SURVIVAL AND RATES OF PREDATION FOR JUVENILE PACIFIC LAMPREY MIGRATING THROUGH THE WELLS HYDROELECTRIC PROJECT
(Juvenile Lamprey Study)

WELLS HYDROELECTRIC PROJECT

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FINAL REPORT
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ABSTRACT

In 2008, a juvenile Pacific lamprey (*Lampetra tridentata*) survival and predation study was conducted at the Wells Hydroelectric Project (Wells Project) in accordance with the Integrated Licensing Process (ILP) promulgated by the Federal Energy Regulatory Commission (FERC). The goal of the study was to collect current information on the survival and predation of juvenile Pacific lamprey macrophthalmia migrating through Columbia River hydroelectric projects and to collect site and species-specific information on juvenile lamprey predation in the waters immediately upstream and downstream of Wells Dam. This information will be used to inform predator control program decisions regarding predation on juvenile lamprey macrophthalmia.

The literature review confirmed that information on the juvenile Pacific lamprey outmigration in the Columbia River is scarce and the lack of conclusive data is largely due to the absence of technology to meet research needs. In other words, no studies currently document the level of survival attributed to a project's operations, nor does an accepted technology currently exist that would achieve this level of assessment for juvenile lamprey. The relevant literature also suggests that there are three areas of concern for juvenile lamprey passing through Columbia River hydroelectric dams, including survival through turbines, impingement on turbine intake screens, and increased predation related to passage through dams.

The field study collected over one thousand piscivorous fishes in the forebay and tailrace of Wells Dam for stomach analysis during spring and early summer of 2008. Eleven birds provided by the U.S. Department of Agriculture (USDA) were also examined. Seven lamprey were collected from five predators, including three northern pikeminnow (*Ptychocheilus oregonensis*) of 1,022 sampled; one double-crested cormorant (*Phalacrocorax auritus*) of five sampled; and one ring-billed gull (*Larus delawarensis*) of three sampled. No lamprey were collected from smallmouth bass (*Micropterus dolomieu*), walleye (*Stizostedion vitreum*), Caspian tern (*Hydroprogne caspia*) or California gull (*Larus californicus*).

These results suggest that:

- Predation of juvenile lamprey by northern pikeminnow in the study area is likely not substantial at this time;
- A difference in predation rates of juvenile lamprey between the Wells forebay and Wells tailrace is not detectable based on these results;
- Predation of juvenile lamprey by walleye and smallmouth bass in the study area is likely not substantial at this time given the relatively small numbers of bass and walleye present during the peak of the macrophthalmia outmigration and the absence of juvenile lamprey within the stomachs of the fish sampled;
- Avian predation of juvenile lamprey in the study area was larger than that observed for predatory fish, though these conclusions are based upon limited sample sizes for the avian predators;
- The lack of the monitoring, trapping, and tagging technology required to produce reliable survival estimates will continue to limit the ability to measure the impact of hydroelectric operations on lamprey populations in the Columbia River.

1.0 INTRODUCTION

1.1 General Description of the Wells Hydroelectric Project

The Wells Hydroelectric Project (Wells Project) is located at river mile (RM) 515.6 on the Columbia River in the State of Washington (Figure 1.1-1). Wells Dam is located approximately 30 river miles downstream from the Chief Joseph Hydroelectric Project, owned and operated by the United States Army Corps of Engineers (COE); and 42 miles upstream from the Rocky Reach Hydroelectric Project, owned and operated by Public Utility District No. 1 of Chelan County (Chelan PUD). The nearest town is Pateros, Washington, which is located approximately 8 miles upstream from the Wells Dam.

The Wells Project is the chief generating resource for the Public Utility District No. 1 of Douglas County (Douglas PUD). It includes ten generating units with a nameplate rating of 774,300 kW and a peaking capacity of approximately 840,000 kW. The design of the Wells Project is unique in that the generating units, spillways, switchyard, and fish passage facilities were combined into a single structure referred to as the hydrocombine. Fish passage facilities reside on both sides of the hydrocombine, which is 1,130 feet long, 168 feet wide, with a crest elevation of 795 feet in height.

The Wells Reservoir is approximately 30 miles long. The Methow and Okanogan rivers are tributaries of the Columbia River within the Wells Reservoir. The Wells Project boundary extends approximately 1.5 miles up the Methow River and approximately 15.5 miles up the Okanogan River. The surface area of the reservoir is 9,740 acres with a gross storage capacity of 331,200 acre-feet and usable storage of 97,985 acre feet at the normal maximum water surface elevation of 781 above mean sea level (msl) (Figure 1.1-1).

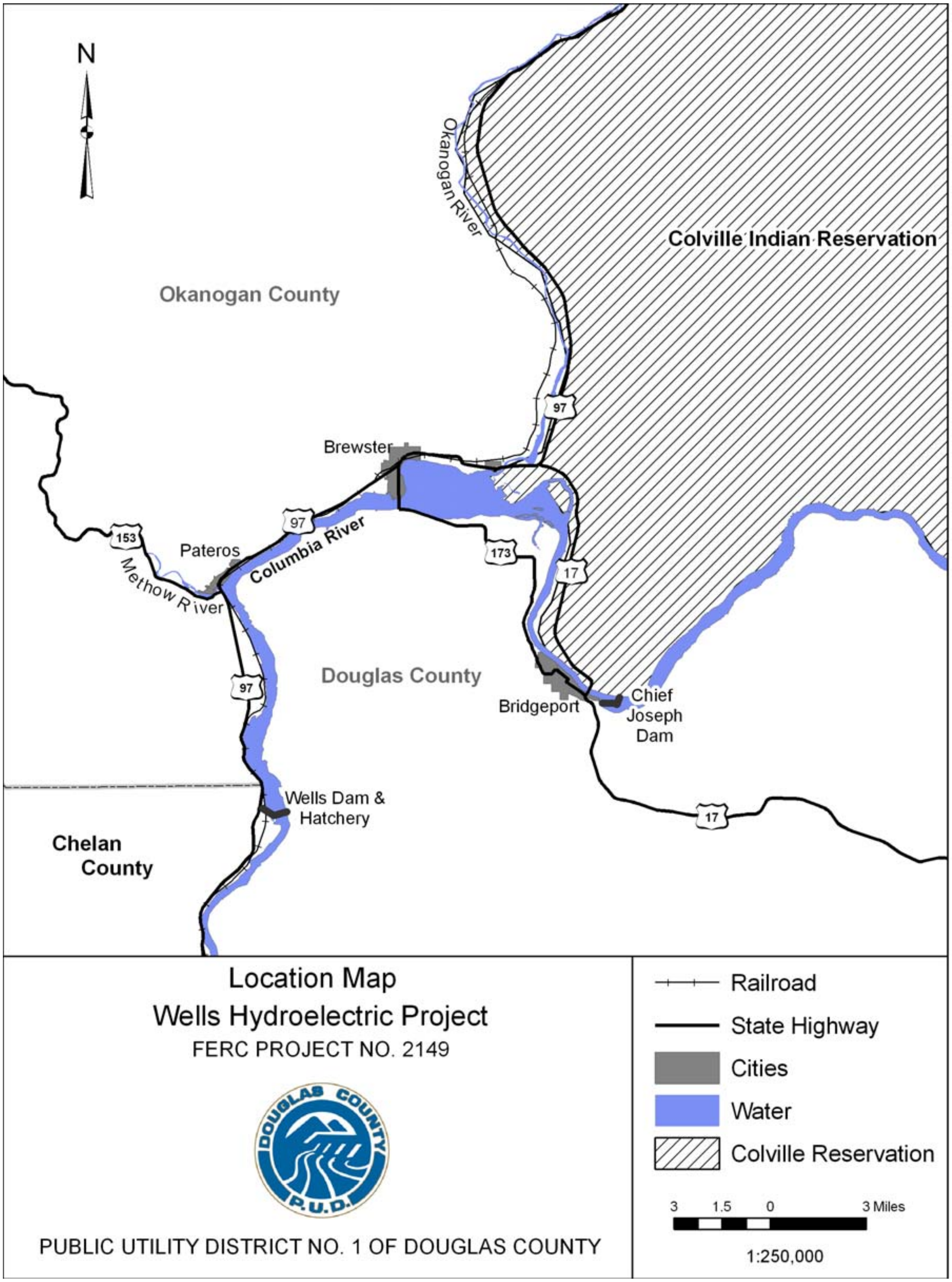

Figure 1.1-1 Location Map of the Wells Hydroelectric Project.

1.2 Relicensing Process

The current Wells Project license will expire on May 31, 2012. Douglas PUD is using the Integrated Licensing Process (ILP) promulgated by Federal Energy Regulatory Commission (FERC) Order 2002 (18 CFR Part 5). Stakeholders consisting of representatives from state and federal agencies, tribes, local governments, non-governmental organizations and the general public have participated in the Wells Project ILP, from a very early stage, to identify information needs related to the relicensing of the Wells Project.

In August 2005, Douglas PUD initiated a series of Resource Work Group (RWG) meetings with stakeholders regarding the upcoming relicensing of the Wells Project. This voluntary effort was initiated to provide stakeholders with information about the Wells Project, to identify resource issues and to develop preliminary study plans prior to filing the Notice of Intent (NOI) and Pre-Application Document (PAD). The RWGs were formed to discuss issues related to the Wells Project and its operations.

The primary goals of the RWGs were to identify resource issues and potential study needs in advance of Douglas PUD filing the NOI and PAD. Through 35 meetings, each RWG cooperatively developed a list of Issue Statements, Issue Determination Statements and Agreed-Upon Study Plans. An Issue Statement is an agreed-upon definition of a resource issue raised by a stakeholder. An Issue Determination Statement reflects the RWGs' efforts to apply FERC's seven study criteria to mutually determine the applicability of each individual Issue Statement. Agreed-Upon Study Plans are the finished products of the informal RWG process.

Douglas PUD submitted the NOI and PAD to FERC on December 1, 2006. The PAD included the RWGs' 12 Agreed-Upon Study Plans. The filing of these documents initiated the relicensing process for the Wells Project under FERC's regulations governing the ILP.

On May 16, 2007, Douglas PUD submitted a Proposed Study Plan (PSP) Document. The PSP Document consisted of the Applicant's Proposed Study Plans, Responses to Stakeholder Study Requests and a schedule for conducting the Study Plan Meeting. The ILP required Study Plan Meeting was conducted on June 14, 2007. The purpose of the Study Plan Meeting was to provide stakeholders with an opportunity to review and comment on Douglas PUD's PSP Document, to review and answer questions related to stakeholder study requests and to attempt to resolve any outstanding issues with respect to the PSP Document.

On September 14, 2007, Douglas PUD submitted a Revised Study Plan (RSP) Document. The RSP Document consisted of a summary of each of Douglas PUD's revised study plans and a response to stakeholder PSP Document comments.

On October 11, 2007, FERC issued its Study Plan Determination based on its review of the RSP Document and comments from stakeholders. FERC's Study Plan Determination required Douglas PUD to complete 10 of the 12 studies included in its RSP Document. Douglas PUD has opted to complete all 12 studies to better prepare for the 401 Water Quality Certification process conducted by the Washington State Department of Ecology (Ecology) and to fulfill its commitment to the RWGs who collaboratively developed the 12 Agreed-Upon Study Plans with

Douglas PUD. These study plans have been implemented during the designated ILP study period. The results from the study plans have been developed into 12 Study Reports. Each report is included in Douglas PUD's Initial Study Report (ISR) Document, which is scheduled for filing with FERC on October 15, 2008.

This report completes the Juvenile Lamprey Study.

2.0 GOALS AND OBJECTIVES

The goals of this study were to collect current information on the survival and predation of juvenile Pacific lamprey macrophthalmia migrating through Columbia River hydroelectric projects and to collect site and species-specific information on juvenile lamprey predation in the waters immediately upstream and downstream of Wells Dam. This information will be used to inform predator control program decisions regarding predation on juvenile lamprey macrophthalmia.

The specific tasks to accomplish these goals were:

- Conduct a literature review on juvenile lamprey macrophthalmia survival and predation studies conducted at Columbia River hydroelectric projects.
- Conduct an analysis on the stomach contents of predatory fish and birds (if feasible) to assess the location (only applicable to fish) and level of predation that may be occurring on juvenile Pacific lamprey macrophthalmia in the Wells forebay and tailrace.

3.0 STUDY AREA

The study area for field activities was the Wells forebay and tailrace. The Wells tailrace was defined, for this study, as the waters immediately below Wells Dam downstream to a distance of 3,000 feet. The initial definition of the Wells forebay, for this study, extended 1,000 feet upstream from the face of the dam. However, to obtain desired sample size above the dam, it was necessary to expand the collection area upstream in the lower reservoir to include the mouth of the Methow River.

4.0 BACKGROUND AND EXISTING INFORMATION

Pacific lamprey are present below Chief Joseph Dam in most tributaries of the Columbia River and in the mainstem during their migrations. Lamprey have cultural, utilitarian and ecological significance including the ceremonial, subsistence and medicinal use of adult lamprey by Native Americans (Close et al. 2002). As an anadromous species, they also contribute marine-derived nutrients to the aquatic ecosystem of the interior Columbia Basin. Little specific information is available on the life history or status of lamprey in the mid-Columbia River watersheds. They are known to occur in the Methow, Wenatchee and Entiat rivers (NMFS, 2002) and recently have been captured during juvenile trapping operations in the Okanogan River (Michael Rayton, Confederated Colville Tribes, personal communication, 2007).

In general, adults are parasitic on fish in the Pacific Ocean while ammocoetes (larvae) are filter feeders that inhabit the fine silt deposits in backwaters and quiet eddies of streams (Wydoski and Whitney, 2003). Adults generally spawn in low-gradient stream reaches in the tail areas of pools and in riffles, over gravel substrates (Jackson et al. 1997). Adults die after spawning. After hatching, the ammocoetes burrow into soft substrate for an extended larval period filtering particulate matter from the water column (Meeuwig et al. 2002). The ammocoetes undergo a metamorphosis to macrophthalmia between 3 and 7 years after hatching, and migrate from their parent streams to the ocean from October to April (Close et al., 2002). Adults typically spend 1-4 years in the ocean before returning to freshwater tributaries to spawn.

Pacific lamprey populations of the Columbia River have declined in abundance over the last 40 years according to counts at dams on the lower Columbia and Snake rivers (Close et al. 2002). Starke and Dalen (2004) reported that adult lamprey counts at Bonneville Dam regularly exceeded 100,000 fish in the 1960s. Lamprey counts have averaged just over 50,000 over the past seven years, with a record low 19,304 fish passing Bonneville Dam in 2007 (DART - www.cqs.washington.edu/dart/adult.html).

Close et al. (1995, 2002) identified several factors that may account for the decline in lamprey counts in the Columbia River Basin. These include reduction in suitable spawning and rearing habitat from flow regulation and channelization, pollution and chemical eradication, reductions of prey in the ocean, and juvenile and adult passage problems at dams (Nass et al., 2005). Although there is a growing body of information on adult Pacific lamprey and their interactions at hydroelectric projects, relatively little information exists describing the effects of hydroelectric plant operations on outmigrating juveniles (macrophthalmia). Recent juvenile lamprey studies at hydroelectric projects have tested for lamprey macrophthalmia survival through juvenile bypass facilities (Bleich and Moursund, 2006), impingement by intake diversion screens (Moursund et al., 2000 and 2003), validation of existing screening criteria (Ostrand, 2005), and responses of juvenile Pacific lamprey to simulated turbine passage environments (Moursund et al., 2001; Dauble and Mueller, 2006). Results of other studies targeting predaceous birds and fish suggest that juvenile lamprey may compose a significant proportion of the diets of these predators (Poe et al., 1991; Merrell, 1959).

A review of the recent body of work addressing juvenile lamprey at hydroelectric facilities concludes that there is a current lack of methods and tools to effectively quantify survival of juvenile lamprey migrating through hydroelectric facilities (Bao Le, Long View Associates, personal communication 2008). Furthermore, no studies exist that determine a level of mortality attributed to a project’s operations. This is due to the lack of miniaturized active tag technologies to overcome two study limitations – macrophthalmia are relatively small in size and unique in body shape, and migrate low in the water column resulting in the rapid attenuation of active tag signal strength. In 1999, the COE funded Oregon State University to assess the applicability of available tag technology to monitor juvenile lamprey macrophthalmia outmigration (Schreck et al., 2000). Results from this effort indicated that the smallest currently available radio-tag is still too large for implantation in the body cavity of a juvenile lamprey (Schreck et. al., 2000). Additionally, external application was not effective as animals removed tags within the first week and fish performance and behavior were affected (Schreck et al., 2000). Internal implantation of Passive Integrated Transponder (PIT) tags is currently the most viable option for tagging juvenile lamprey, however this methodology presents severe limitations due to the limited range of detection systems, and the ability to tag only the largest outmigrating juvenile lamprey (Schreck et al., 2000). No further development in tag technology useful in assessing juvenile lamprey macrophthalmia outmigration has occurred since the 1999 assessment (Schreck, personal communication 2007).

4.1 Aquatic Resource Work Group

As part of the relicensing process for the Wells Project, Douglas PUD established an Aquatic Resource Work Group (Aquatic RWG) which began meeting informally in November, 2005. This voluntary effort was initiated to provide stakeholders with information about the Wells Project, to collaboratively identify potential resource issues related to Project operations and relevant to relicensing, and to develop preliminary study plans to be included in the Wells Pre-Application Document (PAD) (DCPUD, 2006).

Through a series of meetings, the Aquatic RWG cooperatively developed a list of Issue Statements, Issue Determination Statements and Agreed-Upon Study Plans. An Issue Statement is an agreed-upon definition of a resource issue raised by a stakeholder. An Issue Determination Statement reflects the RWG's efforts to review the existing project information and to determine whether an issue matches with FERC's seven criteria and would be useful in making future relicensing decisions. Agreed-Upon Study Plans are the finished products of the informal RWG process.

Based upon these meetings and discussions, the Aquatic RWG proposed a study to: 1) collect and summarize the existing literature related to juvenile lamprey survival at hydroelectric projects; and 2) assess juvenile lamprey predation within the Wells Project forebay and tailrace. The need for this study was agreed to by all of the Aquatic RWG members, including Douglas PUD. This study will help to inform future relicensing decisions and will fill data gaps that have been identified by the Aquatic RWG.

The Issue Statement and Issue Determination Statement listed below were included in the PAD (section number included) filed with FERC on December 1, 2006:

4.1.1 Issue Statement (PAD Section 6.2.1.1)

Operations of the Project may affect juvenile Pacific lamprey dam passage and reservoir survival (survival, route of passage and timing) during their downstream migration.

4.1.2 Issue Determination Statement (PAD Section 6.2.1.1)

It is unknown whether there is a Project effect on juvenile lamprey. At this time, there are no studies documenting Project effects on juvenile lamprey. However, dam passage survival can be broken down into 4 specific areas of concern; survival, route of passage, timing and predation. Currently, there are two limitations to the implementation of a field study for dam passage survival: 1) tag technology for juvenile macrophthalmia is currently being developed; and 2) obtaining macrophthalmia in sufficient numbers within the Project to meet sample size requirements for a statistically rigorous study is not practicable. Reservoir predation on juvenile lamprey is unknown.

The resource work group agreed that a study is needed during the two-year ILP study period. This study included an updated literature review on juvenile lamprey survival and predation on juvenile lamprey and examined the stomach contents of fish and birds collected through existing programs.

4.2 Project Nexus

Anadromous lamprey actively migrate from estuarine and marine waters to freshwater spawning areas as adults. Upon metamorphosis, juveniles participate in both active and passive emigration from freshwater rearing areas. In the Columbia River Basin, lamprey may migrate hundreds of kilometers through both mainstem and tributary habitats. Consequently, they encounter a variety of obstacles to passage that could affect their populations. Recent research has indicated that large hydropower dams delay and obstruct adult passage (LTWG, 2005). These facilities may also affect the downstream passage of juvenile lamprey during their outmigration. Specifically, areas of turbulence in the Wells tailrace could increase the susceptibility of juvenile lamprey macrophthalmia to predation.

5.0 METHODOLOGY

The literature review consisted of a search of all existing information currently available on juvenile lamprey survival and predation at hydroelectric projects in the Columbia River Basin. This search examined the availability of information from peer-reviewed journals, federal and state publications, academia, private industry, and gray literature. Relevant references collected from the literature search were added to the literature database. An annotated bibliography was produced for these references (see Appendix A).

The field collection for analysis of predatory fish stomach contents occurred in the Wells forebay and tailrace. Fish species that were collected include northern pikeminnow (*Ptychocheilus oregonensis*), smallmouth bass (*Micropterus dolomieu*), and walleye (*Stizostedion vitreum*). Fish were collected via angling and through coordination with other programs that were already capturing such species; i.e., northern pikeminnow removal program in the Wells forebay and tailrace, and U.S. Department of Agriculture (USDA) avian control activities. An effort was made to collect 20 samples of both smallmouth bass and walleye from the Wells tailrace via angling. The sampling objective for northern pikeminnow was 500 each from the Wells Dam tailrace and forebay from the existing pikeminnow control program.

Stomach contents of piscivorous birds collected in the Wells tailrace were also analyzed. These samples were collected through coordination with the existing USDA control program that collects avian predators in the Wells tailrace. The number of samples and the species of birds sampled were dependent upon the availability of samples from this effort.

Both predatory fish and bird collection occurred from late April through late June, 2008 to coincide with the juvenile Pacific lamprey outmigration in the mid-Columbia River. Although the study plan indicated sampling would occur from May through July, detailed analyses of available catch data indicated that April through June would be more consistent with the juvenile lamprey outmigration in the Wells Project Area. Fyke net data collected at Wells Dam during 1990, and from 1995-2002 indicated that 73% of juvenile lamprey observations were made during this time frame. Further, screw trap data collected by Washington Department of Fish and Wildlife (WDFW) during the spring months of 2004 through 2007 indicate that the middle 50% of the juvenile lamprey outmigration in the Methow River occurs between April 22nd and May 28th on average (Figure 6.0-1).

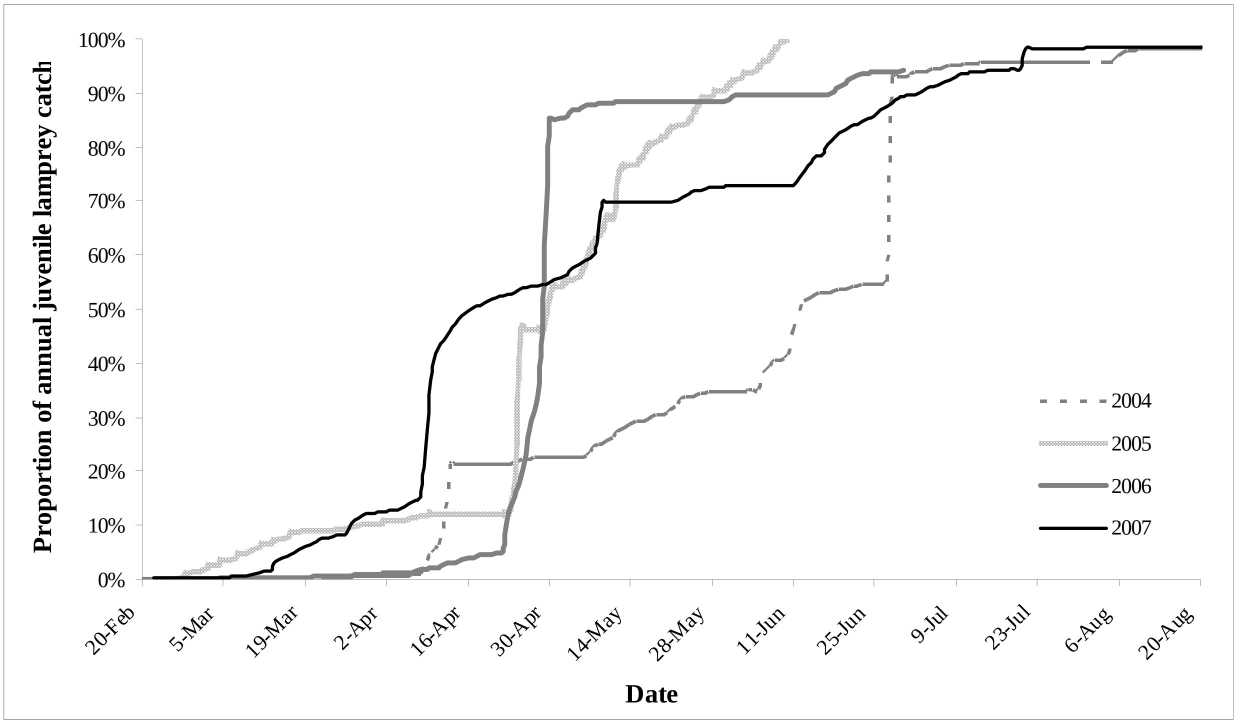

Figure 5.0-1 Proportion of annual outmigrating juvenile lamprey catch at WDFW screw traps in the Methow River by date, 2004-2007.

Sampling effort during the study was stratified to collect samples throughout the entire outmigration period. General information such as location, date, and time of capture was recorded in addition to biological information (length, weight, species, sex, stomach contents). All samples collected by Douglas PUD were analyzed and recorded on-site by trained field staff. Samples were preserved according to Quality Assurance/Quality Control standards in case future evaluation/verification is necessary. Data acquired from the stomach content analysis consists of qualitative observations of prey species diversity, prey species percent composition, and a comparative analysis of the levels of predation observed by location (applicable only to predatory fish) and by predator species.

6.0 RESULTS

6.1 Literature Review

In March 2008 numerous search engines were used to locate relevant publications. Relevant publications constitute literature addressing juvenile lamprey macrophthalmia survival and predation at Columbia River hydroelectric projects. An initial title search on "lamprey" resulted in hundreds of bibliographies from providers including ISI Web of Knowledge (883 entries), EBSCOhost (358 entries), SpringerLink (283 entries), Wiley InterScience (250 entries), Science Direct (187 entries), ProQuest (140 entries), JSTOR (132 entries), Blackwell Synergy (78 entries), and SAGE Journals online (69 entries), among others. A majority of the published literature, however, was related to adult lamprey (especially sea lamprey, (*Petromyzon marinus*) and biology (neurology, endocrinology, anatomy, etc.). Few studies involved juvenile lamprey, and most of these were based on research of pheromones released by ammocoetes. One peer-reviewed publication dealing with juvenile lamprey survival at a Columbia River hydroelectric project was located (Moursund et al., 2003). This publication focuses on juvenile lamprey turbine intake diversion screen survival and is not directly relevant to the Wells Project, which does not have intake screens.

In addition to peer-reviewed sources, the literature search examined "gray literature" from federal and state agency publications, academia, private industry, and studies conducted by tribal entities. The initial reference list of relevant literature was also sent to local lamprey researchers to determine if they knew of other Columbia River juvenile lamprey survival and predation studies (Bao Le, personal communication). Final results of this search revealed that relevant grey literature regarding juvenile lamprey survival and predation was generally limited to assessments of tagging feasibility and downstream passage through hydroelectric projects (especially at turbine intake diversion screens) on the Lower Columbia River. Predation studies in the Columbia River have focused on juvenile salmonids, although lamprey have been noted in these assessments (USDA, 2003). In total, 15 documents were found to be relevant to juvenile lamprey macrophthalmia survival and predation at Columbia River hydroelectric projects. See Appendix A for an annotated bibliography of these documents.

The lack of information on juvenile lamprey out-migrant survival and predation in the Columbia River has been highlighted in many discussions and letters of intent to conduct research. Two primary factors explain this lack of juvenile lamprey information: 1) the lack of validated methodologies to estimate juvenile lamprey abundance limits the ability to determine the population level effects of predation on juvenile lamprey in the Columbia River; and 2) active tagging technologies to accurately assess juvenile lamprey survival at hydroelectric projects do not exist.

6.2 Predation Analyses

One-thousand forty-two (1,042) fishes were collected from the study area during 55 days throughout the study period (April 23rd – June 29th). Species captured and examined included 1,022 pikeminnow, 19 smallmouth bass, and one (1) walleye. Roughly 43% of all fish had one or more food items. Over forty-three percent (43.4%) of pikeminnow (n = 1,022) and 47.4% of smallmouth bass (n = 19) had one or more food items, while the single walleye collected had an empty stomach (Table 6.2-1 and 6.2-2). Food items included mostly other organic items, including insects, crayfish, plant matter, and unidentifiable organic matter (frequency of occurrence = 30%), though other fish, such as salmonids and sticklebacks, were observed regularly (16%). One or more inorganic items were observed in 2% of fish – mostly sand and gravel. Only three fish (all pikeminnow) were found to have lamprey, accounting for 0.3% of all fish sampled. Two of the three pikeminnow found to have lamprey were collected from the forebay, with the remaining fish captured in the tailrace. These proportions both represent less than 0.5% of the fish collected at each location and the differences in predation rates on juvenile lamprey between locations are both statistically and biologically insignificant (Table 6.2-4).

Eleven (11) birds were provided by the USDA, including two California gulls (*Larus californicus*), one Caspian tern (*Hydroprogne caspia*), five double-crested cormorants (*Phalacrocorax auritus*), and three ring-billed gulls (*Larus delawarensis*). All of the bird stomachs contained one or more food items. Birds fed largely on other fish (frequency of occurrence = 91%), though other organic items (55%), inorganic items (18%), and lamprey (18%) were observed (Tables 6.2-1 and 6.2-2). Although one of five cormorants and one of three ring-billed gull sampled contained lamprey, the small sample size (n = 11) and mobility of these birds precludes drawing strong conclusions from these results.

At least 561 food items were collected and enumerated from the 464 predators that did not have empty stomachs. Some items (e.g., ants) were not countable and therefore recorded as a single unit. Seven lamprey were observed, accounting for 0.6% of all items identified in pikeminnow, 9.1% of all items identified in ring-billed gulls, and 19% of all items identified in double-crested cormorants; however, the latter percent compositions are derived from only five cormorants and three ring-billed gulls. No lamprey were observed in California gulls, Caspian tern, smallmouth bass, and walleye (Tables 6.2-3 and 6.2-4).

Table 6.2-1 Number of predators sampled and food items observed, 2008.

Species	Number sampled	Number with food items present	Number with lamprey present	Number with other fish present	Number with other organic items present	Number with inorganic items present
California gull	2	2	0	2	0	0
Caspian tern	1	1	0	1	0	0
Double-crested cormorant	5	5	1	4	5	2
Ring-billed gull	3	3	1	3	1	0
Northern pikeminnow	1,022	444	3	154	307	23
Smallmouth bass	19	9	0	8	3	0
Walleye	1	0	0	0	0	0
Grand Total	1,053	464	5	172	316	25

Table 6.2-2 Frequency of occurrence of food items observed in predator stomachs by predator and food item, 2008.

Species	Percent with food items present	Percent with lamprey present	Percent with other fish present	Percent with other organic items present	Percent with inorganic items present
California gull	100.0%	0.0%	100.0%	0.0%	0.0%
Caspian tern	100.0%	0.0%	100.0%	0.0%	0.0%
Double-crested cormorant	100.0%	20.0%	80.0%	100.0%	40.0%
Ring-billed gull	100.0%	33.3%	100.0%	33.3%	0.0%
Pikeminnow	43.4%	0.3%	15.1%	30.0%	2.3%
Smallmouth bass	47.4%	0.0%	42.1%	15.8%	0.0%
Walleye	0.0%	0.0%	0.0%	0.0%	0.0%
Grand Total	44.1%	0.5%	16.3%	30.0%	2.4%

Table 6.2-3 Total number of food items observed in predator stomachs by predator and food item, 2008.

Species	Number sampled	Total number of food items	Total number of lamprey	Total number of other fish	Total number of other organic items	Total number of inorganic items
California gull	2	7	0	7	0	0
Caspian tern	1	4	0	4	0	0
Double-crested cormorant	5	16	3	5	6	2
Ring-billed gull	3	11	1	9	1	0
Pikeminnow	1,022	505	3	159	315	28
Smallmouth bass	19	18	0	14	4	0
Walleye	1	0	0	0	0	0
Grand Total	1,053	561	7	198	326	30

Table 6.2-4 Percent composition of specific food items compared to total food items observed in predator stomachs by predator and food item, 2008.

Species	Total number of food items	Percent composition of lamprey	Percent composition of other fish	Percent composition of other organic items	Percent composition of inorganic items
California gull	7	0.0%	100.0%	0.0%	0.0%
Caspian tern	4	0.0%	100.0%	0.0%	0.0%
Double-crested cormorant	16	18.8%	31.3%	37.5%	12.5%
Ring-billed gull	11	9.1%	81.8%	9.1%	0.0%
Pikeminnow	505	0.6%	31.5%	62.4%	5.5%
Smallmouth bass	18	0.0%	77.8%	22.2%	0.0%
Walleye	0	-	-	-	-
Grand Total	561	1.2%	35.3%	58.1%	5.3%

Table 6.2-5 Number of predators sampled with one or more stomach items, by location (forebay or tailrace), 2008.

Species	Data	Forebay	Tailrace	#N/A	Grand Total
California gull	One or more lamprey	.	.	.	.
	One or more other fish	.	2	.	2
	One or more other organic	.	.	.	.
	One or more other inorganic	.	.	.	.
Caspian tern	One or more lamprey	.	.	.	.
	One or more other fish	.	1	.	1
	One or more other organic	.	.	.	.
	One or more other inorganic	.	.	.	.
Double-crested cormorant	One or more lamprey	.	1	.	1
	One or more other fish	.	4	.	4
	One or more other organic	.	5	.	5
	One or more other inorganic	.	2	.	2
Ring-necked gull	One or more lamprey	.	1	.	1
	One or more other fish	.	3	.	3
	One or more other organic	.	1	.	1
	One or more other inorganic	.	.	.	.
Pikeminnow	One or more lamprey	2	1	.	3
	One or more other fish	51	100	3	154
	One or more other organic	165	138	4	307
	One or more other inorganic	18	4	1	23
Smallmouth bass	One or more lamprey	.	.	.	.
	One or more other fish	.	8	.	8
	One or more other organic	.	3	.	3
	One or more other inorganic	.	.	.	.
Walleye	One or more lamprey	.	.	.	.
	One or more other fish	.	.	.	.
	One or more other organic	.	.	.	.
	One or more other inorganic	.	.	.	.
Total one or more lamprey		2	3	.	5
Total one or more other fish		51	118	3	172
Total one or more other organic		165	147	4	316
Total one or more other inorganic		18	6	1	25

7.0 DISCUSSION

7.1 Literature Review

The literature reviewed supports the pre-study assessment that information on juvenile Pacific lamprey outmigration in the Columbia River and survival through hydroelectric projects is very limited. No studies have calculated an estimate of survival for any route or time period, five studies inferred potential mechanisms of mortality, and four studies provided information on the frequency of occurrence in predator diets. As mentioned in the Section 2.0 (Background and Existing Information) of this report, the lack of conclusive data is largely due to the lack of technology to meet research needs. The ability to measure the magnitude of these issues, along with development and assessment of management strategies will improve with future advances in technology.

7.2 Predation Analysis

Results from the predator diet composition analyses indicate that a limited number of predators feed on out-migrating juvenile lamprey in the study area. Further, the results of this study indicate:

- Predation of juvenile lamprey by northern pikeminnow in the study area is likely not substantial at this time;
- A difference in predation rates of juvenile lamprey between the Wells forebay and Wells tailrace is not detectable based on these results;
- Predation of juvenile lamprey by walleye and smallmouth bass in the study area is likely not substantial at this time, given the relatively small numbers of bass and walleye present during the peak of the macrophthalmia migration and evident by the absence of juvenile lamprey within the stomachs of the fish sampled;
- Avian predation of juvenile lamprey in the study area was larger than that observed for predatory fish, though admittedly these conclusions were based upon limited samples sizes for the avian predators;
- The lack of the monitoring, trapping, and tagging technology required to produce reliable survival estimates will continue to limit the ability to measure the impact of hydroelectric operations on lamprey populations in the Columbia River.

8.0 STUDY VARIANCE

Variances in the FERC approved study plan for the Juvenile Lamprey Study included the following:

- The definition of the forebay for this study was originally stated as “1,000 feet above Wells Dam.” This sampling area was extended to include forebay waters upstream to the confluence of the Methow River. This extension was made to ensure that the proposed sample size of 500 pikeminnow was achieved as pikeminnow catches immediately above Wells Dam were low during the sampling period (Tyson Gerald, personal communication).

- The original proposed sampling period (May-July) was adjusted to one month earlier (April-June) based on analyses subsequent to development of the Study Plan indicating that an earlier time frame was more consistent with the juvenile lamprey outmigration in the Wells Project (see Methodology, 5.0).

9.0 ACKNOWLEDGMENTS

We thank Tyson Gerald and fisheries technicians at Columbia River Research for conducting pikeminnow sampling. Jim McGee and USDA/Wildlife Services personnel were helpful in providing stomach samples from piscivorous birds in the study area. Beau Patterson, Bao Le, Scott Kreiter and Shane Bickford provided excellent technical support throughout the study, as well as field work during the collection period. Mary Mayo is thanked for her editorial support.

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Moursund, R.A., R. P. Mueller, T. M. Degerman, and D. D. Dauble. 2001. Effects of Dam Passage on Juvenile Pacific Lamprey (*Lampetra tridentata*). Prepared by Pacific Northwest National Laboratory for the U.S. Army Corps of Engineers, Portland District, Portland, Oregon. Contract DE-AC06-76RL01830.

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Ostrand, K.G. 2005. Validation of Existing Screening Criteria for Lamprey Macrophthalmia. United States Fish and Wildlife Service: Abernathy Fish Technology Center, Longview, WA.

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.

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Appendix A

Annotated Bibliography of Relevant Documents Reviewed in Literature Search

Antolos, M., D.D. Roby, D.E. Lyons, K. Collis, A.F. Evans, M. Hawbecker, and B.A. Ryan. 2005. Caspian tern predation on juvenile salmonids in the mid-Columbia River. Transactions of the American Fisheries Society 134:466-480.

> This study quantified the diet of Caspian trens nesting in the mid-Columbia River on Crescent Island, Washington in 2000 and 2001, and used a bioenergetics approach to determine the magnitude of predation on juvenile salmonids. However, the study esimtated that the mean number of lamprey consumed by the Cresent Island Caspian tern population was 4,300 and 4,900 lamprey in 2001 and 2002 (repectively) (95% C.I. of 3,200 to 6,000). An estimate of the total number of terns that consumed this number of lamprey was not actually reported in the study. The percent compostion of lamprey in the tern diet was apperently very low (although not reported). This study estimated the Cresent Island tern population consumed hundreds of thousands of juvenile salmonids.

Bleich, M.D., and R.A. Moursund. 2006. PIT tag evaluation of the juvenile bypass system at the McNary Dam for passage of juvenile Pacific lamprey (*Lampetra tridentata*), 2005. Final report for contract DACW68-02-D-0001. Prepared by Battelle for U.S. Army Corps of Engineers. Walla Walla, Washington.

> This study examined the efficiency of a bypass system at McNary Dam for juvenile lamprey. This report did not directly estimate juvenile lamprey or predation. However, the study reported "*the unexpected observation of juvenile lamprey tags within the adult fish ladders at McNary Dam, less than one day following release, indicates the potential for predation following passage through the JBS* [bypass system]. *Examination into short-term passage effects, including turbine passage effects, and the potential for resulting predation is a research area that may be worth exploring in the future.*"

Collis, K., D.D. Roby, D.P. Craig, S. Adamany, J.Y. Adkins, and D.E. Lyons. 2002. Colony size and diet composition of piscivorous waterbirds on the lower Columbia River: Implications for losses of juvenile salmonids to avian predation. Trans. Am. Fish. Soc. 131:537-550.

> This study investigated the colony size and diet composition of piscivorous waterbirds (gulls, terns, and cormorants) nesting on the lower Columbia River from the mouth (river km 0) to the head of McNary Pool (river km 553) in 1997 and 1998. Lamprey were not specifically, quantified, but it was reported that "other" fish items in the diet, which was defined as lamprey or other unidentified nonsalmonids, comprised 1.9% of diet and 1.1% of bill loads at Rice Island and 3.8 % of diet and bill load samples combined at Three Mile Canyon Island.

Dauble, D. and B. Mueller. 2006. Responses of Juvenile Pacific Lamprey to Turbine Passage. Publication prepared by Pacific Northwest National Laboratory.

> Pacific Northwest National Laboratory scientists conducted laboratory tests designed to simulate juvenile lamprey passage through a turbine environment. Juvenile Pacific lamprey were subjected to two of three aspects of passage: pressure drop and shear stress. The third aspect, blade strike, was not tested. The study showed that at least two of the three main forces present in turbine passage (pressure and shear stress) were not harmful to juvenile Pacific lamprey. The study also concluded "*effects of blade strike or sublethal effects, such as increased vulnerability to predation following turbine passage, are not known*".

Jackson, A.D., D.R. Hatch, B.L. Parker, D.A. Close, M.S. Fizpatrick and H. Li. 1997. Pacific lamprey research and restoration annual report 1997. Report to the U.S. Department of Energy, Bonneville Power Administration, Portland Oregon. USA.

> This report does not actually report survival or predation estimates for juvenile lamprey at Columbia River hydroelectric projects. However, it does provide information on lamprey passage rates, notes limitations for determining lamprey abundance, and makes recommendations on future studies. Discussion of Wells Dam is included in the report.

Moursund, 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 (*Lampreta tridentata*). Final Report. Prepared by Pacific Northwest National Laboratory for the U.S. Army Corps of Engineers. Portland, Oregon.

> This study examined the effect of turbine bypass screens on juvenile lamprey surival at John Day dam. The study determined that juvenile lamprey are mainly demersal and nocturnal and this behavior increases the possibility that they will pass dams via turbines and underneath the screen or surface bypass systems designed to guide juvenile salmonids. The study found that 70% and 97% of test fish became impinged on bar screens at velocities of 1.5 ft/sec for 1-min and 12-hr exposures, respectively. However, this information is not applicable to the Wells Project because the project does not include turbine bypass screens. The study also examined shear stress and found that juvenile lamprey did not suffer any ill effects at exposure to the jet velocities (equivalent to rates of strain 1,220 to 1,830 cm/s/cm) that injured and/or killed salmonids.

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 (*Lampetra tridentata*) at John Day Dam in 2002. Report for Contract DE-AC06-76RL01830. Prepared by Pacific Northwest National Laboratory for U.S. Army Corps of Engineers. Portland, Oregon.

> This study was a continuation of Moursund et al. (2002). Study in 2002 to ascertain the effects of the modified extended-length submerged bar screens (ESBS) on juvenile Pacific lamprey at John Day Dam. The narrower 1.75-mm bar spacing on the modified ESBS prevented juvenile lamprey from becoming wedged between the bar spacing. However, this information is not appicable to the Wells Project because the project does not include turbine bypass screens.

Moursund, R.A., R.P. Mueller, K.D. Ham, T.M. Degerman, and M.E. Vucelick. 2002. Evaluation of the effects of extended length submersible bar screens at McNary Dam on migrating juvenile Pacific lamprey (*Lampetra tridentata*). Report for Contract DACW68-96-D-0002. Prepared by Battelle for the U.S. Army Corps of Engineers. Walla Walla, Washington.

> This study was a continuation of Moursund et al. (2001). They conducted a field study to ascertain the effects of extended-length submersible bar screens on juvenile Pacific lamprey at McNary Dam. All lamprey observed were impinged on the screen (12 total). The study also tested the use of PIT tags on juvenile lamprey to assess bypass rates. However, this information is not appicable to the Wells Project because the project does not include turbine bypass screens.

Moursund, R.A., R.P. Mueller, T.M. Degerman, and D.D. Dauble. 2001. Effects of dam passage on juvenile Pacific lamprey (*Lampetra tridentata*). Report for contract DE-AC06-76RL01830. Prepared by Pacific Northwest National Laboratory for the U.S. Army Corps of Engineers. Portland, Oregon.

> This study was a continuation of Moursund et al. (2000). They tested different turbine bypass screen types and avoidance to various light sources. Juvenile lamprey were not injured during laboratory tests simulating turbine conditions (i.e., pressure and shear) known to cause mortality in other fish species. Both white and strobe forms of light elicited an avoidance response for juvenile Pacific lamprey. Various bar-screen configurations can reduce impingment, but impingent was not eliminate in this study. However, this information is not appicable to the Wells Project because the project does not include turbine bypass screens.

Ostrand, K.G. 2005. Validation of Existing Screening Criteria for Lamprey Macrophthalmia.United States Fish and Wildlife Service: Abernathy Fish Technology Center, Longview, WA.

> This study evaluated in a laboratory whether existing approved salmonid screens will preclude Pacific lamprey macrophthalmia from impingement or entrainment at screened intakes. While this study may be useful in assessing some Columbia Rive projects with intake screens, this study did not actually assess juvenile lamprey survival or predation at Columbia River hydroelectric projects. This information is not appicable to the Wells Project because the project does not include turbine intake screens.

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.

> This study examined the feeding of predacious fishes on out-migrating salmonids in the John Day reservoir. The frequency of occurence of the lamprey family (Petromyzontidae) was reported as 0% in walleye and smallmouth bass, 1.1% in northern pikeminnow, and 0.1% in channel catfish.

Roby, D.D., D.E. Lyons, D.P. Craig, K. Collis, and G.H. Visser. 2003. Quantifying the effect of predators on endangered species using a bioenergetic approach: Caspian terns and juvenile salmonids in the Columbia River estuary. Canadian Journal of Zoology 81(2):250-265.

> This study is an expansion of Roby et al. (2002) and applies a bioenergetics model to the Caspian terns in the Columbia River estuary. The study does estimate energey contribution by lamprey and shows that lamprey are not an important food item/energy source for Caspian terns in the Columbia River estuary.

Roby, D.D., K. Collis, D.E. Lyons, D.P. Craig, J.Y. Adkins, A.M. Myers, and R.M. Suryan. 2002. Effects of colony relocation on diet and productivity of Caspian terns. Journal of Wildlife Management 66(3):662-673.

> This study examined the diet of Caspian terns in the Columbia River estuary. Lamprey were not specifically enumerated by species or life stage, and were lumped in an "other" category with stickleback, sucker, and unidentified nonsalmonids. The "other" category comprised from 1.6 to 8.7% of identified prey items in the Caspian tern samples.

Schreck, C., M. Fitzpatrick, and D. Lerner. 2000. Determination of Passage of Juvenile Lamprey: Development of a Tagging Protocol. Oregon Cooperative Fish and Wildlife Research Unit, Biological Resources Division-U.S. Geological Survey, Oregon State University.

> The overall goal of this study was to develop a means whereby the passage of post-metamorphic lamprey through Columbia River dams can be evaluated. Specific objectives were to evaluate extant tagging technologies for application on outmigrant lamprey and determine the characteristics of a tag or tags and tagging procedures that can be applied without affecting migratory behavior of outmigrant lamprey. This document does not contain actual information on juvenile lamprey survival or predation at Columbia River hydroelectric projects.

Starke, G. and J. Dalen. 2004. Pacific Lamprey (*Lampetra tridentata*) 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, Cascade Locks, Oregon. USA.

> This report contains some limited anecdotal observations of juvenile lamprey survival at Bonneville and other lower Columbia River dams. No comprehnsive assessment of juvenile lamprey survival or predation was made. Predation is not addressed.