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

Annual Report
2000 - 2001

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

ANNUAL PROGRESS REPORT

APRIL 2000 - MARCH 2001

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In Cooperation With:

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

We report on our progress from April 2000 through March 2001 on determining the effects of mitigative measures on productivity of white sturgeon populations in the Columbia River downstream from McNary Dam, and on determining the status and habitat requirements of white sturgeon populations in the Columbia and Snake rivers upstream from McNary Dam. The study is a cooperative effort by the Oregon Department of Fish and Wildlife (ODFW; Report A), Washington Department of Fish and Wildlife (WDFW; Report B), U.S. Geological Survey Biological Resources Division (USGS; Report C), Columbia River Inter-Tribal Fish Commission (CRITFC; Report D), the U.S. Fish and Wildlife Service (USFWS; Report E), and Oregon State University (OSU; Report F)..

This is a multi-year study with many objectives requiring more than one year to complete; therefore, findings from a given year may be part of more significant findings yet to be reported. Highlights of results of our work from April 2000 through March 2001 are:

Report A

(1) We transported 5,182 white sturgeon from below Bonneville Dam to The Dalles (1,163 fish) and John Day (4,019 fish) reservoirs.

(2) Mean fork length of transported fish was 44.4 cm; no fish less than 30 cm or over 90 cm were transported.

(3) We considered white sturgeon less than 31 cm fork length to be young-of-the-year fish, based on analysis of length-frequency distributions.

(4) We did not capture YOY sturgeon in any reservoir but The Dalles, where 14% of nets captured YOY sturgeon.

Report B

(1) We sampled the2000 recreational fishery between Bonneville and McNary dams (Zone 6 management unit) to estimate white sturgeon harvest. We estimated that 1,262; 809; and 434 white sturgeon were harvested from Bonneville, The Dalles, and John Day reservoirs respectively. Managers used our projections of estimated harvest to close the retention season in Bonneville Reservoir on April 9th and on June 19th in The Dalles. The season in John Day Reservoir remained open year-round.

(2) Recreational harvest has averaged 95%(Bonneville), 107%(The Dalles), and 83% (John Day) of the Sturgeon Management Task Force's (SMTF) annual harvest guidelines since 1995. The 1991-2000 average for Zone 6 sport and commercial fisheries is 111% (Bonneville), 116% (The Dalles), and 93% (John Day) of the combined sport and commercial guidelines.

(3) Harvest per angler trip in Bonneville Reservoir increased for the first time since the short winter/spring retention seasons began in 1995. Harvest per angler trip in The Dalles Reservoir increased from the 1999 level and was the second highest of any year since

guidelines were established in 1991. Harvest per angler trip in John Day Reservoir increased for the first time following 1997's eleven-fold increase in the guideline.

Report C

(1) We continued a telemetry study that began in 1998 investigating movements and behavior of pre-spawn and spawning white sturgeon in The Dalles Reservoir in relation to dam operations. Generally fish did not move great distances (typically <1 km) during our monitoring periods, and some fish did remain within the BRZ when water was being spilled.

(2) Fall bottom trawling revealed that recruitment of young-of-the-year white sturgeon occurred in Bonneville Reservoir and in The Dalles Reservoir, but at a low level. No young-of-the-year white sturgeon were collected in John Day Reservoir. The Oregon Department of Fish and Wildlife provided gillnet catch data for an ongoing comparison of indices of abundance derived from the two gears.

(3) Analyses continued on several tasks, including quantifying habitat suitable for spawning of white sturgeon in Bonneville, The Dalles, John Day, and McNary tailraces, and describing the effects of proposed reservoir drawdowns on productivity of white sturgeon.

(4) Laboratory experiments investigating predation on larval and juvenile white sturgeon began in 2000. Higher turbidity levels lowered predation rates of prickly sculpin on white sturgeon larvae. Northern pikeminnow ate sturgeon up to about 120 mm TL.

Report D

(1) Techniques for capturing, holding and spawning white sturgeon from Columbia River reservoirs above McNary dam continue to be developed. A total of 192 white sturgeon were captured in 123 setline sets, during 17 days of fishing. Sixteen sexually mature white sturgeon, 2 females and 14 males, were taken for broodstock trials. We were unable to collect and fertilize female gametes during broodstock trials in 2000. Although we were able to collect gametes from two males, no females exhibited sufficient oocyte maturation to attempt spawning. Trials conducted in 1999 and 2000 indicate that cool water temperatures at the holding facility inhibited oocyte maturation. A new holding facility that mimics the natural Columbia River water temperature regime, or a secondary source of gametes, will be necessary for the future success of the white sturgeon experimental supplementation project.

Report E

(1) For the second year, wild white sturgeon were successfully captured, transported, held through the spawning season, an returned to site of origin.

(2) Due to the lack oocyte maturation during the 2000 season, it was decided that the 12.5^{0}C well water at the AFTC facility was not sufficient to trigger normal oocyte maturation within the normal spawning season.

(3) To provide adult sturgeon with water directly from the Columbia river, which should trigger a more normal maturation, it was decided to move the adult holding/spawning portion of the project from AFTC to the U. S. Army Corps of Engineers facility at McNary Dam.

(4) Observations from the PIT tag loss pilot studies indicate further work is needed to determine proper tagging techniques to ensure minimal tag loss.

Report F

(1) OSU collected paired blood and gonad samples from 216 white sturgeons in the Columbia River between February 2000 and March 2001.

(2) White sturgeon showed sex and maturity-specific levels of plasma steroids and calcium, as well as fork length.

(3) 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.

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

ANNUAL PROGRESS REPORT

APRIL 2000 - MARCH 2001

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: Investigations on white sturgeon recruitment to young-of-year in Columbia and Snake River reservoirs and results of full-scale transplant supplementation efforts in The Dalles and John Day reservoirs.

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ACKNOWLEDGMENTS

We thank Susan Hinton of the National Marine Fisheries Service (NMFS) for the loan of trawling equipment and Lawrence Davis (NMFS, retired) for input regarding methods used to capture juvenile white sturgeon for supplementation of Zone 6 white sturgeon populations. We also greatly appreciated the work of Bob Becker, Harvey Moyer, and Sherman Zimbelman, who maintained liberation trucks and transported juvenile white sturgeon to designated release sites. We appreciate the following staff and volunteers who assisted with fish processing during trawl-and-haul: ODFW Staff – J.T. Hesse, Bonnie Cunningham, Michele Hughes, and Matt Howell; Denis Gilliland, from Washington Department of Fish and Wildlife (WDFW); and volunteers – Mike McNasser, Dick Hemmingson, John Cook, Dennis Wagner, Lon Caroll, Bill Russell, Jim Leddell, and Jim Davis.

We would also like to thank staff who assisted in collecting data for Young-of-Year indexing. Including: Robert Morgan, Brad Cady, and Mike Heppner from WDFW; Chuck Gardee and James Kiona from Columbia River Inter-Tribal Fish Commission; and ODFW staff Matt Howell, J. T. Hesse, and Michele Hughes.

ABSTRACT

This report summarizes data collected on white sturgeon *Acipenser transmontanus* in the Columbia and Snake rivers to document young-of-year (YOY) recruitment and implement transplant supplementation from high-density to low-density populations. The Dalles, John Day, McNary, Ice Harbor, and Little Goose reservoirs were fished with gill nets to determine recruitment of YOY relative to previous years. The Dalles Reservoir was the only reservoir sampled in which YOY sturgeon, fish less than or equal to 31 cm fork length (FL), were captured, suggesting extremely poor recruitment in 2000.

We transplanted juvenile white sturgeon captured downstream from Bonneville Dam to sites in The Dalles and John Day reservoirs. Using trawl gear, a total of 5,705 white sturgeon were captured in tows. White sturgeon measuring 35-90 cm FL were targeted for transplantation and given an external mark for future identification. Of the white sturgeon (≤90 cm FL) transplanted, 1,163 (22%) were released into The Dalles Reservoir and 4,019 (78%) were released into John Day Reservoir.

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INTRODUCTION

This annual report summarizes work performed by the Oregon Department of Fish and Wildlife (ODFW) during the period April 2000 through March 2001 in accordance with tasks outlined in the Bonneville Power Administration funded Project 86-50 Performance Work Statement. We report white sturgeon *Acipenser transmontanus* catch data obtained in 2000 during gill-net sampling for Young-of-Year white sturgeon (YOY) in The Dalles, John Day, McNary, Ice Harbor, and Little Goose reservoirs.

We also describe results of efforts to supplement sub-adult white sturgeon populations in The Dalles and John Day reservoirs by transplanting sub-adult white sturgeon from the unimpounded section of the Columbia River below Bonneville Dam to these reservoirs.

METHODS

Young-of-Year Indexing

During October and November of 2000, we sampled three Columbia River reservoirs and two Snake River reservoirs to determine YOY recruitment relative to previous years sampled (Figure 1). 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 sampling by U. S. Geological Survey (USGS) using trawl gear. On the Columbia River, we sampled The Dalles, John Day, and McNary reservoirs, and on the Snake River we sampled Ice Harbor and Little Goose reservoirs. 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 to allow comparisons of relative catch with previous years. Nets were fished on the river bottom overnight for 21.5 h to 23.1 h. We classified white sturgeon as YOY, based on length frequency distribution (see Results). We calculated mean catch per unit effort (CPUE) and proportion of positive catches for white sturgeon.

Trawl-and-Haul Supplementation

From October to November 2000, we transplanted juvenile sturgeon captured in the Columbia River downstream from Bonneville Dam into The Dalles and John Day reservoirs to supplement these populations (Figure 2). Equipment and techniques for fish collection and transportation were nearly identical to work conducted in previous years (Burner et al. 1999). However, in 2000, trawling was not conducted by the National Marine Fisheries Service (NMFS). Instead, we contracted with a private commercial trawler to capture subadult white sturgeon. Fish were captured from the same areas using GPS locations provided by the NMFS

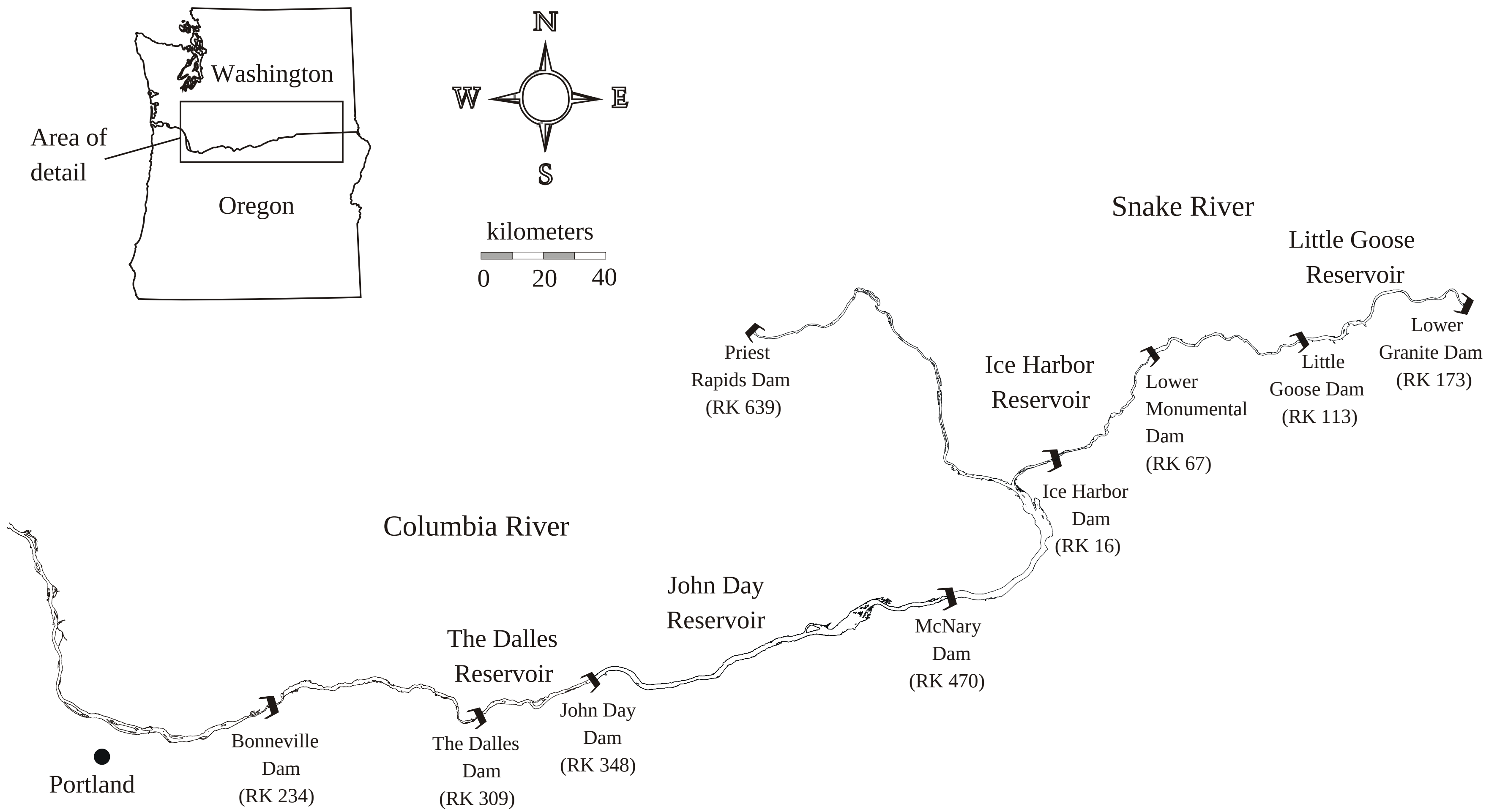

Figure 1. The Columbia River upstream to Priest Rapids Dam and the Snake River upstream to Lower Granite Dam. The scale is approximate. RK = river kilometer.

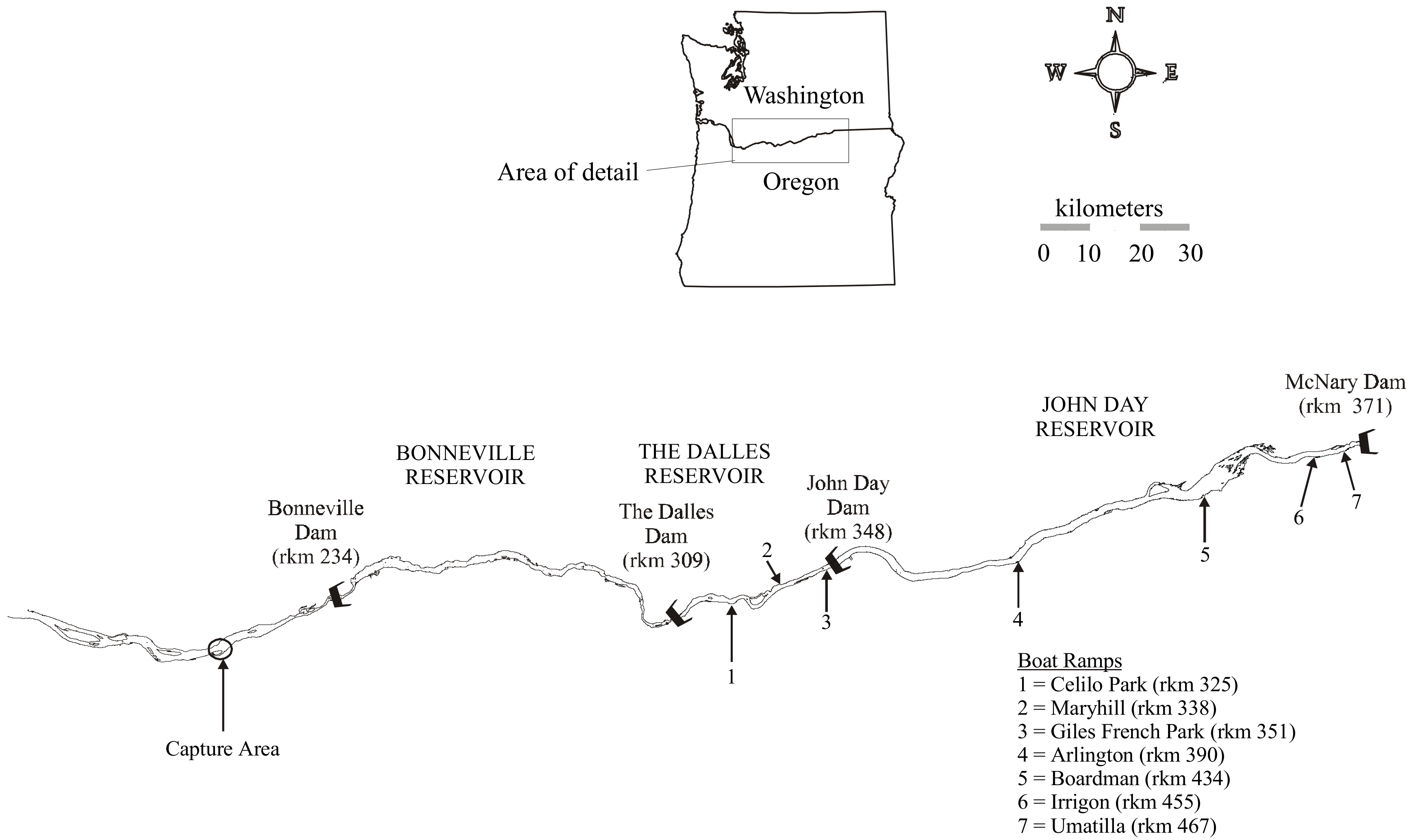

Figure 2. Study area for Trawl and Haul supplementation, October – November 2000.

and the fisher used the same trawl nets as have been used in previous efforts. Fish processing and transportation were conducted primarily by ODFW staff with assistance from many volunteers.

Although most fish transported were between 35-cm and 90-cm fork length (FL), some fish as small as 30 cm were transported on days when catches were low. Fish that were not transported were released at the capture site. We measured a sample of about 100 fish each day to estimate the length frequency of captured fish. All transported fish had their ninth right lateral scute removed for identification. Fish were transported in either a 13,000 L or a 5,300 L fish liberation truck, depending on which vehicle was available. Fish transplanted to The Dalles Reservoir were released at either Celilo Park (river kilometer (RK) 325), at Maryhill boat ramp (RK 338), or at Giles French Park boat ramp (RK 351). In John Day Reservoir, all fish were transplanted on the Oregon side of the Columbia, at the Arlington Boat Ramp (RK 390), the Boardman Boat Ramp (RK 434), the Irrigon Boat Ramp (RK 455), or the Umatilla boat ramp (RK 467).

RESULTS

Young-of-Year Indexing

Catch data from YOY sampling in the five reservoirs studied is shown in Table 1. Based on length frequency, we considered white sturgeon less than 31-cm FL to be YOY (Figure 3). In The Dalles Reservoir, 83% of gill net sets captured white sturgeon, and 14% captured YOY. A total of 144 white sturgeon of all sizes were caught with nine of these classified as YOY. Mean catch of YOY per set was 0.22. In John Day Reservoir, 35% of sets resulted in capture of sturgeon of all sizes, with no YOY out of a total 63 white sturgeon captured. Catch of sturgeon in McNary Reservoir was even lower, with 25% of sets resulting in capture of sturgeon and again, no YOY sturgeon captured. Total catch of sturgeon of all sizes was 15. No YOY were caught in either of the two Snake River reservoirs we sampled.

A few salmonids were captured as by-catch during YOY index sampling. Two coho salmon *Oncorhynchus kisutch*, both smolts, were captured, with one dead at capture and the other released alive. A total of 12 chinook salmon *O. tshawytscha* were captured. All of these fish were smolts, and six were dead at capture and 6 were released alive. We also captured three steelhead *O. mykiss*. One of these was an adult and was released alive immediately after capture. The remaining two fish were smolts and were dead at capture.

Table 1. Young-of-year sampling gill-net effort and catch of white sturgeon in Columbia and Snake river reaches during October - November, 2000.

River Reach	Reservoir Quarter				
Parameter	1	2	3	4	All
The Dalles Reservoir					
Gill Net Sets	6	9	15	6	36
Total Hours	134.7	202.6	341.5	133.4	812.2
White Sturgeon Catch (all sizes)	14	72	36	22	144
White Sturgeon Catch (FL<31 cm)	0	7	0	1	9
White Sturgeon / Set	2.33	8.00	2.40	3.67	4.00
White Sturgeon Catch (FL<31 cm)/Set	0.00	0.78	0.00	0.17	0.22
Sets with >0 white sturgeon (all sizes)	83%	89%	80%	83%	83%
Sets with >0 white sturgeon (FL<31 cm)	0%	44%	0%	17%	14%
John Day Reservoir					
Gill Net Sets	9	9	12	10	40
Total Hours	189.3	201.2	269.5	222.1	882.0
White Sturgeon Catch (all sizes)	0	0	50	13	63
White Sturgeon Catch (FL<31 cm)	0	0	0	0	0
White Sturgeon / Set	0.00	0.00	4.17	1.30	1.58
White Sturgeon (FL<31 cm)/Set	0.00	0.00	0.00	0.00	0.00
Sets with >0 white sturgeon (all sizes)	0%	0%	67%	60%	35%
Sets with >0 white sturgeon (FL<31 cm)	0%	0%	0%	0%	0%
McNary Reservoir/Hanford Reach					
Gill Net Sets	24	12	0	0	36
Total Hours	520.6	260.5	0.0	0.0	781.0
White Sturgeon Catch (all sizes)	10	5			15
White Sturgeon Catch (FL<31 cm)	0	0			0
White Sturgeon / Set	0.42	0.42			0.42
White Sturgeon (FL<31 cm)/Set	0.00	0.00			0.00
Sets with >0 white sturgeon (all sizes)	25%	25%			25%
Sets with >0 white sturgeon (FL<31 cm)	0%	0%			0%
Ice Harbor Reservoir					
Gill Net Sets	8	6	12	10	36
Total Hours	176.2	134.5	275.0	221.1	806.6
White Sturgeon Catch (all sizes)	0	0	5	6	11
White Sturgeon Catch (FL<31 cm)	0	0	0	0	0
White Sturgeon / Set	0.00	0.00	0.42	0.60	0.31
White Sturgeon (FL<31 cm)/Set	0.00	0.00	0.00	0.00	0.00
Sets with >0 white sturgeon (all sizes)	0%	0%	33%	50%	25%
Sets with >0 white sturgeon (FL<31 cm)	0%	0%	0%	0%	0%
Little Goose Reservoir					
Gill Net Sets	9	9	9	9	36
Total Hours	198.8	204.3	196.2	202.6	801.9
White Sturgeon Catch (all sizes)	1	5	2	18	26
White Sturgeon Catch (FL<31 cm)	0	0	0	0	0
White Sturgeon / Set	0.11	0.56	0.22	2.00	0.72
White Sturgeon (FL<31 cm)/Set	0.00	0.00	0.00	0.00	0.00
Sets with >0 white sturgeon (all sizes)	11%	22%	22%	67%	31%
Sets with >0 white sturgeon (FL<31 cm)	0%	0%	0%	0%	0%

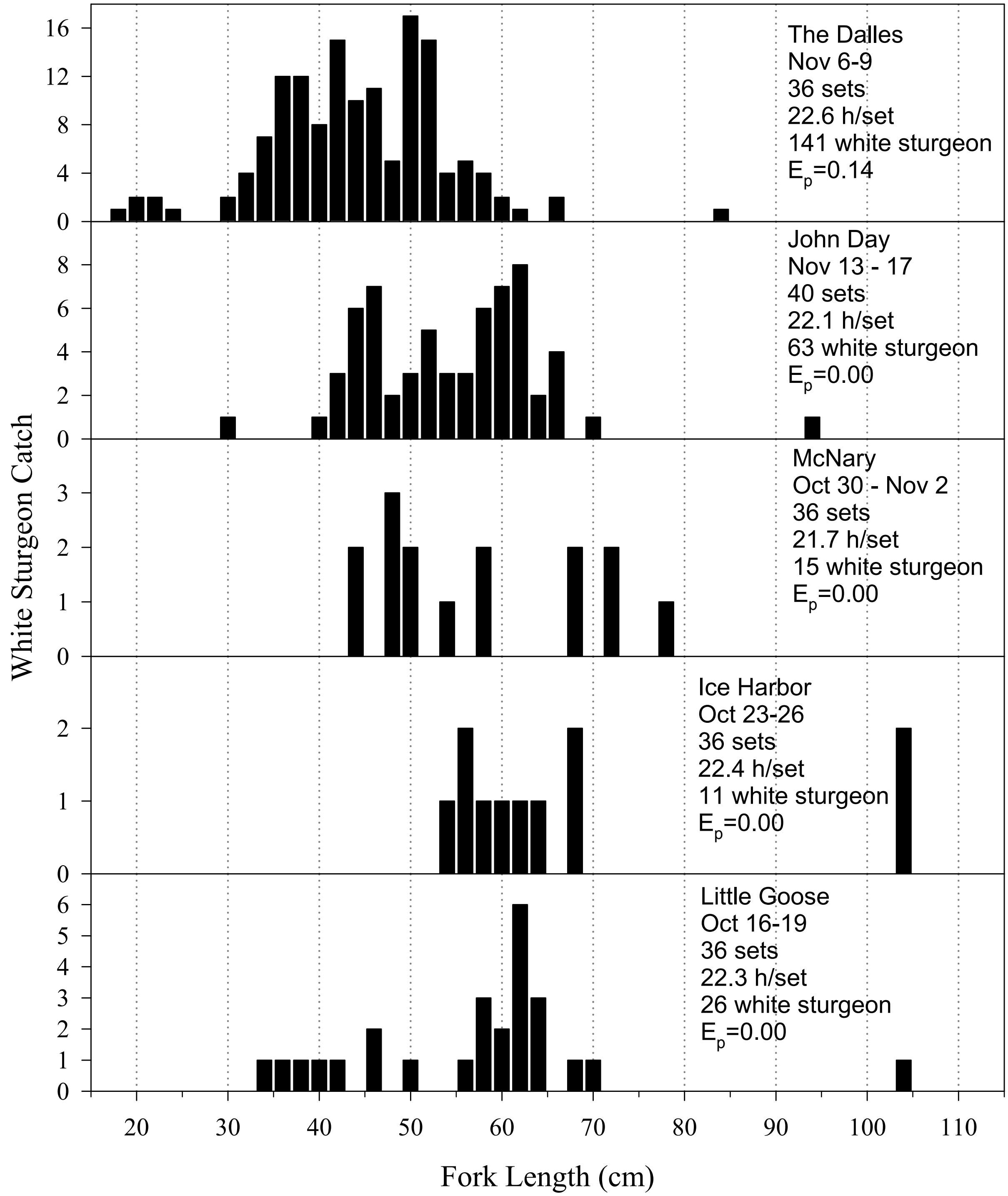

Figure 3. Length-frequency of white sturgeon captured during YOY sampling, fall 2000.

Trawl-and-Haul Supplementation

We captured 5,705 white sturgeon during trawling below Bonneville Dam. The trawler conducted 100 trawl tows for an average of 57 fish per tow (Table 2). White sturgeon of various sizes were captured, although fish of the target size group of 35–90-cm FL dominated the catch (88%, Figure 4).

Of the 5,182 white sturgeon transported, most (4,019) were transplanted into John Day Reservoir (Table 3). The remaining 1,163 fish were transplanted into The Dalles Reservoir, with 37% released at Celilo Park and 63% released at Maryhill. Of the fish transplanted into John Day Reservoir, 11% were released at Giles French boat ramp, 14% at the Boardman boat ramp, 3% near Irrigon Hatchery, 49% at the Arlington boat ramp, and 18% at the Umatilla boat ramp (Table 4). No mortalities occurred during capture and processing, and the only mortalities observed were after release (approximately 9 fish). Mean fork length of transplanted fish estimated from a subsample of 1,422 fish was 44.4 cm (Figure 4). Daily transport densities ranged from 0.0007 kg/L to 0.0927 kg/L. Dissolved oxygen levels in the transport vehicle were nearly always at or above saturation and fish condition during and after transport generally appeared to be excellent.

Table 2. 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, 2000. Data for other years are included for comparison. Hyphens (--) indicate missing data.

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

[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

Table 3. Number of white sturgeon transported from downstream of Bonneville Dam to The Dalles and John Day reservoirs from 1994 to 2000.

Year	Release Reservoir: The Dalles	Release Reservoir: John Day	Total
1994	2,935	--	2,935
1995	5,611	--	5,611
1998	3,257	5,534	8,791
1999	77	4,171	4,248
2000	1,163	4,019	5,182
Total	13,061	13,724	26,767

Table 4. Trawl and Haul fish transport data, 17 October – 8 November, 2000.

Date	Number of fish transplanted	Hours in tanker	Release location	Release site temperature (°C)	Transport temperature (min/max °C)	Transport dissolved oxygen (ppm) (min/max)	Transport volume (liters)	Average fish weight (kg)[a]	Loading density (kg/L)
10/17	41	9:30	Irrigon	16.5	-- / --	10.3 / 10.3	13,265	0.235	0.0007
10/18	220	8:50	Maryhill	11.0	14 / 14	6.8 / 10.5	5,306	0.527	0.0218
10/19	135	6:40	Arlington	16.0	16 / 16	10.5 / 10.9	13,265	0.413	0.0042
10/23	180	9:30	Arlington	14.2	12 / 12	8.0 / 11.5	5,306	0.598	0.0203
10/24	81	9:00	Irrigon	15.0	14 / 14	11.5 / 11.5	13,265	0.561	0.0034
10/25	363	8:30	Arlington	14.7	12 / 12	8.9 / 12.6	5,306	0.539	0.0368
10/26	719	10:30	Umatilla	14.2	14 / --	10.5 / 11.2	13,265	0.682	0.0370
10/30	433	7:15	Celilo	14.1	12 / 12	7.4 / 11.4	5,306	0.735	0.0599
10/31	558	8:55	Boardman	--	13 / 14	10.7 / 11.8	13,265	0.912	0.0384
11/1	510	5:25	Maryhill	14.0	12 / 12	10.2 / 11.6	5,306	0.753	0.0723
11/2	226	6:16	Arlington	15.7	14 / --	10.9 / 12.4	13,265	0.736	0.0125
11/6	670	7:40	Giles French	14.0	11 / --	11.8 / 20.4	5,306	0.734	0.0927
11/7	636	8:25	Arlington	13.0	12 / --	10.3 / 10.3	13,265	0.789	0.0378
11/8	410	7:20	Arlington	14.0	10 / --	10.4 / 11.4	5,306	0.521	0.0403
Total	5,182								

[a] Average weight per fish calculated from fork lengths of daily subsamples of measured fish and estimated weight calculated from a length/weight regression (r^2=0.9542) developed for juvenile sturgeon from previous Trawl and Haul sampling (1993-1997).

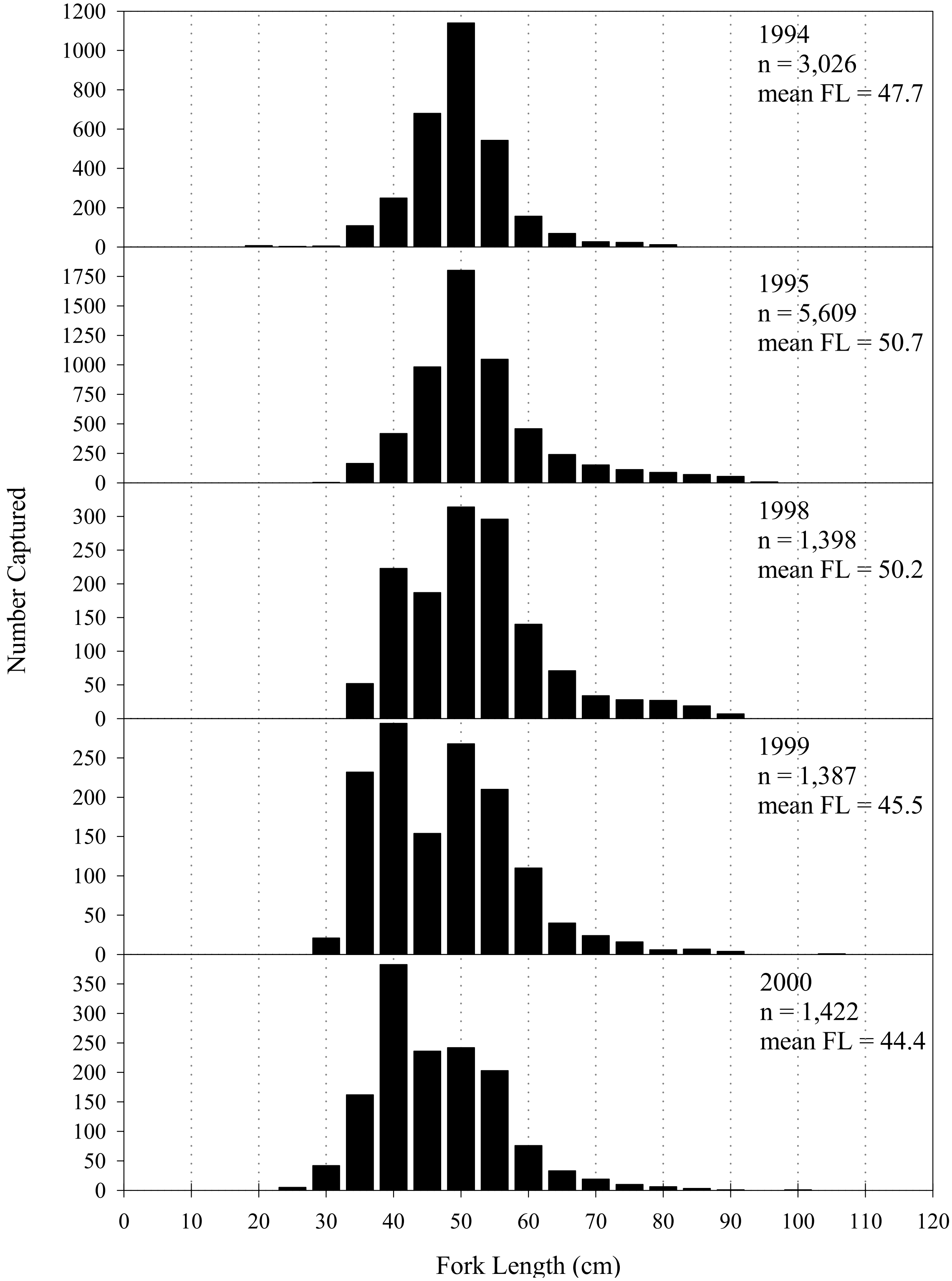

Figure 4. Length-frequency of white sturgeon captured during Trawl and Haul supplementation, fall 2000. Length frequencies from previous years are included for comparison.

DISCUSSION

Young-of-Year Indexing

As indicated by catch rates during YOY sampling, some recruitment was demonstrated in The Dalles Reservoir, but no YOY were captured in upriver reservoirs. This general pattern has been observed in previous years, indicating a consistently low level of recruitment in upper river reservoirs relative to lower river reservoirs (Parsley and Beckman 1994, Rien et al. 1991, North et al. 1998). This information corroborates other findings (DeVore et al. 2000) that indicate low abundances of mature, reproductive adults in the upper reservoirs, and that white sturgeon populations in these reservoirs are limited by poor recruitment resulting from hydrosystem development (Beamesderfer et al. 1995).

The designation of a minimum size for YOY white sturgeon is problematic as yearly differences in growth can greatly impact the average size of fish of this age. However, considering the extremely low numbers of white sturgeon captured that were just over our minimum size designation, it is unlikely that any small increase in this designation would yield a significant difference in YOY numbers. In 2001, we will collect pectoral fin spine sections for aging of white sturgeon collected during YOY sampling to verify length-at-age designations. The data presented for YOY indexing in this report is only an overview. More detailed analysis will be conducted by the USGS.

Trawl-and-Haul Supplementation

As in previous years, supplementation of white sturgeon from below Bonneville Reservoir to The Dalles and John Day reservoirs appears to be largely limited by our ability to capture fish. We have yet to maximize available transport capacity of the liberation trucks. Most of the fish transplanted were released into John Day Reservoir. Due to its greater area and lower density of young white sturgeon, we will probably continue to supplement the John Day population at a higher rate than the population in The Dalles Reservoir. Stock assessment sampling planned for 2001 in John Day Reservoir will allow us to assess the status of transplants to this reservoir over the last several years. Although very little mortality has been observed during handling and transport, we have 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 rate of this mortality is unknown at this time.

PLANS FOR NEXT YEAR

We will conduct stock assessment sampling in John Day Reservoir in 2001 to estimate population abundance and size structure. We will cooperate with staff from the Columbia River Inter-Tribal Fish Commission (CRITFC) and Washington Department of Fish and Wildlife

(WDFW) in these efforts. Commercial fishers will be contracted and supervised by staff from CRITFC to capture and mark white sturgeon in John Day Reservoir from December 2000 through January 2001. Staff from ODFW and WDFW will work cooperatively from May through August 2001 to collect data needed for a mark-recapture population estimate. We estimate the sampling will require approximately 900 setline-days of effort during three passes through the reservoir.

We will continue YOY indexing using gill nets to collect white sturgeon. The USGS will continue to utilize trawl methods for collecting YOY white sturgeon, and will compare the two methods. In the fall of 2001, we will again conduct YOY gill net sampling in The Dalles, John Day, McNary, Ice Harbor, and Little Goose reservoirs.

Prior to and including 1999, methods for capturing juvenile white sturgeon for trawl-and-haul supplementation have been relatively consistent and have resulted in the transplant of up to 5,600 fish annually into each reservoir. However, in 2000, we contracted with a private commercial trawler to collect juvenile white sturgeon. Although there was a delay in catching fish in the early sampling, as the fisher gained experience in the area, catch rates went up dramatically. Over the season, the commercial fisher was able to collect more white sturgeon than the NMFS had captured in 1999. Over the last few years of supplementation work, we have noticed that catch rates are typically higher towards the latter portion of our collection schedule. Due to this factor, we will consider beginning supplementation efforts one week later in 2001, and collecting and transporting fish for an extra week at the end of sampling. However, it is unknown if we will be able to contract with the same fisher, which may result in lower catches as new fishers refine collection methods. For consistency, we will employ trawl nets of the same design and measurements as have been used in previous years.

We will also assist Washington Department of Fish and Wildlife personnel with creel sampling in order to assess harvest rates of white sturgeon.

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Appendix Table A-1. Species composition of catch from young-of-year gillnet sampling, fall 2000.

Species	The Dalles				John Day				McNary				Ice Harbor				Little Goose			
Disposition	1	2	3	All	1	2	3	All	1	2	3	All	1	2	3	All	1	2	3	All
White sturgeon	144			144	63			63	15			15	11			11	26			26
American shad							7	7			1	1			3	3			3	3
Mtn. whitefish																	1		2	3
Steelhead													1		1				2	2
Chinook			1	1									6		2	8			3	3
Coho salmon							1	1									1		1	
Common carp									1			1		2		2	1		18	19
Redside shiner															1	1				
Chiselmouth	3			3	7		5	12	135		101	236	46		16	62	29		19	48
N. pikeminnow	21	1	55	77	1	9	9	19		25	23	48	51	257	44	352	2	78	82	162
Peamouth	20		26	46	1		2	3	44		83	127	117		718	835	45		69	114
Largescale sucker	6		2	8	9		11	20	9		13	22	57		57	114	403		165	568
Bridgelip sucker	13		2	15	8		2	10	8		7	15	4		4	8	14		3	17
Channel catfish	7		1	8	200		3	203	100			100	268		24	292	341		12	353
Bullhead																				
Sandroller																				
Smallmouth bass													1			1				
Crappie													10		22	32	16		15	31
Bluegill																			1	1
Pumpkinseed													1			1			1	1
Walleye	5		9	14																
Yellow perch	4		3	7	36		24	60	213		227	440	82		43	125	20		11	31
Cottidae	1			1	7			7	1		3	4			1	1				
Total	224	1	98	323	332	9	64	405	526	25	458	1,009	654	259	935	1,848	899	78	406	1,383

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

Appendix Table A-2. Species composition of bycatch from trawl and haul sampling, fall 2000.

Species	Date															Total
	10/17	10/18	10/19	10/23	10/24	10/25	10/26	10/30	10/31	11/1	11/2	11/6	11/7	11/8	11/9	
crayfish					1			1		1						3
American shad	41	8	9	7	5	15	14	24	48	169	91	43	199	532	393	1,598
Mtn. whitefish										1						1
Leopard dace		12	13	5			5	8	4	2	5		6	2		62
Largescale sucker		11	14	55	22	24	103	108	78	49	23	75	143	58	66	829
Chiselmouth							2									2
Redside shiner			1		1	1			1					2		6
N. pikeminnow	3	5	6	13		15	43	25	19	26	30	28	85	38	34	370
Peamouth chub	37	29	17	15	3	61	109	148	67	141	108	89	138	160	145	1,267
Brown bullhead							1									1
Sandroller	4	1	3	1	20	7	44	67	23	36	12	32	54	49	31	384
White crappie													1			1
Yellow perch								1								1
Walleye				1												1
Cottidae	3	14	11	6	17	11	28	43	13	8	2	27	19	15	5	222
Starry flounder	2	6	4		2		2	6	1	32		1	1	2		59
Grand Total	90	86	78	103	71	134	351	431	254	465	271	295	646	860	674	4,807

Appendix Table A-3. List of species captured during Trawl and Haul and YOY Indexing.

White sturgeon *Acipenser transmontanus*
American shad *Alosa sapidissima*
Mountain whitefish *Prosopium williamsoni*
Steelhead *Oncorhynchus mykiss*
Coho salmon *Oncorhynchus kisutch*
Chinook *Oncorhynchus tshawytscha*
Common carp *Cyprinus carpio*
Chiselmouth *Acrocheilus alutaceus*
Redside shiner *Richardsonius balteatus*
Northern pikeminnow *Ptychocheilus oregonensis*
Peamouth *Mylocheilus caurinus*
Leopard dace *Rhinichthys falcatus*
Largescale sucker *Catostomus macrocheilus*
Bridgelip sucker *Catostomus columbianus*
Channel Catfish *Ictalurus punctatus*
Bullhead *Ictalurus sp.*
Brown bullhead *Ictalurus nebulosus*
Sandroller *Percopsis transmontanus*
Smallmouth bass *Micropterus dolomieui*
White crappie *Pomoxis annularis*
Pumpkinseed *Lepomis gibbosus*
Walleye *Stizostedion vitreum*
Yellow perch *Perca flavescens*
Cottidae *Cottus spp.*
Starry flounder *Platichthys stellatus*

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

ANNUAL PROGRESS REPORT

APRIL 2000 – MARCH 2001

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 2000 sport and commercial white sturgeon fisheries.

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ABSTRACT

The Washington and Oregon Departments of Fish and Wildlife conducted a survey of the 2000 sport fishery on the Columbia River from Bonneville Dam upstream to McNary Dam (Zone 6 management unit) to estimate white sturgeon *Acipenser transmontanus* harvest. The sport fishery was closed to the retention of sturgeon when harvest was projected to reach respective harvest guidelines April 8 in Bonneville Reservoir and June 19 in The Dalles Reservoir. The guideline was not attained in John Day Reservoir and the retention fishery remained open year-round. An estimated 1,262, 809, and 434 white sturgeon were harvested in 2000 sport fisheries in Bonneville, The Dalles, and John Day reservoirs, respectively. Intense management of Zone 6 sport fisheries since 1995 has kept cumulative harvest at guideline levels and the goal of rebuilding white sturgeon populations is working in all three reservoirs.

Treaty Indian commercial fishers landed 1,145 white sturgeon from Bonneville Reservoir, 1,456 from The Dalles Reservoir, and 846 from John Day Reservoir during gill net and setline fisheries. The Columbia River Inter-Tribal Fish Commission and the Yakama Indian Nation estimated an additional 343 fish were harvested during 2000 subsistence fisheries.

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 1986-50 (00) titled: White Sturgeon Mitigation and Restoration in the Columbia and Snake Rivers Upstream from Bonneville Dam. The reporting period includes activities initiated in January 2000 but focuses on work conducted from 1 April 2000 through 31 March 2001.

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

Objective 1) To develop, recommend, and implement mitigation actions that do not involve changes to hydrosystem operation and configuration.

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

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

WDFW worked on Tasks 1.4, 1.5, 3.2, and 4.4 during the performance period. Task 1.4 is related to developing artificial propagation techniques and protocols in preparation for supplementing impounded white sturgeon populations that lack recruitment. We worked with staff from the CRITFC and the Yakama Indian Nation (YIN) to capture broodstock white sturgeon for this task (see CRITFC Report E in this annual report). Task 1.5 involved regulating white sturgeon fisheries consistent with mitigation efforts designed to optimize harvest where population productivity and resilience have been reduced by hydrosystem development and operations. We worked closely with staff from ODFW and CRITFC to 1) develop an annual management plan regulating January 2000 through December 2000 sport and Columbia River treaty commercial sturgeon fisheries at optimum sustainable exploitation rates and 2) census the sport fishery between Bonneville and McNary dams to estimate weekly and annual white sturgeon harvest to achieve management plan intent. Task 3.2 involved describing annual variation in white sturgeon recruitment in impoundments. We worked with staff from ODFW and the YIN to sample impoundments between The Dalles and Priest Rapids dams on the Columbia River and downstream from Lower Granite Dam on the Snake River to index recruitment of white sturgeon young-of-year (see ODFW Report A and USGS Report C in this annual report). Task 4.4 involved working with sport-fishing guides to capture breeding age adult white sturgeon and surgically examine them to collect paired gonad tissue and blood samples for OSU's work on developing methods to determine sex and stage of maturity of white sturgeon (see OSU Report G in this annual report).

METHODS

Sport Fishery Census

The 2000 sport fishery census was conducted in Bonneville and The Dalles reservoirs, and that portion of the John Day Reservoir downstream from McNary Dam to Arlington, Oregon (river kilometer (rkm) 390) (Figure 1). Methods were similar to those used since 1995 (James et al. 1996) and relied on angling pressure distribution data collected during surveys of Bonneville Reservoir from 1988 to 1990, The Dalles Reservoir from 1987 to 1989, and John Day Reservoir from 1989 to 1991 (Hale and James 1993). Sampling was conducted by two full-time creel samplers hired by ODFW, three full-time samplers hired by WDFW, and one staff member from the WDFW Southwest Regional office.

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

Angling effort (angler hours) was estimated by counting anglers within representative index areas and expanding those counts to the entire reservoir using an established relationship derived from 1987 to 1991 aerial counts of anglers within and outside of index areas. Indices of angler pressure were established at popular fishing locations and vantage points in each reservoir. These index areas were the same as those used since 1995 with two exceptions. The Mitchell Point site was dropped due to restricted access across railroad tracks leading to the site, and two sites adjacent to the Hood River Marina were added. Counts were made of all bank anglers and sport fishing boats within each index area. Average numbers of anglers per boat were determined from angler interviews. Angling pressure within index areas was counted once a day between 1000 and 1300 hours. The proportion of the day's total angling effort represented by the count was calculated from average daily angling pressure distributions derived from prior years' data when systematic counts were made throughout the day. Index to non-index pressure distribution patterns were obtained from prior aerial survey data.

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 2000 was used to adjust the 2000 bank angling HPUE such that boat HPUE vs. bank HPUE matched the pre-one fish daily limit ratio.

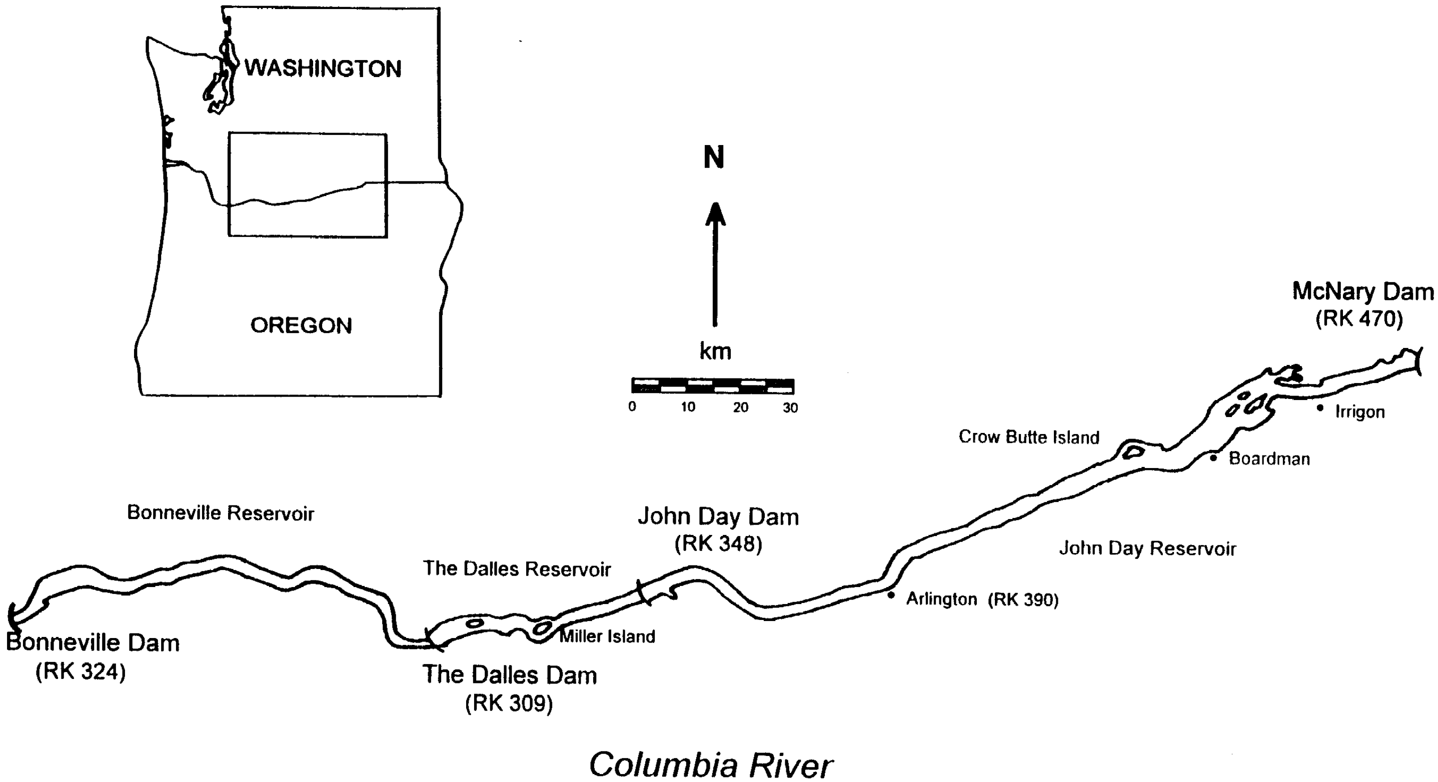

Figure 1. Location of the 2000 recreational fishery census on the Columbia River: Bonneville and The Dalles reservoirs and from Arlington upstream to McNary Dam on John Day Reservoir.

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 poundages reported on fish receiving tickets for each gear type. Poundages of white sturgeon were 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). The Columbia River Inter-Tribal Fish Commission (CRITFC) and the Yakama Indian Nation (YIN) used interviews of treaty Indian fishers to estimate subsistence harvest of white sturgeon.

RESULTS

Sport Fishery Census

Bonneville Reservoir

The 2000 retention season for white sturgeon in Bonneville Reservoir opened January 1 and was scheduled to run through June 30. State fishery managers closed the fishery to retention of white sturgeon on April 8 based on our projection that harvest would reach the guideline by that date.

Anglers fished an estimated 42,726 hours (7,672 trips) in Bonneville Reservoir from January 1 through April 7 (Table 1). Angling effort for sturgeon comprised 90% (6,911 trips) of the total estimated effort. The estimated number of angler trips by species targeted were as follows: 44 (<1%) for anadromous salmonids, 0 (0%) for American shad *Alosa sapidissima*, 575 (7%) for walleye, 15 (<1%) for bass, 2 (<1%) for northern pikeminnow, 125 (2%) for other resident fish, and 0 (0%) for anglers participating in tournaments.

Anglers harvested an estimated 1,262 white sturgeon during 6,911 trips for sturgeon between January 1 and April 16, a 2% increase in harvest and 20% decrease in angler trips from the 1999 retention period (Table 2). Managers announced their decision to close the fishery to retention approximately two weeks prior the actual closing date to provide anglers adequate notice. Angling pressure and HPUE declined once the announcement was made and harvest ended up 17% below the guideline.

The fishery for white sturgeon encompassed the entire reservoir although most of the harvest occurred downstream of Hood River, Oregon (Rkm 271). Harvest per angler trip peaked in February at 0.23 fish per trip and averaged 0.12 fish per trip for bank anglers and 0.26 fish per trip for boat

Table 1. Combined Washington and Oregon sport fishery angling effort estimates for Bonneville Reservoir, January 1 through April 7, 2000; The Dalles Reservoir, January 1 through June 18, 2000; and John Day Reservoir, January 1 through December 31, 2000.

Species / Method	Bonneville		The Dalles		John Day	
	Hours	Trips	Hours	Trips	Hours	Trips
Sturgeon						
Bank	20,517	3,724	37,000	4,202	29,331	5,204
Boat	18,631	3,187	16,334	2,953	54,860	9,230
Total	39,148	6,911	53,334	7,155	84,191	14,434
Salmonid						
Bank	333	44	1,481	215	13,034	2,873
Boat	0	0	2,265	444	10,681	2,141
Total	333	44	3,746	659	23,715	5,014
Shad						
Bank	0	0	1,724	304	55	16
Boat	0	0	49	12	87	28
Total	0	0	1,773	316	142	44
Walleye						
Bank	0	0	694	78	43	7
Boat	2,790	575	13,404	2,387	40,130	6,930
Total	2,790	575	14,098	2,465	40,173	6,937
Bass						
Bank	0	0	1,520	331	90	33
Boat	69	15	2,362	401	24,530	5,880
Total	69	15	3,882	732	24,620	5,913
Northern Pikeminnow						
Bank	1	2	3,530	285	164	40
Boat	0	0	2,477	396	807	2,529
Total	1	2	6,007	681	971	2,569
Other						
Bank	98	32	3,267	386	1,762	496
Boat	287	93	221	44	1,588	292
Total	385	125	3,488	430	3,350	788
Tournament (Boat)	0	0	180	24	7,204	797
Combined Total						
Bank	20,949	3,802	49,216	5,801	44,479	8,669
Boat	21,777	3,870	37,292	6,661	139,887	27,827
Total	42,726	7,672	86,508	12,462	184,366	36,496

Table 2. Washington and Oregon sport fishery harvest, and catch and release estimates for Bonneville Reservoir, January 1 through April 7, 2000; The Dalles Reservoir, January 1 through June 18, 2000; and John Day Reservoir, January 1 through December 31, 2000.

Species	Bonneville	The Dalles	John Day
White Sturgeon [a]			
Legals kept	1,262	809	434
Sublegals released	13,517	8,298	7,856
Legals released	156	183	30
Oversize released	49	404	876
Total	14,984	9,694	9,196
Chinook salmon [b]			
Adults kept	17	0	139
Jacks kept	13	0	373
Total	30	0	512
Released	8	0	278
Coho salmon [b]			
Adults kept	0	0	32
Jacks kept	0	0	0
Total	0	0	32
Steelhead [b]			
Kept	0	195	577
Released	0	51	203
American shad			
Kept	0	256	59
Released	0	532	0
Walleye			
Kept	127	564	2,140
Released	111	161	1,093
Bass			
Kept	0	828	1,108
Released	0	1,546	6,265
Northern Pikeminnow	0	2,328	804
Other resident fish	0	1,152	642

[a] *White sturgeon retention allowed January 1 through April 7 in Bonneville Reservoir, January 1 through June 18 in The Dalles Reservoir, and January 1 through December 31 in John Day Reservoir.*

[b] *Closed to chinook and coho retention January 1 - July 31, steelhead retention April 1 - June 15.*

anglers (Table 3). The 1,416 sturgeon anglers interviewed accounted for 18% of the estimated bank effort (angler hours) and 9% of the estimated boat effort for sturgeon (Table 4).

Anglers released 12% of the legal-size catch from January 1 through April 16 (Table 4), due in part to the daily bag limit regulation which allowed retention of only one fish 107-152 cm (42 - 60 in) TL. The percentage sublegal (<107 cm, <42 in) TL, legal (107-152 cm, 42-60 in, both kept and released) TL, and oversize (>152 cm, >60 in) TL white sturgeon in the reported catch was 90%, 9%, and <1%, respectively (Table 4). The length distribution of the sampled harvest is presented in Table 5. Harvest per trip increased from 1999 levels for both boat and bank anglers (Table 6).

The Dalles Reservoir

The 2000 retention season for white sturgeon in The Dalles Reservoir opened January 1 and was scheduled to close June 30. We began our survey on January 1 and continued sampling through June 18. State fishery managers closed the fishery to retention of white sturgeon on June 19 based on our projection that harvest would reach the guideline by that date.

Anglers fished an estimated 86,508 hours (12,462 trips) in The Dalles Reservoir from January 1 through June 18 (Table 1). Angling effort for white sturgeon comprised 57% (7,155 trips) of the total estimated effort. The number of angler trips estimated by target species were as follows: 659 (5%) for anadromous salmonids, 316 (3%) for American shad, 2,465 (20%) for walleye, 732 (6%) for bass, 681 (5%) for northern pikeminnow, 430 (3%) for other resident fish, and 24 (<1%) for anglers participating in tournaments.

Anglers harvested an estimated 809 white sturgeon during 7,155 trips for sturgeon between January 1 and June 18 (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. Harvest per trip averaged 0.07 for bank anglers and 0.18 for boat anglers targeting sturgeon during the retention fishery (Table 3). The 1,946 white sturgeon anglers interviewed accounted for 19% of the estimated bank effort (angler hours) and 14% of the estimated boat effort for white sturgeon (Table 4).

The percentage sublegal (<122 cm, <48 in) TL, legal (122-152 cm, 48-60 in) TL, and oversize (>152 cm, >60 in) TL white sturgeon in the sampled catch was 86%, 10%, and 4%, 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 declined for bank anglers but increased for boat anglers from 1999 levels. (Table 6).

John Day Reservoir

We began our survey of the 2000 sport fishery in John Day Reservoir on January 1 and continued sampling through December 31. The harvest guideline was not attained and the retention fishery remained open year-round.

Table 3. Estimates of sport fishery angler trips for white sturgeon, white sturgeon harvest, and harvest per angler trip (HPUE) for Bonneville Reservoir, January 1 through April 7, 2000; The Dalles Reservoir, January 1 through June 18, 2000; and John Day Reservoir, January 1 through December 31, 2000.

Month	Bonneville			The Dalles			John Day		
Method	Trips	HPUE	Harvest	Trips	HPUE	Harvest	Trips	HPUE	Harvest
January									
Bank	569	0.00	0	440	0.01	6	159	0.00	0
Boat	583	0.10	59	217	0.04	9	23	0.00	0
Total	1,152	0.05	59	657	0.02	15	182	0.00	0 [a]
February									
Bank	1,000	0.08	82	385	0.01	4	425	0.00	1
Boat	714	0.45	320	162	0.02	3	527	0.02	8
Total	1,714	0.23	402	547	0.01	7	952	0.01	9
March									
Bank	1,929	0.18	352	812	0.08	61	482	0.00	0
Boat	1,727	0.25	438	633	0.22	138	1,350	0.00	6
Total	3,656	0.22	790	1,445	0.14	199	1,832	0.00	6
April									
Bank	226	0.05	11	785	0.06	51	505	0.02	9
Boat	163	0.00	0	575	0.08	47	806	0.05	44
Total	389	0.03	11	1,360	0.07	98	1,311	0.04	53
May									
Bank	--	--	--	1,154	0.07	79	421	0.00	0
Boat	--	--	--	458	0.13	61	453	0.00	0
Total	--	--	--	1,612	0.09	140	874	0.00	0 [a]
June									
Bank	--	--	--	626	0.14	86	459	0.01	3
Boat	--	--	--	908	0.29	264	1,487	0.02	34
Total	--	--	--	1,534	0.23	350	1,946	0.02	37
July									
Bank	--	--	--	--	--	--	981	0.02	22
Boat	--	--	--	--	--	--	2,159	0.06	120
Total	--	--	--	--	--	--	3,140	0.05	142

continued

Table 3. Continued.

Month Method	Bonneville Trips	 HPUE	 Harvest	The Dalles Trips	 HPUE	 Harvest	John Day Trips	 HPUE	 Harvest
August									
Bank	--	--	--	--	--	--	412	0.03	13
Boat	--	--	--	--	--	--	781	0.08	64
Total	--	--	--	--	--	--	1,193	0.06	77
September									
Bank	--	--	--	--	--	--	279	0.04	11
Boat	--	--	--	--	--	--	500	0.08	39
Total	--	--	--	--	--	--	779	0.06	50
October									
Bank	--	--	--	--	--	--	254	0.00	0
Boat	--	--	--	--	--	--	754	0.07	52
Total	--	--	--	--	--	--	1,008	0.05	52
November									
Bank	--	--	--	--	--	--	411	0.00	0
Boat	--	--	--	--	--	--	284	0.00	0
Total	--	--	--	--	--	--	695	0.00	0[a]
December									
Bank	--	--	--	--	--	--	416	0.00	0
Boat	--	--	--	--	--	--	106	0.08	8
Total	--	--	--	--	--	--	522	0.02	8
Combined [b]									
Bank	3,724	0.12	445	4,202	0.07	287	5,204	0.01	59
Boat	3,187	0.26	817	2,953	0.18	522	9,230	0.04	375
Total	6,911	0.18	1,262	7,155	0.11	809	14,434	0.03	434

[a] *Creel samplers did not encounter any insample kept sturgeon from John Day Reservoir during January, May, and November.*

[b] *Harvest per angler trip was 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 sport fisheries in Bonneville Reservoir, January 1 through April 7, 2000; The Dalles Reservoir, January 1 through June 18, 2000; and John Day Reservoir, January 1 through December 31, 2000.

Reservoir Method/Month	Anglers checked	Hours fished	Sublegal released	Legal released	Legal kept	Oversize released
Bonneville						
Bank						
January	212	651	67	0	0	0
February	308	804	188	5	13	0
March	572	2,038	572	6	62	2
April	30	104	10	0	1	0
Bank total	1,122	3,597	837	11	76	2
Boat						
January	105	527	269	4	13	1
February	88	655	443	3	39	0
March	99	563	238	3	28	2
April	2	7	1	0	0	0
Boat total	294	1,752	951	10	80	3
Combined total	1,416	5,349	1,788	21	156	5
The Dalles						
Bank						
January	178	672	36	0	2	4
February	163	604	23	0	1	0
March	281	1,161	110	0	11	2
April	325	1,511	180	2	11	2
May	267	1,365	159	0	9	5
June	312	1,557	245	0	21	15
Bank total	1,526	6,870	753	2	55	28
Boat						
January	21	105	8	0	1	0
February	18	99	11	0	0	0
March	66	368	110	3	16	3
April	85	452	127	3	7	4
May	69	443	115	1	9	6
June	161	813	375	23	56	35
Boat total	420	2,280	746	30	89	48
Combined total	1,946	9,150	1,499	32	144	76

Continued

Table 4. Continued

Reservoir Method/Month	Anglers checked	Hours fished	Sublegal released	Legal released	Legal kept	Oversize released
John Day						
Bank						
January	7	12	0	0	0	0
February	140	367	15	0	0	0
March	176	543	34	0	0	1
April	247	813	25	0	0	1
May	196	705	27	0	0	6
June	197	819	23	0	0	6
July	248	1,098	10	0	2	8
August	110	439	3	0	1	2
September	67	310	1	0	1	1
October	56	120	5	0	2	1
November	87	172	15	0	0	4
December	39	92	0	0	0	1
Bank total	1,570	5,490	158	0	6	31
Boat						
January	4	26	14	0	0	1
February	111	614	42	0	3	2
March	155	878	105	0	2	11
April	210	1,122	129	0	4	8
May	124	663	78	0	0	7
June	415	2,655	373	5	11	89
July	367	2,413	326	1	26	15
August	184	1,113	159	0	15	13
September	102	596	134	0	8	9
October	90	518	108	1	9	8
November	37	156	31	0	0	1
December	13	54	2	0	1	1
Boat total	1,812	10,808	1,501	7	79	165
Combined total	3,382	16,298	1,659	7	85	196

Table 5. Length frequencies of harvested white sturgeon measured during sampling of sport fisheries in Bonneville Reservoir, January 1 through April 7, 2000; The Dalles Reservoir, January 1 through June 18, 2000; and John Day Reservoir, January 1 through December 31, 2000.

Fork length (cm)	Bonneville	The Dalles	John Day	Fork length (cm)	Bonneville	The Dalles	John Day
90				130		3	1
91				131		3	
92				132	3	5	
93	2			133		4	2
94	4			134		5	
95	4			135	1	2	
96	5			136		4	2
97	10			137	1	2	2
98	5			138		2	
99	9			139		1	1
100	7		1	140			
101	14			141		1	
102	11			142			
100	10			143		2	
104	16			144			
105	6		2	145			1
106	8	1		146	1		
107	2	1	4	147			1
108	3	4	2	148			
109	4	3	8	149			
110	3	6	2	150			
111	5	3	3	151			1
112	2		1	152			
113	4	7	1	153			
114	2	6	8	154			
115	3	10	6	155			
116	2	10	4	156			
117	1	2	3	157			
118	1	4	5	158			
119		2	2	159			
120		5	3	160			
121		2	4	161			
122	1	5	3	162			
123		6	1	163			
124		5	2	164			
125	1	4		165			
126		5	2	166			
127		5	2	167			
128		4					
129	1	2	3	Total	152	136	83

Table 6. Estimated angling effort, harvest, and harvest per angler trip (HPUE) of white sturgeon from Bonneville, The Dalles, and John Day reservoirs, 1990 through 2000.

Reservoir		Bank anglers			Boat anglers		
Year	Period	Trips	Harvest	HPUE	Trips	Harvest	HPUE
Bonneville (95-138 cm fork length interval)							
1990	Mar-Oct	7,213	719	0.100	7,349	1,055	0.144
1991	[a]						
1992	[a]						
1993	Mar-Oct	7,599	678	0.089	6,747	736	0.109
1994	Mar-Oct	7,821	1,024	0.131	5,329	1,089	0.204
1995	Feb-Apr	2,541	456	0.180	1,750	857	0.490
1996	Jan-Mar	3,341	823	0.246	1,735	463	0.267
1997	Jan-Apr 4	5,093	808	0.159	2,535	632	0.249
1998	Jan-Apr 19	4,913	358	0.073	4,990	1,214	0.243
1999	Jan-Apr 16	4,724	371	0.079	3,884	782	0.201
2000	Jan-Apr 7	3,724	425	0.114	3,187	779	0.244
The Dalles (110-138 cm fork length interval)							
1990	[a]						
1991	[a]						
1992	[a]						
1993	Mar-Oct	2,058	46	0.022	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	0.032	251	29	0.116
1997	Jan-May 4	2,278	119	0.052	538	16	0.030
1998	Jan-Jun 7	4,102	455	0.111	1,319	296	0.224
1999	Jan-Jun 11	5,396	381	0.071	1,804	192	0.106
2000	Jan-Jun 18	4,202	260	0.062	2,953	472	0.160
John Day (110-138 cm fork length interval)							
1990	Mar-Dec	3,806	33	0.009	3,063	82	0.027
1991	Apr-Sep	1,977	36	0.018	2,463	73	0.030
1992	[a]						
1993	Mar-Oct	3,208	56	0.017	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	0.012
1996	Mar-Apr	1,524	17	0.011	1,396	27	0.019
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	80	0.012	10,110	224	0.022
2000	Jan-Dec	5,204	44	0.008	9,230	280	0.030

[a] *Little or no sampling.*

Anglers fished an estimated 184,366 hours (36,496 trips) in John Day Reservoir during 2000 (Table 1). Angling effort for white sturgeon comprised 40% (14,434 trips) of the total estimated effort. The number of angler trips estimated by target species were as follows: 5,014 (14%) for anadromous salmonids, 44 (<1%) for American shad, 6,937 (20%) for walleye, 5,913 (16%) for bass, 2,569 (7%) for northern pikeminnow, 788 (2%) for other resident fish, and 797 (2%) for tournament anglers.

Anglers harvested an estimated 434 white sturgeon during 14,434 trips for sturgeon in 2000 (Table 2). Anglers concentrated their effort for sturgeon from McNary Dam downstream past Irrigon, Oregon (Rkm 449). Effort for white sturgeon was greatest in July (Table 3). Harvest per trip averaged 0.01 for bank anglers and 0.04 for boat anglers (Table 3). The 3,382 sturgeon anglers interviewed accounted for 19% of the estimated bank effort (angler hours) and 20% of the estimated boat effort for white sturgeon (Table 4).

The percentage sublegal (<122 cm, <48 in) TL, legal (122-152 cm, 48-60 in) TL, and oversize (>152 cm, >60 in) TL white sturgeon in the reported catch was 85%, 5%, and 10%, 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 declined for bank anglers but increased for boat anglers from 1999 levels (Table 6).

Treaty Indian Commercial and Subsistence Harvest

The 2000 treaty Indian commercial harvest estimates for Zone 6 were 1,145 white sturgeon from Bonneville Reservoir, 1,456 white sturgeon from The Dalles Reservoir, and 846 white sturgeon from John Day Reservoir (Table 7). Most of the harvest (1,706 fish) was landed in the winter gill net fishery (February 1 - March 20) with 1,183 fish harvested in the spring setline fishery (April 1 - July 31), 51 fish harvested in the January setline fishery (January 1-31), and 151 fish landed in the fall setline fishery (October 11 – December 31). The treaty Indian Zone 6 subsistence white sturgeon harvest estimated by CRITFC and the Yakama Indian Nation was 343 fish from all three reservoirs (Table 7).

DISCUSSION

Zone 6 Sturgeon Harvest Management

Progress is being made in rebuilding the white sturgeon population in Bonneville Reservoir through application of conservative harvest management and in The Dalles and John Day reservoirs through a combination of conservative harvest management strategies and through trawl and haul stocking efforts. This was born out in the results of the most recent stock assessments (North et al. 1998, North et al. 1999, Kern et al. 2001). Fisheries have benefited from this success. Harvest guidelines increased 860% for John Day Reservoir following the 1996 stock assessment and 300% for The Dalles Reservoir following the 1997 stock assessment.

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 2000.

Fishery	Bonneville		The Dalles		John Day		Unspecified	
Year	Guideline	Harvest	Guideline	Harvest	Guideline	Harvest	Harvest	Total
Sport								
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	1,236	600-800	694	560	422	0	2,352
2000	1,520	1,262	600-800	809	560	434	0	2,505
Indian commercial								
1991	1,250	999	300	457	100	39	0	1,495
1992	1,250	1,146	300	431	100	23	0	1,600
1993	1,250	1,415	300	579	100	12	0	2,006
1994	1,250	1,176	300	309	100	117	0	1,602
1995	1,250	1,421	300	312	100	308	0	2,041
1996	1,250	1,005	300	230	100	360	0	1,595
1997	1,300	1,852	400	498	1,160	1,260	0	3,610
1998	1,300	1,462	1,000-1,200	1,108	1,160	1,100	0	3,670
1999	1,300	1,280	1,000-1,200	1,051	1,160	760	0	3,091
2000	1,300	1,145	1,000-1,200	1,456	1,160	846	0	3,447
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	2,516	1,800	1,745	1,720	1,182	0	5,443
2000	2,820	2,407	1,800	2,265	1,720	1,280	0	5,952

continued

Table 7. Continued.

Fishery	Bonneville		The Dalles		John Day		Unspecified	
Year	Guideline	Harvest	Guideline	Harvest	Guideline	Harvest	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		570		260		320	0	1,150
1996		260		120		110	0	490
1997		130		40		63	0	233
1998		109		86		45	0	240
1999		90		116		28	0	234
2000		--		--		--	0	343

[a] *The SMTF did not establish harvest guidelines for the subsistence fishery, however, the expected annual subsistence harvest was 300 white sturgeon for 1994 through 2000.*
[b] *Not available.*

Managers have been successful since 1995 at keeping harvest within guidelines by adopting in-season retention fishery closures based on weekly projections of harvest. Sport harvest has averaged 95%, 107%, and 86% of the SMTF's annual harvest guidelines for Bonneville, The Dalles, and John Day reservoirs respectively (Table 7). Prior to pro-active in-season management (1991-1994), sport harvest averaged 158%, 163%, and 169% in Bonneville, The Dalles, and John Day reservoirs respectively.

The trend in increased abundance has yet to be corroborated by HPUE data. HPUE has varied from year to year for Bonneville and The Dalles reservoirs and has declined in John Day Reservoir. The decline in HPUE for John Day Reservoir may be a misnomer, as anglers have not adjusted their effort to match the changing distribution of fish observed during the last stock assessment. Continuation of the trawl and haul stocking program for The Dalles and John Day reservoirs should eventually result in increased HPUE.

PLANS FOR NEXT YEAR

We will continue to monitor Zone 6 sport and treaty Indian commercial fisheries in 2001. 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. We will work with ODFW using setlines to assess the status of the white sturgeon population in John Day Reservoir. We will capture broodstock white sturgeon for CRITFC's aquaculture supplementation experiment and work with fishing-guides to obtain breeding age adult white sturgeon from which we will collect paired gonad tissue, blood, and mucus samples to help OSU develop methods to determine sex and stage of maturity.

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

ANNUAL PROGRESS REPORT

APRIL 2000 – MARCH 2001

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 spawning and rearing habitats and recruitment to young-of-the-year in various Columbia and Snake river reservoirs.

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ABSTRACT

During 1 April 2000 through 31 March 2001 the U.S. Geological Survey (USGS) worked on seven tasks. Two are ongoing activities related to the development of long-term data sets, three are studies of moderate duration in which the majority of the field work has already been completed, and two were activities that began during this reporting period.

We continued a telemetry study that began in 1998 investigating movements and behavior of pre-spawn and spawning white sturgeon in The Dalles Reservoir in relation to dam operations. Fifteen previously tagged white sturgeon were tracked during 29 March through 29 June 2000. However, our results were non-conclusive since we were only able to obtain locations prior to and after spill changes for two fish. Generally fish did not move great distances (typically <1 km) during our monitoring periods, and some fish did remain within the BRZ when water was being spilled.

Fall bottom trawling revealed that recruitment of young-of-the-year white sturgeon occurred in Bonneville Reservoir and in The Dalles Reservoir, but at a low level. No young-of-the-year white sturgeon were collected in John Day Reservoir. The Oregon Department of Fish and Wildlife provided gillnet catch data from The Dalles and John Day reservoirs in an ongoing comparison of indices of abundance derived from the two gears.

Analyses continued on several tasks, including quantifying habitat suitable for spawning of white sturgeon in Bonneville, The Dalles, John Day, and McNary tailraces, and describing the effects of proposed reservoir drawdowns on productivity of white sturgeon. Estimates of the availability of spawning habitat for 2000 were considerably lower than average since optimal spawning temperatures only occurred for about two weeks and did not coincide with peak river discharge.

Laboratory experiments investigating predation on larval and juvenile white sturgeon began in 2000. We found that higher turbidity levels lowered predation rates of prickly sculpin on white sturgeon larvae. The two larger predators we tested in our size vulnerability experiments were very different in their predation patterns. Channel catfish only ingested small sturgeon, < about 30 mm TL, while northern pikeminnow ate sturgeon up to about 120 mm TL.

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 86-50 – White Sturgeon Restoration and Enhancement in the Columbia and Snake Rivers Upstream from Bonneville Dam. The reporting period is 1 April 2000 through 31 March 2001.

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 seven tasks related to the four objectives stated above. Those tasks and the objective addressed were to:

1) Update the relationship between river discharge and the location and quantity of spawning habitat for white sturgeon in the lower Columbia River as new information becomes available - Objective 1.

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

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

4) Describe the potential effect of reservoir drawdowns on white sturgeon productivity in John Day, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite reservoirs – Objective 2.

5) Use telemetry to monitor the behavior of pre-spawn and spawning white sturgeon in the tailrace of John Day Dam in relation to dam operations – Objective 2.

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

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

These tasks are in various stages of completion. Tasks 2 and 3 are ongoing activities related to the development of long-term data sets. Tasks 1, 4, and 5 are studies of moderate duration in which the majority of the field work has already been completed and final analyses are ongoing. Tasks 6 and 7 are studies that began during this reporting period.

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 2000 as inputs to create a daily index of white sturgeon spawning habitat for these four known spawning areas. Mean daily river discharges and water temperatures that occurred at the dams during April through July were obtained from the Data Access in Real Time (DART) web page (http://www.cqs.washington.edu/dart/).

Young-of-the-Year Indexing

We sampled for juvenile white sturgeon with a 6.2 m high-rise bottom trawl (Palmer et al. 1988) to determine if recruitment to YOY occurred in Bonneville, The Dalles, and John Day reservoirs. The previously designed sampling program calls for conducting a total of 66 tows at 11 sites in Bonneville Reservoir (6 replicates per site), 24 tows at 12 sites in The Dalles Reservoir (2 replicates per site), and 38 tows at 19 sites in John Day Reservoir (2 replicates per site). Sample sites were designated with a code indicating statute river mile and relative position across the river channel. The last digit of the site designation represents position in the channel, with 0 and 5 designating backwater areas and 1 through 4 designating ¼ channel width increments from left to right facing upstream. Digits preceding the last number represent river miles to the nearest 0.1-mile from the mouth of the Columbia or Snake rivers. For example, a site coded as 34753 indicates that the location 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. 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 mm. Weights were obtained only from white sturgeon. 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 (μ_{cpue}) of white sturgeon was expressed as the number of fish caught per 2,500 m^2. The proportion of positive tows (E*p*) for YOY white sturgeon was calculated as the ratio of tows where at least one YOY was captured to the total number of tows conducted.

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

The USGS is collaborating with the Oregon Department of Fish and Wildlife (ODFW) and Washington Department of Fish and Wildlife (WDFW) to determine if indices of recruitment developed from catches of YOY white sturgeon from 51-mm stretched mesh gillnets follow trends similar to those developed from catches in bottom trawls. Sampling with bottom trawls to index the recruitment of YOY white sturgeon is an effective method (Counihan et al. 1999) but is restricted to areas with suitable bottom topography, and requires specialized boats and boat operator experience. Counihan et al. 1999 described two indices that can be used to assess the relative abundance of YOY white sturgeon from highly skewed trawling data. Comparisons between gears will be made from sampling with both gears in The Dalles and John Day Reservoirs. The USGS has an ongoing sampling program in each of these reservoirs, and in 1999 the ODFW began sampling with gillnets at fixed sites in these reservoirs (Burner et al. 1999). The ODFW conducted sampling in The Dalles and John Day reservoirs and entered, proofed, and summarized the catch data from that sampling.

The statistical design for this comparison calls for sampling with each gear during October or November at fixed locations. Generally, in each reservoir sampling with gillnets is conducted after sampling is done with the bottom trawl. Young-of-the-year are discerned from older white sturgeon through length frequency analysis, and two indices of abundance are derived for each gear and reservoir. The proportion of positive efforts (E*p*; Uphoff 1993) is the ratio of the number of efforts with at least one YOY white sturgeon to the total number of efforts conducted. The

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[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.

arithmetic mean of catch per unit effort (CPUE) is the mean of untransformed CPUE data. For the bottom trawl data, mean CPUE is presented as the number of YOY white sturgeon per 2,500 m^2 of riverbed sampled. For the gillnet data, mean CPUE is presented as the number of YOY per overnight set. Correlation analysis will be used to compare indices of abundance of YOY between gears for each reservoir.

Movements and Behavior of Pre-Spawn and Spawning White Sturgeon

The USGS continued a telemetry study investigating the movements and behavior of pre-spawn and spawning white sturgeon in The Dalles Reservoir that began in 1998 (Kappenman et al. 2000). The study plan called for weekly searches in The Dalles Reservoir for fifteen previously tagged white sturgeon during the spring until water temperatures exceeded 12°C. When water temperatures were between 12°C and 18°C we conducted daily searches, excluding weekends, of the John Day Dam Tailrace. Sampling was structured around planned changes in spill, which usually occurred at 6 AM and 6 or 7 PM. A sampling session occurred once each day and alternated each week between morning and evening. Spill at night was approximately 60% of total discharge and was decreased during the day to either 30% of total discharge or near 0%. We attempted to locate each fish six times during a telemetry session, three locations prior to, and three locations after the change in discharge. Because this study was intended to investigate movements of pre-spawning and spawning fish in relation to discharge operations at John Day Dam, we placed more emphasis on locating fish in the John Day Dam tailrace versus the rest of The Dalles Reservoir. Spawning by white sturgeon has been documented between river km 342.8 and 346 (Miller et al. 1991), and habitat suitable for spawning is influenced by discharge at the dam (Parsley and Beckman 1994).

A wireless hydrophone system remotely monitored movements of tagged fish in and out of the known spawning area during the year 2000 spawning season. Each wireless hydrophone detects acoustic signals on frequency 76.8 kHz and relays them via VHF transmission to a land-based receiver station. Two hydrophones were deployed; one at river km 343.8 and one at river km 345.2. The remote VHF data logging station was positioned on the dredge spoil island at river km 346.5 (Figure 1). In addition to logging wireless hydrophone data, the VHF data logging station detected transmitters on radio frequencies. Because of high ambient noise both on radio and acoustic frequencies, contact was not considered successful unless there were 2 consecutive events on acoustic frequencies and 3 consecutive events on radio frequencies. This configuration enabled us to determine direction of fish movement (upstream or downstream) as well as when fish entered or left the area.

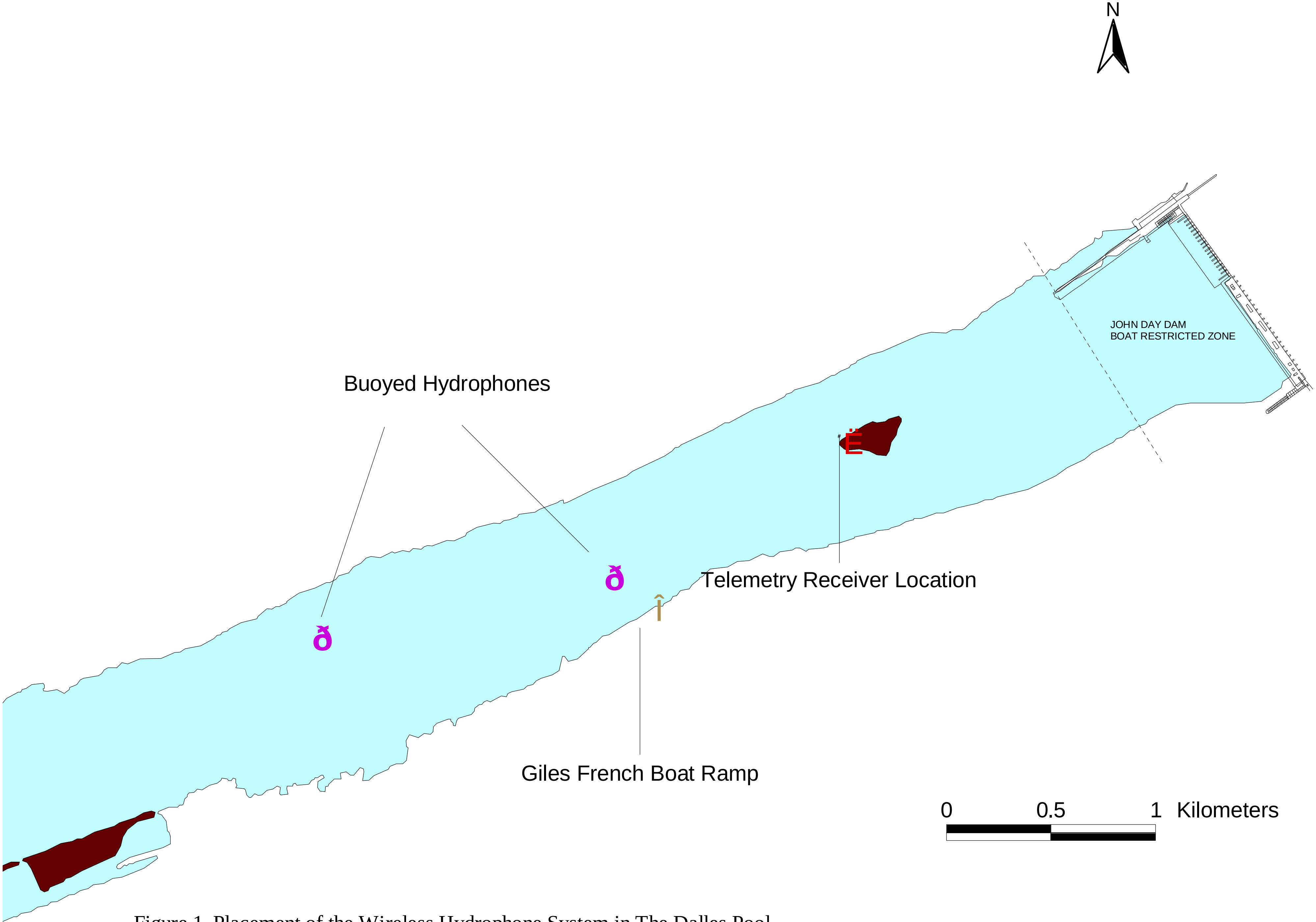

Figure 1. Placement of the Wireless Hydrophone System in The Dalles Pool.

While locating fish via mobile tracking, we implemented two search strategies in The Dalles Reservoir; continuous listening and pre-established listening stations spaced at 0.5 km intervals. Continuous listening was required immediately downstream from John Day Dam because complex channel structure and high ambient noise from operations at the dam limited reception distance of the acoustic transmitters. Therefore, the area downstream of the John Day Dam boat restricted zone between river km 347.6 and 345.5 was searched from a boat along both the Washington and Oregon shorelines by either powering or drifting downstream while continuously listening for acoustic transmitters on 72, 73, 74 and 76 kHz frequencies. At the same time, a radio receiver scanned for radio transmitters on frequencies 149.200, 149.210 and 149.220 MHz.

When water temperatures were less than 12° C, we searched the remainder of The Dalles Reservoir downstream from river km 345.5 by motoring to predetermined listening stations. The boat was stopped at each listening station and the directional hydrophone was deployed and rotated 360 degrees, pausing for several seconds in each of the four 90 degree quadrants. After listening in all four quadrants, the acoustic receiver was set to the next frequency and the process was repeated until all transmitter frequencies were scanned. When a transmitter was detected, the boat was maneuvered until the signal was equal in all four directions, indicating that we were directly above the fish. At each fish location the latitude and longitude were recorded using a GPS, the approximate river mile was recorded and the depth was measured using a fathometer.

Statistical comparisons of tailrace fish positions before and after changes in spill were made using multi-response permutation procedures (MRPP). The MRPP test statistic is based on within group averages of pairwise distance measures between object response values in a euclidian data space (Zimmerman et. al 1985). Only sampling sessions where at least 6 locations (3 before change in spill, 3 after change in spill) were collected for each fish were used in the analysis.

Predation on Larval and Juvenile White Sturgeon

Turbidity Experiments

Trials were conducted in eight 85-l aquariums to determine the effects of four turbidity levels, 0, 20, 60, and 180 NTU (Nephelometric Turbidity Unit), on predation of white sturgeon larvae and juveniles. Aquariums were surrounded by black cloth, and covered with black mesh. Light was supplied by overhead fluorescent bulbs and levels were maintained at about 0.2 lux in clear water during daytime hours; lights were off during normal nighttime hours. Water was supplied with a flow-through system (except during experiments), and temperatures were 17-18^{o}C. White sturgeon were obtained from a commercial hatchery near Portland, Oregon, which collects brood stock each year from the Columbia River. White sturgeon were spawned in mid-June 2000, and we used this cohort of larvae and juveniles as prey as they increased in size. Thirty white sturgeon were measured weekly for total length (TL). Predators for turbidity trials were 100-180 mm TL prickly sculpins *Cottus asper* that were collected with minnow traps from a local marina about a month before experiments were begun.

Two prickly sculpins were placed in each aquarium at least two days prior to an experiment, and food was withheld. To initiate trials, sculpins were moved to one end of each aquarium and a mesh divider was placed midway. The purpose of this was to avoid introducing prey directly over the predators by instead placing prey in the opposite end of the aquarium. Turbidity level in each aquarium was randomly selected with two aquariums per level. Water flow was turned off in each aquarium and turbidities were brought up to the designated levels by stirring pre-determined amounts of a slurried bentonite solution in the water; for 0 NTU, clear water was stirred into the tanks. Water samples were removed from each end of the aquarium and turbidities tested using a Hach model 2100P Turbidimeter. If samples were not within 10% of the designated level, turbidities were adjusted by adding more bentonite. If this was necessary, all tanks were again stirred to standardize treatments. When turbidities were at appropriate levels, a 2-l container of water was removed from each aquarium, and sculpins were allowed to acclimate for one hour before trials began. Air stones in each tank kept bentonite suspended. Fifteen minutes before trials began, thirty 17-19 mm TL yolk-sac white sturgeon larvae were gently scooped into each of the eight 2-l containers. To initiate a trial, larvae were lowered into each aquarium at the end opposite the sculpins, and the divider and air stones were removed. As determined from preliminary experiments, trials were conducted for a period of 15 min. At this time, sculpins were netted from each aquarium to end predation and placed in a common tank. Water was removed from each aquarium, strained, and the remaining number of larvae counted. An experiment was conducted with yolk-sac white sturgeon larvae on five occasions over a 10-day period, resulting in 8-10 replicates per turbidity. Results were analyzed using a one-way ANOVA and Tukey's range test at the level of P=0.05.

Turbidity trials were also conducted using the same basic methodology as above, but instead using 4, 5, and 6 week old juvenile white sturgeon as prey, with mean total lengths (n=30) of 25 mm, 31 mm, and 37 mm, respectively. Two replicates were conducted per each turbidity level and white sturgeon age group.

Size Vulnerability

Experiments were conducted to determine the size at which white sturgeon are no longer vulnerable to three common Columbia River predators--prickly sculpins, northern pikeminnow *Ptychocheilus oregonensis*, and channel catfish *Ictalurus punctatus*. We collected 370-477 mm TL northern pikeminnow by boat electroshocking in the Columbia River during May 2000, and 365-450 mm TL channel catfish were collected by the Washington Department of Fish and Wildlife by gill-netting in the Snake River during November 1999. Prickly sculpins were held in the eight 85-l aquariums described above, with two predators per aquarium. Northern pikeminnow and channel catfish were held in four 1.3 m diameter tanks, with two tanks per species and three fish per tank. All tanks had flow-through water at 17-18^{o}C. White sturgeon juveniles were obtained from a commercial hatchery, held in similar 1.3 m tanks, and feed commercial semi-moist salmon diets to excess.

Each week we alternated between feeding predators white sturgeon juveniles, and another prey type--25-40 mm TL goldfish *Carassius auratus* for sculpins, or 70-100 mm TL juvenile chinook salmon *Oncorhynchus tshawytscha* for pikeminnow and catfish. The purpose of this was to confirm that predators were still eating even if they did not ingest sturgeon. For sculpin experiments, 10 white sturgeon were introduced into each aquarium on Monday, removed 24 hrs later, and counted. On Wednesday, 10 goldfish were placed into each tank and removed in 24 hrs. The experimental design was the same for pikeminnow and catfish, except initially prey alternated between 30 sturgeon and 12 juvenile salmon. Less salmon were used because their size was greater than sturgeon. As sturgeon reached a larger size, trials were conducted every other week, and 30 of each prey type were used.

RESULTS AND DISCUSSION

Availability of Spawning Habitat

Bonneville, The Dalles, John Day, and McNary Tailraces

River discharge and water temperatures that occurred during April through July 2000 provided conditions that were not favorable for spawning by white sturgeon downstream from Bonneville, The Dalles, John Day, and McNary dams. The river hydrograph (Figure 2) shows that daily discharge rose early in the year and peaked at approximately 11,000 cms (280,000 cfs) on 23 April. River discharge then gradually declined throughout May, June, and July. During this period, daily river discharges were erratic with short-term increases and decreases occurring on a weekly basis. Water temperature, one factor which determines the time period when spawning will occur, rose to optimal levels (13.3^{o}C) for spawning by white sturgeon on or about 18 May (Figure 3) and exceeded optimum levels (15.2^{o}C) on 2 June in the Bonneville Dam tailrace, 4 June in The Dalles Dam Tailrace, and on 5 June in the John Day and McNary dam tailraces. Thus optimal spawning temperatures in the four tailraces occurred for just over 2 weeks. However, because the peak in river discharge was asynchronous with optimal temperatures for spawning, the available habitat for spawning was poor. As a result of the hydrograph and temperature regime that occurred in 2000, our monthly estimates of the index of spawning habitat showed that the availability of habitat for spawning peaked in May near the average of levels of past years (Figure 4). The Dalles Dam tailrace was an exception. In this tailrace, the index of spawning habitat for May 2000 was substantially lower than the average for previous years. Annual indices of spawning habitat for The Dalles, John Day, and McNary dam tailraces in 2000 were well below averages for past years, and the annual index for the Bonneville Dam tailrace was slightly lower than the long-term average (Figure 5).

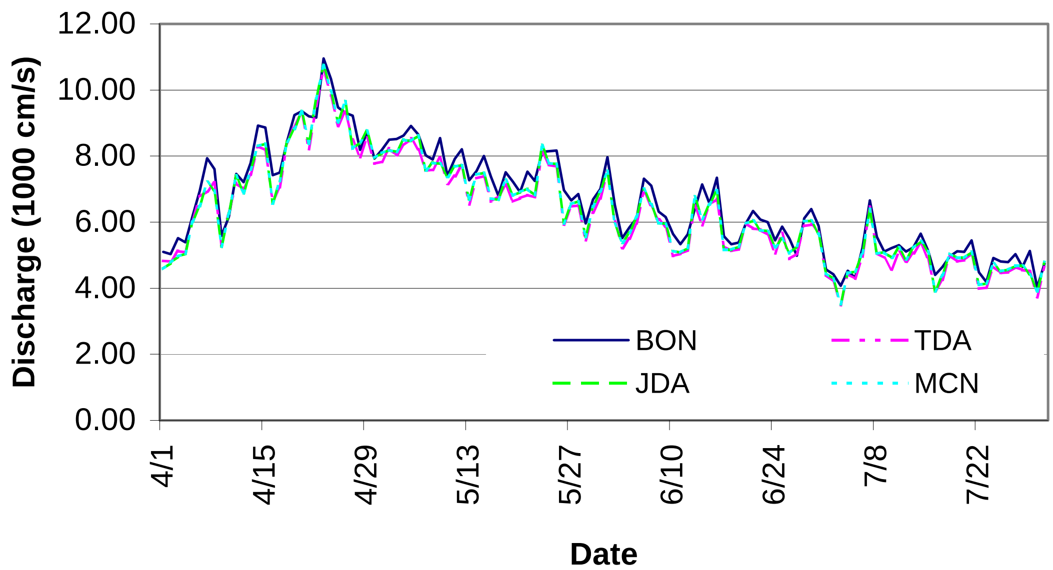

Figure 2. River discharges at Bonneville (BON), The Dalles (TDA), John Day (JDA), and McNary (MCN) dams during 2000. Data were obtained from the DART website (http:\\www.cqs.washington.edu\dart\).

Figure 3. Water temperatures at Bonneville (BON), The Dalles (TDA), John Day (JDA), and McNary (MCN) dams during 2000. Data were obtained from the DART website (http:\\www.cqs.washington.edu\dart\).

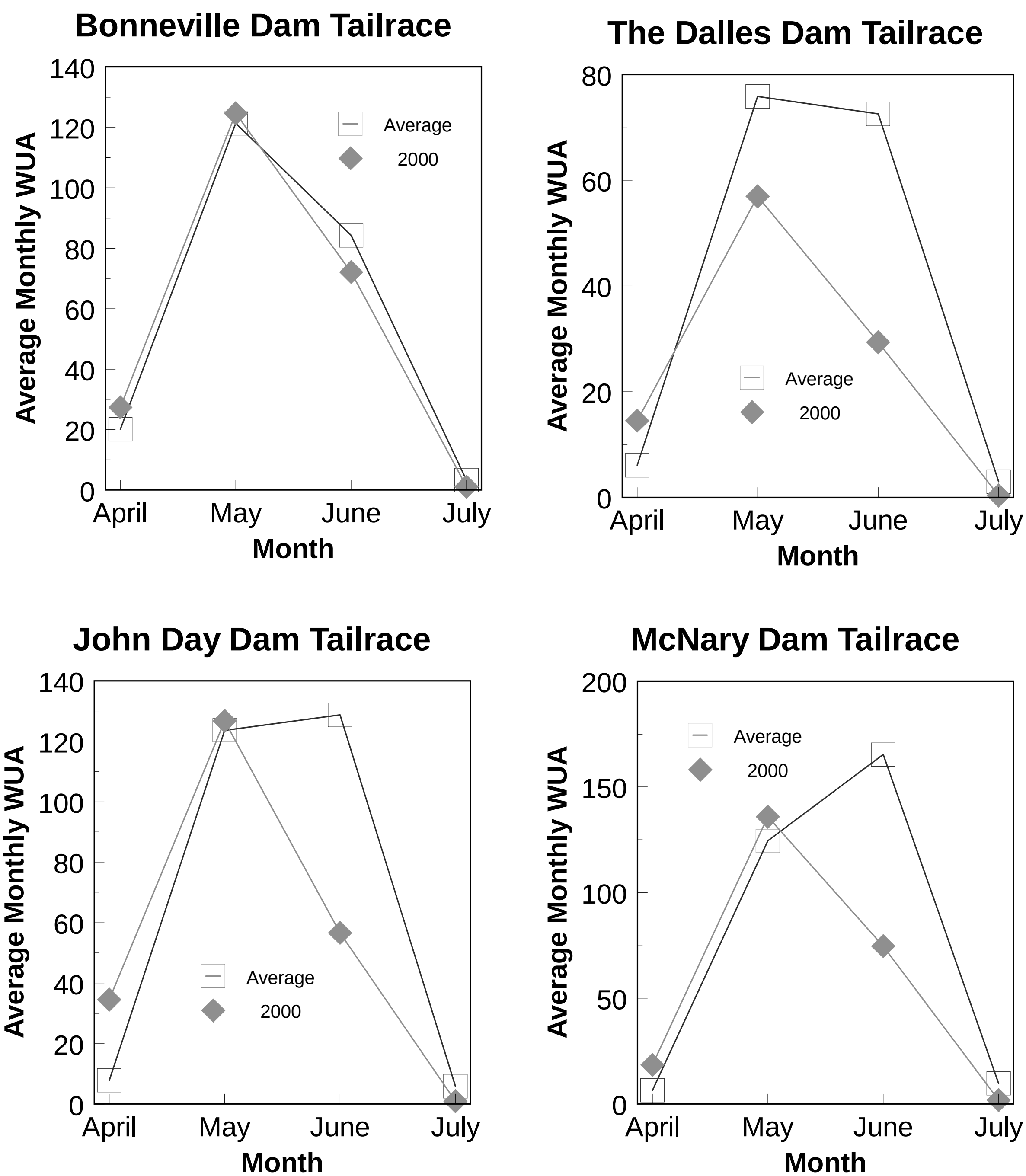

Figure 4. Mean monthly indices of spawning habitat (temperature conditioned weighted usable area (WUA)) for white sturgeon during 2000 and the average for 1985 through 1999 for the four spawning areas that have been modeled.

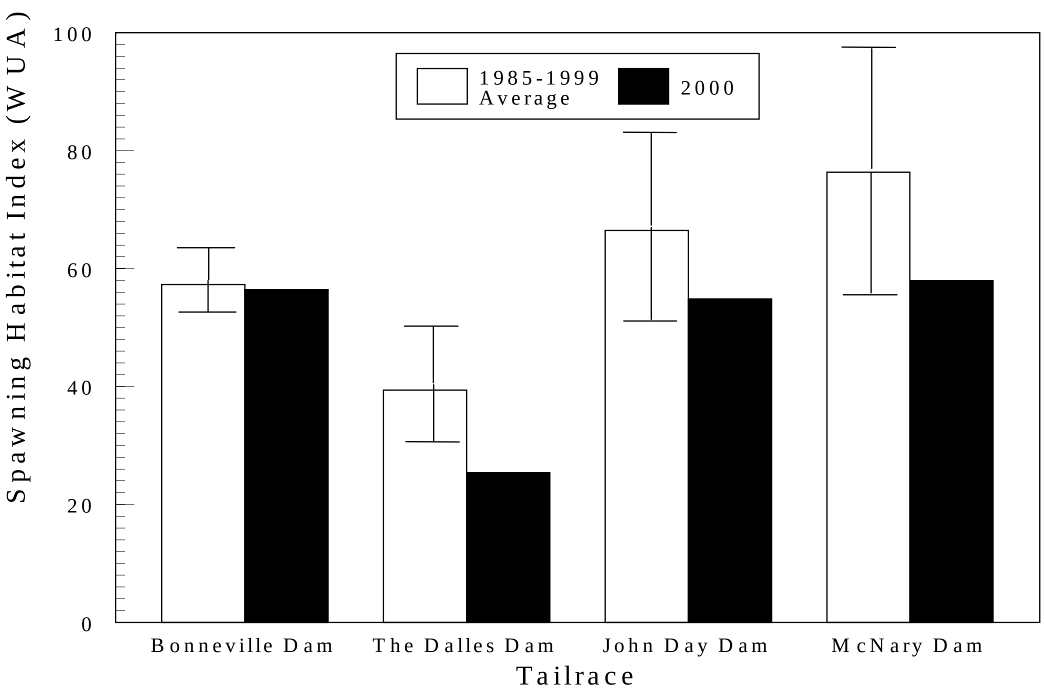

Figure 5. Annual mean composite index of spawning habitat (temperature conditioned weighted usable area (WUA)) for white sturgeon for each of the four dam tailraces that have been modeled (Parsley and Beckman 1994). Shown are the indices for 2000 and the average for 1985 through 1999. The vertical lines within the bars for the averages depict one standard deviation.

Young-of-the-Year Indexing

The bottom-trawl sampling program was completed as scheduled during 2000. We fished the bottom trawl on 12 d from 18 September to 4 October in Bonneville Reservoir, on 5 d from 5 October to 13 October in The Dalles Reservoir, and on 4 d from 23 October to 31 October in John Day Reservoir. Down time due to equipment problems or damaged trawls was not significant this year. Weather conditions were favorable and only one day of effort was rescheduled due to weather-related conditions in Bonneville Reservoir. An additional day was rescheduled due to mechanical problems during The Dalles Reservoir sampling. Strong easterly winds can sometimes preclude sampling at sites in the western end of Bonneville Reservoir near Stevenson, whereas strong westerly winds can preclude sampling at nearly all sites in all reservoirs. No nets were lost while sampling this year.

Bonneville Reservoir

Recruitment of YOY white sturgeon occurred in Bonneville Reservoir in 2000. We captured 133 juvenile white sturgeon with the high-rise trawl during our sampling of Bonneville Reservoir, and 15 (11%) of these were YOY. Young-of-the-year white sturgeon were captured at 6 of the 11 sites (Table 1). Young-of-the-year white sturgeon were easily distinguished from older fish by length frequency analysis (Figure 6). The YOY ranged in length from 139 to 257 mm TL and weighed 12 to 72 g. The mean length of YOY captured was 191 mm TL and mean weight was 33 g. Older juvenile white sturgeon were captured at 10 of the 11 sites (Table 1). The older juvenile white sturgeon measured 274 to 840 mm FL and weighed 120 to 3,550 g.

The CPUE for combined effort for each of the 11 sites sampled with the bottom trawl in Bonneville Reservoir ranged from 0.0 to 0.92 YOY per 2,500 m^2 and from 0.0 to 9.39 fish per 2,500m^2 for all white sturgeon caught (Table 1). The mean CPUE for individual tows was 0.25 YOY per 2,500 m^2 (SE = 0.09) and 2.24 fish per 2,500m^2 (SE = 0.57) for all juvenile white sturgeon. The proportion of positive tows for YOY sturgeon during 2000 for Bonneville Reservoir was 0.12.

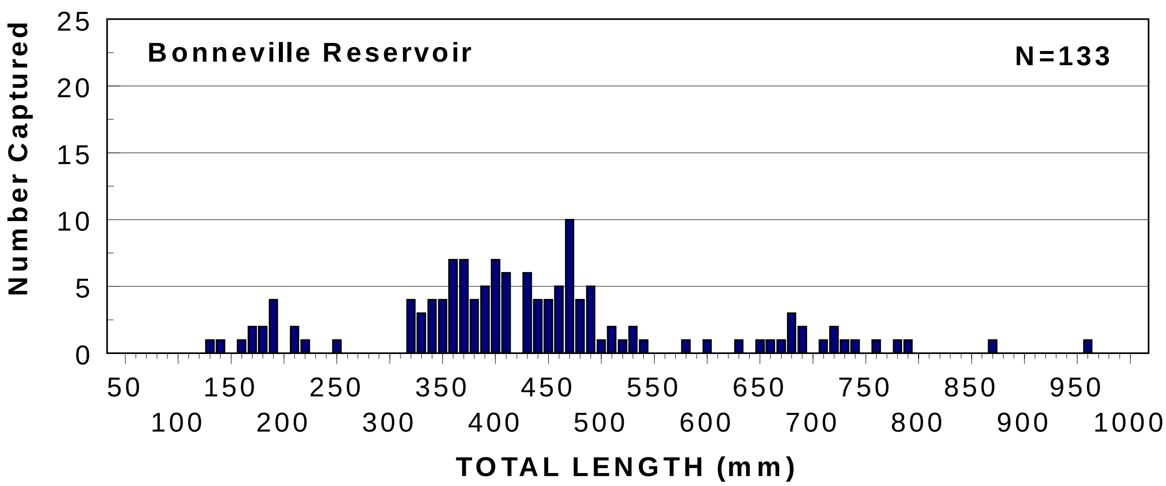

Figure 6. Length frequency distribution of juvenile white sturgeon captured during fall bottom trawling in Bonneville Reservoir in 2000.

The Dalles Reservoir

Recruitment to YOY also occurred in The Dalles Reservoir in 2000. We captured 25 juvenile white sturgeon with the bottom trawl during sampling in The Dalles Reservoir, and only 2 (8.0%) of these were YOY. Young-of-the-year white sturgeon were captured at only 1 of the 12 sites (Table 2). The two YOY white sturgeon collected in The Dalles Reservoir measured 222 and 252 mm TL (Figure 6) and weighed 45 and 73 g, respectively. Older white sturgeon were captured at 2 of the 12 sites trawled. The older juvenile white sturgeon measured 339 to 565 mm FL and weighed 240 to 1,300 g.

The CPUE for combined effort for each of the 12 sites sampled with the bottom trawl in The Dalles Reservoir ranged from 0 to 1.1 YOY per 2,500 m^2 and from 0 to 13.1 fish per 2,500 m^2 for all white sturgeon caught (Table 2). The mean CPUE for the 24 completed tows was 0.09 YOY per 2,500 m^2 (SE = 0.09) and 1.15 fish per 2,500 m^2 (SE = 1.03) for all juvenile white sturgeon. The proportion of positive tows for YOY white sturgeon during 1999 for The Dalles Reservoir was 0.04.

John Day Reservoir

We captured 1 juvenile and no YOY white sturgeon with the bottom trawl during our sampling of John Day Reservoir (Table 3), indicating that no recruitment of young-of-year white sturgeon occurred during 2000. The one juvenile captured in John Day Reservoir measured 511 mm (FL) and weighed 1100 g.

The CPUE for combined effort for each of the 19 sites sampled with the bottom trawl in John Day Reservoir ranged from 0 to 0.56 for all white sturgeon caught (Table 3). The mean CPUE for the 38 completed tows was 0.03 fish per 2,500 m^2 (SE = 0.03) for all juvenile white sturgeon.

Table 1. Characteristics of bottom trawling conducted to index recruitment of white sturgeon in Bonneville Reservoir during 18 September to 4 October 2000. Young-of-the-year (YOY) white sturgeon were differentiated by length frequency analysis.

			Number of white sturgeon collected		White sturgeon catch/2500 m^2	
Site	Number of trawl tows	Total area sampled (ha)	All ages	YOY	All ages	YOY
15052	6	1.3692	2	2	0.37	0.37
15734	6	1.3689	0	0	0.0	0.0
15951	6	1.3846	2	1	0.36	0.18
16522	6	1.3511	1	0	0.19	0.0
16851	6	1.3098	2	0	0.38	0.0
17063	6	1.3617	16	1	2.94	0.18
17374	6	1.3316	17	2	3.19	0.38
17652	6	1.3114	15	0	2.86	0.0
17911	6	1.3575	51	5	9.39	0.92
18351	6	1.3791	24	4	4.35	0.73
18523	6	1.3497	3	0	0.56	0.0
Totals	66	14.8746	133	15		

Table 2. Characteristics of bottom trawling conducted to index recruitment of white sturgeon in The Dalles Reservoir during 5 October to 13 October 2000. 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
19463	2	0.4459	0	0	0	0
19683	2	0.4402	1	0	0.57	0
19981	2	0.4586	22	2	13.08	1.09
20012	2	0.4492	0	0	0	0
20244	2	0.4519	0	0	0	0
20432	2	0.4489	0	0	0	0
20451	2	0.4641	0	0	0	0
20651	2	0.4509	0	0	0	0
20752	2	0.4529	0	0	0	0
21014	2	0.4635	0	0	0	0
21103	2	0.4570	0	0	0	0
21412	2	0.4545	0	0	0	0
Totals	24	5.4376	23	2		

Table 3. Characteristics of bottom trawling conducted to index recruitment of white sturgeon in John Day Reservoir during 23 October to 31 October 2000. Young-of-the-year (YOY) white sturgeon were differentiated by length frequency analysis.

Site	Number of trawl tows	Total area sampled (ha)	Number of white sturgeon collected		White sturgeon catch/2500 m^2	
			All ages	YOY	All ages	YOY
21924	2	0.4522	0	0	0	0
22533	2	0.4401	0	0	0	0
22931	2	0.4497	0	0	0	0
23352	2	0.4504	0	0	0	0
24173	2	0.4472	0	0	0	0
24324	2	0.4483	0	0	0	0
24822	2	0.4524	0	0	0	0
25283	2	0.4384	0	0	0	0
25623	2	0.4530	0	0	0	0
26382	2	0.4482	0	0	0	0

26422	2	0.4587	0	0	0	0
26803	2	0.4476	0	0	0	0
27054	2	0.4441	0	0	0	0
27384	2	0.4501	0	0	0	0
27851	2	0.4471	0	0	0	0
27974	2	0.4478	1	0	0.56	0
28074	2	0.4437	0	0	0	0
28184	2	0.4528	0	0	0	0
28972	2	0.4421	0	0	0	0
Totals	38	8.5139	1	0		

Conclusions

The trawling and gillnet sampling conducted by the USGS and ODFW (Report A) revealed that recruitment to YOY was low to non-existent in 2000. Recruitment was only detected in Bonneville and The Dalles reservoirs. This may be due in part to poor spawning conditions downstream from Bonneville, The Dalles, John Day, and McNary dams during 2000. Optimal spawning temperatures occurred for just over two weeks, but did not coincide with peak river discharge, which was in April rather than in May or June as is typical. Thus, estimates of the availability of spawning habitat for 2000 were considerably lower than averages, particularly the monthly estimates for June, when most white sturgeon spawning in the lower four reservoirs on the Columbia River normally takes place.

Reduced recruitment may be a long-term trend since indices of abundance of YOY white sturgeon derived from trawling have shown a decline since 1996 (Figure 7). These indices are positively related to river discharges and negatively related to water temperatures that occur during summer (Counihan et al. in press). Climate regimes in the Pacific Northwest undergo cyclical fluctuations. The region may be in a prolonged drought cycle, which could result in continued reduced recruitment of white sturgeon in the impoundments. However, since white sturgeon are a very long-lived species, populations can likely tolerate periods of reduced recruitment.

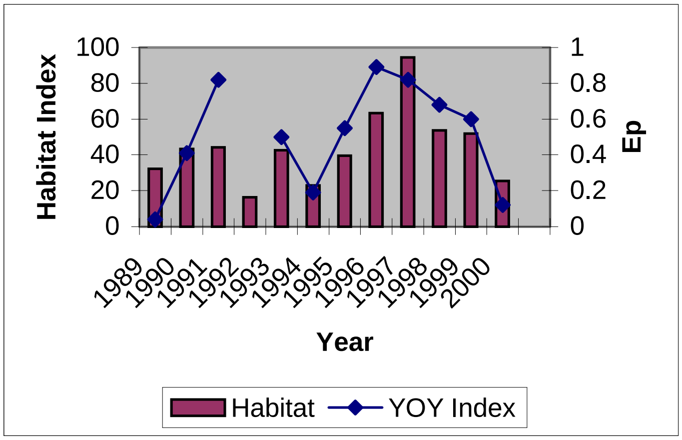

Figure 7. Weighted usable spawning habitat and the proportion of positive tows (E*p*: those efforts with at least one young-of-the-year white sturgeon) for 1989 through 2000.

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

Sampling during 2000 by ODFW and USGS provided the second year of data to be used for comparing indices of abundance derived from gillnet and bottom trawl catches. In The Dalles Reservoir, the ODFW (Report A) sampled 12 fixed sites with gillnets three times each for a total of 36 gillnet efforts while the USGS, as described above, sampled 12 fixed sites with bottom trawls two times each for a total of 24 tows. In John Day Reservoir, ODFW sampled 41 scheduled gillnet efforts. The USGS sampled 19 fixed sites two times each for a total of 38 trawl tows, and captured no YOY white sturgeon during the trawling. Indices of abundance were calculated (Table 4) but additional data points are needed for correlation analysis.

Table 4. Indices of young-of-the-year white sturgeon abundance for 2000 derived from gillnet and bottom trawling sampling data. E*p* represents the proportion of positive efforts (those efforts with at least one young-of-the-year white sturgeon) and CPUE (YOY white sturgeon per 2500 m^2) is the arithmetic mean of untransformed CPUE data. Gillnet catch information was obtained from ODFW (Report A).

		Gillnet	Bottom Trawl
The Dalles Reservoir			
	E*p*	0.14	0.04
	CPUE	0.22	0.09
John Day Reservoir			
	E*p*	0.00	0.00
	CPUE	0.00	0.00

Movements and Behavior of Pre-Spawn and Spawning White Sturgeon

The Wireless Hydrophone System (WHS) successfully detected two fish fitted with acoustic transmitter codes 74 and 98. Code 74 was detected on April 16, 2000 at river KM 343.8 between 10:01 pm and 10:25 pm and later that same day near river KM 345.2 between 11:27 PM and 11:44 PM moving upstream into the tailrace. Code 74 was also detected near river KM 343.8 on May 26, 2000. Code 98 was detected twice on May 7, 2000 between 11:17 PM and 11:21PM near river KM 345.2 moving from the tagging location upstream into the tailrace. Code 62 was not detected by the WHS and presumably moved through the tailrace and into the BRZ prior to deployment of the WHS.

While mobile tracking, fifteen tagged fish were detected 490 times during 29 March through 29 June 2000, of which 424 were from fish detected in the tailrace. We were unable to collect GPS positions at 74 detections because access to the BRZ was restricted. As many as four transmitters, codes 62, 74, 98 and 448 were detected in the tailrace area during a given monitoring session. A maturing female was fitted with transmitter Code 62 on Feb 8, 2000 near the mouth of the Deschutes River at river KM 329.4 and later detected on several occasions within the BRZ but no GPS positions were obtained. We collected 9 tailrace positions on Code 74 and it was detected an additional 14 times within the BRZ. Code 98 was detected 158 times and GPS positions were recorded 157 times. Code 74.448 was located 177 times near where it was located the previous season and we believe the tag was shed.

We appeared to have a higher occurrence of shed tags during this study than in past studies. Of the 15 transmitters deployed during 1999 and 2000, 8 fish are suspected of shedding tags. Fish tagged with transmitters 73/347, 72/247, 73/338, 73/356, 74/448, 74/446, 76.8/73, and 76.8/98 (Figures 8-15) had relatively tight clusters of locations in 2000 and the final location in 2001 was near the where it was located in 2000. Code 76.8/98 was one of the fish that moved into the tailrace which we recorded detailed daily movements before and after spill. We recorded 106 consecutive locations between June 6, 2000 and June 29, 2000 that were within a 65-meter radius of the final location recorded during April of 2001. Only 2 (codes 76.8/73 and 76.8/98) of the 8 fish that are suspected of shedding tags were tagged in 2000. 4 fish (Codes 76.8/50, 76.8/110, 76.8/143, 76.8/156, figures 16-19) located in 2001 were not near locations recorded in 2000. The remaining 3 transmitters deployed during the study were not located in 2001. In general it appeared that most fish retained their tags during the first 5-6 months but may have shed their tags after approximately 14 months.

The MRPP test statistic was calculated for 20 tracking sessions. A frequency distribution of resulting P-values is shown in Figure 20. A small P-value indicates that the group of fish locations recorded prior to a change in discharge are different from fish locations recorded after a change in discharge. A large P-value indicates locations recorded before and after a change in discharge are similar. Results from the MRPP are inconclusive, P-values for 13 tracking sessions were <=.3 and P-values for 7 tracking sessions were >=.5.

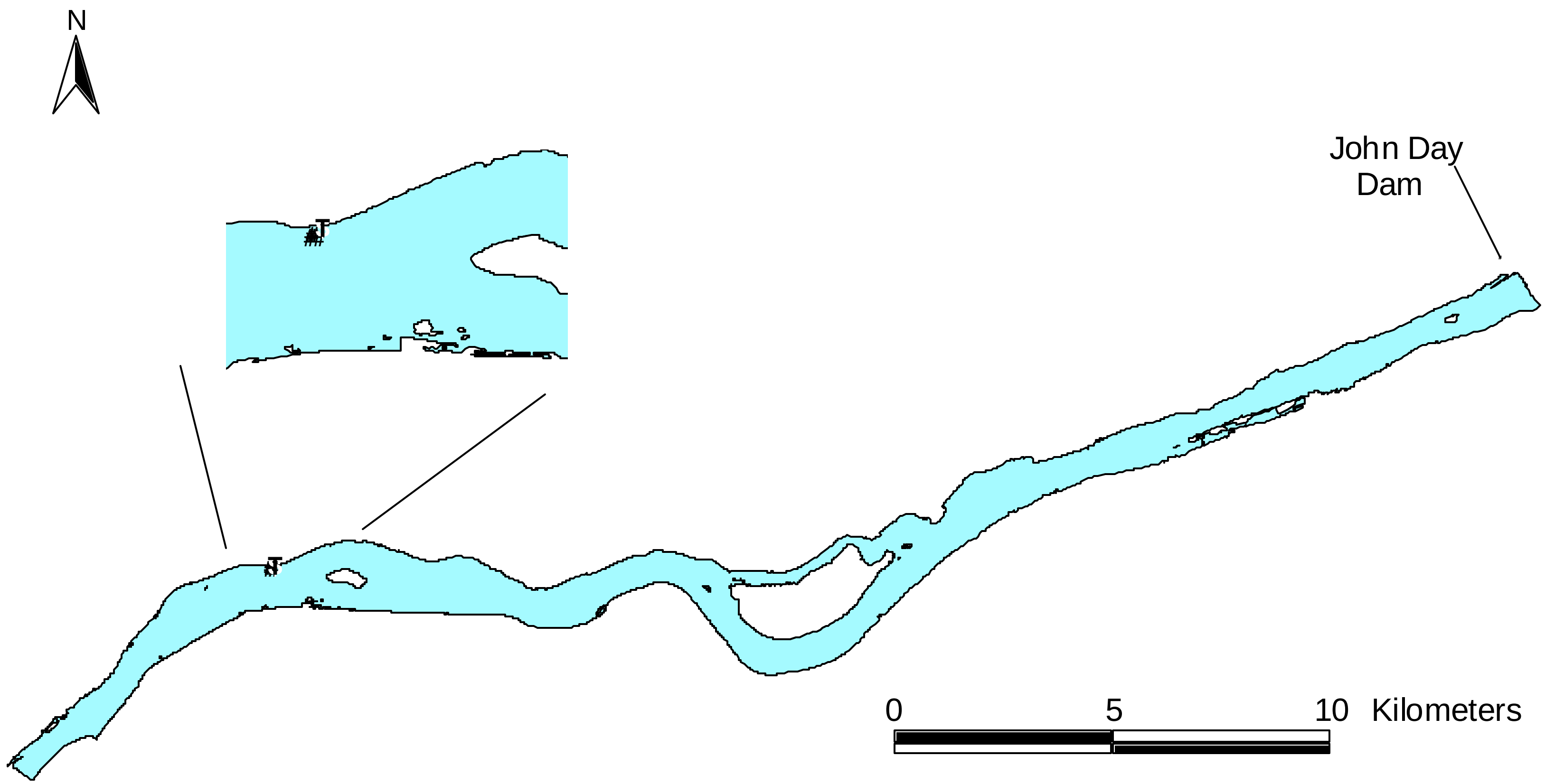

Figure 8. Movements of a white sturgeon in The Dalles Reservoir tagged with acoustic transmitter 73/347. The black dots represent 6 fish locations during the 2000 spawning season. The white triangle represents the final location recorded in April of 2001.

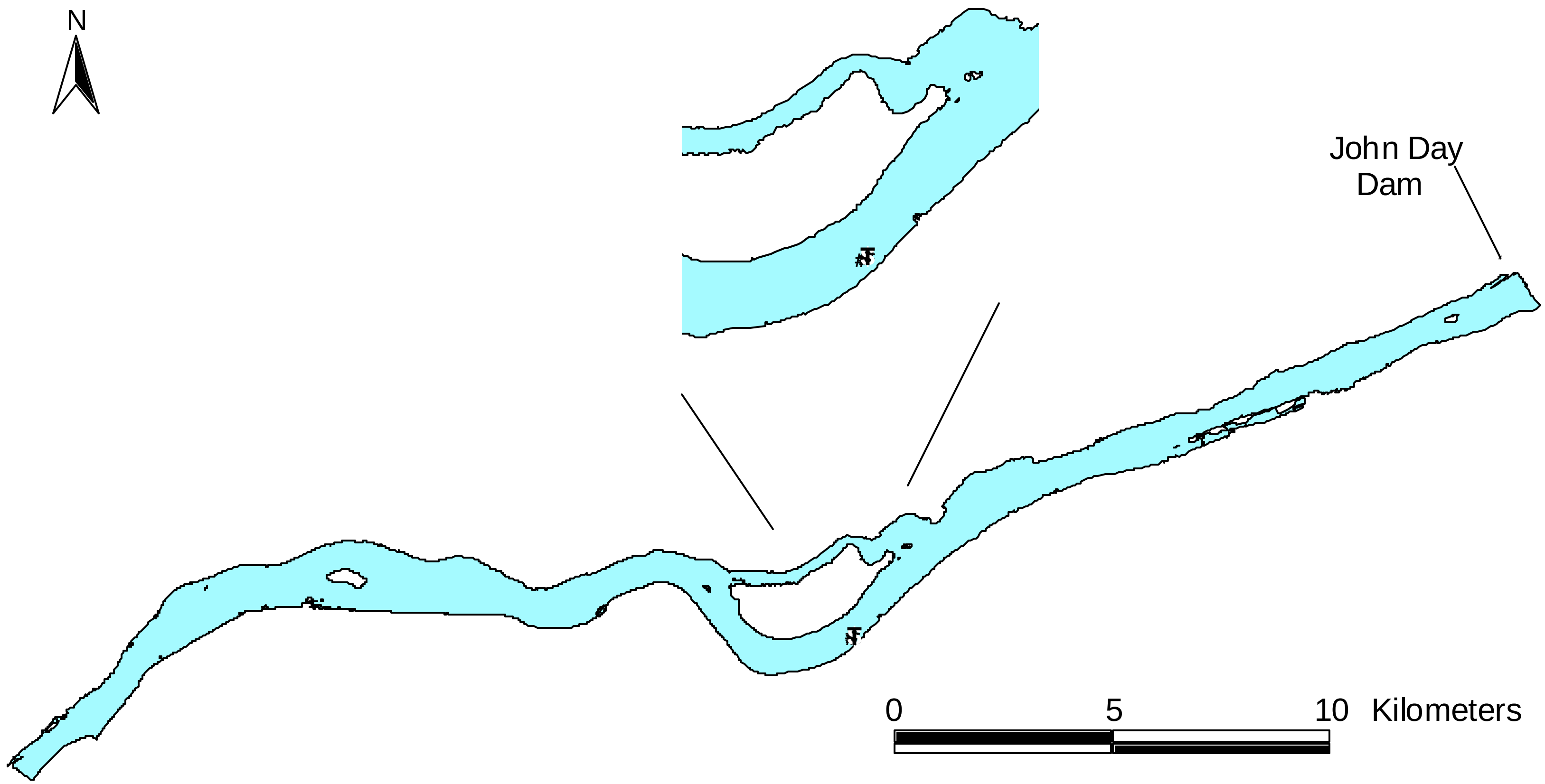

Figure 9. Movements of a white sturgeon in The Dalles Reservoir tagged with acoustic transmitter 72/247. The black dots represent 6 fish locations during the 2000 spawning season. The white triangle represents the final location recorded in April of 2001.

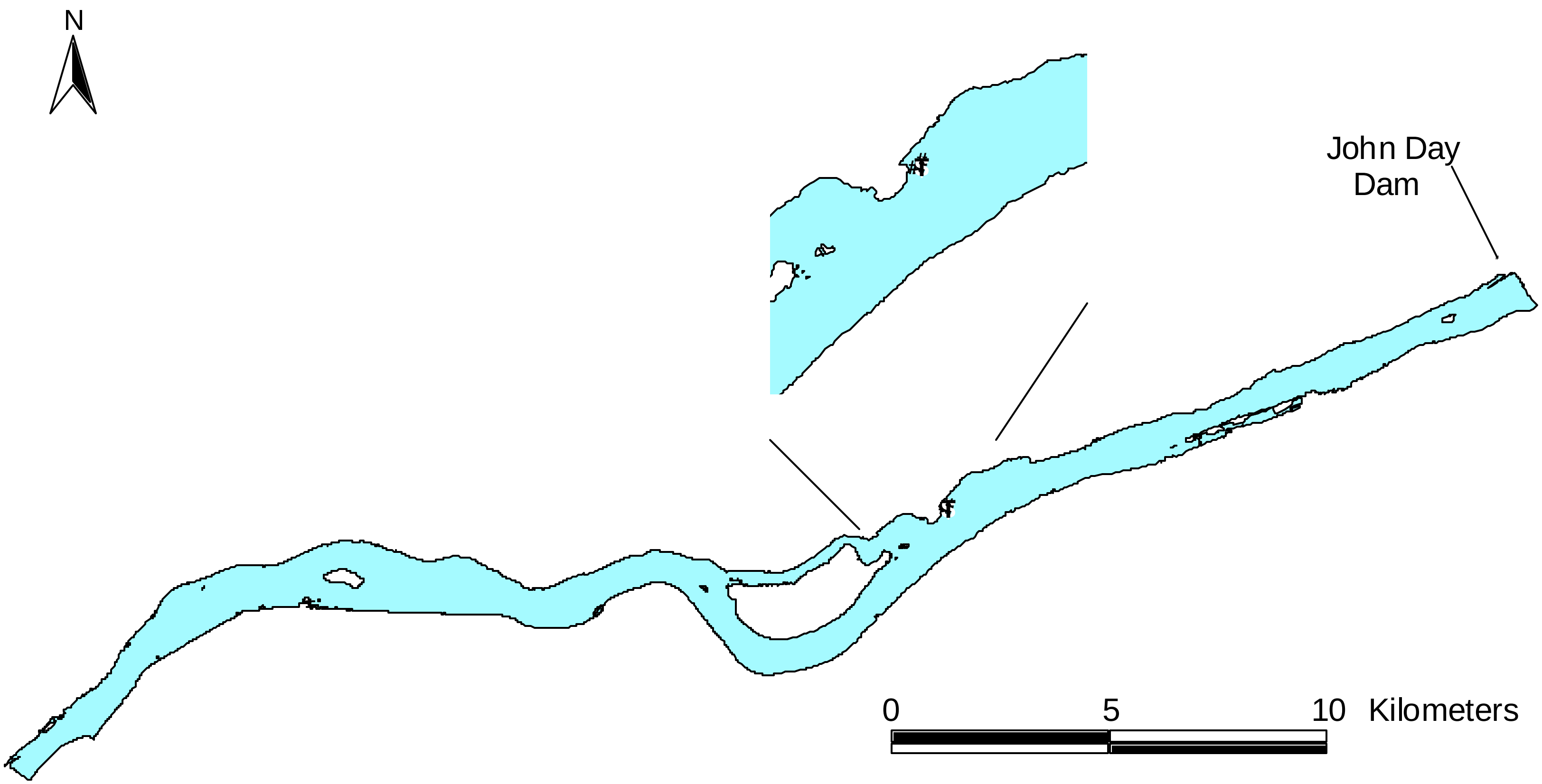

Figure 10. Movements of a white sturgeon in The Dalles Reservoir tagged with acoustic transmitter 73/338. The black dots represent 6 fish locations during the 2000 spawning season. The white triangle represents the final location recorded in April of 2001.

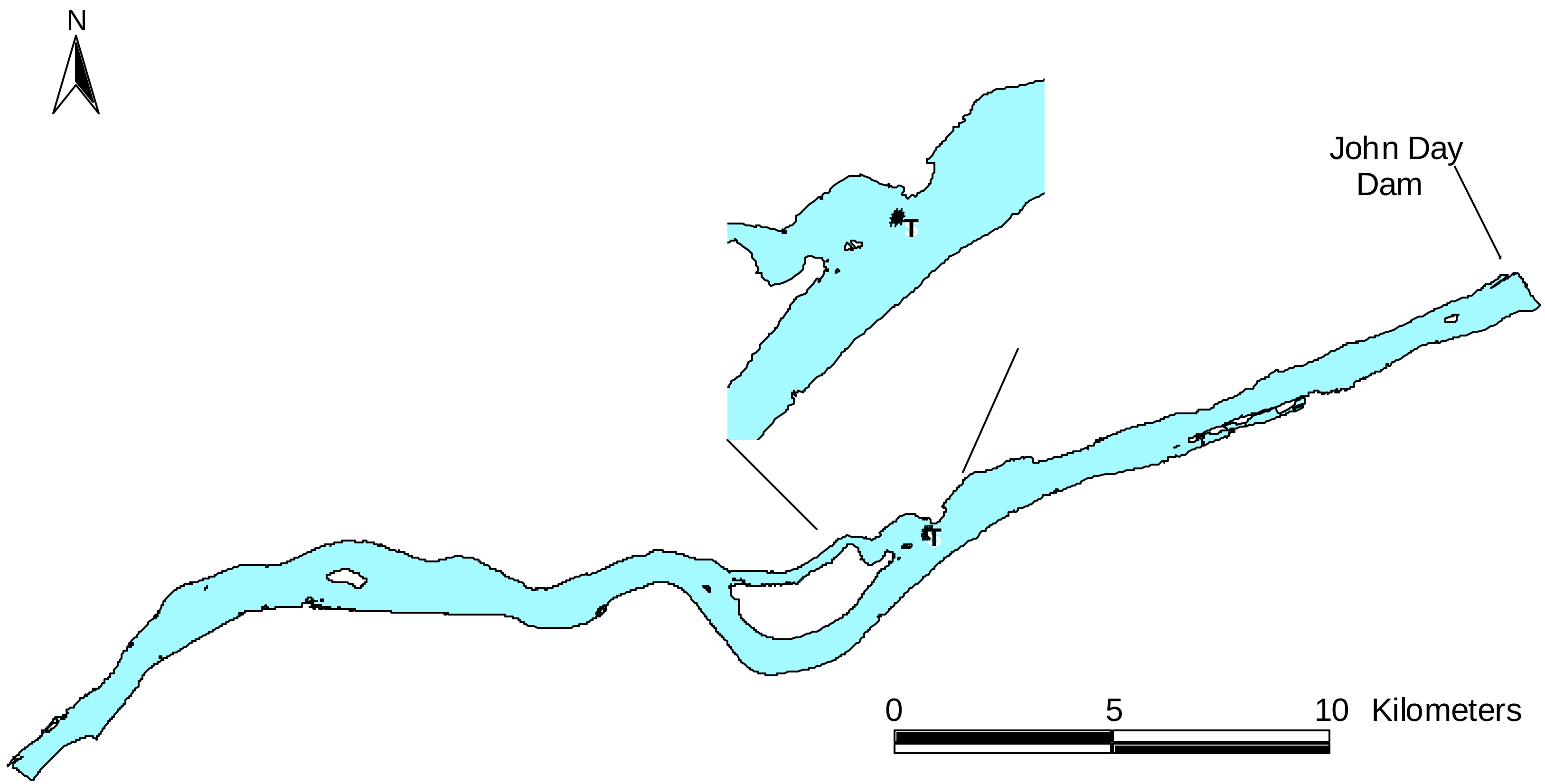

Figure 11. Movements of a white sturgeon in The Dalles Reservoir tagged with acoustic transmitter 73/356. The black dots represent 6 fish locations during the 2000 spawning season. The white triangle represents the final location recorded in April of 2001.

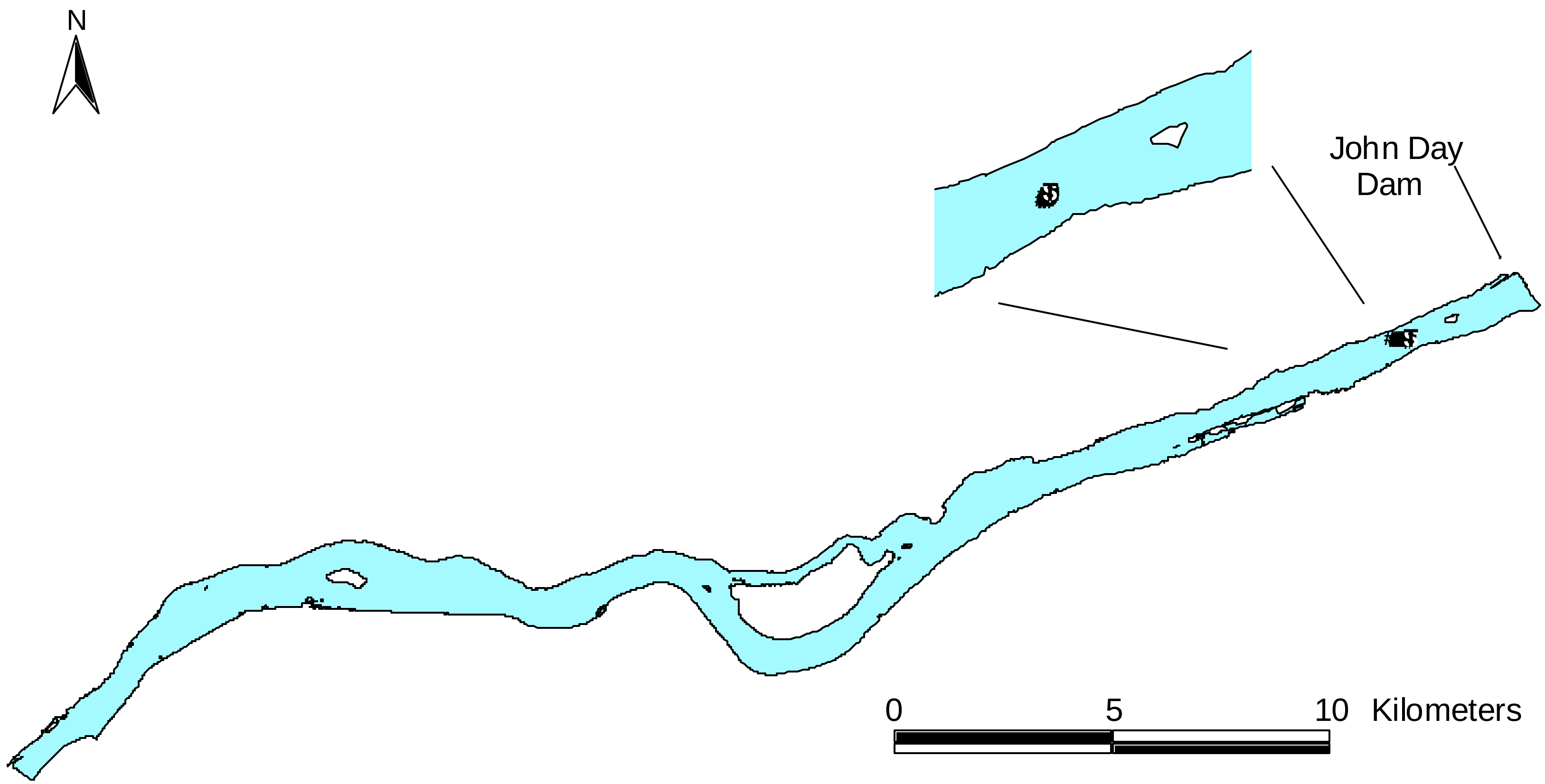

Figure 12. Movements of a white sturgeon in The Dalles Reservoir tagged with acoustic transmitter 74/448. The black dots represent 177 fish locations during the 2000 spawning season. The white triangle represents the final location recorded in April of 2001.

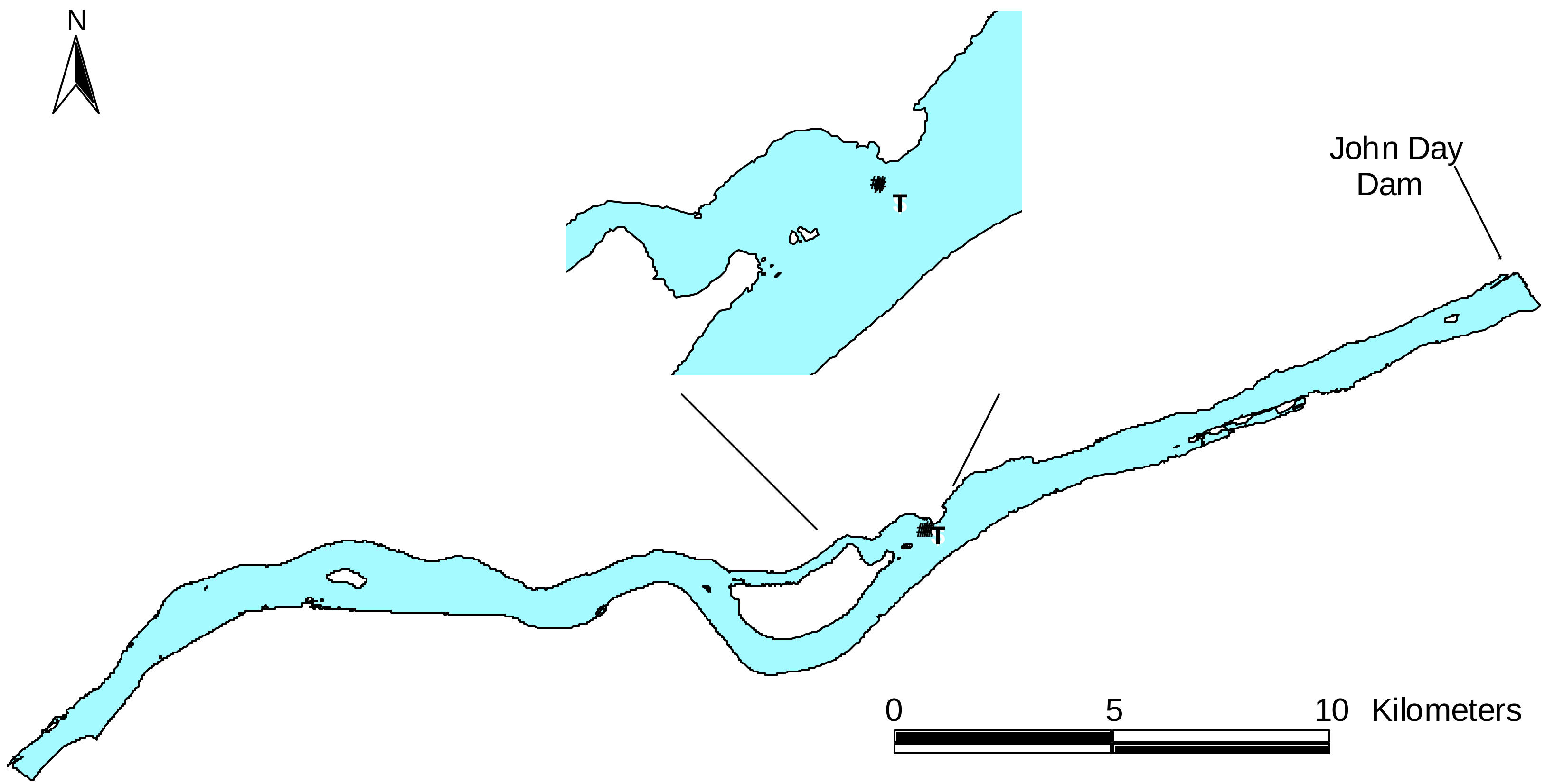

Figure 13. Movements of a white sturgeon in The Dalles Reservoir tagged with acoustic transmitter 74/466. The black dots represent 6 fish locations during the 2000 spawning season. The white triangle represents the final location recorded in April of 2001.

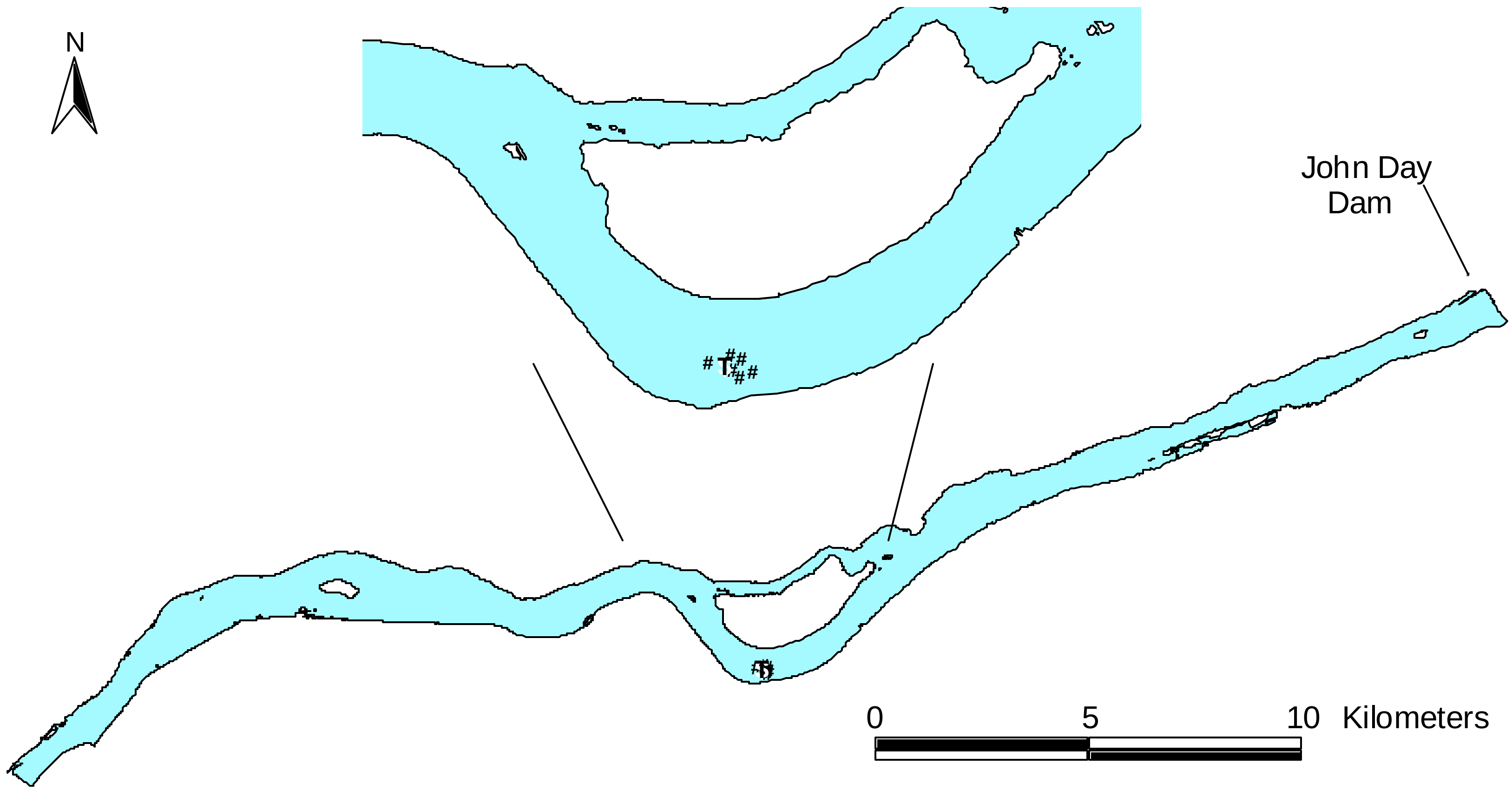

Figure 14. Movements of a white sturgeon in The Dalles Reservoir tagged with acoustic transmitter 76.8/73. The black dots represent 6 fish locations during the 2000 spawning season. The white triangle represents the final location recorded in April of 2001.

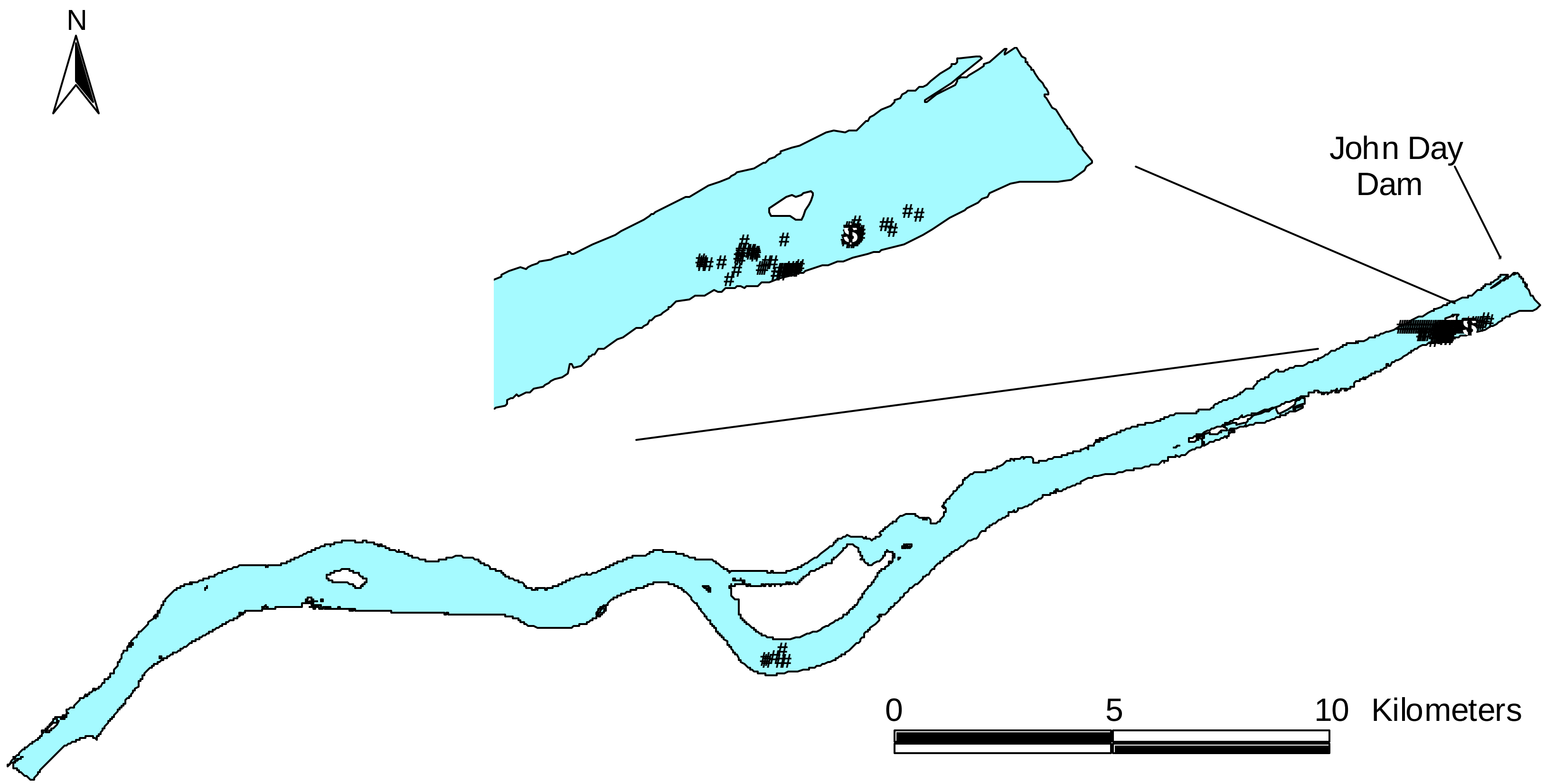

Figure 15. Movements of a white sturgeon in The Dalles Reservoir tagged with acoustic transmitter 76.8/98. The black dots represent 164 fish locations during the 2000 spawning season. The white triangle represents the final location recorded in April of 2001.

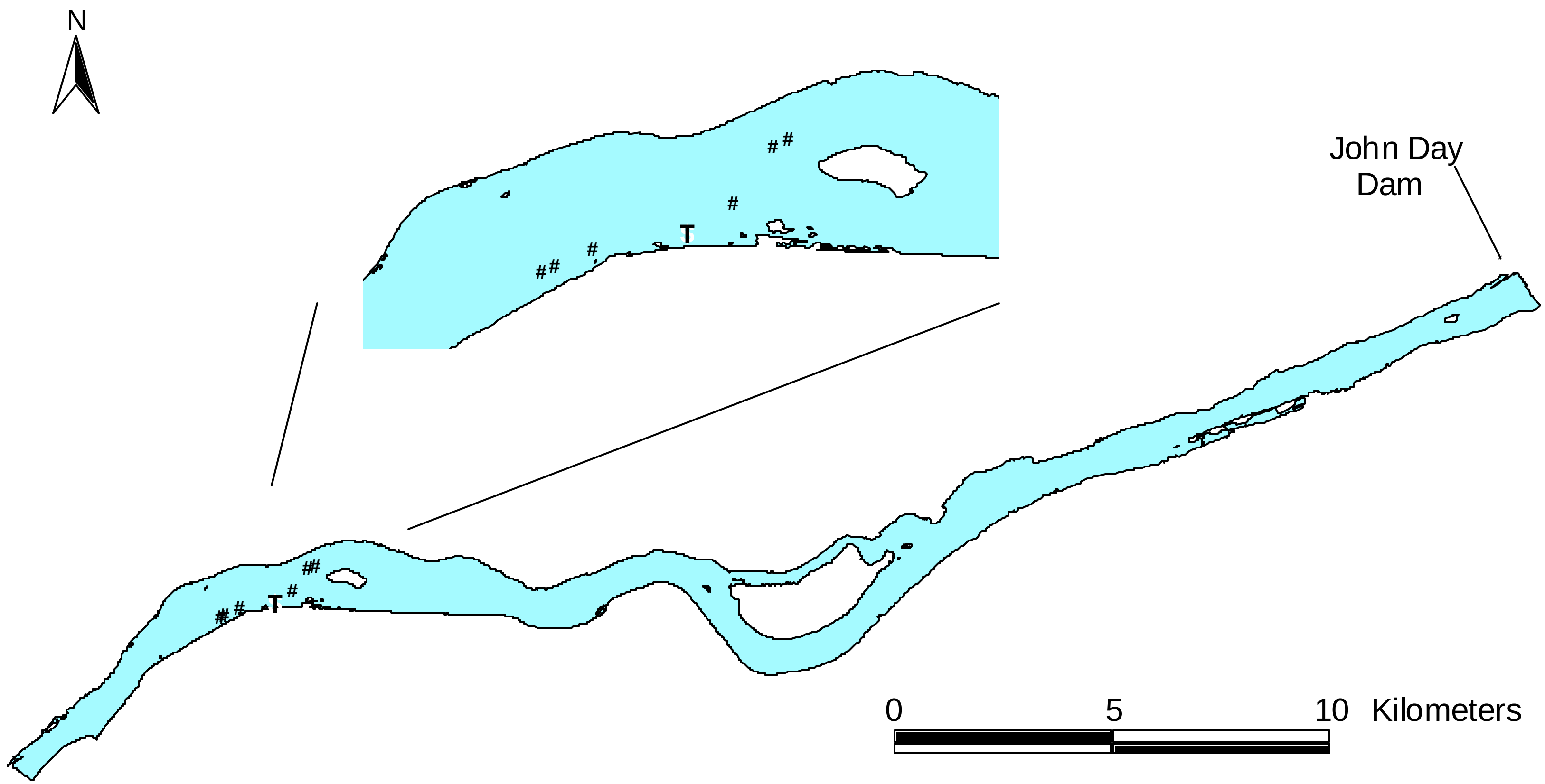

Figure 16. Movements of a white sturgeon in The Dalles Reservoir tagged with acoustic transmitter 76.8/50. The black dots represent 6 fish locations during the 2000 spawning season. The white triangle represents the final location recorded in April of 2001.

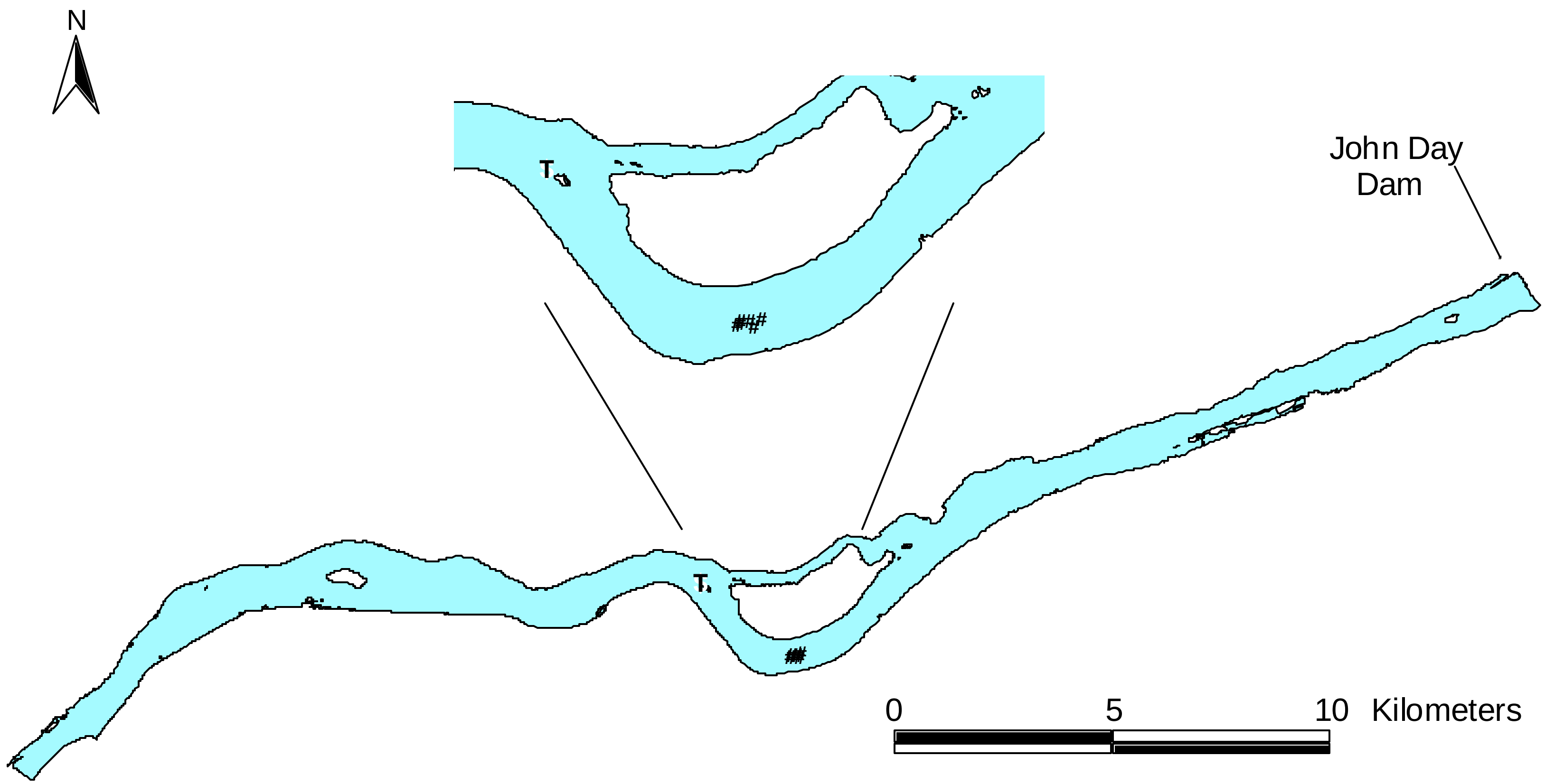

Figure 17. Movements of a white sturgeon in The Dalles Reservoir tagged with acoustic transmitter 76.8/110. The black dots represent 6 fish locations during the 2000 spawning season. The white triangle represents the final location recorded in April of 2001.

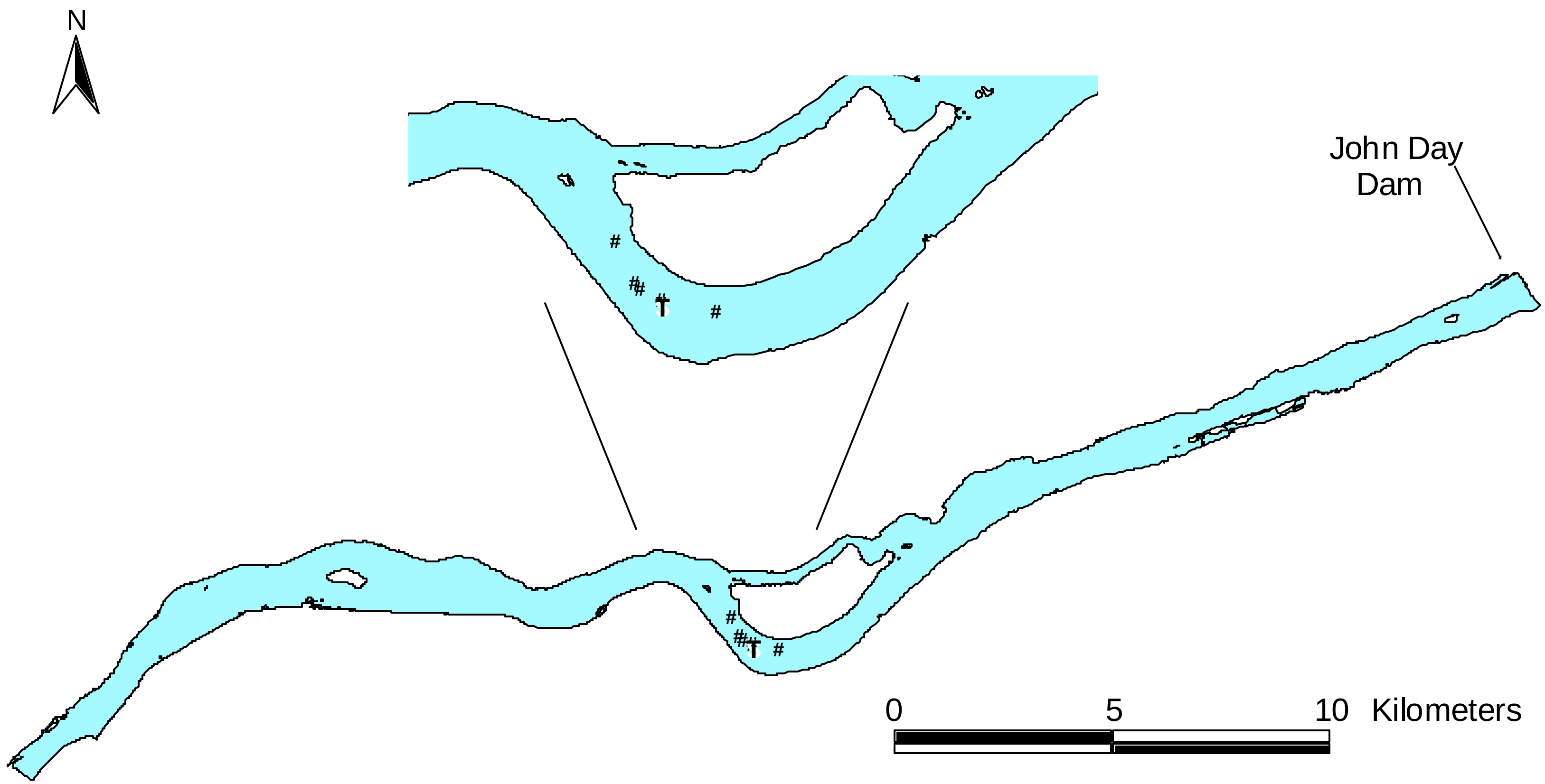

Figure 18. Movements of a white sturgeon in The Dalles Reservoir tagged with acoustic transmitter 76.8/143.
The black dots represent 5 fish locations during the 2000 spawning season. The white triangle represents
the final location recorded in April of 2001.

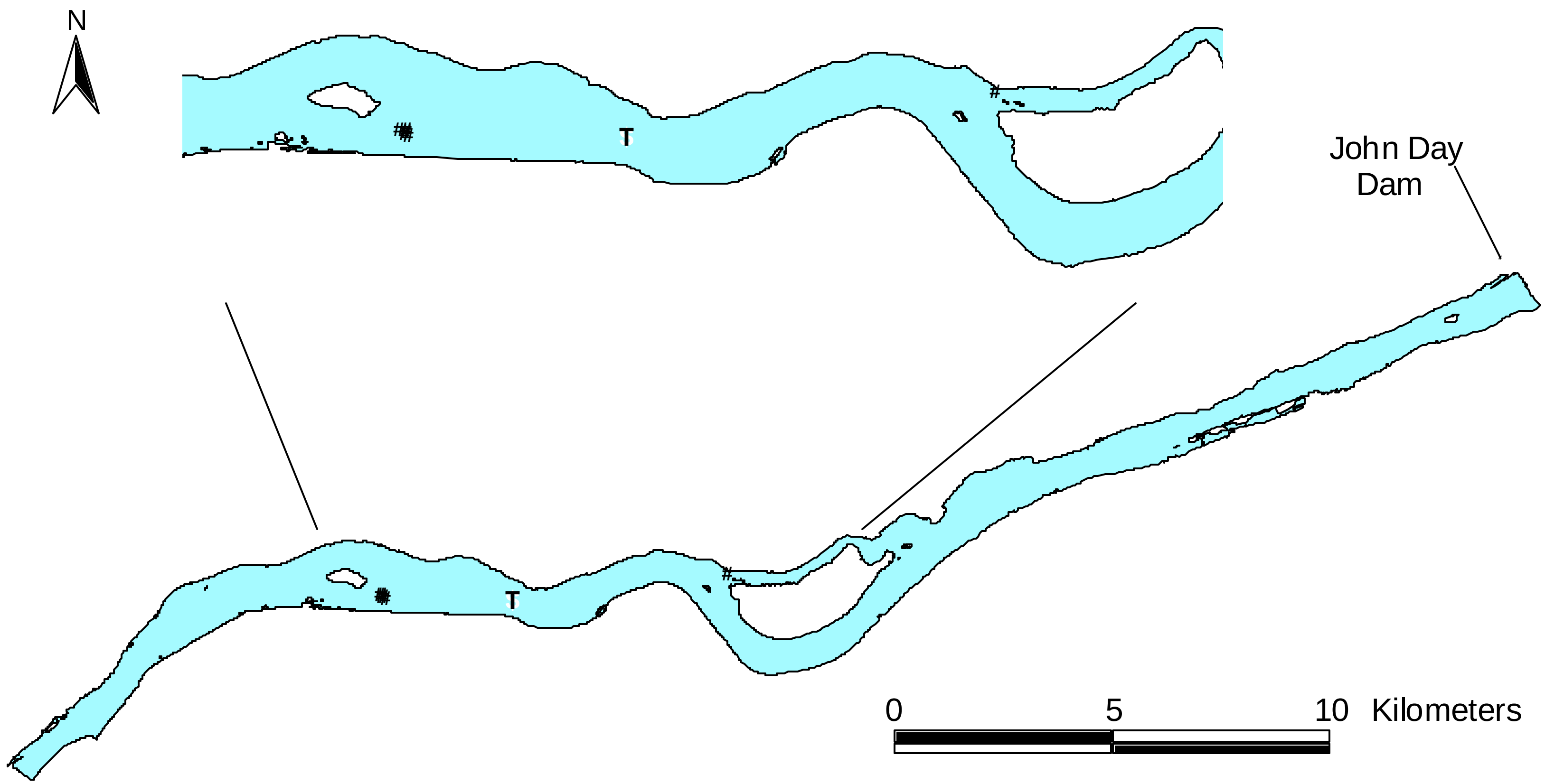

Figure 19. Movements of a white sturgeon in The Dalles Reservoir tagged with acoustic transmitter 76.8/156. The black dots represent 6 fish locations during the 2000 spawning season. The white triangle represents the final location recorded in April of 2001.

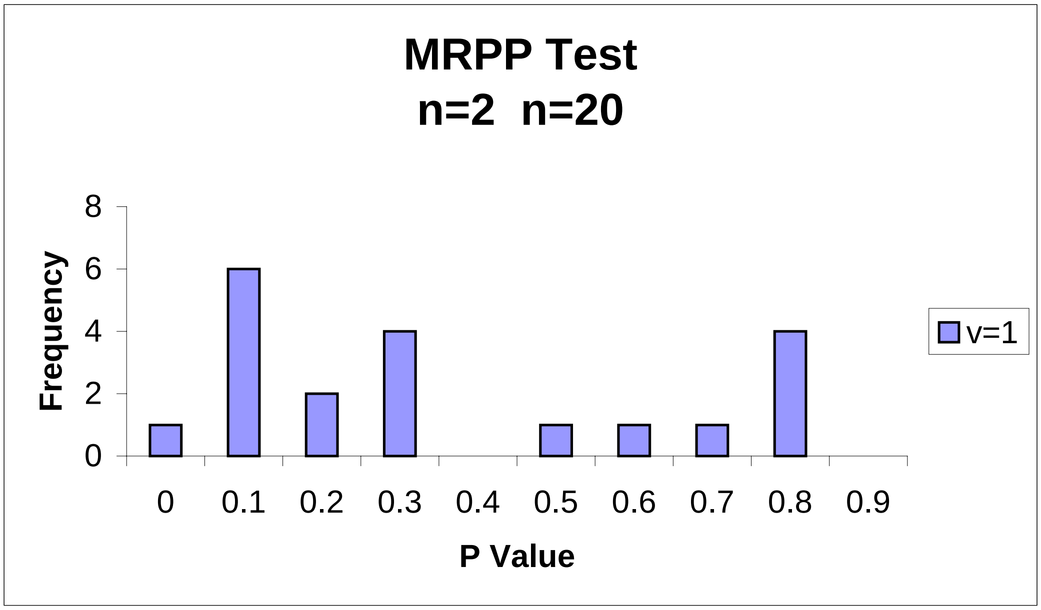

Figure 20. MRPP test statistic for 20 tracking sessions on two adult white sturgeon.

It is unclear what effects daily dam operations have on the movements and locations of pre-spawning and spawning white sturgeon since we were only able to obtain locations prior to and after spill changes during one tracking session on tagged fish 76.8/74 and during 19 sessions on fish 76.8/98. However, in general fish did not move great distances (typically <1 km) during our monitoring periods and some fish remained within the BRZ when water was being spilled.

Predation on Larval and Juvenile White Sturgeon

Turbidity Experiments

Almost all yolk-sac white sturgeon larvae were ingested by sculpins at 0 NTU, although many were still ingested at all turbidity levels (Figure 21). Tukey's range test showed that 0 and 20 NTU were significantly similar and also 20, 60, and 180 NTU were similar ($P<0.05$). As juvenile white sturgeon increased in size, turbidity had almost no effect on the number eaten by sculpins (Figure 22). However, with size increase, less sturgeon were ingested overall.

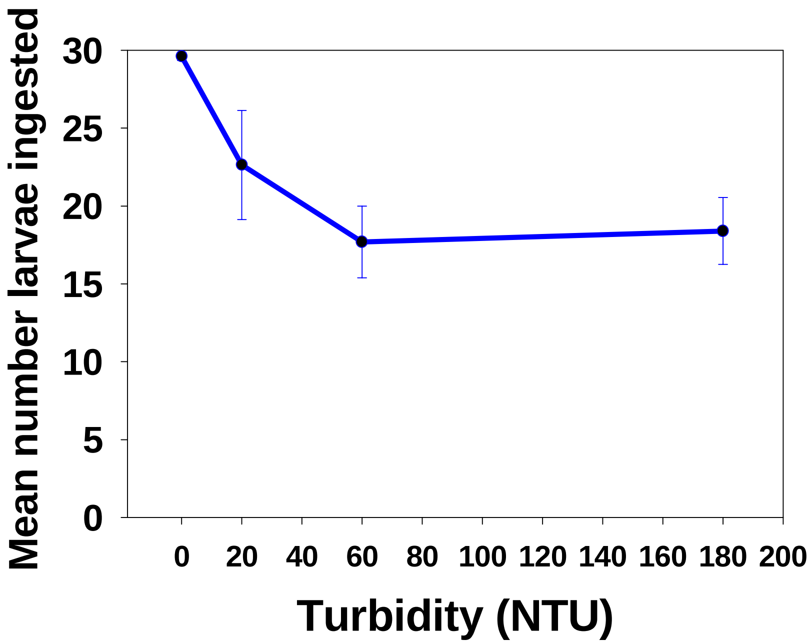

Figure 21. Mean number of white sturgeon yolk-sac larvae ingested by sculpins (two per 85-l aquarium) at each of four turbidity levels. N=8-10 replicates per turbidity level. Vertical lines equal ± one standard error.

Size Vulnerability

Prickly sculpins ate white sturgeon up to a mean size of 53 mm TL (Figure 23). During all weeks, sculpins continued to ingest goldfish. However, although similarly sized to northern pikeminnow in our study, channel catfish only ate relatively small sturgeon, about 30 mm TL or less, although they ingested juvenile salmon (Figure 23). In contrast, northern pikeminnow initially ate all prey placed in a tank, only reducing their level of predation when sturgeon reached a mean size of 120 mm TL (Figure 24).

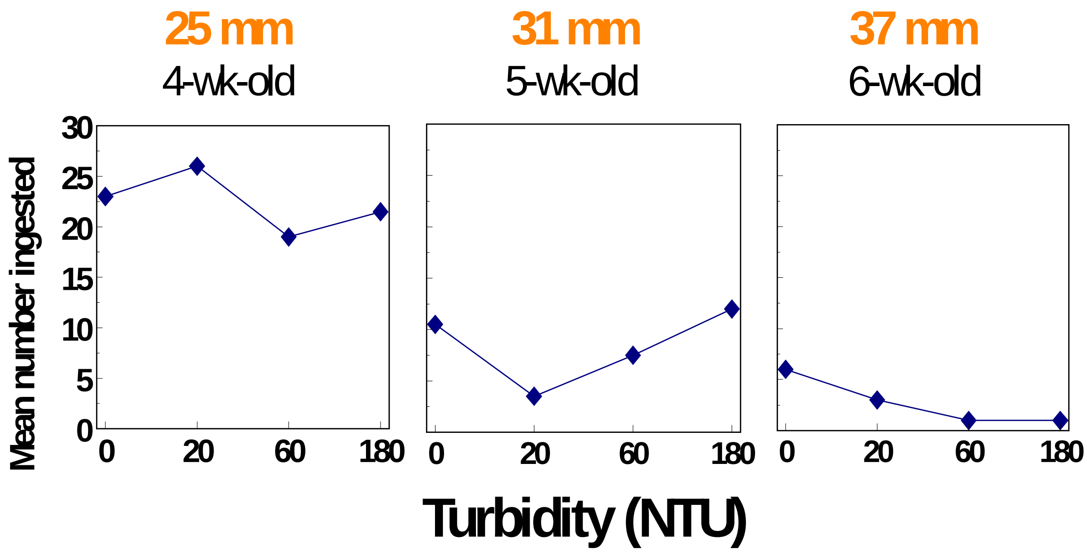

Figure 22. Mean number of 4, 5, and 6-week-old juvenile white sturgeon ingested by sculpins (two per 85-l aquarium) at each of four turbidity levels. N=2 replicates per sturgeon age class and turbidity level. Mean total lengths (n=30) at each age are presented above figures.

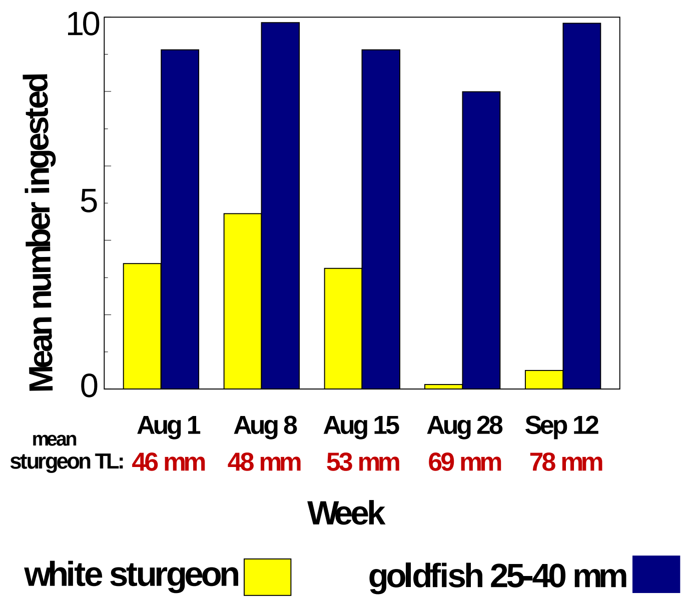

Figure 23. Mean number of juvenile white sturgeon and goldfish ingested each week by sculpins (two per 85-l aquarium). N=8 replicates of each prey type weekly.

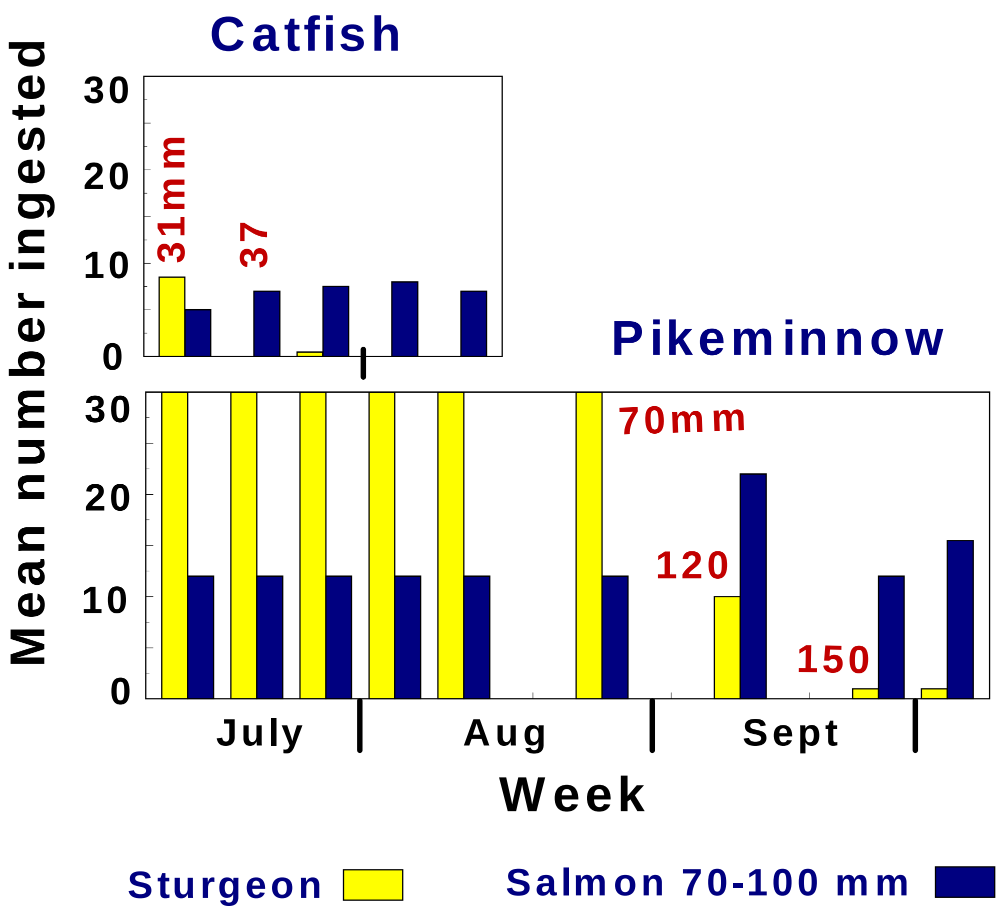

Figure 24. Mean number of juvenile white sturgeon and salmon ingested each week by channel catfish and northern pikeminnow (three per 1.3 m diameter tank). N=2 replicates of each prey type weekly for each predator species.

Conclusions

We found that turbidity affected predation of white sturgeon larvae by prickly sculpins, with less sturgeon ingested at higher turbidities. However, the effects of turbidity on predator-prey interactions are complex since turbidity reduces the distance at which a predator can detect prey, but also reduces prey reaction distance (Vinyard and O'Brian 1976; Miner and Stein 1996). Some sturgeon larvae were ingested at all turbidity levels we tested, even though the trials were brief--only 15 min. This may be due in part to the relatively small container size we used, 85 l, which may have resulted in a high level of encounter rates. As sturgeon size increased, turbidity seemed to have almost no effect, but with size increase, less sturgeon were ingested. This is likely because larger prey with better predator avoidance capabilities can result in increased handling time by predators (Williams et al. 1996; Brooking et al. 1998). During the size vulnerability trials, juvenile sturgeon were exposed to sculpins for 24 hrs versus 15 min. During this longer period, considering the smaller body size of sculpins, 100-180 mm TL, they were able to ingest relatively large sturgeon with a mean size of 53 mm TL.

The two larger predators we tested in our size vulnerability experiments, channel catfish and northern pikeminnow (about 370-580 mm TL), resulted in very different results. Channel catfish only ingested small sturgeon, < about 30 mm TL, although this may because these fish had been in the laboratory for about eight months and were not feeding as they normally might in the wild. Since catfish are a common benthic predator in some areas of the Columbia Basin (Zimmerman and Parker 1995), we plan to repeat these experiments with newly collected fish. In contrast, northern pikeminnow appeared to be primarily size limited in their ability to ingest white sturgeon, since they ate similarly sized sturgeon and salmon. Pikeminnow stopped eating sturgeon at a mean size of 150 mm TL, which is also a size of salmon they have difficulty ingesting (personal observation). However, this is not particularly surprising, since northern pikeminnow have been documented as opportunistic feeders, commonly eating even highly armored prey such as crayfish (Poe et al. 1991).

Our results will help in understanding factors affecting recruitment of white sturgeon juveniles in the Columbia River Basin, and also will aid managers in evaluating the best size to release hatchery fish. It was generally believed that young juvenile sturgeon are not particularly vulnerable to predation, especially after scute development at about 25 mm TL. However, we found that sculpins and northern pikeminnow readily ingested white sturgeon of a relatively large size. During 2001 we plan to try turbidity trials in a larger container size, 170 l, and test a higher turbidity level, 360 NTU. We also will conduct size vulnerability trials in larger tanks with 2.7 m diameters, and will test a predator common in the upper Columbia River, walleye *Stizostedion vitreum vitreum*.

Plans for 2001

During 1 April 2000 through 31 March 2001 the U.S. Geological Survey worked on seven tasks. Two are ongoing activities related to the development of long-term data sets— YOY juvenile indexing, and comparisons of two gear types used to accomplish this. Three are studies of moderate duration in which the majority of the field work has already been completed. Availability of spawning habitat was quantified, both due to annual changes in temperature and discharge, and as a result of possible drawdowns. We also examined movements and behavior of pre-spawn and spawning white sturgeon in relation to dam operations. Two activities began during this reporting period using laboratory trials to determine vulnerability of white sturgeon larvae and juveniles to predation.

During 2001, the USGS will continue several tasks begun in previous years, including indexing the recruitment of white sturgeon to YOY in the Bonneville, The Dalles, and John Day reservoirs, and laboratory trials assessing vulnerability of sturgeon larvae and juveniles to predation. We will continue with the analyses and preparation of manuscripts for completed studies such as our examination of movements of adult white sturgeon prior to and during the spawning period.

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ACKNOWLEDGMENTS

We thank Steve Juhnke and Kevin Kappenman for their assistance in trawling, and Kyle Martens, Holly Gittelin, and Kevin Kappenman for their assistance in the laboratory predation study.

APPENDIX C-1

Effects of Proposed Reservoir Drawdowns on the Productivity of White Sturgeon

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Abstract

The listing of many stocks of anadromous salmonids as threatened or endangered in the Columbia River Basin led fishery managers to propose several scenarios that could permanently lower the John Day Reservoir by as much as 30 m in an effort to restore some level of normative riverine function. The proposed reservoir water levels were: 1) maintain current pool elevation (normal operating pool), 2) lower water levels to minimum operating pool (4 m drawdown), 3) open the spill gates and allow the water to flow freely over the spillway crest (17 m drawdown), and 4) breach the dam and allow the river to return to a natural river level (30 m drawdown). It is expected that the restoration of normative riverine functions would improve survival of endangered anadromous salmonids. This activity would also affect productivity of the resident white sturgeon population now confined between John Day and McNary Dams.

To evaluate potential changes in white sturgeon productivity, we first used two-dimensional steady state hydraulic modeling to estimate water depths and mean column velocities that may exist in the reservoir under the proposed water levels. We then used a geographic information system to integrate that output with biological criteria defining micro and macrohabitats important to white sturgeon. This approach enabled the quantification and visualization of changes in spawning and rearing habitats for white sturgeon that may be expected to occur under the drawdown scenarios. Three river discharges (2,830 m^3/s, 4,420 m^3/s, and 8,490 m^3/s) were modeled for each proposed scenario.

Our analyses showed that the quantity and quality of spawning habitat for white sturgeon would increase as reservoir water levels were lowered, despite a total decrease in surface area of the river. This would occur primarily because water velocities suitable for spawning would increase. Conversely, rearing habitat would decrease as the surface area of the reservoir became smaller. However, productivity of the white sturgeon population overall may increase or decrease depending on the resulting biological habitat provided by a more riverine environment.

Introduction

Population characteristics of white sturgeon *Acipenser transmontanus* in the Columbia River Basin have changed significantly in recent years. For example, white sturgeon numbers and densities in the John Day Reservoir are currently much reduced, and the size composition is skewed towards larger, older fish (Beamesderfer et al. 1995). These changes may be due both to overfishing that occurred during the 1980's and human development within the basin. In particular, since fish in the John Day Reservoir exhibit good growth and condition, and have high fecundity, it has been suggested that habitat changes due to dam construction may be affecting recruitment success. John Day Reservoir was created on the Columbia River in 1968 for power generation, navigation, flood control, and irrigation. The reservoir inundated approximately 129 km of river and water levels at John Day Dam are now approximately 30 m above the natural river level.

The mainstem dams constructed on the Columbia and Snake rivers are barriers to upstream passage and have isolated the white sturgeon populations into discrete river reaches. White sturgeon are capable of completing their life cycle entirely in freshwater, and for isolated populations to persist over time, habitats suitable for all life stages must be present in sufficient quantity and quality at the appropriate time of year. Hydroelectric development has altered physical riverine habitats and operation of the hydroelectric system has changed the flow and thermal regimes from historic conditions.

Reservoir water level manipulations have been proposed as a way to increase survival of outmigrating juvenile salmonids currently listed under the Endangered Species Act. This analysis considered the effects of impoundment and proposed reservoir water level manipulations on the availability of spawning and rearing habitat for white sturgeon in the John Day Reservoir on the Columbia River. Suitable habitat was determined by applying spawning and rearing criteria via a geographic information system to physical characteristics of the river for contemporary conditions and for several reservoir water levels including a free-flowing scenario. The analyses also considered three river discharges for each scenario to provide insight on the effects of flow on habitat.

The goal of the analysis was to make a comparison of white sturgeon habitat availability under current and post drawdown conditions. The analysis was constrained to an assimilation of existing data. That is, no new physical or biological data were to be collected. The approach was to first model the physical environment that could be expected to exist at current and post-drawdown (natural river) conditions for each impounded area by using two-dimensional hydraulic models populated with existing spatial data, then to define the physical habitat used by spawning and rearing white sturgeon. Lastly, the output from the hydraulic modeling was integrated with the habitat definitions using a geographic information system to characterize three types of habitat for spawning and rearing; optimal, suitable, and not used.

This analysis paralleled a similar effort by the authors to investigate physical habitat for spawning and rearing fall chinook salmon in John Day Reservoir (Chapter 4 in Dauble

2000). The source data, methods, and results for the hydraulic modeling for these two studies are the same. Therefore, there is a high degree of similarity in reporting portions of the results for this analysis and that presented in Dauble (2000). The repetition of figures and tables in these two reports is warranted to clearly convey the outputs from the hydraulic modeling, from which the estimates of spawning and rearing habitats that may be expected from proposed reservoir water level scenarios rely.

White Sturgeon Habitat Use

White sturgeon, like other river or stream dwelling fish, chose spawning habitat that differs markedly from rearing habitat that favors somatic growth of older fish. Spawning occurs in swift, turbulent water over coarse substrates that favors egg fertilization and survival during incubation, whereas rearing occurs in areas of the river that are generally characterized by substantially reduced water velocities compared to spawning sites (Parsley et al. 1993). Parsley and Beckman (1994) developed criteria describing the water depths, mean column velocities, and substrates used for spawning and rearing white sturgeon (Figure 1). Spawning habitats observed by other researchers generally fit these spawning habitat criteria (Perrin et al. 1999) with the exception of white sturgeon found in the Kootenai River, which appear to spawn in much slower water velocities and over finer substrates (Paragamian et al. 2001).

Rearing white sturgeon are generalists in their use of habitats. Figure 2 depicts the suitability of water depths and velocities for juvenile and adult white sturgeon. The suitability curves reveal the broad range of water depths and velocities that juvenile and adult white sturgeon use. In essence, only very shallow depths or very swift water preclude use of riverine habitat by rearing white sturgeon. Studies to date have not been able to show if these fish prefer particular substrates. The telemetry work reported in Kappenman et al. (2000) showed that rearing white sturgeon used substrates in proportion to their availability, indicating no preference for particular substrates.

Methods

Source Data

The riverbed elevation information required for the two-dimensional hydraulic modeling came from a bathymetric survey of John Day Reservoir conducted by the U.S. Army Corps of Engineers, Portland District, in 1994. Point elevations were calculated from water depths measured along transversal transects spaced approximately 170 m apart, while within transects the spacing between depth measurements was approximately 25 m. The point survey data was supplemented in the shoreline areas with data extracted from the USGS 30 m by 30 m resolution digital elevation models (DEMs). A riverbed elevation surface (also termed a mesh) with a quasi-uniform node spacing of approximately 90 m was generated by the model.

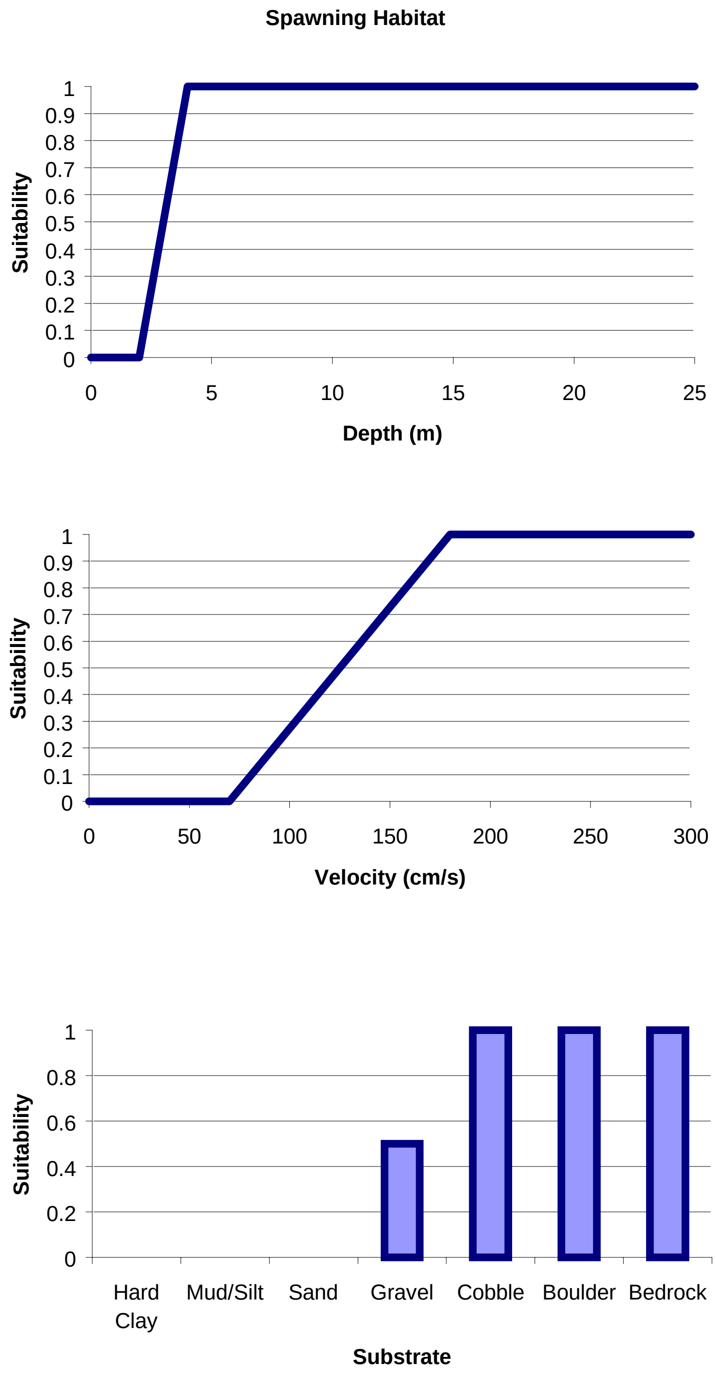

Figure 1. Habitat suitability criteria curves developed by Parsley and Beckman (1994) defining water depths, mean column velocities, and substrates used by spawning white sturgeon.

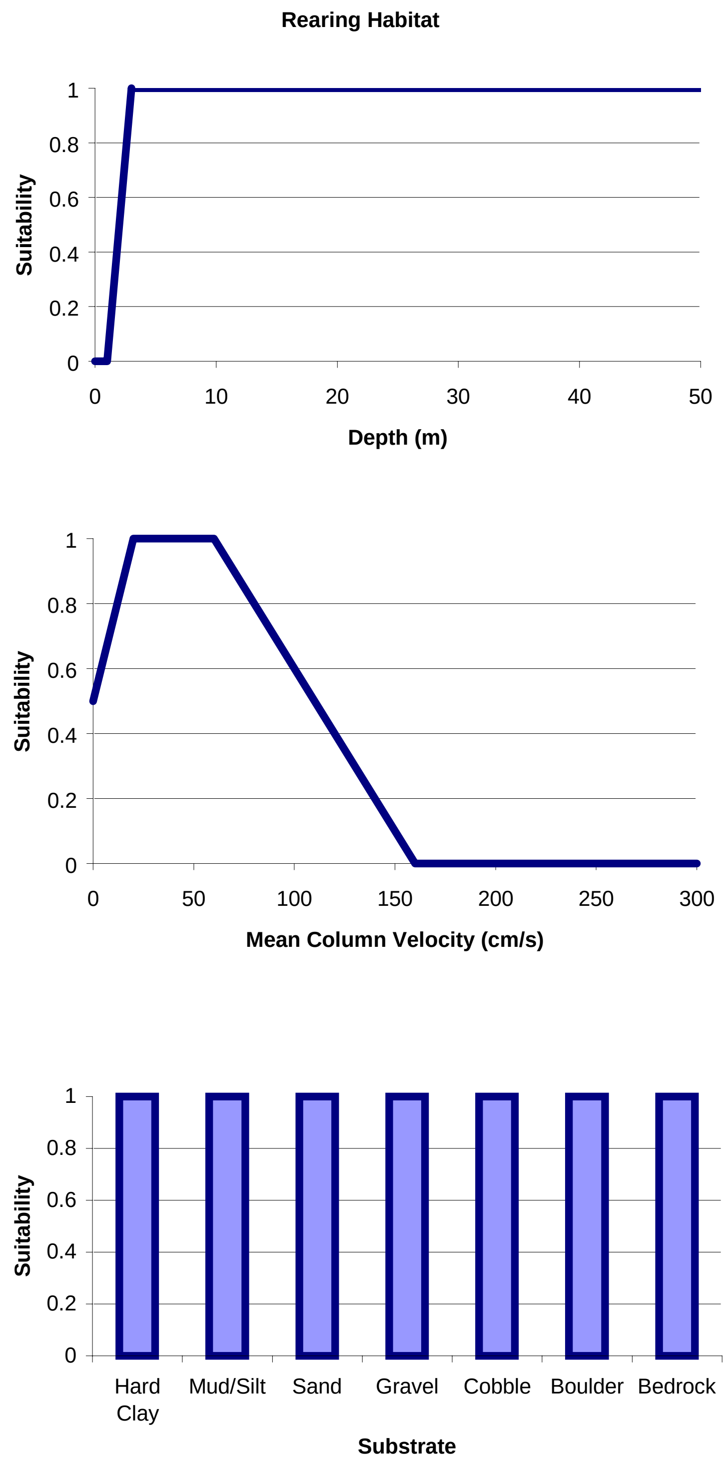

Figure 2. Habitat criteria curves defining the suitability of water depths, mean column velocities, and substrates for rearing white sturgeon. Parsley and Beckman (1994) developed the curve for water depths. The curves for mean column velocity and substrates were developed from recent telemetry studies conducted by the USGS and reported in Kappenman et al. (2000).

One variable that was unavailable for use in this analysis was pre-impoundment riverbed substrates. Post-impoundment substrates within the reservoir were reported by Parsley and Beckman (1994), but because of sedimentation that may have occurred since impoundment, the post-impoundment substrates were not used in simulations of habitat at lowered water levels.

Physical Habitat Simulations

Mean water column velocities and water depths at each scenario were estimated for John Day reservoir under steady-state flow using a two-dimensional hydraulic model. Mean column water velocities and depths were simulated for three discharges; 2,800 m^3/s (100 kcfs), 4,400 m^3/s (156 kcfs), and 8,500 m^3/s (300 kcfs). These discharges represent the 90%, 50%, and 10% exceedence flows for March through October. The model (River2D) applies a two-dimensional finite element method to solve the shallow water flow equations (Ghanem et al. 1995). Values for depth and mean column water velocity were calculated by the model at nodes separated by a mean horizontal distance of approximately 90 m. The model outputs were converted to ARC/INFO grids of a final resolution of 10 m by 10 m using linear interpolation.

Habitat for fish has been related to meso-habitat features such as pools, runs, and riffles or rapids (Yu and Peters 1997). The locations and extent of pools, runs, and riffles are typically determined by direct observation in the field but others have used the Froude number, *Fr* to identify these features (Yu and Peters 1997; Jowett 1993). The dimensionless *Fr* is the ratio of the speed of water flow to the speed of gravity and is defined mathematically by the equation $Fr = V/(gD)^{0.5}$, where V is the mean water column velocity, D is the water depth, and g is the acceleration due to gravity. Streamflows are supercrital when $Fr > 1$ and subcritical when $Fr < 1$ (Kundu 1990). Calculating the Froude number and equating this value to one of the three meso-habitat types identified pool, run, and riffle habitats that may exist for each scenario and river discharge.

In this analysis, each 10 m by 10 m cell in the river was classified as a pool, run, or riffle based on its Froude number. Yu and Peters (1997) identified *Fr* thresholds for run/riffle transitions and pool/run transitions from direct observations. From that work, $Fr < 0.2$ comprised pool habitats, $0.2 \geq Fr \geq 0.4$ comprised run habitats, and $Fr > 0.4$ comprised riffle habitats.

Habitat use

For this analysis, each suitability index curve was condensed into three categories of habitat–optimal, representing habitat types where the suitability for each variable was equal to 1.0, sub optimal, where the suitability ranged from > 0 to < 1.0, and not suitable, where the suitability was equal to 0 (Figures 3 and 4).

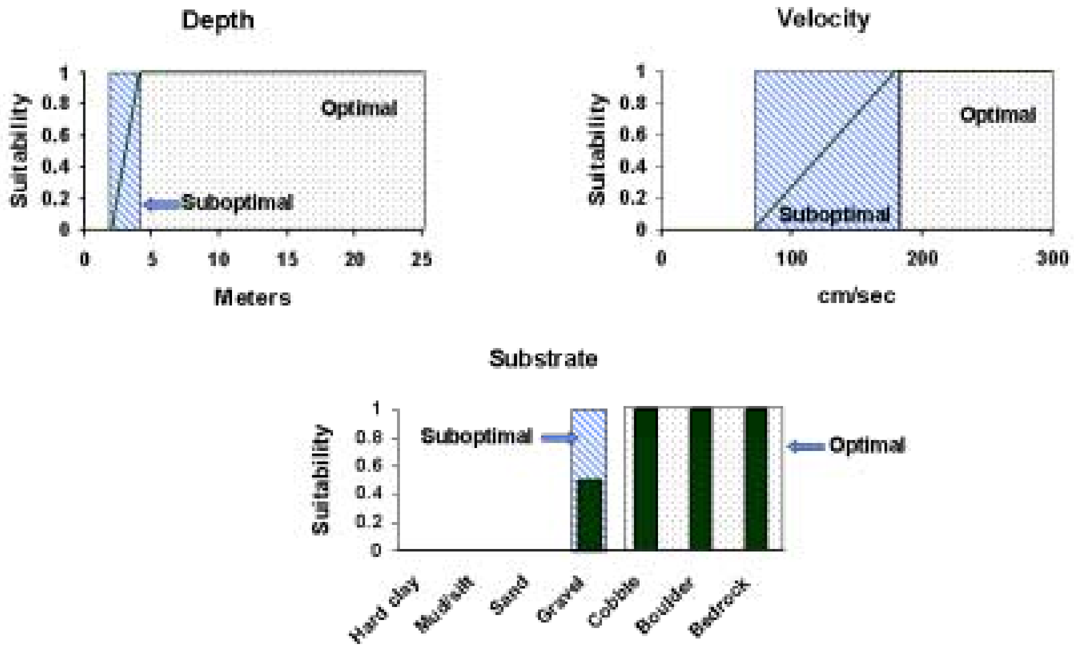

Figure 3. Suitability of habitat for spawning white sturgeon classified into optimal and suboptimal categories. Ranges not classified are considered to be not used by spawning white sturgeon.

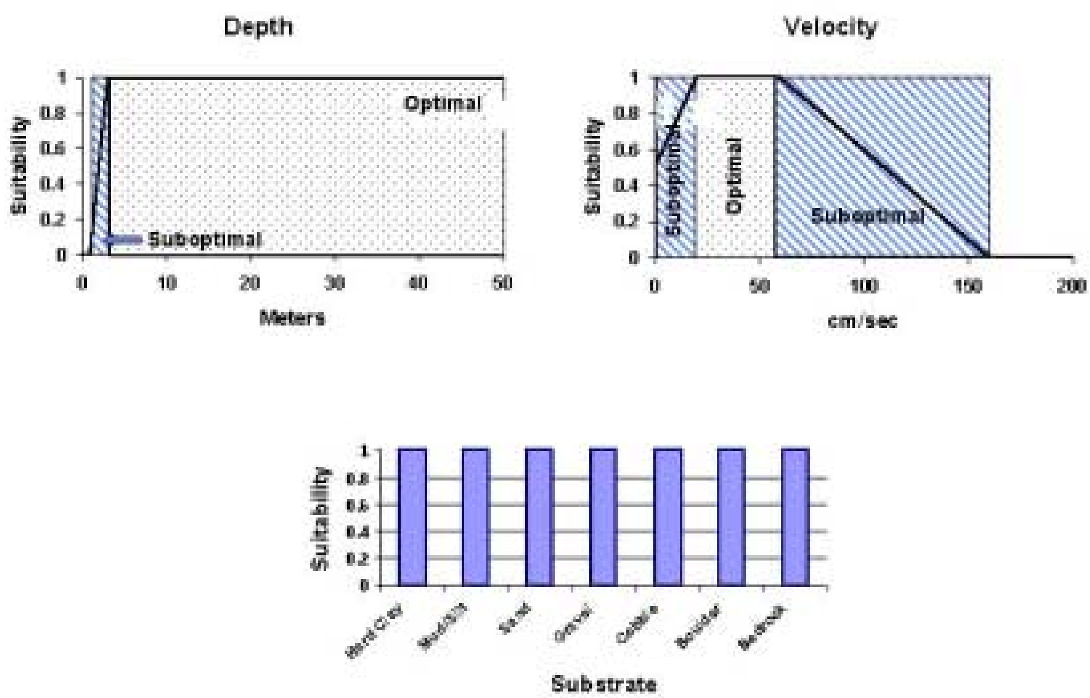

Figure 4. Habitat for rearing white sturgeon classified into optimal and suboptimal categories. All substrates were classified as optimal for this analysis. Rearing white sturgeon do not use depths and velocities that were not classified as suboptimal or optimal.

Integration of simulated habitat and habitat use.

These habitat criteria were applied using ARC/INFO software to the raster data layers of water depth and velocity that were derived from the hydraulic simulations. Simple map overlay techniques were used using a lowest limiting parameter approach. Habitats were classified as optimal only where all criteria were optimal. Habitats were classified as suboptimal where one or more of the criteria were classified as suboptimal and all other criteria were suboptimal or optimal. Habitats were classified as not used where one or more of the criteria were neither optimal nor suboptimal.

Because substrates are critical to estimating spawning habitat for white sturgeon (Figure 1) an alternative approach that used mean water column velocity as a surrogate for substrate was developed. The U.S. Bureau of Reclamation (USBR, 1977) gives an equation for critical velocity, or that velocity required to just move a particle as:

$$V_c = 0.155\sqrt{d}$$

where d is the average particle diameter (mm) and V is the mean velocity (m/s). The smallest particle size suitable for spawning is gravel (particle size >= 64mm). Solving this equation using 64 mm as the smallest particle size gives a V_c of 1.24 m/s. However, because shifting substrates could crush white sturgeon eggs and V_c is the velocity at which particles can move, a slightly lower velocity (1.1 m/s) was chosen as the minimum velocity that should result in a substrate usable for spawning by white sturgeon. At mean column velocities of this magnitude and greater, riverbed substrates should be suitable for white sturgeon spawning.

Results

Hydraulic conditions

The simulations showed that lowered water levels in John Day Reservoir reduced the surface area of the impounded Columbia River. The total surface (wetted) area of the John Day Reservoir varied depending on the water level scenario and river discharge that was modeled. Figure 5 shows the difference in the spatial extent of the river for three water level scenarios; normal operating pool, spillway crest, and natural river levels. As water levels are lowered at John Day Dam, the gradient of the river increases in the upper reaches of the reservoir (Figures 6 to 8). For example, at normal operating pool and a discharge of 4,400 m^3/s (156 kcfs), the water surface from John Day Dam to McNary Dam is relatively constant from river km 346 to river km 462, and backwater effects from John Day Dam decrease only slightly upstream of river km 462 (Figure 7). At the highest discharge modeled for the normal operating pool scenario the river surface rose less than 1.2 m and the backwater effect from John Day Dam is still quite obvious (Figure 8). Under the spillway crest scenario, the gradients are slightly higher and backwater effects from John Day Dam decrease near river km 423. At the natural river level the water surface changes approximately 29 m from the upper to lower end of the 122-km long reservoir. Information on the pre-impoundment river

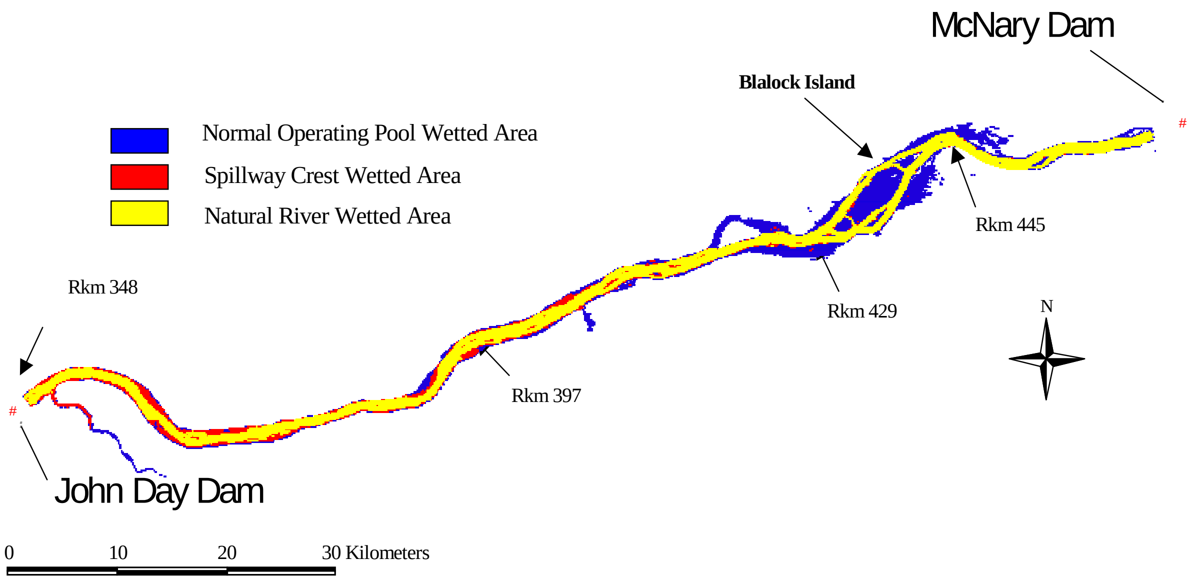

Figure 5. Spatial extent of the wetted surface area of the Columbia River between John Day and McNary dams for normal operating pool, spillway crest, and natural river scenarios at a discharge of 8,500 cms (300 kcfs).

indicates that this stretch of river was characterized by a gradient of 0.2 m/km for non-rapids areas and gradients of 0.4 to 1.5 m/km for rapids (U.S. Army Corps of Engineers 1951).

Water velocities are relatively constant throughout the reservoir under normal operating conditions. For example, at a discharge of 4,400 m^3/s (156 kcfs) the majority of the wetted area (99.6%) under normal operating pool has a mean column water velocity of <0.9 m/s (Figure 9). Under the spillway crest scenario, 84% of the wetted area is characterized by velocities <0.9 m/s. The limited areas with water velocities >= 0.9 m/s are found only upstream of river km 423 (Figure 9). In contrast, only 49% of the wetted surface area for the natural river scenario is characterized by velocities <0.9 m/s, and velocities >= 0.9m/s are found throughout the length of the river.

Lowering water levels in the reservoir increases riverine habitat by increasing the proportion of run and riffle habitat (Table 1). To illustrate, Figure 9 shows that under normal operating conditions and at a river discharge of 4,400 m^3/s (156 kcfs), the river is dominated by pool habitat. As the reservoir water level is lowered to the spillway crest water level scenario, the proportion of run and riffle habitat increases in the upper portion of the reservoir. A drawdown to natural water levels results in the distribution of pool, run, and riffle habitat throughout the river reach.

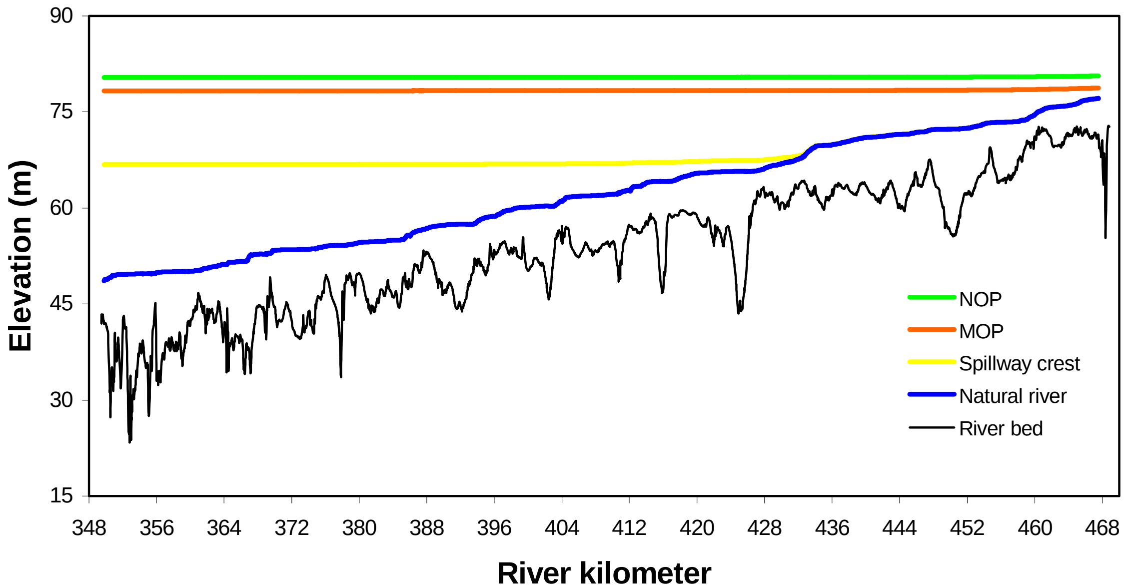

Figure 6. Longitudinal profile of water surface elevations for John Day Reservoir at a river discharge of 2,800 cms (100 kcfs).

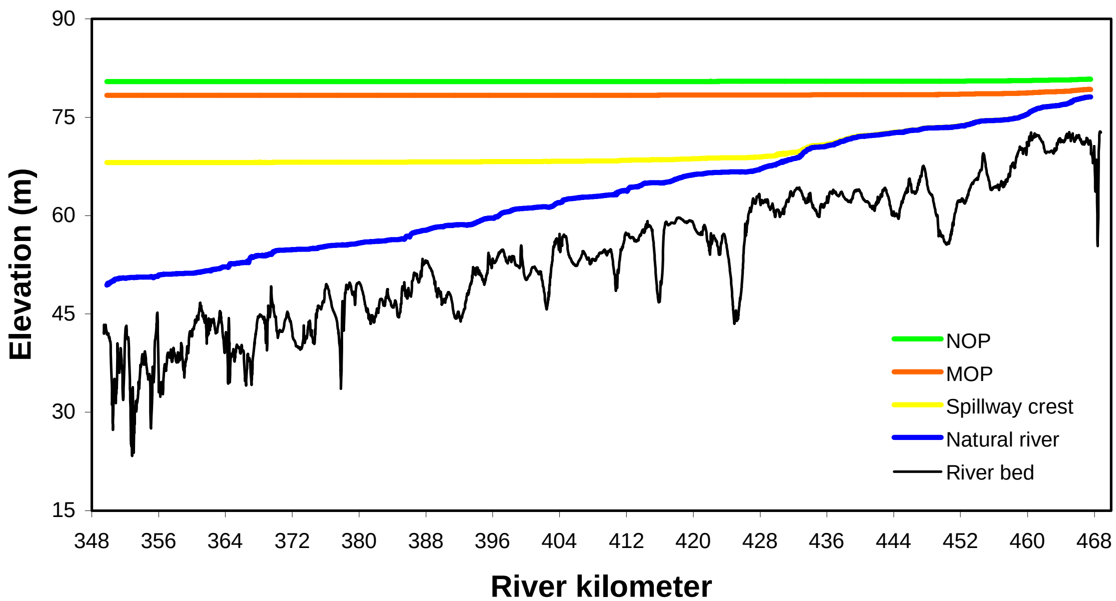

Figure 7. Longitudinal profile of water surface elevations for John Day Reservoir at a river discharge of 4,400 cms (156 kcfs).

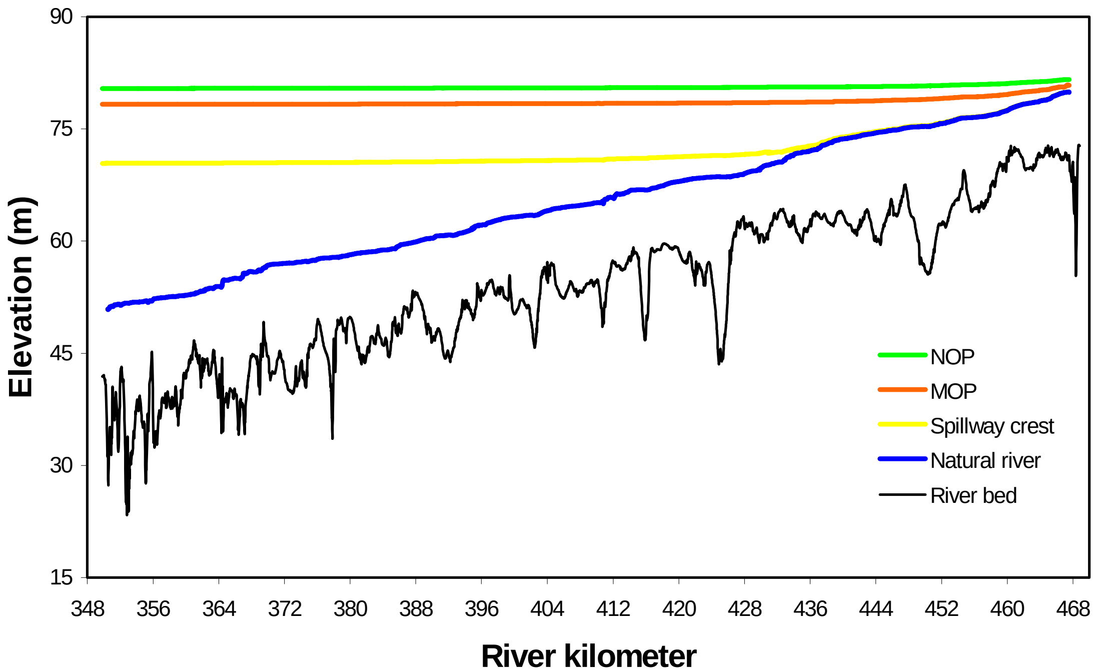

Figure 8. Longitudinal profile of water surface elevations for John Day Reservoir at a river discharge of 8,500 cms (300 kcfs).

Spawning Habitat

Potential spawning habitat for white sturgeon increased with lowered water levels and increased river discharge in John Day Reservoir (Table 2, Figure 13). Very little spawning habitat exists for white sturgeon under the normal operating pool and minimum operating pool scenarios and no habitat classified as optimal was present at the two lowest discharges for these scenarios. Habitat classified as optimal was present for each discharge under the spillway crest and natural river scenarios.

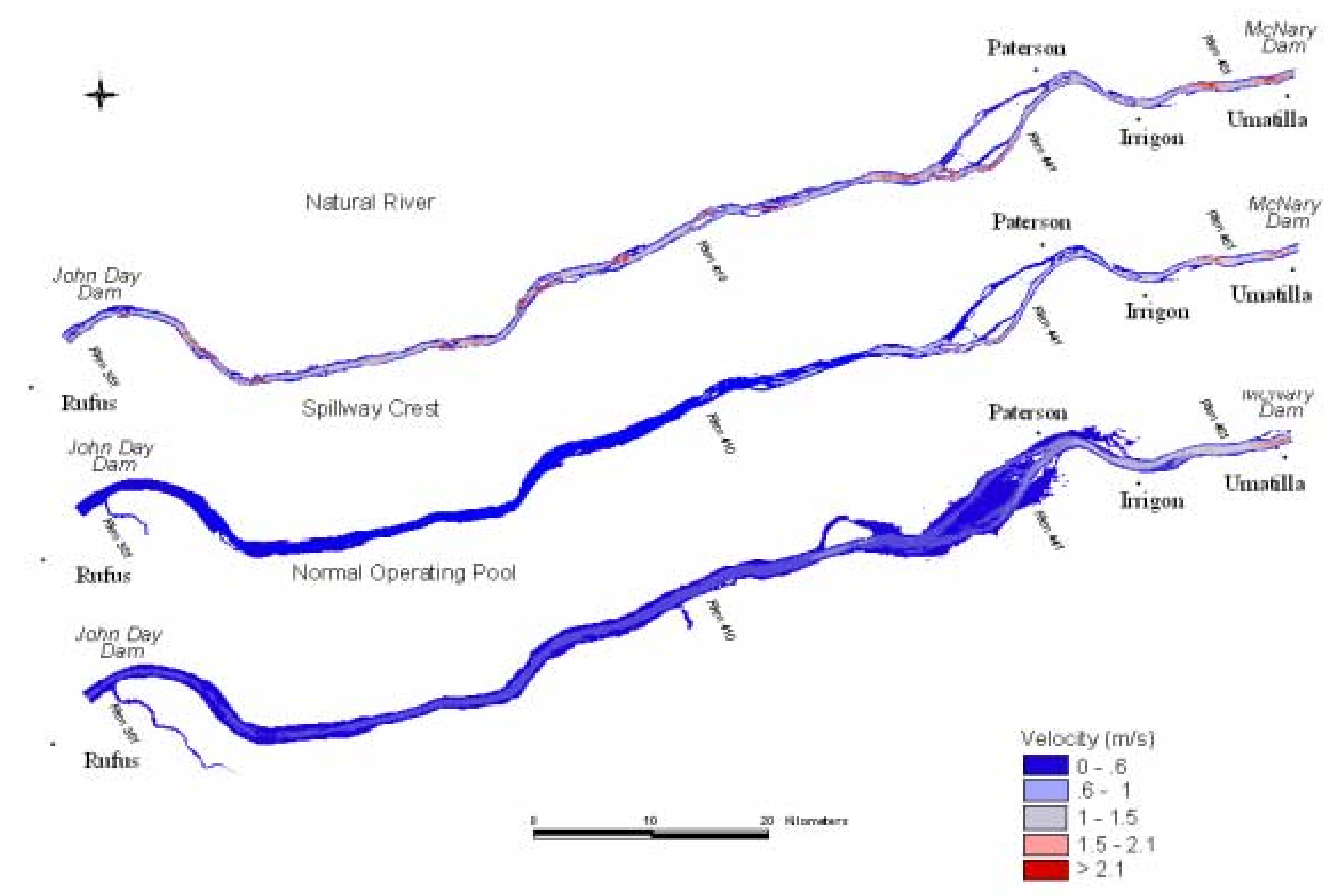

Figure 9. Examples of the distribution of predicted water velocities from hydraulic modeling of different water level scenarios at a discharge of 4,400 m^3/s (156 kcfs).

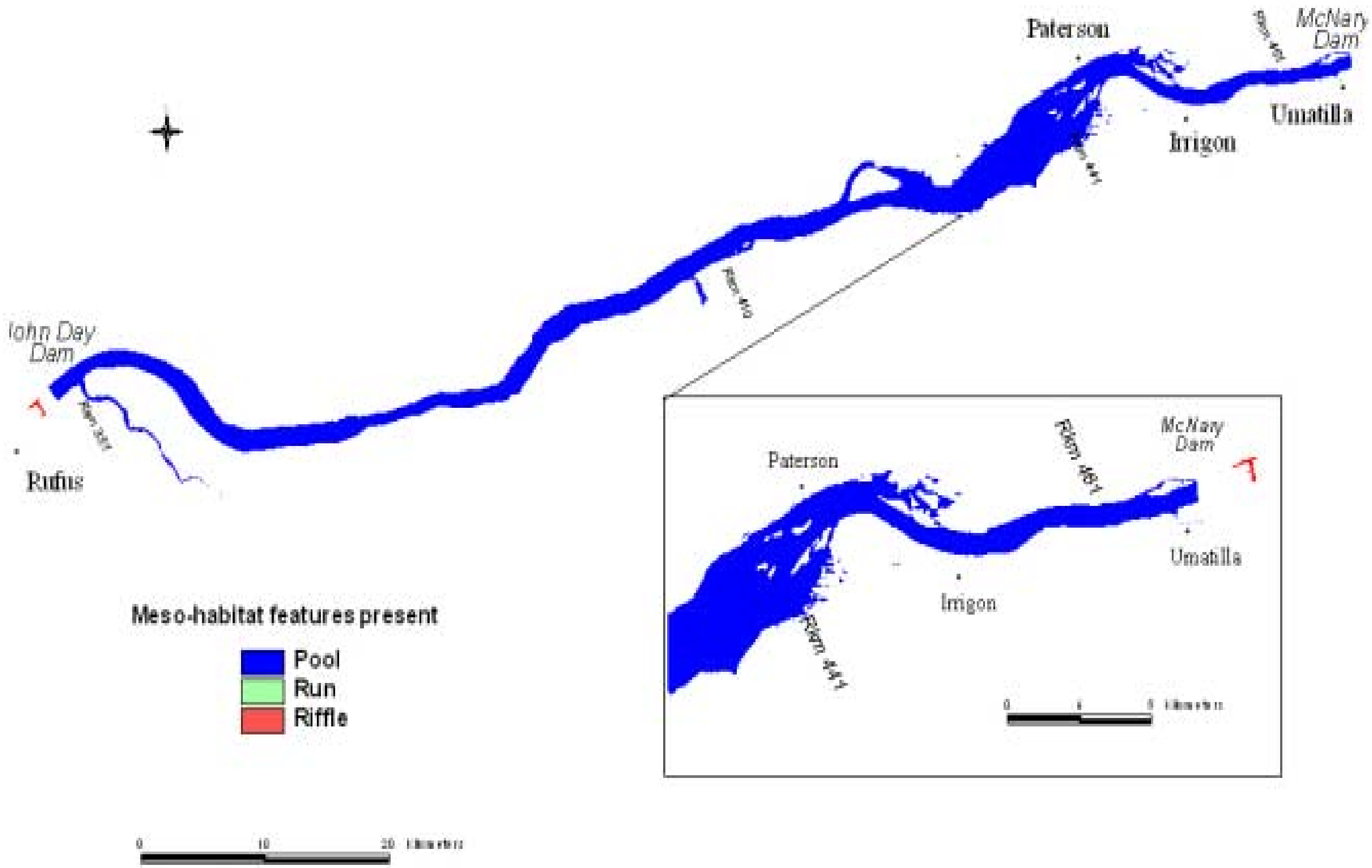

Figure 10. Distribution of pools, runs, and riffles for the normal operating pool scenario at a discharge of 4,400 m^3/s (156 kcfs).

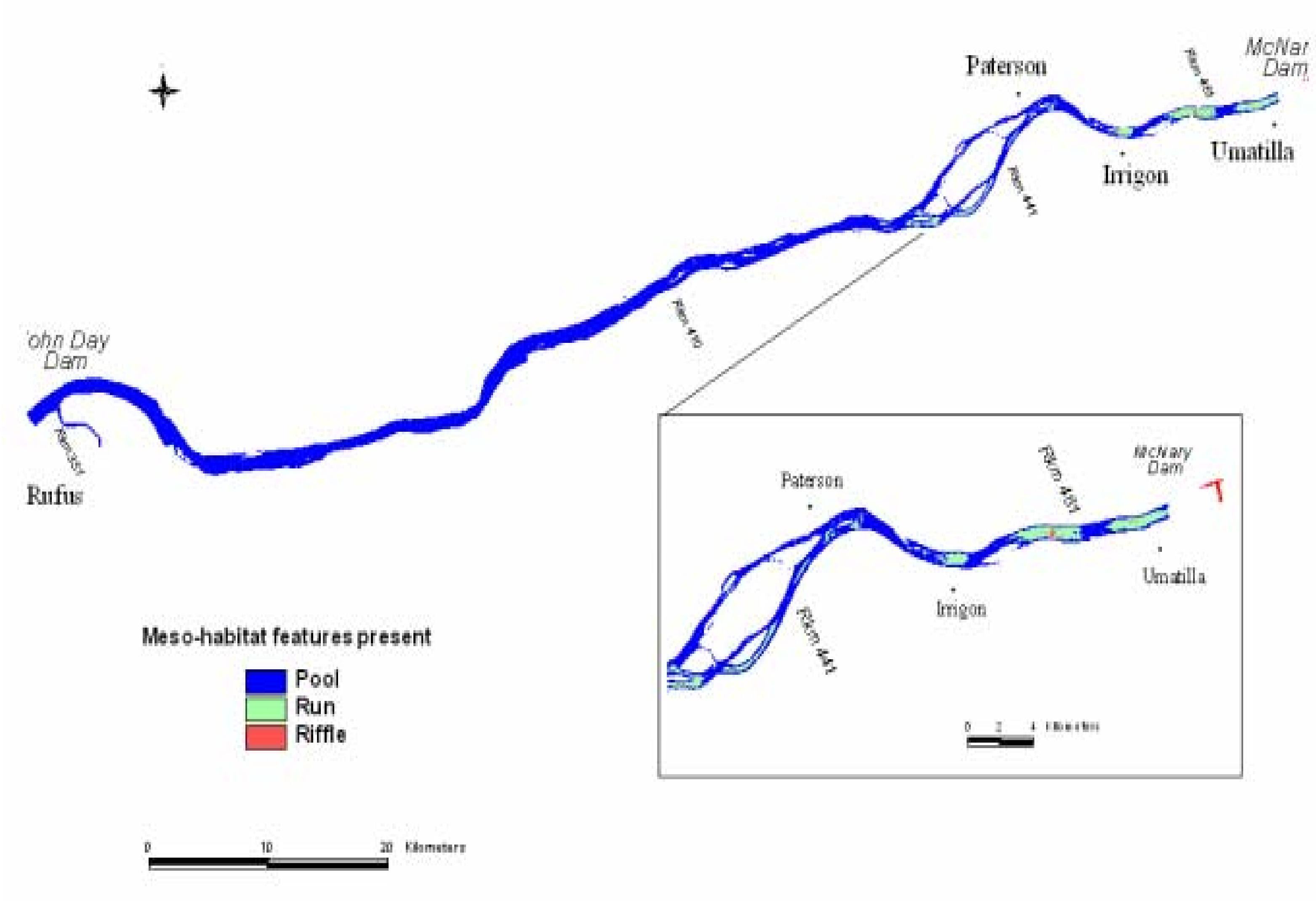

Figure 11. Distribution of pools, runs, and riffles for the spillway crest scenario at a discharge of 4,400 m^3/s (156 kcfs).

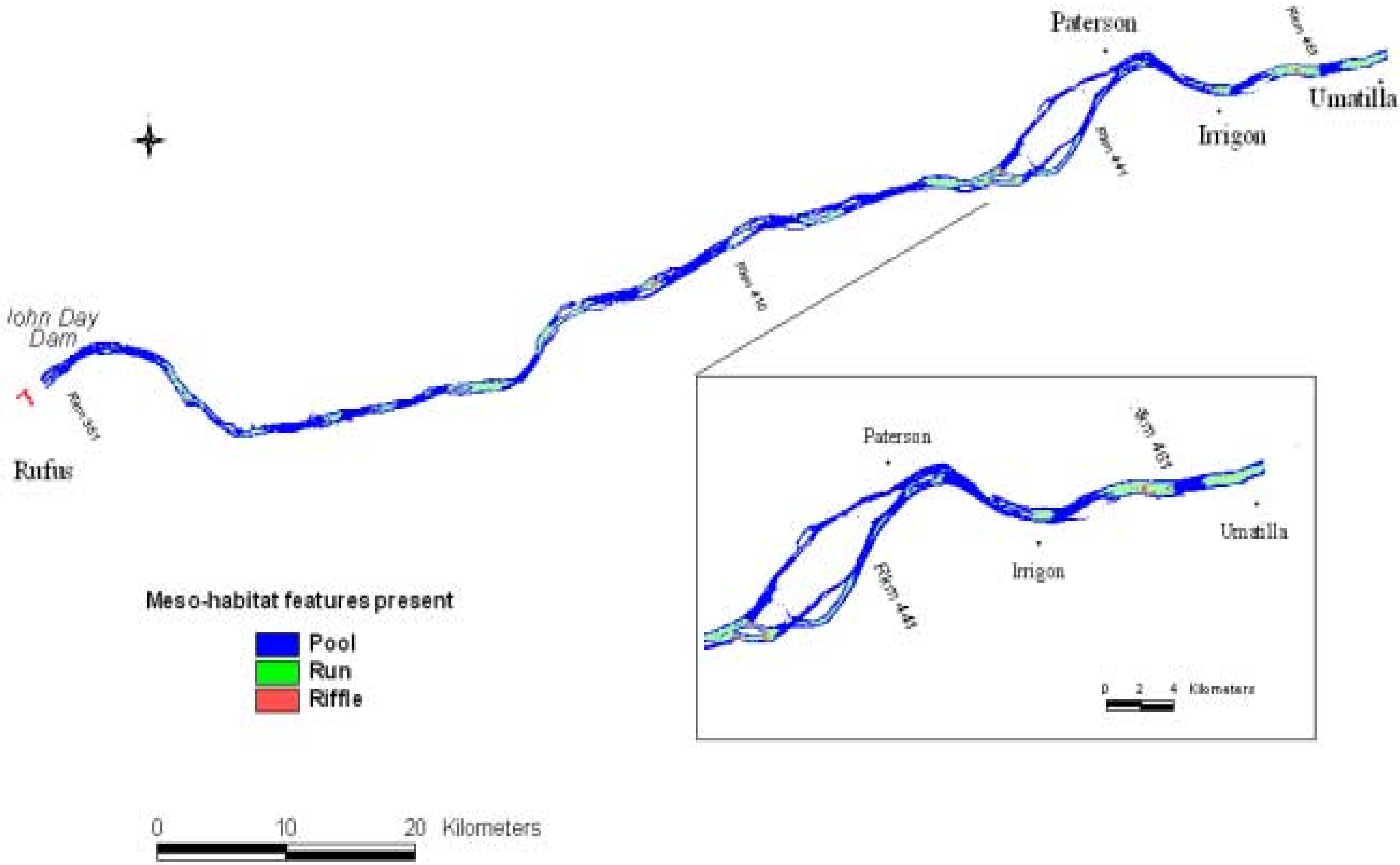

Figure 12. Distribution of pools, runs, and riffles for the natural river scenario at a discharge of 4,400 m^3/s (156) kcfs.

Table 1. Estimated amounts of riverine habitat in John Day Reservoir under four proposed water levels and at three river discharges. Pool, run, and riffle habitats were classified from calculated Froude numbers as per Jowett (1993) and Yu and Peters (1997). Minor differences in total surface area for each scenario in Tables 1, 2, and 3 (range 0-13 ha) arise during processing of the multiple ARC/INFO grids used in these analyses.

		Area (ha)		
Scenario	Habitat category	Discharge (m^3/s)		
		2,800	4,400	8,500
Normal Operating Pool	Pool	19,770	19,793	19,993
	Run	0	1	5
	Riffle	0	1	0
Minimum Operating Pool	Pool	17,671	17,776	17,851
	Run	1	6	271
	Riffle	0	0	4
Spillway Crest	Pool	10,383	10,960	11,698
	Run	625	755	1,233
	Riffle	49	28	23
Natural River	Pool	6,589	6,831	6,526
	Run	1,519	2,098	3,658
	Riffle	145	120	125

Table 2. Potential spawning habitat for white sturgeon in John Day Reservoir under four proposed water levels and at three river discharges. Percent usable area includes habitats classified as optimal and suboptimal

Scenario	Habitat category	Area (ha) Discharge (m^3/s) 2,800	4,400	8,500
Normal Operating Pool	Optimal	0	0	10
	Suboptimal	51	342	1454
	Not Usable	19726	19451	18532
	Total Area	19777	19793	19996
	Percent usable area	0.3	1.7	7.3
Minimum Operating Pool	Optimal	0	0	155
	Suboptimal	169	779	1909
	Not Usable	17515	17015	16072
	Total Area	17684	17794	18136
	Percent usable area	1.0	4.4	11.4
Spillway Crest	Optimal	66	285	1016
	Suboptimal	1675	2169	3812
	Not Usable	9343	9317	8158
	Total Area	11084	11771	12986
	Percent usable area	15.7	20.8	37.2
Natural River	Optimal	285	902	3258
	Suboptimal	3705	4187	3628
	Not Usable	4286	3984	3447
	Total Area	8276	9073	10333
	Percent usable area	48.2	56.1	66.6

Rearing Habitat

The amount and quality of rearing habitat for white sturgeon is influenced by reservoir water levels and discharge. The amount of rearing habitat decreased with lowered reservoir water levels (Table 3, Figure 14) primarily because the total surface area of the river decreased. The normal operating pool scenario provided the greatest amount of habitat and approximately 95% of the total surface area of the impoundment was classified as suitable for white sturgeon for the three discharges.

River discharge had a varying effect on rearing habitat. Under the normal pool level scenario, the higher river discharges resulted in substantial increases in the quality of the available rearing habitat. While the total surface area under the normal operating pool scenario increased only 221 ha between the lowest and highest simulated discharges, the amount of habitat classified as optimal increased by 7,954 ha (Table 3). Results were similar for the minimum operating pool scenario; increased discharge improved the quality of habitat with only small gains in total available habitat. In contrast, under the spillway crest and natural river scenarios, increased discharge provided only marginal increases in quality of habitat while the total usable area decreased despite substantial increases in total surface area (Figure 14).

Discussion

White sturgeon historically existed in a river system with high habitat complexity. Construction of dams on the mainstem Columbia and Snake rivers has reduced that complexity, blocked migrations, and isolated white sturgeon populations into discrete habitat patches (i.e. reservoirs). While the surface areas of these reservoirs are many times larger than the surface areas of the reaches of natural river that were impounded, the reduction in habitat complexity and resulting monotypic pool habitat has undoubtedly altered life history strategies of white sturgeon. Changes in productivity of white sturgeon populations since construction of the reservoirs can be inferred by comparing changes in habitat area and complexity. This analysis showed that complexity and diversity of aquatic habitat in John Day reservoir varied with water level and discharge scenarios. The reservoir is currently typified by deepwater pool habitat, with low channel complexity and a virtually no run or riffle habitat. The natural river channel, now beneath John Day Reservoir, was typified by a complex channel pattern with a diversity of habitats in pools, runs, and riffles.

Two-dimensional hydraulic modeling provided estimates of water depths and velocities that may exist in the John Day Reservoir under several water level scenarios. Coupling this information with biological criteria describing spawning and rearing habitats used by white sturgeon within a geographic information system provided the quantification and visualization of changes in habitats could occur if reservoir water levels are manipulated, and also provided an assessment of changes in habitat due to impoundment. Physical habitat available for spawning white sturgeon has decreased and physical habitat for rearing has increased due to construction of the dams.

Table 3. Potential rearing habitat for white sturgeon in John Day Reservoir under four proposed water levels and at three river discharges. Percent usable area includes habitats classified as optimal and suboptimal.

Scenario	Area (ha)			
	Discharge (m^3/s)			
	Habitat category	2,800	4,400	8,500
Normal Operating Pool	Optimal	1941	4394	9895
	Suboptimal	16848	14438	9083
	Not Usable	988	969	1019
	Total Area	19777	19802	19998
	Percent usable area	95.0	95.1	94.9
Minimum Operating Pool	Optimal	2063	5258	8883
	Suboptimal	14643	11521	7729
	Not Usable	978	1016	1526
	Total Area	17684	17795	18138
	Percent usable area	94.5	94.3	91.6
Spillway Crest	Optimal	3530	4552	3586
	Suboptimal	6629	6024	7492
	Not Usable	904	1172	1883
	Total Area	11063	11748	12961
	Percent usable area	91.8	90.0	85.5
Natural River	Optimal	774	805	776
	Suboptimal	5725	5692	4630
	Not Usable	1763	2558	4909
	Total Area	8261	9055	10315
	Percent usable area	78.7	71.8	52.4

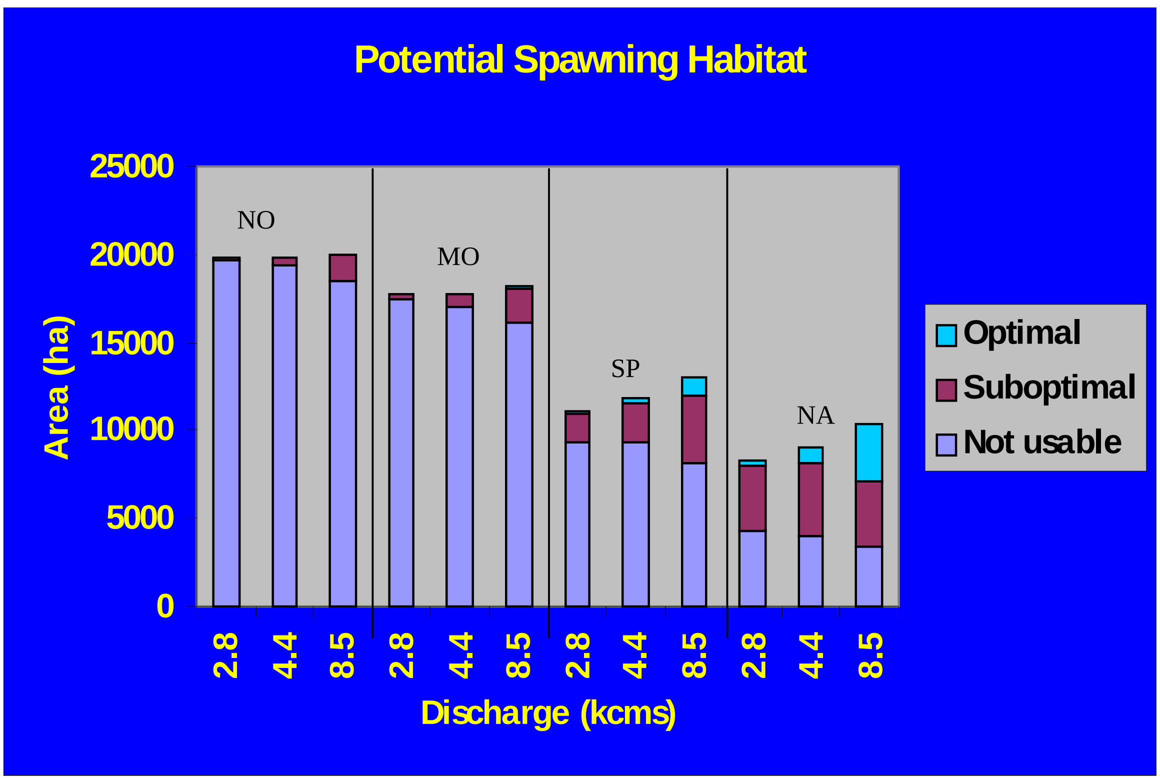

Figure 13. Potential spawning habitat for white sturgeon between John Day and McNary dams at four water level scenarios and three river discharges. The four water level scenarios are NO = normal operating pool, MO = minimum operating pool, SP = spillway crest, and NA = natural river.

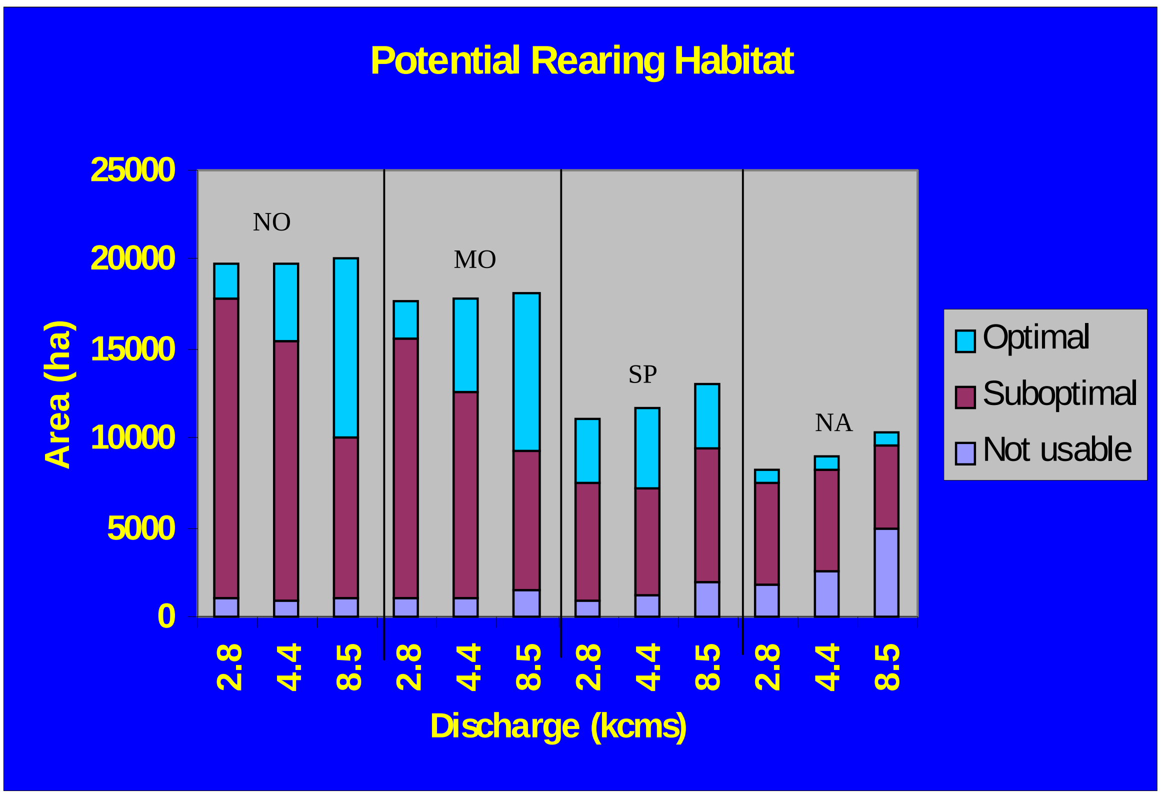

Figure 14. Potential rearing habitat for white sturgeon in John Day Reservoir under four water level scenarios and three river discharges. The four water level scenarios are NO = normal operating pool, MO = minimum operating pool, SP = spillway crest, and NA = natural river.

Potential spawning areas for white sturgeon increased with lowered water surface elevation, which reduced the backwater effect from John Day Dam, and with increased discharge, which increased water velocities in areas where the channel cross-sectional area remained relatively constant due to backwater effects. There are no records denoting historic spawning areas for white sturgeon in the mainstem Columbia or Snake rivers. Currently, most spawning occurs within 8-10 km downstream from hydroelectric dams on the two rivers (Parsley and Kappenman 2000, Parsley et al. 1993, Parsley and Beckman 1994). Backwater effects from downstream dams reduce the water surface gradient and quickly reduce water velocities in the reservoirs as distance from the upstream dam increases. Presumably, white sturgeon would use additional habitats for spawning if they became available through lowered water levels, but this has not been tested.

Potential rearing areas for white sturgeon decreased with lowered water surface elevation and were variably influenced by river discharge for each scenario. However, the proportion of the total wetted area for each scenario that was classified as usable exceeded 90% for all scenarios except for the highest discharge for the spillway crest scenario (85.5%) and all three discharges for the natural river scenario (78.7%, 71.8%, and 52.4%). While rearing white sturgeon are relative generalists in their selection of habitats as illustrated by the broad habitat suitability criteria curves for this life stage (Figures 2 and 4), the ascending left limbs of the curves for depth and velocity and the descending right limb for velocity resulted in substantial changes in the quality and quantity of rearing habitat identified for the scenarios. Differences in quality of habitat, particularly under the normal operating pool scenario where habitat classified as optimal increased from 1,941 ha at the lowest discharge to 9,895 ha at the highest discharge (Table 3), were due to minor changes in water velocity resulting from higher discharge. At higher discharges, water velocities throughout the reservoir increased. This causes resulted in a substantial amount of the habitats classified as suboptimal because of low water velocities to be reclassified as optimal.

Under impounded conditions, water depth has very little effect on estimates of rearing habitat because shallow water occupies only a small proportion of the total surface area of the impoundment, and substantial areas of lower water velocities exist due to backwater effects. However, under riverine conditions, shallow water near shorelines and high water velocities in the middle of the river limited areas classified as suitable for use by rearing white sturgeon.

In this analysis, depth, velocity, and substrate were considered at the microhabitat scale. The results present a maximum potential-use scenario. They are intended to predict where spawning and rearing could be expected occur and are not intended to predict the presence or abundance of fish if reservoir drawdowns were implemented. The estimates of spawning and rearing habitats and meso-habitats used only water depths and water velocities obtained by two-dimensional hydraulic modeling from existing digital data sets. The addition of more criteria such as substrates, lateral bed slope, and small-scale features such as current breaks and eddies would further refine the estimates of potential habitat. While rearing white sturgeon don't appear to exhibit a preference for substrates at the microhabitat scale, substrates differ in biological productivity. Additional analyses of habitat characteristics at a reach or basin scale could reveal differences in productivity of white sturgeon populations due to substrate characteristics that may or may not produce food for fish.

Given the changes in physical habitat suitable for spawning and rearing white sturgeon that would occur if reservoir water levels were lowered, it is difficult to determine if overall productivity of the population would increase or decrease at each scenario. Studies in the Columbia River downstream from Bonneville Dam have shown that relatively small areas of spawning habitat can seed extensive rearing habitats and provide productive fisheries (McCabe and Tracy 1994). Thus, maximizing the quantity of spawning habitat may not be necessary to recover depleted sturgeon populations. Changes in overall white sturgeon population productivity after reservoir drawdown would also be affected by other factors such as changes in biological community structure that would be favored by a more lotic environment.

Lotic environments produce a more diverse food supply than lentic environments (Becker 1973, Dauble et al. 1980, Muir and Emmett 1988, Rondorf et al. 1990) and may have greater potential for production of white sturgeon. Higher water velocities found in riverine systems promote a diversity of substrates and microhabitats that result in richer, more abundant invertebrate communities. Currently, riverine conditions between John Day and McNary dams exist only in the extreme upper reaches of the reservoir. The analyses presented here show that lowering water levels at John Day Dam to spillway crest could restore riverine conditions to approximately the upper one third of the current reservoir.

Drawdown would also influence emigration and immigration of subadult and adult white sturgeon. Currently, there is a net downstream movement of white sturgeon from reservoirs on the mainstem Columbia and Snake rivers (WDFW and ODFW unpublished data). Upstream passage of white sturgeon through existing fishways is negligible (Warren and Beckman 1993), and only one proposed drawdown scenario, dam breaching to return to natural river levels, would provide unimpeded upstream migration into this river reach from the reservoir immediately downstream. However, even if John Day Dam were breached, the remaining upstream and downstream dams would continue to restrict movements of white sturgeon and alter annual flow and thermal regimes, and thus influence productivity in this reach. Analyses incorporating population viability analysis, such as the theoretical analysis of river fragmentation effects on populations recently completed by Jager et al. (2001), provide additional insight on factors such as the genetic consequences of isolating populations.

Acknowledgements

Tom Batt performed the spatial analyses after making modifications to the AML's originally written by the authors for these analyses. This work was performed under BPA project 8605000.

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

ANNUAL PROGRESS REPORT

APRIL 2000 – MARCH 2001

Report D

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

This report includes: A summary of activities and plans to develop and implement artificial propagation techniques and protocols for experimental propagation of white sturgeon.

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CONTENTS

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We offer our appreciation and thanks to Yakama Nation fishery technicians Chuck Gardee and Clifford Alexander, Washington Department of Fish and Wildlife technicians John Hone and 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 supplementation project.

ABSTRACT

During 17 days of setline fishing for broodstock from 19 March 2000 to 26 April 2000, we captured a total of 192 white sturgeon in 123 sets. We successfully captured and transported 16 sexually mature white sturgeon, two females and 14 males, from McNary Reservoir to holding facilities at Abernathy National Fish Technology Center. We were unable to collect and fertilize female gametes during broodstock spawning trials in 2000. Although we were able to collect gametes from two males, no females, including a female held over from the 1999 broodstock trials, exhibited sufficient oocyte maturation to attempt spawning. We determined that static cool well water temperature (12.0-12.5^{o}C) at Abernathy National Fish Technology Center likely inhibited white sturgeon broodstock's oocyte development. Broodstock spawning trials from 1999 and 2000 indicate that a new holding and spawning facility that uses or mimics the natural Columbia River water temperature regime or a secondary source of gametes will be necessary for the future success of the white sturgeon experimental supplementation project.

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 2000 through 31 March 2001 performed to meet objectives of Bonneville Power Administration (BPA) tasks outlined under project 86-50. We describe activities and results of work performed to meet our primary task during this period of developing and implementing techniques for capturing, holding and spawning white sturgeon from McNary Reservoir. This work is being conducted to develop techniques that will mitigate for reduced natural production of white sturgeon due to development and operation of the hydrosystem. Juvenile white sturgeon produced from these efforts will be released into selected Columbia River Basin reservoirs to evaluate supplementation as a recovery and mitigation tool for depressed/declining white sturgeon populations. Within this report we describe the methods, efforts, and results of white sturgeon collection and broodstock spawning trials performed by CRITFC with cooperation and assistance from Washington Department of Fish and Wildlife (WDFW) and United States Fish and Wildlife Service (USFWS).

An additional task conducted by CRITFC and its subcontractor, the Yakama Nation, during this period was to provide assistance to cooperating agencies in conducting young-of-year (YOY) surveys in selected Columbia and Snake river reservoirs. Washington Department of Fish and Wildlife will report on the results of the YOY gill net surveys in their respective section 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 19 March 2000 through 26 April 2000. White sturgeon were caught using setlines fished overnight, except April 24-26 when setlines were fished for 2 consecutive nights (due to boat problems), and using gill nets fished overnight and during the day. 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 and gill nets were generally pulled by hand, although the anchors were generally retrieved with a hydraulic winch. Gill nets were 50 m in length, 3.7 m deep, and 30 cm stretched mesh nylon. They were fished on the bottom and anchored and marked in a similar manner as setlines.

Captured white sturgeon were immediately placed in a live well, or if too large for the live well (greater than 213 cm TL), placed on the deck with water flushed through the

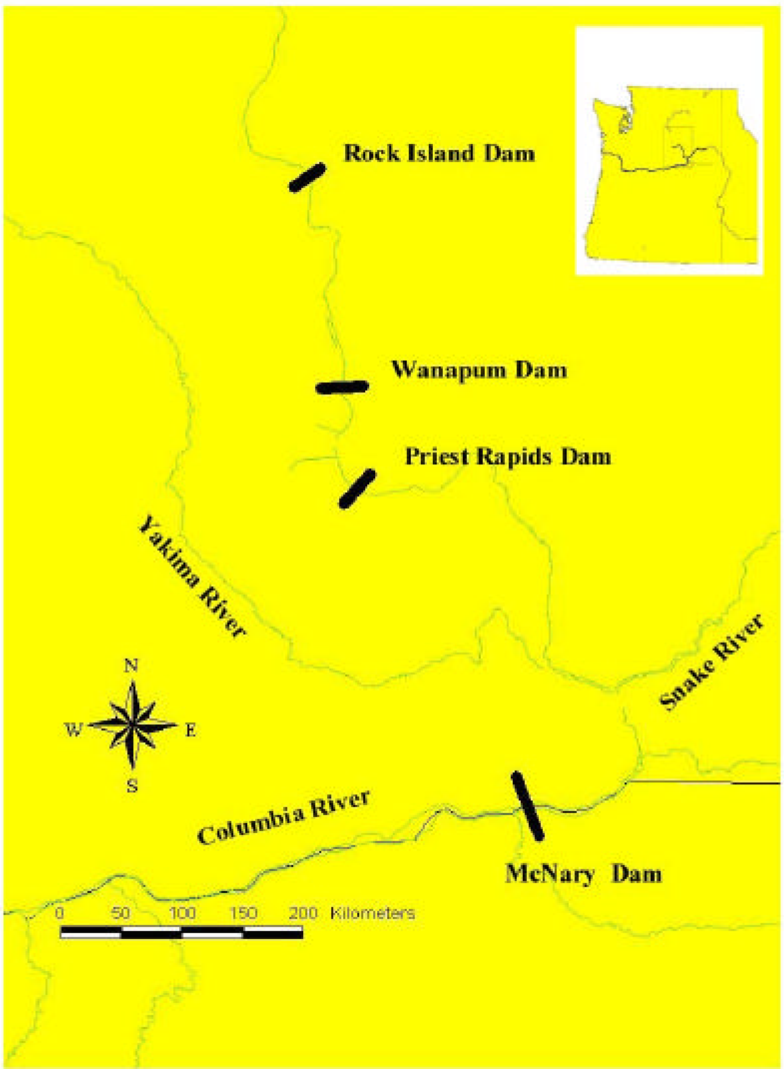

Figure 1. Map of McNary Reservoir in the Columbia River where all white sturgeon broodstock collection efforts were performed from 19 March 2000 to 26 April 2000.

gills via an electric pump, or tied along side the boat. After running a setline or gill net, 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 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 staged gonad maturity of fish ≥ 152 cm TL. Fish excessively stressed, as evident by excessive redness on the ventral surface, were not surgically examined and were released immediately. All fish examined for sexual maturity were PIT tagged and the 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 (Rein et al. 1994). Determination of sex and maturity was made by a surgical examination performed using an otoscope inserted through a 2-3 cm ventral incision. Classification of maturation was based on assessment of oocyte development (Chapman 1989) and methods described by Welch and Beamesderfer (1993). During the surgical examination, fish were placed ventral side up and held in place with sandbags while gills were continuously flushed with water using an electric pump. The incision was closed with two to four stitches. White sturgeon that were assessed to have potential as broodstock were immediately placed into a specialized transport tank and held on fresh river water until the fishing week's end (i.e. 36 to 72 h). All other white sturgeon were immediately released back into the reservoir. At week's end potential broodstock were transported to Abernathy National Fish Technology Center and held in 3 m diameter tanks (Holmes, this report).

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

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RESULTS

Artificial Propagation Research

Broodstock collection

We collected sixteen white sturgeon for broodstock trials, two females measuring 230 and 224 cm in fork length (FL), weighing 113 and 106 kg, respectively, and 14 males ranging from 143 to 199 cm FL and weighing between 24 and 64 kg. We captured a total of 192 white sturgeon in 123 sets in 17 days of fishing during a five-week fishing period from 19 March 2000 to 26 April 2000 (Table 1). Sizes of white sturgeon captured ranged from 63 to 247 cm fork length. We performed 113 surgical examinations on fish suspected of sexual maturity to determine sex and maturity, revealing a total of 67 males, 45 females, and one unknown. All fishing took place in McNary Reservoir from statute river mile 295.5 to 302.9.

Except for two mortalities that occurred during gill net sets, all white sturgeon captured and not taken as broodstock were released in good condition into McNary Reservoir. All white sturgeon taken for broodstock in 2000 were returned in good condition to McNary Reservoir. The female captured in 1999 from Wanapum Reservoir (Kappenman and Parker 2000) and held over year at Abernathy facility for potential spawning in 2000 was returned to Wanapum Reservoir in October 2000. This female was tagged prior to release with a hydroacoustic transmitter, located several times, and reported to be using the same holding areas as other tagged females in a study being performed by RL &L Environmental Services Ltd. (personal communication Louise Porto). Incidental catch mortality consisted of one channel catfish (*Ictalurus punctatus*).

Table 1. Summary of Columbia River Inter-Tribal Fish Commission white sturgeon broodstock capture efforts showing number of days fished, number of gill net and setline sets, number of white sturgeon captured, and number of broodstock kept for the fishing period from 19 March 2000 to 26 April 2000 in McNary Reservoir.

Reservoir	McNary	
Days fished	17	
Number of sets	10 Gill net 113 Setline	
White sturgeon captured	192	
Broodstock kept	Males 14	Females 2

Broodstock spawning trials

We monitored the maturation cycles of the Wanapum Reservoir female from February through September 2000, and both recently captured McNary Reservoir females from March/April through September 2000. The maturation cycle was monitored by performing standard ovarian follicle collections. Oocyte development and spawning date calculation were determined by measurement of ovarian follicle diameter, oocyte polarization index (a ratio of the distance of the germinal vesicle from the animal pole to the animal-vegetal oocyte diameter), and progesterone-induced breakdown of the germinal vesicle (Conte et. al. 1987). Throughout the monitoring period oocytes of all females exhibited irregular patterns or a lack of germinal vesicle migration (Table 2). Only McNary female 230 FL showed any signs of consistently decreasing polarization index scores, but this development remained insignificant (Table 2). Monitoring of these indicators revealed that a spawning attempt would not be successful, and thus no attempt was made to initiate spawning. In mid-September 2000, though no female oocytes would be available for fertilization, we collected gametes from two of the fourteen males after injecting all of them with luteinizing hormone-releasing hormone (LHRH).

DISCUSSION

Artificial Propagation Research

The 2000 spawning season was again a year of technique development. For the second year of this project, we successfully captured, transported, and held wild Columbia River white sturgeon. As with the first year of this project, we were unable to successfully fertilize the gametes of a female white sturgeon. As stated in our 1999 annual report (Kappenman and Parker 2000), our experience holding captive broodstock

Table 2 – A summary of standard oocyte maturation test results for three white sturgeon held for the 2000 spawning season showing females identified by fork length (FL) and/or reservoir, date oocytes were sampled, average ovarian follicle diameter, oocyte polarization index, and percent germinal vesicle breakdown of a sample.

Female Identity (By Reservoir and/or Fork Length)	Sample Date	Average Ovarian Follicle Diameter	Oocyte Polarization Index	Percent Germinal Vesicle Breakdown
Wanapum	2/14/00	-	.16	-
	4/13/00	-	.12	-
	5/17/00	3.55	.11	0
	7/10/00	3.7	.12	0
	8/9/00	3.7	.12	0
McNary 230 FL	3/27/00	-	.22	0
	6/1/00	3.7	.16	0
	7/10/00	3.7	.15	0
	8/9/00	3.7	.13	0
McNary 244 FL	4/10/00	-	.15	0
	6/1/00	3.7	.14	0
	7-10-00	3.8	.13	0
	8/9/00	3.8	.14	0

at the Abernathy Fish Technology Center indicates that static cool well water temperatures (12.0–12.5°C) interrupted the natural sexual maturation of female white sturgeon broodstock and prevented successful development of oocytes. Though we were successful at collecting gametes from male white sturgeon, it became apparent in the 2000 broodstock trials that to successfully spawn white sturgeon, we would have to make significant changes to our plans and develop an alternative spawning and holding facility. At the end of 2000, a site was chosen at the McNary juvenile fish facility and operations were transferred to that site in 2001. Our success with spawning white sturgeon at the McNary spawning and holding facility during the 2001 broodstock season (unpublished results, to be reported in the 2001 Annual Report) confirmed our belief that water temperatures were in fact restricting our ability to spawn wild white sturgeon. We now feel confident that we have developed and refined collecting and holding techniques that will allow us to succeed with the long-term goals of this project. Nonetheless, we will maintain the option of purchasing newly-hatched fry, spawned from wild lower Columbia River white sturgeon broodstock, should we fail to produce juvenile white sturgeon from broodstock above McNary Dam in future years of this project.

PLANS FOR UPCOMING YEARS

Broodstock spawning operations and mark/tagging operations for John Day Reservoir, along with all other completed activities, will be reported in the Annual Report for period April 2001 through March 2002. We will be performing mark/tagging operations in The Dalles Reservoir beginning in late November 2001 and ending in early

February 2002. We plan to pit tag and scute mark approximately 3,000 white sturgeon caught during this effort. We made several changes concerning our artificial spawning operations in 2001. We established a holding and spawning facility at McNary Dam Fish Facility that was completed in March 2001, and held and spawned fish there during the 2001 broodstock collection season. We will continue to utilize the McNary facility for spawning and holding operations in the future. We plan on scute marking and PIT tagging approximately 22,000 to 25,000 of our 2001 brood for release in Rock Island Reservoir in late spring of 2002. We will continue developing a program to monitor the success of juvenile white sturgeon releases.

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

ANNUAL PROGRESS REPORT

APRIL 2000 – MARCH 2001

REPORT E

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

This report includes: A summary of activities and the results of the 2000 spawning season.

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ABSTRACT

A total of sixteen wild maturing white sturgeon, 2 females and 14 males, were successfully captured, held through the spawning season, and then released back to the site of origin. Two females and a female retained from 1999 failed to have sufficient oocyte maturation to attempt spawning. Two males were induced to spawn in mid-September. While this did not result in a successful synchronous spawning, and subsequent juvenile production, it identified problems. The facility's well water temperature, 12.5ºC, was inadequate to trigger normal oocyte development. Therefore a different holding and spawning facility that uses or mimics the natural Columbia River water temperature regime is needed. The U. S. Army Corps of Engineers agreed to allow a temporary facility be placed at their McNary Dam facility. It is believed that this facility will provide a more natural temperature regime through the use of Columbia River water.

In preparation for the potential 2000 juvenile production Passive Integrated Transponder (PIT) tag retention pilot studies were conducted on juvenile white sturgeon obtained from Pelfrey's Sturgeon Hatchery, Troutdale, Oregon. In the first pilot study PIT tags were injected into the abdominal cavity, ventral surface anterior to the vent, using a modified hypodermic needle in two size ranges of juveniles. A second pilot study was conducted examining the tag insertion location, anterior or posterior to internal tag location, and the use of veterinarian tissue adhesive. Tag loss in both studies greatly exceeded the acceptable level of < 5%. The third pilot study examined the use of scalpel incision rather than injection. Although retention rate improved, tag loss exceeded the acceptable level of < 5%.

INTRODUCTION

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

METHODS

Sturgeon Procedures

Pre-spawning

Two females and fourteen males were captured in the McNary Reservoir and via surgical examination were expected to spawn in 2000, and transported to AFTC in March and April 2000, described by Kappenman and Parker (this report). Sturgeon were held in covered 3.05 m diameter tanks supplied with 12.5ºC well water, females were housed one sturgeon per tank, and males two to four sturgeon per tank. Water depth was 0.91 m with a flow rate of 45.3 lpm. As a food source adult sturgeon tanks were stocked with juvenile salmonids, which were periodically added to these tanks to maintain a constant food supply. One female captured in the Wanapum Reservoir in 1999 was held for spawning in 2000. There were no health problems that occurred during adult holding. As in 1999, feeding varied among the adult sturgeon, but not enough to cause health concerns.

Spawning

Oocytes were periodically collected from female sturgeon to determine maturation stage by examination of nucleus/germinal vesicle (GV) position. Oocyte and sperm sampling procedures closely followed those described by Conte et al. (1988). To facilitate this procedure, holding tank water depths were reduced to 0.3 m. Since reduced water depth increased the sturgeon's activity level, handling of the fish was delayed until activity level returned to a resting state. Once a female sturgeon was hand guided into a stretcher, she was positioned ventral side up with her head in the stretcher's built-in hood. The stretcher was raised, elevating the tail bringing the abdomen above the water surface while keeping the head submerged. Thus, the female remained calm, allowing minor surgery and oocyte sampling to occur without use of anesthesia. A small incision was made approximately midway between the pectoral and pelvic fins, and midway between the center-ventral line and the ventral scutes. This allowed the entry of a 4.0 mm internal diameter tygon tubing with the tip cut at a 45º to ease entry. A sample of approximately 60 oocytes was removed by aspiration and placed in a small vial containing 100-200 ml of 16ºC Ringer's Solution. The incision was sutured using 2 to 3 mattress stitches and a veterinary tissue sealant was applied. The female was then released from the stretcher never having been removed from the water.

Once oocytes were determined to be mature by GV position, a progesterone assay was used to confirm that the female was ready to spawn. Again protocol followed Conte et al. (1988), except for the use of Ringer's Solution instead of Leibovitz incubation medium, and a decrease in assay incubation time from 24 h to 16 h.

Spawning induction in both males and females was accomplished with exogenous hormone injection, using [D-Ala^{6}, Des-Gly^{10}]-LH-RH Ethyl amide (Peninsula Laboratories, Inc., San Carlos, CA), hereafter referred to as LHRH. The hormone dose was based on the sturgeon's weight taken at the time of capture. Females were given two injections: an initializing dose of 2 ug/Kg body weight, and a second resolving dose, of 18 ug/Kg, 12 hours later. Ovulation is expected to occur 20 to 40 hours after the resolving injection. Males received a single injection of 10 ug/Kg, with harvest of sperm (milt) occurring approximately 20 hours postinjection.

Males received their LHRH injection in the holding tanks. Water level was lowered to 0.3 m and the males were given time to reach a calm state. Tagging the adults at the time of capture with passive integrated transponder (PIT) tags allowed for positive identification of sturgeon and their corresponding LHRH injection dose. Injection was given underwater in the dorsal muscular mid-body without the use of a stretcher. Milt was extracted and stored in ziplock bags filled with oxygen gas. Ziplock bags were stored over ice, with no direct contact with ice, in a closed cooler. Oxygen was replaced every 24 h and milt agitated three times during the day. Sperm viability was to be checked prior to fertilizing eggs.

Tag Loss Pilot Studies

Since a goal of this project is to track juveniles after release by using PIT tags, pilot studies looking at tag loss and retention were initiated. Salmonids have been shown to have nearly 100% tag retention within the body cavity (Prentice et al. 1990), thus the tag retention goal to be achieved for juvenile white sturgeon was set for 95% or greater.

The first study looked at the effect of sturgeon size. Two size ranges of juveniles were tagged, mean weights of 40.7 g and 78.6 g, with mean fork lengths of 232 mm and 277 mm respectively. Two replicates of 75 fish per size range, a total of 300 sturgeon were tagged. After sturgeon were anesthetized with MS-222 (100 mg/l), PIT tags were injected into the abdominal cavity using a modified syringe and 12-gauge hypodermic needle (Prentice et al. 1990a). Tag insertion was on the ventral surface, anterior to the pelvic girdle, at the edge of the ventral scutes.

The second pilot study used a different tag insertion point and veterinarian tissue adhesive, to seal insertion wound and reduce tag loss. Treatments consisted of the tag insertion point being either anterior or posterior to the tag's internal location, with and without tissue adhesive application to the insertion wound. The posterior insertion point with no tissue adhesive treatment repeated the technique used in the first pilot study. Due to the limited number of small sturgeon no replicates were possible, each treatment consisted of 31 sturgeon. Mean weight was 57.7 g and mean fork length was 206.5 mm across all treatments.

The final pilot study examined a different technique to insert the PIT tag. Sturgeon were anesthetized an a incision in the abdominal wall approximately 3 mm long, just large enough to allow passage of the tag, was made midway from the midventral line and the ventral scutes anterior to the pelvic girdle. A tag was passed through the incision by fingertip, insuring the tag entered the abdominal cavity. Forty sturgeon were tagged, mean weight 108.2 g and mean fork length 243 mm.

RESULTS

Sturgeon Procedures

Sixteen wild adult white sturgeon were successfully captured and transported to AFTC (Table 1). Described by Kappenman and Parker (this report), females were monitored for maturation through periodic oocyte examination. Neither the female held since 1999, nor the two females captured in 2000 reached a level of oocyte maturity to warrant initiating ovulation with hormone injections. Although no viable eggs were obtained, all fourteen males received hormone injection in mid-September. Two males were successfully spawned, resulting in the collection of active sperm.

Tag Loss Pilot Studies

In the first pilot study examining the factor of sturgeon size, a total tag loss for both groups was 20.6%. The majority of the tag loss occurred in the first two weeks, with shed PIT tags still being recovered after 11 weeks (Table 2).

The second pilot study examining tag insertion point and veterinarian tissue adhesive, showed the percent tag loss 6 weeks post tagging ranging from 19.3% to 45.1% (Table 3).

In the final pilot study examining scalpel incision technique, of the 40 sturgeon tagged 7.5% suffered from tag loss at 4 weeks post tagging.

Table 1. Wild adult white sturgeon *Acipenser transmontanus* captured from McNary Reservoir and transported to AFTC, USFWS, 2000.

Capture Date	Sex	PIT tag #	Weight Kgs	Fork Length cm
3-21-00	M	421-F0F-6367	31.0	160
3-22-00	M	201-255-5864	55.0	182
3-22-00	M	422-DIE-4433	59.0	190
3-23-00	M	421-E02-5B77	24.0	143
3-27-00	M	422-D18-703F	34.0	163
3-27-00	F	421-E0F-1E78	113.0	230
4-10-00	M	422-DIE-6C76	26.0	147
4-10-00	F	421-F05-4D3C	106.0	224
4-10-00	M	421-F3D-1D17	24.0	146
4-10-00	M	421-E63-2A32	40.0	185
4-17-00	M	421-E2D-3063	35.0	165
4-18-00	M	421-F06-3D4B	39.0	193
4-27-00	M	421-F35-4038	64.0	199
4-27-00	M	421-EA2-6635	60.0	197
4-27-00	M	421-D7D-7B55	33.0	166
4-27-00	M	421-E3E-7E6D	60.0	185

Table 2. Rate of PIT tag loss in juvenile white sturgeon, pilot study AFTC, USFWS, 2000. Sample size = 300

Percentage of total tag loss (%)	time period post tagging (week)
24.2	0.43
51.4	1
74.2	8
100	11

Table 3. PIT tag loss (%) 6 weeks post tagging in juvenile white sturgeon, pilot study AFTC, USFWS, 2000. Sample size, N = 31, for all groups

Treatment	with tissue adhesive	without tissue adhesive
puncture anterior to tag	35	45.1
puncture posterior to tag	19.3	35.5

DISCUSSION

For the second year, wild adult white sturgeon were successfully captured, transported, held through the spawning season, and returned to site of origin. Due to the lack of oocyte maturation during the 2000 season, it has been decided that the 12.5°C well water at the AFTC facility was not sufficient to trigger normal oocyte maturation within the normal spawning season. The fact that two males were spawned in mid-September, indicates that male maturation may also have been delayed or slowed.

To increase the potential of a successful spawning in the 2001 season it was decided to move the adult holding/spawning portion of the project from AFTC to the U. S. Army Corps of Engineers, McNary Dam facility. There adults will receive water directly from the Columbia River, which should trigger a more normal maturation in the captured adults.

Observations from the PIT tag loss pilot studies indicate further work is needed to determine proper tagging techniques to ensure minimal tag loss. No mortality occurred during the studies indicating that sturgeon in these size ranges could survive the tagging procedures. More studies are planned to improve tag retention, with the use of scalpel incision and tissue adhesive showing the most potential to improve tag retention.

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

ANNUAL PROGRESS REPORT

APRIL 2000 – MARCH 2001

Report F

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

and

Distinguish between sexes and maturational stages of white sturgeon in the Columbia River using plasma sex steroid and calcium concentrations

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

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ABSTRACT

During 1 April 2000 through 31 March 2001, Oregon State University researchers worked on the development of a method to determine sex and stage of maturity using blood plasma indicators. Gonadal tissue and blood from white sturgeon in the Columbia River basin of legal-limit size (caught in commercial and tribal fisheries; referred to as fishery fish) and over the legal-limit size (caught by gill net and sport-fishers; referred to as oversize fish) were collected. White sturgeon showed sex- and maturity-specific levels of plasma steroids and calcium, as well as fork length. Discriminant function analysis (DFA) revealed that plasma testosterone (T) and estradiol (E2) led to the correct classification of 82 and 59% of all (fishery and oversize fish combined) females and males, respectively, while plasma T, E2, 11-ketotestosterone (KT) and fork length led to the correct classification of 41, 81, 88, and 76% of all immature females, immature males, maturing females, and maturing males. In the classification of fishery and oversize fish separately by sex, 86 and 60% of the fishery females and males, respectively, were correctly classified using plasma T, and 80 and 92% of the oversize females and males, respectively, were correctly classified using plasma concentrations of KT and E2 and fork length. Plasma T and E2 led to the correct classification of 77, 25, 86, and 60% of the oversize immature females, immature males, maturing females, and maturing males, respectively.

INTRODUCTION

This annual report describes progress of Oregon State University (OSU) on the Bonneville Power Administration funded Project 86-50 – White Sturgeon Restoration and Enhancement in the Columbia and Snake Rivers Upstream from Bonneville Dam. This report covers the period of 1 April 2000 through 31 March 2001.

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 steroid and calcium (Ca^{2+}) levels, and determine how reproductive plasma steroid and Ca^{2+} levels vary at different stages of maturation to develop predictive indices for the timing of maturation.

METHODS

Collection of Fish

White sturgeon from the commercial, tribal, and recreational fisheries in the Lower Columbia River (John Day, The Dalles, and Bonneville reservoirs, and the unimpounded stretch below Bonneville Dam) were sampled at fish processing facilities in February and March of 2000 and 2001. These fish (n=158) were within the legal size limit (96- to 152-cm fork length; FL). The mean (± SE) FL of these fish was 118 ± 1 cm. These fish are referred to herein as fishery fish. Paired gonad and blood samples were also collected from sturgeon outside of the legal size limit in McNary Reservoir and below Bonneville Dam in March, May, June, and July of 2000. In McNary Reservoir, these samples were taken from fish collected for broodstock in association with Task 1.4, Objective 1 of the Columbia River Inter-Tribal Fish Commission (CRITFC) (see Kappenman and Parker, Report D). Below Bonneville Dam, fish were captured by gill-net and taken from cooperating sport-fishing guides. The mean (± SE) FL of these fish (n=58) was 204 ± 5 cm, which are herein referred to as oversize fish.

Tissue and Blood Collection and Processing

Gonad tissue was collected following the protocol of Conte et al. (1988) and stored in phosphate-buffered formalin. Gonad tissue was embedded in paraffin, sectioned at seven µm, and stained by hematoxylin and eosin (Luna, 1968). Slides were examined under a compound scope (Carl Zeiss, 10x-100x), and the germ cells were scored for stage of development according to the protocol of Van Eenennaam and Doroshov (1998). For development of the discriminant function analysis (DFA) model, Stage 1 (differentiation of testis and ovary) and Stage 2 (proliferation of spermatogonia and endogenous growth of the oocyte) fish were considered "immature", while males in Stages 3 - 6 (onset of meiosis through spermiation) and females in Stages 3 - 7 (early vitellogenesis through ovulation) were considered "maturing".

Blood was collected from the caudal veins with a heparinized vacutainer. The plasma was separated by centrifugation and stored at -80°C until steroids were extracted and analyzed by radioimmunoassay (RIA) and Ca^{2+} analyzed spectrophotometrically. Fork length of each fish was measured (± 0.5 cm).

Radioimmunoassays and Plasma Calcium Measurements

The steroids testosterone (T), 11-ketotestosterone (KT), and estradiol (E2) were extracted from plasma and measured by radioimmunoassay (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. All steroid assay results were corrected for recovery, and all samples were analyzed in duplicate. The lower limit of detection was 1.25 pg/tube for all assays, except KT (3.12 pg/tube). The intra- and inter-assay coefficients of variation for all assays were less than 5 and 10%, respectively. Steroid levels, determined by RIA, were validated by verifying that serial dilutions were parallel to standard curves and by analyzing selected samples by high performance liquid chromatography to show that steroids in plasma eluted at the same time as standards and that concentrations (as reflected by peak height) were consistent with values derived by RIA.

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

Statistical Analysis

Plasma sex steroid and Ca^{2+} concentrations and FL were compared among the four classes of sex and stage of maturity (immature females, immature males, maturing females, and maturing males) using one-way analysis of variance (ANOVA). Mean comparisons were conducted using the Bonferroni procedure.

Discriminant function analysis was used to develop a set of discriminating functions to predict sex or sex and maturity. To attain multivariate normality, the logarithms of the variables T, KT, and E2 were considered for analysis. Stepwise DFA was conducted using log-transformed T, KT, and E2 concentrations and FL to chose the best predictor(s) of sex or sex and stage of maturity. The Ca^{2+} concentrations were not used in the analysis as levels have not been measured for all of the fish used in the data set. 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. The error rate associated with predicting sex or sex and maturity using the chosen discriminant functions was accomplished through cross-validation (see Khattree and Naik 2000). The DFA was also conducted on the fishery fish alone and the oversize fish alone. All analyses were conducted using the SAS System for Windows, release 6.12 (SAS Institute Inc., Cary, NC) following the procedures described in Khattree and Naik (2000).

RESULTS

Maturation cycle

A total of 216 white sturgeon were sampled in the Columbia River between February 2000 and March 2001. Of the fishery fish sampled, 84 were immature females, 66 were immature males, one was a female with ovarian follicles just entering vitellogenesis, and 7 were maturing males. Of these maturing males, all were Stage 5 males with testicular cysts containing spermatozoa, except one Stage 3 male with 50% of the cysts containing spermatogonia and the remaining cysts containing spermatocytes. Of the oversize fish sampled, 30 were immature females, 8 were immature males, 15 were maturing females, and 5 were maturing males (Table 1). The stage of gonadal development of these maturing oversize fish included Stages 3, 4, 5, and 7 in females and Stage 5 in males.

Table 1. The number of white sturgeon of legal-limit size (fishery) and over the legal-limit size (oversize) collected from the Columbia River.

Location	Year	Immature Female	Immature Male	Maturing Female	Maturing Male
Fishery					
Estuary	2000	7	12	0	0
	2001	12	4	0	2
Bonneville	2000	12	8	0	0
	2001	11	7	0	0
The Dalles	2000	13	9	0	2
	2001	9	6	0	1
John Day	2000	9	12	1	2
	2001	11	8	0	0
Oversize					
McNary	2000	5	5	2	1
Below Bonneville	2000	25	3	13	4
Total		114	74	16	12

Determination of Sex

The FL ($P < 0.001$) and concentrations of plasma sex steroids (T and KT, $P < 0.01$; E2, $P < 0.05$) differed significantly between the two genders. Plasma levels of Ca^{2+} did not differ between females and males.

The stepwise DFA of the fish captured in the fisheries, plasma T was the best predictor of sex. This variable led to the correct classification of 86% of the females and 60% of the males (73% overall correct classification; Table 2). In the cross-validation of the model using plasma T as a predictor of sex in white sturgeon of legal-limit size, 14 and 40% error were associated with classifying females and males, respectively.

In the analysis of oversize fish alone, plasma KT, E2, and FL were the best predictors of sex. These variables led to the correct classification of 80% of the females and 92% of the males (Table 2). The overall correct classification was 86%. The cross-validation of the model for the prediction of sex in oversize fish revealed error rates of 27% associated with classifying females and 31% associated with classifying males.

Table 2. Classification summary for determination of sex from the quadratic discriminant function analysis for white sturgeon in the fishery fish only, oversize fish only, and fishery and oversize fish combined (all fish). Log-transformed plasma testosterone was chosen in the analysis of fishery fish, 11-ketotestosterone, estradiol, and fork length were chosen in the analysis of oversize fish, and testosterone and estradiol concentrations were chosen as predictors in the analysis of all fish. Data are percentages (n), with the correctly classified percentages in bold.

	Sex Determined from Predictors		
True Sex	Female	Male	Total (n)
Fishery			
Female	**86** (73)	14 (12)	(85)
Male	40 (29)	**60** (44)	(73)
Oversize			
Female	**80** (36)	20 (9)	(45)
Male	8 (1)	**92** (12)	(13)
All Fish			
Female	**82** (107)	18 (23)	(130)
Male	41 (35)	**59** (51)	(86)

The DFA of the fishery and oversize fish combined revealed that plasma T and E2 were the best predictors to distinguish female from male sturgeon. The use of these derived discriminant functions led to the correct classification of 82% of the females and 59% of the males (Table 2). The probability of classifying females and males by chance alone is 50%. Overall, 71% of the fish were correctly classified by sex. The cross-validation of the model revealed an error rate of 18 and 42% associated with classifying females and males, respectively.

Determination of Sex and Stage of Maturity

The FL differed significantly ($P < 0.0001$) among the four groups of sex and stage of maturity (immature females, immature males, maturing females, and maturing males). Immature females (140 ± 4 cm) had significantly greater FL compared to immature males (125 ± 2 cm). The FL of maturing females (218 ± 6) was significantly greater compared to immature fish and maturing males (142 ± 9 cm), while maturing males did not have significantly greater FL compared to immature fish. The FL of immature females and males caught in the fishery was 116 ± 1 cm and 119 ± 1 cm, respectively, and was significantly different between the groups ($P < 0.05$).

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

To distinguish fish by sex and maturational stage, plasma T, KT, E2, and FL were found to be the best predictors in the analysis of the fishery and oversize fish combined. These derived discriminant functions led to the correct classification of 41% of the immature females, 81% of the immature males, 88% of the maturing females, and 76% of the maturing males (Table 3). In comparison, 25% of the total number of fish would be correctly classified into their respective groups by chance alone. Overall, 71% of the fish were correctly classified by sex and stage of maturity. The cross-validation of the sex-and-stage-of-maturity model using these variables revealed error rates of 61, 24, 19, and 50% associated with classifying immature females, immature males, maturing females, and maturing males, respectively. When only plasma T and E2 were used in the model, 68% of the fish were correctly classified by sex and stage of maturity, with 76% of the immature females, 43% of the immature males, 88% of the maturing females, and 67% of the maturing males correctly classified.

Table 3. Classification summary for determination of sex and stage of maturity in the oversize fish only and the fishery and oversize fish combined (all fish) from the quadratic discriminant function analysis for white sturgeon. Log-transformed plasma testosterone and estradiol were chosen in the analysis of oversize fish only, while testosterone, 11-ketotestosterone, and estradiol concentrations and fork length were chosen as predictors in the analysis of all fish. Data are percentages (n), with the correctly classified percentages in bold.

True Sex	Classification Immature Females	Determined Immature Males	From Maturing Females	Predictors Maturing Males	Total (n)
Oversize					
Immature Females	**77** (23)	13 (4)	3 (1)	7 (2)	(30)
Immature Males	62 (5)	**25** (2)	0 (0)	13 (1)	(8)
Maturing Females	7 (1)	7 (1)	**86** (13)	0 (0)	(15)
Maturing Males	40 (2)	0 (0)	0 (0)	**60** (3)	(5)
All Fish					
Immature Females	**41** (47)	49 (56)	9 (10)	1 (1)	(114)
Immature Males	15 (11)	**81** (60)	0 (0)	4 (3)	(74)
Maturing Females	6 (1)	0 (0)	**88** (14)	6 (1)	(16)
Maturing Males	8 (1)	8 (1)	8 (1)	**76** (9)	(12)

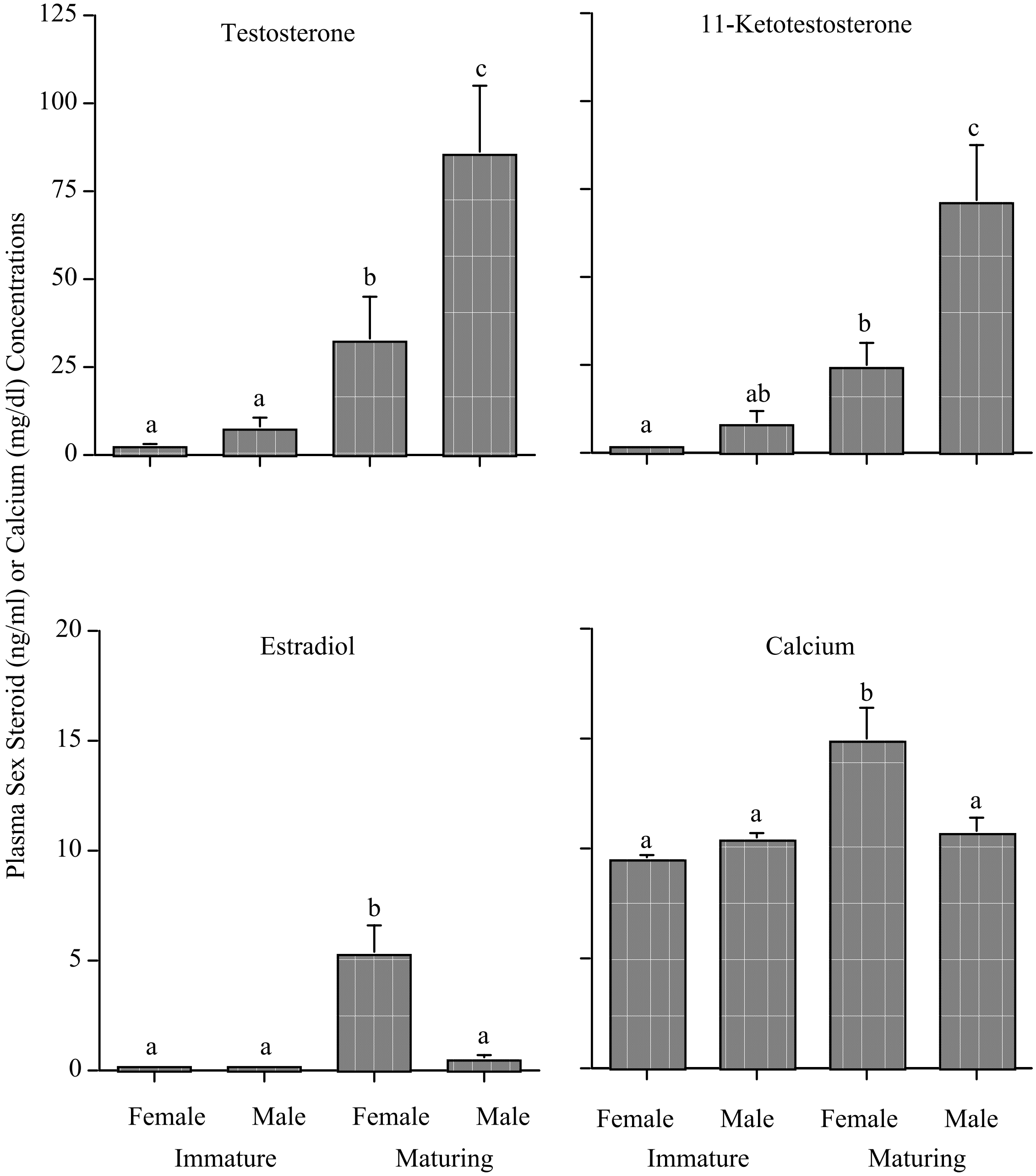

Figure 1. Plasma sex steroid and calcium concentrations in white sturgeon captured in the Columbia River basin (mean + SE). Different letters denote statistically significant differences between the groups (immature females, n=114 for sex steroids and n=71 for calcium; immature males, n=74 for sex steroids and n=49 for calcium; maturing females, n=16 for sex steroids and calcium; and maturing males, n=12 for sex steroids and n=9 for calcium).

Plasma T and E2 were chosen in the stepwise DFA of the oversize fish alone as the best predictors of sex and stage of maturity. These variables led to the correct classification of 77%, 25%, 86%, and 60% of the immature females, immature males, maturing females, and maturing males, respectively (Table 3). Overall, 62% of the fish were correctly classified. In the cross-validation of the model predicting sex and stage of maturity in these fish, 23, 100, 20, and 80% error was associated with predicting immature females, immature males, maturing females, and maturing males, respectively.

DISCUSSION

The fish of legal-limit size were predominately immature, with 1% and 11% of the females and males maturing, respectively. Of the oversize fish sampled, 33% of the females were maturing, while 38% of the males were maturing. Females in all stages of development were found throughout the winter and spring which is consistent with a maturation cycle longer than one year, as previously discussed for white sturgeon by DeVore et al. (1995) and Doroshov et al. (1997). It is interesting to note that all males, except one captured in the tribal fishery, had testes in Stages 1, 2 or 5. This one male had testes in an intermediate stage of development (Stage 3). The lack of intermediate stages of testicular development may be an artifact of season and should be further investigated for description of the maturation cycle of male sturgeon.

Sustainable harvest levels of sturgeon in the Columbia River are based on population models and fecundity estimates (DeVore et al. 1995), of which spawning frequency and an understanding of the maturation cycle are critical elements. Exact knowledge of the maturation cycle in white sturgeon in the Columbia River requires following the stage of development in individual fish over several years. Limited information may be available in 2002 as tagged oversize sturgeon are recaptured below Bonneville Dam (an effort that began in May 2000 for this project, and preliminary results will be reported in the 2001-2002 Annual Report). With an increasing number of samples from oversize fish of different maturational stages, the power of discrimination will increase. These data may also be used to develop a model to discriminate between females in various stages of development as a predictive index for the time to spawning.

To distinguish between immature and maturing sturgeon, plasma concentrations of T may be compared. Testosterone concentrations were significantly higher in maturing fish compared to immature fish (Figure 2). Though the Bonferroni mean comparison tests showed no significant differences between plasma T in immature white sturgeon (Figure 2), one-way analysis of variance revealed significantly higher T ($P < 0.005$) concentrations in immature males compared to immature females. In the examination of individual steroid concentrations (not using DFA), the critical threshold value of plasma T to distinguish the sex of immature white sturgeon appears to be 4 ng/ml.

Maturing females may be separated from maturing males using plasma E2 and/or Ca^{2+}, as concentrations were significantly higher in maturing females compared to all other groups (Figure 1). In maturing females, 75% had plasma E2 concentrations greater than 1 ng/ml, while 1% of the immature fish and 17% (2 of 12) of the maturing males had levels greater than 1 ng/ml. Calcium concentrations were more variable. In maturing females, 50% had Ca^{2+} concentrations greater than 15 mg/dL, while < 1% of the immature fish and maturing males had concentrations greater than 15 mg/dL. The basal level of plasma Ca^{2+} in cultured white sturgeon females with previtellogenic ovaries was 9.89 mg/dL (Linares-Casenave et al. 1994), similar to levels detected in immature sturgeon and maturing males in the Columbia River basin. Use of the Sigma Diagnostics kit not only allows for quick determination of plasma Ca^{2+} but may be used in the field without a spectrophotometer. The kit is a colorimetric test, therefore, maturing females may be detected by visual examination of the sample compared to the different dilutions of the provided standards. It is important to note that Ca^{2+} concentrations in females with ovarian follicles undergoing oocyte maturation will be close to basal level. Consequently this technique will most accurately identify vitellogenic females.

The DFA models were least effective in distinguishing immature female from male white sturgeon. The misclassification of immature males as immature females was the result of a large portion of these males having plasma concentrations of T below 4 ng/ml. It is unclear at this time why wild white sturgeon males in Stage 2 of gonadal development are not producing T at concentrations greater than or equal to 4 ng/ml. It appears that spermatogonia proliferation (Stage 2) in cultured white sturgeon is associated with increased circulating androgen concentrations regardless of age or size (Fitzpatrick, unpublished data). Plasma T and KT have been found to be negatively correlated with liver concentrations of p,p'-DDE (a lipophilic environmental contaminant) in immature male white sturgeon in the lower Columbia River indicating the potential adverse affects of pollutants on white sturgeon reproduction (Foster et al. 2001). The reduced concentration of androgens in Columbia River males must be further investigated. With regard to the model, the misclassification of immature females as immature males may be corrected if discriminating limits of sex steroid concentrations may be incorporated into the model.

Though error does exist in the classification of sex and stage of maturity of white sturgeon using blood plasma indicators, this technique currently has some advantages over the biopsy method. The biopsy method of identifying sex and maturity, while highly accurate under some circumstances, is subject to considerable error for those untrained or inexperienced with the technique, especially under field conditions. 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. This problem is not uncommon among sturgeon biologists/management agencies. Therefore, under certain circumstances, the error associated with misclassifying fish using plasma steroid levels is more accurate than collection of a gonadal biopsy.

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