B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

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

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Bonneville Power Administration
P.O. Box 3621
Portland, OR 97208

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

ANNUAL PROGRESS REPORT

APRIL 2003 - MARCH 2004

Edited by:

Thomas A. Rien
Oregon Department of Fish and Wildlife

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
Oregon State University

Prepared For:
U.S. Department of Energy
Bonneville Power Administration
Environment, Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-3621

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EXECUTIVE SUMMARY

We report on our progress from April 2003 through March 2004 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), and Oregon State University (OSU; Report E).

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 are:

Report A

- From December 2002 through August 2003, combined effort by CRITFC, ODFW, and WDFW resulted in applying PIT-tags to 6,333 white sturgeon in Bonneville Reservoir.
- ODFW, WDFW, and CRITFC crews set 592 baited setlines in Bonneville Reservoir between 2 June 2003 and 21 August 2003, and captured 6,427 white sturgeon, for a CPUE of 10.85.
- Recaptured fish were caught an average of 1.9 km downstream from the location of first-capture.
- There were no significant differences in relative weights of fish >70 cm FL among the three sampling periods when baited setlines were used. Relative weights for fish >70 cm FL were significantly higher in 2003 (mean 92.1) than they were in 1999 (mean 87.6).
- Using multiple mark-recapture estimates, we estimated the total population in Bonneville Reservoir to be 120,000 white sturgeon. We estimated abundance of fish 70-109 cm FL to be 66,000 fish; abundance of fish 110-166 cm FL was estimated to be 1,200 fish; and abundance of fish > 166 cm FL was estimated to be 750 fish.
- Transplant supplementation (Trawl and Haul) continued in 2003. A total of 2,961 juvenile white sturgeon were captured by trawl net and transplanted, with 2,951 released to John Day Reservoir, and the remainder released to The Dalles Reservoir.
- Trawl catches were exceptionally poor this year. The trawler caught fewer fish on average than in past years, and spent more time trawling to do so.
- We continued sampling with small-mesh gillnets to index recruitment of young-of-year white sturgeon in three Columbia River and two Snake River reservoirs. None of the white sturgeon captured in any of the five reservoirs in 2003 were aged as YOY.

Report B

- The 2003 white sturgeon harvest (recreational, commercial, and subsistence) in Management Zone 6 was 3,941 fish. This is the lowest total harvest since 1996, and is reflective of the 43% reduction of the recreational guideline and 18% reduction of the commercial guideline in The Dalles Reservoir, and a low commercial harvest in Bonneville Reservoir (32% of commercial guideline). Retention seasons were closed on June 26 in Bonneville Reservoir, June 28 in The Dalles Reservoir, and July 12 in John Day Reservoir.

- Compliance with the Sturgeon Management Task Force (SMTF) annual harvest guidelines has been addressed through in-season management actions. Harvest in Bonneville Reservoir during the past five seasons (1999-2003) has averaged 90% of the recreational guideline and 72% of the commercial guideline. Harvest in The Dalles Reservoir for the same period averaged 110% of the recreational guideline and 105% of the commercial guideline. Harvest in John Day Reservoir averaged 76% of the recreational guideline and 69% of the commercial guideline.
- Harvest per angler trip in Bonneville Reservoir increased for only the second time since the short winter/spring retention seasons began in 1995. Harvest per angler trip in The Dalles Reservoir decreased each of the last two years to match the third lowest since 1995. Harvest per angler trip in John Day Reservoir was unchanged for the third year in a row.
- The handle of oversize white sturgeon in the John Day recreational fishery has increased since 1995, comprising 11.6% of white sturgeon handled during 2001-2003. The handle of oversize white sturgeon in the John Day Reservoir recreational fishery is more than three times greater than that for Bonneville and The Dalles reservoirs.

Report C

- River discharge and water temperatures that occurred during April through July 2003 provided conditions suitable for spawning by white sturgeon downstream from Bonneville, The Dalles, John Day, and McNary dams. Although optimal spawning temperatures in the four tailraces occurred for less than two weeks, they coincided with a period of relatively high river discharge. Bottom-trawl sampling in Bonneville and The Dalles Reservoirs revealed the presence of young-of-the-year (YOY) white sturgeon in Bonneville Reservoir, but none were captured in The Dalles Reservoir.
- A comparison of five years of indices of abundance of YOY sturgeon from sampling done by ODFW with gill nets and the USGS with bottom trawls was completed. Despite obvious differences in gear sampling characteristics, it appears that either gear can be used to assess relative trends in YOY white sturgeon abundance. The analyses suffered due to poor catches of YOY fish, as YOY were only captured in The Dalles Reservoir during three of the five years of comparison sampling, and during only one of four years in John Day Reservoir. However, both gears detected the presence or absence of YOY white sturgeon within a reservoir equally.
- Concerns have been raised that previously described relationships for Sacramento River white sturgeon may not be applicable to Columbia Basin stocks. However, using laboratory experiments with white sturgeon eggs incubated at 10, 12, 15 and 18 °C, we found no significant differences in development rates of eggs of Columbia, Kootenai, Snake, and Sacramento river fish.

Report D

- The first phase of a multi-tiered project to determine the efficacy of using wild hatchery broodstock pairings to produce juveniles for out-planting that may mitigate for production loss due to hydrosystem management was completed. This phase was designed to develop techniques for capturing, holding and spawning white sturgeon from Columbia River reservoirs above McNary Dam. During five weeks of setline fishing for white sturgeon broodstock in McNary Reservoir and two weeks setline fishing in Bonneville Reservoir, we collected 3 females and 17 males. A spawning attempt resulted in the collection and fertilization of about 40,000 eggs. The fertilized eggs were of poor quality and only four viable larvae resulted from the pairing. Water temperatures outside the known white sturgeon spawning parameters likely contributed to non-viable eggs. A back-up plan for the purchase of 48,000 larvae allowed project goals to be met.

- The second phase of the out-planting project began and ended this year. Due to budget reductions in the white sturgeon project the plan to release three year classes of juvenile white sturgeon of different sizes and in different years was altered. A cooperative effort by CRITFC, the United States Fish and Wildlife Service, and ODFW released 12,000 PIT-tagged and scute-marked YOY and 8,600 scute-marked age 1+ hatchery reared white sturgeon into Rock Island Reservoir. The funding reduction did not allow for pit tagging of the unplanned release. A second unplanned release of 48,000 YOY into the Willamette River followed the reduction in funding of hatchery operations. An effort to assess the releases made in the Columbia River will be made in 2004-05. There was no funding available to mark and evaluate the Willamette release.
- Our mark and tagging operations for the Bonneville Reservoir population survey from 2 December 2002 through 4 January 2003 resulted in marking 2,996 white sturgeon with the 10th left scute removal pattern and PIT tagging 2184 of these fish. A total of 2,996 white sturgeon were captured in 629 gillnet sets in 4 weekly fishing periods from 3 December 2002 through 25 January 2003.
- When we examine the upcoming efforts that will likely be expended to recover white sturgeon populations in the future, managers at CRITFC regret the loss of opportunity for the full evaluation efforts that were planned for this project and are disappointed in its uncoordinated and abrupt termination. Managers involved in the white sturgeon project have clearly identified four actions that might be used to rebuild white sturgeon populations in Zone 6: 1) trawl and haul, 2) hydrosystem management that addresses flows regimes to improve recruitment, 3) out-planting using wild broodstock and hatchery reared white sturgeon, and 4) strict harvest quotas and slot limit regulations that protect broodstock. The removal of research being performed to determine and develop best out-planting strategies and the lack of hydrosystem management to improve recruitment will likely continue the trend of reduced harvest and place the burden of rebuilding these populations on user groups below and above Bonneville Dam.

Report E

- OSU collected paired blood and gonad samples from 137 white sturgeon in the Columbia River between February 2003 and March 2004.
- White sturgeon showed sex- and maturity-specific levels of plasma steroids.
- Discriminant function analysis revealed that blood plasma indicators may be relatively reliable predictors of sex and stage of maturity in white sturgeon if the error associated with misclassification of immature fish is acceptable.
- Preliminary evidence suggests that the gametogenic cycle may be a 2 to 4+ year cycle in males and a 3 to 5+ year cycle in females, with the majority of females displaying a 5+ year cycle.

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

ANNUAL PROGRESS REPORT

APRIL 2003 - MARCH 2004

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 Bonneville 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.

Prepared By:

Michele L. Hughes

J. Chris Kern

and

Thomas A. Rien

Oregon Department of Fish and Wildlife

17330 Southeast Evelyn Street

Clackamas, OR 97015

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ABSTRACT

This report summarizes data collected from April 2003 through March 2004 to update life history parameters and population dynamics of white sturgeon *Acipenser transmontanus* in Bonneville 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 Bonneville 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 Bonneville Reservoir from December 2002 through January 2003. Staff from Oregon Department of Fish and Wildlife (ODFW) and Washington Department of Fish and Wildlife (WDFW) set 592 setlines from 2 June through 21 August 2003, and captured 6,427 white sturgeon. White sturgeon were distributed fairly evenly throughout Bonneville Reservoir. Recaptured fish were most often caught near the site of marking, however, marked fish moved an average of 1.9 km downstream between marking and subsequent recapture. Combined effort by CRITFC, ODFW and WDFW resulted in the marking of 6,333 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 Bonneville Reservoir in 2003 to be 120,000 fish.

Transplant supplementation (Trawl and Haul) continued in 2003 with transplant of juvenile white sturgeon from below Bonneville Dam to The Dalles and John Day reservoirs. Using trawl gear, 2,961 juvenile white sturgeon were captured below Bonneville Dam by a private commercial trawler. We transplanted 2,951 of these fish to John Day Reservoir and 10 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 no YOY in 2003.

INTRODUCTION

This report summarizes work performed by the Oregon Department of Fish and Wildlife (ODFW) during the period April 2003 through March 2004 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 2003 we assessed abundance and productivity measures of white sturgeon in Bonneville Reservoir; 2) During October and November 2003, 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 2003, 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 Bonneville in 1999. Transplant efforts (Trawl and Haul) and young-of-year indexing are annual activities.

METHODS

Stock Assessment

We sampled for white sturgeon in Bonneville Reservoir from June through mid-August to estimate population statistics. The reservoir was divided into eight sections, each between 9 and 10 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. Crews from CRITFC working with tribal commercial fishers captured fish during December and January, the first sampling period for stock assessment. We divided the summer field season into three four-week sampling periods, referred to as periods two through four, 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 22.7 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).

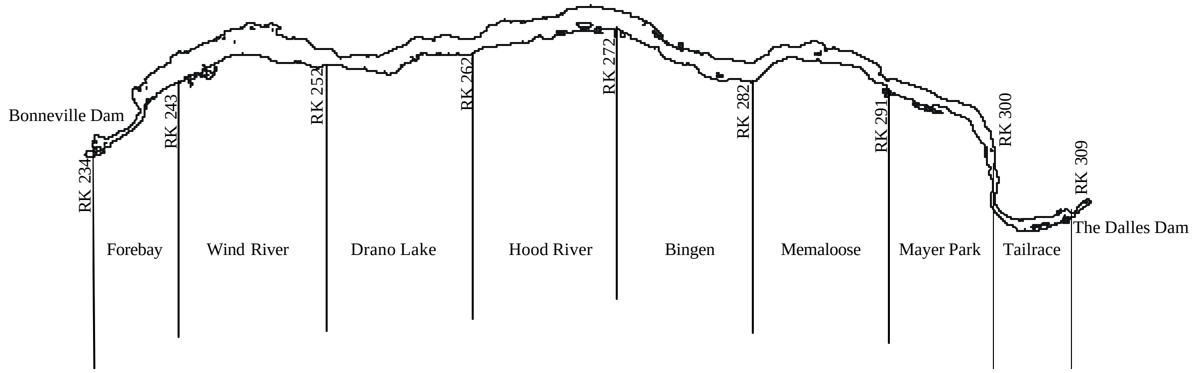

Figure 1. Stock assessment sampling sections, Bonneville Reservoir 2004.

Table 1. Sampling effort (number of setline sets) for white sturgeon in Bonneville Reservoir by week and sampling section, June through August 2003.

		Sampling Section								
	Week	1	2	3	4	5	6	7	8	Total
Period 2	23	--	--	--	--	--	--	24	25	49
	24	26	25	--	--	--	--	--	--	51
	25	--	--	23	19	--	--	--	--	42
	26	--	--	--	--	27	23	--	--	50
Period 3	27	--	--	--	--	--	--	24	24	48
	28	24	25	--	--	--	--	--	--	49
	29	--	--	24	23	--	--	--	--	47
	30	--	--	--	--	26	26	--	--	52
Period 4	31	--	--	--	--	--	--	26	26	52
	32	25	24	--	--	--	--	--	--	49
	33	--	--	27	24	--	--	--	--	51
	34	--	--	--	--	28	24	--	--	52
	Total	75	74	74	66	81	73	74	75	592

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 during periods 1-3. During period 4 most white sturgeon were PIT tagged regardless of size. 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 left lateral scute was removed as a secondary mark to indicate the fish was captured in 2003. 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 25 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).

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 1999 and 2003 and among individual 2003 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 only three PIT-tagged fish over 166 cm were recaptured.

Trawl and Haul Supplementation

From 13 October to 10 November 2003, we transplanted juvenile sturgeon captured in the Columbia River downstream from Bonneville Dam into The Dalles and John Day reservoirs to supplement these populations. Trawling was primarily done in the navigation channel, between RKm 209 and 212. This area was selected because the bottom type is suitable for trawling, and catch rates of subadult white sturgeon are relatively high (McCabe and Hinton 1994). The number and duration of daily tows varies with catch rate and transport goals. Tows are made in both upstream and downstream directions.

A 7.9-m (headrope length) semiballoon shrimp trawl, with 38-mm stretched mesh and a 10.0-mm cod end liner, was used to collect juvenile white sturgeon. Since 2000, we have contracted with private commercial trawlers, so trawl vessels may vary from year-to-year. The net was emptied after completion of each tow. All fish are removed from the trawl and placed into containers with circulating fresh water.

Fish were processed by ODFW staff onboard a contracted barge. Fish were transferred from the trawl to the barge with dipnets and placed in 520-L plastic totes with circulating fresh water. Bycatch was identified, counted, and released immediately. We measured a sub-sample of about 100 white sturgeon each day to estimate length frequency distribution. We only transported fish between 30 and 90 cm fork length. All transported fish had their tenth left lateral scute removed to signify capture in 2003, and the third right scute removed to signify Trawl and Haul handling. After processing, fish were placed into either a 13,000 L or a 5,300 L ODFW liberation truck, also onboard the barge. In John Day Reservoir, all fish were released on the Oregon side of the Columbia at Arlington Boat Ramp (RKm 390), Boardman Boat Ramp (RKm 434), Irrigon Boat Ramp (RKm 455), or Umatilla Boat Ramp (RKm 468). Fish released in The Dalles Reservoir were released at Celilo (RKm 325) boat ramp.

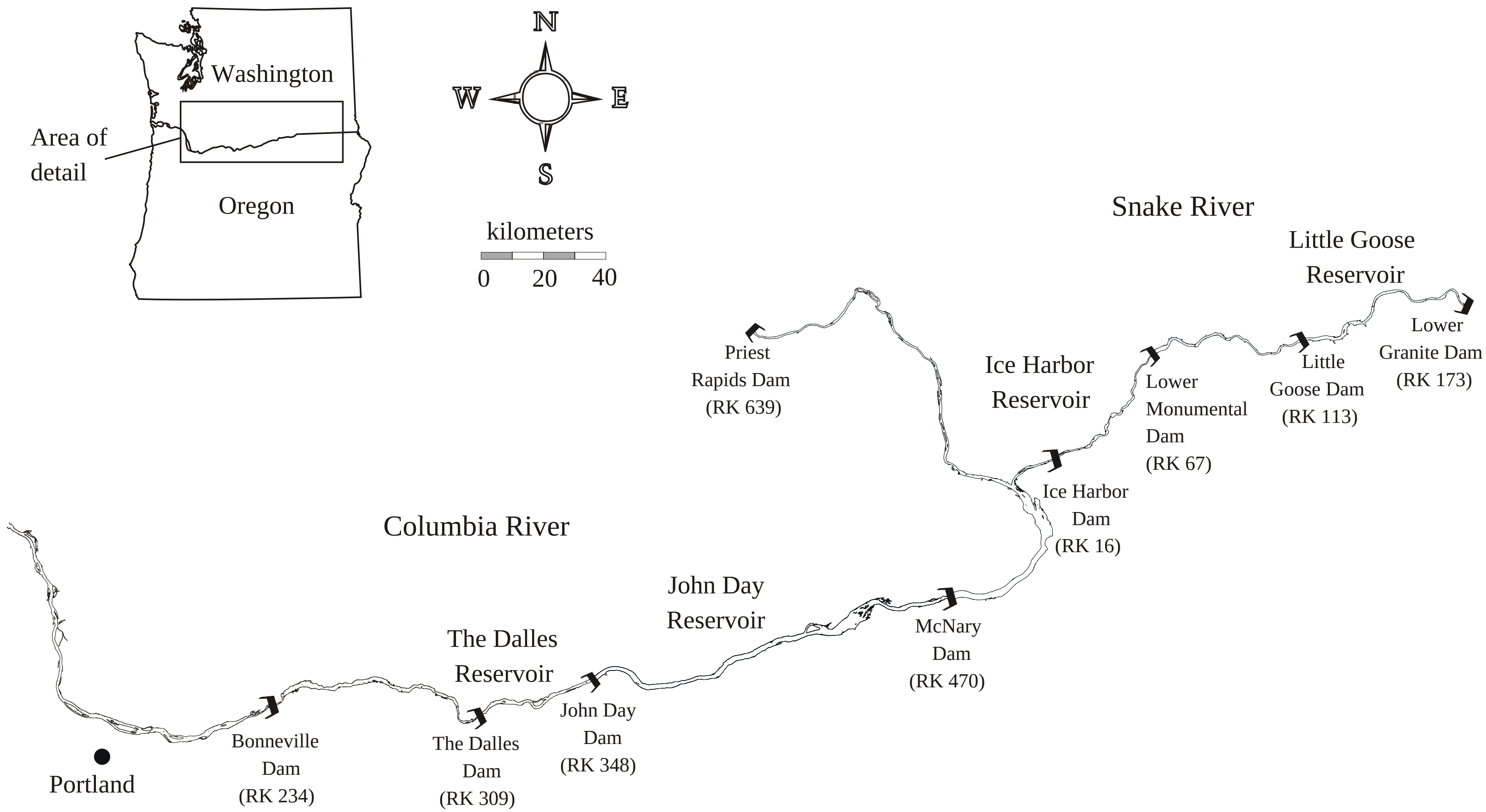

Figure 2. The Columbia River upstream to Priest Rapids Dam and the Snake River upstream to Lower Granite Dam. The scale is approximate. RK = river kilometer.

Young-of-Year Indexing

During October and November of 2003, we sampled The Dalles, John Day, and McNary reservoirs in the Columbia River, and Little Goose and Ice Harbor reservoirs in the Snake River (Figure 2), 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 15-29 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 (Ep) for white sturgeon. The proportion of positive efforts (Ep) is 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 6,427 white sturgeon during sampling activities in Bonneville Reservoir from 2 June through 21 August 2003 (Table 2). Size distribution of setline catch was: 93.9% <96 cm FL, 5.6% 96–137 cm FL, and 0.5% >137 cm. At the time of this stock assessment, regulations allowed sport fishers to harvest fish from 96—137 cm FL (42"—60" TL), and commercial fishers to harvest fish from 110—137 cm FL (48"—60" TL).

Distribution and Movement

We captured white sturgeon fairly evenly throughout the reservoir. Catch rates averaged 10.9 fish per setline, section 2 had the highest rate (12.3) and section 7 the lowest (9.4) (Table 3).

We recaptured 315 PIT-tagged fish. The majority of recaptured fish were caught in the same section as tagged, with 85% recovered within 5 RKm of the original marking location (Table 4). The average movement of recaptured fish was 1.9 RKm downstream from where they were originally marked. We captured eight PIT-tagged fish from previous stock assessment efforts that had moved downstream from The Dalles Reservoir, and one that had moved downstream from John Day Reservoir (Appendix Tables A-2 and A-3).

Table 2. Catches of white sturgeon with setlines in Bonneville Reservoir by week and sampling section, June through August 2003.

		Sampling Section								
	Week	1	2	3	4	5	6	7	8	Total
Period 2	23	--	--	--	--	--	--	182	215	397
	24	187	226	--	--	--	--	--	--	413
	25	--	--	252	281	--	--	--	--	533
	26	--	--	--	--	273	266	--	--	539
Period 3	27	--	--	--	--	--	--	294	311	605
	28	318	359	--	--	--	--	--	--	677
	29	--	--	315	261	--	--	--	--	576
	30	--	--	--	--	303	313	--	--	616
Period 4	31	--	--	--	--	--	--	221	324	545
	32	261	325	--	--	--	--	--	--	586
	33	--	--	263	240	--	--	--	--	503
	34	--	--	--	--	235	202	--	--	437
	Total	766	910	830	782	811	781	697	850	6,427

Table 3. Catch per unit effort of white sturgeon with setlines in Bonneville Reservoir by week and sampling section, June through August 2003.

		Sampling Section								
	Week	1	2	3	4	5	6	7	8	Total
Period 2	23	--	--	--	--	--	--	7.58	8.60	8.10
	24	7.19	9.04	--	--	--	--	--	--	8.10
	25	--	--	10.96	14.79	--	--	--	--	12.69
	26	--	--	--	--	10.11	11.57	--	--	10.78
Period 3	27	--	--	--	--	--	--	12.25	12.96	12.60
	28	13.25	14.36	--	--	--	--	--	--	13.82
	29	--	--	13.13	11.34	--	--	--	--	12.26
	30	--	--	--	--	11.65	12.04	--	--	11.85
Period 4	31	--	--	--	--	--	--	8.50	12.46	10.48
	32	10.44	13.54	--	--	--	--	--	--	11.96
	33	--	--	9.74	10.00	--	--	--	--	9.86
	34	--	--	--	--	8.39	8.42	--	--	8.40
	Total	10.21	12.30	11.22	11.85	10.01	10.70	9.42	11.33	10.86

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
-45	3	0.97%
-40	1	0.32%
-35	1	0.32%
-30	6	1.95%
-25	2	0.65%
-20	5	1.62%
-15	5	1.62%
-10	7	2.27%
-5	175	56.82%
5	87	28.25%
10	7	2.27%
15	2	0.65%
20	0	0.00%
25	2	0.65%
30	1	0.32%
35	0	0.00%
40	4	1.30%
45	0	0.00%
Total	308	

Age and Growth

We assigned ages to 94 white sturgeon captured from Bonneville Reservoir in 2003. Ages ranged from 2-40 and variation between ages assigned by primary readers was great (Table 5). There was 8% agreement between primary readers final ages. Reader 1 aged fish older then Reader 2 78% of the time.

We compared differences in the assigned ages between the three different readers using a subsample of 25 aged fish. Reader 2, who was a new reader this year, aged fish younger then Readers 1 and 3 (Figure 3). Reader 1 tended to age fish slightly older than Reader 3, which is similar to past years (Kern et al. 2002). Due to the magnitude of the discrepancy between Reader 1 and 2, final ages were assigned by Readers 1 and 3 jointly.

These data, combined with previously collected age data (Table 6), were used to estimate parameters of a von Bertalanffy growth equation (Figure 4). There were no significant differences between 2003 ages and previous years ages in Bonneville Reservoir ($p = <0.0001$, df=780, $r^2=0.638$; PROC GLM, SAS 1988).

There were no significant differences ($p<0.05$) in relative weights (Figure 5) between sampling periods (period 2 mean 91.0, period 3 mean 94.1, period 4 mean 91.9). Fish are not weighed during period 1. Relative weights of fish captured in 2003 (mean 92.1) were significantly higher ($p<0.05$) than for fish captured in 1999 (mean 87.6).

Table 5. Discrepancies in aging of white sturgeon pectoral fin spine sections collected in Bonneville Reservoir 2003 between primary two readers.

Age Difference	Final Assigned Age: 2	3	4	5	6	7	8	9	10	11	12-14	15-17	18-20	21-23	24-26	27-29	>29	%	Total
-1			4			1	1				1		1					8.5	8
0	1	1	3		2	2	2			1				1				13.8	13
1						1	2		2	2	6	4	1					19.1	18
2							1	1		1	9	2	2					17.0	16
3											4	6		2				12.8	12
4											3	4	1	3				11.7	11
5												1	1	1				3.2	3
6													1	1				2.1	2
7												2	2	2			1	7.4	7
9															1		1	2.1	2
13																	1	1.1	1
15																	1	1.1	1
All	1	1	7		2	4	6	1	2	4	23	19	9	10	1		4	100.0	94

Table 6. Age and length-frequency distribution of white sturgeon collected in Bonneville Reservoir, 1988-2003.

	Fork Length												
Age	20-39	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	>199	Mean	St. Dev.	N
1	1										33.0		1
2	4										36.0	2.8	4
3	16	4									37.9	4.6	20
4	13	14	2								44.7	9.1	29
5	4	27									49.3	7.3	31
6	5	21	5								52.9	9.5	31
7	2	17	13	1							59.6	9.3	33
8		15	11	1							60.8	9.8	27
9	1	13	13	6							64.8	12.5	33
10	2	4	10	6	2						74.1	18.9	24
11		6	13	7	5	1					78.3	18.1	32
12		5	17	16	5	1					82.0	17.9	44
13		3	9	7	12	2					89.7	20.5	33
14		3	4	13	15	4					96.0	19.7	39
15			9	15	20	12	1				102.4	19.0	57
16		1	6	15	27	12	1				103.8	19.6	62
17		1	6	16	28	20	5				108.0	20.2	76
18			4	13	22	20	1				109.6	18.0	60
19			2	6	15	17	4				113.6	18.2	44
20			4	11	13	15	8	1			113.7	24.1	52
21			2	12	11	15	6	1		1	116.6	26.5	48
22			5	2	10	15	5	1			117.5	22.3	38
23					7	5	7	3			134.1	19.4	22
24				1	6	9	2	2			128.9	19.9	20
25			1		7	7	3	2	1	1	133.3	30.0	22
26				1	4	7	3	1	2	1	138.2	32.1	19
27					1	5	5		1	1	146.4	26.8	13
28				3		5	8	1	1	2	143.3	33.5	20
29				2	4	3	3	2		2	142.4	43.1	16
>29				1	4	13	4	3	11	26	184.2	48.2	62
All	48	134	136	155	218	188	66	17	16	34	102.1	41.2	1,012

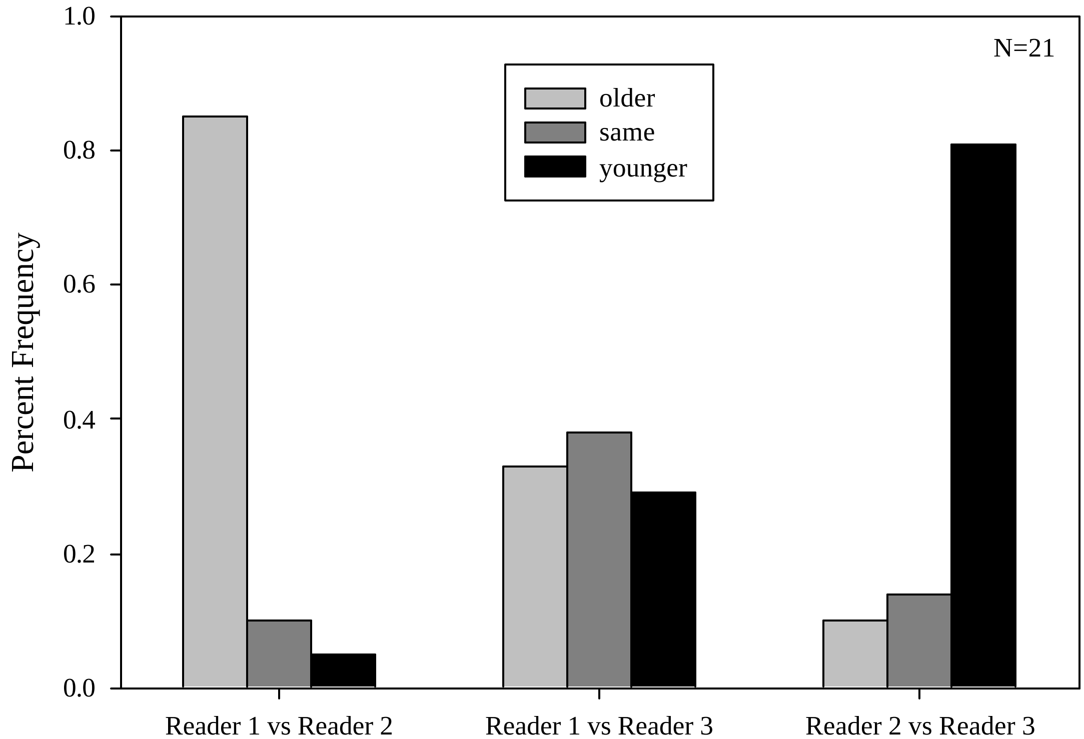

Figure 3. Percent frequency of differences in age assignments by readers of pectoral spine sections collected from white sturgeon in Bonneville Reservoir 2003.

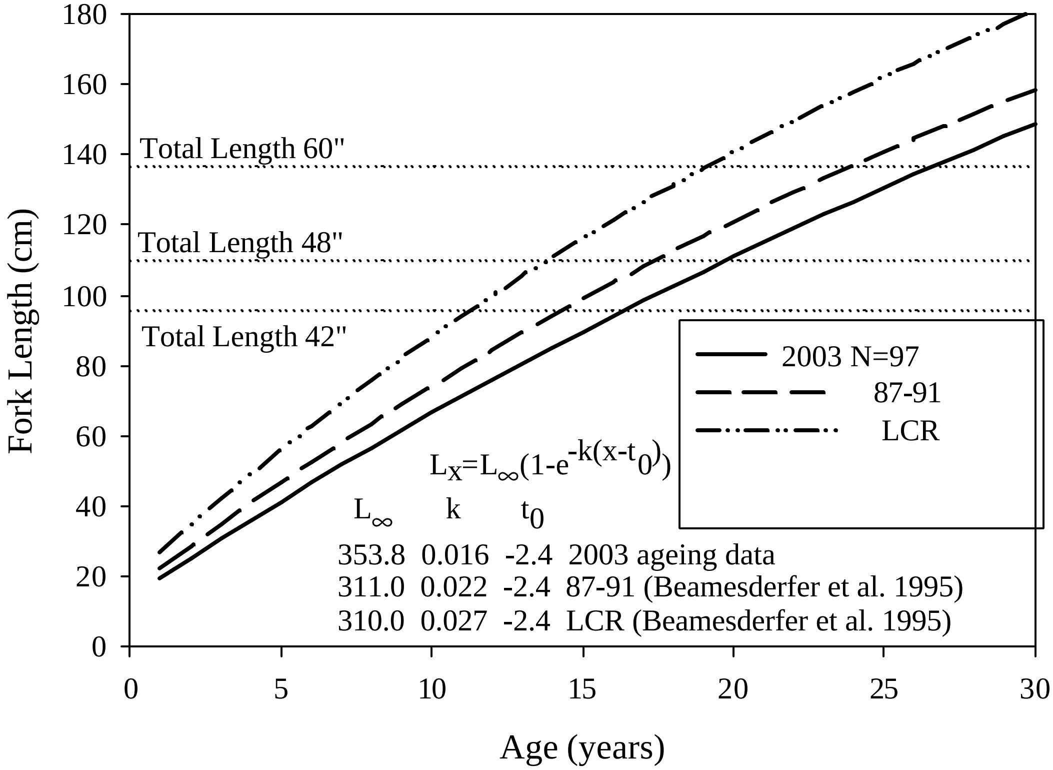

Figure 4. Comparison of von Bertalanffy growth parameters for white sturgeon collected from Bonneville Reservoir in 2003 and previous years, and from the lower Columbia River.

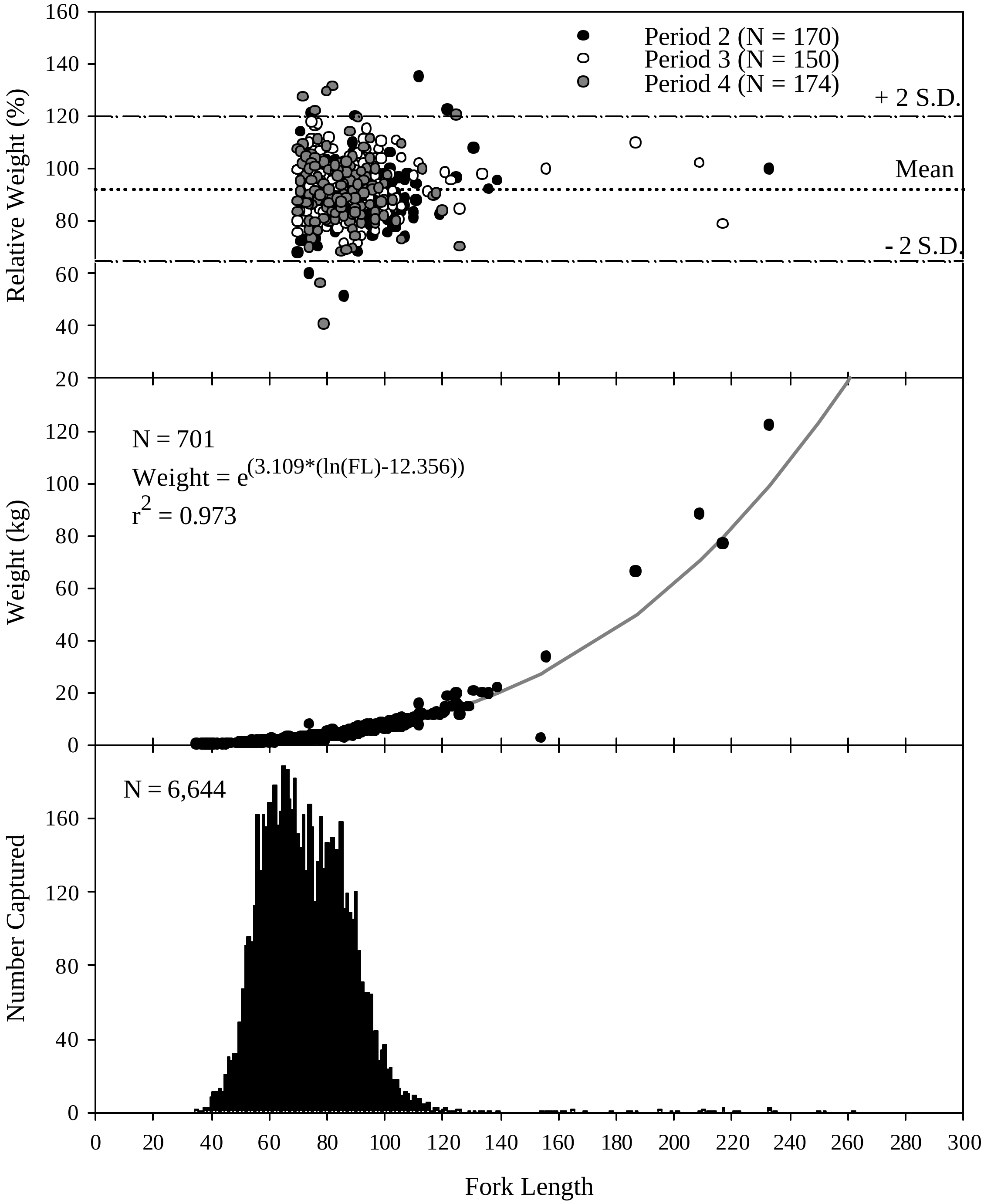

Figure 5. Relative weight, length-weight relationship, and length-frequency distribution of white sturgeon captured during Bonneville Reservoir stock assessment sampling, June – August 2003.

Abundance Estimates

From December 2002 through August 2003, 6,333 white sturgeon of various sizes were marked with PIT-tags by CRITFC and ODFW. Using the Schnabel estimate, we estimated the abundance of 70-109 cm and 110-166 cm white sturgeon to be 65,796 (Table 7) and 1,171 fish (Table 8). We estimated abundance of 110-137 cm white sturgeon (commercial legal-size) to be 1,020 fish (Table 9). We estimated abundance of white sturgeon between 54 and 70 cm to be 52,196, and abundance of fish larger >166 cm to be 746 fish (Table 9). The total estimated population of white sturgeon >54 cm in Bonneville Reservoir in 2003 was approximately 119,909 fish.

Table 7. Mark/Recapture data and Schnabel estimate of abundance of white sturgeon 70-109 cm fork length, Bonneville Reservoir 2003. Based on PIT-tag mark/recapture data. Period 1 is winter sampling by CRITFC crews.

Period	Catch	Marks	Recaps	Mortalities		Marks at Large	Estimate
(t)	(C)	(M)	(R)	Unmarked	Marked	(Mt)	$(M_t*C)/(R+1)$
1	2,424	2,068			13	0	
2	1,035	1,039	25		0	2,055	81,180
3	1,372	1,185	57		0	3,094	73,278
4	1,050	868	82		0	4,279	54,132
Sum	5,881	5,160	164			Estimate	65,796
						Lower 95% CI	56,518
						Upper 95% CI	76,587

Table 8. Mark/Recapture data and Schnabel estimate of abundance of white sturgeon 110-166 cm fork length, Bonneville Reservoir 2003. Based on PIT-tag mark/recapture data. Period 1 is winter sampling by CRITFC crews.

Period	Catch	Marks	Recaps	Mortalities		Marks at Large	Estimate
(t)	(C)	(M)	(R)	Unmarked	Marked	(Mt)	$(M_t*C)/(R+1)$
1	115	92	0		2	0	
2	34	25	3		1	90	765
3	21	17	1		0	114	1,197
4	12	10	1		0	131	786
Sum	182	144	5			Estimate	1,171
						Lower 95% CI	552
						Upper 95% CI	2,253

Table 9. Estimated abundances of white sturgeon in Bonneville Reservoir in 1994, 1999, and 2003, based on mark/recapture Schnabel estimates. Confidence intervals are only given for size groups for which a Schnabel estimate was performed, and not for size groups for which abundance was estimated by expansion from length-frequencies.

	Abundance by size class (95% Confidence Interval)		
Size Class	1994	1999	2003
54-95 cm		113,474 (99,900-128,900)	
96-109 cm		10,991 (8,400-14,400)	
70-109 cm			65,796 (56,518-76,587)
110-137 cm		3,083	1,020
110-166 cm	1,500		1,171 (552-2,253)
70-166 cm	52,000 (24,800-66,000)		67,270
>166 cm	900	420	746
Total Abundance	52,000	128,548	119,909

Trawl and Haul Supplementation

The contracted trawler caught 3,466 white sturgeon in 128 trawl tows for an average of 27.1 fish per tow (Table 10). Mean trawl duration was 24.2 minutes. White sturgeon of various sizes were captured, although fish of the transportable size group of 30–90-cm fork length dominated the catch (86%, N = 1,281; Figure 6). Mean fork length of transplanted fish estimated from a subsample of 1,491 transported fish was 37.8 cm. Incidental catches of other fish species are shown in Appendix Table A-5.

Of the 2,965 white sturgeon transplanted in 2003, the majority (2,951) were transplanted into John Day Reservoir (Table 11). The remaining 10 fish were transplanted into The Dalles Reservoir. There were four mortalities observed at release (Table 12). Daily transport densities ranged from 0.001 to 0.1027 kg/L. The maximum time fish were in the liberation truck ranged from 5.0 to 10.25 hours. Dissolved oxygen levels in the transport vehicle were nearly always at or above saturation (78%—119%) and fish condition during and after transport generally appeared to be excellent.

Table10. 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, 1993-2003.

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	--
2003						
Private trawler	18	124	3,460	28.0	24.2	18.1

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

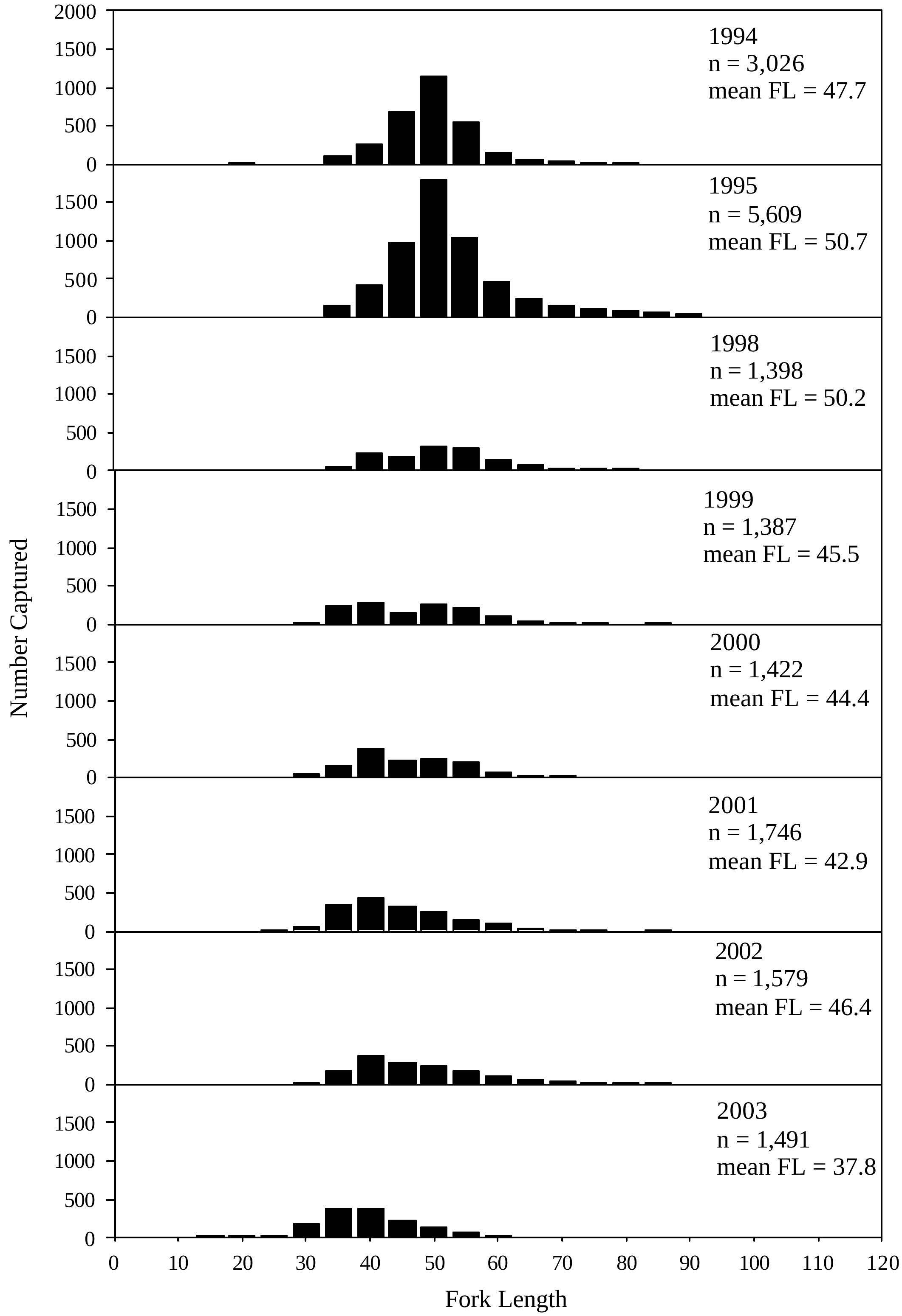

Figure 6. Length-frequency distributions of white sturgeon sampled during Trawl and Haul collections, 1994-2003.

Table 11. Number of white sturgeon transported from below Bonneville Dam to The Dalles and John Day reservoirs from 1994 – 2003.

Year	Release Reservoir		Total
	The Dalles	John Day	
1994	2,935	--	2,935
1995	5,611	--	5,611
1998	3,257	5,534	8,791
1999	77	4,171	4,248
2000	1,163	4,019	5,182
2001	1,257	5,195	6,452
2002	941	4,177	5,118
2003	10	2,941	2,961
Total	15,251	26,047	41,298

Table 12. Transport data for fish captured below Bonneville Dam and transported to The Dalles and John Day reservoirs, October and November 2003

Date (m/d)	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)
10/13	11	1	10	5:45	Celilo	20.0	15.6 / 16.7	10.0 / 11.0	3,500	0.31	0.0010
10/14	65	1	64	5:00	Arlington	20.0	15.8 / 15.8	9.1 / 11.4	1,400	0.47	0.0218
10/15	90	0	90	7:30	Umatilla	20.0	15.6 / 15.6	10.8 / 10.8	3,500	0.54	0.0139
10/16	241	0	241	8:00	Irrigon	20.0	15.4 / --	9.9 / --	1,400	0.39	0.0671
10/20	166	0	166	10:15	Boardman	20.0	17.0 / 19.4	9.7 / 10.0	3,500	0.37	0.0176
10/21	79	0	79	8:30	Arlington	20.0	16.7 / 17.8	9.3 / 9.7	1,400	0.32	0.0183
10/22	239	0	239	10:00	Umatilla	19.4	17.0 / 17.0	9.7 / 9.7	3,500	0.47	0.0324
10/23	175	0	175	8:30	Irrigon	20.0	16.1 / 16.1	7.1 / 12.1	1,400	0.45	0.0565
10/27	122	0	122	8:00	Umatilla	18.3	16.1 / 16.1	11.0 / 11.5	3,500	0.45	0.0157
10/28	161	0	161	6:45	Arlington	16.1	14.8 / 14.9	9.8 / 11.8	1,400	0.40	0.0458
10/29	86	0	86	6:00	Arlington	16.1	15.0 / 15.0	11.0 / 11.0	3,500	0.49	0.0121
10/30	57	0	55	6:45	Arlington	15.6	12.2 / 12.8	10.5 / 12.2	1,400	0.50	0.0202
11/3	755	2	755	7:30	Boardman	11.7	11.0 / --	12.5 / --	3,500	0.48	0.1027
11/4	247	0	247	7:30	Irrigon	15.0	10.6 / --	11.0 / --	1,400	0.48	0.0854
11/5	172	0	172	8:30	Irrigon	11.7	9.0 / 9.0	11.0 / 12.0	3,500	0.40	0.0199
11/6	35	0	35	8:30	Umatilla	13.9	8.9 / 9.4	11.7 / 13.8	1,400	0.40	0.0101
11/10	264	0	264	9:15	Umatilla	11.1	9.0 / --	10.0 / 12.0	3,500	0.49	0.0368
Total	2,965	4	2,961								

Young-of-Year Indexing

None of the white sturgeon captured in any of the five reservoirs in 2003 were classified as YOY (Figure 7). Catch was highest in The Dalles Reservoir with 59 white sturgeon captured in 36 gill nets fished for a total of 809.5 hours (Table 13). We set 40 gill nets in John Day Reservoir and captured 12 white sturgeon in 874.2 hours of fishing. In McNary Reservoir, we caught 3 white sturgeon in 36 gill nets fished for a total of 804.9 hours. We fished 36 gill nets in Ice Harbor Reservoir for a total of 785.0 hours, and caught 2 white sturgeon. In Little Goose Reservoir we captured 4 white sturgeon in 36 nets fished for a total of 791.8 hours.

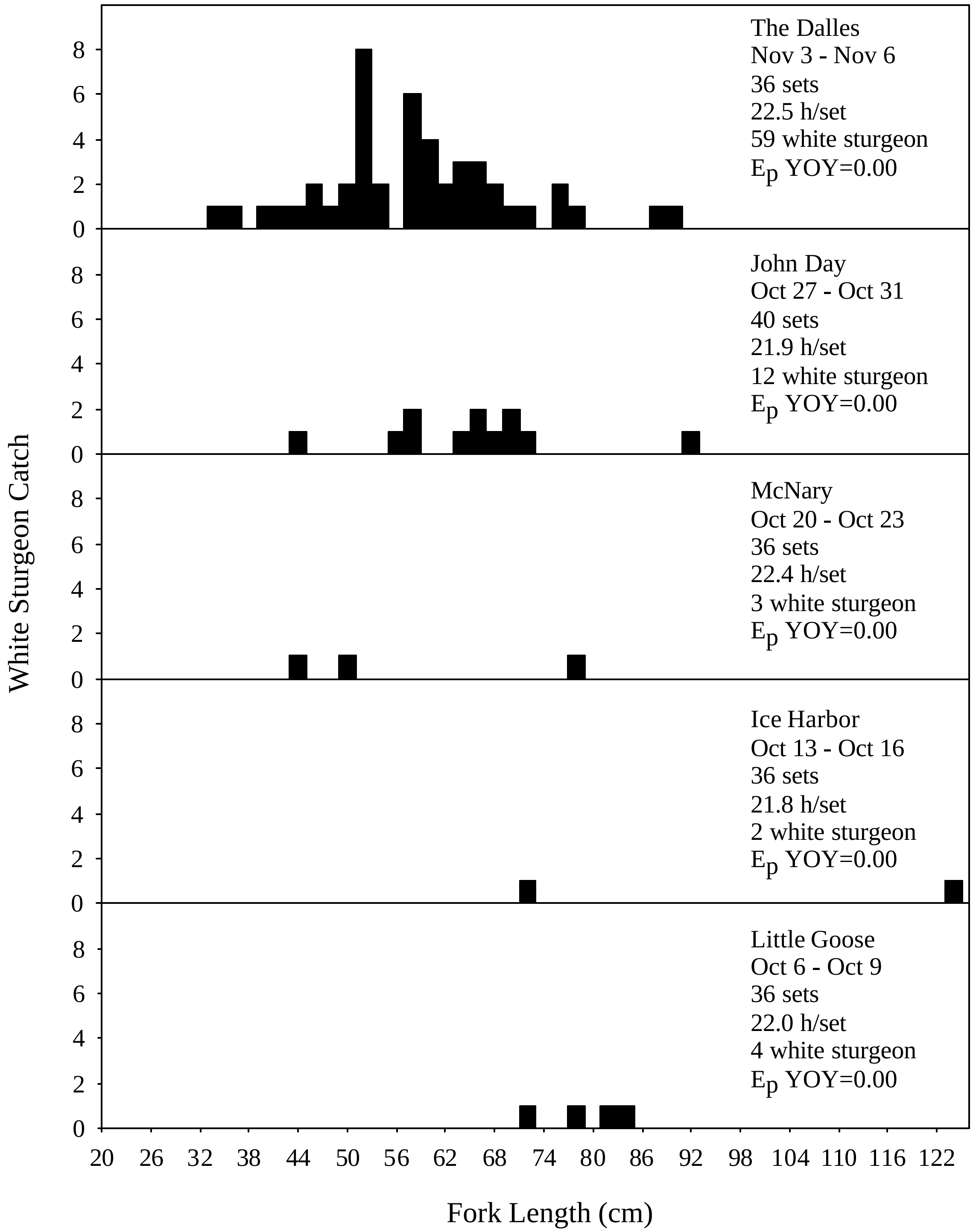

Figure 7. Length-frequency distributions and catch data for white sturgeon captured during Young-of-Year indexing, October – November 2003.

Table 13. Young-of-year sampling gill-net effort and catch of white sturgeon in Columbia and Snake River reaches during October and November 2003.

River Reach	Reservoir Quarter				
Parameter	1	2	3	4	All
The Dalles Reservoir					
Gill Net Sets	9	6	15	6	36
Total Hours	202.6	138.2	334.9	133.8	809.5
White Sturgeon Catch (all sizes)	10	14	29	6	59
White Sturgeon Catch (FL<30 cm)	0	0	0	0	0
White Sturgeon / Set	1.11	2.33	1.93	1.00	1.64
White Sturgeon (FL<30 cm)/Set	0.00	0.00	0.00	0.00	0.00
Sets with >0 white sturgeon (all sizes)	44%	100%	80%	67%	72%
Sets with >0 white sturgeon (FL<30 cm)	0%	0%	0%	0%	0%
John Day Reservoir					
Gill Net Sets	10	8	12	10	40
Total Hours	207.4	197.8	260.1	208.9	874.2
White Sturgeon Catch (all sizes)	0	0	5	7	12
White Sturgeon Catch (FL<30 cm)	0	0	0	0	0
White Sturgeon / Set	0.00	0.00	0.42	0.70	0.30
White Sturgeon (FL<30 cm)/Set	0.00	0.00	0.00	0.00	0.00
Sets with >0 white sturgeon (all sizes)	0%	0%	25%	40%	18%
Sets with >0 white sturgeon (FL<30 cm)	0%	0%	0%	0%	0%
McNary Reservoir/Hanford Reach					
Gill Net Sets	27	9			36
Total Hours	605.0	199.9			804.9
White Sturgeon Catch (all sizes)	2	1			3
White Sturgeon Catch (FL<30 cm)	0	0			0
White Sturgeon / Set	0.07	0.11			0.08
White Sturgeon (FL<30 cm)/Set	0.00	0.00			0.00
Sets with >0 white sturgeon (all sizes)	7%	11%			8%
Sets with >0 white sturgeon (FL<30 cm)	0%	0%			0%
Ice Harbor Reservoir					
Gill Net Sets	9	9	9	9	36
Total Hours	194.9	199.5	194.9	195.7	785.0
White Sturgeon Catch (all sizes)	1	1	0	0	2
White Sturgeon Catch (FL<30 cm)	0	0	0	0	0
White Sturgeon / Set	0.11	0.11	0.00	0.00	0.06
White Sturgeon (FL<30 cm)/Set	0.00	0.00	0.00	0.00	0.00
Sets with >0 white sturgeon (all sizes)	11%	11%	0%	0%	6%
Sets with >0 white sturgeon (FL<30 cm)	0%	0%	0%	0%	0%

Table 13. Con't.

River Reach Parameter	Reservoir Quarter 1	2	3	4	All
Little Goose Reservoir					
Gill Net Sets	9	9	9	9	36
Total Hours	206.9	199.5	189.7	195.7	791.8
White Sturgeon Catch (all sizes)	0	1	2	1	4
White Sturgeon Catch (FL<30 cm)	0	0	0	0	0
White Sturgeon / Set	0.00	0.11	0.22	0.11	0.11
White Sturgeon (FL<30 cm)/Set	0.00	0.00	0.00	0.00	0.00
Sets with >0 white sturgeon (all sizes)	0%	11%	22%	11%	11%
Sets with >0 white sturgeon (FL<30 cm)	0%	0%	0%	0%	0%

DISCUSSION

Stock Assessment

We continue to find very little movement of white sturgeon between reservoirs (Appendix Table A-1). 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%), 155 have been captured in the reservoir immediately downstream (3.2%), and ten have been captured two reservoirs downstream (<1%). However, the majority (4,621, or 97%) of sturgeon recaptured were recaptured within the reservoir they were originally marked in.

Final ages for white sturgeon captured in 2003 were compared to past years and resulted in a slight decrease in length-at-age for fish from Bonneville 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. The difference between ages assigned by Reader 2 compared with Readers 1 and 3 were most likely due to the inexperience of Reader 2. The increases in assigned final ages by Readers 1 and 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, marked, and recaptured, allowing a more robust estimate of abundance by slightly different methods.

For the 2003 abundance estimate, we estimated abundance for fish in the 70-109 cm size class and the 110-166 cm size class. We derived estimates for fish outside these size classes based on relative proportion of fish in the catch length-frequencies and relative vulnerability to capture. This method is basically the same method used before the 1999 Bonneville estimate.

Estimated total abundance in 2003 was slightly lower than in 1999 (Table 9). The reduction was apparent in the <96 cm FL size class (down from 124,465 to 117,992), but was most dramatic in the 110—137 cm FL (down from 3,083 to 1,020). Abundance of fish 138-166 cm FL also decreased, however, sample sizes for these size classes were low in both years. In contrast, abundance of "oversize" fish (>166 cm fork length) appears to have increased since 1999. Estimates of oversize abundance should be viewed with caution, since they are derived from the relative proportion of fish of this size in the catch, not direct abundance estimates (because of low sample sizes).

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 2003, transplant efforts focused mostly on supplementation of the John Day Reservoir population, with all but one small load of fish transported to that reservoir (99%). Because recruitment in John Day Reservoir is generally poorer than recruitment 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 continue to observe a gradually decline in average size of fish captured during the Trawl and Haul program (Figure 6). In the absence of additional sampling to address growth of juvenile white sturgeon in the lower Columbia River, we have no way of determining whether this change is related to our annual collection of fish for transport, or whether it is related to factors beyond our control, such as population density, changes in forage base, or changes in growth patterns of the population. A new project to develop an index of recruitment for the lower river slated to begin in 2004 may help address this concern by collecting additional length-frequency information on fish of similar size in other locations in the lower Columbia.

Young-of-Year Indexing

As indicated by catch rates during YOY sampling, recruitment was extremely poor in all sampled reservoirs in 2003. This is the second year since directed YOY index sampling with gill nets began that no YOY have been captured in any sampled reservoir, the first year was 2001. It is likely that the low flows in the Columbia River contributed to the lack of recruitment (see Report C). Average river flow at McNary Dam between 1 April and 31 July was 113 kcfs in 2001, 249 kcfs in 2002, and 205 kcsf in 2003 (Columbia River DART web page at www.cbr.washington.edu/dart/dart.html). Of the past three years, 2002 has been the only year YOY were present in our samples.

PLANS FOR NEXT YEAR

We will conduct a stock assessment survey in John Day Reservoir in 2004. 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 2004. 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 2004, 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 within and out-of-reservoir recaptures of marked white sturgeon within the Columbia Basin, 1987-2003. 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 2003.

		Recapture Location					
Reservoir	Release year	Upstream 1	Within	Downstream 1	Downstream 2	Downstream 3	Downstream 4
McNary	1993	--	22	4	2	0	0
	1995	--	30	6	0	0	0
	Total	--	*52*	*10*	*2*	*0*	*0*
	Percent	--	81.25%	15.63%	3.13%	0.00%	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	1	--	--
	Total	*0*	*1,128*	*42*	*5*	--	--
	Percent	0.00%	96.00%	3.57%	0.43%	--	--
The Dalles	1987	1	198	4	1	--	--
	1988	0	233	24	1	--	--
	1989	1	36	0	0	--	--
	1991	1	71	1	0	--	--
	1993	0	2	1	1	--	--
	1994	0	431	10	0	--	--
	1995	0	448	12	0	--	--
	1997	1	384	12	0	--	--
	2002		188	6	0	--	--
	Total	*4*	*1,991*	*70*	*3*	--	--
	Percent	0.19%	96.46%	3.39%	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	--	--	--
	2003	0	327	--	--	--	--
	Total	*2*	*1,450*	*33*	--	--	--
	Percent	0.17%	97.77%	2.85%	--	--	--

Appendix Table A-2. 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	2003
Number marked during regular sampling		341	2,131	1,141	--	2,332	6,143	6,333
Number marked during other sampling activities[a]		--	--	--	8[a]	--	--	–
Total number marked		341	2,131	1,141	8	2,332	6,143	6,333
Recaptured in McNary (upstream reservoir)	none to date							
Recaptured in John Day (upstream reservoir)	none to date							
Recaptured in The Dalles (upstream reservoir)	1988		--	--	--	--	--	--
	1989			--	--	--	--	--
	1990			--	--	--	--	--
	1991				--	--	--	--
	1992				--	--	--	--
	1993					--	--	--
	1994						--	--
	1995						--	--
	1996			1			--	--
	1997						--	--
	1998						--	--
	1999						--	--
Recaptured in Bonneville	1988	2	--	--	--	--	--	--
	1989	44	91	--	--	--	--	--
	1990	5	46	--	--	--	--	--
	1991	11	89	33	--	--	--	--
	1992		19	23	--	--	--	--
	1993	2	12	13		--	--	--
	1994	4	37	36		21	--	--
	1995	1	7	4		11	--	--
	1996		9	5		12	--	--
	1997	1	7	4		4	--	--
	1998						--	--
	1999		19	8		90	453	--
	2003							327
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-3. 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									296
Recaptured in Bonneville	1987		--	--	--	--	--	--	--	
	1988			--	--	--	--	--	--	
	1989		4		--	--	--	--	--	
	1990	2	1		--	--	--	--	--	
	1991	1	14			--	--	--	--	
	1992		1			--	--	--	--	
	1993	1	2				--	--	--	
	1994		1					--	--	
	1995								--	
	1996					1			--	

		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	--
	2003				1				1	6
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-4. Summary of white sturgeon marked in John Day Reservoir and recaptured within John Day and in other reservoirs.

		Released in John Day				
		1989	1990	1991	1996	2001
	Number Marked	21	516	85	4,111	3,757
Recaptured in McNary (upstream reservoir)	none to date					
Recaptured in John Day	1989		--	--	--	--
	1990	3	35	--	--	--
	1991		29		--	--
	1992		7	1	--	--
	1993	1	2		--	--
	1994		4	1	--	--
	1995		2	1	--	--
	1996	2	38	12	238	--
	1997			1	126	--
	1998					--
	1999					--
	2001		3	1	621	637
Recaptured in The Dalles	1989		--	--	--	
	1990			--	--	
	1991	1	1		--	
	1992				--	
	1993		1		--	
	1994		3		--	
	1995				--	
	1996					
	1997		7		9	
	1998					
	1999					
Recaptured in Bonneville	1989		--	--	--	
	1990			--	--	
	1991		1		--	
	1992				--	
	1993				--	
	1994				--	
	1995				--	
	1996					
	1997					
	1998					
	1999				3	
	2003					1

Appendix Table A-5. 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-6. Species composition of bycatch from Trawl and Haul, October and November 2003.

	Date																
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
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-7. Bycatch from Young-of-Year index sampling, October – November 2003.

	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

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

Appendix Table A-8. Abundance estimates for Zone 6 reservoirs and the Hanford Reach of McNary Reservoir, 1987 – 2003.

Year	30-72 inch total length Ñ(95% CI)	Number of fish by total length interval (inches) 24-36	36-48	48-60	60-72	72+	Sum	Number/ acre[a]	Pounds/ acre[a]
				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
2003	74,000 [b]	84,500	33,000	1,100	120	780	119,500	5.7	--
				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.

APPENDIX B

An update of individual growth of white sturgeon in Zone 6 reservoirs of the Columbia River

INTRODUCTION

Research into the population dynamics of white sturgeon in the Columbia River has been ongoing since approximately 1987. This research provides continuous refinements of life history parameters of Columbia River white sturgeon populations. One refinement has been an ever-expanding appreciation of the variability in growth of individual fish. Harvest management of white sturgeon in recent years has been based upon population modeling, and projection of Optimum Sustainable Yield (OSY). Harvest of these fish is restricted by slot-length limits. Estimation of OSY relies on estimations of growth to determine the number of fish growing into and out of the legal size limit over time. Past methods for modeling population changes have relied upon length-at-age methods, such as the von Bertalanffy growth function (VBGF). Such methods are inherently problematic when methods of aging are inaccurate and/or biased, as is often the case with white sturgeon (Rien and Beamesderfer 1994), and when growth of individuals is highly variable. However, a length-at-age approach is one of few options available in the absence of measured growth. Since 1990, methods for conducting stock assessments in Zone 6 reservoirs have included marking substantial numbers of white sturgeon with unique marks (PIT tags), which have provided an opportunity for direct calculation of growth over long periods of time.

Following stock assessment of John Day Reservoir in 2001, we began to analyze the growing dataset of individual fish recoveries. We discovered that previous estimates of length-at-age, overestimated growth rates within this population (Appendix B *in* Kern et al. 2002). Since approximately 1990, over 30,000 white sturgeon captured during stock assessment surveys in the three Zone 6 reservoirs (Bonneville, The Dalles, and John Day reservoirs) have been marked with PIT tags. Stock assessment surveys, including PIT-tagging, were conducted in John Day Reservoir in 1990, 1996, and 2001. Recaptures in 2001 of individual fish marked in 1996 and 1990, and recaptures in 1996 of 1990-applied marks, provided an opportunity for direct calculation of growth. We were able to calculate growth for 524 fish that were at large for five to 11 years. Preliminary estimates of growth rate of these fish indicated a mean annual growth increment (AGI) of approximately 3 cm FL (STD 2.2). Previous estimates for fish <110 cm FL based on the VBGF were 5.8 cm FL mean AGI (for fish nine to 13 years old). Because previous harvest limits were based on assumptions of higher growth rates, limits may have been too liberal to be sustainable. In fact, we noted a drastic reduction in estimated abundance of fish 110-137 cm FL in the John Day population between 1996 (4,045 fish) and 2001 (1,077 fish; Kern et al. 2002). Similar declines in abundance of harvestable-size white sturgeon were also seen in the 2002 and 2003 stock assessment efforts in The Dalles (Kern et al. 2003) and Bonneville reservoirs (main body of this report).

Adaptations to harvest management based upon new growth findings were discussed in Appendix C in Kern et al. 2002. This report will discuss findings on individual growth rates of white sturgeon in The Dalles (1994–2002) and Bonneville (1994–2003) reservoirs, and update information on growth rates of white sturgeon in John Day Reservoir (1990–2001) to include new analyses.

METHODS AND RESULTS

Typically, white sturgeon growth rates have been based on ages interpreted from pectoral fin spines and fit to the von Bertalanffy growth function (VBGF):

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

where: L_x.= length at age x

k = growth coefficient

t_0 = theoretical age of a fish with length 0

and x = age of the fish.

However, age estimates of white sturgeon from Columbia River reservoirs are neither accurate nor precise, and tend to underestimate true age (Rien and Beamesderfer 1994). Additionally, the VBGF assumes a linear decline in growth rate, expressed as annual growth increment (AGI), as fish grow larger, and older (Figures 1-3). This yields the familiar asymptotic length-at-age plot associated with the VBGF. Recent findings from tag recoveries indicate that the VBGF does not adequately describe growth of white sturgeon in the Zone 6 reservoirs. Rather, fish in these populations seem to demonstrate different growth patterns at different size stages.

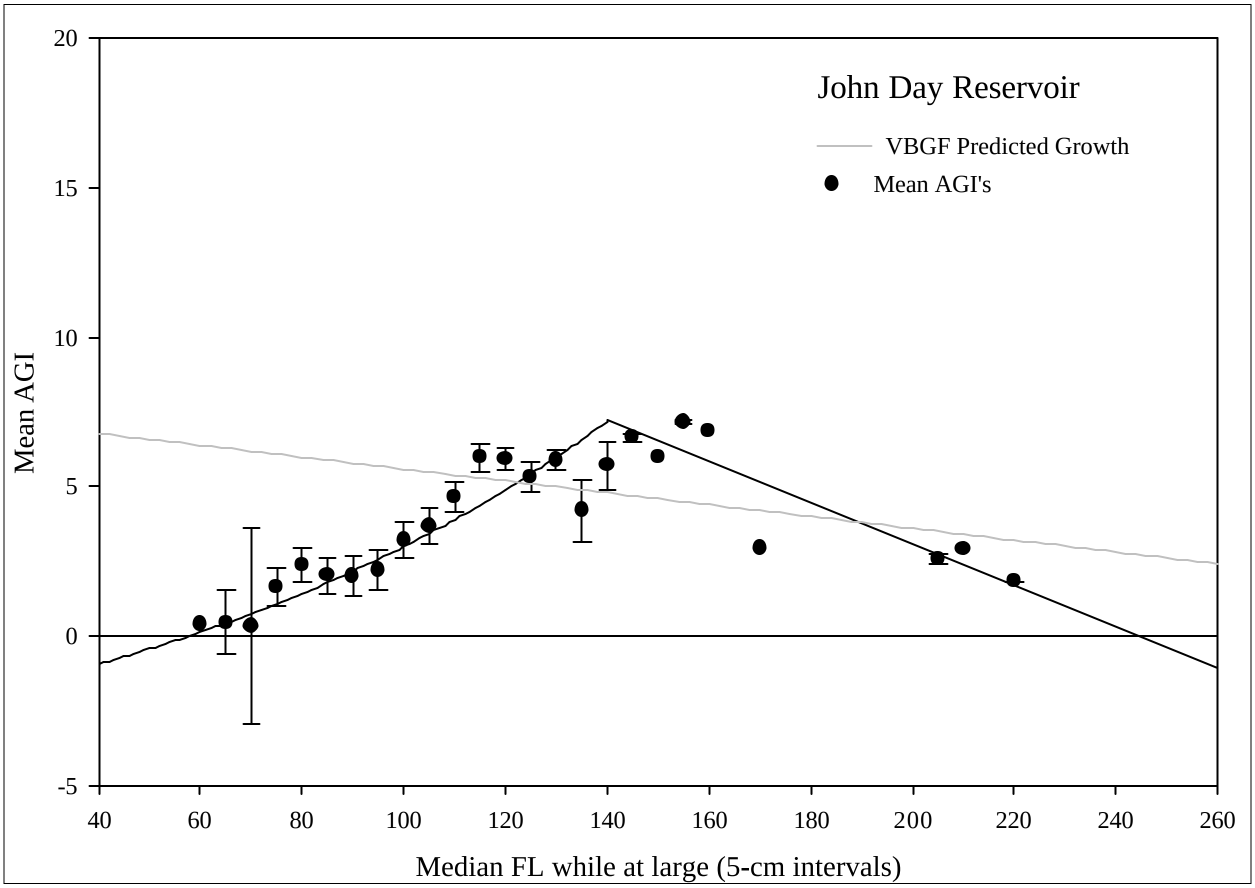

Figure 1. Mean annual growth increments (AGI) of recaptured white sturgeon at large in John Day Reservoir more than one year. Gray line indicates AGI estimated by the VBGF. Black line indicates AGI estimated by the two-phase function. Error bars represent Coefficient of Variation.

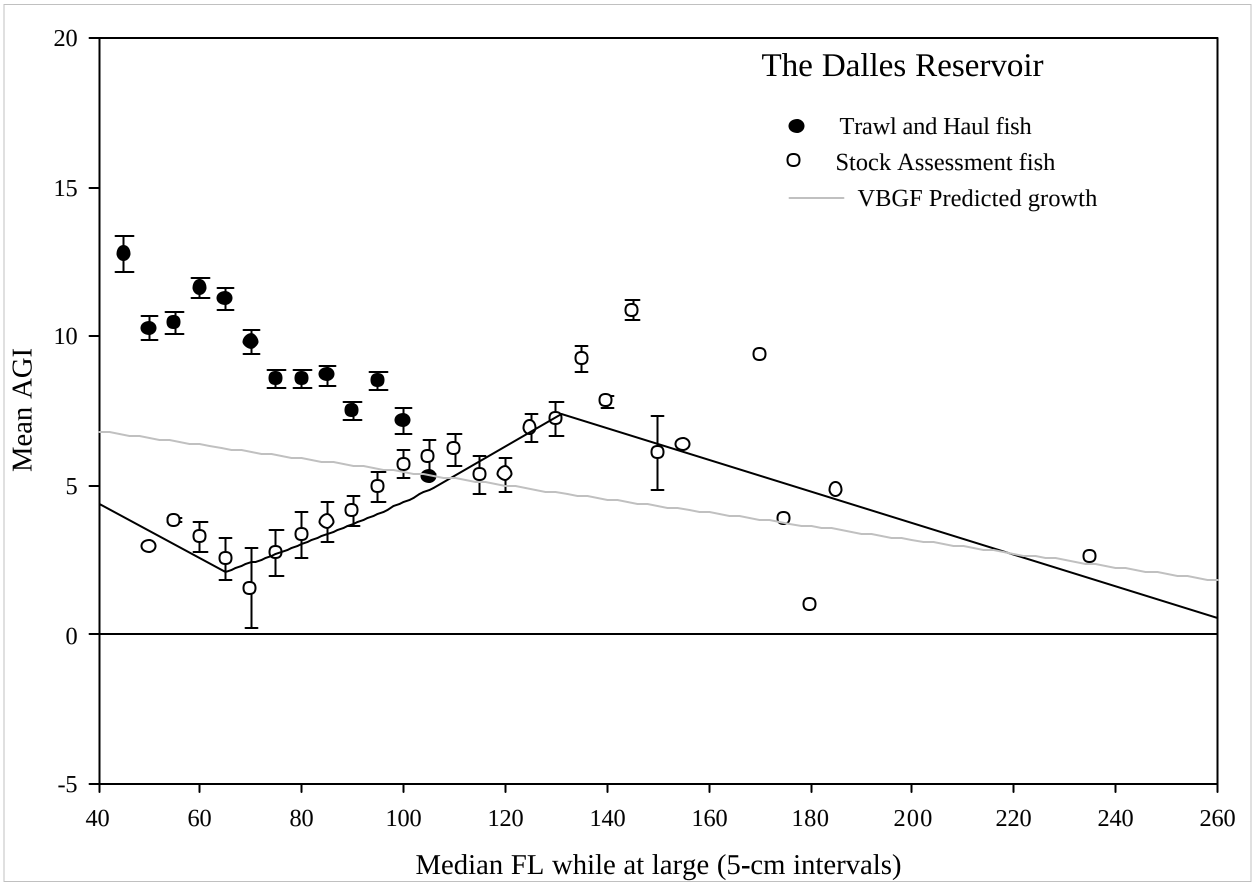

Figure 2. Mean annual growth increments (AGI) of recaptured white sturgeon at large in The Dalles Reservoir more than one year. The black-filled circles represent Trawl-and-Haul Program recaptures whose values are not used in our calculations of growth rates (reference only). Gray line indicates AGI estimated by the VBGF. Black line indicates AGI estimated by the two-phase function. Error bars represent Coefficient of Variation.

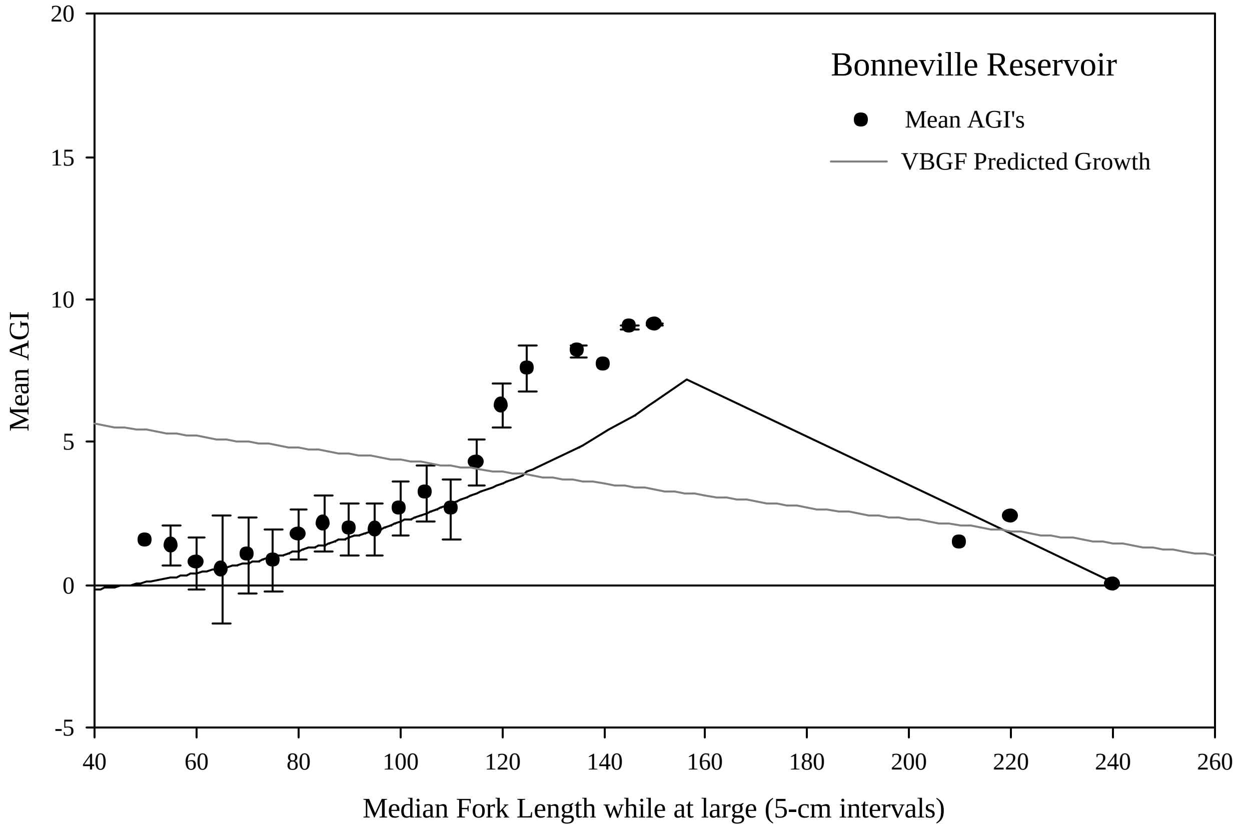

Figure 3. Mean annual growth increments (AGI) of recaptured white sturgeon at large in Bonneville Reservoir more than one year. Gray line indicates AGI estimated by the VBGF. Black line indicates AGI estimated by the two-phase function. Error bars represent Coefficient of Variation.

Recapture records were obtained from recaptures of uniquely marked white sturgeon from: John Day Reservoir 1990, 1996, and 2001; The Dalles Reservoir 1994, 1997, and 2002; and Bonneville Reservoir 1994, 1999, and 2003. From recapture records of fish at large one or more years, we determined length at marking and recapture, years at large (days at large / 365.25 d/yr), growth (?L = length at recapture – length at marking), and annual growth increment (AGI = ?L / years at large). For individual fish recaptured more than once, we calculated growth over the period from first capture to last recapture, disregarding intermediate captures. Because of multiple recaptures and high variability in the amount of time fish were at large between captures, we generally refer to the median fork length of a fish during the period at large where fork length and AGI are discussed concurrently, rather than fork length of the fish at tagging or recapture. Stock assessment efforts have typically focused on fish larger than 70 cm FL at tagging, so smaller fish are under-represented in these analyses. Figures 1-3 show the distributions of mean AGI's versus median FL while-at-large (in 5-cm groups) of fish at large more than one year in each of the three reservoirs. All three reservoirs show the same general pattern of slow growth rates at small sizes, increasing to a maximum growth rate at around 130-150 cm median FL, followed by a decline in growth rate as size increases. In contrast, the VBGF estimates maximum growth rate at the smallest sizes, and a linear decline as fish grow older and larger.

In 1994 and 1995, 8,500 individually marked (PIT-tagged) white sturgeon <90 cm FL were released into The Dalles Reservoir as part of the first phase of the Trawl and Haul program (Rien and North. 2002). These fish were transplanted from the lower Columbia River below Bonneville Dam. Growth rates for these fish after transplantation were quite high compared to reservoir fish (Figure 2). Because stock assessment tagging has typically focused on larger fish (> 70 cm FL) than were transplanted by Trawl and Haul, there is little size-overlap, in terms of median FL while-at-large, between recoveries of transplanted and reservoir white sturgeon. However, where sizes overlapped, transplanted fish had much higher growth rates than the observed rates for reservoir fish, than rates estimated by the VBGF, and than rates for the source population. We are unsure why this occurred, but since the growth patterns were so different, we have assumed that something about the transplantation process influenced growth rates of these fish, or that their origin below Bonneville Dam somehow resulted in different growth potentials than for reservoir fish. So, while the growth rates for these fish are shown for reference in Figure 2, they are not included in the analyses presented here.

In order to be useful in analyzing population changes, growth information is generally converted to a function to estimate growth rate at various sizes. In order to develop this function, we visually identified the general form of lines that appeared to fit the data, then calculated the best-fit line for each dataset. Growth plots for all three reservoirs show the same general pattern of slow growth rates at small sizes increasing non-linearly to maximum, followed by a decline in growth rates as fish grow larger. This pattern of growth is different than what VBGF equations would assume, and may be a form of multiple-stage growth (Soriano et al. 1992).

We have tested several functions describing non-linear relationships that appeared to fit the data, and we continue to search for and test new functions to describe observed growth. For simplicity, we will discuss two functions: the familiar von Bertalanffy function, because of its widespread use and its integral use in previous harvest management of these populations, and a new two-phase function with exponential growth at small sizes, followed by negative linear growth at larger sizes, which we have used in the most recent population projections for estimating suitable harvest rates (Figures 1-3).

Because our current method of population projection is based on growth rates rather than length-at-age (Appendices B and C *in* Kern et al. 2002), both functions will generally be discussed in terms of growth rate, rather than the more familiar length-at-age. We converted the length-at-age curve described by the VBGF and aging information into annual growth increments. Values of variables for the VBGF for each reservoir were published with the results of the most recent stock assessment surveys for each reservoir (for John Day Reservoir, Kern et al. 2002; for The Dalles Reservoir, Kern et al. 2003, and for Bonneville Reservoir, this report).

The VBGF expressed as a function of AGI is given by the equation

$$\text{AGI} = m(\text{FL}) + b$$

with the following variables for each of the Zone 6 reservoirs:

Variable	John Day	Bonneville	The Dalles
m	-0.02	-0.02	-0.02
b	7.56	6.46	7.73

r^2 = 1 because relationship is assumed to be a perfect fit by the VBGF.

To develop the two-phase growth function, we visually identified what appeared to be two separate growth-phases for fish over about 60 cm FL. We visually selected the FL at which maximum AGI appeared to occur (inflection point) and separated the two phases at that point. The first phase of growth appeared to be non-linear, so we transformed the AGI values for sizes below the inflection point by taking the natural log of the AGI. We then performed a linear regression on the transformed AGI versus FL for sizes less than the inflection point. The second growth-phase appeared to be more linear, possibly because of low sample sizes. We performed a simple linear regression on AGI versus FL for all fish with FL greater than the inflection point. The point where the two resulting lines cross is the FL at which maximum AGI occurs (inflection point).

The expression of AGI in the two-phase function is

$$\begin{aligned} \text{AGI} &= \text{if } \le x_{\max} \text{ then } = \exp(m_1 * \text{FL} - b_1) - c \\ &= \text{if } > x_{\max} \text{ then } = m_2 * \text{FL} + b_2 \end{aligned}$$

with the following variables for each of the Zone 6 reservoirs:

	Variable	John Day	Bonneville	The Dalles
First Phase $x = x_{max}$	m_1	0.01	0.01	0.01
	b_1	1.24	0.06	0.94
	c	6	2	3
	x_{max}	140.1	156.5	131.1
	r^2 of regression	*0.204*	*0.135*	*0.121*
Second Phase $x > x_{max}$	m_2	-0.07	-0.08	-0.05
	b_2	16.84	20.44	14.29
	x_{max}	140.1	156.5	131.1
	r^2 of regression	*0.840*	*0.856*	*0.230*

x_{max} = fork length at maximum annual growth increment

To test the fit of the functions, we compared the sum of squares (SSQ) of the residuals (observed value – estimated value) of each function (Table 1). We also calculated the mean squared error (MSE; Groger 2001) between observed and estimated values.

Table 1. Summary fit statistics for VBGF and two-phase function versus observed growth rates.

Reservoir / Model	Sum of Squares (SSQ)	Mean Squared Error* (MSE)
John Day		
Our model	2,479.9	3.6
VBGF model	8,325.0	12.0
The Dalles		
Our model	8,804.8	9.3
VBGF model	10,834.3	11.4
Bonneville		
Our model	2,715.2	4.4
VBGF model	8,431.0	13.7

*Mean Squared Error = (1/n-2)*SSQ

In all three reservoirs, the VBGF resulted in a poorer fit than the two-phase function. The SSQ for our function was substantially higher in The Dalles population than for the other two reservoirs, and was more similar to the SSQ of the VBGF in that population. The SSQ for both functions from The Dalles population implies that the function providing the best fit for The Dalles population does not fit the data as well as even the worst fitting function fits the John Day or Bonneville data. Growth in all of these populations is highly variable, as indicated by the high values for the SSQ, and it is difficult for any function to adequately account for that variability. We assume that by selecting the function that minimizes differences between estimated and observed growth rates as evidenced by SSQ and MSE values, we will select the function that best describes growth.

DISCUSSION

Although neither function fits the observed data especially well for The Dalles population, observed growth in this population has more closely approximated growth estimated by the VBGF. This is apparent by visually comparing the observed AGI's to the VBGF estimated AGI's in Figure 2. If we incorporate growth of the fish transplanted by the Trawl and Haul program in 1994 and 1995, the observed growth rates in The Dalles Reservoir are very close to those estimated by the VBGF. Due to a paucity of uniquely-marked small fish (<70 cm FL) from stock assessments, we have very little information on growth rates of fish under 70 cm FL in The Dalles Reservoir (N = 45). However, most of the fish transported by Trawl and Haul were less than 70 cm FL when tagged, and we have a much higher sample size of recaptures of these fish (N = 732). The pattern of AGI of Trawl and Haul transports fits the VBGF pattern more closely, but since the growth rates for the transplanted fish are so much higher than for reservoir fish of similar size, we are uncomfortable describing growth of reservoir white sturgeon using growth rates of these transplanted fish, even though the sample size for transplanted fish recoveries is high. More information on growth rates of reservoir white sturgeon less than 70 cm FL is needed, and we have recently begun PIT-tagging more small fish for this reason.

For the Bonneville and John Day populations, the two-phase function fit the observed data substantially better than the VBGF did. These populations have typically not responded as expected to management strategies based on OSY developed using the VBGF to describe growth. Because the growth rates of fish in these reservoirs has been slower than originally expected, harvest limits were set at unsustainable levels for several years. The population in The Dalles Reservoir has more closely matched expectations based on this management strategy, possibly because growth rates in that reservoir are more similar to those expected by the VBGF.

Because length-at-age is such a universally accepted method of describing growth, we estimated length-at-age from measured AGI growth rates and from the two functions (VBGF and two-phase). This allows another comparison of the two functions versus observed growth. Figures 4-6 show the conversions of AGI to length-at-age. The observed AGI information and our two-phase function are both independent of age, and we have no description of growth in fish smaller than 70 cm, so we started all fish at 70 cm FL, and set their age equal to what the VBGF would predict for that size. All three figures show the same general pattern and a substantial difference between how the VBGF describes growth and how the recapture data and our two-phase function describe growth.

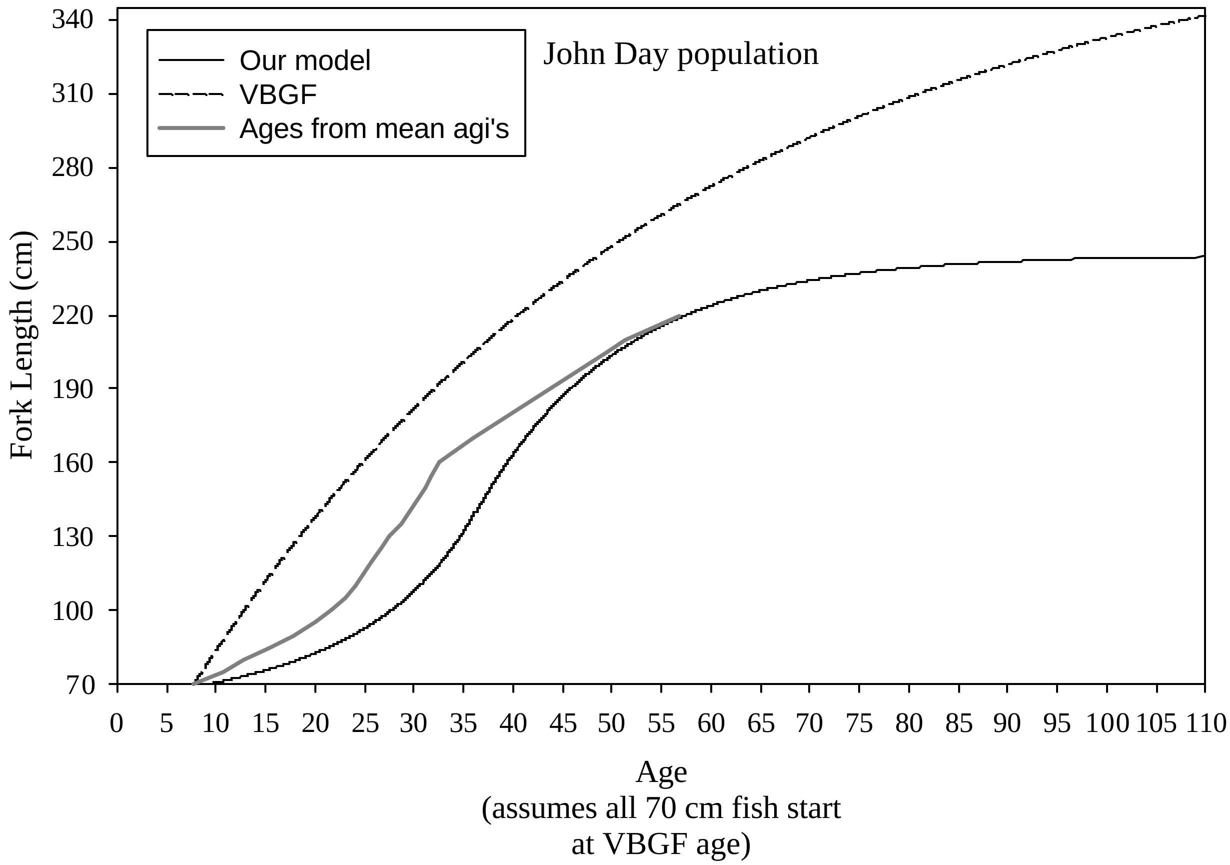

Figure 4. Comparison of age estimates derived from AGI's estimated by the two-phase function, the VBGF, and measured from white sturgeon at large more than one year, John Day Reservoir white sturgeon.

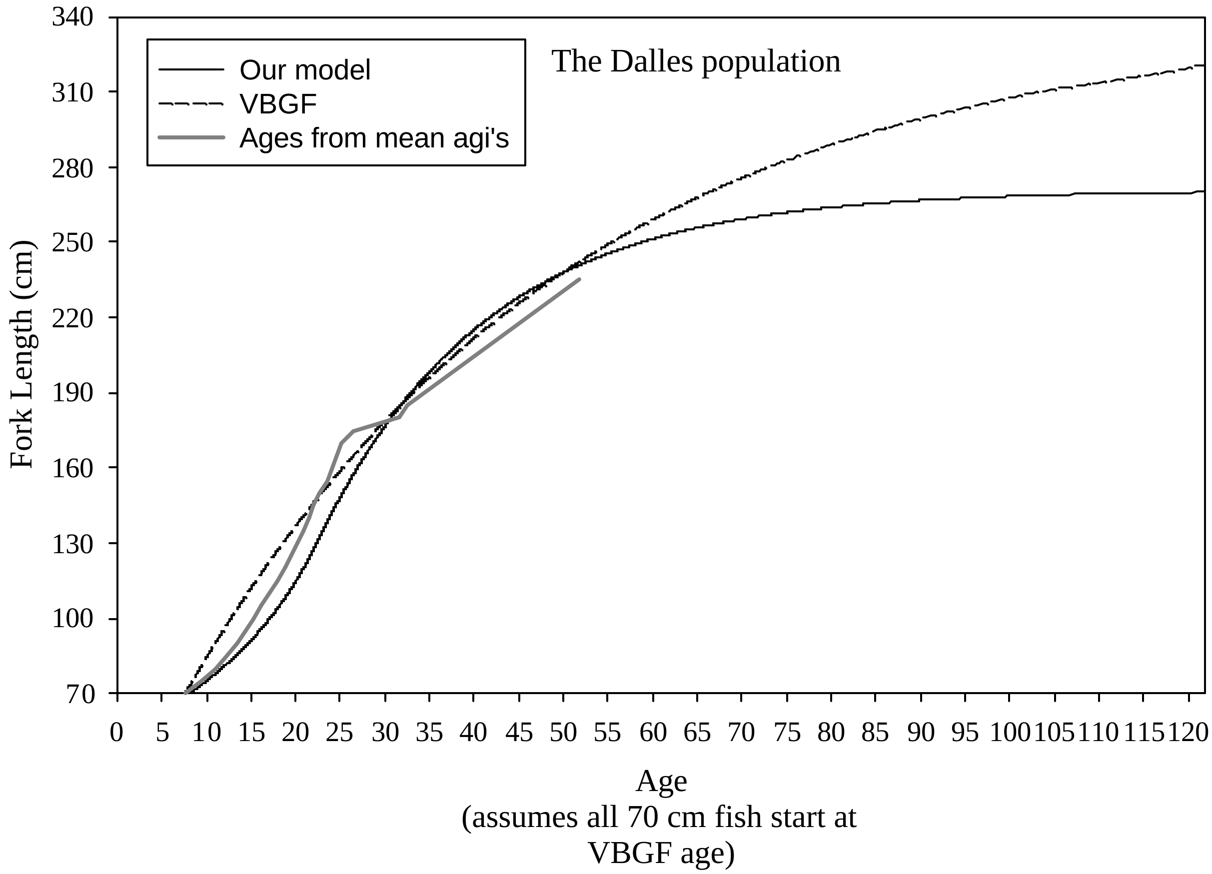

Figure 5. Comparison of age estimates derived from AGI's estimated by the two-phase function, the VBGF, and measured from white sturgeon at large more than one year, The Dalles Reservoir white sturgeon.

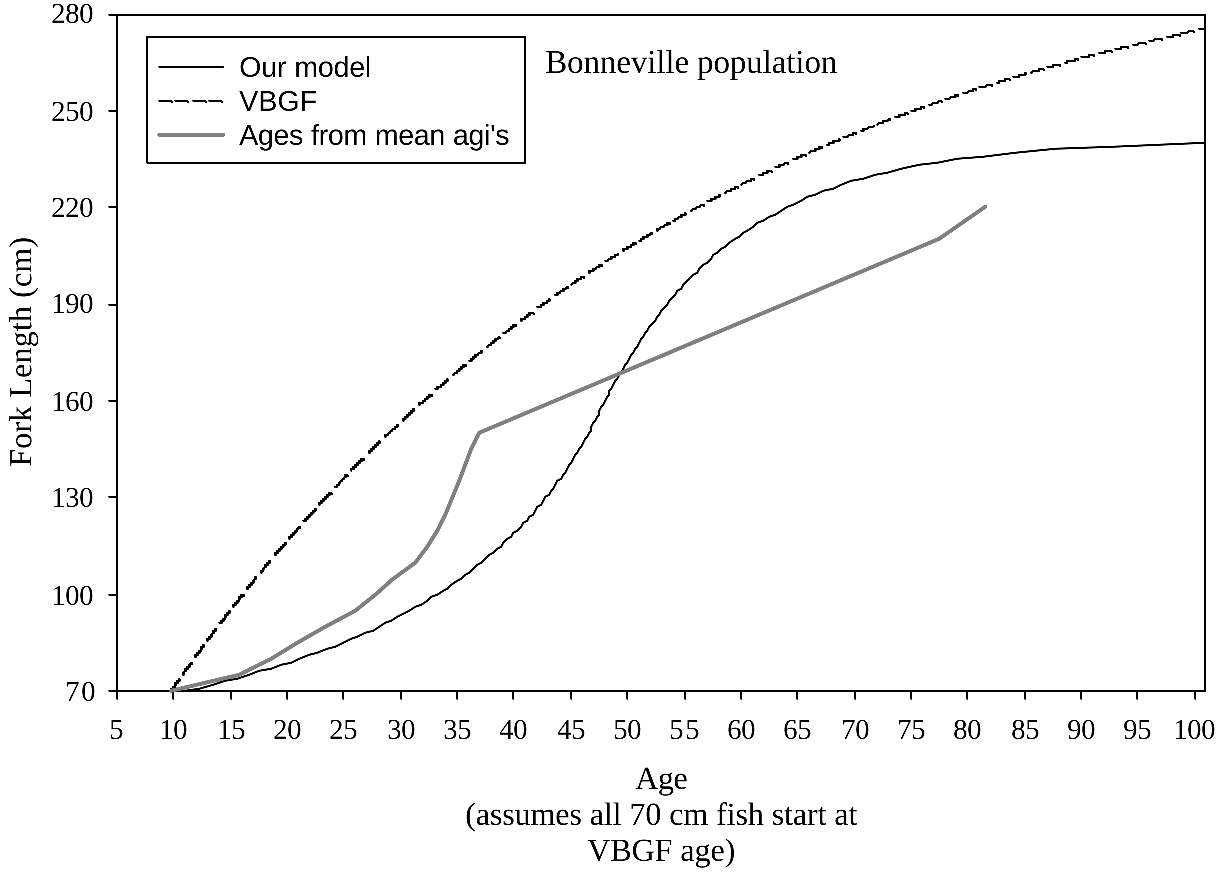

Figure 6. Comparison of age estimates derived from AGI's estimated by the two-phase function, the VBGF, and measured from white sturgeon at large more than one year, Bonneville Reservoir white sturgeon.

These differences are again less pronounced in The Dalles population, for reasons we have already discussed. However, in all three cases, there is a clear pattern whereby small fish grow more slowly than the VBGF would estimate until a certain size, when they begin to grow at a much faster and seemingly exponential rate, until a point of maximum growth rate is reached, after which growth slows as it approaches an asymptote. Because we arbitrarily picked a size and age to start fish at in Figures 4-6, the starting points and asymptotes shown for observed data and our two-phase function should be viewed with caution. We do not have enough data to adequately describe growth from age-0 and the arbitrary 70-cm FL starting point, therefore the length-at-age curves shown for the observed data and our function do not accurately reflect where the start and end points of the curve really lie in relation to the *y*-axis. They only show the relative pattern of change in length-at-age under the two scenarios in comparison to the VBGF. The asymptotes for the observed data and our two-phase function could be higher, lower, or nearly equal to, those for the VBGF, depending on how growth for fish less than 70 cm FL is described.

As stated earlier, we do not have enough growth information from fish <70 cm FL to adequately describe growth of fish below this size. Consequently, we do not know the pattern of growth white sturgeon in these reservoirs display at sizes between 0 and about 60 cm FL. We can assume that growth must be substantially higher during this period, or fish would never reach the larger size classes. This suggests that growth of small fish probably starts out at a relatively high rate, but must decline rapidly to reach the rates we have documented in recaptured fish. This probably indicates at least a third growth phase in addition to the two we attempt to describe here. There is a similar paucity of data on growth of large fish, because of their relatively low abundance in these populations. There may be additional un-described phases of growth in these larger size classes.

Our data only allows us to describe growth-while-at-large in terms of size at the beginning and end of the recovery period. The difference between these values represents growth during the period, which we express as a mean value over the period. In fact, fish may, and probably do, grow at different rates during the period at large. Depending on when in the fish's growth cycle we happen to measure fork length, we may under- or over-estimate the annual rate of growth. For example, if a fish is at large for 4 years between captures growing 10 cm during that time, we would classify the fish's growth as a rate of 2.5 cm per year. This is the mean growth over the period we measured. However, this fish may in fact have grown 7 cm in the first year, followed by 1 cm per year in the following three years. If we had captured this fish a year earlier, its annual rate of growth would have been 3 cm per year, and if we had captured it one year later (assuming another 1 cm per year of growth) the average growth rate would be 2.2 cm per year. Figure 7 shows the relationship between AGI and days-at-large between captures. Annual growth increment is more variable for fish at large for shorter periods, and there appears to be a weak negative relationship ($r^2 = 0.230$) between AGI values and increasing time-at-large. If annual growth rates of individual fish were changing substantially over the period fish were at large, we would expect mean AGI estimates to be quite sensitive to the number of years a fish was at large between captures. Additionally, interpretation of changes in AGI as time-at-large increases is confounded by the fact that fish at large for longer periods are generally larger fish, which we would expect to grow at slower rates. In future analyses, we plan to examine growth-at-large of fish with measured growth over more than one period-at-large to address this potential bias.

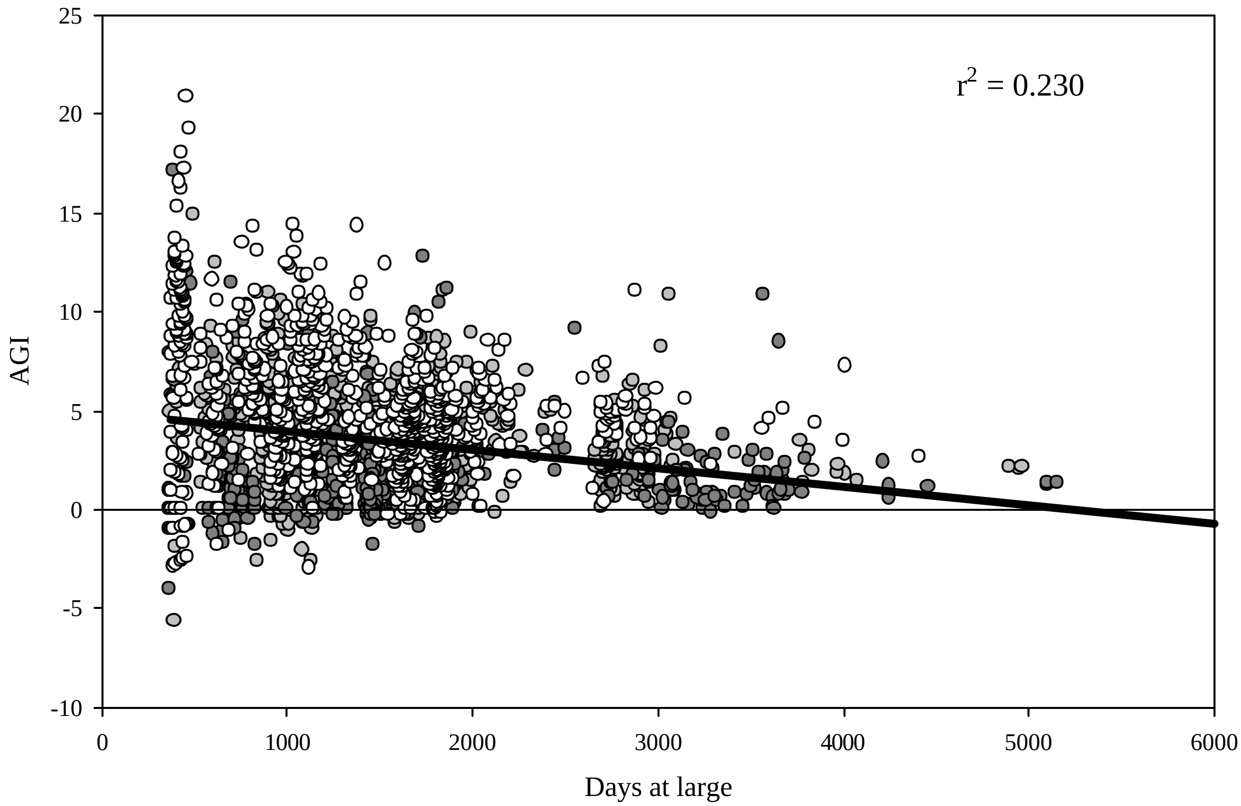

Figure 7. Days-at-large versus annual growth increment (AGI) for white sturgeon in Zone 6 reservoirs.

In Zone 6 reservoirs, white sturgeon population estimates are conducted and harvest limits reviewed about every three years. This time period is relatively short in comparison to life stages of this species, so current methods for projecting harvest limits and abundance of harvestable fish do not rely on recruitment inputs or growth information for fish that are unlikely to grow into, or out of, the harvestable size classes before new estimates are made. The lack of information on growth of very small and very large fish is therefore more of a theoretical problem than a management problem. It does preclude accurate conversion of AGI to length-at-age, and represents a significant hurdle to detailed understanding of the demographics of these populations. Since recognizing both the shortcomings of the VBGF in describing growth, and the lack of information regarding growth of small fish, we have begun to tag more fish <70 cm FL during our stock assessment sampling. In 3-6 years, we should be able to use this data to add to our understanding of white sturgeon growth in Zone 6 reservoirs.

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

ANNUAL PROGRESS REPORT

APRIL 2003 – MARCH 2004

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 2003 sport and commercial white sturgeon fisheries.

Prepared by:

Olaf P. Langness
Dennis R. Gilliland
Brad J. Cady
Brad W. James

Washington Department of Fish and Wildlife
Southwest Region
2108 Grand Boulevard
Vancouver, Washington 98661

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ABSTRACT

The Washington and Oregon Departments of Fish and Wildlife conducted a survey of the 2003 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 during June 21 – December 31 in The Dalles Reservoir, with an estimated harvest of 447 fish (112% of the 2003 guideline). The fishery in Bonneville Reservoir was closed to the retention of sturgeon during July 7 – December 31, with an estimated harvest of 1,542 fish (91% of guideline). The John Day Reservoir was closed to retention during July 28 – December 31, with an estimate harvest of 186 fish (113% of guideline).

Treaty Indian commercial fishers landed 379 white sturgeon from Bonneville Reservoir (32% of the 2003 guideline), 811 from The Dalles Reservoir (90% of guideline), and 251 from John Day Reservoir (75% of guideline), during gill net and setline fisheries. The Columbia River Inter-Tribal Fish Commission and the Yakama Indian Nation estimated an additional 325 fish were harvested from the three reservoirs (93 from Bonneville Reservoir, 202 from The Dalles Reservoir, and 30 from the John Day Reservoir), during the 2003 subsistence fisheries.

The analyses of harvest, effort, catch length-frequency, and season durations, pointed toward the need to reduce the current harvest guidelines in Bonneville Reservoir. Therefore the guideline was reduced to 700 sport and 400 commercial for the 2004 season. The Dalles harvest guidelines were reduced to 400 sport and 900 commercial during 2003. The harvest guidelines in John Day Reservoir were also reduced to 165 sport and 335 commercial following the most recent stock assessment 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 2003 but focuses on work conducted from 1 April 2003 through 31 March 2004.

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 to mitigate for lost white sturgeon productivity in impoundments where development and operation of the hydrosystem has reduced production.

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 3.2 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 Bonneville 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. OSU is using those samples for developing methods to determine sex and stage of maturity of white sturgeon (see Report G in this annual report). Task 3.2 involved describing annual variation in white sturgeon recruitment in impoundments. We worked with staff from ODFW and the 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 2003 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). 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*, are considered minimum estimates, because these species can also be harvested at night.

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 was calculated from average daily angling pressure distributions derived from prior years' data when systematic counts were made throughout the day.

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 2003 was used to adjust the 2003 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

We began our survey of the 2003 sport fishery on January 1 and continued sampling through June 20. State fishery managers closed the fishery to retention of white sturgeon on July 7 based on our in-season projection that harvest would reach the guideline by that date. Effort and harvest both declined significantly during the last 2 weeks. The final harvest was 91% of the guideline.

Anglers fished an estimated 81,512 hours (16,305 trips) in Bonneville Reservoir during the retention season (Table 1). Angling effort for sturgeon comprised 60% (9,825 trips) of the total estimated effort. The estimated number of angler trips by species targeted were as follows: 1,908 (12%) for anadromous salmonids, 635 (4%) for American shad *Alosa sapidissima*, 378 (2%) for walleye, 987 (6%) for bass, 942 (6%) for northern pikeminnow, 1,588 (10%) for other resident fish, and 42 (<1%) for anglers participating in tournaments.

Anglers harvested an estimated 1,542 white sturgeon during 9,825 trips for sturgeon during the retention season; a 8% increase in harvest and 19% decrease in angler trips from the 2002 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 June at 0.27 fish per trip and averaged 0.07 fish per trip for bank anglers and 0.22 fish per trip for boat anglers targeting sturgeon during the retention fishery (Table 3). The 1,740 sturgeon anglers interviewed accounted for 14% of the estimated bank effort (angler hours) and 11% of the estimated boat effort for sturgeon (Table 4).

Anglers released 14% 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. 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 93%, 6%, and

1%, 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 increased from 2002 levels for boat anglers but decreased for bank anglers (Table 6).

The Dalles Reservoir

We began our survey of the 2003 sport fishery on January 1 and continued sampling through June 20. State fishery managers closed the fishery to retention of white sturgeon on June 21. However, high effort and harvest per unit effort during the end of the fishery pushed the harvest to 12% over guideline.

Anglers fished an estimated 107,298 hours (15,804 trips) in The Dalles Reservoir during the retention season (Table 1). Angling effort for white sturgeon comprised 42% (6,518 trips) of the total estimated effort. The number of angler trips estimated by target species were as follows: 4,173 (26%) for anadromous salmonids, 839 (5%) for American shad, 1,771 (11%) for walleye, 1,598 (10%) for bass, 606 (4%) for northern pikeminnow, 299 (2%) for other resident fish, and 0 (0%) for anglers participating in tournaments.

Anglers harvested an estimated 447 white sturgeon during 6,518 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 June at 0.18 fish per trip. Harvest per trip averaged 0.03 for bank anglers and 0.13 for boat anglers targeting sturgeon during the retention fishery. The 1,567 white sturgeon anglers interviewed accounted for 15% of the estimated bank effort (angler hours) and 18% of the estimated boat effort for white sturgeon (Table 4).

Anglers released 10% of the legal-size catch during the retention period (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 92%, 5%, and 3%, respectively (Table 4). This distribution of catch by size is nearly the same as in 2002. The length distribution of the sampled harvest is presented in Table 5. Both bank and boat anglers' harvest per trip, of 110-138 cm FL (48-60 in TL) fish, decreased from the previous year (Table 6).

John Day Reservoir

We began our survey of the 2003 sport fishery in John Day Reservoir on January 1 and continued sampling through July 27. The fishery was closed to retention of white sturgeon on July 28. The guideline was exceeded by 13%.

Anglers fished an estimated 150,816 hours (29,550 trips) in John Day Reservoir during 2003 (Table 1). Angling effort for white sturgeon comprised 29% (8,677 trips) of the total estimated effort. The number of angler trips estimated by target species were as follows: 6,400 (22%) for anadromous salmonids, 908 (3%) for American shad, 5,635 (19%) for walleye, 6,322

(21%) for bass, 134 (<1%) for northern pikeminnow, 1,143 (4%) for other resident fish, and 331 (1%) for tournament anglers.

Anglers harvested an estimated 186 white sturgeon during 8,677 trips for sturgeon in 2003 (Table 2). Anglers concentrated their effort for sturgeon from McNary Dam downstream past Irrigon, Oregon to Rkm 449. Harvest per trip peaked in June at 0.04 fish (Table 3). Harvest per trip averaged 0.01 for bank anglers and 0.03 for boat anglers (Table 3). The 2,486 sturgeon anglers interviewed accounted for 14% of the estimated bank effort (angler hours) and 29% of the estimated boat effort for white sturgeon (Table 4).

Anglers released 27% of the legal-size catch during the retention period (Table 4). The percentage sub-legal (<122 cm TL; <48 in TL), legal (122-152 cm TL, 48-60 in TL), and oversize (>152 cm TL, >60 in TL) white sturgeon in the reported catch was 86%, 3%, and 11%, respectively (Table 4). The length distribution of the sampled harvest is presented in Table 5. Harvest per trip of 110-138 cm FL (48-60 in TL) fish increased for boat anglers but decreased for bank anglers from 2002 levels (Table 6).

Treaty Indian Commercial and Subsistence Harvest

The 2003 treaty Indian commercial harvest estimates for Zone 6 were 379 white sturgeon from Bonneville Reservoir, 811 white sturgeon from The Dalles Reservoir, and 251 white sturgeon from John Day Reservoir (Table 7). More than 87% 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 (Doug Case, ODFW, personal communication). The treaty Indian Zone 6 subsistence white sturgeon harvest estimated by CRITFC and YIN was 325 fish (Table 7): 93 from Bonneville Reservoir; 202 from The Dalles Reservoir; and, 30 from John Day Reservoir.

DISCUSSION

Zone 6 Sturgeon Harvest Management

Bonneville Reservoir

Since the 1,520 fish guideline began in 1997, the recreational boat anglers harvest per unit effort (HPUE) has declined, while their effort has increased. For bank anglers, HPUE has declined, while effort has fluctuated. The proportion of effort attributed to each group has remained roughly stable since 1988 (slightly favoring bank anglers). Since sport-fishing success is declining and the number of angler trips is increasing, it seems likely that the legal-size population abundance is decreasing. Furthermore, the harvest is composed of an increasing proportion of fish just recruited to the legal-size class, which may also indicate a declining population of legal fish. The portion of fish harvested within the smallest 15 cm of the legal-size slot (≤109 cm Fork Length; i.e., 107 - 122 cm Total Length), went from 64% in the 2001 season (Langness et al. 2002) to 76% during the 2003 season. Another indicator that the legal-size population may have declined is that the time to achieve the fish harvest guideline nearly tripled (from 3.5 months in 1997 to over 10 months in 2002).

The 2003 Bonneville Stock Assessment supports the analysis of harvest (See Report A in this annual report). Both approaches pointed to the need to reduce the harvest guidelines.

The Dalles Reservoir

Following the significant harvest guideline increase in 1998, effort declined and HPUE 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. In 2003 effort declined (but not proportionate with guideline reductions), and HPUE was at its lowest level since 1998.

Stock abundance estimates from the 1997 The 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 (except in 2001when anglers came upon an unusual concentration of legal-sized fish). Size composition of the catch has fluctuated (66% of the 2003 harvested fish were in the smallest 15 cm of the legal-size range (≤124 cm Fork Length; i.e., 122-137 cm Total Length), versus 69% of the 2002 harvest and 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 (Kern et al, 2003). In 2003, the harvest guidelines for The Dalles sturgeon fisheries were reduced to 400 for the sport fishery and 900 for the commercial fishery.

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 generally stable since 1989 (slightly favoring boat anglers). Size composition of the catch has shifted towards smaller fish (83% of the 2003 harvested fish were in the smallest 15 cm of the legal-size range (≤124 cm Fork Length; i.e., 122-137 cm Total Length), versus 67% of the 2002 harvest and 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, and in 2003 by late July.

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 (2-4%). 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 2004. We will work with ODFW during the summer of 2004 to assess the status of the white sturgeon population in the John Day Reservoir. We will work with fishing guides to obtain breeding adult white sturgeon, from which we can collect paired gonad-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. In the fall of 2004, we will participate in an assessment of the 2003 hatchery release of juvenile sturgeon in Rock Island Reservoir.

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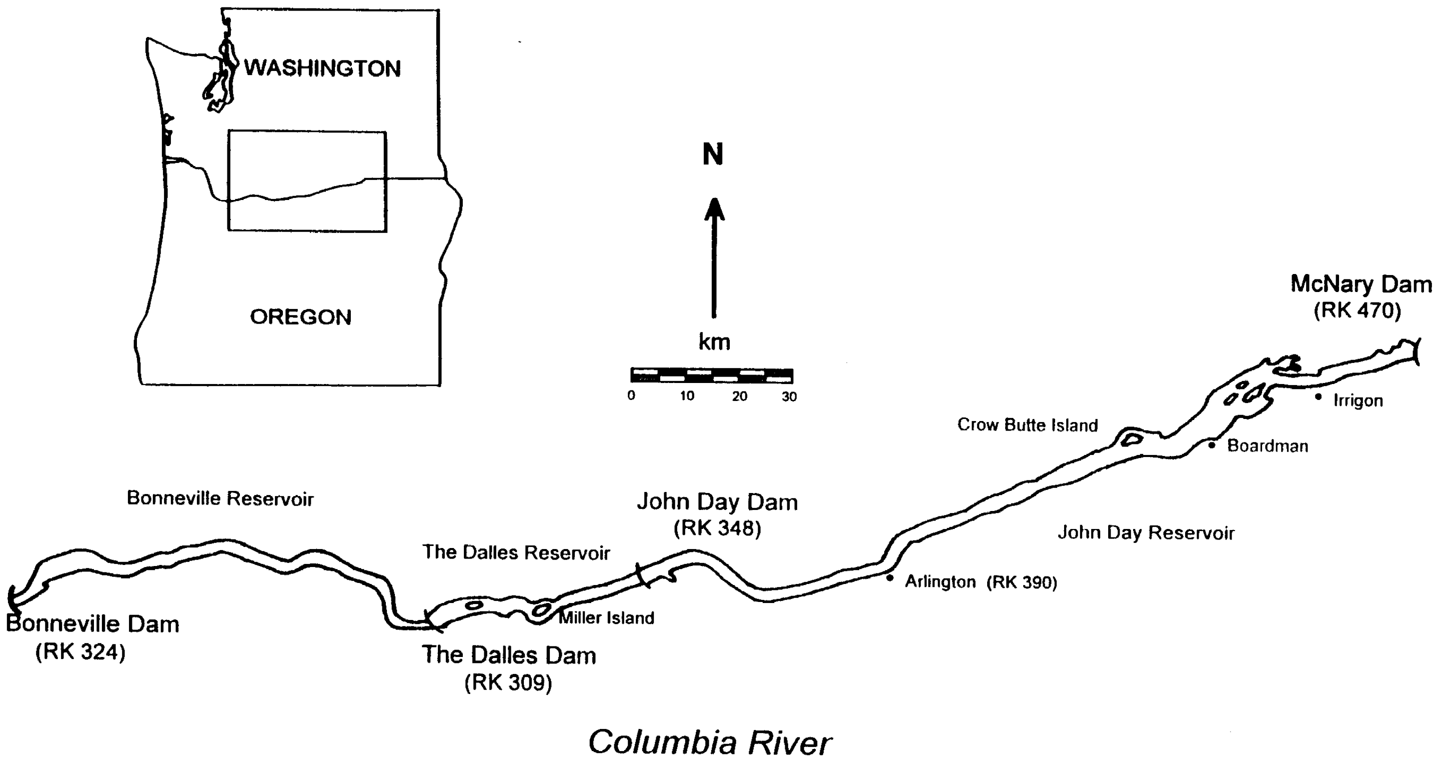

Figure 1. Location of the recreational fishery census on the Columbia River. Bonneville and The Dalles reservoirs, and from Arlington upstream to McNary Dam in John Day Reservoir.

Table 1. Combined Washington and Oregon recreational fishery angling effort estimates for Bonneville Reservoir, January 1 through July 6, 2003; The Dalles Reservoir, January 1 through June 20, 2003; and John Day Reservoir, January 1 through July 27, 2003.

Species / Method	Bonneville		The Dalles		John Day	
	Hours	Trips	Hours	Trips	Hours	Trips
Sturgeon						
Bank	20,905	4,092	30,829	3,797	18,069	3,212
Boat	33,306	5,733	14,885	2,721	29,004	5,465
Total	54,211	9,825	45,714	6,518	47,073	8,677
Salmonid						
Bank	5,957	769	24,418	2,366	11,124	2,004
Boat	5,059	1,139	11,291	1,807	24,476	4,396
Total	11,016	1,908	35,709	4,173	35,600	6,400
Shad						
Bank	2,464	575	3,943	797	785	243
Boat	90	60	171	42	2,406	665
Total	2,554	635	4,114	839	3,191	908
Walleye						
Bank	0	0	76	14	203	55
Boat	1,550	378	9,503	1,757	27,703	5,580
Total	1,550	378	9,579	1,771	27,906	5,635
Bass						
Bank	308	125	1,918	638	2,503	681
Boat	3,743	862	4,759	960	24,533	5,641
Total	4,051	987	6,677	1,598	27,036	6,322
Northern Pikeminnow						
Bank	1,531	274	1,910	250	145	46
Boat	4,277	668	2,098	356	421	88
Total	5,808	942	4,008	606	566	134
Other						
Bank	1,928	1,550	1,446	286	4,472	867
Boat	76	38	51	13	1,222	276
Total	2,004	1,588	1,497	299	5,694	1,143
Tournament						
Bank	0	0	0	0	0	0
Boat	318	42	0	0	3,750	331
Total	318	42	0	0	3,750	331
Combined Total						
Bank	33,093	7,385	64,540	8,148	37,301	7,108
Boat	48,419	8,920	42,758	7,656	113,515	22,442
Total	81,512	16,305	107,298	15,804	150,816	29,550

Table 2. Combined Washington and Oregon recreational fishery harvest, and catch and release estimates for Bonneville Reservoir, January 1 through July 6, 2003; The Dalles Reservoir, January 1 through June 20, 2003; and John Day Reservoir, January 1 through July 27, 2003.

Species	Bonneville	The Dalles	John Day
White sturgeon [a]			
Legals kept	1,542	447	186
Sublegals released	27,166	9,279	7,324
Legals released	282	59	77
Oversize released	583	355	852
Total	29,573	10,140	8,439
Chinook salmon [b]			
Adults kept	148	621	340
Jacks kept	45	81	37
Total kept	193	702	337
Released	116	374	393
Coho salmon [c]			
Kept	0	0	3
Released	0	0	0
Total	0	0	3
Steelhead [d]			
Kept	10	412	392
Released	30	102	659
American shad			
Kept	3,527	5,295	2,281
Released	496	5,220	2,568
Walleye			
Kept	201	1,615	4,838
Released	6	657	3,310
Bass			
Kept	626	2,045	4,290
Released	3,981	7,057	15,924
Northern pikeminnow kept	7,674	2,650	297
Other resident fish kept	6	122	1,421

[a] *White sturgeon seasons were closed to retention July 7 – December 31 in Bonneville Reservoir, June 21 – December 31 in The Dalles Reservoir, and July 28 – December 31 in John Day Reservoir.*
[b] *Chinook seasons were closed to retention January 1 – February 14 and May 16 – June 15, and closed to adult retention June 16 – July 31 in all three reservoirs.*
[c] *Coho seasons were closed to retention January 1 - July 31.*
[d] *Steelhead seasons were closed to retention April 1 - June 15.*

Table 3. Estimates of recreational fishery angler trips for white sturgeon, white sturgeon harvest, and harvest per angler trip (HPUE) for Bonneville Reservoir, January 1 through July 6, 2003; The Dalles Reservoir, January 1 through June 20, 2003; and John Day Reservoir, January 1 through July 27, 2003.

Month	Bonneville			The Dalles			John Day		
Method	Trips	HPUE	Harvest	Trips	HPUE	Harvest	Trips	HPUE	Harvest
January									
Bank	478	0.00	0	345	0.04	13	278	0.00	0
Boat	697	0.29	204	490	0.13	66	78	0.00	0
Total	1,175	0.17	204	835	0.09	79	356	0.00	0
February									
Bank	814	0.04	34	425	0.02	10	214	0.00	0
Boat	784	0.10	82	500	0.11	53	324	0.01	3
Total	1,598	0.07	116	925	0.07	63	538	0.01	3
March									
Bank	633	0.01	9	758	0.00	0	530	0.01	3
Boat	778	0.08	66	545	0.04	23	472	0.02	10
Total	1,411	0.05	75	1,303	0.02	23	1,002	0.01	13
April									
Bank	539	0.05	29	563	0.03	16	330	0.00	1
Boat	1,082	0.34	365	274	0.20	54	1,111	0.01	10
Total	1,621	0.24	394	837	0.08	70	1,441	0.01	11
May									
Bank	789	0.07	59	1,036	0.00	4	397	0.01	3
Boat	769	0.11	84	544	0.05	25	955	0.03	28
Total	1,558	0.09	143	1,580	0.02	29	1,352	0.02	31
June									
Bank	795	0.14	112	670	0.09 [a]	60	826	0.03	25
Boat	1,403	0.34	475	368	0.33 [a]	123	1,331	0.04	54
Total	2,198	0.27	587	1,038	0.18 [a]	183	2,157	0.04	79
July									
Bank	44	0.52 [a]	23	0	0.00	0	637	0.01 [a]	8
Boat	220	0.00 [a]	0	0	0.00	0	1,194	0.03 [a]	41
Total	264	0.09 [a]	23	0	0.00	0	1,831	0.03 [a]	49
August									
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
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	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
November									
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
December									
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
Combined									
Bank	4,092	0.07 [a]	266	3,797	0.03 [a]	103	3,212	0.01	40
Boat	5,733	0.22 [a]	1,276	2,721	0.13 [a]	344	5,465	0.03	146
Total	9,825	0.16 [a]	1,542	6,581	0.07 [a]	447	8,677	0.02	186

[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 July 6, 2003; The Dalles Reservoir, January 1 through June 20, 2003; and John Day Reservoir, January 1 through July 27, 2003.

Reservoir Method/Month	Anglers checked	Hours fished	Sublegal released	Legal Released	Legal kept	Oversize released
Bonneville						
Bank						
January	93	204	13	1	0	0
February	207	482	112	0	5	0
March	246	641	96	1	2	3
April	184	562	163	3	6	0
May	199	692	154	3	10	6
June	122	382	170	2	9	6
July	17	64	32	0	5	0
Bank Total	1,068	3,027	740	10	37	9
Boat						
January	103	606	956	4	37	0
February	140	726	628	0	16	0
March	99	478	235	1	8	0
April	137	834	468	6	51	4
May	79	473	159	2	10	11
June	100	602	315	7	23	20
July	14	85	47	1	5	8
Boat Total	627	3,106	1,471	19	100	73
Combined Total	1,740	6,831	3,548	31	187	52
The Dalles						
Bank						
January	150	593	26	0	5	4
February	196	963	43	0	3	2
March	243	1,006	16	0	0	0
April	175	732	95	0	2	1
May	142	610	48	0	1	2
June	165	680	153	0	6	6
Bank Total	1,071	4,584	381	0	17	15
Boat						
January	80	439	281	1	11	2
February	108	520	147	0	13	5
March	112	533	204	0	7	3
April	60	357	152	2	12	5
May	91	566	142	1	3	15
June	45	240	227	5	15	12
Boat Total	496	2,655	1,153	9	61	42
Combined Total	1,567	7,239	1,534	9	78	57

continued

Table 4. Continued.

Reservoir Method/Month	Anglers checked	Hours fished	Sublegal released	Legal Released	Legal kept	Oversize released
John Day						
Bank						
January	29	60	4	0	0	0
February	63	160	9	0	0	0
March	166	307	29	0	0	0
April	126	276	4	0	0	0
May	136	384	25	0	0	2
June	264	880	57	0	4	4
July	132	482	21	1	0	6
Bank Total	916	2,549	149	1	4	12
Boat						
January	11	49	13	0	0	0
February	110	652	85	5	1	19
March	99	416	41	0	2	2
April	175	817	110	3	3	4
May	249	1,323	265	1	3	28
June	481	2,613	435	4	15	96
July	445	2,650	584	2	16	54
Boat Total	1,570	8,520	1,533	15	40	203
Combined Total	2,486	11,069	1,682	16	44	215

Table 5. Length frequencies of harvested white sturgeon measured during sampling of recreational fisheries in Bonneville Reservoir, January 1 through July 6, 2003; The Dalles Reservoir, January 1 through June 20, 2003; and John Day Reservoir, January 1 through July 27, 2003.

Fork Length (cm)	Bonneville	The Dalles	John Day	Fork Length (cm)	Bonneville	The Dalles	John Day
90	3			130	1		
91	1			131	2		
92				132		3	
93				133		1	
94	9			134			
95	6			135			
96	14			136		3	
97	6			137		4	1
98	7			138		2	1
99	13			139			1
100	20			140		1	
101	11			141			
102	12			142			
103	11			143			
104	6			144			
105	9	1		145			
106	3		1	146			
107	14		1	147			
108	11	1		148			
109	2	4	2	149			
110	2	2	2	150			
111	4	3	2	151			
112	2	6	2	152			
113	2	2	3	153			
114		5	3	154			
115	5	3		155			
116	2	1	4	156			
117	1	2	3	157			
118	1	1	2	158			
119		1	2	159			
120	1	2	3	160			
121		6		161			
122	1	5	2	162			
123		4		163			
124		1	1	164			
125		1		165			
126	1	1	2	166			
127	1	7	2	167			
128							
129		2		Total	184	75	40

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 2003.

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
2003	Jan-July 6	4,092	247	0.060	5,733	1,186	0.207
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
2003	Jan-June 20	3,797	93	0.025	2,721	312	0.115

continued

Table 6 continued.

Reservoir Year	Period	Bank anglers Trips	Harvest	HPUE	Boat anglers Trips	Harvest	HPUE
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
2003	Jan-July 27	3,212	35	0.011	5,465	128	0.023

[a] *Harvest estimates exclude legally kept fish with fork lengths outside the given ranges for each reservoir. Legal size is based on total length.*

[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 2003.

Fishery	Bonneville		The Dalles		John Day		Unspecified	
Year	Guideline	Harvest	Guideline	Harvest	Guideline	Harvest	Harvest	Total
Recreational								
1991	1,350	2,270	100	199	100	150	0	2,619
1992	1,350	1,717	100	139	100	147	0	2,003
1993	1,350	2,307	100	158	100	144	0	2,609
1994	1,350	2,223	100	154	100	234	0	2,611
1995	1,350	1,370	100	50	100	53	0	1,473
1996	1,350	1,353	100	80	100	62	0	1,495
1997	1,520	1,463	200	178	560	464	0	2,105
1998	1,520	1,626	600-800	857	560	593	0	3,076
1999	1,520	1,235	600-800	695	560	422	0	2,352
2000	1,520	1,262	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
2003	1,700	1,542	400	447	165	186	0	2,175
Indian Commercial								
1991	1,250	999	300	457	100	39	0	1,495
1992	1,250	1,446	300	431	100	23	0	1,600
1993	1,250	1,415	300	579	100	12	0	2,006
1994	1,250	1,176	300	309	100	117	0	1,602
1995	1,250	1,421	300	312	100	308	0	2,041
1996	1,250	1,005	300	230	100	360	0	1,595
1997	1,300	1,852	400	498	1,160	1,260	0	3,610
1998	1,300	1,462	1,000-1,200	1,108	1,160	1,100	0	3,670
1999	1,300	1,280	1,000-1,200	1,051	1,160	760	0	3,091
2000	1,300	1,165	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
2003	1,200	379	900	811	335	251	0	1,441
Combined fisheries								
1991	2,600	3,269	400	656	200	189	0	4,114
1992	2,600	2,863	400	570	200	170	0	3,603
1993	2,600	3,722	400	737	200	156	0	4,615
1994	2,600	3,399	400	463	200	351	0	4,213
1995	2,600	2,791	400	362	200	361	0	3,514
1996	2,600	2,358	400	310	200	422	0	3,090
1997	2,820	3,315	600	676	1,720	1,724	0	5,715
1998	2,820	3,088	1,800	1,965	1,720	1,693	0	6,746
1999	2,820	2,515	1,800	1,746	1,720	1,182	0	5,443
2000	2,820	2,427	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
2003	2,900	1,921	1,300	1,258	500	437	0	3,616

Table 7. Continued.

Fishery Year	Bonneville Guideline	Bonneville Harvest	The Dalles Guideline	The Dalles Harvest	John Day Guideline	John Day Harvest	Unspecified Harvest	Total
Indian subsistence [a]								
1991		--[b]		--[b]		--[b]	--[b]	--[b]
1992		89		--[b]		--[b]	119	208
1993		146		31		30	56	263
1994		290		197		163	0	650
1995		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
2003		93		202		30	0	325

[a] *The SMTF did not establish harvest guidelines for the subsistence fishery, however, the expected annual subsistence harvest was 300 white sturgeon for 1991 through 2003.*
[b] *Not available.*

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

ANNUAL PROGRESS REPORT

APRIL 2003 – MARCH 2004

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, comparisons of egg development rates for four white sturgeon stocks, and progress on peer-reviewed publications of past work.

Prepared By:

Michael J. Parsley
Dena M. Gadomski
Pete Kofoot

U.S. Geological Survey
Western Fisheries Research Center
Columbia River Research Laboratory
Cook, Washington 98605-9701, USA

CONTENTS

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ABSTRACT

River discharge and water temperatures that occurred during April through July 2003 provided conditions suitable for spawning by white sturgeon downstream from Bonneville, The Dalles, John Day, and McNary dams. Although optimal spawning temperatures in the four tailraces occurred for less than two weeks, they coincided with a period of relatively high river discharge. Bottom-trawl sampling in Bonneville and The Dalles Reservoirs revealed the presence of young-of-the-year (YOY) white sturgeon in Bonneville Reservoir, but none were captured in The Dalles Reservoir.

A comparison of five years of indices of abundance of YOY sturgeon from sampling done by ODFW with gillnets and the USGS with bottom trawls was completed. Despite obvious differences in gear sampling characteristics (e.g. one gear is actively fished, one passively fished), it appears that either gear can be used to assess relative trends in YOY white sturgeon abundance. The analyses suffered due to poor catches of YOY fish, as YOY were only captured in The Dalles Reservoir during three of the five years of comparison sampling, and during only one of four years in John Day Reservoir. However, both gears detected the presence or absence of YOY white sturgeon within a reservoir equally. That is, if any YOY white sturgeon were captured in any year in a reservoir, both gears captured at least one fish, and if one gear failed to collect any YOY white sturgeon, both gears failed.

Concerns have been raised that the Wang et al. (1985) egg development relationships for Sacramento River white sturgeon may not be applicable to Columbia Basin stocks. However, using laboratory experiments with white sturgeon eggs incubated at 10, 12, 15, and 18^{o}C, we found no significant differences in development rates of eggs of Columbia, Kootenai, Snake, and Sacramento river fish.

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 2003 through 31 March 2004.

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 three 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 2003- Objective 1.

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

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

In addition, the USGS continued analyses of data from past research and preparation of manuscripts describing the results for submission to peer reviewed journals. Specifically, several manuscripts describing results from predation experiments conducted from 2000 - 2003 were revised after receiving comments from reviewers. Analyses were also conducted for past experiments that investigated the timing of the development of white sturgeon eggs in relation to incubation temperature. The results from this analysis are provided as an appendix to this report.

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 2003 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 and The Dalles reservoirs. The previously designed sampling program calls for conducting a total of 66 tows at 11 sites in Bonneville Reservoir (6 replicates per site) and 24 tows at 12 sites in The Dalles 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 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

[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.

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 collaborated 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. At the onset of this task in 1999, comparisons between gears were to be made from sampling with both gears in The Dalles and John Day Reservoirs. The USGS had 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. Trawling was discontinued in John Day Reservoir after 2002 after three years of zero catch of YOY with either gear. Thus, comparisons of trends in trawl versus gillnet gears will only be made for efforts in The Dalles Reservoir.

The design for this comparison called for sampling with each gear during October or November at fixed locations. Generally, sampling with gillnets was conducted after sampling was done with the bottom trawl. Young-of-the-year were 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.

Gear comparisons can be made at several levels. As described by Counihan et al. (1999) E_p – the proportion of positive tows – is best used as an indicator of relative abundance when sampling efforts result in many zero catches. Past sampling with both gears indicates that this will be the norm for YOY white sturgeon sampling programs in these reservoirs. Zero catches result when true abundance is low and is related to the efficiency of the sampling gear. The lowest level of comparison will be to determine if each gear equally detected the presence or absence of YOY white sturgeon within a reservoir. Next, regression analysis will be done to compare E_p between gears to examine correlation. The geographic distribution of YOY white sturgeon is expected to increase with increasing abundance. Because sampling with each gear was stratified along the length of each reservoir, an increase in geographic distribution of YOY should be reflected in a higher E_p. A high correlation between gears would indicate similar capability to detect increasing spatial distribution and thus abundance of YOY, whereas a low correlation would indicate poor concurrence between gears.

RESULTS AND DISCUSSION

Availability of Spawning Habitat Downstream from Bonneville, The Dalles, John Day, and McNary Dams

River discharge and water temperatures that occurred during April through July 2003 provided conditions suitable for spawning by white sturgeon downstream from Bonneville, The Dalles, John Day, and McNary dams. The river hydrograph (Figure 1) shows that daily discharge peaked at 10 kcms at each dam between 30 May 30 and 1 June. 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 24 May in the Bonneville and The Dalles Dam tailraces, 27 May in the John Day tailrace, and 29 May in the McNary Dam tailrace (Figure 2). The optimal spawning period was relatively short, with temperatures exceeding optimum levels (15.2^{o}C) 11-13 days later in each tailrace. Thus optimal spawning temperatures in the four tailraces occurred for less than two weeks but this period of optimal temperatures coincided with the 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 May at levels slightly lower than the average of past years (Figure 3).

Annual indices of spawning habitat allow comparisons of conditions among years. The annual index of spawning habitat for each tailrace was slightly less than the median value for all years in all tailraces (Figure 4).

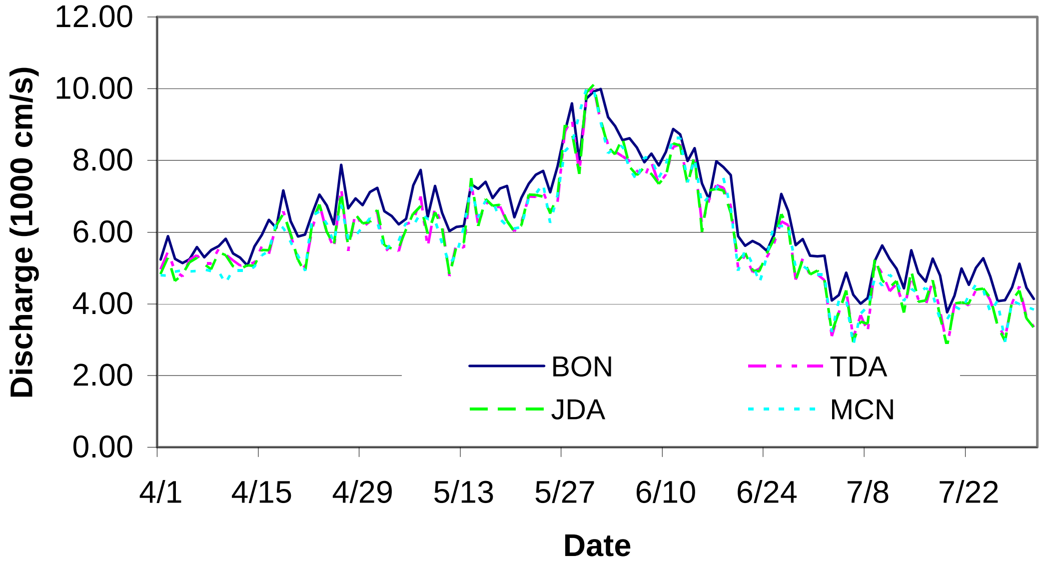


Figure 1. River discharges at Bonneville (BON), The Dalles (TDA), John Day (JDA), and McNary (MCN) dams during 2003. Data were obtained from the DART website (http:\\www.cqs.washington.edu\dart\).

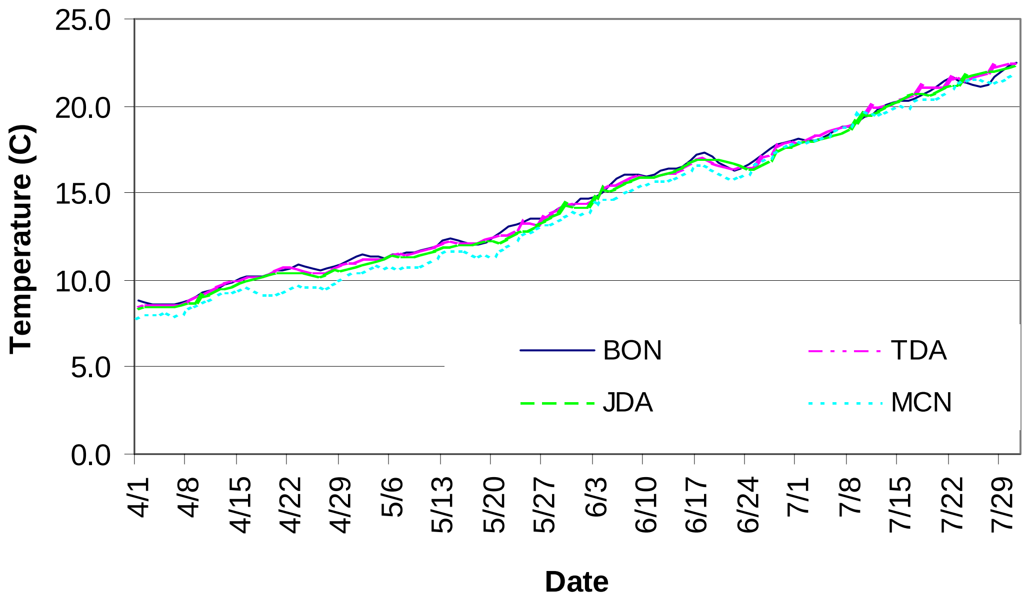


Figure 2. Water temperatures at Bonneville (BON), The Dalles (TDA), John Day (JDA), and McNary (MCN) dams during 2003. Data were obtained from the DART website (http:\\www.cqs.washington.edu\dart\). Optimal temperatures for white sturgeon spawning range from about 13° – 15° C.

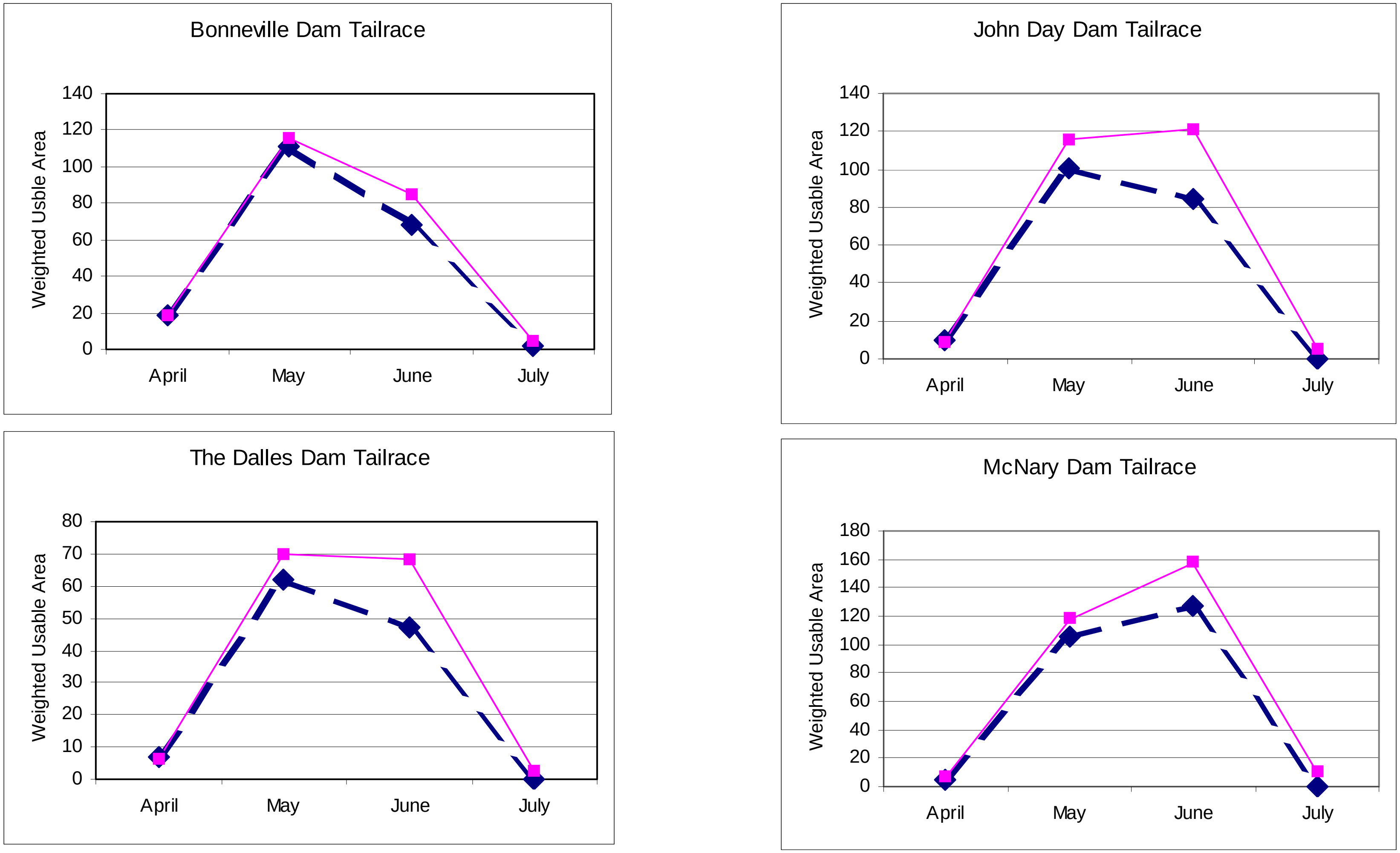


Figure 3. Dashed lines depict mean monthly indices of spawning habitat (temperature conditioned weighted usable area (WUA)) for white sturgeon during 2003. Solid lines depict the average mean monthly index for each month during 1985-2002. Note that the scale differs on the Y-Axis among graphs.

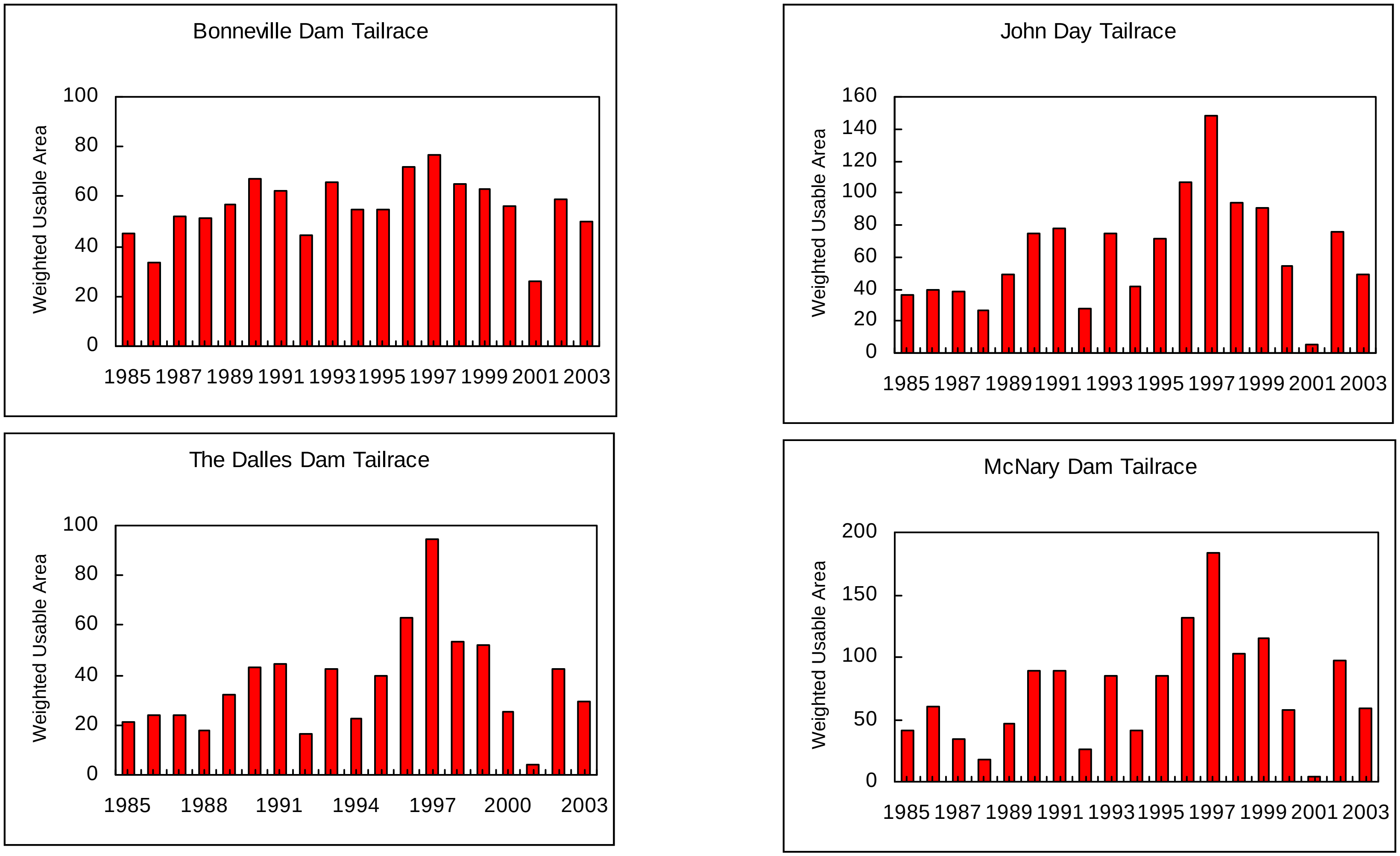


Figure 4. Annual mean composite indices of spawning habitat (temperature conditioned weighted usable area (WUA)) for white sturgeon for each of the four dam tailraces that have been modeled (Parsley and Beckman 1994). Note that the scale differs on the Y-axis among graphs.

Young-of-the-Year Indexing

The bottom-trawl sampling program was completed as scheduled during 2003. We fished the bottom trawl on 12 days from 15 September to 30 September in Bonneville Reservoir, and on 4 days from 6 October to 10 October in The Dalles Reservoir. There were no delays due to adverse weather conditions. 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 trawled. No nets were lost while sampling this year, although several nets required extensive work to repair tears and holes.

Bonneville Reservoir

Recruitment of young-of-the-year white sturgeon occurred in Bonneville Reservoir in 2003. We captured 26 juvenile white sturgeon with the high-rise trawl during our sampling of Bonneville Reservoir, and 7 (27%) of these were YOY. Young-of-the-year white sturgeon were captured at 3 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 185 to 259 mm TL and weighed 24 to 68 g. The mean length of YOY captured was 207 mm TL and mean weight was 37 g. Older juvenile white sturgeon were captured at 6 of the 11 sites (Table 1). The older juvenile white sturgeon measured 392 to 676 mm FL and weighed 250 to 1,240 g.

The CPUE for combined effort at each of the 11 sites sampled with the bottom trawl in Bonneville Reservoir ranged from 0.0 to 0.73 YOY per 2,500 m^2 and from 0.0 to 2.53 fish per 2,500m^2 for all white sturgeon caught (Table 1). The mean CPUE for all sites was 0.12 YOY per 2,500 m^2 (SE = 0.07) and 0.43 fish per 2,500m^2 (SE = 0.23) for all juvenile white sturgeon. The proportion of positive tows for YOY white sturgeon during 2003 for Bonneville Reservoir was 0.09.

Trawl catches in Bonneville Reservoir were dominated by sand rollers, followed by juvenile American shad and prickly sculpin (Table 2).

Table 1. Characteristics of bottom trawling conducted to index recruitment of white sturgeon in Bonneville Reservoir during 15 September to 30 September 2003. 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
15052	6	1.3582	0	0	0.0	0.0
15734	6	1.3460	1	0	0.19	0.0
15951	6	1.3825	3	2	0.54	0.36
16522	6	1.3468	0	0	0.0	0.0
16851	6	1.3454	1	0	0.19	0.0
17063	6	1.3789	6	4	1.08	0.73
17374	6	1.3150	0	0	0.00	0.0
17652	6	1.3503	1	0	0.19	0.0
17911	6	1.3519	0	0	0.0	0.0
18351	6	1.3849	14	1	2.53	0.18
18523	6	1.3488	0	0	0.0	0.0
Totals	66	14.9087	26	7		

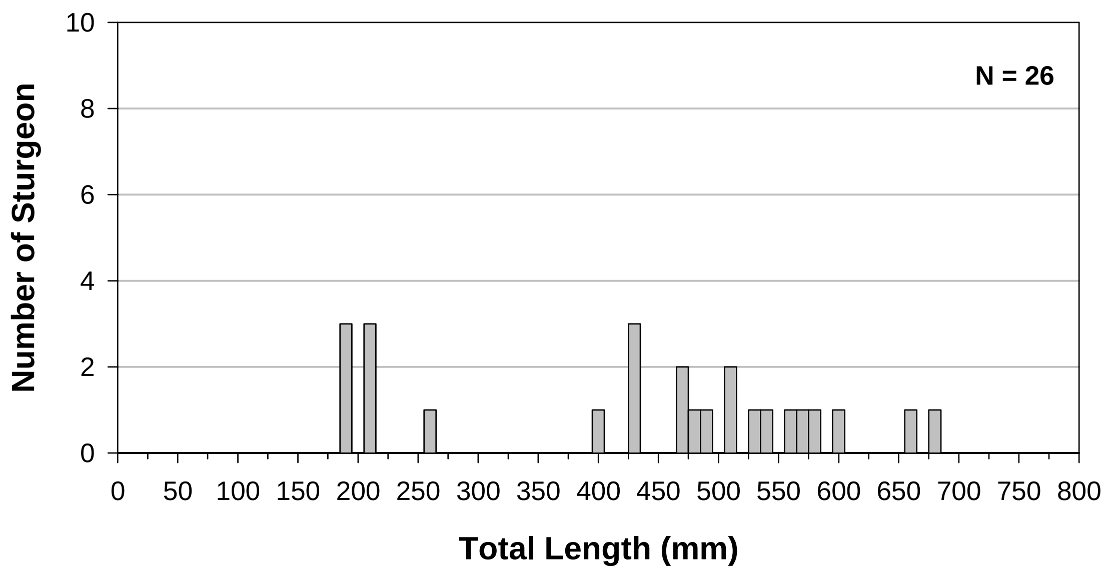


Figure 5. Length frequency of white sturgeon collected during bottom trawling in Bonneville Reservoir from 15 September to 30 September.

Table 2. Number of fish caught in bottom trawls in Bonneville and The Dalles reservoirs during fall sampling in 2003.

Common name	Scientific name	Bonneville Reservoir	The Dalles Reservoir
White sturgeon	*Acipenser transmontanus*	26	
American shad	*Alosa sapidissima*	393	929
Northern pikeminnow	*Ptychocheilus oregonensis*	10	
Redside shiner	*Richardsonius balteatus*	1	
Peamouth	*Mylocheilus caurinus*	20	2
Largescale sucker	*Catostomus macrocheilus*		2
Bridgelip sucker	*Catostomus columbianus*	3	
Channel catfish	*Ictalurus punctatus*	2	
Sand roller	*Percopsis transmontana*	708	
Smallmouth bass	*Micropterus dolomieui*	1	3
Crappie	*Pomoxis spp.*		1
Sunfish	*Lepomis spp.*	1	
Yellow perch	*Perca flavescens*		1
Walleye	*Sander vitreus*	2	1
Prickly sculpin	*Cottus asper*	272	10

The Dalles Reservoir

No white sturgeon were captured during bottom trawl sampling in The Dalles Reservoir. Catches in The Dalles Reservoir were dominated by American shad (Table 2 and 3). It is interesting to note that some species captured in Bonneville Reservoir were entirely absent or substantially reduced in number in the trawl catch from The Dalles Reservoir. This indicates that fish community dynamics among reservoirs differs markedly, which may influence growth, condition, and other population characteristics of white sturgeon residing in the reservoirs.

Table 3. Characteristics of bottom trawling conducted to index recruitment of white sturgeon in The Dalles Reservoir during 6 October to 10 October 2003.

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
19463	2	0.4535	0	0	0.0	0.0
19683	2	0.4484	0	0	0.0	0.0
19981	2	0.4510	0	0	0.0	0.0
20012	2	0.4471	0	0	0.0	0.0
20244	2	0.4502	0	0	0.0	0.0
20432	2	0.4438	0	0	0.0	0.0
20451	2	0.4472	0	0	0.0	0.0
20651	2	0.4470	0	0	0.0	0.0
20752	2	0.4489	0	0	0.0	0.0
21014	2	0.4610	0	0	0.0	0.0
21103	2	0.4464	0	0	0.0	0.0
21412	2	0.4459	0	0	0.0	0.0
Totals	24	5.3904	0	0		

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

Sampling during 2003 by ODFW and USGS provided the fifth year of data from The Dalles Reservoir to be used for comparing indices of abundance derived from gillnet and bottom trawl catches. Sampling in John Day Reservoir was discontinued after 2002 when it became apparent that catches would be insufficient for comparisons between the two gears. In 2003 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. Indices of abundance for YOY white sturgeon were calculated and indices from all years are presented in Table 5.

Young-of-the-year white sturgeon were only captured in The Dalles Reservoir during three of the five years of comparison sampling, and during only one of four years in John Day Reservoir. Hydrologic and environmental conditions, expressed as indices of spawning habitat in Figures 3 and 4, were quite variable during this period. At the lowest level of comparison, both gears detected the presence or absence of YOY white sturgeon within a reservoir equally.

That is, if any YOY white sturgeon were captured in any year in a reservoir, both gears captured at least one fish, and if one gear failed to collect any YOY white sturgeon, both gears failed.

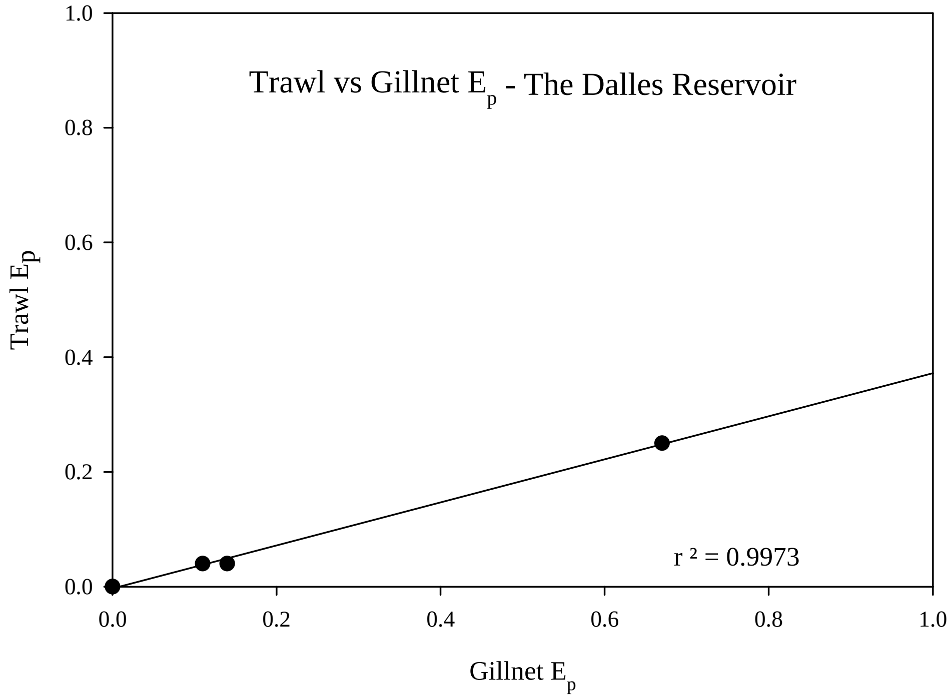
In this spatially stratified sampling program, as numbers of individuals increase, E_p would theoretically increase to maximum value equal to or less than 1.0. Regression analysis showed high positive correlation (r^2 = 0.997) between gears fished in The Dalles Reservoir, indicating that both gears discerned relative increases in abundance (Figure 6). Catches from John Day Reservoir were insufficient for regression analysis. This is unfortunate, as a comparison of the sampling programs and abilities of each gear to detect differences in relative abundance in different reservoirs cannot be made. Had catches in John Day Reservoir been sufficient for analysis, a comparison of the slopes of the two regression lines may have provided insight on the relative efficiency of the individual gears. It is obvious that the intercepts would have been identical but it is unknown if the relation between gillnet and trawl E_p is similar among areas. This precludes any adjustments to past indices derived from bottom trawl data for comparison with current gillnet indices.

Despite obvious differences in gear sampling characteristics (e.g. one gear is actively fished, one passively fished), it appears that either gear can be used to assess relative trends in abundance. Scientists need to consider applicability of each gear and ease of use. The trawl is actively fished for 10 min, whereas the gillnet is passively fished for about 24 hours. The trawl, as fished in this study, requires relatively long stretches with suitable bottom topography. Gillnets can be fished in many areas where current velocities are not excessive, and also have some limitations in areas with excessive bottom topography. Fishing a bottom trawl requires a specialized vessel and a crew with experience in trawling, whereas gillnets can be fished from a variety of non-specialized vessels with a competent crew. That is, the learning curve for implementing a sampling program for gillnetting is less steep and potentially less costly than for bottom trawling.

Ideally, a gear used in a single-species assessment program would provide catches useful for biological sampling as well as for indexing abundance. E_p and CPUE were higher for sampling done with gillnets than trawls, indicating a greater probability of encountering more fish when sampling with gillnets than with trawls. However, bottom trawl sampling does appear to provide more information on fish community composition than the species and size selective gillnets.

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. Sampling was discontinued in John Day Reservoir after 2002 when it became apparent that catches would not permit comparisons of trends between the two gears during the 5-year duration of the work.

	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
2003	12	12	36	24	0.00	0.00	0.00	0.00
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



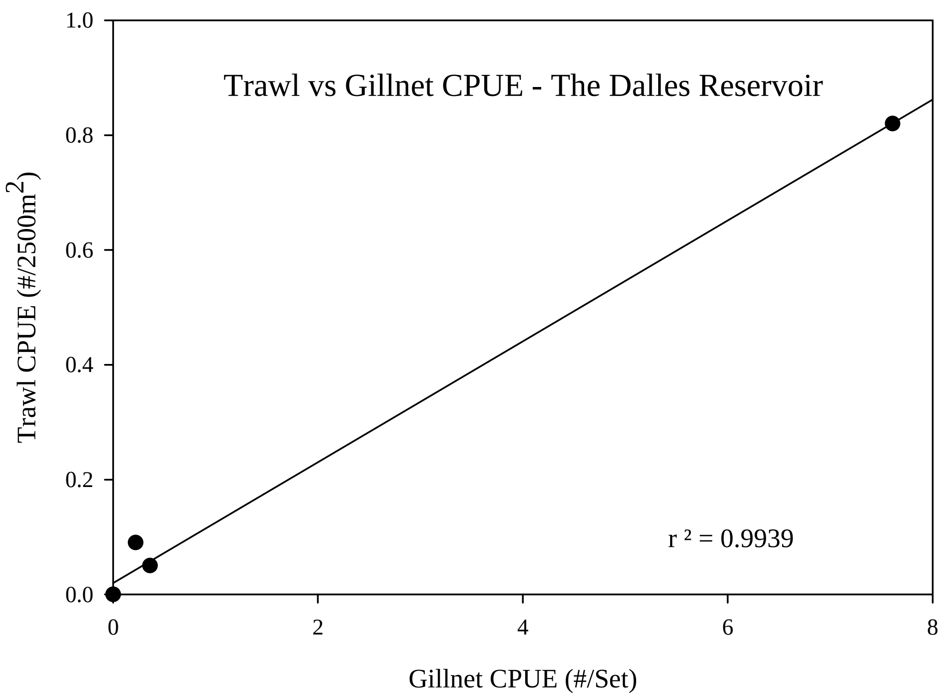


Figure 6. Comparisons of age-0 white sturgeon catch statistics from overnight gillnet sets and10 min bottom trawl tows.

Progress on Publishing Manuscripts

Two manuscripts were submitted to scientific journals for publication during this performance period. These are currently under review, and we expect to receive comments during 2005. One manuscript on laboratory studies on the vulnerability of young white sturgeon to predation was submitted to the North American Journal of Fisheries Management. A manuscript describing laboratory studies to examine the effects of turbidity, light level, and cover on predation on white sturgeon by prickly sculpins was submitted to the Transactions of the American Fisheries Society.

Plans for 2004

During 2004, the USGS will conduct bottom trawling only in Bonneville Reservoir. The USGS will also evaluate the availability of spawning habitat during 2004 as determined by river discharge and water temperature, and will continue working on manuscripts describing results obtained in previous years.

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APPENDIX C-1

Comparison of the Development Rates of White Sturgeon Eggs from Brood Stocks from the Columbia, Kootenai, Snake, and Sacramento Rivers

Dena M. Gadomski and Michael J. Parsley
U.S. Geological Survey
Western Fisheries Research Center, Columbia River Research Laboratory
5501A Cook-Underwood Road, Cook, WA 98605

Introduction

Staging and estimates of fertilization times of field collected white sturgeon eggs is common throughout the Columbia River Basin. Egg development rates are based on work by Wang et al. (1985) using white sturgeon from the Sacramento River. However, while it is well-known that rates of egg development are species specific, differences in development between stocks or populations of the same species may also occur and are important to consider (Beacham et al. 1988; Beacham and Murray 1989). Concerns have been raised that the Wang et al. (1985) relations may not be applicable to Columbia Basin stocks because of differences due to geography, because the relationships were developed from work using eggs obtained from only a single female, and finally, estimates of variance were not given. To address these concerns, we conducted a series of laboratory experiments to determine if egg development rates for white sturgeon differ among stocks from the Columbia, Kootenai, Snake, and Sacramento rivers. Furthermore, we conducted trials at a range of temperatures because rates of development of fish eggs are strongly dependent on temperature (Haynes and Ignell 1983; Wang et al. 1985; Gadomski and Caddell 1995).

Methods

We incubated white sturgeon eggs taken from brood stocks obtained with set lines or gill nets in the Columbia, Kootenai, and Snake rivers during June and July of 1997, 1998, and 1999. Information concerning the development of white sturgeon eggs from brood stocks from the Sacramento River is published in Wang et al. (1985). Eggs were incubated from fertilization to hatching at the Columbia River Research Laboratory (CRRL) in Cook, Washington, the Kootenai Tribal Experimental Hatchery (KTEH) in Bonners Ferry, Idaho, and the University of Idaho Hagerman Fish Culture Experiment Station (HFCES) in Hagerman, Idaho. Eggs were not incubated from each brood stock source each year; the facility where experiments were performed varied with brood stock source, and different temperature regimes were used for different brood stocks (Table 1).

Table 1. White sturgeon brood stock origin, the location of the experiment, the years it was conducted, the temperature of incubation, the number of jars per temperature, and eggs per jar.

Broodstock origin	Columbia River	Kootenai River	Snake River
Experiment Location	Columbia River Research Laboratory (CRRL) Cook , Washington	Kootenai Tribal Experimental Hatchery (KTEH) Bonners Ferry, Idaho	University of Idaho Hagerman Fish Culture Experiment Station (HFCES) Hagerman, Idaho
Year, no. jars, no. eggs, and incubated temperature	1998- 1 jar 12,000 @ 12°C 1998- 1 jar 10,000 @15°C 1998- 1 jar 8,000 @ 18°C	1997- 1 jar 10,000 @ 15°C 1997- 1 jar 10,000 @ 18°C 1998- 1 jar 12,000 @ 12 C 1998- 1 jar 3,200 @ 15°C 1999- 2 jars 10,000 ea.@ 10°C	1997- 2 jars 3,000 ea. @ 15°C

Experiments began during the normal spawning season, June, and at a temperature at which normal spawning would occur for white sturgeon. Gamete collection, insemination, de-adhesion, and incubation followed procedures described in Conte et al. (1988). Females were induced to spawn with injections of luteinizing hormone releasing hormone (LHRH). After fertilization and de-adhesion, eggs were placed in MacDonald jars. The eggs were then gradually transitioned from the ambient hatchery water temperature to the experimental incubation temperatures by incremental addition of progressively warmer or cooler (1° C 10 min^{-1}) water. At HFCES and KTEH, gamete collection, insemination, de-adhesion, and incubation occurred at the same facility. At the CRRL, gamete collection occurred at a commercial sturgeon spawning operation (Pelfrey's Sturgeon Hatchery) in Troutdale, Oregon. Eggs were then transported to the CRRL as per Conte et. al. (1988) where insemination, de-adhesion, and incubation occurred. At CRRL and KTEH, each MacDonald jar received water from heated recirculation tanks equipped with one or two 1000 W thermostatically controlled heaters, an ultraviolet (UV) sterilizer and a submerged pump. Fresh water of the specified temperature (10°, 12°, 15°, or 18° C) flushed through the tank at 0.5 l min^{-1}. At the HFCES, eggs were incubated at ambient hatchery water temperature (15° C). Thus, the water did not require heating, was continuously replaced with fresh water, and did not pass through sterilization units. During egg development, samples were taken every 15 min for the first 8 h, every 30 min between 8 and 24 h, and every 2 h after the first 24 h until most eggs had hatched. Eggs were collected from the MacDonald jars at each prescribed time interval by drawing up ten or more eggs with a large pipette. Samples were preserved in a solution of 10% unbuffered formalin. Preserved eggs were then examined under a dissecting microscope and assigned a development stage using classifications developed by Beer (1981)--Egg stage 12: fertilized egg, 13: first cleavage, 14: second cleavage, 15: third cleavage, 16: fourth through sixth cleavage, 17: late cleavage, 18: early epithelial, 19: late epithelial, 20: involution (early gastrulation), 21: large yolk plug, 22: small yolk plug, 23: early neurulation, 24: closure of the neural tube, 25: elongation of the pronephros, 26: formation of the heart, 27: pre-hatch.

Analysis

Comparison I: Columbia, Kootenai, and Snake Rivers

For Columbia, Kootenai, and Snake river stocks, the relationships between egg stages 12-27 and hours after fertilization for 50% of sampled eggs to reach each egg stage (the dependent variable) were examined. Hours were regressed on stage (SAS Institute, Inc., 1999-2000; REG procedures) to determine if replicates differed and if, at a temperature, stocks differed in development rate (the regression slopes).

To illustrate the variability in the time it took for eggs to reach an egg stage in our experiments, 95% confidence intervals were calculated for eggs incubated in 1997; i.e., for each stock, temperature, and egg stage, there is a 95% probability that the true mean development time (hours after fertilization) falls within this time interval (hours) (SAS MEANS procedures).

Comparisons II, III, and IV: Columbia, Kootenai, Snake, and Sacramento Rivers

We compared development rates for Columbia, Kootenai, and Snake river stocks to four temperatures used by Wang (1985) for Sacramento River white sturgeon – 11, 14, 17, and 20^{o}C. However, only four egg stages were similar between Wang and the egg staging system used for other stocks: I) third cleavage (stage 15); II) involution (early gastrulation, stage 20); III) closure of the neural tube (stage 24); and IV) formation of the heart (stage 26). SAS GLM procedures were used with stock as a class and stage a covariate to compare if there were significant differences in timing of egg development (hours after fertilization) due to stock at each temperature.

Results

Comparison I: Columbia, Kootenai, and Snake Rivers

The relationship between hours after fertilization and egg stage was exponential (Figure 1). Replicated jars for a stock and temperature were not significantly different and were combined ($P > 0.05$). Furthermore, for each temperature (12, 15, and 18^{o}C), there were no significant differences ($P > 0.05$) between stocks for the slope of ln (hours after fertilization) regressed on egg stage. Egg development at 10^{o}C was only examined for white sturgeon from the Kootenai River (Table 1), and there was no significant difference between the two jars. Actual mean values are presented in Table 2.

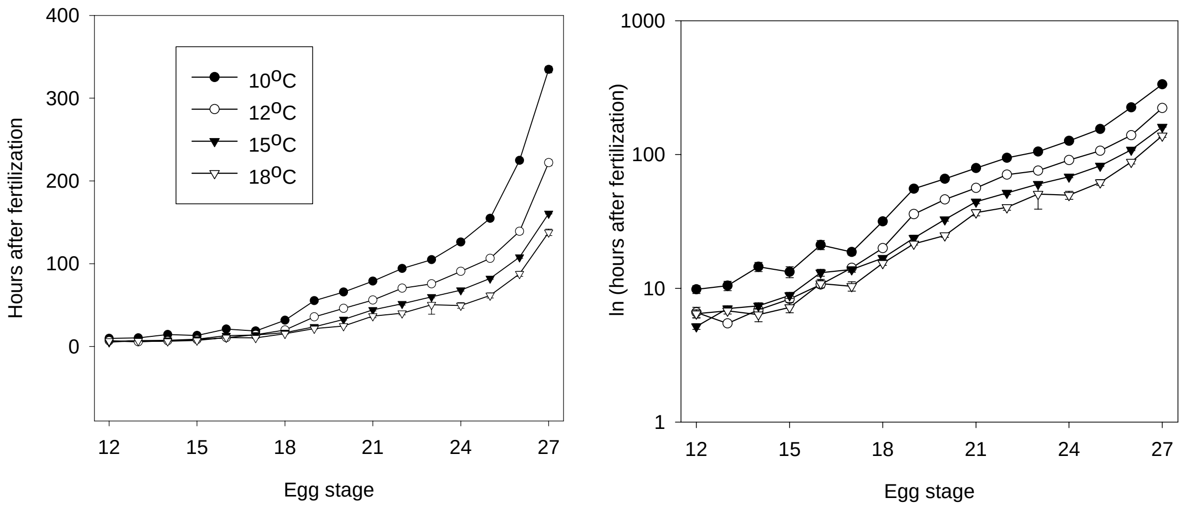

Figure 1. Mean white sturgeon egg development rates at 10, 12, 15, and 18°C for Columbia, Kootenai, and Snake river fish.

Table 2. Hours after fertilization for 50% of sampled white sturgeon eggs to reach stages 12 through 27 at four temperatures. Values are means of eggs from Columbia, Kootenai, and Snake river fish.

	Temperature			
Egg stage	10°C	12°C	15°C	18°C
12: fertilized egg	9.8	6.6	5.2	6.5
13: first cleavage	10.5	5.5	7.0	6.8
14: second cleavage	14.5	6.9	7.4	6.3
15: third cleavage	13.3	8.3	8.8	7.2
16: fourth through sixth cleavage	21.1	10.7	13.1	10.9
17: late cleavage	18.7	14.2	13.8	10.4
18: early epithelial	31.6	19.9	16.8	15.4
19: late epithelia	55.4	35.8	23.8	21.5
20: involution (early gastrulation)	65.8	46.0	32.7	24.8
21: large yolk plug	78.9	56.1	44.3	36.8
22: small yolk plug	94.2	70.5	51.6	40.2
23: early neurulation	104.8	75.5	60.0	50.5
24: closure of the neural tube	126.2	90.7	68.1	49.5
25: elongation of the pronephros	154.8	106.5	82.2	61.7
26: formation of the heart	224.6	139.1	108.0	87.7
27: pre-hatch	334.6	221.9	160.6	137.9

The evaluations above are based the on the time after fertilization when 50% of sampled eggs reached an egg stage. However, this does not take into account the variability of development times. Therefore, we calculated 95% confidence intervals for the times (hours after fertilization) it took for eggs to reach each stage during 1997 (Figure 2).

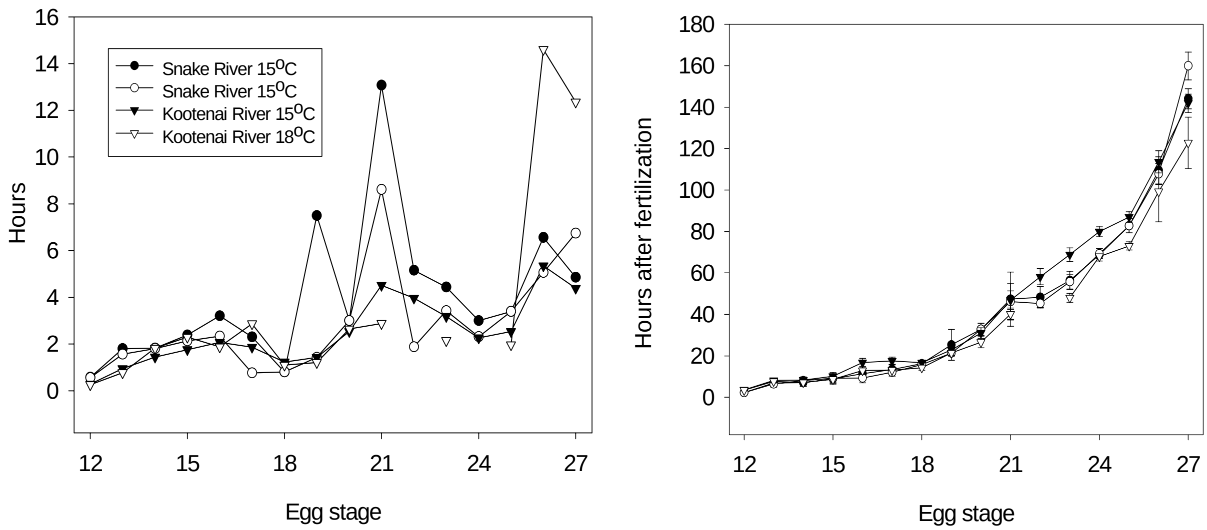

Figure 2. 95% confidence intervals (CI) for mean development times of eggs incubated in 1997. Both actual CI hours (left) and CI hours in relation to the entire development period (right; vertical bars) are presented.

As eggs developed, confidence intervals also increased somewhat (Figure 2). However, excluding the five greatest values, the mean confidence interval was 2.51 h (SE 1.55 h, N = 57), which is only about 2% of time of development to egg stage 27.

Comparison 2: Sacramento River 14°C, and Three Other Stocks 15°C

Our primary temperature comparison was 14-15°C because all four stocks had eggs incubated at this temperature. Replicates were not significantly different ($P > 0.05$), and means were used in the analysis. There was a significant ($P < 0.05$) overall difference in egg development due to stock, with no significant difference between Kootenai, Snake, and Sacramento rivers and between Columbia, Kootenai, and Snake rivers (Figure 3).

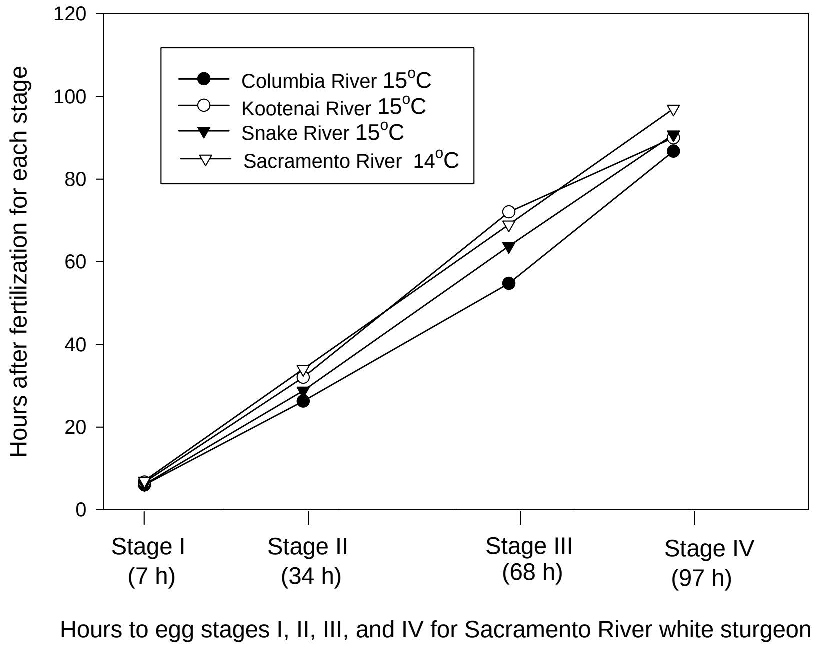

Figure 3. White sturgeon egg development at 14 or 15°C for Columbia, Kootenai, Snake, and Sacramento river fish. See "Analysis" section for descriptions of egg stages. At each temperature and for each stock, time after fertilization for 50% of sampled eggs to reach each of the four egg stages was regressed on time for Sacramento River fish to reach each egg stage. Eggs of white sturgeon from the Sacramento River hatched at 165 h.

Comparison 3: Columbia River 12°C; Kootenai River 10, 12°C; and Sacramento River 11°C

Replicates were not significantly different ($P > 0.05$), and means were used. There was a significant ($P < 0.05$) overall difference in egg development due to stock, with no significant difference between Columbia River 12°C, Kootenai River 12°C, and Sacramento River 11°C ; but these significantly differed ($P < 0.05$) from Kootenai River at 10°C (Figure 4).

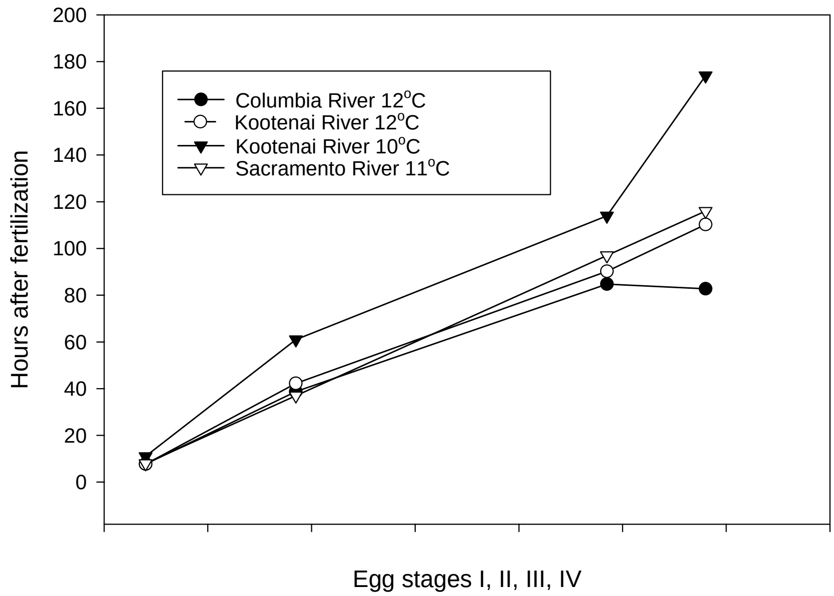

Figure 4. White sturgeon egg development at 10, 11, or 12°C for Columbia, Kootenai, and Sacramento river fish.

Comparison 4: Columbia River 18°C; Kootenai River 18°C; and Sacramento River 17°C

There was no significant ($P > 0.05$) difference in egg development due to stock (Figure 5).

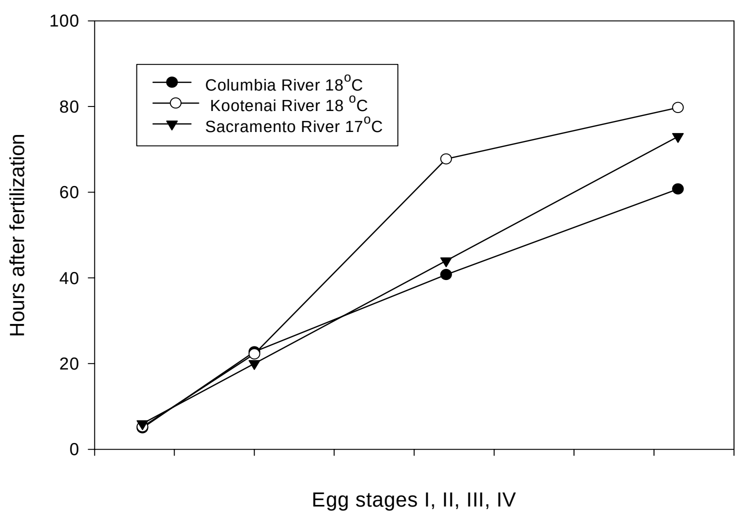

Figure 5. White sturgeon egg development at 17 or 18°C for Columbia, Kootenai, and Sacramento river fish.

Conclusions

Development rates of eggs of Columbia, Kootenai, and Snake river white sturgeon were compared at 15°C for stages 12-27, and no significant difference was found between stocks. There were also no differences between Columbia and Kootenai river stocks at 12°C and 18°C. During 1997, most stages had confidence intervals of less than 3 hours, which is fairly narrow. The large confidence intervals that occurred in a few instances may have been due to experimental error. Another factor that would affect confidence intervals is the variability in the number of eggs sampled at each time interval.

There were few significant differences in the rates of egg development between white sturgeon stocks from the Columbia, Kootenai, Snake, and Sacramento rivers within a similar temperature range. At the coldest temperature range tested, 10-12°C, one group of eggs from the Kootenai River developed at a significantly slower rate, but these were at the lower range of these temperatures, 10°C. Thus it would appear that the exponential relationship between temperature and development rates determined by Wang et al. (1985) could be used for white sturgeon stocks from other river systems within the overall range of tested temperatures, 12-18°C, and for egg stages 15, 20, 24, and 26.

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

ANNUAL PROGRESS REPORT

APRIL 2003 – MARCH 2004

Report D

Developing, implementing, and evaluating 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, the release of white sturgeon from past propagation efforts, and the results of efforts to capture and mark white sturgeon in Bonneville Reservoir for population abundance estimates.

Prepared by:
Kevin Kappenman
Blaine L. Parker

Columbia River Inter-Tribal Fish Commission

729 NE Oregon Street, Suite 200

Portland, Oregon 97232, USA

CONTENTS

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We offer our appreciation and thanks to Yakama Nation fishery technicians Alvin McConnville, Chuck Gardee, and James Kiona, commercial fishermen Robert Brigham, Mathew McConville, Greg George and their crew members, and Oregon Department of Fish and Wildlife staff for their efforts in conducting the mark and recapture operations in Bonneville Reservoir and marking of hatchery reared white sturgeon. We also thank Columbia River Inter-Tribal Fish Commission fishery technician Clifford Alexander, Dr. Molly Webb of Oregon State University, Joel Van Eenennaam of University of California at Davis, Washington Department of Fish and Wildlife technicians Robert Morgan, and United States 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 United States Army Corps of Engineer's Biologist Brad Eby 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. Thanks to National Marine Fisheries Service Pit Tagging crews for tagging and marking juvenile white sturgeon for release into Rock Island Reservoir. We also thank Robert Becker of ODFW and staff at Chelan County Public Utility District for their efforts in coordinating and releasing the hatchery white sturgeon.

ABSTRACT

During five weeks of set line fishing for white sturgeon broodstock from March 9 – May 10 2003 in McNary Reservoir and two weeks set line fishing from May 12 – May 22 2003 in Bonneville Reservoir, we collected 3 females and 17 males. The McNary Reservoir effort consisted of 142 sets capturing a total of 149 white sturgeon. The Bonneville Reservoir setline effort will be reported by Oregon Department of Fish and Wildlife (ODFW) in section A of this report. One female was taken from Bonneville Reservoir; the remaining fish were taken from McNary Reservoir. All fish were held at the McNary spawning facility.

A cooperative effort by Columbia River Inter-Tribal Fish Commission (CRITFC), United States Fish and Wildlife Service (USFWS), and ODFW released 12,000 pit tagged and scute marked young of year (YOY) and 8600 scute marked 1+ hatchery reared white sturgeon into Rock Island Reservoir. A second unplanned release of 48,000 YOY into the Willamette River followed a reduction in funding of hatchery operations.

Columbia River Inter-Tribal Fish Commission's mark and tagging operations for the Bonneville Reservoir population survey from 2 December 2002 through 4 January 2003 resulted in marking 2996 white sturgeon with the 10th left scute removal pattern and PIT tagging 2184 of these fish. A total of 2996 white sturgeon were captured in 629 gillnet sets in 4 weekly fishing periods from 3 December 2002 through 25 January 2003. ODFW 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 2003 through 31 March 2004 performed to meet objectives of Bonneville Power Administration (BPA) tasks outlined under project 198605000. The primary objectives for CRITFC under this project were to perform management activities and 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) Mark, pit tag, and release hatchery reared white sturgeon into Rock Island Reservoir.
3) Capture and mark/tag approximately 3000 white sturgeon in Bonneville Reservoir for a population survey.
4) Provide assistance to cooperating agencies in conducting young-of-year (YOY) surveys in selected Columbia River and Snake River reservoirs.
5) Sample Zone 6 tribal commercial and subsistence fishery and work jointly with ODFW and Washington Department of Fish and Wildlife (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, WDFW will report the results of the harvest and exploitation rates, and ODFW will report YOY surveys in their respective sections of this report.

METHODS

Artificial Propagation Research

Broodstock Collection

A joint crew from CRITFC and WDFW fished for white sturgeon broodstock in McNary Reservoir in the Columbia River (Figure 1) from March 9 2003 through 10 May 2003. All fishing during this period took place in McNary Reservoir from about statute river kilometer (Rkm) 473 to 485 or river mile (RM) 294 to 301. A second crew from ODFW and CRITFC performed set line and gillnet fishing from May 12 2002 through May 22 2002 in Bonneville Reservoir, specifically in the area just downstream of The Dalles Dam (Rkm 309 or RM 192) commonly referred to as the "Bucket" or "Cul-de-Sac" area. This second effort to collect broodstock was coordinated with ODFW and was considered part of The Bonneville Reservoir population survey effort, it was performed as a combined effort to capture broodstock and improve the estimate for oversize white sturgeon in this reservoir (ODFW, section A this report). The McNary effort consisted only of set line fishing while the Bonneville effort used both gillnets and set lines. Gill net sets were fished directly on the bottom and were performed for 1-2 hour per set during daylight hours only. Gillnets were approximately 50 m in length, 3.8 m deep, and 20.5 cm webbing. Setlines were 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 total length (TL)), placed on the deck with water flushed through the gills via an electric pump. After running a set line, 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

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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 in all but one case 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. In the single case that differed from this protocol a white sturgeon was held in the broodstock trailer overnight with a water source from The Dalles Dam to supply fresh water. Unfortunately, this deviation from protocol caused the only known broodstock holding mortality to date for this program. It was later determined that inadequate oxygen due to the water sources well origin was the cause of the mortality.

Fishing in McNary Reservoir began in early March 2003 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 until conditions improved. Generally 6-9 setlines were set each day depending on catch rates. Fishing in McNary was scheduled to occur until broodstock harvest was completed or opportunities to fish were no longer available due to other project commitments.

Satellite Spawning and Holding Facility Operations

All broodstock were held at the temporary spawning facility located below the McNary Dam 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 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 originates 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 maturation and spawning

Upon surgical examination and transportation to the holding facility all broodstock were kept at ambient river temperatures and monitored for sexual maturation. All holding, maturation, and spawning techniques for white sturgeon used are described in Conte et al. (1988) and Van Eenennam et al. (2001). Hand stripping procedures are used for removing male and female gametes during spawning rather than surgical operations due to the low number of fertilized eggs needed for our operations and reduced stress on fish. During maturation, males require less intensive monitoring than females. For males, the degree of maturation was subjectively ranked during the initial examination of gonad development. Later, males were randomly chosen in lots for spawning trials. Female maturation is determined using standard maturation assays performed on ovarian follicles (Conte et. al. 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 have attempted to spawn females outside these parameters, but success of these operations was improbable, and the primary impetus behind these attempts was to increase our knowledge of white sturgeon maturation.

Marking, Tagging and Release of hatchery reared White Sturgeon

In April 2003 CRITFC and USFWS held approximately 23,000 juvenile white sturgeon at Abernathy Fish Technology Center (AFTC). These fish were a combination of progeny from a 2002 broodstock pairing of a lower Bonneville Reservoir female with four McNary Reservoir males and the purchase of larvae from a private aqua culturist that were progeny of a single pairing of two below Bonneville Reservoir white sturgeon (Kappenman and Parker, 2002). We contracted with National Marine Fisheries Service (NMFS) salmon pit tagging crews to perform pit tagging operations for the white sturgeon hatchery release. Tagging operations were modified to accommodate white sturgeon and program needs. Pit tagging crews began tagging juveniles on 14 April and tagging was completed by 25 April. Pit tagging operations included pit tagging, scute marking, length, weight and physical observations. The scute mark application pattern included the removal of the 2^{nd} left to signify a pit tag had been applied, the 10^{th} left to signify the April 2003 release, and the 3^{rd} left to signify hatchery released fish. These twelve thousand young-of-year (9 months) white sturgeon ranging from 199 – 303 mm fork length (FL) were released in Rock Island Reservoir the week of April 28 to May 1. One tanker truck carried two loads with each round trip taking two days. Fish were released at an unnamed ramp downstream of Rocky Reach Dam near the visitor center.

This site provided white sturgeon a deep holding and acclimatization pool just downstream of the ramp.

The additional 8600 + juveniles were originally scheduled to remain at Abernathy for future releases as 1+ and 2+ aged fish in 2004-05. Budget re-alignments in 2003-04 altered those plans. A cooperative effort between CRITFC, ODFW and USFWS scute marked the remaining 8600 (approximately) 1+ (13 months) juvenile white sturgeon held at Abernathy Fish Technology Center. These fish ranged in size from 49 to 448 mm FL. Pit tags were not applied to these fish due to funding changes, fish were scute marked with the removal pattern of 3rd left and 10th right to indicate the September 2003 hatchery release. These fish were transported and released at the same site as the previous release into Rock Island Reservoir the week of September 22 – 26 in two trips via an ODFW transport truck.

In late June of 2004, prior to changes in funding structure, CRITFC purchased approximately 48,000 white sturgeon larvae from a private aquaculture facility to ensure sufficient number of juveniles for future project release plans. These larvae were spawned from a single pairing of wild broodstock white sturgeon collected below Bonneville Dam. These fish were held and reared at AFTC until October 2003. When budget changes were initiated leaving no money for hatchery operations, CRITFC released the remaining 48,000 + YOY (3 months) juveniles into the Willamette River unmarked the first week in October. Because of their small size approximately (55 - 85 mm TL), no scute mark pattern was used to differentiate these fish from wild fish and no future evaluation is planned for this release. CRITFC released these fish at two locations, the Harrisburg boat ramp and downstream from Island Park (Springfield, OR) using the broodstock truck and trailer tank to transport the fish. White Sturgeon spawning is believed to be rare in the upper Willamette River, but there was a minor risk that these 48,000 fish may affect the genetic diversity of white sturgeon in the Willamette River if they survive to spawning size (72 inches at age >25 years; Table 1).

Bonneville Reservoir Population Survey

Capture, Mark and Pit Tagging

Columbia River Inter-Tribal Fish Commission captured, marked, and tagged white sturgeon in Bonneville Reservoir in order to perform population monitoring. The capture, mark, and pit tag operation for Bonneville Reservoir was performed for four weekly fishing periods from 2 December, 2003 through 4 January, 2004. We sampled the area from about Rkm 240 to 299 (RM 149 to 186). We divided the sampling area into four sections 14.4 to 16.1 Rkm long in an effort to systematically sample the entire reservoir (Figures 3-6). Areas restricted from commercial white sturgeon fishing were observed and thus incorporated into our sampling strategy. All crews began sampling in section one and moved upriver one section each week. We employed this strategy in an effort to mark fish throughout the entire reservoir and also to reduce the possibility of recapturing newly marked fish. A fishing week usually began on Monday and ran through Saturday. Nets were checked and reset each day, with Monday being the first set day of the week and Saturday being the last pull day of the week, except when limited by severe weather or mechanical problems.

Three Yakama Nation (YN) 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 YN 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. At weeks end data was turned over to ODFW.

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 70 to 120 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 FL and the 10th left lateral scute was removed to indicate year of capture was 2002 - 2003. 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 FL 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.

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RESULTS

Artificial Propagation Research

Broodstock collection and Spawning Trials

We collected 3 females and 17 males in setline fishing in McNary and Bonneville reservoirs. One female was taken from Bonneville Reservoir; the remaining fish were taken from McNary Reservoir. During holding and periodic sampling two females showed egg maturation. The McNary female collected on 2 April and the Bonneville female collected on 21 May exhibited the same oocyte PI indices of egg development of 0.19 on their date of collection and again showed similar indices of 0.13 when sampled in June. The second McNary female showed very little egg maturation from initial capture through June and was not a candidate for spawning. Tailrace and holding tank temperatures from 2 April through 10 July ranged from 7.5 to 18^{o}C (Figure 4), within the known spawning regime. Tank water temperatures at the McNary facility on July 11 were between 18 - 19° C, the high end of the spawning regime for white sturgeon. Egg samples taken on 11 July revealed that the McNary female that previously showed egg development had arrested development and was no longer exhibiting decreasing oocyte PI. The Bonneville female sampled on the same date showed a marginal decrease in oocyte PI and was still a candidate for spawning. Due to time constraints associated with elevating water temperature and sample process time, we did not sample the female again for oocyte PI, but rather decided to spawn the following week. On 16 July, with water temperatures at 20° C (Figure 4) an attempt was made to collect eggs and milt from broodstock before temperatures had passed the threshold for successful spawning. We successfully collected eggs from the female but eggs appeared soft, mottled and of low quality. Approximately 40,000 eggs were collected using hand stripping techniques. All males were injected on 16 July and four males produced milt on 17 July. Motility tests showed that only one male had high quality gametes, and this male was used in the fertilization of all eggs. The other three males showed light milt with very low sperm motility indicating these fish were likely in the late stages of spermiation. Fertilized eggs were transferred to AFTC for incubation. Due to poor egg quality likely associated with the high water temperatures, less than 4 % of the eggs fertilized were viable upon arrival at AFTC and only 4 larvae survived.

The white sturgeon captured during fishing efforts and not taken as broodstock were immediately released in good condition into McNary Reservoir. White sturgeon taken for broodstock from McNary in 2003 were returned to McNary Reservoir at the end of spawning trials. All McNary fish were released from shore directly into the reservoir just upstream from Hat Rock Park (Rkm 483) on two release dates. On 18 July, nine male sturgeon were released in good condition. On 22 July, the remaining six males and three females were released and judged to be in fair condition. Most of these fish had minor weight loss while in captivity. An unprecedented event at the McNary holding facility lead to the downgrading in the condition of the fish released on the 22 July. This event also caused two mortalities during the last few days of the holding period at McNary. Extra-ordinary manipulations of the hydro-system performed to increase water levels in McNary Reservoir resulted in lower than normal water levels below McNary Dam and de-watered the pumps below McNary Dam between 12:00 AM and 6:00 AM on 20 July. This resulted in decreasing water flow to the holding tanks and causing mortality of two male sturgeon. The Bonneville female was released into John Day Reservoir approximately 2 KM downstream of the fish facility in order to avoid further stress associated with transport to Bonneville Reservoir.

Bonneville Capture, Mark and PIT Tagging

Effort and White Sturgeon Catch

A total of 2,996 white sturgeon were captured in 629 gillnet sets. We marked all of these fish with the 10th left scute removal pattern described in the methods section. Of the 2996 captured, we applied pit tags to 2184. White sturgeon captured ranged from 22 to 283 cm FL (Figure 5), with a mean length of 88 cm. The total white sturgeon catch consisted of 2964 commercial sub legal size (less than 48 inches or 121.92 cm), 18 commercial legal size (between 48 inches and 60 inches or 121.92 cm and 152. 4 cm) and 18 over legal size (greater than 60 inches or 152.4 cm). The total mean white sturgeon catch per set for all sets combined was 4.77. All of the white sturgeon captured and handled in Bonneville Reservoir were released alive.

DISCUSSION

Bonneville Capture, Mark and Pit Tagging

The 2003 tagging operation performed by CRITFC and ODFW is the third cooperative effort to determine population abundance and structure in Bonneville 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, determine harvest quotas and determine the effect of ongoing mitigative activities on white sturgeon between Bonneville and John Day dams.

Artificial Propagation Research

The 2003 spawning season and subsequent planned and unplanned releases of white sturgeon mark the end of the out-planting and propagation phases of the experimental supplementation project (Kappenman and Parker, 2001, 2002, 2003). Budget cuts within the 198605000 white sturgeon program have currently eliminated this project. The final evaluation stage of the project will be limited due to the altered release strategy and the limited resources available going into 2004-05. Several of the original goals of this project have not been met and large knowledge gaps exist in the research questions white sturgeon managers were asking: 1) can supplementations be used as a tool to alleviate the problem of low production that has occurred because of hydro system management?, and 2) what are the most effective ways to use supplementation as a management tool? Uncertainty remains concerning questions like the necessary out-planting numbers to influence recovery, survival rates of out-plants, and best fish size to release. White sturgeon populations are currently at historic low levels in all reservoirs above Bonneville Dam. Tribal interest to increase harvest potential in both the Snake and Columbia rivers remains high and the current projects and mitigative activities do not adequately address these interests.

For managers concerned with harvestable populations, there are overwhelming concerns that the scale of the existing projects (Kootenai and Lake Roosevelt recovery efforts) will not be significant enough to address the question researchers were asking in this work. It also appears unlikely that these projects will lead to improvements in Zone 6 harvest fisheries. When we examine the upcoming efforts that will likely be expended to recover white sturgeon populations in the future, managers at CRITFC regret the loss of opportunity for the full evaluation efforts that were planned for this project and are disappointed in its uncoordinated and abrupt termination. Managers involved in the white sturgeon project have clearly identified four actions that might be used to rebuild white sturgeon populations in Zone 6; 1) trawl and haul, 2) hydrosystem management that addresses flows regimes to improve recruitment, 3) out-planting using wild broodstock and hatchery reared white sturgeon and 4) strict harvest quotas and slot limit regulations that protect broodstock. The removal of research being performed to determine and develop best out-planting strategies and the lack of hydrosystem management to improve recruitment will likely continue the trend of reduced harvest and place the burden of rebuilding these populations on user groups below and above Bonneville Dam.

The planned release of the 12,000 pit tagged and marked white sturgeon, along with the unplanned release of 8,600 scute marked white sturgeon into Rock Island Reservoir will be evaluated within the existing 2004 -05 funding. We will modify project strategies to get the most information possible from these two releases. We plan to do three weeks of gill net sampling in Rock Island and Wanapum reservoirs and hope to get information concerning presence/absence (an indication of survival), growth rates and condition factor (individual and possibly comparative within release groups and within other populations), downstream immigration, reservoir distribution, and we may analyze the diet of a small portion of captured fish. The 40,000+ white sturgeon released into the Willamette River were not marked and there is no plan to evaluate this release. At the time of the release there was no funding available or method in place to mark fish of this small size. Recent conversations with visiting Russian scientists have identified a method of clipping nares that has potential as a simple and permanent mark for identifying hatchery released white sturgeon that are too small to scute mark (Andre Shmigirlov, personnel communication). Visual implant elastomer tags (currently used in marking hatchery salmon) have also shown promise, and this technology may be applicable to white sturgeon. We hope that in the future a marker for smaller juvenile fish will be developed for white sturgeon and feel that an important opportunity was lost with the unmarked release of these fish in a non-study area.

The 2003 spawning effort revealed little new information in technique development. In lieu of new information, we prepared a list of bullets we feel might provide some insight and useful recommendations for out-planting projects that are currently being developed.

- Recovering and supplementing populations via out-planting juvenile sturgeon and using wild broodstock is an expensive and long term project. Funding sources and facilities must remain adequate to be successful in any endeavor of this nature. If hatcheries are developed to supplement populations in the future, the project scale and budget requirements will need to be at least similar and likely larger in size and scale as the Kootenai Tribe of Idaho White Sturgeon Recovery Project. Projects will need to have similar commitment levels as those demonstrated in the Kootenai Recovery effort, which after several years of challenges in its program development, now produces large numbers of white sturgeon used in its out-planting program.
- As more data becomes available from current management and research projects it appears that state agencies are also coming to the conclusion that propagation will be necessary to recover many of the populations in the Columbia and Snake rivers. It is critical that cooperating managers clearly define the goals of each out-planting or supplementation project (i.e. experimental, population recovery without a fishery, population recovery geared to support a fishery, or out-planting directed at supplementing harvest in stocks that are self sustaining but functioning at reduced levels).
- Adaptive management should be the cornerstone to any out-planting effort and all cooperators should bring a willingness to be flexible and adaptable to support the projects from initiation to the realization of the goals of the project.
- Risk analyses addressing all known risks should be conducted for each out-planting project prior to its initiation. Experts in genetics and disease should be consulted in the initial planning efforts, and though adaptable management is critical, agreements of acceptable risk need to be determined prior to the development of projects so that cooperating agencies have clearly defined the paths toward recovery efforts. Concerns and risks over genetics and the use of out of reservoir broodstock and out of reservoir out-plants need to be considered on the scale of the project or experiment and the relative risk that project poses to the population. For example if the risk of extirpation in some reservoirs is more likely and imminent than the risk of genetic loss, this need should be considered in the out-planting project strategy. Or, as in the case of the CRITFC project, if the numbers being released are lower than what represents a significant genetic risk to the existing population, the genetic risk/concerns need to be weighed against the value of the research project. For example, an early developed strategy to purchase fish from a private aquaculture firm or the potential to tap into the below Bonneville broodstock population would

have allowed the release of white sturgeon in the first years of this project, meeting original goals, while continuing to develop the other project goals of developing spawning and capture techniques specific to the mid-Columbia.

- Water is the key resource to a successful hatchery and out-planting operation. It is the limiting factor in the health and number of juveniles that can be held at a hatchery, and it is critical to the spawning regime of captive broodstock. 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 to spawning late maturing females. This was a critical factor missing in the CRITFC efforts. Also, production goals and the hatcheries capacity to hold fish of various sizes and numbers must be carefully calculated before committing a hatchery site to a specific project.
- White sturgeon taken directly off the spawning grounds and already in spawning condition optimize success as demonstrated by the below Bonneville Dam private operation run by Henry Pelfrey and the Kootenai Tribe's success. Future projects may wish to strive for this type of collection method.
- The effort to collect in-reservoir broodstock or adjacent reservoir broodstock proved challenging for CRITFC and will likely prove challenging for many of the mid- and upper-Columbia River reservoir recovery efforts if that technique is determined necessary. Fishing efforts will need to be developed and holding regimes may need redefined. Captive broodstock may need to be collected years out from spawning and held for more than one year as eggs develop. Few populations on the Columbia River have similar access to broodstock as the Kootenai or below Bonneville projects, so an increased effort requiring greater funding for personnel than what was available for the project CRITFC attempted may be necessary.
- Managers and researchers working with reduced populations and out-planting projects need to look at any offspring produced from these projects that are not necessary to the specific projects designated needs, not as "surplus" fish, but as a cautiously approached "resources of opportunity". These fish should be considered for use in other experiments or other out-planting efforts. The cost and opportunity lost on not taking advantage of these fish is significant when one looks at the dollar expense, knowledge gaps that exist in many Columbia River reservoirs, and the lack of recruitment that is occurring in many reservoirs where commercial fishing opportunities are limited.
- Research dollars are limited and the need to cooperate with ongoing and existing projects is obvious and critical. The opportunities are beyond the scope of this report but for example, a small number of fish from the Roosevelt Hatchery project (i.e. numbers similar to those provided from trawl and haul operations but low enough to pose little risk to population genetics) might be used in out-planting experiments in Zone 6 where

monitoring and evaluation efforts are already ongoing. This evaluation could be easily incorporated into current evaluation plans given a small investment in marking and releasing the fish. These releases could be structured to answer many of the current questions concerning carrying capacity and production limitations in these reservoirs.

PLANS FOR UPCOMING YEARS

Population surveys and estimates for John Day Reservoir, young of year sampling throughout Columbia and the Snake Rivers and efforts to monitor the success of juvenile white sturgeon releases in Rock Island Reservoir are planned for 2004-05.

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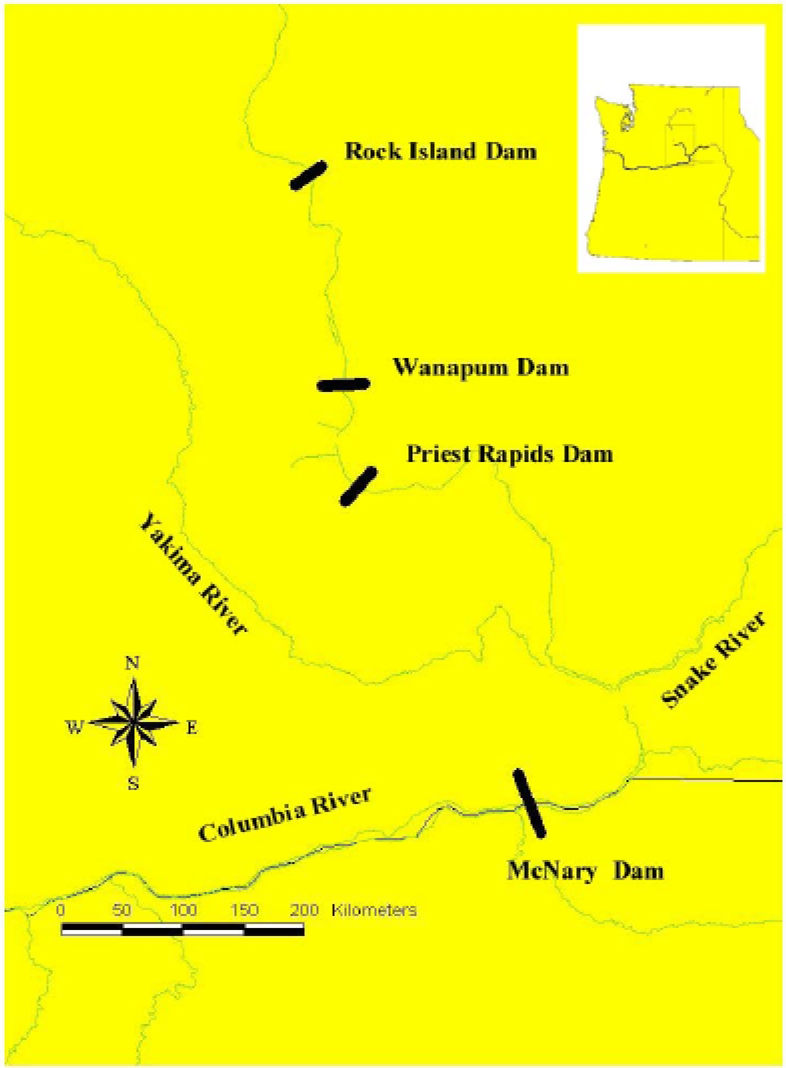

Figure 1. Map of McNary Reservoir in the Columbia River where white sturgeon broodstock collection efforts and out-planting releases were performed in 2003-04.

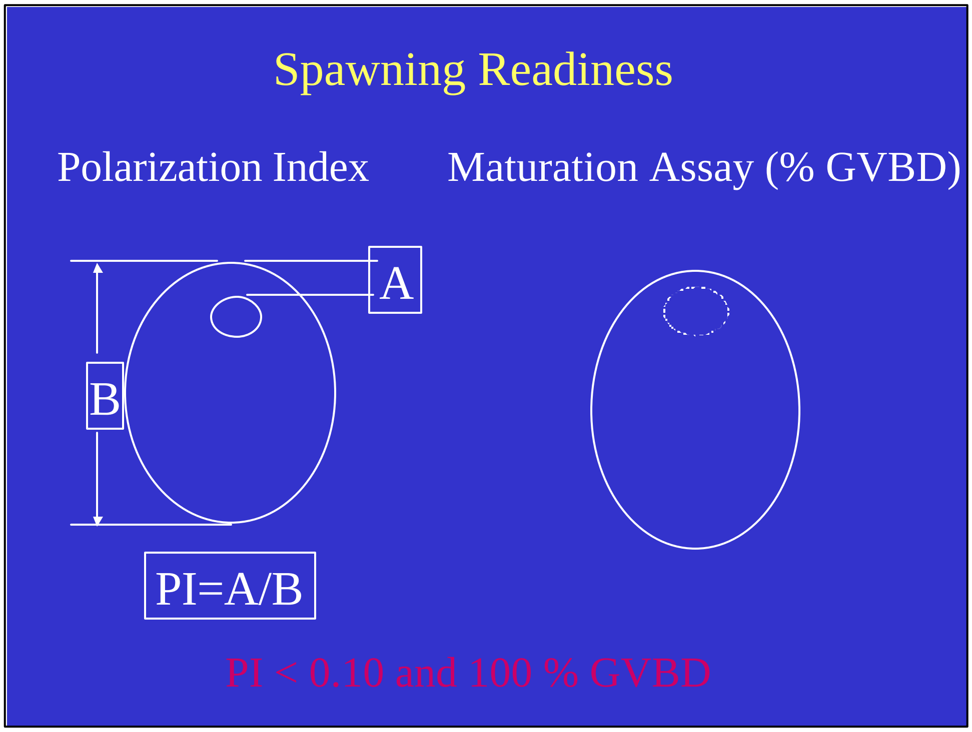

Figure 2 - To monitor egg development and determine spawning readiness, two pieces of information are needed. The first is polarization index or PI (Conte et al. 1988). The PI is the ratio of the distance from the top of the nucleus to the animal pole to the animal-vegetal oocyte diameter. The second is the percent of ovarian follicles that undergo germinal vesicle breakdown in the presence of progesterone. This is called the germinal vesicle breakdown (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).

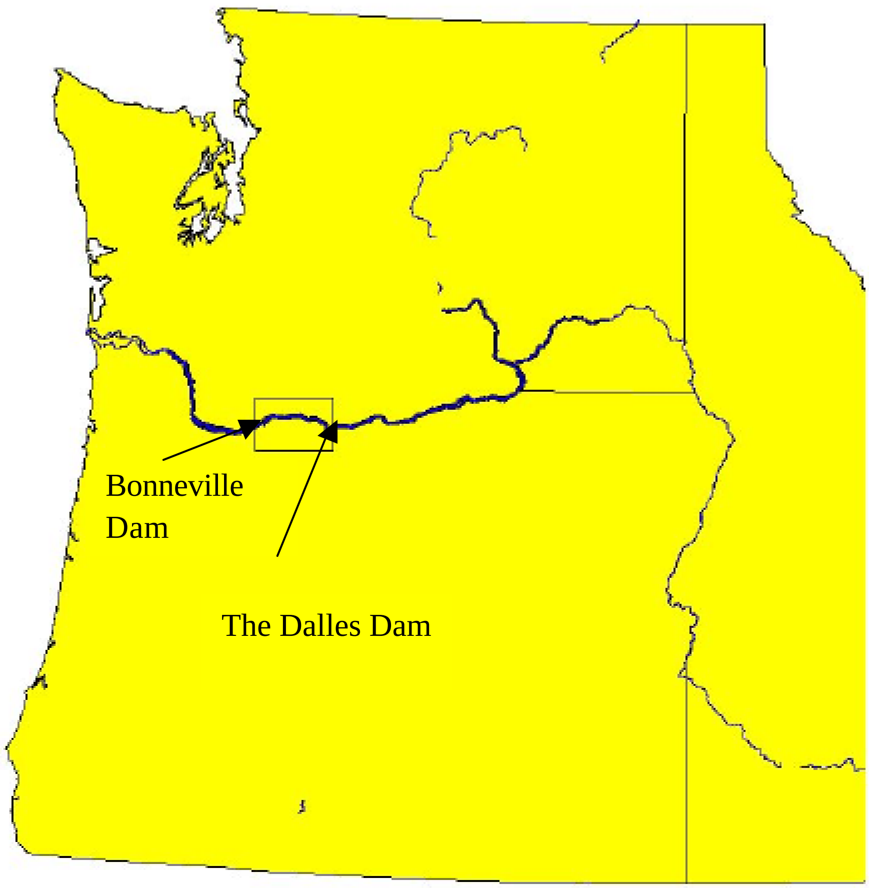

Figure 3. The Columbia River Basin, area within box represents Bonneville Reservoir statute river mile 149 to 186, where mark/tagging operations were performed. Broodstock collection in Bonneville Reservoir occurred just below The Dalles Dam.

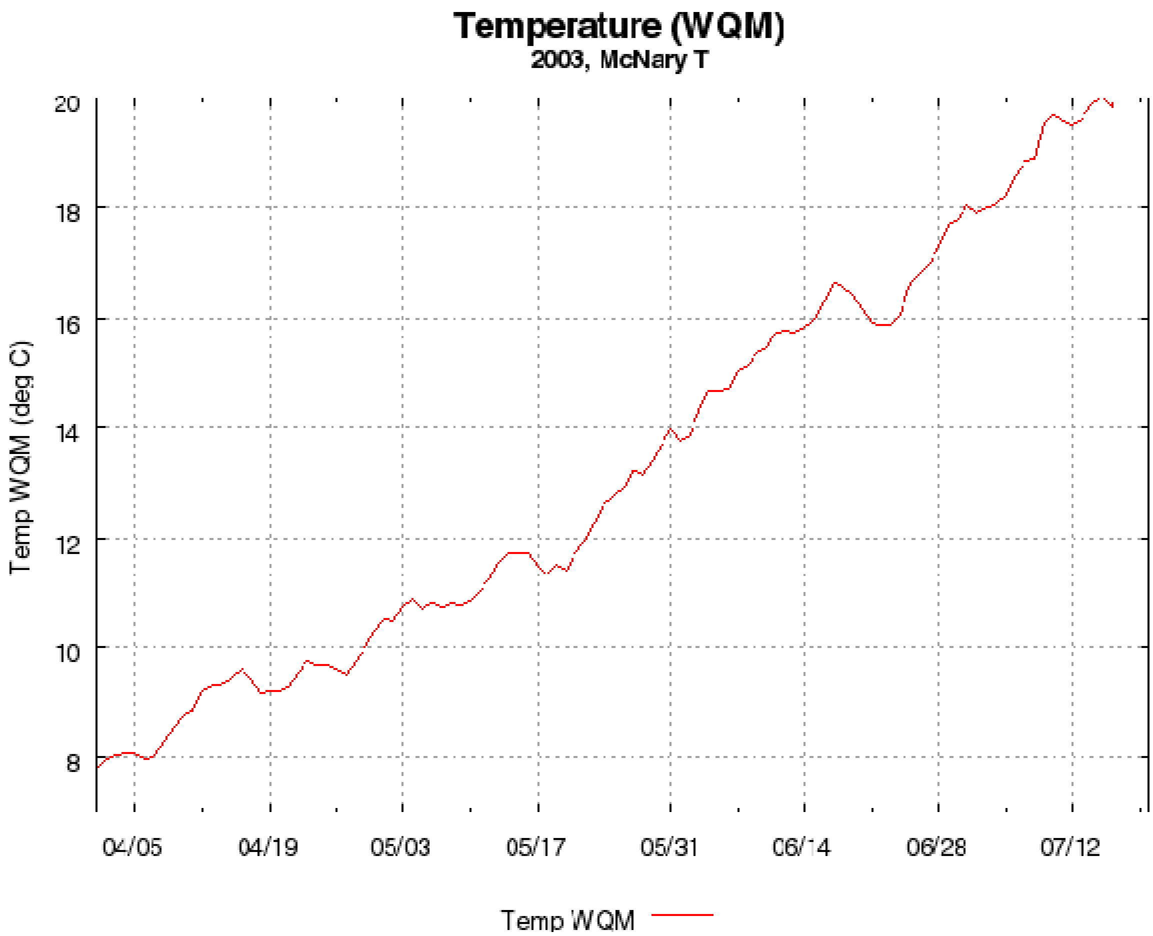

Figure 4. Temperature profiles of McNary Dam tailrace, the water source at the McNary satellite spawning facility.

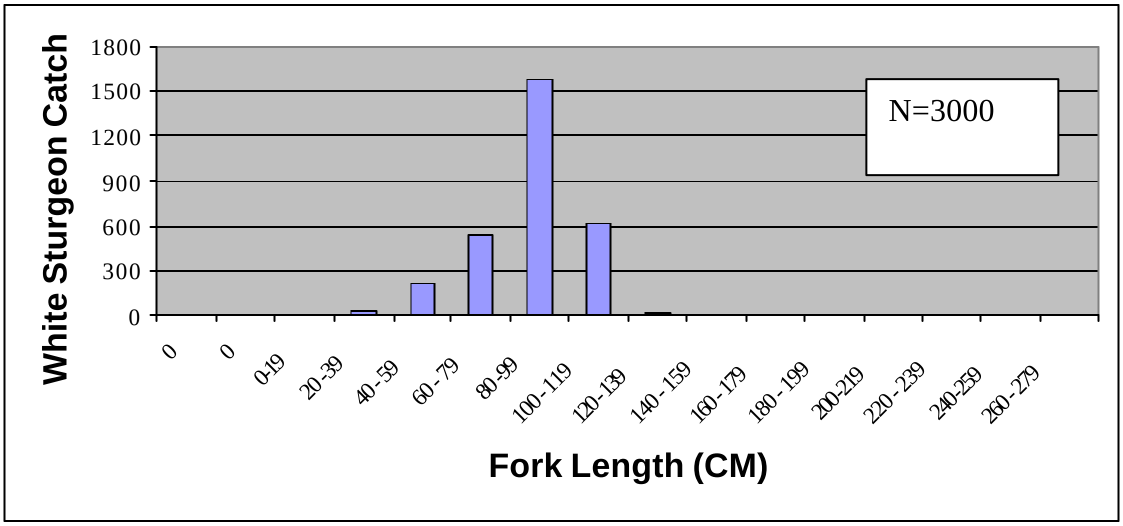

Figure 5. Length frequency distribution (19 cm increments) for white sturgeon collected with gill nets in Bonneville Reservoir in December 2002 and January 2003 by tribal fishers and Yakama Nation fish technicians.

Table 1. Estimated total length and abundance of 48,000 age-0 white sturgeon at several time periods after release. Survival rates represent a reasonable range of potential natural annual survival. No transport mortality, harvest mortality, or downstream entrainment rates were applied in estimates

Age (years)	Year	Total Length	Constant survival rate after release.			60% survival in year 1. Constant survival thereafter.		
			95%	90%	85%	95%	90%	85%
1	2004	12"	45,600	43,200	40,800	28,800	28,800	28,800
10	2013	39"	28,739	16,737	9,450	18,151	11,158	6,671
15	2018	51"	22,238	9,883	4,193	14,045	6,589	2,960
20	2023	61"	17,207	5,836	1,860	10,868	3,890	1,313
25	2028	71"	13,315	3,446	825	8,409	2,297	583
30	2033	79"	10,303	2,035	366	6,507	1,357	259

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

ANNUAL PROGRESS REPORT

APRIL 2003 – MARCH 2004

Report E

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.

Prepared by:

Molly A.H. Webb[1]
Carisska L. Anthony[1]
Carl B. Schreck[2]
Martin S. Fitzpatrick[3]

[1]Oregon State University
[2]Oregon Cooperative Fisheries and Wildlife Research Unit
Department of Fisheries and Wildlife
104 Nash Hall
Corvallis, OR 97331, USA

[3]Oregon Department of Environmental Quality
Water Quality Division
811 SW 6th Avenue, Portland, OR 97204 USA

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ABSTRACT

During 1 April 2003 through 31 March 2004, Oregon State University researchers worked on the development and optimization of a method to determine sex and stage of maturity using blood plasma and mucus indicators. Biological samples from white sturgeon in the Columbia River basin over the legal size (caught by setline, gill net and sport-fishers, referred to as oversize fish) were collected in 2003. The samples were analyzed and combined with samples collected and analyzed in 2000-2002. White sturgeon had sex- and maturity-specific levels of plasma and mucus steroids, as well as fork length. Discriminant function analysis revealed that plasma testosterone (T), 11-ketotestosterone (KT), and estradiol (E2), as well as fork length (FL) led to the correct classification of 65, 51, 95, and 86% of the non-reproductive females, non-reproductive males, reproductive females, and reproductive males, respectively, that were of legal and over-legal size. The term " non-reproductive" 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., a non-reproductive fish may have reached first maturity but is in the resting phase of the reproductive cycle). In the adult population alone, discriminant function analysis revealed that plasma T, E2, and FL led to the correct classification of 63, 58, 96, and 74% of the non-reproductive females, non-reproductive males, reproductive females, and reproductive males, respectively. Mucus T, KT, and E2 led to the correct classification of 29, 50, 43, and 29% of the oversize non-reproductive females, non-reproductive males, reproductive females, and reproductive 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. It appears that the gametogenic cycle may be a 2 to 4+ year cycle in males and a 3 to 5+ year cycle in females.

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 2003 through 31 March 2004.

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 The Dalles Dam with the help of Oregon Department of Fish and Wildlife and Columbia River Inter-Tribal Fish Commission in May of 2003 and below Bonneville Dam with the help of Washington Department of Fish and Wildlife in June and July of 2003. Fish were captured by setline, gill net, cooperating sport-fishing guides, and private sport fishers. 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=113) was 212 ± 2 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 7 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 maturation 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 “non-reproductive”, while males in Stages 3 - 5 (onset of meiosis through spermiation) and females in Stages 3 - 6 (early vitellogenesis through ovulation) were considered “reproductive” (Table 1). Post-spawned females (Stage 7) and males (Stage 6) and females undergoing ovarian regression (Stage 8) were considered "non-reproductive" as sex steroid levels were equivalent to levels measured in Stage 1 and 2 fish. The term "non-reproductive" is used to represent only the reproductive state of the fish at the time of sampling and is not meant to connote not having reached first maturity (i.e., a non-reproductive 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 2003 because the Sigma Diagnostics kit used to measure total calcium is no longer being produced 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.

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.

The steroids in urine were not measured as validation of the unconjugation (sulfate or glucuronide groups removed) prior to assay has not been completed.

Statistical Analysis

Steroid concentrations and FL were compared among the four classes of sex and stage of maturity (non-reproductive females, non-reproductive males, reproductive females, and reproductive 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 2003 were combined with data from the fishery fish sampled in 2000, 2001, and 2002 and the oversize fish sampled in 2000, 2001, and 2002 for the development of the model presented in this report. The mucus and histological data from oversize fish sampled in 2000, 2001, 2002, and 2003 were used for the development of the DFA model. To attain multivariate normality, the logarithms of the plasma 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 and 2) 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 727 white sturgeon have been sampled for biological material in the Columbia River between February 2000 and March 2004. Plasma sex steroid analysis and gonadal histology have been completed on 549 fish. Of these 727 fish, mucus steroid concentrations have been measured in 314 fish. Mucus cannot be collected from fish captured in the commercial or tribal fisheries as fish are brought into the processing facilities touching one another; hence mucus is mixed among fish. The data reported here will include the 549 fish, except for the mucus analysis that will include 314 fish.

Of the fishery fish sampled, 127 were immature females, 100 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, 138 were non-reproductive/resting females, 63 were non-reproductive/resting males, 73 were maturing/reproductive females, and 39 were maturing/reproductive males. The stage of gonadal development of these reproductive oversize fish included Stages 3, 4, 5, 7, and 8 in females and Stages 3, 4, 5, and 6 in males.

A total of 470 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, n=114 in 2003). Paired biological samples were not collected from each of these 470 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 2003, 13 fish were recaptured (11% of the total fish captured in 2003). Of these 13 fish, 4 were tagged in 2000, 6 were tagged in 2001, and 3 were tagged in 2002. Sex determined at the time of gonadal biopsy in 2003 revealed 7 females and 5 females (Table 2). One fish was not biopsied due to poor condition upon bringing the fish on board. Histological examination of the gonadal tissue revealed the field determination of sex was correct on all fish biopsied.

The reproductive structure of the oversize white sturgeon population below Bonneville Dam was determined using the 2000-2003 data. Of the females (n=195), 66% were non-reproductive/refractory (Stage 2), 23% were vitellogenic (Stages 3 and 4), 3% were ripe (Stage 5), 4% were postovulatory (Stage 7), and 4% were atretic (Stage 8). Of the males (n=94), 61% were non-reproductive (Stage 2), 8% were mid-spermatogenic (Stage 3 and 4), 29% were spermiating (Stage 5), and 2% were post-spermiation (Stage 6).

Twenty three fish were caught and biological samples were collected in the cul-de-sac of The Dalles Dam. All fish but one were caught by setline; one fish was caught by gill net. These fish were scute marked and PIT tagged. Sixteen fish were identified as females, five fish were identified as males, the gender of one fish could not be determined because of a regressed gonad, and one fish was hermaphroditic. The hermaphrodite was visually determined to be a female as tiny immature oocytes were seen, however histological analysis of the gonadal tissue revealed spermatocytes and one oocyte. Seven of the females were iteroparous as seen by residual pigment remaining in the gonadal tissue. Two females had Stage 5 (ripe) ovarian follicles upon visual examination, however histological analysis revealed that both of these females were undergoing ovarian regression. Two vitellogenic females (Stage 4) were also undergoing ovarian regression. One postovulatory follicle was seen in the histological analysis of a single female suggesting that this female may have recently spawned. One male was in Stage 4 of gonadal development and may have spawned later in the season, while one male was in Stage 5 of gonadal development and was ready to spawn.

Determination of Sex and Maturity Using Plasma Indicators

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 non-reproductive fish but were significantly higher in reproductive fish, with concentrations significantly greater in reproductive males compared to reproductive females (Figure 1). Plasma concentrations of E2 were significantly higher in reproductive females compared to non-reproductive fish and reproductive 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 65, 51, 95, and 86% of the non-reproductive females, non-reproductive males, reproductive females, and reproductive males, respectively (Table 3). Overall, 72% of the fish were correctly classified. In the cross-validation of the model predicting sex and stage of maturity in these fish, 38%, 51%, 5%, and 18% error was associated with predicting non-reproductive females, non-reproductive males, reproductive females, and reproductive males, respectively.

In the oversize white sturgeon population alone, plasma T, E2, and FL were chosen as the best predictors of sex and stage of maturity. These variables led to the correct classification of 63, 58, 96, and 74% of the non-reproductive females, non-reproductive males, reproductive females, and reproductive males, respectively (Table 4). Overall, 71% of the fish were correctly classified. In the cross-validation of the model predicting sex and stage of maturity in these fish, 39%, 47%, 5%, and 23% error was associated with predicting non-reproductive females, non-reproductive males, reproductive females, and reproductive males, respectively.

Determination of Sex and Maturity Using Mucus Indicators

Concentrations of mucus T and KT differed significantly ($P < 0.0001$ and $P = 0.0077$, respectively; Figure 2) 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 ($P = 0.1912$).

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 29, 50, 43, and 29% of the non-reproductive females, non-reproductive males, reproductive females, and reproductive males (Table 5). The overall percentage of fish correctly classified was 30%. In the cross-validation of the model predicting sex and stage of maturity in these fish, 73, 53, 66, and 87% error was associated with predicting non-reproductive females, non-reproductive males, reproductive females, and reproductive males, respectively.

DISCUSSION

Of the fishery fish sampled in 2000-2002, < 1% of the females were maturing (Stage 3), while close to 8% of the males were maturing (Stages 3 and 5). Of the oversize fish sampled in 2000-2003, 23% of the females were vitellogenic (Stages 3 and 4), 3% were ripe (Stage 5), 4% were postovulatory (Stage 7), and 4% were atretic (Stage 8). Welch and Beamesderfer (1995) found 37% of the females > 166 cm FL in Bonneville, The Dalles, and John Day Reservoirs were maturing (equivalent to Stages 3 and 4 in this study), while 10% of the females were mature or spent (equivalent to Stages 5 and 6 in this study). DeVore et al. (1995) found 2% of the females ≥ 110 cm FL below Bonneville Dam were ripe or spent (equivalent to Stages 5 and 6 in this study). Of the oversize males in this study, 61% were non-reproductive (Stage 2), 8% were mid-spermatogenic (Stage 3 and 4), 29% were spermiating (Stage 5), and 2% were post-spermiation (Stage 6). Seven percent of the adult females in this study were capable of or had spawned successfully, while 31% of the adult males were capable of or had spawned successfully. It is difficult to determine histologically the exact timing of follicular atresia (i.e., this spawning season or last) as the rate of atresia differs greatly among individuals. In culture, white sturgeon females that undergo follicular atresia have been found to have residual pigment in gonadal tissue 1 year after gonadal regression occurred (pers. obs.). Therefore, the percentage of wild adult females that developed ovarian follicles and failed to complete maturation and/or ovulate may range from 0-4% per season.

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 many years. Females in all stages of development were found throughout the winter and spring below Bonneville Dam 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). The data collected from recaptured oversize fish below Bonneville Dam in 2000-2003 revealed that males of reproductive size are not spawning every year. It appears that the gametogenic cycle in males may be a 2 to 4+ year cycle. No evidence has yet been found to demonstrate that adult white sturgeon females in the Columbia River have a 2-year gametogenic cycle similar to cultured white sturgeon. All of the recaptured females to date have 3 to 5+

year reproductive cycles. It is essential to continue this work to determine 1) the true maturation cycle in wild white sturgeon and 2) the proportion of fish spawning on 3, 4, 5, 6, etc. year cycles. This information is critical to management of Zone 6 white sturgeon populations as well as the endangered Kootenai River white sturgeon, the upper Columbia River white sturgeon, and the Snake River white sturgeon populations. The maximum fraction of mature wild white sturgeon in the Columbia River is estimated to be 33% based on a 3-year cycle (Welch and Beamesderfer 1995). Given that the preliminary results of this study show a 3 to 5+ year cycle and that 7% of the adult females in this study were capable of or had spawned successfully, it appears that this estimate of the maximum fraction of spawning females may not be reached in any given year, even with consideration of capture gear and location biases.

To distinguish between non-reproductive and reproductive sturgeon, plasma concentrations of T may be compared. Testosterone concentrations were significantly higher in reproductive fish compared to non-reproductive fish (Figure 1). Reproductive females may be separated from reproductive males using plasma T and E2, as concentrations were significantly different (Figure 1). It remains difficult to distinguish between non-reproductive females and males using sex steroids as the concentrations are similar in both groups.

The DFA models were least effective in distinguishing non-reproductive female from non-reproductive male white sturgeon. The misclassification of non-reproductive males as non-reproductive 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 non-reproductive 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 non-reproductive females as non-reproductive 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).

Though error does exist in the classification of sex and stage of maturity of white sturgeon using blood plasma (28% error overall), 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 steroid levels is more accurate than collection of a gonadal biopsy. The classification of maturing females using plasma T, E2 and FL is highly accurate (96% correctly classified) and may prove useful in certain situations to assess a population for the number of reproductive females (vitellogenic and ripe) in any given year. 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. Stages of gonadal development identified from gonadal biopsies of white sturgeon based on classifications described in Van Eenennaam and Doroshov (1998).

	Developmental Stage	Description
Females		
Differentiation	1	Clusters of oogonia
Previtellogenic	2	Endogenous growth of oocyte, small translucent oocytes < 0.6 mm
Early vitellogenic	3	Enlarged oocytes with thin vitelline envelope surrounded by granulosa cell layer and yolk globules, cream to grey colored 0.6-2.1 mm
Mid-vitellogenic	4	Fully differentiated follicular layer and yolk platelets, pigmented ovarian follicles 2.2-2.9 mm
Migratory nucleus	5	Fully grown ovarian follicles with differentiated chorion and germinal vesicle displaced to animal pole, fully pigmented ovarian follicles > 3.0 mm
Oocyte maturation	6	Ovulated oocytes that have undergone germinal vesicle breakdown
Postovulatory	7	Ovaries contain numerous postovulatory follicles and the next generation of oocytes similar to Stage 2
Atretic	8	Atretic vitellogenic follicles containing residual yolk, atretic mature follicles containing residual yolk and dark pigment, presence of atretic bodies
Males		
Differentiation	1	Clusters of primary spermatogonia
Mitotic proliferation	2	Spermatogonia undergoing mitosis
Onset of meiosis	3	Spermatogonia (~50%) and spermatocytes
Mid-spermatogenesis	4	Majority of cysts contain spermatocytes and spermatids, less than 25% of cysts contain spermatogonia
Spermiation	5	Cysts and ducts contain spermatozoa
Post-spermiation	6	Residual spermatozoa in testicular lobules

Table 2. Oversize white sturgeon recaptured in 2003 below Bonneville Dam. Fish identification is the spaghetti 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) when a biopsy was conducted. Stage of maturity in fish that did not have gonadal tissue collected was determined by sex steroid concentrations (these fish are denoted by an asterisk).

Fish ID	Year Tagged	Fork Length (cm) (year tagged / 2003)	Field Sex	Stage of Maturity (year tagged / 2003)
H113710	2001	211 / 207	Female	Stage 2 / Stage 3
H113714	2001	204 / 204	Female	Stage 2* / Stage 2
H113726	2001	219 / 216	Female	Stage 2 / Stage 2*
H115045	2002	217 / 216	Male	Stage 2 / Stage 3
H111590	2000	225 / 222	Male	Stage 2* / Stage 2
H111577	2000	234 / 232	Female	Stage 2* / Stage 2
H113746	2001	245 / 245	Female	Stage 2 / Stage 4
H115017	2002	213 / 216	Male	Stage 2 / Stage 5
H111614	2000	242 / 236	Female	Stage 2* / Stage 2
H111569	2000	228 / 228	Male	Stage 2* / Stage 2
H115034	2002	232 / 234	Female	Stage 2 / Stage 2
H109949	2000	209 / 207	Female	Stage 2* / Stage 2
H113783	2001	225 / 225	Male	Stage 2* / Stage 4

Table 3. Classification summary for determination of sex and stage of maturity from the quadratic discriminant function analysis for all 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 Non-reproductive Females	Determined Non-reproductive Males	From Reproductive Females	Predictors Reproductive Males	Total n
Non-reproductive Females	**65** (183)	24 (68)	5 (13)	6 (18)	282
Non-reproductive Males	29 (49)	**51** (84)	1 (1)	19 (31)	165
Reproductive Females	0 (0)	2 (1)	**95** (56)	3 (2)	59
Reproductive Males	12 (5)	2 (1)	0 (0)	**86** (37)	43

Table 4. Classification summary for determination of sex and stage of maturity from the quadratic discriminant function analysis for oversize white sturgeon using log-transformed plasma testosterone, estradiol, and fork length. Data are percentages (n), with the correctly classified percentages in bold.

True Sex	Classification Non-reproductive Females	Determined Non-reproductive Males	From Reproductive Females	Predictors Reproductive Males	Total n
Non-reproductive Females	**63** (97)	30 (47)	3 (4)	4 (7)	155
Non-reproductive Males	21 (14)	**58** (38)	0 (0)	21 (14)	66
Reproductive Females	1 (1)	1 (1)	**96** (55)	1 (1)	58
Reproductive Males	3 (1)	23 (8)	0 (0)	**74** (26)	35

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 Non-reproductive Females	Determined Non-reproductive Males	From Reproductive Females	Predictors Reproductive Males	Total n
Non-reproductive Females	**29** (44)	36 (54)	20 (30)	15 (23)	151
Non-reproductive Males	22 (13)	**50** (30)	22 (13)	6 (4)	60
Reproductive Females	12 (8)	26 (17)	**43** (28)	19 (12)	65
Reproductive Males	8 (3)	29 (11)	34 (13)	**29** (11)	38

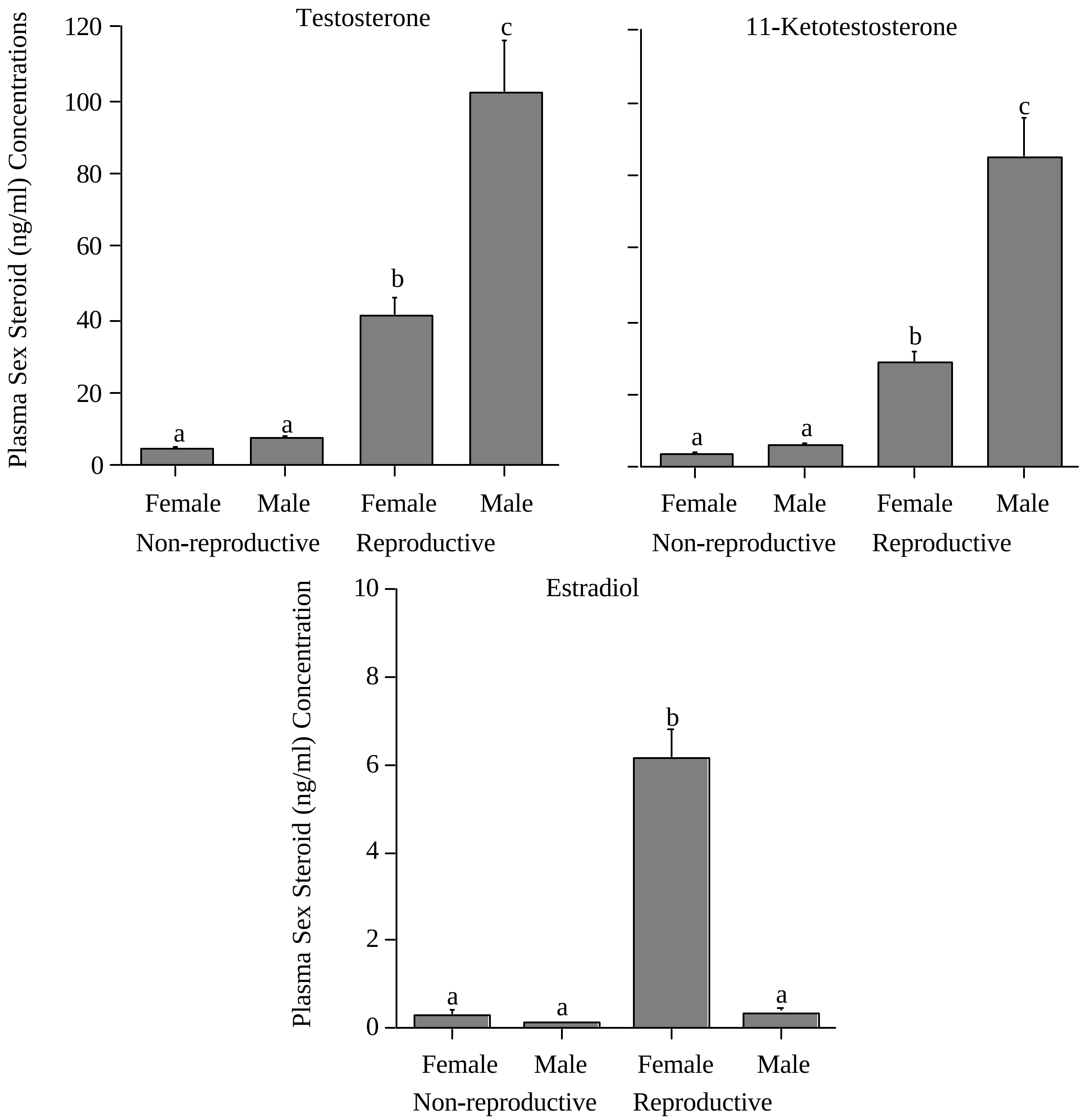

Figure 1. Plasma sex steroid concentrations in white sturgeon captured in the Columbia River basin in 2000, 2001, 2002, and 2003 (mean + SE). Different letters denote statistically significant differences between the groups (non-reproductive females, n=282; non-reproductive males, n=165; reproductive females, n=59; and reproductive males, n=43).

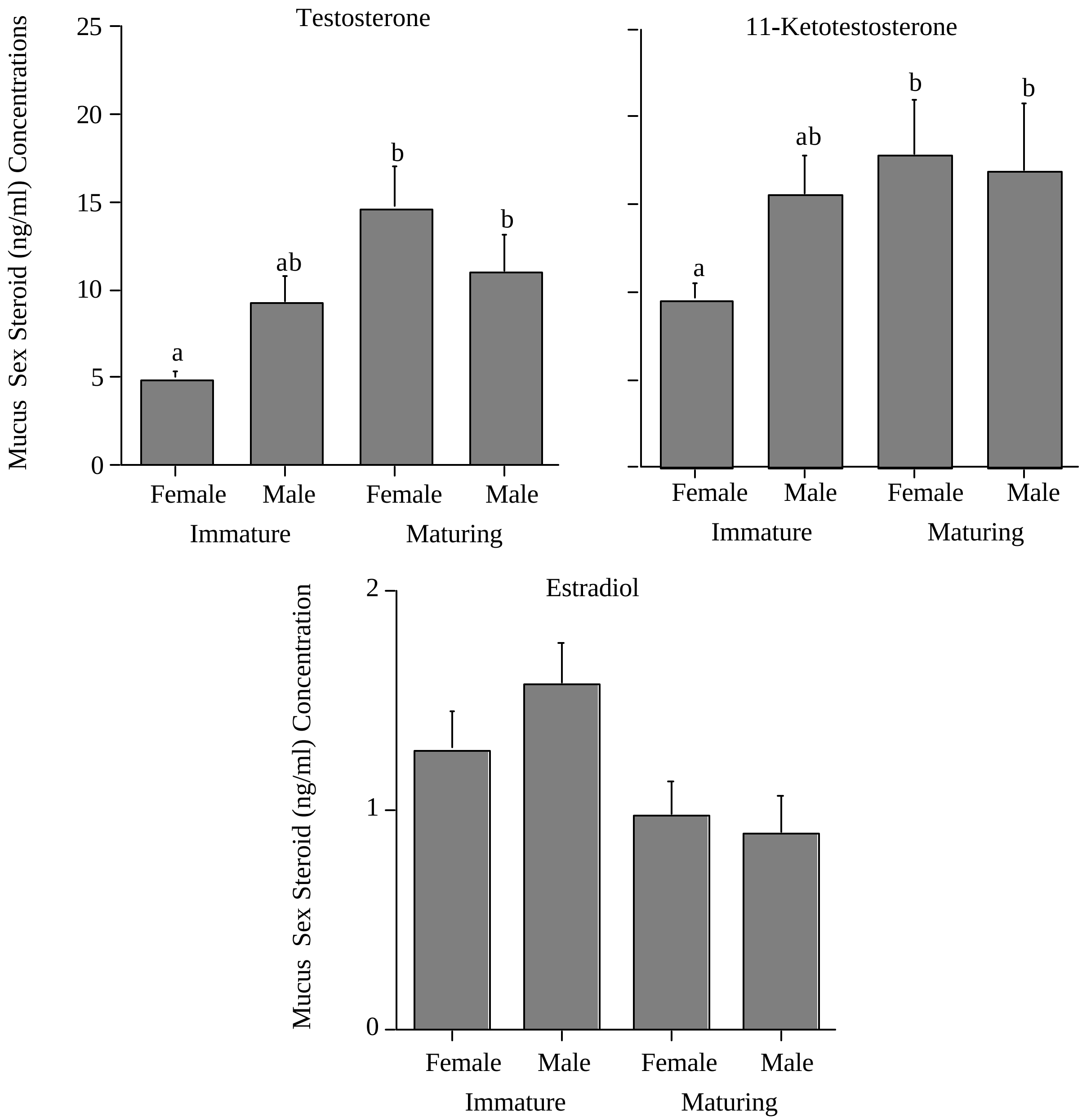

Figure 2. Mucus sex steroid concentrations in white sturgeon captured in the Columbia River basin in 2000, 2001, 2002, and 2003 (mean + SE). Different letters denote statistically significant differences between the groups (non-reproductive females, n=151; non-reproductive males, n=60; reproductive females, n=65; and reproductive males, n=38).