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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

2002 Annual Report

1997 – 2002

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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 report presents a summary of results from the 1997-2002 Phase II data collection and represents the end of phase II.

From 1997 to 2001 white sturgeon were captured, marked, and population data were collected in the Snake and Salmon. A total of 1,785 white sturgeon were captured and tagged in the Snake River and 77 in the Salmon River. Since 1997, 25.8 percent of the tagged white sturgeon have been recaptured. Relative density of white sturgeon was highest in the free-flowing segment of the Snake River, with reduced densities of fish in Lower Granite Reservoir, and low densities the Salmon River. Differences were detected in the length frequency distributions of white sturgeon in Lower Granite Reservoir, the free-flowing Snake River and the Salmon 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 30 percent since the 1970's. 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 2,483 fish, with a 95% confidence interval of 1,208-7,477. Total annual mortality rate was estimated to be 0.14 (95% confidence interval of 0.12 to 0.17).

A total of 35 white sturgeon were fitted with radio-tags during 1999-2002. The movement of these fish ranged from 53 km (33 miles) downstream to 77 km (48 miles) upstream; however, 38.8 percent of the detected movement was less than 0.8 km (0.5 mile). 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.

Analysis of the length-weight relationship indicated that white sturgeon in Lower Granite Reservoir had a higher relative weight factor than white sturgeon in the free-flowing Snake River. The results suggest fish are currently growing faster than fish historically inhabiting the study area, as well as other Columbia River basin white sturgeon populations.

Artificial substrate egg mats documented white sturgeon spawning in four consecutive years. A total of 49 white sturgeon eggs were recovered in the Snake River from 1999-2002, and seven from the Salmon River during 2000.

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The Bonneville Power Administration provided funding for this project. Charles Axtell and Clint Chandler conducted the field sampling. Dr. Dennis Scarnecchia of the University of Idaho, Department of Fish and Wildlife provided generous use of his laboratory for pectoral fin ray analysis. We thank Ken Lepla and Phil Bates with Idaho Power Company for their cooperation and data sharing. We also appreciate the Nez Perce Tribe for administration of this project.

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 population. In 1996, a 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 on critical uncertainties 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, 1998, 1999, 2000, and 2001 is reported in Hoefs (1998), Tuell and Everett (2000), Tuell and Everett (2003), Everett and Tuell (2003a), and Everett and Tuell (2003b), respectively. The primary objective of sampling in 2002 was to collected data on white sturgeon movement, spawning and rearing. This report presents a summary of results from the 1997-2002 Phase II data collection and represents the end of phase II as outlined in the Multi-year Study Plan (Hoefs 1997).

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 actions 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 by Hoefs (1997).

Table 1. Phase II research tasks 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 white 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.

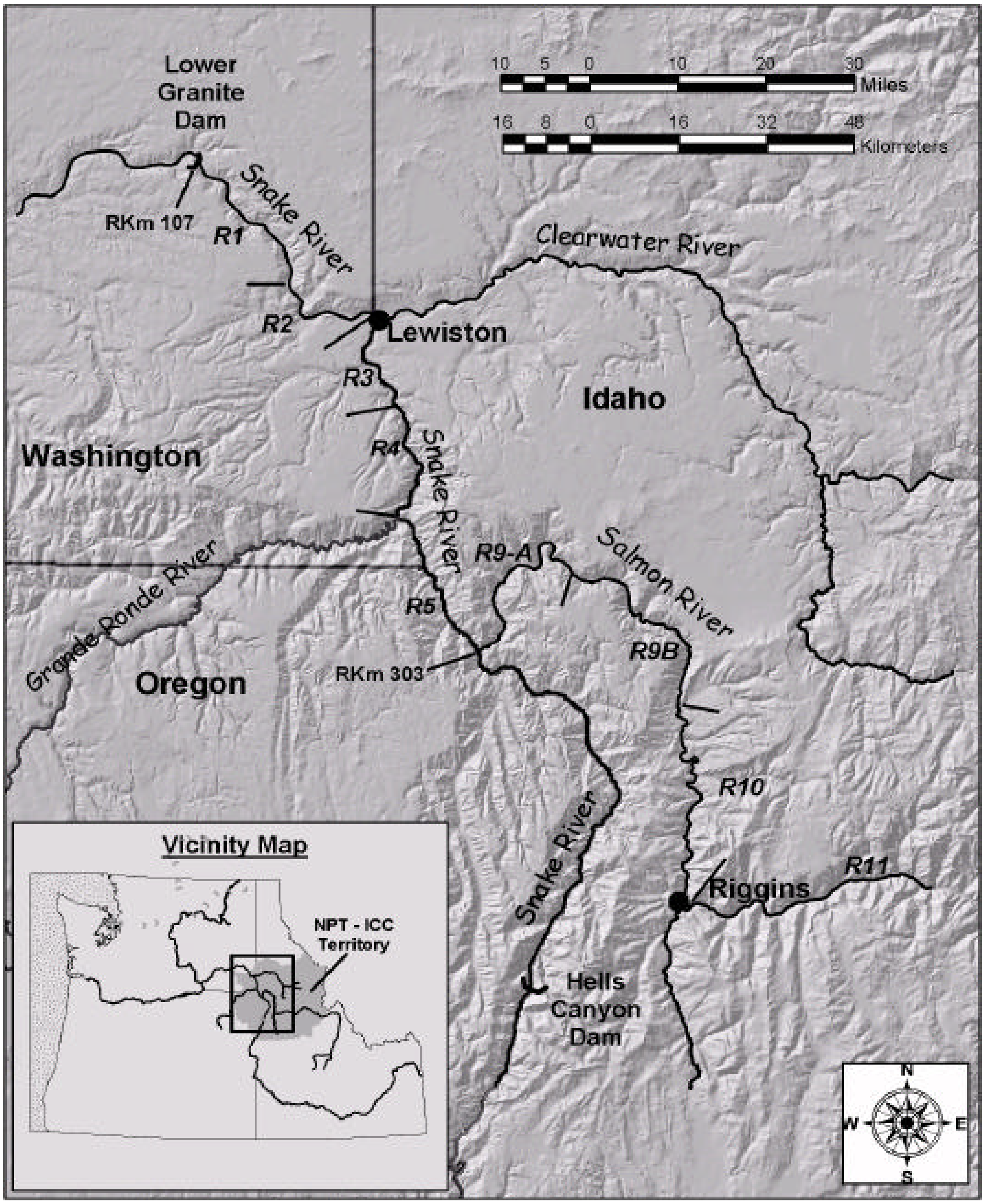

Figure 1. Map of study area. Sampling reaches are identified as R1 through R11.

Fish Sampling

The research study design (Hoefs 1997) called for stratified random sampling of reaches (Table 2) at weekly intervals from January through December. 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, gill nets, 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.

Table 2. Reach locations for white sturgeon sampling in the Snake, Salmon and Clearwater rivers, 1997-2001.

Study Reach	Location Description	Lower Rkm	Upper Rkm
1	Lower Segment Lower Granite Reservoir	174	206.5
2	Upper Segment Lower Granite Reservoir	207	223.5
3	Clearwater River - Tenmile Rapids	224	239.5
4	Tenmile Rapids - Grand Ronde River	240	270.5
5	Grande Ronde River - Salmon River	271	302.5
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
9b	Upper Salmon River Gorge	42	83.5
10	Middle Salmon River[2]	84	131.5
11	Upper Salmon River[2]	132	185
12	Clearwater River	0	74

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

Gill nets were rigged with lead-lines and anchors that held nets on the bottom of the channel (diver nets). Gill nets were 61 m long and 5.5 m deep. Each net consisted of panels with mesh sizes that varied from approximately 10 to 25 cm (stretched diagonal).

Nets were generally set for 24 hours periods. Net set time was recorded and catch-per-unit-effort (CPUE) was calculated based on an average net of 334 m^2, fished for 1000 hours. Gill nets were used only during 1997 in Lower Granite Reservoir.

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. Each setline used a combination of ten 8/0, 10/0, 12/0, 14/0 and 16/0 hooks. Pickled squid and lamprey were used as bait. Setlines were checked twice a day and empty hooks rebaited. Set hours were recorded and the CPUE was calculated based on 1000 hours for a single setline with ten hooks.

Sampling for white sturgeon young-of-the-year (YOY; < 25 cm TL) was conducted in 2001. Setlines were rigged with 50 'J' hooks, ranging in size from 6 to 16, and were baited with worms, salmon eggs, pickled squid, herring and/or shad. Setlines were deployed and checked as described above. YOY sampling was conducted in areas adjacent to where white sturgeon abundance sampling was conducted. Sampling sites were randomized within each reach and selected as described above. Sampling effort consisted of six setlines per reach.

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 1000 angler-hours.

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 1997-2001 random stratified sampling conducted for population abundance did not include the Snake River above the mouth of the Salmon River.

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 Floy tags and/or 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.

Habitat data were collected throughout the study area and at most sampling sites, including: water depth, velocity, substrate, water temperature and discharge. Water column depth was measured to the nearest 0.3 m using boat mounted, commercially available depth finders Various models of Hummingbird®, Lowrance®, Bottomline®, and Eagle® brand depth finders were used on the research vessels. Near substrate velocity was measured using a March-McBirney® Model 2000 flow meter fitted with a 45 m sensor cable. The velocity sensor was attached to 11.3 kg sounding weight and stainless steel retrieval cable. Substrate type was determined through visual inspection. In 2002, an underwater camera was used to conduct a substrate survey of the study area. Substrate type was defined by particle size (Table 3). Each 0.8 km was assigned a substrate type based on the dominant substrate observed during the survey. Water temperature and discharge data was gathered by the United State Geological Survey (USGS) at the Anatone and White Bird gauging stations, and IPC at the mouth of the Salmon River. Site specific water temperature was measured using hand held mercury thermometers.

Differences in CPUE across temperature intervals (five-degree) were tested using ANOAVA procedures for Lower Granite Reservoir, the free-flowing Snake River, and the Salmon River.

Table 3. Substrate types by particle size.

Substrate Type	Particle Size
Silt	< 2 mm
Sand	2 - < 4 mm
Gravel	4 -< 75 mm
Cobble	75 -< 300 mm
Boulder	> 300 mm
Bedrock	Not classified by particle size

Due to the constantly changing flow regimes experienced throughout the Snake and Salmon rivers during the study period, both depth and near substrate velocity varied accordingly. In order to establish preference for these habitat variables, both the range of the habitat variable's availability and use need to be measured (Bramblett 1996). It is not practical to measure use and availability simultaneously over such a large study area. Thus, we will describe only white sturgeon's use of these two habitat variables not preference.

Substrate utilization was visual displayed using Jacobs' (1974) electivity index. This index compared the percentage of different substrates where white sturgeon were captured to the percentage of the available substrate sampled. The electivity index ranged from +1 to –1. Positive values indicated that the substrate was used in greater frequency than its availability, and negative values indicated the substrate was used in lesser frequency than its availability.

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, Tuell and Everett 2003, Everett and Tuell 2003a, Everett and Tuell 2003b). 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. Also, white sturgeon captured during the YOY sampling were not included in the abundance calculations due to differences in sampling effort and gear type.

In order to better evaluate changes in abundance, both a closed population and open population model were selected to calculate the current population abundance (Tuell and Everett 2003, Everett and Tuell 2003a, Everett and Tuell 2003b). 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, Growth and Mortality

Pectoral fin rays were collected for age determination from a sub-sample of fish in 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). Each fin ray was analyzed using the procedure described in Everett et al. (2003). 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.

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). 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. 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 Lower Granite Reservoir, the free-flowing Snake River, and the Salmon River using analysis of variance (ANOVA). Pairwise comparisons were made using Tukey's pairwise test. 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.

Mortality was estimated from a catch curve (Ricker 1975). Length-at-age data was applied to the length frequency distribution of white sturgeon captured from 1997-2001 to calculate the proportion in each age class. Apparent age (t) for any fish size (L_t) was estimated from the reformulation of the von Bertalanffy growth equation:

$$t = t_0 - [\ln(1 - L_t/L_{\infty})/k]$$

The resulting age frequency distribution was used to generate the catch curve. Log transformed catch proportions were regressed on age using only age classes with greater than five observations. Instantaneous total mortality (Z) was estimated as the slope of the descending limb of the catch curve. The total annual mortality (A) was calculated as A = 1 – S, where $S = e^{-z}$. Approximate 95% confidence intervals of the rate estimates were calculated from the regression as ±2 S.E.

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), and were deployed and checked using the method outlined in Tuell and Everett (2003). Eggs and larvae were preserved in formalin for later identification. Temperature, depth, near substrate velocity and substrate were recorded at sampling sites during 1999-2002 (near substrate velocity measurements were not taken during 2002).

Movement

Movement and migration patterns of white sturgeon were investigated using telemetry and mark-recapture data. Fish were selected for telemetry tagging 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, Combined Acoustic and Radio Tag (CART; Deary et al. 1998), using a method similar to Haynes et al. (1978), Apperson and Anders (1990) and modified by Tuell and Everett (2003). 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.

Distribution patterns were assessed using an index (I) defined by North et al. (1993) as:

$$I = \frac{S - L}{T}$$

where S is the river km at capture, L is the river km at the lowest segment boundary, and T is the length of the segment in km. An average index was calculated for each month for both Lower Granite Reservoir and the free-flowing Snake River. A high index value means distribution in the upper portion of the segment, and a low index value means distribution in the lower portion of the segment. In addition, average monthly CPUE values were compared for both Lower Granite Reservoir and the free-flowing Snake River in order to identify differences or patterns in catch rates across seasons.

RESULTS

Sampling Effort

A total of 1,545 hours of gillnet effort, 153,581 hours of setline effort and 3,703 hours of hook-and-line effort was employed in from 1997-2001 (Hoefs 1998, Tuell and Everett 2000, Tuell and Everett 2003, Everett and Tuell 2003a, Everett and Tuell 2003b; Table 4). In Lower Granite Reservoir (reaches 1-3), 1,545 hours of gill nets sampling was conducted with 85,603 hours of setline sampling, and 302 hours of hook-and-line effort. In the free-flowing Snake River (reaches 4-5), 52,692 hours of setline sampling was conducted with 1,779 hours of hook-and-line effort. In the Salmon River (reaches 9-12), 14,683 hours of setline sampling was conducted with 1,456 hours of hook-and-line effort. In the Clearwater River (reach 12), 603 hours of setline sampling was conducted with 106 hours of hook-and-line effort. A total of 1,844 white sturgeon were sampled from 1997-2001; 527 from Lower Granite Reservoir, 1,240 from the free-flowing Snake River, 77 from the Salmon River (Hoefs 1998, Tuell and Everett 2000, Tuell and Everett 2003, Everett and Tuell 2003a, Everett and Tuell 2003b). The CPUE ranged from 21.3 to 105.1 for gill nets, 0 to 28.8 for setlines, and 0 to 151.1 for hook-and-line (Table 4, Figure 2). From 1997 to 2001, incidental captures consisted of 54 channel catfish (*Ictalurus punctatus*), 37 largescale suckers (*Catostomus macrocheilus*), 26 northern pikeminnow (*Ptychocheilus oregonensis*), 19 smallmouth bass (*Macropterus dolomieui*), 12 carp (*Cyprinus carpio*), and 3 chiselmouth (*Acrocheilus alutaceus*).

In 2001, 6,644 hours of white sturgeon YOY setline sampling effort was employed. Sampling was conducted in the Snake River reaches 1-5. No white sturgeon YOY setline sampling was conducted in the Salmon River. A total of 48 white sturgeon were captured. Fish ranged from 52 cm to 94 cm total length and averaged 75.5 cm (Everett and Tuell 2003b). However, no YOY (<25 cm TL) white sturgeon were collected. Incidental captures consisted of 34 channel catfish, 17 largescale suckers, 12 smallmouth bass, and 4 carp.

Table 4. Sampling effort, catch and catch per unit effort (CPUE; 1000 hours) per reach using gill nets, setlines and hook-and-line sampling in the Snake, Salmon and Clearwater rivers during 1997-2001.

Reach	Gill Nets			Setlines			Hook-and-Line		
	Hours	**Catch**	**CPUE**	**Hours**	**Catch**	**CPUE**	**Hours**	**Catch**	**CPUE**
1	485	51	105.1	29,746	220	7.4	61	0	0
2	966	16	16.6	28,943	166	5.7	57	0	0
3	94	2	21.3	26,914	72	2.7	184	0	0
4	0	0	0	26,210	234	8.9	886	134	151.2
5	0	0	0	26,482	764	28.8	893	108	121.0
9a	0	0	0	9,407	62	6.6	88	4	45.5
9b	0	0	0	5,019	10	2.0	311	1	3.2
10	0	0	0	257	0	0	714	0	0
11	0	0	0	0	0	0	343	0	0
12	0	0	0	603	0	0	166	0	0
Total	1,545	69	44.7	153,581	1,528	9.9	3,703	247	66.7

White sturgeon were present throughout the Snake River (Rkm 173.8 to 303.3) and Salmon River (Rkm 0 to Rkm 96.5). White sturgeon were functionally absence in the transition zone between Lower Granite Reservoir and the free-flowing habitat of the Snake River (approximately 15 km). White Sturgeon presence in the Clearwater River was not documented. White sturgeon were sampled throughout the ranges observed for water column depth, near substrate velocities, discharges, and water temperature (Table

5). Jacob's electivity index indicated white sturgeon have a positive association with habitat with substrates of bedrock, boulder, cobble, and sand, and a negative association with habitats with substrates of gravel and silt (Figure 3). No significant differences were found in CPUE (ANOVA, $P>0.05$) across different temperatures where sampling occurred in Lower Granite Reservoir, the free-flowing Snake River, and the Salmon River for the

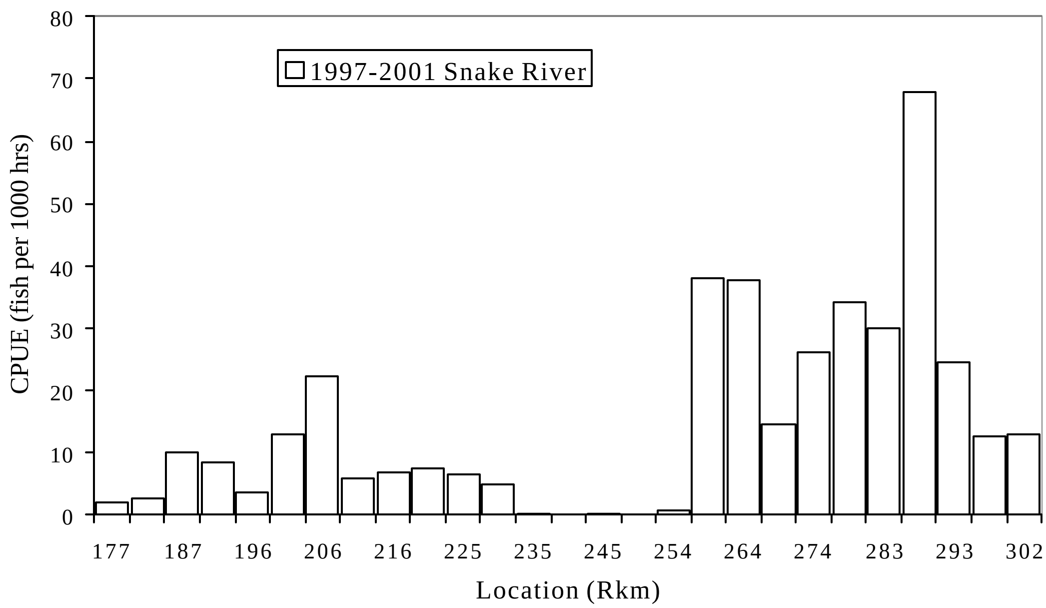

Figure 2. Distribution of CPUE (fish/1000 hours) per five km segments in the Snake River, from 1997 to 2001.

Table 5. Summary of habitat characteristics where white sturgeon were captured in Lower Granite Reservoir, the free-flowing Snake River, and the Salmon River.

Habitat Characteristic	**Lower Granite Reservoir**	**Free-flowing Snake River**	**Salmon River**
Average Discharge (m^3/s)	896	667	188
Range	315-2,974	332-1807	131-462
Average Depth (m)	16	11.4	7.4
Range	4.6-37.2	2.7-34.0	3.4-12.8
Near Substrate Velocity (m^2/s)	1.21	1.19	N/A
Range	0.04-2.40	0.04-2.70	N/A
Average Temperature (C°)	17.5	15.4	16.2
Range	4-23.4	2.5-23.5	4.1-22.5

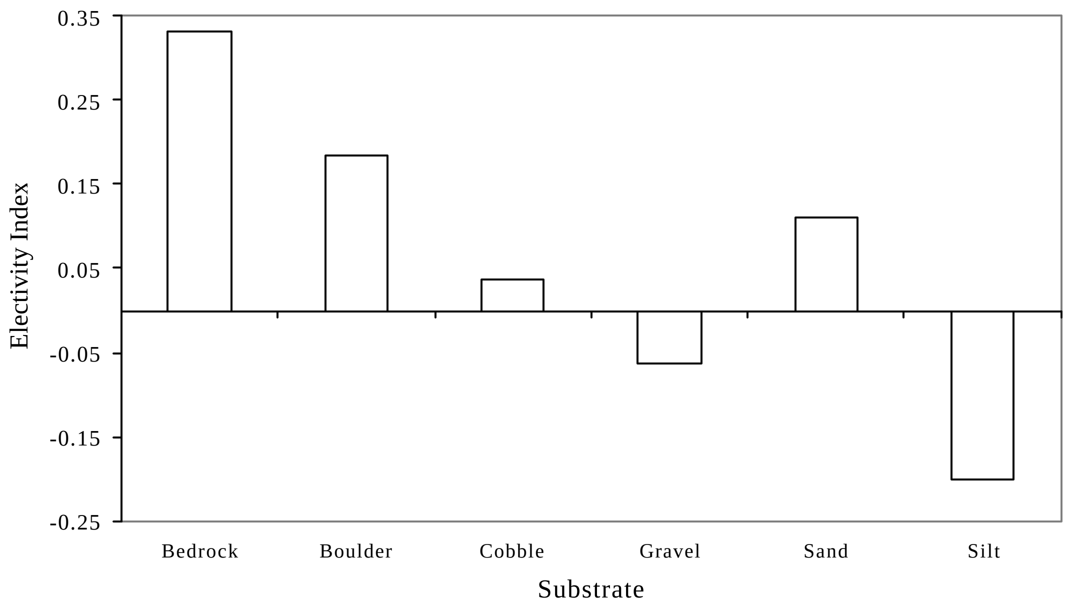

Figure 3. Jacob's index of substrate use by white sturgeon in the Snake River, 1997-2001.

Abundance

Of the 1,862 white sturgeon captured from 1997-2001, 1,335 were unmarked and 527 were previously marked fish. No mortalities occurred during collection or processing. In Lower Granite Reservoir white sturgeon ranged from 46 cm to 252 cm total length with a median of 117 cm (Figure 4; average 111 cm). White sturgeon captured in the free-flowing segment of the Snake River ranged from 27 cm to 307 cm total length with a median of 88 cm (Figure 5; average 106 cm). White sturgeon captured in the Salmon River ranged from 66 cm to 244 cm total length with a median of 169 cm (Figure 6; average 165 cm).

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 during each year from 1997 to 2001 (Hoefs 1998, Tuell and Everett 2000, Tuell and Everett 2003, Everett and Tuell 2003a, Everett and Tuell 2003b). Within each river segment, no significant differences (Chi-Square test, $P>0.05$) were detected in the proportions of different size classes across years. The size class proportions of white sturgeon from the Salmon River from the 1998-2001 combined catch was tested against the combined catch from 1997-2001 for both Lower Granite Reservoir and the free-flowing Snake River. Differences in these proportions were detected between Salmon River white sturgeon and white sturgeon captured in both Lower Granite Reservoir and the free-flowing Snake River (Chi-Square test, $P > 0.05$).

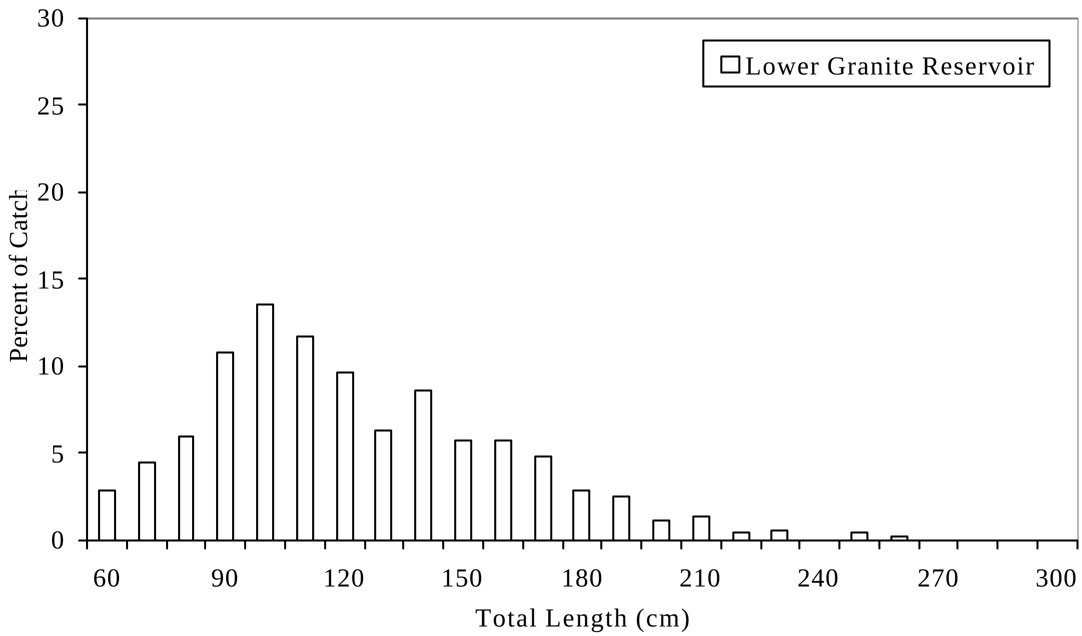

Figure 4. Length frequency distribution of white sturgeon captured in Lower Granite Reservoir during 1997-2001.

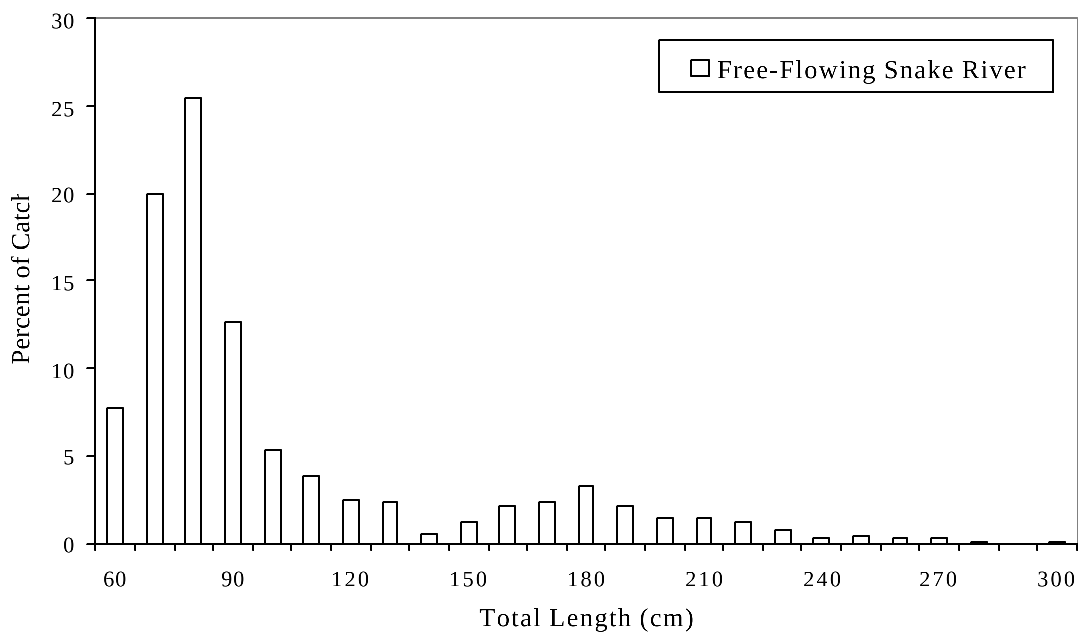

Figure 5. Length frequency distribution of white sturgeon captured in the free-flowing Snake River during 1997-2001.

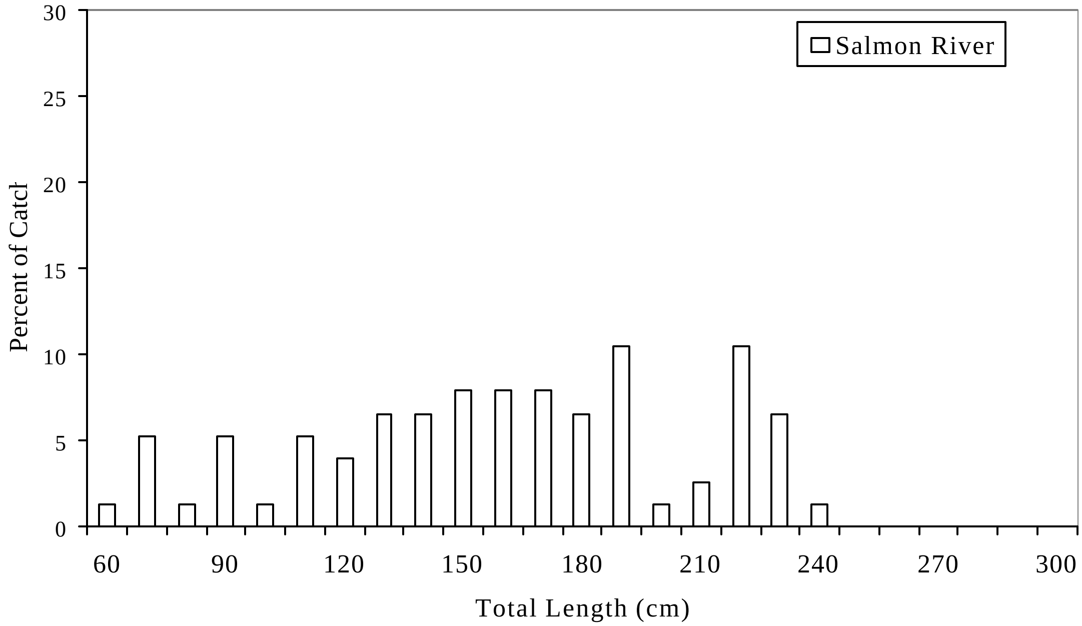

Figure 6. Length frequency distribution of white sturgeon captured in the Salmon River during 1997-2001.

Since 1997, 22 complete sampling passes have been conducted in the Snake River study area. Both the closed and open model abundance estimators were based on a 13-pass model. In the Salmon River, the level of effort was too inconsistent, and 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 2,859 with a 95 percent confidence interval of 2,574-3,214. Using the open model, Jolly-Seber estimate, the abundance was estimated to be 2,139 with a 95 percent confidence interval of 839-9,105. 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, personal communication). Therefore, the density of white sturgeon in that segment of the Snake River is estimated between 0.58 and 0.72 fish/ha using the Schnabel estimate, or 0.19 and 2.05 fish/ha using the Jolly-Seber estimate.

Age, Growth and Mortality

From 1999 to 2001, 335 white sturgeon pectoral fin rays were examined for age from three river segments: 92 fish from Lower Granite Reservoir, 208 fish from the free-flowing Snake River, and 35 from the Salmon River. The age assignment procedure resulted in 26 fish being removed from all samples due to age discrepancies (Table 6). The 309 white sturgeon assigned ages ranged from 2 to 63 years old. The largest white sturgeon aged was a 63-year-old, 307 cm TL, and the smallest an age-2 fish, 52 cm TL. The von Bertalanffy growth curve (Figure 7) generated from length-at-capture data from fish sampled in 1999, 2000 and 2001 (n=309) is given by $L(t)=311(1-e^{-0.045(t+1.34)})$ where L(t) is total length in cm.

From 1997-2001, a total of 1,794 white sturgeon from the Snake and Salmon rivers were measured for weight (kg). These fish ranged in weight between 0.1 and 136 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 $W = (1.59\text{ E-}06)L^{3.25}$ (Figure 8), $W = (1.22\text{ E-}06)L^{3.29}$ (Figure 9, and $W =(1.74\text{ E-}06)L^{3.22}$ (Figure 10), 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 90.5, 84.6 and 83.4, respectively. The W_r differed significantly between Lower Granite Reservoir and both the free-flowing Snake River and the Salmon River (ANOVA; $P<0.05$).

Table 6. Summary of pectoral fin rays collected by river segment, aged, and removed from analysis because of age discrepancies in 1999, 2000 and 2001.

	Number of Samples		
Location	**Collected**	**Removed**	**Aged**
Lower Granite Reservoir	92	11	81
Free-Flowing Snake River	208	14	194
Salmon River	35	1	34
Total	335	26	309

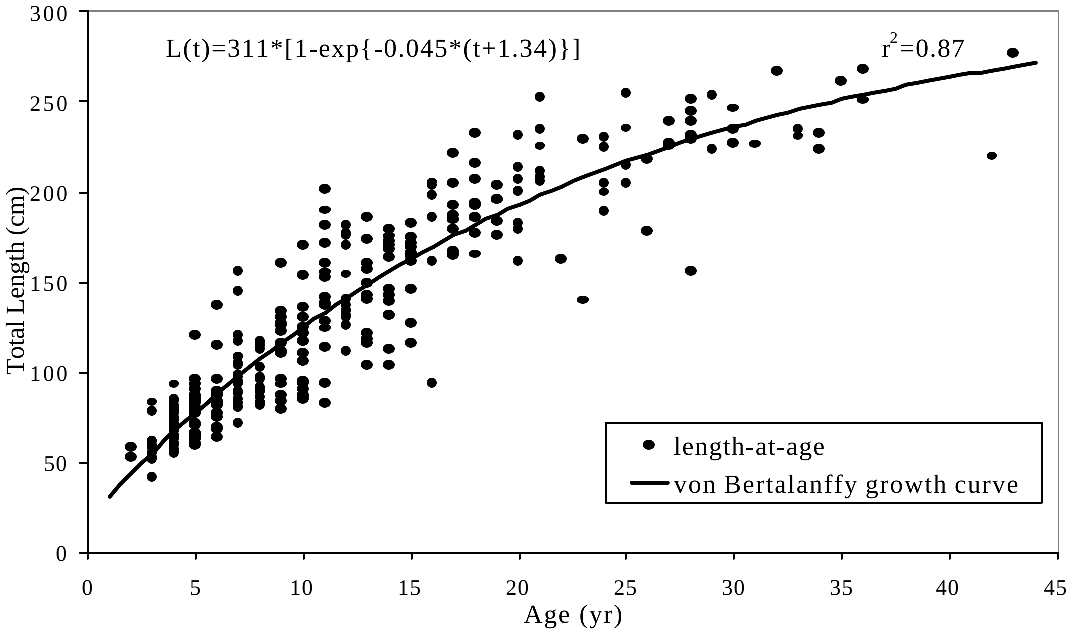

Figure 7. The von Bertalanffy growth curve fitted to 309 aged white sturgeon in the Snake and Salmon Rivers, 1999, 2000 and 2001.

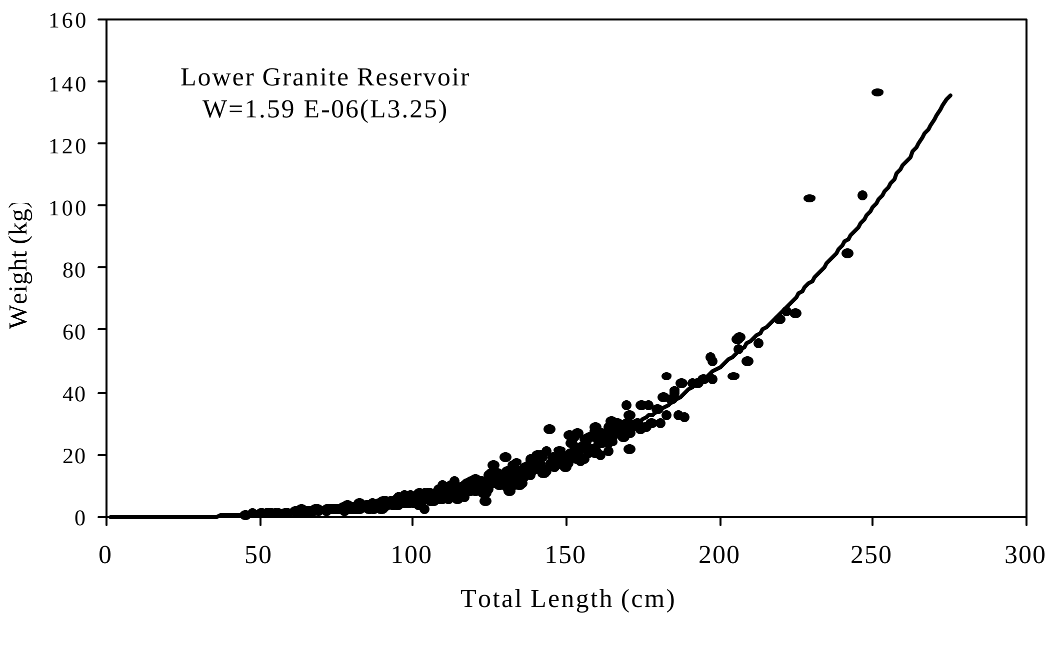

Figure 8. Allometric relationship between weight (kg) and total length (cm) for white sturgeon collected in Lower Granite Reservoir during 1997-2001.

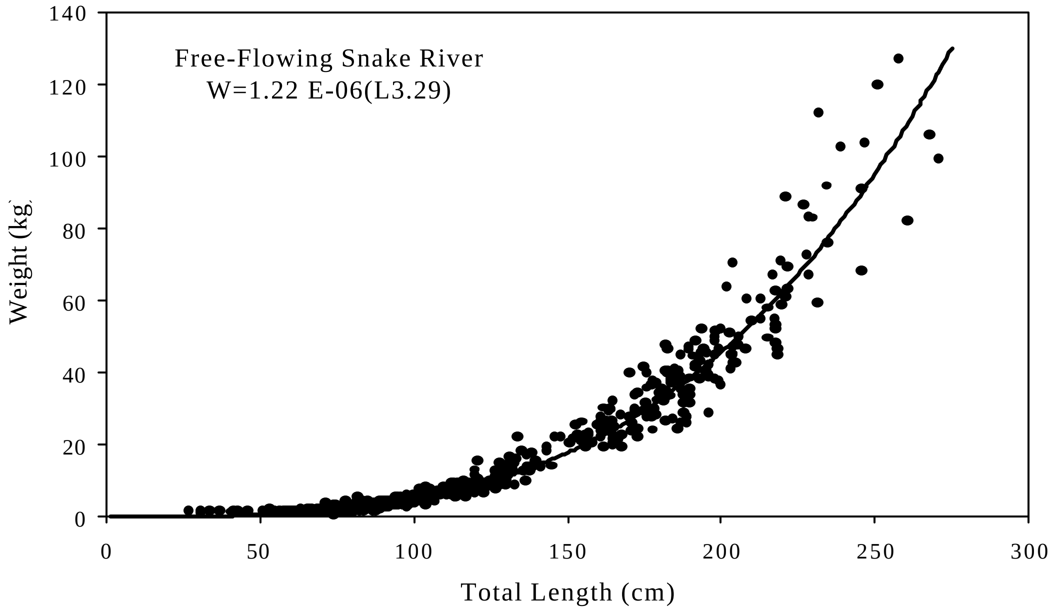

Figure 9. Allometric relationship between weight (kg) and total length (cm) for white sturgeon collected in the free-flowing Snake River during 1997-2001.

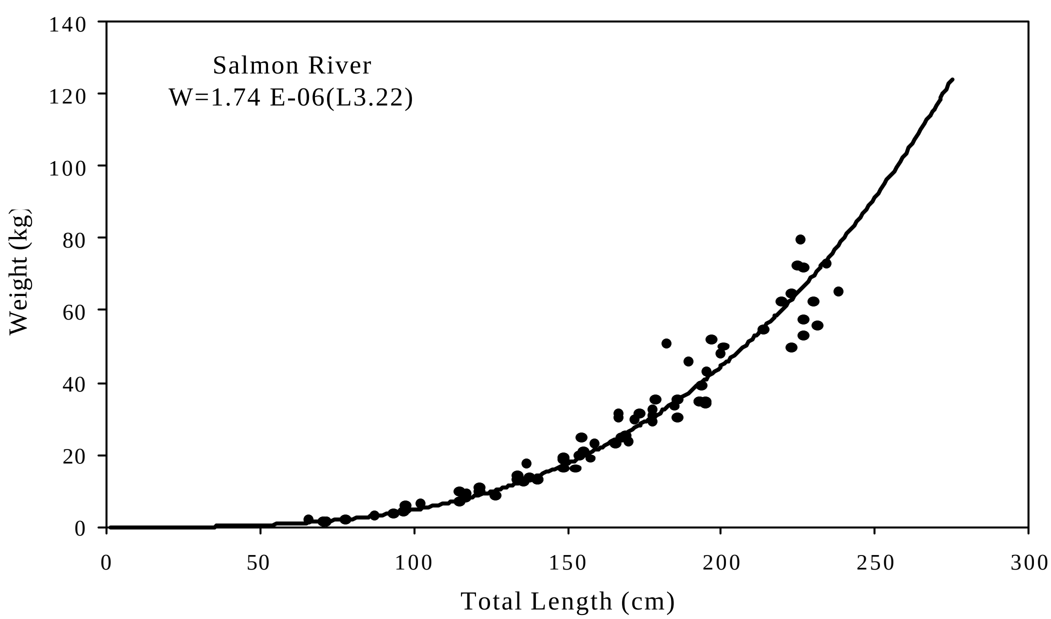

Figure 10. Allometric relationship between weight (kg) and total length (cm) for white sturgeon collected in the Salmon River during 1997-2001.

The total instantaneous mortality rate (Z) derived from the catch curve for 1997-2001 was estimated at 0.15 (95% C.I. of 0.12 to 0.18) for white sturgeon aged 6-25 (90-210 cm TL; Figure 11). Few fish were observed in age classes over 25 years old. The total annual mortality (A) rate was estimated at 0.14 (95% C.I. of 0.12 to 0.17), and the survival rate (S) was estimated at 0.86 (95% C.I. of 0.83 to 0.88).

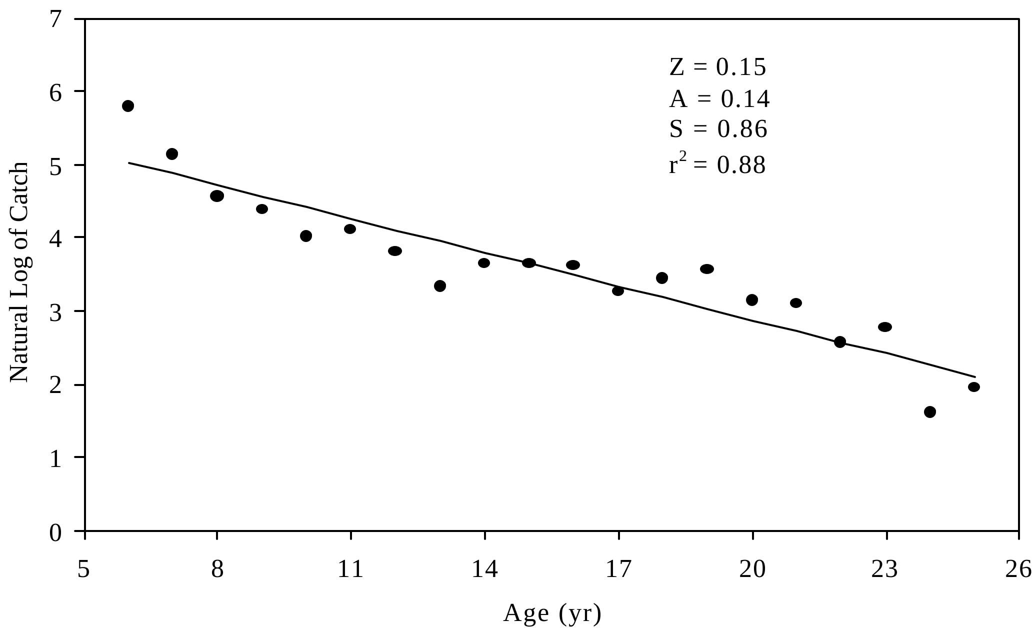

Figure 11. Catch curve and estimated mortality and survival rates for white sturgeon captured in the Snake River during 1997-2001.

Spawning

From 1997-2001, 59.3% of the captured white sturgeon over 150 cm TL were examined by surgical biopsy to determine gender. Gender was assigned to 181 of the 219 white sturgeon examined. A total of 92 fish were determined to be female, and 89 fish were determined to be male, resulting in a 0.97:1 male to female sex ratio.

From 1999-2001, 122 artificial egg mats were deployed in the Snake River. During 2000, 12 artificial substrate mats were deployed in the Salmon River. A total 129,408 hours of artificial egg mat effort was conducted in the Snake River, and 8,928 hours in the Salmon River. In the Snake River, artificial substrate mats were located from Rkm 131 to Rkm 188, and eggs were recovered from Rkm 164.5 to Rkm 183. In the Salmon River, artificial substrate mats were located from Rkm 40.2 to Rkm 44.0, and eggs were recovered from Rkm 40.5 to Rkm 40.7. Fifty-six white sturgeon eggs were recovered, 49 in the Snake River and seven in the Salmon River (Appendix A). During the time the eggs were found, the daily mean discharge at the Anatone Snake River gauge (13334300; Rkm 269) ranged from 436 to 3,540 m^3/s (15,395 to 125,000 cfs; Figures 12, 13, 14, and 15), and 476 to 1,178 m^3/s (16,808 to 41,596 cfs) at the Salmon River gauge at White Bird (Rkm 84; Figure 16). At sites where eggs were found in the Snake River, the mean near substrate velocity was 1.0 m/s, mean water temperature was 16EC and mean depth was 5.5 m. At sites where eggs were found in the Salmon River, the mean near substrate velocity was 1.2 m/s, mean water temperature was 13.7EC and mean depth was 2.9 m. At each egg location, the primary substrate type was sand or gravel.

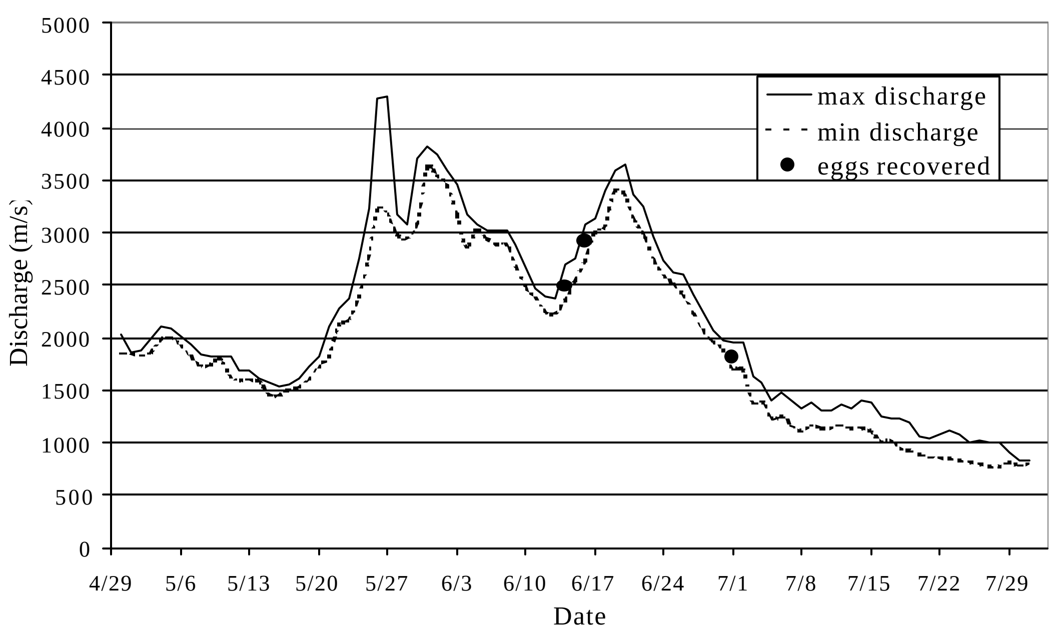

Figure 12. Daily minimum and maximum discharge at the Snake River, Anatone gauge when white sturgeon eggs were collected in the Snake River, 1999 (USGS gauge number 13334300).

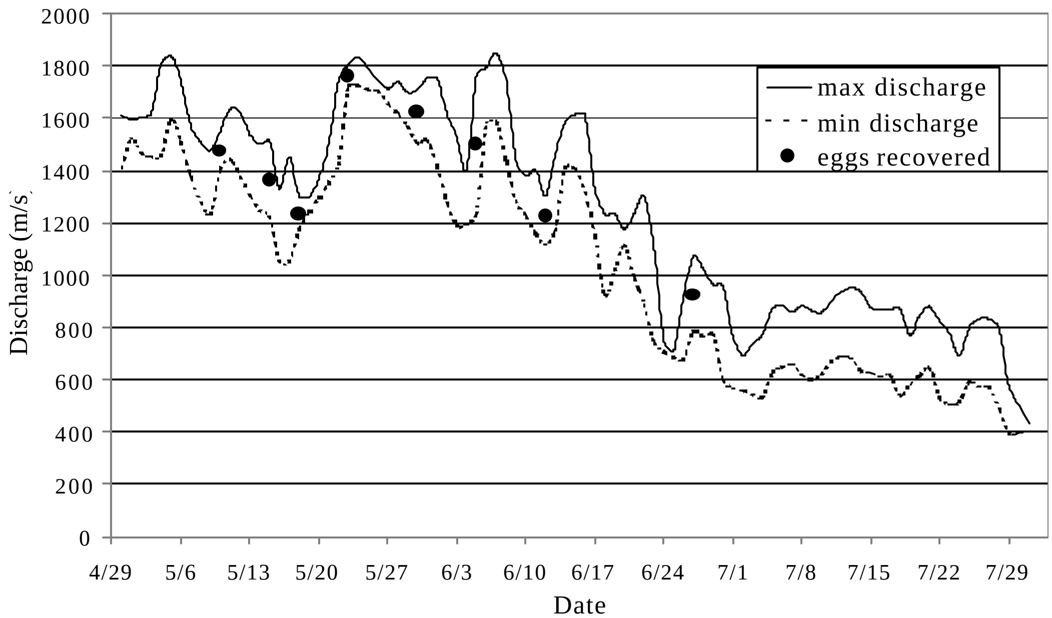

Figure 13. Daily minimum and maximum discharge at the Snake River, Anatone gauge when white sturgeon eggs were collected in the Snake River, 2000 (USGS gauge number 13334300).

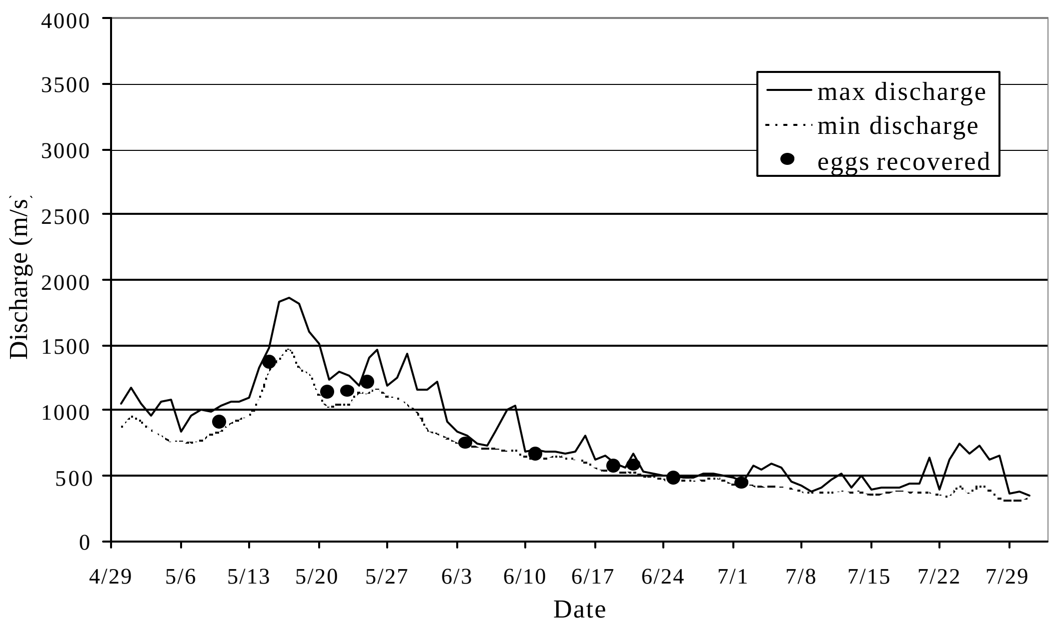

Figure 14. Daily minimum and maximum discharge at the Snake River, Anatone gauge when white sturgeon eggs were collected in the Snake River, 2001 (USGS gauge number 13334300).

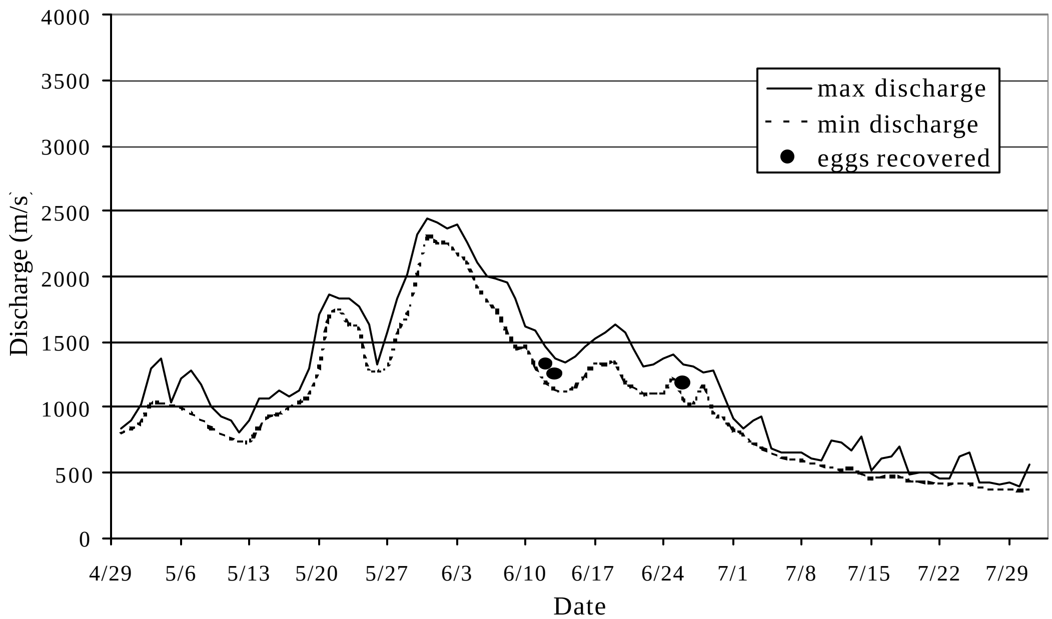

Figure 15. Daily minimum and maximum discharge at the Snake River, Anatone gauge when white sturgeon eggs were collected in the Snake River, 2002 (USGS gauge number 13334300).

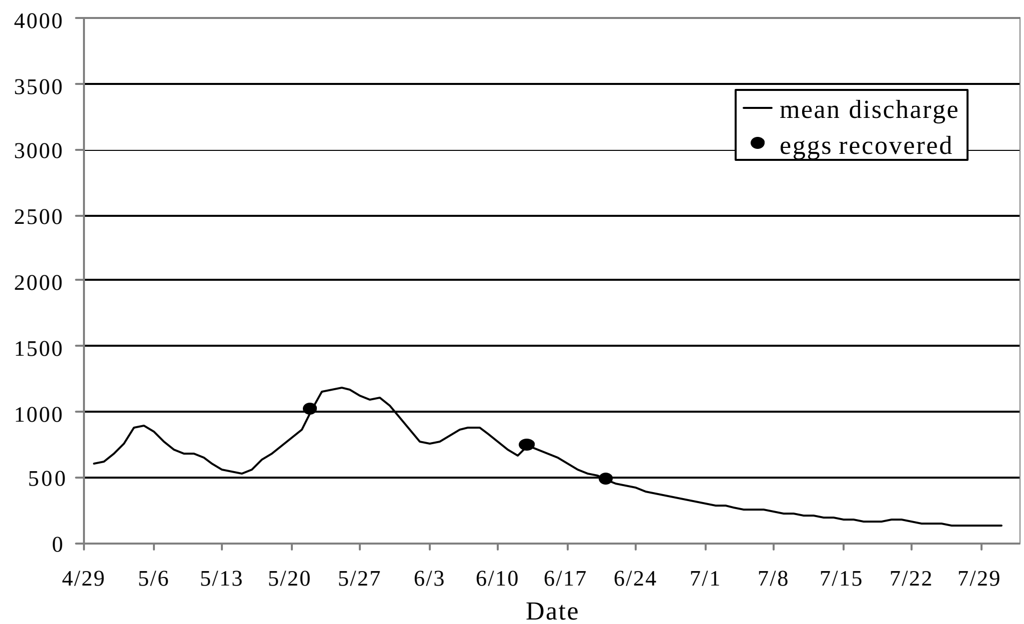

Figure 16. Daily mean discharge at the Salmon River, White Bird gauge when white sturgeon eggs were collected in the Snake River, 2000 (USGS gauge number 13317000).

Movement

A total of 35 white sturgeon were fitted with radio/acoustic tags from 1999 to 2001 (Appendix B). Radio/acoustic-tagged fish ranged in total length from 89.0 to 276.5 cm. White sturgeon were tracked throughout the year approximately every two-weeks. The interval between detections ranged from one to 379 days. Movements of radio/acoustic-tagged fish were both upstream and downstream (Table 7, Figures 17 and 18). Individual fish movement histories are presented in Appendix C. White sturgeon originating in Lower Granite Reservoir moved an average of 6.8 km (4.2 miles; Figure 19) between detections; whereas, white sturgeon originating from the free-flowing Snake River and the Salmon River moved an average of only 1.4 km (0.9 miles; Figure 20) and 1.3 km (0.8 miles; Figure 21), respectively. No seasonal movement pattern was detected for radio-tagged fish, and no movement pattern was detected among radio/acoustic-tagged fish of different size-classes.

Table 7. Summary of movement of radio tagged white sturgeon from 1997-2002.

River Segment	Average Distance (km)	Range (km)	Percent < 0.8 km	Percent 0.8 - 16 km	Percent > 16 km
Lower Granite Reservoir	6.8	0 – 78.8	53.2	38.7	8.1
Free-flowing Snake River	1.4	0 – 53.1	84.6	14.1	1.3
Salmon River	1.3	0 – 13.7	69.1	30.9	0

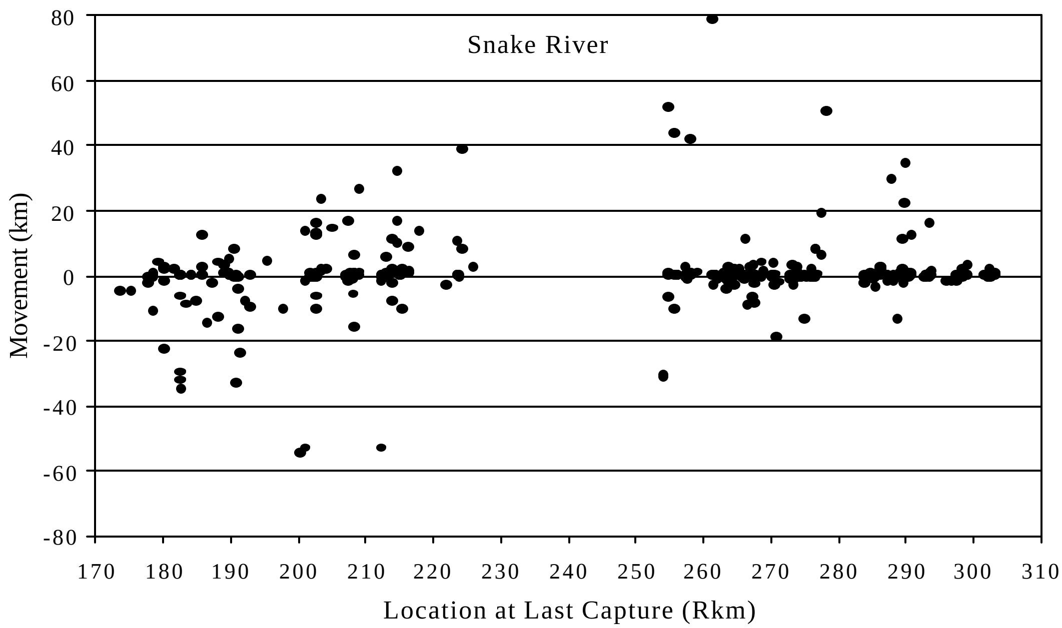

Figure 17. Total movement of the 29 radio-tagged white sturgeon tracked in the Snake River during 1999 to 2002. Points represent movement from previous capture. Negative values indicate movement downstream and positive values indicate movement upstream.

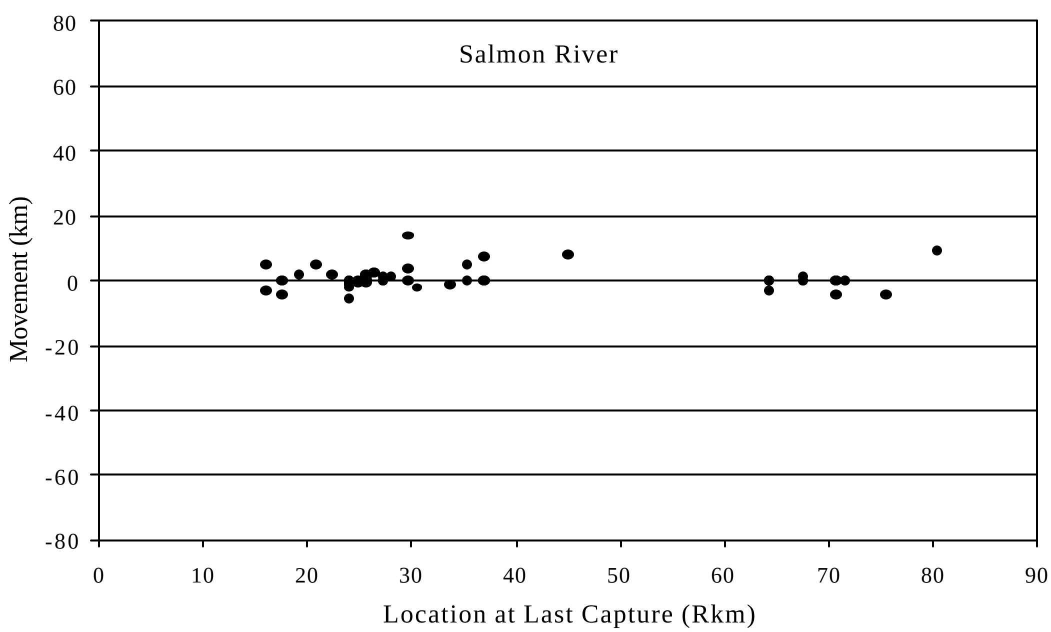

Figure 18. Total movement of the 7 radio-tagged white sturgeon tracked in the Salmon River during 1999 to 2002. Points represent movement from previous capture. Negative values indicate movement downstream and positive values indicate movement upstream.

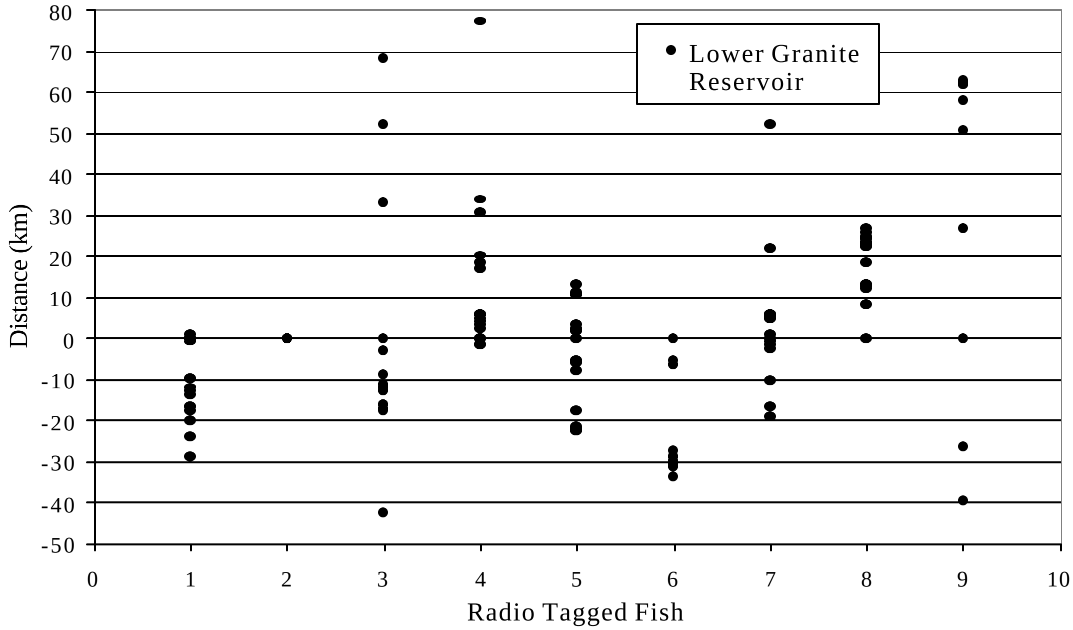

Figure 19. Movement individual white sturgeon originally radio-tagged in Lower Granite Reservoir. Points represent movement from tagging location capture. Negative values indicate movement downstream and positive values indicate movement upstream.

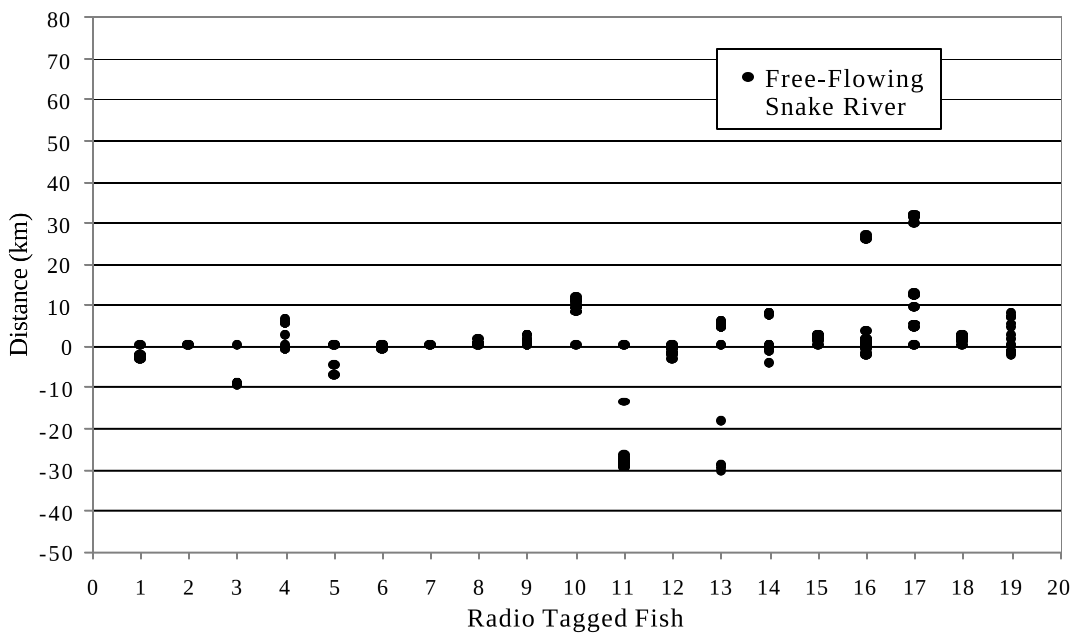

Figure 20. Movement individual white sturgeon originally radio-tagged in the free-flowing Snake River. Points represent movement from tagging location capture. Negative values indicate movement downstream and positive values indicate movement upstream.

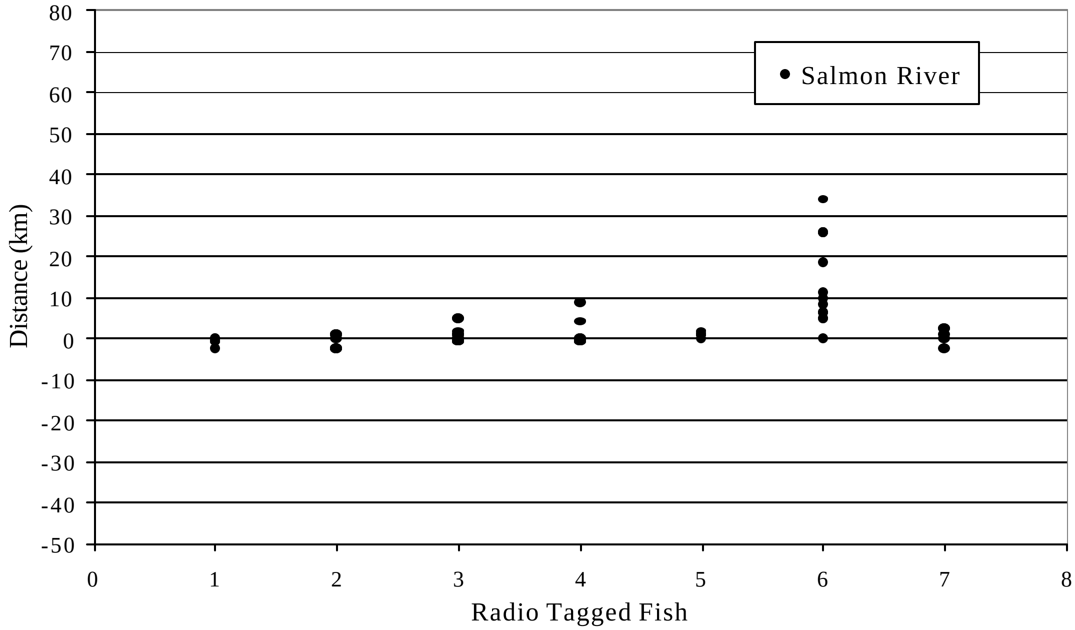

Figure 21. Movement individual white sturgeon originally radio-tagged in the Salmon River. Points represent movement from tagging location capture. Negative values indicate movement downstream and positive values indicate movement upstream.

From 1997 to 2001, a total of 527 PIT/Floy tagged white sturgeon were recaptured. Of these, 345 were distinct recaptures and 182 were multiple recaptures. From 1997 to 2001, 25.8 percent (345 of 1,335) of the marked white sturgeon were detected at least once. In the Snake River, movement of 49.7% of the recaptured fish was less than or equal to 0.8 km (0.5 miles) or had no discernable movement (Table 8). A total of 34.9% of the fish moved more than 0.8 km up to 16 km (10 miles) while 15.9 % moved more than 16 km up to 90.1 km (56 miles). Nine fish were recaptured from previous sampling performed by other agencies. Duration between captures ranged from 0 to 1,267 days. Movements were both upstream and downstream, with 17 fish moving from Lower Granite Reservoir into the free-flowing Snake River and 14 fish moving from the free-flowing Snake River into Lower Granite Reservoir. White sturgeon originating in Lower Granite Reservoir moved an average of 19.0 km (11.8 miles) between recaptures (Figure 22); whereas, white sturgeon originating from the free-flowing Snake River moved an average of only 7.1 km (4.4 miles; Figure 23). In the Salmon River, movements of five recaptured fish were less than or equal to 0.8 km (0.5

miles) or had no discernable movement, and four fish moved between 1.0 km (0.6 miles) and 5.6 km (3.5 miles). For PIT/Floy tagged fish, no clear seasonal movement pattern was detected (Figure 24), and no movement pattern was detected among fish of different size-classes (Figure 25).

Table 8. Summary of movement for recaptured PIT/FLOY tagged white sturgeon from 1997-2002.

River Segment	Average Distance (km)	Range (km)	Percent < 0.8 km	Percent 0.8 - 16 km	Percent > 16 km
Lower Granite Reservoir	1.3	0 - 5.6	22.2	77.8	0
Free-flowing Snake River	19.0	0 – 91.7	4.1	38.5	57.4
Salmon River	7.1	0 – 136.6	39.5	52.5	8.0

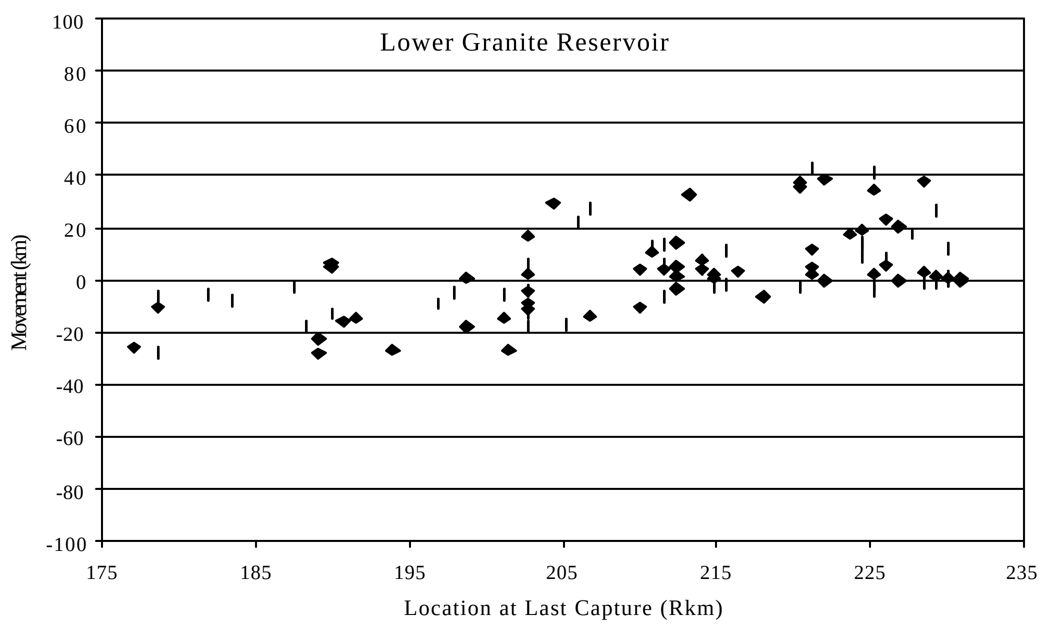

Figure 22. Total movement of 122 recaptured PIT/Floy tagged white sturgeon initially captured in Lower Granite Reservoir. Negative values indicate movement downstream and positive values indicate movement upstream.

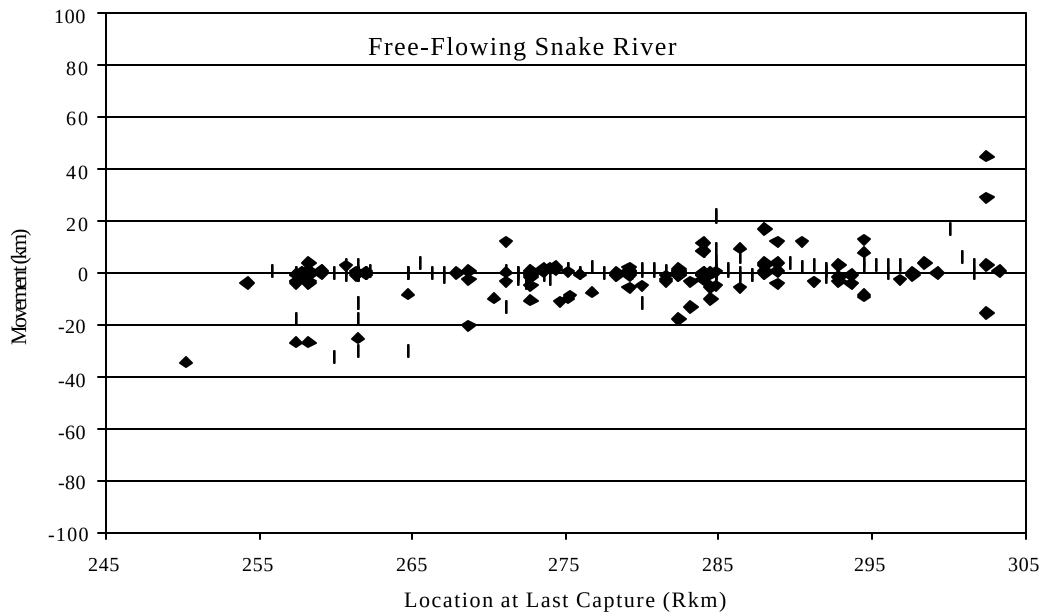

Figure 23. Total movement of 387 recaptured PIT/Floy tagged white sturgeon initially captured in the free-flowing Snake River. Negative values indicate movement downstream and positive values indicate movement upstream.

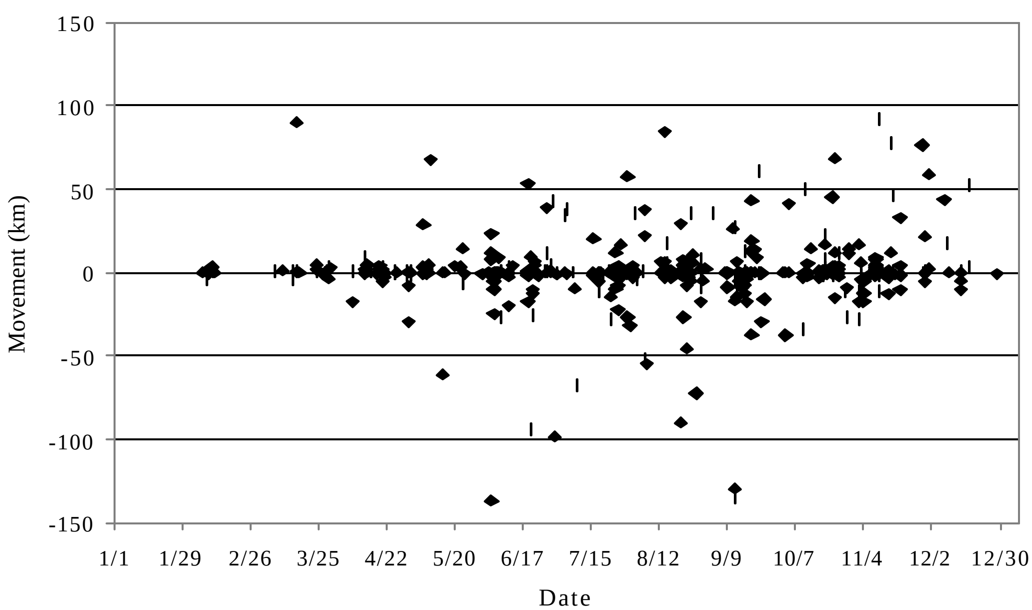

Figure 24. Seasonal movement of 518 recaptured PIT/Floy tagged white sturgeon. Negative values indicate movement downstream and positive values indicate movement upstream.

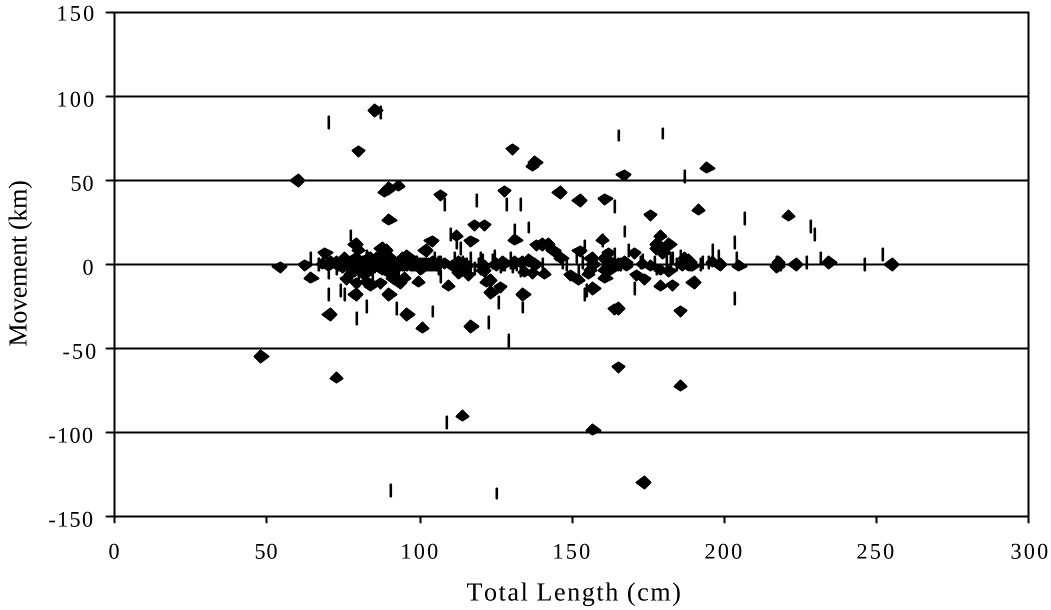

Figure 25. Size and movement of 518 recaptured PIT/Floy tagged white sturgeon. Negative values indicate movement downstream and positive values indicate movement upstream.

No seasonal distribution or migration was apparent for white sturgeon during the months of April through December (Figure 26). The relative number of fish captured in upstream and downstream locations did not appear to differ substantially, with the exception of the month of December where white sturgeon from both Lower Granite Reservoir and the free-flowing Snake River appear to make an upstream movement.

The catch rates for Lower Granite Reservoir and the free-flowing Snake River peaked in June and May, respectively (Figure 27) Both segments experienced a drop in CPUE during July.

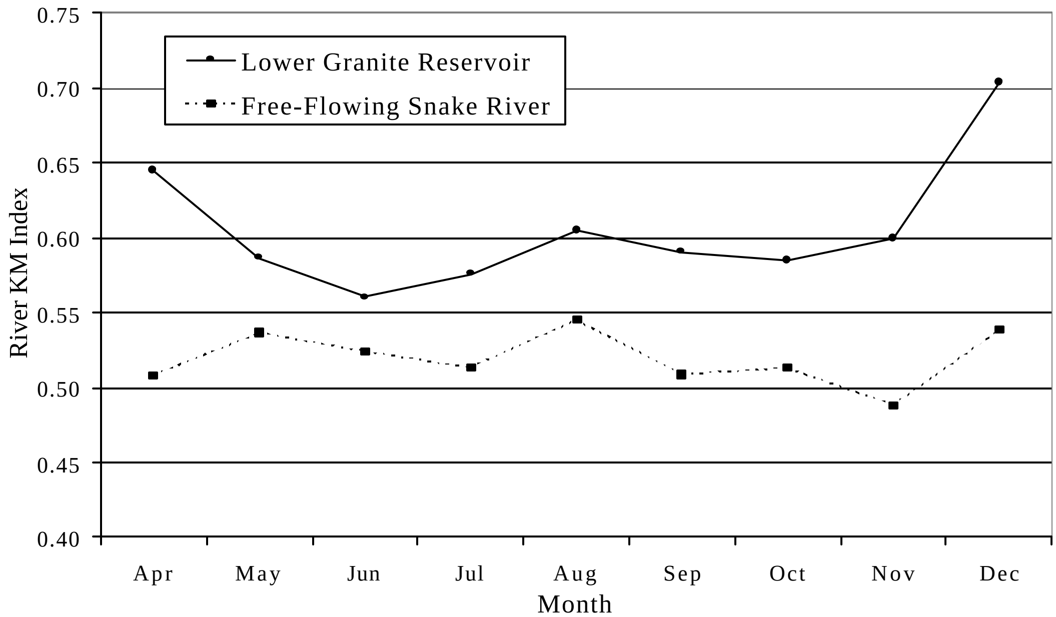

Figure 26. Index of white sturgeon distribution in Lower Granite Reservoir and the free-flowing Snake River, 1997-2001.

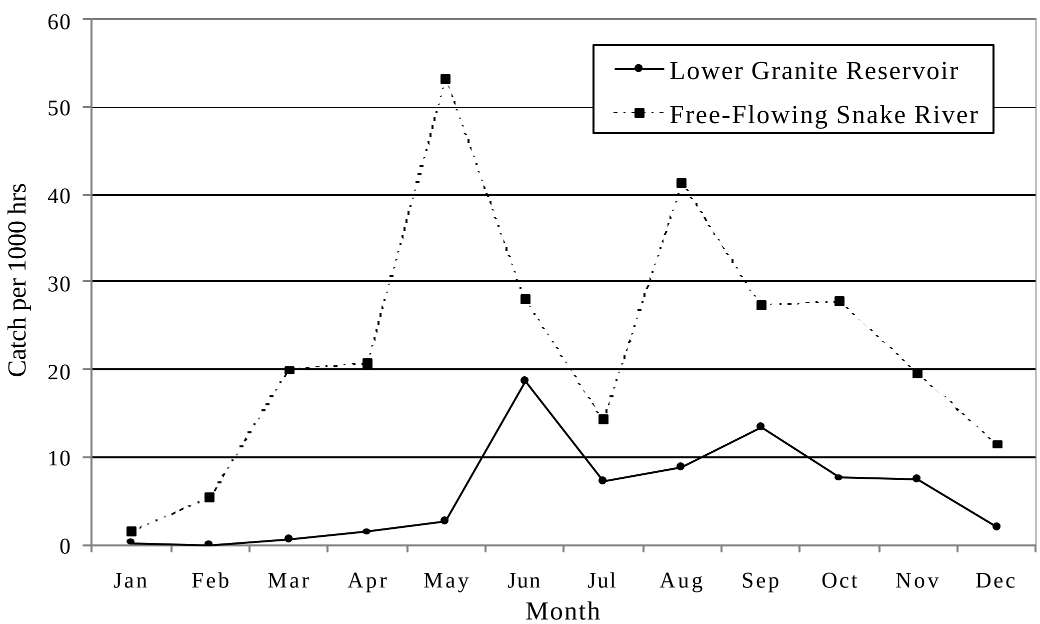

Figure 27. Mean CPUE for white sturgeon by month for Lower Granite Reservoir and the free-flowing Snake River, 1997-2001.

DISCUSSION

White sturgeon were not evenly distributed throughout the study area. The catch rate for white sturgeon was lower in Lower Granite Reservoir than the free-flowing Snake River. In Lower Granite Reservoir the highest catch rates were noted in three areas, one near Rkm 188, one near Rkm 206 and one near Rkm 225. As suggested by Lepla (1994), this may be associated with food availability from tributaries nearby (Knoxway Bay, Rkm 188; Steptoe Canyon, Rkm 206; Clearwater River, Rkm 225). In the transition zone between Lower Granite Reservoir and the free-flowing Snake River, an approximate 15 km segment, we have documented a near lack of catch since 1997. Relatively shallow water depths (<5m) distinguish this segment. Although similar effort was employed in each Snake River reach, the overall catch and CPUE was greater in the reach 5. Moreover, the combined CPUE in the free-flowing Snake River was over three times greater than the CPUE in Lower Granite Reservoir. CPUE was lowest in the Salmon River.

The analysis of the length frequency distributions of white sturgeon within each river segment has revealed no difference in the size class composition between 1997 and 2001. Due to this similarity, the data were pooled across years to analyze trends in the available historic data (Figure 28). 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 1997-2001, only 56 percent were less than 92 cm, while 34 percent ranged between 92 and 183 cm.

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) size class dominated the population in the free-flowing Snake River. 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 4 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 31 percent and 23 percent, respectively.

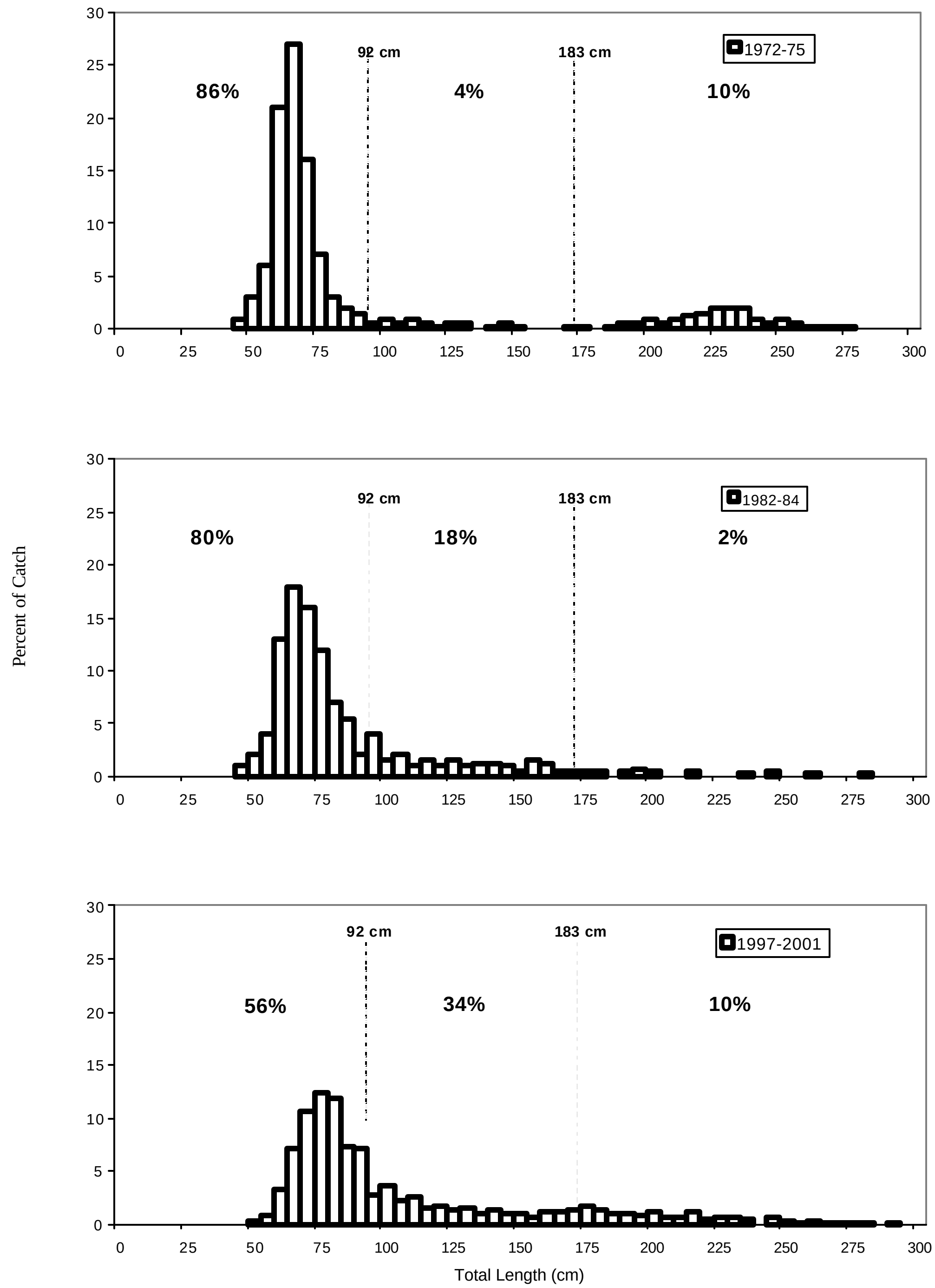

Figure 28. The length (total length) frequency distributions of white sturgeon sampled from the Hells Canyon reaches of the Snake River, 1997-2001, 1982-84 (Lukens 1985), and 1972-75 (Coon et al. 1977) and the percent of the populations < 92 cm, between 92 and 183 cm, and >183 cm.

Point estimates of population size generated by both the closed and open estimators are similar; however, the related precision of estimates differs greatly. We have observed movement from the 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. In addition, Morrill et al. (2001) has observed entrained white sturgeon at the smolt monitoring facility at Lower Granite Dam. 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.

Comparing the historic estimates of Snake River white sturgeon abundance indicates a changing population (Table 9). 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). Combining the 2001 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 4,171 (Schnabel) or 3,740 (Jolly-Seber). 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. 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 9. 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)	Report
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)	2,859 (Schnabel) 2,140 (Jolly-Seber)	1997-2001	this report

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 29). For 1997-2001, 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 30). Lepla (1994) showed that the relative weight of white sturgeon collected after impoundment was higher than white sturgeon sampled prior to impoundment. For 1997-2001, 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 31). 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 32, Table 10).

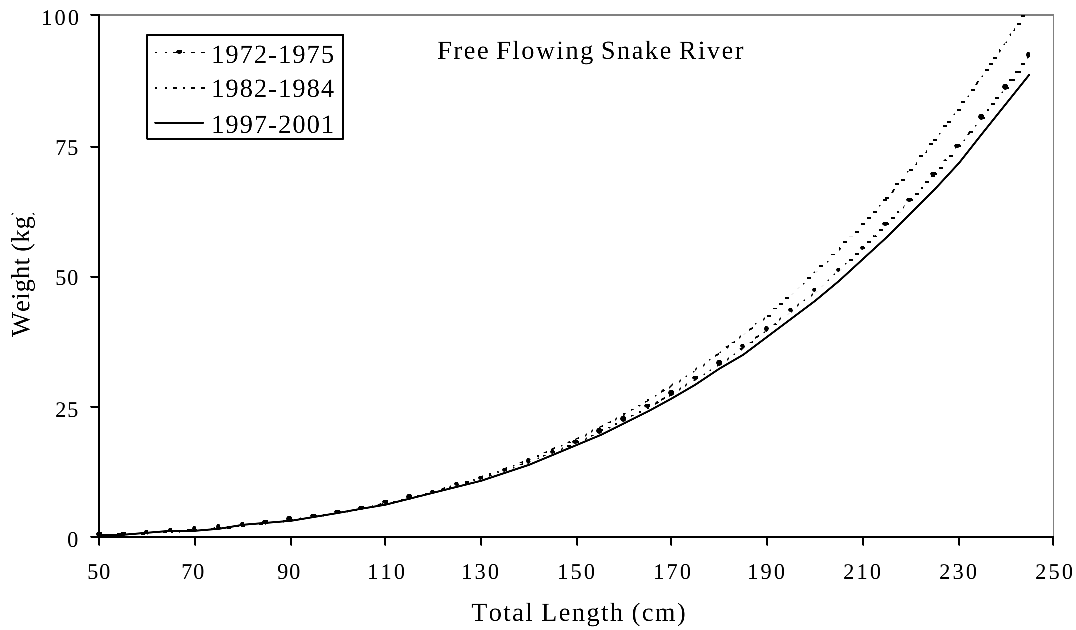

Figure 29. Comparison of the length-weight relationship for white sturgeon sampled from the free-flowing segment of the Snake River during 1997-2001, 1982-84 (Lukens 1985), and 1972-75 (Coon et al. 1977).

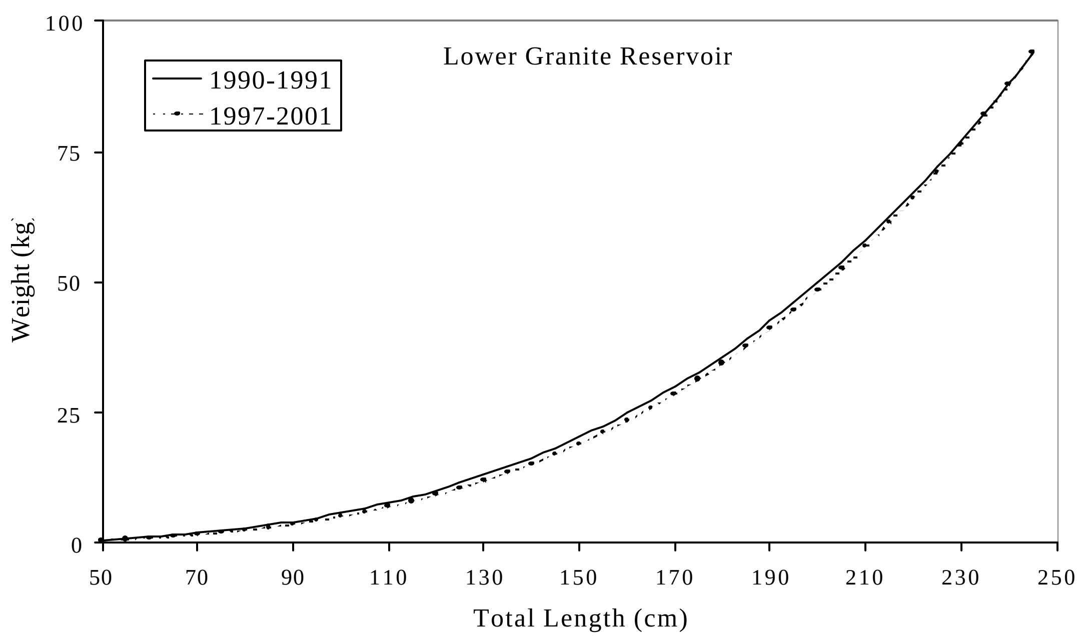

Figure 30. Comparison of the length-weight relationship for white sturgeon sampled from Lower Granite Reservoir during 1997-2001, and 1990-91 (Lepla 1994).

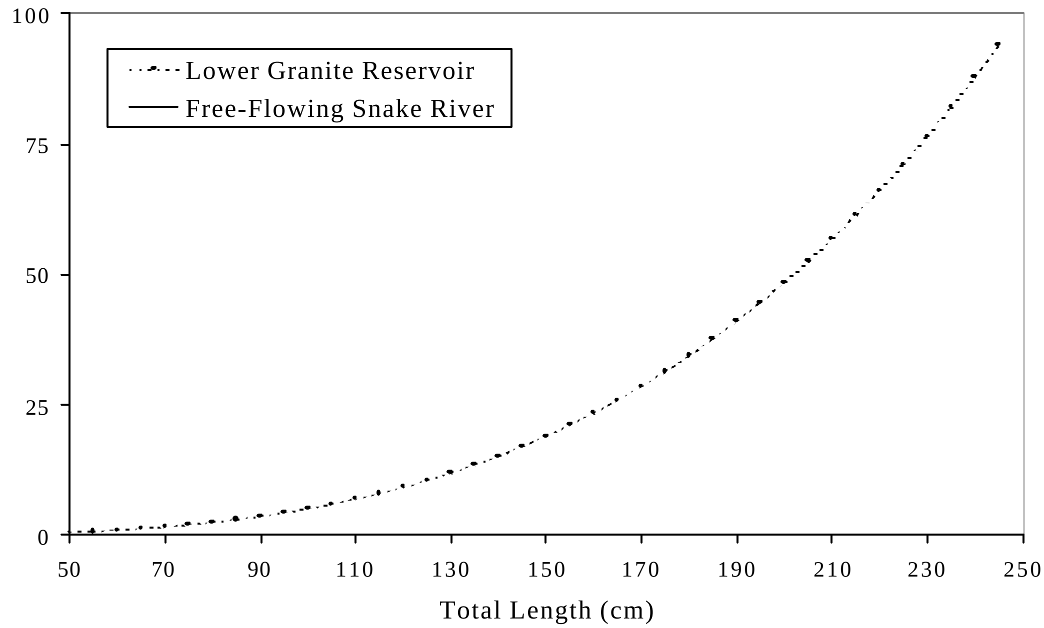

Figure 31. Comparison of the length-weight relationship for white sturgeon sampled from Lower Granite Reservoir and the free-flowing segment of the Snake River during 1997-2001.

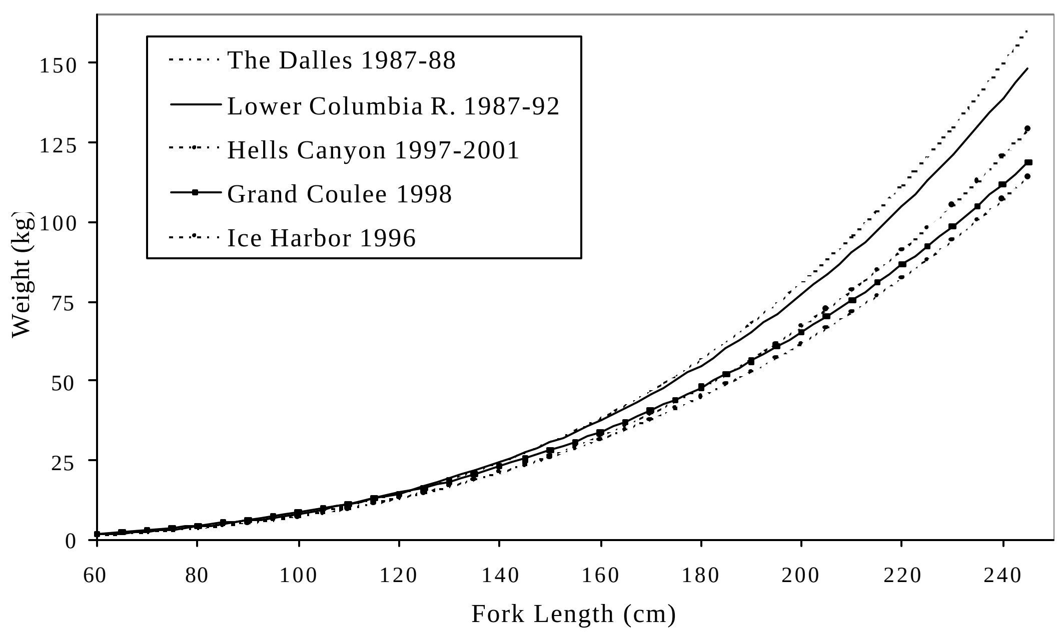

Figure 32. Comparison of the length-weight relationship for white sturgeon sampled from several Columbia River Basin populations. Hells Canyon data represent fish between Lower Granite to Hells Canyon dams from combined data with IPC (2001).

Table 10. 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	Ward 2000
Ice Harbor Reservoir 1996	6.85E-06	3.02	92	Ward 1998
Lower Monumental Reservoir 1997	7.61E-06	3.01	99	Ward 1999
Little Goose Reservoir 1997	1.31E-05	2.91	97	Ward 1999
Lower Granite Reservoir 1990-91	4.00E-06	3.14	103	Lepla 1994
Lower Granite Dam to Salmon River 1997-2001	2.39E-06	3.24	85	this report
Salmon River to Hells Canyon Dam 1997-2000	2.89E-06	3.19	88	Lepla et al. 2001

*W = aLb

White sturgeon captured in Hells Canyon from 1999-2001 appear to be growing faster based on age and growth comparisons with historical data (Figure 33). Based on the von Bertalanffy growth equations, white sturgeon age 1 to 20 that were captured from 1972-75 and 1982-84 grew approximately 7.0 cm/year and 6.6 cm/year, respectively. In contrast, white sturgeon captured from 1999-2001 exhibited a growth rate of 9.6 cm/year. The von Bertalanffy growth equation also suggests that the Hells Canyon white sturgeon population grows faster than several other Columbia River Basin populations (Figure 34). However, mean growth of recaptured fish differs from predicted annual growth from pectoral fin ray analysis. Current methods are being developed using recaptured fish to develop growth curves that more accurately represent growth (Kern et al. 2001, Paragamian and Beamesderefer, *In Press*). Table 11 compares the parameters of the von Bertalanffy growth equation for several Columbia River Basin white sturgeon populations.

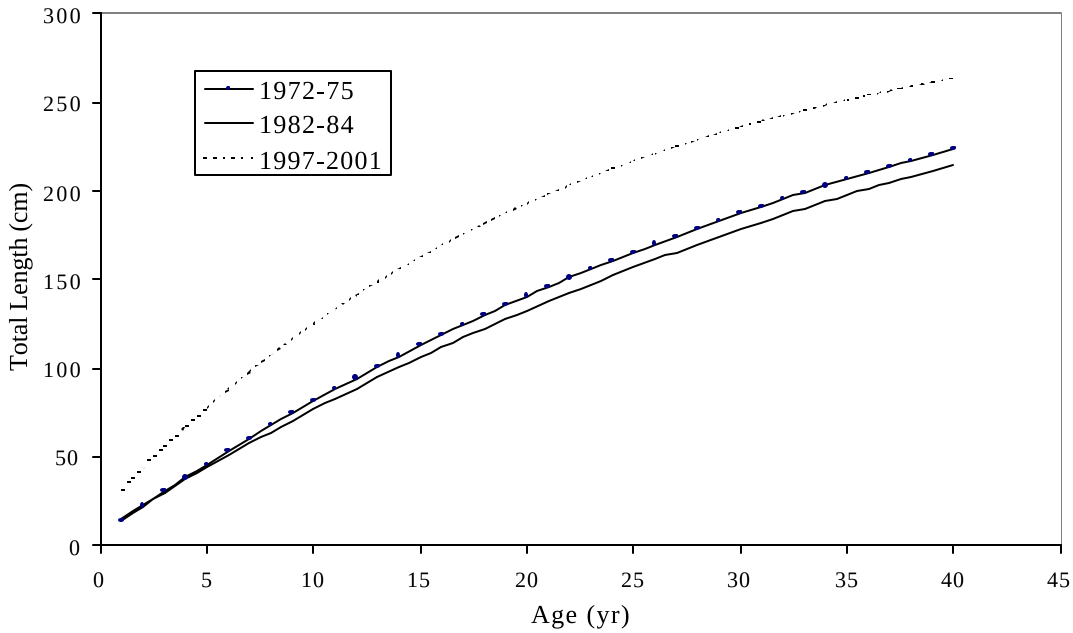

Figure 33. Comparison of the von Bertalanffy growth curves for white sturgeon sampled from the free-flowing segment of the Snake River during 1997-2001, 1982-84 (Lukens 1985), and 1972-75 (Coon et al. 1977).

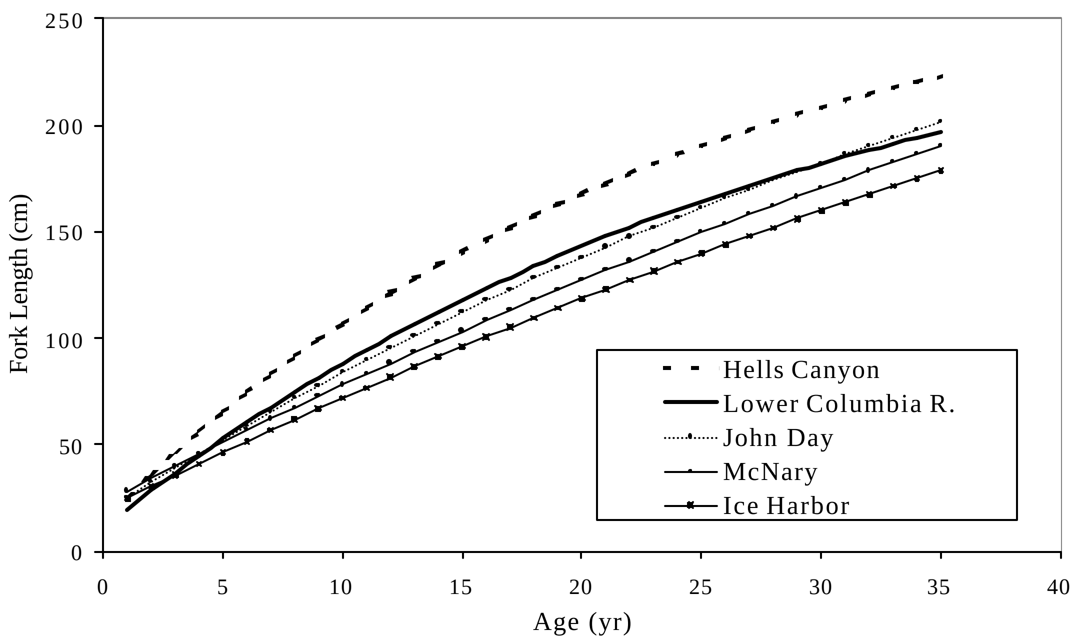

Figure 34. Comparison of the von Bertalanffy growth curves for white sturgeon sampled from several Columbia River Basin populations. Hells Canyon fish are represented by fish from Lower Granite Dam to Hells Canyon Dam from combined data with IPC (2001).

Table 11. Parameters for the von Bertalanffy growth equation* for 12 Columbia River Basin white sturgeon populations.

Location	L_4	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 1997-2001	278	0.046	-1.12	this report
Salmon River to Hells Canyon Dam 1997-2000	331	0.305	-1.54	Lepla et al. 2001

$*L_{(t)} = L_4(1-e^{-K(t-t0)})$

A wide range of mortality rates has been reported for the Hells Canyon white sturgeon population temporally (Table 12). These mortality estimates encompass various avenues for population reduction, such as: natural death, harvest (legal and illegal), and emigration. The magnitude of these removals from the population is likely to fluctuate annually and by age class. Estimates of mortality rates spatially during the same time period are similar for the Hells Canyon and Lower Granite to Salmon River reaches.

Table 12. Instantaneous total mortality (Z), total annual morality (A), and annual survival (A) reported for Hell Canyon white sturgeon.

Location	Z	A	S	Ages	Reference
Lower Granite Dam site to Hells Canyon Dam 1972-75	.043	0.35	0.65	10-20	Coon et al. 1975
Clearwater River to Hells Canyon Dam 1982-84	0.13	0.12	0.88	6-25	Lukens 1985
Lower Granite Reservoir 1990-91	0.70-0.73	0.50-0.48	0.50-0.52	~6-11	Lepla 1994
Lower Granite Dam to Salmon River 1997-2001	0.15	0.14	0.86	6-25	this report
Salmon River to Hells Canyon Dam 1997-2000	0.14	0.13	0.87	6-13	Lepla et al. 2001

Based on the presence of eggs, white sturgeon spawned in 1999, 2000, 2001 and 2002. 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 actual spawning location could not be identified due to the nature of egg dispersal; thus, the actual habitat characteristics at the spawning locations could not be measured.

Movement data from recaptured PIT/Floy tagged fish from 1997-2001 indicate white sturgeon make migrations between Lower Granite Reservoir and the free-flowing Snake River. A total of 5.9 percent (2.7 percent downstream; 31 of 527) of the recaptured white sturgeon moved between the two segments. North et al. (1993) reported 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 or the Salmon River. 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. 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.

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.

Collecting YOY white sturgeon proved more difficult than anticipated. Using the sampling gear available, the intensity of effort most likely needed to collect appreciable numbers of YOY white sturgeon would be substantial. Therefore, sampling for YOY white sturgeon using setlines was suspended in 2002.

PLANS FOR 2003

In 2003, we plan to reconvene the BRAT and incorporate new information from the 1997-2002 sampling and from other researchers. Further analysis may be necessary and will be conducted through the co-manager process of the BRAT. We plan to generate a new biological risk assessment and complete an adaptive management plan for Hells Canyon white sturgeon.

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APPENDIX A

1999-2002 White Sturgeon Egg Recovery and Habitat Data

Table A-1. White sturgeon artificial substrate spawning data.

Date	River	Location (Rkm)	Depth (m)	Substrate	Near Substrate Velocity (m/s)	Temp. (°C)	Number of Eggs
6/14/99	Snake	274.3	4.6	sand	1.2	15	1
6/16/99	Snake	289.6	6.4	sand	0.7	15.5	3
7/1/99	Snake	290.4	4.6	sand	1.5	17	1
5/10/00	Snake	288.0	1.8	sand	0.79	12	1
5/15/00	Snake	286.4	6.4	sand	1.1	14	2
5/15/00	Snake	291.2	7.0	sand	1.1	14	1
5/18/00	Snake	286.4	6.4	sand	0.95	14.5	1
5/23/00	Snake	282.4	9.4	sand	2.07	14.5	1
5/23/00	Snake	286.4	6.1	sand	0.97	14.5	1
5/23/00	Snake	264.7	5.1	sand	0.87	14.5	1
5/30/00	Snake	291.2	6.7	gravel	0.82	13	1
5/30/00	Snake	291.2	7.3	sand	0.65	13	1
5/30/00	Snake	265.2	4.5	sand	1.4	13	1
6/5/00	Snake	275.1	3.6	sand	0.95	16.5	1
6/5/00	Snake	277.6	3.0	sand	1	16.5	2
6/5/00	Snake	277.6	3.0	sand	0.75	16.5	2
6/5/00	Snake	282.4	7.0	sand	0.6	16.5	1
6/5/00	Snake	291.2	8.2	sand	0.9	16.5	3
6/12/00	Snake	291.2	10.0	sand	1.3	14.5	1
6/27/00	Snake	276.7	3.9	sand	0.5	19.5	1
6/27/00	Snake	276.7	4.8	gravel	0.5	19.5	1
6/27/00	Snake	277.6	2.7	sand	0.65	19.5	2
6/27/00	Snake	282.4	6.4	sand	0.75	19.5	1
6/27/00	Snake	286.4	3.3	sand	0.55	19.5	1
5/11/01	Snake	290.4	5.1	sand	0.72	13	1
5/15/01	Snake	291.2	5.1	sand	1.16	12	1
5/21/01	Snake	293.6	4.2	sand	1.61	13.5	1
5/23/01	Snake	267.1	3.3	sand	0.89	15	2

Table A-1. Continued.

Date	River	Location (Rkm)	Depth (m)	Substrate	Near Substrate Velocity (m/s)	Temp. (°C)	Number of Eggs
5/25/01	Snake	293.6	4.8	sand	0.72	16.5	1
6/4/01	Snake	267.1	3.3	sand	1.03	14.5	3
6/11/01	Snake	280.0	6.7	sand	1.27	16	1
6/19/01	Snake	267.1	3.3	sand	1.03	17.5	1
6/21/01	Snake	280.0	6.7	sand	0.78	19	1
6/25/01	Snake	293.6	4.8	sand	1.26	18.5	1
7/2/01	Snake	264.7	7.6	sand	1.84	21.5	1
6/12/02	Snake	292.0	8.7	sand	n/a	15.5	1
6/13/02	Snake	282.4	7.3	sand	n/a	15.5	1
6/26/02	Snake	294.4	7.4	sand	n/a	19	1

APPENDIX B

1999-2001 White Sturgeon Radio Tag Data

Table B-1. White sturgeon fitted with Combined Acoustic/Radio Tags (CART) in the Snake and Salmon Rivers, 1999-2001.

Tag Date	Code*	River	Location (Rkm)	Gender	Total Length (cm)
3/23/99	138	Snake	170.0	Male	108.5
3/25/99	142	Snake	162.8	Undetermined	134
4/13/99	127	Snake	160.0	Undetermined	176
4/20/99	134	Snake	113.5	Undetermined	141
4/21/99	162	Snake	114.2	Female	165
5/17/99	151	Salmon	44.5	Undetermined	225
5/20/99	161	Salmon	41.5	Female	179
11/4/99	153	Snake	126.0	Male	183
11/4/99	150	Snake	126.0	Undetermined	136
11/9/99	103	Snake	176.5	Undetermined	187
11/9/99	139	Snake	186.0	Male	222
11/16/99	141	Salmon	15.5	Undetermined	193
11/16/99	104	Salmon	16.5	Female	226
11/16/99	59	Salmon	20.5	Female	238.5
3/7/00	73	Salmon	11.3	Female	227
6/22/00	143	Snake	118.0	Male	185.5
6/27/00	61	Snake	130.0	Male	171
7/4/00	115	Snake	140.0	Female	164
7/11/00	71	Snake	166.0	Male	175
7/26/00	98	Salmon	26.5	Undetermined	140.5
8/2/00	62	Snake	164.0	Female	247
8/15/00	137	Snake	141.5	Female	229.5
11/16/00	154	Snake	168.5	Undetermined	133
11/29/00	74	Snake	182.5	Undetermined	148
3/15/01	3	Snake	177.0	Female	232
3/22/01	96	Snake	132.5	Male	167.5
5/8/01	50	Snake	188.0	Female	221
6/12/01	120	Snake	165.0	Undetermined	111
6/13/01	70	Snake	167.0	Male	234.5
6/20/01	132	Snake	187.0	Female	266
6/21/01	138B	Snake	181.5	Undetermined	89
7/30/01	116	Snake	167.0	Female	276.5
7/31/01	14	Snake	160.5	Male	250.5
8/2/01	72	Snake	164.5	Female	239
10/25/01	71B	Snake	173.2	Male	211

*radio frequency: 149.880 Mhz, acoustic frequency: 150.077 Mhz (with 150 Mhz up-converter)

APPENDIX C

1999 –2002 White Sturgeon Telemetry Movement Data

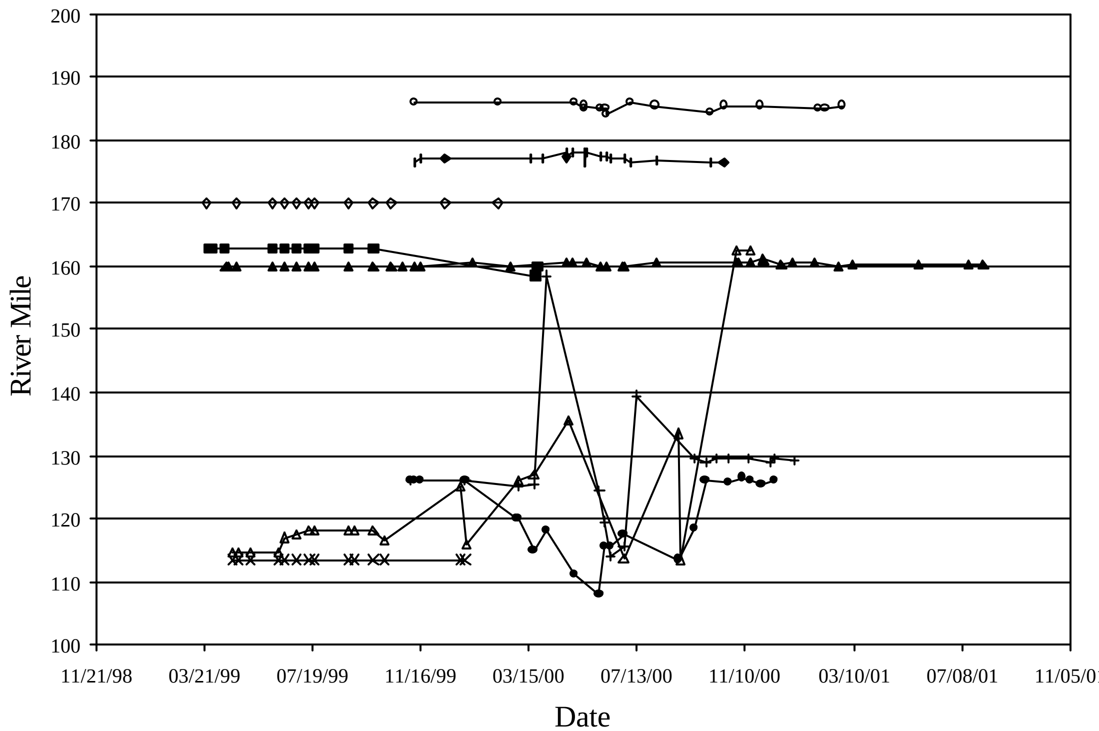

Figure C-1. Individual fish movement from 1999 to 2002 for white sturgeon in the Snake River telemetry tagged during 1999.

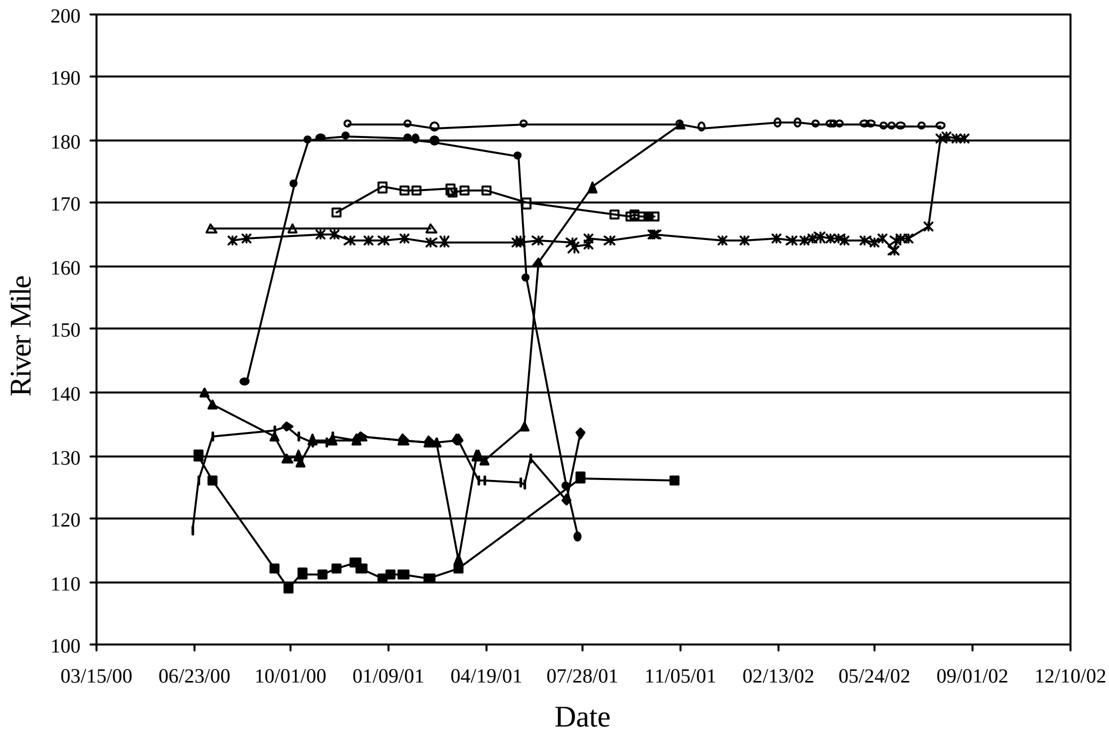

Figure C-2. Individual fish movement from 2000 to 2002 for white sturgeon in the Snake River telemetry tagged during 2000.

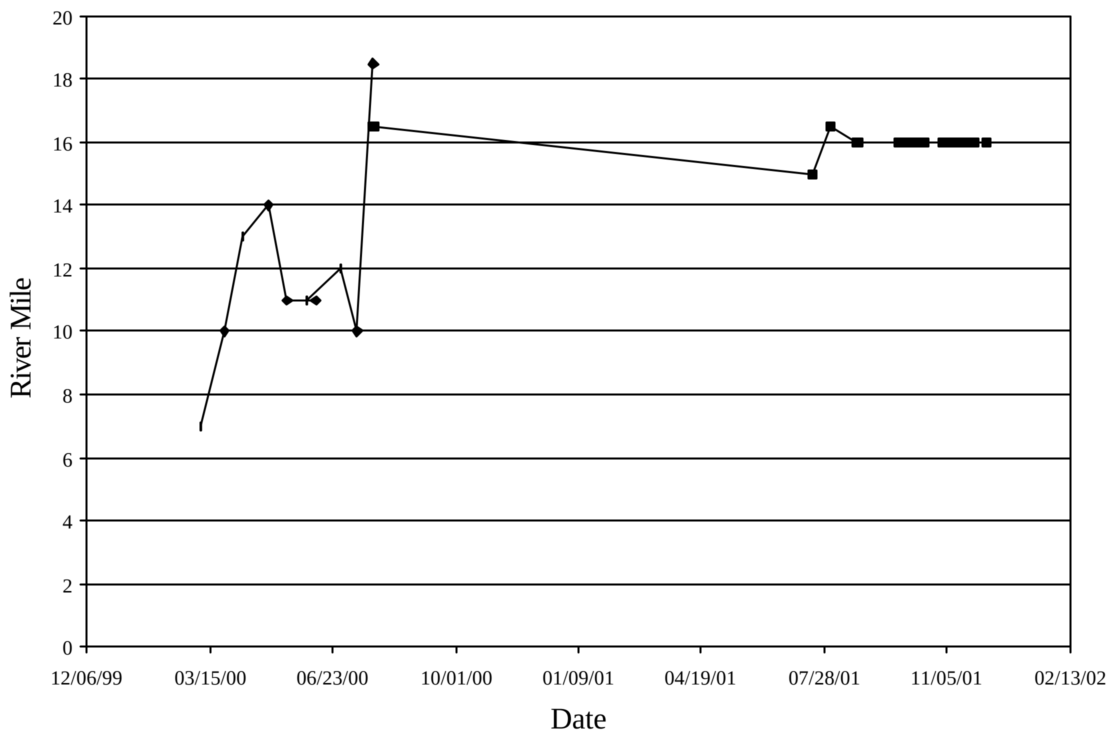

Figure C-3. Individual fish movement from 2000 to 2002 for white sturgeon in the Salmon River telemetry tagged during 2000.

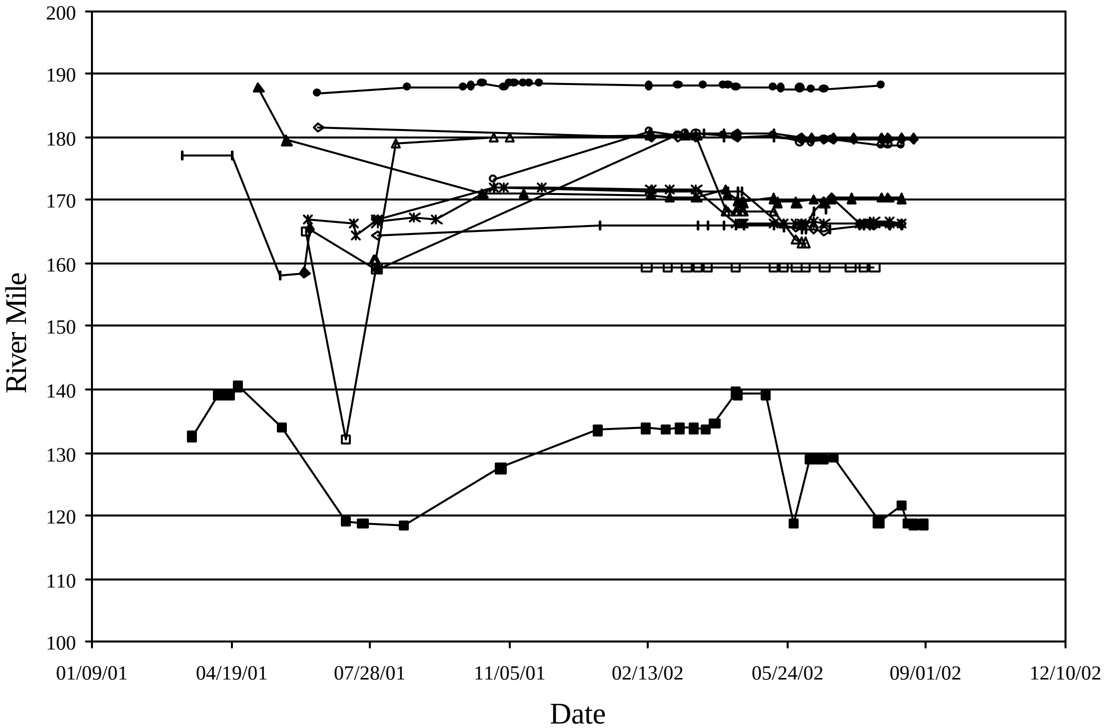

Figure C-4. Individual fish movement from 2001 to 2002 for white sturgeon in the Snake River telemetry tagged during 2001.