WHITE STURGEON (*Acipenser transmontanus*) POPULATION ASSESSMENT

IN WELLS RESERVOIR

A Thesis

Presented To

The Graduate Faculty

Central Washington University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Science

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by

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January 24, 2007

ABSTRACT

WHITE STURGEON (*Acipenser transmontanus*) POPULATION ASSESSMENT AND PREFERRED HABITATS IN WELLS DAM RESERVOIR

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This project focused on acquiring information regarding white sturgeon population structure, movement patterns, and preferred habitats within Wells Reservoir. Prior to this study, no research had been conducted on white sturgeon populations in Wells Reservoir and therefore the status of these fish has been poorly understood.

Set lines were deployed throughout the entire Wells Reservoir during 2001 and 2002. A total of 13 individual white sturgeon were captured on the set line gear. Additionally, 5 recaptures were recorded bringing the total number of captures events to 18. All white sturgeon were captured near the confluence of the Okanogan and Columbia Rivers

Two of the captured fish were classified as juveniles (i.e. less than 90 centimeters fork length) and the remaining 11 fish were classified as adult. White sturgeon ranged in length from 65 centimeters to 202 centimeters. Using pectoral fin analysis, ages ranged from 5 to 30 years, representing the 1972 to 1997 year classes.

A variable capture probability Schnabel abundance estimate from the mark-recapture data was computed at N=31.35. The 95% confidence interval for sturgeon was large due to a small number of recaptured fish CI $(13.15 \leq N \leq 217.50) = 0.95$.

A total of 6 white sturgeon were outfitted with radio transmitters. All telemetry observations during boat surveys were recorded near the confluence of the Okanogan and Columbia rivers. One fixed telemetry receiver located within the Okanogan River (10 kilometers upstream from the mouth) recorded two white sturgeon during the spring of 2002 and one white sturgeon during the spring of 2003.

White sturgeon were only observed via set line capture and telemetry in the Okanogan Columbia River confluence area and upstream in the Okanogan River. These areas were defined as preferred holding locations within the study area. However, white sturgeon were not recorded during telemetry surveys or set line surveys in these locations during probable spring spawning periods. White sturgeon may migrate from the confluence area to spawn in the upper portions of the reservoir during the spring. The upper portion of Wells Reservoir is heavily influenced by discharges from Chief Joseph Dam. High flows through Chief Joseph project in June coincide with preferred white sturgeon egg incubation temperatures in the tailrace area. This provides evidence that white sturgeon may utilize the upper reservoir for spawning purposes.

Data collected during this study should provide a strong foundation for future white sturgeon monitoring and management programs in the Wells Reservoir. Future population level monitoring of these fish, as well as the identification of preferred habitats, will be necessary to promote an expansion of the small population that was identified during this study. Future research regarding white sturgeon in Wells reservoir should include an analysis of supplementation options and evaluation of the carrying capacity of white sturgeon in Wells Reservoir. This information will ultimately provide regional biologists with the ability to implement strategies that promote white sturgeon abundance within Wells Reservoir.

ACKNOWLEDGEMENTS

Special thanks to Dr. Paul James for his guidance on this project. Dr. James' in-depth understanding of ichthyology provided a strong background for this Thesis. Dr. Darda and Dr. Bryan are also thanked for their input and support.

I would also like to thank Shane Bickford and Public Utility District No. 1 of Douglas County. Mr. Bickford arranged for funding of this project through Douglas PUD. Mr. Bickford also helped coordinate the field research and provided valuable technical and field collaboration.

Ken LePla at Idaho power is graciously thanked for his instruction regarding telemetry tag application onto white sturgeon. Mr. Lepla provided valuable direction in regards to data analysis, white sturgeon ecology. He also provided valuable length frequency data from sturgeon populations within the Snake River Basin.

Brad James with Washington Department of Fish and Wildlife supplied valuable length frequency data for lower Columbia River fish stocks. Mr. James also provided valuable input on the project and supplied recent life history data white sturgeon on the lower Columbia River.

John Skalski and Richard Townsend are appreciated for their help in developing an accurate white sturgeon population estimate for the project.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

A total of 24 sturgeon species are recognized worldwide. These fish are all restricted to the Northern Hemisphere and spawn in freshwater environments (Helfman et al. 1999). Anadromy (spawning in freshwater and spending a portion of life in saltwater) is exhibited by some (but not all) sturgeon species. White Sturgeon (*Acipensar transmontanus*) have changed little since their appearance in the fossil record. Documentation of these prehistoric fishes has been dated back to the Upper Cretaceous, with these fish evolving approximately 400 million years ago (Hanson 1992).

Historically, white sturgeon populations existed throughout the west coast of North America from the Aleutian Islands to central California. Currently, spawning populations have been identified in three large river systems of their native range (the Sacramento-San Joaquin in California, the Columbia River in Washington State, and the Fraser River in Canada). Tag recovery has shown that some sturgeon may utilize more than one river on the West Coast during different life stages (Kohlhorst et al. 1991). Analysis of mitochondrial deoxyribonucleic acid (mtDNA) has implied that the Columbia River and Fraser River populations are genetically similar (Brown et al. 1990). After the last ice age, the Columbia River population probably provided the founders for the Fraser River population. Small numbers of clonal lines within the mtDNA suggest a recent genetic bottleneck and imply that a small number of females founded the present populations in the Columbia and Fraser river systems (Brown et al. 1990).

White sturgeon are the largest of all North American freshwater fishes. These fish possess an armor like skin that covers a cartilaginous skeleton. Distinct bony plates called scutes run along the body. This anadromous species may complete their life cycle in fresh water or spend a portion of their life in brackish or marine environments. The largest authentic record of a white sturgeon was recorded as a 630 kg specimen taken from the Fraser River in 1897 (Scott and Crossman 1973). White sturgeon are long lived fishes, with fin ray analysis documentation of fish over 100 years in age (Beamesderfer et al. 1995; Rien and Beamesderfer. 1994).

Commercial and sport fishing have impacted Columbia River sturgeon. A commercial fishery was initiated in the 1880’s. During the peak, in 1892, approximately 80,000 fish were harvested weighing 2.5 million kg (Rieman and Beamesderfer 1990). By 1900 the extensive white sturgeon population had collapsed from overexploitation. Over the last 100 years sport angling for white sturgeon has grown dramatically while commercial fishing has been reduced. Most of the fishing activity has been focused on the lower 100 mile stretch of Columbia River, downstream of Bonneville Dam (Devore et al. 1995).

Regional federal, state, and county agencies have expressed growing concern over the status of white sturgeon within the Columbia River. The once free flowing Columbia River has been segmented by a series of hydroelectric projects that have altered habitats within the aquatic ecosystem. White sturgeon historically migrated throughout the entire river system. The construction of Rock Island Dam in 1934 cut off the sturgeon populations in the mid-Columbia from accessing the ocean. Currently Priest Rapids Dam is thought to be the upstream migration terminus for adult white sturgeon in the Lower Columbia River. Upstream of Priest Rapids, resident populations of sturgeon remain between each of the Mid-Columbia River hydroelectric projects. It is estimated that there are as many as 18 landlocked sub populations of white sturgeon within the Columbia and Snake River impoundments (Hanson et al, 1992). Resource managers typically consider sturgeon confined between hydroelectric projects as discrete populations, even if fish passage facilities are available, as white sturgeon do not readily use fish ladders (Kreitman and LaVoy 1989).

Male white sturgeon reach sexually maturity at around 18 to 25 years of age at approximately 120 CM fork length. Females do not reach sexual maturity until 16 to 35 years of age (Devore et al. 1995) at approximately 150 cm fork length. This old age of maturity results in large generation times. Sexually mature female white sturgeon may only spawn every two to five years (Smith, 1985). Female white sturgeon spawn only when environmental conditions are favorable, reabsorbing their eggs during years in which environmental conditions are unfavorable. This ultimately restricts the fish's ability to respond to factors such as altered habitat. During successful spawning events, mature female white sturgeon release from .1 million to 7 million eggs, depending on fish size and age (Hanson et al. 1992). It has been documented that white sturgeon preferred spawning habitats consist of high water velocities over 0.8 m/s and focus spawning activities downstream of hydroelectric projects (Parsley and Kappenman 2000, Parsley et al. 1993). Presently, spawning habitat is restricted to dam tailrace areas and tributary streams. It is in the dam tailrace locations that high water velocities can be found within the impounded Columbia River ecosystem. Moderate to high flow velocities can also be found within tributary streams of the Columbia

River. Confluence areas of tributary streams within the Columbia River have been documented as preferred sturgeon habitats. Haynes et al. (1978) documented white sturgeon movements to the mouths of the Snake and Walla Walla rivers, where the fish remained until transmitter failure. White sturgeon may conduct spawning migrations into tributary rivers or tributary confluences with suitable spawning habitats. Within Wells Reservoir, the Okanogan River and Methow River tributaries have moderate to high flow velocities. Therefore, suitable spawning habitats within the study area are located downstream of Chief Joseph Dam and within the Okanogan and Methow rivers.

It has been observed that white sturgeon spawn at water temperatures from 10 degrees C to 18 degrees C (Parsley et al 1993). The Columbia River reaches these temperatures in the spring of each year and triggers white sturgeon spawning events. Therefore, any observed movements of white sturgeon during this time period may provide evidence of spawning migrations within the study area.

A white sturgeon population assessment was conducted in Rocky Reach Reservoir in 2001. This reservoir is located immediately downstream from Wells Reservoir. The mark recapture population estimate for the Rocky Reach Reservoir was determined to be 29 adult sturgeon with a 95% confidence interval ranging from 11 to 108 fish. From 2000 to 2002, an extensive study was conducted within Wanapum Reservoir and Priest Rapids Reservoir located approximately 110 km downstream from Wells Reservoir. The project involved an extensive mark-recapture evaluation and in-depth analysis of fish movements within both reservoirs. The population estimates derived for the Wanapum and Priest Rapids reservoirs were also relatively low with 134 adult fish (95% CI 48-2,680) estimated for the Wanapum Reservoir and 551 adult fish (95% CI 143-4,746) estimated in the Priest Rapids Reservoir (Golder 2003). These population estimates were relatively small when compared to population estimates for the lower Columbia River.

The Public Utility District No. 1 of Douglas County (PUD) owns and operates the Wells Hydroelectric Project (Wells Project), located at river km 829.8 on the Columbia River (Figure 1). The Wells Project boundary encompasses 47.5 km of the mainstem Columbia River upstream to Bridgeport Bridge which is 0.5 km downstream of the Chief Joseph Hydroelectric Project (Rkm 877.3). The Wells Reservoir has riverine characteristics in the upper 15-km section downstream from the Chief Joseph Dam tailrace. The middle section is more characteristic of a lacustrine environment. The lowermost section of the reservoir slows and deepens as it nears the forebay of Wells Dam (Beak, 1999). The drainage area of the Columbia River Basin upstream of the Wells Project is approximately 220,900 square kilometers.

Within the Mid-Columbia River, white sturgeon populations have been studied in the Priest Rapids, Wanapum and Rocky Reach reservoirs (Golder 2002, Golder 2003). These studies were conducted as part of the relicensing of those respective hydroelectric projects. The license for the Wells Project expires in May of 2012. Biological data was collected regarding white sturgeon research as part of this relicensing process. The purpose for this study is to analyze the white sturgeon population structure within Wells Reservoir. Because little historical data exists on white sturgeon in the reservoir, it has been difficult for regional biologists to accurately assess hydroelectric impacts on these fish. Prior to this study there was little documentation that a resident population of white sturgeon existed in the reservoir. However, it was assumed that a population of sturgeon was present, as viable populations of these fish were documented within Columbia River reservoirs both immediately upstream and downstream from the study area (Golder 2002, Ward et al. 2003). Additionally, recreational fishing took place for white sturgeon in the Wells Pool up through the 1980's as indicated from punch card returns from Washington Department of Fish and Wildlife (WDFW). These catch cards recorded the presence of white sturgeon in the study area during that time period.

Analysis of the white sturgeon population within the Wells Reservoir was composed of two primary objectives. The first objective was to capture an adequate number of individual white sturgeon to provide a basic analysis of the population abundance, age structure, size, growth, and ecology within the study area. Age structure and population estimates were derived using mark-recapture techniques. The age of each individual fish was determined through the collection and analysis of fin rays. It was of particular interest to determine whether juvenile and sub-adult sturgeon were present within the reservoir. The presence of fish younger than the project, completed in 1967, would indicate that recruitment, either through spawning or entrainment (downstream migration of white sturgeon), is occurring within the population. Lengths of captured fish were recorded to construct a length frequency histogram. The length frequency histogram was then analyzed to determine the age structure of the white sturgeon population in Wells Reservoir.

The second objective of this study was to analyze the movement of radio tagged white sturgeon within the reservoir. This objective was accomplished through the application of external radio transmitter tags onto adult and juvenile white sturgeon. Fixed and mobile telemetry stations were then utilized to track radio tagged fish. Tracked movements were then investigated in regards to possible spawning migrations, feeding activity, and habitat use.

Taking into account the importance of developing a baseline data collection project, this Masters of Science Thesis has been designed to develop an initial assessment of ecological and biological characteristics of white sturgeon populations within Wells Reservoir. A crucial goal for this project is to ensure information contained within is scientifically valuable to regional biologists involved in white sturgeon research and management activities. Information from this study will ultimately promote the development of effective white sturgeon enhancement and research activities within Wells Reservoir.

MATERIALS AND METHODS

Study Area: Wells Reservoir

The Columbia River originates at Columbia Lake in British Columbia and flows approximately 2,000 km to the Pacific Ocean. The Columbia River drains a majority of the inland Pacific Northwest and is fed from over 175 streams and rivers. The Columbia drains more than 650,000 square kilometers and averages a drop of one meter-per-five km drop. The river has been divided into three regions known as the Lower, Mid, and Upper Columbia. The Upper Columbia is described as that portion of the river from the international boundary between United States and Canada upstream to the headwaters of Columbia Lake. The Mid Columbia River is known as that portion of the river from the international boundary downstream to the Snake River Confluence (Figure 1). The Lower Columbia is described as that portion of the river downstream from the Snake River Confluence. The Lower Columbia River forms a deep gorge through the Cascade Mountains on its way to the Pacific Ocean designating the border between Oregon and Washington.

The Mid-Columbia River traverses 589 kilometers from the international boundary to the Snake River and once dropped 315 meters in elevation in a series of 50 rapids and one major waterfall at Kettle Falls. Historically, the Mid-Columbia River was a free flowing system, and it is suspected that white sturgeon migrated throughout the system from the Pacific Ocean and Columbia River estuary as far upstream as Kettle Falls. Upstream migrations of adult white sturgeon have been impeded by the hydroelectric projects following the construction of the Columbia River hydroelectric projects. Dams containing navigation locks and fish ladders presently provide limited upstream passage for adult sturgeon and it is generally accepted that Priest Rapids Dam is the upstream terminus of white sturgeon migrations within the lower Columbia River.

The climate of the Mid-Columbia Region is primarily influenced by the Pacific Ocean and winds from the Arctic. Moisture containing rains from the coast are dispersed on the west slope of the Cascade Mountains, leaving the eastern slopes sunny and dry. The rain shadow effect results in a semi arid inland shrub steppe community with an average of 46 millimeters of rain per year. The Mid-Columbia Region is a dry land farming area with little water resources other than the Columbia River and Snake River drainages. Over the last century irrigation requirements have played a major role in construction of Hydroelectric projects on the Columbia River.

Wells Reservoir study area is located within the mainstem Columbia River from Wells Dam (river km 829.8) to the tailrace of Chief Joseph Dam (river km 877.9)(Figure 1). Wells Reservoir has two major tributaries, the Okanogan River and Methow River. The Okanogan River flows 185 km beginning at the headwaters of Lake Okanogan near Penticton, British Columbia. The river flows in a southerly direction passing through Osoyoos Lake near the international border. From there the river is a relatively free flowing system to the Confluence with the Columbia River.

The Methow River enters the Columbia River approximately 20 kilometers miles downstream of the Okanogan River and flows 129 km through an irrigated agricultural valley. The river rises from the Cascade mountain range north of Lake Chelan (Cohen 2000).

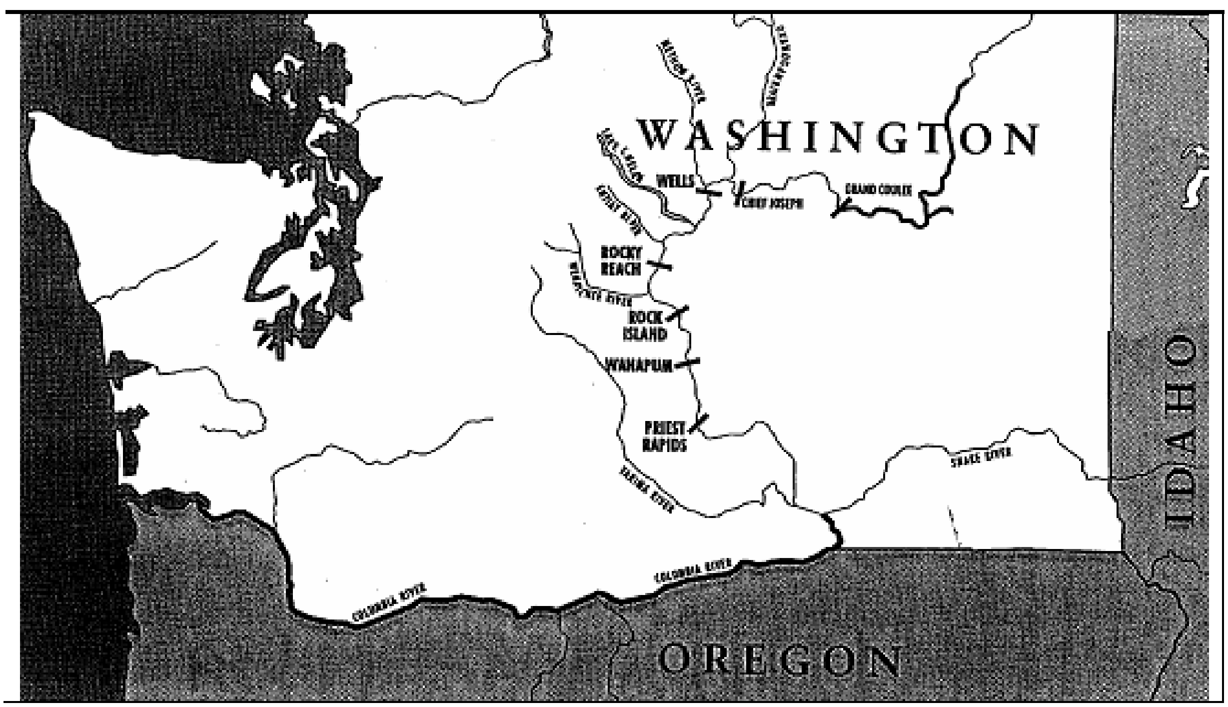


Figure 1 Mid-Columbia Hydroelectric Operations on the Columbia River in Washington State.

Field Methods

Methodology for the first phase of this study involved the deployment of set lines to capture white sturgeon within Wells Reservoir. Set lines have been used extensively for white sturgeon capture and research activities within the lower Columbia River (Elliott and Beamesderfer, 1990, Nigro et al. 1988, North et al. 1993, Rien et al. 1994). Set lines have also been utilized in recent white sturgeon research activities in the Mid-Columbia (Golder 2002, Golder 2003). A successful application of setline methodology was crucial to the success of this project.

Fish captured on set lines were measured, marked with PIT-tags and secondarily marked by scoot removal. Some of the fish were also radio-tagged and had pectoral fin rays removed for age analysis. The collection of fish information was essential to developing a population estimate, understanding recruitment and population demographics and was used to understand general movement patterns for juvenile and adult white sturgeon. Wells Reservoir was sampled with setline gear over a 2 year period (2001 and 2002). Sampling activities during 2001 were initiated on June 18 and conducted through August 28. Sampling in 2002 was initiated on June 26 and conducted through September 19.

The study area was divided into four sampling locations (Figure 2). Zone 1 included the Columbia River from Wells Dam to the town Pateros, including the Methow River. Zone 2 included waters from Pateros to Brewster Bridge. Zone 3 was designated from Brewster Bridge to Park Island and included the Okanogan Columbia River confluence area. Zone 4 was designated from Park Island to the tailrace of Chief Joseph Dam. These four sampling locations were further sub-divided into 4 locations providing a total of 16 sample locations to ensure all areas and habitat types would be sampled throughout the reservoir.

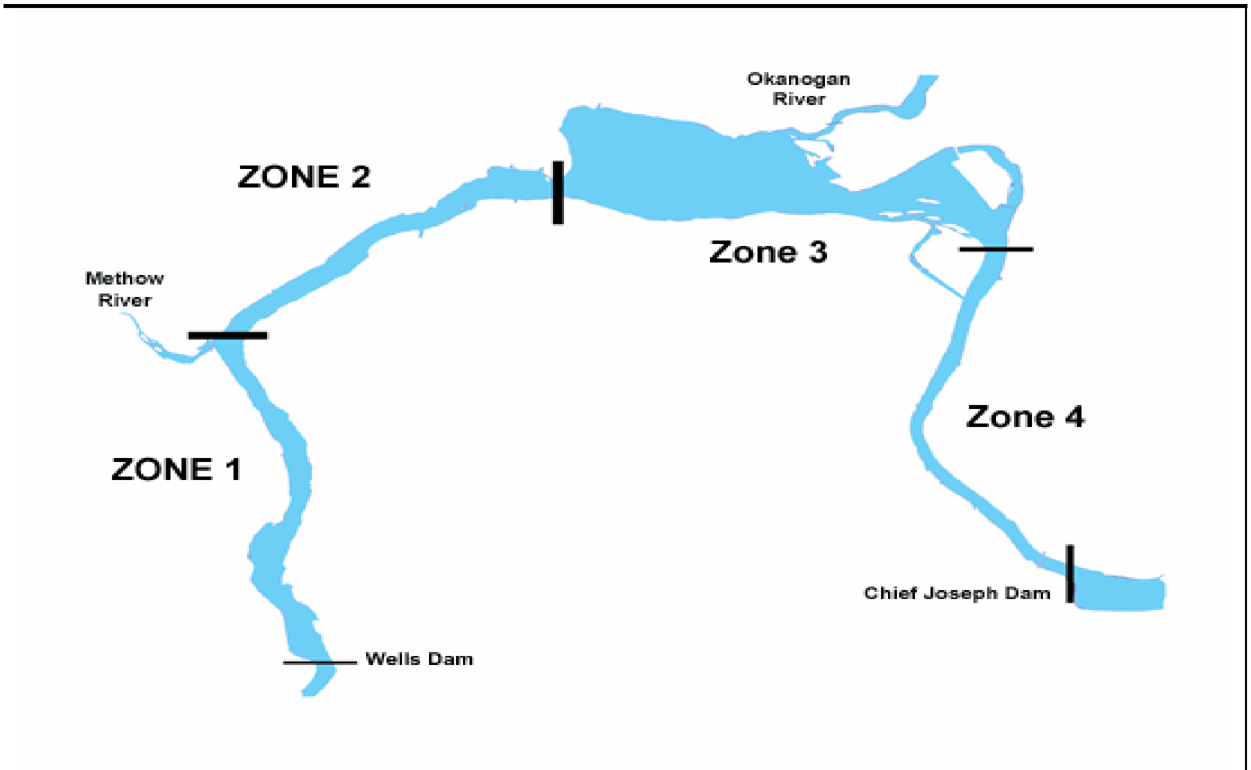


Figure 2 Sampling Zones within Wells Reservoir, Washington State.

A three person field crew conducted a majority of the collection and research. The crew was equipped with all necessary equipment to complete the project. A majority of the equipment (vehicle, vessel, and gear) was provided by Public Utility District No. 1 of Douglas County. Crews typically operated for 3 days during a designated sampling week. The first day consisted of setting the setline gear. Day 2 consisted of checking, re-baiting, and re-setting the lines. On day 3 the set lines were typically pulled from the water.

Set line configurations were similar to those used by Oregon Department of Fish and Wildlife (ODFW) and WDFW for white sturgeon capture in the lower Columbia River (Elliott and Beamesderfer 1990, North et al. 1996). This capture method has been a successful sampling technique for white sturgeon in the mid Columbia over the last two decades. The system provides high catch rates for adult white sturgeon, and is less size selective than other methods, and has resulted in low levels of non-target catch (Elliot and Beamesderfer, 1990).   Even though set lines were less size selective than other techniques, this sampling technique is by no means unbiased. The set lines provide a sampling technique that is successful in capturing white sturgeon over 50 cm in Fork Length (Elliott and Beamesderfer 1990, Nigro 1988).

Smaller white sturgeon are not susceptible to the larger hooks and baits used on the set line gear. As such, set lines do not provide accurate sampling of fish under 50 cm.

Set lines for this study measured 133 meters in length. This is 66 meters less then the standard gear used by WDFW and ODFW for white sturgeon capture. The shorter gear allowed deployment in smaller areas of the Mid-Columbia River and was more manageable when fishing in high velocity sections of the river. The shorter lines were also less likely to tangle when oversized sturgeon were hooked. The mainline or ground line consisted of 1600 lb multi-strand nylon rope. Each circle hook was attached to the mainline with a 2-foot long section of 300 lb. nylon fishing line and a Berkley-McMahon bright snap. The gabions were attached to the mainline by a stainless steel trolling snap. Set lines were typically placed parallel to the river flow. The upstream anchor consisted of an 80 lb rocking chair anchor and the downstream setline was typically held on the bottom with 20 lb. pyramid anchor. Each anchor attached to a surface line terminating at a single buoy. Lower pyramid anchors were attached to 68 pound LD series buoys. The larger upstream anchors were attached to multiple buoys to ensure that the gear would be located.

Size 11/0, 13/0 and 15/0 VMC Circlematic 2000 carbon-steel hooks were baited primarily with commercially available pickled squid *(Loligo spp*). This has been determined to be the best bait for sturgeon capture on similar setline research programs conducted by WDFW (North et al. 1993). Herring (*Misc. clupidae*), salmon fillets, (*Oncorhynchus spp.)* and fresh water clams (*Corbicula manilensis*) were also used to a lesser extent. This hook configuration provided a diverse range of sturgeon lengths in lower Columbia River research activities with sizes of white sturgeon ranging from 34 to 274 cm in fork length (Beamesderfer et al. 1989). Each line was baited with 25 to 35 hooks.

Sturgeon captured on the set lines were tethered to the boat using cotton web rope long enough for the entire body of the fish to remain submerged. Crew members then continued to pull the setline and remove any additional fish from the gear prior to working up the captured fish. Smaller sturgeon were placed in an on-board live well, while larger fish were tethered and brought to shore for processing. Hoods were placed on sturgeon during processing and wet towels were set around the skin to prevent moisture loss. Fresh river water was poured over the gills to further promote respiration. After data collection was complete, technicians applied necessary respiration measures to ensure the healthy release of the fish.

Field data were recorded on standardized sheets and transferred to a computer database. Each setline locations and depth was recorded. Depths were recorded using a Lowrance X135 depth sounder at the beginning of the setline and the end of the setline to provide an overview of the entire water column in which the lines were placed. Total hooks, hook size, and bait types for each setline were recorded. Field data for each white sturgeon capture event consisted of capture location, capture depth, hook size, and bait (if discernable). Size data from each captured white sturgeon consisted of fork length and total length measured to the nearest 1.0 cm.

A small portion of the pectoral fin ray was removed for age sampling. It has been determined that calcified structures of white sturgeon pectoral fins, opercles, clavicles, cleithra, medialnuchals and dorsal scutes do not result in significantly different age estimates (Brennen and Cailliet 1991). Pectoral fins age analysis provided the highest level of accuracy and did not require lethal sampling of the fish. Two perpendicular cuts were made in the rays with a hacksaw. The first cut was made 5 to 10 mm outside of the pectoral fin knuckle. The second cut was made approximately 5 mm outside of the first cut resulting in the removal of approximately 5 mm of pectoral fin. The samples were then placed in sample envelopes and frozen for future lab analysis. Removal of the pectoral fin ray for aging purpose provides a noticeable mark for several years (Rien et al 1994) enabling technicians to identify recaptured fish during future encounters.

Each fish was injected with a Passive Integrated Transponder tag (PIT tag) to identify individual fish. ISO 134 kHz PIT tags were injected under the armor of the head near the dorsal midline. A series of scutes (bony armor-like plates located on sturgeon head and back areas) were also removed to indicate a tag was administered. During the 2001 sample period right scutes 2 and 3 were removed. In 2002 left scutes 2 and 3 were removed. Scutes were removed from different areas in subsequent years to provide a year-specific external mark.

Laboratory Methods

Population Estimate

An adult white sturgeon abundance estimate was developed for the Wells Reservoir population using the University of Washington's RECAP.GLM program. The program RECAP.GLM allowed for the examination of several mark-recapture models and provided for the comparison of these models using likelihood ratio tests.

The program was used to examine two specific Schnabel methods; the Schnabel constant capture probability (Mo) and the Schnable variable capture probability (Mt). The Schnabel constant capture probability model assumes that all fish within the population have an equal chance of capture throughout the sampling periods. The Schnable variable capture probability assumes variable probability of capture throughout the sampling period. Population estimates were determined using capture data from five sampling periods. (i.e. July 2001, early August 2001, late August 2001, early September 2002, and late September 2002).

Standard assumptions were applied to the Schnabel population estimate. A primary assumption was that a closed population of white sturgeon existed within the study area. For the purpose of this study it was assumed that Chief Joseph hydroelectric project provided a barrier for downstream migrants into the study area. No fish ladder exists at Chief Joseph Dam so upstream migrations do not take place. The downstream terminus of migration into or out of the study area was defined as Well Dam. It was assumed that within a sampling period, each fish had an equal probability of being captured. For the purpose of this study it was assumed that prior capture histories did not affect present or future capture histories.

The RECAP.GLM program provided for examination of the residuals associated with the lack-of-fit to individual capture histories. Examination of these residuals provided information as to whether certain individual white sturgeon exhibited gear selectivity towards the set-lines (Certain individual fish within a sampled population may frequent capture gear, therefore being more prone to capture events than other individuals). Juvenile white sturgeon were expected to be less susceptible to being hooked but more susceptible to capture once hooked. This is the opposite case for very large or oversize adult sturgeon. These fish were susceptible to being hooked but were much less susceptible to direct capture due to their ability to break the gabions, hooks and setline snaps.

Physical Data

Length of each captured white sturgeon was entered into a database to construct a length-frequency histogram. Length frequency histograms were used to determine age class strength, and strong age classes may indicate periods of high recruitment. The histogram was constructed using slot increments of 15 centimeters. These data were then compared to length frequency histograms constructed for other white sturgeon sub-populations within the Columbia River.

Flow velocity patterns and water temperatures have been linked to white sturgeon spawning intensity in the lower Columbia River (Anders and Beckman 1993, Parsley at al. 1993,). Research has indicated that white sturgeon prefer fast flowing water velocities for spawning activities. Parsley et al. (1993) recorded a fast mean water column velocity of 1.46 m/s at white sturgeon spawning sites within lower Columbia River reservoirs. These high water velocities typically occur within the tailrace section of hydroelectric projects. Parsley et al. also recorded water temperatures during spawning activities from 10C to 18C, with most spawning events occurring at near 14C.   Additionally, 13C to 17 C has been identified as the optimal temperature for white sturgeon egg development (Wang et al. 1985). Wang et al. recorded elevated mortality of white sturgeon embryos incubated at 18C and complete mortality of embryos incubated at 20C.

Surface water temperatures were collected for this study during set line sampling activities. Temperatures were also collected from fixed field sites within the tailrace of Chief Joseph Dam, Wells Dam Forebay and the Okanogan River. These data were collected to correlate any existing relationships that may exist between fluctuating water temperatures and white sturgeon movements within the study area (e.g. migrations within the reservoir or use of tributary streams for spawning or feeding activities).

Physical data collected from sampled white sturgeon consisted of pectoral rays. Pectoral fins were air dried for several days and standard methodology for counting growth rings was applied (Cuerrier 1951, Beamesderfer et al. 1989). It was first necessary to section the samples into approximately 0.5 millimeter sections. To accomplish this, the samples were glued with a standard model epoxy onto a wooden dowel. This allowed for the handling of the fins during the sectioning process. A 2 millimeter balsa wood saw was then used to section the fins. The sections were then hand sanded to approximately 0.2mm and mounted on microscope slides using clear epoxy. A dissecting microscope was then used to count the translucent pectoral fin annuli. One year of age was assigned to fish captured in the spring and early summer as these individuals were captured prior to annulus formation for that year.

Discharge and temperature information was obtained from Army Corps of Engineers at Chief Joseph Dam. These data were graphed to form a temperature discharge window. The window represents the suspected spawning period in Chief Joseph Tailrace or Upper Wells Reservoir based on preferred flow velocities and optimal egg incubation temperatures.

Radio Telemetry

White sturgeon were outfitted with 7 volt Lotek Micro Coded Fish Transmitters. The radio tags had a minimum 18 month life expectancy allowing researchers the ability to acquire telemetry information on the tagged fish for two summer field sessions.

Radio tags were attached externally to the posterior portion of the dorsal fin using 1mm wire cable (Figure 3). This tag application procedure has been used with a high degree of success during white sturgeon telemetry studies conducted throughout the upper Snake River (K. Lepla, personal communication 2000). The process involved running a pair of small tubes through the base of the dorsal fin . A stainless steel wire was then fed through the radio tag and then ran through the tubes. With the wire through the dorsal, the tubes were then backed out and the wire free ends were fed through a 1" PVC and then secured with a crimp.

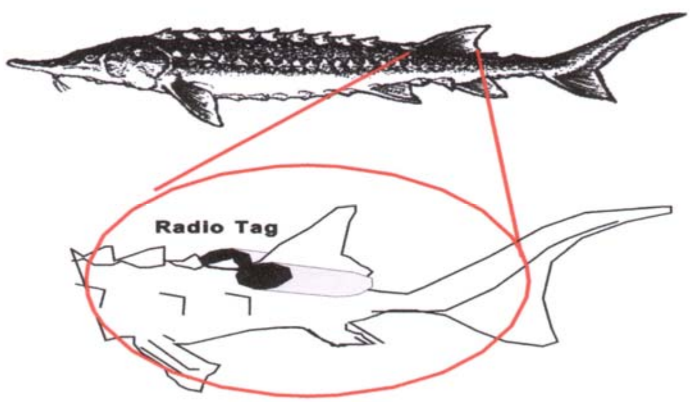


Figure 3 Radio tag placement on white sturgeon (borrowed from Ken LePla, Idaho Power Company).

Movements of radio tagged white sturgeon within the study area were recorded using Lotek Wireless SRX-400 telemetry receivers. Aerial surveys, boat surveys, and fixed land surveys were all attempted to identify activated transmitters. After the capture and outfitting of the first radio tagged fish, bi-monthly aerial surveys were conducted over Wells Reservoir for activated radio tags. These surveys were conducted between July of 2001 and July of 2002. Sweeps of the reservoir study area were performed approximately 50 feet from each bank. The aerial surveys were conducted in conjunction with the Douglas PUD bull trout survey which typically only reads activated tags within the first 15 meters of the water column. Boat surveys were conducted intermittently throughout the study. The SRX-400 receivers were mounted on the research vessel and transects along the west and east shore of the reservoir were conducted in an attempt to locate tagged fish. Three fixed site receivers were located within the study area. The receivers were functional throughout the study and were downloaded onto a laptop computer every two weeks. One receiver was located approximately 10 kilometers upstream of the Okanogan River near Crazy Rapids Pump Station. Two receivers were located near the mouth of the Methow River. One of these receivers was located approximately 400 meters upstream from the confluence area and one receiver was located approximately two kilometers downstream from the mouth of the Methow River.

RESULTS

Field Sampling Results

A total of 13 individual white sturgeon were captured on the set line gear during the two year mark-recapture study. Additionally, five recaptures were recorded bringing the total number of captures events to 18. Of the 18 events, 13 were recorded in 2001 and five were recorded in 2002. Two of the captured fish were classified as juveniles (i.e. less than 90 centimeters fork length)) and the remaining 11 fish were classified as adult. White sturgeon ranged in length from 65 centimeters to 202 centimeters. Twelve of the fish were injected with PIT tags. One fish was not PIT-tagged because it escaped after being measured but before being PIT-tagged. All 18 of the white sturgeon capture events took place within zone 3 near the Okanogan Columbia rivers confluence. Data collected on the 13 individual fish are summarized in Table 1.

Table 1 Fork length, PIT-tag number, radio tag codes, capture location, number of capture events and estimated age for 13 white sturgeon sampled in Wells Reservoir, Washington State.

Fish #	Fork Length (cm)	Pit Tag #	Radio Tag #	Capture Location	Capture Events	Estimated Age
1	124	3D9.1BFOE220404		3	1	11
2	96	3D9.1BF1092483		3	1	7
3	133	3D9.1BFOFD31EF		3	1	13
4	118	3D9.1BF109F2B9		3	1	11
5	105	3D9.1BF10916A2		3	1	N/A**
6	65	3D9.1BF10920B9	204-209	3	4	6
7	183	3D9.1BFOE473EF	13-6	3	1	27
8	197	3D9.1BFODCA36A	13-5	3	2	23
9	183	3D9.1BFODDD71A	13-7	3	1	26
10	184	3D9.1BF188EAFB	13-4	3	1	28
11	202	3D9.1BF1890574	204-211	3	1	30
12	73	3D9.1BF1890404		3	2	6
13	90	N/A*		3	N/A*	N/A*

*Fish lost at water surface

**Technicians failed to remove sample

Set lines were placed within the study area at surface water temperatures from 9 C to 25 C and placed in depths from 6 to 45 meters. 129 set lines were fished throughout the study. A total of 83 set lines were fished in 2001 (June 18 to August 28), and 45 set lines fished in 2002 (June 26 to September 27). 3,060 hooks were placed on the 129 set lines resulting in 72,006 hook hours of effort. Hook CPUE was .025 fish per 100 hook hours (18 capture events / 72,006 hook hours).

A total of 15 set-lines were placed in zone 1, 16 set-lines were placed in zone 2, 68 set-lines were placed in zone 3, and 21 set-lines were placed in zone 4. A mimimum of 1 set-line was placed in each of the 16 sub zones. A majority of effort was placed in zone 3 as it was necessary to obtain an adequate sample size for the population assessment and telemetry portion of this study.

Laboratory Results

Population Estimate

The utilization of Program RECAP.GLM provided for the examination and comparison of several versions of the Schnabel population estimate. Due to unequal trapping effort over time, it was determined that the variable capture probability Schnabel Model (Mt) most adequately fit the data compared to the constant-capture Schnabel Model (Mo).

The program provided the ability to examine the residuals associated with the various capture histories (i.e. to determine if certain individual fish were more likely to be encountered due to gear selectivity). Examination of the various capture histories found fish #6 to have significant lack of fit, an indication that the fish was highly susceptible to capture on the set-line gear. White sturgeon #6 was a small juvenile fish that was recaptured three times. Because this fish exhibited capture prone behavior, the recapture information from this fish was excluded from the calculation of the Wells Reservoir population estimate.

With fish #6 not included in the data set, abundance was estimated at N=31.35 and a standard error of 17.51 (Table 2). Factoring in unequal trapping effort over time, the abundance estimate of N= 31.35 is suggested to be the most appropriate. The 95% confidence interval for sturgeon abundance was calculated to be CI(13.15 $\leq$ N $\leq$ 217.50) =0.95.

Table 2 Modified Schnabel variable capture probability model used to estimate white sturgeon abundance in Wells Reservoir

Session	Number Fish Caught (Ct)	Number of Recaptures (Rt)	Number of Fish Newly Marked	Marked Fish At Large (Mt)	CtMt
July of 2001	5	0	5	0	0
Early August 2001	3	0	3	5	15
Late August 2001	1	1	0	8	8
Early September 2002	4	1	3	8	32
Late September 2002	1	0	1	11	11
Totals	14	2	12	32	66

Population	N=Sum (CT x Mt)	66	N = 31.35
Estimate	Sum (Rt)	2-Mt Correction factor	

Physical Data

Ages were estimated for 11 white sturgeon captured during the study. These fish were estimated from 5 years to 30 years, representing the 1972 to 1997 year classes. Three groupings within the age class data are apparent. The first grouping was concentrated between the 1972 to 1978 year classes (Figure 4) and was comprised of five individual fish. The second grouping of three fish took place within the 1988 to 1990 age classes. The third grouping took place from 1995 to 1997 (3 fish).

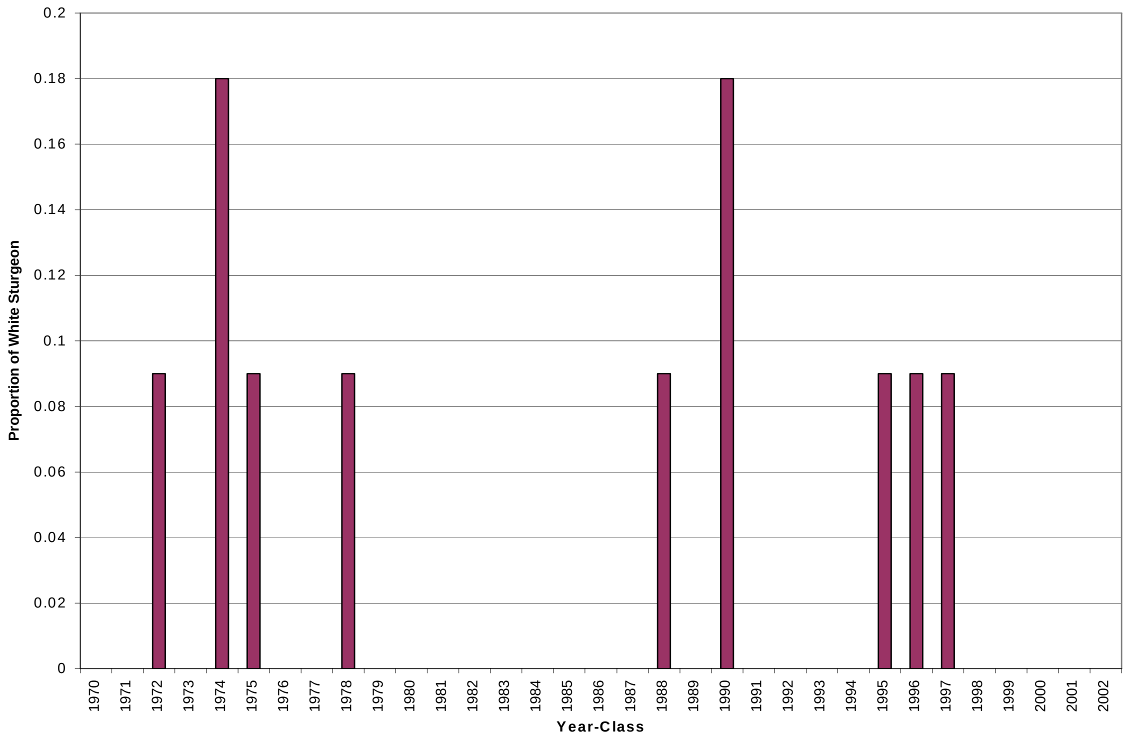


Figure 4 Year class composition of white sturgeon in Wells Reservoir 1970 to 2002

Two white sturgeon were captured and subsequently recovered to provide growth rate information. One Juvenile fish was measured at 65 cm in fork length on July 11, 2001. The fish was again captured on September 26, 2002 and measured 87 cm in fork length. This represented a growth rate of 22 cm in 14 months. One adult fish was captured on August 9, 2001 measuring 197 cm in fork length. The fish was subsequently captured on September 6, 2002 and measured 199 cm in fork length representing a 2 cm growth rate over approximately 13 months. This fish was found deceased in October of 2006 along the west bank of the Columbia River above the town of Brewster. At that time biologists measured the fish at 228.5 cm representing a 29.5 cm increase in length over an approximate four year period, or an average of 7.4 cm of growth per year.

A length frequency histogram was constructed from the white sturgeon length data (Figure 5). Two fish were captured within each of the length slots from 60 to 75 centimeters, 90 to 105 centimeters, 105 to 120 centimeters, and 195 to 210 centimeters. Three fish were captured within the length slot from 165 to 180 centimeters. Catch on the set line gear was dominated by white sturgeon from 60 to 135 centimeters in fork length, and from 180 to 210 centimeters in fork length. These two age class distributions accounted for all captures. The histogram showed a relatively low distribution of juvenile white sturgeon, with 15% of the total catch composed of juvenile fish (i.e. less than 90 cm).

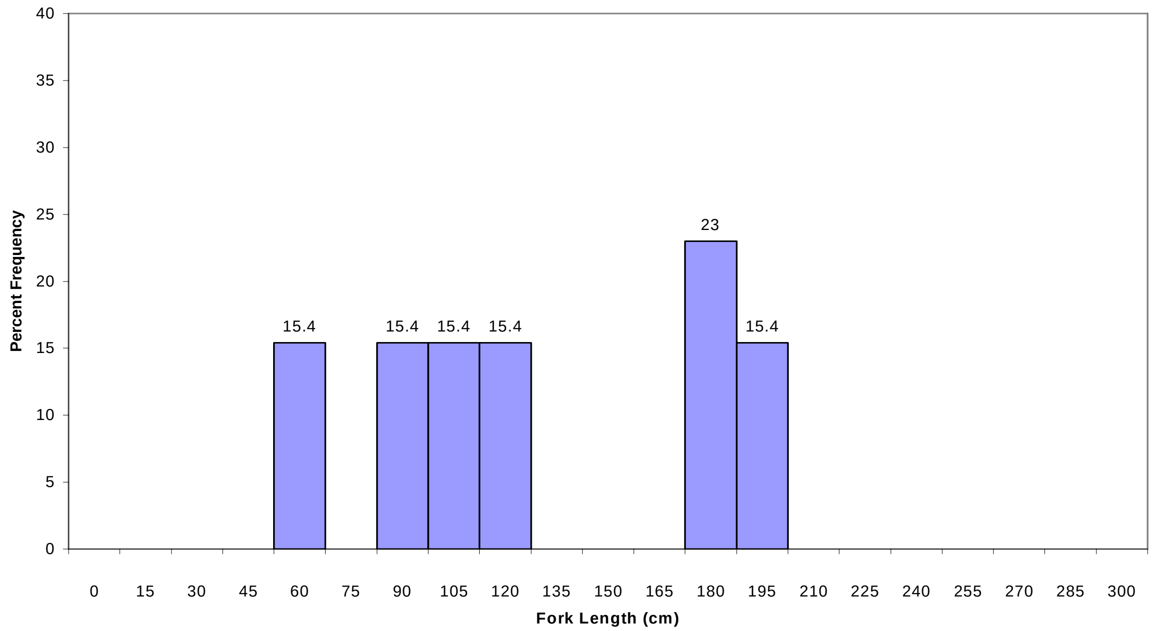


Figure 5 Length frequency distribution for white sturgeon captured by set lines in Wells Reservoir Washington State, during 2001 and 2002.

Radio Telemetry

A total of six white sturgeon were outfitted with radio transmitters (Figure 3). Five of the fish were mature adults (Fork Length 183cm, 183cm, 184cm, 197cm, and 202cm). One juvenile fish was tagged measuring 65cm in fork length. Transmitters were not available for this study until August 8, 2001. At that time the transmitters were administered to the first six captured white sturgeon to ensure a maximum amount of telemetry data could be obtained from the tagged fish.

Table 3 Telemetry information on six radio tagged white sturgeon released in Wells Reservoir, Washington State.

Date	Fish Tag Code	Length (cm)	Capture Zone	Encounters
7/12/01	13-3	65	3	5
8/8/2001	13-6	183	3	11
8/9/2001	13-5	197	3	6
8/9/2001	13-7	183	3	10
9/5/2002	13-4	184	3	2
11/27/2002	204-211	201	3	2

Encounters were recorded as the initial capture of the fish, recapture of the fish, and telemetry observations. Telemetry observations consisted of vessel recordings and fixed telemetry receiver recordings. Four reservoir surveys were conducted by boat. Three of the surveys were conducted in late summer of 2001 (August 27, 2001, August 28, 2001). One survey was conducted in late summer of 2002 (September 6) and one survey was conducted in late winter of 2002 (November 27). The number of boat telemetry surveys was limited by personnel and budget constraints at Douglas PUD as they owned and operated the vessel. During all 4 telemetry surveys, all white sturgeon were recorded within zone 3. The winter survey conducted in November of 2002 identified all outstanding tagged fish within zone 3 and within 100 meters of one another. No white sturgeon were recorded during the aerial surveys. It was suspected that the aerial antennas would not pick up any of the activated tags as the aerial surveys typically only pick up transmissions from water depths less than 15 meters.

A total of 17 encounters were recorded at the fixed telemetry receiver located approximately 10 kilometers upstream from the mouth of the Okanogan River. These 17 encounters were from three individual mature fish. The first two encounter were recorded from May 19 to June 19 of 2002. Two white sturgeon frequented the area passing upstream and downstream of the fixed receiver. The third encounter was recorded from May 10 to May 24 of 2003. No white sturgeon were recorded near the fixed telemetry receiver at the mouth of the Methow River or the fixed telemetry receiver 2 kilometers downstream from the mouth of the Methow River. Capture histories of the six radio tagged white sturgeon are outlined below:

White Sturgeon 13-3

White Sturgeon 13-3 was a juvenile fish approximately 65 cm in length. The fish was first captured on July 12, 2001 approximately 1 kilometer east of the confluence of the Okanogan and Columbia River (Figure 6). The fish was subsequently captured on the set line gear in the same vicinity on August 8, 2001, August 28, 2001, and September 26, 2002. The fish was tracked by boat telemetry to the west bank of the Columbia River approximately 1 kilometer below the Okanogan River confluence on November 27, 2002. It is possible that the boat telemetry observation may have identified a shed tag as the telemetry signal was coming from a vicinity of the shoreline area.

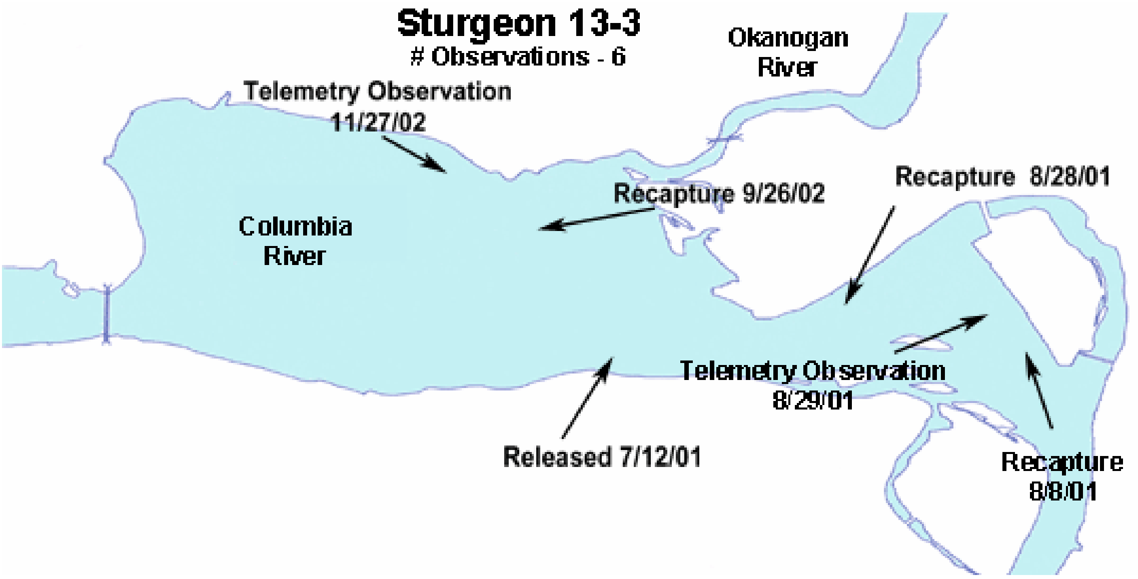


Figure 6 Telemetry observations for radio tag 13-3, Wells Reservoir, Washington

White Sturgeon 13-6

White sturgeon 13-6 was captured on August 8, 2001 and encountered on 10 separate occasions (Figure 7). This fish was 183 cm long and was initially captured and released approximately 1 kilometer south of the Okanogan-Columbia River confluence area. The fish was then recorded during vessel telemetry transects on August 27, 2001. A majority of encounters were recorded at the fixed telemetry station within the Okanogan River. Telemetry observations of the fish moving through the Okanogan River were recorded on May 19, 2002, June 2, 2002, June 8, 2002, June 9, 2002, June 12, 2002, June 18, 2002 and June 19, 2002. The fish was once again recorded during a vessel telemetry survey conducted within Wells Reservoir on November 27, 2002.

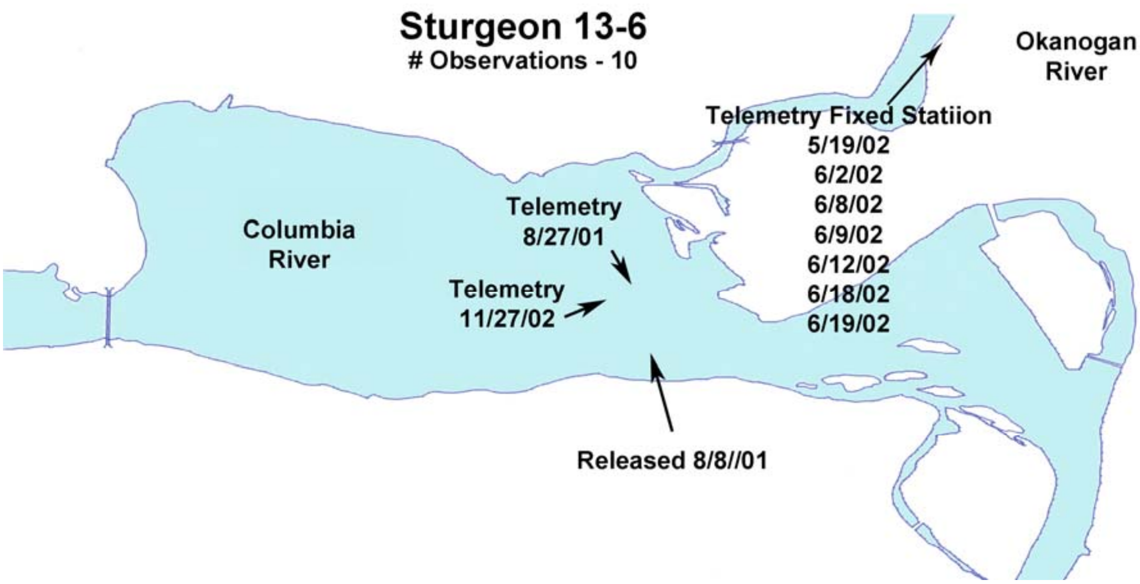


Figure 7 Telemetry observations for radio tag 13-6, Wells Reservoir, Washington

White Sturgeon 13-5

White sturgeon 13-5 was 197 cm in length and was captured and outfitted with a radio transmitter on August 9, 2001. The fish was encountered on seven separate occasions (Figure 8). In the spring of 2002 white sturgeon 13-5 was recorded at the Okanogan River fixed telemetry station on four different dates (May 16, May 29, May 31, and June 3). The fish was again recorded during a vessel telemetry survey conducted on August 1, 2002 approximately 200 meters downstream from the mouth of the Okanogan River. White sturgeon 13-5 was recaptured on September 6, 2002 at which time the radio transmitter was removed. It was assumed the remaining battery life of the transmitter was short and removing the tag would promote the fish's health. During October of 2006 biologists at Douglas PUD received reports of a white sturgeon washed ashore near the east bank of the Columbia River across from the confluence of the Okanogan River**.** Upon investigation and PIT tag confirmation, it was determined that fish was white sturgeon 13-5. White sturgeon 13-5 was the second largest fish sampled during this study at 197 cm (very close in length to the largest fish sampled at 202 cm). The cause of death was undetermined. There were no signs of hemorrhaging or heavy parasite loads on the fish.

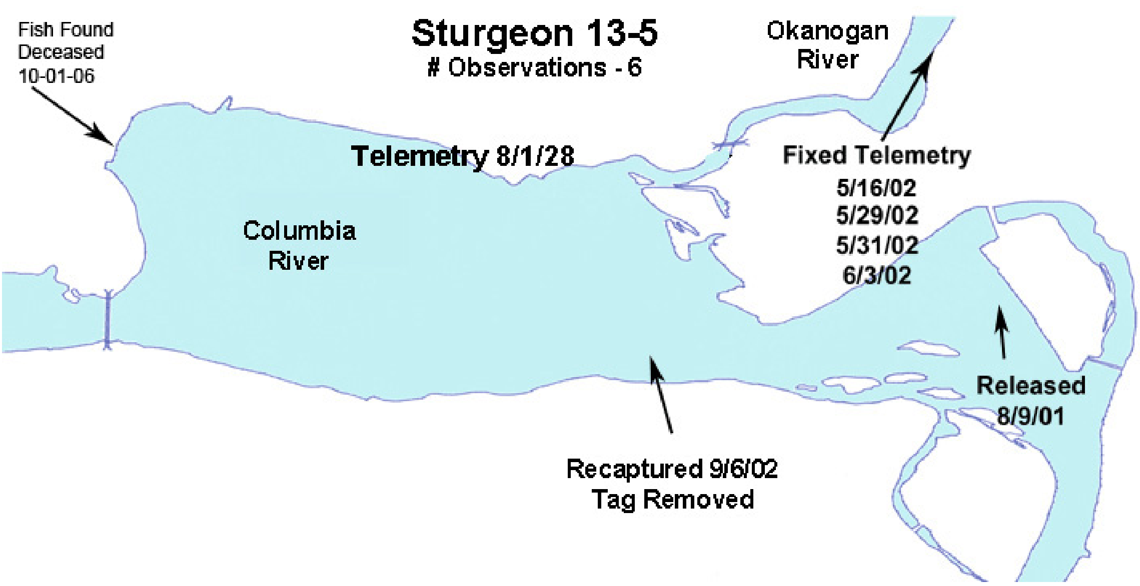


Figure 8 Telemetry observations for radio tag 13-5, Wells Reservoir, Washington

White Sturgeon 13-7

White sturgeon 13-7 was captured and outfitted with a radio transmitter on August 9, 2001. The fish was 183 cm long and was subsequently identified during three vessel telemetry surveys in 2002 (August 8, September 9, and November 27)(Figure 9). During the spring of 2003 white sturgeon 13-7 was recorded at the Okanogan River fixed telemetry site six times within a two week period (May 10, May 14, May 16, May 22, May 23, and May 24).

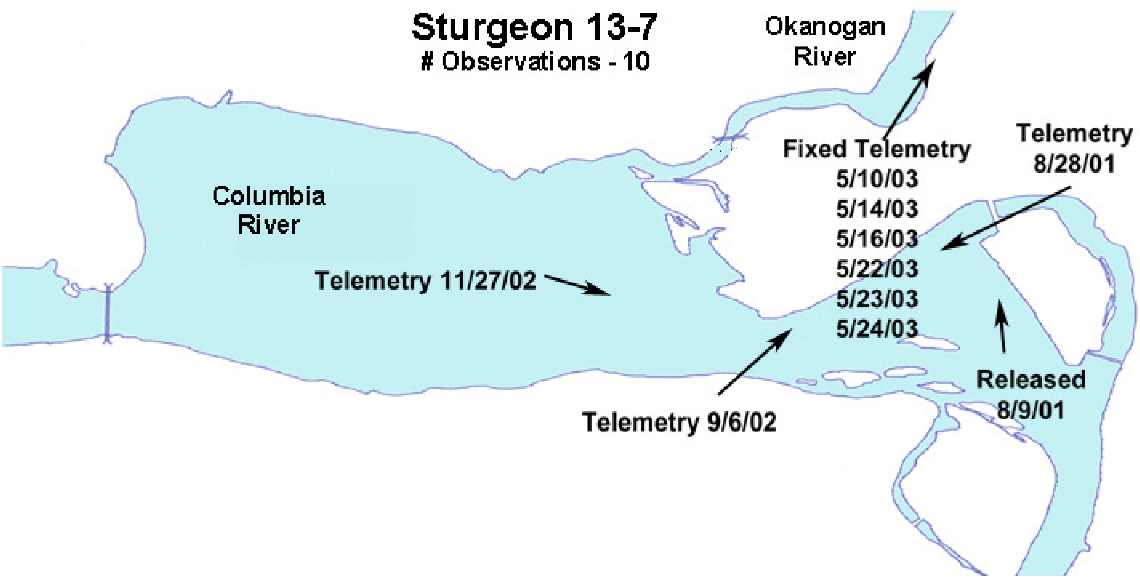


Figure 9 Telemetry observations for radio tag 13-7, Wells Reservoir, Washington

White Sturgeon 13-4

White sturgeon 13-4 was captured and outfitted with a radio transmitter on September 5, 2002. This fish was 184 cm long. The following day a vessel telemetry survey identified the fish near the mouth of the Okanogan River (Figure 10). The fish was once again identified during the final telemetry survey conducted on November 27, 2002.

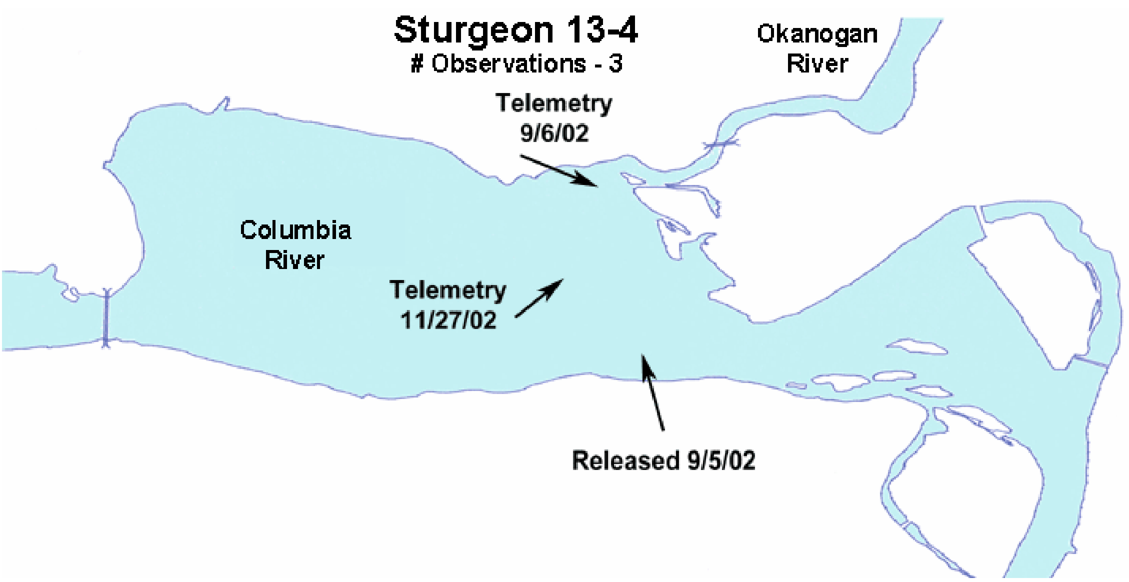


Figure 10 Telemetry observations for radio tag 13-4, Wells Reservoir, Washington

White Sturgeon 204-211

White Sturgeon 204-211 was captured and outfitted with a radio transmitter on September 9, 2002. This fish was 201 cm long. The fish was only recorded one additional time during the final vessel telemetry survey conducted on November 27, 2002 (Figure 11). At that time the fish was recorded within 100 meters of three other tagged fish in the mid-channel of the Columbia River across from the confluence of the Okanogan River.

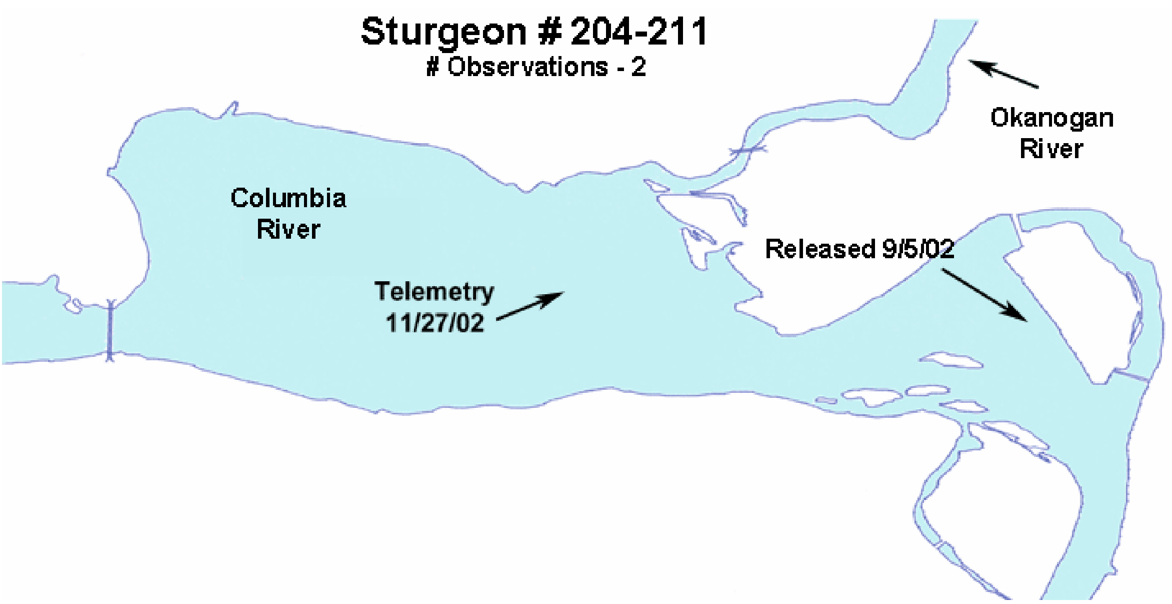


Figure 11 Telemetry observations for radio tag 13-4, Wells Reservoir, Washington

DISCUSSION

Field Sampling

For the purposes of this study, it was necessary to apply effort in the field to accomplish several objectives. The first objective was to sample an adequate number of individual fish that would provide basic information on population abundance, age class structure, growth, and ecology. An additional objective was the capture and outfitting of an adequate number of white sturgeon with radio tags to provide information on movement patterns and possible spawning migrations or feeding patterns within Wells Reservoir.

Success of this project was contingent upon capturing enough individuals within the population to obtain the primary objectives. Application of the set-line system proved to be a successful capture method for this project. However, set-line placement and retrieval was a time consuming and labor intensive process. A crew of three individuals was necessary to operate the vessel and successfully work the gear. Only four to five lines were set and checked during an average eight hour day. A typical sample week consisted of setting the gear on Monday, checking and resetting on Tuesday and Wednesday and retrieving the gear on Thursday. Therefore, only 12 to 15 set-lines were worked each sample week.

Prior to initiating set-line sampling in June of 2001, the white sturgeon distribution within Wells Reservoir was unknown. In an effort to sample the entire study area and ensure that all locations within Wells Reservoir were surveyed, the reservoir was divided into four zones and further into four sub zones. This provided 16 sampling areas within study area. It was surmised that spreading the gear throughout the reservoir it would increase the chances of capturing white sturgeon, as it was unknown which zone, if any, would be the most productive sampling location.

The goal of the sampling effort was to place set-lines within each of the four main zones. It was believed that white sturgeon densities could be highest within zone 4 as it has been documented that white sturgeon frequent high flow velocities in the tailrace areas of hydroelectric projects (Parsley and Beckman 1994). Zone 4 was heavily influenced by Chief Joseph Dam, and of the 4 sub-zones contained the highest flow velocities. Zones 2 and 3 both contained large tributary rivers with moderate flow velocities that white sturgeon may utilize for feeding or spawning migrations. For the first 2 weeks of sampling activities, no white sturgeon were captured. On July 10, three white sturgeon were captured in zone 3. Subsequently, two fish were captured on July 11 and one fish was captured on July 12. These fish were also captured in zone 3.

For the remainder of the study all white sturgeon were captured in zone 3. An adequate amount of effort was focused there for the remainder of the study to accomplish the objective of capturing white sturgeon for lab analysis and radio tag application. A smaller but consistent amount of effort was continuously applied to the other zones for the remainder of the project in an attempt to capture fish outside of zone 3.

It may have been possible to more intensively sample zones 1, 2, and 4 during this study. However, an increase in effort within these zones would have resulted in a decrease of effort in zone 3 and ultimately compromised the objective of obtaining adequate sample size. It was also unclear as to whether applying additional effort into the other zones would result in the capture of any white sturgeon within these areas. Within zone 3 a total of 68 sets were placed resulting in the capture of 18 white sturgeon translating into one sturgeon capture per 3.77 sets. A total of 15 sets were placed in zone 1, a total of 16 sets were placed in zone 2, and 21 sets were placed in zone 4. These sets were randomly distributed within each sub-zone. At an average of one sturgeon capture per 3.77 sets as recorded in zone 3, the 15 set-lines placed in zone 1 would have resulted in approximately four white sturgeon captures.

Set-lines have been the primary sampling gear utilized for white sturgeon capture in the Columbia River. However, it should be addressed that the set-line sampling efficiency on sturgeon under 50 cm is greatly reduced (Beamesderfer et al. 1989. Beamesderfer and Rien, 1993). Smaller white sturgeon are not generally susceptible to the larger hook sizes used on the gear. Attempts to decrease hook size during this study resulted in broken hooks. During July of 2001, smaller hooks were placed on the gear and when pulled the next day these hooks were straightened or broken at the shank by larger white sturgeon. Similar results have been encountered on other white sturgeon sampling projects (K. LePla, personal communication). It is therefore assumed that sampling bias of the set-line gear resulted in a misrepresentation of younger year class recruitment. This bias was evident in this study and could be observed by the absence of any white sturgeon captured under 50 cm in fork length.

The gear used in this study was also limited in its ability to capture fish in the larger size categories (e.g. greater than 215 cm). This was evident during the study from the relatively high number of straightened hooks (11), broken snaps (7) and broken gabions (3). It is difficult to estimate the number of fish that were lost as it was not possible to determine whether hooks were snagged on the bottom or broken off by larger white sturgeon. During sampling activities in 2002, smaller hooks on the set line gear were removed to promote the capture of larger hooked fish. This likely resulted in additional bias towards hooking large fish in 2002 and overall skewed the data towards intermediate sized fish. Small fish were not as apt to get hooked due to hook and bait size and very large fish were hooked but not landed due to their ability to break the set line gear.

The set line CPUE for this study (CPUE = 0.025 fish per 100 hook hours) was similar to that of other reported CPUE rates for white sturgeon captures in the Mid Columbia (Golder, 2003). Golder reported 523,204 hook hours of set line sample effort to capture 115 white sturgeon in Wanapum and Priest Rapids Reservoirs resulting in a CPUE of 0.022 fish/100 hook hours. It appears that set line gear efficiency observed during this study was similar to that of other white sturgeon monitoring programs within the Columbia River Region.

The population estimate for the Wells Reservoir (n = 31) was similar to that developed for other Mid-Columbia River white sturgeon populations (Golder 2003, Golder 2002). In 2001 and 2002, a white sturgeon survey was conducted within Rocky Reach Reservoir located immediately downstream from Wells Reservoir (Golder, 2002). During the Rocky Reach study, a total of 24 individual white sturgeon were captured and four fish were recaptured during two years of sampling activities

Population Estimate

. This resulted in a Schnabel population estimate of 47 fish. An extensive white sturgeon study was conducted within Wanapum Pool and Priest Rapids pool from 2000 to 2002 (Golder, 2003). A relatively high number of white sturgeon were captured in the Wanapum Pool (n = 118) with 8 recaptures translating into a population estimate of 551 fish. A total of 29 white sturgeon were captured in the Priest Rapids Pool and only one fish was recaptured translating into a population estimate of 134 fish. These abundance estimates indicate the presence of small localized populations within mid-Columbia Reservoirs.

Initially it was hypothesized that white sturgeon would be captured throughout the study area, as Wells Reservoir has a variety of diverse habitats including two tributary streams and a large section of free-flowing water for 10 kilometers below Chief Joseph Dam. The study area was divided into zones in an attempt to ensure that all habitat types were sampled within the study area. White sturgeon were only marked and recaptured in zone 3 making it difficult to determine whether the population estimate pertains only to zone 3 or the entire study area. The absence of any white sturgeon encounters within zones 1, 2, and 4 prohibited statistical analysis between the zones. There are currently no statistical models that enable the analysis of fish populations between locations when no fish are captured within one of the locations (R. Townsend, personal communication).

Absence of fish within the sampled zones indicates one of three possibilities. Either there are no fish in the zones or the location was not sampled enough to capture a very small population of fish within the zone. It is also plausible that white sturgeon may utilize zones 1, 2, and 4 on a limited basis. There are no physical barriers between zones and it is possible that at some time white sturgeon travel out of zone 3. The most probable explanation of movements out of zone 3 would be the seasonal movements of fish into zone 4 for feeding or spawning migrations within the Chief Joseph Tailrace. Dam tailrace areas have been documented as preferred locations for white sturgeon spawning activities, and it is possible that flow velocities within Chief Joseph tailrace attract white sturgeon to spawn during the spring months. The limited telemetry data collected during this study does not support movements into zone 4. However, these movements may not have been documented during this study as vessel telemetry sweeps within zone 4 were limited due to personnel and budget constraints.

Additional evidence that white sturgeon may not utilize zones 1, 2 and 4 (or only utilize them occasionally) is present in the telemetry data. A total of four boat telemetry surveys were conducted (limited by personnel and budget). Three of the surveys were conducted in late summer or fall of 2001 and 2002 and one survey was conducted in the winter of 2002. During the telemetry surveys, no white sturgeon were recorded outside zone 3. The telemetry data shows that white sturgeon probably stay within zone 3 during the winter months as the winter survey conducted in late November verified all outstanding tagged fish were in zone 3 and within 100 meters of one another. It has been documented in similar studies that white sturgeon congregate together during the winter months within the deep water pools (Golder, 2003, North et al. 1993). Additionally, no white sturgeon were recorded passing through zone 2 at the fixed receiver sites near the mouth of the Methow River. This provides evidence that white sturgeon do not utilize or rarely utilize habitats in the lower Wells Reservoir.

When analyzing the white sturgeon telemetry data, it is important to take into consideration that white sturgeon do not spawn on an annual basis. Typically, gravid female white sturgeon spawn every two to five years (Smith 1985). It is possible that during the two year time frame of this study, radio tagged white sturgeon were not recorded moving out of zone 3. Spawning movements of the radio tagged fish may have been limited or these fish simply did not conduct spawning migrations during the study.

A primary assumption for the abundance estimate was that a closed population of white sturgeon existed within the study area. Data collected during the set-line sampling and telemetry tracking surveys supports the assumption of no immigration out of the study area. Throughout the study two fixed receivers were present in zone 2. These receivers should have recorded any radio tag transmissions from radio tagged fish that were tagged in zone 3 and were passing through zone 2 and out of the study area. In regards to upstream migrations out of the study area, white sturgeon cannot pass through Chief Joseph Dam as there is no fish ladder at that project.

Sturgeon migrations into the study area may occur. Migrations of white sturgeon have been documented, and the incidences of white sturgeon passing through hydroelectric projects is highly variable (Hanson et al. 1992, Ward et al. 2003). Wells Dam contains two fish ladders. It is possible that white sturgeon could travel upstream from Rocky Reach Reservoir as a white sturgeon population has been documented in that reservoir (Golder 2002). However, there have been few documented observations of white sturgeon moving upstream through Wells Dam fish ladders by fish counting personnel since dam construction in 1967. The most probable route of immigration into the study area is the passage of juvenile or sub-adult individuals from the upstream Chief Joseph Reservoir. Downstream migrations may be a factor in recruitment within Columbia River white sturgeon populations as these fish historically migrated downstream to the Pacific Ocean. Ward et al. (2003) analyzed movements of white sturgeon between lower Columbia River reservoirs from 1987 to 2002. During this time period, 4,294 white sturgeon were recaptured. A total of six white sturgeon were recaptured in reservoirs above the release site (.13%) and 147 fish were captured below the release area (3.3%). These data indicate that migrations between reservoirs in the Columbia River system are limited. Upstream migrations are rare and downstream migrations may occur at a limited rate. Therefore, movements of white sturgeon from upstream or downstream reservoirs into Wells Reservoir may take place but are probably limited events.

The assumption that each white sturgeon within the study area had an equal chance of capture was violated by fish #6 (a juvenile white sturgeon). The RECAP.GLM program provided analysis of the data and examination of the residuals associated with the lack-of-fit to individual capture histories (Skalski et al. 2005). Examination of these residuals provided information as to whether certain individual white sturgeon exhibited gear selectivity towards the set-lines. The program identified fish # 6 as an individual exhibiting gear selectivity towards the set line gear, and therefore the fish was removed from the data set. Fortunately, enough fish were recaptured that a population estimate was possible without using the data from this "capture prone" fish.

Physical Data

Large variances in growth rates were recorded for fish sampled in Wells Reservoir. Related literature has shown similar trends of relatively high growth rates in juvenile white sturgeon compared to adult white sturgeon (Hanson 1992). For this study, one juvenile and one adult white sturgeon were recovered to providing growth data. The small juvenile fish exhibited a high growth rate of 22 cm during 14 months. The adult fish was recorded as only growing 2 cm from August 2001 to September 2002. However, the same fish was found deceased and washed ashore nearly four years later and had grown an average of 7.4 cm per year over the 4 year period. The average growth rate of 7.4 cm per year for this individual fish is consistent with a growth rate of 6.8 cm per year reported in Wanapum Reservoir (Golder, 2003). White sturgeon may exhibit yearly growth fluctuations due to varying environmental variables such as water temperature and food abundance (K. LePla, personal communication).

Presently, fin ray analysis is the most precise method for aging white sturgeon. However, Rien and Beamesderfer (1994) concluded that fin ray analysis to age white sturgeon is not a precise method and determining age for younger individuals is more precise than older individuals. In regards to older aged individuals, assigned ages may underestimate their true age due to crowded annuli. Additionally, some annuli are very small due to environmental variance (e.g. short supplies of prey items during certain years) and may be overlooked by technicians. These factors ultimately lead to discrepancies in age frequencies and year class strengths. For the purpose of this report, sturgeon ages were presented in the form of an exact year class. It should be addressed that ages should be viewed as approximated rather than exact. Fish aged within one to five years of one another may be from the same age class, with the variance growing larger in older aged individuals.

This effect could be displayed in the data from the population of white sturgeon that are designated within the 1972 to 1978 age classes. Within this time period, five adult white sturgeon were age estimated (one fish from each of years 1972, 1975, and 1978, and two fish from year 1974). It is possible that these fish originated from one or two productive year classes during this time period. Additional studies in the Mid-Columbia have shown strong age classes for these years (Golder 2002, Golder 2003). Within Wanapum and Priest Rapids Reservoirs, Golder (2003) reported that the 1976 age class made up the second largest number of sampled white sturgeon.

In the Golder (2003) study, the highest number of individuals sampled within Wanapum and Priest Rapids Reservoirs were documented to be juvenile white sturgeon from the 1997 age class. Water flows during that spring were the highest on record since the construction of the project in 1961. Golder (2003) suggests that high flow years increase the survival and recruitment of juvenile white sturgeon. Several other studies have documented a positive relationship between white sturgeon year class strength and high flows (Kohlhorst et al. 1991, Miller and Beckman 1995). Three juvenile white sturgeon were sampled during our collection activities in Wells Reservoir and estimated to come from the 1995, 1996, and 1997 year classes. Given the margin for error during fin ray analysis, it is possible that these 3 fish may be from the 1997 age class. Flows through Wells Reservoir were some of the highest on record in 1997 (S. Bickford, personal communication).

All female white sturgeon within a population will not spawn during ideal environmental conditions. However, a certain number of highly gravid white sturgeon will conduct spawning activities during year with such conditions. A combination of high fecundity and inconsistent spawning periods would ultimately result in large year classes. High flows may have produced strong year class recruitment for white sturgeon throughout the mid-Columbia region in 1997. These groups of similarly aged fish present evidence that strong age classes of white sturgeon may have hatched in the mid-Columbia during specific time periods. If these small groups of similarly aged fish represent a few year classes, it is possible that recruitment of white sturgeon within Wells Reservoir is limited by environmental factors such as water temperature, velocity and/or turbidity.

Regional Comparisons

This study was intended to provide an initial assessment of white sturgeon abundance, population structure, and movement patterns within Wells Reservoir. It is difficult to compare the current population to historic populations as no previous data exists on the status of white sturgeon in the study area. However, it is possible to draw inferences when comparing data collected from this project with other regional data. The Wells Reservoir length frequency histogram was compared with data obtained from three regional agencies studying white sturgeon within the Columbia River Region. One histogram was constructed for data assimilated within the Mid-Columbia Region, one histogram was constructed for the Lower-Columbia Region, and one histogram was constructed for a population of white sturgeon studied in the upper Snake River Basin.

The histogram constructed for the Wells Reservoir population of white sturgeon contains a low proportion of juvenile white sturgeon under 90 CM. This is partially a result of the size bias of the long-line gear and the removal of smaller hooks half way through the study. Even though the incidence of juvenile fish was low during the study, the fact that any were captured at all shows that there is recruitment within the Wells Reservoir population either through natural reproduction or immigration from upstream populations.

The Mid-Columbia histogram taken from the Wanapum Pool represents a population of white sturgeon with an age class structure that most resembles the Wells Reservoir population (Figure 12). Two distinct peaks can be identified within both populations. These peaks indicate strong recruitment for white sturgeon from 60 to 105 centimeters and 165 to 195 centimeters, suggesting strong recruitment classes of white sturgeon within the Mid-Columbia in the mid 1970's, the late 1980's, and the mid 1990's. Lepla and Chandler (2001) documented decreased recruitment of white sturgeon upstream of Hells Canyon from 1987 to 1994 that was observed to correspond with a drought that lasted eight consecutive years. Effects of this drought may have impacted white sturgeon populations throughout the Columbia and Snake River basins.

If strong year classes were present throughout the mid-Columbia, white sturgeon in Wells Reservoir may grow faster than those in the Wanapum reservoir. This is demonstrated in the Wells Reservoir length frequency histogram as both peaks are shifted slightly to the right. If the two peaks shown within each population were from the same age classes then the Wells Reservoir population exhibits a higher growth rate.

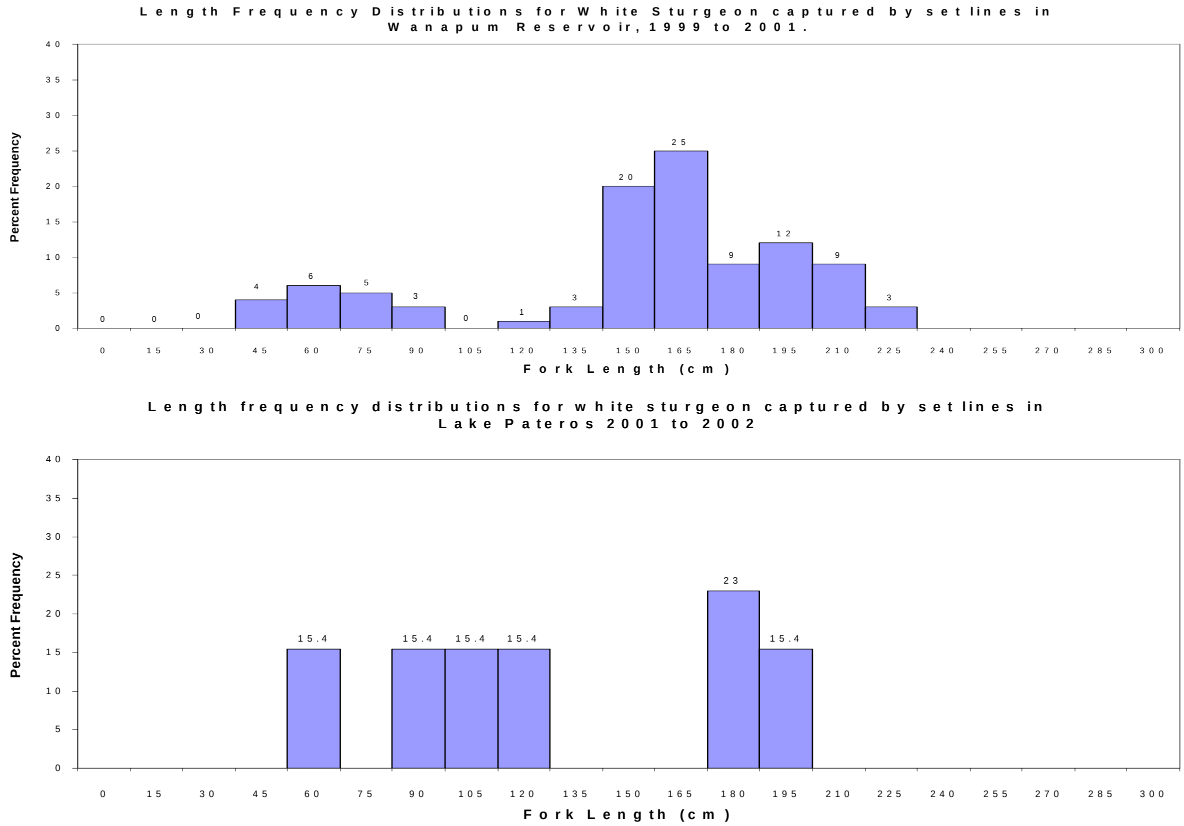


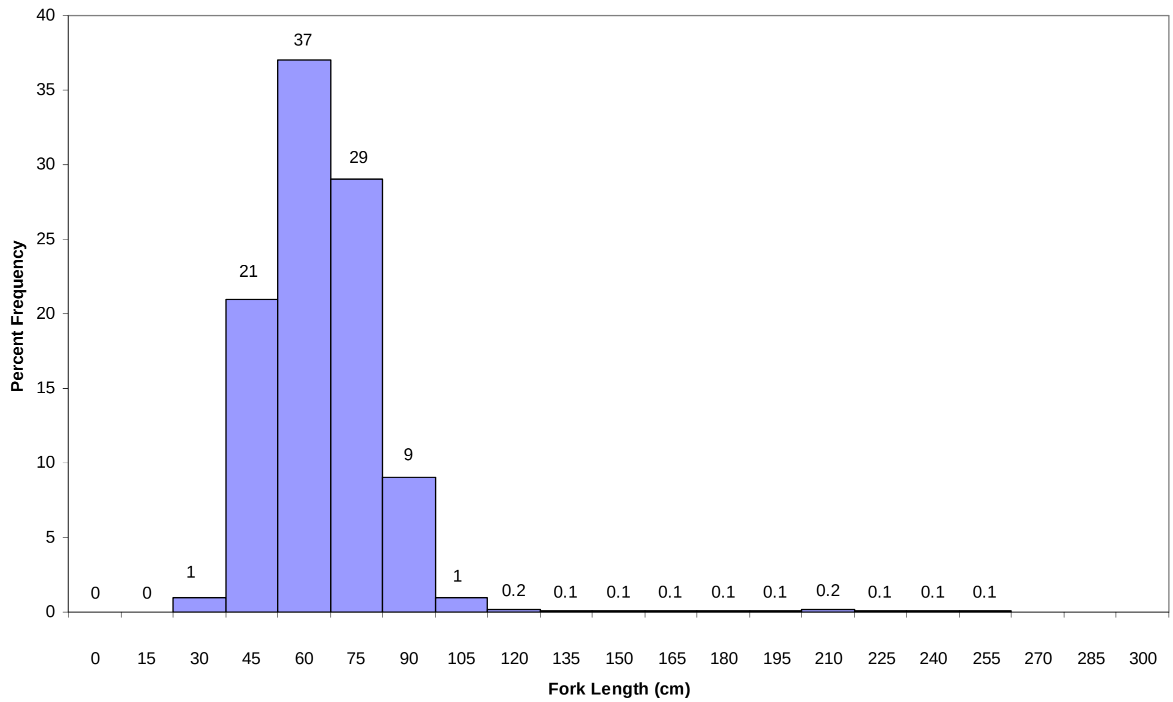
Figure 12 Length frequency histogram comparison for white sturgeon captured in Wanapum Reservoir and white sturgeon captured in Wells Reservoir.

The white sturgeon population in Bonneville Reservoir represents a Lower Columbia River population that has been heavily influenced by sport and tribal set line fisheries (Figure 13). There are currently harvest fisheries for white sturgeon within all lower Columbia River reservoirs. Within Bonneville Reservoir, sport anglers are allowed to retain white sturgeon from 107 centimeters to 152 centimeters. The tribal commercial fishery allows for the harvest of white sturgeon from 114 centimeters to 152 centimeters. These management slot regulation are designed to provide for the take of sub-adult sturgeon. The adult segment of the population then provides recruitment within the population. This management strategy results in a steep decline in the number of adult white sturgeon over 100 cm and can be clearly seen in the Bonneville Reservoir length frequency histogram.

Compared to the Bonneville Reservoir population, the Wells Reservoir population contains a higher portion of adult fish and a smaller portion of juvenile fish. Recruitment within the Wells Reservoir population may be occurring at a lower rate. Only two white sturgeon were captured during this study in the juvenile age bracket from under 90 centimeters. The remaining fish were all over 90 cm in length and classified as sub-adults or adults. The Wanapum Reservoir Length Frequency Histogram (Figure 12) also exhibits a high proportion of adult to juvenile ratios. This is further evidence that low recruitment levels are occurring in the impounded mid-Columbia white sturgeon populations.

The Bonneville reservoir data indicate low numbers of adult spawning white sturgeon can provide high levels of recruitment. White sturgeon are extremely gravid, with large females able to disperse from as many as 7 million eggs (Hanson et al. 1992). It may not take a large number of adults to provide adequate levels of recruitment within white sturgeon populations if favorable spawning conditions and environmental conditions exist on a consistent basis, which may be the case in Bonneville Reservoir. It has been well documented that white sturgeon do not spawn each year and oocyte development may take from two to five years (Smith 1985). If environmental factors are not ideal when female white sturgeon have completed oocyte development, these fish may reabsorb the gametes or spawn in unfavorable environmental conditions. This reproductive strategy may benefit the species, as ideal spawning conditions may not occur each year.

Length Frequency for White Sturgeon captured by set lines Below Bonneville Dam, 2001 and 2002



Length frequency distributions for white sturgeon captured by set lines in Lake Pateros 2001 to 2002

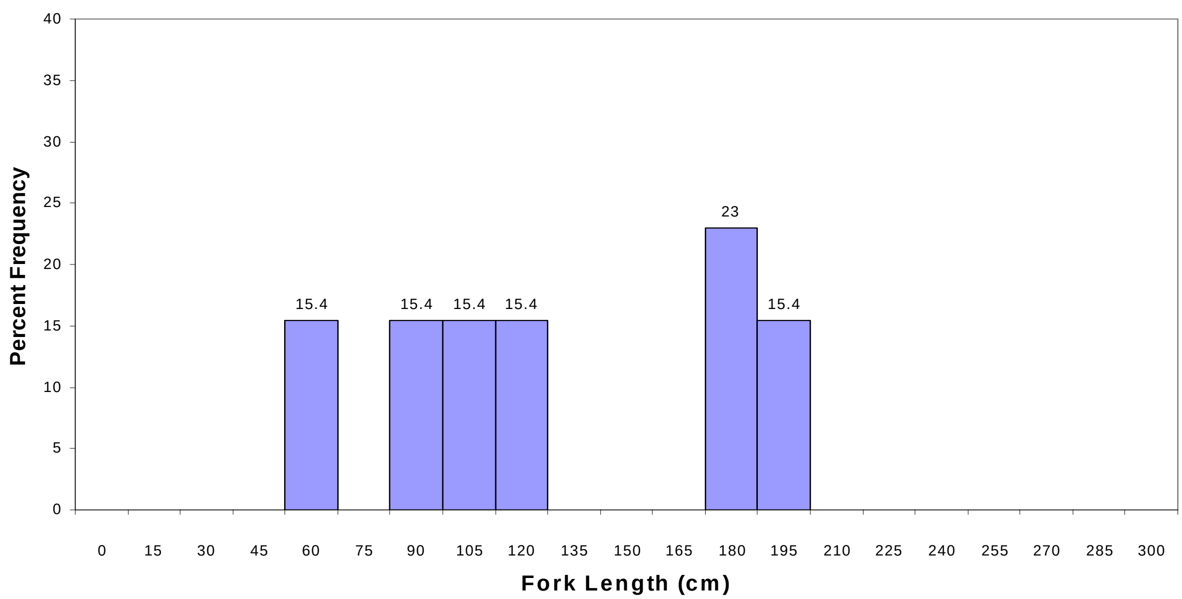
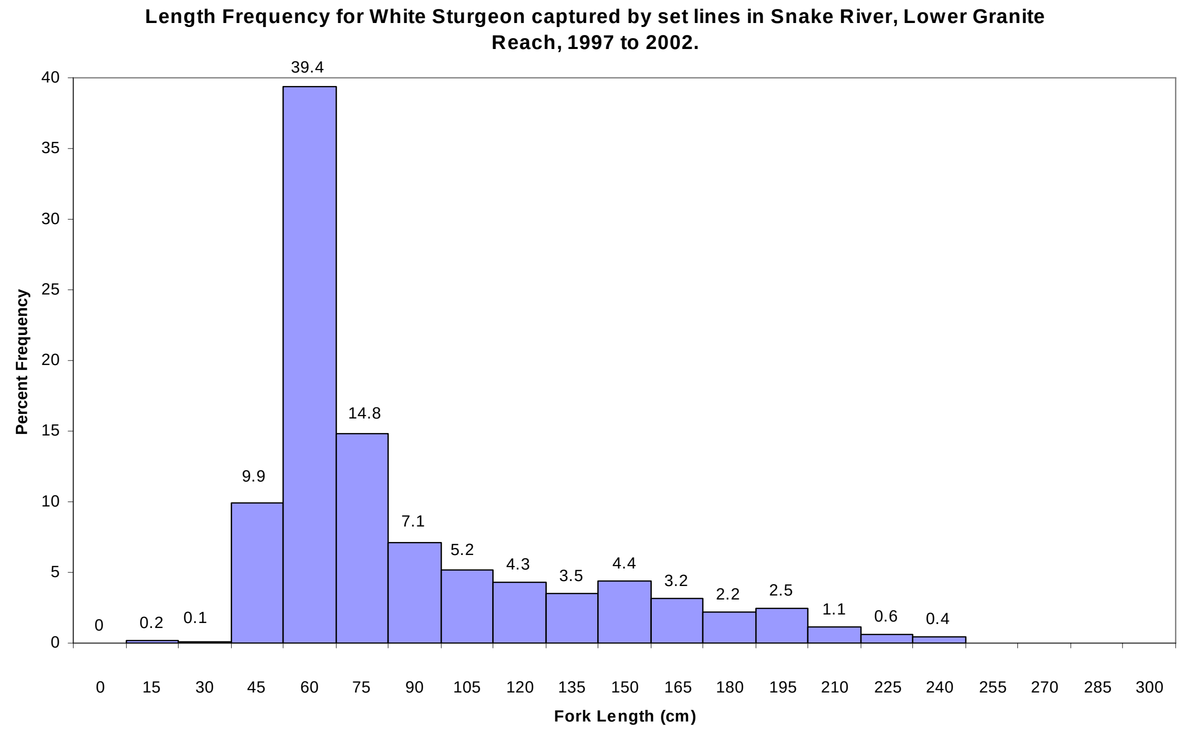


Figure 13 Length frequency histogram comparison for white sturgeon captured in Bonneville reservoir and white sturgeon captured in Wells Reservoir.

The Lower Granite – Hells Canyon sturgeon population exhibits a healthy population structure, based on a current stock structure that is dominated by juveniles and contains a wide range of size classes and stages of maturity from immature juveniles to reproductive adults (Figure 14). A steady down slope curve occurs at slot lengths for older fish, evidence of strong stock structure and a wide range of individuals throughout the population. The last sport fishery that was conducted on the population took place in 1970. From 1970 to present a small tribal fishery has occurred on the reservoir, however the impacts of that fishery are not clear at the present time (Everett et al. 2003).

A high incidence of younger aged individuals within the Snake River population can be observed when compared to the Wells Reservoir population. High levels of recruitment exist within the Snake River population, likely a result of ideal rearing conditions and relatively high rates of productivity in that river compared to the Mid-Columbia River. Additionally, Idaho Power has sporadically stocked white sturgeon within the reservoir. Higher water velocity, temperatures and turbidity in Hells Canyon may promote high levels of recruitment within the Snake River sturgeon population.



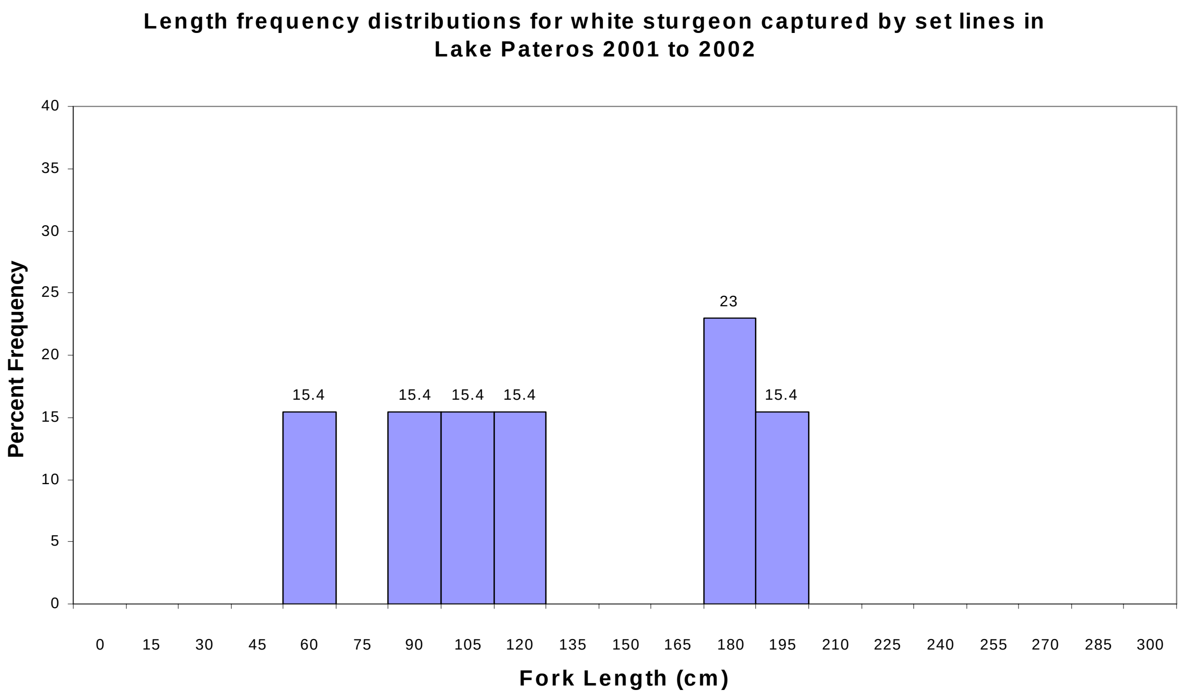


Figure 14 Length frequency histogram comparison for white sturgeon captured in Wells Reservoir and white sturgeon captured in Lower Granite Reservoir, Snake River Idaho.

Analysis of the length frequency data should be interpreted with caution. The identification of year classes based on fish lengths is highly variable (Rien et al. 1994). Once white sturgeon are over one year old, lengths may not be a good predictor of age. As juveniles age, growth variability and age inaccuracy make it increasingly difficult to correlate environmental conditions with specific year classes, particularly when based on lengths of older fish.

Additional caution should be taken when analyzing the Wells Reservoir white sturgeon population as the length frequency graphs assumed age structure are composed of a very small sample size (n=13). This small sample size may result in inaccuracies or gaps in the presented stock structure. If the sample size were increased, more distinct trends in the population could be observed.

Radio Telemetry

The 7 volt Lotek Micro Coded Fish Transmitters can transmit signals up to 20 meters (M. Vandentillart, personal communication). This range of transmittal may be limited by conductivity of the water and the efficiency of the receivers and antenna. Aerial surveys typically locate radio transmitters within 5 to 10 meters of the water surface. All white sturgeon during this project were captured and recorded during boat telemetry surveys at depths greater than 15 meters. Therefore, it is probable that the transmitted signals from the 7 volt tags were not recorded during the aerial surveys due to poor signal strength transmitted from tags at depths greater than 15 meters.

Boat telemetry surveys were the most productive method for locating activated tags. However, only four boat surveys were conducted (this telemetry gathering procedure was limited by funding and availability of the research vessel). White sturgeon were detected during each survey, often within close vicinity of each other and all within zone 3. Several of these fish were located within depths of over 20 meters, an indication that the receiver and antenna setup on the telemetry vessel was functioning with a high degree of accuracy. The final telemetry survey on November 27, 2003 identified four tagged fish within 100 meters of one another near the mid-Channel of the Columbia River across from the confluence of the Okanogan and Columbia rivers. It is presumed that these four tags were the only active tags (of the six applied tags, one radio tag had been removed from a fish three months prior and one tag was presumed to have been shed). The November 27 survey was the only mobile tracking survey that was conducted during the winter months. There is evidence that white sturgeon congregate in specific areas of the Mid-

Columbia River reservoirs during the winter (Golder Associates, 2003). White sturgeon were located in similar "pods" within Wanapum Reservoir during the winter of 2000 and 2001. Movement information collected on white sturgeon within Priest Rapids Reservoir in the Mid-Columbia indicated white sturgeon were relatively inactive from October to early April, and usually remained in one of four overwintering areas. It is probable that the deep channel of the Columbia River near the Okanogan River confluence is a preferred over wintering location for white sturgeon within Wells Reservoir.

The fixed station telemetry data presented in this report indicates white sturgeon were at the Okanogan River telemetry site during May and June of 2002 and May of 2003. In an attempt to correlate white sturgeon movements with environmental factors, discharge flows and water temperatures were collected near the fixed telemetry receiver in the Okanogan River during the spring of 2002 and 2003. Discharge data were collected from the Okanogan River at the USGS gauging station located near Malott Bridge approximately 8 kilometers upstream from the fixed telemetry site. Water temperature data were not available on a consistent basis for the Okanogan River due to temperature probe malfunction in 2002 and 2003. Intermittent temperature readings for the Okanogan River were obtained from the Colville tribe and Department of Ecology

Yearly hydrographs for the Okanogan River consist of low flows from September to April, typically under 4000 cubic feet per second (cfs). Peak spring run-off usually occurs in June when flows may range from 16,000 to 20,000 cfs. From mid-May to mid-July of 2002 peak discharges occurred in the Okanogan River. Two radio tagged white sturgeon were present at the site during this peak flow period from May 19 to June 19 (Figure 15). Water temperatures ranged from approximately 11 C to 12.5 C during this time period. In 2003 peak discharges occurred during the first two weeks of June One radio tagged white sturgeon was present at the fixed telemetry site prior to the peak flow period from May 10 to May 24 (Figure 16). Water temperatures ranged from approximately 10 C to 11.5 C during this time period.

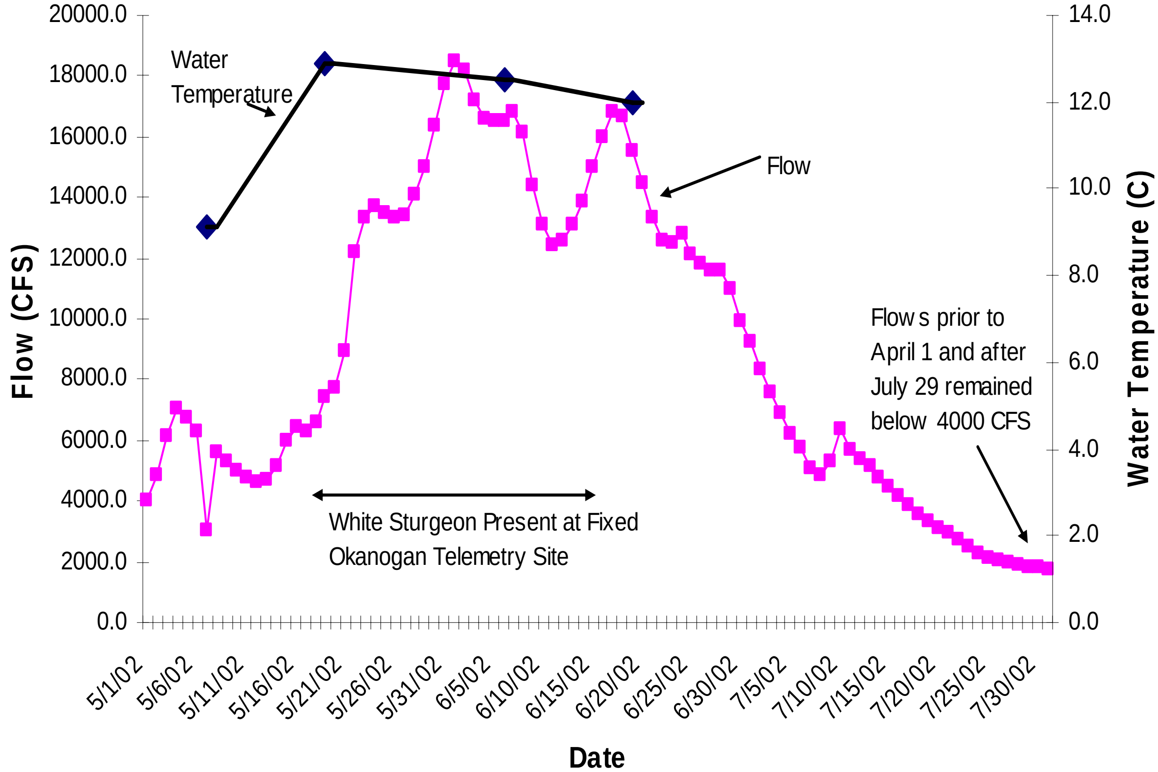


Figure 15 Daily mean discharge (cubic feet per second) from May 1, 2002 to July 30, 2002 within Okanogan River taken at Malott Bridge USGS gauging station approximately 8 kilometers upstream from the Columbia River confluence.

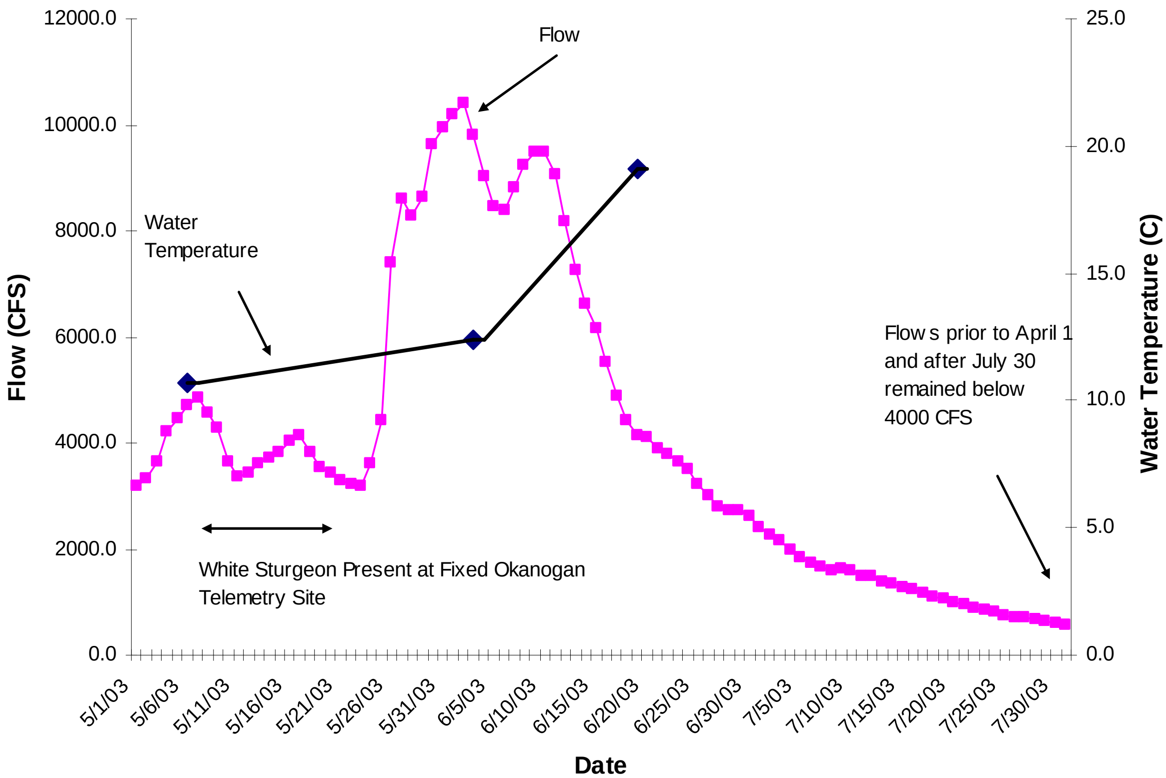


Figure 16 Daily mean discharge (cubic feet per second) from May 1, 2003 to July 30, 2003 within Okanogan River taken at Malott Bridge USGS gauging station approximately 8 kilometers upstream from the Columbia River confluence.

White sturgeon movements are often related to spawning and/or feeding activities (Hynes 1978). The presence of white sturgeon within the relatively shallow depths of the Okanogan River (less then 15 meters) provides evidence of these movements. White sturgeon left the vicinity of the site when water temperatures neared 11 to 12 C. Therefore, it is unlikely that white sturgeon frequented the Okanogan River relative to spawning activities. White sturgeon did exit the Okanogan River just prior to the lower egg incubation temperature of 13 C. Radio tagging studies in the Fraser River document gravid fish moving upstream from 11.3 to 16.1 km per day (Hanson et al. 1992). It is possible that white sturgeon may have been leaving the Okanogan River to conduct spawning activities elsewhere in the study area.

White sturgeon may be utilizing the Okanogan River for foraging purposes in the spring. During the high spring flows, large amounts of decayed material and juvenile salmonids are washed out of the Okanogan River, which may include steelhead carcasses and juvenile sockeye (S. Bickford, personal communication). White sturgeon may be scavenging on steelhead carcasses, juvenile sockeye or other food sources that are washed downstream during the yearly spring run-off.

Research throughout the Columbia River system has indicated that white sturgeon prefer dam tailrace areas for spawning attempts as these areas contain fast flowing water velocities and suitable spawning habitat (Brannon and Setter 1992, Haynes et al. 1978, Lepla and Chandler 2001, Parsley et al. 1993, Parsley and Beckman 1994). Additionally, changes in hydroelectric facility operations have been documented to effect sturgeon movements in tailrace areas (Auer 1996, Votinov NP and Kas'yanov 1978). Parsley and Kappenman (2000) documented 17 white sturgeon spawning locations on the Snake River. All 17 locations contained high water velocities and were located within five kilometers downstream of hydroelectric projects. It is possible that white sturgeon are migrating out of zone 3 to spawn in or near the tailrace of Chief Joseph Dam. Golder and Associates (2003) observed distinct movements of white sturgeon from over wintering areas upstream to the base of Rock Island Dam within Wanapum Reservoir. These movements occurred during the spawning period in early June, and most fish remained below Rock Island Dam until July.

Chief Joseph Dam heavily influences water velocity and pool levels within Wells Reservoir. All of zone 4 and the upper part of zone 3 within the study area are subject to high water discharges from the project, especially during spring run-off periods. Waters below the tailrace of Chief Joseph Dam are much more heavily influenced by hydroelectric operations than most other dams on the Columbia River due to a narrow river channel that exists there. Water velocities remain high for approximately 15 kilometers below the project and water does not begin to pool within the reservoir until far downstream of the project. This scenario ultimately results in a large section of river that contains high flow velocities and may be suitable white sturgeon spawning habitat.

During this study it was not possible to conclude whether spawning events took place, however it was possible to create a temperature discharge graph and define time periods when white sturgeon spawning events may have occurred within the upper reservoir. A temperature discharge curve was constructed for the upper Wells Reservoir for spring periods in 2002 and 2003. Water temperature and discharge information were obtained from the United States Corps of Engineers for the immediate Chief Joseph Dam Tailrace. Water temperatures from 13 to 18 C that coincide with high spring flows create a spawning window indicating the most probable time white sturgeon spawning events would occur. Given high water velocities throughout the upper study area, the spawning window is suggested to be appropriate for all areas of the upper reservoir that are influenced by Chief Joseph Dam. This would include the entire section of zone 4 and the upper section of zone 3 near the confluence of the Columbia and Okanogan rivers.

During 2002, the spawning window within the upper reservoir should have taken place from approximately June 25 to July 10 (Figure 17). During this time, period peak discharge occurred from Chief Joseph Dam nearing 20,000 cfs and water temperatures ranged from 13 C to 15 C. The estimated spawning window in 2003 also occurred near the end of June from approximately June 17 To July 8 (Figure 18). Flow velocities were high and water temperatures ranged from 13 C to 15 C.

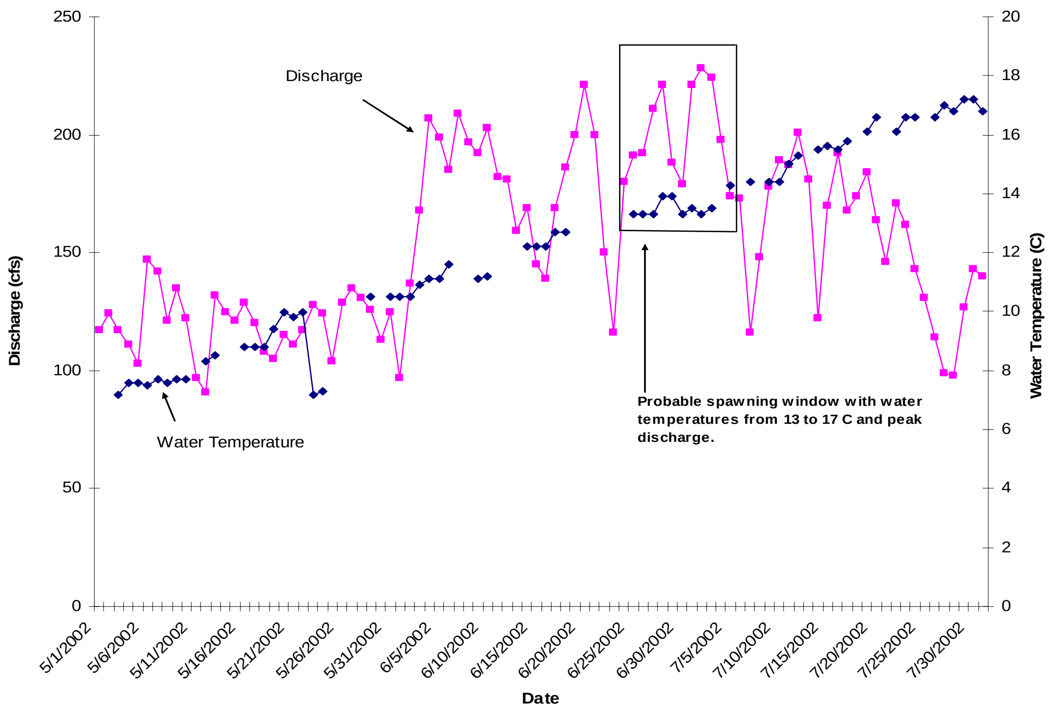


Figure 17 Daily average water temperature (C) and daily average discharge (cfs) in Chief Joseph Dam tailrace from May 1 to July 30, 2002. Spawning window represents optimal white sturgeon egg incubation temperature (13 C to 17 C) and high flow velocities.

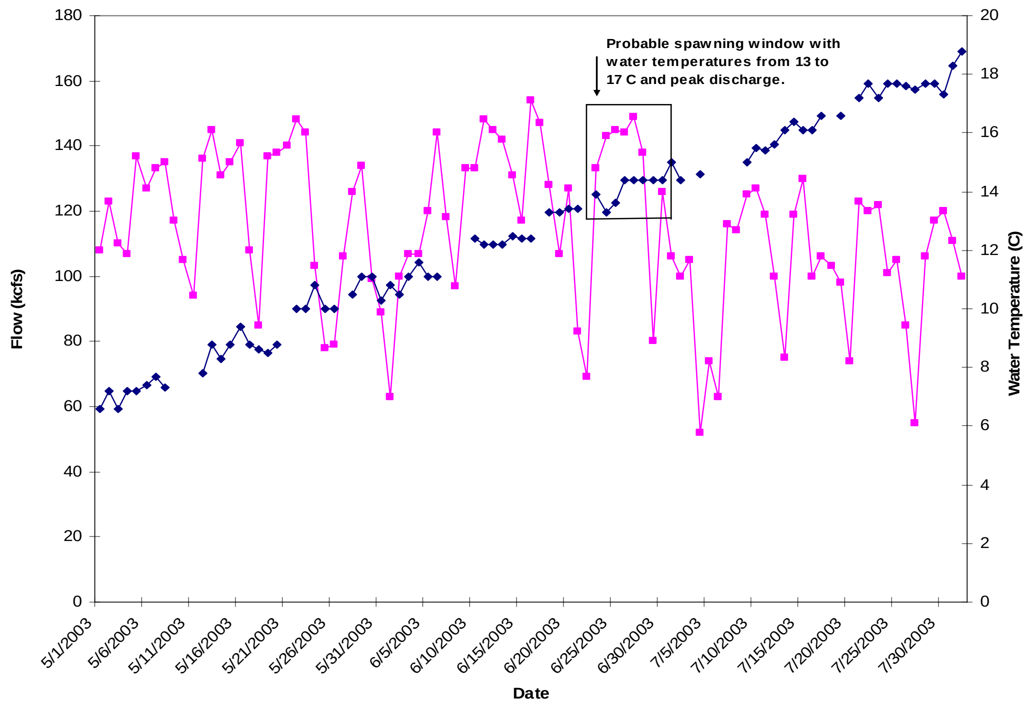


Figure 18 Daily average water temperature (C) and daily average discharge (cfs) in Chief Joseph Dam tailrace from May 1 to July 30, 2003. Spawning window represents optimal white sturgeon egg incubation temperature (13 C to 17 C) and high flow velocities.

White sturgeon were not captured on the set line gear during the spring of 2001 or the spring of 2002 within zone 3. A number of set lines were placed throughout zone 3 from mid to late June of 2001 with no incidence of white sturgeon captures. White sturgeon were only encountered on the set line gear within zone 3 during the summer and fall sampling periods. Golder and Associates (2003) noted low catch rates during the spring and early summer months in mid-Columbia sampling efforts. In Priest Rapids reservoir, no white sturgeon were encountered during sampling efforts during the spring of 2000. However, a total of nine fish were captured during fall sampling of that same year. Lack of captures during the spring periods may indicate white sturgeon are more susceptible to the set line gear during the summer and fall months. Because fish metabolism is related to water temperature, low water temperatures in spring may have inhibited the fish's feeding response to baits placed on the set line gear.

Low incidences of white sturgeon captures in the spring may also indicate that white sturgeon are utilizing habitats within the reservoir that were not sampled or could not be sampled. During high flow, velocities it was not feasible to place set line gear in the immediate Chief Joseph Tailrace due to dangerous and turbulent water conditions. It is possible that white sturgeon were present within the Chief Joseph tailrace area and not sampled. The absence of fish captures within zone 3 during high flow events and the presence of high flow velocities in the upper reservoir indicate the possibility that white sturgeon may have traveled out of zone 3 to conduct spawning efforts in or below the Chief Joseph tailrace area.

Management Implications

The Schnabel mark-recapture estimate (n=31.35) indicates that the white sturgeon population within Wells Reservoir is composed of a low number of individual fish. This project has verified the presence of a white sturgeon population within Wells Reservoir and future strategies will need to be implemented that will enhance and expand the existing population. Future management objectives should include promoting white sturgeon enhancement and monitoring the effects of these restoration efforts. A larger population of white sturgeon within Wells Reservoir would better withstand variable environmental conditions as a sufficient number of adult spawning individuals would be available to reproduce during productive environmental conditions. Ultimately, strong spawning events during productive environmental conditions should provide recruitment levels that allow the population to exist even during periods of un-favorable environmental conditions (i.e. extended droughts from low snow packs).

Promoting white sturgeon growth within Wells Reservoir will require the collection of brood stock and the culture of juvenile sturgeon. Studies have successfully identified white sturgeon spawning locations throughout the Columbia and Snake Rivers (Anders and Beckman 1993, Parsley and Kappenman 2000, Parsley at al. 1993, Parsley and Beckman 1994). These spawning locations have been discovered through the tagging of mature white sturgeon with radio and sonic tags and the tracking of the fish to spawning sites. Positive verification of spawning sites within Columbia River reservoirs has entailed the use of egg matts (Parsley and Kappenman 2000, Parsley at al. 1993). These matts are deployed downstream of suspected spawning areas to capture eggs or larvae that are dispersed during spawning events.

It is not presently possible to determine whether brood stock could be obtained from the existing Wells Reservoir population. Because the population of fish within Wells Reservoir is relatively low, it may not be feasible to obtain spawners from the existing population. Assuming a population of 31 fish (of which 50% are mature) and a sex ratio of 50% females, there could be up to eight mature females in the population. However, as white sturgeon females may only spawn every two to five years, it is possible that only one to three females may spawn within Wells Reservoir within a given year. The capture of these ripe females during a limited spring spawning period is highly questionable.

Seven evolutionary significant units (ESUs) for white sturgeon have been defined for white sturgeon on the Pacific Coast of North America. The Columbia River white sturgeon population consists of two ESUs. These two ESUs consist of the Upper Columbia River Population in Canada and the United States and the lower/middle Columbia River in the United States. Because the lower and mid Columbia regions are considered the same ESU, additional options may be available regarding acquisition of brood stock and/or juvenile white sturgeon for stocking purposes. It may not be possible to acquire brood stock from nearby reservoirs within the Mid-Columbia as these populations also contain low numbers of individual fish and similar problems regarding brood stock capture would probably be experienced.

It may be possible to collect white sturgeon within the lower Columbia River for brood stock or transplant purposes. Brood stock could be collected from the lower Columbia River to provide managers with the ability to begin a hatchery supplementation program. Additionally juvenile or adult sturgeon could be trapped within the lower Columbia River and transported for direct release into Wells Reservoir.

Regardless of which future management options is implemented, continued monitoring programs will be vital to evaluate the success of restoration efforts within the study area.

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