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 2002 - MARCH 2003

Edited by:

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In Cooperation With:

Washington Department of Fish and Wildlife
U.S. Geological Survey Biological Resources Division
Columbia River Inter-Tribal Fish Commission
U.S. Fish and Wildlife Service
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EXECUTIVE SUMMARY

We report on our progress from April 2002 through March 2003 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 2002 through March 2003 are:

Report A

- The population estimate for The Dalles Reservoir was 104,350 white sturgeon greater than 54 cm total length. Only 5,928 of these were in the legal size class. Population estimates were higher than estimates in 1997, with most of the increase in the sublegal size class.
- We transported 4,177 juvenile white sturgeon from below Bonneville Dam to John Day Reservoir and 941 to The Dalles Reservoir.
- We estimate abundance of transported fish from previous years to be 10,588 in The Dalles Reservoir, approximately 10% of the white sturgeon population.
- Young-of-year (YOY) indexing surveys in 2002 resulted in the capture of 16 YOY white sturgeon in The Dalles Reservoir and 3 in McNary Reservoir, but none in Little Goose, Ice Harbor, or John Day reservoirs.

Report B

- The 2002 total white sturgeon harvest (recreational, commercial, and subsistence) in Management Zone 6 was 4,945 fish. This is the lowest total harvest since 1996, and is reflective of the 70% reduction of recreational and commercial guidelines in John Day Reservoir, and a low commercial harvest in Bonneville Reservoir (36% of commercial guideline).
- For the previous three seasons, the John Day Reservoir recreational harvest guideline was not obtained despite retention being allowed year-round. With the lower guideline set in 2002, the fishery was closed to retention August 23rd. As a result, even more anglers targeted oversize fish for catch and release (13% of sturgeon handled in John Day Reservoir during the 2002 season were over the legal size limit as opposed to 11% in

2001 and 10% in 2000; all much higher that the 3% oversize handling in the other reservoirs).

- In general, compliance with Sturgeon Management Task Force (SMTF) annual harvest guidelines during the past five seasons (1998-2002) has been good. Harvest in Bonneville Reservoir has averaged 94% of the recreational guideline and 87% of the commercial guideline. In The Dalles Reservoir the harvest averaged 112% of the recreational guideline and 107% of the commercial guideline. In John Day Reservoir the harvest averaged 84% of the recreational guideline and 78% of the commercial guideline.
- Trends in catch, effort, season length, and size composition suggest that the legal-sized populations in all three reservoirs have declined.

Report C

- Analyses by the USGS showed that river discharges and water temperatures during April through July 2002 provided relatively good conditions for spawning by white sturgeon downstream from Bonneville, The Dalles, John Day, and McNary dams. Optimal spawning temperatures in the four tailraces occurred for approximately three weeks and during a period of relatively high river discharge. The availability of spawning habitat peaked in June at levels higher than the average of past years. However, moderate recruitment of age-0 white sturgeon was only observed in one reservoir; seventeen YOY white sturgeon were collected during bottom trawling in Bonneville Reservoir, while only one YOY sturgeon was captured in The Dalles Reservoir, and none in the John Day Reservoir
- The third year of a three-year laboratory predation study was completed. Adult channel catfish ingested white sturgeon up to a mean total length of about 120 mm, and juvenile walleye ate white sturgeon up to a mean length of 53 mm. When white sturgeon and coho salmon were both available as prey, northern pikeminnow continued to ingest white sturgeon, but in most cases preferred salmon. Conversely, prickly sculpins preferred white sturgeon over goldfish as prey. The presence of cover and also lower light levels reduced predation by prickly sculpins on white sturgeon larvae, but cover did not reduce predation on white sturgeon juveniles. Similar to the past two years, turbidity affected predation of white sturgeon larvae by prickly sculpins, with less sturgeon ingested at higher turbidities.

Report D

- A total of 236 white sturgeon were captured in 225 setline sets between 4 March and 22 May 2002. We held one sexually mature female and 19 sexually mature males at our spawning location below the McNary Dam Juvenile Fish Facility. We spawned one female, crossing gametes with four males, resulting in 80,000 white sturgeon larvae. Prior to the successful spawn we acquired 50,000 white sturgeon larvae from a private facility.

- The CRITFC marked and released approximately 3,000 white sturgeon in The Dalles Reservoir as part of the population estimate reported by ODFW (Report A).

Report E

- 21,700 sub-yearling white sturgeon were produced, nearly reaching the production goal of 22,000.
- We made changes in culture procedures to reduce stress, and no outbreak of WSIV occurred.

Report F

- We have collected paired blood and gonad samples from 590 white sturgeon in the Columbia River between February 2000 and March 2003.
- Discriminant function analysis revealed that blood plasma indicators and fork length led to correct classification of 62%, 53%, 89%, and 80% of immature females, immature males, maturing females, and maturing males, respectively.
- Urine indicators led to correct classification of 76%, 35%, 75%, and 55% of oversize immature females, immature males, maturing females, and maturing males, respectively.
- It does not appear that mucus steroid levels will prove useful in classifying fish by sex and maturity.

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

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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 The Dalles 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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Thanks to the field crews who collected the data used in this report. Stock Assessment: ODFW – Travis Eoff and Jody Gabriel; WDFW – Brad Cady, Robert Morgan, Matt Howell and Eric Evans. Creel surveys: ODFW – Wendy Martin, Jody Gabriel, and Richard Allen; WDFW – Tom Mallory, Matt Howell, and Eric Evans. YOY Surveys: ODFW – Travis Eoff and Jody Gabriel; WDFW - Brad Cady and Robert Morgan; CRITFC – Charles Gardee and James Kiona.

ABSTRACT

This report summarizes data collected from April 2002 through March 2003 to update life history parameters and population dynamics of white sturgeon *Acipenser transmontanus* in The Dalles 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 Columbia River below Bonneville Dam to The Dalles and John Day reservoirs.

Sampling to estimate white sturgeon abundance in The Dalles Reservoir 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 The Dalles Reservoir from December 2001 through January 2002. Staff from Oregon Department of Fish and Wildlife (ODFW) set 562 setlines from 3 June through 8 August 2002, and captured 5,608 white sturgeon. White sturgeon were distributed throughout The Dalles Reservoir, but catch rates were generally higher 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 0.5 km downstream between marking and subsequent recapture. Combined effort by CRITFC and ODFW resulted in the marking of 2,736 white sturgeon with passive integrated transponder (PIT) tags between December 2002 and August 2003. Using multiple mark-recapture estimates, we estimated the total population of white sturgeon in The Dalles Reservoir in 2002 to be 104,000 fish. Based on expansions from stock assessment data, we estimated approximately 10,588 of these fish were the result of Trawl and Haul transplants from previous years.

Transplant supplementation (Trawl and Haul) continued in 2002 with transplant of juvenile white sturgeon from below Bonneville Dam to The Dalles and John Day reservoirs. Using trawl gear, 5,375 juvenile white sturgeon were captured below Bonneville Dam by a private commercial trawler. We transplanted 4,177 of these fish to John Day Reservoir and 941 to The Dalles 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 Survey to facilitate comparison of the two methods. We caught more YOY in 2002 than we did in 2001.

INTRODUCTION

This report summarizes work performed by the Oregon Department of Fish and Wildlife (ODFW) during the period April 2002 through March 2003 in accordance with tasks outlined in the Bonneville Power Administration funded Project 198605000 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: 1) During June through August 2002 we assessed abundance and productivity measures of white sturgeon in The Dalles Reservoir; 2) During October and November 2002, 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 2002, we participated in assessing recruitment of young-of-year white sturgeon (YOY) 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 regular basis. Stock assessment surveys have generally been conducted once every five years for each of the three reservoirs in Zone 6 (Bonneville, The Dalles, and John Day). Since 2001, stock assessment survey schedules have been modified to survey each reservoir every three years. A stock assessment survey was last conducted in The Dalles Reservoir in 1996. Transplant efforts (Trawl and Haul) and young-of-year indexing are annual activities.

METHODS

Stock Assessment

We sampled for white sturgeon in The Dalles Reservoir from June through mid-August to estimate population statistics. The reservoir was divided into six sections, each between 5.6 and 7.2 km long (Figure 1). We distributed setline sampling effort equally among and within these 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 three-week sampling periods and sampled all sections during each period (Table 1).

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 (Elliot 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 h, 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).

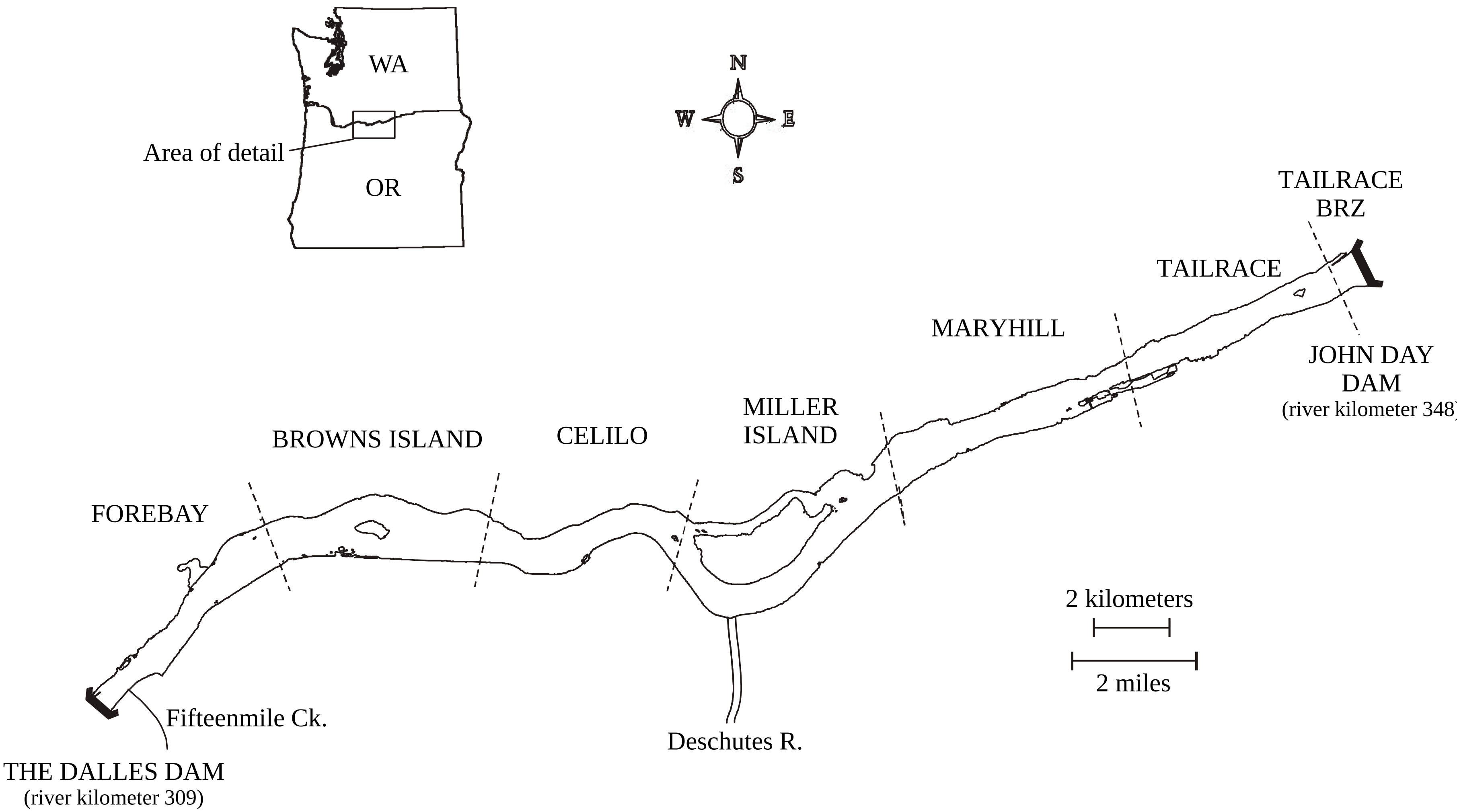

Figure 1. The Columbia River between The Dalles and John Day dams. Sampling section boundaries are indicated by dashed lines. The scale is approximate. Boat-restricted zone (BRZ).

Table 1. Sampling effort (number of setline sets) for white sturgeon in The Dalles Reservoir by week and sampling section. June through August 2002.

	Sampling Section						
Week	1	2	3	4	5	6	Total
23	--	--	23	29	--	--	52
24	--	--	--	--	29	27	56
25	30	31	--	--	--	--	61
26	--	--	29	31	3	--	63
28	--	--	--	--	31	34	65
29	34	29	--	--	--	--	63
30	--	--	31	33	2	--	66
31	--	--	--	--	32	33	65
32	36	33	--	--	--	--	69
Total	100	93	83	93	99	94	562

We measured fork length (cm), and looked for tags, tag scars, fin marks, and scute marks on all white sturgeon captured. All length measurements hereafter 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). 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). We no longer mark white sturgeon with external tags, and any recaptured tags are removed from fish at capture. The tenth right lateral scute was removed as a secondary mark to indicate the fish was captured in 2002. Recaptures were weighed to estimate changes in condition factor.

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.

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 third reader, who previously did the majority of our aging, aged a subsample of 40 fish to assess potential digression in application of aging criteria by newer readers. 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 between 1997 and 2002 and among individual 2002 sampling periods.

To estimate population abundance, we used the Schnabel multiple mark-recapture estimate based on PIT-tags applied and recaptured for the 70-109 cm and 110-166 cm size classes (the two groups with the largest sample sizes), and then expanded the estimates to the remaining size groups (<70 cm and >166 cm) based on the relative length frequency of these size classes in the total setline catch and differences in gear vulnerability of these size groups (Beamesderfer et al. 1995). Schnabel estimates for these size classes were inappropriate since white sturgeon under 70 cm fork length are typically not PIT-tagged and no PIT-tagged fish over 166 cm were recaptured.

Trawl and Haul Supplementation

From 21 October to 15 November 2002, 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 previous years (Kern et al. 2001). We contracted with the same private commercial trawler who collected fish in 2000 and 2001.

Although most fish transported were between 35 and 90 cm fork length, fish 30-34 cm were also transported on days when catches were low. We measured a sub-sample of about 100 fish each day to estimate length frequency distribution. All transported fish had their tenth right lateral scute removed to signify capture in 2002 and the third right scute was removed to signify Trawl and Haul handling. Fish were transported in either a 13,000 L or a 5,300 L ODFW liberation truck. In John Day Reservoir, all fish were released on the Oregon side of the Columbia at Giles French Boat Ramp (river km (RKm) 351), Arlington Boat Ramp (RKm 390), Boardman Boat Ramp (RKm 434), or Irrigon Boat Ramp (RKm 455). Fish released in The Dalles Reservoir were released at Maryhill (RKm 338) or Celilo (RKm 325) boat ramps.

Stock assessment work in The Dalles Reservoir in 2002 allowed us to monitor fish transported by the Trawl and Haul program in previous years. From 1994-1995 and 1998-2001, we transported 15,241 fish to The Dalles Reservoir. A lateral scute was removed from all of these fish to indicate year of transport, and fish released during 1994-1995 were PIT-tagged. 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 of similar size, and multiplying this result by the estimated abundance of all fish in the same size group. We also examined commercial and sport creel data to evaluate the contributions of transported fish to Zone 6 fisheries, and to look for evidence of movement of fish between reservoirs.

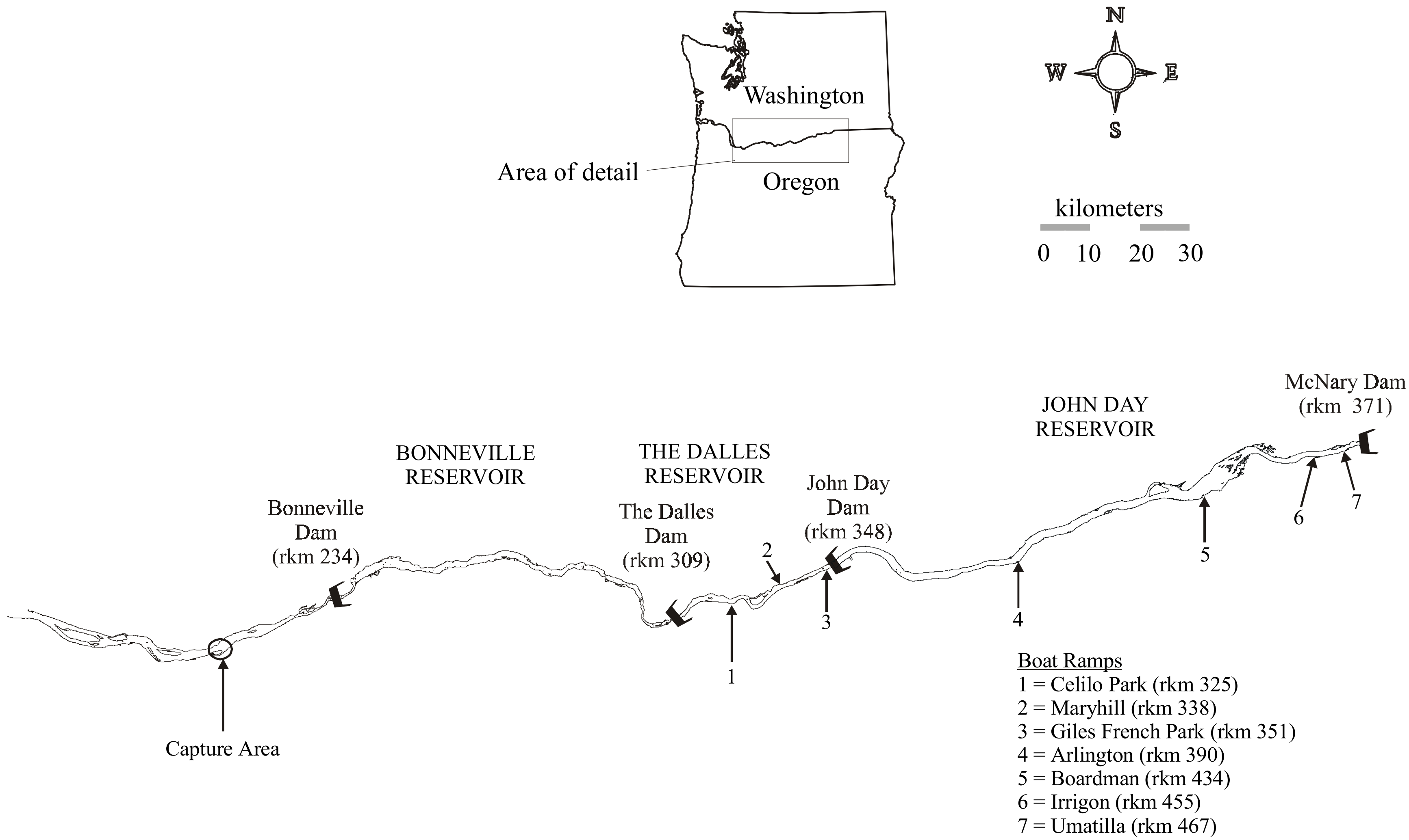

Figure 2. Study area for Trawl and Haul supplementation, October – November 2002.

Young-of-Year Indexing

During October and November of 2002, 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 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 18-27 h. 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 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. The proportion of positive efforts (E_p) is simply the proportion of fishing efforts that captured white sturgeon and is calculated both for white sturgeon of all sizes and for YOY white sturgeon specifically.

RESULTS

Stock Assessment

Catch

We caught 5,608 white sturgeon during sampling activities in The Dalles Reservoir from 3 June through 8 August 2002 (Table 2). Setline catch consisted of 95.8% sublegal size (<110 cm), 3.1% legal size (110–137 cm), and 1.1% fish over legal size (>137 cm).

Distribution and Movement

We captured white sturgeon throughout the reservoir, but catch rates were generally highest in upstream sections (Table 3). However, the section with the highest catch rate was section 2 near the downstream end of the reservoir. The majority of recaptured fish were caught in the same section as tagged, with 77% recovered within 5 RKm of the original marking location (Table 4). The average movement of recaptured fish was 0.5 RKm downstream from where they were originally marked. We captured one tagged fish that had moved upstream from Bonneville, and 20 tagged fish that had moved downstream from John Day Reservoir.

Table 2. Catches of white sturgeon with setlines in The Dalles Reservoir by week and sampling section, June through August 2002.

	Sampling Section						
Week	1	2	3	4	5	6	Total
23	--	--	113	205	--	--	318
24	--	--	--	--	312	218	530
25	96	228	--	--	--	--	324
26	--	--	202	285	23	--	510
28	--	--	--	--	379	461	840
29	307	451	--	--	--	--	758
30	--	--	329	409	12	--	750
31	--	--	--	--	367	417	784
32	284	510	--	--	--	--	794
Total	687	1,189	644	899	1,095	1,096	5,610

Table 3. Catch per unit effort of white sturgeon with setlines in The Dalles Reservoir by week and sampling section, June through August 2002.

	Sampling Section						
Week	1	2	3	4	5	6	Mean
23	--	--	4.91	7.07	--	--	
24	--	--	--	--	10.76	8.07	
25	3.20	7.35	--	--	--	--	
26	--	--	6.97	9.19	7.67	--	
28	--	--	--	--	12.23	13.56	
29	9.03	15.55	--	--	--	--	
30	--	--	10.61	12.39	6.00	--	
31	--	--	--	--	11.47	12.64	
32	7.89	15.45	--	--	--	--	
Mean	6.87	12.78	7.76	9.67	11.27	11.66	10.01

Table 4. 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
-30	2	0.72%
-25	3	1.08%
-20	5	1.79%
-15	7	2.51%
-10	21	7.53%
-5	111	39.78%
5	105	37.63%
10	17	6.09%
15	5	1.79%
20	2	0.72%
25	0	0.00%
30	1	0.36%
Total	279	

Age and Growth

We assigned ages to 204 white sturgeon captured from The Dalles Reservoir in 2002. Ages ranged from 0-46 and variation between ages assigned by readers increased with fish age (Table 5). These data, combined with previously collected age data (Table 5), were used to estimate parameters of a von Bertalanffy growth equation (Figure 3).

We compared differences in the assigned ages between three different readers using a subsample of 40 aged fish (Table 6). Reader 3, who was the primary reader in previous years, tended to age fish younger than Readers 1 and 2. Reader 1 tended to age fish slightly younger than Reader 2, however agreement was more frequent with Reader 2 than with Reader 3 (Figure 4).

Relative weights (Figure 5) in sampling period 2 (mean 100.4) differed significantly ($p<0.05$) from those in sampling periods 3 (mean 106.8) and 4 (mean 106.6). Relative weights in periods 3 and 4 did not differ significantly ($p<0.05$). Relative weights of fish captured in 2002 (mean 104.6) were not significantly different ($p<0.05$) than for fish captured in 1997 (mean 107.1).

Table 5. Age and length-frequency distribution of white sturgeon collected in The Dalles Reservoir, 1988-2002.

	Fork Length													
Age	0-19	20-39	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	>199	Mean	Std	N
0	5	50										22.6	2.8	55
1		25	6									34.8	5.8	31
2		16	41									40.8	5.4	57
3		6	50									45.7	5.6	56
4		3	47	9								52.6	6.6	59
5		1	35	21								57.6	8.9	57
6		1	21	38	2							61.8	9	62
7		2	21	22	2							60.7	10.9	47
8			10	16	6							67.9	11.8	32
9			9	12	12	1						72.9	14.1	34
10			6	20	17	8						80.2	16.1	51
11			1	6	20	12	1					91.8	14.6	40
12			1	6	15	16	1					93.9	17.1	39
13				5	18	27	3	2				101.1	15.9	55
14				3	18	25	10	1	1			105.8	17.9	58
15					8	27	8	2	1			111.7	17.2	46
16				1	7	28	15	5	3			118.7	18.3	59
17				1		20	26	8				122.7	14.4	55
18					3	18	34	12	4	1		128.7	18.9	72
19					3	17	30	18	9			132.9	20.8	77
20					2	12	35	37	7	4		138.2	20.3	97
21					1	10	22	16	6	2		137	20	57
22					1	3	8	30	5	5	3	150.9	24.1	55
23						3	5	16	5	2	1	149.7	21.6	32
24					1	4	8	10	11	1	1	147.9	25	36
25						2	5	9	5			142.7	16.2	21
26						1	3	6	5	1	3	160.3	30.7	19
27							4	1	8	1	4	168.7	27.3	18
28							1	2	4	3		168.9	18.5	10
29							1	2	2	1	3	178.3	34.9	9
>29								11	7	3	20	194.9	37.8	41
All	5	104	248	160	136	234	220	188	83	24	35	101.9	46.6	1,437

Table 6. Discrepancies in aging of white sturgeon pectoral fin spine sections collected in The Dalles Reservoir 2002 by primary two readers.

	Final Assigned Age																				
Age Difference	0	1	2	3	4	5	6	7	8	9	10	11	12-14	15-17	18-20	21-23	24-26	27-29	>29	total	%
-24																			1	1	0.005
-15																			1	1	0.005
-12															1					1	0.005
-11																	1			1	0.005
-10																1			1	2	0.010
-8															3					3	0.015
-7																2		1		3	0.015
-6																2	2		1	5	0.025
-5															2		1			3	0.015
-4							1								2	2			1	6	0.029
-3												1		2	2	2	1			8	0.039
-2				1	2		1	1	2				1	3	2	1	2			16	0.078
-1			2	5	3	6	5	5	3				5	2	4					40	0.196
0	14	3		3	2	10	20		8	1	1	1	5	8	4					80	0.392
1					3	4		1	2				3	4	3	1				21	0.103
2						1	1						1	3	3	1			1	11	0.054
3													0	0	1	1				2	0.010
All	14	3	2	9	10	21	28	7	15	1	1	2	15	22	27	13	7	1	6	204	1.000

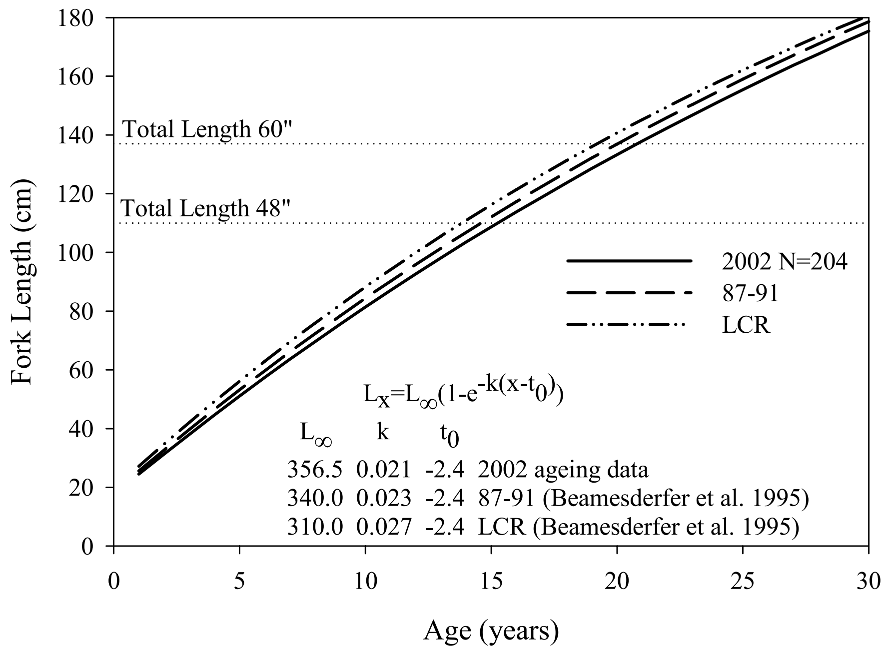

Figure 3. Comparison of von Bertalanffy growth parameters for white sturgeon collected in The Dalles Reservoir in 2002, and based on previous years' and Lower Columbia River data (Beamesderfer et al. 1995).

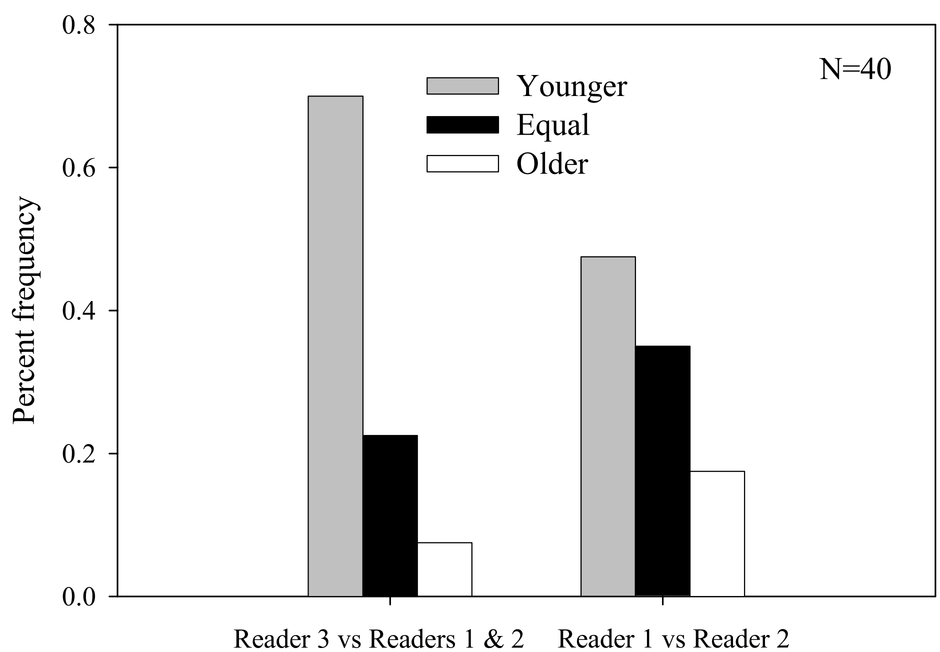

Figure 4. Percent frequency of differences in age assignments by readers of pectoral spine sections collected from white sturgeon in The Dalles Reservoir 2002.

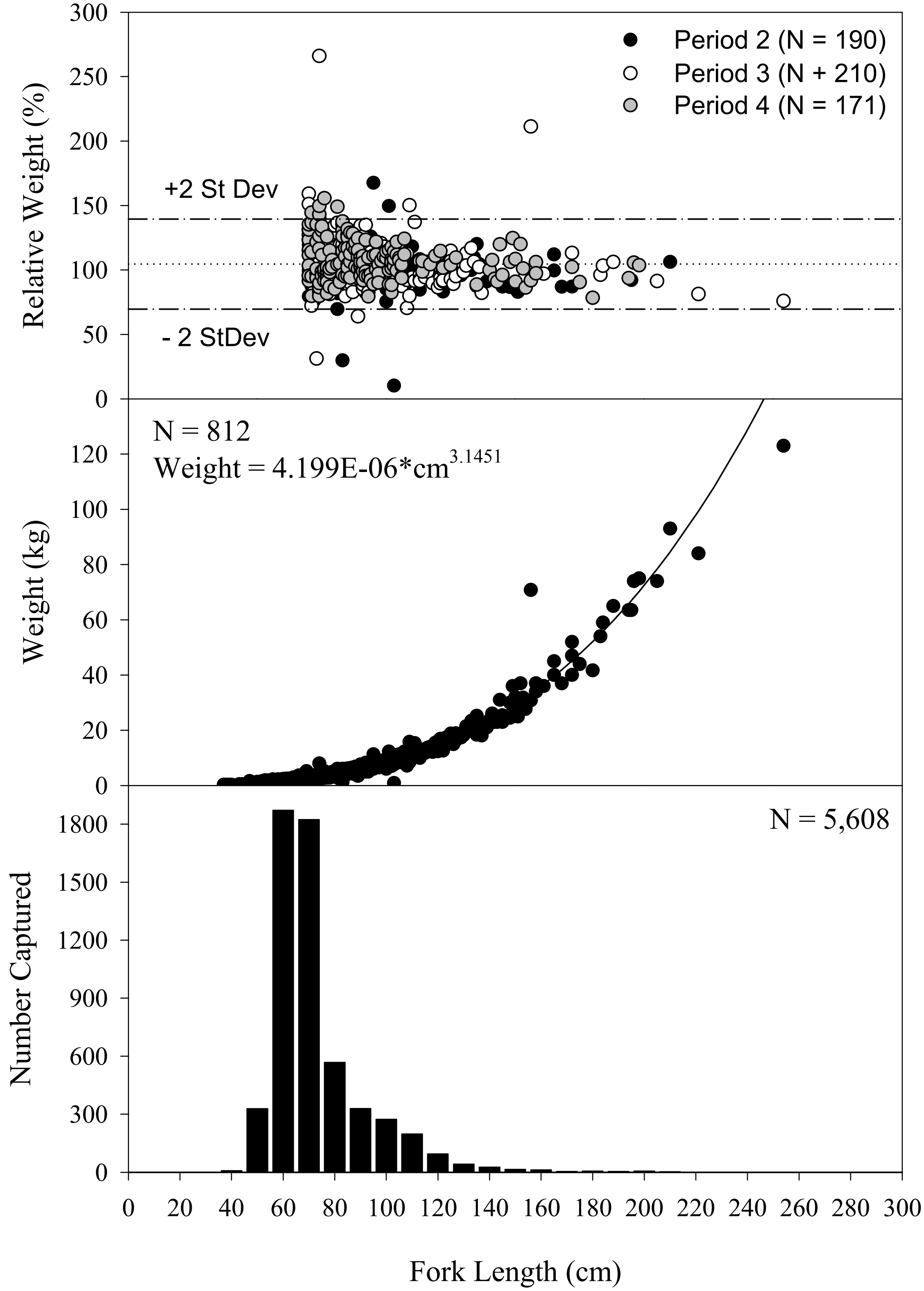

Figure 5. Relative weight, length-weight relationship, and length-frequency distribution of white sturgeon captured during 2002 The Dalles Reservoir stock assessment sampling.

Abundance Estimates

From December 2001 through August 2002, 2,736 white sturgeon of various sizes were marked with PIT-tags by CRITFC and ODFW. Approximately 73% of these marks were applied to white sturgeon from 70–110 cm fork length, another 20% were applied to fish in the 110–137 cm range, and 7% were applied to fish over 137-cm fork length. No fish over 166 cm were recaptured. Using the Schnabel estimate, we estimated the abundance of 70-109 cm and 110-166 cm white sturgeon to be 25,914 (Table 7) and 7,100 fish (Table 8). We estimated abundance of 110-137 cm white sturgeon (legal-sized) to be 5,928 fish (Table 9). We estimated abundance of white sturgeon between 54 and 70 cm to be 70,566 and larger than 166 cm to be 769 fish (Table 9). The total estimated population of white sturgeon >54 cm in The Dalles Reservoir in 2002 was approximately 104,350 fish.

Table 7. Mark/Recapture data and Schnabel estimate of abundance of white sturgeon 70-109 cm fork length, The Dalles Reservoir 2002. Based on PIT-tag mark/recapture data.

Period (t)	Catch (C)	Marks (M)	Recaps (R)	Mortalities Unmarked	Mortalities Marked	Marks at Large (M_t)	Estimate (M_t *C)/(R+1)
1	1,594	1,576		248	40	0	
2	364	313	23	9	0	1,536	23,296
3	594	525	37	11	0	1,849	28,903
4	579	60	56	5	0	2,374	24,115
Sum	3,131	2,474	116				25,914
						Lower 95% CI	21,638
						Upper 95% CI	31,027

Table 8. Mark/Recapture data and Schnabel estimate of abundance of white sturgeon 110-166 cm fork length, The Dalles Reservoir 2002. Based on PIT-tag mark/recapture data.

Period (t)	Catch (C)	Marks (M)	Recaps (R)	Mortalities Unmarked	Mortalities Marked	Marks at Large (M_t)	Estimate (M_t *C)/(R+1)
1	634	629	0	970	86	0	
2	59	52	4	160	0	543	6,407
3	78	63	11	205	0	595	3,868
4	75	29	2	79	0	658	16,450
Sum	846	773	17			Estimate	7,100
						Lower 95% CI	4,526
						Upper 95% CI	11,013

Table 9. Estimated abundance by length interval The Dalles Reservoir, 1997 and 2002.

Size class	1997	2002
54-70 cm	10,360	70,566
70-109 cm	54,604	25,914
110-166 cm	8,300	7,100
167+ cm	200	769
all sizes	73,464	104,350
110-137 cm[a]	8,100[a]	5,928[a]

[a] The 110-137 cm group is contained within the 110-166 cm group estimates and is provided here because it represents the size range of legally harvestable fish.

Trawl and Haul Supplementation

The trawler caught 5,375 white sturgeon in 101 trawl tows for an average of 53.2 fish per tow (Table 10). Mean trawl duration was 17.2 minutes. White sturgeon of various sizes were captured, although fish of the target size group of 35–90-cm fork length dominated the catch (98%, N = 1,579; Figure 6). Mean fork length of transplanted fish estimated from a subsample of 1,555 transported fish was 46.5 cm. Incidental catches of other fish species are shown in Appendix Table A-5.

Of the 5,118 white sturgeon transplanted in 2002, the majority (4,177) were transplanted into John Day Reservoir (Table 11). The remaining 941 fish were transplanted into The Dalles Reservoir. Few mortalities occurred during capture and processing or were observed at release (Table 12). Daily transport densities ranged from 0.0046 to 0.0768 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.

Based on the relative proportions of fish bearing Trawl and Haul scute marks in setline catches and estimated abundance of fish of similar size in the population, we estimated an abundance of 10,588 pre-2002 Trawl and Haul transplants in The Dalles population. This estimate would indicate that roughly 10% of the white sturgeon population in The Dalles Reservoir may have been transplanted from below Bonneville Dam via the Trawl and Haul program.

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 1993-2002.

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	--
2002						
Private trawler	16	101	5,375	53.2	17.2	--

[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 (now NOAA Fisheries).
[c] U. S. Geological Survey-Biological Resources Division.

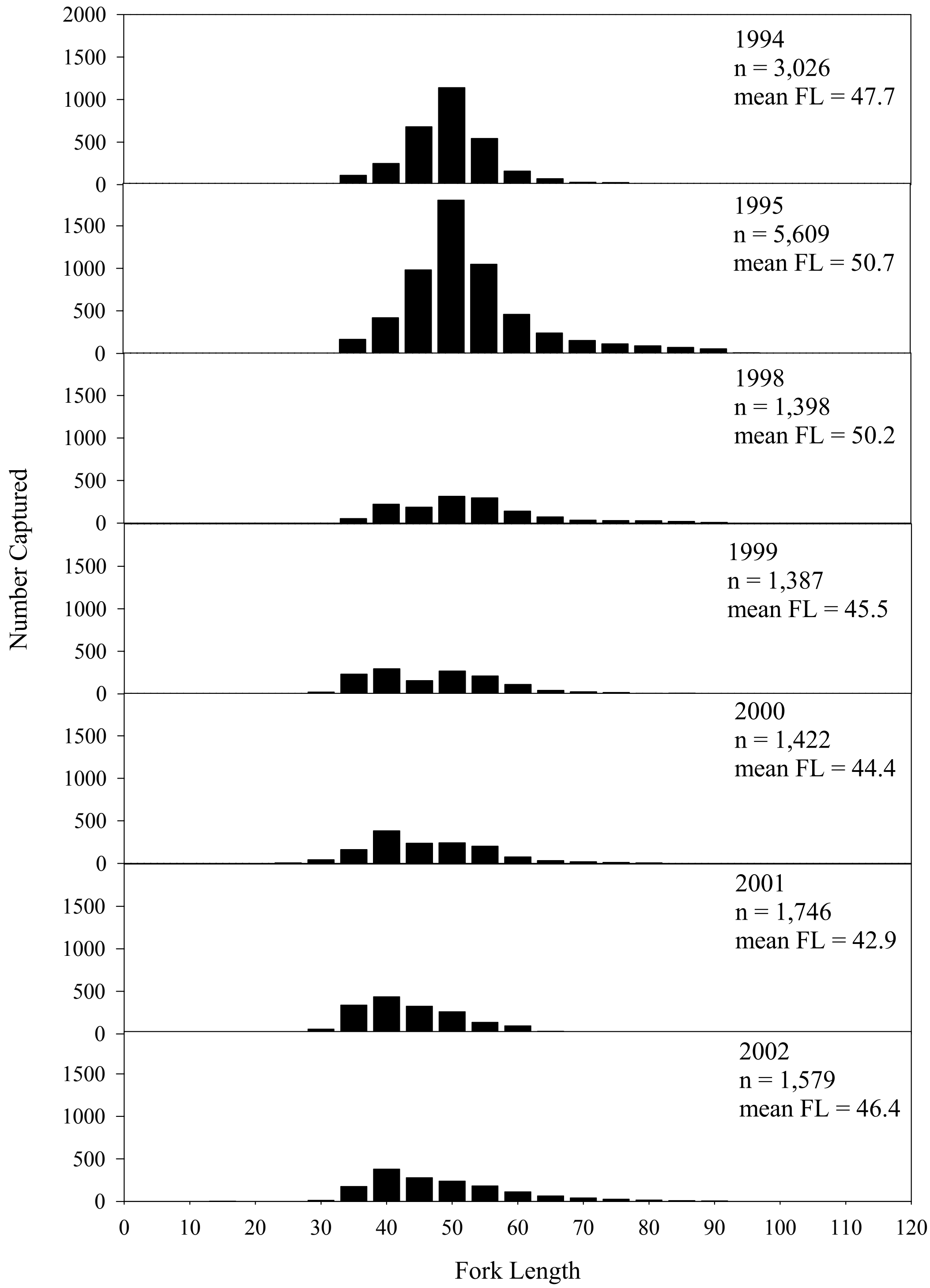

Figure 6. Length-frequency distributions of white sturgeon sampled during Trawl and Haul collections, 1994-2002.

Table 11. Number of white sturgeon transported from below Bonneville Dam to The Dalles and John Day reservoirs from 1994 – 2002.

	Release Reservoir		
Year	The Dalles	John Day	Total
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
2002	941	4,177	5,118
Total	15,241	23,096	38,337

Table 12. Transport data for fish captured below Bonneville Dam and transported to The Dalles and John Day reservoirs, October and November 2002.

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)
10/21	147	0	147	8:00	Maryhill	16.6	15.0/15.0	--/--	13,265	0.51	0.0056
10/22	569	6	563	10:05	Irrigon	13.8	14.4/15.0	13.6/13.6	5,306	0.68	0.0730
10/23	510	3	507	9:35	Boardman	13.6	13.0/15.5	14.0/14.0	13,265	0.63	0.0242
10/24	65	0	65	5:15	Irrigon	13.4	12.7/13.5	10.5/11.5	5,306	0.40	0.0049
10/28	453	1	452	7:45	Arlington	14.2	12.2/13.9	9.0/14.0	13,265	0.85	0.0289
10/29	413	1	412	6:30	Giles French	12.5	11.8/12.2	12.0/14.9	5,306	0.82	0.0640
10/30	302	2	300	7:05	Irrigon	11.5	11.7/11.7	11.0/14.0	13,265	1.05	0.0239
10/31	201	0	201	8:00	Irrigon	10.2	9.4/10.0	12.8/15.1	5,306	1.01	0.0381
11/4	195	0	195	7:00	Giles French	12.2	8.9/8.9	10.0/10.0	13,265	0.72	0.0107
11/5	296	0	296	5:30	Umatilla	12.6	--/--	--/--	5,306	0.94	0.0523
11/6	308	0	308	6:25	Arlington	12.1	9.4/9.4	12.2/12.2	13,265	0.77	0.0179
11/7	143	0	143	7:35	Irrigon	10.6	8.9/8.9	10.0/10.0	5,306	0.65	0.0174
11/12	266	1	265	5:30	Celilo	10.8	9.4/9.4	6.9/10.4	13,265	1.16	0.0233
11/13	432	0	432	5:30	Maryhill	11.2	9.8/9.9	12.2/12.8	5,306	0.94	0.0768
11/14	423	1	422	7:00	Boardman	11.2	9.4/9.4	13.0/13.0	13,265	0.74	0.0237
11/15	410	0	410	6:30	Arlington	--	8.9/9.1	9.8/13.2	5,306	0.64	0.0498
Total	5,133	15	5,118								

Young-of-Year Indexing

Catch and effort data from YOY sampling in the five reservoirs studied is shown in Table 13. We captured 16 YOY in The Dalles Reservoir and 3 in McNary Reservoir in 2002 (Figure 7). No YOY were captured in gill nets in any of the other reservoirs. In The Dalles Reservoir, we caught 68 white sturgeon in 36 gill nets set and fished for a total of 809.8 hours. We set 40 gill nets in John Day Reservoir and captured 13 white sturgeon in 887.2 hours of fishing. In McNary Reservoir, we caught 10 white sturgeon in 36 gill nets fished for a total of 813.1 hours. We fished 36 gill nets in Ice Harbor Reservoir for a total of 815.1 hours, and caught 1 white sturgeon. Catch was slightly higher in Little Goose Reservoir, with 7 white sturgeon captured in 36 nets fished for a total of 785.8 hours. All white sturgeon less than 32 cm fork length were found to by YOY when aged.

Table 13. Young-of-year sampling gill-net effort and catch of white sturgeon in Columbia and Snake River reaches during October and November 2002.

River Reach	Reservoir Quarter				
Parameter	1	2	3	4	All
The Dalles Reservoir					
Gill Net Sets	9	6	15	6	36
Total Hours	201.6	135.4	337.4	135.4	809.8
White Sturgeon Catch (all sizes)	9	32	18	9	68
White Sturgeon Catch (FL<32 cm)	2	14	0	0	16
White Sturgeon / Set	1.00	5.33	1.20	1.50	1.89
White Sturgeon (FL<32 cm)/Set	0.22	2.33	0.00	0.00	0.44
Sets with >0 white sturgeon (all sizes)	44%	100%	47%	100%	64%
Sets with >0 white sturgeon (FL<32 cm)	11%	83%	0%	0%	17%
John Day Reservoir					
Gill Net Sets	10	8	12	10	40
Total Hours	217.2	179.8	272.2	218	887.2
White Sturgeon Catch (all sizes)	0	0	11	2	13
White Sturgeon Catch (FL<32 cm)	0	0	0	0	0
White Sturgeon / Set	0.00	0.00	0.92	0.20	0.33
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%	42%	20%	18%
Sets with >0 white sturgeon (FL<32 cm)	0%	0%	0%	0%	0%
McNary Reservoir/Hanford Reach					
Gill Net Sets	27	9	0	0	36
Total Hours	611.5	201.6	0	0	813.1
White Sturgeon Catch (all sizes)	8	2	0	0	10
White Sturgeon Catch (FL<32 cm)	3	0	0	0	3
White Sturgeon / Set	0.30	0.22	0.00	0.00	0.28
White Sturgeon (FL<32 cm)/Set	0.11	0.00	0.00	0.00	0.08
Sets with >0 white sturgeon (all sizes)	26%	22%	0%	0%	25%
Sets with >0 white sturgeon (FL<32 cm)	7%	0%	0%	0%	6%
Ice Harbor Reservoir					
Gill Net Sets	9	9	9	9	36
Total Hours	206.3	199.3	208	201.6	815.1
White Sturgeon Catch (all sizes)	0	0	1	0	1
White Sturgeon Catch (FL<32 cm)	0	0	0	0	0
White Sturgeon / Set	0.00	0.00	0.11	0.00	0.03
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%	11%	0%	3%
Sets with >0 white sturgeon (FL<32 cm)	0%	0%	0%	0%	0%

Table 13. Con't.

River Reach	Reservoir Quarter				
Parameter	1	2	3	4	All
Little Goose Reservoir					
Gill Net Sets	9	9	9	9	36
Total Hours	197	198	191.9	199	785.8
White Sturgeon Catch (all sizes)	1	2	2	2	7
White Sturgeon Catch (FL<32 cm)	0	0	0	0	0
White Sturgeon / Set	0.11	0.22	0.22	0.22	0.19
White Sturgeon (FL<32 cm)/Set	0.00	0.00	0.00	0.00	0.00
Sets with >0 white sturgeon (all sizes)	11%	22%	22%	22%	19%
Sets with >0 white sturgeon (FL<32 cm)	0%	0%	0%	0%	0%

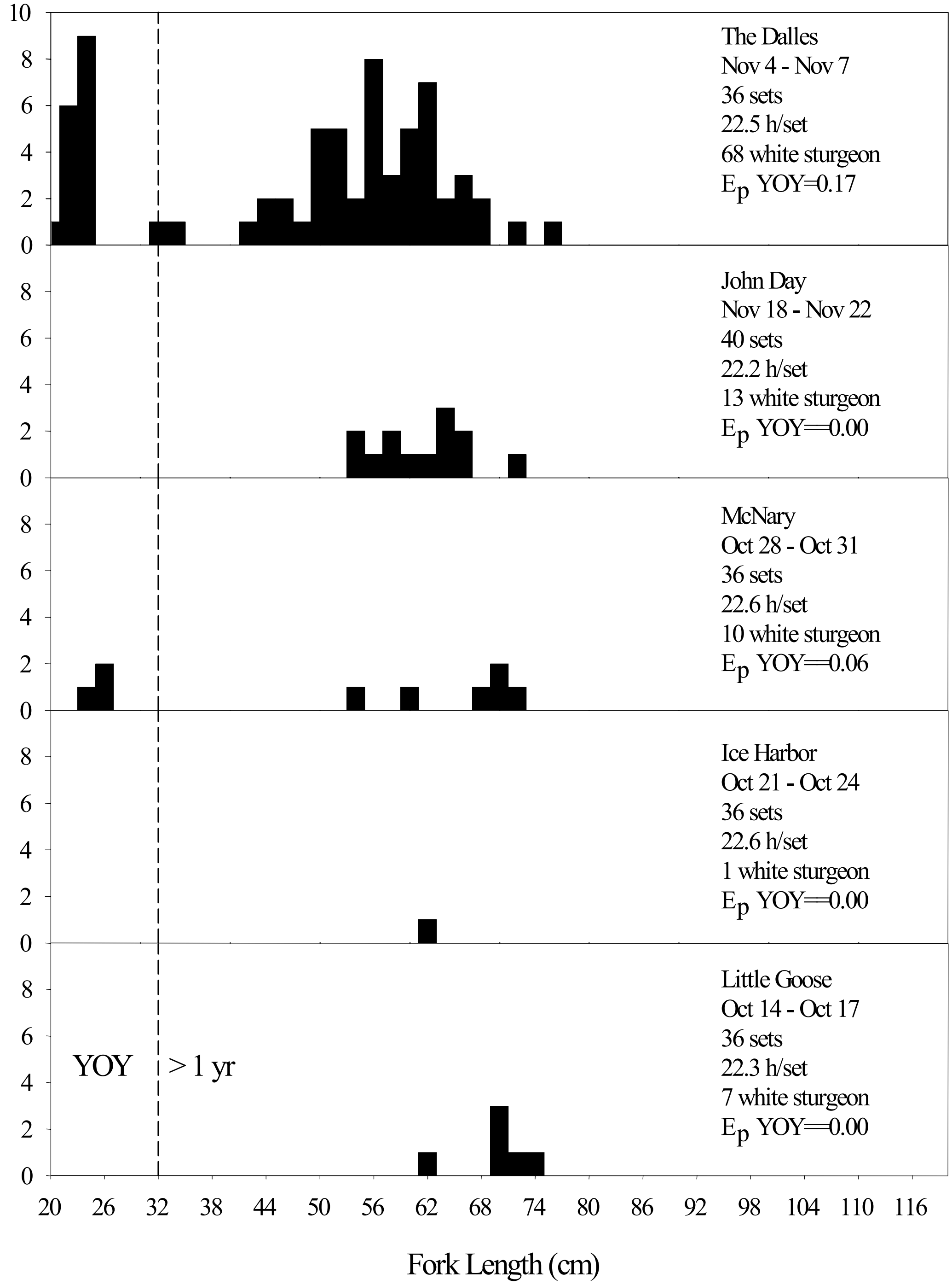

Figure 7. Length-frequency distributions and catch data for white sturgeon captured during Young-of-Year indexing, October – November 2002.

DISCUSSION

Stock Assessment

We continue to find very little movement of white sturgeon between reservoirs. Since 1987, only six marked white sturgeon have been verified from stock assessment sampling as being captured in a reservoir upstream of the original marking location (<1%), 147 have been captured in the reservoir immediately downstream (3%), and nine have been captured two reservoirs downstream (<1%; Table 14, Appendix Tables A-2 to A-5). However, the majority (4,294, or 97%) of sturgeon recaptured were recaptured within the reservoir they were originally marked in.

Final ages for white sturgeon captured in 2002 were compared to past years and resulted in a slight decrease in length-at-age for fish from The Dalles Reservoir from previous years. The von Bertalanffy growth curve was compared to past years (Figure 3) and there appeared to be a slight increase in assigned age. Differences between ages assigned by current readers (Readers 1 and 2) and the previous reader (Reader 3) may reflect a bias developed from our awareness that we tend to underestimate ages of individual samples (Rien and Beamesderfer 1994). Recent findings provide further impetus to develop or identify more accurate and objective means to quantify growth and age.

In past stock assessment surveys, white sturgeon 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 and adjusted for relative vulnerability of each size to capture by setline as estimated from recapture rates of marked fish. In the 1999 Bonneville (Kern et al. 2001) and 2001 John Day (Kern et al. 2002) stock assessments, larger numbers of fish were captured and marked, allowing a more robust estimate of abundance by slightly different methods.

In the 2001 John Day estimate, 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 fish between 110-137 cm and between 138-166 cm based upon their relative length frequencies in the catch of fish between 110-166. In the John Day 2001 estimate, we were able to use the number of scute marks applied and recaptured as the mark-recapture data for the estimate. This allowed us to more accurately represent the 54-109 cm size group (PIT-tags are only applied to fish >69 cm FL). In this estimate, we had to account for multiple-recaptures of fish within individual recovery periods, since we used non-unique marks. To accomplish this, we calculated the rate at which PIT-tagged fish were marked and recaptured in the same sampling period, and applied this rate to adjust the number of scute marks and recaptures.

Table 14. Summary of within and out-of-reservoir recaptures of marked white sturgeon within the Columbia Basin, 1987-2002. 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 2002 sampling.

	Release	Recapture Location					
	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	0.00	0.00
John Day	1989	0	6	1	0	0	--
	1990	0	120	12	1	0	--
	1991	0	17	0	0	0	--
	1996	0	364	27	3	0	--
	2001	--	621	2	--	--	--
	Total	*0*	*1,128*	*42*	*4*	--	--
	Percent	0.00	96.08	3.58	0.34	--	--
The Dalles	1987	1	198	4	1	--	--
	1988	0	233	24	1	--	--
	1989	1	36	0	0	--	--
	1991	1	71	0	0	--	--
	1993	0	2	1	1	--	--
	1994	0	431	10	0	--	--
	1995	0	448	12	0	--	--
	1997	1	384	11	0	--	--
	2002		188	0	0	--	--
	Total	*4*	*1,991*	*62*	*3*	--	--
	Percent	0.19	96.84	3.02	0.15	--	--
Bonneville	1988	0	70	4	--	--	--
	1989	0	336	17	--	--	--
	1991	1	126	12	--	--	--
	1993	0	0	0	--	--	--
	1994	0	138	0	--	--	--
	1999	1	453	0	--	--	--
	Total	*2*	*1,123*	*33*	--	--	--
	Percent	0.17	97.15	2.85	--	--	--
All Reservoirs	Total	6	4,294	147	9	0	0
	Percent	0.13	96.49	3.30	0.20	0.00	0.00

The 2002 The Dalles estimate did not fit this scenario. We attempted to utilize scute marks as our mark-recapture data set in the same way as the 2001 estimate. However, within-period recapture rates of PIT-tagged fish were too low to adequately represent the rate at which fish were marked and recaptured in the same period. Using scute marks as our mark/recapture data set would have been inappropriate without a way to represent the bias of using non-unique marks. Because of this, the 2002 The Dalles abundance estimate is more similar to estimates conducted prior to 1999.

The population abundance estimate for white sturgeon from The Dalles Reservoir in 2002 was 104,350 fish >54 cm total length, compared to 73,500 fish in 1997, and 12,600 in 1994 (North et al. 1998; Appendix Table A-7). Most of the change from 1997 to 2002 was in the sublegal size class. From 1997 to 2002, the estimated abundance of sublegal (<110 cm) fish increased from 65,000 fish in 1997 to 96,500 fish in 2002. During this same period, estimates of the legal-sized population decreased from 8,300 in 1997 to 5,900 fish in 2002. Numbers of over-sized (167+ cm) fish appear to have increased since 1997, with abundance estimates of 200 in 1997 and nearly 800 in 2002. 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.

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 limited by the number of fish we are able to capture. Although we have approached the total capacity of smaller trucks, we have yet to maximize the capacity of large liberation trucks. In 2002, transplant efforts focused mostly on supplementation of the John Day Reservoir population, with 82% 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. 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 estimated the abundance of fish bearing Trawl and Haul scute marks in The Dalles population by extrapolating from the 2002 setline catch of fish of similar sizes. Using these methods, we estimated an abundance of 10,588 fish; approximately 74% of the 14,300 fish released in The Dalles Reservoir since the program began. The abundance of fish marked as 1999 and 2000 transplants was higher than the number of these fish released into the reservoir. These are the same groups of fish that we found in less than expected proportions during 2001 sampling in John Day Reservoir (Kern et al. 2002). This may indicate entrainment of fish from John Day Reservoir to The Dalles Reservoir; one explanation proposed for the apparent low abundance of 1999 and 2000 transplants in John Day Reservoir in 2001. Another explanation proposed was that fish transplanted in those years had not grown large enough to be adequately recruited to the sampling gear and were not captured often enough to adequately estimate abundance. Data from The Dalles sampling may support this theory because we estimated abundance of 2001 transplants into The Dalles Reservoir to be only 245 fish remaining from the original release of 1,257 fish.

The higher than expected number of 1999 and 2000 transplants in The Dalles Reservoir and lower than expected number of these same fish in John Day Reservoir has prompted us to analyze records for PIT tagged fish recovered in Zone 6 reservoirs recently to estimate rates of entrainment between reservoirs. Fish transplanted by the Trawl and Haul program are no longer marked with individual marks, however, the first two releases into The Dalles Reservoir (1994 and 1995) were PIT tagged (Rien and North 2002). These were also the two largest releases to this reservoir. These fish are now becoming large enough to enter the fishery, and so are now being recovered by harvest surveys as well as our stock assessment sampling efforts. Creel surveys from The Dalles Reservoir commercial fisheries sampled 531 fish from an estimated harvest of 1,138 fish. Within the 531 sampled fish, 9 were from 1994 transplants, and 10 were from 1995 transplants. When expanded for sampling effort, the 1994 and 1995 transplants made up approximately 3% (33 of 1,138 estimated harvest) of the total commercial harvest in The Dalles Reservoir in 2002. Sport creel surveys found no transplanted fish harvested by the sport fishery in The Dalles Reservoir in 2002. In 2001, one 1994 transplant was harvested in The Dalles Reservoir commercial fisheries. In 2000, eight 1994 transplants and one 1995 transplant were harvested from The Dalles Reservoir by commercial fisheries. One fish released in The Dalles Reservoir during the 1995 transplant effort was sampled in commercial creel surveys of catch from John Day Reservoir. This indicates some level of entrainment or movement between reservoirs, however the dynamics of this movement are unclear.

Young-of-Year Indexing

Recruitment of YOY in 2002 was higher than in 2001 in The Dalles and McNary reservoirs, however, we documented no YOY recruitment in the remaining reservoirs sampled. It is likely that the extreme low flows in the Columbia River during 2001 contributed to the lack of recruitment seen in that year. Average river flow at McNary Dam between 1 April and 31 July 2001 was 113 kcfs, compared to 249 kcfs during the same period in 2002 (Columbia River DART webpage at www.cbr.washington.edu/dart/dart.html). In fact, 2001 spring flows at McNary Dam were the lowest recorded since at least 1987.

PLANS FOR NEXT YEAR

We will be conducting a stock assessment survey in Bonneville Reservoir in 2003. 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 2003. 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, and will perform analyses to compare the two methods. In the fall of 2003, 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						--
	2002						1
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	2002
Number marked during regular sampling		837	1,248	147	379	--	1,312	--	5,797	2,736
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	2,736
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									
	2002		1		3	2	12		116	188
Recaptured in Bonneville	1987		--	--	--	--	--	--	--	
	1988			--	--	--	--	--	--	
	1989		4		--	--	--	--	--	
	1990	2	1		--	--	--	--	--	
	1991	1	14			--	--	--	--	
	1992		1			--	--	--	--	
	1993	1	2				--	--	--	
	1994		1					--	--	
	1995								--	
	1996					1			--	

Appendix Table A-2 (con't).

		Released in The Dalles								
		1987	1988	1989	1991	1993	1994	1995	1997	2002
Number marked during regular sampling		837	1,248	147	379	--	1,312	--	5,797	2,736
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	2,736
Recaptured in Bonneville (con't.)	1997									
	1998									
	1999		1				10[c]	12[c]	11	
Recaptured in Lower Columbia River	1987	1	--	--	--	--	--	--	--	
	1988			--	--	--	--	--	--	
	1989				--	--	--	--	--	
	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					
	2002				18	2
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	
	2002		
Recaptured in Bonneville	none to date		

Appendix Table A-5. Species composition of bycatch from Trawl and Haul, October and November 2002.

Species	10/21	10/22	10/23	10/24	10/28	10/29	10/30	10/31	11/4	11/5	11/6	11/7	11/12	11/13	11/14	11/15	Total
	Date																
American shad	7	12	15	8	33	112	104	109	220	139	165	25	66	23	6	60	1,104
Chinook salmon									1								1
Unid'd cottid	10	10	18	3	19	14	9		9	4	12	11	7	9	6	9	150
Common carp									1								1
Goldfish				1													1
Leopard dace	6	28		6	1	3	6			1	6	1	1	5		4	68
Largescale sucker	45	9	24	28	36	92	6	21	3	4	5	5	99	29	40	7	453
N. pikeminnow	21	7	13	12	13	22	9	10	8	3	12	9	23	12	7	4	185
Peamouth chub	198	133	243	178	169	220	207	80	128	71	93	168	75	167	129	185	2,444
Redside shiner	1						3	1									5
Sandroller	41	4	48	26	50	14	31	22	10	3	13	13	15	19	21	25	355
Starry flounder	2	2			1		1	1			2						9
Smallmouth Bass								1				1					2
Threespine Stickleback						1		1									2
Walleye			1	1													2
Yellow Perch			1					1									2
Season Total	331	205	363	263	322	478	376	247	380	225	308	233	286	264	209	294	4,784

Appendix Table A-6. Bycatch from Young-of-Year index sampling, October – November 2002.

	Reservoir																			
	Little Goose				Ice Harbor				McNary				John Day			The Dalles				
	Disposition				Disposition				Disposition				Disposition			Disposition				
	1	2	3	All	1	2	3	All	1	2	3	All	1	3	All	1	2	3	All	Total
American Shad			2	2			3	3			1	1			2	2				8
Bullhead	1			1																1
Bridgelip Sucker	5		8	13	2		2	4	12		2	14	14		4	18	4	5	9	58
Channel Catfish	593		62	655	761		54	815	438		10	448	33			33	1		1	1,952
Chinook	17		27	44	1			1									1	2	3	48
Chiselmouth	70		129	199	19		18	37	50		40	90	6			6	6		6	338
Carp		1		1																1
Crappie	12		9	21	19		33	52			1	1					1		1	75
Largescale Sucker	100		92	192	12		5	17	11		8	19	2			2	5	1	6	236
Pikeminnow	107		351	458	1	13	73	87	4	12	50	66		6	7	13	6	196	202	826
Peamouth Chub	261		381	642	152		481	633	15		63	78	4		6	10	95	200	295	1,658
Smallmouth Bass					4			4					1			1	1		1	6
Steelhead					1		1	2									1		1	3
Walleye													1		1	2	3	10	13	15
Whitefish			1	1													2		2	3
Yellow Perch	8		6	14	75		95	170	195		211	406	37		59	96	83	34	117	803
Sculpin													6			6	3	3	6	12
Sockeye	1		1	2																2
Sandroller							1	1												1
All species	1,175	1	1,069	2,245	1,047	13	766	1,826	725	12	386	1,123	106	6	79	191	212	451	663	6,048

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

Appendix Table A-7. Abundance estimates for Zone 6 reservoirs and the Hanford Reach of McNary Reservoir, 1987 – 2002.

Year	30-72 inch total length Ñ(95% CI)	Number of fish by total length interval (inches)						Number/ acre[a]	Pounds/ acre[a]
		24-36	36-48	48-60	60-72	72+	Sum		
				Hanford Reach and McNary Reservoir					
1995	5,234 (3,782-9,086)	900	2,700	3,400		1,250	8,250	0.2	8
				Bonneville Reservoir					
1989	35,400 (27,500-45,400)	32,900	16,700	1,000	200	600	51,400	2.5	27
1994	35,200 (24,800-66,000)	31,300	18,300	1,300	200	900	52,000	2.5	--
1999	85,400[b]	82,400	41,800	3,200	600	400	128,400	6.2	59
				The Dalles Reservoir					
1987	23,600 (15,700-33,600)	7,800	11,000	6,100	1,800	1,000	27,700	2.5	73
1988	9,000 (7,300-11,000)	4,200	4,300	1,500	500	800	11,300	1.0	32
1994	9,700 (7,500-14,000)	5,800	5,700	800	<50	300	12,600	1.1	--
1997	59,800 (52,400-68,100)	26,500	38,500	8,100	200	200	73,500	6.6	59
2002	33,000 (26,200-42,000)	82,900	13,500	5,900	1,200	800	104,300	9.4	104
				John Day Reservoir					
1990	3,900 (2,300-6,100)	16,600	1,700	400	100	500	19,300	0.4	3
1996	27,100 (23,800-30,800)	5,800	19,700	4,050	350	700	30,600	0.6	11
2001	19,600[b]	14,900	12,800	1,100	300	900	30,000	0.6	9

[a] Hanford Reach and McNary Reservoir = 45,500 acres; Bonneville Reservoir = 20,800 acres; The Dalles Reservoir = 11,100 acres; John Day Reservoir = 51,900 acres.

[b] Confidence intervals for these estimates are not provided because they are pooled from estimates of other size classes, not directly calculated from Mark-Recapture data.

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

ANNUAL PROGRESS REPORT

APRIL 2002 – MARCH 2003

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 2002 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 2002 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 July 13 – December 31 in The Dalles Reservoir, with an estimated harvest of 878 fish (125% of the 2002 guideline). The fishery in Bonneville Reservoir was closed to retention of sturgeon August 5 – September 27, with an estimated harvest of 1,560 fish (102% of guideline). The John Day Reservoir was closed to retention August 24 – December 31, with an estimate harvest of 187 fish (113% of guideline).

Treaty Indian commercial fishers landed 472 white sturgeon from Bonneville Reservoir (36% of the 2002 guideline), 1,152 from The Dalles Reservoir (105% of guideline), and 326 from John Day Reservoir (97% of guideline), during gill net and setline fisheries. The Columbia River Inter-Tribal Fish Commission and the Yakama Indian Nation estimated an additional 370 fish were harvested from the three reservoirs (146 from Bonneville Reservoir, 197 from The Dalles Reservoir, and 27 from the John Day Reservoir), during the 2002 subsistence fisheries.

The analyses of harvest, effort, catch length-frequency, and season durations, point toward the need to reduce the current harvest guidelines in Bonneville Reservoir. The Dalles harvest guidelines may also need to be reduced, though the argument for such reductions is only weakly supported by the fishery data and mostly supported by the 2002 stock assessment results. The harvest guidelines in John Day Reservoir were reduced in 2002.

A growing interest in catch and release of oversized sturgeon will require additional monitoring of anglers, especially during the non-retention seasons, and especially in the John Day Reservoir where such activity is already established.

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 2002 but focuses on work conducted from 1 April 2002 through 31 March 2003.

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 1.2, 1.3, 3.1, and 3.3 during the performance period. Task 1.2 required WDFW to work with CRITFC to collect mature adult white sturgeon for spawning at a satellite sturgeon facility at the McNary Dam Juvenile Fish Facility. This work is described in further detail by CRITFC, in Report E of this annual report. Task 1.3 involved population modeling to estimate exploitation rates at which optimum-sustainable-yield is achieved in Bonneville, The Dalles, and John Day populations. This work was presented to the Sturgeon Management Task Force of the Columbia Basin Fish and Wildlife Authority for review and use in developing the annual white sturgeon fisheries management plan for Zone 6 reservoirs. The task also required WDFW to conduct periodic sampling of the Zone 6 recreational and commercial fisheries, and to provide technical input to the in-season management of those fisheries. Task 3.1 involved monitoring the status of populations in the three reservoirs. WDFW worked closely with ODFW in a multiple pass mark-recapture study of The Dalles reservoir population (see Report A in this annual report). Another aspect of this task was 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). Task 3.3 involved describing annual variation in white sturgeon recruitment in impoundments. We worked with staff from ODFW and the Yakama Indian Nation (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 (YOY; Age-0) white sturgeon (see Report A and Report C in this annual report).

METHODS

Sport Fishery Census

The 2002 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 every year 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 the 1987 to 1991 aerial counts of anglers within and outside of established 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 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 derived from the 2002 counts 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 2002 was used to adjust the 2002 bank angling HPUE such that boat HPUE versus 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 2002 retention season for white sturgeon in Bonneville Reservoir opened January 1 and projected to run through August 31 (pre-season estimate of when the guideline would be met). Based on in-season projections, state fishery managers announced that the fishery would be closed to retention of white sturgeon early, on August 5. During the two weeks between the announcement and the closing date, the angling pressure and HPUE declined, resulting in the harvest falling 20% short of the guideline. Because the shortfall was a significant number of fish (276), the season was reopened on September 28 to allow more harvest through the end of the year. The final harvest exceeded the guideline by 2%.

Anglers fished an estimated 126,615 hours (27,501 trips) in Bonneville Reservoir during the retention season (Table 1). Angling effort for sturgeon comprised 52% (14,261 trips) of the total estimated effort. The estimated number of angler trips by species targeted were as follows: 8,655 (31%) for anadromous salmonids, 1,081 (4%) for American shad *Alosa sapidissima*, 187 (1%) for walleye, 1,499 (5%) for bass, 1,571 (6%) for northern pikeminnow, 171 (<1%) for other resident fish, and 76 (<1%) for anglers participating in tournaments.

Anglers harvested an estimated 1,560 white sturgeon during 14,261 trips for sturgeon during the retention season; a 19% increase in harvest and 17% increase in angler trips from the 2001 retention period (Table 2). 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 November at 0.21 fish per trip and averaged 0.08 fish per trip for bank anglers and 0.14 fish per trip for boat anglers targeting sturgeon during the retention fishery (Table 3). The 2,164 sturgeon anglers interviewed accounted for 11% of the estimated bank effort (angler hours) and 11% of the estimated boat effort for sturgeon (Table 4).

Anglers released 18% of the legal-size catch during the retention period (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 90%, 7%, and 3%, respectively (Table 4). 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 2001 levels for boat anglers but increased for bank anglers (Table 6).

The Dalles Reservoir

The 2002 retention season for white sturgeon in The Dalles Reservoir opened January 1 and was projected to close August 31 (pre-season estimate of when guideline met). We began our survey on January 1 and continued sampling through July 12. State fishery managers closed the fishery to retention of white sturgeon on July 13 based on our in-season projection that harvest would reach the guideline by that date. However, high effort and harvest per unit effort during the end of the fishery pushed the harvest to 25% over guideline.

Anglers fished an estimated 108,291 hours (16,924 trips) in The Dalles Reservoir during the retention season (Table 1). Angling effort for white sturgeon comprised 47% (8,019 trips) of the total estimated effort. The number of angler trips estimated by target species were as follows: 2,868 (17%) for anadromous salmonids, 1,484 (9%) for American shad, 1,896 (11%) for walleye, 1,100 (7%) for bass, 1,097 (6%) for northern pikeminnow, 460 (3%) for other resident fish, and 0 (0%) for anglers participating in tournaments.

Anglers harvested an estimated 878 white sturgeon during 8,019 trips for sturgeon during the retention period (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 (Table 3). The harvest per trip (bank and boat combined) peaked in July at 0.27 fish per trip. Harvest per trip averaged 0.07 for bank anglers and 0.14 for boat anglers targeting sturgeon during the retention fishery. The 1,668 white sturgeon anglers interviewed accounted for 15% of the estimated bank effort (angler hours) and 14% 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 88%, 9%, and 3%, respectively (Table 4). This distribution of catch by size is nearly the same as 2001. 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, increased from the pervious year, while harvest per trip for boat anglers decreased (Table 6). This represents a return to more typical conditions from last year (when boat anglers discovered a large concentration of legal-size fish).

John Day Reservoir

We began our survey of the 2002 sport fishery in John Day Reservoir on January 1 and continued sampling through August 23. The fishery was closed to retention of white sturgeon on August 24. The guideline was exceeded by 13%, despite the shorter season than last year. This was probably attributed, in part, to the 70% reduction in the guideline (from 560 fish to 165 fish).

Anglers fished an estimated 157,919 hours (27,974 trips) in John Day Reservoir during 2002 (Table 1). Angling effort for white sturgeon comprised 31% (8,671 trips) of the total estimated effort. The number of angler trips estimated by target species were as follows: 5,938 (21%) for anadromous salmonids, 767 (3%) for American shad, 5,954 (21%) for walleye, 5,686 (20%) for bass, 217 (<1%) for northern pikeminnow, 273 (1%) for other resident fish, and 468 (2%) for tournament anglers.

Anglers harvested an estimated 187 white sturgeon during 8,671 trips for sturgeon in 2002 (Table 2). Anglers concentrated their effort for sturgeon from McNary Dam downstream past Irrigon, Oregon (Rkm 449). Effort for white sturgeon was greatest in May (Table 3). Harvest per trip averaged 0.02 for bank anglers and 0.02 for boat anglers (Table 3). The 1,546 sturgeon anglers interviewed accounted for 15% of the estimated bank effort (angler hours) and 12% 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 84%, 3%, and 13%, 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 boat anglers but decreased for bank anglers from 2001 levels (Table 6).

Treaty Indian Commercial and Subsistence Harvest

The 2002 treaty Indian commercial harvest estimates for Zone 6 were 472 white sturgeon from Bonneville Reservoir, 1,152 white sturgeon from The Dalles Reservoir, and 326 white sturgeon from John Day Reservoir (Table 7). More than 80% 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, (Joint Columbia River Management Staff, 2002). The treaty Indian Zone 6 subsistence white sturgeon harvest estimated by CRITFC and YIN was 370 fish (Table 7): 146 from Bonneville Reservoir; 197 from The Dalles Reservoir; and, 27 from John Day Reservoir.

DISCUSSION

Zone 6 Sturgeon Harvest Management

Bonneville Reservoir

Since the 1,520 fish guideline began in 1997, the recreational harvest per unit effort (HPUE) has declined, while the effort has increased. The relationship is similar 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 and the number of angler trips is increasing, it seems 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 an increasing proportion of fish just recruited to the legal-size class. This appears to be the case. The portion of fish harvested within the smallest 15cm of the legal-size slot (95-109 cm Fork Length), went from 64% in the 2001 season (Langness et al. 2002) to 74% during the 2002 season. Furthermore, harvest in Bonneville Reservoir is more skewed toward smaller fish than The Dalles and John Day fisheries (69% and 67% of the fish harvested in 2002 were within the smallest 15 cm of the legal-size slot 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 1,520 fish harvest guideline has more than doubled (from 3.5 months in 1997 to 10 months in 2002). This longer time to achieve harvest guideline, combined with the doubling of effort, supports the notion that anglers had to fish twice as long in 2002 to get a keeper, as they did in 1997.

At the time of the last Bonneville Reservoir stock assessment in 1999 (Kern et al. 2001), stock abundance estimates supported the current harvest guideline. Recent harvest data suggests that the legal-sized population in Bonneville Reservoir may be declining, and therefore a lower harvest guideline may be appropriate. The 2003 Bonneville Reservoir stock assessment will give us a new estimate of the population abundance, new estimates of growth rates, and a better idea of whether the harvest guideline should be adjusted or not.

The Dalles Reservoir

Following the significant harvest guideline increase in 1998, effort has declined and HPUE has fluctuated in both the boat and bank angler fisheries. The 2002 season reversed the declining trend in effort, especially by boat anglers where record effort was seen. Despite this increase in effort, the HPUE remained similar to previous seasons. For the first time, boat angler effort exceeded bank angler effort. The conflicting trends in effort and the shift in fishing methods, make it difficult to assess the status of the stock from catch and effort data.

Stock abundance estimates from the 1997 Dalles Reservoir stock assessment (North et al., 1999), supported the tripling of the recreational harvest guideline to 700 fish in 1998. That guideline has been achieved slightly later each year (with the exception of 2001, when high harvests per unit effort occurred as a result of anglers coming upon an unusual concentration of legal size fish). Size composition of the catch has shifted towards smaller fish (69% of the 2002 harvested fish were in the smallest 15 cm of the legal-size range (110-124 cm Fork Length), versus 64 % of the 2001 harvest). These weak trends in season-length and size-composition suggest that the legal-size population may not be able to support the 700 fish guideline.

The 2002 stock assessment in The Dalles provides additional information that supports the above findings. Specifically, the legal-sized population estimate in the reservoir declined from 8,300 fish in 1997 (North et al. 1999) to 5,900 fish in 2002 (Report A in this Annual Report). Given the results of the 2002 stock assessment and the trends in recent harvest data, WDFW recommends that the harvest guidelines for The Dalles sturgeon fisheries be reduced.

John Day Reservoir

Recreational effort initially rose following the adoption of the 560 fish guideline in 1997. After peaking in 1999, the effort declined. Boat and bank angler HPUEs have shown a general decline since 1997. The proportion of effort attributed to each group has remained quite stable since 1989 (slightly favoring boat anglers). Size composition of the catch has shifted towards smaller fish (67% of the 2002 harvested fish were in the smallest 15 cm of the legal-size range (110-124 cm Fork Length), versus 37 % of the 2001 harvest). The 2001 stock assessment (Kern et al. 2002) estimated a slight increase in the sub-legal population size from 25,500 in 1996 to 27,667 in 2001, and a drastic decline in the legal-sized population from 4,040 in 1996 to 1,077 in 2001. Thus, the shift in size composition of harvested fish may reflect the passing of a series of poor year-classes through the legal-size slot.

The recreational harvest guideline was not achieved in most years from 1997-2001. This inability to harvest 560 fish, combined with a lower legal-sized population abundance estimate, and indications of poor recruitment into the fishery, resulted in lowering the guideline in 2002 to 165 fish. This lower guideline was achieved in the 2002 season by late August. Additional years of data are needed before refinements to the guideline are justified.

For the last few years, there has been a high proportion of the catch (10-13%) that is oversized, relative to the levels seen in the other reservoirs (3%). It appears that the John Day Reservoir sturgeon anglers have developed a small but growing oversize catch and release fishery. Since the repeated catch and release of oversized sturgeon may have adverse consequences to the population (disruption of the maturation process, increased mortality of mature fish, etc.), this aspect of the John Day fishery may need closer inspection and increased monitoring.

PLANS FOR NEXT YEAR

WDFW will continue to monitor Zone 6 sport and treaty Indian commercial fisheries in 2003. We will work with ODFW, during the summer of 2003, to assess the status of the white sturgeon population in the Bonneville Reservoir. Also, we will capture broodstock white sturgeon for CRITFC's aquaculture supplementation experiment. We will work with fishing guides to obtain breeding 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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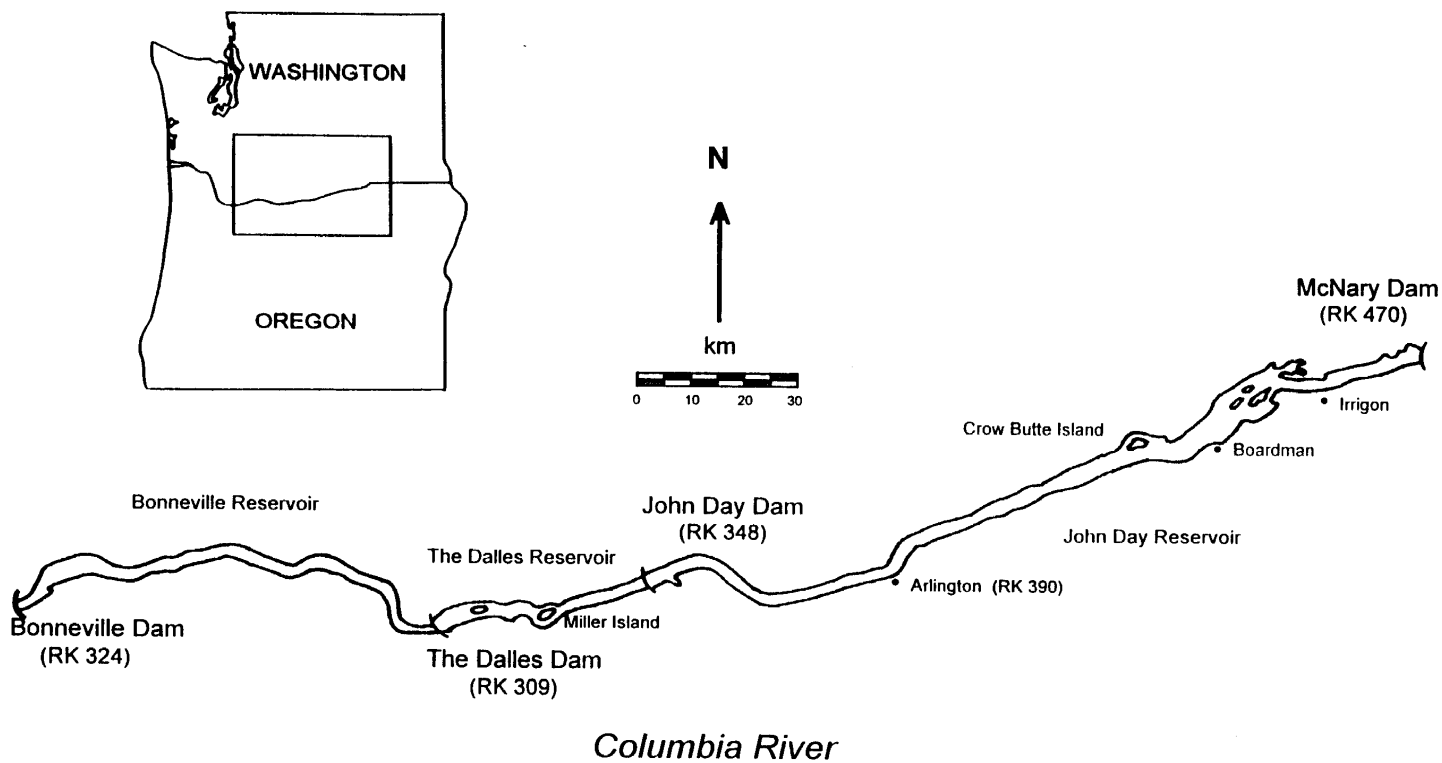

Figure 1. Location of the 2000 recreational fishery census on the Columbia River: Bonneville and The Dalles reservoirs and from Arlington upstream to McNary Dam on John Day Reservoir.

Table 1. Combined Washington and Oregon recreational fishery angling effort estimates for Bonneville Reservoir, January 1 through August 4 and Sept 28 through December 31, 2002; The Dalles Reservoir, January 1 through July 12, 2002; and John Day Reservoir, January 1 through August 23, 2002.

Species	Bonneville		The Dalles		John Day	
Method	Hours	Trips	Hours	Trips	Hours	Trips
Sturgeon						
Bank	36,820	7,838	32,516	3,879	16,256	2,794
Boat	29,438	6,423	22,568	4,140	35,288	5,877
Total	66,258	14,261	55,084	8,019	51,544	8,671
Salmonid						
Bank	12,478	1,492	15,082	1,451	10,244	2,112
Boat	25,107	7,163	7,271	1,417	23,275	3,826
Total	37,585	8,655	22,353	2,868	33,519	5,938
Shad						
Bank	4,812	1,069	7,824	1,484	1,324	431
Boat	59	12	0	0	1,802	336
Total	4,871	1,081	7,824	1,484	3,126	767
Walleye						
Bank	0	0	266	43	0	0
Boat	738	187	9,370	1,853	31,240	5,954
Total	738	187	9,636	1,896	31,240	5,954
Bass						
Bank	866	262	1,426	365	298	60
Boat	5,917	1,237	3,059	735	31,800	5,626
Total	6,783	1,499	4,485	1,100	32,098	5,686
Northern Pikeminnow						
Bank	5,215	909	1,942	249	88	12
Boat	3,871	662	4,267	848	1,197	205
Total	9,086	1,571	6,209	1,097	1,285	217
Other						
Bank	539	151	2,673	451	733	126
Boat	74	20	27	9	597	147
Total	613	171	2,700	460	1,330	273
Tournament						
Bank	0	0	0	0	0	0
Boat	681	76	0	0	3,777	468
Total	681	76	0	0	3,777	468
Combined Total						
Bank	60,730	11,721	61,729	7,922	28,943	5,535
Boat	65,885	15,780	46,562	9,002	128,976	22,439
Total	126,615	27,501	108,291	16,924	157,919	27,974

Table 2. Combined Washington and Oregon recreational fishery harvest, and catch and release estimates for Bonneville Reservoir, January 1 through August 4 and Sept 28 through December 31, 2002; The Dalles Reservoir, January 1 through July 12, 2002; and John Day Reservoir, January 1 through August 23, 2002.

Species	Bonneville	The Dalles	John Day
White sturgeon [a]			
Legals kept	1,560	878	187
Sublegals released	26,824	9,029	6,384
Legals released	334	8	92
Oversize released	980	303	977
Total	29,698	10,218	7,640
Chinook salmon [b]			
Adults kept	554	448	589
Jacks kept	16	11	0
Total kept	570	459	589
Released	1,012	213	607
Coho salmon [c]			
Bank	2,173	0	10
Boat	1,367	0	0
Total	3,540	0	10
Steelhead [d]			
Kept	480	337	905
Released	186	66	772
American shad			
Kept	6,522	6,833	6,975
Released	1,461	10,218	630
Walleye			
Kept	38	999	3,884
Released	1,045	181	19,867
Bass			
Kept	1,335	1,614	2,093
Released	3,614	4,485	10,592
Northern pikeminnow kept	6,981	3,537	2,812
Other resident fish kept	231	179	421

[a] *White sturgeon seasons were closed to retention August 5 – September 27 in Bonneville Reservoir, July 13 – December 31 in The Dalles reservoir, and August 24 – December 31 in John Day Reservoir.*

[b] *Chinook seasons were closed to retention January 1 – April 5 in Bonneville Reservoir, January 1 through March 15 in The Dalles and John Day reservoirs, and May 16 through June 15 in all three reservoirs.*

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

[d] *Steelhead seasons were closed to retention May 16 - 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 4 and Sept 28 through December 31, 2002; The Dalles Reservoir, January 1 through July 12, 2002; and John Day Reservoir, January 1 through August 23, 2002.

Month	Bonneville			The Dalles			John Day		
Method	Trips	HPUE	Harvest	Trips	HPUE	Harvest	Trips	HPUE	Harvest
January									
Bank	893	0.05	41	518	0.02	9	31	0.00	0
Boat	817	0.21	171	418	0.19	81	35	0.00	0
Total	1,710	0.12	212	936	0.10	90	66	0.00	0
February									
Bank	489	0.00	0	438	0.00	0	120	0.01	1
Boat	1,144	0.15	171	408	0.05	22	71	0.03	2
Total	1,633	0.10	171	846	0.03	22	191	0.02	3
March									
Bank	413	0.03	14	487	0.00	0	276	0.00	0
Boat	610	0.09	55	465	0.15	68	362	0.00	0
Total	1,023	0.07	69	952	0.07	68	638	0.00	0
April									
Bank	502	0.08	38	557	0.06	33	395	0.03	12
Boat	346	0.05	19	497	0.19	95	505	0.08	42
Total	848	0.07	57	1,054	0.12	128	900	0.06	54
May									
Bank	460	0.17	76	825	0.01	11	408	0.00	0
Boat	383	0.05	18	546	0.05	26	1,873	0.00	2
Total	843	0.11	94	1,371	0.03	37	2,281	0.00	2
June									
Bank	1,044	0.05	47	811	0.23	189	404	0.01	5
Boat	914	0.03	28	960	0.06	53	924	0.04	39
Total	1,958	0.04	75	1,771	0.14	242	1,328	0.03	44
July									
Bank	2,231	0.12	275	243	0.16 [a]	38	753	0.05	36
Boat	1,040	0.20	210	846	0.30 [a]	253	1,457	0.03	48
Total	3,271	0.15	485	1,089	0.27 [a]	291	2,210	0.04	84
August									
Bank	102	0.14 [a]	14	0	0.00	0	407	0.00 [a]	0
Boat	220	0.30 [a]	67	0	0.00	0	650	0.00 [a]	0
Total	322	0.25 [a]	81	0	0.00	0	1,057	0.00 [a]	0
September									
Bank	0	0.00	0	0	0.00	0	0	0.00	0
Boat	0	0.00	0	0	0.00	0	0	0.00	0
Total	0	0.00	0	0	0.00	0	0	0.00	0

continued

Table 3. Continued.

Month Method	Bonneville Trips	Bonneville HPUE	Bonneville Harvest	The Dalles Trips	The Dalles HPUE	The Dalles Harvest	John Day Trips	John Day HPUE	John Day Harvest
October									
Bank	807	0.11	91	0	0.00	0	0	0.00	0
Boat	225	0.00	0	0	0.00	0	0	0.00	0
Total	1,032	0.09	91	0	0.00	0	0	0.00	0
November									
Bank	661	0.10	69	0	0.00	0	0	0.00	0
Boat	386	.038	148	0	0.00	0	0	0.00	0
Total	1,047	0.21	217	0	0.00	0	0	0.00	0
December									
Bank	236	0.00	0	0	0.00	0	0	0.00	0
Boat	338	0.02	8	0	0.00	0	0	0.00	0
Total	574	0.01	8	0	0.00	0	0	0.00	0
Combined									
Bank	7,838	0.08 [a]	665	3,879	0.07 [a]	280	2,794	0.02	54
Boat	6,423	0.14 [a]	895	4,140	0.14 [a]	598	5,877	0.02	133
Total	14,261	0.11 [a]	1,560	8,019	0.11 [a]	878	8,671	0.02	187

[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 4 and Sept 28 through December 31, 2002; The Dalles Reservoir, January 1 through July 12, 2002; and John Day Reservoir, January 1 through August 23, 2002.

Reservoir Method/Month	Anglers checked	Hours fished	Sublegal released	Legal Released	Legal kept	Oversize released
Bonneville						
Bank						
January	180	455	23	1	4	1
February	160	410	24	0	0	0
March	184	446	27	0	3	0
April	179	402	106	3	6	2
May	172	577	177	7	12	0
June	138	364	127	0	4	1
July	226	661	390	3	17	3
August	24	89	72	2	2	0
September	0	0	0	0	0	0
October	130	413	123	1	7	0
November	88	266	20	0	5	0
December	56	111	10	0	0	0
Bank Total	1,537	4,194	1,107	17	60	7
Boat						
January	120	630	334	8	29	1
February	90	389	232	4	17	0
March	104	472	159	0	9	0
April	61	281	65	0	3	4
May	62	334	93	1	3	29
June	28	180	30	0	1	12
July	73	370	135	0	13	19
August	39	217	164	0	12	5
September	0	0	0	0	0	0
October	7	37	12	0	0	1
November	23	110	222	5	12	1
December	20	86	25	1	1	1
Boat Total	627	3,106	1,471	19	100	73
Combined Total	2,164	7,300	2,578	36	160	80

continued

Table 4. Continued.

Reservoir Method/Month	Anglers checked	Hours fished	Sublegal released	Legal Released	Legal kept	Oversize released
The Dalles						
Bank						
January	194	802	15	0	4	7
February	163	868	2	0	0	1
March	157	783	2	0	0	2
April	198	850	35	0	5	0
May	114	465	62	0	2	0
June	182	787	204	1	19	5
July	94	370	103	0	7	2
Bank Total	1,102	4,925	423	1	37	17
Boat						
January	58	289	120	0	11	0
February	84	413	42	0	4	3
March	158	1,037	208	0	20	1
April	108	539	153	0	22	2
May	74	442	94	0	6	3
June	54	265	95	0	6	5
July	30	171	71	0	11	3
Boat Total	566	3,154	783	0	80	20
Combined Total	1,668	8,079	1,206	1	117	37
John Day						
Bank						
January	45	132	0	0	0	1
February	63	155	3	0	0	0
March	85	245	26	0	0	1
April	175	507	105	0	1	1
May	81	265	11	2	0	0
June	142	419	33	0	0	15
July	135	248	35	0	2	3
August	96	278	9	0	0	0
Bank Total	822	2,429	258	2	3	21
Boat						
January	17	89	3	0	0	2
February	37	187	8	2	2	2
March	92	428	39	0	0	3
April	150	808	129	0	2	4
May	64	354	42	2	1	3
June	148	1,069	140	0	9	51
July	140	860	134	1	7	38
August	76	450	138	0	0	5
Boat Total	724	4,245	633	5	21	108
Combined Total	1,546	6,674	855	7	24	129

Table 5. Length frequencies of harvested white sturgeon measured during sampling of recreational fisheries in Bonneville Reservoir, January 1 through August 4 and Sept 28 through December 31, 2002; The Dalles Reservoir, January 1 through July 12, 2002; and John Day Reservoir, January 1 through August 23, 2002.

Fork Length (cm)	Bonneville	The Dalles	John Day	Fork Length (cm)	Bonneville	The Dalles	John Day
90				130	2		
91				131		2	
92				132		3	
93	1			133	1	4	
94	3			134		1	
95	7			135		2	
96	10			136		1	
97	9			137		1	
98	17			138		2	
99	18			139		1	
100	6			140		1	
101	2			141			
102	8			142		1	
103	8			143			
104	7			144			
105	2			145			
106	6			146			
107	8			147			
108	3	1		148			
109	7	4	4	149			
110	4	2	5	150			
111	1	5	2	151			
112	6	11	1	152			
113	4	3	2	153			
114	3	11	2	154			
115	4	10	3	155			
116	2	6		156			
117		2		157			
118	1	2		158			
119	1	5		159			
120		6		160			
121	2	2		161			
122	2	8		162			
123		3		163			
124		2	1	164			
125		2	1	165			
126			1	166			
127	1	7	1	167			
128	2	1	1				
129	1	1		Total	160	113	24

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 2002.

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) [a]							
1987	-- [b]						
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	-- [b]						
1992	-- [b]						
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
2002	Jan-Aug 4; Sep 28-Dec	7,838	644	0.082	6,423	867	0.135
The Dalles (110-138 cm fork length interval) [a]							
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	-- [b]						
1991	-- [b]						
1992	-- [b]						
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
2002	Jan-July 12	3,879	260	0.067	4,140	556	0.134

Table 6 continued.

John Day (110-138 cm fork length interval) [a]							
1987	-- [b]						
1988	-- [b]						
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	-- [b]						
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
2002	Jan-Aug 23	2,794	45	0.016	5,877	111	0.019

[a] *Harvest estimates exclude legally kept fish with fork lengths outside the given ranges for each reservoir.*

[b] *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 2002.

Fishery	Bonneville		The Dalles		John Day		Unspecified	
Year	Guideline	Harvest	Guideline	Harvest	Guideline	Harvest	Harvest	Total
Recreational								
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	600-800	809	560	434	0	2,505
2001	1,520	1,426	700	677	560	299	0	2,402
2002	1,520	1,560	700	878	165	187	0	2,625
Indian Commercial								
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	1,165	1,000-1,200	1,342	1,160	788	0	3,295
2001	1,300	1,287	1,100	1,215	1,160	755	0	3,257
2002	1,300	472	1,100	1,152	335	326	0	1,950
Combined fisheries								
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	2,427	1,800	2,151	1,720	1,222	0	5,800
2001	2,820	2,713	1,800	1,892	1,720	1,054	0	5,659
2002	2,820	2,032	1,800	2,030	500	513	0	4,575
Indian subsistence [a]								
1993		146		31		30	56	263
1994		290		197		163	0	650
1995		566		260		320	0	1,146
1996		256		116		110	0	482
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
2002		146		197		27	0	370

[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 2002.*

[b] *Not available.*

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

ANNUAL PROGRESS REPORT

APRIL 2002 – MARCH 2003

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 2002 through 31 March 2003, 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 discharge and water temperatures that occurred during April through July 2002 provided relatively good conditions for spawning by white sturgeon downstream from Bonneville, The Dalles, John Day, and McNary dams. Optimal spawning temperatures in the four tailraces occurred for approximately three weeks and during a period of relatively high river discharge. Our monthly estimates of the index of spawning habitat showed that the availability of habitat for spawning peaked in June at levels higher than the average of past years. However, indices for the month of May were less than average in all four tailraces.

YOY white sturgeon were collected during bottom trawling in Bonneville and The Dalles reservoirs, but none were captured in the John Day Reservoir. In an ongoing comparison of indices of abundance derived from bottom trawls and gill nets, the Oregon Department of Fish and Wildlife also caught YOY white sturgeon in gill nets set in The Dalles Reservoir, but none in the John Day Reservoir.

The third year of a three-year laboratory predation study was completed. Adult channel catfish ingested white sturgeon up to a mean total length of about 120 mm, and juvenile walleye ate white sturgeon up to a mean length of 53 mm. When white sturgeon and coho salmon were both available as prey, northern pikeminnow continued to ingest white sturgeon, but in most cases preferred salmon. Conversely, prickly sculpins preferred white sturgeon over goldfish as prey. The presence of cover and also lower light levels reduced predation by sculpins on white sturgeon larvae, but cover did not reduce predation on white sturgeon juveniles. Similar to the past two years, turbidity affected predation of white sturgeon larvae by prickly sculpins, with less sturgeon ingested at higher turbidities.

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 198605000 – White Sturgeon Restoration and Enhancement in the Columbia and Snake Rivers Upstream from Bonneville Dam. The reporting period is 1 April 2002 through 31 March 2003.

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 2002- 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 was 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 2002 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 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

[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.

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 gillnets 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 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 gillnets 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 gillnets 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 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 catch per unit effort (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 gillnet 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

Fish collection and maintenance

Predators. Channel catfish *Ictalurus punctatus* (mean TL, 464 mm; SE, 15 mm; *N* = 10) were collected by angling in the Lower Monumental Dam tailrace of the Snake River during early May 2002. Five channel catfish were held in each of two indoor 2.4-m diameter tanks (0.9-m depth). We collected northern pikeminnow *Ptychocheilus oregonensis* (TL, 417 mm; standard error, SE, 14 mm; *N* = 8) from the Columbia River by angling in early June 2002. Three were held in each of two indoor 2.4-m diameter tanks, and the remainder were placed in one outdoor 1.5-m tank (0.8-m depth). All tanks had heated flow-though well water at temperatures approximating those in the Columbia River--10°C in early May, rising gradually to17-18°C in late June, and maintained at this temperature throughout summer. Indoor tanks had overhead lighting that mimicked a natural photoperiod. When not being used in experiments, northern pikeminnow and channel catfish were fed a diet of live juvenile coho salmon *Oncorhynchus kisutch*.

Prickly sculpins *Cottus asper* (mean TL, 138 mm; SE, 3; *N* = 47) were collected during early May from a Columbia River marina using baited minnow traps. Except during experiments, they were held in an indoor 1.2-m diameter tank (0.7-m depth) with flow-though heated well water at river temperatures. Prickly sculpins were fed goldfish *Carassius auratus*, and food was withheld a day before each predation trial.

Walleye *Sander vitreus* (mean TL, 184 mm; SE, 5 mm; *N* = 8) were obtained from a commercial hatchery. Four were placed in each of two 160-l gray plastic tanks with flow-through heated well water of 17-18°C. Light was supplied at a natural photoperiod by overhead fluorescent bulbs. Prior to experiments, walleye were fed goldfish.

Prey. Coho salmon were obtained from a local hatchery and held at 7-8°C in outdoor 1.5-m diameter tanks with flow-through well water. Throughout the experimental period, they had a mean TL of 94 mm (SE, 1 mm; *N* = 216) and mean weight of 9 gm (SE, 0.2 gm). White sturgeon used in predation experiments were also obtained from a local hatchery and were held in indoor 1.2-m diameter tanks with flow-through well water at 17-18°C. White sturgeon ranged in size from newly-hatched in late June with a mean TL of 15 mm (SE, 0.1 mm; *N* =20), to a mean TL of 158 mm (SE, 4; N = 20) at the last trial (late October). Goldfish were obtained weekly from a pet store and had a mean total length of 34 mm (SE, 0.4; *N* = 100) and mean weight of 0.7 gm (SE, 0.03). White sturgeon were fed commercial semi-moist salmon diets to excess, while coho salmon received this food at a limited daily ration of about 1.3% of their body weight.

Experiment I. Channel catfish and juvenile walleye predation: sturgeon 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, channel catfish and walleye. Trials with channel catfish as predators were conducted in two 2.4-m diameter tanks. Each week we alternated between feeding channel catfish juvenile white sturgeon and coho salmon. 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 diameter tank containing five catfish on Monday, removed 24 hrs later, and counted. On Thursday, 30 juvenile salmon were placed into each tank and removed in 24 hrs. Trials were conducted from July 8 through October 31, and white sturgeon ranged from an initial size of about 25 mm TL to a mean size of 158 mm TL at the end of the experiment. Approximately weekly, 20 of each prey type were measured.

During predation trials in 2001, adult walleye ate essentially no white sturgeon juveniles. Therefore we tested if juvenile walleye would eat white sturgeon larvae, and at what size were white sturgeon no longer ingested. Trials were conducted in two 160-l gray plastic tanks, with four walleye each. Experimental procedure was the same as for channel catfish, except each week we alternated between 30 sturgeon and 12 goldfish. Trials were conducted from July 1 through August 23, and white sturgeon ranged from an initial size of 20 mm TL to a mean size of 70 mm TL at the end of the experimental period.

Experiment II. Northern pikeminnow predation: alternate prey and cover

We examined if northern pikeminnow selectively feed on white sturgeon if an alternate prey, coho salmon, is available, and also the effects of cover. Trials were conducted twice weekly in two 2.4-m diameter tanks, each with three northern pikeminnow. One tank was randomly chosen to initially contain cover, which was placed in the tank an hour before the trials began. Cover consisted of seven clusters of rigid black plastic pipe evenly spaced on the bottom of the tank. Each cluster was composed of seven 5-cm diameter elbows glued together and weighted to maintain position. Experimental temperatures were 17-18^{o}C.

Trials were initiated on Monday morning by introducing fifteen coho and fifteen white sturgeon juveniles into each tank by lowering a covered bucket to the bottom and removing the cover. Trials lasted 24 hours, at which time cover was taken out of the tank and the remaining prey were removed and counted. A second set of trials was conducted during each week from Thursday morning to Friday morning. Methods were the same as above, except cover was placed in the opposite tank. Over the weekend, northern pikeminnow tanks contained no prey or cover. The initial experimental period was August 19–September 6. Then two northern pikeminnow were exchanged between tanks, and one fish from each tank was replaced by a fish being held in the 1.5 m diameter outdoor tank. A second group of trials was conducted during September 23 -October 11. During each week of these two three-week periods, 20 coho salmon and 20 white sturgeon were measured.

Experiment III. Prickly sculpin predation: acclimation period and cover

Trials were conducted to examine the effects of acclimation period on predation of white sturgeon by prickly sculpins in tanks both with and without cover. This experiment took place in four shaded outdoor tanks with 0.9-m diameters and 0.6-m depth. Water was not flow-through and was replaced daily or as needed between trials to maintain temperatures of 16-18^{o}C . Cover consisted of 40 stacked river rocks per tank with a mean length of 90 mm

(SE, 4), width of 67 mm (SE, 3), and thickness of 17 mm (SE, 1). We randomly chose which two of the four tanks would contain cover during an experiment. Thirty 5-12 d-old white sturgeon (14-16 mm TL) were acclimated to each of the four experimental tanks for one or 24 hours. After this period, two prickly sculpins that had been randomly chosen from the 1.2-m holding tank were placed in each tank. Predation was allowed to proceed for 15 min and then the predators were removed. Cover was removed, and the remaining white sturgeon were counted. The one-hour acclimation and 15 min predation periods were during daylight, while the 24-hr acclimation was a natural photoperiod. Six replicates were conducted at each of following four treatments—one hour acclimation with cover, one hour acclimation without cover, 24-hr acclimation with cover, and 24-hr acclimation without cover.

Experiment IV. Prickly sculpin predation: light levels and cover

An experiment was also conducted examining the effects of light levels on predation by prickly sculpins on white sturgeon both with and without cover. Experimental procedures were the same as described above, with a one-hour acclimation period for white sturgeon. Light levels were measured near the surface and bottom of the tanks' water column using an International Light, Inc., Photometer Model 1400. We tested two light levels, 7-15 lux, and 1-4 lux. The lower light level was accomplished by wrapping tanks in black plastic. Two size groups of white sturgeon were a tested —14-17 mm TL, and 20-24 mm TL. Five or six replicates were conducted at each combination of cover, light level, and sturgeon size class.

Experiment V: Prickly sculpin predation: alternate prey and cover

We examined if prickly sculpins selectively feed on white sturgeon if an alternate prey, goldfish, is available, and also the effects of cover. Experimental procedure was the same as above, with an hour prey acclimation period and the lower light level, except that 15 white sturgeon and 15 goldfish were introduced simultaneously as prey. Two mean sizes of white sturgeon were tested, 34 and 44 mm TL. Six replicates were conducted at each combination of cover (present or absent) and white sturgeon size.

Experiment VI: Prickly sculpin predation: turbidity

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 by prickly sculpins. 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.

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 yolk-sac white sturgeon larvae (15 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 five occasions during June 12-21, resulting in six replicates per turbidity level.

Analyses

We used analysis of variance (ANOVA; GLM procedures; SAS Institute, Inc., 1999-2000) to examine if the proportions of white sturgeon eaten were significantly affected by various factors: Experiment II—tank, experimental period, and cover; Experiment III—acclimation period and cover; Experiment IV—light level, cover, and prey size; Experiment V— cover and prey size, and Experiment VI—turbidity level. For Experiments II and V, our dependent variable was the proportion of white sturgeon ingested in each tank-- the number of white sturgeon eaten/(white sturgeon and coho salmon or goldfish ingested). For experiments III, IV, and VI, the dependent variable was the number of white sturgeon eaten divided by 30. Proportions were arcsine transformed before analysis (Snedecor and Cochran 1980). Trials were combined in each experiment for further analyses if it was determined that the factors tested above did not significantly affect the proportion of white sturgeon ingested.

Using chi-square analyses (FREQ procedures; SAS Institute, Inc., 1999-2000), we examined data from Experiments II and V to determine if predators were selecting a prey type. The expected ratio of white sturgeon and the alternate prey (coho salmon or goldfish) consumed (no selection) was 1:1.

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 2002 provided relatively good conditions for spawning by white sturgeon downstream from Bonneville, The Dalles, John Day, and McNary dams. The river hydrograph (Figure 1) showed that daily discharge rose rapidly in early April to about 10 kcms, then fell during late April and early May to approximately 6 kcms before rising again during June to a peak of just over 10 kcms. 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^{o}C) for spawning by white sturgeon on or about 24 May (Figure 2) in the Bonneville and The Dalles Dam tailraces, 27 May in the John Day tailrace, and 28 May in the McNary Dam tailrace. The optimal spawning period was relatively long, a duration of 21-24 days before temperatures exceeded optimum levels (15.2^{o}C). Thus optimal spawning temperatures in the four tailraces occurred for approximately three weeks and during a period of relatively high river discharge. Our monthly estimates of the index of spawning habitat showed that the availability of habitat for spawning peaked in June at levels higher than the average of past years (Figure 3). However, indices for the month of May were less than average in all four tailraces.

Annual indices of spawning habitat allow comparisons of conditions among years. The annual index of spawning habitat for each tailrace was the highest since 1999 (Figure 4) with the exception of the Bonneville Dam tailrace, but was still well below the peak index seen in 1997.

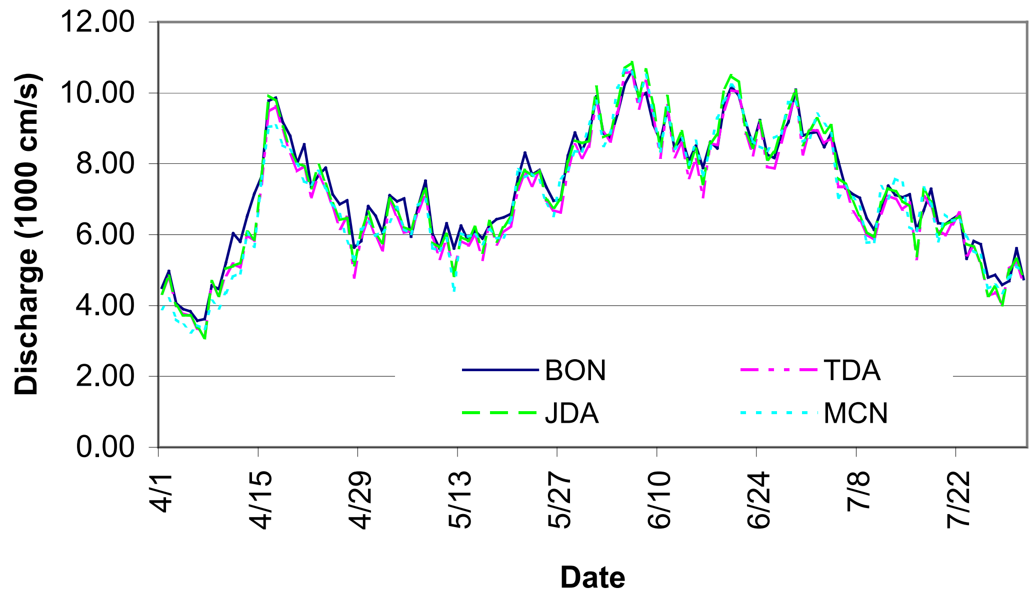

Figure 1. River discharges at Bonneville (BON), The Dalles (TDA), John Day (JDA), and McNary (MCN) dams during 2002. Data were obtained from the DART website (http:\\www.cqs.washington.edu\dart\).

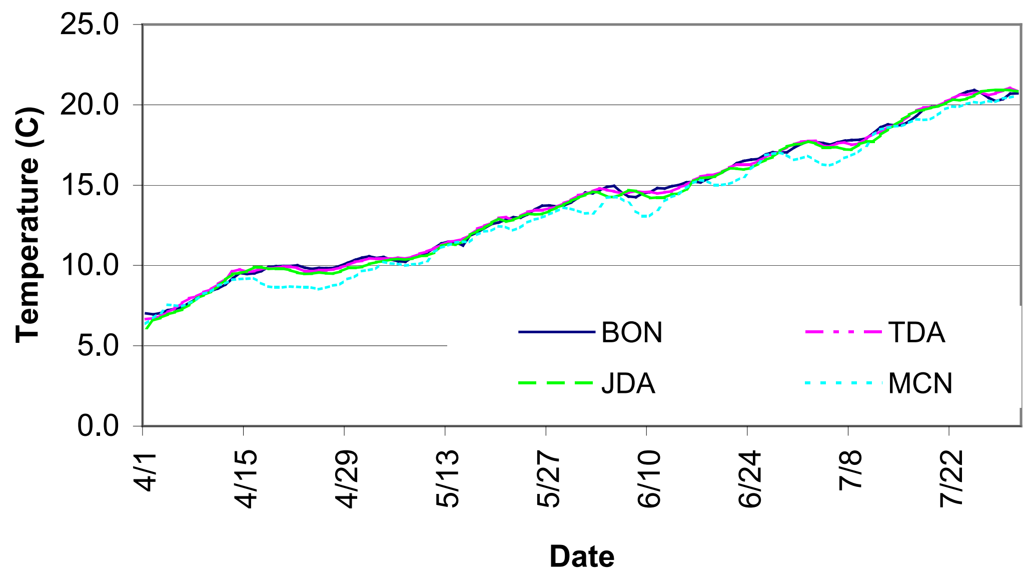

Figure 2. Water temperatures at Bonneville (BON), The Dalles (TDA), John Day (JDA), and McNary (MCN) dams during 2002. Data were obtained from the DART website (http:\\www.cqs.washington.edu\dart\).

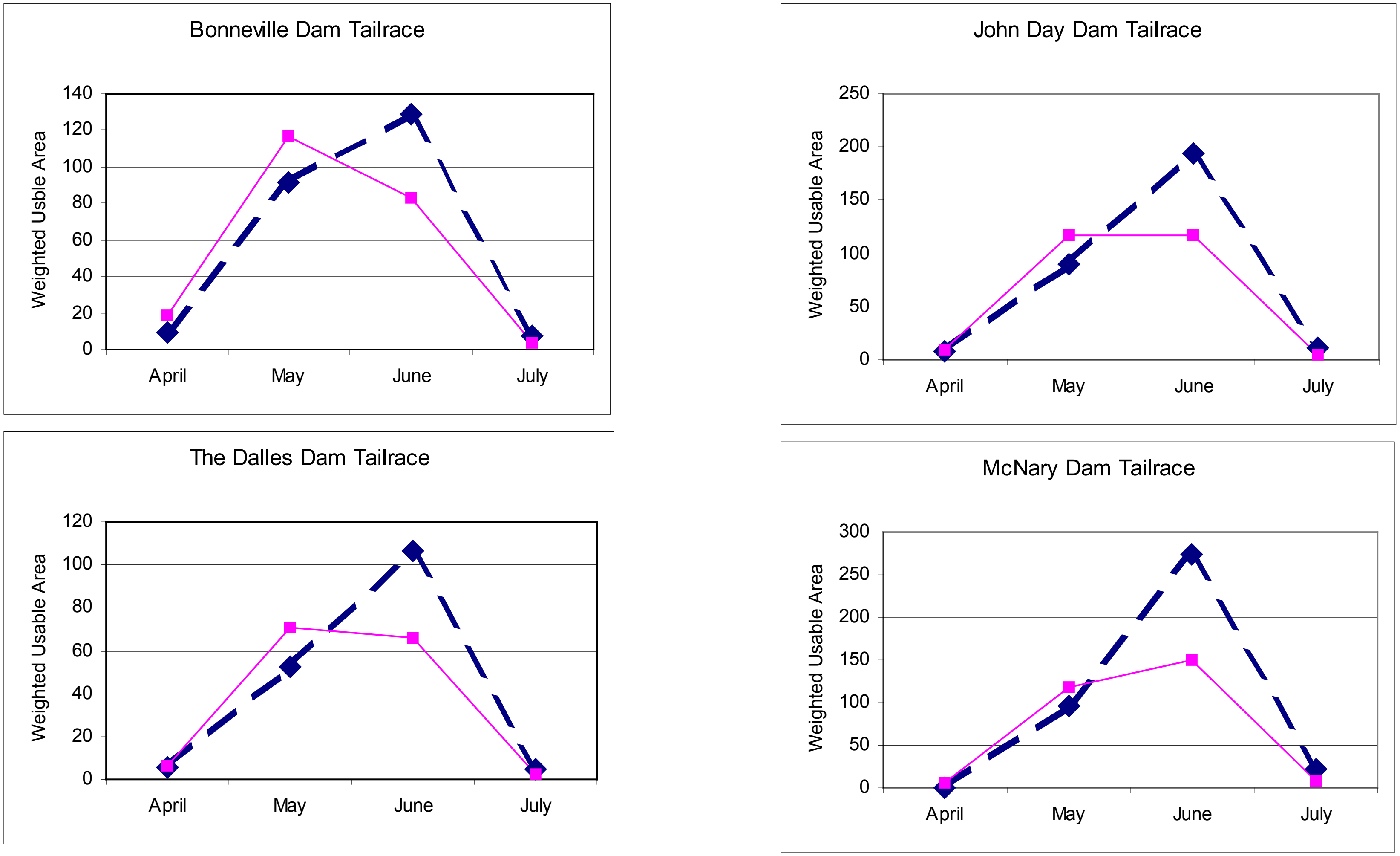

Figure 3. Monthly indices of spawning habitat. Dashed lines depict mean monthly indices of spawning habitat (temperature conditioned weighted usable area (WUA)) for white sturgeon during 2002. Solid lines depict the average mean monthly index for each month during 1985-2001. Note that the scale differs on the Y-Axis among graphs.

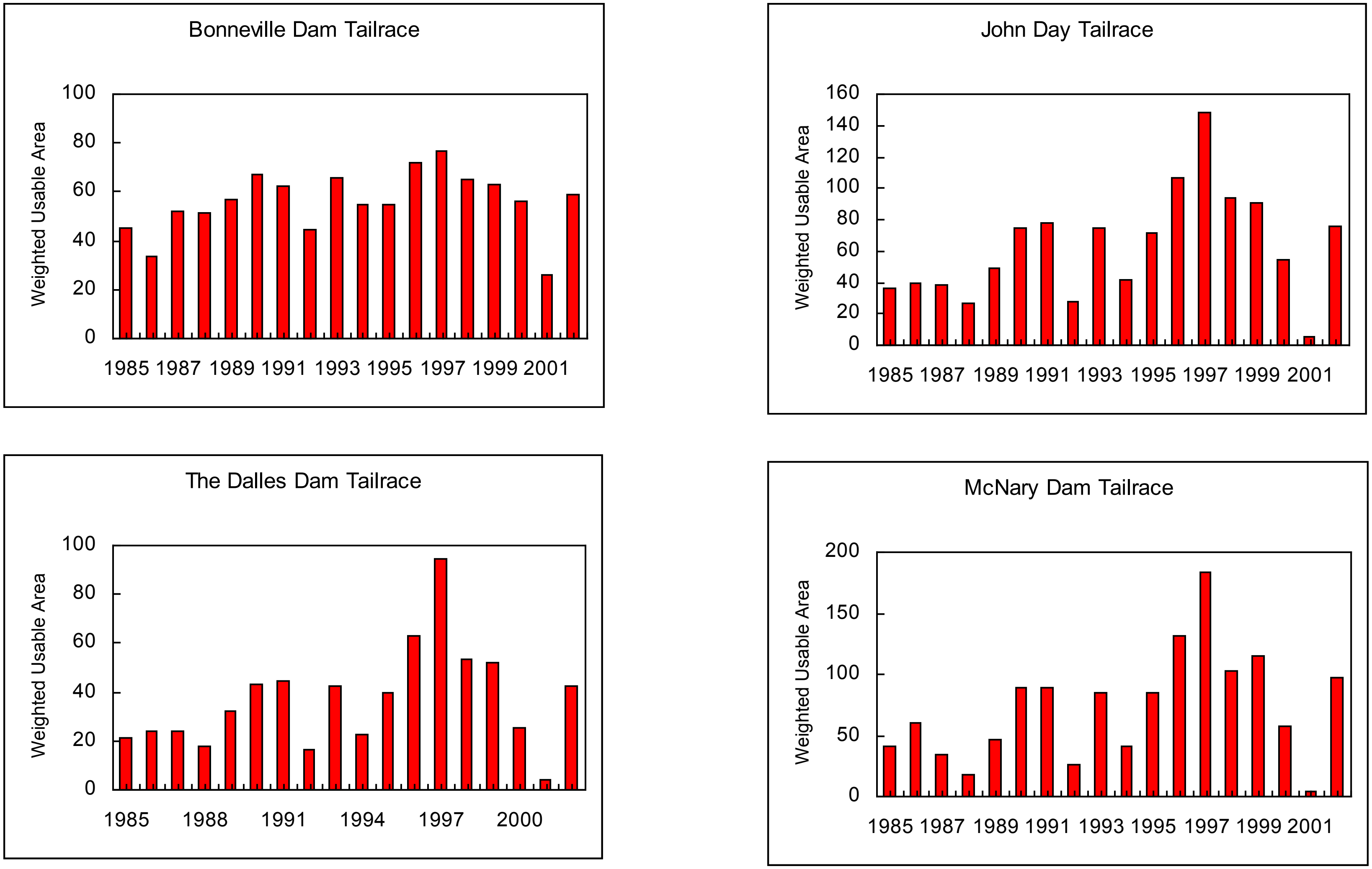

Figure 4. Annual mean composite indices of spawning habitat (temperature conditioned weighted usable area (WUA)) for white sturgeon for each of the four dam tailraces that have been modeled (Parsley and Beckman 1994). Note that the scale differs on the Y-axis among graphs.

Young-of-the-Year Indexing

The bottom-trawl sampling program was completed as scheduled during 2002. We fished the bottom trawl on 12 d from 16 September to 1 October in Bonneville Reservoir, on 6 d from 7 October to 1 November in The Dalles Reservoir, and on 6 d from 16 October to 7 November in John Day Reservoir. Weather conditions were favorable during sampling in all three reservoirs, and no days were rescheduled due to adverse weather. However, we did experience delays in The Dalles Reservoir due to our inability to sample two sites because of the presence of Tribal fishing gear, and delays in John Day Reservoir due to mechanical problems with the trawling vessel. All sites were eventually sampled and work was completed by 7 November. As typically happens, several trawl tows were aborted when the gear became snagged on the riverbed or when debris such as trees, rocks, or other items encumbered the trawl during a tow. The sampling protocol calls for clearing the net and resampling the location. Thus, all sites were successfully completed. No nets were lost while sampling this year, although several will require extensive work to repair tears and holes.

While sampling in John Day Reservoir, our trawling vessel experienced a critical engine failure. We then outfitted a second vessel to complete the work. The second vessel was of the same make and model. Since our trawl tows are made using speed-over-ground derived from GPS rather than engine rpm as many offshore trawl surveys use, we are not concerned that minor differences in engine and propulsion systems between the two vessels affected the consistency of our sampling.

Bonneville Reservoir

Recruitment of young-of-the-year white sturgeon occurred in Bonneville Reservoir in 2002. We captured 40 juvenile white sturgeon with the high-rise trawl during our sampling of Bonneville Reservoir, and 17 (43%) of these were YOY. Young-of-the-year white sturgeon were captured at 6 of the 11 sites (Table 1). Young-of-the-year white sturgeon were distinguished from older fish by length frequency analysis (Figure 5). The YOY ranged in length from 126 to 215 mm TL and weighed 8 to 40 g. The mean length of YOY captured was 178 mm TL and mean weight was 26 g. Older juvenile white sturgeon were captured at 5 of the 11 sites (Table 1). The older juvenile white sturgeon measured 287 to 637 mm FL and weighed 150 to 1,280 g.

The CPUE for combined effort for each of the 11 sites sampled with the bottom trawl in Bonneville Reservoir ranged from 0.0 to 1.84 YOY per 2,500 m^2 and from 0.0 to 2.55 fish per 2,500m^2 for all white sturgeon caught (Table 1). The mean CPUE for the 66 individual completed tows was 0.28 YOY per 2,500 m^2 (SE = 0.09) and 0.67 fish per 2,500m^2 (SE = 0.13) for all juvenile white sturgeon. The proportion of positive tows for YOY white sturgeon during 2002 for Bonneville Reservoir was 0.17.

Trawl catches in Bonneville Reservoir were dominated by prickly sculpin, followed by juvenile American shad and sandroller (Table 2). Peamouth were common in the trawl catch, and were captured only in this reservoir.

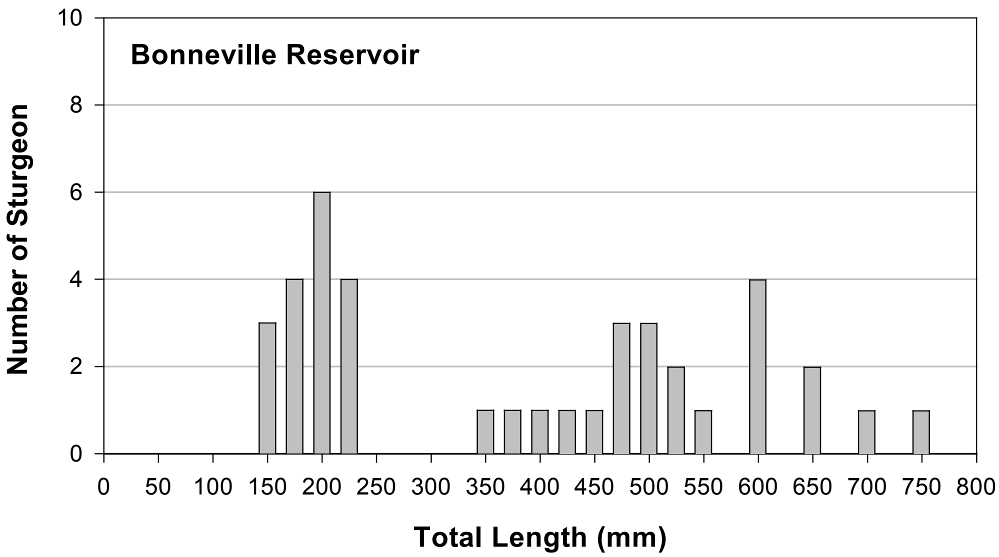

Figure 5. Length frequency of white sturgeon collected during bottom trawling in Bonneville reservoir from 17 September to 1 October 2002.

The Dalles Reservoir

Recruitment to YOY also occurred in The Dalles Reservoir in 2002, but at a lower level. We captured 3 juvenile white sturgeon with the bottom trawl during sampling in The Dalles Reservoir, and only 1 (33.3%) of these were YOY. Young-of-the-year white sturgeon were captured at only 1 of the 12 sites (Table 3).

The one YOY white sturgeon collected in The Dalles Reservoir measured 229 mm TL and weighed 48 g. Older white sturgeon were captured at 2 of the 12 sites trawled. The two older juvenile white sturgeon measured 452 and 610 mm FL and weighed 700 and 1,580 g, respectively.

The CPUE for combined effort for each of the 12 sites sampled with the bottom trawl in The Dalles Reservoir ranged from 0 to 0.55 YOY per 2,500 m^2 and from 0 to 1.11 fish per 2,500 m^2 for all white sturgeon caught (Table 3). The mean CPUE for the 24 individual completed tows was 0.05 YOY per 2,500 m^2 (SE = 0.05) and 0.14 fish per 2,500 m^2 (SE = 0.1) for all juvenile white sturgeon. The proportion of positive tows for YOY white sturgeon during 2002 for The Dalles Reservoir was 0.042.

Trawl catches in The Dalles Reservoir were dominated by American shad and prickly sculpin (Table 2). It is interesting to note that many species captured in Bonneville and John

Day reservoirs were entirely absent or substantially reduced in number in the trawl catch from The Dalles Reservoir. We have no explanation for this difference. However, it does show that fish community dynamics among reservoirs differs markedly, which may influence growth, condition, and other population characteristics of white sturgeon residing in the reservoirs.

John Day Reservoir

We captured one juvenile and no YOY white sturgeon with the bottom trawl during our sampling of John Day Reservoir (Table 4), indicating that no recruitment of young-of-year white sturgeon occurred during 2002. The one juvenile captured in John Day Reservoir measured 591 mm (FL) and weighed 1,570 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 fish per 2,500 m^2 for all white sturgeon caught (Table 4). The mean CPUE for the 38 individual completed tows was 0.03 fish per 2,500 m^2 (SE = 0.03) for all juvenile white sturgeon. The proportion of positive tows for YOY white sturgeon during 2002 for John Day Reservoir was 0.

Trawl catches in John Day Reservoir were dominated by prickly sculpin and American shad (Table 2). Common carp *Cyprinus carpio* and yellow perch *Perca flavescens* were common in the catch, and were captured only in this reservoir.

Table 1. Characteristics of bottom trawling conducted to index recruitment of white sturgeon in Bonneville Reservoir during 17 September to 1 October 2002. Young-of-the-year (YOY) white sturgeon were differentiated by length frequency analysis (Figure 5).

			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	1.3551	1	1	0.18	0.18
15734	6	1.3354	0	0	0.0	0.0
15951	6	1.3607	11	10	2.02	1.84
16522	6	1.3404	1	1	0.19	0.19
16851	6	1.3481	1	1	0.19	0.19
17063	6	1.3444	4	1	0.74	0.19
17374	6	1.3013	3	0	0.58	0.0
17652	6	1.3415	0	0	0.0	0.0
17911	6	1.3516	5	0	0.92	0.0
18351	6	1.3743	14	3	2.55	0.55
18523	6	1.3394	0	0	0.0	0.0
Totals	66	14.7922	40	17		

Table 2. Number of fish caught with bottom trawls in three reservoirs during fall sampling in 2002.

Common name	Scientific name	Bonneville Reservoir	The Dalles Reservoir	John Day Reservoir
White sturgeon	*Acipenser transmontanus*	40	3	1
American shad	*Alosa sapidissima*	362	7369	471
Common carp	*Cyprinus carpio*			10
Northern pikeminnow	*Ptychocheilus oregonensis*	27	1	1
Redside shiner	*Richardsonius balteatus*	5		
Peamouth	*Mylocheilus caurinus*	94		
Largescale sucker	*Catostomus macrocheilus*	7		4
Bridgelip sucker	*Catostomus columbianus*	4		1
Channel catfish	*Ictalurus punctatus*	1	1	48
Brown bullhead	*Ameiurus nebulosus*			1
Sandroller	*Percopsis transmontana*	151		23
Smallmouth bass	*Micropterus dolomieui*	1	7	
Threespine stickleback	*Gasterosteus aculeatus*			
Walleye	*Sander vitreus*		2	2
Yellow perch	*Perca flavescens*			76
Prickly sculpin	*Cottus asper*	750	57	425
Unidentified			1	

Table 3. Characteristics of bottom trawling conducted to index recruitment of white sturgeon in The Dalles Reservoir during 7 October to 15 October 2002. 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	0.4485	0	0	0.0	0.0
19683	2	0.4488	1	0	0.56	0.00
19981	2	0.4515	2	1	1.11	0.55
20012	2	0.4549	0	0	0.0	0.0
20244	2	0.4461	0	0	0.0	0.0
20432	2	0.4450	0	0	0.0	0.0
20451	2	0.4501	0	0	0.0	0.0
20651	2	0.4529	0	0	0.0	0.0

20752	2	0.4483	0	0	0.0	0.0
21014	2	0.4502	0	0	0.0	0.0
21103	2	0.4516	0	0	0.0	0.0
21412	2	0.4479	0	0	0.0	0.0
Totals	24	5.3958	3	1		

Table 4. Characteristics of bottom trawling conducted to index recruitment of white sturgeon in John Day Reservoir during 16 October to 7 November 2002. 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	0.4481	0	0	0.0	0.0
22533	2	0.4442	0	0	0.0	0.0
22931	2	0.4496	0	0	0.0	0.0
23352	2	0.4449	0	0	0.0	0.0
24173	2	0.4471	0	0	0.0	0.0
24324	2	0.4509	0	0	0.0	0.0
24822	2	0.4477	0	0	0.0	0.0
25283	2	0.4453	0	0	0.0	0.0
25623	2	0.4447	0	0	0.0	0.0
26382	2	0.4593	0	0	0.0	0.0
26422	2	0.4485	1	0	0.56	0.0
26803	2	0.4504	0	0	0.0	0.0
27054	2	0.4473	0	0	0.0	0.0
27384	2	0.4478	0	0	0.0	0.0
27851	2	0.4480	0	0	0.0	0.0
27974	2	0.4527	0	0	0.0	0.0
28074	2	0.4466	0	0	0.0	0.0
28184	2	0.4441	0	0	0.0	0.0
28972	2	0.4459	0	0	0.0	0.0
Totals	38	8.5131	1	0		

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

Sampling during 2002 by ODFW and USGS provided the fourth year of data to be used for comparing indices of abundance derived from gillnet and bottom trawl catches. In The Dalles Reservoir, ODFW (Report A) sampled 12 locations with gillnets and made 36 overnight sets, and USGS, as described above, sampled 12 fixed sites with bottom trawls twice each for a total of 24 tows. In John Day Reservoir, ODFW made 40 gillnet sets and USGS sampled 19 fixed sites twice each for a total of 38 trawl tows. Indices of abundance for YOY white sturgeon were calculated (Table 5). It appears that trends in abundance indicated by catches from both gears are similar but additional data points should be obtained prior to correlation analysis. Comparisons of trawl and gillnet data from John Day Reservoir will be problematic because of an apparent absence of recruitment of YOY white sturgeon during the past three years in this reservoir. Recruitment has been seen in The Dalles Reservoir during three of the last four years. Hydrologic conditions during the past four years have been variable, as evident in the indices of spawning habitat presented in Figures 3 and 4.

Table 5. Indices of abundance of YOY white sturgeon derived from gillnet and bottom trawl sampling in The Dalles (TDA) and John Day (JDA) reservoirs. The proportion of positive tows (E_p) represents to proportion of efforts conducted that captured at least one YOY white sturgeon. Catch per unit effort (CPUE) represents the arithmetic mean of the number of YOY white sturgeon captured per gillnet set or per 2,500 m^2 of bottom area trawled.

	Number of locations sampled by gear type		Number of efforts by gear type		E_p		CPUE	
	Gillnet	Trawl	Gillnet	Trawl	Gillnet	Trawl	Gillnet	Trawl
TDA								
1999	12	12	36	24	0.67	0.25	7.61	0.82
2000	12	12	36	24	0.14	0.04	0.22	0.09
2001	12	12	32	24	0.00	0.00	0.00	0.00
2002	12	12	36	24	0.11	0.04	0.36	0.05
JDA								
1999	27	19	41	38	0.22	0.13	0.39	0.30
2000	23	19	40	38	0.00	0.00	0.00	0.00
2001	23	19	40	38	0.00	0.00	0.00	0.00
2002	23	19	40	38	0.00	0.00	0.00	0.00

Predation on Larval and Juvenile White Sturgeon

Experiment I: Channel catfish and juvenile walleye predation: sturgeon size vulnerability

Channel catfish ate coho salmon throughout the experiment, but consumption of white sturgeon decreased after week 9 (Figure 6). Coho salmon mean length and weight remained fairly constant during the experimental period, while white sturgeon size increased (Figure 7). During the period of decreased consumption, white sturgeon increased in mean total length from about 80 to 120 mm, and increased in mean weight from 3 to 8 g (Figure 7).

Juvenile walleye ingested goldfish throughout the experiment, but ate decreasingly less white sturgeon during weeks 6-8 (Figure 8). During weeks 6-8, white sturgeon ranged in mean total length from 43 to 53 mm, and ranged in mean weight from 0.6 to 0.9 g.

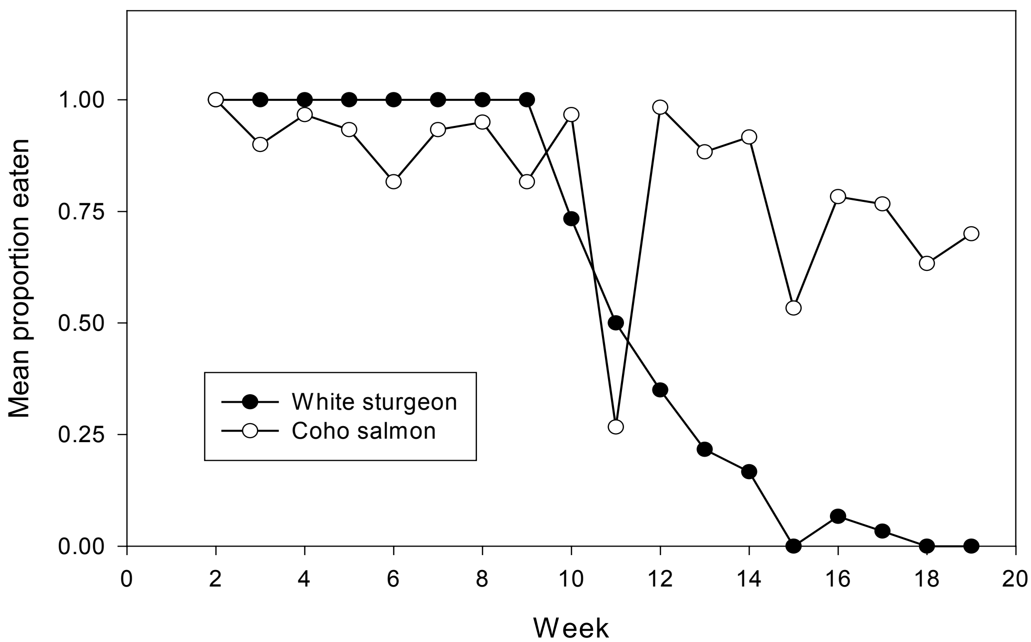

Figure 6. Predation by channel catfish on white sturgeon and coho salmon. Trials were conducted in two 2.4 m diameter tanks with five catfish each. Each week we alternated between 30 sturgeon and 30 coho salmon as prey in each tank.

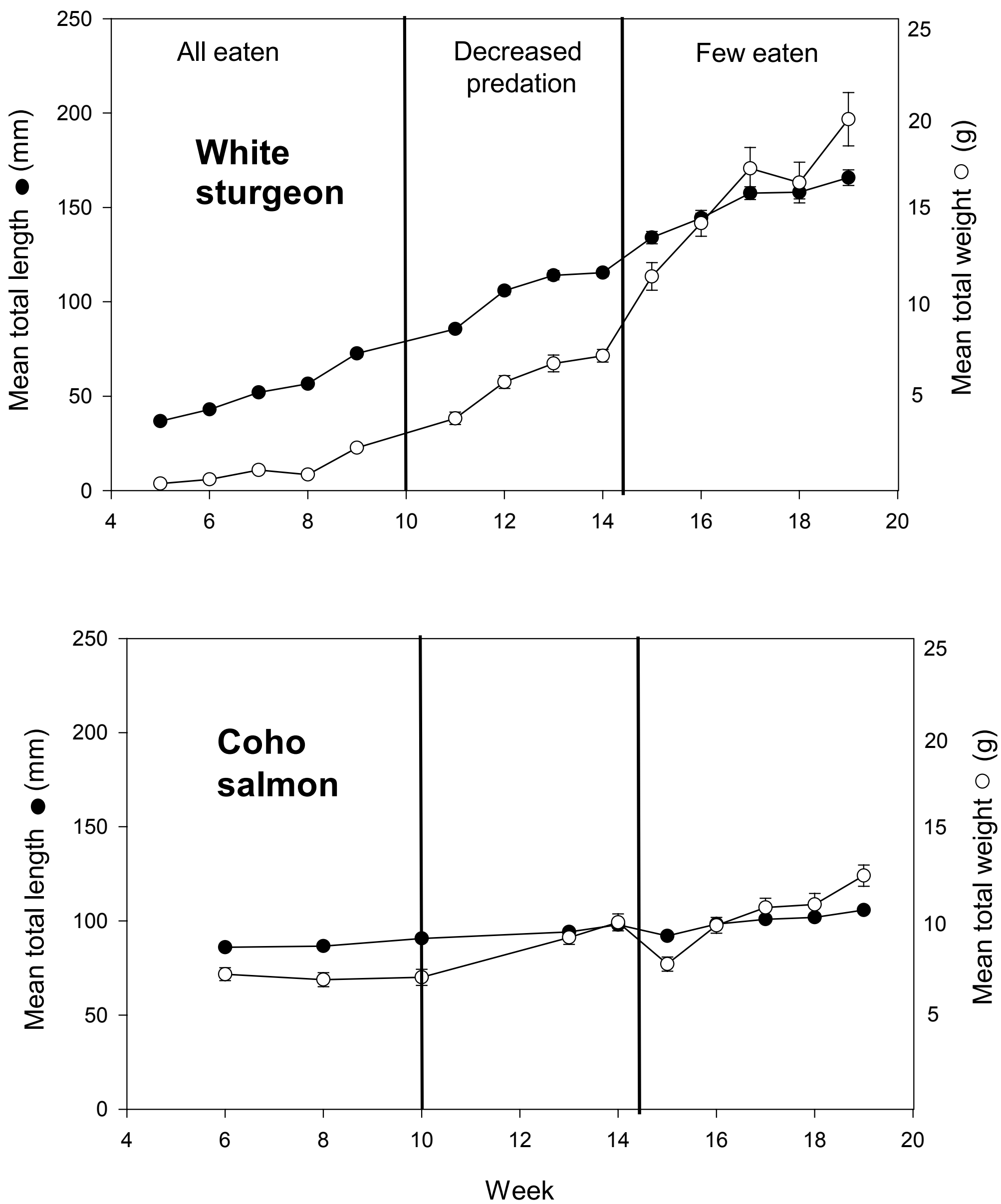

Figure 7. White sturgeon and coho salmon mean total lengths and weights during channel catfish predation experiment. Twenty white sturgeon were measured each week, and twenty coho salmon at less frequent intervals. Each vertical bar indicates one standard error. Levels of predation by channel catfish on white sturgeon during three intervals are indicated.

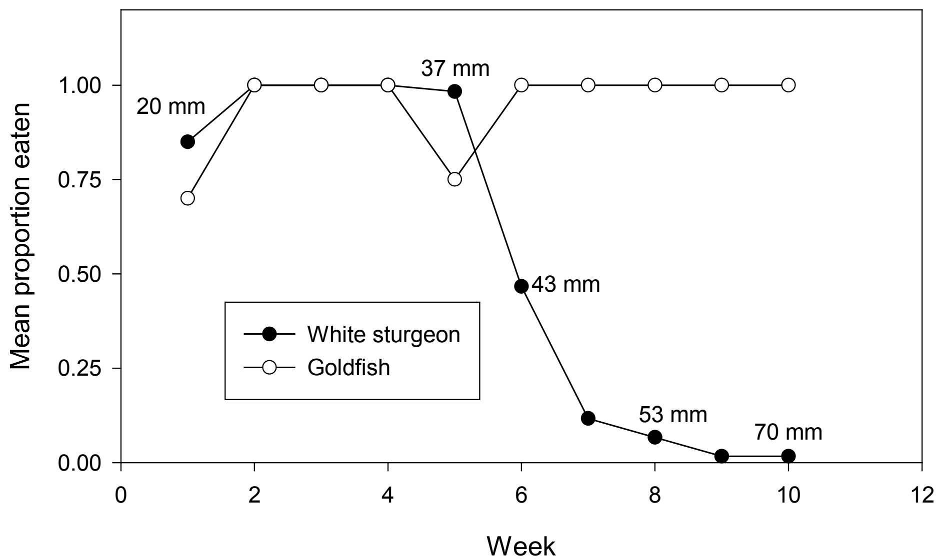

Figure 8. Juvenile walleye predation on white sturgeon. Trials were conducted in two 160-l gray plastic tanks with four walleye each. Each week we alternated between 30 sturgeon and 12 goldfish as prey. Mean white sturgeon total lengths are presented.

Experiment II. Northern pikeminnow predation: alternate prey and cover

Cover had no significant effect on the proportion of white sturgeon eaten by northern pikeminnow ($P = 1.00$). However, tank and experimental period both significantly affected the proportion of white sturgeon eaten, as did the interaction between these two factors ($P < 0.001$). Thus, we conducted further chi-square analyses on four groups of trials. All four analyses resulted in significantly ($P < 0.001$) different proportions of prey types eaten than expected, but the selected prey type varied with tank and period. Significantly more white sturgeon were eaten during Period 1 in Tank 2, whereas significantly more coho salmon were eaten during Period 1 in Tank 1, and during Period 2 in both tanks (Figure 9). During Period 1, coho salmon were both longer and heavier than white sturgeon (Figures 10), whereas during Period 2, white sturgeon were similar in length to salmon, but salmon weighed about twice as much.

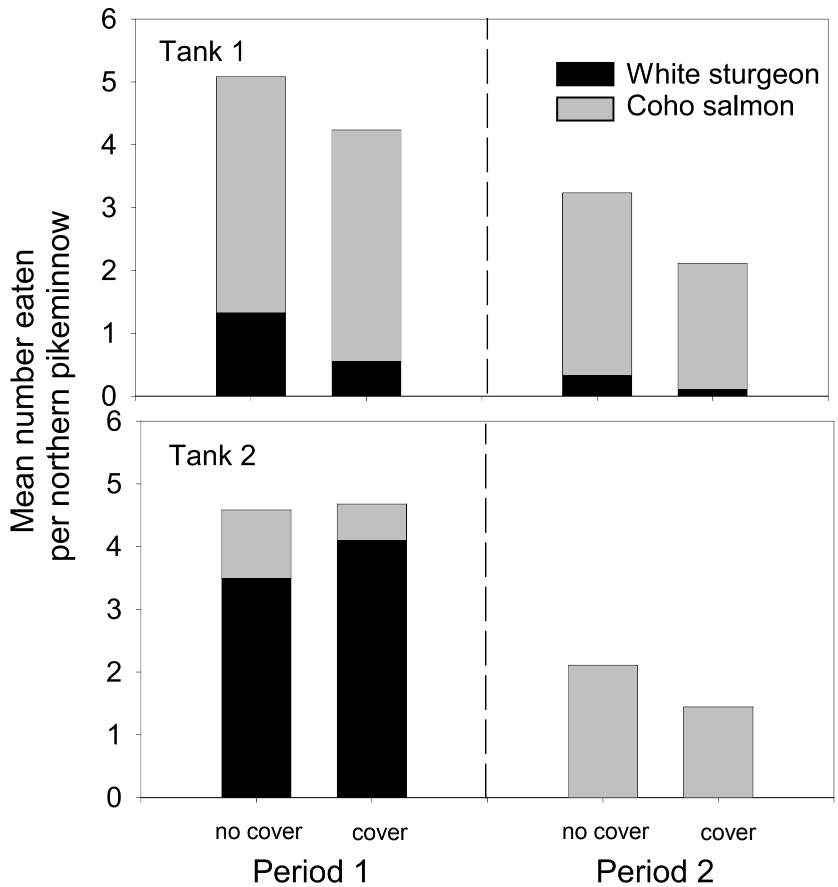

Figure 9. Mean numbers of white sturgeon and coho salmon ingested per northern pikeminnow in trials with and without cover during two 3-week periods. Trials were conducted twice weekly in two 2.4-m diameter tanks with three northern pikeminnow each. For each trial, 15 white sturgeon and 15 coho salmon were present as prey in each tank for 24 h. Prey size (Figure 10) and northern pikeminnow used as predators differed between periods. Six replicates were conducted at each combination of cover and period.

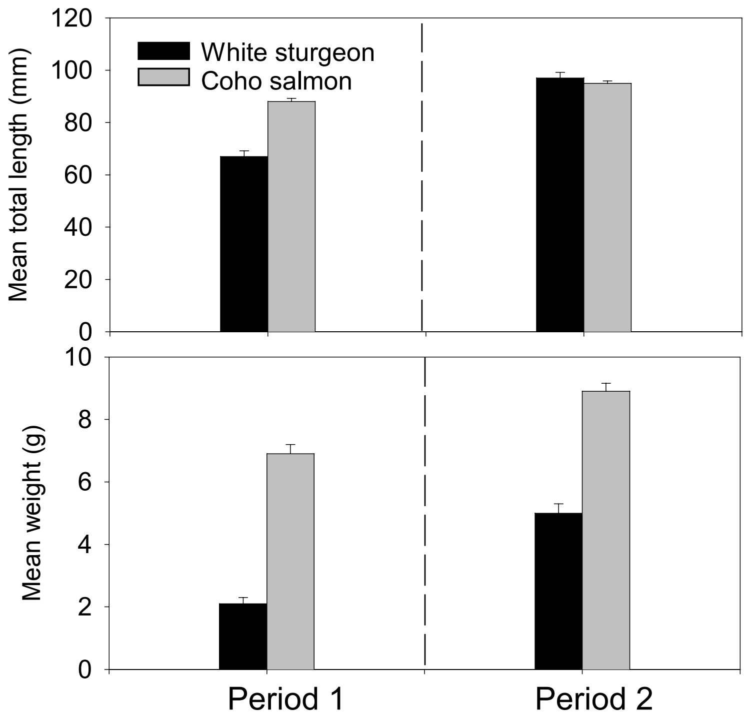

Figure 10. Mean total lengths and weights of white sturgeon and coho salmon used in northern pikeminnow predation trials during two periods. Each vertical bar equals one standard error. N = 60 for each prey type and period.

Experiment III. Prickly sculpin predation: acclimation period and cover

Acclimation period (one versus 24 h) did not significantly affect ($P = 0.19$) the proportion of white sturgeon eaten, and thus these trials were combined for further analyses. However, cover did significantly affect ($P < 0.001$) white sturgeon ingestion by prickly sculpins, with all white sturgeon ingested during the 12 trials without cover, and a mean proportion of 0.93 ingested in trials with cover (SE, 0.01, N = 12).

Experiment IV. Prickly sculpin predation: light levels and cover

Proportions of white sturgeon eaten were significantly affected by light level ($P < 0.05$), cover ($P < 0.001$), white sturgeon size ($P < 0.001$), and the interaction between cover and size ($P < 0.001$). Less white sturgeon were ingested at lower light levels and when cover was present (Figure 11). Also, trials using small white sturgeon as prey (14-17 mm TL) resulted in less fish eaten during the 15 min predation period than trials using larger individuals (20-24 mm TL).

Experiment V: Prickly sculpin predation: alternate prey and cover

The proportion of white sturgeon eaten (white sturgeon/(white sturgeon + goldfish)) was not significantly affected by cover and white sturgeon size (P = 0.20; Figures 12 and 13). However, white sturgeon size did significantly affect (P < 0.001) the proportion of total prey ingested, with 0.58 white sturgeon ingested in trials using smaller white sturgeon as prey, and 0.24 in trials with larger white sturgeon. For both prey sizes, significantly (P < 0.001) more white sturgeon were eaten than goldfish.

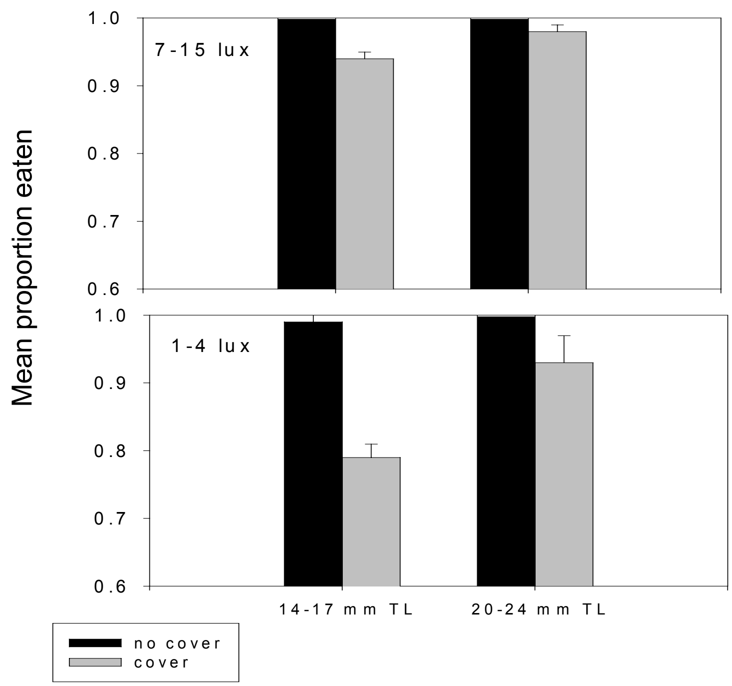

Figure 11. Predation by prickly sculpins on white sturgeon of two sizes at two light levels both with and without rock cover. Five or six replicates were conducted per each combination of sturgeon size, light level, and cover. Two prickly sculpins were allowed to prey on 30 sturgeon for 15 min for each replicate.

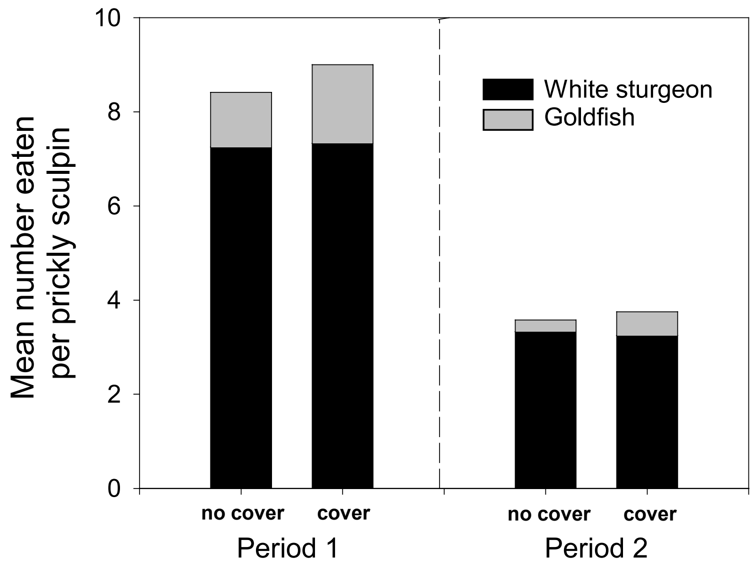

Figure 12. Mean numbers of white sturgeon and goldfish ingested per prickly sculpin in trials with and without cover during two experimental periods. White sturgeon size (Figure 13) differed between periods. Trials were conducted in 0.9-m diameter tanks with two prickly sculpins each. For each trial, 15 white sturgeon and 15 goldfish were present as prey in each tank for 15 min. Prickly sculpins differed during each trial and were randomly selected. Six replicates were conducted at each combination of cover and period.

Experiment VI: Prickly sculpin predation: turbidity

More white sturgeon larvae were eaten by prickly sculpins at 20 NTU, with decreasing predation at the highest turbidities tested (Figure 14). The overall ANOVA model was significant ($P < 0.01$), but the results are difficult to interpret since mean proportions of white sturgeon larvae ingested were not significantly different for turbidity levels of 0 and 20 NTU; 20 and 60 NTU; and 60, 180, and 360 NTU.

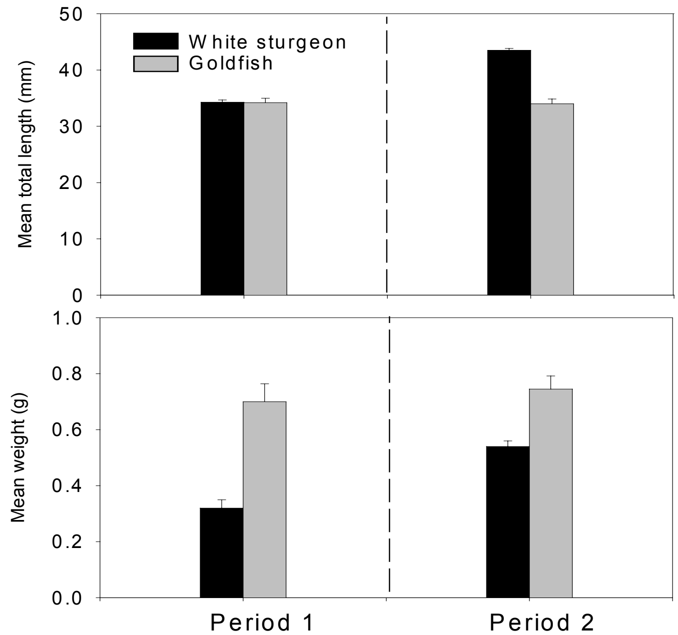

Figure 13. Mean total lengths and weights of white sturgeon and goldfish used in prickly sculpin predation trials during two periods. Each vertical bar equals one standard error. N = 18-20 for each prey type and period.

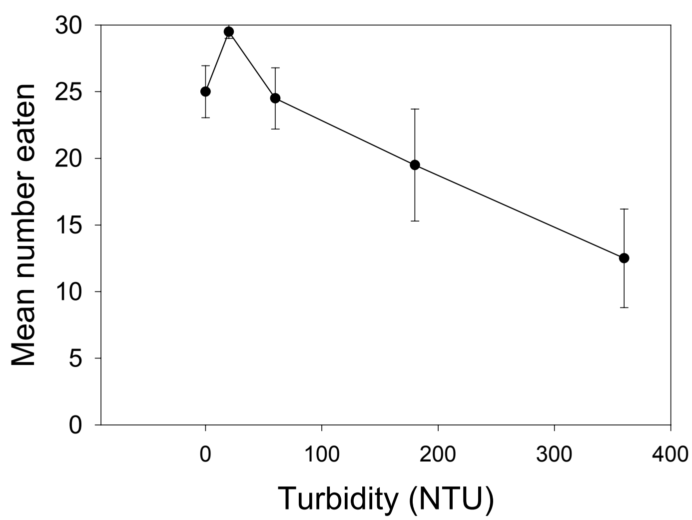

Figure 14. Mean numbers of white sturgeon ingested by prickly sculpins in 160-l tanks at five turbidity levels. For each trial, two sculpins were allowed to prey on 30 yolk-sac sturgeon (15 mm TL) for 15 minutes There were six replicates each at 0, 20, 60, 180, and 360 NTU. Each vertical bar equals one standard error.

Summation of Predation Experiments

Experiments conducted in 2002 completed the third year of a three-year laboratory predation study. We found that adult channel catfish ingested white sturgeon up to a mean total length of about 120 mm, which was similar to past results using adult northern pikeminnow as predators (Gadomski et al. 2001-2002). Since channel catfish in the wild feed on or near the bottom where white sturgeon larvae and juveniles also occur, they are potential predators of young white sturgeon. Larger channel catfish (200-500 mm FL) were collected by Zimmerman and Parker (1995) in greatest densities in the lower Snake River and tailraces of the lower Columbia River. White sturgeon spawn primarily in tailraces (Parsley and Beckman 1994), and thus the distributions of young white sturgeon and catfish may overlap. In areas where hatchery augmentation is occurring or has been proposed, white sturgeon should be released at a size large enough not to be vulnerable to predation by channel catfish and other fishes.

During 2001, we found that adult walleye that were offered white sturgeon ranging from 25 to 150 mm TL ate almost none—a few 50-65 mm TL individuals were ingested (Gadomski et al. 2001-2002). Conversely, in 2002 juvenile walleye ate almost all 20-37 mm TL white sturgeon they were offered, and a portion of 37-53 mm TL white sturgeon. It is unclear why adult walleye did not eat white sturgeon, since in the wild they are highly piscivorous but also opportunistic, feeding on a variety of fishes and invertebrates (Ryder and Kerr 1978). Since we fed white sturgeon larvae to juvenile walleye before scute development, it is possible they were accustomed to this prey type when scutes developed at about 25 mm TL and continued feeding.

When white sturgeon and coho salmon were both available as prey, northern pikeminnow continued to ingest white sturgeon, but in most cases preferred salmon. However, our results were confounded during Period 1 by a tank effect, with white sturgeon strongly preferred as prey in Tank 2, and coho salmon in Tank 1 (Figure 9). The cause for this is unclear. It is possible that individual northern pikeminnow developed a search image for a prey type (Ware 1971).

Conversely, prickly sculpins consistently preferred white sturgeon over goldfish as prey. This could be due to differences in predation strategies between prickly sculpins and northern pikeminnow, and also predator and prey distribution patterns. Prickly sculpins are bottom dwelling ambush feeders (Broadway and Moyle 1978); white sturgeon are also benthic and thus were probably encountered more than pelagic goldfish and were eaten first. Northern pikeminnow may have encountered coho salmon more frequently since they are both pelagic, and consequently ate more of this prey type.

Complex habitats have commonly been shown to provide fishes refuge from predation (Bartholomew et al. 2000). Corroborating this, we found that the presence of cover (river rocks) reduced predation by prickly sculpins on white sturgeon larvae, although the results were linked to white sturgeon size. Small sturgeon larvae appeared to be more likely to use cover as protection from predation. White sturgeon used as prey in Experiment III were 14-24 mm TL, and cover decreased predation, particularly for the smaller fish (Figure 11). Conversely, cover did not affect predation in Experiment V, and white sturgeon used as prey had mean total lengths of 34 and 43 mm (Figure 13).

Lower light levels also reduced predation on white sturgeon larvae. Light most likely affected the behavior of white sturgeon, and not prickly sculpin feeding behavior, since sculpins have been shown to be very active predators at light levels < 1 lux (Gadomski et al. 2001-2002). These results corroborate white sturgeon behavior observed in the laboratory, since smaller larvae aggregate in protected areas and darker sections of the tanks (Gadomski, personnel observation).

Similarly to larger white sturgeon larvae, the presence of cover did not affect the vulnerability of white sturgeon juveniles to predation by northern pikeminnow. We do not know if the failure to use cover was a natural behavior or a result of using naive hatchery fish. However, both hatchery-reared juvenile lake sturgeon *Acipenser fulvescens* and lake sturgeon in the wild preferred sand substrates instead of more complex habitats, indicating that cover preference may have a genetic component for some sturgeon species (Peake 1999). Possibly because of their protective scutes, foraging habits, or other traits, white sturgeon juveniles are not naturally "cover-oriented".

The result of our turbidity experiment was very similar to the last two years (Gadomski et al. 2000-2001; 2001-2002). We found that turbidity affected predation of white sturgeon larvae by prickly sculpins, with less sturgeon ingested at higher turbidities. Also very similar to last year (Gadomski et al. 2001-2002), less white sturgeon larvae were eaten at 0 NTU than at 20 NTU. Perhaps at 0 NTU, white sturgeon were better able to avoid predators, since low turbidities increase both predator detection abilities and prey reaction distance (Vinyard and O'Brian 1976; Miner and Stein 1996).

Plans for 2003

USGS participation in this project is being reduced due to a decision among project collaborators to reduce the research component and focus primarily on mitigative measures and the evaluation of management activities of the states of Oregon and Washington and the Columbia River Inter-Tribal Fish Commission to restore white sturgeon populations. The project collaborators have clearly stated to BPA, the Columbia Basin Fish and Wildlife Authority, and the Independent Scientific Review Panel that this decision does not imply that there is no longer a need for research on white sturgeon ecology and biology. The decision to reduce research conducted under BPA Project 198605000 follows the guidelines outlined by Fickheisen et al. (1984).

During 2003, the USGS will index the recruitment of YOY white sturgeon in Bonneville, The Dalles, and John Day reservoirs, and evaluate the availability of spawning habitat as determined by river discharge and water temperature. We will continue working on manuscripts describing results obtained in previous years.

ACKNOWLEDGMENTS

We thank Bjorn Van der Leeuw, Matt Sholtis, and Ken Bennett for their aid in trawling, and Jennifer Young for conducting laboratory predation trials. Special thanks to Bill Spurgeon of the U.S. Army Corps of Engineers at Lower Monumental Dam for his assistance in collecting channel catfish.

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

ANNUAL PROGRESS REPORT

APRIL 2002 – MARCH 2003

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 leading to the experimental hatchery release of white sturgeon and the results of efforts to capture and mark white sturgeon in The Dalles Reservoir for population abundance estimates.

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CONTENTS

ACKNOWLEDGEMENTS

We offer our appreciation and thanks to Yakama Nation fishery technicians Alvin McConnville, Chuck Gardee, and James Kiona, commercial fishermen Robert Brigham, Mathew McConville, Butch Lumley and their crew members, and ODFW staff for their efforts in conducting the mark and recapture operations in The Dalles 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 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. 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 40 days of setline fishing in McNary Reservoir for broodstock from 4 March 2002 to 22 May 2002, we captured a total of 236 white sturgeon in 225 sets. Of those captured, we kept 20 sexually mature white sturgeon, 1 female and 19 males, and an additional female collected from below Bonneville, at our satellite spawning station located below the McNary Dam Juvenile Fish Facility. We spawned one female, crossing gametes from the female with four males, resulting in approximately 80,000 white sturgeon larvae. Throughout spawning trials gametes were collected from four of nineteen male white sturgeon. Both females showed positive oocyte maturation. The maturation cycle of the non-ovulated female may have been interrupted by water temperature spikes or stress associated with holding conditions. Our move in 2001 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. Success of spawning was ensured by collecting a female from below Bonneville Dam. Prior to the successful spawn we acquired approximately 50,000 white sturgeon larvae from a private aquaculture facility to ensure we had sufficient number of juveniles for future project release plans. A proportion of the stock from this single parental pair and the stock from our four Bonneville/McNary brood crosses will be used in future hatchery release experiments.

Mark and tagging operations for The Dalles Reservoir resulted in marking approximately 3,000 white sturgeon with the 10^{th} right scute removal pattern and PIT tagging 1,879 of these fish. A total of 3,063 white sturgeon were captured in 1031 gillnet sets in eight weekly fishing periods from 3 December 2001 through 25 January 2002. Oregon Department of Fish and Wildlife performed the recapture effort, and they provide an update of the population estimate and structure 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 2002 through 31 March 2003 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 The Dalles 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 and 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 continued work at the holding and spawning facility located below the McNary Dam juvenile fish sorting facility. For this period, due to maintenance issues with the juvenile fish sorting facility, the primary water source for broodstock holding tanks was drawn from the McNary Dam tailrace water via two electric pumps submerged in the river directly down the riverbank from the juvenile separating facility. The new system utilizes two pumps in line that act as an emergency fail-safe should one pump fail; water from the sorting facility was also available as a back up source. Typically water from the submerged pumps is 0.5 to 1.0° C cooler than water from the juvenile facility that comes from the dam head. 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 were held in ambient temperature Columbia River water and were not fed throughout the holding period.

Broodstock Collection

A joint crew from CRITFC and WDFW fished for white sturgeon broodstock in McNary Reservoir in the Columbia River (Figure 1) from 4 March 2002 through 22 May 2002. All fishing took place in McNary Reservoir from about statute river kilometer 473 to 485 (river mile 294 to 301). 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 redness on the ventral surface, were not surgically examined and were released immediately. All fish examined for sexual maturity were PIT tagged, and the 2nd 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).

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.

Fishing began in early March when water temperatures and daylight hours were increasing. Fishing was generally performed 4-5 days a week with weekly and daily efforts dependent on catch rates. If catch rates were considered low, fishing was discontinued for one to

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

two weeks. Generally 6-9 setlines were set each day depending on catch rates. Fishing was scheduled to occur until broodstock harvest was completed or opportunities to fish were no longer available due to other project commitments.

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. (1987) 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. 1987, 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). 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.

The Dalles Capture, Mark and Pit Tagging

Columbia River Inter-Tribal Fish Commission captured, marked, and tagged white sturgeon in The Dalles Reservoir in order to perform population monitoring. The capture, mark, and PIT tag operation for The Dalles Reservoir was performed for seven weekly fishing periods from 3 December, 2001, through 25 January, 2002. We sampled the area from about statute river kilometer 254 to 349 (river mile 158 to 217). We divided the sampling area into three 11-13 kilometer (7-8 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.

All sections were sampled simultaneously and on a rotating basis with each crew beginning in an individually assigned section and rotating through each section on a weekly schedule. We employed this strategy in an effort to mark fish throughout the entire reservoir, reduce the possibility of recapturing newly marked fish, and give each fisher an equal opportunity to fish each section. Nets were checked and reset each day, with Monday being the first set day of the week and Friday 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 one 8 m bow pickers and two 5.5 m open boats. The length of nets fished ranged from approximately 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 10^{th} right lateral scute was removed to indicate year of capture was 2001 - 2002. 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 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.

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

RESULTS

Artificial Propagation Research

Broodstock collection

We collected twenty one white sturgeon for broodstock trials, two females measuring 213 and 193 cm in fork length (FL), and weighing 84 and 90 kg, respectively, and 19 males measuring 138 to 208 cm FL and weighing from 21 to 69 kg. We captured a total of 236 white sturgeon in 225 sets during 40 days of fishing 9 weekly periods from 4 March 2001 to 24 May 2002 (Table 1). Sizes of white sturgeon captured ranged from 59 to 233 cm fork length. We performed 91 biopsies on fish suspected of sexual maturity to determine sex and maturity, revealing a total of 66 males, 22 females, and 3 undetermined. Of those captured from McNary, we kept 20 sexually mature white sturgeon, 1 female and 19 males. An additional female originating from below Bonneville Dam was collected for broodstock purposes via a cooperative effort with OSU and WDFW staff working on a separate project. Permits for the transport of the below Bonneville Dam female were obtained from ODFW and WDFW, and the fish was transported to and held at the McNary spawning facility

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 2002 from McNary were returned to McNary Reservoir at the end of spawning trials. Fish were transported using the broodstock trailer and released from shore directly into the reservoir just upstream from Hat Rock Park (RKM 483). Most of these fish had some minor weight loss while in captivity and all were judged to be in good condition. The below Bonneville female was returned to her origin and released from shore just upstream from the Fishery (approximately RKM 225).

Broodstock spawning trials

We performed intensive monitoring and husbandry of the 21 captured broodstock white sturgeon throughout the spring of 2002. We monitored the maturation cycles of the McNary female from March through July 2002 and the Bonneville female from capture through June 2002. Throughout the monitoring period, oocytes of both females exhibited varying levels of germinal vesicle migration (Table 2). Decreasing PI and increasing GVBD were evident in both females. We attempted to spawn both females and successfully spawned the below Bonneville female. During the first spawning trials (below Bonneville female) beginning June 16,th nine randomly chosen males were injected with luteinizing releasing hormone and four of the nine produced milt. Sperm motility trials were conducted on all four collections and all were determined to be of good quality. On June 18th we successfully collected and fertilized eggs from the below Bonneville female. Eggs from the female were fertilized with milt taken from four McNary Reservoir males. Approximately 80,000 white sturgeon larvae (held at Abernathy Fish Technology Center) from the four parental crosses were produced during this spawning. In the second spawning trial (McNary Reservoir female) beginning July 9th, the remaining 10 males were injected with none producing milt, subsequently the 4 previous milt producers were injected for a second time, with 3 of the 4 producing milt. All three males produced sperm of good quality based on motility trials. On July 10 we attempted to spawn the McNary female but were unsuccessful. Though water temperatures remained favorable through most of the maturation holding period (May – July), and oocyte maturation assays including polarization index assays and germinal vesicle breakdown assays were indicative of a proper maturation cycle leading to a successful spawn, the female underwent atretic reabsorption of her eggs.

The Dalles Capture, Mark and PIT Tagging

Effort and White Sturgeon Catch

A total of 3,063 white sturgeon were captured in 1,031 gillnet sets. We marked 2,788 of these fish with the 10^{th} right scute removal pattern described in the methods section. Of the 3,063 captured, 508 were less than 70 cm (approximately 17 percent), and 2,555 (approximately 83 percent) were 70 cm or greater. We applied pit tags to 1879 white sturgeon. White sturgeon captured ranged from 33 to 275 cm FL (Figure 3), with a mean length of 97 cm. The total white sturgeon catch consisted of 2730 commercial sub legal size (less than 48 inches or 121.92 cm), 233 commercial legal size (between 48 inches and 60 inches or 121.92 cm and 152. 4 cm) and 100 over legal size (greater than 60 inches or 152.4 cm). The total mean white sturgeon catch per set for all sets combined was 2.97. All of the 3,063 white sturgeon captured and handled in The Dalles Reservoir were released alive. Abundance estimates for The Dalles Reservoir are reported by ODFW in section A of this report.

DISCUSSION

Artificial Propagation Research

The 2002 spawning season marked the second successful spawning of wild white sturgeon for this project. Instrumental to the successful spawning was the capture of the below Bonneville female near spawning maturity. Strategies outlined and developed over the last year allowed the collection of broodstock from areas other than reservoirs above McNary Dam with key areas identified below Bonneville and The Dalles dams. These strategies are necessary given the current conditions governing our spawning station (limited spawning temperature regime) and historic broodstock capture efforts in McNary Reservoir (low numbers of female broodstock, typically in early stages of oocyte maturation) (Kappenman et al 2001, 2002).

Broodstock collection efforts for 2002 were more challenging than they have been in the past four years. More effort was expended for broodstock collection than in any previous fishing year, still we were able to collect only one gravid female. Even with the strategies allowing take of fish outside McNary Reservoir, we were unable to collect the four females we would like to have collected for broodstock spawning trials. However, the strategies developed to collect a mature female from below Bonneville ensured a successful spawn. The Bonneville fish had a PI of less than 0.10 at capture. Generally, fish taken during the collection period from McNary Reservoir tend to be in early stages of oocyte maturation and have PI's of 0.15 or greater. Our experience with holding fish at the McNary facility has shown that water temperature increases can exceed white sturgeon spawning parameters before oocytes reach maturation in fish with high PI's , and that fish with lower PI's at capture have a higher likelihood of reaching maturation, and thus a higher likelihood of successful artificial spawning.

We successfully collected and fertilized eggs from the below Bonneville female with milt taken from four male white sturgeon creating four paternal crosses. The fertilized eggs were taken to AFTC for hatching and rearing. Our attempt to spawn the McNary female was unsuccessful. We speculate that temperature spikes, ranging from 15º C to 17º C degrees, during the final week (Figure 4) of maturation may have caused atresia, but we can only speculate on what might have occurred under ideal conditions.

The spawning facility at McNary allows access to normative river temperatures and is a success in respect to the successful spawning of sturgeon in 2001 and 2002. The facility allows us to hold mature males throughout the spawning season and gives us access to milt. It still does not provide the ideal conditions for successful spawning on a no-fail-basis, and 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 2002 and 2001, an alternative spawning and holding facility or alternative capture methods will continue be necessary to guarantee success in the future. A facility where river water and cooler well water could be mixed for a controlled optimal spawning temperature regime would likely be ideal for all spawning operations and especially beneficial in spawning late maturing females. Also, fish taken directly off the spawning grounds and already in spawning condition optimize success as proved by the below Bonneville female's successful spawning. Still, we have developed and refined collecting and holding techniques and developed a back-up strategy to purchase fish from a private aqua-culture firm that will allow us to meet the long-term goals of this project.

In early June 2002 we acquired approximately 50,000 white sturgeon larvae from a private aquaculture facility to ensure we had sufficient number of juveniles for future project release plans. These fish were acquired prior to the collection and successful spawning of the below Bonneville female. The larvae were spawned from a single pairing of wild broodstock white sturgeon collected below Bonneville Dam. A proportion of the stock from this parental pair and the stock from our four Bonneville/McNary brood crosses will be used in future hatchery release experiments.

The Dalles Capture, Mark and Pit Tagging

The 2002 tagging operation performed by CRITFC and ODFW is the third effort to determine population abundance and structure in The Dalles Reservoir. We provide a summary of CRITFC 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 The Dalles and John Day dams.

PLANS FOR UPCOMING YEARS

Broodstock spawning operations, hatchery releases, and marking/tagging operations for Bonneville Reservoir, along with all other completed activities for period April 2003 through March 2004 will be reported in detail in the subsequent Annual Report. At time of writing this report, budget cuts have terminated the hatchery propagation research segment of this project. The first hatchery release was performed in April 2003 and the remaining hatchery fish will be released in September 2003. We will continue developing a program to monitor the success of juvenile white sturgeon releases. We will be marking and tagging white sturgeon in John Day Reservoir beginning in late November 2003 and ending in early February 2004. We plan to PIT tag and scute mark approximately 3,000 white sturgeon during this effort

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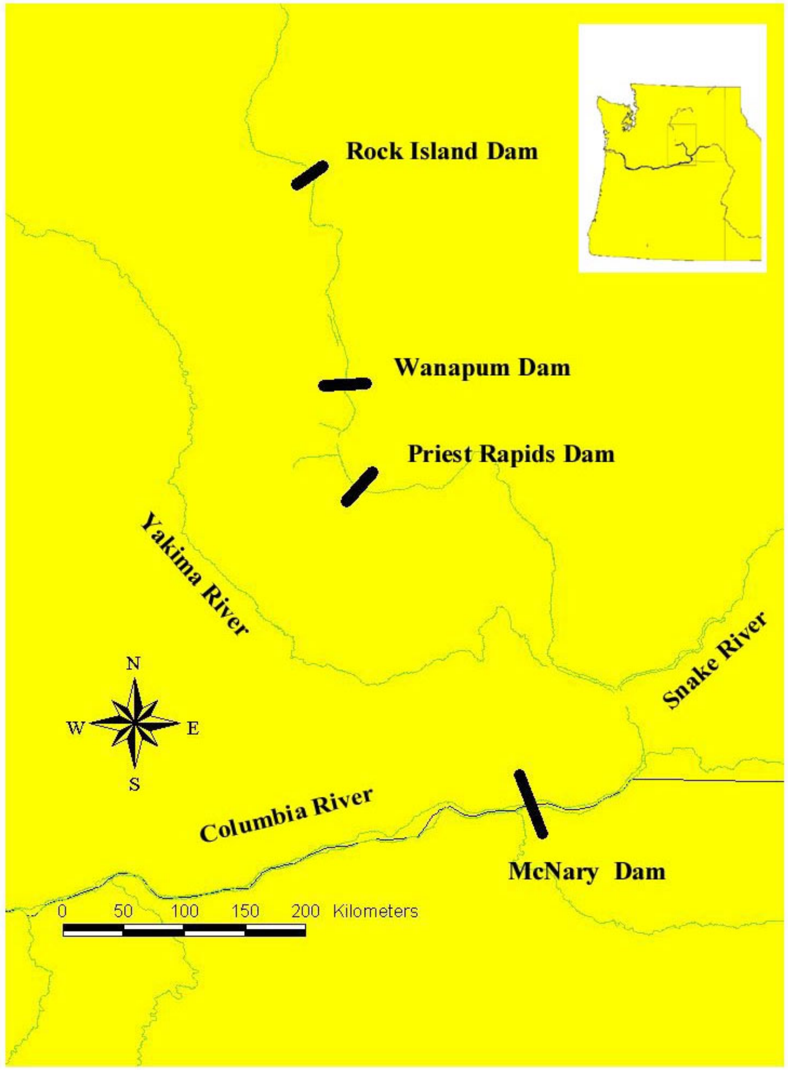

Figure 1. Map of McNary Reservoir in the Columbia River where white sturgeon broodstock collection efforts were performed from 4 March 2002 to 22 May 2002.

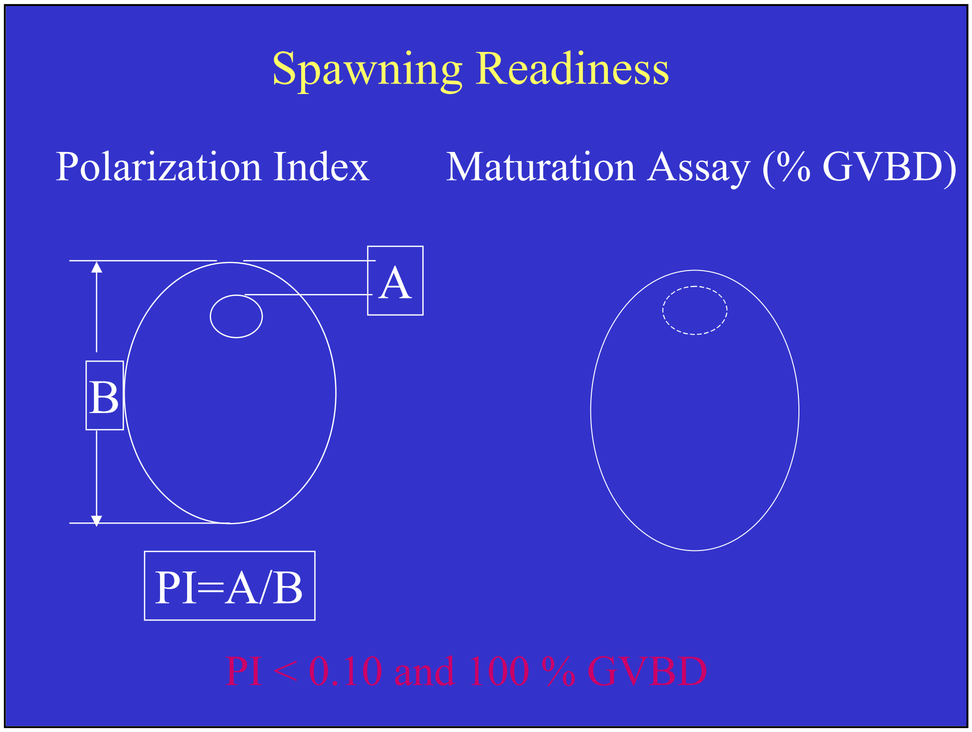

Figure 2. To monitor egg development and determine spawning readiness, two pieces of information are needed. The first is polarization index or PI (Conte et al. 1987). The PI is the ratio of the distance from the top of the nucleus to the animal pole to the animal-vegetal oocyte diameter. The second 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).

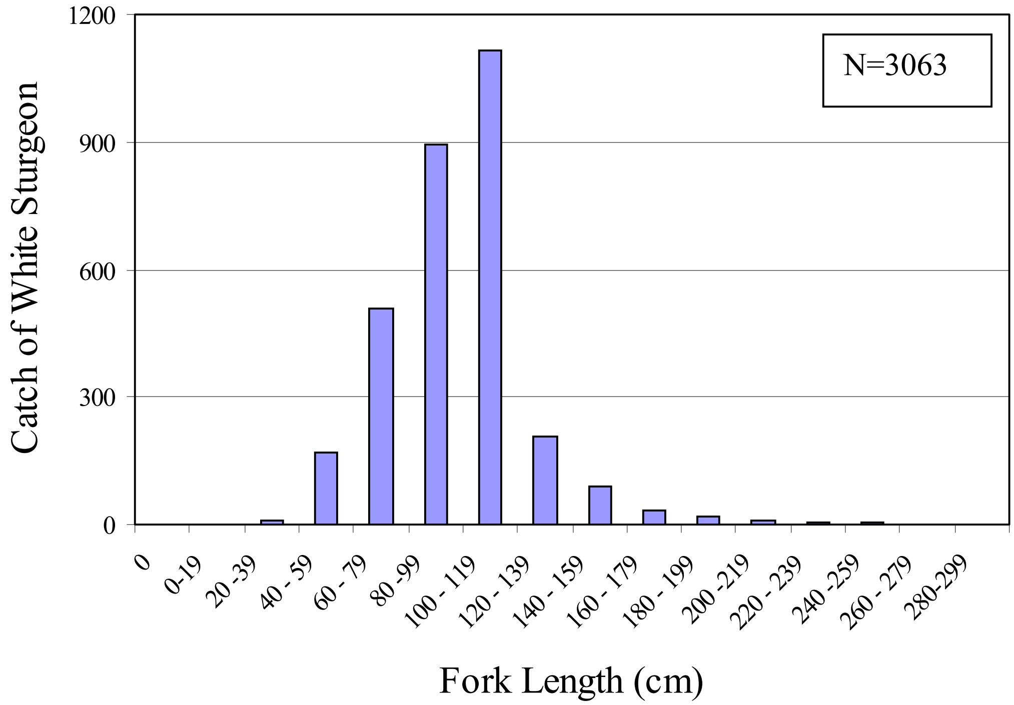

Figure 3. Length – frequency distribution (19 cm increments) for white sturgeon collected by CRITFC using gill nets in The Dalles Reservoir November through January 2002.

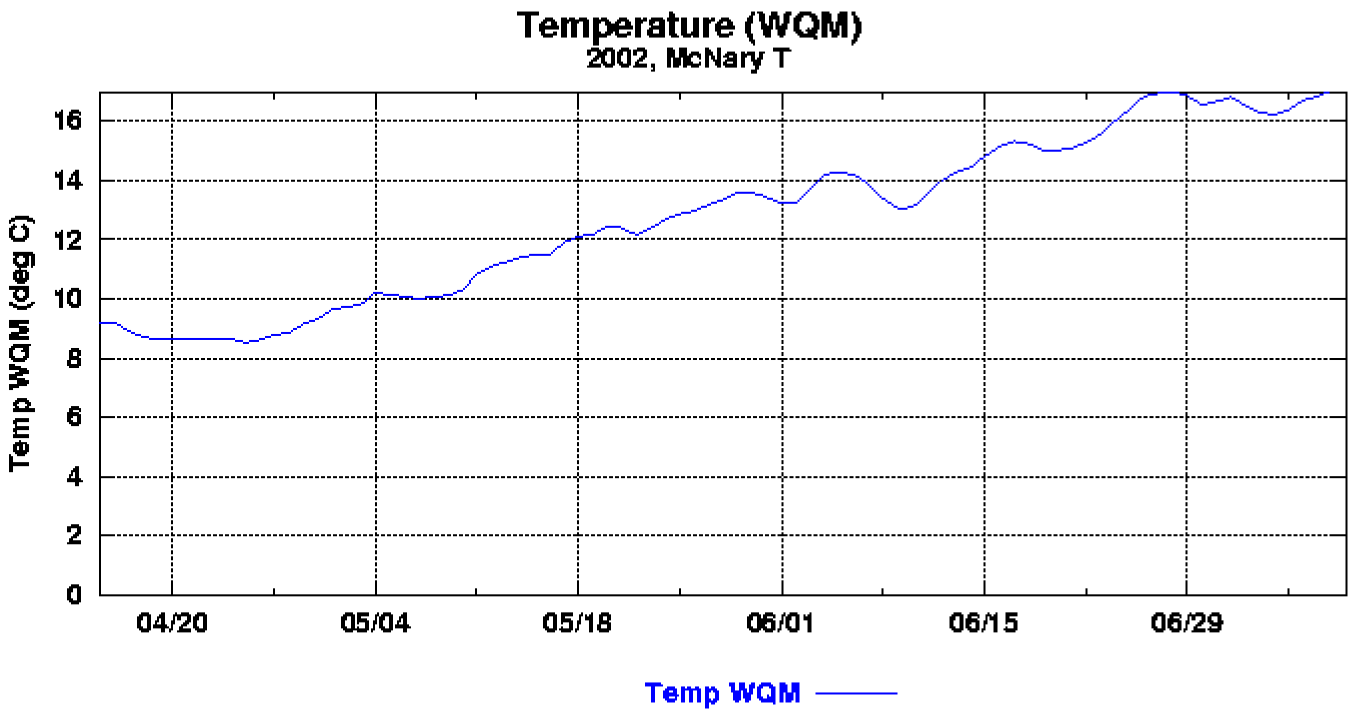

Figure 4. Temperature profile of McNary Forebay, the water source at the McNary Satellite Spawning Facility.

Table 1. 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 4 March 2002 to 22 May 2002 in McNary Reservoir.

Days fished	40	
Number of sets	225	
Number of white sturgeon captured	236	
	Males	Females
Number of broodstock kept	19	1

Table 2. A summary of standard oocyte maturation test results of white sturgeon held for the 2002 spawning season showing females identified by reservoir, date oocytes were sampled, oocyte polarization index, and result of spawning trials.

Female Identity (By Fork Length)	Sample Date	Oocyte Polarization Index	Spawning Results
Bonneville Female	6/6/02	0.08	
	6/18/02	N/A	Successful spawn
McNary Female	3/13/02	0.15	
	6/3/02	0.13	
	6/27/02	0.11	
	7/10/02	N/A	Went atretic

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

ANNUAL PROGRESS REPORT

APRIL 2002 – MARCH 2003

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 2002 white sturgeon spawning season.

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This project is the result of many people lending their support via their hard work and their expertise: Jeff Poole and Stephanie Poerstel, U.S. Fish & Wildlife Service (USFWS), Abernathy Fish Technology Center; Blaine Parker and Kevin Kappenman, Columbia River Inter-Tribal Fish Commission; the staffs of the USFWS, Lower Columbia and Idaho Fish Health Centers; Dr. Joseph Groff, School of Veterinary Medicine, University of California, Davis. And a special thanks to Jack Siple, Kootenai Tribe of Idaho, for sharing his knowledge on white sturgeon culture which assisted us in improving our rearing program.

ABSTRACT

Fifty thousand sturgeon larvae originating from wild adults captured downstream of Bonneville Dam were initially purchased. Subsequently, a female sturgeon captured downstream of Bonneville Dam was successfully spawned; eggs were hand stripped and fertilized using milt from four males captured in McNary Reservoir. Approximately 84,000 eggs were incubated with a hatch success of 98%. High mortality of newly hatched larvae occurred when screens were clogged with shed eggshells, resulting in 22,640 larvae. To provide needed rearing space for the spawned larvae, the original 50,000 sturgeon purchased were reduced to 22,300 at 30 days post fertilization (dpf). Acceptance of commercial diet (41 and 45 dpf) resulted in 64.7% and 57.8% survival, respectively, for the spawned and purchased sturgeon. Survival from feed acceptance to 146 and 149 dpf was 63.9% and 99.5%, respectively, for the spawned and purchased sturgeon. The production goal of 22,000 sub-yearling sturgeon was nearly reached with 21,700 sturgeon. No evidence of white sturgeon irido virus was found during the 2002 fiscal year. Predation by blue heron *Andea herodias* was eliminated with the construction of a new net structure enclosing the raceways.

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: to 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 rearing in small tanks occurred in a building having photocell controlled lighting. Single pass well water at 12.5°C was utilized for both incubation and rearing. Twelve McDonald type hatching jars (7 L) plumbed in fiberglass troughs were 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) were used. Water was supplied to all circular tanks via spray bars.

Outside rearing continued in 16 circular fiberglass tanks (3.05 m diameter, 23 L/min flow, single pass well water at 12.5°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, the raceways were totally enclosed by a net structure. Plastic netting (10.16-cm square) was supported 4-m above the water surface and covered the sides of the structure. Plastic netting (1-m high, 1.25-cm mesh) was installed at ground level to restrict potential predation by mammals.

Incubation

A female sturgeon captured downstream of Bonneville Dam was successfully spawned; eggs were hand stripped and fertilized using milt from four males captured in McNary Reservoir. Fertilized eggs were transported to AFTC from the Columbia River Inter-Tribal Fish Commission's McNary Dam Facility (Kappenmen and Parker, in press), 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. Transport time was approximately four hours.

Upon arrival, the transport bags containing the eggs were floated in the incubation water source (12.5^{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 at 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. The sturgeon produced in this manner will be referred to as "spawned" sturgeon.

Rearing

To ensure production of juvenile sturgeon in the event spawning of the project's wild adults failed, 50,000 white sturgeon larvae (10 dpf) were purchased. The sturgeon larvae originated from the artificial spawning of a single wild female fertilized by an unknown number of males, all adults were captured downstream from Bonneville Dam. Larvae were purchased from Pelfrey's Sturgeon Hatchery, Troutdale, Oregon. The sturgeon obtained in this manner will be referred to as "purchased" sturgeon.

In order to make comparisons between purchased and spawned sturgeon, both groups were treated similarly. The purchased sturgeon and the four half siblings families of the spawned sturgeon were reared separately.

At 14 to 16 days post fertilization (dpf), purchased and spawned larvae were stocked into 0.7-m tanks at 500 larvae per tank and into 1.2-m tanks at 2100 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 ensure feed contact. Rations were reduced to 5% body weight at 104 dpf when fry were actively feeding, reducing the amount of uneaten feed. Feed amounts were calculated using the growth rate obtained in the 2001-rearing season. To prevent rejection when diet particle size was increased, larger particles were gradually mixed into the original 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.

From the end of August through mid-September (86 dpf), it was necessary to reduce rearing densities. From each tank the smallest sturgeon were visually graded, captured individually by hand net, and combined in tanks. The remaining sturgeon were netted and transported in water to new tanks. Between 50-200 fry were stocked in each of the 0.7-m tanks, 200-1000 fry were stocked in each of the 1.2-m tanks and 800-1400 fry were stocked into 3.05-m tanks located outside. The 3.05-m tanks were covered with 70% shade cloth and 24-hour belt feeders provided feed.

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

From mid-September through March (91-280 dpf) white sturgeon were visually graded, the largest individuals were captured by hand net and transported in water to raceways. Visual grading occurred every 1 to 3 weeks, dependent on growth rates and rearing densities. Raceways were covered with 70% shade cloth with feed provided by 24-hour belt feeders. Sturgeon reared in raceways were initially restricted to a portion of the raceway using a screen barrier to ensure they would come in contact with feed. As rearing densities increased, rearing area was increased until the full raceway was utilized. Starting in late February (266 dpf), small sturgeon were visually graded, removed by hand net, and segregated into a separate portion of the raceway using a screen barrier. The goal was to prevent mortality caused from competition with larger, faster growing siblings.

RESULTS

Sturgeon Culture

Incubation

On June 18th , the eggs from a female sturgeon that was captured downstream of Bonneville Dam were successfully fertilized using milt from four male sturgeon captured in McNary Reservoir (Kappenman and Parker, this report). The female's eggs were hand stripped and divided into four lots. Each lot was fertilized using milt from a single male. Hatch occurred from 10 to 15 dpf. Hatch rate of spawned sturgeon was high, greater than 98 %. High mortality (73%) occurred after hatching when eggshell debris clogged the screens in the troughs, causing water flow to pull larvae into the screens. A total of 22,640 larvae were successfully produced from an estimated 84,700 eggs spawned. Table 1 provides a summary of the spawning data.

Table 1. Results from the spawning of a single female white sturgeon with four males.

Male PIT tag #	Eggs Fertilized	Larvae Production
…F0E6	18,200	11,520
…1EA9	18,200	4,180
…3694	22,750	4,050
…80DE	25,550	2,890
Total	**84,700**	**22,640**

Rearing

In early July, the number of "purchased" sturgeon fry was reduced from 45,600 to 22,300 in order to provide rearing space for the "spawned" larvae produced in June. At 45 dpf, an estimated 57.8% of the purchased sturgeon fry had accepted the commercial diet, resulting in 12,900 fry. Survival to 149 dpf for the purchased sturgeon was 99.5% (12,840 juveniles).

At 41 dpf an estimated 64.7% of the spawned sturgeon fry had accepted the commercial diet, resulting in 14,660 fry. Survival at 146 dpf was 63.9% (9,370 juveniles). Table 2 provides comparison of survival of the sturgeon production of 2001 and 2002.

Due to the benthic behavior of sturgeon resulting in limited use of the water column, rearing density was monitored in relation to benthic area (kg/m^2) rather than the standard use of rearing volume (kg/m^3). Rearing densities for purchased and spawned sturgeon were kept similar. Table 3 presents the rearing densities for the purchased sturgeon and the 2001 sturgeon for comparison.

Table 2. White sturgeon survival data for spawned (2001 and 2002) and purchased (2002 only) sturgeon, dpf = days post fertilization.

Spawning Year	Male PIT tag#	Eggs Spawned	% Hatch	% Accepting commercial diet (dpf)	% Survival from feed acceptance to (dpf)
2001		104,000	44	69.0 (43)	90.6 (145)
2002		84,700	98	64.7 (41)	63.9 (146)
2002	…F0E6			65.6 (41)	52.2 (146)
2002	…1EA6			50.1 (41)	72.6 (146)
2002	…3694			80.8 (41)	77.1 (146)
2002	…80DE			59.6 (41)	79.5 (146)
2002	Purchased larvae			57.8 (45)	99.5 (149)

In the 2002 rearing season stressors were minimized to reduce the threat of a white sturgeon irido virus (WSIV) outbreak. Periodic sampling of sturgeon weights were not performed. Weights were estimated from data collected during the 2001 rearing season. However, when sturgeon were transferred to different rearing environments, average weight data was obtained. The data shown in Table 4 are the average weights for the fastest growing portion of the two groups reared in 2002 with data from the 2001 rearing included for comparison. Since within each group there was growth variability, these values represent maximum growth for the rearing conditions at AFTC.

Table 3. Rearing densities in kg/m^2 of purchased sturgeon 2002 and 2001 sturgeon in parenthesis.

Date	Days Post Fertilization	0.7-m circular tank	1.2-m circular tank	3.05-m circular tank	Raceway
06/25/02	23	0.0005	0.07		
07/29/02	57	0.34	0.48		
08/27/02	86	0.35 (0.60)	0.93 (2.62)	0.33	
09/27/02	117	0.34 (3.15)	1.77 (3.41)	1.09 (1.68)	
10/29/02	149	0.97	2.74	2.23	2.94
12/04/02	185	0.75	1.52	1.86	2.69
01/08/03	220	1.04	1.92	2.36	3.40
02/22/03	265	0.75	2.74	2.50	3.15
03/26/03	297	0.88	3.49	3.16	3.50

Table 4. Average weight (grams) of the largest juvenile white sturgeon in two groups reared in 2002 and 2001.

Days post fertilization	Purchased sturgeon	Spawned sturgeon	2001 Sturgeon
82			1.6
86	2.3	1.7	
96			3.7
107	7.1		
114		4.0	
124			8.3
130	9.5		
138			11.3
144		8.9	
164	13.4		
168		16.3	
184	20.7		
205		22.6	
233	33.3	26.1	
244	45.6		
250		30.7	

The water temperature during rearing was dependent on environment and season. The 0.7-m and 1.2-m tanks were housed inside a building and were supplied well water that remained a constant 12.5°C. Although supplied with well water, the 3.05-m tanks and raceways water temperature varied both diurnally and seasonally (Table 5).

Table 5. Monthly water temperature ranges (^oC) of two rearing environments for juvenile white sturgeon.

Month/Year	3.05 m diameter circular tanks	Raceways on re-use well water system
April/2002	10.5 - 13.3	10.5 – 13.9
May	10.0 – 13.3	11.1 – 15.0
June	10.5 – 14.4	12.2 – 16.6
July	11.1 – 14.4	13.3 – 19.4
August	11.1 – 14.4	12.8 – 16.6
September	11.1 – 13.3	12.2 – 15.5
October	10.5 – 12.7	10.5 – 13.9
November	10.0 – 12.2	8.9 – 12.2
December	10.0 – 11.6	8.9 – 11.1
January/2003	10.0 – 11.6	8.9 – 12.2
February	9.4 – 11.6	8.9 – 11.6
March	10.0 – 12.2	10.0 – 12.2

DISCUSSION

The culture of white sturgeon juveniles at AFTC was successful; eggs were incubated, hatched, larvae were started on a commercial diet, and approximately 21,700 juveniles were produced nearly meeting the production goal of 22,000 sub-yearling juveniles.

The occurrence of the WSIV outbreak in 2001 required changes in culture protocol. During 2002 rearing season handling stress was minimized by: 1) reducing the number of times sturgeon needed to be moved, 2) sampling for weight data only when sturgeon were moved, 3) not using bar-graders to segregate sturgeon by size, (visual grading occurred where only sturgeon graded were handled). To reduce stress, early rearing densities were reduced in 2002 (Table 3). To help minimize the spread of disease, each tank was equipped with separate nets and brushes. The effect of these culture changes in reducing the chance of a WSIV outbreak is not known since it is possible the virus was not present in the eggs or larvae reared in 2002. No evidence of WSIV was found during the 2002 fiscal year.

The high mortality of newly hatched larvae (72.5%) that occurred when screens became clogged with eggshells should have been avoided by closely monitoring the hatch. Mortality did not occur in 2001 due to the lower numbers of hatching larvae, 46,000 versus 82,000 larvae in 2002. Close monitoring of the hatching phase is critical, especially when large numbers of larvae are expected to hatch.

Success in propagating juvenile white sturgeon for supplementation may have a genetic component. The study showed large ranges in acceptance to commercial diet (50.1%-80.8%) and survival to 146 dpf (52.2%-79.5%) in the four half sibling groups. A supplementation facility should have the capability to separately propagate sibling groups until release.

The loss of sturgeon to bird predation (~2,000 juveniles) in 2001 when adequate bird netting was not in place reinforced the need to have proper protection. The new net structure constructed to cover the raceways was effective in eliminating predation at AFTC.

Further work needs to be conducted to determine optimum rearing densities for all stages of juvenile white sturgeon. Studies determining how rearing density affects stress in white sturgeon may aid in reducing WSIV outbreaks.

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

ANNUAL PROGRESS REPORT

APRIL 2002 – MARCH 2003

Report F

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

and

Determine how reproductive plasma, urine, and mucus steroid 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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ABSTRACT

During 1 April 2002 through 31 March 2003, 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 and urine steroids, as well as fork length. Discriminant function analysis (DFA) revealed that plasma testosterone (T), 11-ketotestosterone (KT), and estradiol (E2), as well as fork length (FL) led to the correct classification of 62, 53, 89, and 80% of the immature females, immature males, maturing females, and maturing males, respectively. 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). Urine T, KT, and E2 led to the correct classification of 76, 35, 75, and 55% of the oversize immature females, immature males, maturing females, and maturing males, respectively, while mucus T, KT, and E2 led to the correct classification of 22, 56, 57, and 52% of the oversize immature females, immature males, maturing females, and maturing males, respectively. To date, it does not appear that mucus sex steroid levels will prove useful in the classification of fish by sex and maturity.

INTRODUCTION

This annual report describes progress of Oregon State University (OSU) on the Bonneville Power Administration funded Project 198605000 – White Sturgeon Restoration and Enhancement in the Columbia and Snake Rivers Upstream from Bonneville Dam. This report covers the period of 1 April 2002 through 31 March 2003.

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 levels, and determine how reproductive plasma, mucus and urine steroid concentrations vary at different stages of maturation to develop predictive indices for the timing of maturation.

METHODS

Collection of Fish

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 2002 with the help of Washington Department of Fish and Wildlife. Fish were captured by gill net as well as 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=75) was 212 ± 3 cm.

White sturgeon from the commercial and tribal 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 (110- to 137-cm fork length, herein referred to as fishery fish). The mean (± SE) FL of these fish (n=75) was 115 ± 1 cm.

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 (Motic, 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 discriminant function analysis (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 - 5 (onset of meiosis through spermiation) and females in Stages 3 - 6 (early vitellogenesis through ovulation) were considered "maturing". Post-spawned females (Stage 7) and males (Stage 6) were considered "immature" as sex steroid levels were equivalent to levels measured in Stage 1 and 2 fish. 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). 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 spatula 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). Plasma calcium was not measured in the samples collected in 2002 and hence will not be used in the discriminant function analysis.

Radioimmunoassays

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.

The steroids in urine were unconjugated (sulfate or 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. The preliminary DFA revealed classification of sex and maturity was greater with unglucuronidated urine steroids compared to unsulphated urine steroids (Webb et al., 2002), hence the DFA was conducted with unglucuronidated urine steroids.

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.

Statistical Analysis

Steroid 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.

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 2002 were combined with data from the fishery fish sampled in 2000, 2001, and 2002 and the oversize fish sampled in 2000 and 2001 for the development of the model presented in this report. The urine and mucus and histological data from oversize fish sampled in 2000, 2001, and 2002 were used for the development of the DFA model. To attain multivariate normality, the logarithms of the plasma, urine, and mucus variables T, KT, and E2 were considered for analysis. Stepwise DFA was conducted using 1) log-transformed plasma T, KT, and E2 concentrations and FL, 2) log-transformed urine T, KT, and E2 concentrations, and 3) log-transformed mucus T, KT, and E2 concentrations 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). 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).

RESULTS

Maturation cycle

A total of 590 white sturgeon were sampled for biological samples in the Columbia River between February 2000 and March 2003. Plasma sex steroid analysis and gonadal histology have been completed on 431 fish. Of these 431 fish, urine sex steroids were measured in 186 fish, while mucus steroid concentrations have been measured in 192 fish. Urine and mucus cannot be collected from fish captured in the commercial or tribal fisheries as fish are brought into the processing facilities dead (hence no urine) and touching one another (hence mucus is mixed among fish). The data reported here will include these 431 fish, except for the urine and mucus analyses that include the respective number of fish for which analyses have been completed.

Of the fishery fish sampled, 127 were immature females, 99 were immature males, one was a female with ovarian follicles just entering vitellogenesis, and 8 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, 93 were immature/resting females, 45 were immature/resting males, 36 were maturing females, and 22 were maturing males (Table 1). The stage of gonadal development of these maturing oversize fish included Stages 3, 4, 5, 7, and 8 in females and Stages 3, 4, 5, and 6 in males.

A total of 356 oversize sturgeon have been marked with spaghetti tags, scute marks, and PIT tags below Bonneville Dam (n=183 in 2000, n=98 in 2001, n=75 in 2002). Paired biological samples were not collected from each of these 356 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 2002, 12 fish were recaptured (16% of the total fish captured in 2002). Of these 12 fish, 8 were tagged in 2000 and 4 were tagged in 2001. Sex determined at the time of gonadal biopsy revealed 7 males and 4 females and 1 hermaphrodite (Table 2). Histological examination of the gonadal tissue revealed the field determination of sex was correct on all fish biopsied.

Determination of Sex 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 (157 ± 3 cm) had significantly greater FL compared to immature males (145 ± 4 cm). The FL of maturing females (221 ± 4 cm) was significantly greater compared to immature fish and maturing males (170 ± 7 cm), while maturing males did not have significantly greater FL compared to immature females.

Concentrations of plasma sex steroids 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 were significantly higher in maturing females compared to immature fish and maturing males (Figure 1).

Plasma T, KT, E2, and FL were chosen in the stepwise DFA as the best predictors of sex and stage of maturity. These variables led to the correct classification of 62, 53, 89, and 80% of the immature females, immature males, maturing females, and maturing males, respectively

(Table 3). Overall, 71% of the fish were correctly classified. In the cross-validation of the model predicting sex and stage of maturity in these fish, 41, 49, 16, and 20% error was associated with predicting immature females, immature males, maturing females, and maturing males, respectively.

Determination of Sex and Maturity Using Urine Indicators

Concentrations of urine sex steroids differed significantly ($P < 0.0001$; Figure 2) 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 and maturing females, but the concentrations of these androgens were significantly greater in maturing males. Plasma concentrations of E2 were significantly higher in maturing females compared to immature fish and maturing males.

In the stepwise DFA, urine T, KT, and E2 were chosen as the best predictors of sex and maturity resulting in the correct classification of 76, 35, 75, and 55% of the immature females, immature males, maturing females and maturing males (Table 4). The overall percentage of fish correctly classified was 60%. In the cross-validation of the model predicting sex and stage of maturity in these fish, 30, 70, 30, and 45% error was associated with predicting immature females, immature males, maturing females, and maturing males, respectively.

Determination of Sex and Maturity Using Mucus Indicators

Concentrations of mucus T and KT differed significantly ($P < 0.0001$ and $P = 0.0006$, respectively; Figure 3) among the four groups of sex and stage of maturity. Mucus concentrations of E2 were not significantly different among the four groups of sex and maturity ($P = 0.2885$).

In the stepwise DFA, mucus T, KT, and E2 were chosen as the best predictors of sex and maturity resulting in the correct classification of 22, 56, 57, and 52% of the immature females, immature males, maturing females and maturing males (Table 5). The overall percentage of fish correctly classified was 47%. In the cross-validation of the model predicting sex and stage of maturity in these fish, 78, 56, 49, and 65% error was associated with predicting immature females, immature males, maturing females, and maturing males, respectively.

DISCUSSION

Of the fishery fish sampled in 2000-2002, < 1% of the females were maturing, while close to 8% of the males were maturing. Of the oversize fish sampled, 29% of the females were maturing, while 45% 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 and 2002 reveals that males of reproductive size are capable of spawning in sequential years (2001 data) but do not necessarily spawn every year (2002 data). Fish H113708 was ripe in 2001 (Stage 5) and was reproductively immature/resting in 2002 (Stage 2) upon recapture. Fish H113760 and 08351513 were reproductively immature/resting (Stage 2) in both 2001 and 2002. Female 07560838 was vitellogenic in 2000 and immature/resting in 2002. Histological analysis of the gonadal tissue did not reveal any residual pigment that would be seen if atresia had ensued indicating this female successfully spawned in 2001. This would suggest a 3+ year reproductive cycle. Female H111577 was reproductively immature/resting (Stage 2) in 2000 and was visually identified as an immature/resting female in 2002 though a good histological sample could not be collected in 2002 due to a regressed gonad. Based on the biennial cycle described for cultured female white sturgeon (Doroshov et al. 1997), the fastest reproductive cycle for this female would be 5 years.

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 T and E2, as concentrations were significantly different (Figure 1). It remains difficult to distinguish between immature females and males using sex steroids as the concentrations are similar in both groups.

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 (Feist et al. 2004). 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 and maturity, the overall correct classification using plasma steroids remains to be 71% as in the analysis of the 2000 and 2000 - 2001 data. The overall correct classification using urine steroids was 60% and 47% for mucus steroids. The use of sex steroid concentrations in urine to discriminate sex and maturity appears promising (Table 4) though further work to optimize the model is needed. However, the use of mucus steroids does not appear to be promising.

Though error does exist in the classification of sex and stage of maturity of white sturgeon using blood plasma and 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. Therefore, under certain circumstances, the error associated with misclassifying fish using plasma and urine steroid levels is more accurate than collection of a gonadal biopsy. To date, the error associated with classifying sex and stage of maturity in white sturgeon using mucus indicators is too great to warrant its use.

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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
	2002	13	6	0	1
Bonneville	2000	12	8	0	0
	2001	11	7	0	0
	2002	11	9	0	0
The Dalles	2000	13	9	0	2
	2001	9	6	0	1
	2002	7	11	0	0
John Day	2000	9	12	1	2
	2001	11	9	0	0
	2002	12	6	0	0
Oversize					
McNary	2000	5	5	2	1
Below Bonneville					
Gill Net	2000	8	1	1	3
Gill Net	2001	12	6	9	4
Gill Net	2002	9	3	2	1
Sport Fishers	2000	19	3	12	2
Sport Fishers	2001	22	14	5	4
Sport Fishers	2002	18	13	5	7
Total		220	144	37	30

Table 2. Oversize white sturgeon recaptured in 2002 below Bonneville Dam. Fish identification is the spaghetti tag or PIT tag number. Field sex is based on visual examination of the gonad at the time of biopsy. 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). Visual examination of gonad tissue only was conducted on several fish (no sample), and several samples collected for histology were adipose tissue (unknown) or were not able to be collected due to very regressed gonads (regressed). One fish was hermaphroditic (herm.).

Fish ID	Year Tagged	Fork Length (cm) (year tagged / 2002)	Field Sex	Stage of Maturity (year tagged / 2002)
H113708	2001	198 / 201	Male	Stage 5 / Stage 2
H113726	2001	219 / 218	Male	No Biopsy / Regressed
H113760	2001	192 / 188	Male	Stage 2 / Stage 2
H111577	2000	234 / 235	Female	Stage 2 / Regressed
H111643	2000	190 / 187	Male	No Sample / Unknown
07560838	2000	224 / 224	Female	Stage 4 / Stage 2
07540368	2000	256 / 254	Male	Stage 2 / Stage 2
H109984	2000	210 / 206	Male	No Biopsy / Stage 2
08351513	2001	210 / 208	Male	Stage 2 / Stage 2
07575675	2000	219 / 223	Herm.	No Biopsy / Stage 2
H109978	2000	231 / 230	Female	No Biopsy / Stage 2
H111576	2000	217 / 214	Female	No Biopsy / Stage 2

Table 3. Classification summary for determination of sex and stage of maturity from the quadratic discriminant function analysis for white sturgeon using log-transformed plasma testosterone, 11-ketotestosterone, estradiol, and fork length. 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)
Immature Females	**62** (136)	21 (46)	8 (18)	9 (20)	(220)
Immature Males	26 (37)	**53** (77)	7 (10)	14 (20)	(144)
Maturing Females	3 (1)	5 (2)	**89** (33)	3 (1)	(37)
Maturing Males	17 (5)	3 (1)	0 (0)	**80** (24)	(30)

Table 4. Classification summary for determination of sex and stage of maturity from the quadratic discriminant function analysis for white sturgeon using urine testosterone, 11-ketotestosterone, and estradiol (free + glucuronidated). 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)
ImmatureFemales	**76** (68)	18 (16)	5 (5)	1 (1)	(90)
Immature Males	52 (21)	**35** (14)	3 (1)	10 (4)	(40)
Maturing Females	16 (6)	6 (2)	**75** (27)	3 (1)	(36)
Maturing Males	20 (4)	25 (5)	0 (0)	**55** (11)	(20)

Table 5. Classification summary for determination of sex and stage of maturity from the quadratic discriminant function analysis for white sturgeon using mucus testosterone, 11-ketotestosterone, and estradiol. Data are percentages (n), with the correctly classified percentages in bold.

True Sex	Classification Determined From Predictors				Total (n)
	Immature Females	Immature Males	Maturing Females	Maturing Males	
ImmatureFemales	**22** (20)	54 (49)	10 (9)	14 (13)	(91)
Immature Males	7 (3)	**56** (23)	25 (10)	12 (5)	(41)
Maturing Females	3 (1)	24 (9)	**57** (21)	16 (6)	(37)
Maturing Males	0 (0)	17 (4)	31 (7)	**52** (12)	(23)

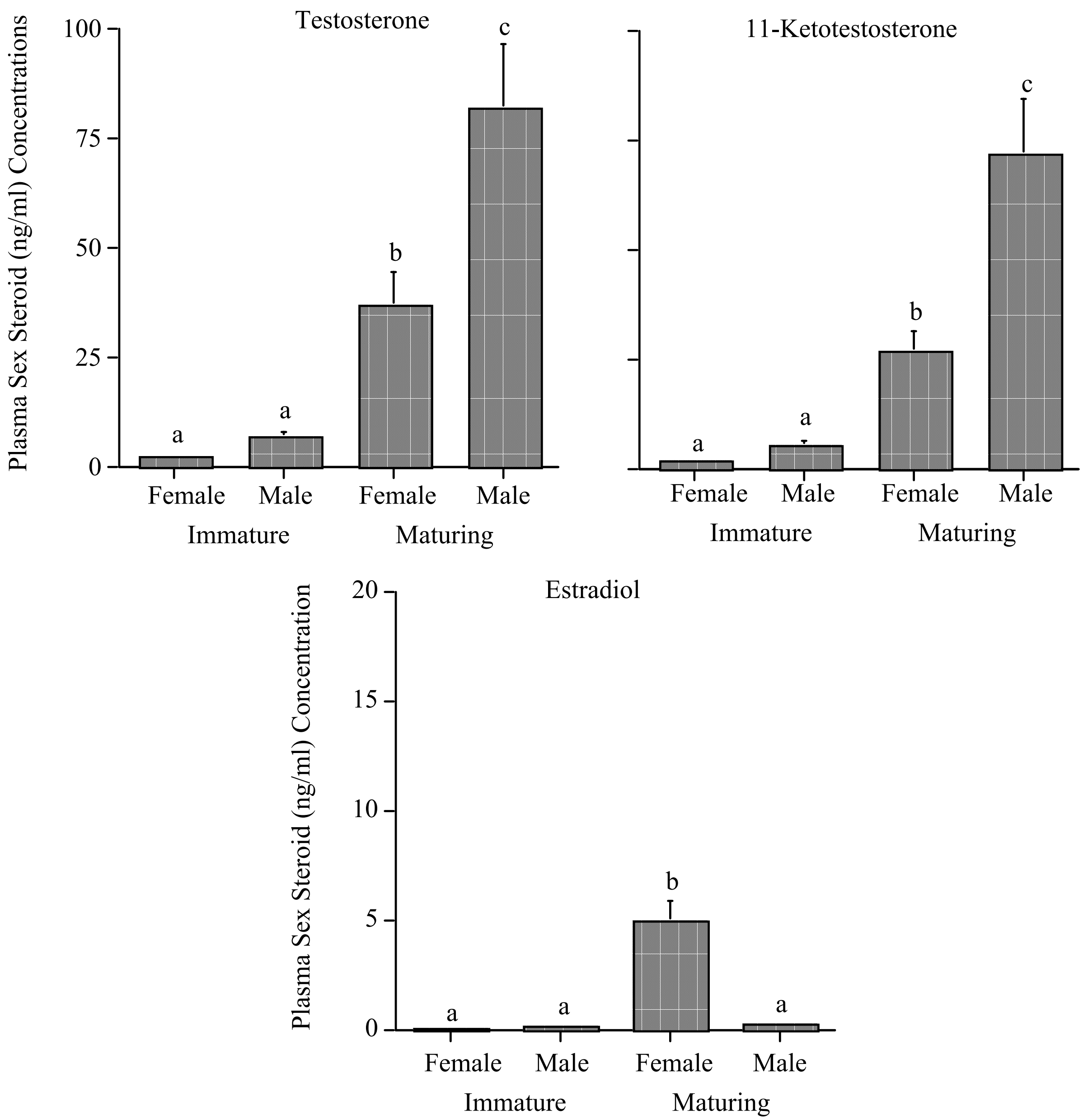

Figure 1. Plasma sex steroid concentrations in white sturgeon captured in the Columbia River basin in 2000, 2001, and 2002 (mean + SE). Different letters denote statistically significant differences between the groups (immature females, n=220; immature males, n=144; maturing females, n=37; and maturing males, n=30).

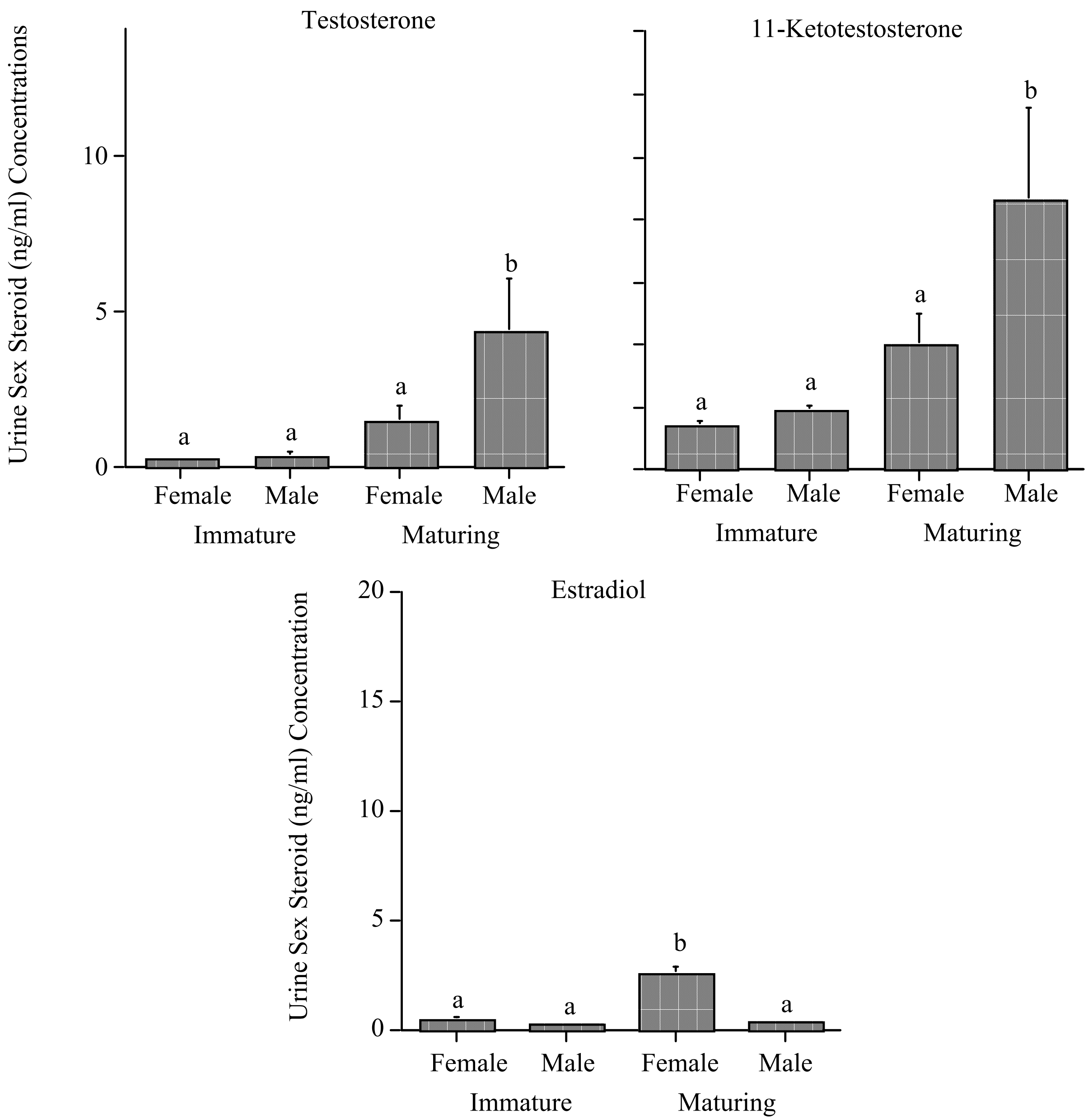

Figure 2. Urine sex steroid concentrations in white sturgeon captured in the Columbia River basin in 2000, 2001, and 2002 (mean + SE). Different letters denote statistically significant differences between the groups (immature females, n=90; immature males, n=40; maturing females, n=36; and maturing males, n=20).

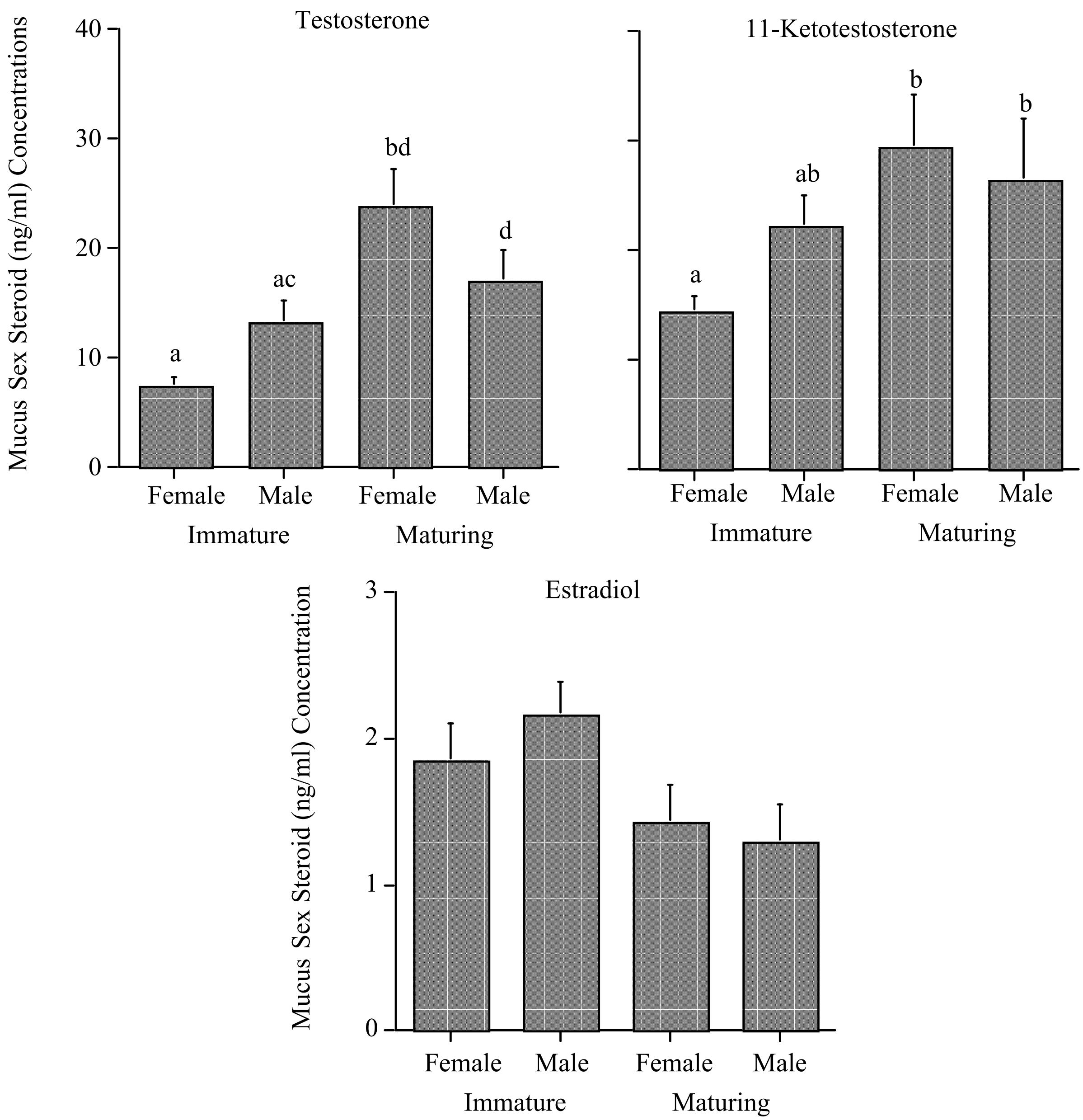

Figure 3. Mucus sex steroid concentrations in white sturgeon captured in the Columbia River basin in 2000, 2001, and 2002 (mean + SE). Different letters denote statistically significant differences between the groups (immature females, n=96; immature males, n=41; maturing females, n=38; and maturing males, n=23).