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Evaluate Potential Means of Rebuilding Sturgeon Populations in the Snake River between Lower Granite and Hells Canyon Dams

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EVALUATE POTENTIAL MEANS OF REBUILDING STURGEON POPULATIONS IN THE SNAKE RIVER BETWEEN LOWER GRANITE AND HELLS CANYON DAMS

1999 Annual Report

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ABSTRACT

The specific research goal of this project is to identify means to restore and rebuild the Snake River white sturgeon (*Acipenser transmontanus*) population to support a sustainable annual subsistence harvest equivalent to 5 kg/ha/yr (CBFWA 1997). Based on data collected, a white sturgeon adaptive management plan will be developed. This 1999 annual report covers the third year of sampling of this multi-year study.

In 1999 white sturgeon were captured, marked and population data were collected in the Snake and Salmon rivers. A total of 33,943 hours of setline effort and 2,112 hours of hook-and-line effort was employed in 1999. A total of 289 white sturgeon were captured and tagged in the Snake River and 29 in the Salmon River. Since 1997, 11.1 percent of the tagged white sturgeon have been recaptured. In the Snake River, white sturgeon ranged in total length from 27 cm to 261 cm and averaged 110 cm. In the Salmon River, white sturgeon ranged in total length from 98 cm to 244 cm and averaged 183.5 cm. Using the Jolly-Seber model, the abundance of white sturgeon <60 cm, between Lower Granite Dam and the mouth of the Salmon River, was estimated at 1,823 fish, with a 95% confidence interval of 1,052-4,221.

A total of 15 white sturgeon were fitted with radio-tags. The movement of these fish ranged from 6.4 km (4 miles) downstream to 13.7 km (8.5 miles) upstream; however, 83.6 percent of the detected movement was less than 0.8 kilometers (0.5 miles). Both radio-tagged fish and recaptured white sturgeon in Lower Granite Reservoir appear to move more than fish in the free-flowing segment of the Snake River. No seasonal movement pattern was detected, and no movement pattern was detected for different size fish.

Differences were detected in the length frequency distributions of white sturgeon in Lower Granite Reservoir and the free-flowing Snake River (Chi-Square test, $P<0.05$). The proportion of white sturgeon greater than 92 cm (total length) in the free-flowing Snake River has shown an increase of 29 percent since the 1970's.

Analysis of the length-weight relationship indicated that white sturgeon in Lower Granite Reservoir were slightly larger than white sturgeon in the free-flowing Snake

River. A von Bertalanffy growth curve was fitted to 49 aged white sturgeon. The results suggests the fish are currently growing faster than fish historicly inhabiting the study area, as well as other Columbia River basin white sturgeon populations.

Artificial substrate mats were used to document white sturgeon spawning. Five white sturgeon eggs were recovered in the Snake River.

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INTRODUCTION

Traditionally, the Nez Perce people harvested Snake River white sturgeon (*Acipenser transmontanus*) for subsistence purposes. However, subsistence fishing has been severely limited as a result of low white sturgeon numbers between Hells Canyon and Lower Granite dams. Development of the Columbia River Basin hydroelectric system has created impoundments that have altered the habitat and movement of white sturgeon and their principal food resources in the Lower Snake River between Hells Canyon and Lower Granite dams. The goal of this project is to identify means to restore and rebuild the Snake River white sturgeon population between Hells Canyon and Lower Granite dams capable of supporting a sustainable annual subsistence harvest of white sturgeon equivalent to 5 kg/ha/yr (CBFWA 1997). If the population has not changed dramatically over the last 25-29 years since the completion of Lower Granite Dam in 1975, and the closure of catch-and-keep fishing in 1970, then implementation of scientifically sound mitigative strategies would be needed to realize the harvest objective.

It is hypothesized that: 1) natural production of white sturgeon is less than what it was before construction and operation of the hydropower system, 2) white sturgeon rearing habitat in many areas is under seeded because of the reduction in spawning habitat caused by the hydropower system construction and operations, 3) white sturgeon production can be significantly enhanced by some combination of spawning and rearing habitat restoration, and/or supplementation, and 4) naturally spawning white sturgeon populations can be preserved and optimum rates of production can be restored while concurrently maintaining tribal and recreational fishing opportunities (CBFWA 1997). However, additional data are needed to fully assess these hypotheses and develop a strategy to restore the Snake River white sturgeon population between Hells Canyon and Lower Granite dams.

The 1994 Northwest Power Planning Council Fish and Wildlife Program (NPPC - FWP) section 7.3B.1 called for fisheries managers to complete a biological risk assessment that addressed the informational needs pertaining to the Hells Canyon white sturgeon population. In 1996, the Biological Risk Assessment Team (BRAT), consisting of regional fisheries managers and researchers, was convened. The highly coordinated

Phase I assessment was completed during 1997. This assessment identified: 1) potential mitigative actions to meet the project goal, and 2) data needs to fully assess the risks associated with applied actions. In addition, a multi-year study plan (Hoefs 1997) was developed to collect information identified by the BRAT. The 1994 NPPC -FWP (sections 10.4A.1 and 10.4A.4) called for the Bonneville Power Administration (BPA) to fund the Nez Perce Tribe to prepare an evaluation of potential means of rebuilding white sturgeon populations between Lower Granite Dam and Hells Canyon Dam (NPPC 1994). Phase II, the data collection phase of the project, was initiated in 1997 and will continue through 2002. Research conducted in 1997 and 1998 is reported in Hoefs (1998) and Tuell and Everett (2000).

Based on data collected during Phase II an adaptative management plan will be developed. The adaptative management plan will: 1) fully assess the risks and uncertainties associated with potential mitigative actions identified by the BRAT (Carmichael et al. 1997), 2) make recommendations to implement alternative mitigative actions designed to restore and rebuild the white sturgeon population to obtain a sustainable annual tribal subsistence harvest of 5 kg/ha/yr (CBFWA 1997), and 3) develop an adaptive management plan for the implementation, evaluation and monitoring of effects of applied mitigation action on the Snake River white sturgeon population between Hells Canyon and Lower Granite dams. Table 1 outlines specific tasks for data collection during Phase II as identified in Hoefs (1997).

The primary focus of sampling in 1999 was to capture and mark white sturgeon in the Snake and Salmon rivers in order to estimate population abundance, distribution and growth. In addition, data were collected on white sturgeon movement, spawning and rearing. This report presents results from 1999 Phase II data collection.

Table 1. Phase II research objectives designed to collect information to fully assess the risk and effectiveness associated with potential management actions (modified from Hoefs 1997).

Goal: Collect biological and environmental data identified by the *Upper Snake River White Sturgeon Biological Risk Assessment* that will allow identification and assessment of mitigative actions designed to restore, protect and enhance the sturgeon population between Hells Canyon and Lower Granite dams and will establish a baseline on which to assess effectiveness of applied mitigative actions.

Objective 1. Assess the health and status of the Snake River white sturgeon population between Hells Canyon and Lower Granite Dams.

Task 1.1 Estimate white sturgeon abundance throughout entire reach and determine if there has been any marked change in abundance or age structure of the population over the last 25 years.

Task 1.2 Determine distribution/movements of fish, abundance of various age classes of white sturgeon per reach throughout the system and determine what environmental factors (velocity, flow, temperature, substrate) may affect distribution.

Task 1.2 Collect life history data for subadult and adult white sturgeon to model population dynamics.

Objective 2. Define habitat used for spawning and rearing of white sturgeon in the Snake River between Lower Granite and Hells Canyon Dams.

Task 2.1 Define habitat used for spawning. Identify environmental conditions associated with spawning: document timing, duration, location and environmental conditions.

Task 2.2 Identify distributions of larvae and young of the year throughout the area and identify associated environmental factors that define 'nursery' habitat.

Task 2.3 Identify rearing habitat for juvenile and adult white sturgeon.

Objective 3. Develop plans to address other informational needs identified by the BRAT not covered by tasks listed above.

METHODS

Study Area

The study area included 314 river kilometers (Rkms; 195 river miles) in the Snake and Salmon rivers (Figure 1). Sampling occurred in the Snake River between Lower Granite Dam (Rkm 174) and the mouth of the Salmon River (Rkm 303) and in the Salmon River from its mouth to Vinegar Creek (Rkm 185). The Snake River was divided into eight sampling reaches, while the Salmon River was divided into four sampling reaches. Reaches ranged from 16 km to 33 km in length in the Snake River and 42 km to 53 km in length in the Salmon River. The habitat encountered in these 314 Rkm was diverse, ranging from deep (>30 m) slack water pools in Lower Granite Reservoir to class

III and IV rapids in the free-flowing Snake and Salmon rivers. Furthermore, one-third of the study area was accessible by boat only. In addition to sampling the Snake and Salmon rivers, select areas of the Clearwater River were sampled from its mouth upstream to near Orofino, Idaho (Rkm 74).

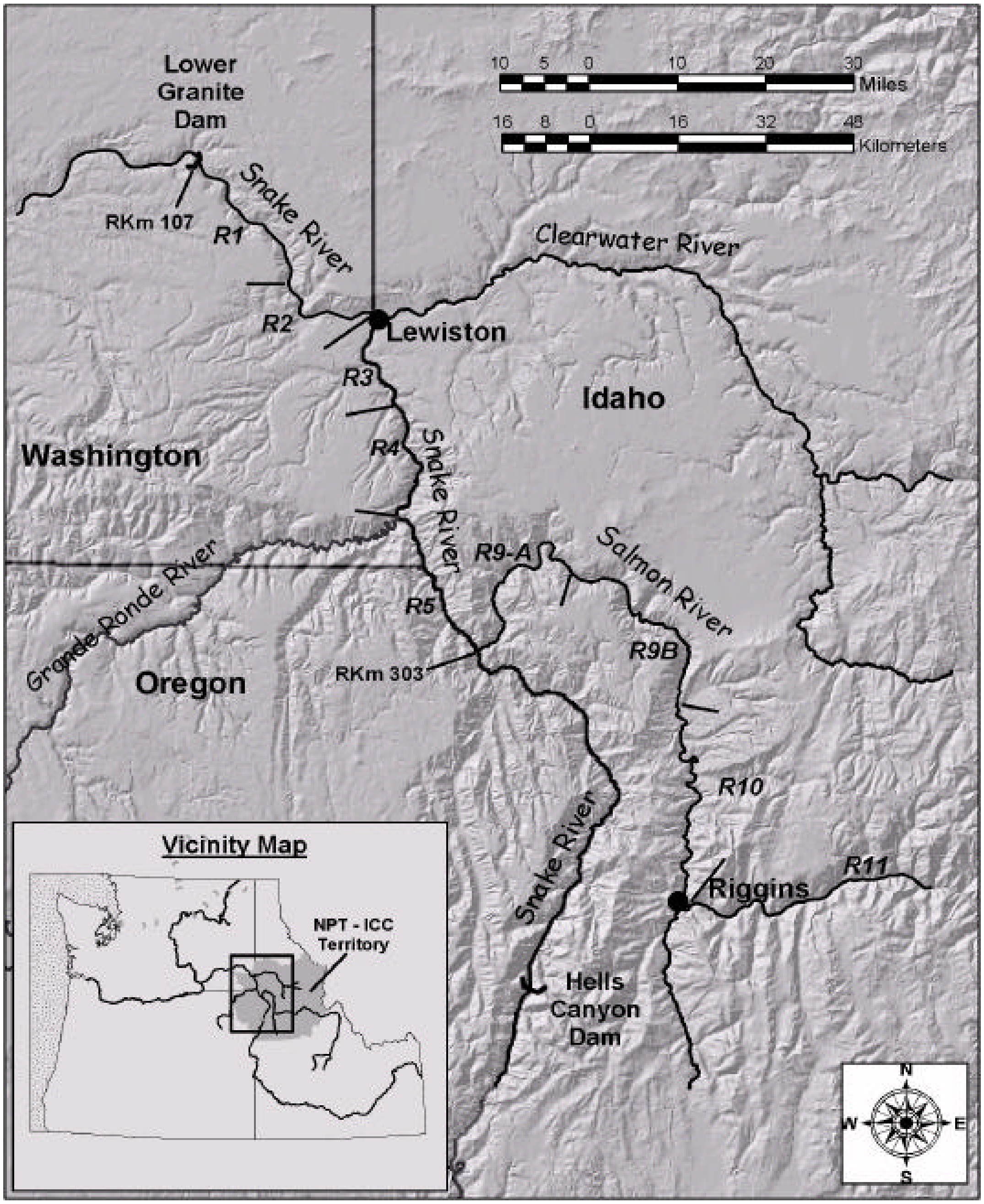

Figure 1. Map of study area. Sampling reaches identified as R1 through R11.

Fish Sampling

The research study design (Hoefs 1997) called for stratified random sampling of reaches at weekly intervals from January through December (Table 2). Sampling sites were randomized within each reach. Reaches were divided into 0.8 km (0.5 mile) sampling segments, each segment was considered a potential sampling site, and 20 sampling sites were randomly chosen within a reach. Setlines and hook-and-line sampling were used to capture white sturgeon, depending on flow characteristics. Sampling sites were not stratified by habitat characteristics (depth, velocity or substrate type), thus catches were unbiased by habitat conditions to which white sturgeon may or may not be responding. Habitat data were collected at each sampling site. These data will be used to test correlations between white sturgeon presence and habitat characteristics.

Setlines consisted of 30 m of anchored bottom-line with ten gangen lines attached by snaps approximately every 3 m (Apperson and Anders 1990, Lepla 1994, Thomas and Haas 1999). Gangen were rigged with galvanized circle hooks to reduce potential hooking injury. A combination of ten 8/0, 10/0, 12/0, 14/0 and 16/0 galvanized hooks were used on each line. Pickled squid and lamprey were used as bait. Setlines were checked twice a day and empty hooks rebaited. Set hours were recorded and the catch-per-unit-effort (CPUE) was calculated based on the hours a line with ten hooks was fished. White sturgeon size selectivity was evaluated by examining total length frequency distributions of catch among hook sizes (Elliott and Beamesderfer 1990). In 1999, the addition of 8/0 hooks was evaluated to see if the total length frequency distribution of captured white sturgeon shifted toward smaller fish. Comparisons were made using a Chi-squared analysis on the proportion of fish sampled in each 20 cm (total length) size class.

Hook-and-line sampling was used primarily in the upper reaches of the Salmon River where water conditions prevented the use of setlines. Hook-and-line sampling was used throughout the remaining study area to supplement setline sampling. Sixty-pound test or greater Dacron line with either barbless 'J' hooks or barbless circle hooks of varying size (8/0 to 16/0) were used. A variety of bait types (e.g., lamprey, pickled squid) were used also. Hours fished were recorded, and the CPUE was calculated based on man-hours spent fishing.

Table 2. Location and calendar week for white sturgeon sampling in the Snake, Salmon and Clearwater rivers, 1999.

Study Reach	Location Description	Lower Rkm	Upper Rkm	Weeks Sampled
1	Lower Segment Lower Granite Reservoir	174	206.5	7, 16, 23, 44
2	Upper Segment Lower Granite Reservoir	207	223.5	11, 21, 34, 41
3	Clearwater River - Tenmile Rapids	224	239.5	3, 19, 24, 28, 35, 42
4	Tenmile Rapids - Grand Ronde River	240	270.5	5, 15, 27, 36, 49
5	Grande Ronde River - Salmon River	271	302.5	9, 15, 37, 45, 50
6	Salmon River - West Creek[1]	303	343.5	
7	West Creek – Sheep Creek[1]	344	368.5	
8	Sheep Creek – Hells Canyon Dam[1]	369	398	
9a	Lower Salmon River Gorge	0	41.5	30, 32, 46
9b	Upper Salmon River Gorge	42	83.5	6, 20, 31, 48
10	Middle Salmon River[2]	84	131.5	2, 4, 14, 26, 38, 43
11	Upper Salmon River[2]	132	185	8, 13, 22, 23, 28, 29
12	Clearwater River	0	74	21

[1]Sampled by Idaho Power Company
[2]Hook-and-line effort only

Concurrent with the work being done by the Nez Perce Tribe, Idaho Power Company (IPC) is assessing the status of white sturgeon in the Hells Canyon Reach of the Snake River (Rkm 303 to Rkm 462; IPC 1997). Because of the similarity in objectives and tasks, the Nez Perce Tribe and IPC have a formal agreement for data sharing. Thus, our 1999 random stratified sampling conducted for population abundance did not include the Snake River above the mouth of the Salmon River. The Clearwater River was sampled using both setlines and hook-and-line. Because the number of white sturgeon reported in the Clearwater River is historically low, areas where white sturgeon have been reported in the Clearwater River were targeted instead of applying a randomized sampling design. The objective of sampling in the Clearwater River was to document the current distribution of white sturgeon, not to estimate the population abundance.

All white sturgeon captured were processed aboard the collection boat, or at the site of collection near the shore. White sturgeon brought aboard the boat were placed in a vinyl stretcher or large PVC trough, and their gills flushed with river water while being processed. After the fish were processed they were released at their location of capture.

Fish captured were checked for previous marks and tags (tag scars, fin marks, scute marks, and missing barbels and tags). New captures were tagged using a 15 mm, 134 Khz, Passive Integrated Transponder (PIT) tag injected near the armor of the head on the left side (North et al. 1996). Total and fork length (cm), girth (cm), and weight (0.1 kg) of the fish were measured and recorded.

Abundance

A mark-recapture study design was used to investigate the abundance of white sturgeon between Lower Granite Dam and the mouth of the Salmon River. Using a multiple sampling-pass model, white sturgeon have been captured, marked and released in the study area since 1997 (Hoefs 1999, Tuell and Everett 2000). Sampling passes were arranged as complete surveys of the entire study area and combined to consist of similar sampling effort. White sturgeon recaptured within the same pass were not regarded as recaptures for use in the population estimate.

Several authors have reported white sturgeon abundance estimates for the Hells Canyon reach of the Snake River (Coon et al. 1977, Lukens 1985, Lepla 1994, Bennett et al. 1993). In these previous studies, both open and closed population estimators were utilized to calculate abundance. In order to better evaluate changes in the abundance, both types of estimators, a closed model and an open model, were selected to calculate the current population abundance. The first was a modified Schnabel estimate (Schnabel 1938) given by the following:

$$\hat{N} = \frac{\#\#\# (C_t M_t)}{\#\#\# (R_t)+1}$$

where $\hat{N}$ is the population abundance estimate, C_t is the total number of fish caught in sampling pass t, R_t is the number of fish already marked when captured during sampling pass t, and M_t is the number of marked fish in the population before sample pass t. The Schnabel model has the following assumptions:

1. The population is closed;
2. All fish are equally likely to be captured in each sample;
3. Capture and marking do not affect catchability;
4. Each sample is random, and;
5. Marks are not lost between sampling.

The 95% confidence interval for the Schnabel model's population abundance estimate was calculated using the method described in Zar (1996).

The second method estimates population abundance according to the method of Jolly (1965) and Seber (1982). This estimator assumes an open population structure and was calculated using computer software (Krebs 1998). The model equation is given by:

$$\hat{N} = \frac{\hat{M}_t n_t}{m_t}$$

where $\hat{N}$ is the population abundance estimate for sampling pass t, m_t is the number of fish marked prior to sampling pass t, n_t is the number of fish captured at sampling pass t, and $\hat{M}_t$ is calculated by the following:

$$\hat{M}_t = \frac{Z_t R_t}{r_t}$$

where Z_t is the number of marked fish that were not recaptured during sampling pass t, R_t is the number of fish released with marks at sampling pass t, and r_t is the number of fish captured during sampling pass t that were recaptured after sampling pass t. The Jolly-Seber model has the following assumptions:

1. The population need not be closed;

2. All fish are equally likely to be captured in each sample;
3. Capture and marking do not affect catchability;
4. Marks are not lost between sampling, and;
5. Sampling time is negligible in relation to intervals between samples.

The 95% confidence interval for the Jolly-Seber model's population abundance estimate was calculated using the method described in Manly (1984).

Specific size groups, based on the previous harvestable slot limit, were compared for fish captured in Lower Granite Reservoir (reaches 1-3), the free-flowing Snake River (reaches 4-5) and the Salmon River (reaches 9a and 9b). White sturgeon were separated into three size groups: less than 92 cm, 92-183 cm and greater than 183 cm (Coon et al. 1977). Comparisons were made using a Chi-squared analysis on the proportion of fish sampled in each size group.

Age and Growth

Pectoral fin rays was collected for age determination from a subsample of fish from three river segments: Lower Granite Reservoir, the free-flowing Snake River and the Salmon River. The lead ray of the left pectoral fin was clipped near the point of attachment and distally about 2.5 cm from this point (Wilson 1987, Devore et al. 1995, Beamesderfer et al. 1995). Each ray was cleaned and cut using a procedure similar to that outlined by Brennan and Cailliet (1989). This method has been validated for both lake sturgeon (Rossiter et al. 1995) and white sturgeon (Brennan and Cailliet 1991, Tracy and Wall 1994). From near the proximal end of each ray, three sections were cut of 0.635 mm thickness with a Buehler Isomet low-speed saw with a diamond-edged blade. Sections were mounted on slides and aged using the aide of BioSonic's Optical Pattern Recognition System (OPRS). Annual growth rings were counted from the center of ossification (focus) anteriorly along the longest axis to the distal edge of each section (Rossiter et al. 1995). All work was done without specific knowledge of the length, weight, origin or gender of the fish. Two technicians interpreted each fin ray independently. If there was a discrepancy between the two annuli counts, then the fin ray was re-read by each technician. If the discrepancy was not resolved after the second reading, then the fin ray was re-read with both technicians present. If the discrepancy was not resolved after the third reading, then the fin ray was considered unreadable and removed from the sample.

We compared the results of the aging methods used in both the Lower Columbia River and previous Snake River (Hells Canyon) white sturgeon research studies with our method to verify their consistency. A random sample of 15 pectoral fin rays from our study was sent to the Oregon Department of Fish and Wildlife (ODFW) laboratory in Clackamas, OR. In addition, we aged a random sample of 15 pectoral fins rays from the Idaho Department of Fish and Game's (IDFG) previous study on the Snake River. A paired t-test was used to test for significant differences in age assignment between our methods and the two other studies.

Lengths-at-age were used to create a von Bertalanffy growth curve (Misra 1980; Moreau 1987). Fish from the reservoir, and the free-flowing segment of the Snake River, as well as the Salmon River were combined to create the growth curve. The von Bertalanffy growth function is given by:

$$L(t)=L_{\infty}\{1-e^{-K(t-t_0)}\}$$

where L_{∞} represents the length of an infinitely-old fish, K represents a curvature parameter or how fast the fish reach L_{∞}, and t_0 is an initial condition parameter. The data were fitted to the von Bertalanffy growth curve using nonlinear regression computer software (Sherrod 1992). Due to the small sample size, no statistical comparisons were made with historical data or white sturgeon populations in other Columbia River Basin reaches. However, graphical displays were included for visual comparison. Similarly, differences in growth rate between males and females were not examined due to small sample size.

Paired samples of total length and weight were fitted to the allometric weight equation:

$$W = aL^b$$

where W represents the weight of the fish in kg, and L represents its total length in cm. Relative weights (W_r) were calculated for the reservoir and free-flowing segments of the Snake River and the Salmon River using the standard weight equation given by:

$$W_s = 2.735\ E\text{-}6 * L^{3.232}$$

developed by Beamesderfer (1993). Relative weight was determined by dividing the actual weight of the fish by the standard weight (W_s) for a fish of that length and then multiplying by 100. Only white sturgeon 60 cm and larger were included in the calculation of W_r. Using W_r, Snake River white sturgeon condition factor was compared between the reservoir and free-flowing segments using a two-sample t-test. Due to the small sample size, no statistical comparisons were made with Salmon River white sturgeon using W_r. However, graphical comparisons were included in the analysis. The allometric growth curves reported for several Columbia River Basin white sturgeon populations were plotted with the growth curves from the Lower Granite Reservoir, the free-flowing Snake River and the Salmon River. In addition, historical growth curves reported for the Snake River population were also graphically displayed for visual comparison.

Spawning

Artificial substrate mats (McCabe and Beckman 1990) were used to document white sturgeon spawning. The substrate mats were modified by Parley and Kappenman (2000). The mats were held to the river bottom with concrete anchors that were secured to the substrate frame with a steel cable. A buoy line was attached to the anchors for retrieval. The substrate mats provided a course surface area for the highly adhesive white sturgeon eggs to attach. Sampling time was selected to correspond with the peak spawning temperatures, approximately 10 to 18º C (Parley and Kappenman 2000). Mats were retrieved every 48-72 hours (Marchant and Shutters 1996) and examined for eggs and larvae. Eggs and larvae were preserved in formalin for later identification. Temperature, near substrate velocity and substrate were recorded at sampling sites.

Movement

Movement and migration patterns of white sturgeon were investigated using telemetry and mark-recapture data. Fish were selected based on three criteria. First, large maturing fish were targeted in order to identify spawning migrations and spawning habitat. Second, fish were selected based on location in order to get a representative sample throughout the study area. Finally, juvenile fish were selected to identify rearing locations and general movement patterns. White sturgeon were fitted with telemetry tags using a method similar to Haynes et al. (1978) and modified by Apperson and Anders (1990). Tags were placed on the left side of the proximal edge of the dorsal fin (Figure 2). A neoprene pad was inserted between the tag and the fish to cushion the tag and to reduce abrasion. In addition, instead of a PVC counter balance, a plastic plate cushioned with a neoprene pad was used on the opposite side of the tag. This plastic plate served to prevent the binding wires from working their way through the fish's flesh. Because of the diverse habitat encountered throughout the study area, a Combined Acoustic and Radio Tag (CART; Deary et al. 1998) was utilized. The CART's dual capability of transmitting both acoustic and radio frequencies allowed for tag detection in a variety of habitats. Acoustic frequencies can be detected in deep water; whereas, radio frequencies can be detected in shallow, more turbulent water. Tags were outfitted with three-year batteries.

Radio tracking was conducted by boat, vehicle, and plane/helicopter. Habitat data were recorded at sites where fish were detected by boat. Fish locations were tracked every two weeks. A tracking period covered several days, i.e. crews were given several days to locate a fish. A directional hydrophone deployed from a boat was used to receive acoustic signals. Four or six-element antennas were used to receive radio signals. Recaptured PIT tagged white sturgeon were used to supplement movement analysis.

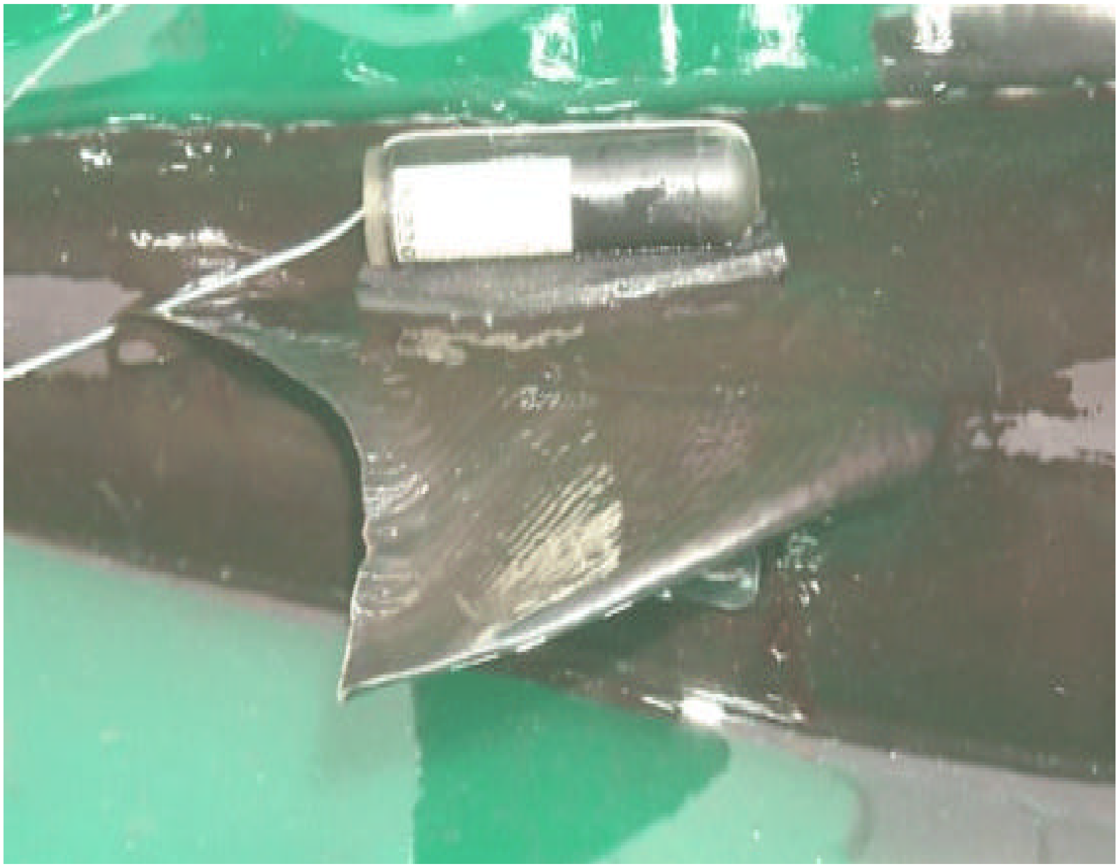

Figure 2. Placement of a Combined Acoustic Radio Tag (CART) on a white sturgeon.

RESULTS

Sampling Effort

A total of 33,943 hours of setline effort and 2,112 hours of hook-and-line effort was employed in 1999 (Table 3). In Lower Granite Reservoir (reaches 1-3), 18,116 hours of setline sampling was conducted with 154 hours of hook-and-line effort. In the free-flowing Snake River (reaches 4-5), 9,322 hours of setline sampling was conducted with 784 hours of hook-and-line effort. In the Salmon River (reaches 9-12), 6,402 hours of setline sampling was conducted with 1,146 hours of hook-and-line effort. A total of 80 white sturgeon were sampled from Lower Granite Reservoir, 209 from the free-flowing Snake River and 29 from the Salmon River (Appendix A). Although greater effort was employed in Lower Granite Reservoir, the overall catch was greater in the free-flowing segment of the Snake River. Moreover, the overall CPUE in the free-flowing Snake River reaches was 4.5 times greater than the CPUE in Lower Granite Reservoir.

Table 3. Sampling effort, catch and catch per unit effort (CPUE) per reach using setlines and hook-and-line sampling in the Snake, Salmon and Clearwater rivers in 1999.

Study Reach	Setline			Hook-and-Line		
	Effort (hrs)	**Catch**	**CPUE**	**Effort (hrs)**	**Catch**	**CPUE**
1	5,833	37	**0.006**	36	0	**0**
2	5,484	30	**0.005**	44	0	**0**
3	6,465	13	**0.002**	74	0	**0**
4	4,855	30	**0.006**	421	23	**0.054**
5	4,801	144	**0.030**	363	12	**0.033**
9a	2,949	20	**0.007**	19	0	**0**
9b	3,435	8	**0.002**	218	1	**0.005**
10	0	0	**0**	566	0	**0**
11	0	0	**0**	343	0	**0**
12	103	0	**0**	28	0	**0**
Total	33,943	282	**0.008**	2,112	36	**0.017**

Approximately 103 hours of setline sampling and 28 hours of hook-and-line sampling were conducted in the Clearwater River during 1999. No fish were captured. Sampling was concentrated around Slaughter House Hole near Orofino (Rkm 67), the mouth of the North Fork near Orofino (Rkm 65), Pink House Hole near Orofino (Rkm 63), the mouth of Big Canyon Creek near Peck (Rkm 56), Big Eddy near Lenore (Rkm 45), the bridge near Cherry Lane (Rkm 34), the beach at Myrtle (Rkm 29), and Lapwai Creek near Spalding (Rkm 19).

Abundance

During 1999, 289 white sturgeon were captured in the Snake River and 29 in the Salmon River. Of these, 232 were unmarked and 86 were previously marked fish. These 232 fish plus the 536 from 1997-98 bring the total number of marked fish in the study area to 768. No fish mortalities occurred during collection or processing. In Lower Granite Reservoir white sturgeon ranged from 54 cm to 225 cm total length and averaged 122 cm (Figure 3). White sturgeon captured in the free-flowing segment of the Snake River ranged from 27 cm to 261 cm total length and averaged 105 cm (Figure 4). White sturgeon captured in the Salmon River ranged from 98 cm to 244 cm total length and averaged 184 cm (Figure 5).). In 2000, incidental captures consisted of 9 channel catfish (*Ictalurus punctatus*), 6 largescale suckers (*Catostomus macrocheilus*) 4 smallmouth bass (*Macropterus dolomieui*) and 3 carp (*Cyprinus carpio*).

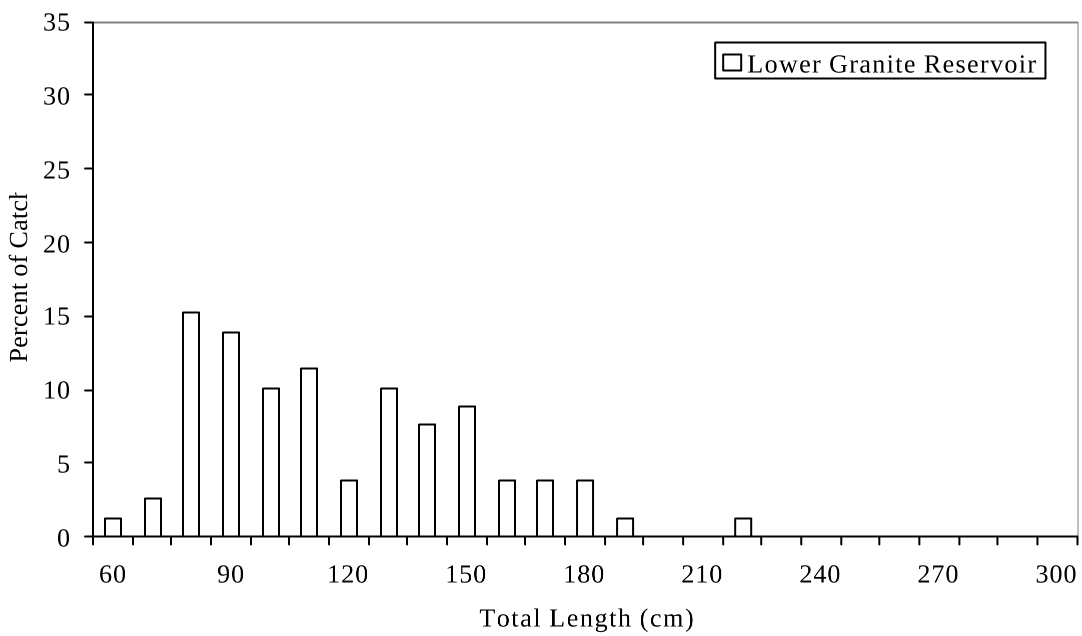

Figure 3. Percent length frequency distribution of white sturgeon captured in Lower Granite Reservoir in 1999.

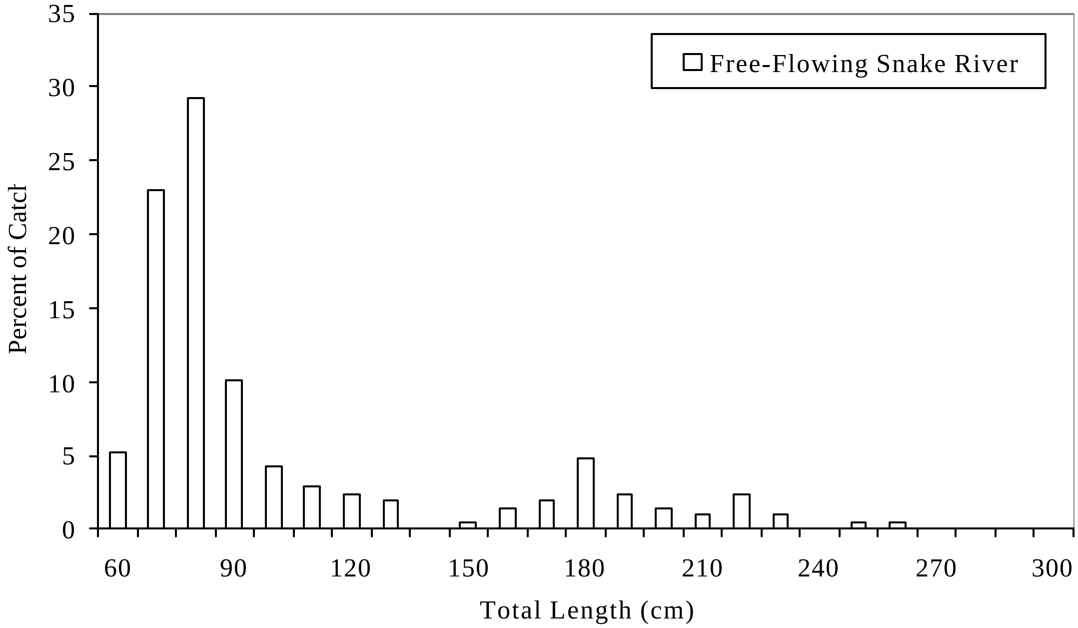

Figure 4. Percent length frequency distribution of white sturgeon captured in the free-flowing Snake River in 1999.

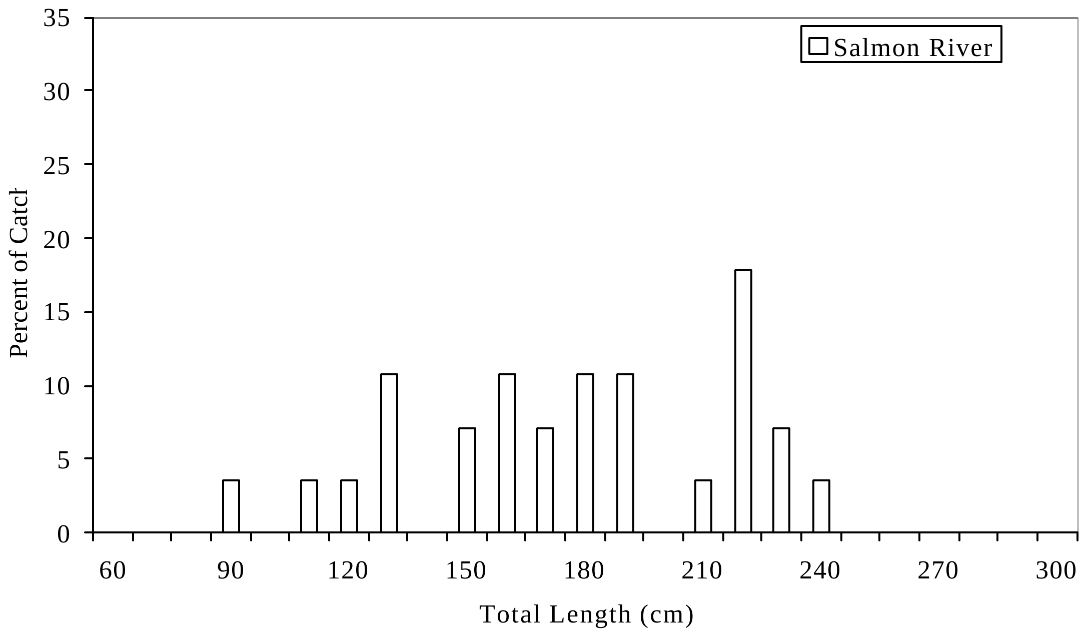

Figure 5. Percent length frequency distribution of white sturgeon captured in the Salmon River in 1999.

The proportion of white sturgeon within each size class significantly differed (Chi-Square test, $P<0.05$) between fish captured in Lower Granite Reservoir and the free-flowing segment of the Snake River in 1999. Similarly, these proportions differed significantly (Chi-Square test, $P<0.05$) between these two river segments in both 1997 (Hoefs 1998) and 1998 (Tuell and Everett 2000). However, within each river segment, no significant differences (Chi- Square test, $P>0.05$) were detected in the proportions of different size classes between 1997-99. Due to small sample size no comparisons were made with Salmon River fish.

A comparison of length frequency distributions indicate different hook sizes select for different fish size (Figure 6). The proportion of white sturgeon captured within the 20 cm length intervals was significantly different across the various hook sizes ($\div^2=77.0$; d.f.=44; $P<0.05$). A larger proportion of small fish were captured with small hooks and a larger proportion of large fish were captured with large hooks. However, no significant difference ($\div^2=5.5$; d.f.=9; $P>0.05$) was detected in the length frequency distributions between 1997-98 and 1999 with the addition of 8/0 hooks during setline sampling (Figure 7). Furthermore, white sturgeon 60 cm and larger appear fully recruited to the range of hook sizes (8/0 to 16/0) employed during this study.

Since 1997, 12 complete sampling passes have been conducted in the Snake River study area. Due to the low numbers of recaptured white sturgeon within individual passes, several complete passes were combined. Both the closed and open model abundance estimators were based on a five-pass model. In the Salmon River, the number of recaptures was too low to calculate an abundance estimate. The abundance of white sturgeon >60 cm TL was estimated by the modified Schnabel estimator to be 2,544 with a 95 percent confidence interval of 2,001-3,492. Using the open model, Jolly-Seber estimate, the abundance was estimated to be 1,823 with a 95 percent confidence interval of 1,052-4,221. The surface area of the Snake River from Lower Granite Dam to the mouth of the Salmon River is estimated at 4,450 ha (Les Cunningham, U.S. Army Corps of Engineers, pers. comm.). Therefore, the density of white sturgeon in that segment of the Snake River is estimated between 0.45 and 0.78 fish/ha using the Schnabel estimate, or 0.24 and 0.95 fish/ha using the Jolly-Seber estimate.

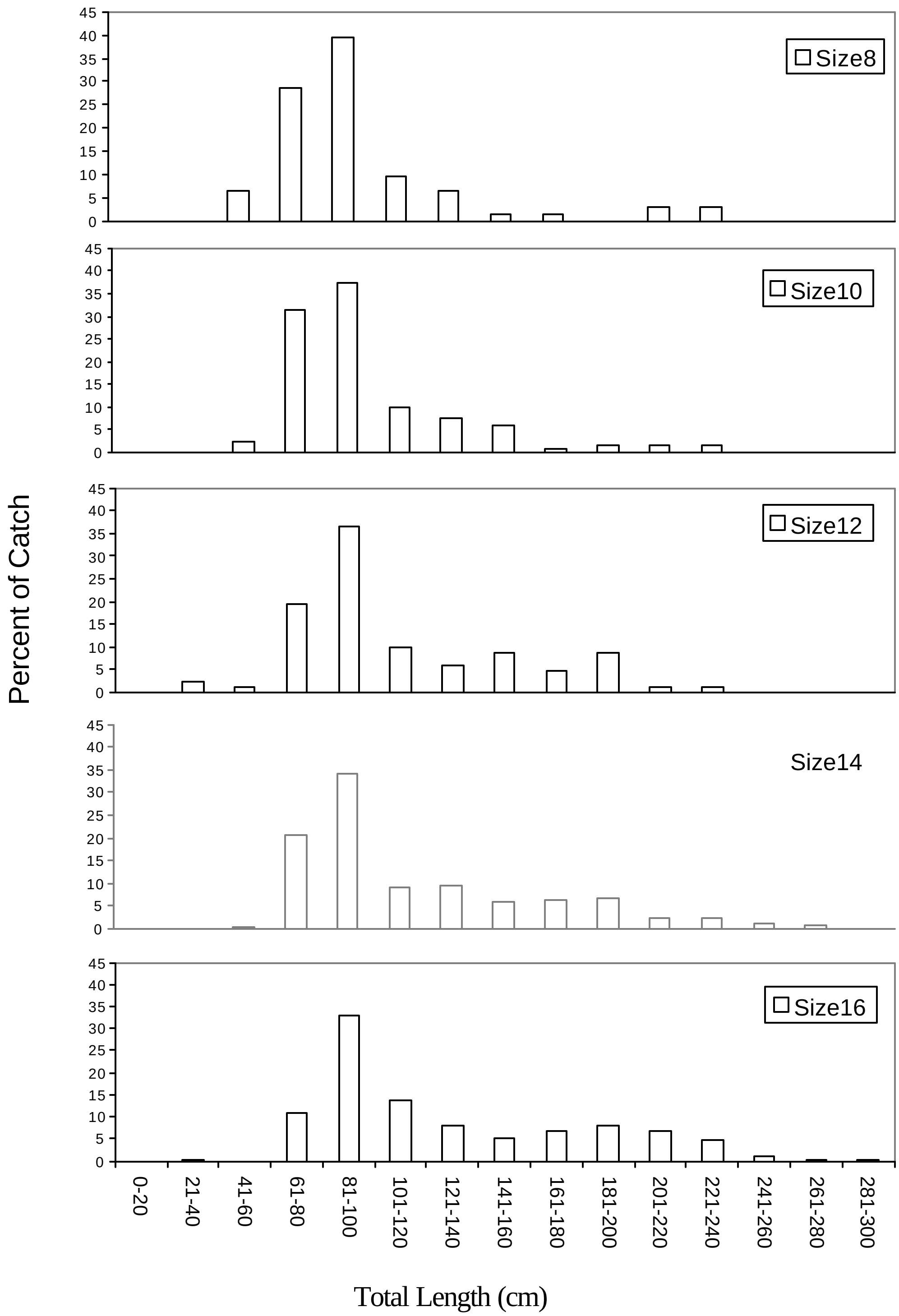

Figure 6. Length frequency distribution of white sturgeon captured in the Snake and Salmon rivers by hook size, 1997-1999.

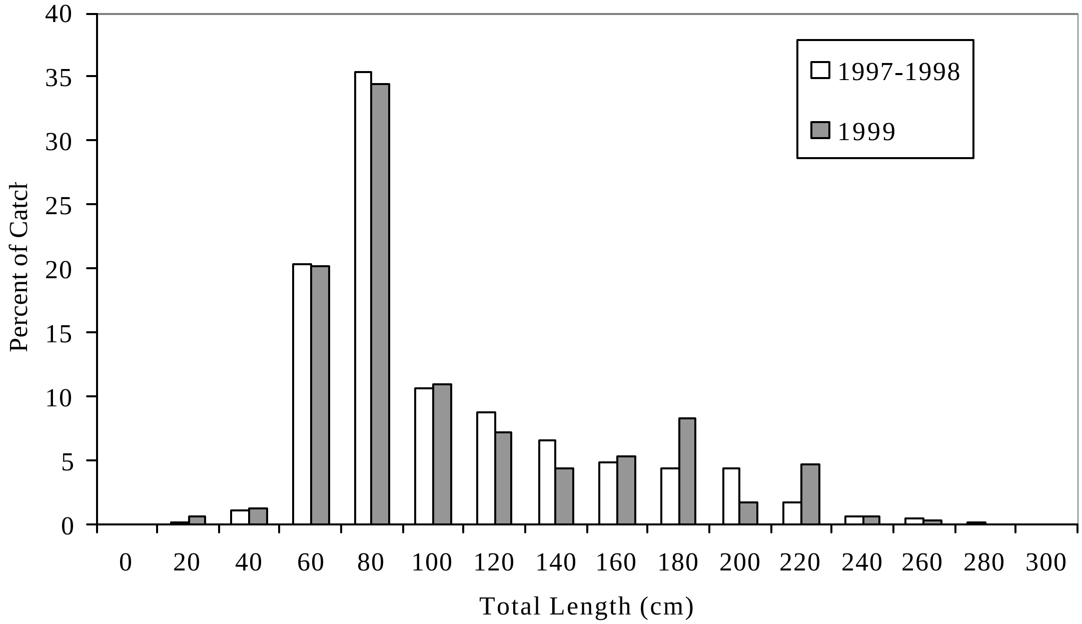

Figure 7. Comparison of the total length frequency distributions of white sturgeon catch during 1997-98 and 1999.

Age and Growth

A total of 56 white sturgeon had pectoral fin rays sampled for age determination from the three river segments: 9 fish from the reservoir segment, 32 fish from the free-flowing segment, and 15 from the Salmon River. The age assignment procedure resulted in 7 fish being removed from all samples due to age discrepancies (Table 4). The 49 white sturgeon assigned ages ranged from four to 35 years old. The largest white sturgeon aged was a 35-year-old female, 261 cm TL, and the smallest an age-4 fish, 60 cm TL. The von Bertalanffy growth curve (Figure 8) generated from length-at-capture data is given by $L(t)=288(1-e^{-0.05(t+0.8)})$ where L(t) is total length in cm. We found no significant difference (paired t-test; $P<0.05$) in age assignments between our method and either ODFW's method (Lower Columbia River studies) or IDFG's method (previous Snake River studies).

Table 4. Summary of pectoral fin rays collected by river segment, aged, and removed from analysis because of age discrepancies.

Location	Number of Samples		
	Collected	Removed	Aged
Lower Granite Reservoir	9	2	7
Free- Flowing Snake River	32	4	28
Salmon River	15	1	14
Total	56	7	49

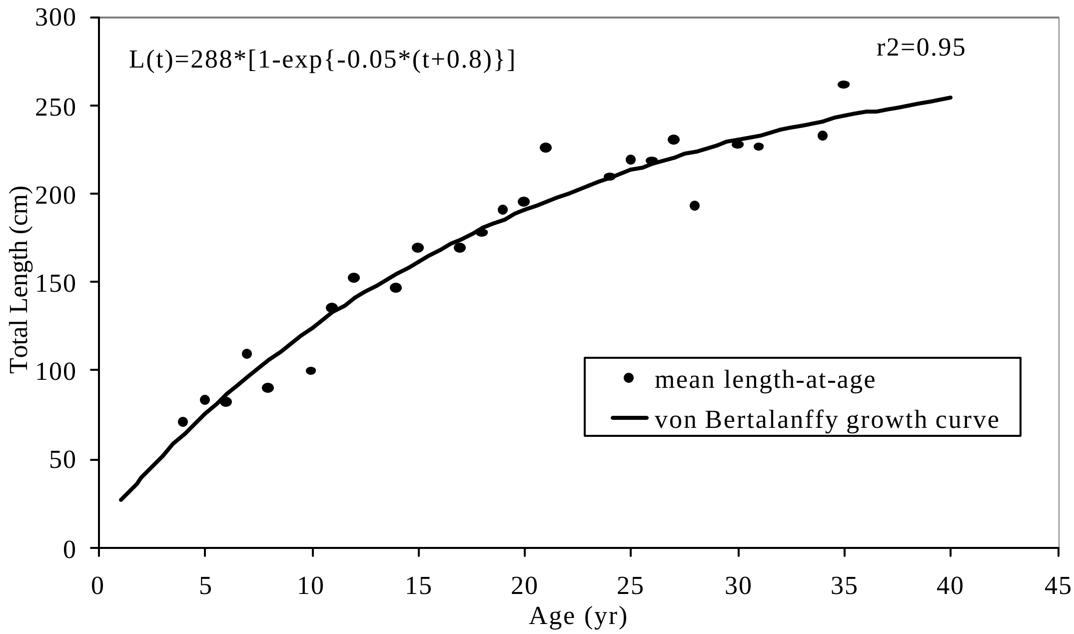

Figure 8. The von Bertalanffy growth curve fitted to 49 aged white sturgeon in the Snake and Salmon Rivers, 1999.

A total of 264 of the 278 white sturgeon from the Snake and Salmon rivers were measured for weight (kg). These fish ranged from 27 to 261 cm in total length and weighed between 0.4 and 119.6 kg. The allometric relationship between weight (kg) and total length (cm) derived for white sturgeon collected in Lower Granite Reservoir, the free-flowing Snake River and the Salmon River was $W = (1.80 E\text{-}06)L^{3.22}$ (Figure 9), W

= (1.10 E-06)$L^{3.31}$ (Figure 10), and W =(6.83 E-06)$L^{2.95}$ (Figure 11), respectively. The overall mean W_r for white sturgeon 60 cm and larger captured in Lower Granite Reservoir, the free-flowing Snake River and the Salmon River was 93.4, 87.1 and 86.4, respectively. The W_r differed significantly between the reservoir and free-flowing segments (t-test; $P<0.05$). Due to small sample size no comparisons were made with Salmon River fish.

Spawning

Select fish over 150 cm total length were examined for gender and spawning stage. Gender was determined for 32 of the 43 white sturgeon examined. A total of 17 fish were determined to be female, and 15 fish were determined to be male.

In 1999, 22 artificial egg mats were deployed in selected areas throughout the study area based on suspected use of spawning white sturgeon and/or the reported presence of young-of-the-year (YOY) white sturgeon. A total of 8,448 hours of artificial egg mat effort was conducted in the Snake River. Five white sturgeon eggs were recovered (Table 5). During the time the eggs were found, the average daily discharge at the Snake River gage at Anatone (Rkm 269) ranged from 1,812 to 3,500 m^3/s (64,000 to 125,000 cfs) (Figure 12). At sites where eggs were found, the mean substrate velocity was 1.1 m^3/s, mean water temperature was 15.8º C and mean depth was 5.2 m. At each egg location, the primary substrate type was sand. All eggs were recovered between 100 and 200 meters below a major rapid.

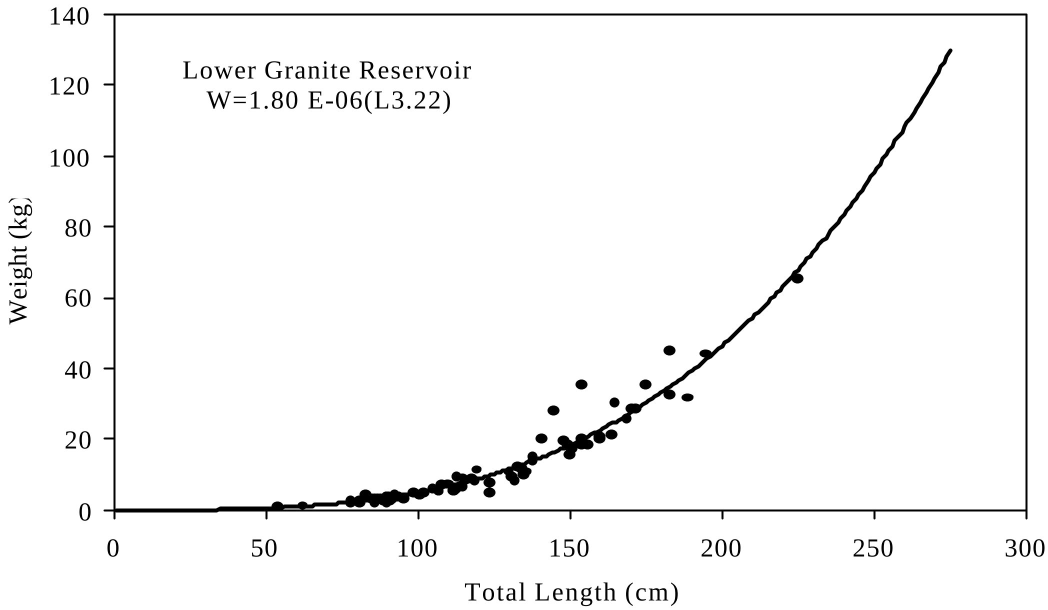

Figure 9. Allometric relationship between weight (kg) and total length (cm) for white sturgeon collected in Lower Granite Reservoir during 1999.

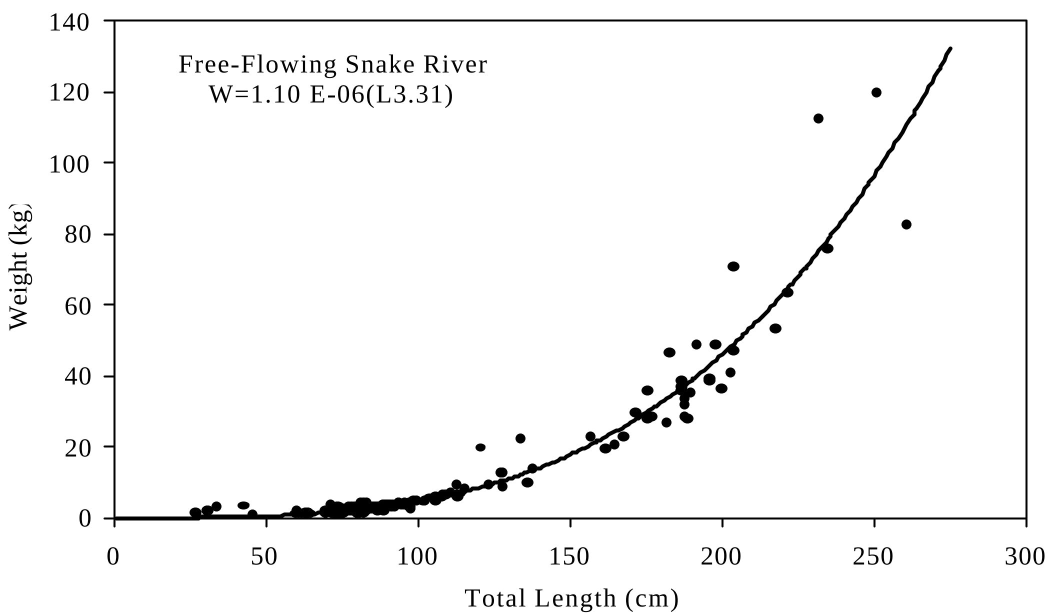

Figure 10. Allometric relationship between weight (kg) and total length (cm) for white sturgeon collected in the free-flowing Snake River during 1999.

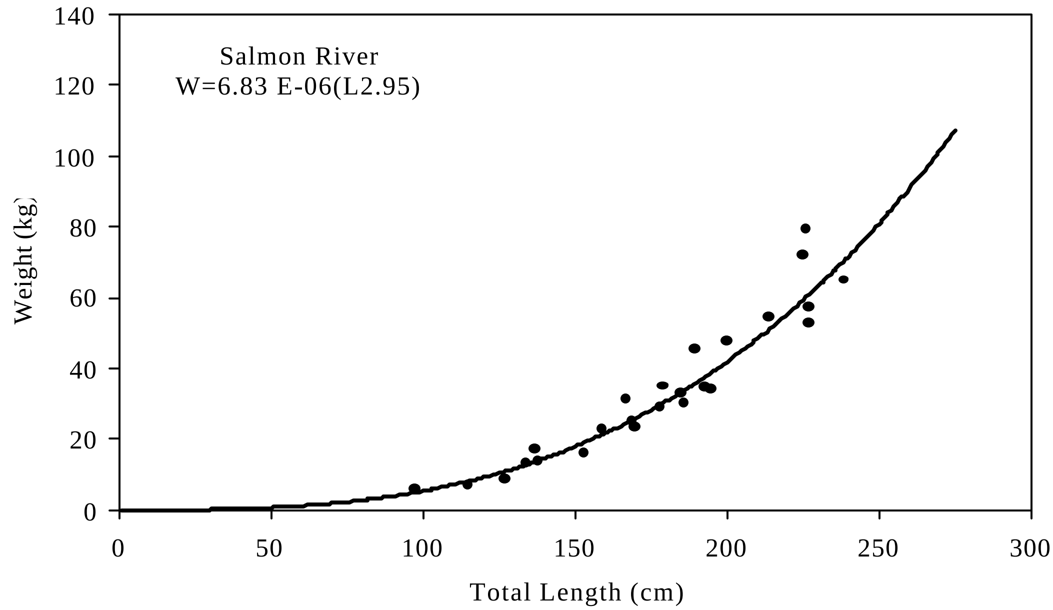

Figure 11. Allometric relationship between weight (kg) and total length (cm) for white sturgeon collected in the Salmon River during 1999.

Table 5. Habitat characteristics at sites where white sturgeon eggs were recovered in 1999.

Date	**Rkm**	**Depth (m)**	**Substrate**	**Near Substrate Velocity (m^3/s)**	**Temp. (° C)**	**Number of Eggs**
6/14	274.3	4.6	sand	1.2	15	1
6/16	290	6.4	sand	0.7	15.5	3
7/1	290	4.6	sand	1.5	17	1

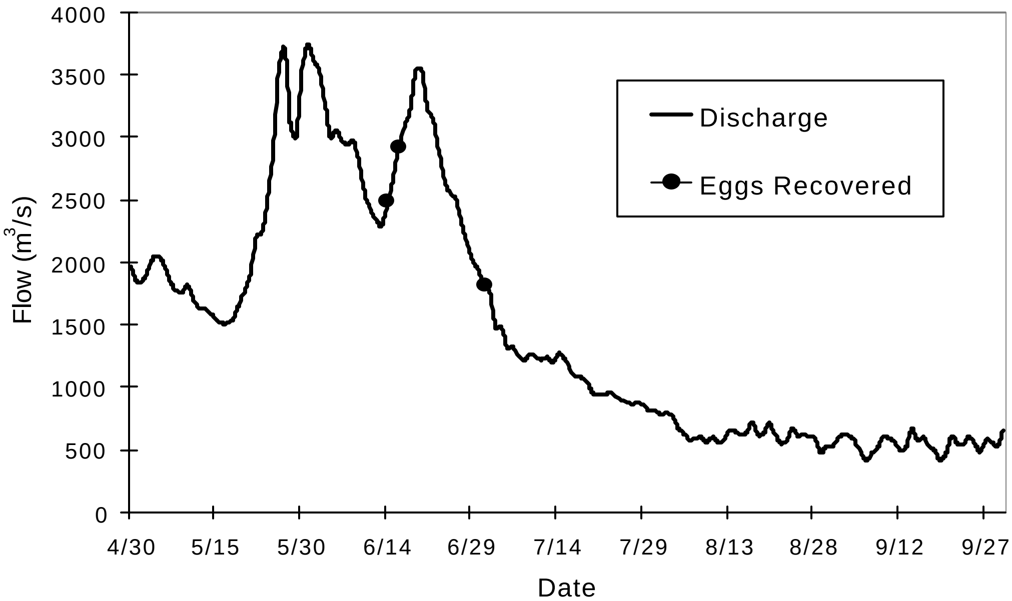

Figure 12. Daily average discharge at the Snake River, Anatone gauge when white sturgeon eggs were collected in the Snake River, 1999 (USGS gauge number 13334300).

Movement

A total of 15 white sturgeon were fitted with radio tags in 1999 (Appendix B). Radio-tagged fish ranged in total length from 108.5 to 261 cm. White sturgeon were tracked throughout the year beginning in March with the first radio-tagged fish. The interval between detections ranged from one to 83 days. Movements of radio-tagged fish were both upstream and downstream (Figures 13 and 14). Radio-tagged white sturgeon originating in Lower Granite Reservoir moved an average of 0.8 km (0.5 miles) between detections, whereas white sturgeon originating from the free-flowing Snake River moved an average of only 0.2 km (0.1 miles) between detections. Radio-tagged white sturgeon in the Salmon River moved an average of 1.25 km (0.7 miles) between detections. The distance of individual fish movement ranged from 0 km to 14 km (8.5 miles) and averaged 0.6 km (.4 miles). Due to small sample size, no seasonal movement pattern was detected for radio-tagged fish, and no movement pattern was detected among radio-tagged fish of different size-classes.

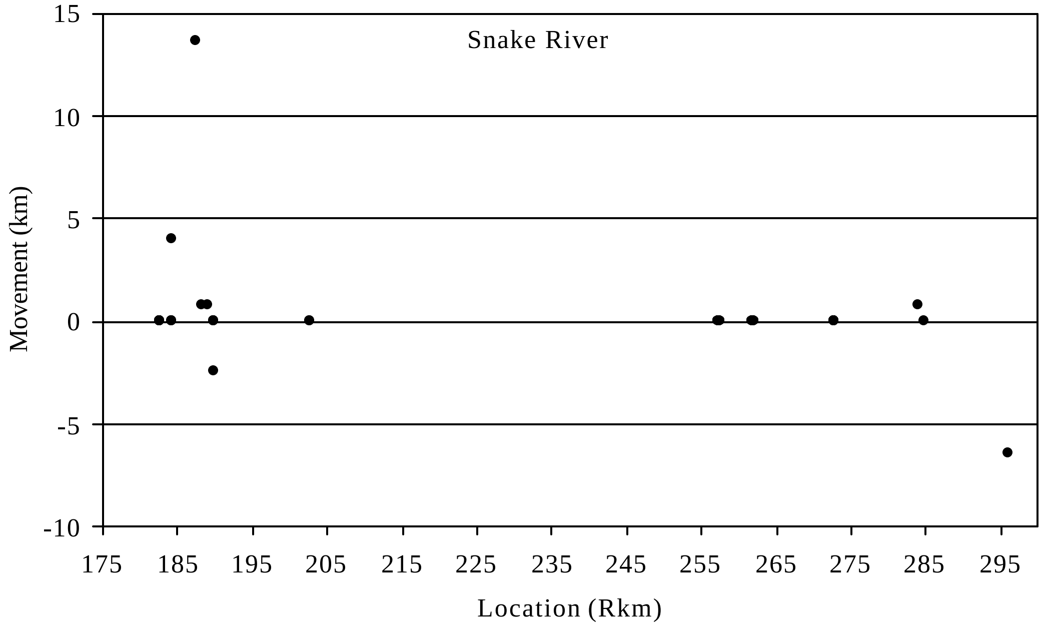

Figure 13. Total movement of 8 white sturgeon fitted with Combined Acoustic Radio Tags in the Snake River during 1999. Points represent distance from previous detection. Negative values indicate movement downstream and positive values indicate movement upstream.

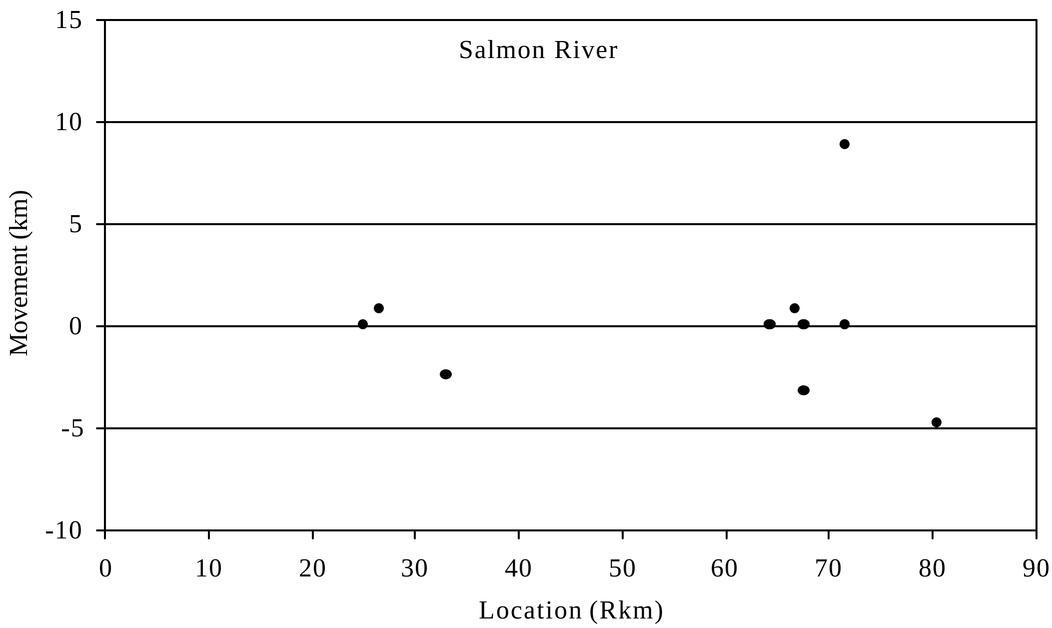

Figure 14. Total movement of 5 white sturgeon fitted with Combined Acoustic Radio Tags in the Salmon River during 1999. Points represent distance form previous detection. Negative values indicate movement downstream and positive values indicate movement upstream.

In 1999, a total of 85 distinct PIT/Floy tagged white sturgeon were recaptured. Of these, 76 were fish that had been previously tagged in 1997-98 (Hoefs 1998, Tuell and Everett 2000). During 1999, 11.1 percent (85 of 768) of the marked white sturgeon were detected at least once. One white sturgeon was captured three times. From 1997 to 1999 a total of 132 white sturgeon have been recaptured. These fish ranged from 48 cm to 204 cm in total length. In the Snake River, movements of 58 recaptured fish were less than or equal to 0.8 km (1 mile) or had no discernable movement. Forty-seven fish moved more than 0.8 km up to 16 km (10 miles) while 20 others moved more than 16 km up to 61.2 km (98.5 miles). Several fish were recaptured from previous sampling performed by other agencies. Duration between captures ranged from 0 to 2,557 days. Movements were both upstream and downstream, with seven moving from Lower Granite Reservoir into the free-flowing Snake River and four fish moving from the free-flowing Snake River into Lower Granite Reservoir. White sturgeon originating in Lower Granite Reservoir moved an average of 20.6 km (12.8 miles;) between recaptures (Figure 15); whereas, white sturgeon originating from the free-flowing Snake River moved an average of only 5.3 km (3.3 miles; Figure 16). In 1999, two PIT/Floy tagged white sturgeon were recaptured within the Salmon River, both moved less than 0.8 km (1 mile). For PIT/Floy tagged fish, no clear seasonal movement pattern was detected (Figure 17), and no distinct movement pattern was detected among fish of different size-classes (Figure 18).

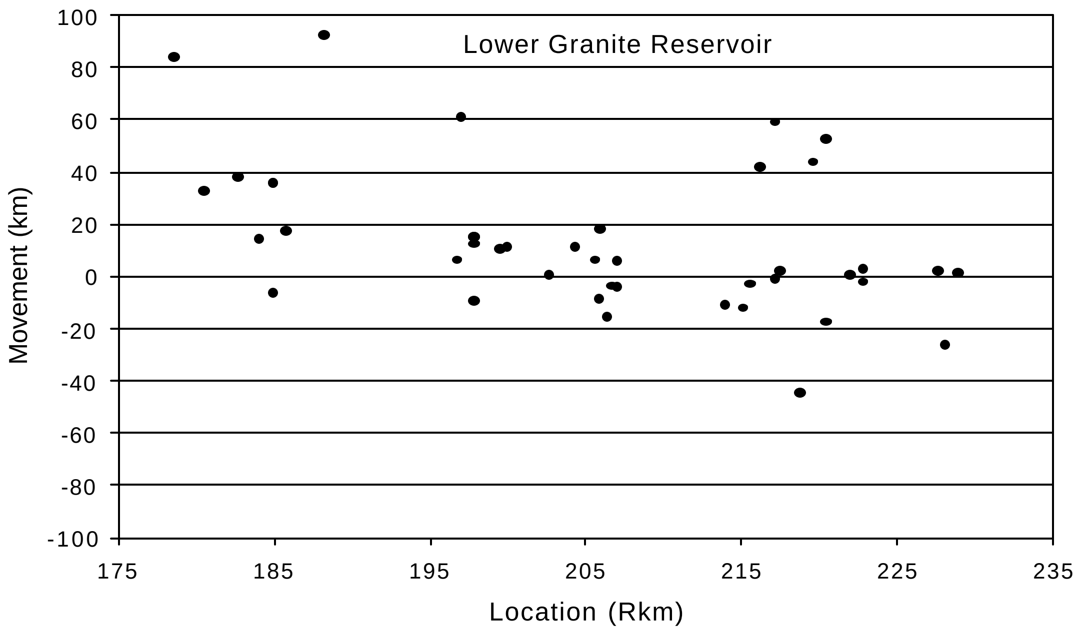

Figure 15. Total movement of 44 recaptured PIT/Floy tagged white sturgeon initially captured in Lower Granite Reservoir from 1997-99. Negative values indicate movement downstream and positive values indicate movement upstream.

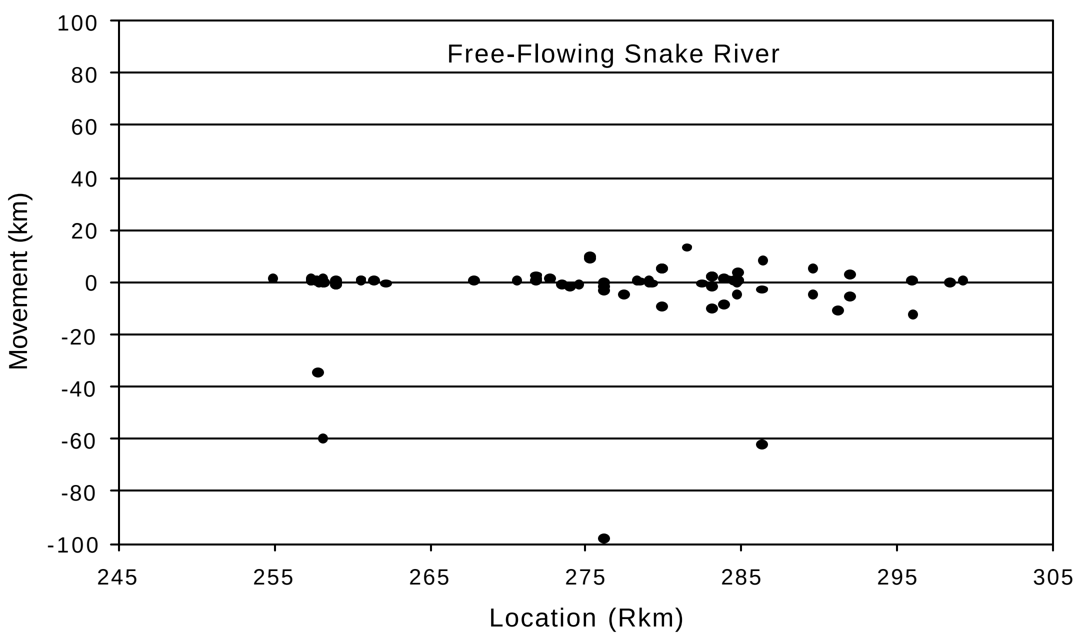

Figure 16. Total movement of 79 recaptured PIT/Floy tagged white sturgeon initially captured in the free-flowing Snake River from 1997-99. Negative values indicate movement downstream and positive values indicate movement upstream.

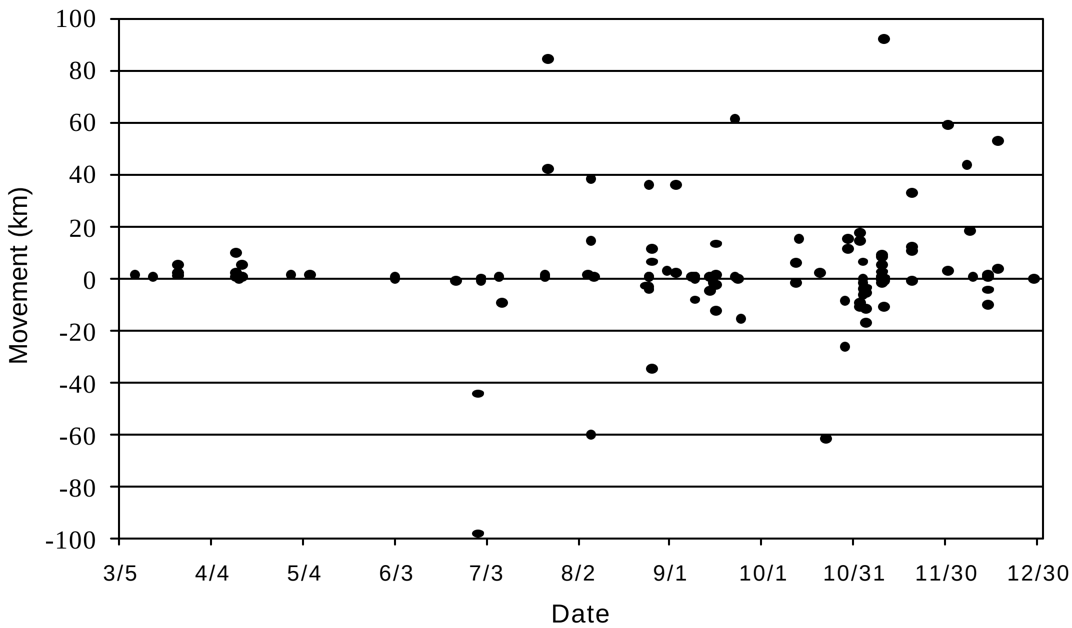

Figure 17. Seasonal movement of 132 recaptured PIT/Floy tagged white sturgeon from 1997-99. Negative values indicate movement downstream and positive values indicate movement upstream.

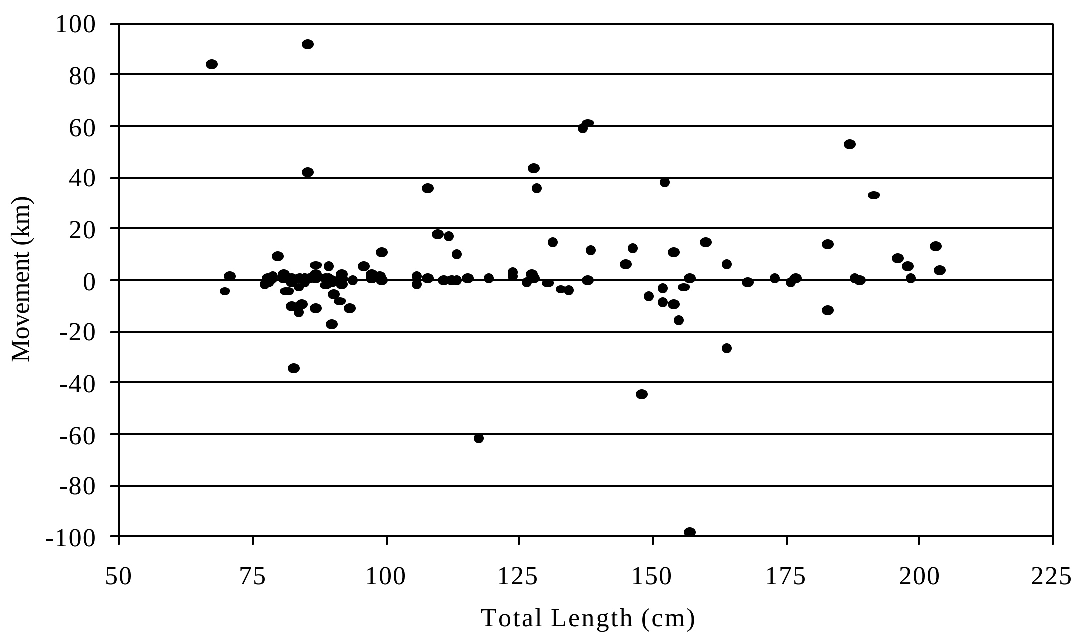

Figure 18. White sturgeon size and movement of 132 recaptured PIT/Floy tagged white sturgeon from 1997-99. Negative values indicate movement downstream and positive values indicate movement upstream.

DISCUSSION

Since 1997, the analysis of the length frequency distributions of white sturgeon in the Snake River has revealed a difference the size class composition between Lower Granite Reservoir and the free-flowing segment. Specifically, differences were detected in the proportion of catch with total lengths less than 92 cm, between 92 and 183 cm and greater than 183 cm. The analysis of the length frequency distributions of white sturgeon within each river segment has revealed no difference in these size groups between 1997 and 1999. Due to this similarity, the data were pooled across years to analyze trends in the available historic data. Examining the free-flowing segment of the Snake River, we observe a trend in the change of the length frequency distribution of white sturgeon (Figure 19). Earlier studies found that a large proportion of the white sturgeon population was comprised of fish with total lengths less than 92 cm (Coon et al. 1977; Lukens 1985). In 1972-75, 86 percent and in 1982-84, 80 percent of the population was comprised of white sturgeon less than 92 cm. In addition, the proportion of white sturgeon between 92 and 183 cm, which were heavily harvested until 1970, comprised 4 and 18 percent of the populations sampled in the 1970's and 1980's, respectively. In contrast, of the white sturgeon collected during 1997-99, only 57 percent were less than 92 cm, while 30 percent ranged between 92 and 183 cm. Before these findings can be attributed to changes in the population, or the recovery of a size class that was over harvested, further sampling is needed.

The mean total length of the fish collected in Lower Granite Reservoir was larger than fish collected in the free-flowing Snake River. The length frequency distributions indicate that the white sturgeon population in Lower Granite Reservoir is dominated by white sturgeon measuring between 92 and 183 cm, with few large white sturgeon (>183 cm). In contrast, white sturgeon in the small (< 92 cm) and middle (between 92 and 183 cm) size classes are more evenly distributed in the free-flowing Snake River. Furthermore, the proportion of large white sturgeon is more than twice as large in the free-flowing Snake River than in Lower Granite Reservoir. Coon et al. (1977) observed differences in the percent of the population between 92 and 183 cm long between these two segments. According to Coon et al. (1977) 29 percent of the white sturgeon collected between the Lower Granite Dam site and 20 km upstream was between 92 and

183 cm, but only 3 percent of the population in the upper river was comprised of fish in this length class. This study was conducted from 1972-75, which was just after the closure of the recreational white sturgeon harvest, but prior to the closure of Lower Granite Dam. Considering each river segment separately, we observe a shift in the length frequency distribution of white sturgeon since the 1970's. The proportion of white sturgeon in the middle size class sampled from Lower Granite Reservoir and the free-flowing Snake River has increased 41 percent and 27 percent, respectively.

The majority of the sampling in 1997 and 1998 was done with setlines rigged with 12/0, 14/0 and 16/0 hooks. Elliott and Beamesderfer (1990) determined that white sturgeon did not fully recruit to setline gear until they reached 90 cm in length or greater. However, examining the length frequency distribution for white sturgeon captured throughout the study area shows few fish smaller than 60 cm. In earlier studies, smaller hooks were used and white sturgeon appeared to be recruited to the gear at smaller sizes (Coon et al. 1977, Lukens 1985, Lepla 1994). In 1999 the addition of a smaller hook size did not significantly change the length frequency distribution of white sturgeon captured throughout the study area. Our results suggest that white sturgeon are fully recruited to our setline methods at size 60 cm. The smaller hooks (size 8/0 and 10/0) will continue to be used for setlines. In 2000, the addition of 8/0 hooks will again be evaluated.

In 1999, an additional 232 white sturgeon were sampled in the study area bringing the total number of marked fish to 768. Since 1997, 11.1 percent of the tagged fish have been recaptured. North et al. (1993) reported a tag recovery rate of 7.3 percent (79 of 1,081) of PIT tagged white sturgeon in 1994 in two Lower Columbia River reservoirs using both setlines and gillnets. Recapture data from these marked fish in 2000 and beyond will allow us to estimate the current population and more accurately assess the movement dynamics of white sturgeon in the study area.

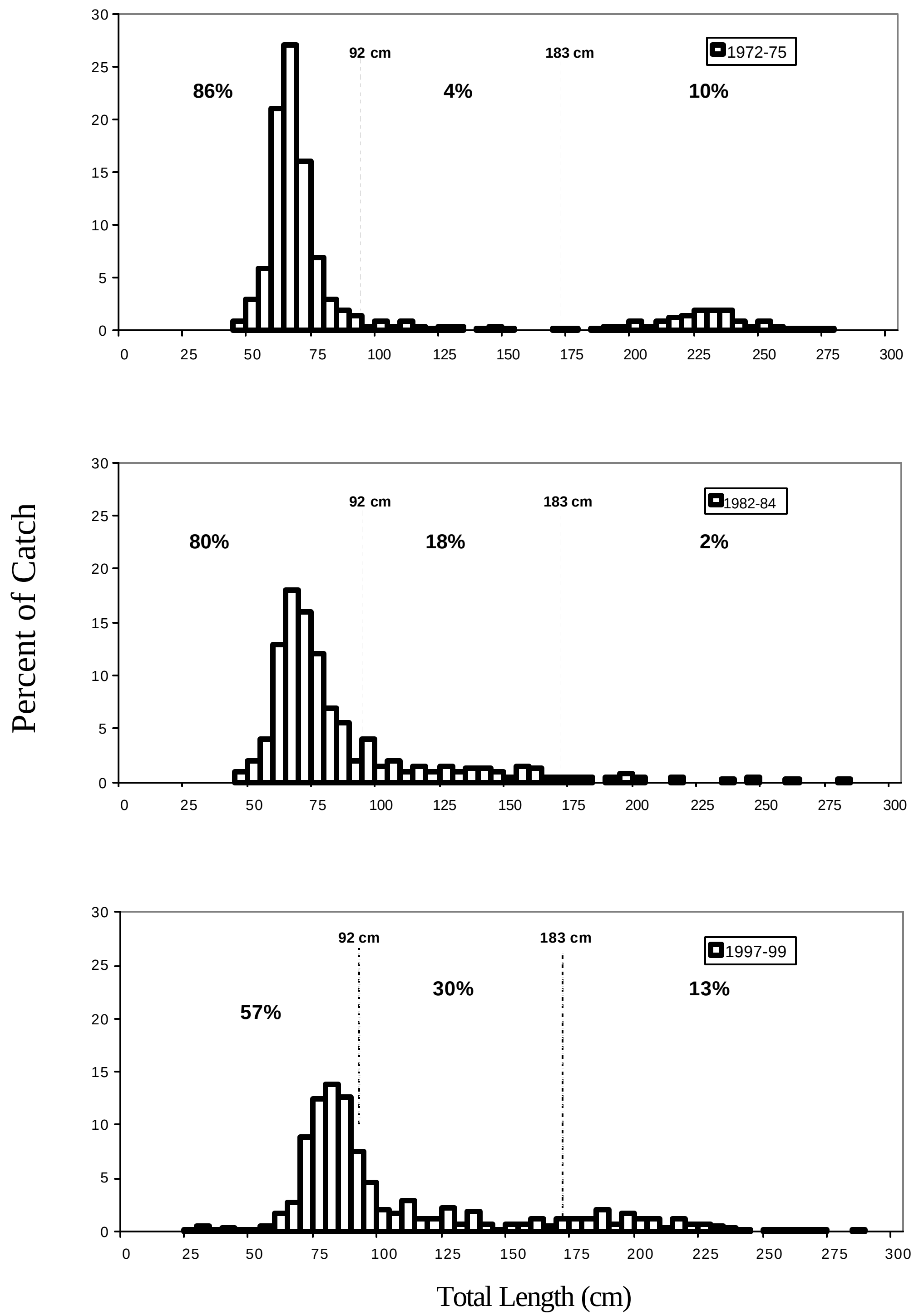

Figure 19. The length (total length) frequency distributions of white sturgeon sampled from the Hells Canyon reaches of the Snake River, 1997-99, 1982-84 (Lukens 1985), and 1972-75 (Coon et al. 1977) and the percent of the populations < 92 cm, between 92 and 183 cm, and >183 cm.

Comparing the historic estimates of Snake River white sturgeon abundance indicates a changing population (Table 6). Differences in methodology may account for some of the differences observed. Historically, the Schnabel estimate has been used to report white sturgeon abundance in the middle Snake River. However, the model assumes a closed population. We have observed movement from free-flowing segment to reservoir and visa versa. In addition, the Washington Department of Fish and Wildlife has recovered 18 PIT tagged white sturgeon that originated in Lower Granite Reservoir (John Devore, Washington Department of Fish and Wildlife, pers. comm.). These fish were tagged by the University of Idaho and recaptured in Little Goose or Lower Monumental reservoirs. Therefore, the assumptions for the Jolly-Seber model are more practical for this population's data. This model assumes an open but geographically closed population. Further difficulties are encountered with comparing historical data due to the specific area where surveys were conducted. Several previous surveys started and ended at varying locations.

Table 6. Population abundance estimates reported for white sturgeon between Lower Granite Dam (Rkm 108) and Hells Canyon Dam (Rkm 398).

Location	Abundance (estimator)	Sample Year(s)	Author
Lower Granite Dam site to Hells Canyon Dam (Rkm 174-398)	8,000-12,000 (Schnabel)	1972-75	Coon et al. 1977
Clearwater River to Hells Canyon Dam (Rkm 224-398)	3,955 (Schnabel)	1982-84	Lukens 1985
Lower Granite Reservoir (Rkm 174-240)	1,524 (Schnabel) 1,372 (Jolly-Seber)	1990-91	Lepla 1994
Lower Granite Reservoir (Rkm 174-240)	1,804 (Schnabel)	1992	Bennett el al. 1993
Salmon River to below Hells Canyon Dam (Rkm 303-383)	1,312 (Schnabel) 1,600 (Jolly-Seber)	1997-2000	Lepla et al. 2001
Lower Granite Dam to Salmon River (Rkm 174-303)	2,544 (Schnabel) 1,823 (Jolly-Seber)	1997-1999	this report

In 1975, the population from Rkm 174 (lower Granite Dam site) to Rkm 398 (Hells Canyon Dam) was estimated at between 8,000 and 12,000 fish (Coon et al. 1975), with between 700 to 1,000 being approximate spawning size. Combining the 1999 abundance estimates for white sturgeon between Lower Granite Dam to the mouth of the Salmon River with the estimated abundance above the Salmon River to Hells Canyon Dam (Lepla et al. 2001) result in a total population of 3,856 (Schnabel) or 3,423 (Jolly-Seber). The Multi-year Study Plan (Hoefs 1997) calls for five years of data collection in order to adequately develop an estimate of the population of white sturgeon in the Snake River between Lower Granite Dam and the mouth of the Salmon River. The findings reported here constitute the results of only the third year of data collection. Other abundance models and computer software programs are being considered to provide a better population abundance estimate. Although we did not find any white sturgeon in the Clearwater River from 1997 to 1999 this does not mean that white sturgeon do not utilize the Clearwater River. Use may be seasonal or numbers may be low enough that they were undetected. We will continue to periodically sample for white sturgeon in the Clearwater River throughout the year.

Based on the plotted length-weight relationships from historical data for the Hells Canyon population, the condition factor appears to have fluctuated since the 1970's (Figure 20). For 1997-99, the condition of white sturgeon captured in the free-flowing Snake River segment is similar to the condition observed for white sturgeon in 1973-75 (Coon et al. 1977) and lower than in 1982-84 (Lukens 1985). For the reservoir fish, the condition factor appears similar to that observed in 1990-91 (Lepla 1994; Figure 21). Lepla (1994) showed that the relative weight of white sturgeon collected after impoundment was higher than white sturgeon sampled prior to impoundment. For 1997-99, the mean W_r was significantly higher for fish from Lower Granite Reservoir than for fish from the free-flowing Snake River. However, comparing the plotted length-weight relationship between white sturgeon in Lower Granite Reservoir and the free- flowing Snake River shows little difference for fish less than 250 cm total length (Figure 22). Comparing the parameters of the length-weight equations fitted for several Columbia River Basin white sturgeon populations shows an intermediate condition factor for the Hells Canyon population (Figure 23, Table 7).

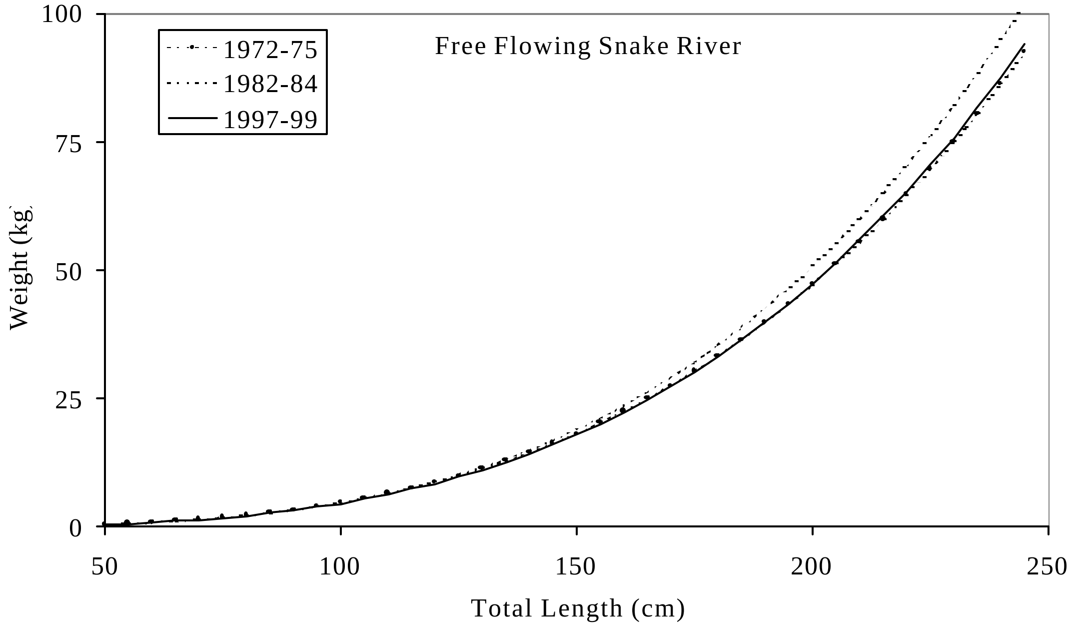

Figure 20. Comparison of the length-weight relationship for white sturgeon sampled from the free-flowing segment of the Snake River during 1997-99, 1982-84 (Lukens 1985), and 1972-75 (Coon et al. 1977).

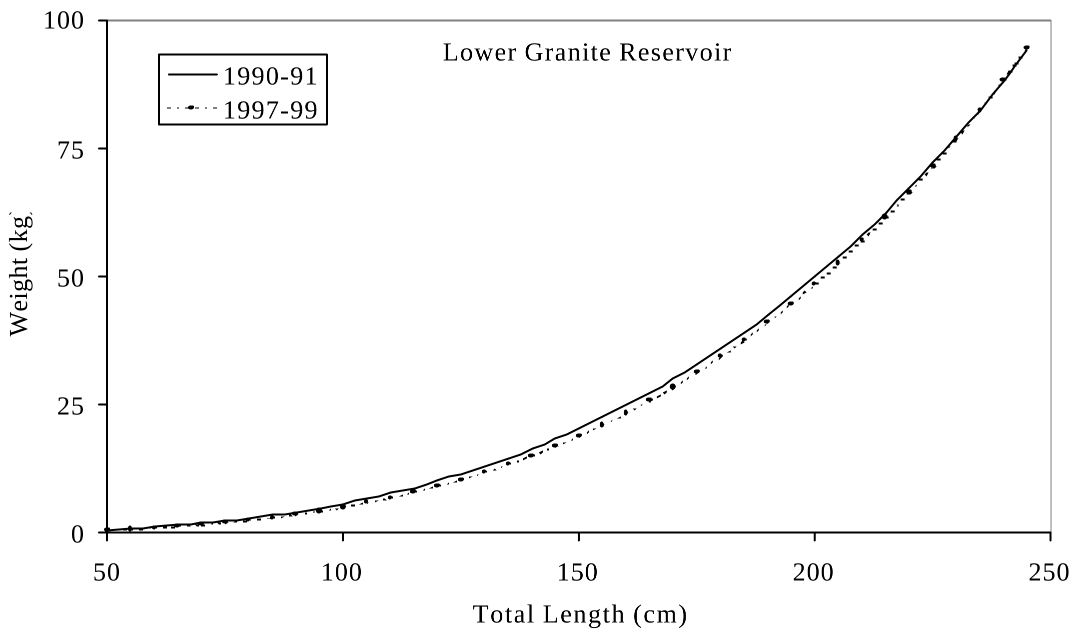

Figure 21. Comparison of the length-weight relationship for white sturgeon sampled from Lower Granite Reservoir during 1997-99, and 1990-91 (Lepla 1994).

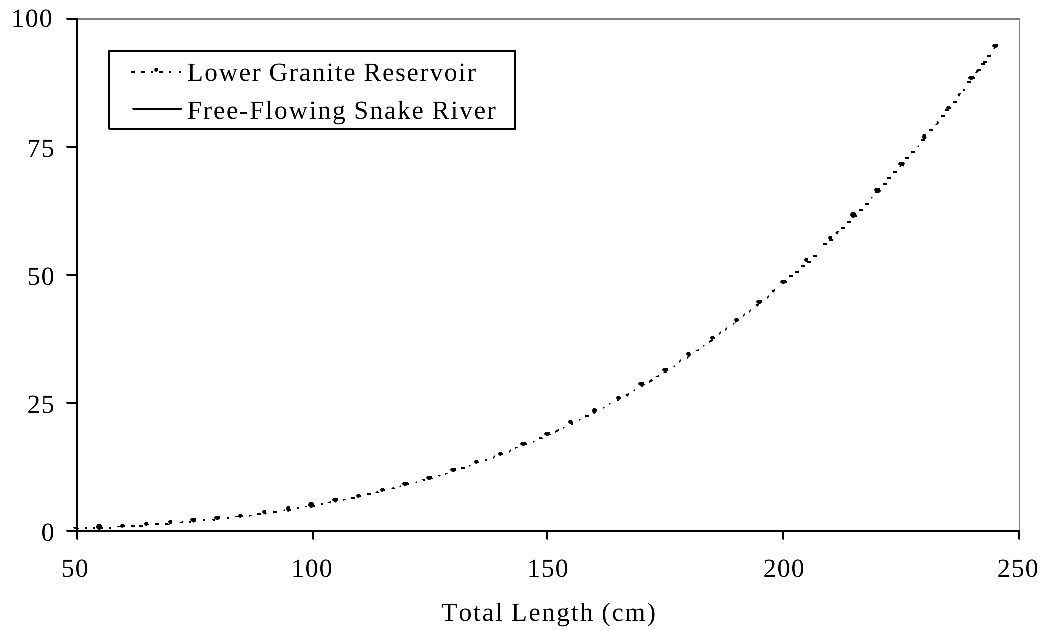

Figure 22. Comparison of the length-weight relationship for white sturgeon sampled from Lower Granite Reservoir and the free-flowing segment of the Snake River during 1997-99.

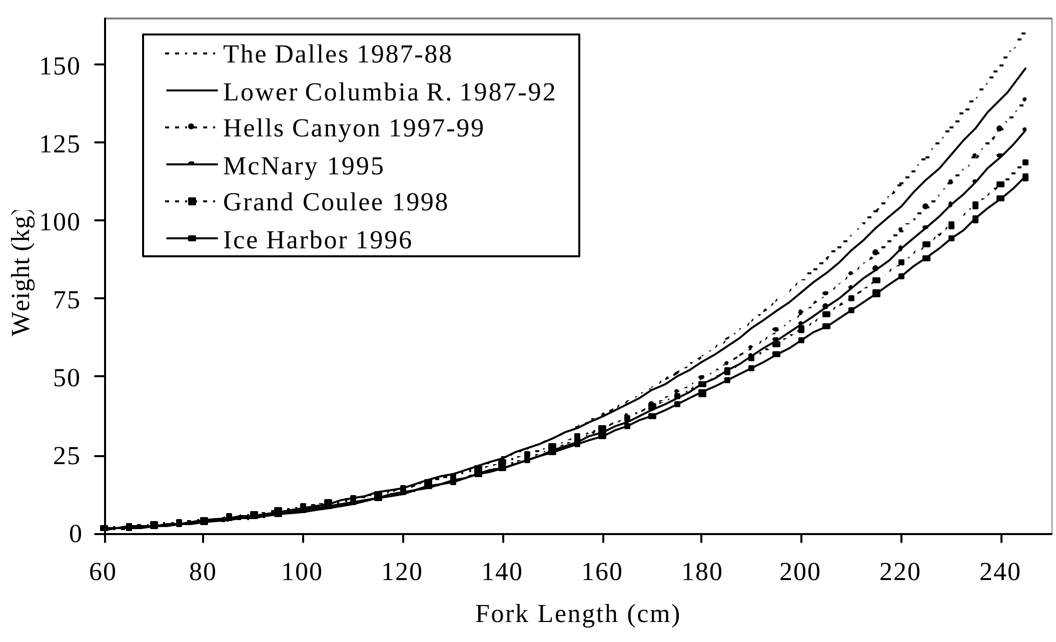

Figure 23. Comparison of the length-weight relationship for white sturgeon sampled from several Columbia River Basin populations.

Table 7. Parameters for the fork length (cm) and weight (kg) equation* and relative weights (W_r) for 12 Columbia River basin white sturgeon populations.

Location	a	b	W_r	Reference
Lower Columbia River 1987-92	2.85E-06	3.23	112	Devore et al. 1995
Bonneville Reservoir 1989	3.11E-06	3.19	97	Beamesderfer et al. 1995
The Dalles Reservoir 1987-88	1.35E-06	3.38	97	Beamesderfer et al. 1995
John Day Reservoir 1990	2.40E-06	3.26	100	Beamesderfer et al. 1995
McNary Reservoir 1993 & 1995	2.47E-06	3.23	97	Rien and Beiningen 1997
Grand Coulee Reservoir 1998	1.11E-05	2.94	91	Devore 2000
Ice Harbor Reservoir 1996	6.85E-06	3.02	92	Devore 1998
Lower Monumental Reservoir 1997	7.61E-06	3.01	99	Devore 1999
Little Goose Reservoir 1997	1.31E-05	2.91	97	Devore 1999
Lower Granite Reservoir 1990-91	4.00E-06	3.14	103	Lepla 1994
Lower Granite Dam to Salmon River 1997-99	1.55E-06	3.33	89	this report
Salmon River to Hells Canyon Dam 1997-2000	2.89E-06	3.19	88	Lepla et al. 2001

$*W = aL^b$

Information on age and growth of a long-lived species, such as white sturgeon, can reveal the effect of habitat changes over decades. Habitat alterations over the 25-year period following impoundment may be reflected in differential growth rates of white sturgeon between the free-flowing segment and the reservoir segment. Collins and Smith (1996) reported that the complete removal of the lead pectoral fin ray was non-deleterious in both shortnose sturgeon (*Acipenser brevirostrum*) and atlantic sturgeon (*A. oxyrinchus*). Our method was less invasive in that we removed only a portion of the pectoral fin ray.

White sturgeon captured in 1999 from Hells Canyon appear to be growing faster based on age and growth comparisons with historical data (Figure 24). Based on the von Bertalanffy growth equations, white sturgeon age 1 to 20 that were captured from 1972-75 and 1982-84 grew approximately 6.3 cm/year and 5.8 cm/year, respectively. In contrast, white sturgeon captured from 1997-99 exhibited a growth rate of 8.2 cm/year. The von Bertalanffy growth equations also suggest that the Hells Canyon white sturgeon population grows faster than several other Columbia River Basin populations (Figure 25).

Table 8 compares the parameters of the von Bertalanffy growth equation for several Columbia River Basin white sturgeon populations. The growth rate reported for the 1999 white sturgeon population is based on a sample size of 49 pectoral fin clips, whereas other studies analyzed several hundred fin rays (e.g. n=605, Coon et al. 1977; n=409, Lukens 1985). Clearly, further sampling is warranted to validate the differences observed in the current growth rate.

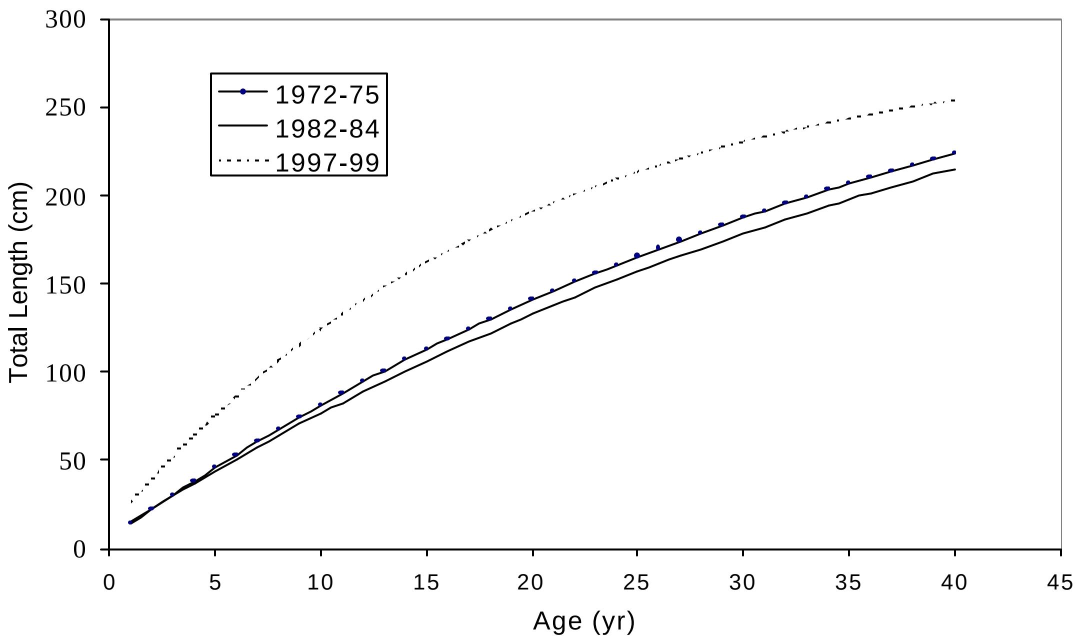

Figure 24. Comparison of the von Bertalanffy growth curves for white sturgeon sampled from the free-flowing segment of the Snake River during 1997-99, 1982-84 (Lukens 1985), and 1972-75 (Coon et al. 1977).

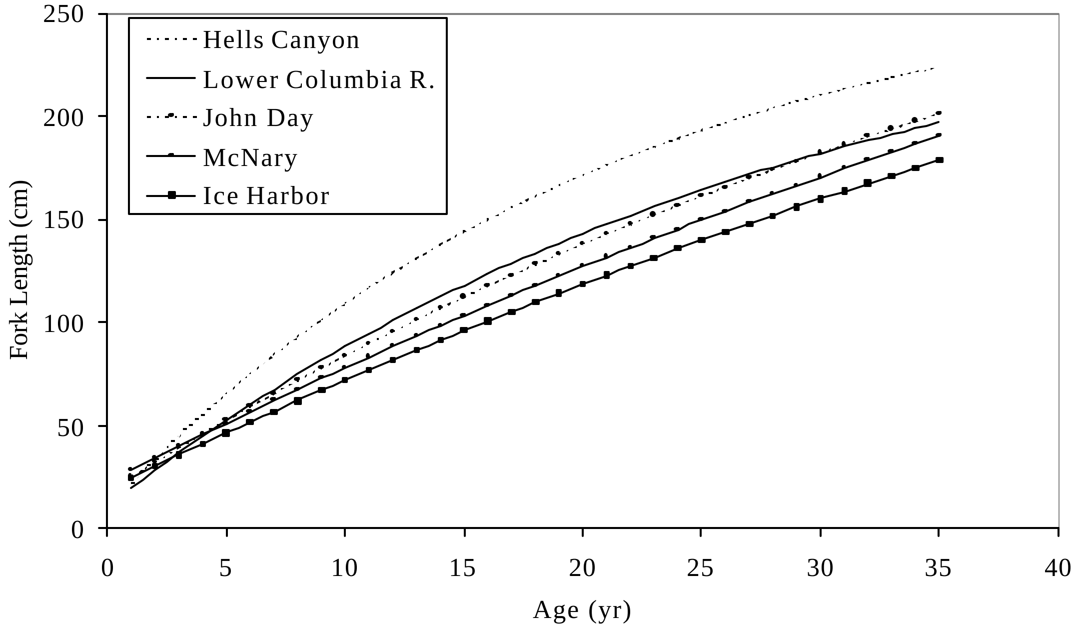

Figure 25. Comparison of the von Bertalanffy growth curves for white sturgeon sampled from several Columbia River Basin populations.

Table 8. Parameters for the von Bertalanffy growth equation* for 12 Columbia River Basin white sturgeon populations.

Location	L4	K	t_0	Reference
Lower Columbia River 1987-92	276	0.035	-1.13	Devore et al. 1995
Bonneville Reservoir 1989	311	0.022	-2.40	Beamesderfer et al. 1995
The Dalles Reservoir 1987-88	340	0.023	-2.40	Beamesderfer et al. 1995
John Day Reservoir 1990	382	0.020	-2.40	Beamesderfer et al. 1995
McNary Reservoir 1993 & 1995	496	0.013	-3.69	Rien et al. 1997
Grand Coulee Reservoir 1998	255	0.035	-3.45	Devore et al. 2000
Ice Harbor Reservoir 1996	478	0.012	-3.37	Devore et al. 1998
Lower Monumental Reservoir 1997	596	0.010	-5.69	Devore et al. 1999
Little Goose Reservoir 1997	278	0.034	-1.16	Devore et al. 1999
Lower Granite Reservoir 1990-91	225	0.049	-2.31	calculated from Lepla 1994
Lower Granite Dam to Salmon River 1997-99	275	0.047	-0.77	this report
Salmon River to Hells Canyon Dam 1997-2000	331	0.305	-1.54	Lepla et al. 2001

*$L(t)=L_{\equiv}\{1-e^{-K(t-t_0)}\}$

Based on the presence of eggs, white sturgeon appear to have spawned in 1999. The temperatures, depths and near substrate velocities where white sturgeon eggs were recovered in the Snake River are within the range reported for other Columbia River Basin white sturgeon populations (Parsley et al. 1993; McCabe and Tracy 1994; Parsley and Kappenman 2000). In contrast, the primary substrate type where eggs were found differed between the Snake River and Columbia River. The five eggs recovered in the free-flowing segment of the Snake River in 1999 were found over a sandy substrate, whereas the primary substrate reported for the Columbia River was cobble and boulder. The actual spawning location could not be identified due to the nature of the dispersal eggs; thus, the actual habitat characteristics at the spawning locations could not be measured. Paragamian et al. (1999) reported tracking the spawning migrations of 14 white sturgeon in the Kootenai River of Idaho to locations where eggs were eventually recovered. Therefore, the continued radio tracking of mature fish may allow for greater precision in identifying actual spawning locations and habitat preference for white sturgeon in the Hells Canyon reach of the Snake River.

Movement data from recaptured PIT/Floy tagged fish from 1997-1999 indicate white sturgeon make migrations between Lower Granite Reservoir and the free-flowing Snake River. A total of 12.9 percent (11 of 85) of the recaptured white sturgeon moved between the two segments. North et al. (1993) reported only 4 percent (27 of 636) of the recaptured white sturgeon from three reservoirs in the Columbia River moved between reservoirs or out of the study area.

The movement of white sturgeon in Lower Granite Reservoir was more pronounced than those tagged in the free-flowing segment. Data from both radio-tagged and recaptured PIT/Floy tagged fish suggest a tendency for white sturgeon in Lower Granite Reservoir to move more than fish in the free- flowing segment. However, in 1999 a majority of our recaptured PIT/Floy tagged fish (62 of 85) spent over 90 days at-large (between captures). This 90 days would encompass any potential spawning migrations made by white sturgeon, thus the degree of movement may be larger. Other authors have reported seasonal and directional movement patterns with a distinct sedentary period during winter (Devore and Grimes 1994, Haynes et al. 1978). However, because of the large time intervals between recaptures, seasonal and directional movement patterns were difficult to assess. Further sampling is needed in order to accurately quantify the degree of seasonal migrations.

No discernable movement pattern was detected for white sturgeon of varying length. In contrast, Coon et al. (1977) observed a downstream movement trend in smaller white sturgeon. Coon et al. (1977) found that white sturgeon less than 92 cm in length generally tended to move downstream, while larger white sturgeon, although movements were localized, moved both upstream and downstream. However, both Lepla (1994) and North et al. (1993) found no relationship between white sturgeon length and direction or distance traveled. Continued tracking of the movement of white sturgeon of different sizes throughout the Snake and Salmon rivers using radio-telemetry will help to clarify habitat use throughout the system, as well as reduce the time marked white sturgeon are at-large.

PLANS FOR 2000

Specific sampling plans and objectives for 2000 are outlined in the Multi-year Study Plan (Hoefs 1997). In 2000, we will continue to capture white sturgeon using a randomized sampling design between Lower Granite Dam and the mouth of the Salmon River. Recapture data and new capture data will be used to estimate population size and collect additional population data as outlined by Task 1 (Table 2). To complete Task 1 we intend to expand our sampling to include the Salmon River and begin measuring environmental conditions at locations where white sturgeon are sampled. Furthermore, we plan to increase our effort at collecting and analyzing white sturgeon age and growth data (Task 1.2).

We intend to continue our assessment of habitat used by white sturgeon for spawning and rearing (Task 2). This will be accomplished by increasing the number of radio tagged white sturgeon and investigating habitat use and movement of juvenile, adult and spawning white sturgeon using radio tracking techniques developed and used in the Columbia River Basin by other white sturgeon researchers (see Hoefs 1997). In addition, during the spring, substrate mats will be deployed throughout the study area to collect white sturgeon eggs in order to verify spawning locations and timing. Furthermore, we intend to initiate YOY sampling (Task 2.2). During late fall and early winter YOY white sturgeon will be collected to identify movement and rearing habitat.

Finally, in 2000 we plan to combine the available data from the IPC Snake River white sturgeon survey above the mouth of the Salmon River to Hells Canyon Dam. The combined data will allow for the investigation of the population as a whole. The additional information should provide for a more precise analysis of the population's abundance, age and growth, as well as contribute details about white sturgeon habitat preference and movement dynamics.

LITERATURE CITED

Apperson, K., and P.J. Anders. 1990. Kootenai River white sturgeon investigations and experimental culture. Annual Progress Report FY 1989. Idaho Department of Fish and Game and Bonneville Power Administration. Contract Number DE-A179-88BP93497, Project 88-65. Portland, OR.

Beamesderfer, R.C. 1993. A standard weight (W_s) equation for White Sturgeon. California Fish and Game. 79(2):63-69.

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

Bennett, D.L., T.L. Dresser, T.S. Curet, K.B. Lepla, and M.A. Madsen. 1993. Lower Granite Reservoir in-water disposal test: Results of the fishery, benthic and habitat monitoring program-year 4 (1991). Completion report. U.S. Army Corps of Engineers, Walla Walla, WA.

Brennan, J.S., and G.M. Cailliet. 1989. Comparative age-determination techniques for white sturgeon in California. Transactions of the American Fisheries Society. 118:296-310.

Brennan, J.S., and G.M. Cailliet. 1991. Age-determination and validation studies of white sturgeon, *Acipenser transmontanus*, in California. Pages 209-234 in P. Williott, editor. Acipenser. Centre National du Machinisme Agricole du Genie Rural des Eaux et des Forets, Bordeaux, France.

Carmichael, R., L. Lestelle, L. Mobrand, D. Statler, R. Carter, D. Bennett, J. Chandler, K. Lepla, T. Cochnauer, J. Devore, T. Rien, R. McMullin, M. J. Parsley, and A. Seamans. 1997. Upper Snake River White Sturgeon Biological Risk Assessment. Prepared for Nez Perce Tribe by Mobrand Biometrics Inc. Vashon Island, WA.

CBFWA (Columbia Basin Fish and Wildlife Authority). 1997. Draft Multi-year implementation plan for resident fish protection, enhancement and mitigation in the Columbia River Basin. CBFWA Tech. Planning Document. Portland, OR.

Collins, M.R., and T.I.J. Smith. 1996. Sturgeon fin ray removal is nondeleterious. North American Journal of Fisheries Management. 16:939-941.

Coon, J.C. , R.R. Ringe, and T.C. Bjornn. 1977. Abundance, growth and movements of white sturgeon in the mid-snake river. Research Technical Completion Report Project B-026-IDA. Idaho Water Resources Research Institute. University of Idaho. Moscow, ID.

Deary, C., D.A. Scruton, G.H. Niezgoda, S. McKinley, D. Cote, K.D. Clarke, D. Perry, T. Lindstrom, and D. White. 1998. A dynamically switched combined acoustic and radio transmitting (CART) tag: An improved tool for the study of diadromous fishes. Marine Technology Society. 32:63-69.

Devore, J.D., and J.G. Grimes. 1994. Migration and distribution of White Sturgeon in the Columbia River downstream from Bonneville Dam. Pages 83-100 *in* R.C. Beamesderfer and A.A. Nigro, editors. Status and habitat requirements of the White Sturgeon populations in the Columbia river downstream of Mc Nary Dam, Final Report of Research, Volume I. Project Number 86-50, Contract Number DE-AI79-86BP63584 to Bonneville Power Administration, Portland OR.

Devore, J.D., B.W. James, C.A. Tracy, and D.A. Hale. 1995. Dynamics and potential production of White Sturgeon in the unimpounded Lower Columbia River. Transactions of the American Fisheries Society. 124:845-856.

Devore, J.D., B.W. James, D.R. Gilliland, and B.J. Cady. 1998. Report B. Evaluate the success of developing and implementing a management plan for white sturgeon in reservoirs between Bonneville and McNary dams in enhancing production and Describe the life history and population dynamics of subadult and adult white sturgeon upstream of McNary Dam and downstream from Bonneville Dam. Pages 34 to 69 *in* D.L. Ward editor. White Sturgeon mitigation and restoration in the Columbia and Snake Rivers upstream from Bonneville Dam, and Effects of mitigative measures on productivity of white sturgeon populations in the Columbia River downstream of McNary Dam. Annual Progress Report. Project Number 86-50, Contract Number DE-AI79-86BP63584 to Bonneville Power Administration, Portland, OR.

Devore, J.D., B.W. James, and D.R. Gilliland. 1999. Report B. Evaluate the success of developing and implementing a management plan for white sturgeon in reservoirs between Bonneville and McNary dams in enhancing production and Describe the life history and population dynamics of subadult and adult white sturgeon upstream of McNary Dam and downstream from Bonneville Dam. Pages 55 to 93 *in* D.L. Ward editor. White Sturgeon mitigation and restoration in the Columbia and Snake Rivers upstream from Bonneville Dam, and Effects of mitigative measures on productivity of white sturgeon populations in the Columbia River downstream of McNary Dam. Annual Progress Report. Project Number 86-50, Contract Number DE-AI79-86BP63584 to Bonneville Power Administration, Portland, OR.

Devore, J.D., B.W. James, D.R. Gilliland, and B.J. Cady. 2000. Report B. Evaluate the success of developing and implementing a management plan for white sturgeon in reservoirs between Bonneville and McNary dams in enhancing production and Describe the life history and population dynamics of subadult and adult white sturgeon upstream of McNary Dam and downstream from Bonneville Dam, and Effects of mitigative measures on productivity of white sturgeon populations in the Columbia River downstream of McNary Dam. Pages 41 to 74 *in* D.L. Ward editor. White Sturgeon mitigation and restoration in the Columbia and Snake Rivers upstream from Bonneville Dam. Annual Progress Report. Project Number 86-50, Contract Number DE-AI79-86BP63584 to Bonneville Power Administration, Portland, OR.

Elliott, J.C., and R.C. Beamesderfer. 1990. Comparison of efficiency and selectivity of three gears used to sample white sturgeon in a Columbia River Reservoir. Calif. Fish and Game. 76:174-190.

Haynes, J.M., R.H. Gray, and J.C. Montgomery. 1978. Transactions of the American Fisheries Society. 107(2):275-280.

Hoefs, N.J. 1997. Phase Two: Multi-year study plan to evaluate potential means of rebuilding sturgeon populations in the Snake River between Lower Granite and Hells Canyon Dams. Nez Perce Tribe Department of Fisheries Resource Management and Bonneville Power Administration. Contract Number 97-AM-30423, Project 97-09. Portland, OR.

Hoefs, N.J. 1998. Evaluation of potential means of rebuilding sturgeon populations in the Snake River between Lower Granite and Hells Canyon dams. 1997 Annual Report. Report to Bonneville Power Administration. Contract Number 97-AM-30423, Project 9700900. Portland, OR.

IPC (Idaho Power Company). 1997. Status and habitat use of white sturgeon in the Hells Canyon Complex. Formal Consultation Package for Relicensing. Hells Canyon Project, FERC no. 1971. Volume 1. Idaho Power Company. Boise, ID.

Jolly, G. M. 1965. Explicit estimates from capture-recapture data with both death and immigration-Stochastic Model. Biometrika 52:225-247.

Krebs, C.J. 1998. Krebs ecological methodology for windows. Version 0.94. University of Alberta, Edmonton.

Lepla, K.B. 1994. White sturgeon abundance and associated habitat in Lower Granite Reservoir, Washington. Thesis. University of Idaho. Moscow, ID.

Lepla, K.B., J. A. Chandler, and P. Bates. 2001. Status and habitat use by white sturgeon associated with the Hells Canyon Complex. In progress. Idaho Power Company, Boise, ID.

Lukens, J.R. 1985. Hells Canyon White Sturgeon Investigations. Idaho Department of Fish and Game, River and Stream investigations, Job Performance Report, Project No. F-73-R-7. Idaho Fish and Game, Boise, ID.

Manly, B.F.J. 1984. Obtaining confidence limits on parameters of the Jolly-Seber model for capture-recapture. Biometrics 40:749-758.

Marchant, S.R., and M.K. Shutters. 1996. Artificial substrates collect Gulf Sturgeon eggs. North American Journal of Fisheries Management. 16:445-447.

McCabe, T.C., Jr., and L.G. Beckman. 1990. Use of artificial substrate to collect White Sturgeon eggs. California Fish and Game. 76(4):248-250.

McCabe, T.C., Jr. and C.A. Tracy. 1994. Spawning and early life history of White Sturgeon, *Acipenser transmontanus*, in the lower Columbia River. Fisheries Bulletin. 92:760-772.

Misra, R. K. 1980. Statistical comparisons of several growth curves of the von Bertalanffy type. Canadian Journal of Fisheries and Aquatic Sciences. 37:920-926.

Moreau, J. 1987. Mathematical and biological expression of growth in fishes: Recent trend and further developments. Pages 81-113 *in* R.C. Summerfelt and G. E. Hall, editors. The age and growth of fish. The Iowa State University Press, Ames.

North, J.A., R.C. Beamesderfer, and T.A. Rien. 1993. Distribution and movements of white sturgeon in three lower Columbia River reservoirs. Northwest Science 67:105-111.

North, J. A., T. A. Rien, and R. A. Farr. 1996. Report A. Evaluate success of developing and implementing a management plan for white sturgeon in reservoirs between Bonneville and McNary dams in enhancing production and Evaluate growth, mortality, and contributions to fisheries of juvenile white sturgeon transplanted from areas downstream from The Dalles Dam to areas in The Dalles and John Day reservoirs. Pages 5 to 36 *in* K. T. Beiningen, editor. Effects of mitigative measures on productivity of white sturgeon populations in the Columbia River downstream of McNary Dam, and determine the status and habitat requirements of white sturgeon populations in the Columbia and Snake rivers upstream from McNary Dam. Annual Progress Report. Project Number 86-50, Contract Number DE-AI79-86BP63584 to Bonneville Power Administration, Portland, OR.

NPPC (Northwest Power Planning Council). 1994. 1994 Columbia River Basin fish and wildlife program. Northwest Power Planning Council, Portland, OR.

Paragamian, V.L., G. Kruse, and V.D. Wakkinen. 1999. Kootenai River white sturgeon investigation: Kootenai River White Sturgeon spawning and recruitment evaluation. Annual Progress Report. Project Number 88-65. Contract Number DE-AI79-88B193497 to Bonneville Power Administration, Portland, OR.

Parsley, M.J., L.G. Beckman, and G.T. McCabe. 1993. Spawning and rearing habitat use by White Sturgeons in the Columbia River downstream of McNary Dam. Transactions of the American Fisheries Society. 122:217-227.

Parsley, M.J., and K.M. Kappenman. 2000. White Sturgeon spawning areas in the Lower Snake River. Northwest Science. 74:192-201.

Rien, T.A., J.A. North, and R.A. Farr. 1997. Report A1. Description of the life history and population dynamics of subadult and adult white sturgeon in the Columbia River between McNary, Priest Rapids, and Ice Harbor dams. Pages 7 to 29 *in* T.A. Rien and K. T. Beiningen, editors. Effects of mitigative measures on productivity of white sturgeon populations in the Columbia River downstream of McNary Dam, and Determine the status and habitat requirements of white sturgeon populations in the Columbia and Snake rivers upstream from McNary Dam. Annual Progress Report. Project Number 86-50, Contract Number DE-AI79-86BP63584 to Bonneville Power Administration, Portland, OR.

Rossiter, A., D.L.G. Noakes, and F.W.H. Beamish. 1995. Validation of age estimation for the lake sturgeon. Transactions of the American Fisheries Society. 124:777-781.

Schnabel, Z.E. 1938. The estimation of the total fish population of a lake. American Mathematics Monograph 45:348-352.

Seber, G. A. F. 1982. A note on the multiple recapture census. Biometrika 52:249-259.

Sherrod, P.H. 1992. NLREG, Nonlinear Regression Analysis Program. Version 5.1. Nashville, TN.

Thomas, M.V., and R.C. Hass. 1999. Capture of Lake Sturgeon with setlines in the St. Clair River, Michigan. North American Journal of Fisheries Management. 19:610-612.

Tracy, C.A., and M.F. Wall. 1994. Length at age relationships for White Sturgeon in the Columbia River downstream from Bonneville Dam. Pages 185-200 *in* R.C. Beamesderfer and A.A. Nigro, editors. Status and habitat requirements of the White Sturgeon populations in the Columbia river downstream of Mc Nary Dam, Final Report of Research, Volume II. Project Number 86-50, Contract Number DE-AI79-86BP63584 to Bonneville Power Administration, Portland OR.

Tuell, M.A., and S.R. Everett. 2000. Evaluation of potential means of rebuilding sturgeon populations in the Snake River between Lower Granite and Hells Canyon dams. 1998 Annual Report. Report to Bonneville Power Administration. Contract Number 97-AM-30423, Project 9700900. Portland, OR.

Wilson, N.C. 1987. Age determination of Lake Sturgeon (Acipenser fulvescens) by use of the marginal pectoral fin ray. Pages 77-83 in C.H. Oliver, editor. Proceedings of a workshop on the Lake Sturgeon. Ontario Ministry of Natural Resources, Ontario Fisheries Technical Report Series 23, Toronto.

Zar, J.H. 1996. Biostatistical Analysis. Prentice-Hall, Englewood Cliffs, New Jersey.

APPENDIX A

1999 White Sturgeon Capture and Marking Data

Table A-1. White sturgeon data collected in 1999.

Fish No.	Date	PIT tag Number	Floy tag number	Location (Rkm)	Fork Length (cm)	Total Length (cm)	Girth (cm)	Weight (kg)
1	01/20/99	1510083206		261.9	79	91	31	7.2
2	01/20/99	1510100E0C		261.9	75	84	27	5.4
3	01/20/99	151008242		261.9	84	96	25	8.8
4	02/02/99	1510081868		261.5	71	82	29	6.4
5	03/01/99	1510106E38		292.0	204	223	81	
6	03/10/99	151008367A		230.1	111	124	1	22.7
7	03/16/99	1510084151		261.9	69	77	28	4.9
8	03/16/99	1510081868		261.9	74	82.5	30	6.1
9	03/23/99	1510106178		272.7	95	108.5	37	14.3
10	03/24/99	151010561A		284.8	71	81	26	4.9
11	03/24/99	151010405A		284.8	80	90	30	7.9
12	03/24/99	1510085679		284.8	78	89.5	30	7.6
13	03/24/99	1510107628	174	284.8	96	108	35	12.4
14	03/25/99	1510105820		261.9	119	134	48.5	27.3
15	03/25/99	1510105426		261.9	69	77	25.5	4.6
16	04/05/99	1510081900		260.7	25	27	10	0.3
17	04/05/99	1510083264		260.7	28	31	12	0.4
18	04/05/99	1510082409		260.7	38	43	18	2.0
19	04/12/99	1510100464		284.8	71	79	25	4.8
20	04/12/99	1510103451		284.8	71	80	24.5	4.6
21	04/12/99	1510101429		284.8	72.5	80	26	5.3
22	04/12/99	151008285C		284.8	102.5	113.5	36	13.8
23	04/12/99	1510104021		284.8	79	89	30	7.6
24	04/12/99	1510100A26		284.8	72	79.5	25	5.3
25	04/12/99	151010447C		284.8	68.5	78.5	23.5	4.2
26	04/12/99	1510085679		284.8	80	89.5	28	7.5
27	04/12/99	1510084A68		284.8	81	89	30	7.6
28	04/12/99	1510082E74		284.8	117	127.5	47	27.2
29	04/13/99	151008265A		261.1	109	121	43	19.1
30	04/13/99	1510105A18		261.1	66.5	75.5	24.5	4.6
31	04/13/99	1510101C12		294.4	63	72	19	2.7
32	04/13/99	1510083C61		261.3	67	75	24	4.3
33	04/13/99	1510101902		284.8	70	79	24.5	4.9
34	04/13/99	1510101A40		294.4	70	81	26	4.9
35	04/13/99	1510100221		284.8	76	87.5	28	5.6
36	04/13/99	1510085C26		261.3	81	90	27	5.9
37	04/13/99	1510083264		261.3	74	81	29	5.9
38	04/13/99	1510102E0C		284.8	78	87.5	27	6.5

Table A-1. cont.

Fish No.	Date	PIT tag Number	Floy tag number	Location (Rkm)	Fork Length (cm)	Total Length (cm)	Girth (cm)	Weight (kg)
39	04/13/99	1510100609		296.1	79	89	31	7.3
40	04/13/99	1510100A28		294.4	86	95	26	7.0
41	04/13/99	7F700F2803		257.9	160	176	83	78.2
42	04/14/99	1510104C49	198	284.8	180	198	77	107.0
43	04/14/99	151008125C	283	284.8	70	79	24	4.3
44	04/14/99	1510104116		291.2	60	72	21	3.2
45	04/14/99	151010686E		291.2	68	74	21	3.6
46	04/14/99	1510100E01		284.8	70	81	24	4.4
47	04/14/99	1510104476		291.2	73	83	22	4.5
48	04/14/99	1510083C2A		291.2	63	73	20.5	3.0
49	04/14/99	1510101C11		284.8	66	76	27	5.0
50	04/14/99	1510100978		284.8	72.5	82	28	5.5
51	04/14/99	1510106112		284.8	74	85	28	5.7
52	04/14/99	1510084858		284.8	80	89	27.5	6.3
53	04/15/99	1510104C2C		260.7	28	31	10	0.4
54	04/15/99	1510100E00		260.7	28	34	10.5	0.6
55	04/20/99	7F7F7F2530		181.8	121.5	141	60	43.5
56	04/21/99	151010567C		183.7	158	165	72	66.5
57	04/21/99	1510104606		183.7	133	148	58	42.2
58	04/22/99	1510101056		183.7	149	169	61.5	56.0
59	04/22/99	1510082116		188.3	134	146	67	
60	04/29/99	151010203C		273.2	84	92	31	7.5
61	04/30/99	1f4d0c5137	125	255.8	70	79	28	5.6
62	05/04/99	1510101A62		272.7	73.5	81.5	26	8.7
63	05/06/99	1510106178		273.5	96	106	36.5	13.0
64	05/06/99	1510102632		273.5	92	102	33	9.5
65	05/06/99	1510104A04		273.5	66.5	75	26	4.0
66	05/06/99	1510101629		286.1	80.5	91.5	27.5	6.9
67	05/06/99	1510105070		286.1	88.5	98	20.5	5.6
68	05/11/99	151010105A		227.7	77	85	31	6.6
69	05/12/99	1510103628		225.3	72	81	28	5.6
70	05/17/99	151008244C		257.8	54	60	20	2.0
71	05/17/99	1510101C01		71.6*	207	225	90	158.7
72	05/20/99	1510100C6E		66.8*	162	179	70	77.0
73	06/03/99	1510101101	336	258.2				
74	06/03/99	1510105018		258.2	101.6		35.56	14.0
75	06/08/99	1510105628		190.7	134	154	64	48.0
76	06/08/99	151010524E		200.3	158	175	77	78.0
77	06/08/99	7F7F762238		193.9			47	
78	06/09/99	151008245E		189.1	104	118	45	19.2
79	06/09/99	1510084412		189.1	69	78	32	5.9
80	06/09/99	1510080151		189.1	99	113	47.5	20.6
81	06/10/99	151010285C		177.0	78	90	35	8.6
82	06/23/99	1510104A04		271.9	69.5	78	25.5	4.8

Table A-1. cont

Fish No.	Date	PIT tag number	Floy tag number	Location (Rkm)	Fork Length (cm)	Total Length (cm)	Girth (cm)	Weight (kg)
83	06/24/99	151010224E		280.8	55	61	20	2.5
84	06/24/99	151008220E		274.3	64	73	23	3.0
85	07/01/99	151010044A	333	257.8	69	78.5	23	4.0
86	07/01/99	1510101A69		257.8	56	65	23	2.0
87	07/01/99	1510101216		257.8	74	84	31	6.0
88	07/01/99	1510104218	153	257.8	72	85	28	5.0
89	07/01/99	1510103166		257.8	89	94	31	9.0
90	07/07/99	1510103A36		257.8	54	62	23.5	2.0
91	07/07/99	1510083911		257.8	87.5	100	33.5	10.4
92	07/07/99	1510104218	153	257.8	73	82	28.5	7.0
93	07/07/99	1510083012		257.8	80	90	31	7.0
94	07/07/99	1510103E60		260.7	73.5	85	24	5.3
95	07/07/99	1510083622		270.3	92.5	102.5	30.5	9.8
96	07/07/99	1510105822		271.9	166	188	66	73.5
97	07/07/99	1510082822		271.9	67.5	78	24	4.0
98	07/07/99	1510082409		260.7	103.5	115.5	41	17.4
99	07/08/99	1510102A5A		267.1	40.5	46	16	0.9
100	07/08/99	1510082A32		260.7	77.5	90.5	31.5	7.5
101	07/08/99	1510082A56		270.3	68.5	76	25	4.8
102	07/08/99	1510103216		270.3	74.5	84.5	21.5	4.6
103	07/14/99	1510080A48		225.3	122	138	51	30.0
104	07/27/99	1510083958		2.4*	121.5	134	47	28.8
105	07/27/99	1510102C6A		15.1*			61	61.4
106	07/29/99	1510102936		24.1*	172.5	195	55	75.0
107	08/03/99	151008282C		71.6*	198	214	85	120.0
108	08/03/99	1510103E5C		44.7*	200.5	227	79	115.9
109	08/04/99	1510107A71		71.6*	224	244	86	
110	08/05/99	151008144E		78.8*	152	167	62	69.0
111	08/11/99	151010464E		4.2*	175	200	78.5	105.0
112	08/11/99	1510107A54		15.1*	208	240	80	
113	08/11/99	151010144E		15.1*	160	186	60	66.0
114	08/11/99	151010261E		16.4*	170	185	63	73.0
115	08/11/99	151008295C		17.4*	132	153	50	35.0
116	08/11/99	151008441C		16.4*	151	169	59	55.0
117	08/12/99	1510080064		25.7*	122.5	138	50	30.0
118	08/12/99	1510102A51		12.2*	139	159	60	50.0
119	08/12/99	151008314C		17.4*	155	178	64	64.0
120	08/24/99	4158470F08		212.4	135	156	60	40.3
121	08/24/99	151010765A		218.0	206	225	78	143.7
122	08/25/99	1510082161		220.4	95	108	42	15.1
123	08/25/99	1510080060		215.6	121	138	56	33.0
124	08/25/99	1510106E66		222.8	76.5	86	30	6.5
125	08/25/99	1510102631		222.0	109	119.5	51	24.7
126	08/26/99	151010615C		211.6	85	101	35	9.6

Table A-1. cont.

Fish No.	Date	PIT tag number	Floy tag number	Location (Rkm)	Fork Length (cm)	Total Length (cm)	Girth (cm)	Weight (kg)
127	08/26/99	1510085A11	120	222.8	74.5	83	31	9.0
128	08/26/99	1510083E7E		222.8	72.5	86	24	4.1
129	08/26/99	151008241A		211.6	78	91	29	5.6
130	08/26/99	1510103E32		219.6	100	115	48	19.8
131	08/26/99	1510082156		213.2	113	130	45	23.4
132	08/26/99	1510103E11		216.4	120	150	56	34.1
133	08/26/99	1510102410		211.6	126	145	51	31.9
134	08/26/99	1510104A5C		210.8	132	154	63.5	44.0
135	08/31/99	1510085A11		225.3				
136	08/31/99	1510082E6E		226.9	85	99	36	10.0
137	09/08/99	1510104218	153	257.8	71	81	26	4.5
138	09/08/99	1510104176		257.8	72.5	82	26	5.5
139	09/08/99	1510101658		257.8	78	87	28	6.0
140	09/08/99	151010611C		257.8	85	96	32	8.0
141	09/08/99	1510103E42		262.3	63	70	50	4.0
142	09/08/99	1510082829		262.3	205	220	80	
143	09/09/99	1510102408		257.8	80	91	30.5	7.5
144	09/09/99	151010310A		268.7	84.5	93	28	7.6
145	09/09/99	1510103232		257.8	97	109.5	37.5	14.2
146	09/09/99	151010423A	261	257.8	77	85	27.5	6.6
147	09/09/99	151010114C	330	271.1	112	128	38.5	19.2
148	09/09/99	1510100269		257.8	57	64	20	2.3
149	09/09/99	1510082226		271.1	59.5	70	20	2.8
150	09/09/99	1510105272		257.8	78	86	27.5	6.1
151	09/09/99	1510105018		257.8	84	94	31	8.7
152	09/09/99	1510103166		257.8	88	97.5	31	8.7
153	09/09/99	1510083A22		271.1	154	172	63	65.0
154	09/14/99	151010041C		297.7	56	63	18	2.0
155	09/14/99	1510103641		286.4	66	71.5	23	7.5
156	09/14/99	1510105978		275.1	75	84	29	7.0
157	09/14/99	1510101222		284.8	77	87	26	5.0
158	09/14/99	1510082846		273.5	77	99	33	10.0
159	09/14/99	1510101442		294.4	125	140	51.5	
160	09/14/99	1510103149	162	284.8	74	87	26	7.0
161	09/14/99	1510105E16	291	284.8	61	70	19	3.0
162	09/14/99	1510101640	121	284.8	78.5	92	27	7.0
163	09/14/99	1510104C28		297.7	197	224	88	
164	09/14/99	1510105116		294.4	67.5	78.5	20.5	6.0
165	09/14/99	1510101624		294.4	74	81.5	22	7.5
166	09/14/99	1510105139		283.2	74	85	22	4.5
167	09/14/99	1510103C11		286.4	103	113	40	20.5
168	09/14/99	1510100848		284.8	162	182	63	58.0
169	09/15/99	1510105428		275.1	202	230	94	
170	09/15/99	1510083H49		284.8	166	192	82	107.0

Table A-1. cont.

Fish No.	Date	PIT tag number	Floy tag number	Location (Rkm)	Fork Length (cm)	Total Length (cm)	Girth (cm)	Weight (kg)
171	09/15/99	1510084851		297.7	51	60.5	21	3.9
172	09/15/99	1510082620		294.4	64.5	76	24.5	3.8
173	09/15/99	1510101639		297.7	65.5	75.5	20	2.5
174	09/15/99	1510107650		271.9	66	74	23.5	7.0
175	09/15/99	1510082828		283.2	66	74	21	6.0
176	09/15/99	1510101612		283.2	67.5	78.5	23	4.5
177	09/15/99	151010340C		297.7	68	80	29.5	5.0
178	09/15/99	1510102911		273.5	69	79.5	26	6.0
179	09/15/99	1510100679		283.2	69.5	75	22.5	5.0
180	09/15/99	1510103C42		271.9	71	77.5	23	6.5
181	09/15/99	1510103C0E		271.9	75.5	83.5	26	9.0
182	09/15/99	1510082620		294.4	80.5	92.5	27.5	7.0
183	09/15/99	1510102829		280.0	111	123.5	40.5	20.0
184	09/15/99	1510084E42	407	273.5	73	82.5	27.5	9.0
185	09/15/99	151008247C		302.5	74	84	23.5	4.5
186	09/15/99	1510083218		283.2	71	80	24	7.0
187	09/15/99	1510103100		294.4	77	89	23	5.2
188	09/15/99	151010222C		302.5	200	227.5	89	
189	09/16/99	1510103262		271.9	185	204	88	155.0
190	09/16/99	1510105826		276.7	212	232	77	247.0
191	09/16/99	1510104426		271.9	171	183	84	102.0
192	09/16/99	1510104C46		294.4	53.34	63.5	17.78	2.9
193	09/16/99	1510103A69		284.8	66	77	22	3.5
194	09/16/99	1510082E24		297.7	66.04	76.2	24.13	4.3
195	09/16/99	151010011A		284.8	67	77	23	3.5
196	09/16/99	151008264A		283.2	71.12	83.82	20.32	4.6
197	09/16/99	151008284E		273.5	72	89	23	4.0
198	09/16/99	1F4D122959		283.2	73.66	83.82	22.86	5.1
199	09/16/99	1510103056		284.8	75	87	23	4.5
200	09/16/99	1510103E20		271.9	80	90	29	8.0
201	09/16/99	151008512C		294.4	83.82	96.52	25.4	7.8
202	09/16/99	1510105452		294.4	175.26	203.2	78.74	89.5
203	09/16/99	1510082834		283.2	60.96	71.12	20.32	3.3
204	09/16/99	151010246A		284.8	67	77	21	3.5
205	09/16/99	1510081862		284.8	71	81	24	5.0
206	09/16/99	151008143A		276.7	95	107	32	12.0
207	10/12/99	1510084A11	361	212.4	76	87	29	6.8
208	10/12/99	1510106E66		220.4	80	89	32	5.5
209	10/12/99	1510083262		210.8	82.5	95.5	30	7.1
210	10/12/99	1510102210		218.8	93	102	36	10.0
211	10/12/99	7F7D43572F		212.4	96	107	38	11.8
212	10/12/99	1510102158		217.2	97	107	36	11.0
213	10/13/99	1510084A40	196	212.4	138	160	61	45.6
214	10/13/99	1510082230		211.6	52.5	62.5	21.5	2.2

Table A-1. cont.

Fish No.	Date	PIT tag number	Floy tag number	Location (Rkm)	Fork Length (cm)	Total Length (cm)	Girth (cm)	Weight (kg)
215	10/13/99	1510082944		211.6	69	81	27	4.5
216	10/13/99	1510084854		213.2	73	88	30.5	6.5
217	10/13/99	151008222C		213.2	73	93	33	8.2
218	10/13/99	1510105E78		213.2	77	93	35	8.5
219	10/13/99	1510100910		210.8	81	94	32	8.2
220	10/13/99	1510081979		212.4	94	112	38	11.8
221	10/13/99	151008341E		220.4	120	135	42	21.2
222	10/19/99	1510083A50		229.3	69.5	78	23	3.4
223	10/19/99	1510103650		229.3	94	105	37	13.3
224	10/20/99	1510085A3C		226.9	77	90	32.5	8.2
225	10/20/99	1510101C1A		228.5	78	90.5	30.5	7.3
226	10/20/99	151010105A		229.3	80	92	31.5	7.1
227	10/21/99	151010293A		226.1	46	54	16.5	1.3
228	10/21/99	1510081204		230.1	108	124	43	16.5
229	11/02/99	1510101618		202.7	164	189	70.5	69.5
230	11/02/99	1510082A7A	281	188.3	131	154	53	40.0
231	11/02/99	1510083C49	368	202.7	99	112	35.5	12.0
232	11/02/99	1510101C7A	379	188.3	161	183	73	71.0
233	11/02/99	151010084A		202.7	80	93.5	31	8.0
234	11/02/99	1510100C04		202.7	86	101	32	9.0
235	11/02/99	1510102852		202.7	96	110	41.5	16.0
236	11/02/99	1510080000		202.7	98	113	37.5	12.5
237	11/02/99	1510107658		201.1	101	115	39	14.5
238	11/02/99	151010290A		202.7	102.5	119	43	18.0
239	11/03/99	1510080018		202.7	171	195	78	97.0
240	11/03/99	15008563E	359	202.7	116	134.5	47.5	25.0
241	11/03/99	151010642C		183.4	81	92.5	34	9.6
242	11/03/99	1510101661		202.7	111	131	45	20.0
243	11/03/99	1510081902		178.6	131.5	151	52	37.3
244	11/03/99	1510107634		202.7	135	160	61	44.0
245	11/03/99	1510106E64		202.7	137	164	57	46.0
246	11/03/99	1510103A78		202.7	148	172	65	63.0
247	11/03/99	1510106E41		178.6	130.5	149.5	57.5	40.6
248	11/04/99	1510100261		202.7	116	136	47	23.5
249	11/04/99	7F7D400E70		202.7	160	183	72	99.0
250	11/04/99	41584D0916	13	202.7	114	133	151	26.0
251	11/04/99	7F7F745554	146	202.7	106	132	43	17.5
252	11/04/99	1510101C26	349	202.7	79.5	90	27.5	4.0
253	11/04/99	1510102914		202.7	80	90.5	32	8.0
254	11/04/99	1510082179		201.1	150	170.5	50	63.0
255	11/09/99	151008440E		296.1	229	261	92	181.0
256	11/09/99	1510105470	299	294.4	85.5	96	29	8.2
257	11/09/99	1510103A0C		281.6	63	74	21	1.0
258	11/09/99	1510104C66		275.9	71	83	24.5	4.0

Table A-1. cont.								
Fish No.	**Date**	**PIT tag number**	**Floy tag number**	**Location (Rkm)**	**Fork Length (cm)**	**Total Length (cm)**	**Girth (cm)**	**Weight (kg)**
259	11/09/99	1510084812		291.2	76	87.5	29	6.4
260	11/09/99	1510105638		278.4	142	162	49	42.0
261	11/09/99	1510082E06		299.3	161	188	71.5	69.3
262	11/09/99	1510102C21		289.6	164	187	71	78.1
263	11/09/99	151010480E		284.0	165	187	68	85.0
264	11/09/99	1510105601		299.3	191.5	222	83	139.3
265	11/09/99	1510101640	121	284.8	83	97.5	29	6.5
266	11/09/99	1510101450		284.8	175	200	73	80.0
267	11/09/99	1510102C28		275.9	68	80	24	3.0
268	11/09/99	151008561A		284.0	68	80	24.5	2.0
269	11/09/99	151010215E		284.8	73	85	25	5.0
270	11/09/99	151010517E		274.0	76	87	30	5.0
271	11/09/99	1510103141		280.0	79	87	32	5.0
272	11/09/99	1F4D034C45		274.0	89	106	36	10.5
273	11/09/99	1510082224		278.4	97	111	40	15.0
274	11/09/99	1510105844		281.6	142	168	60.5	50.0
275	11/09/99	1510101A19		276.7	144	165	57.5	45.0
276	11/09/99	1510082C40		275.9	163	189	63.5	60.5
277	11/09/99	1510105830		294.4	172	196	74	84.5
278	11/10/99	1510101C6A		278.4	65	76	24	3.0
279	11/10/99	1510102C72		281.6	68	81	22	3.0
280	11/10/99	1510101606		284.0	79	92.5	29	6.0
281	11/10/99	1510085131	466	278.4	152	176	66	61.0
282	11/10/99	1510080660		299.3	64	75	22.5	4.2
283	11/10/99	1510101448		288.0	68	78.5	23	4.7
284	11/10/99	1510106E30		288.0	70	82.5	21	4.5
285	11/10/99	1510102C74		294.4	71	82	22.5	4.4
286	11/10/99	1510104476		280.0	73	87	21	3.5
287	11/10/99	1510102A2A		288.0	74.5	86.5	26	5.9
288	11/10/99	1510101C7A		280.0	75	85.5	30.5	6.5
289	11/10/99	1510102918		275.9	90	104	38	12.0
290	11/10/99	1510085A70		275.9	99	113.5	36	13.0
291	11/10/99	1510101E56		278.4	120	138	53	29.5
292	11/10/99	1510080149		294.4	162	188	67.5	62.6
293	11/10/99	1510082E0A		289.6	166.5	190	69	77.7
294	11/16/99	1510100E60		26.5*	202	226	84	175.0
295	11/16/99	1510107A44		33.0*	205	238.5	76	143.0
296	11/16/99	1510102936		24.9*	170	193	67	76.0
297	11/16/99	1510103271		30.6*	109	127	42	19.0
298	11/16/99	1510103041		33.0*	153.5	170	60	52.0
299	11/17/99	151010287A		30.6*	93	97.5	40	12.5
300	11/17/99	1510083958		1.1*	119	137	47	38.0
301	11/18/99	1510082200		33.0*	102	115	38	15.4
302	11/30/99	1510103E34		74.0*	205	227	83	126.2

Table A-1. cont.

Fish No.	Date	PIT tag number	Floy tag number	Location (Rkm)	Fork Length (cm)	Total Length (cm)	Girth (cm)	Weight (kg)
303	11/30/99	1510107A11		57.1*	195	225	88	
304	12/02/99	151010764A		74.0*	173	189.5	78	100.0
305	12/07/99	151010366A		255.8	226.5	251	113	263.7
306	12/07/99	1510085A29	351	263.1	111	128	53	27.0
307	12/09/99	1510106E56		267.9	138	157	63	49.9
308	12/14/99	151008163		296.1	63.5	74	20	3.0
309	12/14/99	1510082822		272.7	65.5	71	24	3.5
310	12/14/99	1510082E70		272.7	69	82	24.5	4.5
311	12/14/99	1510085131	466	278.4	153	177	67	62.0
312	12/14/99	1510103970		285.6	173	196	75	86.0
313	12/14/99	151008264A		272.7	71	82.5	20.5	3.0
314	12/15/99	1510105A70		299.3	56	64	19	2.2
315	12/16/99	1510083201		288.0	119	136.5	40.5	21.3
316	12/16/99	1510101842		273.5	209	235	94	167.0
317	12/16/99	1510102A10		275.9	188	218	82.5	117.0
318	12/16/99	1510083952		272.7	98.5	114	40	14.5
319	12/17/99	1510104C49		288.0	181.5	204	84	103.0
320	12/17/99	1510100C1A		287.2	75	85.5	25	4.5
321	12/17/99	151008341E		272.7	163	187	88.5	81.0

* Salmon River

APPENDIX B

1999 White Sturgeon Radio Tag Data

Table B-1. White sturgeon fitted with Combined Acoustic/Radio Tags (CART) in the Snake and Salmon rivers, 1999.

Tag Date	River	Location (Rkm)	Total Length (cm)	Weight (kg)	Gender
3/23	Snake	273	108.5	6.5	Male
3/25	Snake	262	134	12.4	Undetermined
4/13	Snake	258	176	35.5	Undetermined
4/20	Snake	182	141	19.7	Undetermined
4/21	Snake	184	165	30.2	Female
5/17	Salmon	71.5	225	72	Undetermined
5/20	Salmon	67	179	34.9	Female
11/4	Snake	126	136	10.7	Undetermined
11/4	Snake	203	183	44.9	Male
11/9	Snake	296	261	82.1	Female
11/9	Snake	284	187	38.6	Undetermined
11/9	Snake	299	222	63.2	Male
11/16	Salmon	33	238.5	64.9	Female
11/16	Salmon	26.5	226	79.4	Female
11/16	Salmon	25	193	34.5	Undetermined