Service policies regarding trust responsibilities to Tribes (e.g., The Native American Policy of the Service, June 28, 1994; Secretarial Order # 3206, American Indian Tribal Rights, Federal-Tribal Trust Responsibilities, and the ESA, June 5, 1997).
- Provide Treaty Trust Responsibility training for staff.
- Engage Regional Tribal Liaison to advise staff when complex issues arise.

Rangewide Conservation of Pacific Lamprey

The Region 1 Fisheries Program is working with Columbia Basin and other Northwest Tribes on the conservation of Pacific Lamprey. This effort is in recognition of the cultural significance of this species to Tribes and its biological importance to the aquatic ecosystems of the Northwest. We commit to continue this effort with the mutual goal of restoring healthy populations of Pacific lamprey to the regions aquatic ecosystems. We commit to work with Tribes in bringing the attention to and coordinating efforts of other Federal, State, and private organizations in this effort.

Focus Area:

Leadership in Science and Technology ‘

Science and Technology form the foundation of successful fish and aquatic resource conservation and management and is a strength of the R1 Fisheries program. To that end, the Fisheries Program is committed to:

- Working with our partners to improve the connections between science and fishery conservation and management.
- Using sound science to evaluate effectiveness of our programs so they can be adaptively managed.
- Ensuring our policies and protocols result in science products that meet the highest standards of excellence for our partners and stakeholders.

National Goal**: *Science developed and used by Service employees for aquatic resource restoration and management is state-of-the-art, scientifically sound and legally defensible, and technological advances in fisheries science developed by Service employees are available to partners.***

> ***Regional Objective 9.1.*** ***Develop and share state-of-the-art, scientifically sound, legally defensible scientific and technological tools, including databases, with other Service programs and in conjunction with our partners.***
>
> ***Regional Objective 9.2.*** ***Use state-of-the-art, scientifically sound, legally defensible scientific and technological tools in formulating and executing fishery-related plans and policies.***

Challenges and Opportunities:

Science Support in Recovery of Listed Aquatic Species

There remain many challenges to protecting and recovering aquatic species listed under the ESA. Many stocks of anadromous fish, resident salmonids, and other species remain far below recovery objectives. We must focus our science and technical resources across a broad array of species and landscapes for optimum effect in supporting recovery efforts. We must work to strengthen our science and technical capabilities in order to support Service and regional efforts in conservation planning and delivery. In defining our priorities we will ask ourselves:

- Are we appropriately coordinated with governmental and external partners?
- Are we targeting species and issues of highest priority to the Service mission?
- Are we addressing the needs and priorities of our partners and customers?

As a result of asking these questions over the term of our last strategic plan, we made significant shifts in science support efforts of the Fisheries Program into the areas listed below. The Fisheries Program will continue to strengthen these efforts:

- Technical support to Service ESA listing and recovery processes.
- Conservation efforts directed at non-salmon species such as lamprey and Oregon chub, native Hawaiian fish, and white sturgeon.
- Leading hatchery reform efforts in the Columbia Basin.
- Expansion of Abernathy Fish Technology Center functions that support aquatic species conservation including genetic analysis, ecological physiology, fish nutrition, and hatchery reform.

Recovery of anadromous fish remains a high priority. New regional recovery plans and processes are in place for partners to collaboratively work together (e.g., Regional Implementation Oversight Group (RIOG), the Tribal Fish Accords, Puget Sound Federal Caucus). Science, whether it is applied research or monitoring and evaluation of efforts in hydropower, habitat, hatchery, or harvest, will continue to support informed policy decisions. To address the continuing efforts at anadromous fish recovery, the Fisheries Program will:

- Support NOAA Fisheries and State, Federal, and Tribal agencies in anadromous fish recovery efforts.
- Annually, develop a cooperative work plan with USGS Biological Research Division for anadromous fish research and monitoring and evaluation based on strategic goals and priorities that defines lead offices, funding sources, and cooperative research efforts.
- Support regional efforts to coordinate, share, and develop common data systems such as the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) and Collaborative System-wide Monitoring and Evaluation Project (CSMEP) in the Columbia Basin.
- Work within existing and newly defined processes to bring the scientific expertise of the Service to bear on critically important anadromous fish issues to avoid duplication of effort and coordinate related science support and research efforts.

Emerging Issues and Priorities

Complex issues often emerge more rapidly than programs can be developed to provide management options. This is made especially challenging by new sets of issues such as Climate Change and new invasive species. To better focus our efforts on emerging issues and address the imbalance between what we would like to do and what we can accomplish, the Fisheries Program will:

- Provide training on how to interpret information generated by modeling tools and incorporate the uncertainty that comes with the model predictions when making management decisions.
- Seek to develop new technology, expertise, and partnerships through participation in landscape level conservation initiatives.
- Promote the establishment of a regional cross programmatic scientific meeting about climate change in the Pacific Region that would be held regularly to promote collaborative research and information sharing.
- Seek to develop research projects with an adaptive management framework that use staff expertise to better address how the combined effect of changes to hatchery practices and habitat restoration is helping to conserve and restore aquatic resources in Pacific Region.
- Promote new research regarding climate change using an adaptive management framework.

Scientific Outreach

The Service's Fisheries Program is one of many natural resource management agencies in the region. We have significant scientific expertise that can help address the region's conservation and management problems. To increase the level and quality of communication with partners in regards to the technical expertise we can provided, the Fisheries Program will:

- Increase staff involvement in professional scientific organizations by encouraging activities such as presenting scientific results at professional conferences and sponsoring a Service booth at scientific conferences leading to outreach opportunities.
- Ensure staff is afforded time to write and review articles for professional publications.
- Provide training opportunities for staff and partners to facilitate understanding of how to use newly developed scientific and technological tools.
- Coordinate a regional cross-programmatic scientific meeting to be held regularly with the intention of promoting collaborative research between Service programs.
- Work with agencies, state, tribal, outside researchers, and partners to develop new research opportunities.
- Participate in cooperative landscape conservation to facilitate sharing of expertise.

Hatchery Data Management

The Fisheries Program has not yet developed modern databases for sharing hatchery information with our partners and the public. To address this shortcoming the Fisheries Program will:

- Develop and implement systems and methodology to demonstrate how hatchery improvement technology is minimizing impacts on wild fish and ESA-listed species.
- Develop and implement processes to develop timely reports on hatchery effectiveness that includes annual updates on hatchery fish production, adult return rates, harvest rates, brood year survival, and ecological effects of hatchery operations.
- Develop and implement systems to track implementation of hatchery reform recommendations including related fiscal expenditures, schedules, and accomplishments.

Focus Area:

Workforce Management

The Fisheries Program relies on a broad range of professionals to accomplish its mission: managers, administrators, scientists, program assistants, fish culturists, maintenance workers, and administrative and clerical staff. Without their skills and dedication, the Fisheries Program cannot succeed. Employees must be trained and equipped to perform their jobs safely, often under demanding environmental conditions, and must keep abreast of the constantly expanding science of fish and aquatic resource management and conservation. Also needed is the recruitment of new expertise to address hatchery reform actions, climate change, and habitat based activities.

***National Goal*: Maintain and support an adequately-sized, strategically positioned workforce with state-of-the-art training, equipment, and technologies in their career fields.**

> ***Regional Objective 10.1.* Identify the critical staff and functions needed to support various types and sizes of Pacific Region's Fisheries Program offices and to be able to fill critical vacancies and gaps in the current workforce with well-qualified individuals.**
>
> ***Regional Objective 10.2.* Train and develop employees for the most effective utilization of their skills and positions.**
>
> ***Regional Objective 10.3.* Ensure Fisheries Program employees are equipped with the technology, tools, and equipment to effectively and efficiently conduct their jobs.**

Challenges and Opportunities:

Our initial challenge is to carefully and fully identify the complete skill sets needed by our future employees. For current employees, we will need to both update position descriptions and ensure staff is provided the training they need to meet the new challenges. To address these challenges the Fisheries Program will:

- Consider new skill sets needed to address emerging priorities.
- Identify additional base and/or targeted funding sources to address new staffing needs.
- Seek opportunities to develop new positions that possess skills related to habitat and native species restoration. To do this field offices will review their organizational structure and station priorities to strategize how they will further develop this expertise.
- Take full advantage of the National Conservation Training Center to ensure employees maintain professional currency.
- Encourage active participation in professional organizations to ensure employees maintain technical proficiency.
- When applicable, use existing youth employment projects such as Youth Conservation Corps, AmeriCorps, Student Conservation Association, and the Service's SCEP and STEP programs to temporarily employ the next generation of conservation professionals, seeking where possible to recruit from underserved communities and/or convert recruits into term or permanent positions.
- Work with the Region's Connecting People with Nature Team and Division of Diversity and Civil Rights to identify new or existing programs or facilities positioned to initiate or expand hiring of youth for temporary positions and conservation projects.

Implementation

This Strategic Plan will be implemented through step-down plans developed by each field station in consultation with the Regional Office. Programmatic and station-specific activities will be prioritized using the following criteria:

- Strength of Federal authority and responsibility or existing legal and administrative directives.
- Measurable and meaningful resource results.

- Economic or social benefits.
- Partner support.
- Funds available to fully accomplish the task.
- Relation to other fisheries and aquatic resource conservation efforts.

Evaluation, Reporting and Revision

This *Strategic Plan* will guide the Fisheries Program through the 2013 fiscal year. Determining the success of implementing the *Strategic Plan* and the need for revision will be based on annually monitoring and evaluating accomplishments. The evaluation feedback will supply information needed to "fine tune" regional Fisheries Program priorities, station specific step-down plans, and budgets.

Equally important is communicating successes and failures to Tribes, States, partners, stakeholders, Congress, and the Administration. The Fisheries Program will report on its progress towards achieving strategic plan objectives through meetings with the Tribes, States, partners, stakeholders and through accomplishment reporting.

Regional Contact Information

This *Strategic Plan* was prepared through the efforts and contributions of a vast number of individuals within the Pacific Region, as well as Tribes, States, partners and other stakeholders. Our thanks go out to all who contributed their valuable time and shared their insightful perspectives to aide the Fisheries Program in developing this document. For more information concerning the development, refinements, and/or implementation of the information presented in this document, please feel free to contact:

Daniel Diggs
Assistant Regional Director - Fishery Resources
911 NE 11th Avenue
Portland, Oregon 97232-4181
(503) 872-2763

Appendix A.—Station contact information.

Office	Project Leader/Deputy	Office Phone #	Email Address
Abernathy Fish Technology Center 1440 Abernathy Creek Rd Longview, WA 98642	**Judith Gordon** Center Director **Patty Crandell** Deputy Center Director	360 425-6072	Judith_Gordon@fws.gov Patricia_Crandell@fws.gov
Carson NFH[2] 14041 Wind River Hwy Carson, WA 98610	**John W. Hitron** Project Leader **Tom Hogan** Assistant Project Leader	509 427-5905	John_Hitron@fws.gov Thomas_Hogan@fws.gov
Columbia River Fisheries Program Office 1211 SE Cardinal Crt, Suite 100 Vancouver, WA 98683	**Howard Schaller** Project Leader **Tim Roth** Deputy Project Leader	360 604-2500	Howard_Schaller@fws.gov Timothy_Roth@fws.gov
Dworshak Fisheries Complex P.O. Box 18 4147 Ahsahka Rd. Ahsahka, ID 83520	**Larry Peltz** Complex Manager	208 476-4591	Larry_Peltz@fws.gov
Dworshak NFH P.O. Box 18 4147 Ahsahka Rd. Ahsahka, ID 83520	**Mark Drobish** Project Leader	208 476-4591	Mark_Drobish@fws.gov
Eagle Creek NFH 34288 SE Rainbow Rd Estacada, OR 97023	**Larry Telles** Project Leader **Mark Galloway** Assistant Project Manager	503 630-6270	Larry_Telles@fws.gov Mark_Galloway@fws.gov
Entiat NFH 6970 Fish Hatchery Drive Entiat, WA 98822	**Craig Eaton** Project Leader	509 784-1131	Craig_Eaton@fws.gov
Hagerman NFH 3059-D National Fish Hatchery Road Hagerman, ID 83332	**Bryan Kenworthy** Project Leader **Natan Wiese** Assistant Project Leader	208 837-4896	Bryan_Kenworthy@fws.gov Nathan_Wiese@fws.gov
Idaho Fish Health Center P.O. Box 272 Orofino, ID 83544	**Kathy Clemens** Project Leader **Marilyn Blair** Assistant Project Leader	208 476-9500	Kathy_Clemens@fws.gov Marilyn_Blair@fws.gov

[2] National Fish Hatchery

Office	Project Leader/Deputy	Office Phone #	Email Address
Idaho FRO[3] P.O. Box 18 4147 Ahsahka Road Ahsahka, ID 83520	**Howard Burge** Project Leader **Mike Faler** Assist Project Leader	208 475-7242	Howard_Burge@fws.gov Micheal_Faler@fws.gov
Kooskia NFH Rt. 1 Box 98A Kooskia, ID 83539	**Adam Izbicki** Assistant Hatchery Mgr	208 926-4272	Adam_Izbicki@fws.gov
Leavenworth NFH Complex 12790 Fish Hatchery Rd Leavenworth, WA 98826	**Julie Collins** Complex Mgr **Steve Croci** Deputy Complex Mgr	509 548-7641 or 6085	Julie_Collins@fws.gov Steve_Croci@fws.gov
Leavenworth NFH 12790 Fish Hatchery Rd Leavenworth, WA 98826	**Al Jensen** **Hatchery Manager**	509-548-7641	Al_Jensen@fws.gov
Little White Salmon NFH 56961 SR 14 Cook, WA 98605	**Speros Doulos** Complex Manager **James Rockowski** Deputy Complex Manager	509 538-2755	Speros_Doulos@fws.gov James_Rockowski@fws.gov
Lower Columbia River Fish Health Center 201 Oklahoma Road Willard, WA 98605	**Susan Gutenberger** Project Leader **Eric Pelton** Assistant Project Leader	509 538-2400	Susan_Gutenberger@fws.gov Eric_Pelton@fws.gov
Lower Snake River Comp Plan 1387 S. Vinnell Way, Suite 343 Boise, ID 83709	**Scott Marshall** Project Leader	208 378-5298	Scott_Marshall@fws.gov
Makah NFH P.O. Box 739 Neah Bay, WA 98357 897 Hatchery Rd	**Caroline Peterschmidt** Hatchery Manager	360 645-2521 or 2499	Caroline_Peterschmidt@fws.gov
Mid Columbia River Fisheries Resource Office 7501 Icicle Road Leavenworth, WA 98826	**Jim Craig** Project Leader **William Gale** Deputy Project Leader	509 548-7573	Jim_L_Craig@fws.gov William_Gale@fws.gov
Olympia Fish Health Center 3859 Martin Way E, Suite 101 Olympia, WA 98506	**Ray Brunson** Project Leader **Joy Evered**	360 753-9046	Ray_Brunson@fws.gov

[3] Fishery Resource Office

Office	Project Leader/Deputy	Office Phone #	Email Address
	Deputy Project Leader		Joy_Evered@fws.gov
Quilcene NFH 281 Fish Hatchery Road Quilcene, WA 98376	**Ron Wong** Project Leader **Dan Magneson** Assistant Project Leader	360 765-3334 or 3330	Ron_Wong@fws.gov Dan_Magneson@fws.gov
Quinault NFH 3 Sockeye Road Humptulips, WA 98552	**Bill Edwards** Project Leader	360 288-2508	Bill_Edwards@fws.gov
Spring Creek NFH 61552 SR 14 Underwood, WA 98651	**Larry Marchant** Project Leader **Mark Ahrens** Deputy Project Leader	509 493-1730	Larry_Marchant@fws.gov Mark_Ahrens@fws.gov
Warm Springs NFH #1 Hatchery Road Warm Springs, OR 97761	**Roger Sorensen** Acting Project Leader	541 553-1692	Roger_Sorensen@fws.gov
Western Washington FRO 510 Desmond Dr. Lacey, WA 98503	**Brad Thompson** Division Manager	360 753-9509	Brad_Thompson@fws.gov
Willard NFH 5501B Cook-Underwood Rd Cook, WA 98605	**Steve Wingert** Assistant Hatchery Manager	509 538-2305	Steve_Wingert@fws.gov
Winthrop NFH P.O. Box 429 Winthrop, WA 98862	**Chris Pasley** Hatchery Manager	509 996-2424	Chris_Pasley@fws.gov

APPENDIX B: Summary Table, Program Performance and Strategic Plan Links

PARTNERSHIPS AND ACCOUNTABILITY FOCUS AREA

DOI STRATEGIC GOAL	**MANAGEMENT EXCELLENCE**						
DOI Mission Goal:	**Manage the Department to be highly-skilled, accountable, modern, functionally-integrated, citizen-centered, and result-oriented**						
DOI End Outcome Goal:	**DOI 52 Advance Modernization/Integration -**						
Fisheries Strategic Plan Goal: Partnerships	Open, interactive communication between the Fisheries Program and its partners.						
Fisheries Strategic Plan Goal: Accountability	Effective measuring and reporting of the Fisheries Program's progress toward meeting short-term and long-term fish and other aquatic resource conservation goals and objectives.						
Fisheries Program Long-Term Performance Goals:	*By September 30, 2013, X # of conservation projects that actively involve the use of knowledge and skills of people in the area, and local resources in priority setting, planning, and implementation processes – FWCO* *By September 30, 2013, X # of conservation projects that actively involve the use of knowledge and skills of people in the area, and local resources in priority setting, planning, and implementation processes – NFHS* *By September 30, 2013, X # of conservation projects that actively involve the use of knowledge and skills of people in the area, and local resources in priority setting, planning, and implementation processes – AIS* *By September 30, 2013, achieve 19,400 (annual) volunteer participation hours supporting Fisheries objectives for Hatcheries* *By September 30, 2013, achieve 440 (annual) volunteer participation hours supporting Fisheries objectives for FWCO.*						
			2009 Planned	2010 Planned	2011 Planned	2012 Planned	2013 Planned
Performance Measures:	52.1.2	# of volunteer participation hours aresupporting Fisheries objectives for Hatcheries (GPRA)	400	410	420	430	440
	52.1.3	# of volunteer participation hours aresupporting Fisheries objectives for FWMA (GPRA)	19,020	19,100	19,200	19,300	19,400
	52.1.7	Percent of NFHS with Friends Groups	53.3% (8/15)	53.3% (8/15)	60% (9/15)	60% (9/15)	60% (9/15)

AQUATIC HABITAT CONSERVATION AND MANAGEMENT FOCUS AREA

DOI STRATEGIC GOAL	**RESOURCE PROTECTION**						
DOI Mission Goal:	**Protect the Nation's natural, cultural, and heritage resources**						
DOI End Outcome Goal:	**1. Improve the health of watersheds, landscapes, and marine natural resources that are DOI-managed or influenced in a manner consistent with obligations regarding the allocation and use of water. Sustain biological communities on DOI-managed or influence**						
Fisheries Strategic Plan Goal: Habitat Conservation	America's streams, lakes, estuaries, and wetlands are functional ecosystems that support self-sustaining communities of fish and other aquatic resources.						
Fisheries Long-Term Performance Goals:	By September 30, 2013, 205 (additional) of acres will be reopened to fish passage By September 30, 2013, 616 (additional) miles reopened to fish passage						
Performance Measures:			2009 Planned	2010 Planned	2011 Planned	2012 Planned	2013 Planned
	5.1.12	Number of miles re-opened to fish passage	115.5	120	125	125	130
	5.1.13	Number of acres re-opened to fish passage	35	35	40	45	50
Supporting Workload Measures:			2009 Planned	2010 Planned	2011 Planned	2012 Planned	2013 Planned
	5.1.3	Number of habitat assessments completed (not acres)	130	130	130	130	130
	5.1.4	Total number of miles of in-stream/shoreline habitat assessed	161	150	150	150	150
	5.1.10	Total number of in-stream/shoreline miles restored	6.7	7	7	7	7
	5.1.11	Total number of fish passage barriers removed or bypassed	38	40	45	45	50

AQUATIC SPECIES CONSERVATION AND MANAGEMENT: NATIVE SPECIES FOCUS AREA

DOI STRATEGIC GOAL	**RESOURCE PROTECTION**						
DOI Mission Goal:	**Protect the Nation's natural, cultural, and heritage resources**						
DOI End Outcome Goal:	**2**	**Sustain Biological Communities on DOI-Managed and Influenced Lands and Waters Consistent with Obligations and State Law Regarding the Allocation and Use of Water**					
DOI End Outcome Performance Measure:	*32*	*Percent of fish species of management concern that are managed to self-sustaining levels, in cooperation with affected States and others, as defined in approved management documents (GPRA)*	2009 Planned	2010 Planned	2011 Planned	2012 Planned	2013 Planned
Performance Measure	5.1.1		6.2% (1/16)	6.2% (1/16)	6.2% (1/16)	6.2% (1/16)	6.2% (1/16)
Fisheries Strategic Plan Goal: Native Species	Self-sustaining populations of native fish and other aquatic resources that maintain species diversity, provide recreational opportunities for the American public, and meet the needs of tribal communities						
Fisheries Long-Term Performance Goals:	*By September 30, 2013, 19 % of populations of native aquatic non-T&E species that are self-sustaining in the wild, as prescribed in management plans - Fisheries (PART)* *By September 30, 2013, 51% of populations of native aquatic non-T&E species managed or influenced by the Fisheries Program for which current status (e.g., quantity and quality) and trend is known - Fisheries (PART)* *By September 30, 2013, 71% of populations of native aquatic non-T&E species with approved management plans - Fisheries (PART)* *By September 30, 2013 manage 45% of tasks implemented, as prescribed in management plans - Fisheries (PART)*						
			2009 Planned	2010 Planned	2011 Planned	2012 Planned	2013 Planned
Performance Measures:	5.1.2	Percent of populations of native aquatic non T&E species that are self-sustaining in the wild, as prescribed in management plans - Fisheries (PART)	18% (14/78)	18% (14/78)	18% (14/78)	18% (14/78)	19% (15/78)
	P-5.2.1	Percentage of populations of native aquatic non-T&E species for which current status and trend is known (PART)	49% (38/78)	49% (38/78)	50% (39/78)	50% (39/78)	51% (40/78)
	P-5.2.2.3	Percentage of populations of native aquatic non-T&E species with approved management plans (PART)	68% (53/78)	68% (53/78)	68% (54/78)	68% (54/78)	71% (55/78)
Supporting Workload Measures:	5.2.4	Total number of population assessments completed	787	780	780	780	780
	5.2.7	Total number of management plans completed or revised during the fiscal year for non-T&E populations	7	5	5	5	5
Performance Measures:	P-5.3.1	% of all tasks implemented, as prescribed in Fishery Management Plans	43% (451/1,044)	43% (451/1,044)	44% (459/1,044)	44% (459/1,044)	45% (470/1,044)

APPENDIX B: Summary Table, Program Performance and Strategic Plan Links

DOI End Outcome Performance Measure:	33	*Percent of threatened or endangered species that are stabilized or improved*
Fisheries Long-Term Performance Goals:		By September 30, 2013, X % of populations of aquatic threatened and endangered species (T&E) that are self-sustaining in the wild - Fisheries (PART).
		By September 30, 2013, X % of populations of aquatic threatened and endangered species (T&E) with known biological status that are self-sustaining in the wild - Fisheries (PART).
		By September 30, 2013, 47% of aquatic T&E populations managed or influenced by the Fisheries Program for which current status (e.g., quantity and quality) and trend is known - Fisheries (PART).
		By September 30, 2013, 72% of aquatic T&E populations managed or influenced by the Fisheries Program with approved Recovery plans - Fisheries
		By September 30, 2013, 50% of tasks implemented as prescribed in Recovery Plans - Fisheries (PART).

			2009 Planned	2010 Planned	2011 Planned	2012 Planned	2013 Planned
Performance Measures:	P-7.12.1	Percentage of aquatic T and E populations, as prescribed in Recovery Plans, that are self-sustaining, in the wild (PART)	0% (0/235)	0% (0/235)	0% (0/235)	0% (0/235)	0% (0/235)
	P-7.12.2	Percentage of aquatic T and E populations, with known biological status, that are self-sustaining in the wild (PART)	0% (0/235)	0% (0/235)	0% (0/235)	0% (0/235)	0% (0/235)
	P-7.12.3	Percentage of aquatic T and E populations for which current condition status and trend is known (PART)	45% (106/235)	45% (106/235)	46% (108/235)	46% (108/235)	47% (110/235)
	P-7.12.4	Percentage of aquatic T and E populations with approved Recovery Plans (PART)	72% (169/235)	72% (169/235)	72% (169/235)	72% (169/235)	72% (171/235)
	P-7.12.5	% of all tasks implemented, as prescribed in Recovery Plans - Fisheries (PART)	46% (243/525)	46% (243/525)	46% (243/525)	46% (243/525)	50% (263/525)

AQUATIC SPECIES CONSERVATION AND MANAGEMENT: AQUATIC INVASIVE SPECIES FOCUS AREA

DOI STRATEGIC GOAL	**RESOURCE PROTECTION**	
DOI Mission Goal:	**Protect the Nation's natural, cultural, and heritage resources**	
DOI End Outcome Goal:	**2**	**Sustain Biological Communities on DOI-Managed and Influenced Lands and Waters Consistent with Obligations and State Law Regarding the Allocation and Use of Water**
Fisheries Strategic Plan Goal: Aquatic Invasive Species (AIS)	Risks of aquatic nuisance species invasions are substantially reduced, and their economic, ecological, and human health impacts are minimized.	
Fisheries Long-Term Performance GoalS:	By September 30, 2013, four state/interstate management plans supported to prevent and control aquatic invasive species (annually).	
	By September 30, 2013, X 60 surveys conducted for early detection and rapid response for aquatic invasive species (over the past 5 years)	
	By September 30, 2013, 116 activities conducted to support the management/control of aquatic invasive species - Fisheries (PART)	

			2009 Planned	2010 Planned	2011 Planned	2012 Planned	2013 Planned
Performance Measures:	12.2.3	Number of aquatic invasive species populations controlled/managed	*reported nationally*	*reported nationally*	*reported nationally*	*reported nationally*	*reported nationally*
	P-12.2.4	Number of activities conducted to support the management and control of aquatic invasive species (PART)	22	22	23	24	25
	12.2.7	Number of public awareness campaigns conducted and supported	*reported nationally*	*reported nationally*	*reported nationally*	*reported nationally*	*reported nationally*
	12.2.9	Number of risk assessments conducted	2	1	1	1	1
	12.2.11	Number of surveys conducted for aquatic invasive species baseline/trend information	8	8	8	8	8
	12.2.12	Number of surveys conducted for early detection and rapid response	10	11	12	13	14
	12.2.13	Number of state/interstate ANS plans supported	4	4	4	4	4
	12.2.14	Number of AIS partnerships	26	27	28	29	30

AQUATIC SPECIES CONSERVATION AND MANAGEMENT: INTERJURSIDICTIONAL FISHERIES FOCUS AREA

DOI STRATEGIC GOAL	**RESOURCE PROTECTION**	
DOI Mission Goal:	**Protect the Nation's natural, cultural, and heritage resources**	
DOI End Outcome Goal:	**2**	**Sustain Biological Communities on DOI-Managed and Influenced Lands and Waters Consistent with Obligations and State Law Regarding the Allocation and Use of Water**
Fisheries Strategic Plan Goal: Interjurisdictional Fisheries	Interjurisdictional fish populations are managed at self-sustaining levels.	
Fisheries Long-Term Performance GoalS:	By September 30, 2013, 780 assessments completed	
	By September 30, 2013, 27 (additional) management plans completed or revised during the fiscal year	
	September 30, 2013, 19% of fish species of management concern that are managed to self-sustaining levels, in cooperation with affected States and others, as defined in approved management documents (GPRA).	

THE FOLLOWING PERFORMANCE VALUES ARE ALSO REPORTED UNDER THE NATIVE SPECIES FOCUS AREA

			2009 Planned	2010 Planned	2011 Planned	2012 Planned	2013 Planned
Performance Measures:	5.1.2	Percent of populations of native aquatic non T&E species that are self-sustaining in the wild, as prescribed in management plans - Fisheries (PART)	18% (14/78)	18% (14/78)	18% (14/78)	18% (14/78)	19% (15/78)
	P-5.2.1	Percentage of populations of native aquatic non-T&E species for which current status and trend is known (PART)	49% (38/78)	49% (38/78)	50% (39/78)	50% (39/78)	51% (40/78)
	P-5.2.2.3	Percentage of populations of native aquatic non-T&E species with approved management plans (PART)	68% (53/78)	68% (53/78)	68% (54/78)	68% (54/78)	71% (55/78)
Supporting Workload Measures:	5.2.4	Total number of population assessments completed	787	780	780	780	780
	5.2.7	Total number of management plans completed or revised during the fiscal year for non-T&E populations	7	5	5	5	5

APPENDIX B: Summary Table, Program Performance and Strategic Plan Links

PUBLIC USE: MITIGATION FISHERIES FOCUS AREA

DOI STRATEGIC GOAL	**RECREATION**						
DOI Mission Goal:	**Improving recreation opportunities for America**						
DOI End Outcome Goal:	**1. Improve the Quality and Diversity of Recreation Experiences and Visitor Enjoyment on DOI Lands.**						
Fisheries Strategic Plan Goal: Interjurisdictional Fisheries	The Federal government meets its responsibilities to mitigate for the impacts of Federal water projects, including restoring habitat and/or providing fish and associated technical support to compensate for lost fishing opportunities.						
Fisheries Long-Term Performance Goal:	*By September 30, 2013, 100% of mitigation tasks implemented as prescribed in approved management plans - Fisheries (PART)*						
			2009 Planned	2010 Planned	2011 Planned	2012 Planned	2013 Planned
Performance Measures:	15.4.1	% of mitigation tasks implemented as prescribed in approved management plans - Fisheries (PART)	77%	92%	100%	100%	100%

PUBLIC USE: RECREATIONAL FISHERIES FOCUS AREA

DOI STRATEGIC GOAL	**RECREATION**						
DOI Mission Goal:	**Improving recreation opportunities for America**						
DOI End Outcome Goal:	**1. Improve the Quality and Diversity of Recreation Experiences and Visitor Enjoyment on DOI Lands.**						
DOI End Outcome Goal:	**2. Expand Seamless Recreation Opportunities With Partners**						
Fisheries Strategic Plan Goal: Recreational Fishing	Quality opportunities for responsible fishing and other related recreational enjoyment of aquatic resources on Service lands, on Tribal and military lands, and on other waters where the Service has a role.						
Fisheries Long-Term Performance Goals:	*By September 30, 2013, 40 fish populations representing recreational fish species for which the Fisheries Program has a defined statutory or programmatic responsibility, that potentially provides recreational fishing opportunities* *By September 30, 2013, 61% of fish populations at levels sufficient to provide quality recreational fishing opportunities - Fisheries (PART).* *By September 30, 2013, X # of waters where recreational fishing opportunities are provided – Fisheries (PART) (GPRA)* *By September 30, 2013, achieve X index of productivity of pounds per dollar (lbs/$) for healthy rainbow trout produced for recreation – Fisheries (PART).*						
			2009 Planned	2010 Planned	2011 Planned	2012 Planned	2013 Planned
Performance Measures:	15.4.6	% of fish populations at levels sufficient to provide quality recreational fishing opportunities - Fisheries/FWMA (PART)	58%	58%	59%	59%	61%
	15.4.6.1	# of fish populations for which the Fisheries Program has a defined statutory or programmatic responsibility, that currently provide recreational fishing opportunities - Fisheries/FWMA (PART)	38	38	39	39	40
	15.4.6.2	Total # fish populations, representing recreational fish species for which the Fisheries Program has a defined statutory or programmatic responsibility, that potentially provide recreational fishing opportunities - Fisheries/FWMA (PART)	66	66	66	66	66
	15.4.8	# of aquatic outreach and education activities and/or events - NFHS	622	625	625	630	630
	15.4.9	# of aquatic outreach and education activities and/or events - FWMA	141	145	145	150	150
	15.4.10	Pounds per dollar (lbs./$) of healthy rainbow trout produced for recreation -FisheriesNFHS (PART)	*reported nationally*	*reported nationally*	*reported nationally*	*reported nationally*	*reported nationally*
	15.4.12	Total # of visitors to NFHS facilities	261,500	262,000	262,225	262,500	262,500
	15.5.4	NFHS Recreation-related Facilities Improvement: Overall condition of NFHS buildings and structures (as measured by the FCI) that are mission critical and mission dependent (as measured by the API) with emphasis on improving the condition of assets	0.155	0.155	0.14	0.12	0.1
	15.5.4.1	Value ($) of deferred maintenance backlog for NFHS public use assets (GPRA)	867,576	841,549	816,302	791,813	768,059
	15.5.4.2	Replacement value ($) of NFHS public use assets (GPRA)	5,580,056	5,803,258	6,035,389	6,276,804	6,527,876
	15.8.10	# of waters where recreational fishing opportunities are provided - NFHS (GPRA)(PART)	*reported nationally*	*reported nationally*	*reported nationally*	*reported nationally*	*reported nationally*

APPENDIX B: Summary Table, Program Performance and Strategic Plan Links

COOPERATION WITH NATIVE AMERICAN TRIBES FOCUS AREA

DOI STRATEGIC GOAL	**SERVING COMMUNITIES**
DOI Mission Goal:	**Improve protection of lives, property and assets, advance the use of scientific knowledge, and improve the quality of life for communities we serve**
DOI End Outcome Goal:	**3. Fulfill Indian Fiduciary Trust Responsibilities; Indian Natural Resource Trust Assets**
Fisheries Strategic Plan Goal: Leadership in Science and Technology	Assistance is provided to Tribes that results in the management, protection, and conservation of their treaty-reserved or statutorily defined trust natural resources which helps Tribes develop their own capabilities.
Fisheries Strategic Plan Objectives: Native Americans	4.1 Provide technical assistance to Tribes. 4.2 Identify sources of funds to enhance Tribal resource management. 4.3 Provide fish for Tribal resource management. 4.4 Recognize and promote the Service's distinct obligations toward Tribes within the Fisheries Program.
Fisheries Long-Term Performance Goals:	By September 30, 2013, 88% of planned tasks implemented for Tribal fish and wildlife conservation as prescribed by Tribal plans or agreements By September 30, 2013, 4 new or modified cooperative agreements with Tribes or IPA Agreements that support Tribal fish and wildlife conservation By September 30, 2013, 15 (annual) training sessions to support Tribal fish and wildlife conservation

			2009 Planned	2010 Planned	2011 Planned	2012 Planned	2013 Planned
Performance Measures :	18.1.2	% of planned tasks for Tribal fish and wildlife conservation as prescribed by Tribal plans or agreements (Fisheries)	84% (86/102)	85% (87/102)	86% (88/102)	86% (88/102)	88% (90/102)
	18.1.2	% of planned tasks for Tribal fish and wildlife conservation as prescribed by Tribal plans or agreements (NFHS)	53% (54/102)	54% (55/102)	54% (54/102)	54% (54/102)	55% (56/102)
	18.1.3	% of planned tasks for Tribal fish and wildlife conservation as prescribed by Tribal plans or agreements (FWMA)	41% (42/102)	41% (42/102)	42% (43/102)	42% (43/102)	43% (44/102)
	18.1.6	Number of training session to support Tribal fish & wildlife conservation	13	14	14	15	15
	18.1.9	Number of new or modified cooperative agreements or IPA Agreements that support Tribal fish & wildlife conservation	4	4	5	4	4
	18.1.12	Number of consultations conducted to support Tribal fish & wildlife conservation	8	8	8	10	10

LEADERSHIP IN SCIENCE AND TECHNOLOGY FOCUS AREA

DOI STRATEGIC GOAL	**RESOURCE PROTECTION**
DOI Mission Goal:	**Protect the Nation's natural, cultural, and heritage resources**
DOI End Outcome Goal:	**1. Improve the health of watersheds, landscapes, and marine natural resources that are DOI-managed or influenced in a manner consistent with obligations regarding the allocation and use of water. Sustain biological communities on DOI-managed or influence**
Fisheries Strategic Plan Goal: Leadership in Science and Technology	Science developed and used by Service employees for aquatic resource restoration and management is state-of-the-art, scientifically sound and legally defensible, and technological advances in fisheries science developed by Service employees are available
Fisheries Long-Term Performance Goal:	*a. By September 30, 2013, 408 (additional) applied aquatic science and technologic tools developed through publications.*

			2009 Planned	2010 Planned	2011 Planned	2012 Planned	2013 Planned
Supporting Workload Measure:	5.3.7	Number of applied aquatic scientific and technologic tools developed and shared with partners through publications	78	80	80	80	80

APPENDIX B: Summary Table, Program Performance and Strategic Plan Links

WORKFORCE MANAGEMENT FOCUS AREA							
DOI STRATEGIC GOALS:		**RESOURCE PROTECTION; MANAGEMENT EXCELLENCE**					
DOI Mission Goal:		**Protect the Nation's natural, cultural, and heritage resources**					
DOI Mission Goal:		**Manage the Department to be highly-skilled, accountable, modern, functionally-integrated, citizen-centered, and result-oriented**					
DOI End Outcome Goal:		**Protect Cultural and Natural Heritage Resources**					
DOI End Outcome Goal:		**DOI 52 Advance Modernization/Integration -**					
Fisheries Strategic Plan Goal: Workforce Managemewnt		Maintain and support an adequately-sized, strategically-positioned workforce with state-of-the-art training, equipment, and technologies in their career fields.					
Fisheries Long-Term Performance Goal:		a. By September 30, 2013, the condition of NFHS mission critical water management assets, as measured by the DOI FCI, is .100					
			2009 Planned	2010 Planned	2011 Planned	2012 Planned	2013 Planned
Performance Measures :	13.1.5	% of NFHS historic structures in FWS inventory that are in good condition (GPRA)	89% (29/36)	89% (29/36)	89% (29/36)	89% (29/36)	89% (29/36)
	13.1.7	NFHS Cultural & Natural Heritage-related Facilities in Good Condition-FCI	4% (511,103/ 13,373,009)	4% (511,103/ 13,373,009)	4% (511,103/ 13,373,009)	4% (511,103/ 13,373,009)	4% (511,103/ 13,373,009)
	13.2.3	% of cultural collections in FWS inventory in good condition (combined NWRS and NFHS) (GPRA)	30% (669/2,205)	30% (669/2,205)	30% (669/2,205)	30% (669/2,205)	30% (669/2,205)
	52.1.2	# of volunteer participation hours are supporting Fisheries objectives for Hatcheries (GPRA)	19,020	19,020	19,500	19,500	19,500
	52.1.3	# of volunteer participation hours are supporting Fisheries objectives for FWMA (GPRA)	400	410	420	425	430
	52.1.17.9	# of conservation projects that actively involve the use of knowledge and skills of people in the area, and local resources in priority setting, planning, and implementation processes (NFHS/GPRA)	*reported nationally*	*reported nationally*	*reported nationally*	*reported nationally*	*reported nationally*
	52.1.17.10	# of conservation projects (NFHS/GPRA)	*reported nationally*	*reported nationally*	*reported nationally*	*reported nationally*	*reported nationally*
	52.1.17.11	# of conservation projects that actively involve the use of knowledge and skills of people in the area, and local resources in priority setting, planning, and implementation processes (FWMA/GPRA)	*reported nationally*	*reported nationally*	*reported nationally*	*reported nationally*	*reported nationally*
	52.1.17.12	# of conservation projects (FWMA/GPRA)	*reported nationally*	*reported nationally*	*reported nationally*	*reported nationally*	*reported nationally*
	5.5.1	5.5.1 The condition of NFHS mission critical water management assets, as measured by the DOI FCI, is x. (GPRA)	0.119 (129,476,777/ 1,087,233,873)	0.100 (129,476,777/ 1,087,233,873)	0.100 (129,476,777/ 1,087,233,873)	0.100 (129,476,777/ 1,087,233,873)	0.100 (129,476,777/ 1,087,233,873)
	54.1.6	NFHS Administrative Facilities Improvement: Overall condition of NFHS buildings and structures (e.g. storage, administrative, employee housing) (as measured by the FCI) that are mission critical and mission dependent (as measured by the API) with emphasis	7%	7%	7%	7%	7%
	54.1.6.1	value ($) of deferred maintenance cost estimate for NFHS direct infrastructure support assets (GPRA)	867,576	841,549	816,302	791,813	768,059
	54.1.6.2	total replacement value ($) of NFHS direct infrastructure support assets (GPRA)	5,580,056	5,803,258	6,035,389	6,276,804	6,527,876

fisheries management **feature**

Resident Fish in the Columbia River Basin: Restoration, Enhancement, and Mitigation for Losses Associated with Hydroelectric Development and Operations

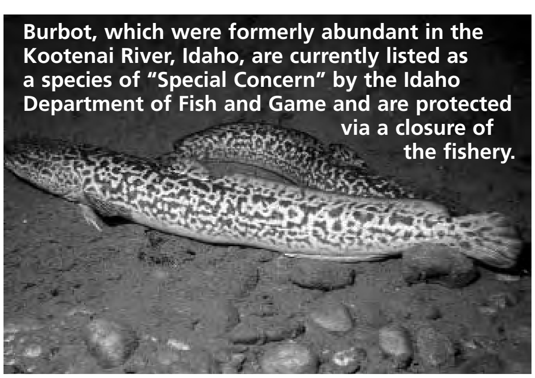
ABSTRACT

Development and operation of Columbia River Basin hydroelectric facilities have contributed to the reduction in diversity and abundance of some native resident fish. To mitigate for effects of hydroelectric development and operations, the Bonneville Power Administration (BPA) annually funds fisheries research and management efforts. In 2003, the BPA provided $19.2 million for the implementation of 54 resident fish projects that were recommended for funding by the Columbia Basin Fish and Wildlife Authority and Northwest Power and Conservation Council through the council's Columbia River Basin Fish and Wildlife Program. Through the resident fish segment of this program, managers have begun to better understand and manage impacted resident fish habitats and populations; however, restoration of resident fish populations will require cooperation among resident and anadromous fish mangers, hydrosystem operators, and federal regulators. Managers must ensure that power, water management, and land-use decisions consider effects on all fish populations. Only by better understanding the effects of hydroelectric operations on all potentially affected fish populations can fisheries managers develop an integrated program to mitigate and enhance resident fish resources of the Columbia River Basin. Costs, time, necessary cooperation, and existing regulations are challenges that could compromise the effort.

Neil E. Ward
David L. Ward

Neil E. Ward is a fish and wildlife project coordinator at the Columbia Basin Fish and Wildlife Authority in Portland, OR. He can be reached at neil.ward@cbfwa.org. David L. Ward is a program leader at Columbia River Investigations, Oregon Department of Fish and Wildlife, Clackamas, OR.

The Columbia River flows for over 1,900 km and drains 670,000 km^2 in 7 states and Canada (Figure 1). Within this watershed are approximately 1,239 dams (Lee et al. 1997), 29 of which are federal hydroelectric facilities. Construction of these facilities eliminated or isolated habitats that were available to migratory salmonids (Thurow et al. 1997) and other resident fish. Habitat fragmentation can jeopardize resident fish populations by reducing habitat area, complexity, and connectivity (Dunham 1996; Dunham et al. 1997). The effects of hydroelectric operations on some resident fish species, although less chronicled than those of anadromous fish, have been deleterious, resulting in the losses of numbers and diversity of native resident fishes. Thurow et al. (1997) evaluated the population status of native resident salmonids and chars in the interior Columbia River Basin and found that all species exhibited declines in abundance and distribution and an increase in population fragmentation. The magnitude of these declines has resulted in a number of resident fish species receiving consideration for protection via state or federal regulations (Table 1).



Burbot, which were formerly abundant in the Kootenai River, Idaho, are currently listed as a species of "Special Concern" by the Idaho Department of Fish and Game and are protected via a closure of the fishery.

ERNEST KEELEY

In 1980, the U.S. Congress passed the Pacific Northwest Electric Power Planning and Conservation Act (Power Act), which resulted in the creation of the Pacific Northwest Electric Power and Conservation Planning Council (Council), and the Columbia River Basin Fish and Wildlife Program to protect, mitigate, and enhance fish and wildlife in the Columbia River Basin affected by the construction and operation of hydroelectric dams. The Northwest Power Planning Council (2000) identified objectives to address resident fish losses. The objectives were to: (1) complete assessments of resident fish losses throughout the Columbia River Basin resulting from the hydrosystem, (2) maintain and restore healthy ecosystems and watersheds, (3) protect and expand habitat ecosystem functions, and (4) achieve population characteristics within 100 years that represent full mitigation for losses. To mitigate for the loss of anadromous fish associated with the lack of fish passage facilities at Chief Joseph and Hells Canyon dams, the Northwest Power Planning Council (2000) identified the following resident fish substitution objectives to mitigate anadromous fish losses associated with those dams: (1) restore native resident fish species to near historic abundance throughout their historic ranges where original habitat conditions exist and where habitats can be feasibly restored, and (2) administer and increase opportunities for consumptive and non-consumptive resident fisheries for native, introduced, wild, and hatchery-reared stocks that are compatible with the continued persistence of native resident fish species and their restoration to near historic abundance.

The Power Act also established Bonneville Power Administration's obligation to fully mitigate for fish and wildlife impacts resulting from the development and operation of the federal hydroelectric system. Actions implemented through the

Columbia River Basin Fish and Wildlife Program are funded by the Bonneville Power Administration via revenues from electricity ratepayers. The Bonneville Power Administration currently allocates approximately $139 million annually to protect, enhance, and mitigate for the effects of the development, operation, and management of hydroelectric operations on fish and wildlife populations in the Columbia River Basin. Of the $139 million, approximately $19.2 million is currently allocated to resident fish efforts.

The Columbia Basin Fish and Wildlife Authority, which consists of the 4 state and 2 federal fish and wildlife management entities and 13 Indian tribes (Table 2) of the Columbia River Basin, assists with the coordination of Bonneville Power Administration funded efforts of fish and wildlife managers with the goal to protect, enhance, and mitigate fish and wildlife resources of the Columbia River Basin through joint planning and action. The Columbia Basin Fish and Wildlife Authority also provides the council and Bonneville Power Administration with project recommendations representing the best available information from fish and wildlife managers.

The objectives of this article are to describe: (1) coordination of state, federal, and tribal resident fish research and management projects implemented in the Columbia River Basin through the Columbia Basin Fish and Wildlife Program and funded by the Bonneville Power Administration, (2) accomplishments of resident fish research and management projects, and (3) the need for coordination among resident and anadromous fish managers within the Columbia River Basin.

Background:
Columbia River Basin Resident Fishes and the Effects of Hydroelectric Development

Although a comprehensive list of native resident fish species that historically occurred throughout the Columbia River Basin is not available, several efforts (e.g., Reimers and Bond 1967; Farr and Ward 1993; Wydoski and Whitney 2003) have compiled lists for specific areas. A compilation of these lists (Table 1) shows that at least 53 native resident fish species are present in the Columbia River Basin.

Hydroelectric development and operations have affected resident fish populations in the Columbia River Basin in various ways. Thousands of kilometers of habitat have been inundated, with many shallow, free-flowing rivers converted to reservoirs. For example, completion of Libby Dam (Figure 1) resulted in the inundation of 175 km of the mainstem Kootenai River and 64 km of critical, low-gradient tributary habitat (Montana Fish, Wildlife and Parks et al. 1998) for burbot (*Lota lota*), white sturgeon (*Acipenser transmontanus*), bull trout (*Salvelinus confluentus*), and westslope cutthroat trout (*Oncorhynchus clarki lewisii*). Hungry Horse Dam (Figure 1) blocked access from Flathead Lake to 584 km of tributary reaches and 137 km of the South Fork Flathead River, eliminating 40% of the spawning and rearing habitat for bull trout and westslope cutthroat trout from Flathead Lake (Montana Fish, Wildlife, and Parks and Confederated Salish and Kootenai Tribes 1991). Completion of Grand Coluee Dam (Figure 1) inundated 243 km of the upper Columbia River.

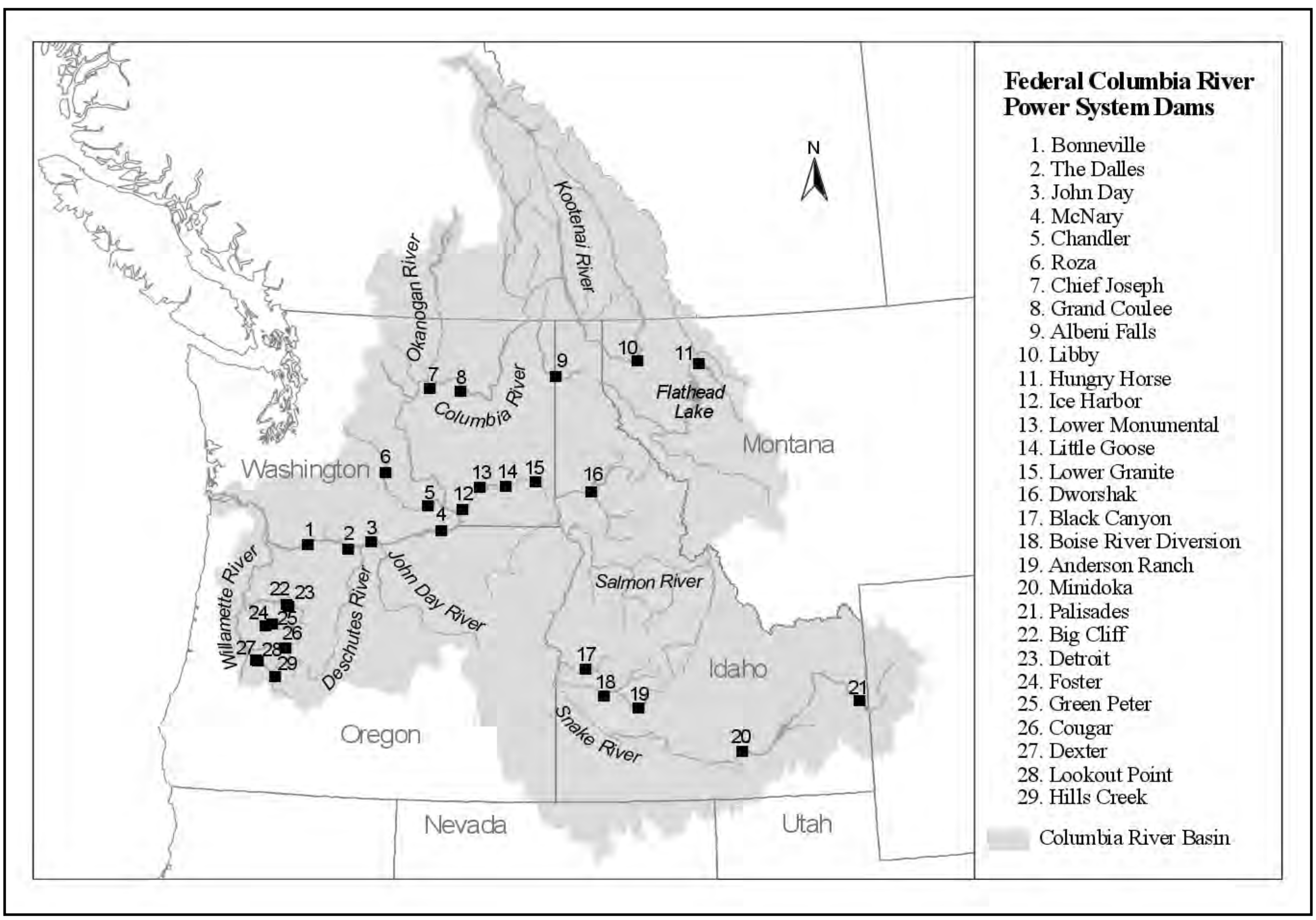


Figure 1 – Watershed of the Columbia River Basin and location of federal hydroelectric dams.

Table 1. Native and introduced resident fish species known to exist in the Columbia River Basin and those receiving protection via state and federal regulations.

COMMON AND SCIENTIFIC NAMES	ORIGIN[a]	FEDERAL LISTING[b]	STATE LISTING[c]
Petromyzontidae			
River lamprey (*Lampetra ayresi*)	N	Consideration	SC (Washington)
Western brook lamprey (*Lampetra richardsoni*)	N	NA	NA
Pacific lamprey (*L. tridentata*)		N	NA NA
Acipenseridae			
White sturgeon (*Acipenser transmontanus*)	N	Endangered (Kootenai River)	SC SC (Idaho , Snake and Salmon rivers) SC (Montana)
Cyprinidae			
Chiselmouth (*Acrocheilus alutaceus*)	N	NA	NA
Goldfish (*Carassius auratus*)	I	NA	NA
Lake chub (*Couesius plumbeus*)	N	NA	SC (Washington)
Grass carp (*Ctenopharygodon idella*)	I	NA	NA
Common carp (*Cyprinus carpio*)	I	NA	NA
Utah chub (*Gila atraria*)	N	NA	NA
Tui chub (*G. bicolor*)	I	NA	NA
Blue chub (*G. coerulea*)	I	NA	NA
Leatherside chub (*G. copei*)	N	NA	SC (Idaho)
Peamouth chub (*Mylocheilus caurinus*)	N	NA	NA
Spottail shiner (*Notropis hudsonius*)	I	NA	NA
Oregon chub (*Oregonichthys crameri*)	N	Endangered	NA
Fathead minnow (*Pimephales promelas*)	I	NA	NA
Northern pikeminnow (*Ptychocheilus oregonensis*)	N	NA	NA
Redside shiner (*Richardsonius balteatus balteatus*)	N	NA	NA
Longnose dace (*Rhinichthys cataractae*)	N	NA	NA
Leopard dace (*R. falcatus*)	N	NA	SC (Washington)
Speckled dace (*R. osculus*)	N	NA	NA
Umatilla dace (*R. umatilla*)	N	NA	SC (Washington)
Tench (*Tinca tinca*)	I	NA	NA
Cobitidae			
Oriental weatherfish (*Misgurnus anguillicaudatus*)	I	NA	NA
Catostomidae			
Utah sucker (*Catostomus ardens*)	N	NA	NA
Longnose sucker (*C. catostomus*)	N	NA	NA
Bridgelip sucker (*C. columbianus*)	N	NA	NA
White sucker (*C. commersoni*)			
Blue sucker (*C. discobolus*)	N	NA	NA
Largescale sucker (*C. macrocheilus*)	N	NA	NA
Mountain sucker (*C. platyrhynchus*)	N	NA	SC (Washington)
Ictaluridae			
White catfish (*Ameiurus catus*)			
Black bullhead (*A. melas*)	I	NA	NA
Yellow bullhead (*A. natalis*)	I	NA	NA
Brown bullhead (*A. nebulosus*)	I	NA	NA
Blue catfish (*I. furcatus*)	I	NA	NA
Channel catfish (*I. punctatus*)	I	NA	NA
Tadpole madtom (*Notorus gyrinus*)	I	NA	NA
Flathead catfish (*Pylodictis olivaris*)	I	NA	NA
Percopsidae			
Sandroller (*Percopsis transmontana*)	N	NA	SC (Idaho) SM (Washington)
Esocidae			
Northern pike (*Esox lucius*)	I	NA	NA
Tiger muskie (*E. lucius* x *E. masquiongy*)	I	NA	NA
Grass pickerel (*E. americanus vermiculatus*)	I	NA	NA
Salmonidae			
Lake whitefish (*Coregonus clupeaformis*)	I	NA	NA
Bear Lake whitefish (*Prosopium abyssicola*)	N	NA	SC (Idaho)
Pygmy whitefish (*P. coulteri*)	N	NA	NA
Bonneville cisco (*P. gemmifer*)			
Bonneville whitefish (*P. spilonotus*)	N	NA	SC (Idaho)
Mountain whitefish (*P. williamsoni*)	N	NA	NA
Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*)	N	NA	SC (Idaho)
Coastal cutthroat trout (*O. c. clarki*)	N	NA	NA
Lahontan cutthroat trout (*O. c. henshawi*)	I	NA	NA
Westslope cutthroat trout (*O. c. lewisii*)	N	NA	SC (Idaho) SC (Montana)

Bear Lake cutthroat trout (*O. c.* spp.)	N	NA	SC (Idaho)
Snake River fine-spotted cutthroat trout (*O. c.* spp.)	N	NA	SC (Idaho)
Bonneville cutthroat trout (*O. c. utah*)	N	NA	SC (Idaho)
Rainbow trout (*O. mykiss*)	N and I	NA	NA
Interior redband trout (*O. m. gairdneri*)	N	Consideration	SC (Idaho) SC (Montana)
Golden trout (*O. m. aguabonita*)	I	NA	NA
Kokanee salmon (*O. nerka*)	N and I	NA	NA
Brown trout (*Salmo trutta*)	I	NA	NA
Blueback trout (*Salvelinus alpinus oquassa*)	I	NA	NA
Bull trout (*S. confluentus*)	N	Threatened	SC (Montana) SC (Washington)
Brook trout (*S. fontinalis*)	I	NA	NA
Lake trout (*S. namaycush*)	I	NA	NA
Arctic grayling (*Thymallus arcticus*)	I	NA	NA
Montana grayling (*T.arcticus montanus*)	I	NA	NA
Gadidae			
Burbot (*Lota lota*)	N	NA	SC (Idaho)
Fundulidae			
Banded killifish (*Fundulus diaphanus diaphanus*)	I	NA	NA
Poeciliidae			
Mosquitofish (*Gambusia affinis*)	I	NA	NA
Guppy (*Poecilia reticulata*)	I	NA	NA
Green swordtail (*Xiphophorus helleri*)	I	NA	NA
Platy (*X.* ssp.)	I	NA	NA
Gasterosteidae			
Brook stickleback (*Culaea inconstans*)	I	NA	NA
Threespine stickleback (*Gasterosteus aculeatus*)	N and I	NA	NA
Cottidae			
Coastrange sculpin (*Cottus aleuticus*)	N	NA	NA
Prickly sculpin (*C. asper*)	N	NA	NA
Mottled sculpin (*C. bairdi*)	N	NA	NA
Paiute sculpin (*C. beldingi*)	N	NA	NA
Slimy sculpin (*C. cognatus*)	N	NA	SM (Washington)
Shorthead sculpin (*C. confusus*)	N	NA	NA
Bear Lake sculpin (*C. extensus*)	N	NA	SC (Idaho)
Riffle sculpin (*C. gulosus*)	N	NA	NA
Shoshone sculpin (*C. greenei*)	N	NA	SC (Idaho)
Wood River sculpin (*C. leiopomus*)	N	NA	SC (Idaho)
Margined sculpin (*C. marginatus*)	N	Consideration	SS (Washington)
Reticulate sculpin (*C. perplexus*)	N	NA	SM (Washington)
Torrent sculpin (*C. rhotheus*)	N	NA	SC (Montana) SM (Washington)
Centrarchidae			
Green sunfish (*Lepomis cyanellus*)	I	NA	NA
Pumpkinseed (*L. gibbosus*)	I	NA	NA
Warmouth (*L. gulosus*)	I	NA	NA
Bluegill (*L. macrochirus*)	I	NA	NA
Redear sunfish (*L. microlophus*)	I	NA	NA
Smallmouth bass (*Micropterus dolomieu*)	I	NA	NA
Largemouth bass (*M. salmoides salmoides*)	I	NA	NA
White crappie (*Pomoxis annularis*)	I	NA	NA
Black crappie (*P. nigromaculatus*)	I	NA	NA
Percidae			
Yellow perch (*Perca flavescens*)	I	NA	NA
Sauger (*Sander canadensis*)	I	NA	NA
Walleye (*S. vitreus*)	I	NA	NA
Cichlidae			
Convict cichlid (*Cichlasoma nigrofasciatum*)	I	NA	NA
Mozambique tilapia (*Tilapia mossabica*)	I	NA	NA
Redbelly tilapia (*T. zilli*)	I	NA	NA

[a] N = native and I = introduced
[b] U.S. Endangered Species Act of 1973
[c] SC (Washington) = state candidate in Washington,
SS (Washington) = state sensitive in Washington,
SM (Washington) = state monitor in Washington,
SC (Idaho) = species of concern in Idaho,
SC (Montana) = species of special concern in Montana

Habitat changes selected against many native resident fish species. Downstream entrainment, poor upstream passage at dams, and lost habitat connectivity contributed to population declines (USFWS 2000). Studies (e.g., Paragamian 2000; Paragamian and Wakkinen 2002) have shown that altered seasonal hydrographs and thermal regimes associated with hydroelectric development and operations also impact resident fish populations in the Columbia River Basin. Habitat degradation related to land uses (e.g., agriculture, logging, and urbanization), some of which are facilitated by the presence of the hydroelectric system, contributed to declines as well. Resident fish populations also have been affected by declines in system productivity, partially due to the decline or absence of marine-derived nutrients associated with anadromous fish (USFWS 2000).

Introductions of at least 50 non-native species (Table 1) have contributed to declines of some native resident fish. Zaroban (1999) suggested that most introduced species are relatively tolerant of elevated water temperatures, sedimentation, and organic pollution, attributes that could allow introduced species to out-compete native species in marginal environments of the Columbia River Basin. Predation by introduced species (e.g., Poe et al. 1991; Zimmerman 1999) and hybridization (e.g., Knudsen et al. 2002; Weigel et al. 2003) also may have contributed to declines of some native resident fish populations.

The economic and cultural importance of resident fish has increased above Chief Joseph and Hells Canyon dams (Figure 1) because these structures preclude passage of anadromous fish. In some areas where anadromous fish no longer have access and are not present, habitat conditions are marginal and in many cases unsuitable for native resident species, particularly salmonids. Consequently, interest in management of introduced gamefish such as largemouth bass (*Micropterus salmoides salmoides*), smallmouth bass (*M. dolomieui*), and walleye (*Sander vitreus*) has increased as states and Native American Indian tribes attempt to provide alternative recreational and subsistence opportunities, respectively.

Resident Fish Projects: Coordination, Implementation, and Successes

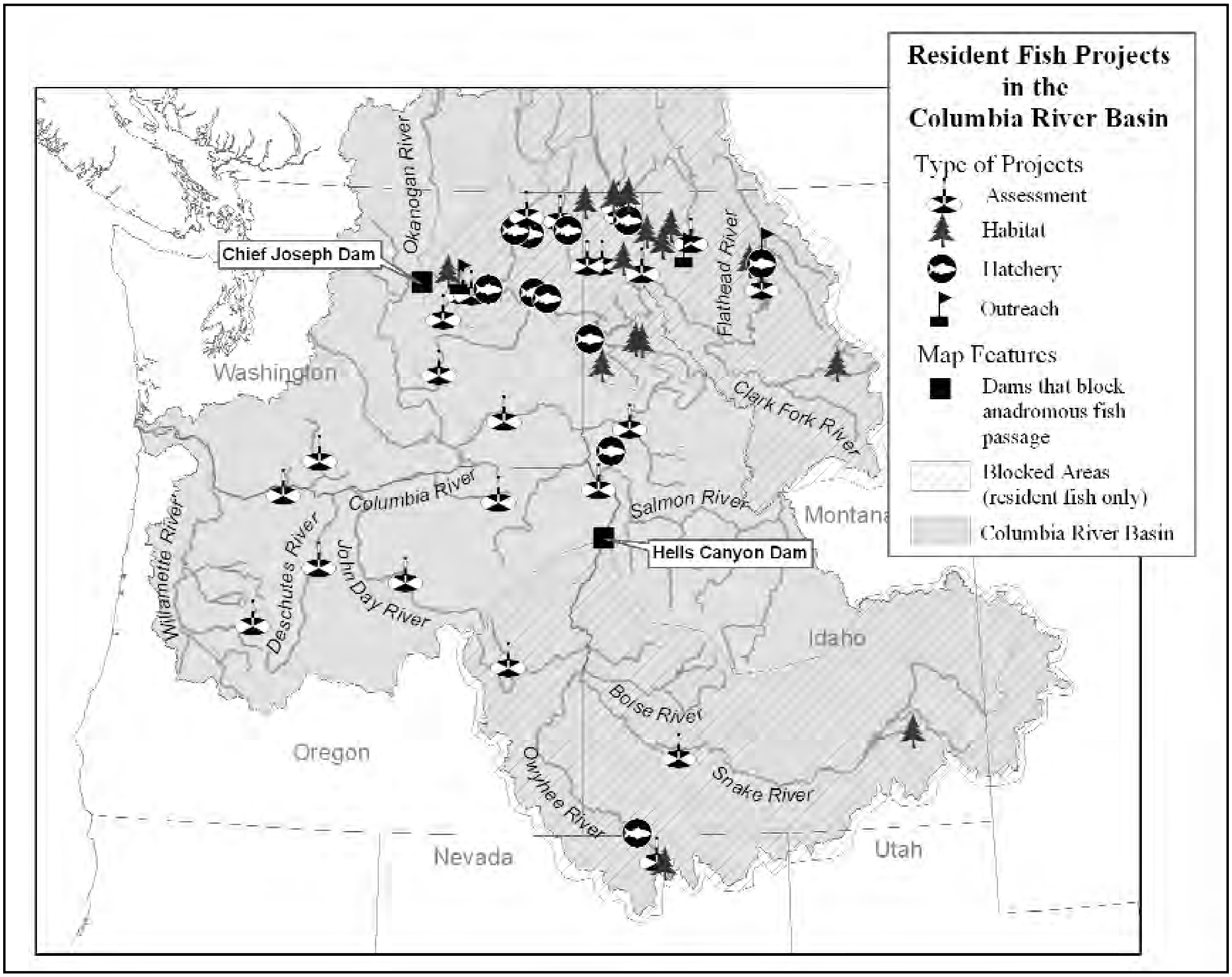
Currently, the Bonneville Power Administration allocates approximately $19.2 million annually towards 54 resident-fish-oriented projects recommended by the Columbia Basin Fish and Wildlife Authority. Types of projects receiving funds include hatchery and stocking programs (*N* = 11), habitat improvements (*N* = 15), population assessments (*N* = 25), and outreach (*N* = 3) (Table 2). Of the 54 projects, 44 are implemented in the "blocked area" above Chief Joseph and Hells Canyon dams (Figure 2). Thirty-nine percent of the resident fish projects focus on bull trout (*N* = 12), and white sturgeon (*N* = 9), which are protected via the Endangered Species Act throughout the Columbia River Basin, and the Kootenai River, respectively. The remaining projects involve species that although not federally protected, are of significant cultural, commercial, or recreational importance.

Despite receiving only 14% of the available mitigation funds from the Bonneville Power Administration, the resident fish segment of the council's Columbia River Basin Fish and Wildlife Program has developed into a successful effort characterized by increases in size,

Table 2. Enumeration of Bonneville Power Administration funded fish projects, by entity and type, in the Columbia River Basin during 2003.

ENTITY		TYPES OF RESIDENT FISH PROJECTS HATCHERY	HABITAT	ASSESSMENT	OUTREACH
Columbia Basin Fish and Wildlife Authority (CBFWA) Members					
State	Idaho Department of Fish and Game	0	2	4	0
	Montana Department of Fish, Wildlife, and Parks	0	2	0	0
	Oregon Department of Fish and Wildlife	0	0	3	0
	Washington Department of Fish and Wildlife	2	0	3	0
Federal	National Oceanic and Atmospheric Administration	0	0	0	0
	U. S. Fish and Wildlife Service	1	0	1	0
Indian Tribes	Burns Paiute Tribe	0	0	1	0
	Coeur d'Alene Tribe of Indians	1	2	1	0
	Confederated Salish and Kootenai Tribes of the Flathead Reservation	0	0	1	0
	Confederated Tribes of the Colville Reservation	1	1	1	0
	Confederated Tribes of the Umatilla Indian Reservation	0	0	1	0
	Confederated tribes of the Warm Springs Reservation	0	0	1	0
	Confederated Tribes and Bands of the Yakama Nation	0	0	0	0
	Kalispel Tribe	1	1	2	0
	Kootenai Tribe of Idaho	1	3	1	0
	Nez Perce Tribe of Idaho	1	1	1	0
	Shoshone-Bannock Tribes of Fort Hall	0	1	0	0
	Shoshone-Paiute Tribes of Duck Valley	1	1	1	0
	Spokane Tribe of Indians	1	0	2	0
Non-CBFWA project sponsors		1	1	1	3
Total (*N* = 54)		11	15	25	3
Funds (in millions except for outreach projects) and percentage of total dollars allocated for resident fish efforts		**$4.2 (21.7%)**	**$5.8 (30.1%)**	**$9.1 (47.1%)**	**$212,098 (1.1%)**

Figure 2. Location of resident fish projects in the Columbia River Basin funded by the Bonneville Power Administration.



diversity, and range of a number of resident fish populations affected by hydroelectric development and operations. The relevance and credibility of these efforts is illustrated by the appearance of at least 49 papers (white sturgeon (N = 34), burbot (N = 4), cutthroat trout (N = 4), kokanee (N = 3), bull trout (N = 2), and general fish assemblages (N = 2)) in peer-reviewed journals since 1993. These papers document approaches and progress towards achieving goals of the Columbia River Basin Fish and Wildlife Program. The following examples describe some of the projects that have demonstrated progress towards reaching these goals.

Middle Fork Willamette River, Oregon, Bull Trout Reintroduction and Basinwide Monitoring

Bull trout formerly occupied a number of subbasins west of the Cascade Mountains in Oregon. Currently, all but three populations in the McKenzie River subbasin have been extirpated (Ratliff and Howell 1992; Buchanan et al. 1997). Of the three tributaries containing bull trout, two are considered at a "high risk" of extinction (Buchanan et al. 1997). Through the resident fish segment of the Columbia River Basin Fish and Wildlife Program, this project completed a risk assessment, rehabilitation plan, and monitoring program of Middle Fork Willamette River bull trout. From 1998–2001, over 7,700 juvenile bull trout were transferred from the McKenzie River Subbasin to the Middle Fork Willamette River Subbasin (Seals and Reis 2003). Survival of transferred fish was monitored, and in 2001, Seals and Reis (2003) found that approximately 230 age 2+ bull trout were residing in 8.8 km of the upper Middle Fork Willamette River. Survival of transferred fish begins to address the distribution criteria of the Draft Bull Trout Recovery Plan (USFWS 2002), which requires four or more local populations of bull trout in this area, including one population in the upper Middle Fork Willamette River. This project also made progress toward the abundance criteria of the Draft Bull Trout Recovery Plan which prescribes 600–1,000 adult bull trout in this area.

White Sturgeon Mitigation and Restoration in the Columbia River Upstream from Bonneville Dam

Although the white sturgeon population downstream from Bonneville Dam supports one of the most productive recreational and commercial sturgeon fisheries in the world (McCabe and Tracy 1994), populations impounded in Bonneville, The Dalles, and John Day reservoirs support limited recreational and tribal fisheries (Beamesderfer et al. 1995). Parsley and Beckman (1994) found that The Dalles and John Day reservoirs provide white sturgeon little habitat for successful spawning and recruitment to young-of-the-year. Through the resident fish segment of the Columbia River Basin Fish and Wildlife Program, this project has implemented mitigation actions for white sturgeon in these reservoirs including intensified fisheries management and transplants of juvenile fish from the healthy population downstream from Bonneville Dam (Rien and North 2002). After implementation of these actions, abundance of white sturgeon ($\geq$54 cm total length) in John Day Reservoir increased from 6,300 in 1990 to 30,600 in 1996 (North et al. 1998). This increase was maintained through 2001, when abundance was estimated at 30,000 (Kern et al. 2003). Abundance increases in The Dalles Reservoir have been even more dramatic, with estimates of 11,300 in 1988, 12,600 in 1994, 73,500 in 1997, and 104,300 in 2002 (Kern et al. in press).

Fisheries managers have established a white sturgeon biomass goal for the Bonneville, The Dalles, and John Day reservoirs of 5 kg/ha (Columbia Basin Fish and Wildlife Authority 1997), similar to the population biomass downstream from Bonneville Dam. In Bonneville and The Dalles reservoirs, populations are near or exceeding that goal, but because of slow growth of individuals in reservoirs, most of the increase is from juveniles. Sexually mature fish remain relatively uncommon in the reservoirs and the abundances of white sturgeon in the harvestable size slot (97–137 cm fork length in Bonneville Reservoir and 110–137 cm fork length in The Dalles and John Day reservoirs) have declined in recent estimates (Kern et al. in press). Current work continues to monitor recruitment, ensure sustainable harvest levels, and better understand growth in reservoirs.

OREGON DEPARTMENT OF FISH AND WILDLIFE

Although white sturgeon are federally listed as endangered in the upper portion of the Columbia River Basin, lower Columbia River populations, such as those below John Day Dam, Oregon, continue to provide angling opportunities.

Kootenai River, Idaho, White Sturgeon Studies and Conservation Aquaculture

The Kootenai River white sturgeon population, which has experienced a lack of year-class recruitment during the past two decades (Ireland et al. 2002), was listed as endangered by the U. S. Fish and Wildlife Service in 1994. The U. S. Fish and Wildlife Service (1999) identified conservation aquaculture as an action to preserve genetic variability, begin rebuilding age-class structure, and prevent extinction of Kootenai River white sturgeon while measures were identified and implemented to rehabilitate natural recruitment and production. Through the resident fish segment of the Columbia River Basin Fish and Wildlife Program., the Kootenai Tribal Conservation Aquaculture Program released over 2,600 age 1–4 juvenile white sturgeon in the Kootenai River from 1992–1999 (Ireland et al. 2002). Annual monitoring activities resulted in the recapture of 620 hatchery-reared and 39 wild juvenile white sturgeon (Ireland et al. 2002).

Recapture data confirm that the recruitment of wild Kootenai River white sturgeon is currently too low to sustain a viable population, and that most juvenile white sturgeon released from the hatchery are successfully adapting to natural conditions (Ireland et al. 2002). Initial results provide a basis for adjusting releases of hatchery fish consistent with the Recovery Plan for the Kootenai River Population of White Sturgeon (USFWS 1999), and also provide a baseline for comparison with the results of future monitoring to determine the carrying capacity of the Kootenai River for juvenile white sturgeon. This information highlights the continuing importance of the Kootenai Tribal Conservation Aquaculture Program to meet recovery plan goals.

Hungry Horse, Montana, Mitigation Program

The completion of Hungry Horse Dam on the South Fork Flathead River negatively impacted aquatic and riparian environments by altering stream hydrology, reducing biological production, and imposing barriers to fish migration. Losses attributed to Hungry Horse Dam include 124 km of high quality spawning and rearing habitat in the South Fork Flathead River (Montana Fish, Wildlife, and Parks and Confederated Salish and Kootenai Tribes 1991). Approximately 20% of existing spawning and rearing habitat above the reservoir full pool elevation was blocked by poorly placed culverts (Montana Fish, Wildlife, and Parks and Confederated Salish and Kootenai Tribes 1991). Montana Fish, Wildlife, and Parks and Confederated Salish and Kootenai Tribes (1991) suggested that annual losses of 65,500 juvenile westslope cutthroat trout and 250,000 juvenile bull trout can be attributed to the completion of Hungry Horse Dam.

Through the Columbia River Basin Fish and Wildlife Program, the Hungry Horse Mitigation Program has restored fish passage to several critical spawning and rearing streams for native bull trout and westslope cutthroat trout. Completion of fish passage projects has increased the available spawning and rearing habitat for adfluvial trout by 16% (Knotek et al. 1997). Knotek et al. (1997) found adfluvial westslope cutthroat trout spawning activity upstream of all previous barriers and an increase in juvenile densities in natal rearing streams. For example, in Murray Creek, juvenile westslope cutthroat (age-1 and older fish) densities prior to 1997 averaged 48 fish per 150 m prior to barrier removal, whereas mean densities almost tripled (136 fish per 150 m) following the barrier removal (Montana Fish, Wildlife, and Parks, unpublished data).

Continuing Challenges for Resident Fish Managers

Management of resident fish populations in the Columbia River Basin must anticipate and respond to changes in the political and economic environment due to increasing power demands in the Pacific Northwest, alternative uses of water such as navigation and irrigation, and landscape changes resulting from logging, agriculture, and urbanization. Managers must ensure that power, water management, and land use decisions fully consider the effects on resident fish. When those effects are negative, managers should provide leadership in developing mitigation and restoration programs. For example, fisheries management in the upper Columbia River Basin is likely to remain challenging and will require a collaborative approach. The upper Columbia River Basin historically experienced large spring freshets; however, current operations of hydroelectric facilities and management of reservoir levels has resulted in manipulated river flows and a reversed hydrograph in locations such as the Kootenai River (USFWS 1999). The impact of hydrographic changes on resident fish is illustrated by, but not limited to, the current status of white sturgeon and burbot populations in the Kootenai River.

White sturgeon studies (e.g., Parsley and Beckman 1994; Auer 1996; Nilo et al. 1997) have identified the need for high spring flows for white sturgeon recruitment. Current hydroelectric and reservoir operations limit natural flows in the Kootenai River during periods of historically high discharge (i.e., May–June) and increase flows via reservoir releases during periods of historical low flows (i.e., November–March). Partridge (1983) and Apperson and Anders (1991) suggested that since the construction of Libby Dam, white sturgeon recruitment has been limited.

Effects of a reversed hydrograph on burbot were identified by Paragamian (2000) who found that high water flows during winter months inhibited burbot from reaching spawning tributaries below Libby Dam. In addition, Paragamian (2000) suggested that daily changes in water flow and stage in the tailwater below Libby Dam may result in a false migration cue to spawning burbot. Burbot are currently listed as a species of "Special Concern" by the Idaho Department of Fish and Game and are protected via a closure of the fishery.

Fisheries managers have tried to meet the challenge of developing mitigation and recovery measures that address existing needs; however, reservoir operations designed to meet the biological requirements of federally protected anadromous fish (NMFS 2000; USFWS 2000) may not meet the needs of or may negatively impact some Upper Columbia River Basin resident fish populations. It is critical that fisheries managers emphasize that resident fish represent a significant component of the ecosystem and the needs of resident and anadromous fish are not mutually exclusive.

Resident and Anadromous Fish Management: Regional Need for a Risk Assessment

Integration of programs to protect and restore resident and anadromous fish populations affected by operation of hydroelectric facilities in, for example, the Upper Columbia River Basin is needed. These facilities provide the majority of the Pacific Northwest's hydroelectric power and generate the greatest revenues. Reservoirs associated with these facilities provide the augmented flows needed for survival of federally protected anadromous fish and provide important recreational and tribal fisheries for resident fish species. Potential conflicts arise if water release schedules imposed by hydroelectric system operators and federal regulations benefit some fish populations, but potentially harm others.

Because effects of changes in reservoir operations on Columbia River Basin resident and anadromous fish are poorly understood, fisheries managers must be inclusive and creative when identifying measures that promote the protection, enhancement, and mitigation of all fish in the Columbia River Basin. An example of potential changes in operation is recommended in the council's *Mainstem Amendments* to the Columbia River Basin Fish and Wildlife Program. (Northwest Power Planning Council 2003). The council recommended an "experiment" in which summer releases at Hungry Horse and Libby reservoirs are limited, to protect fisheries resources both in the reservoirs and downstream, while still providing flow augmentation for anadromous fish. Objectives of the experiment include: (1) evaluations of the nature, extent, and reasons for flow/survival relationships for anadromous fish, (2) determining whether flow augmentation from upper Columbia River reservoirs affects survival of anadromous fish, and (3) determining benefits to resident fish from the operation. The council's evaluation is a limited and focused example of a risk assessment. Such assessments are needed for a variety of potential hydroelectric system operations. Only by better understanding the effects of operations on all potentially affected populations can managers develop a truly integrated program to mitigate and enhance fish resources of the Columbia River Basin.

Proposals for Columbia River Basin risk assessments are currently being developed and reviewed by fisheries managers. Although fisheries managers recognize the need for comprehensive assessments, challenges exist that could compromise the success of the proposed studies. Challenges include costs, time required to complete multiple-year studies, cooperation among fisheries managers and hydroelectric system operators, and existing regulations requiring specified seasonal flows for federally-listed anadromous fish. Costs include direct costs of funding large-scale studies (several million dollars annually) while maintaining funding for existing projects, and revenue lost by hydroelectric system operators while providing flows required for studies. Multiple-year studies will be required to ensure statistical validity and to accommodate fluctuations in environmental conditions such as annual precipitation and river flow. Coordination and cooperation will require agreements among resident and anadromous fish managers as well as hydrosystem operators and federal regulators to allow for the implementation of experimental flows during the proposed studies.

Acknowledgments

We thank members of the Columbia Basin Fish and Wildlife Authority's Resident Fish Committee for reviewing an earlier version of this manuscript. Clint Muhlfeld, Brian Marotz, Tony Nigro, Tom Rien, Joe Maroney, and four anonymous reviewers provided constructive criticism of the manuscript. We are especially grateful to Amy Langston for assisting with the figures. This effort was funded by the Bonneville Power Administration, Portland, Oregon, through contract 00005864.

References

Apperson, K. A., and **P. J. Anders.** 1991. Kootenai River white sturgeon investigations and experimental culture. Idaho Department of Fish and Game. Annual Report to Bonneville Power Administration. Project Number 88-65, Portland, Oregon.

Auer, N. A. 1996. Response of spawning lake sturgeon to changes in hydroelectric facility operation. Transactions of the American Fisheries Society 125:66-77.

Beamesderfer, R. C. P., T. A. Rien, and **A. A. Nigro.** 1995. Dynamics and potential production of white sturgeon populations in three Columbia River reservoirs. Transactions of the American Fisheries Society 124:857-872.

Buchanan, D. V., M. Hanson, and **B. Hooton.** 1997. Bull trout status report for Oregon. Oregon Department of Fish and Wildlife, Portland.

Columbia Basin Fish and Wildlife Authority. 1997. Multi-year implementation plan for the protection, restoration, and enhancement of Columbia River Basin fish and wildlife resources. Northwest Power Planning Council, Portland, Oregon.

Dunham, J. B. 1996. The population ecology of stream-living Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*). Doctoral dissertation. University of Nevada, Reno.

Dunham, J. B., G. L. Vinyard, and **B. E. Rieman.** 1997. Habitat fragmentation and extinction risk of Lahontan cutthroat trout. North American Journal of Fisheries Management 17:1126-1133.

Farr, R. A., and **D. L. Ward.** 1993. Fishes of the lower Willamette River, near Portland, Oregon. Northwest Science 67:16-22.

Ireland, S. C., R. C. P. Beamesderfer, V. L. Paragamian, V. D. Wakkinen, and **J. T. Siple.** 2002. Success of hatchery-reared juvenile white sturgeon (*Acipenser transmontanus*) following release in the Kootenai River, Idaho, USA. Journal of Applied Ichthyology 18:642-650.

Kern, J. C., M. L. Hughes, and **T. A. Rien.** 2003. Evaluate the success of developing and implementing a management plan for enhancing production of white sturgeon in reservoirs between Bonneville and McNary dams. Report A in D. L. Ward, ed. White sturgeon mitigation and restoration *in* the Columbia and Snake rivers upstream from Bonneville Dam. Annual Report to Bonneville Power Administration, Contract Number 00004005, Portland, Oregon.

_____. In Press. Evaluate the success of developing and implementing a management plan for enhancing production of white sturgeon in reservoirs between Bonneville and McNary dams. Report A *in* D. L. Ward, ed. White sturgeon mitigation and restoration in the Columbia and Snake rivers upstream from Bonneville Dam. Annual Report to Bonneville Power Administration, Contract Number 00004005, Portland, Oregon.

Knotek, W. L., M. Deleray, and **B. Marotz.** 1997. Fish passage and habitat improvement in the upper Flathead River basin. Montana Fish, Wildlife, and Parks. Annual Report to Bonneville Power Administration, Contract Number 00005043, Portland, Oregon.

Knudsen, K. L., C. C. Muhlfeld, G. K. Sage, and **R. F. Leary.** 2002. Genetic structure of Columbia River redband trout populations in the Kootenai River drainage, Montana, revealed by miscrosatellite and allozyme loci. Transactions of the American Fisheries Society 131:1093-1105.

Lee, D. C., J. R. Sedell, B. E. Rieman, R. F. Thurow, and **J. E. Williams.** 1997. Broadscale assessment of aquatic species and habitats. U. S. Forest Service General Technical Report PNW-405 (volume 3):1057-1496.

McCabe, G. T., Jr. and **C. A. Tracy.** 1994. Spawning and early life history of white sturgeon, *Acipenser transmontanus*, in the lower Columbia River. Fishery Bulletin 92:760-772.

Montana Fish, Wildlife and Parks and Confederated Salish and Kootenai Tribes. 1991. Fisheries mitigation plan for losses attributable to the construction and operation of Hungry Horse Dam. Montana Fish, Wildlife & Parks and Confederated Salish and Kootenai Tribes, Kalispell and Pablo, Montana.

Montana Fish, Wildlife and Parks, Confederated Salish and Kootenai Tribes, and Kootenai Tribe of Idaho. 1998. Fisheries mitigation and implementation plan for losses attributable to the construction and operation of Libby Dam. Annual Report to the Bonneville Power Administration. Project Number 199500400, Portland, Oregon.

NMFS (National Marine Fisheries Service). 2000. Federal Columbia River power system biological opinion: reinitiation of consultation on operation of the federal Columbia River power system, including the juvenile fish transportation program, and 19 Bureau of Reclamation projects in the Columbia Basin. National Marine Fisheries Service-Northwest Region, Seattle, Washington.

Nilo, P., P. Dumont, and **R. Furtin.** 1997. Climatic and hydrological determinants on year-class strength of St. Lawrence River lake sturgeon (*Acipenser fulvescens*). Canadian Journal of Aquatic Science 54:774-780.

North, J. A., T. A. Rien, and **R. A. Farr.** 1998. Evaluate the success of developing and implementing a management plan for white sturgeon in reservoirs between Bonneville and McNary dams in enhancing production. Report A *in* D. L. Ward, editor. White sturgeon mitigation and restoration in the Columbia and Snake rivers upstream from Bonneville Dam. Annual Report to Bonneville Power Administration, Contract Number DE-AI79-86BP63584, Portland, Oregon.

Northwest Power Planning Council. 2000. Columbia River Basin fish and wildlife program, Council document 2000-19, Portland, Oregon.

_____. 2003. 2003 Mainstem amendments to the Columbia River Basin fish and wildlife program, Council document 2003-4, Portland, Oregon.

Paragamian, V. L. 2000. The effects of variable flows on burbot spawning migrations in the Kootenai River, Idaho, USA and Kootenay Lake, British Columbia, Canada, after construction of Libby Dam. Pages 111-123 *in* V.L. Paragamian and D.W. Willis, eds. Burbot biology, ecology, and management. American Fisheries Society, Fisheries Management Section, Publication Number 1, Bethesda, Maryland.

Paragamian, V. L., and **V. D. Wakkinen.** 2002. Temporal distribution of Kootenai River white sturgeon spawning events and the effect of flow and temperature. Journal of Applied Ichthyology 18:542-549.

Parsley, M. J., and **L. G. Beckman.** 1994. White sturgeon spawning and rearing habitat in the Lower Columbia River. North American Journal of Fisheries Management 14:812-827.

Partridge, F. 1983. Kootenai River fisheries investigations. Idaho Department of Fish and Game. Job completion report. Project F-73-R-5, Subproject IV, Study VI, Boise, Idaho.

Poe, T. P., H. C. Hansel, S. Vigg, D. E. Palmer, and **L. A. Prendergast.** 1991. Feeding of predaceous fishes on out-migrating juvenile salmonids in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:405-420.

Ratliff, D., and **P. Howell.** 1992. The status of bull trout populations in Oregon. Pages 10-17 *in* P. J. Howell and D. V. Buchanan, eds. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter American Fisheries Society, Corvallis.

Reimers, P. E. and **C. E. Bond.** 1967. Distribution of fishes in the tributaries of the lower Columbia River. Copeia 3:541-550.

Rien, T. A., and **J. A. North.** 2002. White sturgeon transplants within the Columbia River. Pages 223-236 *in* W. VanWinkle, P. Anders, D. Dixon, and D. Secor, eds. Biology, management and protection of North American sturgeons. American Fisheries Society, Bethesda, Maryland.

Seals, J., and **K. Reis.** 2003. Bull trout population monitoring in the McKenzie and Middle Fork Willamette Rivers. Annual Report to Bonneville Power Administration, Contract Number 00004093, Portland, Oregon.

Thurow, R. F., D. C. Lee, and **B. E. Rieman.** 1997. Distribution and status of seven native salmonids in the interior Columbia River Basin and portions of the Klamath River and Great Basins. North American Journal of Fisheries Management 17:1094-1110.

USFWS (U. S. Fish and Wildlife Service). 1999. Recovery plan for the Kootenai River population of white sturgeon (*Acipenser transmontanus*). Region 1, USFWS, Portland, Oregon.

_____. 2000. Biological opinion: effects to listed species from operation of the federal Columbia River power system. Region 1, USFWS, Portland, Oregon.

_____. 2002. Bull trout draft recovery plan. Region 1, USFWS, Portland, Oregon.

Weigel, D. E., J. T. Peterson, and **P. Spruell.** 2003. Introgressive hybridization between cutthroat trout and introduced rainbow trout. Ecological Applications 13:38-50.

Wydoski, R. S., and **R. R. Whitney.** 2003. Inland fishes of Washington, second edition, revised and expanded. University of Washington Press, Seattle.

Zaroban, D. W., M. P. Mulvey, T. R. Maret, R. M. Hughes, and **G. D. Merritt.** 1999. Classifications of species attributes of Pacific northwest freshwater fishes. Northwest Science 73:81-93.

Zimmerman, M. P. 1999. Food habits of smallmouth bass, walleyes, and northern pikeminnow in the lower Columbia River Basin during outmigration of juvenile anadromous salmonids. Transactions of the American Fisheries Society 128:1036-1054.