White Sturgeon Mitigation and Restoration in the Columbia and Snake Rivers Upstream from Bonneville Dam

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WHITE STURGEON MITIGATION AND RESTORATION IN THE COLUMBIA AND SNAKE RIVERS UPSTREAM FROM BONNEVILLE DAM.

ANNUAL PROGRESS REPORT

APRIL 2001 - MARCH 2002

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EXECUTIVE SUMMARY

We report on our progress from April 2001 through March 2002 on determining the effects of mitigative measures on productivity of white sturgeon populations in the Columbia River downstream from McNary Dam, and on determining the status and habitat requirements of white sturgeon populations in the Columbia and Snake rivers upstream from McNary Dam. The study is a cooperative effort by the Oregon Department of Fish and Wildlife (ODFW; Report A), Washington Department of Fish and Wildlife (WDFW; Report B), U.S. Geological Survey Biological Resources Division (USGS; Report C), Columbia River Inter-Tribal Fish Commission (CRITFC; Report D), the U.S. Fish and Wildlife Service (USFWS; Report E), and Oregon State University (OSU; Report F).

This is a multi-year study with many objectives requiring more than one year to complete; therefore, findings from a given year may be part of more significant findings yet to be reported. Highlights of results of our work from April 2001 through March 2002 are:

Report A

- The population estimate for John Day Reservoir was 29,831 fish greater than 54 cm total length. Only 1,077 of these were in the legal size class. Population estimates for sub-legal and over-sized fish were higher than estimates in 1996.
- We transported 5,195 juvenile white sturgeon from below Bonneville Dam to John Day Reservoir and 1,257 to The Dalles Reservoir.
- Estimates of abundance of transported fish from previous years were much lower than expected, indicating potential problems in the estimate, poor survival of transported fish, or migration of transported fish from the reservoir.
- Young-of-year indexing surveys captured 0 YOY white sturgeon in any of the five sampled reservoirs. Low river flows this year have resulted in extremely poor recruitment of YOY white sturgeon.

Report B

- We sampled the 2001 recreational fishery between Bonneville and McNary dams (Zone 6 management unit) to estimate white sturgeon harvest. We estimated that 1,426, 677, and 299 white sturgeon were harvested from Bonneville, The Dalles and John Day reservoirs respectively. Managers used our projections of estimated harvest to close the retention season in Bonneville Reservoir on August 13th and on April 9th in The Dalles. The season in John Day Reservoir remained open year-round.
- Recreational harvest has averaged 95% (Bonneville), 105% (The Dalles), and 78% (John Day) of the Sturgeon Management Task Force's (SMTF) annual harvest guidelines since 1995. The 1991-2001 average for Zone 6 sport and commercial fisheries is 109% (Bonneville), 115% (The Dalles), and 86% (John Day) of the combined sport and commercial guidelines.

- Following a one-year increase, harvest per angler trip in Bonneville Reservoir continued its decline from the 1995 season, and was the second lowest of any year since the guidelines were established in 1991. Harvest per angler trip in The Dalles Reservoir increased each of the last 2 years, and was the second highest since 1991. Harvest per angler trip in John Day Reservoir continued to decline, being the third lowest since 1991, and the lowest since its high point in 1997.
- Trends in catch, effort, season length, and size composition over the past 5 seasons, suggest that the legal-size populations, in Bonneville and John Day reservoirs, have declined.

Report C

- Analyses by the USGS showed that river discharges and water temperatures during April through July 2001 provided some of the worst conditions since 1985 for spawning by white sturgeon downstream from Bonneville, The Dalles, John Day, and McNary dams. Daily discharge remained low (< 5 kcms) during April through June. The river hydrograph was relatively flat, with no discernable prolonged peak as normally occurs. Optimal spawning temperatures in the four tailraces occurred for less than two weeks and well before some of the highest discharges of the year. Probably because of these poor spawning conditions, no YOY white sturgeon were collected by the USGS during bottom trawling in Bonneville, The Dalles, and John Day reservoirs.
- The second year of a three-year laboratory predation study conducted by the USGS was completed. Northern pikeminnow 300-600 mm total length ate white sturgeon up to about 120 mm, whereas walleye of a similar size ingested almost no white sturgeon.

Report D

- A total of 200 white sturgeon were captured in 85 setline sets between 11 March and 10 April 2001. We held four sexually mature females and 23 sexually mature males at our new spawning location below the McNary Dam Juvenile Fish Facility. We spawned one of the four females, crossing gametes with two males, resulting in 32,000 white sturgeon larvae.
- The CRITFC marked and released 2,515 white sturgeon in John Day Reservoir as part of the population estimate reported by ODFW (Report A).

Report E

- For the third year, wild white sturgeon were successfully captured, transported, held through the spawning season, and returned to site of origin.
- The spawning of a single female white sturgeon with two males resulted in approximately 104,000 eggs being incubated. Hatch success was 44%, resulting in an estimated 46,000 yolk sac fry. Approximately 32,000 fry, a 69% success rate, accepted a commercial diet.

- As the juvenile sturgeon approached five months of age, an outbreak of white sturgeon irido virus resulted in an estimated 90% mortality. An estimated 7% of the juvenile sturgeons being reared in raceways were lost to blue heron *Ardea herodias* predation. Overall survival of 3% eliminated the possibility of having any year class releases from the 2001 spawning.
- To minimize the potential of future virus outbreaks, changes in culture methods have been identified for implementation. To reduce handling and its related stress the following methods will be used; no sample weights will be taken, tank stocking protocols will be used which minimize the need to transfer fish, and grading of juveniles will not occur.
- To protect sturgeon from future bird predation a new net structure will be constructed over the raceways. This structure will totally enclose the raceways, with netting (10.16-cm square) supported 4-m above the water surface and covering the sides of the structure. At ground level a perimeter fence 1-m high, 1.25-cm mesh, will be installed to restrict potential predation by otter and mink.

Report F

- OSU has collected paired blood and gonad samples from 373 white sturgeon in the Columbia River between February 2000 and March 2002.
- White sturgeon had sex- and maturity-specific levels of plasma steroids and calcium, as well as fork length.
- Discriminant function analysis revealed that blood plasma indicators and urine indicators may be relatively reliable predictors of sex and stage of maturity in white sturgeon if the error associated with misclassification of immature fish is acceptable.
- Plasma cortisol levels were elevated in oversize white sturgeon captured by both gill net and the catch-and-release sport fishery below Bonneville Dam.
- The time a fish was on-line in the sport fishery was positively correlated with plasma cortisol concentration.

WHITE STURGEON MITIGATION AND RESTORATION IN THE COLUMBIA AND SNAKE RIVERS UPSTREAM FROM BONNEVILLE DAM

ANNUAL PROGRESS REPORT

APRIL 2001 - MARCH 2002

Report A

Evaluate the success of developing and implementing a management plan for enhancing production of white sturgeon in reservoirs between Bonneville and McNary dams

This report includes: An update of abundance, life history parameters, and population dynamics of white sturgeon in John Day Reservoir, results of transplant supplementation in The Dalles and John Day reservoirs, and a summary of gill-net effort and catch targeting young-of-year white sturgeon in Columbia and Snake River reservoirs.

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ABSTRACT

This report summarizes data collected from April 2001 through March 2002 to update life history parameters and population dynamics of white sturgeon *Acipenser transmontanus* in John Day Reservoir, document young-of-year recruitment of white sturgeon in three Columbia River and two Snake River reservoirs, and continue transplant supplementation of juvenile white sturgeon from the lower Columbia River below Bonneville Dam to The Dalles and John Day reservoirs.

Sampling to estimate white sturgeon abundance was coordinated with staff of the Columbia River Inter-Tribal Fish Commission (CRITFC) who contracted with commercial fishers to capture and mark white sturgeon in John Day Reservoir from December 2000 through January 2001. Staff from Oregon Department of Fish and Wildlife (ODFW) set 813 setlines from 14 May through 29 August 2001, and captured 5,562 white sturgeon. White sturgeon were distributed throughout John Day Reservoir, but catch rates were highest in the upper portions of the reservoir. Recaptured fish were most often caught near the site of marking, however, marked fish moved an average of 3.7 km upstream between marking and subsequent recapture. Combined effort by CRITFC and ODFW resulted in the marking of 3,757 white sturgeon with passive integrated transponder (PIT) tags between December 2000 and August 2001. Using multiple mark-recapture estimates, we estimated the total population of white sturgeon in John Day Reservoir in 2001 to be 29,831 fish. As in abundance surveys in Bonneville Reservoir in 1999, a large data set of marks and recaptures of fish of various sizes allowed us to use a more robust method to estimate population abundance than was possible in surveys conducted prior to 1999.

Transplant supplementation (Trawl and Haul) continued in 2001 with transplant of juvenile white sturgeon from below Bonneville Dam to The Dalles and John Day reservoirs. Using trawl gear, 6,937 juvenile white sturgeon were captured below Bonneville Dam by a private commercial trawler. The majority of transplants were made to John Day Reservoir, with 5,195 of 6,452 white sturgeon transplanted being transplanted to this reservoir. All transplanted fish were marked by removal of two scutes, one to identify them as Trawl and Haul fish, and one to identify the year of their capture. None of these fish were PIT-tagged.

We assessed recruitment of young-of-year (YOY) white sturgeon using standardized gill nets and fishing locations in The Dalles, John Day, McNary, Ice Harbor, and Little Goose reservoirs. Sampling efforts were coordinated with similar surveys conducted using trawl gear by the United States Geological Service to facilitate comparison of the two methods. We captured no young-of-year white sturgeon in any of these reservoirs in 2001.

INTRODUCTION

This report summarizes work performed by the Oregon Department of Fish and Wildlife (ODFW) during the period April 2001 through March 2002 in accordance with tasks outlined in the Bonneville Power Administration funded Project 86-50 Performance Work Statement. During this period we participated in three distinct efforts to assess or restore productivity of white sturgeon *Acipenser transmontanus* in the Columbia River upstream from Bonneville Dam (Figure 1). 1) During May through August 2001 we assessed abundance and productivity measures of white sturgeon in John Day Reservoir. 2) During October and November 2001, we coordinated an effort to transplant juvenile white sturgeon from the Columbia River downstream of Bonneville Dam to The Dalles and John Day reservoirs. 3) During October and November 2001, we participated in assessing recruitment of young-of-year (YOY) white sturgeon in The Dalles, John Day, and McNary reservoirs in the Columbia River, and Ice Harbor and Little Goose reservoirs in the Snake River.

These objectives are repeated on an annual or semi-annual basis. Stock assessment surveys are currently conducted once every five years for each of the three reservoirs in Zone 6 (Bonneville, The Dalles, and John Day). A stock assessment survey was last conducted in John Day Reservoir in 1996. Transplant efforts (Trawl and Haul) and young-of-year indexing are conducted annually.

METHODS

Stock Assessment

We sampled for white sturgeon in John Day Reservoir from early May through late August to estimate population statistics. The reservoir was divided into ten sections, each about 12 km long (Figure 1). We distributed setline sampling effort equally among and within the ten sections to obtain a representative sample of the population. Factors in selecting sampling sites included maintaining an equal distribution of sets per river mile and crew knowledge of previous catches in specific locations. We divided the field season into three five-week sampling periods and sampled all sections during each period (Table 1).

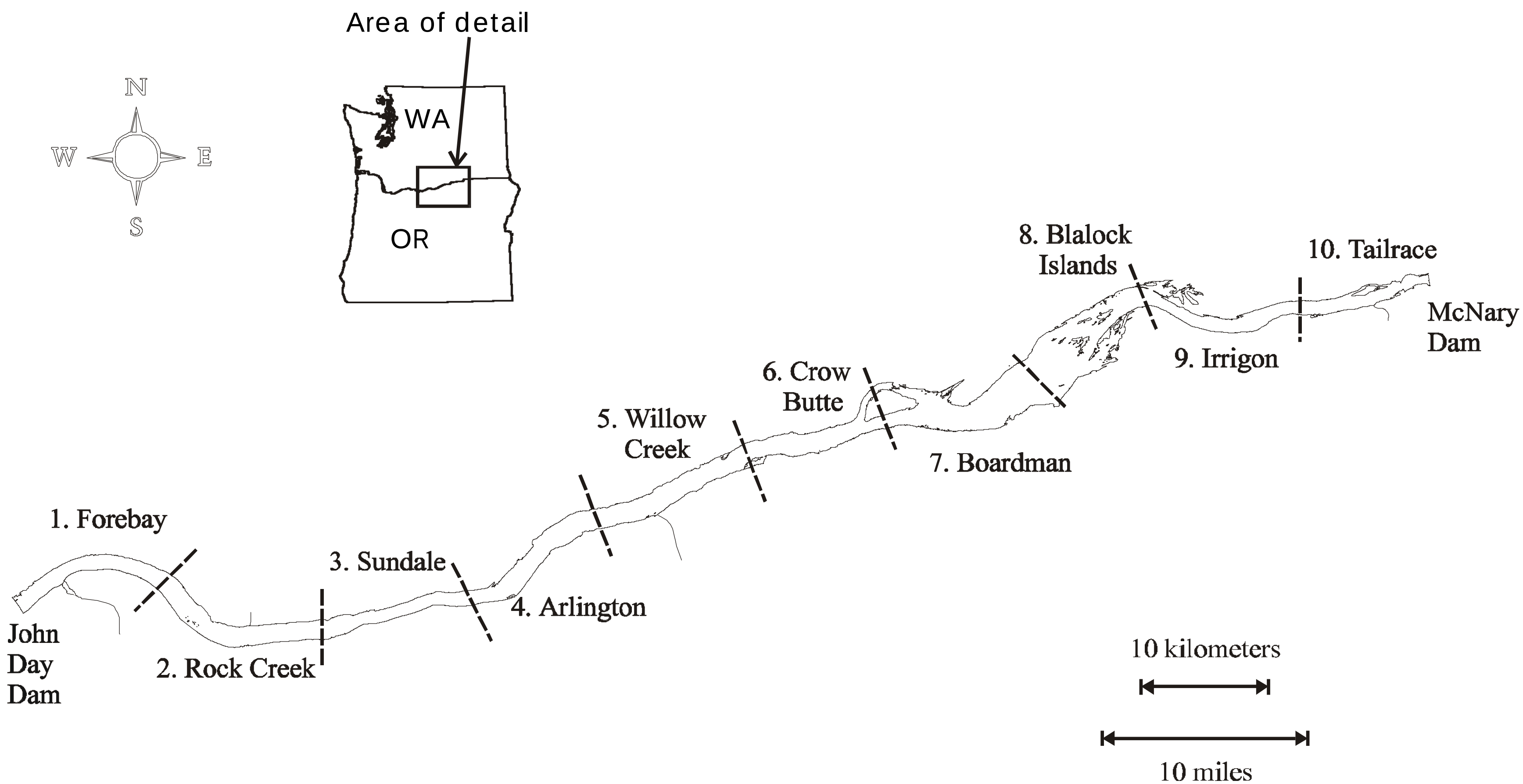

Figure 1. The Columbia River between John Day and McNary dams. Numbers indicate sampling section and boundaries are indicated by dashed lines.

Table 1. Sampling effort (number of setline sets) for white sturgeon in John Day Reservoir by week and sampling section. May through August 2001.

	Sampling Section										
Week	1	2	3	4	5	6	7	8	9	10	Total
20	--	--	--	--	--	--	20	24	3	--	47
21	--	--	--	--	--	--	--	--	21	30	51
22	27	24	3	--	--	--	--	--	--	--	54
23	--	--	27	27	--	--	--	--	--	--	54
24	--	--	--	--	25	24	--	--	--	--	49
25	--	--	--	--	--	--	29	23	1	--	53
26	--	--	--	--	--	--	--	--	28	25	53
28	25	31	--	--	--	--	--	--	--	--	56
29	--	--	28	27	--	--	--	--	--	--	55
30	--	--	--	--	30	26	--	--	--	--	56
31	--	--	--	--	--	--	27	27	3	--	57
32	--	--	--	--	--	--	--	--	30	30	60
33	30	30	--	--	--	--	--	--	--	--	60
34	--	--	25	27	--	--	--	--	--	--	52
35	--	--	--	--	29	27	--	--	--	--	56
Total	82	85	83	81	84	77	76	74	86	85	813

We used setlines as our sampling gear because they are less size selective and less damaging to sturgeon than other gears and provide suitable catch rates for our objectives (Elliott and Beamesderfer 1990). Setlines were equipped with 12/0, 14/0, and 16/0 hooks with individual lines containing 13 hooks each of two sizes and 14 hooks of the remaining size, which was chosen randomly for each line. Setlines were fished overnight for an average of 22.9 hours, and all lines were baited with pickled squid *Loligo* spp., which yields higher catch rates than baits used prior to 1997 (North et al. 1998).

We measured fork length (cm), and looked for tags, tag scars, fin marks, and scute marks on all white sturgeon captured. All measurements herein are fork length unless otherwise indicated. We removed a pectoral fin-spine section for aging and weighed a subsample of the catch (up to 30 fish per 20-cm length interval). We also attempted to weigh fish thought to be previously transplanted Trawl and Haul fish to assess their condition. Most white sturgeon 70 cm and larger were tagged with a 134.2-MHz ISO passive integrated transponder (PIT) tag. The second left lateral scute was removed to identify PIT-tagged fish (Rien et al. 1994). No white sturgeon were externally tagged. Existing external tags detected on fish recaptured from previous sampling were removed. The ninth left lateral scute was removed as a secondary mark to indicate the fish was captured in 2001. Recaptures were weighed to estimate changes in condition factor. Unlike previous field seasons, we did not perform surgeries on any white sturgeon during 2001 to determine sex and maturity, nor did we inject any fish with oxytetracycline (OTC).

Recoveries of tags applied during previous years were used to determine movement patterns among reservoirs. Recaptured fish with known mark histories were grouped according to the year and reservoir in which they were originally marked. In cases of multiple captures within 2001, only the first capture was used to determine movement among reservoirs.

Ages of white sturgeon were estimated from thin cross-sections of pectoral fin-spines following procedures outlined in Beamesderfer et al. (1989). Each fin-spine section was aged twice each by two experienced staff, and up to 20 fish for each 20-cm length interval were aged. A subsample of 42 fish were aged by a third reader. An age-length frequency distribution was developed from these age assignments and added to a database of existing length-at-age information. We derived a Von Bertalanffy age and growth equation using age-at-length data and SAS (PROC GLM; SAS 1988) two-way Analysis-of-variance (ANOVA).

Paired samples of fork length and weight were used to calculate a length-weight regression. Relative weights (W_r) were calculated to assess the relative condition of white sturgeon larger than 70 cm. We used ANOVA and a Tukey's studentized range test (SAS 1988) to test for significant differences in relative weights of fish.

Sampling in 2001 allowed us the first opportunity to recover large numbers of PIT-tagged white sturgeon in John Day Reservoir. Recoveries of PIT tags allowed us to calculate direct growth for large numbers of fish. We compared the average growth rate of fish at-large from 1996-2001 to growth estimates from previous years.

In past years, fish abundance has been estimated using a Schnabel multiple mark and recapture estimator (Ricker 1975) for fish in the 70–166 cm size class (Beamesderfer et al. 1995). After an abundance estimate for fish 70–166 cm was made, estimates for fish below and above this size class were made based on their relative proportion in the catch, adjusted for relative vulnerability of each size to capture by setline as estimated from recapture rates of marked fish. In 1999 Bonneville (Kern et al. 2001) and 2001 John Day stock assessments, larger numbers of fish were captured and marked, allowing a more robust estimate of abundance by a different method. In 2001, we calculated Schnabel estimates for fish from 54-109 cm FL, and from 110-166 cm FL, because these two size classes have been shown by past work (Beamesderfer et al. 1995) to have different capture vulnerabilities to setline gear. We then apportioned sturgeon between 110-137 cm and between 138-166 cm based upon their relative length frequencies in the catch of fish between 110-166. We performed a Schnabel estimate for fish over 166 cm FL, although the number of fish recaptured in this size range was low (6 fish). We also estimated the abundance of fish in this size group by extrapolating their numbers based on the total population estimate and their length frequencies within the total catch.

We utilized a slightly different set of mark/recapture data in the John Day 2001 estimate than in the Bonneville 1999 estimate (Kern et al. 2001). In 1999, we used the numbers of PIT-tags applied and recaptured. In 2001, we used the numbers of scute marks applied and recaptured. This allowed us to more accurately represent the 54-109 cm size group, as PIT-tags are only applied to fish greater than 70 cm FL. However, we did have to account for multiple-recaptures of fish within individual recovery periods, since we utilized non-unique marks. To accomplish this, we calculated the rate at which PIT-tagged fish were recaptured during each recovery period. We subtracted the percentage of PIT-tagged fish that were recovered more than once per recovery period multiplied by the number of scute marks recovered from the same period from the total number of scute marks recovered to get an estimate of total number of scute marks recovered only one time per recovery period.

Trawl and Haul Supplementation

From 22 October to 16 November 2001, we transplanted juvenile sturgeon captured in the Columbia River downstream from Bonneville Dam into The Dalles and John Day reservoirs to supplement these populations (Figure 2). Equipment and techniques for fish collection and transportation were identical to work conducted in 2000 (Kern et al. 2001). The same private commercial trawler who collected fish in 2000 was contracted to collect fish in 2001. Fish processing and transportation were conducted primarily by ODFW staff with assistance from volunteers.

Although most fish transported were between 35 and 90 cm fork length, some smaller fish were transported on days when catches were low. We measured a sample of about 100 of the first fish captured each day to estimate length frequency distribution. All transported fish had their ninth left lateral scute removed to signify capture in 2001 and the third right scute was removed to signify Trawl and Haul handling. Fish were transported in either a 13,000-liter or a 5,300-liter ODFW liberation truck. In John Day Reservoir, all fish were transplanted on the Oregon side of the Columbia at the Arlington Boat Ramp (river km 390), the Boardman Boat Ramp (river km 434), or the Irrigon Boat Ramp (river km 455). Fish released in The Dalles Reservoir were released at Maryhill (river km 338) or Celilo (river km 325) boat ramps.

Stock assessment work in John Day Reservoir in 2001 gave us the opportunity to monitor fish transported by the Trawl and Haul program in previous years. From 1998 through 2000, we transported 13,724 fish to John Day Reservoir. A lateral scute was removed from all of these fish to indicate year of transport. We estimated abundance of Trawl and Haul transports by dividing the number of transplanted fish in setline catches by the total setline catch of fish 61-110 cm, and multiplying this result by the estimated abundance of all fish 61-110 cm.

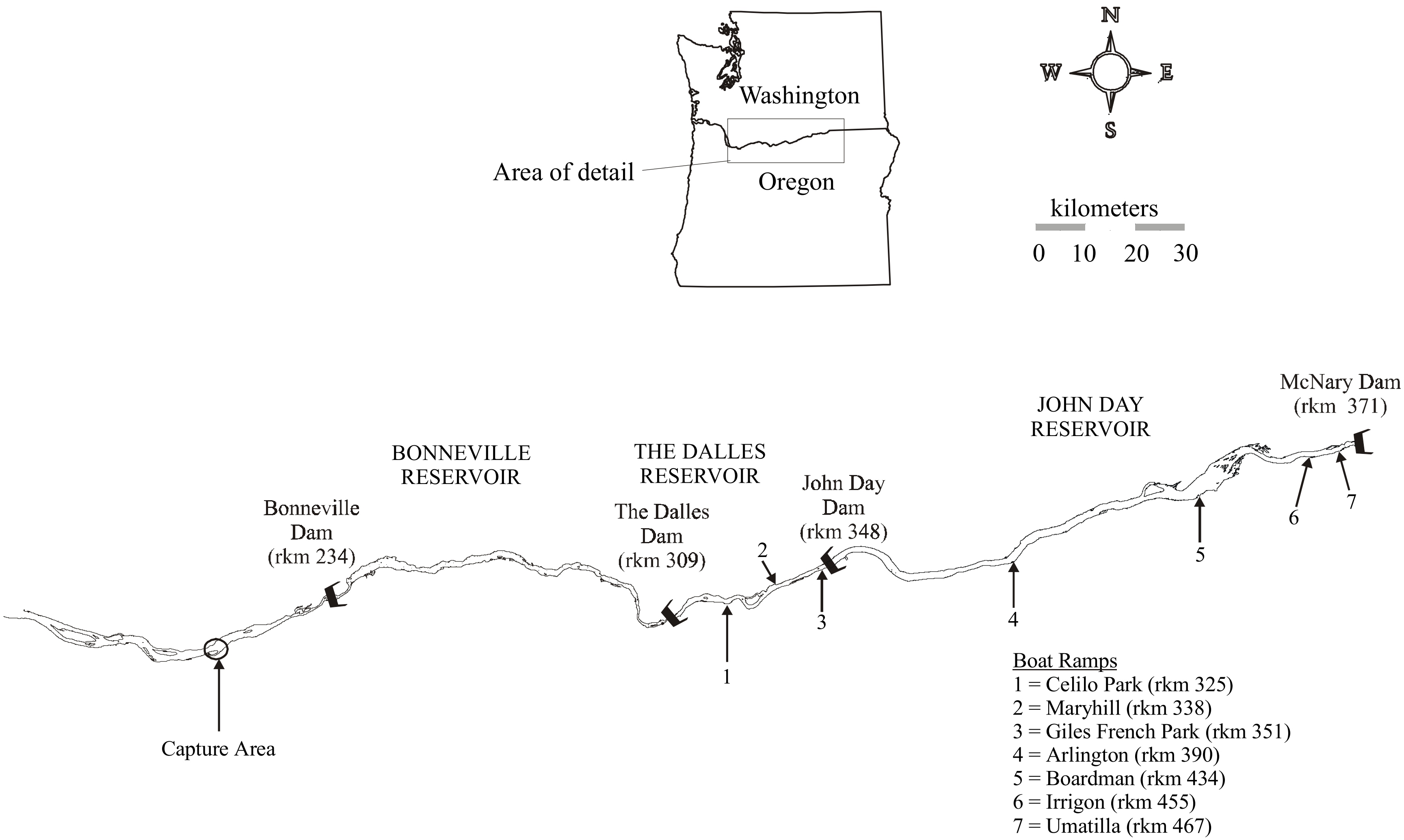

Figure 2. Study area for Trawl and Haul supplementation, October – November 2001.

Young-of-Year Indexing

During October and November of 2001, we sampled The Dalles, John Day, and McNary reservoirs in the Columbia River, and Little Goose and Ice Harbor reservoirs in the Snake River to determine YOY white sturgeon recruitment relative to previous years sampled. Gill nets were used to collect white sturgeon and sampling methodology was similar to past years (Burner et al. 1999). To facilitate comparisons between two methods, gill net sampling was done immediately following trawl sampling by U.S. Geological Survey (USGS). Nets were 91.4 m long and 3.7 m deep and were constructed of 5.1-cm stretched measure multifilament nylon webbing. Nets were set in standardized locations (Parsley et al. 1999) to allow comparisons of relative catch with previous years, and with USGS trawl data. Nets were fished on the river bottom overnight for 17.1 h to 26.7 h. Because of poor weather conditions, 12 nets fished in McNary Reservoir were fished for nearly 48 hrs. Each overnight set was considered a single effort. We classified white sturgeon as YOY or older based on length frequency distribution. Aging of pectoral fin spines on the smallest fish captured verified the classification of Age 1 and older fish. We calculated mean catch per unit effort (CPUE) and proportion of positive efforts (E_p) for white sturgeon.

RESULTS

Stock Assessment

Catch

We caught 5,562 white sturgeon during sampling activities in John Day Reservoir from 14 May to 29 August 2001 (Table 2). Setline catch consisted of 90.4% sublegal size (<110 cm), 6.4% legal size (110–137 cm), and 3.2% 'oversize' (>137 cm) fish.

Table 2. Catches of white sturgeon with setlines in John Day Reservoir by week and sampling section, May through August 2001.

	Sampling Section										
Week	1	2	3	4	5	6	7	8	9	10	Total
20	--	--	--	--	--	--	197	326	46	--	569
21	--	--	--	--	--	--	--	--	194	300	494
22	11	11	8	--	--	--	--	--	--	--	30
23	--	--	73	100	--	--	--	--	--	--	173
24	--	--	--	--	121	203	--	--	--	--	324
25	--	--	--	--	--	--	284	308	13	--	605
26	--	--	--	--	--	--	--	--	394	343	737
28	54	70	--	--	--	--	--	--	--	--	124
29	--	--	73	123	--	--	--	--	--	--	196
30	--	--	--	--	166	180	--	--	--	--	346
31	--	--	--	--	--	--	254	432	75	--	761
32	--	--	--	--	--	--	--	--	318	289	607
33	22	11	--	--	--	--	--	--	--	--	33
34	--	--	49	97	--	--	--	--	--	--	146
35	--	--	--	--	196	221	--	--	--	--	417
Total	87	92	203	320	483	604	735	1,066	1,040	932	5,562

Distribution and Movement

We captured white sturgeon throughout the reservoir, but catches were highest in the three uppermost sections (Table 2). The majority of recaptured fish were caught in the same section as tagged, with 63% recovered within 10 RK of the original marking location (Table 3). The average movement of recaptured fish was 3.68 RK upstream from where they were originally marked. We captured one tagged fish that had moved upstream from The Dalles Reservoir, and four tagged fish that had moved downstream from McNary Reservoir. Since 1987, only 5 marked white sturgeon have been verified as being captured in a reservoir upstream of the original marking location, 127 have been captured in the reservoir immediately downstream, and 9 have been captured two reservoirs downstream (Table 4, Appendix Tables A-2 to A-5). However, the majority (3,972, or 97%) of sturgeon recaptured have been recaptured within the reservoir they were originally marked in.

Table 3. Frequency of movement of fish between marking and recapture events. Negative numbers indicate downstream movement and positive numbers indicate upstream movement. Multiple recaptures of individual fish are included.

Number of River KM Moved	Frequency of Recaptures	% Frequency of Recaptures
-100	0	0.0%
-90	1	0.1%
-80	4	0.4%
-70	3	0.3%
-60	9	1.0%
-50	10	1.1%
-40	19	2.1%
-30	23	2.6%
-20	48	5.4%
-10	286	31.9%
10	282	31.4%
20	69	7.7%
30	51	5.7%
40	37	4.1%
50	26	2.9%
60	11	1.2%
70	8	0.9%
80	7	0.8%
90	2	0.2%
100	1	0.1%
Total	897	

Table 4. Summary of within and out-of-reservoir recaptures of marked white sturgeon within the Columbia Basin, 1987-2001. Upstream 1 refers to sturgeon captured upstream of the reservoir they were marked in (no fish were recaptured more than one reservoir upstream). Downstream 1 refers to sturgeon recaptured one reservoir downstream of where they were originally marked, Downstream 2 refers to fish recaptured two reservoirs downstream, etc. Numbers of recaptures are cumulative from date of release until the end of 2001 sampling.

		Recapture Location					
Reservoir	Release year	Upstream 1	Within	Downstream 1	Downstream 2	Downstream 3	Downstream 4
McNary	1993	--	22	4	2	0	0
	1995	--	30	6	0	0	0
	Total	--	52	10	2	0	0
	Percent	--	81.25	15.63	3.13	0	0
John Day	1989	0	6	1	0	0	--
	1990	0	120	12	1	0	--
	1991	0	17	0	0	0	--
	1996	0	364	9	3	0	--
	2001	--	621	--	--	--	--
	Total	0	1,128	22	4	0	--
	Percent	0	97.75	1.91	0.35	0	--
The Dalles	1987	1	198	4	1	--	--
	1988	0	232	24	1	--	--
	1989	1	36	0	0	--	--
	1991	1	68	0	0	--	--
	1993	0	0	1	1	--	--
	1994	0	419	10	0	--	--
	1995	0	448	12	0	--	--
	1997	1	268	11	0	--	--
	Total	4	1,669	62	3	--	--
	Percent	0.23	96.03	3.57	0.17	--	--
Bonneville	1988	0	70	4	--	--	--
	1989	0	336	17	--	--	--
	1991	1	126	12	--	--	--
	1993	0	0	0	--	--	--
	1994	0	138	0	--	--	--
	1999	--	453	0	--	--	--
	Total	1	1,123	33	--	--	--
	Percent	0.09	97.06	2.85	--	--	--

Age and Growth

We assigned ages to 191 white sturgeon captured from John Day Reservoir in 2001. These data, combined with previously collected age data (Table 5), were used to estimate parameters of a Von Bertalanffy growth equation (Figure 3). Ages ranged from 2-49 and variation between ages assigned by readers increased with fish age (Table 6). Final ages for this year were compared to past years and resulted in a slight decrease in length-at-age. The Von Bertalanffy growth curve was compared to past years (Figure 3) and there appeared to be a slight increase in assigned age. Reader 3 tended to age fish younger than readers 1 and 2. Readers 1 and 2 agreed with each other more of the time, and variation occurred relatively equally between older and younger ages (Figure 4).

Table 5. Age and length-frequency distribution of white sturgeon collected in John Day Reservoir, 1987-2001.

	Fork Length (cm)												
Age (yr)	20-39	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	>199	MEAN	STD	N
1											-	-	0
2	5	1									35.5	5.3	6
3	7	7									42.4	8.3	14
4	8	18	2								48.0	10.3	28
5	6	19	5								49.7	8.8	30
6	3	17	17	1							58.7	11.9	38
7		18	18	7							66.3	13.3	43
8		7	19	4	4						74.1	14.7	34
9		13	19	15	3	1					72.8	16.6	51
10		4	21	13	3	1					78.6	16.1	42
11		3	8	7	11						87.8	19.4	29
12		2	10	20	12	1					90.0	16.1	45
13		3	4	9	25	9					102.5	18.7	50
14			3	9	19	10	3				110.1	19.1	44
15			1	11	14	19	3				114.2	17.9	48
16			1	9	12	10	4				113.8	19.5	36
17				10	17	15	3	1		1	116.0	22.6	47
18				5	15	23	7	2			123.4	17.5	52
19				5	9	12	9				124.0	21.9	35
20				2	8	13	6	1	2		128.8	23.4	32
21				1	6	8	14	5			136.9	22.1	34
22				2	2	12	6	3	2	1	140.5	29.8	28
23						3	3	1	2		153.1	26.4	9
24			1		2	2	7	2	1		142.5	27.6	15
25					3	1	3	3	2		149.7	30.0	12
26					1	1	1	2	4	2	173.6	30.7	11
27							1	2	1		171.3	22.7	4
28					1					1	167.5	74.2	2
29							1		2	3	192.7	28.3	6
>29						1	2	1	8	19	202.5	26.4	31
All	29	92	109	111	159	141	73	23	24	27	104.0	41.5	856

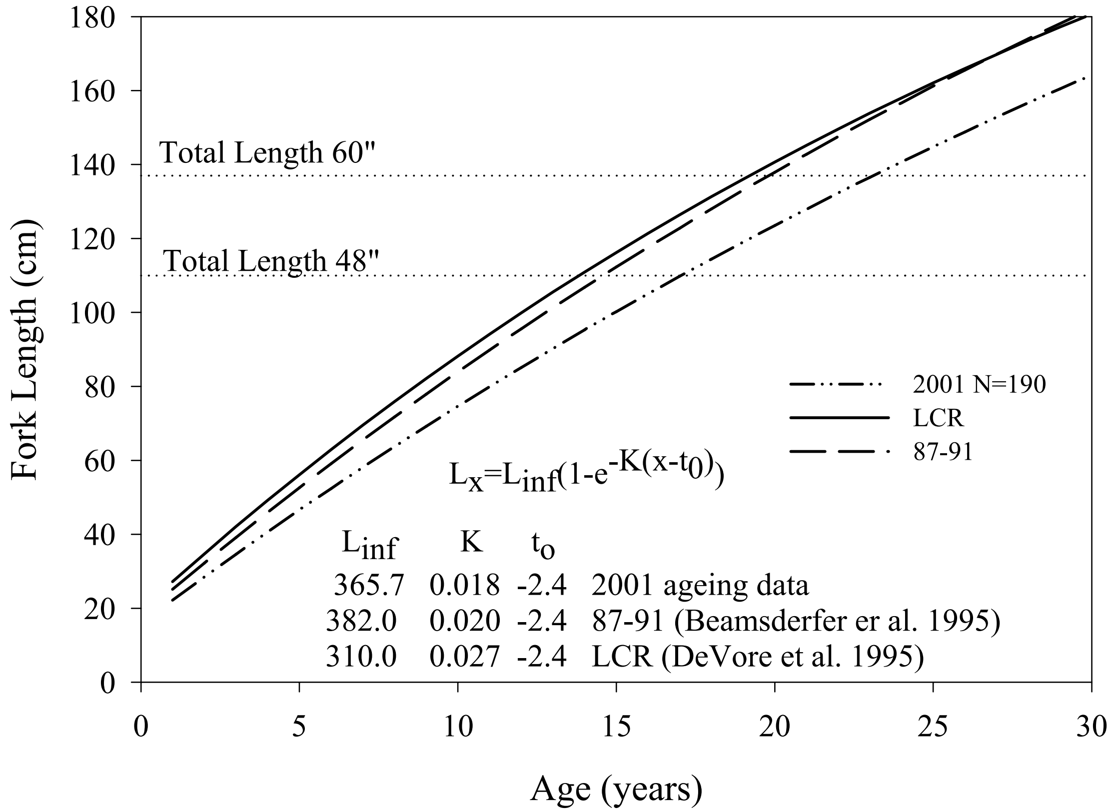

Figure 3. Comparison of Von Bertalanffy growth parameters for white sturgeon collected in John Day Reservoir in 2001, and based on previous years' (Beamesderfer et al. 1995) and Lower Columbia River (Devore et al. 1995) data.

Table 6. Discrepancies in aging of white sturgeon pectoral fin spine sections collected in John Day Reservoir 2001 by primary two readers.

Age Differ-ence	Final Assigned Age 2	3	4	5	6	7	8	9	10	11	12-14	15-17	18-20	21-23	24-26	27-29	>29	Total	%
9																		0	0.00
8																		0	0.00
7																	1	1	0.01
6														1				1	0.01
5														2	2		1	5	0.03
4															1			1	0.01
3													1		1		4	6	0.03
2						1					1	2	4	2	1	1		12	0.07
1		1			2	2			1	1	1	3	3	4	3	1	2	24	0.14
0	1		3	8	2	6	2	2	1	2	1	9	13	5			3	58	0.33
-1		2	2	2	5	3					1	3	6	7	2	1		34	0.19
-2					1	1			1		1	6	6	3	1	1	3	24	0.14
-3												1	1	2				4	0.02
-4													1	1	1	1	1	5	0.03
-5																	1	1	0.01
-6														1			1	2	0.01
-7																	1	1	0.01
-8																	1	1	0.01
-9																	1	1	0.01
All	1	2	5	7	10	13	2	2	3	3	5	24	35	28	12	5	20	177	1.00

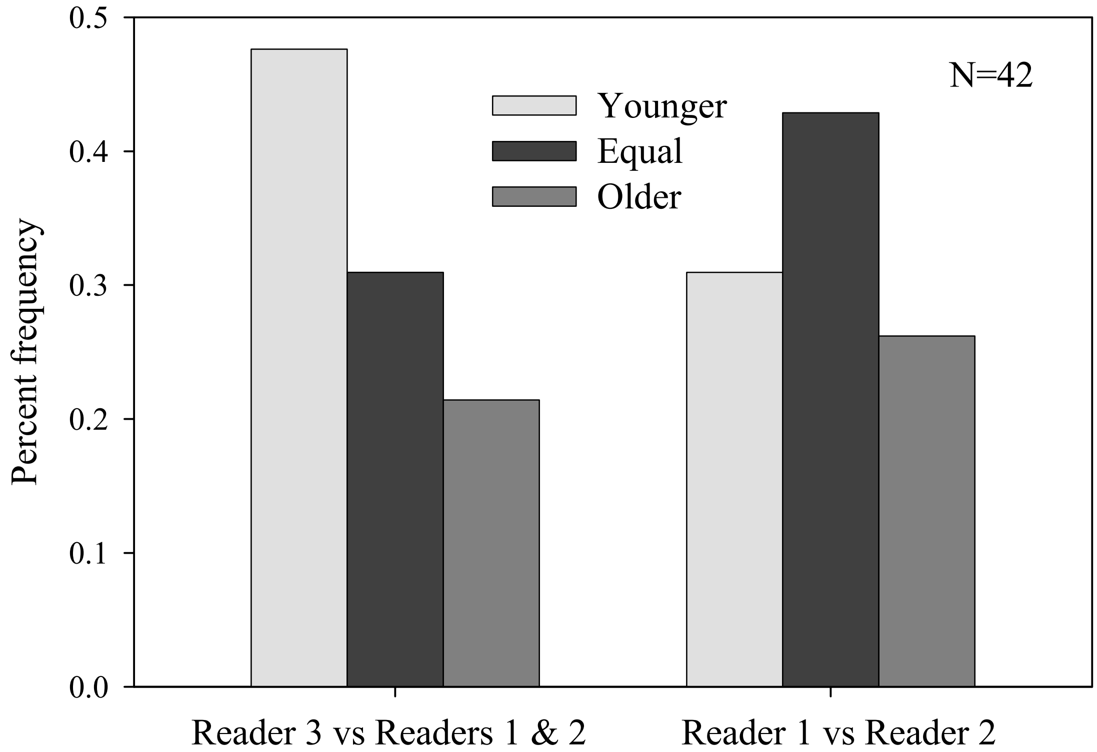

Figure 4. Percent frequency of differences in age assignments by readers of pectoral spine sections collected from white sturgeon in John Day Reservoir 2001.

Relative weights (Figure 5) in sampling period 2 (mean 92.9) differed significantly ($p<0.05$) from those in sampling periods 3 (mean 102.3) 4 (mean 99.9) at the 95% confidence level. Relative weights in periods 3 and 4 did not differ significantly ($p<0.05$) from one another. Relative weights of fish captured in 2001 (mean 95.0) were significantly lower ($p<0.05$) than relative weights of fish captured in 1996 (mean 98.8).

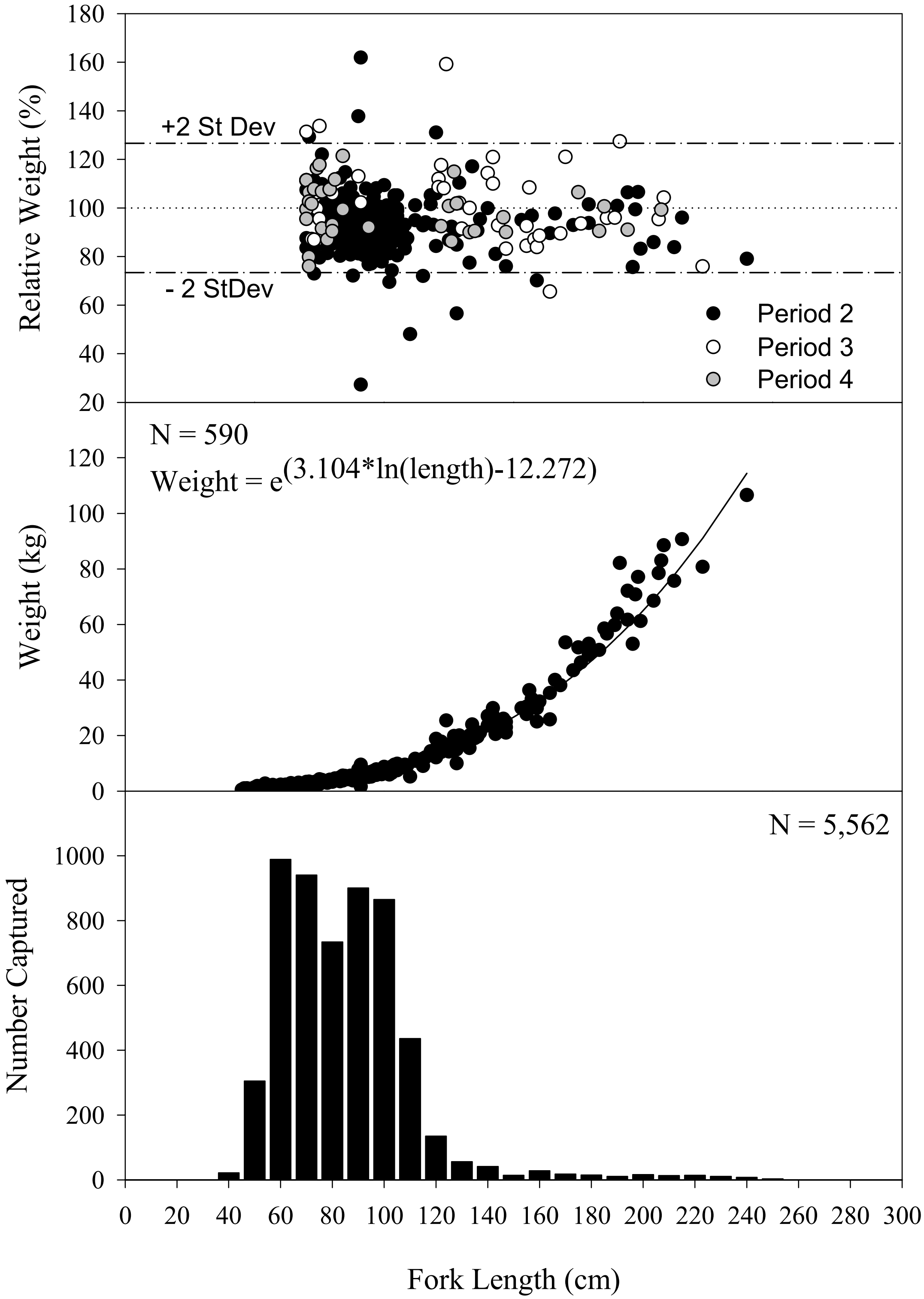

Figure 5. Relative weight, length-weight relationship, and length-frequency distribution of white sturgeon captured during stock assessment sampling.

Abundance Estimates

From December 2000 through August 2001, 3,757 white sturgeon of various sizes were marked with PIT-tags by CRITFC and ODFW. Approximately 85% of these marks were applied to white sturgeon from 70–110 cm fork length, another 11% were applied to fish in the 110–137 cm range, and the remaining marks were applied to fish over 137-cm fork length. We recaptured fish in all size classes. We estimated the abundance of 54-109 cm and 110-166 cm white sturgeon to be 27,667 (Table 7) and 1,290 fish (Table 8). We estimated abundance of 110-137 cm white sturgeon (legal-sized) to be 1,077 fish (Table 8). Estimated abundance of white sturgeon larger than 166 cm totaled 874 fish (Table 9). The total estimated population of white sturgeon >54 cm in John Day Reservoir in 2001 was 29,831 fish.

Table 7. Mark/Recapture data and Schnabel estimate of abundance of white sturgeon 54-109 cm fork length, John Day Reservoir 2001.

Period (t)	Catch (C)	Marks (M)	Recaps (R)	Mortalities Unmarked	Mortalities Marked	Marks at Large (M_t)	Estimate (M_t *C)/(R+1)
1	2,104	2,104		--	--	0	
2	1,307	1,199	108	--	--	2,104	25,259
3	1,745	1,539	206	--	--	3,303	27,872
4	1,712	1,419	293	--	--	4,842	28,227
Sum	6,867	6,261	606			Estimate	27,667
						Lower 95% CI	25,553
						Upper 95% CI	29,954

Table 8. Mark/Recapture data and Schnabel estimate of abundance of white sturgeon 110-166 cm fork length, John Day Reservoir 2001.

Period (t)	Catch (C)	Marks (M)	Recaps (R)	Mortalities Unmarked	Mortalities Marked	Marks at Large (M_t)	Estimate (M_t *C)/(R+1)
1	339	339		--	34	0	
2	119	95	24	--	0	271	1,300
3	150	117	33	--	26	340	1,503
4	150	95	55	--	17	414	1,111
Sum	758	646	112			Estimate	1,290[a]
						Lower 95% CI	1,074
						Upper 95% CI	1,550

[a] Estimated abundance of fish 110-137 cm is 1,077 fish, based upon length-frequency distribution within the 110-166 cm interval.

Table 9. Mark/Recapture data and Schnabel estimate of abundance of white sturgeon >166 cm fork length, John Day Reservoir 2001.

Period (t)	Catch (C)	Marks (M)	Recaps (R)	Mortalities Unmarked	Mortalities Marked	Marks at Large (M_t)	Estimate (M_t *C)/(R+1)
1	30	30		--	--		
2	46	43	3	--	--	30	367
3	34	31	3	--	--	73	654
4	26	25	1	--	--	104	1,370
Sum	135	129	6			Estimate	874
						Lower 95% CI	443
						Upper 95% CI	1,618

Trawl and Haul Supplementation

The trawler caught 6,937 white sturgeon in 116 trawl tows for an average of 59.8 fish per tow (Table 10). Mean trawl duration was 14.5 minutes. White sturgeon of various sizes were captured, although fish of the target size group of 35–90-cm fork length dominated the catch (99%; Figure 6). Mean fork length of transplanted fish estimated from a subsample of 1,746 fish was 43 cm. Incidental catches of other fish species are shown in Appendix Table A-5.

Of the 6,452 white sturgeon transplanted in 2001, the majority (5,195) were transplanted into John Day Reservoir (Table 11). The remaining 1,257 fish were transplanted into The Dalles Reservoir. No mortalities occurred during capture and processing, and, with one exception, few mortalities were observed at release (Table 12). The exception occurred on a day when the trawler delivered an exceptionally large load of fish in the first haul. Fish condition was poor on delivery, however, fish appeared to recover well in the oxygen-rich transport truck. Nevertheless, 49 dead white sturgeon were reported from the Arlington release site the following day by the local sheriff's office. Table 12 reports only mortalities observed by ODFW staff during handling, transport, or release. Daily transport densities ranged from 0.0031 to 0.1107 kg/L. Dissolved oxygen levels in the transport vehicle were nearly always at or above saturation and fish condition during and after transport generally appeared to be excellent.

Table 10. Effort and catch of juvenile and sub-adult white sturgeon captured in the Columbia River downstream of Bonneville Dam (river kilometers 209-212) during October and November, 1993-2001.

Year, Agency	Sampling days	Number of trawls	Total catch[a]	Mean catch	Mean trawl time (min)	Mean fishing depth (m)
1993						
NMFS[b]	3	19	564	29.7	10.0	18.6
USGS[c]	3	14	358	25.6	14.0	--
1994						
NMFS[b]	15	59	3,428	58.1	9.9	19.5
USGS[c]	5	22	365	16.6	10.0	--
1995						
NMFS[b]	12	102	5,974	58.6	10.4	20.3
1998						
NMFS[b]	14	118	10,362	87.8	8.6	17.8
1999						
NMFS[b]	14	132	4,728	32.2	12.3	18.0
2000						
Private trawler	15	100	5,705	57.1	20.5	11.2
2001						
Private trawler	16	116	6,937	59.8	14.5	--

[a] Approximate number since some white sturgeon were not counted and immediately released at the capture site when tow catches were very large.
[b] National Marine Fisheries Service.
[c] U. S. Geological Survey

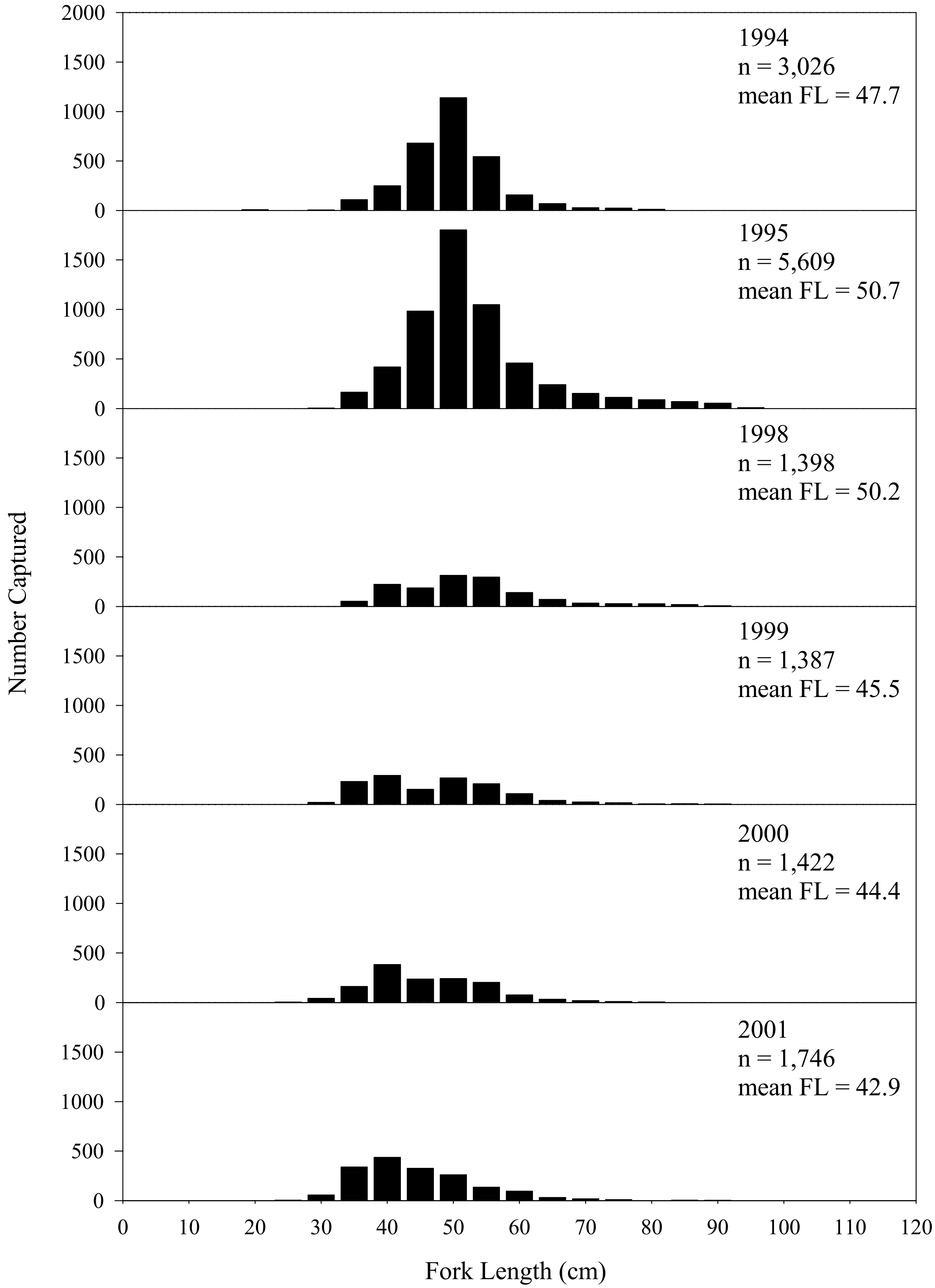

Figure 6. Length-frequency distributions of white sturgeon sampled during Trawl and Haul collections, 1994-2001.

Table 11. Number of white sturgeon transported from below Bonneville Dam to The Dalles and John Day reservoirs from 1994 – 2001.

Year	Release Reservoir		Total
	The Dalles	John Day	
1994	2,935	--	2,935
1995	5,611	--	5,611
1998	3,257	5,534	8,791
1999	77	4,171	4,248
2000	1,163	4,019	5,182
2001	1,257	5,195	6,452
Total	14,300	18,919	33,219

Table 12. Transport data for fish captured below Bonneville Dam and transported to The Dalles and John Day reservoirs, October and November 2001.

Date	Number trans-ported	Mortal -ities	Number released	Max time in tanker	Release location	River temp (°C)	Tank temp (°C) (min/max)	Tank DO (ppm) (min/max)	Transport tank volume (L)	Average weight (kg)	Loading density (kg/L)
10/22	174	0	174	8:30	Boardman	13.5	13.9/14.5	10.0/17.0	13,265	0.471	0.00618
10/23	599	1	598	9:10	Irrigon	13.4	12.8/13.3	10.5/15.0	5,306	0.375	0.04232
10/24	272	0	272	9:00	Irrigon	12.2	10.0/12.2	11.7/14.0	13,265	0.431	0.00884
10/25	402	0	402	8:40	Arlington	12.8	11.7/12.8	9.0/17.0	5,306	0.446	0.03381
10/29	154	0	154	8:15	Arlington	12.0	10.6/11.6	9.8/10.0	13,265	0.505	0.00586
10/30	526	1	525	9:10	Irrigon	13.0	10.6/11.1	10.0/11.0	5,306	0.866	0.08584
10/31	821	8	813	7:30	Maryhill	12.2	11.1/11.7	9.0/13.7	13,265	0.829	0.05134
11/1	168	0	168	7:05	Irrigon	12.0	11.1/12.2	8.7/10.2	5,306	0.552	0.01749
11/5	648	12	636	7:45	Arlington	11.5	11.4/11.9	15.0/16.0	13,265	0.388	0.01897
11/6	341	1	340	8:10	Celilo	11.5	10.6/10.6	10.5/16.0	5,306	0.544	0.03493
11/7	474	6	468	9:00	Umatilla	12.0	---/---	---/---	13,265	0.391	0.01398
11/8	252	0	252	8:15	Irrigon	11.0	10.6/10.6	10.9/15.0	5,306	0.901	0.04278
11/13	104	0	104	7:00	Celilo	12.1	9.4/9.5	10.0/11.2	13,265	0.399	0.00313
11/14	248	0	248	7:15	Boardman	11.1	10.0/10.6	10.2/12.0	5,306	0.545	0.02547
11/15	699	14	685	9:20	Irrigon	12.2	9.9/10.2	9.7/10.9	13,265	1.234	0.06501
11/16	615	2	613	8:45	Arlington	12.2	9.4/10.0	10.2/11.0	5,306	0.955	0.11072
Total	6,497	45	6,452								

Based on the relative proportions of fish bearing Trawl and Haul scute marks in setline catches and estimated abundance of fish 61-110 cm in the population, we estimated an abundance of 1,515 pre-2001 Trawl and Haul transplants in the John Day population.

Young-of-Year Indexing

Catch and effort data from YOY sampling in the five reservoirs studied is shown in Table 13. None of the white sturgeon captured in any of the five reservoirs in 2001 were classified as YOY (Figure 7). In The Dalles Reservoir, we caught 247 white sturgeon in 32 gill nets set and fished for a total of 726.5 hours. We set 40 gill nets in John Day Reservoir and captured 39 white sturgeon in 895.7 hours of fishing. In McNary Reservoir, we caught 5 white sturgeon in 24 gill nets fished for a total of 826.3 hours. We fished 36 gill nets in Ice Harbor Reservoir for a total of 815.5 hours, and caught 3 white sturgeon. Catch was slightly higher in Little Goose Reservoir, with 14 white sturgeon captured in 36 nets fished for a total of 797.9 hours.

Table 13. Young-of-year sampling gill-net effort and catch of white sturgeon in Columbia and Snake River reaches during October and November 2001.

River Reach	Reservoir Quarter				
Parameter	1	2	3	4	All
The Dalles Reservoir					
Gill Net Sets	9	6	13	4	32
Total Hours	201.8	137.5	296.2	91.0	726.5
White Sturgeon Catch (all sizes)	89	72	72	14	247
White Sturgeon Catch (FL<32 cm)	0	0	0	0	0
White Sturgeon / Set	9.89	12.00	4.80	2.33	6.86
White Sturgeon (FL<32 cm)/Set	0.00	0.00	0.00	0.00	0.00
Sets with >0 white sturgeon (all sizes)	67%	100%	87%	67%	81%
Sets with >0 white sturgeon (FL<32 cm)	0%	0%	0%	0%	0%
John Day Reservoir					
Gill Net Sets	10	8	12	10	40
Total Hours	217.1	173.8	278.0	226.9	895.7
White Sturgeon Catch (all sizes)	0	0	33	6	39
White Sturgeon Catch (FL<32 cm)	0	0	0	0	0
White Sturgeon / Set	0.00	0.00	2.75	0.60	0.98
White Sturgeon (FL<32 cm)/Set	0.00	0.00	0.00	0.00	0.00
Sets with >0 white sturgeon (all sizes)	0%	0%	58%	50%	30%
Sets with >0 white sturgeon (FL<32 cm)	0%	0%	0%	0%	0%
McNary Reservoir/Hanford Reach					
Gill Net Sets	18	6	0	0	24
Total Hours	619.5	206.8	0	0	826.3
White Sturgeon Catch (all sizes)	4	1	0	0	5
White Sturgeon Catch (FL<32 cm)	0	0	0	0	0
White Sturgeon / Set	0.22	0.17	0.00	0.00	0.21
White Sturgeon (FL<32 cm)/Set	0.00	0.00	0.00	0.00	0.00
Sets with >0 white sturgeon (all sizes)	17%	17%	0%	0%	17%
Sets with >0 white sturgeon (FL<32 cm)	0%	0%	0%	0%	0%
Ice Harbor Reservoir					
Gill Net Sets	9	9	9	9	36
Total Hours	201.6	204.7	208.2	201.0	815.5
White Sturgeon Catch (all sizes)	0	1	1	1	3
White Sturgeon Catch (FL<32 cm)	0	0	0	0	0
White Sturgeon / Set	0.00	0.11	0.11	0.11	0.08
White Sturgeon (FL<32 cm)/Set	0.00	0.00	0.00	0.00	0.00
Sets with >0 white sturgeon (all sizes)	0%	11%	11%	11%	8%
Sets with >0 white sturgeon (FL<32 cm)	0%	0%	0%	0%	0%

Table 13 (con't).

River Reach Parameter	Reservoir Quarter 1	 2	 3	 4	 All
Little Goose Reservoir					
Gill Net Sets	9	9	9	9	36
Total Hours	200.8	199.9	195.9	201.4	797.9
White Sturgeon Catch (all sizes)	0	5	3	6	14
White Sturgeon Catch (FL<32 cm)	0	0	0	0	0
White Sturgeon / Set	0.00	0.56	0.33	0.67	0.39
White Sturgeon (FL<32 cm)/Set	0.00	0.00	0.00	0.00	0.00
Sets with >0 white sturgeon (all sizes)	0%	56%	22%	33%	28%
Sets with >0 white sturgeon (FL<32 cm)	0%	0%	0%	0%	0%

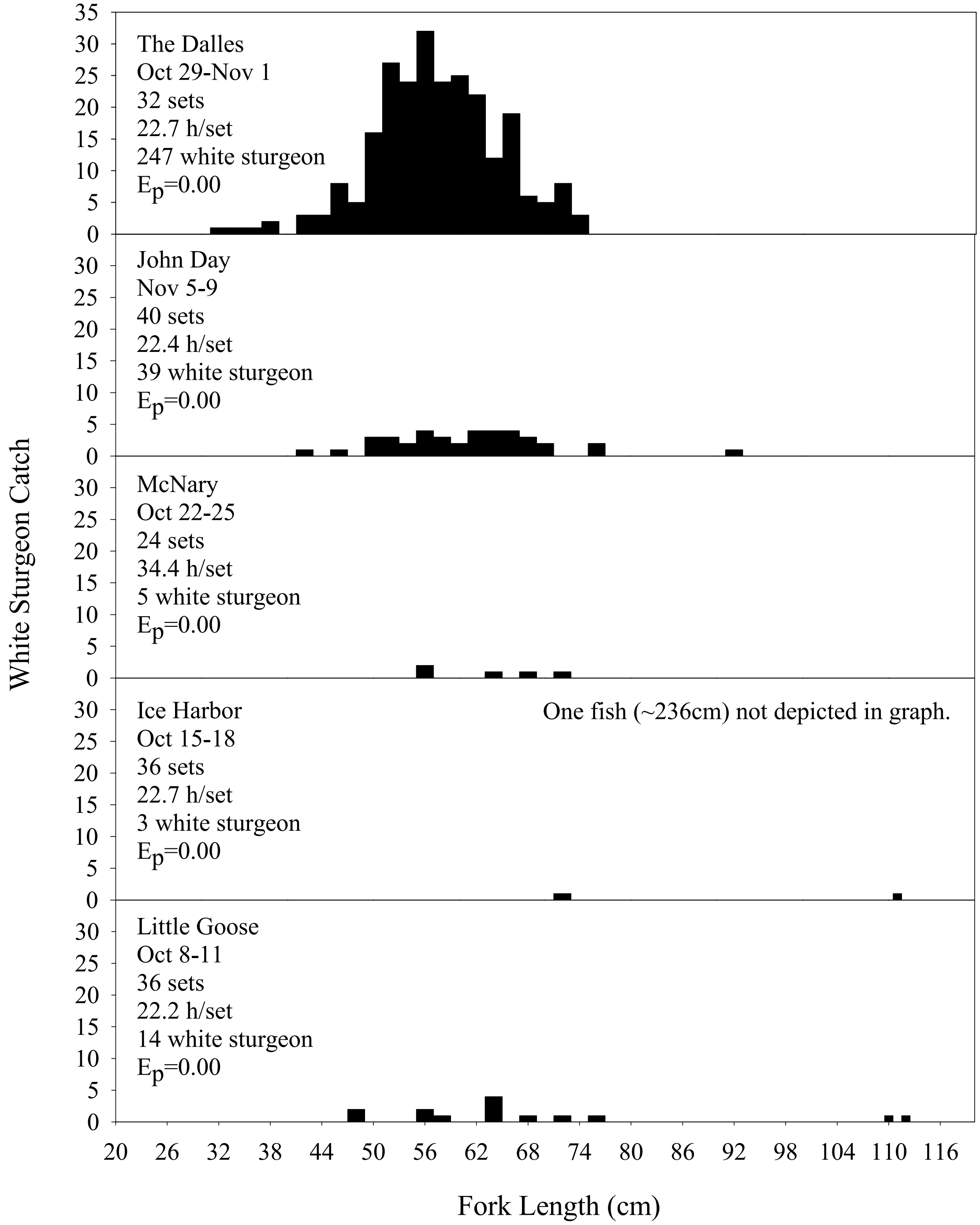

Figure 7. Length-frequency distributions of white sturgeon captured during Young-of-Year indexing, October – November 2001.

DISCUSSION

Stock Assessment

The population abundance estimate for white sturgeon from John Day Reservoir in 2001 was 29,831 fish >54 cm total length, compared to 30,600 fish in 1996, and 6,300 in 1990 (North et al. 1998). Most of the change from 1996 to 2001 was related to a shift in abundance between legal and sublegal size classes. From 1996 to 2001, the estimated abundance of sublegal (<110 cm) fish increased from 25,500 fish in 1996 to 27,667 fish in 2001. During this same period, estimates of the legal-sized population decreased from 4,040 in 1996 to 1,077 fish in 2001. Numbers of over-sized fish appear to have been steadily rising since 1990, with abundance estimates of 500 in 1990, 700 in 1996, and 874 in 2001. Caution should be used in interpreting abundance estimates for over-sized fish because the estimates are based on captures of only a few individual fish.

The reduction in abundance of fish in the harvestable size class was most likely caused by over-harvest resulting from improper parameters being used in modeling the population in the interim between abundance estimates conducted in 1996 and 2001. In past years, growth rates were estimated using length-at-age data, because no other method was available. Length-at-age data for white sturgeon, and many other long-lived fish species, are inherently prone to error, largely due to difficulties in accurately aging individual fish. Because length-at-age data is utilized in the modeling of the population for harvest quotas, any inaccuracies in aging will be propagated by the modeling as well. Recoveries of PIT-tagged fish at-large from 1990, 1996, and 2001 indicate that actual growth rates are significantly slower than rates currently used in modeling abundance of the John Day Reservoir population (Appendix B). This would lead to an overestimate of fish growth and of the size of the harvestable population in years following the 1996 stock assessment, resulting in establishment of unsustainable harvest levels. Incorporation of new growth data, coupled with new modeling techniques based on actual growth rates instead of length-at-age data, (Appendix C), should help refine the process for establishing harvest quotas and reduce the potential for over-harvest. We recommend that stock assessment studies for Zone 6 reservoirs be conducted on a 3-year rotation, rather than the current 5-year rotation. This will result in closer monitoring of the population, allowing managers to modify harvest quotas at more frequent intervals.

The 2001 estimate indicates relatively little change in the abundance of over-sized white sturgeon in John Day Reservoir. It should be noted that the estimate we present (874 fish), is derived using a Schnabel estimate based on a low number of recaptures (6 fish; Table 9). However, using methods similar to past stock assessments that estimate abundance of over-sized fish based on the abundance of the 70-166 cm size class, the proportion of over-sized fish in the total catch, and gear vulnerability adjustments for over-sized fish catch rates, yields a similar estimate of approximately 906 fish.

In the past, there has been a recognized tendency to under-age sturgeon (Rien and Beamesderfer 1994). Although there was no obvious change in criteria this year, knowing this may have caused a bias in aging 2001 samples. This year we also began aging green sturgeon *A. medirostris* for another project. Two of the readers may have unintentionally biased their estimates based on familiarity with the criteria used to age green sturgeon. Green sturgeon annuli are generally more difficult to recognize and samples are therefore more difficult to age. This may have caused readers to look for more annuli in white sturgeon samples, or to identify faint or weak annuli compared to past readers, who were working on white sturgeon samples only. We need to refine our methods for aging fish, either by concentrating on one species at a time, or by redefining aging criteria for both species. We also have 242 samples from OTC-injected white sturgeon that have not been aged yet. Aging of these samples may help verify aging methodologies.

Trawl and Haul Supplementation

As in previous years, supplementation of white sturgeon from below Bonneville Reservoir to The Dalles and John Day reservoirs appears to be largely limited by our ability to capture fish. Although we have approached the total capacity of the smaller trucks, we have yet to maximize the capacity of the large liberation trucks. In 2001, transplant efforts focused mostly on supplementation of the John Day Reservoir population, with 81% of the fish transported to that reservoir. Because of concerns about high densities of young white sturgeon in The Dalles Reservoir, we will continue to supplement the John Day population at a higher rate than the population in The Dalles Reservoir. Stock assessment sampling planned for 2002 in The Dalles Reservoir will allow us to assess the status of transplants to this reservoir over the last several years. Although very little mortality has been observed during handling and transport, we have occasionally received reports of dead scute-marked white sturgeon at release sites following releases of Trawl and Haul fish. This indicates some amount of delayed mortality is occurring, but the magnitude of this mortality is unknown at this time.

We expected that the proportion of fish bearing Trawl and Haul scute marks in the John Day population would be equal to their proportion in the total setline catch, and that we would be able to estimate the abundance of these fish in the reservoir by extrapolating from the 2001 setline catch. However, using these methods, we were only able to account for an abundance of 1,515 fish, which is only 11% of the total number of fish transported to this reservoir prior to 2001 (13,724 fish).

One possible explanation for this discrepancy is that vulnerability of Trawl and Haul transports to setline gear is significantly lower than for the population at large. The Trawl and Haul program targets relatively small sturgeon, from 30-90 cm at the time of capture, and low vulnerability to setline gear may explain some of the discrepancy. However, stock assessment work is also subject to this gear vulnerability issue, and adjusting the estimates of Trawl and Haul transports for gear vulnerability using the same methods used for stock assessment estimates in previous years (North et al. 1998) did not account for the discrepancy. The possibility remains that these fish may still not be large enough to fully recruit to our sampling gear.

Another explanation is that mortality of Trawl and Haul fish in the reservoir is much higher than anticipated. Before full-scale implementation of the Trawl and Haul program, a study was conducted to examine the growth and survival of transported fish (Rien and North 2002). Fish transplanted to The Dalles Reservoir in 1994 and 1995 were captured using gill nets in 1997. Estimated survival rates were 99% for 1994-released fish and 80% for 1995-released fish.

A third possibility is that significant numbers of transported fish migrated out of the reservoir, and were simply not available for us to catch. Sampling in The Dalles Reservoir scheduled for 2002 will give us the opportunity to test this possibility. Alhough fish were not given reservoir-unique marks, we will be able to infer migration of Trawl and Haul fish from John Day Reservoir if the estimated number of Trawl and Haul fish in The Dalles Reservoir is significantly higher than the number of fish transported to the reservoir. Additionally, because transplantation has occurred over a longer period of time in The Dalles Reservoir, we may be able to utilize growth data from these older fish to help explain the apparent discrepancy in John Day Reservoir.

Young-of-Year Indexing

As indicated by catch rates during YOY sampling, recruitment was extremely poor in all sampled reservoirs in 2001. This is the first year since directed YOY index sampling with gill nets began that no YOY have been captured in any sampled reservoir. Although some sets in McNary Reservoir were fished for more than 24 h, violating our sampling methodology, none of these sets captured YOY sturgeon, so E_p results of zero for these samples should still be valid. It is likely that the extreme low flows in the Columbia River during 2001 contributed to this lack of recruitment.

PLANS FOR NEXT YEAR

We will be conducting a stock assessment survey in The Dalles Reservoir in 2002. We will continue to pursue options for describing sturgeon growth in Zone 6 reservoirs and will attempt to create a new model, or refine existing models, to incorporate verified sturgeon growth information using PIT-tag recoveries.

We will again contract with a private commercial trawler to collect fish for Trawl and Haul supplementation in 2002. For consistency, we will employ trawl nets of the same design and measurements as have been used in previous years.

We will continue YOY indexing using gill nets to collect white sturgeon. The USGS will continue to utilize trawl methods for collecting YOY white sturgeon, and will perform analyses to compare the two methods. In the fall of 2002, we will conduct YOY gill net sampling in The Dalles, John Day, McNary, Ice Harbor, and Little Goose reservoirs.

We will also assist Washington Department of Fish and Wildlife personnel with creel sampling in order to assess harvest rates of white sturgeon in Bonneville, The Dalles, and John Day reservoirs.

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Appendix Table A-1. Summary of white sturgeon tagged in Bonneville Reservoir and recaptured within Bonneville and in other reservoirs.

		Released in Bonneville					
		1988	1989	1991	1993	1994	1999
Number marked during regular sampling		341	2,131	1,141	--	2,332	6,143
Number marked during other sampling activities[a]		--	--	--	8[a]	--	--
Total number marked		341	2,131	1,141	8	2,332	6,143
Recaptured in McNary (upstream reservoir)	none to date						
Recaptured in John Day (upstream reservoir)	none to date						
Recaptured in The Dalles (upstream reservoir)	1988		--	--	--	--	--
	1989			--	--	--	--
	1990			--	--	--	--
	1991				--	--	--
	1992				--	--	--
	1993					--	--
	1994						--
	1995						--
	1996			1			--
	1997						--
	1998						--
	1999						
Recaptured in Bonneville	1988	2	--	--	--	--	--
	1989	44	91	--	--	--	--
	1990	5	46	--	--	--	--
	1991	11	89	33	--	--	--
	1992		19	23	--	--	--
	1993	2	12	13		--	--
	1994	4	37	36		21	--
	1995	1	7	4		11	--
	1996		9	5		12	--
	1997	1	7	4		4	--
	1998						--
	1999		19	8		90	453
Recaptured in Lower Columbia River	1988		--	--	--	--	--
	1989	4	4	--	--	--	--
	1990		1	--	--	--	--
	1991		7	2	--	--	--
	1992		3	1	--	--	--
	1993		1	5		--	--
	1994			1			--
	1995			2			--
	1996		1	1			--
	1997						--
	1998						--
	1999						

[a] Sturgeon marked during radio tagging experiments.

Appendix Table A-2. Summary of white sturgeon tagged in The Dalles Reservoir and recaptured within The Dalles and in other reservoirs.

		Released in The Dalles							
		1987	1988	1989	1991	1993	1994	1995	1997
Number marked during regular sampling		837	1,248	147	379	--	1,312	--	5,797
Number marked during other sampling[a,b]		--	--	--	--	7[a]	2,935[b]	5,611[b]	--
Total number marked		837	1,248	147	379	7	4,247	5,611	5,797
Recaptured in McNary (upstream reservoir)	none to date								
Recaptured in John Day (upstream reservoir)	1987	1	--	--	--	--	--	--	--
	1988			--	--	--	--	--	--
	1989				--	--	--	--	--
	1990				--	--	--	--	--
	1991					--	--	--	--
	1992				1	--	--	--	--
	1993						--	--	--
	1994							--	--
	1995								--
	1996			1					--
	1997								
	1998								
	1999								
	2001								1
Recaptured in The Dalles	1987	69	--	--	--	--	--	--	--
	1988	86	115	--	--	--	--	--	--
	1989	16	58	3	--	--	--	--	--
	1990	6	15	1	--	--	--	--	--
	1991	13	24	4	7	--	--	--	--
	1992	3	7	1	5	--	--	--	--
	1993	1	7	1	9		--	--	--
	1994	3	6	6	15		30	--	--
	1995						3		--
	1996				1		1		--
	1997	1	17	20	31		385	448	268
	1998								
	1999								
Recaptured in Bonneville	1987		--	--	--	--	--	--	--
	1988			--	--	--	--	--	--
	1989		4		--	--	--	--	--
	1990	2	1		--	--	--	--	--
	1991	1	14			--	--	--	--
	1992		1			--	--	--	--
	1993	1	2				--	--	--
	1994		1					--	--
	1995								--
	1996					1			--
	1997								
	1998								
	1999		1				10[c]	12[c]	11
Recaptured in Lower Columbia River	1987	1	--	--	--	--	--	--	--
	1988			--	--	--	--	--	--
	1989				--	--	--	--	--

		Released in The Dalles							
		1987	1988	1989	1991	1993	1994	1995	1997
Number marked during regular sampling		837	1,248	147	379	--	1,312	--	5,797
Number marked during other sampling[a,b]		--	--	--	--	7[a]	2,935[b]	5,611[b]	--
Total number marked		837	1,248	147	379	7	4,247	5,611	5,797
Recaptured in Lower Columbia River (con't)	1990				--	--	--	--	--
	1991					--	--	--	--
	1993					1	--	--	--
	1994		1					--	--
	1995								--
	1996								--
	1997								
	1998								
	1999								

[a] Sturgeon marked during radio tagging experiments.

[b] Sturgeon marked as part of Trawl and Haul Program. Fish were captured in the Lower Columbia River, marked, and transported to The Dalles Reservoir in the fall of 1994 and 1995.

[c] Some recaptures (7 from 1994 and all 12 from 1995 markings) were originally marked as part of the Trawl and Haul program, released into The Dalles Reservoir, and recaptured in Bonneville Reservoir in 1999.

Appendix Table A-3. Summary of white sturgeon marked in John Day Reservoir and recaptured within John Day and in other reservoirs.

		Released in John Day				
		1989	1990	1991	1996	2001
	Number Marked	21	516	85	4,111	3,757
Recaptured in McNary (upstream reservoir)	none to date					
Recaptured in John Day	1989		--	--	--	--
	1990	3	35	--	--	--
	1991		29		--	--
	1992		7	1	--	--
	1993	1	2		--	--
	1994		4	1	--	--
	1995		2	1	--	--
	1996	2	38	12	238	--
	1997			1	126	--
	1998					--
	1999					--
	2001		3	1	621	637
Recaptured in The Dalles	1989		--	--	--	
	1990			--	--	
	1991	1	1		--	
	1992				--	
	1993		1		--	
	1994		3		--	
	1995				--	
	1996					
	1997		7		9	
	1998					
	1999					
Recaptured in Bonneville	1989		--	--	--	
	1990			--	--	
	1991		1		--	
	1992				--	
	1993				--	
	1994				--	
	1995				--	
	1996					
	1997					
	1998					
	1999				3	

Appendix Table A-4. Summary of white sturgeon tagged in McNary Reservoir and recaptured within McNary and in other reservoirs.

		Released in McNary	
		1993	1995
Number marked		156	787
Recaptured in McNary	1993	6	--
	1994	4	--
	1995	7	13
	1996	2	10
	1997	3	7
Recaptured in John Day	1993	2	--
	1994	1	--
	1995		
	1996		2
	1997		1
	2001	1	3
Recaptured in The Dalles	1993		--
	1994		--
	1995		
	1996		
	1997	2	
Recaptured in Bonneville	none to date		

Appendix Table A-5. Species composition of bycatch from Trawl and Haul sampling, October – November 2001.

	Date															
Species	10/17	10/18	10/19	10/23	10/24	10/25	10/26	10/30	10/31	11/1	11/2	11/6	11/7	11/8	11/9	Species Total
American shad	41	8	9	7	5	15	14	24	48	169	91	43	199	532	393	1,598
Brown bullhead							1									1
Chiselmouth chub							2									2
Unidentified cottid	3	14	11	6	17	11	28	43	13	8	2	27	19	15	5	222
Crayfish					1			1		1						3
Leopard dace		12	13	5			5	8	4	2	5		6	2		62
Largescale sucker		11	14	55	22	24	103	108	78	49	23	75	143	58	66	829
Mountain whitefish										1						1
N. pikeminnow	3	5	6	13		15	43	25	19	26	30	28	85	38	34	370
Peamouth chub	37	29	17	15	3	61	109	148	67	141	108	89	138	160	145	1,267
Redside shiner			1		1	1			1					2		6
Sandroller	4	1	3	1	20	7	44	67	23	36	12	32	54	49	31	384
Starry flounder	2	6	4		2		2	6	1	32		1	1	2		59
Walleye				1												1
White crappie													1			1
Yellow Perch								1								1
Season Total	90	86	78	103	71	134	351	431	254	465	271	295	646	860	674	4,809

Appendix Table A-6. Bycatch from Young-of-Year index sampling, October – November 2001.

	Reservoir																			
	The Dalles				Little Goose				Ice Harbor				John Day			McNary				
	Disposition				Disposition				Disposition				Disposition			Disposition				Total
	1	2	3	All	1	2	3	All	1	2	3	All	1	3	All	1	2	3	All	
American shad	2		96	98	1		16	17	1		15	16	2	8	10	1		1	2	143
Bullhead					2			2												2
Bridgelip sucker	8		1	9	6		6	12	20		15	35	12	4	16	2		9	11	83
Channel catfish	4			4	580		144	724	614		47	661	105	6	111	218		40	258	1,758
Chinook					19		12	31												31
Chiselmouth chub	5		3	8	25		31	56	24		12	36	5	3	8	18		30	48	156
Common carp										2		2	1		1	1			1	4
Crappie					4		8	12	12		18	30								42
Largescale sucker	10		5	15	95		41	136	21		3	24	7	4	11	5		16	21	207
N. pikeminnow		39	28	67		484	242	726		98	68	166		33	33		6	52	58	1,050
Peamouth chub	18		47	65	126		338	464	154		722	876	1	11	12	3		17	20	1,437
Pumpkinseed									1			1								1
Sculpin spp.	1			1									5		5	1		1	2	8
Smallmouth bass									2			2	1		1					3
Steelhead					1		4	5	1			1						1	1	7
Walleye	20		11	31									2	4	6			1	1	38
Whitefish					1		4	5					1	2	3					8
Yellow perch	7		3	10	5		16	21	26		25	51	193	177	370	70		360	430	882
All species	75	39	194	308	865	484	862	2,211	876	100	925	1,901	335	252	587	319	6	528	853	5,860

Diposition: 1 = alive and released, 2 = sacrificed, 3 = dead or dying at capture.

APPENDIX B

GROWTH RATES OF RECAPTURED WHITE STURGEON IN JOHN DAY RESERVOIR

INTRODUCTION

Typically white sturgeon growth rates have been based on ages interpreted from pectoral fin spines and fit to a Von Bertalanffy growth relationship:

$$L_x = L_\infty(1 - e^{(-k(x - t_0))})$$

where: L_x.= length at age x

k = the growth coefficient

t_0 = the theoretical age of a fish with length 0

and x = the age of the fish

However age estimates from of white sturgeon Columbia River reservoirs are neither accurate nor precise and underestimate the true age (Rien and Beamesderfer 1994). Tagging efforts through the years have resulted in a substantial data base of recapture information for fish that were at large from one to several years. Fish in this evaluation were tagged with external spaghetti tags and/or passive integrated transponder (PIT) tags.

The objective of this exercise is to examine recapture data to provide an independent description of growth rate.

METHODS

Recapture records were obtained from data collected in John Day Reservoir in 1990, 1996, and 2001. From recapture records of fish at large one or more years, we determined length at marking and recapture, years at large (days at large / 365.25 d/yr), growth (ΔL = length at recapture – length at marking), and annual growth increment (AGI = ΔL / years at large). We also summarized data for fish that started in, or grew into the legal slot limit, 110-137 cm fork length (FL).

We attempted to derive k and L_∞ using two techniques (t_0 cannot be estimated from recapture data alone). We used non-linear regression (PROC NLIN; SAS 1990a) to describe a growth relationship based on the rearrangement of the Von Bertalanffy equation (Fabens 1965):

$$\Delta L=(L_{\infty}-L_t)(1-e^{-k\Delta t})$$

where Δt = period at large

We used linear regression (Proc REG, SAS 1990a) of AGI on average FL while at large (L_{avg}) to derive L_{∞} from the x-intercept and k from the slope (slope = $e^{-k\ -1}$) (Gulland 1983).

For visual comparison of the alternative growth rate estimates, we plotted predicted growth based on our 2001 Von Bertalanffy growth relationship (**see main body of this report**) and AGI from recapture data versus FL.

The foregoing analyses prompted us to look for significant differences in AGI among length groups. We grouped fish into FL size categories corresponding to total length increments of interest to fisheries managers: <70 cm FL (<30 inches TL) , 70- 82 cm FL (30-36 inches TL), 82-109 cm FL (36-48 inches TL), 110-137 cm FL (48-60 inches TL – the legal slot size), and >137 cm FL (>60 inches TL). We used analysis of variance to compare AGI among size categories (PROC GLM; SAS 1990b).

We also estimated mean relative weight (W_r; Beamesderfer 1993) among FL size categories to examine a potential basis for growth rate differences. Relative weight was estimated for 851 white sturgeon (70-244 cm FL) captured in John Day Reservoir in 1996 and 2001. We used analysis of variance to compare W_r among size categories (PROC GLM; SAS 1990b).

RESULTS

The 525 white sturgeon in this analysis ranged from 61-210 cm FL at first capture and from 63-230 cm at recapture. AGI for these fish ranged from -1.8 to 9.2 cm/yr and averaged of 2.5 cm/yr (Figure B-1). Fish were at large an average of 4.9 years (1.0 to 11.2 years) and they grew -2.0 to 50 cm while at large. Among these were 101 fish that fell within the legal slot limit for some period while at large (fish that were 110-137 cm at marking or recapture and fish that were <110 cm at marking and >137 cm at recapture). The average AGI for these fish was 4.7 cm per year (Figure B-1). This subgroup of fish was at large 1 - 10 years and grew 5 - 49 cm.

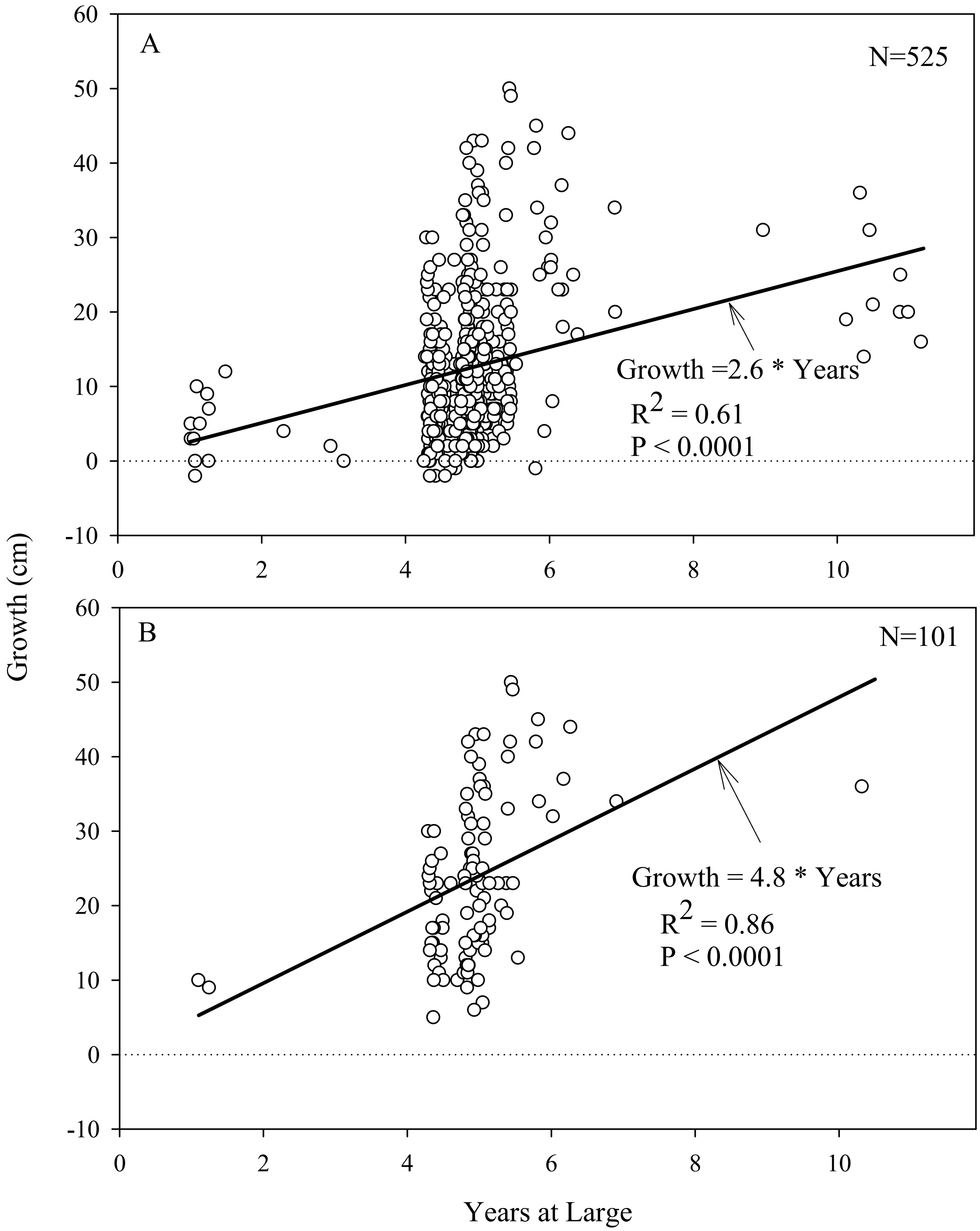

Figure B-1. Growth (change in FL) for white sturgeon recaptured after being at large at least one year in John Day Reservoir, 1990-2001: A) includes fish of all lengths; B) only includes fish that were 110 – 137 cm FL (legal slot) during at least part of the period at large.

Non-linear regression of ΔL on Δt failed to converge. Regression of AGI on L_{avg} described a line with a positive slope, which does not allow us to interpret k and L_{∞} (Figure B-2).

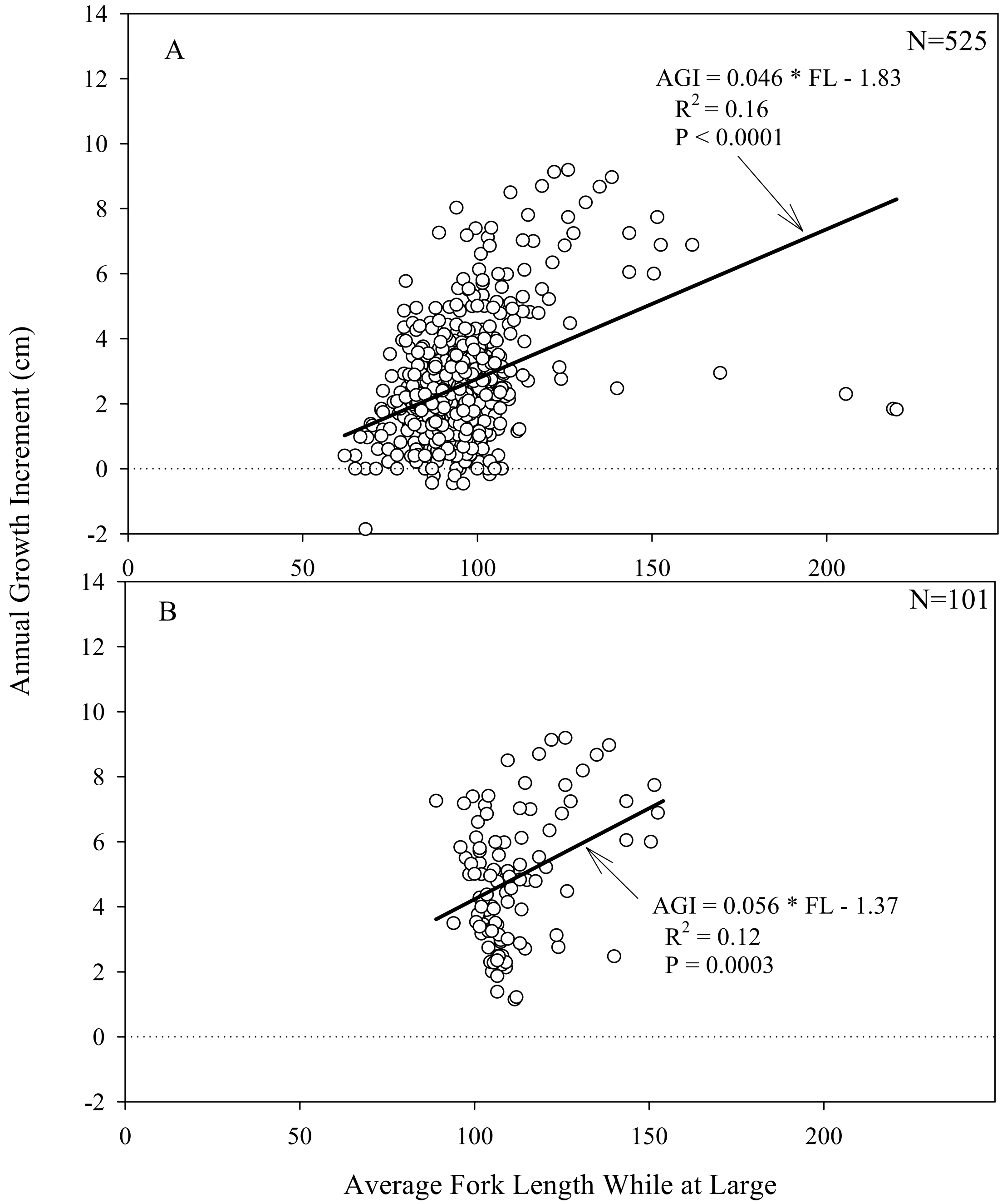

Figure B-2. Annual growth rate for white sturgeon recaptured after being at large at least one year in John Day Reservoir, 1990-2001: A) includes fish of all lengths; B) only includes fish that were 110 – 137 cm FL (legal slot) during at least part of the period at large.

Analysis of AGI among length groups showed mean AGI ranged from 0.3 cm/year for the eight fish in the smallest size category (<70 cm FL) to 5.6 cm/year for 29 fish with average lengths while at large between 110-137 cm FL (Figure B-3). Fish in small size categories grew at significantly slower rates than fish in larger size categories (df=4, F=41.32, P<0.0001).

Mean W_r ranged from 96 to 101 among four FL categories (Figure B-4). Analysis of variance identified significant differences in relative weight between fish 82-109 cm FL and those 110-137 cm FL, and between fish 110-137 cm FL and those >137 cm FL (df=3, F=6.07, P=0.0004).

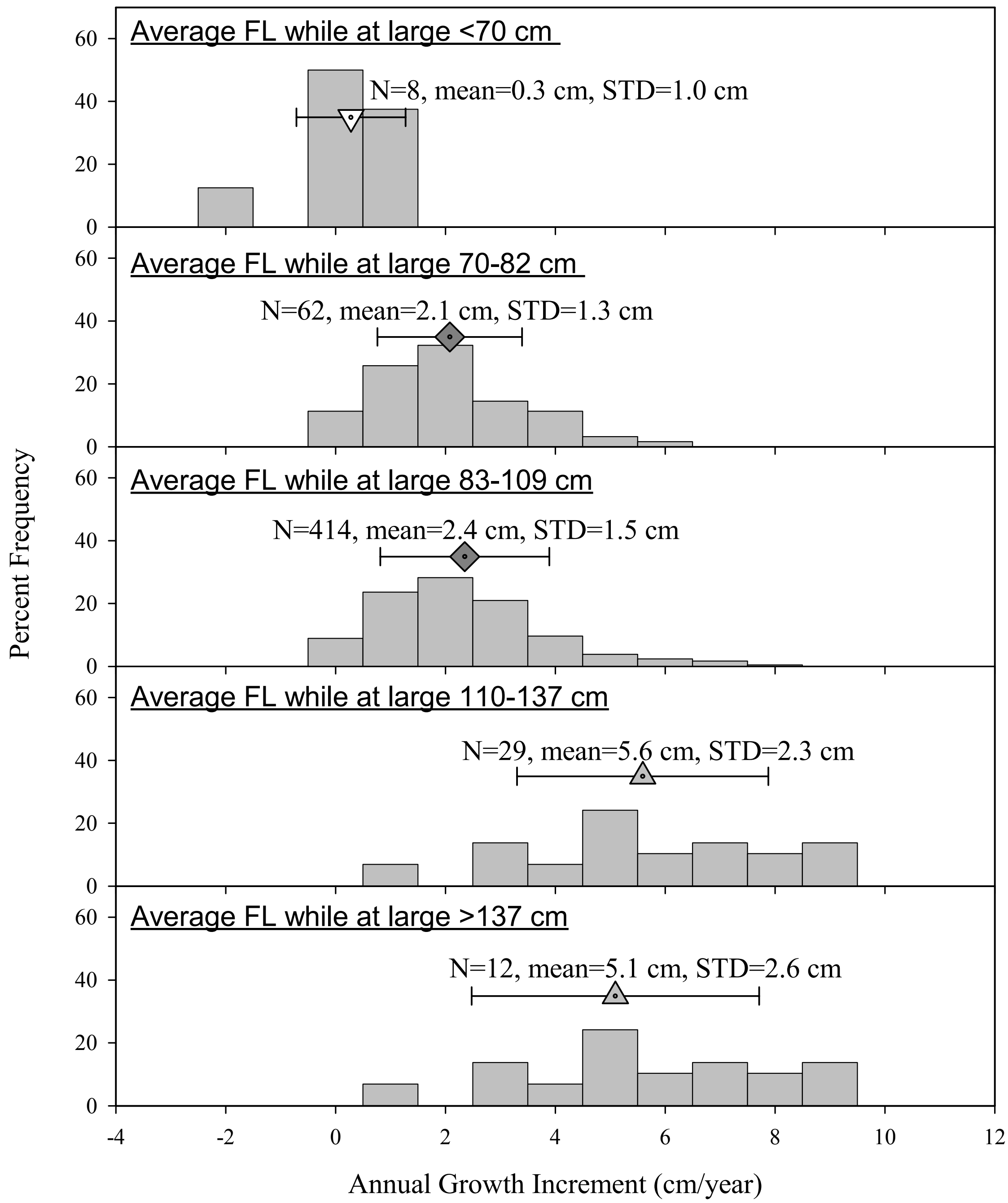

Figure B-3. Frequency distributions of annual growth increment (AGI) for white sturgeon in John Day Reservoir grouped by mean FL while at large. Fish were at large 1-11 years. Symbols and error bars represent the mean and STD for that group. Groups sharing the same symbol had AGIs that were not significantly different (P>0.95).

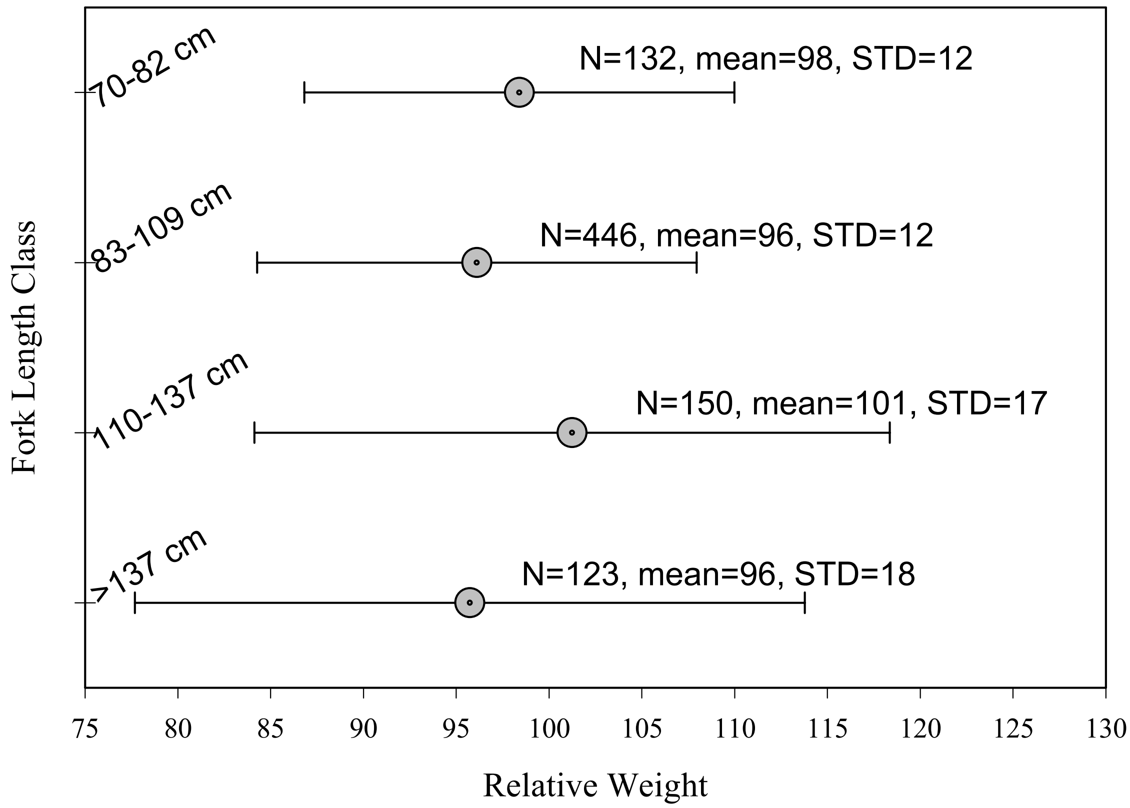

Figure B-4. Relative weight for white sturgeon captured in John Day Reservoir, 1996 and 2001, by fork-length class. Symbols and error bars represent the mean and STD for that group. Analysis of variance identified significant differences in relative weight between fish 83-109 cm and fish 110-137 cm FL, and between fish 110-137 cm and fish >137 cm FL ($P<0.05$).

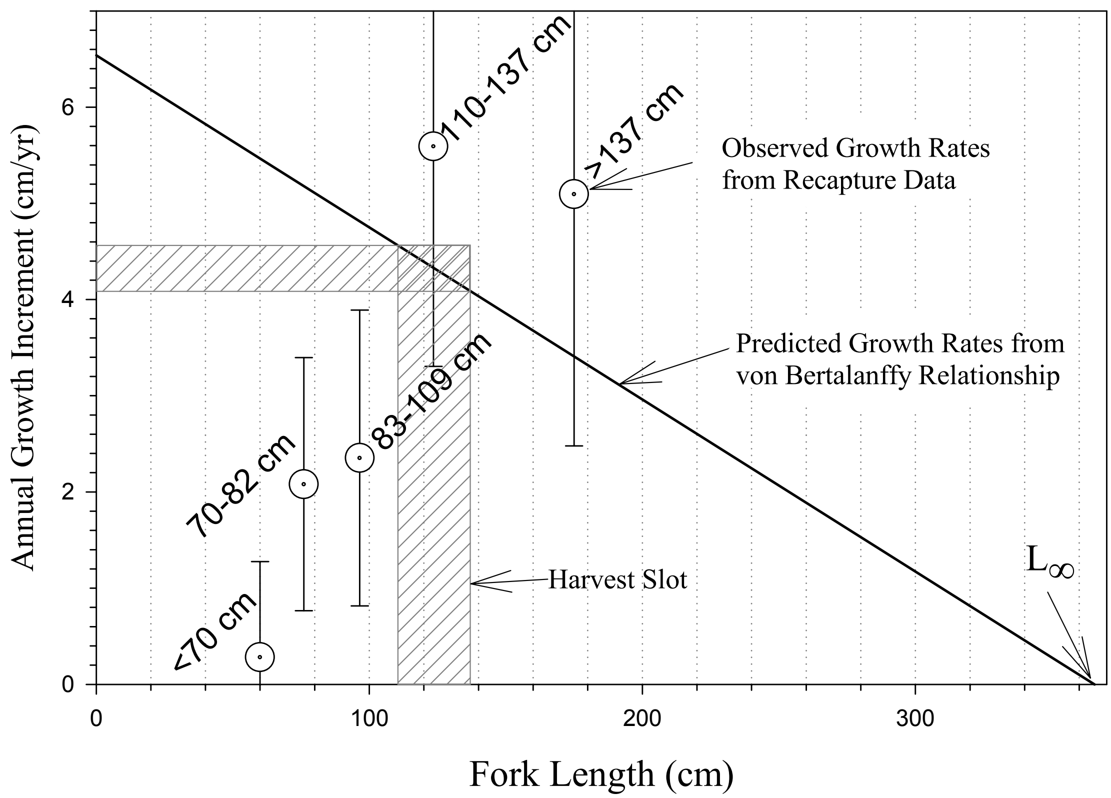

Figure B-5. Annual growth increments versus FL estimated from recapture data for various length increments (error bars associated with symbols represent 1 STD) and predicted by Von Bertalanffy regression (**see main body of this report**; t_0 = -2.4, k = 0.018, and L_∞ = 365.6).

DISCUSSION

This exercise has renewed our appreciation for variability in individual growth rates in white sturgeon and led us to explore alternative models for projecting fish growth. Factors that may control growth in fish include temperature, dissolved oxygen, ammonia, salinity, competition, food availability, age and maturity, photoperiod (Moyle and Cech 1988), and environmental contaminants (Foster et al. 2001). We suspect that our observation of increasing growth rate with increasing size is an artifact of size-selective gear vulnerability, variability in individual growth among years, and environmental factors influencing growth rate.

Gear vulnerability bias has been described for setlines. While this gear captures a broader size range of fish than either angling or gill nets (Elliott and Beamesderfer 1990), the smallest and largest white sturgeon are less vulnerable to capture than fish 110-166 cm (Beamesderfer et al. 1995). Thus, our data set under-represents small and large fish. The lack of large fish in our sample is particularly problematic as these fish would help us identify the negative correlation between growth rate and size (which must exist) and derive an alternative estimate for L_{∞}. Within the relatively narrow size range of fish in our sample, variation in individual growth rate seems to mask the logical relationship of reduced growth rate with increasing size. The several instances of negative growth among recaptures led us to consider that measurement error may also contribute to variance in our sample. However we have no reason to suspect there is a bias in these measurements. A fish is equally likely to be measured too short or too long. Stress of handling and tagging may reduce growth rate (Schreck 1993), and all of the fish in this sample had been captured and tagged. However, fish were at large an average of 4.9 years and this long time period should ameliorate relative growth rate reductions.

Environmental factors may be affecting growth rate in John Day Reservoir. Significant differences in relative weight among length classes of white sturgeon lead us to speculate that available prey may limit growth of white sturgeon until they are large enough to switch to a different food source. A proposed investigation of prey availability and distribution would help us determine the merit of this explanation (Parsley 2002). Organochlorine pollutants have been suggested as potential agents affecting growth and condition of white sturgeon in Bonneville Reservoir (Foster et al. 2001). To date, white sturgeon in John Day Reservoir have not been extensively tested for these toxins. Density-dependent factors have been implicated for observed poor condition and growth of white sturgeon in Bonneville Reservoir (Beamesderfer et al. 1995, Kern et al. 2001). In John Day Reservoir density of white sturgeon is much lower than in The Dalles or Bonneville reservoirs, and density of white sturgeon >83 cm is far lower than that for smaller fish (**see main body of this report**), so it seems unlikely that density alone is causing reduced growth rates. Perhaps several factors are at play and interacting to influence growth rate in John Day Reservoir.

In 2001, we estimated the parameters of a Von Bertalanffy growth relationship to be $t_0 = -2.4$, $k = 0.018$, and $L_{\infty} = 365.6$ (**see main body of this report**). Observed growth rates from recapture data are dramatically different from those estimated from length-at-age data. Juvenile fish growth is less than half of that predicted by our Von Bertalanffy regression, and fish of harvestable size and larger are growing somewhat faster than we predicted.

In a closed population, changes in abundance are the result of recruitment and survival rates. Sustainable fishery management requires an understanding of growth rates to optimize yield in commercial harvest and provide desirable-sized fish for recreational fisheries. In John Day, The Dalles, and Bonneville reservoirs white sturgeon management and harvest guidelines are based on three key population parameters: 1) a size-structured abundance estimate completed every three to five years for each reservoir, 2) an estimate of length-at-age based on aging of pectoral fin spines, and 3) age-specific natural mortality rates. Age interpretations and derived growth rates directly affect current harvest management, and overestimates of growth rate may result in harvest guidelines that are not sustainable. This exercise has led us to consider alternatives to the age-based population projections currently used to forecast the future size structure of the population. In Appendix C we describe preliminary efforts to forecast population size structure based on observed growth rather than age.

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APPENDIX C

DEVELOPMENT OF GROWTH-BASED MODELS FOR PREDICTING ABUNDANCE OF WHITE STURGEON POPULATIONS.

INTRODUCTION

Research into the population dynamics of white sturgeon in the Columbia River has been ongoing since approximately 1987. This ongoing research has provided continuous refinements of life history parameters of Columbia River white sturgeon populations. One such refinement has been an ever-expanding appreciation of growth variability in these fish. Harvest management of white sturgeon is based upon modeling of the population, and prediction of Optimum Sustainable Yield. Additionally, harvest of these fish is restricted by slot-length limits. Therefore, prediction of OSY is complicated by estimations of growth, i.e. fish growing into and out of the legal size limit over time. Past methods for modeling population growth have relied upon length-at-age estimates. Such estimates for white sturgeon are inherently inaccurate due to difficulties in accurately aging these fish.

Results from a 1996 stock assessment study conducted in John Day Reservoir estimated abundance of legal-sized (110-137 cm fork length) white sturgeon in the reservoir to be 4,045 fish. Using age-structured models based on the Von Bertalanffy growth function (Beamesderfer et al. 1995), this segment of the population, managed for OSY, was expected to grow to over 12,000 fish by 2001 (personal communication, Brad James, WDFW 2002). However, sampling conducted in 2001 yielded an abundance estimate of only 1,077 legal-sized sturgeon (**see main body of this report**).

Following stock assessment of John Day Reservoir in 2001, we discovered that previous estimates of length-at-age, and therefore growth rates as determined by the Von Bertalanffy function, may have seriously overestimated actual growth rates within this population (**see Appendix B**). Since approximately 1990, thousands of white sturgeon captured during stock assessment surveys have been marked with PIT tags. Population surveys have been conducted in John Day Reservoir in 1990, 1996, and 2001. Recaptures in 2001 of individual fish marked in 1996 and 1990, and past data from recaptures in 1996 of 1990-applied marks, have provided the first opportunity for large-scale verification of growth in these fish. We were able to calculate growth for 524 fish in 2001 that were at large for up to 11 years, providing a large data set. Preliminary estimates of mean growth rate of these fish indicated an average annual growth interval (AGI) of approximately 2.5 cm. Previous estimates of growth rates for sublegal-sized fish based on the Von Bertalanffy function averaged approximately 5.8 cm AGI (average AGI for fish 9 to 13 years old). Thus, harvest levels, based on the higher growth rate, may have been set above OSY. This point was reinforced by a drastic difference in estimated abundance of legal-sized fish in the John Day population between 1996 (4,045 fish) to 2001 (1,077 fish), shown in Figure C-1. Because work on this issue required multiple iterations of various methods of modeling the population, the **Methods** and **Results** sections below are structured to explain the two techniques we used separately.

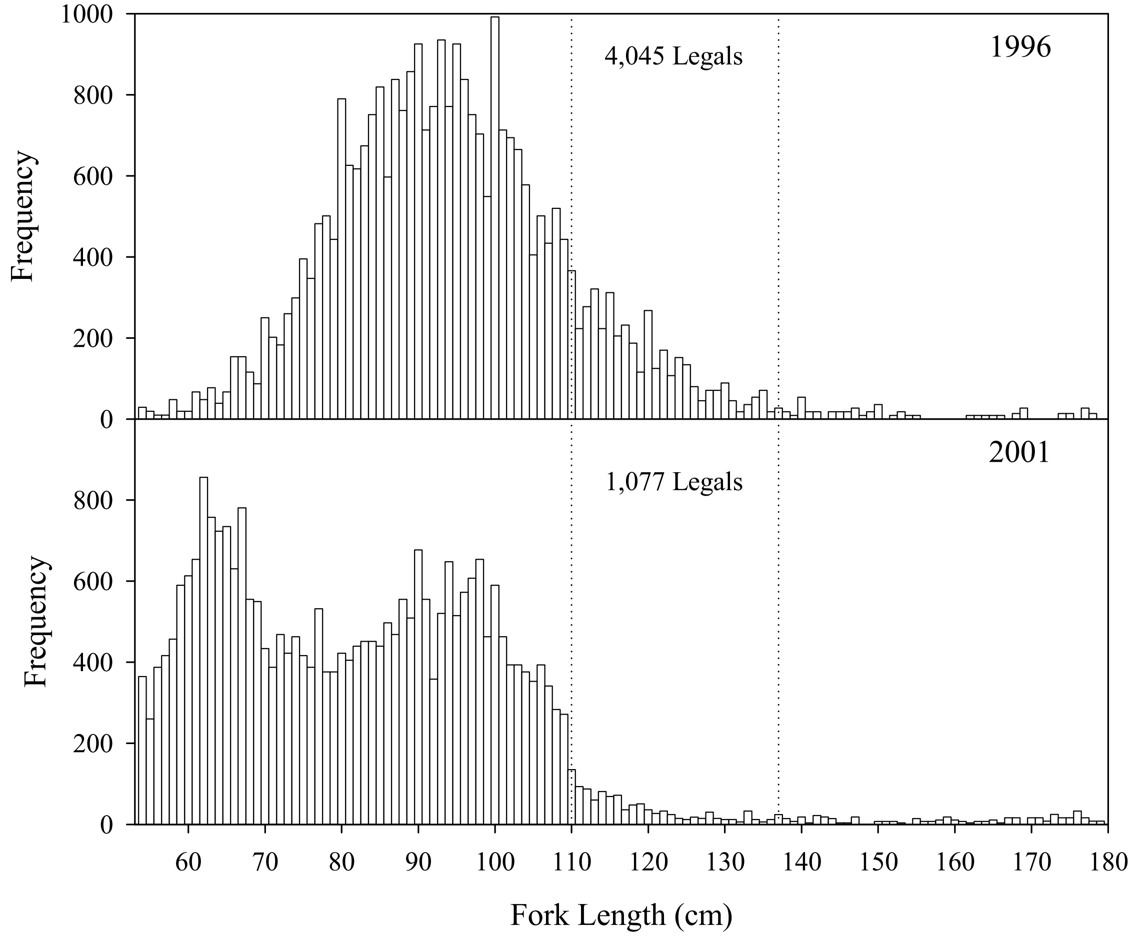

Figure C-1. Estimated abundances of white sturgeon in John Day Reservoir resulting from 1996 and 2001 stock assessment surveys. Dotted lines indicate harvestable size slot.

Modeling based on average growth rates

We first modeled the population using a simple spreadsheet and average annual growth rates specified by the Von Bertalanffy function (Beamesderfer et al. 1995) and by actual recoveries of PIT-tagged fish (**see Appendix B**).

Methods

We compared the length frequency distributions of predictions made by various growth rates to the length frequencies observed in the population in 1996 and 2001. We started with 1996 abundance estimates by fork length interval, subtracted natural annual mortality of 4.2% (Beamesderfer et al. 1995), and applied average growth rates of 5.8 and 2.5 cm per year, then removed harvest estimated by creel and commercial fishing surveys. We then compared the resulting predictions in 2001 between the two methods with estimated abundance of legal-sized fish based on population estimates conducted in 1996 and 2001.

Results

Beginning with 1996 abundance estimates and length distributions, we predicted the population of legal-sized fish to be 13,101 fish by 2001 and 12,680 fish by 2002 at a 5.8 cm per year AGI (Figure C-2). This is similar to the abundance predicted by the age-based model used to estimate OSY of 12,400 fish (personal communication, Brad James, WDFW 2002), but is more than ten times the 2001 population estimate of 1,077 legal-sized fish. When we performed the same exercise using an average growth rate of 2.5 cm per year, we predicted 4,105 legal-sized fish in 2001 and 4,265 by 2002. Both estimates were closer to the 2001 population estimate (Figure C-3).

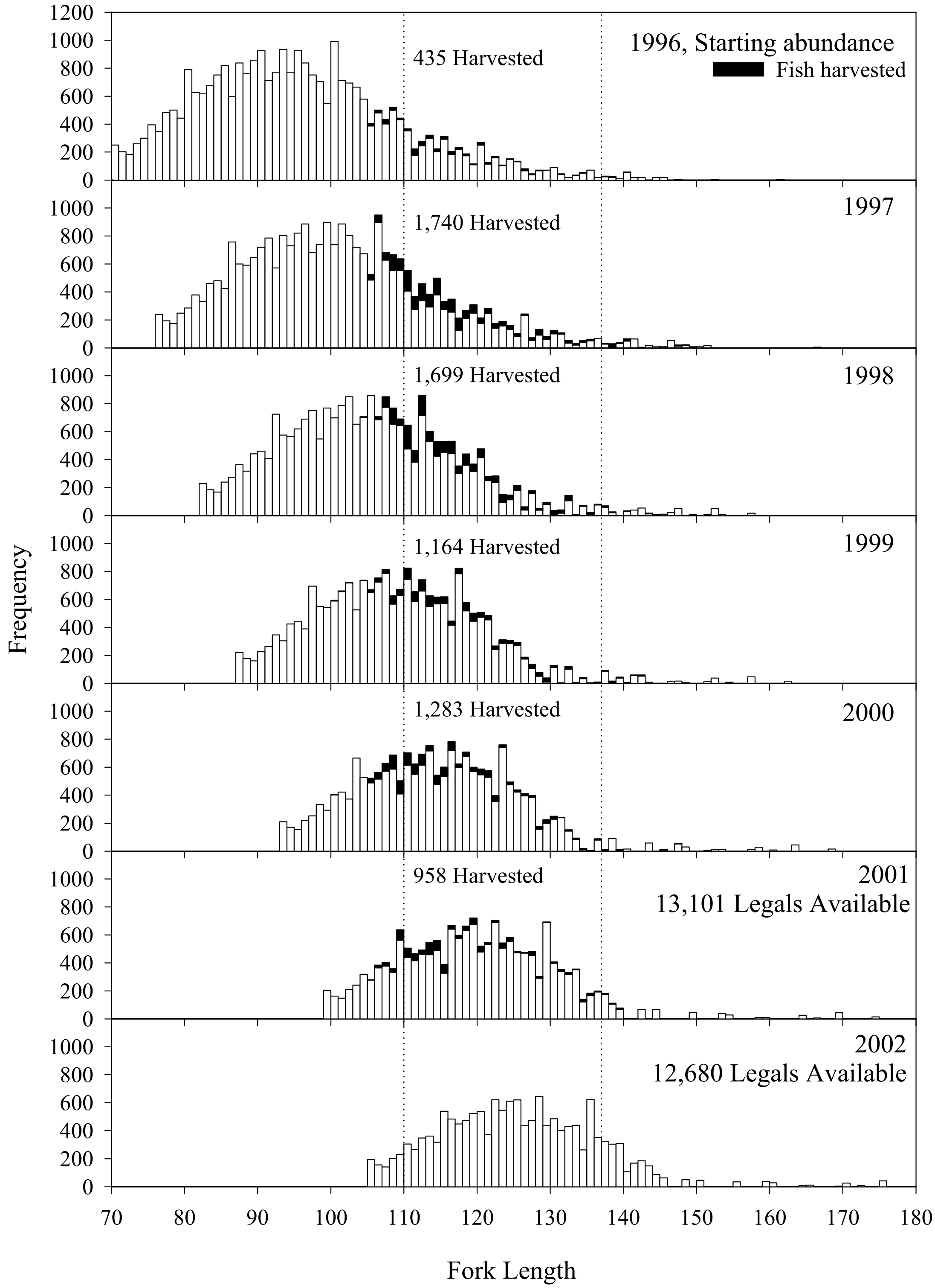

Figure C-2. Predicted John Day sturgeon abundance 1996-2002 based on a flat 5.8 cm AGI for all sizes, and starting with 1996 abundance estimates. Dotted lines indicate harvestable size slot.

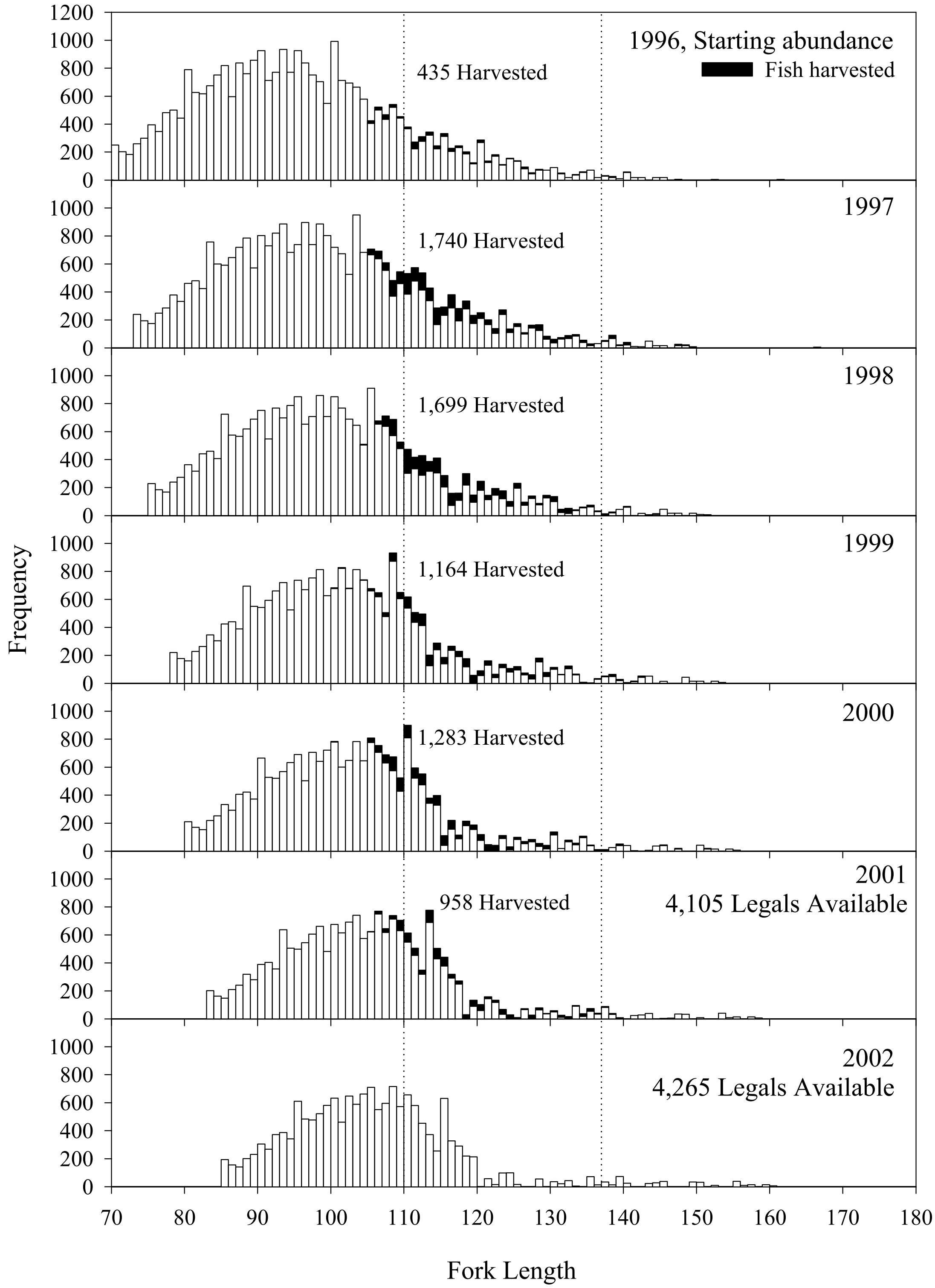

Figure C-3. Predicted John Day sturgeon abundance 1996-2002 based on a flat 2.5 cm AGI for all sizes, and starting with 1996 abundance estimates. Dotted lines indicate harvestable size slot.

Modeling based on a matrix of growth rates

Modeling of the sturgeon population between 1996 and 2001 based on an average growth rate of 2.5 cm per year more closely approximated abundance estimated by the 2001 population survey than did modeling based on the growth rate supplied by the Von Bertalanffy function (5.8 cm per year AGI). However, even this method predicted a higher number of legal-sized fish than the 2001 abundance estimate indicated. Application of a flat rate of growth to the entire population may not be appropriate due to differences in fish growth at different sizes and life stages.

Modeling of the sturgeon population based on aging data and determination of the Von Bertalanffy function is problematic due to difficulties in accurately aging these fish. One alternative to using age-based models is to develop a size-transition matrix based on actual growth rates. We developed our model based loosely on previous work conducted by Punt et al. (1997), Sullivan et al. (1990), and on methods presented in Haddon (2001). However, our model is probably more simplistic than any of these examples.

Methods

We separated recoveries of PIT-tagged fish with known growth over time into 1-cm fork length intervals based on size at tagging. We then calculated the frequency at which fish in each length interval grew at AGI's ranging from –1 cm per year up to 9 cm per year. This process resulted in the development of a spreadsheet matrix table 248 (53-300 cm FL) by 11 (-1-9 cm AGI) cells in size. With a matrix of this size (2,728 total cells), it was not possible to fill in all growth frequencies with actual data, or with adequate numbers of replicates of each frequency. Therefore, some level of interpolation was necessary. To complete the table, we first compared mean AGI of 10-cm size intervals using ANOVA (SAS PROC GLM). The results showed no significant differences between 10-cm size groups from 60-110 cm. Fish in the interval 111-130 cm were significantly different in mean AGI than almost every other interval (**see Appendix B**). Based on these results, we used three patterns of growth. Intervals between 53 and 110 cm were given the average frequency of AGI for the entire group of 53-110 cm fish. Similarly, intervals between 111-130 cm were given the average frequency for the entire group of 111-130 cm fish, and intervals 131 cm and over were given the average frequency for the entire group of 131+ cm fish.

The frequencies of AGI for each fork length interval were multiplied by estimated abundance of that fork length interval in the starting year (1996) and all values for that interval were summed to predict abundance of the interval in the following year. Successive years were calculated from the estimated abundance for the preceding year. For example, abundance of 100 cm fish in 1997 is predicted by adding to the starting 1996 abundance of fish in the 100 cm class the abundance of 101 cm fish that grew at –1 AGI, the abundance of 100 cm fish that grew at 0 AGI, the abundance of 99 cm fish that grew at 1 cm AGI, the abundance of 98 cm fish that grew at 2 cm AGI, and so on.

Abundances were reduced by known harvest and by estimated annual natural mortality of 4.2% (Beamesderfer et al. 1995).

Results

Predictions based on the matrix model of growth appeared to more closely approximate the estimated abundance of sturgeon from 2001 sampling data. Using the matrix model, we predicted a total of 18,444 fish above 53 cm fork length in 2001 based on starting abundances by fork length from the 1996 estimate (Figure C-4). We predicted 532 legal-sized fish by 2001 using this method. The actual abundance estimate from 2001 stock assessment sampling was 29,831 fish greater than 53-cm fork length, with 1,077 of these being in the legal size slot (Figure C-5).

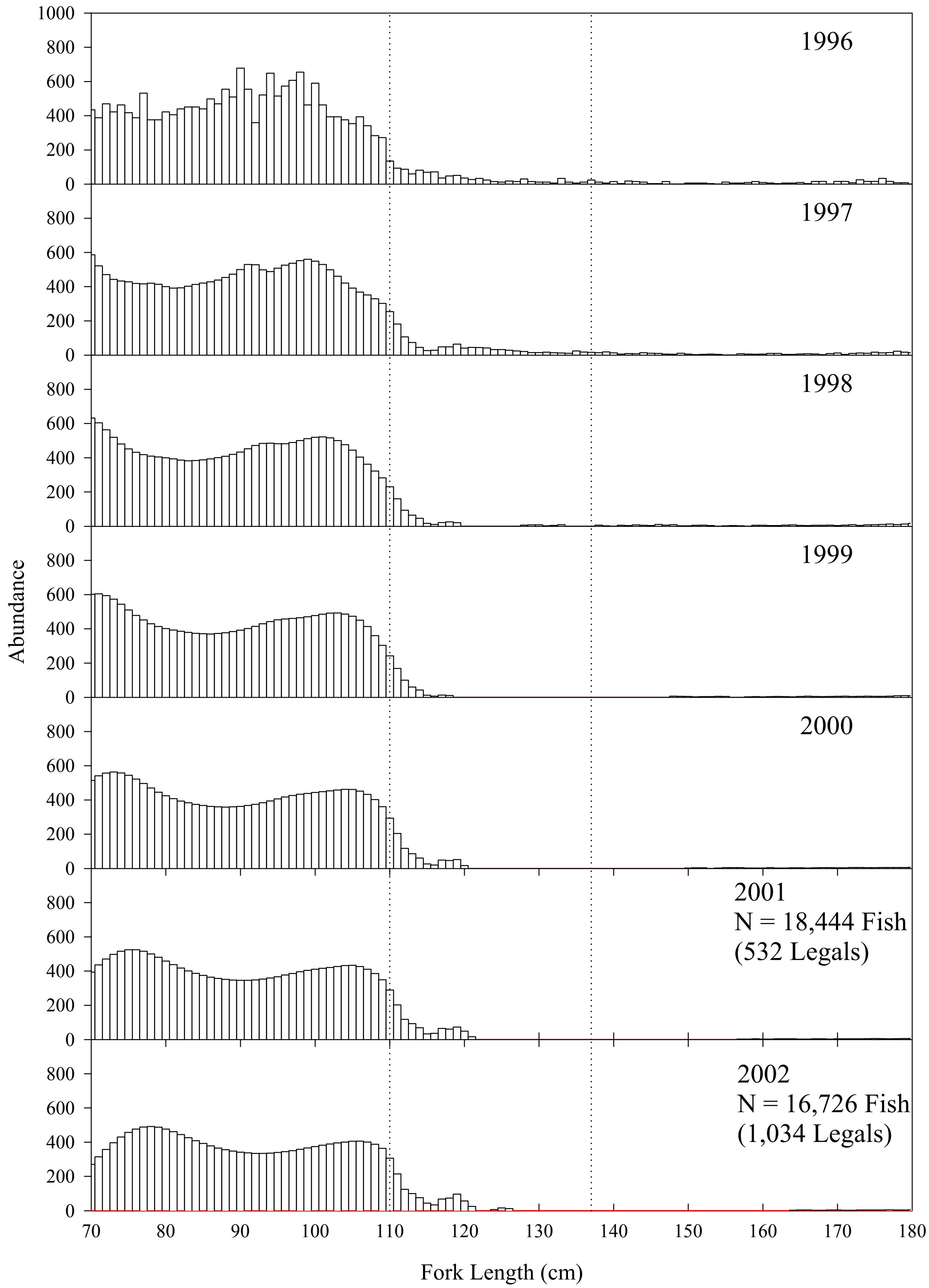

Figure C-4. Predicted John Day sturgeon abundance over time based on a matrix model of growth rates, and starting 1996 abundance estimate. Dotted lines indicate harvestable size slot.

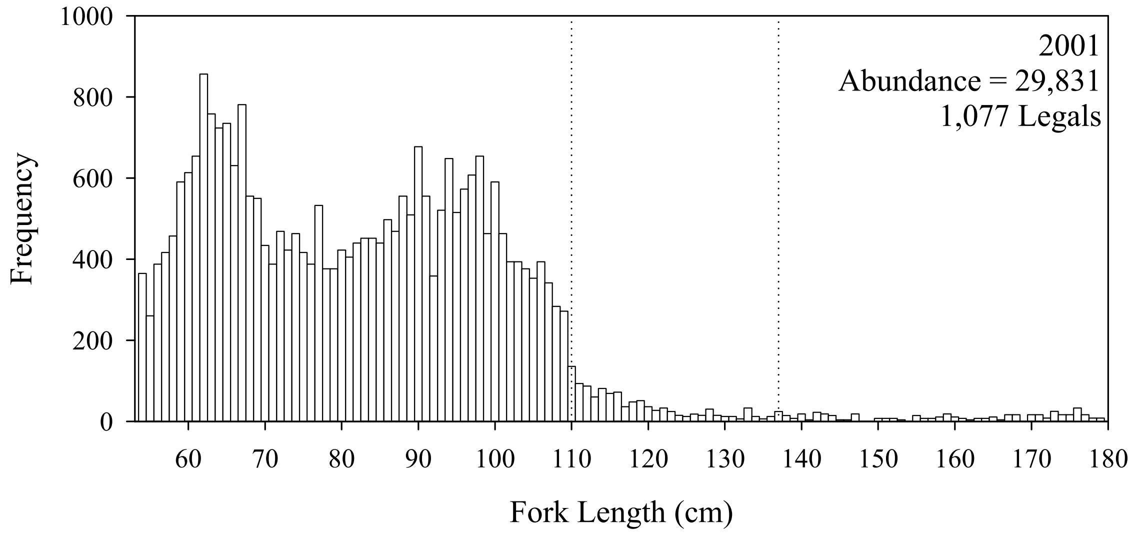

Figure C-5. Estimated abundance by length frequency from setline samples, John Day Reservoir 2001. Dotted lines indicate harvestable size slot.

DISCUSSION

The results of these modeling exercises showed potential for improving the accuracy of population predictions based on individual growth parameters in place of length-at-age data. Modeling based on average growth of all fish is less desirable because it assumes constant growth of all fish sizes, which is rarely the case. The results of our attempts to model the population using this method demonstrate the result of compounded errors over time. Beginning with 1996 abundances, we predicted abundances of legal-sized fish in 2001 that were 4-10 times greater than abundances determined by stock assessment in 2001.

Utilization of observed growth rates in a matrix more closely predicted observed 2001 abundance from estimated 1996 abundance, however, some problems exist with this method. One problem is in distributing AGI frequencies per fork length interval. Because of missing values, interpolation was necessary, but probably does not accurately reflect the true distribution. Experimentation with other methods, such as area-under-the-curve of the distributions, may provide a more useful method of dealing with missing values. Also, collection of more data in future surveys should provide more data points, reducing the number of missing values.

Another problem with the method is in distributing harvest by length frequency interval. Due to differing seasons of data collection, measuring, and methods used to estimate numbers of fish, predicted abundance of fish and estimated harvest sometimes conflict. In many of the fork length intervals, predicted abundance became negative over time, as estimates of harvest per fork length were sometimes greater than the predicted abundance of fish in the interval. We chose to look at the entire population estimate in sum, leaving negative values in the data set, rather than try to adjust for this aspect. However, it is obvious that real abundance in each interval cannot be less than zero. Any inaccuracies in the abundance and harvest estimates contribute to this problem. In future models, it may be necessary to combine fork length intervals into larger groups, such as 2 or 4 cm intervals, rather than the 1 cm used in this model. A balance between high resolution of length frequency distributions and the ability to adequately cope with inaccuracies in the estimates will have to be achieved.

Additionally, final abundance predicted by modeling is highly influenced by what step in the model harvest and mortalities are removed at. In other words, whether growth of the fish is calculated before or after losses. We assumed most of the natural mortality would occur during winter, and removed losses to natural mortality from total abundance before growth was calculated, where this was appropriate. Because most harvest of white sturgeon in John Day Reservoir occurs in the fall and winter of the year, and most growth occurs during the spring and summer (the same season stock assessment surveys are conducted), we chose to add growth to the population before subtracting losses to harvest.

While improvements to this modeling technique are certainly needed, it appears to provide a useful tool to explain growth of individuals, changes in population length-frequency distributions, and changes in harvestable abundance of white sturgeon. This may help modify population models used to calculate OSY for these populations to more accurately reflect harvestable levels, and prevent future over-harvest of legal-sized fish.

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WHITE STURGEON MITIGATION AND RESTORATION IN THE COLUMBIA AND SNAKE RIVERS UPSTREAM FROM BONNEVILLE DAM

ANNUAL PROGRESS REPORT

APRIL 2001 – MARCH 2002

Report B

Evaluate the success of developing and implementing a management plan to enhance production of white sturgeon in reservoirs between Bonneville and McNary dams

This report includes: Progress on implementing the fisheries management component of the white sturgeon management plan for the Columbia River between Bonneville and McNary dams including results of surveying 2001 sport and commercial white sturgeon fisheries.

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ABSTRACT

The Washington and Oregon Departments of Fish and Wildlife conducted a survey of the 2001 sport fishery on the Columbia River from Bonneville Dam upstream to McNary Dam (Zone 6 management unit) to estimate white sturgeon *Acipenser transmontanus* harvest. The sport fishery was closed to the retention of sturgeon when harvest was projected to reach respective harvest guidelines: The fishery closed on April 9 in The Dalles Reservoir, on August 13 in Bonneville Reservoir, and remained open throughout the year in John Day Reservoir. An estimated 1,426, 677, and 299 white-sturgeon were harvested in 2001 sport fisheries in Bonneville, The Dalles, and John Day reservoirs, respectively. This corresponds to 94%, 97%, and 53% of guidelines, respectively.

Treaty Indian commercial fishers landed 1,287 white sturgeon from Bonneville Reservoir, 1,258 from The Dalles Reservoir, and 646 from John Day Reservoir during gill net and setline fisheries. That corresponds to 99%, 114%, and 56% of guidelines, respectively. The Columbia River Inter-Tribal Fish Commission and the Yakama Indian Nation estimated an additional 476 fish were harvested from the three reservoirs (174 from Bonneville Reservoir, 276 from The Dalles Reservoir, and 26 from the John Day Reservoir) during 2001 subsistence fisheries.

Trends in catch, effort, season length, and size composition for the past five seasons, suggest that the legal-size populations, in Bonneville and John Day reservoirs, may have declined.

INTRODUCTION

This annual report describes progress made by the Washington Department of Fish and Wildlife (WDFW) on tasks contained in the Statement of Work for Bonneville Power Administration funded Project 198605000 titled: White Sturgeon Mitigation and Restoration in the Columbia and Snake Rivers Upstream from Bonneville Dam. The reporting period includes activities initiated in January 2001 but focuses on work conducted from 1 April 2001 through 31 March 2002.

The WDFW worked closely with staff from the Oregon Department of Fish and Wildlife (ODFW), the Columbia River Inter-Tribal Fisheries Commission (CRITFC), and Oregon State University (OSU) to address tasks related to two of the three multi-agency project objectives:

Objective 1) Develop, recommend, and implement mitigation actions that do not involve changes to hydro-system operation and configuration.

Objective 3) Monitor and evaluate actions to mitigate for lost white sturgeon production due to development, operation, and configuration of the hydro-system.

WDFW was contracted to work on Tasks 1.1, 1.2, 1.4, 1.5, 3.1 and 3.2 during the performance period. Task 1.1 involves planning and review of restoration and mitigation activities. Specifically, WDFW was tasked to assist ODFW in completing a comprehensive master plan that summarizes information and production goals for transplant and hatchery supplementation of white sturgeon. No direct work was done on the master plan; however, WDFW participated in the development of the draft White Sturgeon Program Summary (Ward et al., 2002), which identified adaptive management implications, benefits, and future needs for mitigation and restoration in the Columbia and Snake rivers. Furthermore, WDFW participated in the development of a draft comprehensive sturgeon management plan for Lake Roosevelt (Upper Columbia White Sturgeon Recovery Initiative, 2002). Task 1.2 involves the description of the genetic stock structure of white sturgeon in the Columbia River Basin. Blood and tissue samples were taken for the University of Idaho, by WDFW, ODFW, and CRITFC during stock assessment and young-of-year indexing efforts. Task 1.4 is related to developing artificial propagation techniques and protocols in preparation for supplementing impounded white sturgeon populations that lack recruitment. We worked with staff from the CRITFC and the Yakama Indian Nation (YIN) to capture broodstock white sturgeon for this task (see CRITFC Report E in this annual report). Task 1.5 involved regulating white sturgeon fisheries consistent with mitigation efforts designed to optimize harvest where population productivity and resilience have been reduced by hydro-system development and operations. We worked closely with staff from ODFW and CRITFC to 1) develop an annual management plan regulating January 2001 through December 2001 sport and Columbia River treaty commercial sturgeon fisheries at optimum sustainable exploitation rates, and 2) to census the sport fishery between Bonneville and McNary dams to estimate weekly and annual white sturgeon harvest to achieve management plan goals. Task 3.1 involved assessment of the productivity of the white sturgeon population in John Day Reservoir. WDFW worked closely with ODFW in a multiple pass mark-recapture study of the population (see Kern et al. 2002--Report A in this annual report). Task 3.2 involved describing annual variation in white sturgeon recruitment in impoundments. We worked with staff from ODFW and the YIN to sample impoundments between The Dalles and Priest Rapids dams on the Columbia River and downstream from Lower Granite Dam on the Snake River to index young-of-year white sturgeon (see Report A and Report C in this annual report). Another task involved working with sport-fishing guides to capture adult white sturgeon of breeding age and surgically examine them to collect paired gonad tissue and blood samples for OSU's work on developing methods to determine sex and stage of maturity of white sturgeon (see Report G in this annual report).

METHODS

Sport Fishery Census

The 2001 sport fishery census was conducted in Bonneville and The Dalles reservoirs, and that portion of the John Day Reservoir between McNary Dam and Crow Butte Island (Rkm 423; Figure 1), where fishing is concentrated. Methods were similar to those used since 1995 (James et al. 1996) and relied on angling pressure distribution data collected during surveys of Bonneville Reservoir from 1988 to 1990, The Dalles Reservoir from 1987 to 1989, and John Day Reservoir from 1989 to 1991 (Hale and James 1993). Sampling was conducted by WDFW and ODFW (WDFW having lead responsibility for this task).

The survey was limited to legal angling hours for sturgeon (one hour before sunrise to one hour after sunset). Therefore, estimates in this report of angling effort and harvest for steelhead *Oncorhynchus mykiss*, walleye *Stizostedion vitreum*, smallmouth bass *Micropterus dolomieui,* largemouth bass *Micropterus salmoides*, and northern pikeminnow *Ptychocheilus oregonensis*, which are harvested at night in Washington, are considered minimum estimates.

Angling effort (angler hours) was estimated by counting anglers within representative index areas and expanding those counts to the entire reservoir using an established relationship derived from 1987 to 1991 aerial counts of anglers within and outside of index areas (Hale and James, 1993). Indices of angler pressure were established at popular fishing locations and vantage points in each reservoir. These 39 index areas (17 in Bonneville Reservoir, 10 in The Dalles Reservoir, and 12 in John Day Reservoir) have remained essentially the same since 1995. During the 2000 field season, one index area was changed to account for a shift in Oregon bank angler effort within the Bonneville Reservoir (James et al., 2001). Counts were made of all bank anglers and sport fishing boats within each index area. Average numbers of anglers per boat were determined from angler interviews. Angling pressure within index areas was counted once a day between 1000 and 1300 hours. The proportion of the day's total angling effort represented by the count was calculated from average daily angling pressure distributions derived from prior years' data when systematic counts were made throughout the day. Index to non-index pressure distribution patterns were obtained from prior aerial survey data (Hale and James, 1993).

Harvest estimates for boat anglers were calculated by multiplying the observed catch per hour for boat anglers within a reservoir subsection by the total estimated effort for boat anglers for that subsection. White sturgeon harvest by bank anglers was calculated in a different manner. The one fish daily bag limit, enacted in 1991 for The Dalles and John Day reservoirs and in April 1996 for Bonneville Reservoir, made it likely that some successful bank anglers left the river before we could interview them, thus biasing our estimate of harvest per hour of bank angling effort. Boat angler catch per hour of effort was not biased by the one fish daily bag limit since we only interviewed boat anglers after they had completed their trip. Therefore, we calculated reservoir specific ratios of boat angler harvest per unit effort (HPUE) vs. bank angler HPUE for years prior to one fish bag limits (1993-95 for Bonneville Reservoir, 1988-89 for The Dalles Reservoir, and 1989-90 for John Day Reservoir). The boat angler HPUE for 2001 was used to adjust the 2001 bank angling HPUE such that boat HPUE vs. bank HPUE matched the pre-one fish daily limit ratio. Harvest estimates were derived for each angling method (bank/boat), reservoir subsection, and weekend/weekday type to account for differential catch and sampling rates. Harvest and angling effort estimates were derived weekly.

Treaty Indian Commercial and Subsistence Harvest

Numbers of white sturgeon harvested in Zone 6 treaty Indian commercial fisheries were estimated from poundage reported on fish receiving tickets for each gear type. Poundage of white sturgeon was converted to numbers of fish by dividing by an average fish weight obtained during random biological sampling of treaty Indian commercial landings by field crews. Landings by reservoir were estimated from the catch area reported on fish receiving tickets. The legal size slot for treaty Indian commercial fisheries was 122-152 cm (48-60 in) total length (TL). CRITFC and YIN used interviews of treaty Indian fishers to estimate subsistence harvest of white sturgeon, in each reservoir.

RESULTS

Sport Fishery Census

Bonneville Reservoir

The 2001 retention season for white sturgeon in Bonneville Reservoir opened January 1 and was scheduled to run through August 31. State fishery managers closed the fishery to retention of white sturgeon on August 13, based on our projection that harvest would reach the guideline by that date.

Anglers fished an estimated 95,985 hours (18,037 trips) in Bonneville Reservoir from January 1 through August 12 (Table 1). Angling effort for sturgeon comprised 68% (12,195 trips) of the total estimated effort. The estimated number of angler trips by species targeted were as follows: 1,686 (9%) for anadromous salmonids, 172 (<1%) for American shad *Alosa sapidissima*, 341 (2%) for walleye, 1,276 (7%) for bass, 1,597 (9%) for northern pikeminnow, 684 (4%) for other resident fish, and 86 (<1%) for anglers participating in tournaments.

Anglers harvested an estimated 1,426 white sturgeon during 12,195 trips for sturgeon between January 1 and August 12, a 13% increase in harvest and 76% increase in angler trips from the 2000 retention period (Table 2). Managers announced their decision to close the fishery to retention approximately two weeks prior to the actual closing date to provide anglers adequate notice. Angling pressure and HPUE declined once the announcement was made and harvest ended at 6% below the guideline.

The fishery for white sturgeon encompassed the entire reservoir although most of the harvest occurred downstream of Hood River, Oregon (Rkm 271). Harvest per angler trip peaked in

February at 0.15 fish per trip and averaged 0.07 fish per trip for bank anglers and 0.17 fish per trip for boat anglers targeting sturgeon during the retention fishery (Table 3). The 2,513 sturgeon anglers interviewed accounted for 13% of the estimated bank effort (angler hours) and 16% of the estimated boat effort for sturgeon (Table 4).

Anglers released 13% of the legal-size catch from January 1 through August 12 (Table 4), due in part to the daily bag limit regulation which allowed retention of only one fish 107-152 cm (42 - 60 in) TL. The percentage of sub-legal (<107 cm TL; <42 in TL), legal (107-152 cm TL; 42-60 in TL; both kept and released), and oversize (>152 cm TL; >60 in TL) white sturgeon in the reported catch was 85%, 7%, and 8%, respectively (Table 4). The increase in the oversize catch portion (from <1% in 2000) may be due to guides offering sport fishers catch and release trips targeting large sturgeon. The length distribution of the sampled harvest is presented in Table 5. Harvest per trip of 95-138 cm FL (42-60 in TL) fish decreased from 2000 levels for both boat and bank anglers (Table 6).

The Dalles Reservoir

The 2001 retention season for white sturgeon in The Dalles Reservoir opened January 1 and was scheduled to close August 31. We began our survey on January 1 and continued sampling through April 8. State fishery managers closed the fishery to retention of white sturgeon on April 9 based on our projection that harvest would reach the guideline by that date. This significantly early closure is attributed to boat anglers discovering a large concentration of sturgeon in Preacher's Eddy (RKm 345).

Anglers fished an estimated 36,069 hours (5,431 trips) in The Dalles Reservoir from January 1 through April 8 (Table 1). Angling effort for white sturgeon comprised 73% (3,982 trips) of the total estimated effort. The number of angler trips estimated by target species were as follows: 461 (8%) for anadromous salmonids, 0 (0%) for American shad, 927 (17%) for walleye, 8 (< 1%) for bass, 11 (< 1%) for northern pikeminnow, 42 (1%) for other resident fish, and 0 (0%) for anglers participating in tournaments.

Anglers harvested an estimated 677 white sturgeon during 3,982 trips for sturgeon between January 1 and April 8 (Table 2). The primary sport fishery for white sturgeon extended from the John Day Dam tailrace downstream to Miller Island (Rkm 327). More white sturgeon anglers fished from the bank than from boats. The Harvest per trip (bank and boat combined) peaked in March at 0.24 fish per trip. Harvest per trip averaged 0.06 for bank anglers and 0.30 for boat anglers targeting sturgeon during the retention fishery (Table 3). The 1,193 white sturgeon anglers interviewed accounted for 18% of the estimated bank effort (angler hours) and 25% of the estimated boat effort for white sturgeon (Table 4).

The percentage of sub-legal (<122 cm TL; <48 in TL), legal (122-152 cm TL; 48-60 in TL), and oversize (>152 cm TL; >60 in TL) white sturgeon in the sampled catch was 82%, 14%, and 4%, respectively (Table 4). This distribution of catch by size is nearly the same as 2000. The length distribution of the sampled harvest is presented in Table 5. Bank anglers' harvest per trip, of 110-138 cm FL (48-60 in TL) fish, continued to decline for the third year.

Harvest per trip for boat anglers increased from the previous year to the highest recorded level since the survey began in 1987 (Table 6).

John Day Reservoir

We began our survey of the 2001 sport fishery in John Day Reservoir on January 1 and continued sampling through December 31. The harvest guideline was not attained and the retention fishery remained open year-round.

Anglers fished an estimated 166,776 hours (38,630 trips) in John Day Reservoir during 2001 (Table 1). Angling effort for white sturgeon comprised 39% (14,880 trips) of the total estimated effort. The number of angler trips estimated by target species were as follows: 6,296 (16%) for anadromous salmonids, 629 (2%) for American shad, 10,913 (28%) for walleye, 4,511 (12%) for bass, 271 (< 1%) for northern pikeminnow, 634 (2%) for other resident fish, and 496 (1%) for tournament anglers.

Anglers harvested an estimated 299 white sturgeon during 14,880 trips for sturgeon in 2001 (Table 2). Anglers concentrated their effort for sturgeon from McNary Dam downstream past Irrigon, Oregon (Rkm 449). Effort for white sturgeon was greatest in July (Table 3). Harvest per trip averaged 0.02 for bank anglers and 0.02 for boat anglers (Table 3). The 3,846 sturgeon anglers interviewed accounted for 17% of the estimated bank effort (angler hours) and 21% of the estimated boat effort for white sturgeon (Table 4).

The percentage sub-legal (<122 cm TL; <48 in TL), legal (122-152 cm TL, 48-60 in TL), and oversize (>152 cm TL, >60 in TL) white sturgeon in the reported catch was 86%, 3%, and 11%, respectively (Table 4). The length distribution of the sampled harvest is presented in Table 5. Harvest per trip of 110-138 cm FL (48-60 in TL) fish increased for bank anglers but decreased for boat anglers from 2000 levels (Table 6).

Treaty Indian Commercial and Subsistence Harvest

The 2001 treaty Indian commercial harvest estimates for Zone 6 were 1,287 white sturgeon from Bonneville Reservoir, 1,258 white sturgeon from The Dalles Reservoir, and 646 white sturgeon from John Day Reservoir (Table 7). More than half of the harvest was landed in the winter gill net fishery, with the rest of the harvest spread throughout the January, summer, and fall setline fisheries, and the sockeye gill net fishery (Joint Columbia River Management Staff, 2001). The treaty Indian Zone 6 subsistence white sturgeon harvest estimated by CRITFC and the Yakama Indian Nation was 476 fish (Table 7): 174 from Bonneville Reservoir; 276 from The Dalles Reservoir; and, 26 from John Day Reservoir.

DISCUSSION

Zone 6 Sturgeon Harvest Management

Bonneville Reservoir

The recreational harvest per unit effort (HPUE) has declined, since the 1,520 fish guideline began in 1997. Conversely, during these past 5 seasons, effort has increased. The patterns in effort and HPUE are nearly the same for both bank and boat anglers. The proportion of effort attributed to each group has remained quite stable since 1988 (slightly favoring bank anglers). Since sport-fishing success is declining with increased numbers of angler trips, it would seem unlikely that the legal-size population abundance is increasing or staying the same.

If the legal-size population were declining, we would expect the harvest to be composed of a higher proportion of fish recruiting into the legal-size class. This appears to have occurred in the 2001 season, when most fish were harvested within the first 15 cm of the legal-size slot (64 % of the catch, versus 52% and 37% in The Dalles and John Day reservoirs, respectively).

Another indicator, that the legal-size population may have declined, is that the time to achieve the harvest guideline has doubled (from 3.5 months in 1997 to 7 months in 2001). This longer time to achieve harvest guideline, combined with the doubling of effort, supports the notion that anglers are having to fish twice as long to get a keeper, than they use to.

At the time of the last Bonneville Reservoir stock assessment (1999; Kern et al., 2001), stock abundance estimates supported the high harvest guideline. Recent harvest data suggests that the legal-size population in Bonneville Reservoir is declining, and that recruitment into the fishery is slower than previously thought. This needs to be verified. The 2003 stock assessment will give us an adjusted estimate of the legal-size population abundance, new estimates of growth rate, and a better idea of whether the harvest guideline should be adjusted or not.

The Dalles Reservoir

The boat angler HPUE has increased, since the guideline increased significantly in 1998. During these past four seasons, boat angler effort has also increased. On the other hand, bank angler effort and HPUE have declined. There has been a steady turn toward boat angling during this time, and in 2001 bank angling was only slightly preferred over boat angling. The conflicting trends, and movement between fishing methods, complicate our efforts to assess the status of the stock from catch and effort data.

At the time of the last The Dalles Reservoir stock assessment (1997; North et al., 1999), stock abundance estimates supported a tripling of the harvest guideline. Rapid achievements of that higher guideline, and steady age composition in the catch, indicate that the fishery is being managed correctly.

John Day Reservoir

The recreational harvest per unit effort (HPUE) has declined, since the 560 fish guideline began in 1997. Conversely, during these past 5 seasons, effort has increased. The patterns in effort and HPUE are similar between bank and boat anglers (the exceptions being that bank angling effort has increased slower than boat angling effort, and in 2001 the bank anglers saw some increase in HPUE from the previous year). The proportion of effort attributed to each group has remained quite stable since 1989 (slightly favoring boat anglers). Since sport-fishing success is declining with increased numbers of angler trips, it would seem unlikely that the legal-size population abundance is increasing or staying the same. The 2001 stock assessment estimated a legal-size population abundance that is lower than what was estimated in 1996 (Report A). Our catch and effort data also suggest that there was a decline in the legal-size population.

The catch and harvest composition does not reflect the correct size structure demonstrated in the stock assessment (Report A). Sublegals only composed 10% of the catch in John Day, and oversize fish composed a high 12 % of the catch. Very few fish were harvested within the first 15 cm of the legal-size slot (37 % of the harvest, versus 64% and 52% in Bonneville and The Dalles reservoirs, respectively). It appears that anglers focused their fishing effort on catch and release of oversized fish, and subsequently retained larger legal-size fish.

It has taken almost all year to achieve the harvest guideline during these past 5 seasons. With each passing year, the harvest falls further from the guideline (with the 2001 annual harvest being almost half the guideline level). This longer time to achieve harvest guideline, combined with the doubling of effort, supports the notion that anglers are fishing longer to get a keeper, than they use to.

The lower legal-size population abundance estimate, the indications of poor recruitment into the fishery, and the increasing inability to achieve the 560 fish harvest, justify a reduction of the harvest guideline.

PLANS FOR NEXT YEAR

We will continue to monitor Zone 6 sport and treaty Indian commercial fisheries in 2002. We will work with ODFW, during the summer of 2002, to assess the status of the white sturgeon population in The Dalles Reservoir. Also, we will capture broodstock white sturgeon for CRITFC's aquaculture supplementation experiment. We will work with fishing guides to obtain breeding age adult white sturgeon, from which we can collect paired gonadal tissue, blood, urine, and mucus samples, to help OSU develop methods to determine sex and stage of maturity. We will conduct young-of-year white sturgeon recruitment indexing using small mesh gill nets in Little Goose and Ice Harbor reservoirs on the Snake River and in McNary, John Day, and The Dalles reservoirs on the Columbia River. These activities will be reported in next year's annual progress report.

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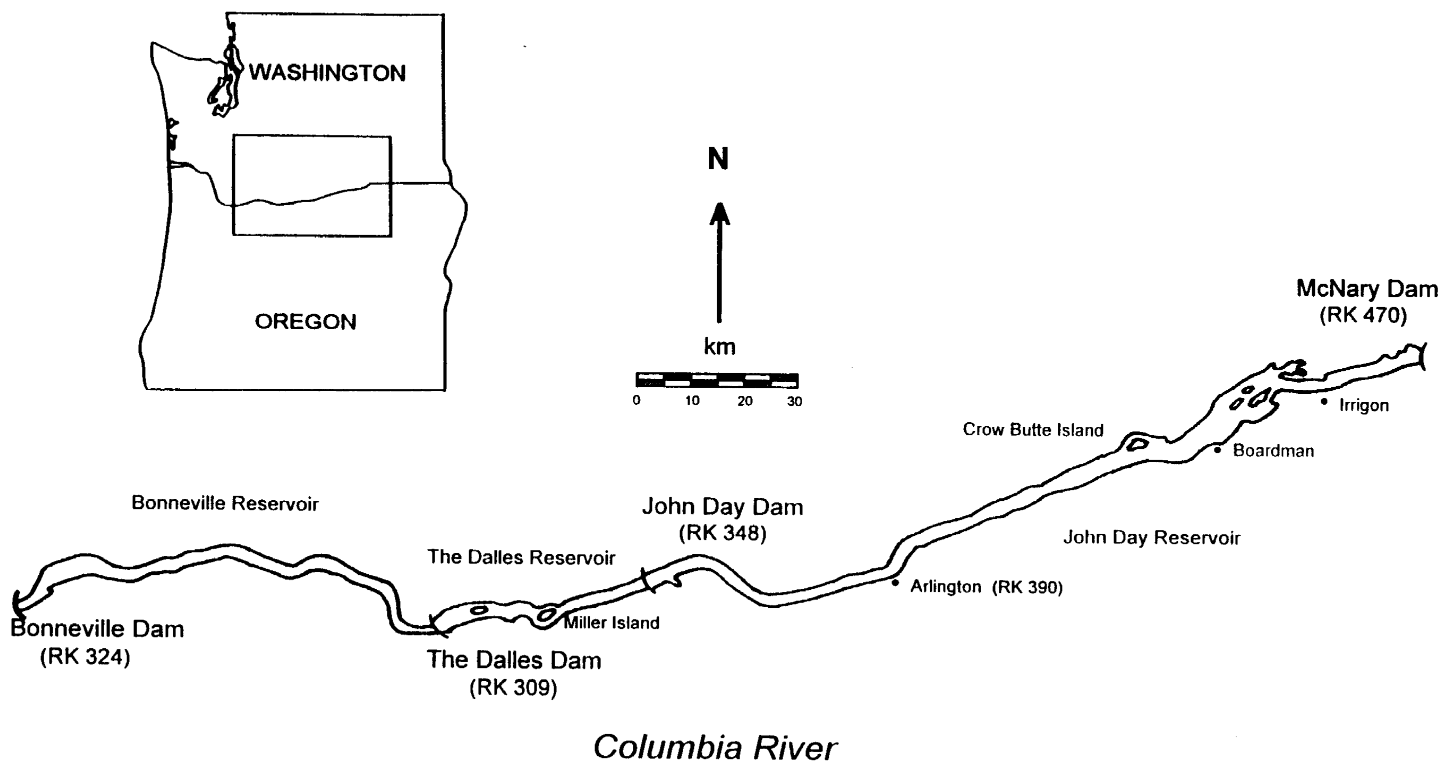

Figure 1. Location of the 2000 recreational fishery census on the Columbia River: Bonneville and The Dalles reservoirs and from Arlington upstream to McNary Dam on John Day Reservoir.

Table 1. Combined Washington and Oregon recreational fishery angling effort estimates for Bonneville Reservoir, January 1 through August 12, 2001; The Dalles Reservoir, January 1 through April 8, 2001; and John Day Reservoir, January 1 through December 31, 2001.

Species	Bonneville		The Dalles		John Day	
Method	Hours	Trips	Hours	Trips	Hours	Trips
Sturgeon						
Bank	36,460	6,867	17,168	2,124	33,145	5,939
Boat	31,519	5,328	10,667	1,858	49,904	8,941
Total	67,979	12,195	27,835	3,982	83,049	14,880
Salmonid						
Bank	8,299	1,033	764	114	3,252	3,374
Boat	2,627	653	1,726	347	1,560	2,922
Total	10,926	1,686	2,490	461	4,812	6,296
Shad						
Bank	227	132	0	0	587	172
Boat	98	40	0	0	1,780	457
Total	325	172	0	0	2,367	629
Walleye						
Bank	45	10	105	20	32	5
Boat	1,363	331	5,357	907	48,198	10,908
Total	1,408	341	5,462	927	48,230	10,913
Bass						
Bank	928	348	13	8	120	39
Boat	4,316	928	0	0	19,308	4,472
Total	5,244	1,276	13	8	19,428	4,511
Northern Pikeminnow						
Bank	3,945	861	42	11	174	18
Boat	3,313	736	0	0	1,640	253
Total	7,258	1,597	42	11	1,814	271
Other						
Bank	1,515	563	196	37	1,100	273
Boat	482	121	31	5	1,534	361
Total	1,997	684	227	42	2,634	634
Tournament						
Bank	0	0	0	0	0	0
Boat	848	86	0	0	4,442	496
Total	848	86	0	0	4,442	496
Combined Total						
Bank	51,419	9,814	18,288	2,314	38,410	9,820
Boat	44,566	8,223	17,781	3,117	128,366	28,810
Total	95,985	18,037	36,069	5,431	166,776	38,630

Table 2. Combined Washington and Oregon recreational fishery harvest, and catch and release estimates for Bonneville Reservoir, January 1 through August 12, 2001; The Dalles Reservoir, January 1 through April 8, 2001; and John Day Reservoir, January 1 through December 31, 2001.

Species	Bonneville	The Dalles	John Day
White sturgeon [a]			
Legals kept	1,426	677	299
Sub-legals released	21,005	4,387	7,258
Legals released	230	109	17
Oversize released	1,378	244	1,034
Total	24,039	5,417	8,608
Chinook salmon [b]			
Adults kept	0	0	417
Jacks kept	16	0	486
Total kept	16	0	903
Released	40	0	1,056
Coho salmon [c]			
Bank	0	0	80
Boat	0	0	64
Total	0	0	144
Steelhead [d]			
Kept	182	214	1,027
Released	338	49	1,108
American shad			
Kept	7	0	2,502
Released	7	0	99
Walleye			
Bank	39	101	2,336
Boat	637	59	5,139
Bass			
Bank	904	3	6,500
Boat	2,579	0	12,602
Northern pikeminnow kept	6,411	19	2,422
Other resident fish kept	0	0	861

[a] *White sturgeon seasons were closed to retention August 13 – December 31 in Bonneville Reservoir, and April 9 – December 31 in The Dalles Reservoir. John Day Reservoir remained open to retention year-round.*

[b] *Chinook seasons were closed to retention January 1 - July 31 in Bonneville Reservoir, and January 1 through May 5 and May 9 through July 31 in The Dalles and John Day reservoirs.*

[c] *Coho seasons were closed to retention January 1 - July 31.*

[d] *Steelhead season was closed to retention April 1 - June 15.*

Table 3. Estimates of recreational fishery angler trips for white sturgeon, white sturgeon harvest, and harvest per angler trip (HPUE) for Bonneville Reservoir, January 1 through August 12, 2001; The Dalles Reservoir, January 1 through April 8, 2001; and John Day Reservoir, January 1 through December 31, 2001.

Month	Bonneville			The Dalles			John Day		
Method	Trips	HPUE	Harvest	Trips	HPUE	Harvest	Trips	HPUE	Harvest
January									
Bank	865	0.04	34	325	0.02	6	234	0.00	0
Boat	924	0.18	169	236	0.17	39	140	0.00	0
Total	1,789	0.11	203	561	0.08	45	374	0.00	0
February									
Bank	1,293	0.07	86	493	0.02	11	423	0.00	0
Boat	963	0.27	263	497	0.27	135	258	0.00	0
Total	2,256	0.15	349	990	0.15	146	681	0.00	0
March									
Bank	1,130	0.09	98	960	0.09	88	310	0.00	0
Boat	970	0.11	106	1,016	0.37	377	728	0.00	0
Total	2,100	0.10	204	1,976	0.24	465	1,038	0.00	0
April									
Bank	792	0.07	52	346	0.05 [a]	17	558	0.00	2
Boat	390	0.17	68	109	0.04 [a]	4	850	0.01	10
Total	1,182	0.10	120	455	0.05 [a]	21	1,408	0.01	12
May									
Bank	773	0.08	65	---	---	---	656	0.01	4
Boat	452	0.13	58	---	---	---	970	0.02	19
Total	1,225	0.10	123	---	---	---	1,626	0.01	23
June									
Bank	499	0.13	67	---	---	---	636	0.02	10
Boat	1,066	0.14	153	---	---	---	1,434	0.02	33
Total	1,565	0.14	220	---	---	---	2,070	0.02	43
July									
Bank	1,211	0.08	97	---	---	---	1,048	0.03	33
Boat	293	0.30	89	---	---	---	2,043	0.03	52
Total	1,504	0.12	186	---	---	---	3,091	0.03	85
August									
Bank	304	0.00 [a]	0	---	---	---	529	0.01	7
Boat	270	0.08 [a]	21	---	---	---	1,130	0.03	31
Total	574	0.04 [a]	21	---	---	---	1,659	0.02	38
September									
Bank	---	---	---	---	---	---	284	0.03	8
Boat	---	---	---	---	---	---	360	0.00	0
Total	---	---	---	---	---	---	644	0.01	8

continued

Table 3. Continued.

Month Method	Bonneville			The Dalles			John Day		
	Trips	HPUE	Harvest	Trips	HPUE	Harvest	Trips	HPUE	Harvest
October									
Bank	---	---	---	---	---	---	607	0.01	9
Boat	---	---	---	---	---	---	821	0.01	8
Total	---	---	---	---	---	---	1,428	0.01	17
November									
Bank	---	---	---	---	---	---	400	0.10	41
Boat	---	---	---	---	---	---	163	0.04	6
Total	---	---	---	---	---	---	563	0.08	47
December									
Bank	---	---	---	---	---	---	254	0.03	7
Boat	---	---	---	---	---	---	44	0.43	19
Total	---	---	---	---	---	---	298	0.09	26
Combined									
Bank	6,867	0.07 [a]	499	2,124	0.06 [a]	122	5,939	0.02	121
Boat	5,328	0.17 [a]	927	1,858	0.30 [a]	555	8,941	0.02	178
Total	12,195	0.12 [a]	1,426	3,982	0.17 [a]	677	14,880	0.02	299

[a] *Harvest per angler trip calculated for the period when retention was allowed.*

Table 4. Numbers of sturgeon anglers interviewed and numbers of white sturgeon kept and released reported during sampling of recreational fisheries in Bonneville Reservoir, January 1 through August 12, 2001; The Dalles Reservoir, January 1 through April 8, 2001; and John Day Reservoir, January 1 through December 31, 2001.

Reservoir Method/Month	Anglers checked	Hours fished	Sub-legal released	Legal Released	Legal kept	Oversize released
Bonneville						
Bank						
January	189	535	65	3	4	1
February	338	932	184	1	13	4
March	404	1,244	243	4	19	1
April	257	658	196	3	9	1
May	156	446	202	4	9	4
June	162	421	128	1	9	1
July	76	247	46	1	4	3
August	61	205	58	0	0	0
Bank Total	1,643	4,688	1,122	17	67	15
Boat						
January	94	601	192	0	16	1
February	159	915	467	4	41	2
March	142	845	408	4	16	0
April	74	365	206	2	16	7
May	74	383	100	1	9	31
June	268	1,726	414	6	38	218
July	46	303	175	0	14	16
August	13	54	25	0	1	0
Boat Total	870	5,192	1,987	17	151	275
Combined Total	2,513	9,880	3,109	34	218	290
The Dalles						
Bank						
January	166	619	20	1	2	2
February	163	678	5	0	2	2
March	284	1,339	34	0	14	5
April	113	508	11	1	3	4
Bank Total	726	3,144	70	2	21	13
Boat						
January	42	199	29	0	7	0
February	111	600	308	5	33	10
March	285	1,771	667	20	100	35
April	29	117	11	1	1	0
Boat Total	467	2,687	1,015	26	141	45
Combined Total	1,193	5,831	1,085	28	162	58

continued

Table 4. Continued.

Reservoir Method/Month	Anglers checked	Hours fished	Sub-legal released	Legal Released	Legal kept	Oversize released
John Day						
Bank						
January	46	119	0	0	0	0
February	151	428	6	0	0	4
March	166	371	5	0	0	4
April	275	741	31	0	0	4
May	186	566	10	0	0	7
June	260	1,131	26	0	2	18
July	388	1,106	66	0	8	20
August	233	636	30	0	1	4
September	28	102	3	0	1	6
October	84	222	29	0	8	31
November	51	117	46	0	6	5
December	63	142	6	0	2	1
Bank Total	1,931	5,681	258	0	28	104
Boat						
January	24	131	8	0	0	0
February	73	381	7	0	0	1
March	187	944	102	0	0	8
April	303	1,535	431	3	4	8
May	153	803	177	0	3	22
June	437	2,666	352	0	10	83
July	442	2,542	551	1	14	31
August	186	1,057	208	0	6	9
September	41	245	38	1	0	2
October	31	163	50	0	1	4
November	28	178	39	1	1	5
December	10	48	32	0	3	0
Boat Total	1,915	10,693	1,995	6	42	173
Combined Total	3,846	16,374	2,253	6	70	277

Table 5. Length frequencies of harvested white sturgeon measured during sampling of recreational fisheries in Bonneville Reservoir, January 1 through August 12, 2001; The Dalles Reservoir, January 1 through April 8, 2001; and John Day Reservoir, January 1 through December 31, 2001.

Fork Length (cm)	Bonneville	The Dalles	John Day	Fork Length (cm)	Bonneville	The Dalles	John Day
90				130	4	1	4
91				131		2	4
92				132	2		5
93	1			133		1	2
94	6			134	2	1	1
95	5			135	2	2	3
96	11			136	4	1	2
97	10			137	2	1	
98	13			138	1	1	3
99	16			139	2		
100	12			140	4	1	1
101	8			141	1		
102	11			142	1		
103	11		1	143			
104	7			144			
105	8		1	145	1	1	
106	4		2	146	1		
107	5	3	3	147			
108	4	2	3	148			
109	3	5	5	149			
110	5	2	10	150			
111		4	3	151			
112	8	1	6	152			
113	2	9	8	153			
114	2	4	8	154			
115	1	5	7	155			
116	3		7	156			
117	3	1	7	157			
118	2	1	7	158			
119	2	5	3	159			
120	5	2	6	160			
121	2		4	161			
122		1	4	162			
123	5	3	5	163			
124	1	2	7	164			
125	1	1	9	165			
126	2		7	166			
127	2	4		167			
128	2		4				
129			4	Total	210	67	156

Table 6. Estimated angling effort, harvest, and harvest per angler trip (HPUE) of white sturgeon from Bonneville, The Dalles, and John Day reservoirs, 1987 through 2001.

Reservoir Year	Period	Bank anglers Trips	Bank anglers Harvest	Bank anglers HPUE	Boat anglers Trips	Boat anglers Harvest	Boat anglers HPUE
Bonneville (95-138 cm fork length interval)							
1987	-- [a]						
1988	Mar-Oct	5,653	532	0.094	4,776	688	0.144
1989	Mar-Oct	8,028	1,316	0.164	5,792	1,099	0.190
1990	Mar-Oct	7,213	719	0.100	7,349	1,055	0.144
1991	-- [a]						
1992	-- [a]						
1993	Mar-Oct	7,599	678	0.089	6,747	736	0.109
1994	Mar-Oct	7,821	1,024	0.131	5,329	1,089	0.204
1995	Feb-Apr	2,541	456	0.180	1,750	857	0.490
1996	Jan-Mar	3,341	823	0.246	1,735	463	0.267
1997	Jan-Apr 4	5,093	808	0.159	2,535	632	0.249
1998	Jan-Apr 19	4,913	358	0.073	4,990	1,214	0.243
1999	Jan-Apr 16	4,724	374	0.079	3,884	789	0.203
2000	Jan-Apr 7	3,724	425	0.114	3,187	779	0.245
2001	Jan-Aug 12	6,867	459	0.067	5,328	852	0.160
The Dalles (110-138 cm fork length interval)							
1987	Jun-Oct	5,019	465	0.093	3,618	339	0.094
1988	Mar-Oct	5,043	257	0.051	2,566	170	0.066
1989	Mar-Oct	3,659	119	0.033	1,760	99	0.056
1990	-- [a]						
1991	-- [a]						
1992	-- [a]						
1993	Mar-Oct	2,058	46	0.023	1,902	61	0.032
1994	Mar-Oct	3,124	75	0.024	1,863	68	0.037
1995	Mar-May	957	28	0.029	510	18	0.035
1996	Mar-Apr	655	21	0.031	251	29	0.115
1997	Jan-May 4	2,278	119	0.052	538	16	0.030
1998	Jan-June 7	4,102	455	0.111	1,319	296	0.225
1999	Jan-June 11	5,396	411	0.076	1,804	207	0.115
2000	Jan-June 18	4,202	260	0.062	2,953	472	0.160
2001	Jan-Apr 8	2,124	100	0.047	1,858	456	0.245
John Day (110-138 cm fork length interval)							
1987	-- [a]						
1988	-- [a]						
1989	May-Jul	3,572	22	0.006	3,401	34	0.010
1990	Mar-Dec	3,806	33	0.009	3,063	82	0.027
1991	Apr-Sep	1,977	36	0.018	2,463	73	0.030
1992	-- [a]						
1993	Mar-Oct	3,208	56	0.018	4,466	111	0.025
1994	Mar-Oct	3,221	42	0.013	6,860	164	0.024
1995	Mar-May	1,891	12	0.006	2,407	30	0.013
1996	Mar-Apr	1,524	17	0.011	1,396	27	0.020
1997	Feb-Aug	4,780	166	0.035	5,968	287	0.048
1998	Jan-Oct	5,531	161	0.029	8,540	371	0.043
1999	Jan-Dec	6,542	99	0.015	10,110	278	0.028
2000	Jan-Dec	5,204	44	0.008	9,230	280	0.030
2001	Jan-Dec	5,939	109	0.018	8,941	160	0.018

[a] *Minimal or no sampling.*

Table 7. Sturgeon Management Task Force (SMTF) harvest guidelines and estimated harvest of white sturgeon from Bonneville, The Dalles, and John Day reservoirs, 1991 through 2001.

Fishery	Bonneville		The Dalles		John Day		Unspecified	
Year	Guideline	Harvest	Guideline	Harvest	Guideline	Harvest	Harvest	Total
Recreational								
1991	1,350	2,270	100	199	100	150	0	2,619
1992	1,350	1,717	100	139	100	147	0	2,003
1993	1,350	2,307	100	158	100	144	0	2,609
1994	1,350	2,223	100	154	100	234	0	2,611
1995	1,350	1,370	100	50	100	53	0	1,473
1996	1,350	1,353	100	80	100	62	0	1,495
1997	1,520	1,463	200	178	560	464	0	2,105
1998	1,520	1,626	600-800	857	560	593	0	3,076
1999	1,520	1,235	600-800	695	560	422	0	2,352
2000	1,520	1,262	700	809	560	434	0	2,505
2001	1,520	1,426	700	677	560	299	0	2,402
Indian Commercial								
1991	1,250	999	300	457	100	39	0	1,495
1992	1,250	1,146	300	431	100	23	0	1,600
1993	1,250	1,415	300	579	100	12	0	2,006
1994	1,250	1,176	300	309	100	117	0	1,602
1995	1,250	1,421	300	312	100	308	0	2,041
1996	1,250	1,005	300	230	100	360	0	1,595
1997	1,300	1,852	400	498	1,160	1,260	0	3,610
1998	1,300	1,462	1,000-1,200	1,108	1,160	1,100	0	3,670
1999	1,300	1,280	1,000-1,200	1,051	1,160	760	0	3,091
2000	1,300	1,145	1,100	1,456	1,160	846	0	3,447
2001	1,300	1,287	1,100	1,258	1,160	646	0	3,191
Combined fisheries								
1991	2,600	3,269	400	656	200	189	0	4,114
1992	2,600	2,863	400	570	200	170	0	3,603
1993	2,600	3,722	400	737	200	156	0	4,615
1994	2,600	3,399	400	463	200	351	0	4,213
1995	2,600	2,791	400	362	200	361	0	3,514
1996	2,600	2,358	400	310	200	422	0	3,090
1997	2,820	3,315	600	676	1,720	1,724	0	5,715
1998	2,820	3,088	1,800	1,965	1,720	1,693	0	6,746
1999	2,820	2,515	1,800	1,746	1,720	1,182	0	5,443
2000	2,820	2,407	1,800	2,265	1,720	1,280	0	5,952
2001	2,820	2,713	1,800	1,935	1,720	945	0	5,593
Indian subsistence [a]								
1991		-- b		-- b		-- b	-- b	-- b
1992		89		-- b		-- b	119	208
1993		146		31		30	56	263
1994		290		197		163	0	650
1995		570		260		320	0	1,150
1996		260		120		110	0	490
1997		130		40		63	0	233
1998		109		86		45	0	240
1999		90		116		28	0	234
2000		191		128		24	0	343
2001		174		276		26	0	476

[a] *The SMTF did not establish harvest guidelines for the subsistence fishery, however, the expected annual subsistence harvest was 300 white sturgeon for 1994 through 2001.*

[b] *Not available.*

WHITE STURGEON MITIGATION AND RESTORATION IN THE COLUMBIA AND SNAKE RIVERS UPSTREAM FROM BONNEVILLE DAM

ANNUAL PROGRESS REPORT

APRIL 2001 – MARCH 2002

Report C

Describe reproduction and early life history characteristics of white sturgeon populations in the Columbia River between Bonneville and Priest Rapids dams

and

Define habitat requirements for spawning and rearing white sturgeon and quantify the extent of habitat available in the Columbia River between Bonneville and Priest Rapids dams

This report includes: Progress updates on investigations of young-of-the-year recruitment in various Columbia River reservoirs, and laboratory predation studies.

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ABSTRACT

During 1 April 2001 through 31 March 2002, the U.S. Geological Survey (USGS) continued work on several tasks, including quantifying habitat suitable for white sturgeon (*Acipenser transmontanus*) spawning, a long-term survey of young-of-the-year (YOY) white sturgeon recruitment in the lower Columbia River, and a laboratory study investigating predation on larval and juvenile white sturgeon.

River discharges and water temperatures during April through July 2001 provided some of the worst conditions since 1985 for spawning by white sturgeon downstream from Bonneville, The Dalles, John Day, and McNary dams. Daily discharge remained low (< 5 kcms) during April through June. The river hydrograph was relatively flat, with no discernable prolonged peak as normally occurs. Optimal spawning temperatures in the four tailraces occurred for less than two weeks and well before some of the highest discharges of the year.

Probably because of these poor spawning conditions, no YOY white sturgeon were collected during bottom trawling in Bonneville, The Dalles, and John Day reservoirs. Similarly, the Oregon Department of Fish and Wildlife did not catch YOY white sturgeon in gill nets set in The Dalles and John Day reservoirs in an ongoing comparison of indices of abundance derived from the two gears.

The second year of a three-year laboratory predation study was completed. We installed four 2.4-m diameter tanks for experiments. Northern pikeminnow 300-600 mm total length ate white sturgeon up to about 120 mm, whereas walleye of a similar size ingested almost no white sturgeon.

INTRODUCTION

This annual report describes progress of the U.S. Geological Survey, Western Fisheries Research Center, Columbia River Research Laboratory, on the Bonneville Power Administration funded Project 19860-5000 – White Sturgeon Restoration and Enhancement in the Columbia and Snake Rivers Upstream from Bonneville Dam. The reporting period is 1 April 2001 through 31 March 2002.

The multi-agency project has four common objectives. Those objectives are to:

1) Develop and implement mitigation actions that do not involve changes to hydrosystem operation and configuration.

2) Mitigate for effects of hydrosystem operation and configuration by developing and recommending actions that involve changes to hydrosystem operation and configuration to optimize physical habitat conditions for white sturgeon production.

3) Monitor and evaluate actions to mitigate for lost white sturgeon production due to development, operation, and configuration of the hydrosystem.

4) Assess losses to white sturgeon production due to development, operation, and configuration of the hydrosystem.

During this reporting period the U.S. Geological Survey worked on five tasks related to the four objectives stated above. Those tasks and the objective addressed were to:

1) Determine the availability of habitat for spawning by white sturgeon based on river discharges and water temperatures that occurred in 2001- Objective 1.

2) Use trawls to determine if recruitment of white sturgeon to young-of-the-year (YOY) occurred in Bonneville, The Dalles, and John Day reservoirs – Objective 3.

3) Compare catches of YOY from gill nets and trawls to index the abundance of YOY white sturgeon in The Dalles and John Day reservoirs – Objective 3.

4) Conduct laboratory trials to test the hypothesis that predation on larval and age-0 juvenile white sturgeon is not affected by turbidity – Objective 4.

5) Conduct laboratory trials to determine the size at which white sturgeon are no longer vulnerable to predation – Objective 1.

These tasks are in various stages of completion. Tasks 1, 2, and 3 are ongoing activities related to the development of long-term data sets. Tasks 4 and 5 are a study that began during 2000-- laboratory work will be completed in 2002, and much of the write-up will be completed in 2003.

METHODS

Availability of Spawning Habitat

Parsley and Beckman (1994) presented the results of hydraulic simulations of the physical habitat downstream of McNary, John Day, The Dalles, and Bonneville dams in response to river discharges. The methods, models, and results from that paper were used with river discharges and water temperatures that occurred during 2001 as inputs to create a daily index of white sturgeon spawning habitat availability for these four known spawning areas. Mean daily river discharges and water temperatures that occurred at the dams during April through July were obtained from the Data Access in Real Time (DART) web page (http://www.cqs.washington.edu/dart/).

Young-of-the-Year Indexing

We sampled for juvenile white sturgeon with a 6.2-m high-rise bottom trawl (Palmer et al. 1988) to determine if recruitment to YOY occurred in Bonneville, The Dalles, and John Day reservoirs. The previously designed sampling program calls for conducting a total of 66 tows at 11 sites in Bonneville Reservoir (6 replicates per site), 24 tows at 12 sites in The Dalles Reservoir (2 replicates per site), and 38 tows at 19 sites in John Day Reservoir (2 replicates per site). Sample sites were designated with a code indicating statute river mile and relative position across the river channel. The last digit of the site designation represents position in the channel, with 0 and 5 designating backwater areas and 1 through 4 designating ¼ channel width increments from left to right facing upstream. Digits preceding the last number represent river miles to the nearest 0.1-mile from the mouth of the Columbia or Snake rivers. For example, 34753 indicates that the site is near river mile 347.5 and in the third quadrant of the river from the left bank (looking upstream).

Trawling was conducted in an upstream direction and each tow was typically 10 minutes in duration. We estimated the distance fished during each tow with a Rockwell PLGR+ Global Positioning System (GPS) receiver using the Precise Positioning Service[1] and determined the area fished by multiplying the distance by 4.4 m, the estimated fishing width of our bottom trawl. We also used a Trimble, NAVTRAC GPS unit to navigate the trawling vessel and to maintain a speed-over-ground of approximately 3 km/h during each tow.

All fish captured were enumerated and released. Generally, all fish were measured with the exception of American shad (*Alosa sapidissima*). When catch of an individual species was high, a subsample of 50 individuals was measured. We measured the total length (TL) on all fish and fork length (FL) on fish with forked caudal fins to the nearest 1mm. Only white sturgeon were weighed. Generally, YOY white sturgeon were weighed to the nearest 1 g, and larger juveniles were weighed to the nearest 5 or 10 g.

Catch-per-unit-effort (CPUE) of white sturgeon was expressed as the number of fish caught per 2,500 m^2. The proportion of positive tows (E_p) for YOY white sturgeon was calculated as the ratio of tows where at least one YOY was captured to the total number of tows conducted.

Comparison of Gill Nets and Bottom Trawls to Index Recruitment to Young-of-the-Year

The USGS is collaborating with the Oregon Department of Fish and Wildlife (ODFW) and Washington Department of Fish and Wildlife (WDFW) to determine if indices of recruitment developed from catches of YOY white sturgeon from 51-mm stretched mesh gill nets follow trends similar to those developed from catches in bottom trawls. Sampling with bottom trawls to index the recruitment of YOY white sturgeon is an effective method (Counihan et al. 1999) but is restricted to

[1]Precise Positioning Service (PPS) is available to the military and certain Federal civilian agencies. This service differs from the Standard Positioning Service available to civilian users. The GPS receiver incorporates the Wide Area GPS Enhancement (WAGE) system and can achieve less than 4 m error in horizontal positioning autonomously in real-time without the need for broadcast variables or post-processing. The WAGE also provides position error estimates to indicate the quality of the data.

areas with suitable bottom topography, and requires specialized boats and boat operator experience. Counihan et al. (1999) described two indices that can be used to assess the relative abundance of YOY white sturgeon from highly skewed trawling data. Comparisons between gears will be made from sampling with both gears in The Dalles and John Day reservoirs. The USGS has an ongoing sampling program in each of these reservoirs, and in 1999 the ODFW began sampling with gill nets at fixed sites in these reservoirs (Burner et al. 1999). The ODFW conducted sampling in The Dalles and John Day reservoirs and entered, proofed, and summarized the catch data from that sampling.

The statistical design for this comparison calls for sampling with each gear during October or November at fixed locations. Generally, in each reservoir sampling with gill nets is conducted after sampling is done with the bottom trawl. Young-of-the-year are discerned from older white sturgeon through length frequency analysis, and two indices of abundance are derived for each gear type and reservoir. The proportion of positive efforts (E_p; Uphoff 1993) is the ratio of the number of efforts with at least one YOY white sturgeon to the total number of efforts conducted. The arithmetic mean of CPUE is the mean of untransformed CPUE data. For the bottom trawl data, mean CPUE is presented as the number of YOY white sturgeon per 2,500 m^2 of riverbed sampled. For the gill-net data, mean CPUE is presented as the number of YOY per overnight set. Correlation analysis will be used to compare indices of abundance of YOY between gears for each reservoir.

Predation on Larval and Juvenile White Sturgeon

Turbidity Experiments

We initiated a study in 2000 to determine how turbidity might affect predation on white sturgeon larvae and juveniles. During 2000, some white sturgeon larvae were ingested by predators (prickly sculpins *Cottus asper*) at all turbidity levels we tested, even though the trials were brief--only 15 min. This could have been in part because of the relatively small container size we used, 85-l, which may have resulted in a high level of encounter rates. To account for this, in 2001 we used tanks with nearly twice the volume. Also in 2001, we added a higher turbidity level, 360 NTU (Nephelometric Turbidity Units).

Trials were conducted in 160-l gray plastic tanks testing the effects of five turbidity levels, 0, 20, 60, 180, and 360 NTU, on predation of white sturgeon larvae. Light was supplied by overhead fluorescent bulbs and levels were maintained at about 0.3-0.4 lux in clear water. Water was supplied with a flow-through system (except during experiments), and temperatures were 17-18^{o}C. White sturgeon larvae and juveniles were obtained from a commercial hatchery near Portland, Oregon, and were offspring of fish collected during 2001 from the Columbia River and spawned in mid-June. Predators for turbidity trials were 160-203 mm TL prickly sculpins that were collected with bottom trawls in the lower Columbia River during the fall of 2000.

Two prickly sculpins were placed in each tank at least two days prior to an experiment, and food was withheld. To avoid introducing prey directly over the predators, sculpins were moved to one end of each tank before each trial, and a mesh divider was placed midway. Turbidity level in each tank was randomly selected. Water flow was stopped in each tank and turbidities were brought up to the designated levels by stirring pre-determined amounts of a slurried bentonite solution in the water; for 0 NTU, clear water was stirred into the tanks. Water samples were removed from each end of the tank and turbidities tested using a Hach model 2100P Turbidimeter. If samples were not within 10% of the designated level, turbidities were adjusted by adding more bentonite or clear water. If this was necessary, all tanks were again stirred to standardize treatments. When turbidities were at appropriate levels, a 2-l container of water was removed from each tank, and sculpins were allowed to acclimate for one hour before trials began. Air stones in each tank kept bentonite suspended. Fifteen minutes before trials began, 30 white sturgeon larvae (18-20 mm TL) were gently scooped into each of the five 2-l containers. To initiate a trial, larvae were lowered into each tank at the end opposite the sculpins, and the divider and air stones were removed. Based on preliminary experiments, trials were conducted for a period of 15 min. At this time, sculpins were netted from each tank to end predation and placed in a common tank. Water was removed from each tank, strained, and the remaining number of larvae counted. Experiments were conducted on four occasions during 25 June - 2 July, resulting in 3-4 replicates per turbidity level. However, trials could not be continued after this period because of high mortality of sculpins. Results were tested for significance with analysis of variance (ANOVA; GLM procedures; SAS Institute, Inc., 1999-2000).

Size Vulnerability

Experiments were conducted to determine the size at which white sturgeon are no longer vulnerable to predation by two common Columbia River predators--northern pikeminnow (*Ptychocheilus oregonensis*), and walleye (*Stizostedion vitreum*). During 2001, we primarily conducted trials in 2.4-m diameter tanks. However, in order to compare results to those of 2000 when 1.3-m diameter tanks were used, during 2001 we also tested size vulnerability using two walleye in each of two 1.3-m tanks. We collected 300-600 mm TL northern pikeminnow by boat electroshocking in the Columbia River during May 2001, and 400-600 mm TL walleye were collected by the Washington Department of Fish and Wildlife in Moses Lake, WA, during April 2001. Northern pikeminnow and walleye were held in four 2.4 -m diameter tanks, with two tanks per species and five fish per tank. All tanks had flow-through water at 17-18^{o}C. White sturgeon juveniles were obtained from both the Kootenai Tribal Hatchery in Idaho and from a local commercial hatchery. They were held in 1.3-m diameter tanks and fed commercial semi-moist salmon diets to excess.

Each week we alternated between feeding predators white sturgeon juveniles and 60-110 mm TL juvenile chinook salmon (*Oncorhynchus tshawytscha)* or coho salmon (*O. kisutch*). The purpose of this was to confirm that predators were still eating even if they did not ingest white sturgeon. For an experiment, thirty white sturgeon were introduced into each 2.4 m tank containing five predators on Monday, removed 24 hrs later, and counted. On Thursday, 30 juvenile salmon were placed into each tank and removed in 24 hrs. The same experimental regime was conducted in the two 1.3-m tanks with walleye, except we used 20 of each prey type.

Trials were initiated in late June with 100-150 mm TL yearling white sturgeon to determine if predators will initiate feeding on larger white sturgeon. During 2000, we began trials with white sturgeon of a mean size of 31 mm TL. It was suggested that beginning with small fish may have trained predators to eat white sturgeon of increasing sizes, whereas otherwise they might not have fed on larger white sturgeon. Thus, we conducted four weeks of trials with yearling white sturgeon, and then switched to smaller (25-30 mm TL) white sturgeon as prey. Prey size increased as the group of sturgeon we were using in experiments grew.

RESULTS AND DISCUSSION

Availability of Spawning Habitat

Bonneville, The Dalles, John Day, and McNary Tailraces

River discharge and water temperatures that occurred during April through July 2001 provided some of the worst conditions since 1985 for spawning by white sturgeon downstream from Bonneville, The Dalles, John Day, and McNary dams. The river hydrograph (Figure 1) shows that daily discharge was relatively flat from April through June. Mean daily discharge only approached 5 kcms (1000 m^3/s) on a few occasions during May and June, and there was no discernable peak to the hydrograph as normally happens. During this period, daily river discharges were erratic with short-term increases and decreases occurring on a weekly basis. Water temperature, one factor which determines the time period when spawning will occur, rose to optimal levels (13.3^oC) for spawning by white sturgeon on or about 11 May (Figure 2) and exceeded optimum levels (15.2^oC) only 11 d later on 22 May in the Bonneville and The Dalles Dam tailraces, and on 24 May in the John Day and McNary dam tailraces. Thus optimal spawning temperatures in the four tailraces occurred for less than two weeks and well before some of the highest discharges of the year, resulting in extremely low available habitat for spawning. Our monthly estimates of the index of spawning habitat showed that the availability of habitat for spawning peaked in May, but at far below the average levels of past years (Figure 3). Annual indices of spawning habitat for The Dalles, John Day, and McNary dam tailraces in 2001 were also well below indices for past years (Figure 4).

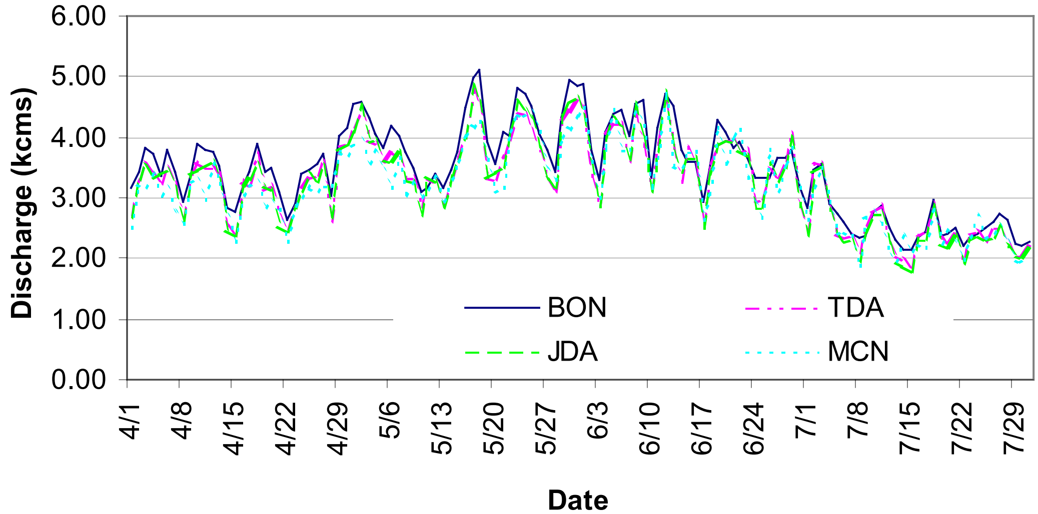

Figure 1. River discharges at Bonneville (BON), The Dalles (TDA), John Day (JDA), and McNary (MCN) dams during 2001. Data were obtained from the DART website (http:\\www.cqs.washington.edu\dart\). Kcms = 1000 m^3s^{-1}

Figure 2. Water temperatures at Bonneville (BON), The Dalles (TDA), John Day (JDA), and McNary (MCN) dams during 2001. Data were obtained from the DART website (http:\\www.cqs.washington.edu\dart\).

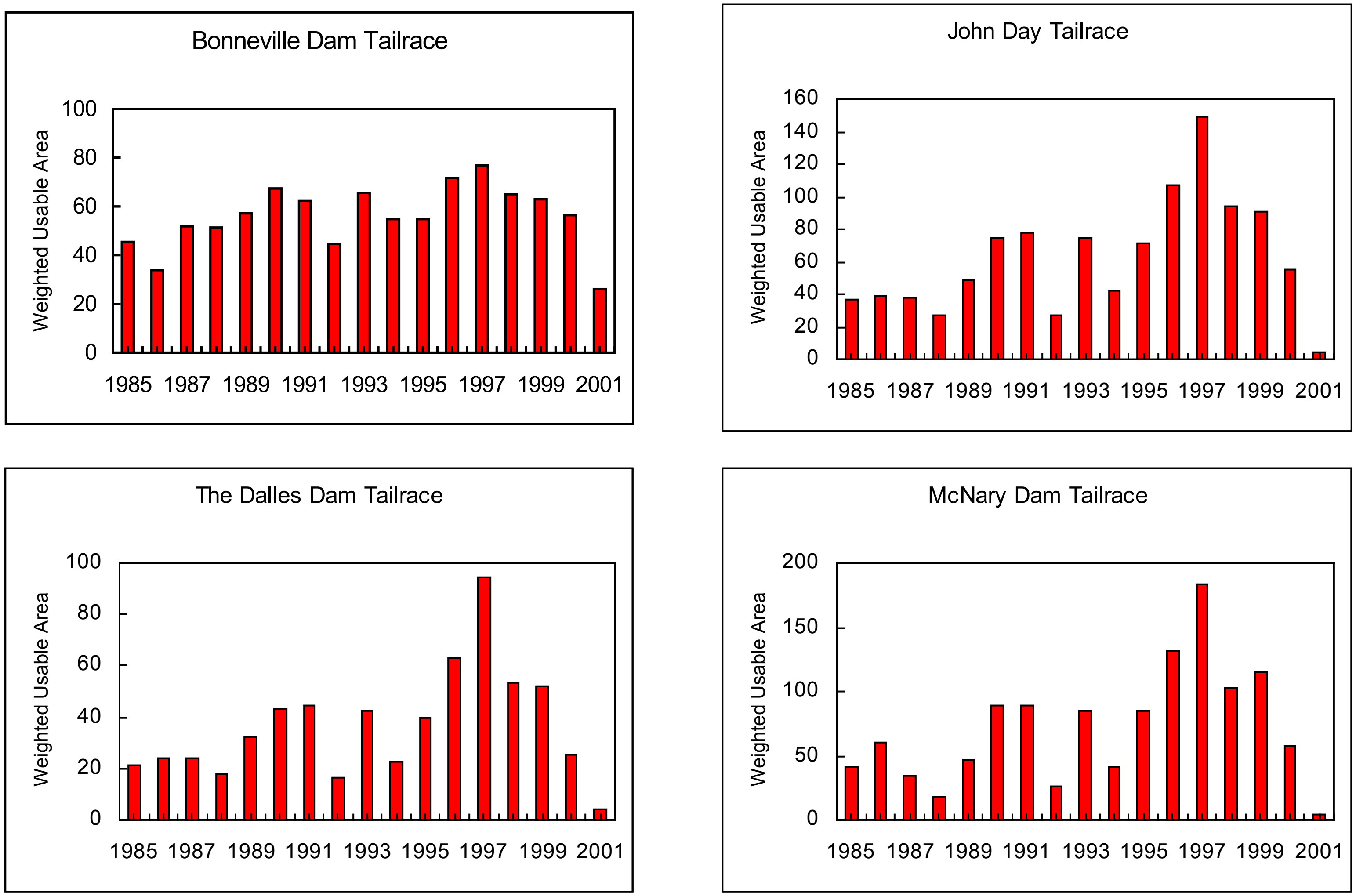

Figure 3. Annual mean composite indices of spawning habitat (temperature conditioned weighted usable area (WUA)) for white sturgeon for each of the four dam tailraces that have been modeled (Parsley and Beckman 1994). Note that the scale differs on the Y-axis among graphs.

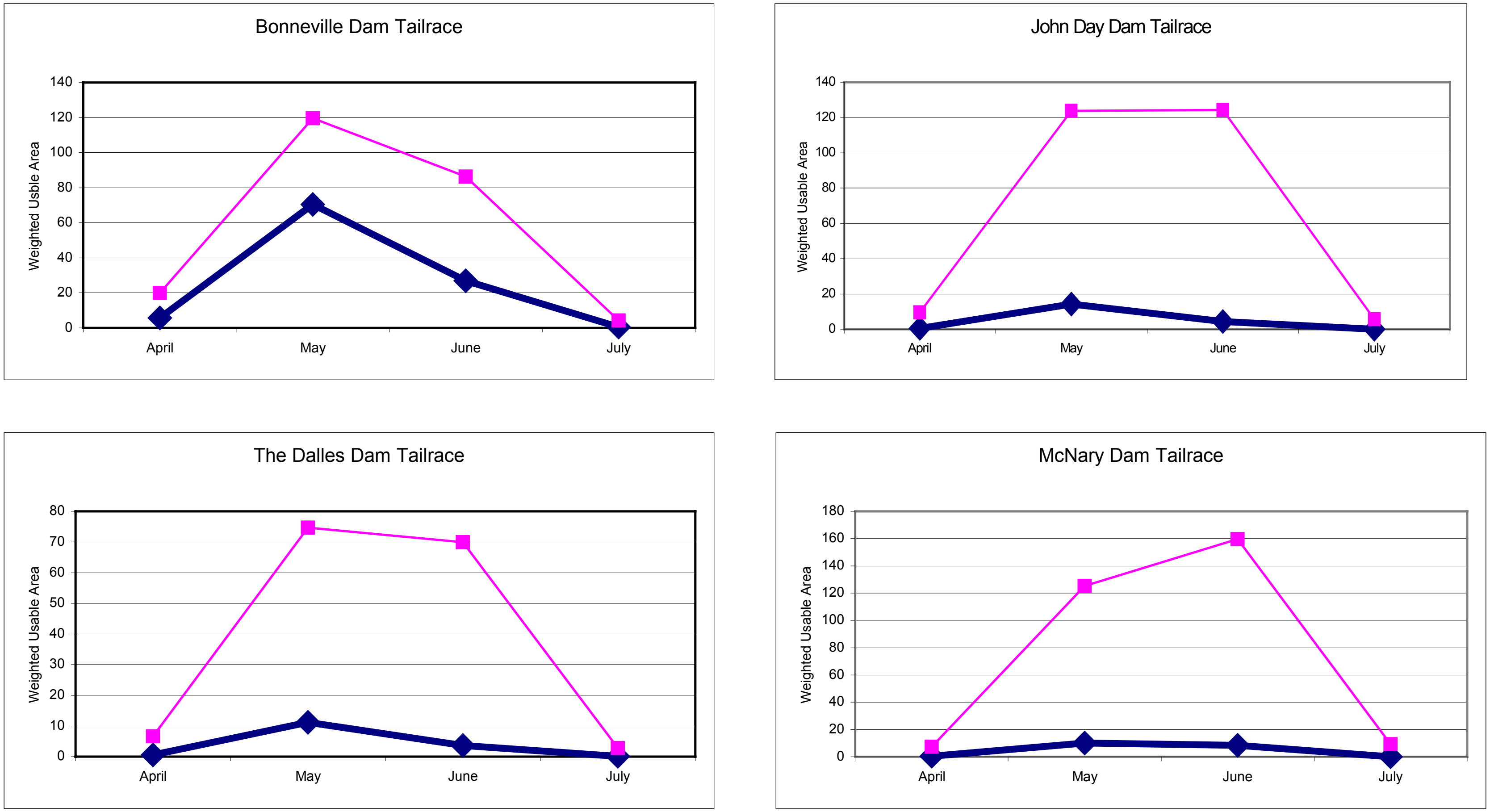

Figure 4. Mean monthly indices of spawning habitat (temperature conditioned weighted usable area (WUA)) for white sturgeon during 2001 (lower lines), and the average mean monthly index for each month during 1985-2000 (upper lines). Note that the scale differs on the Y-Axis among graphs.

Young-of-the-Year Indexing

Bottom-trawl sampling was completed as scheduled during 2001. We fished the bottom trawl on 12 d from 18 September to 3 October in Bonneville Reservoir, on 4 d from 10 October to 25 October in The Dalles Reservoir, and on 6 d from 29 October to 6 November in John Day Reservoir. Down time due to equipment problems and weather conditions caused a delay of 7 d during trawling activities in The Dalles Reservoir. No nets were lost while sampling this year.

Bonneville Reservoir

No recruitment of young-of-the-year white sturgeon was observed in Bonneville Reservoir in 2001. We captured 33 juvenile white sturgeon with the bottom trawl during our sampling of Bonneville Reservoir, but none of these were YOY. Juvenile white sturgeon were captured at 7 of the 11 sites (Table 1). The juvenile white sturgeon ranged from 338 to 940 mm FL and weighed 150 to 4,700 g. The CPUE for combined effort for each of the 11 sites sampled with the bottom trawl in Bonneville Reservoir was 0 for YOY white sturgeon and ranged from 0.0 to 4.80 fish per 2,500 m^2 for all white sturgeon caught (Table 1).

Table 1. Characteristics of bottom trawling conducted to index recruitment of white sturgeon in Bonneville Reservoir during 18 September to 2 October 2001. Young-of-the-year (YOY) white sturgeon were differentiated by length frequency analysis.

			Number of white sturgeon collected		White sturgeon catch/2500 m^2	
Site	Number of trawl tows	Total area sampled (ha)	All ages	YOY	All ages	YOY
15052	6	1.3673	0	0	0.0	0.0
15734	6	1.3315	0	0	0.0	0.0
15951	6	1.3852	1	0	0.18	0.0
16522	6	1.3462	0	0	0.0	0.0
16851	6	1.3244	1	0	0.19	0.0
17063	6	1.3550	1	0	0.18	0.0
17374	6	1.3307	2	0	0.38	0.0
17652	6	1.3463	0	0	0.0	0.0
17911	6	1.3633	1	0	0.18	0.0
18351	6	1.3547	26	0	4.80	0.0
18523	6	1.3456	1	0	0.19	0.0
Totals	66	14.8502	33	0		

The Dalles Reservoir

No recruitment to YOY was observed in The Dalles Reservoir in 2001. We captured two juvenile white sturgeon at one site with fork lengths of 567 and 609 mm, and weights of 450 and 650 g, respectively. The CPUE for all white sturgeon for each of the 12 sites sampled with the bottom trawl in The Dalles Reservoir ranged from 0 to 1.1 juveniles per 2,500 m^2.

Table 2. Characteristics of bottom trawling conducted to index recruitment of white sturgeon in The Dalles Reservoir during 10 October to 25 October 2001. Young-of-the-year (YOY) white sturgeon were differentiated by length frequency analysis.

			Number of white sturgeon collected		White sturgeon catch/2500 m^2	
Site	Number of trawl tows	Total area sampled (ha)	All ages	YOY	All ages	YOY
19463	2	0.4495	0	0	0.0	0.0
19683	2	0.4456	0	0	0.0	0.0
19981	2	0.4580	2	0	1.09	0.0
20012	2	0.4440	0	0	0.0	0.0
20244	2	0.4501	0	0	0.0	0.0
20432	2	0.4420	0	0	0.0	0.0
20451	2	0.4640	0	0	0.0	0.0
20651	2	0.4399	0	0	0.0	0.0
20752	2	0.4411	0	0	0.0	0.0
21014	2	0.4694	0	0	0.0	0.0
21103	2	0.4666	0	0	0.0	0.0
21412	2	0.4514	0	0	0.0	0.0
Totals	24	5.4216	2	0		

John Day Reservoir

We captured three juveniles and no YOY white sturgeon with the bottom trawl during our sampling of John Day Reservoir (Table 3). Two juveniles had their ninth left lateral scute and third right scute removed indicating they were captured and released in 2001 by the ODFW trawl and haul program. These measured 407 and 366 mm FL, and weighed 445 and 275 g, respectively. The fork length of the third juvenile was 375 mm, and the weight was 360 g. The CPUE for combined effort for each of the 19 sites sampled with the bottom trawl in John Day Reservoir ranged from 0 to 0.56 for all white sturgeon caught (Table 3).

Table 3. Characteristics of bottom trawling conducted to index recruitment of white sturgeon in John Day Reservoir during 29 October to 1 November 2001. Young-of-the-year (YOY) white sturgeon were differentiated by length frequency analysis.

Site	Number of trawl tows	Total area sampled (ha)	Number of white sturgeon collected		White sturgeon catch/2500 m^2	
			All ages	YOY	All ages	YOY
21924	2	0.4466	0	0	0.0	0.0
22533	2	0.4486	0	0	0.0	0.0
22931	2	0.4533	0	0	0.0	0.0
23352	2	0.4627	0	0	0.0	0.0
24173	2	0.4486	0	0	0.0	0.0
24324	2	0.4506	0	0	0.0	0.0
24822	2	0.4483	0	0	0.0	0.0
25283	2	0.4504	0	0	0.0	0.0
25623	2	0.4506	0	0	0.0	0.0
26382	2	0.4506	0	0	0.0	0.0
26422	2	0.4501	0	0	0.0	0.0
26803	2	0.4519	1	0	0.55	0.0
27054	2	0.4440	0	0	0.0	0.0
27384	2	0.4540	0	0	0.0	0.0
27851	2	0.4471	0	0	0.0	0.0
27974	2	0.4518	1	0	0.55	0.0
28074	2	0.4460	0	0	0.0	0.0
28184	2	0.4483	1	0	056	0.0
28972	2	0.4453	0	0	0.0	0.0
Totals	38	8.5488	3	0		

Comparison of Gill Nets and Bottom Trawls to Index Recruitment to Young-of-the-Year

Sampling during 2001 by ODFW and USGS provided the third year of data to be used for comparing indices of abundance derived from gill-net and bottom trawl catches. In The Dalles Reservoir, the ODFW (Report A) set 32 nets and fished for a total of 726.5 hours, while the USGS, as described above, sampled 12 fixed sites with bottom trawls twice each for a total of 24 tows. In John Day Reservoir, ODFW set 40 gill nets for 896.3 hours of fishing. The USGS sampled 19 fixed sites twice each for a total of 38 trawl tows. No YOY white sturgeon were collected by either gear type, and thus CPUE and E*p* for all efforts equaled zero.

Predation on Larval and Juvenile White Sturgeon

Turbidity Experiments

More white sturgeon larvae were ingested by sculpins at 20 NTU than at other turbidities, with decreasing predation at the highest turbidities tested (Figure 5). However, the results were highly variable, and differences were not significant (P = 0.62). The variability of our results could be due to the complexity of the effects of turbidity on predator-prey interactions--turbidity reduces the distance at which a predator can detect prey, but also reduces prey reaction distance (Vinyard and O'Brian 1976; Miner and Stein 1996) However, highly variable feeding by sculpins may have also been due to poor health of the predators. The sculpins had a bacterial infection, and many died, resulting in termination of the experiments.

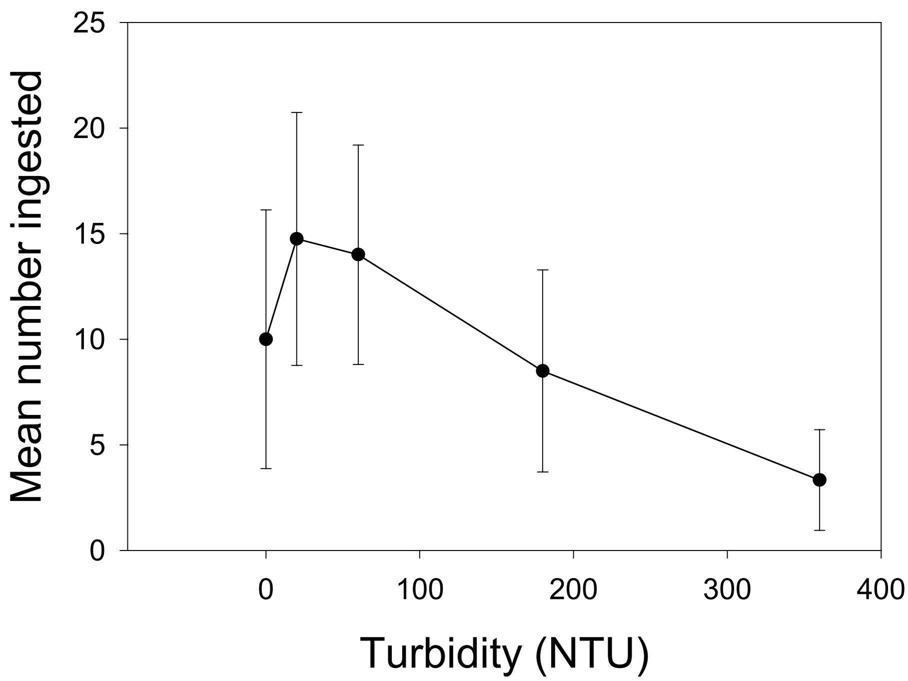

Figure 5. Mean numbers of white sturgeon ingested by two prickly sculpins in each tank at five turbidity levels. There were three replicates at 360 NTU, and four each at 0, 20, 60, and 180 NTU. Each vertical bar equals one standard error.

Size Vulnerability

Northern pikeminnow ingested a few larger (100-150 mm TL) white sturgeon initially, and ate more each week as the trials progressed (Figure 6). During this period they also consistently ate salmon. When we began feeding northern pikeminnow smaller white sturgeon (25-50 mm TL), they ingested all of these. Similarly, almost all intermediate-sized white sturgeon (50-65 mm) were ingested. As the trials progressed, the overall predation rate on both white sturgeon and salmon decreased (Figure 6). However, northern pikeminnow continued to ingest some salmon, but stopped eating white sturgeon as they reached about 120-130 mm TL.

Walleye displayed a completely different pattern of predation. They consistently ingested salmon throughout the trials in 2.4 m diameter tanks (Figure 6). However, only a few intermediate sized (25-65 mm TL) white sturgeon were ingested.

Results were similar in the two 1.3-m diameter tanks, each containing two walleye. During 20 trials, a mean of five salmon were ingested per trial, for a total of 100 salmon. During this period, only two white sturgeon juveniles were ingested.

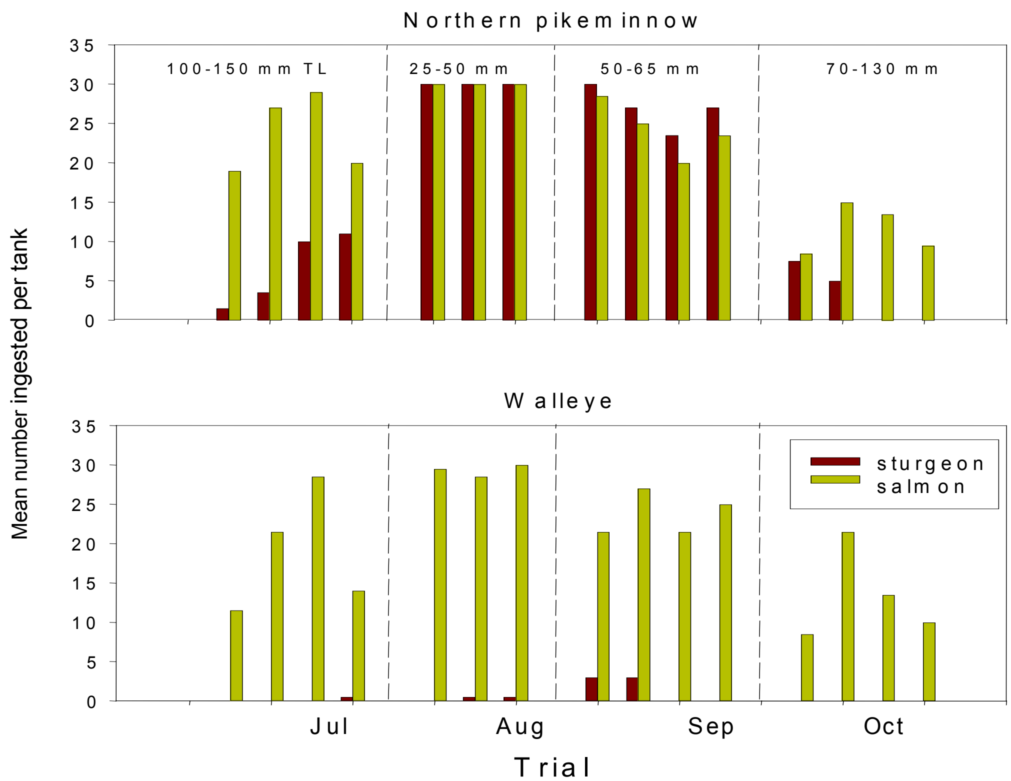

Figure 6. Mean numbers of white sturgeon and salmon ingested weekly per tank by northern pikeminnow and walleye in four 2.4-m diameter tanks with five predators per tank and two tanks per species. White sturgeon sizes (total length: TL) are presented above the bars. Juvenile salmon were 60-110 mm TL.

Conclusions

Similar to 2000, we found that turbidity affected predation on white sturgeon larvae by prickly sculpins, with fewer white sturgeon ingested at higher turbidities. However, results in 2001were not significant because of highly variable feeding rates probably due to the poor health of sculpins. In 2001, sculpins were collected in the fall during bottom trawling and held over-winter, which may have been a factor in their mortalities. We plan to repeat this experiment in 2002 using sculpins collected in the spring from the Bingen Marina, Columbia River, as we successfully did in 2000.

The two larger predators we tested in our size vulnerability experiments, northern pikeminnow and walleye, had very different feeding patterns. Similar to 2000 when trials were conducted in 1.3-m diameter tanks, in 2001 northern pikeminnow in 2.4 -m diameter tanks ingested white sturgeon up to 120-130 mm TL. This is not surprising, since northern pikeminnow have been documented as opportunistic feeders, commonly eating even highly armored prey such as crayfish (Poe et al. 1991).

In contrast, walleye ate almost no white sturgeon. These results were unexpected, since in the wild, walleye are highly piscivorous but also opportunistic, feeding on a variety of fishes and invertebrates (Ryder and Kerr 1978). These results suggest that walleye predation on juvenile white sturgeon may not be a factor limiting recruitment success. However, we did not test predation by walleye on white sturgeon larvae, which could contribute to young-of-the year recruitment failure--we plan to examine this in 2002.

Plans for 2002

During 2002, the USGS will continue several tasks begun in previous years, including indexing the recruitment of YOY white sturgeon in Bonneville, The Dalles, and John Day reservoirs, and evaluating the availability of spawning habitat as determined by river discharge and water temperature. We will continue with the analyses and preparation of manuscripts for completed studies such as our examination of movements of adult white sturgeon prior to and during the spawning period.

In 2002, we will conduct the third and final year of laboratory trials assessing the vulnerability of white sturgeon larvae and juveniles to predation. We plan to test size-vulnerability of white sturgeon to predation by channel catfish (*Ictalurus punctatus*) in the larger tanks. We conducted preliminary tests with channel catfish in 2000, but these fish were of smaller sizes and had been held over-winter. In 2002, fish will be collected in the spring by hook and line from the lower Snake River. Trials will also be conducted in 2002 examining the effects of substrate on predation of white sturgeon larvae and juveniles, using sculpins and northern pikeminnow as predators. Lastly, we will examine predation on white sturgeon by these two predators if an alternate prey, goldfish (*Carassius auratus)* or juvenile salmon, are also available in the tank.

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WHITE STURGEON MITIGATION AND RESTORATION IN THE COLUMBIA AND SNAKE RIVERS UPSTREAM FROM BONNEVILLE DAM

ANNUAL PROGRESS REPORT

APRIL 2001 – MARCH 2002

Report D

Evaluate the success of developing and implementing a management plan for enhancing production of white sturgeon in reservoirs between Bonneville and McNary dams.

This report includes: A summary of work performed to develop and implement propagation techniques that will lead to an experimental hatchery release of white sturgeon and the results of efforts to capture and mark white sturgeon in John Day Reservoir for population abundance estimates.

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CONTENTS

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We offer our appreciation and thanks to Yakama Nation fishery technicians Alvin McConnville, Chuck Gardee, James Kiona, and Cecil James, and commercial fishermen Robert Brigham, Mathew McConville, Wilson Begay and their crew members, and ODFW staff for their efforts in conducting the mark and recapture operations in John Day Reservoir. We also thank CRITFC fishery technician Clifford Alexander, Dr. Molly Webb of OSU, Joel Van Eenennaam of UC Davis, Washington Department of Fish and Wildlife technicians John Hone and Robert Morgan, and U.S. Fish and Wildlife Service biologists John Holmes and Jeff Poole for their work and assistance with the experimental white sturgeon propagation and supplementation project. Special thanks to U.S. Army Corps of Engineer's Biologist Brad Ebby and his staff for providing assistance and the site for the satellite spawning facility at McNary Dam. We also acknowledge staff at UC Davis for development of now standard white sturgeon maturation and spawning techniques.

ABSTRACT

During 18 days of setline fishing for broodstock from 11 March 2001 to 10 April 2001, we captured a total of 200 white sturgeon in 85 sets. We captured and held 27 sexually mature white sturgeon, 4 females and 23 males, at our new satellite spawning station located below the McNary Dam Juvenile Fish Facility. We spawned one out of four females, crossing gametes from the female with two males, resulting in 36,000 white sturgeon larvae. Throughout spawning trials gametes were collected from five of twenty-three male white sturgeon. Spawning attempts were made on two females that showed positive oocyte maturation. No attempt was made on a third female that showed arrested maturation. The maturation cycle of the two non-ovulated females were interrupted by unseasonably high water temperatures. Our move to the McNary facility improved our ability to mature and spawn white sturgeon, but broodstock spawning trials show evidence that success is still limited by our inability to control water temperature.

Mark and tagging operations for John Day Reservoir resulted in marking 2,515 white sturgeon with the 9th left scute removal pattern and PIT tagging 1,971 of these fish. A total of 3,019 white sturgeon were captured in 1,537 gillnet sets in nine weekly fishing periods from 27 November 2000 through 26 January 2001. Oregon Department of Fish and Wildlife performed the recapture effort, and they provide an update of the population estimate and structure of John Day Reservoir in section A of this report.

INTRODUCTION

In this report, we summarize work completed by Columbia River Inter-Tribal Fish Commission (CRITFC) staff, under subcontract with Oregon Department of Fish and Wildlife (ODFW), from 1 April 2001 through 31 March 2002 performed to meet objectives of Bonneville Power Administration (BPA) tasks outlined under project 198605000. The primary objectives for CRITFC under this project were to develop techniques that will mitigate for reduced natural production of white sturgeon due to development and operation of the hydro-system and to monitor the status of white sturgeon populations between Bonneville and Priest Rapids dams in the Columbia River.

Our tasks for this period were to:

1) Develop and implement techniques for capturing, holding, and spawning white sturgeon.
2) Capture and mark/tag approximately 3000 white sturgeon in John Day Reservoir.
3) Provide assistance to cooperating agencies in conducting young-of-year (YOY) surveys in selected Columbia and Snake River reservoirs.
4) Sample Zone 6 tribal commercial and subsistence fishery for exploitation estimates. Work jointly with ODFW and WDFW to estimate harvest and exploitation and characterize the commercial fishery for white sturgeon between Bonneville and McNary dam.

In addressing tasks 3 and 4, Washington Department of Fish and Wildlife will report the results of the harvest and exploitation rates, and Oregon Department of Fish and Wildlife will report YOY surveys in their respective sections of this report.

METHODS

Artificial Propagation Research

Satellite Spawning and Holding Facility Operations

CRITFC constructed a new holding and spawning facility below the McNary Dam juvenile fish sorting facility. Construction of the facility began in October of 2000 and was complete in February 2001. This site was designed to replace the holding and spawning facilities previously located at Abernathy Fish Technology Center (AFTC), which lacked the necessary water temperature regime for sexual maturation in white sturgeon (Kappenman et. al. 2001, Kappenman et. al. 2002). Our new facility is located along the Columbia River at the McNary Dam, directly below the juvenile fish sorting facility operated by the U.S. Army Corps of Engineers (USACE). It is a temporary facility, consisting of six 3 m diameter x 1.2 m deep circular tanks, a broodstock holding tank, and two egg bath tanks. It is operated using surplus water from the juvenile fish sorting facility with the cooperation of the USACE. The primary water source draws water from the juvenile separating facility. This water is drawn from the forebay upstream from McNary Dam. A secondary source is drawn from the McNary Dam tailrace water via an electric pump submerged in the river directly down the riverbank from the juvenile separating facility. Water exchange is provided at approximately 10 to 15 volumes per day and dissolved oxygen is maintained at approximately 5.0 mg/L or greater. Males and females are divided among the tanks and no more than 6 males or 2 females are placed in each tank. Broodstock are held in ambient temperature Columbia River water pumped into the tanks and are fed live juvenile suckers (*Catostomus* spp.) that are collected at various sources specifically for this purpose.

Broodstock Collection

A joint crew from CRITFC and WDFW fished for white sturgeon broodstock in McNary Reservoir in the Columbia River (Figure 1) from 11 March 2001 through 10 April 2001. All fishing took place in McNary Reservoir from statute river kilometer 473.2 to 485 (river mile 294.1 to 301.4). White sturgeon were captured using setlines fished overnight. Each setline was made up of 183 m of nylon mainline and was equipped with 40 detachable gangions snapped on approximately every 5.2 m. Gangions were approximately 46 cm long and attached to circle halibut hooks in sizes 10/0, 12/0, and 14/0. Near even numbers of each hook size were deployed, with 14 of one hook size and 13 of the other two sizes. Hooks were baited with pickled squid (*Loligo* spp.) and only rebaited when bait was missing. Each end of the line was held on the river bottom with an anchor. Anchors varied in weight and style, but most weighed approximately 14 to 17 kg. A large inflated buoy (i.e. 60 cm diameter) was attached to each anchor and the end of the setline to mark the location of each end of the line. A numbered smaller buoy (i.e. 30 cm diameter) was attached to one of the two marker buoys for individual identification. Setlines were generally pulled by hand, although the anchors were retrieved with a hydraulic winch.

Captured white sturgeon were immediately placed in a live well, or if too large for the live well (greater than 213 cm TL), placed on the deck with water flushed through the gills via an electric pump. After running a setline, all captured white sturgeon were measured for fork and total length (cm), examined for tags, tag scars, missing scutes, past biopsy scars, pectoral fin scars, and missing barbels. White sturgeon with missing scutes or tag scars were scanned with a Destron-Fearing[1] and/or an Avid[1] passive integrated transponder (PIT) tag detector. Large fish likely of sexual maturity and stressed fish were examined first. We determined sex and visually staged gonad maturity of fish ? 152 cm TL. Fish excessively stressed, as evident by excessive redness on the ventral surface, were not surgically examined and were released immediately. All fish examined for sexual maturity were PIT tagged and the 2[nd] left lateral scute was removed to indicate that a PIT tag had been implanted underneath the bony plates on the posterior margin of the head (Rien et al. 1994).

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[1] Use of trade names does not imply endorsement by CRITFC.

Determination of sex and maturity was made by surgical examination performed using an otoscope inserted through a 2-3 cm ventral incision. Classification of maturation was based on assessment of oocyte development (Chapman 1989) and methods described by Welch and Beamesderfer (1993). During the surgical examination, fish were placed ventral side up and held in place with sandbags while gills were continuously flushed with water using an electric pump. The incision was closed with two to four stitches. White sturgeon that were assessed to have potential as broodstock were immediately placed into a specialized transport tank and held on fresh river water until the fishing day's end and transported to a circular tank at the spawning and holding facility.

Broodstock maturation and spawning

Upon surgical examination and transportation to the holding facility all broodstock were kept at ambient river temperatures and monitored for sexual maturation. All holding, maturation, and spawning techniques for white sturgeon used are described in Conte et al. (1988) and Van Eenennam et al. (2001). Hand stripping procedures are used for removing male and female gametes during spawning rather than surgical operations due to the low number of fertilized eggs needed for our operations and reduced stress on fish. During maturation, males require less intensive monitoring than females. For males, the degree of maturation was subjectively ranked during the initial examination of gonad development. Later, males were randomly chosen in lots for spawning trials. Female maturation is determined using standard maturation assays performed on ovarian follicles (Conte et. al. 1988, Van Eenenmaam et.al. 2001). Ovarian follicles collected upon capture are examined for diameter, polarization index (PI), and germinal vesicle breakdown (GVBD) in the presence of progesterone. Figure 2 describes the PI and ovarian follicle maturation assay. Our samples were sent to Joel Van Eenennaam at UC Davis for PI and GVBD analyses. The spawning time or additional maturation assays to determine spawning time are calculated based on assay results and holding temperature. Generally, only females with PI's less than 0.10 are selected for spawning induction, but preference is for females with oocyte PI's of 0.06 – 0.08 and 100% GVBD response in the progesterone assay (Van Eenennaam et al. 2001). When necessary we attempt to spawn females outside these parameters, but success of these operations is improbable, and the primary impetus behind these attempts is to increase our knowledge of white sturgeon maturation.

John Day Capture, Mark and Pit Tagging

Columbia River Inter-Tribal Fish Commission captured, marked, and tagged white sturgeon in John Day Reservoir in order to perform population monitoring. The capture, mark, and PIT tag operation for John Day Reservoir was performed for nine weekly fishing periods from 27 November, 2000, through 26 January, 2001. We sampled the area from about statute river kilometer 354 to 467 (river mile 220 to 290) (Figure 3). We divided the sampling area into seven ten-mile sections in an effort to systematically sample the entire reservoir. Areas restricted from commercial white sturgeon fishing were observed and incorporated into our sampling strategy. Columbia River Inter-Tribal Fish Commission's systematic sampling and reservoir divisions differ from the strategy ODFW uses when sampling. We present Tables 1 and 2 and Figure 3 using their sampling strategy for comparative analysis when reviewing section A and D of this report.

All crews began sampling in section one and moved upriver one section each week for the first seven weeks. During the last two weeks of sampling, fishers were allowed to fish freely throughout the seven sections. We employed this strategy in an effort to mark fish throughout the entire reservoir and also to reduce the possibility of recapturing newly marked fish. Nets were checked and reset each day, with Monday being the first set day of the week and Saturday being the last pull day of the week, except when limited by severe weather or mechanical problems. Fishing operations were also adjusted to accommodate seasonal holidays during the weeks of Christmas and New Years.

Three Yakima Indian Nation (YIN) fishery technicians and three tribal commercial fishermen with crew performed all sampling operations. Each contract fisher was required to provide three crewmembers to perform marking, measuring, and tagging of white sturgeon along with any other requested data collections. Columbia River Inter-Tribal Fish Commission biologists and YIN technicians were responsible for training fishers with measuring techniques, identifying marked fish, and tag application procedures. Fishery technicians recorded all data while fishers worked up the catch according to established protocol.

Fishing was performed from commercial fishing vessels with diver gill nets. Vessels consisted of two 8 m bow pickers and one 5.5 m open boat. The length of nets fished ranged from 76 to 122 m, and mesh size was either 20.3 or 25.4 cm stretched mesh. A variety of materials were used for anchors and floats. Fishers were paid a daily boat lease rate and a set fee for each captured and processed white sturgeon recorded on the data sheets. Because fishers were rewarded on a catch rate basis they were motivated to search out areas they felt would be productive fishing sites within the pre-described boundaries. Each fisher was typically able to run 10 – 15 nets per day working daylight hours. The number of nets fished each day depended on catch rates and crew efficiency.

The standard operating procedure for processing white sturgeon collected with a gill net was as follows. White sturgeon were brought on board and removed from the gill net. All white sturgeon were examined for tags, tag scars, missing scutes, pectoral fin scars, and missing barbels. White sturgeon with missing scutes or tag scars were scanned with an Avid[1] and/or a Destron Fearing[1] passive integrated transponder (PIT) tag detector. All white sturgeon were measured to the nearest cm fork length and the 9th left lateral scute was removed to indicate year of capture was 2000 - 2001. We did not weigh fish. Fish less than 70 cm were then released. In most cases, if the fork length was equal to or greater than 70 cm and the fish did not possess a PIT tag (125 or 134 mghtz), a Destron 134 mghtz pit tag was injected into the musculature beneath the armor posterior of the head, near the dorsal midline. The second left lateral scute was also removed in order to identify a PIT-tagged fish (Rein et al. 1994). We used a biomark[1] MK5 general-purpose implanter with standard 12 gauge needles to inject PIT tags. All PIT tag

[1] Use of trade names does not imply endorsement by CRITFC.

numbers found upon examination or applied were recorded with biological information corresponding to the fish and later entered into a database maintained by ODFW. Once processed all fish were released.

RESULTS

Artificial Propagation Research

Broodstock collection

We collected twenty seven white sturgeon for broodstock trials, four females measuring 168, 171, 192, and 214 cm in fork length (FL), weighing 39, 40, 61 and 76 kg, respectively, and 23 males measuring 159 to 219 cm FL and weighing between 20 and 66 kg. We captured a total of 200 white sturgeon in 85 sets in 18 days of fishing during 5 weeks of fishing from 11 March 2001 to 10 April 2001 (Table 3). Sizes of white sturgeon captured ranged from 77 to 275 cm fork length. We performed 114 surgical examinations on fish suspected of sexual maturity to determine sex and maturity, revealing a total of 76 males and 38 females.

All white sturgeon captured and not taken as broodstock were immediately released in good condition into McNary Reservoir. All white sturgeon taken for broodstock in 2001 were returned to McNary Reservoir at the end of spawning trials. Fish were transported using the broodstock trailer, loaded into a vessel's live-well and released in middle reservoir just upstream from Hat Rock Park (RKM 483). Most of these fish had some minor weight loss while in captivity, one exhibited excessive abdominal scute wear from rubbing on the tank bottom, but all were judged to be in good condition. The average weight loss for the 23 males was 1.83 kg and the average weight loss for the 3 females not spawned was 4 kg. The absorption of eggs may account for some of the weight loss.

Broodstock spawning trials

We monitored the maturation cycles of the four females from March through June 2001. Throughout the monitoring period, oocytes of all females exhibited varying levels or a complete lack of germinal vesicle migration (Table 4). Decreasing PI and increasing GVBD were evident in 3 females, but absent in FL 168 female. Throughout the maturation period, only the 192 FL fish showed PI levels and GVBD breakdown indicative of a potential successful spawning (Table 4). On 29 May, we injected a random lot of 6 males with leutinizing hormone releasing hormone (LHRH) and successfully collected milt from 2 of these males on 30 May. On 1 June, approximately 36 hours after the initial LHRH injection, we collected eggs from female FL 192. Gametes from the female were fertilized with gametes from two males, and fertilized eggs were transferred AFTC for hatching.

The PI for female FL 168 showed arrested ovarian follicle maturation, thus no attempt was made to initiate spawning. The PI's for females FL 214 and FL 171 on 31 May 2001, were 0.13 and 0.15 respectively. We determined that another series of assays would be performed in three to four weeks. In mid-June, temperatures in McNary Reservoir began to range from 16º to 18º C, with the daily high temperature bordering on the upper known spawning parameters for white sturgeon (Figure 4). Weather forecasts for the week beginning 18 June predicted high temperatures that would likely elevate water temperatures to 20º within days. Though we processed no new assay information to confirm the spawning readiness of the two females, we decided to initiate spawning as soon as possible. On 19 June, after injecting all males with LHRH, we attempted to collect milt from the remaining 17 males resulting in 3 males producing milt. On June 20th, we injected the two remaining females with LHRH. Neither female underwent ovulation. Early histological examination of ovarian follicles showed that female FL 214 appeared to have undergone follicular atresia (absorption of ovarian follicles), while female FL 171 follicles appeared normal but no ovulation occurred.

John Day Capture, Mark and PIT Tagging

Effort and White Sturgeon Catch

A total of 3,019 white sturgeon were captured in 1,537 gillnet sets. We marked 2,515 of these fish with the 9th left scute removal pattern described in the methods section. Of the 3,019 captured, 263 were less than 70 cm (approximately 9 percent), 2,750 (approximately 91 percent) were 70 cm or greater, and 6 fish were not measured. We applied pit tags to 1,971 white sturgeon, with 1,967 of these tags applied to white sturgeon equal to or greater than 70 cm, (four fish were tagged but not measured). White sturgeon captured ranged from 34 to 253 cm FL (Figure 5), with a mean length of 97 cm.

The total white sturgeon catch consisted of 2,823 commercial sublegal size (less than 48 inches or 121.92 cm), 141 commercial legal size (between 48 inches and 60 inches or 121.92 cm and 152. 4 cm) and 49 over legal size (greater than 60 inches or 152.4 cm). A total of 2,716 white sturgeon between 70 and 166 cm, the size range used by ODFW in the past to estimate population abundance, were captured by CRITFC.

Distribution, Marking, and Mark Recovery

We captured white sturgeon from all seven sampling sections throughout John Day Reservoir. Section 5 had the highest number of fish caught, with a total of 1130 white sturgeon in 343 sets[1]. This accounted for 37% of the total catch from 20% of the total sets. Sampling section four was next highest with 471 fish caught in 226 sets (15% of the catch from approximately 15% of the sets). Section one had the least catch and effort with 92 fish in 168 sets (3 % total catch and 11% total sets). Sections two and seven had similar catch numbers with 268 (~ 9 %) white sturgeon caught in 166 (~11 %) sets, and 273 (~9%) white sturgeon caught in 181 (~12%) sets, respectively. Sections three and six had similar catches but less equal effort with 390 (~13%) and 381 (~13%) white sturgeon caught in 255 (17%) and 168 (~11%) sets, respectively.

[1] Some samples from total catch were missing location data and not included in this summary.

The total mean white sturgeon catch per set for all sets combined was 2.0. The highest mean catch rate per set by week was 3.8, and occurred in week five when fishers were fishing in section five. The lowest mean catch per set by week was 0.6 and occurred in week one when fishers were mandated to fish in section one. All of the 3,019 white sturgeon captured and handled in John Day Reservoir were released alive. Abundance estimates for John Day Reservoir are reported by ODFW in section A of this report.

DISCUSSION

Artificial Propagation Research

The 2001 spawning season marked the first successful spawning of wild white sturgeon for this project. Broodstock collection efforts for 2001 showed the best results of record over the last three years (Kappenman et al 2001, 2002). More broodstock were collected in a shorter time period, albeit with an increased effort, than in any previous fishing year, and the number of gravid females collected was higher than in any of the last two years efforts. Of special note, leading to the successful spawning, was the taking of a female near spawning maturity. This is the first time we have taken a female at this stage of development. Generally, fish taken during the collection period and in the area fished, tended to be in early stages of oocyte maturation and have PI's of 0.15 or greater.

We successfully collected and fertilized eggs from female FL 192 with milt taken from two male white sturgeon creating two paternal crosses. The fertilized eggs were taken to AFTC for hatching and rearing. We attempted to spawn females Fl 171 and 214 but were unsuccessful. Oocytes for both of these females as of May 31 had not developed as needed for successful spawning. In mid-June, high water temperatures, attributed to low run-off from a light snow pack and unseasonably warm summer weather, began to exceed the known spawning temperature parameters for white sturgeon. Due to the high temperatures, on June 17 we attempted to induce spawning even though success was unlikely. Although it is likely that oocytes of both females continued to develop in the two weeks between the spawning attempt and our last maturation cycle, it is unlikely that they ever reached maturation. It is also possible that temperature-induced atresia may have already been occurring in female FL 214 prior to the spawning attempt. We speculate that high temperatures in McNary Reservoir the week following our unsuccessful spawning attempt would have disrupted oocyte development had we waited any longer to induce spawning (Figure 4). We consider high water temperatures to be the cause of the failed spawning attempts, but we can only speculate on what might have occurred under ideal conditions

Our new spawning facility at McNary allows access to normative river temperatures and is a success in respect to the successful spawning we performed this year. The facility allows us to hold mature males throughout the spawning season and appears to give us excellent access to milt when needed. As positive as the improvement appears, it still does not provide the ideal conditions for successful spawning on a no-fail-basis. Though we are no longer hampered by the static cool well water temperatures present at AFTC, we remain unable to regulate temperature as is needed to ensure successful maturation and spawning on a yearly basis. The difficulty is evident in our inability to mature late-developing or early-captured pre-spawning females (those with oocytes with a high PI and low percentage GVBD) over a several month period and bring them to spawning maturity. Though we were successful at spawning fish in 2001 and 2002 (unpublished results), an alternative spawning and holding facility or alternative capture methods may be necessary to guarantee success of any expanded artificial propagation operation.

Our success with spawning white sturgeon at the McNary spawning and holding facility during the 2001 broodstock season confirmed our belief that water temperatures were in fact restricting our ability to spawn wild white sturgeon at AFTC. We have developed and refined collecting and holding techniques and developed a back-up strategy to use fish purchased from a private aqua-culture firm that will likely allow us to meet the long-term goals of this project. However, strategies that employ taking fish directly off the spawning grounds, especially females that are likely to be further along in oocyte maturation, should be developed. Recent genetic evidence relative to the scale of our project's plan indicates that collecting mature broodstock below Bonneville, The Dalles, and John Day dams may present relatively little genetic risk to populations above McNary Dam, (Paul Anders and M.S. Powell, February, 2001, memo to 19860500 cooperators). Collecting broodstock from these areas might yield a higher success rate and potentially lower project costs.

John Day Capture, Mark and Pit Tagging

The 2001 tagging operation performed by CRITFC and ODFW is the third historic effort to determine population abundance and structure in John Day Reservoir. It follows up on the 1996 effort performed by CRITFC and ODFW and the 1990 estimate performed solely by ODFW. We provide a summary of CRITFC's tagging efforts here, however ODFW reports the results of recapture efforts and abundance estimates. The information this cooperative effort yields will be used to update population estimates and structure and to determine the effect of mitigative activities on white sturgeon between John Day and McNary dams.

PLANS FOR UPCOMING YEARS

Broodstock spawning operations and marking/tagging operations for The Dalles Reservoir, along with all other completed activities, will be reported in the Annual Report for period April 2002 through March 2003. We will be marking and tagging white sturgeon in Bonneville Reservoir beginning in late November 2002 and ending in early February 2003. We plan to PIT tag and scute mark approximately 3,000 white sturgeon during this effort. We plan on scute marking and PIT tagging approximately 12,000 of our 2002 brood for release in Rock Island Reservoir in late spring of 2003. We will continue developing a program to monitor the success of juvenile white sturgeon releases. We continue to develop plans and strategies that will allow us to collect and spawn broodstock in the most efficient and productive manner.

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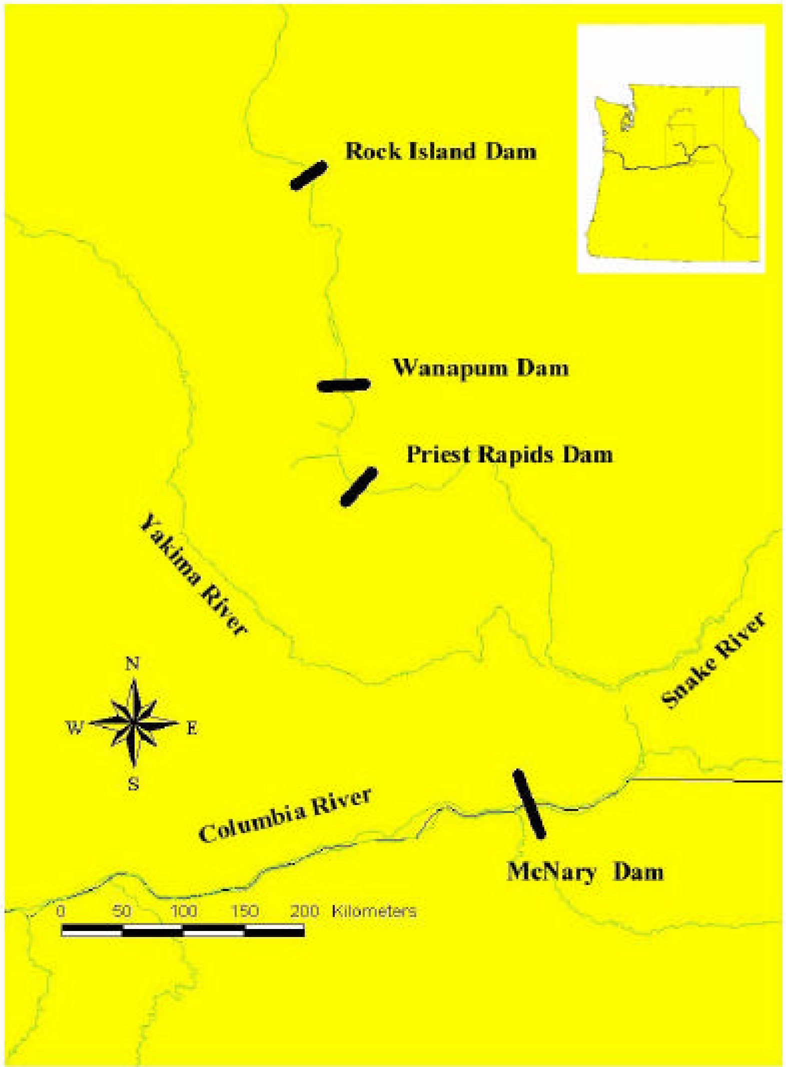


Figure 1. Map of McNary Reservoir in the Columbia River where all white sturgeon broodstock collection efforts were performed from 11 March 2001 to 10 April 2001.

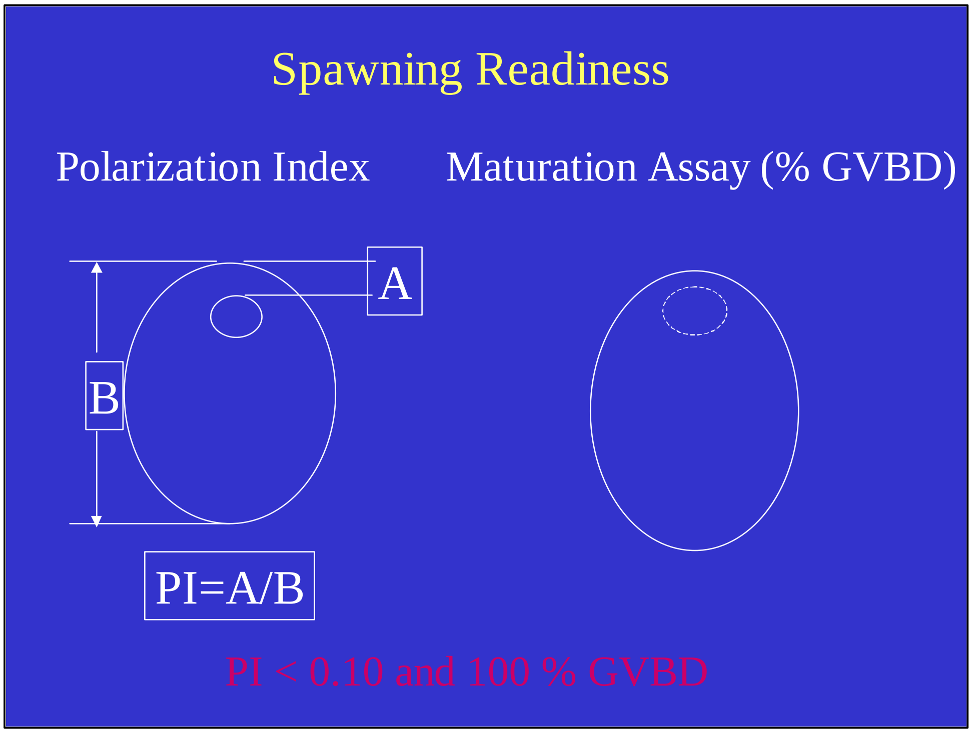


Figure 2 - To monitor egg development and determine spawning readiness, two pieces of information are needed. The first is polarization index or PI (Conte et al. 1987). The PI is the ratio of the distance from the top of the nucleus to the animal pole to the animal-vegetal oocyte diameter. The second is the percent of ovarian follicles that undergo germinal vesicle breakdown in the presence of progesterone. This is called the GVBD or maturation assay. A female is hormonally-induced to ovulate when the PI is <0.10 and 100% GVBD occurs in the maturation assay (Van Eenennaam et al, 2001) (Figure provided by Molly Webb, OSU).

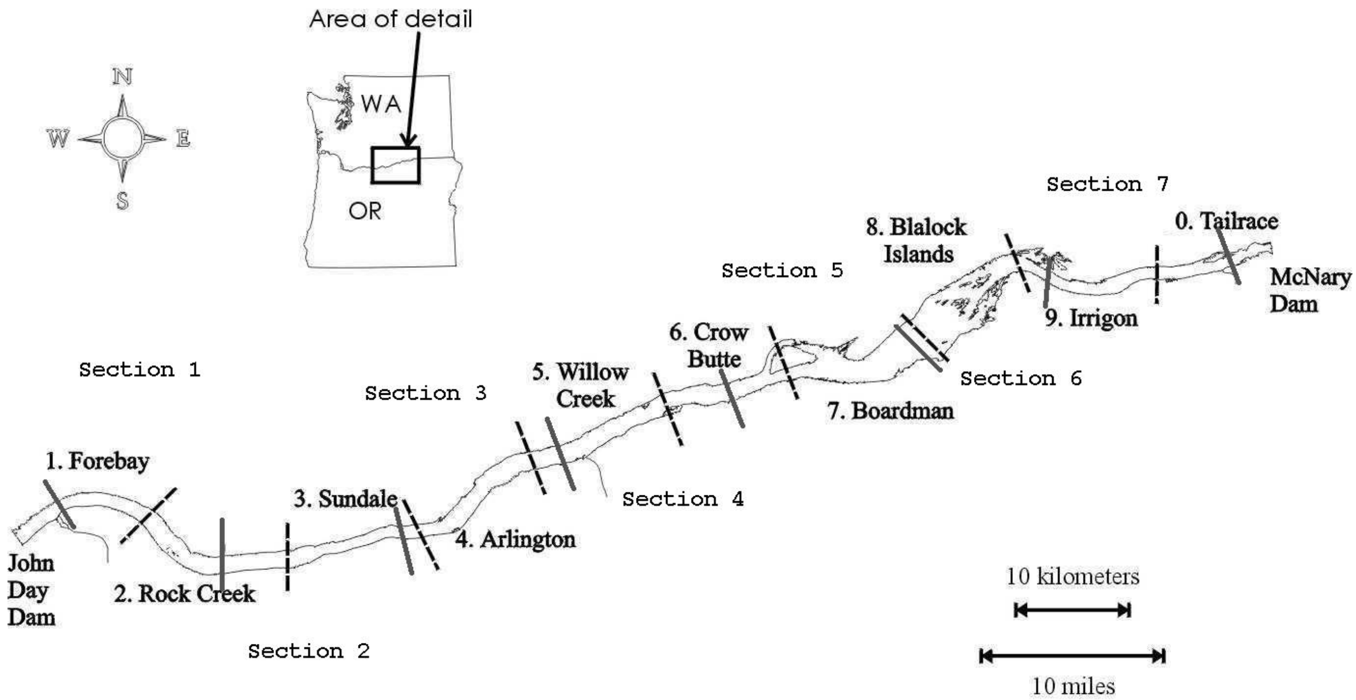
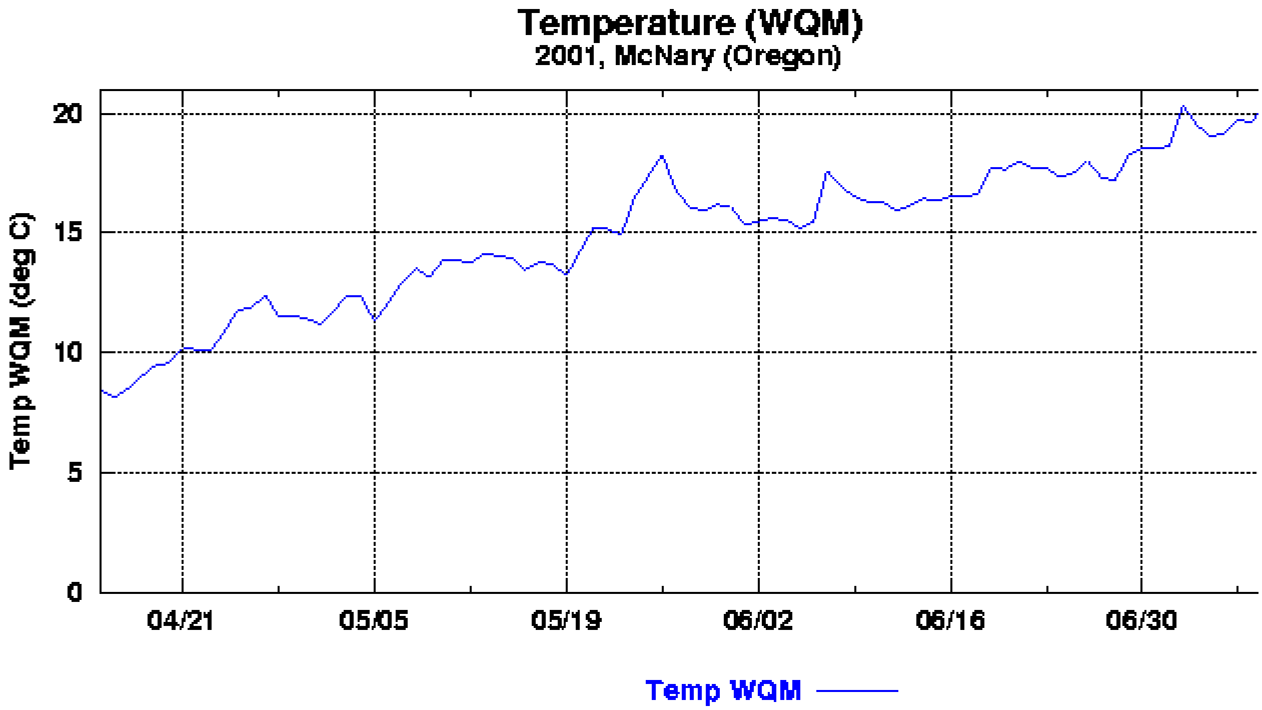


Figure 3 - Map of Columbia River from John Day Dam to McNary Dam showing area sampled by CRITFC and ODFW. CRITFC section boundaries are shown as solid lines and ODFW section boundaries are shown as dashed lines. Scale and boundaries are approximate.

Figure 4- Temperature profile of McNary Forebay, the water source at the McNary Satellite Spawning Facility.



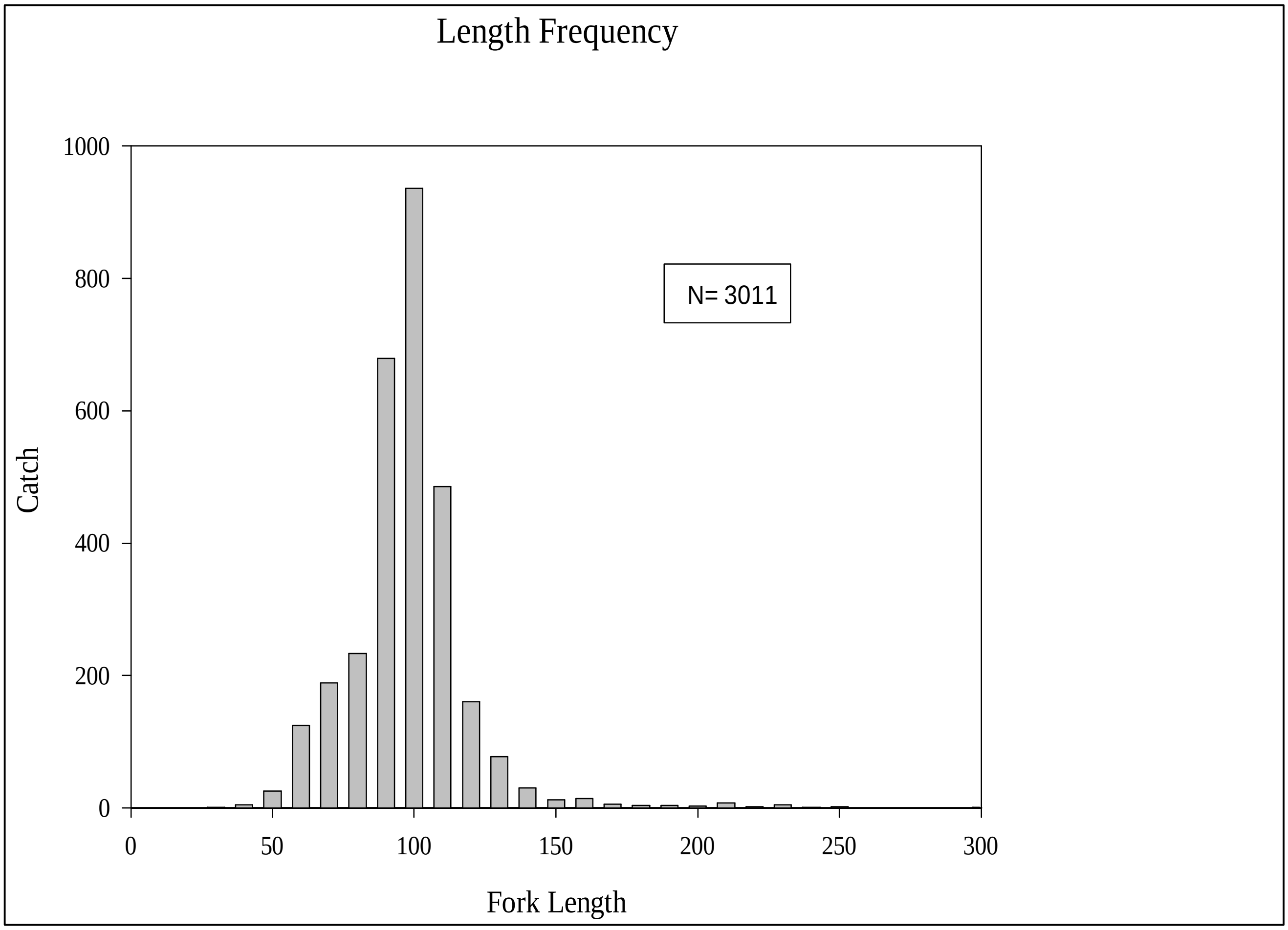


Figure 5. Length – frequency distribution (10 cm increments) for white sturgeon collected by CRITFC using gill nets in John Day Reservoir November through January 2001[1].

[1] Length – frequency sample number is not equal to total catch, length data for all fish was not available.

Table 1. Columbia River Inter-Tribal Fish Commission catches of white sturgeon with gill nets in John Day Reservoir from 27 November, 2000 through 26 January, 2001. Shows catch by week, river mile, ODFW section sampling strategy, number of sets, catch per set and total catch (table provided by Michele Hughes, ODFW).

	Section	1	2	3	4	5	6	7	8	9	10	11	Total		
	River Mile	215.6-224.5	224.6-232.0	232.1-239.5	239.6-247.0	247.1-254.5	254.6-262.0	262.1-269.5	269.6-277.0	277.1-284.5	284.6-292.0	292.1-292.5	#sets	catch /set	total
Catch															
Week 1	11/27-12/1	2	90										155	0.6	92
Week 2	12/4-12/8		1	249	1								178	1.4	251
Week 3	12/11-12/15				219	29							152	1.6	248
Week 4	12/18-12/22					39	374						183	2.3	413
Week 5	12/26-12/29			1			171	331	74				153	3.8	577
Week 6	1/2-1/5								217	145			153	2.4	362
Week 7	1/8-1/12									259	20		194	1.4	279
Week 8	1/15-1/20			10	31	2	225	166	19				210	2.2	453
Week 9	1/20-1/26				82	32	105	107					159	2.1	326
Total		2	91	260	333	102	875	604	310	404	20	0	1537	2.0	3001[2]

[2] Some samples from total catch were missing location or catch date data and not included in this table.

Table 2. Columbia River Inter-Tribal Fish Commission catches of white sturgeon with gill nets in John Day Reservoir from 27 November, 2000 through 26 January, 2001. Shows effort by week, river mile, ODFW section sampling strategy, and total number of sets (table provided by Michele Hughes, ODFW).

Effort by week/section													
	Section	1	2	3	4	5	6	7	8	9	10	11	Total
	River Mile	215.6 - 224.5	224.6 - 232.0	232.1 - 239.5	239.6 - 247.0	247.1 - 254.5	254.6 - 262.0	262.1 - 269.5	269.6 - 277.0	277.1 - 284.5	284.6 - 292.0	292.1 - 292.5	
Effort													
Week 1	11/27-12/1	25	130										155
Week 2	12/4-12/8		2	173	3								178
Week 3	12/11-12/15				144	8							152
Week 4	12/18-12/22		1	1		26	155						183
Week 5	12/26-12/29						40	93	20				153
Week 6	1/2-1/5								86	67			153
Week 7	1/8-1/12									155	39		194
Week 8	1/15-1/20			17	27	1	82	70	13				210
Week 9	1/20-1/26				66	10	36	46	1				159
Total		25	133	191	240	45	313	209	120	222	39	0	1537

.

Table 3. Summary of Columbia River Inter-Tribal Fish Commission white sturgeon broodstock capture efforts showing number of days fished, number of setline sets, number of white sturgeon captured, and number of broodstock kept for the fishing period from 11 March 2001 to 10 April 2001 in McNary Reservoir.

Reservoir	McNary	
Days fished	18	
Number of sets	85	
White sturgeon captured	200	
Broodstock kept	Males 23	Females 4

Table 4 – A summary of standard oocyte maturation test results for four white sturgeon held for the 2000 spawning season showing females identified by fork length (FL) and/or reservoir, date oocytes were sampled, average ovarian follicle diameter, oocyte polarization index, and percent germinal vesicle breakdown of a sample.

Female Identity (By Fork Length)	Sample Date	Average Ovarian Follicle Diameter	Oocyte Polarization Index	Percent Germinal Vesicle Breakdown
168	3/13/01	3.22	0.1905	-
	5/31/01	3.23	0.191	-
214	3/19/01	3.5	0.1505	-
	5/7/01	3.44	0.1481	0
	5/31/01	3.56	0.1348	67
171	3/20/01	3.52	0.1719	-
	5/31/01	3.42	0.1582	67
192	3/26/01	3.51	0.0966	-
	5/7/01	3.51	0.0930	20
	5/28/01	3.58	0.0911	93

WHITE STURGEON MITIGATION AND RESTORATION IN THE COLUMBIA AND SNAKE RIVERS UPSTREAM FROM BONNEVILLE DAM

ANNUAL PROGRESS REPORT

APRIL 2001 - MARCH 2002

REPORT E

Develop artificial propagation techniques and protocols in preparation for supplementation of selected white sturgeon populations.

This report includes: A summary of activities and results of the 2001 white sturgeon spawning season.

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CONTENTS

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ABSTRACT

The spawning of a single female white sturgeon with two males resulted in approximately 104,000 eggs being incubated. Hatch success was 44%, resulting in an estimated 46,000 yolk sac fry. Approximately 32,000 fry, a 69% success rate, accepted a commercial diet. At approximately five months of age an outbreak of white sturgeon irido virus occurred. The outbreak resulted in an estimated 90% mortality over a six-month period. An estimated 7% (2000) of the juvenile sturgeon being reared in raceways were lost to great blue heron *Ardea herodias* predation. Overall survival of 3% or approximately 900, eliminated the possibility of having any releases from the 2001 spawning. To minimize the potential of future virus outbreaks, changes in culture methods have been identified for implementation. To reduce handling and its related stress the following methods will be used: no sample weights will be taken, tank stocking protocols will be used which minimize the need to transfer fish, and grading of juveniles will not occur. To protect sturgeon from future bird predation a new net structure will be constructed over the raceways. This structure will totally enclose the raceways, with netting (10.16 cm square) supported 4 m above the water surface and covering the sides of the structure. At ground level 1 m high, 1.25 cm mesh, will be installed to restrict potential predation by otter and mink.

INTRODUCTION

This annual report describes work completed by the U.S. Fish and Wildlife Service, Abernathy Fish Technology Center (AFTC), as part of the Bonneville Power Administration white sturgeon *Acipenser transmontanus* Research Project 86-50. The AFTC was responsible for portions of tasks related to Objective 1: develop, recommend, and implement actions that do not involve changes to hydrosystem operation and configuration to mitigate for lost white sturgeon productivity in impoundments where development and operations of the hydrosystem has reduced production. These tasks included assisting in spawning wild white sturgeon to produce age-specific cohorts and evaluating the feasibility of using artificial propagation as a mitigation tool to rebuild declining stocks in the mid-Columbia River.

METHODS

Sturgeon Culture

Rearing Facility

Incubation and early rearing occurs in a building that has photocell controlled lighting. Single pass well water at 12.5^{o}C is utilized for both incubation and rearing. Twelve McDonald type hatching jars (7 L) plumbed in fiberglass troughs are used for incubation. Twenty-four circular fiberglass tanks (0.7 m diameter, 4 L/min flow) and 16 circular fiberglass tanks (1.2 m diameter, 12 L/min flow) are used for early rearing. Water is supplied to all circular tanks via spray bars.

Outside rearing continues in 16 circular fiberglass tanks (3.05 m diameter, 23 L/min flow, single pass well water 12.5^{o}C) and 6 concrete raceways (2.4 m x 22.8 m, 1700 L/min flow, re-use well water system, variable temperature). To protect against bird predation 10.16 cm square plastic bird netting was supported 1 m above raceway walls and water surface.

Incubation

Fertilized eggs were transported to AFTC from the Columbia River Inter-Tribal Fish Commission's McNary Dam Facility (Kappenmen and Parker, in press), 4 hour travel time, in plastic fish transport bags. Eggs were packaged in river water and bags were filled with oxygen. The packaged eggs were transported in ice chests. To maintain temperature during transport and prevent eggs from receiving temperature shock, ice packing was attached to the interior of the lids.

Upon arrival the transport bags containing the eggs were floated in the incubation water source (12^{o}C well water). This allowed eggs to slowly acclimate to the new water temperature. After approximately 30 minutes eggs were transferred to McDonald type hatching jars, 300 to 850 ml of eggs per jar. Initial water flows were 2.6 - 2.8 L/min per jar. After embryos had developed past the closure of the neural tube stage (Conte et al. 1988), flows were increased to 6.4 -7.2 L/min. Incubation jars and troughs that captured hatching larvae were darkened with black plastic.

Rearing

At 14 to 16 days post fertilization (dpf), larvae were stocked into the 0.7 m tanks at approximately 2,000 larvae per tank. At 22 dpf feed (Bio-Oregon[1] starter #1) was presented in small amounts to aid in imprinting larvae to the scent of the commercial ration (Conte et al. 1988). External feeding started at 27 dpf, although rations were not totally consumed, rations of 7.5% body weight were provided via 24 hour aquarium feeders to insure fry and feed contact. Rations were reduced to 5% body weight at 104 dpf, fry were actively feeding, reducing the amount of uneaten feed. Feed ration amounts were calculated based on sample weights taken at 10 to 14 day intervals. To prevent rejection when diet particle size was increased, larger particles were gradually mixed into the current diet over a period of days. Transition from starter #1 to #2 occurred over 28 days. The three other transitions (starter #2 to #3, #3 to 1 mm pellet, and 1 mm to 1.3 mm pellet) occurred over 5 days.

By mid-July, 46 dpf, it was necessary to reduce the density of white sturgeon per tank. To accomplish this 500 - 800 fry were left in each of the 0.7 m tanks and the extra fry were transferred into 1.2 m tanks (~2,000 fry/ tank).

In early August, 61 - 69 dpf, all white sturgeon were graded using a 5.16 mm bar grader. Smaller sturgeon were segregated into separate tanks to reduce the loss of the slower growing sturgeon. Tank densities were approximately 300 juveniles per 0.7 m tank and 1,400 – 2,100 juveniles per 1.2 m tanks.

In late August, 82 - 90 dpf, white sturgeon growth required moving larger fish to outside 3.05 m tanks. The tanks were covered by 70% shade cloth, and feed was provided by 24 hour belt feeders. Since a bar grader of the correct size was not available, white sturgeon were visually hand graded for this transfer. Tank densities were approximately 250 juveniles per 0.7 m tank, 500 – 1,000 juveniles per 1.2 m tanks, and 2,000 juveniles per 3.05 m tanks.

In late October, 140 - 146 dpf, white sturgeon were graded using a 15.08 mm bar grader, transferring the larger juveniles to concrete raceways. Tank densities were 500 – 1,400 juveniles per 3.05 m tanks and 7,900 and 8,200 per raceway.

White Sturgeon Irido Virus

In early November the 180 dpf white sturgeon were diagnosed with White Sturgeon Irido Virus (WSIV), for which there is no known treatment. Once identified, culture protocols were changed as follows: sample weights were no longer taken (to reduce handling stress); visibly

[1] Use of trade names does not imply endorsement by USFWS

infected juveniles were removed; and mild salt baths were given to reduce stress from secondary infections. The raceways were treated with 1 ppt NaCl on January 11, 16, and 21 (163 - 173 dpf). Each treatment required 636 kgs of NaCl be added to the re-use system. The 3.05 m tanks were treated 7 times, 1 ppt for one hour every third day, from January 11 to February 1 (163 - 184 dpf).

RESULTS

Sturgeon Culture

Incubation

At 6 dpf, post fertilization egg viability was much lower in the second take, 44% viable compared to 81% from the first take. A difference was also noted in post fertilization egg viability between the two half-sibling families, 60% and 80%. The high number of non-viable eggs created an elevated level of fungus *Saprolegnia* growth. Control by removing infected eggs daily proved unsuccessful as fungus mats still formed. Egg hatch occurred from 10-15 dpf. Approximately 46,000 eggs hatched successfully from the estimated 104,000 eggs transported to AFTC.

Rearing

By 43 dpf, an estimated 69% of the sturgeon fry had accepted the commercial diet, resulting in 32,000 fry. Overall survival through late October, 145 dpf, was 90.6% (29,000 juveniles). In Table 1 weights are given for the juvenile sturgeon during the rearing season.

White Sturgeon Irido Virus

On November 8 (160 dpf) the U.S. Fish and Wildlife Service Idaho Fish Health Center staff verified the presence of WSIV. Using histological examination, 28 out of 60 juveniles sampled on September 18 (109 dpf) were positive for WSIV. Dr. Joseph M. Groff, U.C. Davis, confirmed the iridoviral infection in juvenile sturgeon sent December 12. The WSIV caused approximately 90% mortality (Figure 1), with mortality peaking at 2.3% per day (Figure 2).

Although 1 ppt salt baths were applied there were no indications that these treatments were beneficial. Post treatment secondary fungus infections were still present with many juveniles having visible fungus growth in the nares.

In addition to the mortality caused by WSIV, heavy predation by great blue herons *Ardea herodias* occurred. Approximately 2,000 white sturgeon (7%), were lost to blue herons feeding through the existing bird netting. The remaining 900 white sturgeon (3%), would be insufficient for any future year class release.

Table 1. Weight of white sturgeon reared on 12°C well water at the Abernathy Fish Technology Center during the 2001-rearing season. (As the rearing season progressed the range in size increased)

Days post fertilization (dpf)	Weight (g)
13	0.03
23	0.04
34	0.09
44	0.19
55	0.39
68	0.82
82	1.63
96	2.2 – 3.7
110	4.0 – 6.2
124	5.7 – 8.3
138	6.4 – 11.3
152	6.5 – 11.8

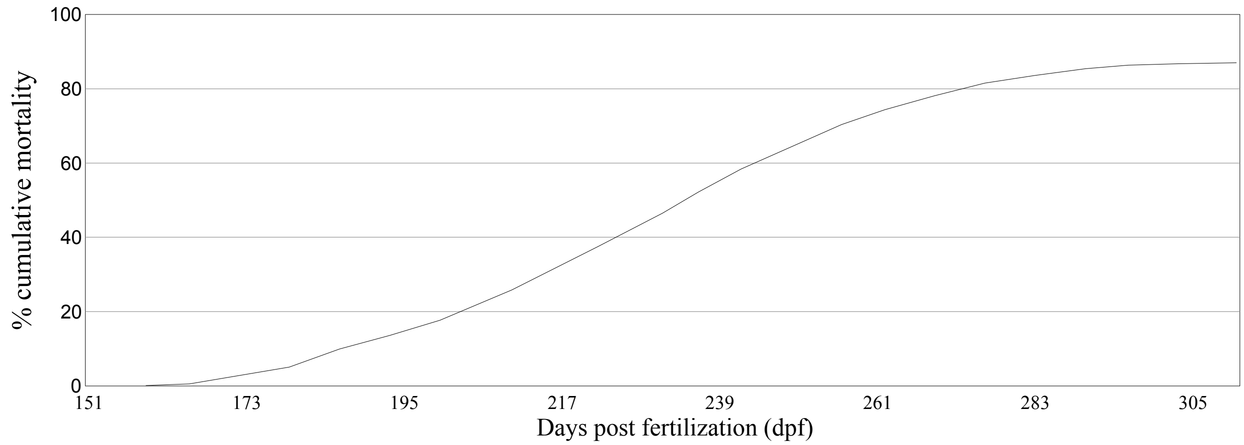

Figure 1. Percent cumulative mortality resulting from an outbreak of white sturgeon irido virus in 29,000 juvenile white sturgeon, Abernathy Fish Technology Center, November 2001- March 2002.

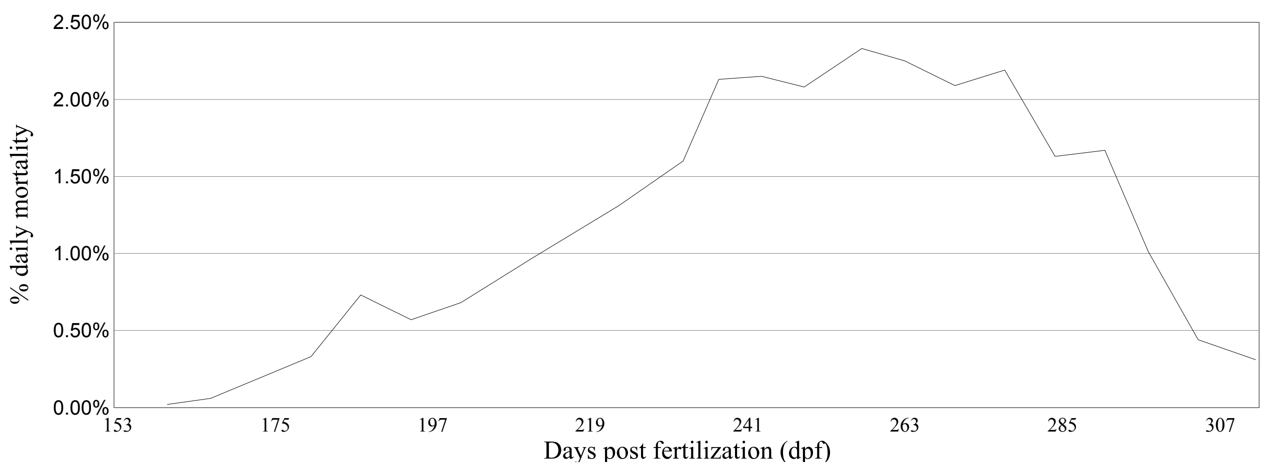

Figure 2. Percent daily mortality resulting from an outbreak of white sturgeon irido virus in 29,000 juvenile white sturgeon, Abernathy Fish Technology Center, November 2001-March 2002.

DISCUSSION

The culture of white sturgeon juveniles at AFTC was successful; eggs were incubated, hatched, larvae were started on a commercial diet, and 29,000 juveniles were produced exceeding the production goal of 22,000 sub-yearling juveniles. The low hatch rate (44%) was most likely related to poor quality of the eggs. Water temperature during spawning was unseasonably high (17^{o}C) and may have negatively affected egg quality. The difference in post fertilization egg between the two half-siblings families (60% and 80%) seems most likely due to genetic differences between the males.

The white sturgeon irido virus outbreak demonstrated that, for the project to be viable, future outbreaks must be avoided. Jack Siple, Sturgeon Hatchery Manager for the Kootenai Tribe of Idaho, visited AFTC on February 27, 2002 to make recommendations on preventing future outbreaks of WSIV. He recommended that the sturgeon be treated as if the virus was always present. Handling stress should be minimized. If sturgeon are stressed by sampling, etc. it was recommended that fish be destroyed rather than returned to the population. Mr. Siple recommended a stocking plan that reduced white sturgeon moves to 2 to 3 moves from hatch to yearling, compared to the 4 to 7 moves that occurred during the 2001 rearing. These recommendations will be incorporated into the culture of the 2002 spawning.

WSIV is a threat to successful white sturgeon supplementation and its use as a restoration tool. More research is needed to investigate: conditions that cause outbreaks, treatments to reduce mortality, and methods to identify WSIV presence prior to an outbreak.

The current predation netting is not effective and we plan to construct a new net structure. This structure will totally enclose the raceways, with netting (10.16 cm square) supported 4 m above the water surface and covering the sides of the structure. At ground level 1 m high, 1.25 cm mesh, will be installed to restrict potential predation by otter and mink.

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WHITE STURGEON MITIGATION AND RESTORATION IN THE COLUMBIA AND SNAKE RIVERS UPSTREAM FROM BONNEVILLE DAM

ANNUAL PROGRESS REPORT

APRIL 2001 – MARCH 2002

Report F

Develop methods to determine sex of white sturgeon in the Columbia River using plasma, urine, and mucus sex steroid and calcium concentrations

and

Determine how reproductive plasma, urine, and mucus steroid and calcium levels vary at different stages of maturation to develop predictive indices for the timing of white sturgeon maturation

This report includes: Progress update on the development of methods to determine and distinguish sex and stage of maturity in wild white sturgeon.

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ACKNOWLEDGMENTS

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ABSTRACT

During 1 April 2001 through 31 March 2002, Oregon State University researchers worked on the development and optimization of a method to determine sex and stage of maturity using blood plasma, urine, and mucus indicators. Biological samples from white sturgeon in the Columbia River basin over the legal size (caught by gill net and sport-fishers, referred to as oversize fish) were collected. The samples were analyzed and combined with samples collected and analyzed in 2000-2001. White sturgeon had sex- and maturity-specific levels of plasma steroids and calcium, as well as fork length. Discriminant function analysis (DFA) revealed that plasma testosterone (T), estradiol (E2) and calcium (Ca^{2+}) as well as fork length (FL) led to the correct classification of 53 and 80% of all (fishery and oversize fish combined) females and males, respectively. These same variables led to the correct classification of 48, 64, 87, and 85% of all immature females, immature males, maturing females, and maturing males, respectively. In the classification of fishery and oversize fish separately by sex, 82 and 68% of the fishery females and males, respectively, were correctly classified using plasma T and E2, while 73 and 86% of the oversize females and males, respectively, were correctly classified using plasma concentrations of T, E2, and Ca^{2+} and FL. Plasma T and E2 plus FL led to the correct classification of 61, 44, 83, and 92% of the oversize immature females, immature males, maturing females, and maturing males, respectively. The preliminary DFA using urine sex steroids in oversize sturgeon led to the correct classification of 59 and 90% of the females and males, respectively, and 100, 33, 80, and 100% of the immature females, immature males, maturing females, and maturing males, respectively. Plasma cortisol levels were elevated in oversize white sturgeon captured by both gill net and the catch-and-release sport fishery below Bonneville Dam. The time a fish was on-line in the sport fishery was positively correlated with plasma cortisol concentration.

INTRODUCTION

This annual report describes progress of Oregon State University (OSU) on the Bonneville Power Administration funded Project 86-50 – White Sturgeon Restoration and Enhancement in the Columbia and Snake Rivers Upstream from Bonneville Dam. This report covers the period of 1 April 2001 through 31 March 2002.

During this reporting period, OSU worked on one task related to Objective 4 of the common objectives listed in the multi-agency project. Objective 4 involves assessment of losses to white sturgeon production due to development, operation, and configuration of the hydrosystem. Specifically, the task was to describe the maturation cycle for white sturgeon, develop methods to determine sex of white sturgeon by measuring plasma, mucus and urine steroid and plasma calcium (Ca^{2+}) levels, and determine how reproductive plasma, mucus and urine steroid and plasma Ca^{2+} levels vary at different stages of maturation to develop predictive indices for the timing of maturation.

METHODS

Collection of Fish

Paired gonad, blood, urine, and mucus samples were collected from sturgeon over the legal size limit (> 137-cm fork length (FL), herein referred to as oversize fish) below Bonneville Dam in June and July of 2001 with the help of Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife personnel. Fish were captured by gill net and taken from cooperating sport-fishing guides. Individual fish were marked with spaghetti tags, scute marks, and passive integrative transponder (PIT) tags as described in Rien et al. (1994). The mean (± SE) FL of these fish (n=76) was 212 ± 3 cm.

White sturgeon from the commercial, tribal, and recreational fisheries in the Lower Columbia River (John Day, The Dalles, and Bonneville reservoirs, and the unimpounded stretch below Bonneville Dam) were sampled at fish processing facilities in February and March of 2002. It was not possible to collect urine and mucus from fish at the processing facilities. Blood and gonadal tissue were collected from a total of 76 fish within the legal size limit (96- to 137-cm fork length, herein referred to as fishery fish). Gonadal histology has not been completed for these fish, hence they will be included in the discriminant function analysis (DFA) in the 2002-2003 Annual Report.

Collection of Biological Samples and Gonadal Histology

Gonadal tissue was collected following the protocol of Webb (1999) and stored in phosphate-buffered formalin. Gonadal tissue was embedded in paraffin, sectioned at seven µm, and stained by hematoxylin and eosin (Luna 1968). Slides were examined under a compound scope (Carl Zeiss, 10x-100x), and the germ cells were scored for stage of development according to the protocol of Van Eenennaam and Doroshov (1998). For development of the DFA model, Stage 1 (differentiation of testis and ovary) and Stage 2 (proliferation of spermatogonia and endogenous growth of the oocyte) fish were considered "immature", while males in Stages 3 - 6 (onset of meiosis through spermiation) and females in Stages 3 - 7 (early vitellogenesis through ovulation) were considered "maturing". The term "immature" is used to represent the reproductive state of the fish at the time of sampling and is not meant to connote not having reached first maturity (i.e., an immature fish may have reached first maturity but is in the resting phase of the reproductive cycle).

Blood was collected from the caudal veins with a heparinized vacutainer. The plasma was separated by centrifugation and stored at -80°C until steroids were extracted and analyzed by radioimmunoassay (RIA) and Ca^{2+} analyzed spectrophotometrically. Urine was collected from the urogenital pore using a plastic disposable pipet. Mucus was collected from the ventral side of the fish using a metal spoon used for weighing chemicals. The urine and mucus were placed in separate 2 ml vials and stored at -80°C until steroids were extracted and analyzed by RIA. The mucus scraper was cleaned between fish using ethanol. Fork length of each fish was measured (± 0.5 cm).

Play time was determined for each fish caught by sport fishers in the catch-and-release sport fishery. Play time was the time a fish was hooked to when the fish was brought on board the boat. A blood sample was taken within 5 minutes of landing each fish.

Radioimmunoassays and Plasma Calcium Measurements

The steroids testosterone (T), 11-ketotestosterone (KT), and estradiol (E2) were extracted from plasma and measured by RIA following the method of Fitzpatrick et al. (1987) and modified by Feist et al. (1990). The average recovery efficiencies for T, KT, and E2 were 86, 84, and 76%, respectively. Plasma cortisol was also measured in oversize fish caught below Bonneville Dam following the protocol of Foster et al. (1974) and modified by Reddington et al. (1984).

The steroids in urine were unconjugated (sulfate and glucuronide groups removed) prior to RIA following the protocol of Scott and Canario (1992). To isolate the sulphated steroids, 20 µl of urine was incubated with 2.5 ml of trifluoroacetic acid:ethyl acetate (1.4:100, v/v) for 18 hours at 45°C. Following the incubation, the solvents were evaporated under a stream of nitrogen at 45°C and reconstituted in assay buffer. To unconjugate the glucuronide group, 50 µl of urine was incubated overnight at 37°C with 500 µl of sodium acetate buffer (pH 5.0) plus 15 µl of snail juice (containing 2000 I.U. glucuronidase activity). The hydrolysed steroids were extracted with 3 ml of diethyl ether following the method of Fitzpatrick et al. (1987) and modified by Feist et al. (1990). This fraction contained both free and glucuronidated steroids. The average extraction efficiencies for T, KT, and E2 in urine were 86, 79, and 87%, respectively.

A 0.1 g aliquot of mucus was combined with 900 µl of 20% ethanol, vortexed, allowed to sit for 30 minutes, and extracted with 8 ml of diethyl ether following the method of Fitzpatrick et al. (1987) and modified by Feist et al. (1990) prior to RIA. The average extraction efficiencies for T, KT, and E2 in mucus were 74, 70, and 72%, respectively.

All steroid assay results were corrected for recovery, and all samples were analyzed in duplicate. The lower limit of detection was 1.25 pg/tube for all assays, except KT (3.12 pg/tube). The intra- and inter-assay coefficients of variation for all assays were less than 5 and 10%, respectively. Steroid levels, determined by RIA, were validated by verifying that serial dilutions were parallel to standard curves and by analyzing selected samples by high performance liquid chromatography to show that steroids in plasma eluted at the same time as standards and that concentrations (as reflected by peak height) were consistent with values derived by RIA.

Total plasma Ca^{2+} was analyzed using the Sigma Diagnostics kit (587; Sigma Co.). The Ca^{2+} was quantified using a Beckman DU-64 spectrophotometer.

Statistical Analysis

Steroid and Ca^{2+} concentrations and FL were compared among the four classes of sex and stage of maturity (immature females, immature males, maturing females, and maturing males) using one-way analysis of variance (ANOVA). Mean comparisons were conducted using the Bonferroni procedure. Plasma F was compared between fish captured below Bonneville Dam by gill net and sport fisher. Regression analysis was used to examine the relationship between play time and F concentrations in fish caught by sport fishers.

Discriminant function analysis was used to develop a set of discriminating functions to predict sex or sex and maturity. The plasma and histological data from the oversize fish sampled in 2001 were combined with data from the fishery fish sampled in 2000 and 2001 and the oversize fish sampled in 2000 for the development of the model presented in this report (see Webb et al. 2001a for methods associated with the fishery fish sampled in 2000 and 2001 and the oversize fish sampled in 2000). To attain multivariate normality, the logarithms of the plasma variables T, KT, E2 and Ca^{2+} were considered for analysis. Stepwise DFA was conducted using log-transformed T, KT, E2, Ca^{2+} concentrations and FL to chose the best predictor(s) of sex or sex and stage of maturity. The significance level to enter and remain in the model was $\alpha = 0.05$. Quadratic DFA was then conducted with the variables chosen in the stepwise procedure to determine the number of observations and percent classified into the two groups of sex or four groups of sex and stage of maturity. Determination of the error rates associated with predicting sex or sex and maturity using the chosen discriminant functions was accomplished through cross-validation (see Khattree and Naik 2000). The DFA was also conducted on the fishery fish alone and the oversize fish alone. All analyses were conducted using the SAS System for Windows, release 6.12 (SAS Institute Inc., Cary, NC) following the procedures described in Khattree and Naik (2000).

A preliminary DFA model for urine was developed using T, KT, and E2 concentrations from oversize sturgeon. The DFA for mucus will be reported in the 2002-2003 Annual Report.

RESULTS

Maturation cycle

A total of 373 white sturgeon were sampled for blood and gonadal tissue in the Columbia River between February 2000 and March 2002. Of these 373 fish, analyses (plasma sex steroid concentrations and gonadal histology) have been completed on 297. Hence, the data reported here will include only these 297 fish. Of the fishery fish sampled, 84 were immature females, 67 were immature males, one was a female with ovarian follicles just entering vitellogenesis, and 7 were maturing males. Of these maturing males, all were Stage 5 males with testicular cysts containing spermatozoa, except one Stage 3 male with 50% of the cysts containing spermatogonia and the remaining cysts containing spermatocytes. Of the oversize fish, 66 were immature females, 30 were immature males, 29 were maturing females, and 13 were maturing males (Table 1). The stage of gonadal development of these maturing oversize fish included Stages 3, 4, 5, and 7 in females and Stage 5 in males.

Table 1. The number of white sturgeon from the Columbia River of legal size (fishery) and over the legal size (oversize) from which samples were collected and used in the development of the model to predict sex and stage of maturity.

Location	Year	Immature Female	Immature Male	Maturing Female	Maturing Male
Fishery					
Estuary	2000	7	12	0	0
	2001	12	4	0	2
Bonneville	2000	12	8	0	0
	2001	11	7	0	0
The Dalles	2000	13	9	0	2
	2001	9	6	0	1
John Day	2000	9	12	1	2
	2001	11	9	0	0
Oversize					
McNary	2000	5	5	2	1
Below Bonneville					
Gill Net	2000	8	2	1	2
Gill Net	2001	12	6	9	4
Sport Fishers	2000	19	3	12	2
Sport Fishers	2001	22	14	5	4
Total		150	97	30	20

A total of 281 oversize sturgeon have been marked with spaghetti tags, scute marks, and PIT tags below Bonneville Dam (n=183 in 2000 and n=98 in 2001). Paired biological samples were not collected from each of these 281 individuals as some fish appeared too stressed due to long play time by sport fishers, high water temperatures, poor condition due to hooks extruding from the urogenital pore, or other unknown factors. In 2001, 9 fish were recaptured (9% of the total fish captured in 2001). Of these 9 fish, 8 were tagged in 2000. One fish was tagged (spaghetti tag, no PIT tag) in 1993 by ODFW near the Astoria Bridge. This fish was 96 cm FL in 1993 and 155 cm FL in 2001. Of these 9 fish, sex determined at the time of gonadal biopsy revealed 3 males and 5 females (Table 2). One fish not biopsied in 2001 cannot be tracked to the 2000 data set as the PIT tag reader failed in the field and the spaghetti tag had been removed. Histological examination of the gonadal tissue revealed the field sex was correct on all fish biopsied. To date, the only information that this recapture data reveals is that an immature male with spermatogonia undergoing mitosis can reach sexual maturity in one year (H109922 was actively spermiating at the time of capture).

Table 2. Oversize white sturgeon recaptured in 2001 below Bonneville Dam. Fish identification is the spaghetti tag, PIT tag, or sample number . Field sex is based on visual examination of the gonad at the time of biopsy (all fish were sexed correctly in the field). Stage of maturity is based on histological examination of the gonadal tissue and classified according to Van Eenennaam and Doroshov (1998). Biopsies were not conducted on several fish (no biopsy), and several samples collected for histology were adipose tissue (unknown).

Fish ID	Fork Length (2000* / 2001 cm)	Field Sex in 2000 or 2001	Histological Stage of Maturity (2000* / 2001)
H109922	202 / 207	Male	Stage 2 / Stage 5
H109983	243 / 251	Female	No Biopsy / Stage 4
H111592	191 / 198	Male	Unknown / Stage 2
H111631	213 / 212	Female	Unknown / Stage 2
H109998	214 / 213	Female	Stage 4 / No Biopsy
7527086	229 / 233	Female	No Biopsy / Stage 2
7525085	209 / 211	Female	Unknown / Stage 2
H059680*	96* / 155	Male	No Biopsy* / Stage 2
16-01**	** / 201	No Biopsy	** / No Biopsy

* Fish H059680 spaghetti tagged in 1993, not 2000, near Astoria Bridge; no biospy conducted in 1993.

** PIT tag reader was not working in 2001. Spaghetti tag had been removed, hence this fish cannot be tracked to the 2000 data set.

Determination of Sex Using Plasma Indicators

The FL of females and males caught in the fishery was 120 ± 2 cm and 122 ± 2 cm, respectively, and was not significantly different between the groups ($P > 0.05$). The FL of oversize females and males was 217 ± 2 and 192 ± 4 cm, respectively, and was significantly different ($P < 0.001$). The concentrations of plasma sex steroids (T and E2, $P < 0.01$; KT, $P < 0.001$) in fishery and oversize fish combined differed significantly between the two genders, while plasma levels of Ca^{2+} did not differ between females and males.

In the stepwise DFA of the fish captured in the fisheries, plasma T and E2 were the best predictors of sex. These variables led to the correct classification of 82% of the females and

68% of the males (75% overall correct classification, Table 3). In the cross-validation of the model using plasma T and E2 as predictors of sex in white sturgeon of legal-limit size, 20 and 36% error were associated with classifying females and males, respectively.

In the analysis of oversize fish alone, plasma T, KT, E2, Ca^{2+}, and FL were the best predictors of sex. These variables led to the correct classification of 73% of the females and 86% of the males (Table 3). The overall correct classification was 79%. The cross-validation of the model for the prediction of sex in oversize fish revealed error rates of 32% associated with classifying females and 28% associated with classifying males.

In the stepwise DFA of the fishery and oversize fish combined, plasma T, E2, Ca^{2+}, and FL were the best predictors of sex. These variables led to the correct classification of 54% of the females and 80% of the males (67% overall correct classification, Table 3). In the cross-validation of the model, 47 and 21% error were associated with classifying females and males, respectively.

Table 3. Classification summary for determination of sex from the quadratic discriminant function analysis for white sturgeon in the fishery fish only, oversize fish only, and fishery and oversize fish combined (all fish). Log-transformed plasma testosterone and estradiol were chosen in the analysis of fishery fish; testosterone, estradiol, calcium, and fork length were chosen in the analysis of oversize fish and all fish. Data are percentages (n), with the correctly classified percentages in bold.

	Sex Determined from Predictors		
True Sex	Female	Male	Total (n)
Fishery			
Female	**82** (70)	18 (15)	(85)
Male	32 (24)	**68** (50)	(74)
Oversize			
Female	**73** (69)	27 (26)	(95)
Male	14 (6)	**86** (37)	(43)
All Fish			
Female	**53** (95)	47 (85)	(180)
Male	20 (24)	**80** (93)	(117)

Determination of Sex and Stage of Maturity Using Plasma Indicators

The FL differed significantly ($P < 0.0001$) among the four groups of sex and stage of maturity (immature females, immature males, maturing females, and maturing males). Immature females (160 ± 4 cm) had significantly greater FL compared to immature males (143 ± 4 cm). The FL of maturing females (221 ± 5) was significantly greater compared to immature fish and maturing males (162 ± 8 cm), while maturing males did not have significantly greater FL compared to immature fish.

Concentrations of plasma sex steroids and Ca^{2+} differed significantly ($P < 0.0001$; Figure 1) among the four groups of sex and stage of maturity. The Bonferroni mean comparison tests revealed that plasma T and KT were not significantly different between immature fish but were significantly higher in maturing fish, with concentrations significantly greater in maturing males compared to maturing females (Figure 1). Plasma concentrations of E2 and Ca^{2+} were significantly higher in maturing females compared to immature fish and maturing males (Figure 1).

Plasma T, E2, Ca^{2+}, and FL were chosen in the stepwise DFA of the oversize fish alone as the best predictors of sex and stage of maturity. These variables led to the correct classification of 61, 44, 83, and 92% of the immature females, immature males, maturing females, and maturing males, respectively (Table 4). Overall, 70% of the fish were correctly classified. In the cross-validation of the model predicting sex and stage of maturity in these fish, 48, 80, 21, and 62% error was associated with predicting immature females, immature males, maturing females, and maturing males, respectively.

Table 4. Classification summary for determination of sex and stage of maturity in the oversize fish only and the fishery and oversize fish combined (all fish) from the quadratic discriminant function analysis for white sturgeon. Log-transformed plasma testosterone and estradiol and fork length were chosen in the analysis of oversize fish only, while testosterone, estradiol, and calcium concentrations and fork length were chosen as predictors in the analysis of all fish. Data are percentages (n), with the correctly classified percentages in bold.

True Sex	Classification Immature Females	Determined Immature Males	From Maturing Females	Predictors Maturing Males	Total (n)
Oversize					
Immature Females	**61** (40)	12 (8)	18 (12)	9 (6)	(66)
Immature Males	13 (4)	**44** (13)	10 (3)	33 (10)	(30)
Maturing Females	10 (3)	3 (1)	**83** (24)	3 (1)	(29)
Maturing Males	8 (1)	0 (0)	0 (0)	**92** (12)	(13)
All Fish					
Immature Females	**48** (71)	34 (51)	13 (20)	5 (8)	(150)
Immature Males	14 (14)	**64** (62)	4 (4)	18 (17)	(97)
Maturing Females	3 (1)	0 (0)	**87** (26)	10 (3)	(30)
Maturing Males	5 (1)	5 (1)	5 (1)	**85** (17)	(20)

To distinguish fish by sex and maturational stage in fishery and oversize fish combined, plasma T, E2, Ca^{2+}, and FL were found to be the best predictors. These derived discriminant functions led to the correct classification of 48% of the immature females, 64% of the immature males, 87% of the maturing females, and 85% of the maturing males (Table 4). In comparison,

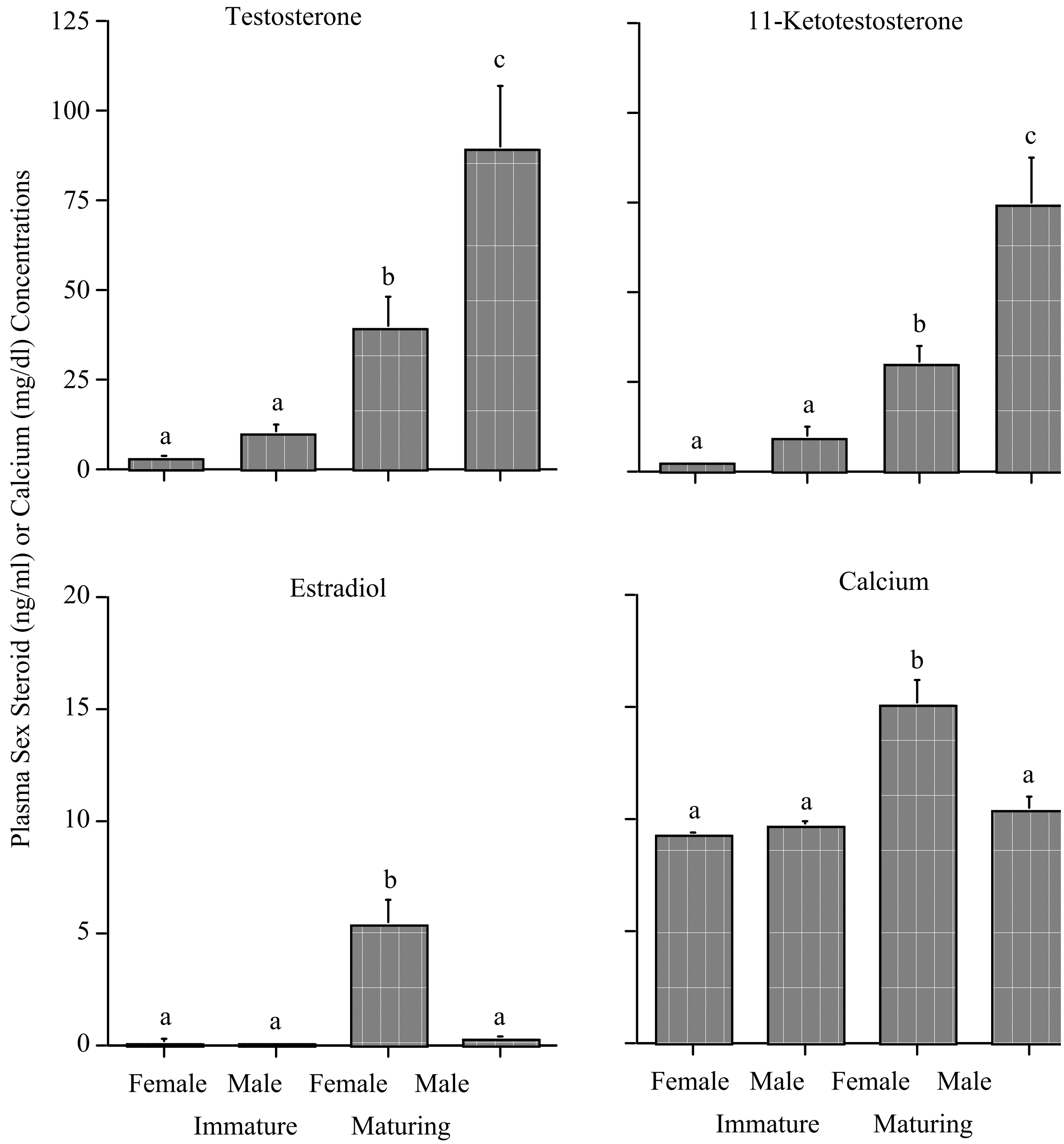

Figure 1. Plasma sex steroid and calcium concentrations in white sturgeon captured in the Columbia River basin in 2000 and 2001 (mean + SE). Different letters denote statistically significant differences between the groups (immature females, n=150; immature males, n=97; maturing females, n=30; and maturing males, n=20).

25% of the total number of fish would be correctly classified into their respective groups by chance alone. Overall, 71% of the fish were correctly classified by sex and stage of maturity. The cross-validation of the sex-and-stage-of-maturity model using these variables revealed error rates of 54, 38, 13, and 25% associated with classifying immature females, immature males, maturing females, and maturing males, respectively. When only plasma T and E2 were used in the model, 62% of the fish were correctly classified by sex and stage of maturity, with 63% of the immature females, 31% of the immature males, 83% of the maturing females, and 70% of the maturing males correctly classified.

Preliminary Determination of Sex and Maturity Using Urine Indicators

To develop the protocol for unconjugation and measurement of sex steroids in urine, samples from 27 fish (7 immature females, 6 immature males, 10 maturing females, and 4 maturing males) were used. These results were then utilized for the development of a preliminary DFA to determine the usefulness of urine sex steroids in the prediction of sex and stage of maturity. Testosterone and E2 (glucuronidated) were the most useful predictors (Figure 2).

Table 5. Classification summary for determination of sex from the quadratic discriminant function analysis for white sturgeon using urine estradiol (glucuronidated). Data are percentages (n), with the correctly classified percentages in bold.

	Sex Determined from Predictors		
True Sex	Female	Male	Total (n)
Female	**59** (10)	41 (7)	(17)
Male	10 (1)	**90** (9)	(10)

In the stepwise DFA of these 27 fish, urine E2 (glucuronidated) was the best predictor of sex. This variable led to the correct classification of 59% of the females and 90% of the males (74% overall correct classification, Table 5). Urine T and E2 were chosen as the best predictors of sex and maturity resulting in the correct classification of 100, 33, 80, and 100% of the immature females, immature males, maturing females and maturing males (Table 6). The overall percentage of fish correctly classified was 78%.

Table 6. Classification summary for determination of sex and stage of maturity from the quadratic discriminant function analysis for white sturgeon using urine testosterone and estradiol (glucuronidated). Data are percentages (n), with the correctly classified percentages in bold.

	Classification	Determined	From	Predictors	
True Sex	Immature Females	Immature Males	Maturing Females	Maturing Males	Total (n)
ImmatureFemales	**100** (7)	0 (0)	0 (0)	0 (0)	(7)
Immature Males	67 (4)	**33** (2)	0 (0)	0 (0)	(6)
Maturing Females	20 (2)	0 (0)	**80** (8)	0 (0)	(10)
Maturing Males	0 (0)	0 (0)	0 (0)	**100** (4)	(4)

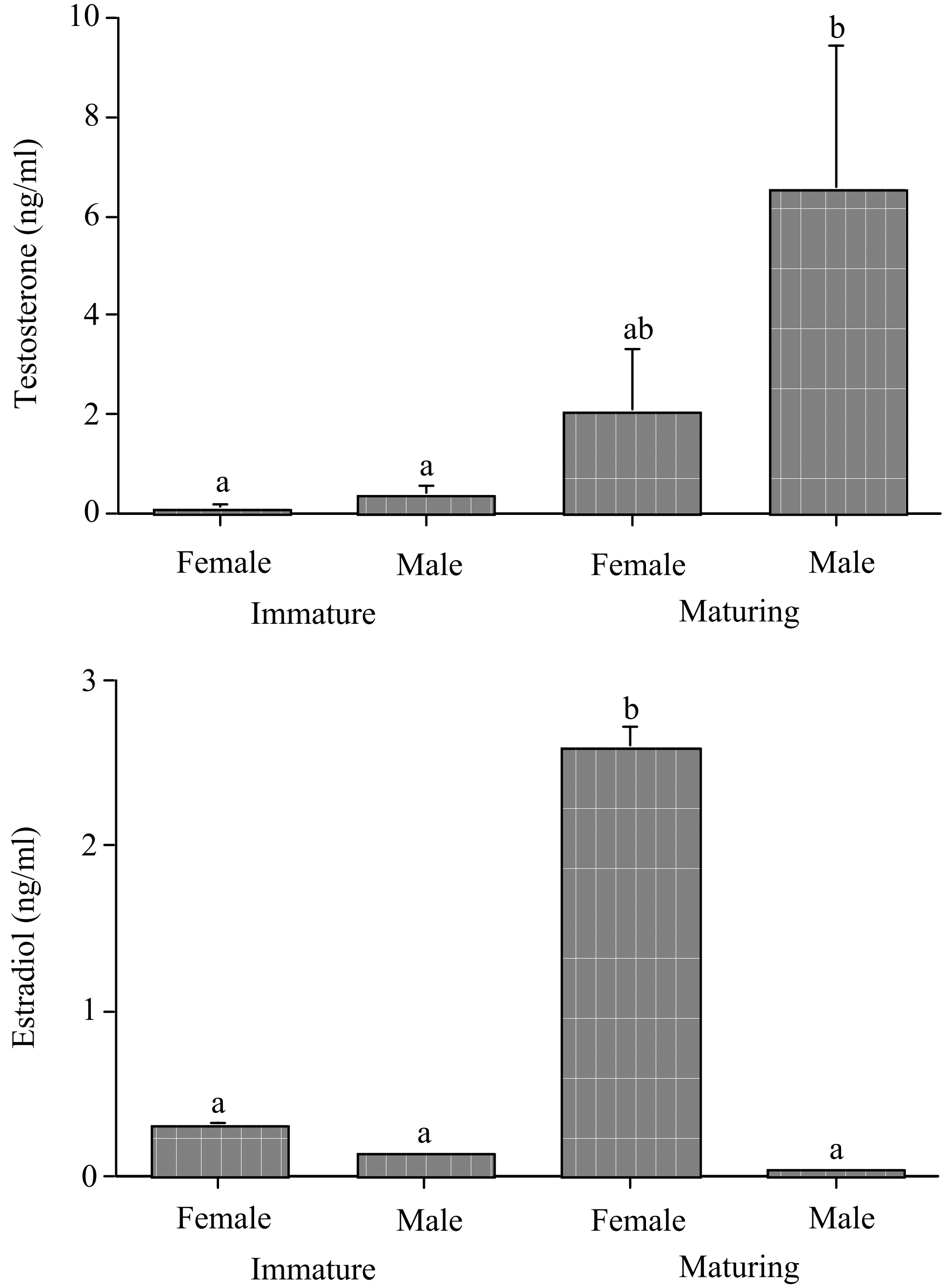

Figure 2. Uncongujated (glucuronidated) urine sex steroids in white sturgeon. Data are means ± sem (n=7 for immature females, n=6 for immature males, n=10 for maturing females, n=4 for maturing males). Letters denote significantly different steroid concentrations between groups of sex and maturity.

Cortisol Concentrations in Oversize Sturgeon

Plasma cortisol concentrations in oversize white sturgeon captured below Bonneville Dam by gill net were significantly higher compared to those captured in the catch-and-release sport fishery (Figure 3). There was no significant difference in cortisol levels of fish caught by gill net in 2000 compared to 2001 nor the sport fishery in 2000 compared to 2001. Plasma cortisol concentrations in gill-net-caught and sport-caught fish did not differ significantly between the four groups of sex and stage of maturity (P = 0.2151).

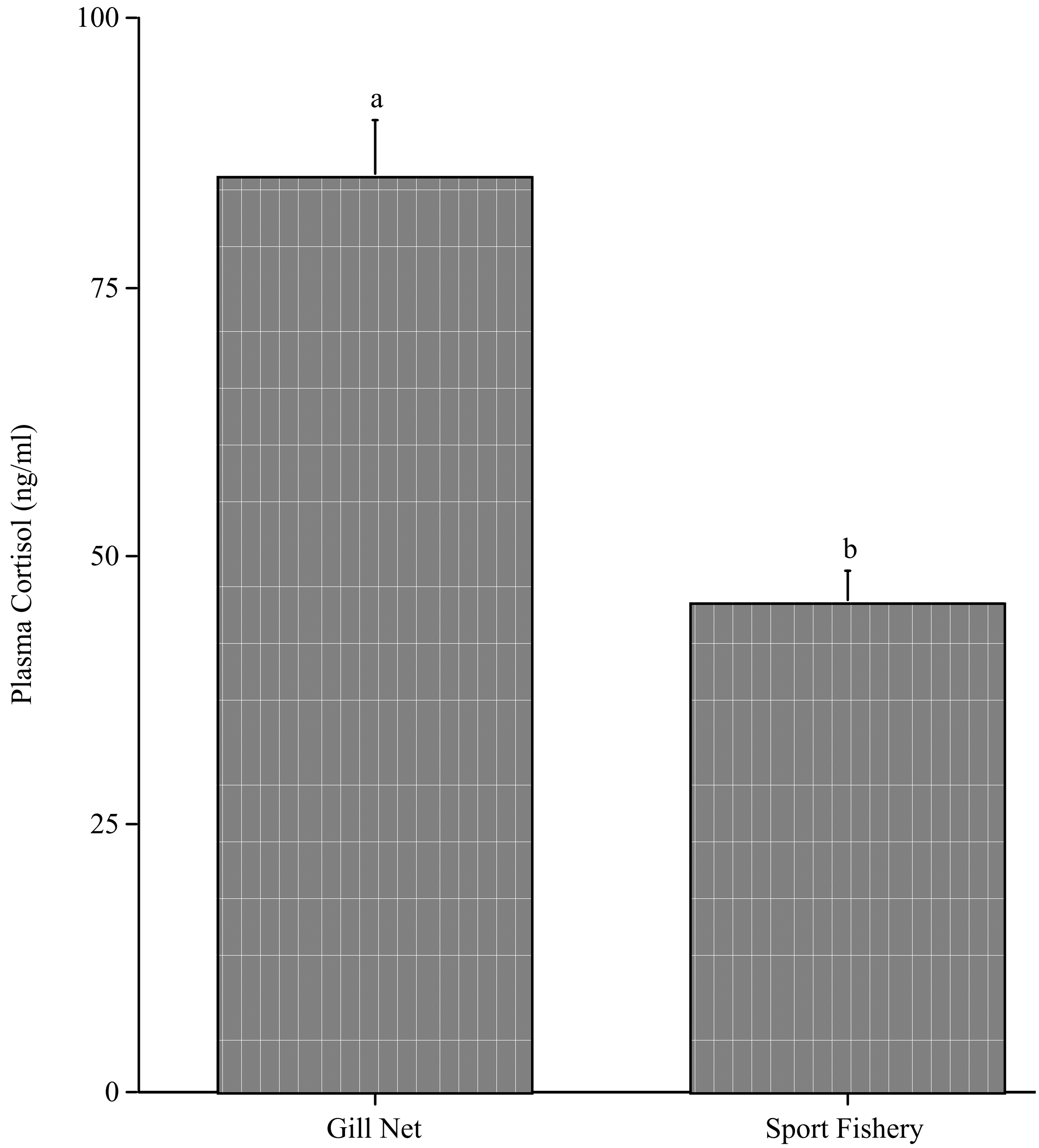

Figure 3. Plasma cortisol concentrations in oversize white sturgeon captured below Bonneville Dam by gill net (n= 83) and in the catch-and-release sport fishery (n=96).

Simple linear regression analysis revealed a significant positive correlation between play time and plasma cortisol concentrations (P = 0.0031, Figure 4). However, the R^2 value was low (R^2 = 0.089).

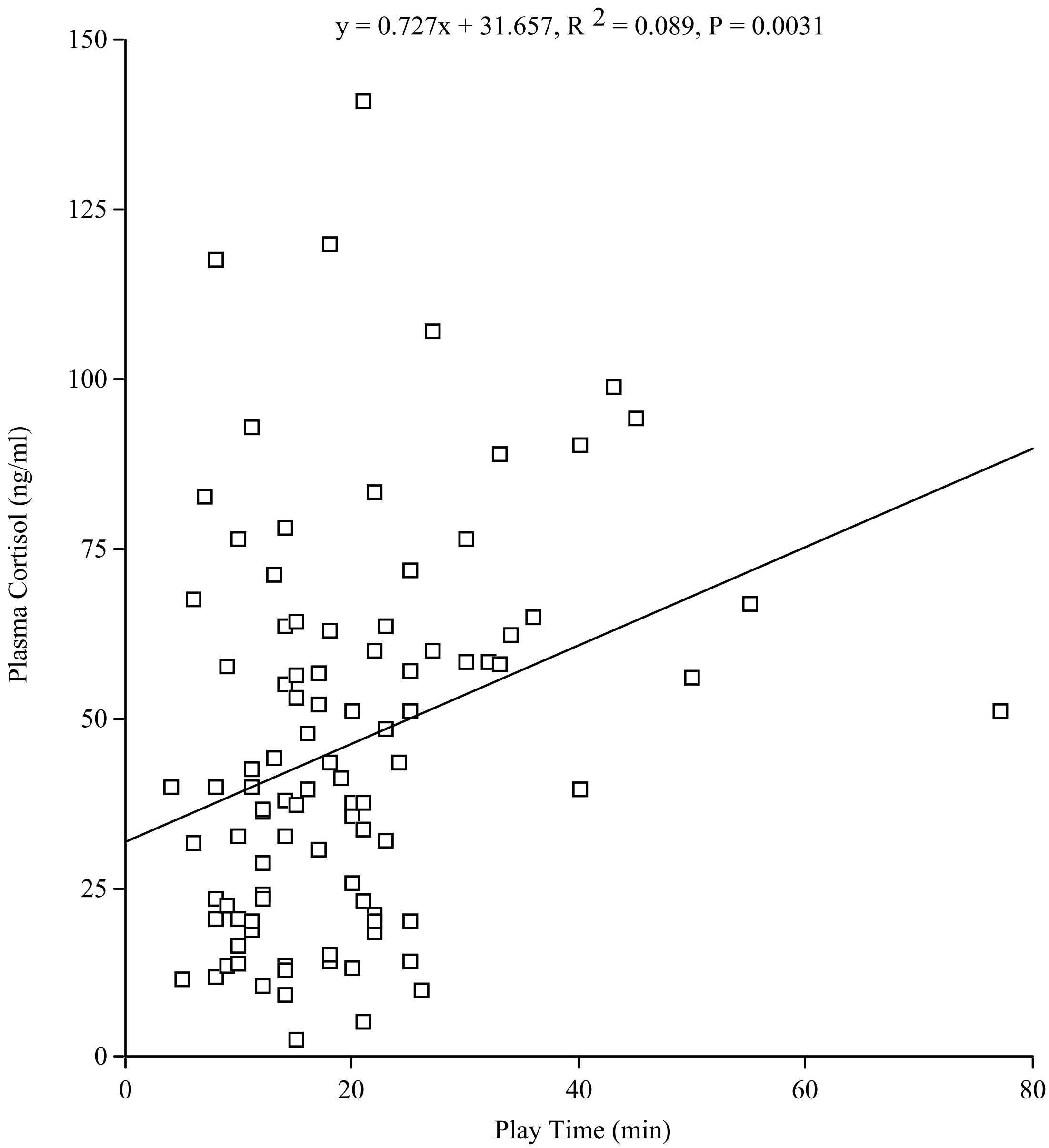

Figure 4. Oversize white sturgeon plasma cortisol versus play time (n=96). Fish were caught in the catch-and-release sport fishery below Bonneville Dam in 2000 and 2001.

DISCUSSION

Of the oversize fish sampled in 2000 and 2001, 21% of the females were maturing, while 9% of the males were maturing. Females in all stages of development were found throughout the winter and spring which is consistent with a maturation cycle longer than one year, as previously discussed for white sturgeon by DeVore et al. (1995) and Doroshov et al. (1997).

Sustainable harvest levels of sturgeon in the Columbia River are based on population models and fecundity estimates (DeVore et al. 1995), of which spawning frequency and an understanding of the maturation cycle are critical elements. Exact knowledge of the maturation cycle in white sturgeon in the Columbia River requires following the stage of development in individual fish over several years. The data collected from recaptured oversize fish below Bonneville Dam in 2001 does not yet reveal much information regarding the maturation cycle in wild white sturgeon as several of these fish were not biopsied in both years. The recapture of one male revealed that a one-year maturation cycle for males is possible as this male developed from Stage 2 (mitotic proliferation of spermatogonia) to Stage 5 (actively spermiating) in one year, similar to what has been described in cultured white sturgeon (Doroshov et al. 1997). Whether males in the wild spawn every year is still unknown. With an increasing number of tagged fish and biological samples from fish of different maturational stages, we will gain more information about spawning frequency and the development of a predictive index for the time to spawning will be more powerful.

To distinguish between immature and maturing sturgeon, plasma concentrations of T may be compared. Testosterone concentrations were significantly higher in maturing fish compared to immature fish (Figure 1). Maturing females may be separated from maturing males using plasma E2 and/or Ca^{2+}, as concentrations were significantly higher in maturing females compared to all other groups (Figure 1).

The DFA models were least effective in distinguishing immature female from immature male white sturgeon. The misclassification of immature males as immature females was the result of a large portion of these males having plasma concentrations of T below 4 ng/mL. It is unclear at this time why wild white sturgeon males in Stage 2 of gonadal development are not producing T at concentrations greater than or equal to 4 ng/mL. It appears that spermatogonia proliferation (Stage 2) in cultured white sturgeon is associated with increased circulating androgen concentrations regardless of age or size (M. Fitzpatrick, Oregon Department of Environmental Quality, unpublished data). Plasma T and KT have been found to be negatively correlated with liver concentrations of p,p'-DDE (a lipophilic environmental contaminant) in immature male white sturgeon in the lower Columbia River indicating the potential adverse effects of pollutants on white sturgeon reproduction (Foster et al. 2001). The reduced concentration of androgens in Columbia River males must be further investigated. The misclassification of immature females as immature males appears to be the result of increasing plasma T prior to the increase in E2 associated with vitellogenesis. Because T is a precursor to E2, plasma T levels increase just prior to vitellogenesis and continue to remain elevated during vitellogenesis as E2 concentrations remain high (Doroshov et al. 1997; Webb et al. 2001b).

In the DFA model for the prediction of sex, the overall correct classification for oversize fish was 86% in 2000 and 79% in 2000 + 2001 and for all fish was 71% in 2000 and 67% in 2000 + 2001. It is unclear at this time why the increase in number of fish led to the decrease in discrimination between the sexes. It is possible that the increase in number of fish captured more individual variation in plasma steroid concentrations. For the prediction of sex and maturity, 62% of the oversize fish were correctly classified in 2000 while 70% were correctly classified in 2000 + 2001. For all fish, the overall correct classification was 71% in both 2000 and 2000 + 2001. The increase in the number of individuals used in the model lead to an increase in the case of oversize fish or no change in the case of all fish in the percentage of fish correctly classified into four groups of sex and stage of maturity. The misclassification of fish in the model will be examined on an individual basis to assess the impact of setting different discriminating steroid levels or FL on classification rates.

The use of sex steroid concentrations in urine to discriminate sex and maturity appears promising (Tables 5 and 6). However, within these models a high percentage of immature males are misclassified as immature females similar to what is seen in the models that use plasma sex steroids as the discriminating tool. Logistically, urine is easier to collect than blood, which requires the presence of a centrifuge to collect plasma, but the collection of urine from fish at processing facilities is often not possible. Fish brought into processing facilities have been dead for some time or have been out of the water for extended periods of time and no longer are producing urine. A DFA will be conducted to predict both sex and stage of maturity using urine collected from all oversize fish collected to date.

The use of sex steroid concentrations in mucus to differentiate between sexes and stages of maturity in white sturgeon is under way. The techniques for extraction of steroids from mucus have been determined. Mucus cannot be collected from fish at fish processing facilities as the fish are thrown into tubs together, therefore collection of mucus only occurred from oversize sturgeon. The DFA will be reported in 2002.

The collection of biological samples from fish captured in the oversize catch-and-release fishery has provided an opportunity to examine fish "handled" by sport fishers (sport fishers are not allowed to remove fish from the water). Cortisol concentrations in unstressed wild white sturgeon have been found to be 13.4 ± 3.4 ng/ml (9.7 ± 2.7 ng/ml in subadults; North et al. unpublished). The cortisol concentrations were significantly higher in both gill-net-caught (85.3 ± 5.3 ng/ml, range 3.8 - 213 ng/ml) and sport-caught (45.8 ± 2.9 ng/ml, range 3.0 - 141.3 ng/ml) oversize sturgeon below Bonneville Dam. The cortisol concentrations in the sturgeon caught in the oversize catch-and-release sport fishery were significantly correlated with play time (i.e. the longer the fish was on the line, the more stressed the fish), similar to results found by North et al. (unpublished data). The low R^2 value appears to be driven by high cortisol concentrations in fish with short play times. This may be due to fish being handled multiple times within the sport fishery. Multiple hook scars in the buccal cavity of these oversize sturgeon does indicate that individual fish are handled repeatedly in the catch-and-release fishery. As well, it is very common to find multiple fishing lines extruding out of the urogenital pore. Sturgeon undergo a stress response typical of modern teleosts. Stress can impede reproduction in fishes by reducing gamete and/or progeny quality (e.g., Campbell et al. 1994; Pankhurst and Van der Kraak 1997; Semenkova et al. 1999; Schreck et al. 2001), increasing the incidence of gonadal atresia (e.g., Clearwater and Pankhurst 1997; Pankhurst and Van der Kraak 1997; Cleary et al. 2000), and compromising immune function (e.g., Georgiadis et al. 2001). Stress may also lead to direct mortality (Schreck 2000). Sport and commercial fisheries targeting white sturgeon in the Columbia River basin have proliferated in the last twenty years, and a significant increase in fishing pressure, including the catch-and-release effort on oversize sturgeon, has occurred within the last decade (Watts and Hunter 1999). Because of the life history characteristics of sturgeon (long lives, late age at first maturity, and long spawning interval), the effects of the oversize catch-and-release sport fishery on the white sturgeon population below Bonneville Dam will not become fully evident for 20 or more years as declining recruitment to broodstock reduces production (DeVore et al. 1995). It is imperative to understand the impacts of this fishery on the productivity of sturgeon.

Though error does exist in the classification of sex and stage of maturity of white sturgeon using blood plasma or urine indicators, this technique currently has some advantages over the biopsy method. The biopsy method of identifying sex and maturity, while highly accurate under some circumstances, is subject to error when conducted by untrained or inexperienced personnel. For example, in 1995 and 1996 62 and 74%, respectively, of the biopsy samples provided to us could not be identified for sex or maturity because the samples contained only adipose tissue or were from other organs. As well, error exists in the collection of gonadal tissue by trained personnel (Table 2). Therefore, under certain circumstances, the error associated with misclassifying fish using plasma or urine steroid levels is more accurate than collection of a gonadal biopsy.

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