February 1998

Effects of Mitigative Measures on Productivity of White Sturgeon Populations in the Columbia River Downstream from McNary Dam

Determine the Status and Habitat Requirements of White Sturgeon Populations in the Columbia and Snake Rivers Upstream from McNary Dam

Annual Report 1996

DOE/BP-63584-12

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EFFECTS OF MITIGATIVE MEASURES ON PRODUCTIVITY OF WHITE STURGEON POPULATIONS IN THE COLUMBIA RIVER DOWNSTREAM FROM MCNARY DAM, AND DETERMINE THE STATUS AND HABITAT REQUIREMENTS OF WHITE STURGEON POPULATIONS IN THE COLUMBIA AND SNAKE RIVERS UPSTREAM FROM MCNARY DAM.

ANNUAL PROGRESS REPORT

APRIL 1996 - MARCH 1997

Edited by:

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In Cooperation With:

Washington Department of Fish and Wildlife
U.S. Geological Survey Biological Resources Division
National Marine Fisheries Service
U.S. Fish and Wildlife Service
Columbia River Inter-Tribal Fish Commission
Nez Perce Tribe

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EXECUTIVE SUMMARY

We report on our progress from April 1996 through March 1997 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), National Marine Fisheries Service (NMFS; Report D), U.S. Fish and Wildlife Service (USFWS; Report E), Columbia River Inter-Tribal Fish Commission (CRITFC; Report F), and the Nez Perce Tribe (NPT; Report G).

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 1996 through March 1997 are:

Report A

(1) Abundance of white sturgeon in John Day Reservoir was estimated to be 27,100 fish 70-166 cm fork length, of which 4,040 were within the legal harvest slot (110-137 cm). This is a seven-fold increase over the 1990 estimate of 3,900 white sturgeon 70-166 cm. This difference is attributed to possible underestimation in 1990, and to restrictive harvest guidelines, which have allowed the population to rebound.

(2) Setline catch rates were 1.2 fish/set using Pacific lamprey as bait, 1.6 fish/set using American shad, and 8.7 fish/set using pickled squid. These differences were statistically significant. We will use pickled squid as our primary bait in future mark-recapture studies.

(3) Laboratory analysis of blood steroids may provide a less invasive alternative to surgical biopsy for determining sex and maturity of white sturgeon. We recommend further work using paired samples of gonad tissue and blood plasma collected from fish larger than legal size (137 cm fork length) at various times of year and locations.

Report B

(1) Recreational fisheries for white sturgeon in Zone 6 (between Bonneville and McNary dams) were sampled throughout the 1996 season and fishery managers were provided with weekly updates of estimated harvest. When harvest approached recommended limits (1,550 fish) fisheries were closed to retention: April 1 for Bonneville Reservoir and May 1 for The Dalles and John Day reservoirs. Recreational white sturgeon harvest was kept within guidelines for the second consecutive year.

(2) Harvest in the 1996 treaty Indian Zone 6 commercial fishery (1,595 white sturgeon) was 55 fish fewer than the combined three pool guideline; however, the guideline for John Day Reservoir was exceeded by 260 fish. A later stock assessment in John Day Reservoir by ODFW and CRITFC indicated that the 100 fish guideline for 1996 was overly conservative.

(3) Set lines baited with pickled squid and salted shad were used to capture and release 1,231 white sturgeon in Ice Harbor Reservoir from May through September 1996. Abundance of fish >54 cm fork length was estimated at 4,830. White sturgeon density (1.5 fish/ha) was lower than densities previously measured in The Dalles and Bonneville reservoirs, but was similar to the density measured in 1996 for John Day Reservoir, and greater than the density of the McNary Pool/Hanford Reach population.

(4) The size structure of the Ice Harbor Reservoir white sturgeon population tended towards larger fish compared to more heavily exploited populations previously studied. Fish over 137 cm fork length (mature spawner size fish) were plentiful; however, a lack of small fish (<58 cm fork length) indicated a recruitment problem independent of mature fish abundance. Growth was slower and fitness lower than other Columbia Basin populations.

Report C

(1) Monitoring of acoustic transmitters attached to 52 white sturgeon indicated that some fish were sedentary, while others made extensive movements up and down the river.

(2) Indices of spawning habitat from four known spawning areas downstream from McNary, John Day, The Dalles, and Bonneville dams indicated that environmental conditions were favorable for spawning in 1996.

(3) Recruitment to young of year occurred in Bonneville Reservoir in 1996. Of 490 juvenile white sturgeon captured while trawling, 86% (419) were young of the year, compared to 59% in 1995.

Report D

(1) Young of the year comprised approximately 35% of the total trawl catch of juvenile white sturgeon downstream from Bonneville Dam in September. Densities of young of the year in 1996 (11.7 fish/ha) were similar to densities found in previous years (6.7 - 11.0 fish/ha).

Report E

(1) Stage-discharge work included measurement of 231 data pairs for 117 cross sections in the Columbia River at discharges ranging from 1,459 to 7,593 m^3/s. Discharge fluctuations of up to 3,102 m^3/s were observed within a 24-hour period. In some areas, Columbia River water surface elevations increased over 5.0 vertical meters from the lowest to the highest calibration flow. Data collection for Snake River cross sections was conducted at discharges ranging from 567 to 2,833 m^3/s.

(2) In-river substrates were characterized with an underwater video camera for all main channel cross sections in the Columbia River between the White Bluffs boat ramp and Priest Rapids Dam. All substrate data points were labeled with either measured or calculated GPS waypoints. Data were provided to the USGS-BRD for input into their database.

(3) We observed the massive landslide and corresponding erosion of Locke Island during our reconnaissance survey of the White Bluffs island complex. Cross sections established for our

white sturgeon habitat work will allow us to quantify the effect of the landslide on river channel morphology in the area and the extent of the resulting erosion on Locke Island, which is an important archeological site.

(4) Hydraulic model calibration for Columbia River cross sections has been partially completed, and hydraulic simulations are presently being conducted. Most of the models have calibrated to measured data extremely well, and we have a high level of confidence that simulations will be representative of hydraulic conditions that actually occurred during the period of record, as well as conditions that might be associated with future hydrographs.

Report F

(1) Tribal fishers caught 1,212 white sturgeon in 804 overnight gillnet sets in John Day Reservoir. A total of 1,161 fish were marked with PIT tags, and 1,111 fish were marked with individually-numbered spaghetti tags. Mark and subsequent recapture information was used to estimate the abundance of white sturgeon in the reservoir (Report A).

(2) The use of fin removal to permanently mark small white sturgeon was not successful. Regeneration rates after a five-month trial period were 93% for anal fins and 75% for pelvic fins.

Report G

(1) A biological risk assessment team compiled consensus views of important regional management objectives, status of the Snake River system and white sturgeon population, mitigative actions to achieve regional objectives, and risks and uncertainties associated with those actions. A multi-year research effort based on these findings has been initiated to collect specific data to help protect and enhance white sturgeon between Hells Canyon and Lower Granite dams.

EFFECTS OF MITIGATIVE MEASURES ON PRODUCTIVITY OF WHITE STURGEON POPULATIONS IN THE COLUMBIA RIVER DOWNSTREAM FROM MCNARY DAM, AND DETERMINE THE STATUS AND HABITAT REQUIREMENTS OF WHITE STURGEON POPULATIONS IN THE COLUMBIA AND SNAKE RIVERS UPSTREAM FROM MCNARY DAM.

ANNUAL PROGRESS REPORT

APRIL 1996 - MARCH 1997

Report A

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

This report includes: An update of abundance, life history parameters, and population dynamics of white sturgeon in John Day Reservoir

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ABSTRACT

We report on work performed from April 1996 through March 1997 to update life history parameters and population dynamics of white sturgeon *Acipenser transmontanus* in John Day Reservoir. Mark and recapture sampling was coordinated with staff of Columbia River Inter-Tribal Fish Commission (CRITFC) who contracted commercial fishers to capture and tag white sturgeon in John Day Reservoir from January through March 1996. We set 1,124 setlines from April through September and caught 3,192 white sturgeon. An additional 6 white sturgeon were collected in 17 gill net sets. We applied 2,939 passive integrated transponder (PIT) tags and 2,512 wire-core spaghetti tags to fish 70-166 cm fork length (FL). We recaptured 228 fish (70-166 cm FL), including 98 fish tagged by CRITFC and estimated an abundance of 27,100 white sturgeon in this size range, and 4,040 legal-size fish (110-137 cm FL). This estimate represents a seven-fold increase in abundance from our 1990 estimate of 3,900 fish. Differences between these population estimates are likely due to an underestimate of fish abundance in 1990, and restrictive harvest guidelines and slot limits established in 1991. The density of white sturgeon (>54 cm FL) was estimated to be 0.30 fish/hectare in 1990 and 1.46 fish/hectare in 1996.

INTRODUCTION

In 1986, the Bonneville Power Administration (BPA) funded a 6-year study of white sturgeon *Acipenser transmontanus* in the Columbia River downstream from McNary Dam. The study addressed objectives of a research program implementation plan developed in response to the Northwest Power Planning Council's 1987 Fish and Wildlife Program measure 903(e)(1). Phase I of this research was completed in 1992. In 1993, BPA extended funding for further white sturgeon research in the original study area and in areas upstream from McNary Dam.

In this report we describe activities and results of work conducted from April 1996 through March 1997 that will be used to update an estimate of, and evaluate the effects of mitigative measures on productivity of white sturgeon between John Day and McNary dams. We conducted mark and recapture sampling in John Day Reservoir jointly with staff of Columbia River Inter-Tribal Fish Commission (CRITFC). The CRITFC contracted commercial tribal fishers to capture, mark, and tag white sturgeon in John Day Reservoir from January through March 1996 to increase the number of tagged fish available for recapture. A summary of this work is provided by Parker (this report); however, we report results involving our recaptures of fish tagged by CRITFC.

METHODS

We sampled for white sturgeon in John Day Reservoir from mid April through early September to estimate population statistics. The reservoir was divided into 10 sections 12.1 to 14.5 km long (Figure 1). The boat-restricted zone (BRZ) adjacent to and immediately downstream from McNary Dam was considered an additional section with results reported separately. Past sampling has shown white sturgeon densities are typically higher in the BRZ (North et al. 1993)

We distributed setline sampling effort equally among and within sections to obtain a representative sample of the population. We divided the field season into four, 5-week sampling periods. All sections were sampled in each period, except the BRZ, where spill prevented sampling in most periods (Table 1).

We used setlines as our primary sampling gear because they are less size selective than other gears and provide adequate catch rates for our objectives (Elliott and Beamesderfer 1990). Setlines were fished overnight for 9.0 to 47.0 h (average 23.2 h). Lines had 12/0, 14/0, and 16/0 hooks baited with pieces of Pacific lamprey *Lampetra tridentata,* salted American shad *Alosa sapidissima,* or pickled squid *Loligo* sp. We used Pacific lamprey and American shad throughout the season and pickled squid during the last two sampling periods. Each line had 40 hooks baited with a single bait type.

Gill nets, described by Rien et al. (1991), were used in an attempt to increase our catch of white sturgeon <80 cm fork length. Gill nets were fished 1.0 to 2.0 h (average 1.1 h).

We measured fork length (cm), and looked for tags, tag scars, fin marks, and scute marks on each white sturgeon captured. We weighed and removed a pectoral fin-ray section from a subsample of the catch (up to 30 fish per 20-cm length interval). Most white sturgeon were

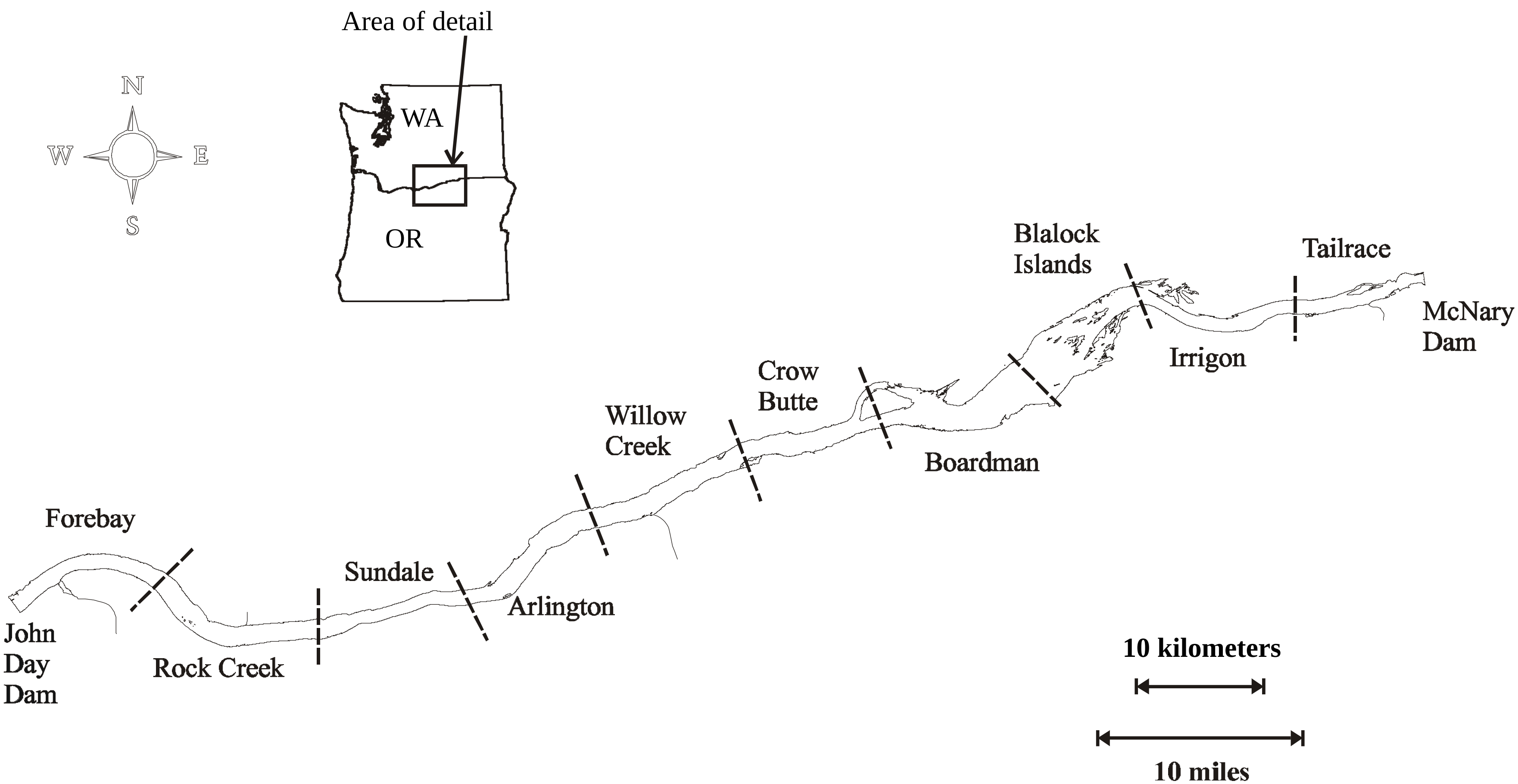

Figure 1. The Columbia River between John Day and McNary dams. Sampling section boundaries are indicated by dashed lines. The scale is approximate.

Table 1. Sampling effort (number of setline or gill net sets) for white sturgeon in John Day Reservoir, April through September 1996.

Gear Week of year	Sampling section[a] 1	2	3	4	5	6	7	8	9	10	11	Total
Setlines												
16	0	0	0	0	0	0	0	0	7	0	0	7
17	0	0	0	0	18	24	2	0	0	0	0	44
18	24	21	3	0	0	0	0	0	0	0	0	48
19	0	0	24	30	5	0	0	0	0	0	0	59
20	0	0	0	0	0	0	21	30	4	0	0	55
21	0	0	0	0	0	0	0	0	26	32	0	58
22	0	0	0	0	21	23	3	0	0	0	0	47
23	21	27	1	0	0	0	0	0	0	0	0	49
24	0	0	27	30	3	0	0	0	0	0	0	60
25	0	0	0	0	0	0	15	30	6	0	0	51
26	0	0	0	0	0	0	0	0	27	33	0	60
27	0	0	0	0	0	0	6	4	0	0	0	10
28	0	0	0	0	26	28	5	0	0	0	0	59
29	24	25	5	0	0	0	0	0	0	0	0	54
30	0	0	18	38	3	0	0	0	0	0	0	59
31	0	0	0	0	0	0	18	32	6	0	0	56
32	0	0	0	0	0	0	0	0	25	26	3	54
33	0	0	0	0	20	33	6	0	0	0	0	59
34	27	30	3	0	0	0	0	0	0	0	0	60
35	0	0	24	33	3	0	0	0	0	0	0	60
36	0	0	0	0	0	0	27	27	6	0	0	60
37	0	0	0	0	0	0	0	0	25	24	6	55
Total	96	103	105	131	99	108	103	123	132	115	9	1,124
Gill nets												
21	0	0	0	0	0	0	0	0	4	5	0	9
24	0	0	0	1	0	0	0	0	0	0	0	1
25	0	0	0	0	0	0	1	0	0	0	0	1
26	0	0	0	0	0	0	0	0	1	2	0	3
32	0	0	0	0	0	0	0	0	0	1	0	1
37	0	0	0	0	0	0	0	0	0	0	2	2
Total	0	0	0	1	0	0	1	0	5	8	2	17

[a] Sampling sections: 1=John Day Dam forebay, 2=Rock Creek, 3=Sundale, 4=Arlington, 5=Willow Creek, 6=Crow Butte, 7=Boardman, 8=Blalock Islands, 9=Irrigon, 10=McNary Dam tailrace, 11=McNary Dam tailrace boat-restricted zone.

tagged with a 125 Mhz passive integrated transponder (PIT) tag. The second left lateral scute was removed to identify PIT-tagged fish (Rien et al. 1994). White sturgeon >79 cm were also tagged with a wire-core spaghetti tag placed about 1 cm beneath the dorsal fin insertion. The seventh left lateral scute was removed as a secondary mark to indicate the fish was tagged or marked in 1996.

We injected 482 white sturgeon (<80 cm or >164 cm) with oxytetracycline (OTC) to validate age interpretations from fin-ray sections that may be obtained from fish recaptured in future years (Rien and Beamesderfer 1994). We injected 100 mg/ml OTC into the red muscle under the dorsal scutes immediately posterior to the head. Doses were adjusted such that each fish received 25 mg/kg of body weight (McFarlane and Beamish 1987). The second right lateral scute was removed from OTC-injected fish for identification if recaptured.

We surgically examined the gonads of most white sturgeon >150 cm to determine sex and stage of maturity following procedures outlined in Beamesderfer et al. (1989). A small sample (<1 g) of the gonad was removed from most fish using biopsy forceps. Samples were preserved in a 10% buffered formalin solution. Incisions were closed with sutures and sealed with a surgical adhesive. We verified field sex identification in the laboratory by microscopic examination and classified stage of maturity for females according to criteria modified slightly from Chapman (1989). Gonad tissue samples were also examined for sex-specific germ cells by Department of Fisheries and Wildlife staff at Oregon State University (OSU) to assess the accuracy of our classifications.

Distribution of white sturgeon was examined by comparing setline catch rate among sampling sections. Statistical differences ($P<0.05$) in catch rates were evaluated on transformed catch-per-set data [$\log_e$(catch+1)] with programs of the Statistical Analysis System (SAS 1988a; 1988b). Comparisons between sample means were made using analysis of variance (ANOVA) and Tukey's studentized range test. We determined movement of individual tagged fish by comparing river kilometer of capture and recapture locations.

The within-year retention rate of PIT tags was estimated as the percent of recaptured fish with readable PIT tags which were originally fitted with both PIT and spaghetti tags or appropriately scute-marked when first captured. Passive integrated transponder tags were considered lost whenever they could not be detected at recapture regardless of whether the tag was expelled, missing, defective, or not applied. We determined the within-year retention rate of wire-core spaghetti tags as the percent of recaptured fish retaining this external tag which were also PIT-tagged or appropriately scute-marked at first capture. Wire-core spaghetti tags were considered lost when physically missing at recapture, unreadable, or not applied.

Age of white sturgeon <110 cm was estimated from thin cross sections of pectoral fin rays following procedures outlined in Beamesderfer et al. (1989). Each fin-ray section was aged twice each by two experienced staff, and up to 20 fish for each 20-cm length interval were aged. An age-length frequency distribution was developed from these age assignments.

Paired samples of fork length and weight were used to calculate a regression. Relative weights (W_r) were calculated to estimate the condition of white sturgeon captured and were compared to values for fish sampled in 1990 using ANOVA (Beamesderfer 1993). We compared the mean length of white sturgeon captured by bait type during the last two sampling periods when all three bait types were used.

We measured head and snout lengths and classified snout type from a subsample of the catch following methods outlined in North et al. (1996). We used ANOVA to compare 1996 mean head to snout length ratios by 20-cm fork length intervals with similar data collected during 1994 and 1995 while sampling in Bonneville and The Dalles reservoirs and McNary Reservoir and the Hanford Reach (North et al. 1995; 1996).

We collected blood samples from white sturgeon for analyses of cortisol levels, sex steroids, and deoxyribonucleic acid (DNA). We used an evacuated tube and needle to draw blood from the caudal vein. Paired blood samples for future DNA analyses were collected periodically from the first two fish caught each day. Blood plasma samples for sex steroid analyses were collected from most surgically-examined fish. These samples were analyzed for levels of testosterone, 11-ketotestosterone, and estradiol by personnel at OSU. Blood plasma samples for cortisol analyses were collected during July to evaluate the stress experienced by white sturgeon captured with setline gear.

Abundance of fish 70-166 cm was estimated with a Schnabel multiple mark and recapture estimator (Ricker 1975) according to methods outlined in Beamesderfer et al. (1995). Mark and recapture samples were grouped by sampling period; CRITFC sampling was considered period one, and Oregon Department of Fish and Wildlife (ODFW) sampling comprised periods two through five. We accounted for harvest of tagged fish by expanding the number observed in recreational and commercial fisheries based on the sampling rate. Fish that lost all tags were identified from secondary marks. We adjusted the observed length frequency based on size-specific recapture rates reported by Beamesderfer et al. (1995) and expanded our abundance estimate based on the adjusted length frequency (Beamesderfer and Rieman 1988).

To corroborate the abundance estimate we used 1996 recaptures by ODFW of fish that were 70-166 cm when marked prior to 1996 to perform a Petersen estimate of abundance. We adjusted the number of marks at large based on known harvest and emigration prior to April 1996. We also performed an additional Schnabel estimate excluding CRITFC marks and recaptures (period 1) for comparison with the combined-agency estimate (periods 1-5).

RESULTS

Catch

We caught 3,192 white sturgeon (50-244 cm) with setlines in John Day Reservoir (2.8 fish per setline; Table 2; Figure 2; Appendix A-1); however, all baits were not equally effective. We caught 1,885 white sturgeon on lines baited with pickled squid (8.7 fish per setline), 758 on lines baited with salted American shad (1.6 fish per setline), and 549 on lines baited with Pacific lamprey (1.2 fish per setline; Table 3). We caught 6 white sturgeon (57-123 cm) with gill nets (0.4 fish per gill net; Table 2; Appendix A-1). The setline catch consisted of 83.1% sublegal (≤109 cm), 15.1% legal (110-151 cm), and 1.8% “over-size” (≥152 cm) white sturgeon. In 1990, these size groups represented 86.6%, 7.6%, and 5.8% of the catch, respectively (Table 4).

Table 2. Catches of white sturgeon (all lengths) with setlines and gill nets in John Day Reservoir, April through September 1996. A "-" indicates sampling was not conducted.

Gear Week of year	Sampling section[a] 1	2	3	4	5	6	7	8	9	10	11	Total
Setlines												
16	-	-	-	-	-	-	-	-	8	-	-	8
17	-	-	-	-	2	18	0	-	-	-	-	20
18	2	2	7	-	-	-	-	-	-	-	-	11
19	-	-	6	7	2	-	-	-	-	-	-	15
20	-	-	-	-	-	-	28	50	3	-	-	81
21	-	-	-	-	-	-	-	-	38	49	-	87
22	-	-	-	-	16	30	2	-	-	-	-	48
23	3	1	0	-	-	-	-	-	-	-	-	4
24	-	-	9	8	4	-	-	-	-	-	-	21
25	-	-	-	-	-	-	23	42	12	-	-	77
26	-	-	-	-	-	-	-	-	107	77	-	184
27	-	-	-	-	-	-	43	16	-	-	-	59
28	-	-	-	-	85	268	41	-	-	-	-	394
29	23	49	8	-	-	-	-	-	-	-	-	80
30	-	-	74	157	4	-	-	-	-	-	-	235
31	-	-	-	-	-	-	132	397	36	-	-	565
32	-	-	-	-	-	-	-	-	134	38	9	181
33	-	-	-	-	103	264	35	-	-	-	-	402
34	7	39	0	-	-	-	-	-	-	-	-	46
35	-	-	45	56	2	-	-	-	-	-	-	103
36	-	-	-	-	-	-	126	134	44	-	-	304
37	-	-	-	-	-	-	-	-	156	65	46	267
Total	35	91	149	228	218	580	430	639	538	229	55	3,192
Gill nets												
21	-	-	-	-	-	-	-	-	0	0	-	0
24	-	-	-	0	-	-	-	-	-	-	-	0
25	-	-	-	-	-	-	0	-	-	-	-	0
26	-	-	-	-	-	-	-	-	0	0	-	0
32	-	-	-	-	-	-	-	-	-	0	-	0
37	-	-	-	-	-	-	-	-	-	-	6	6
Total	-	-	-	0	-	-	0	-	0	0	6	6

[a] Sampling sections: 1=John Day Dam forebay, 2=Rock Creek, 3=Sundale, 4=Arlington, 5=Willow Creek, 6=Crow Butte, 7=Boardman, 8=Blalock Islands, 9=Irrigon, 10=McNary Dam tailrace, 11=McNary Dam tailrace boat-restricted zone.

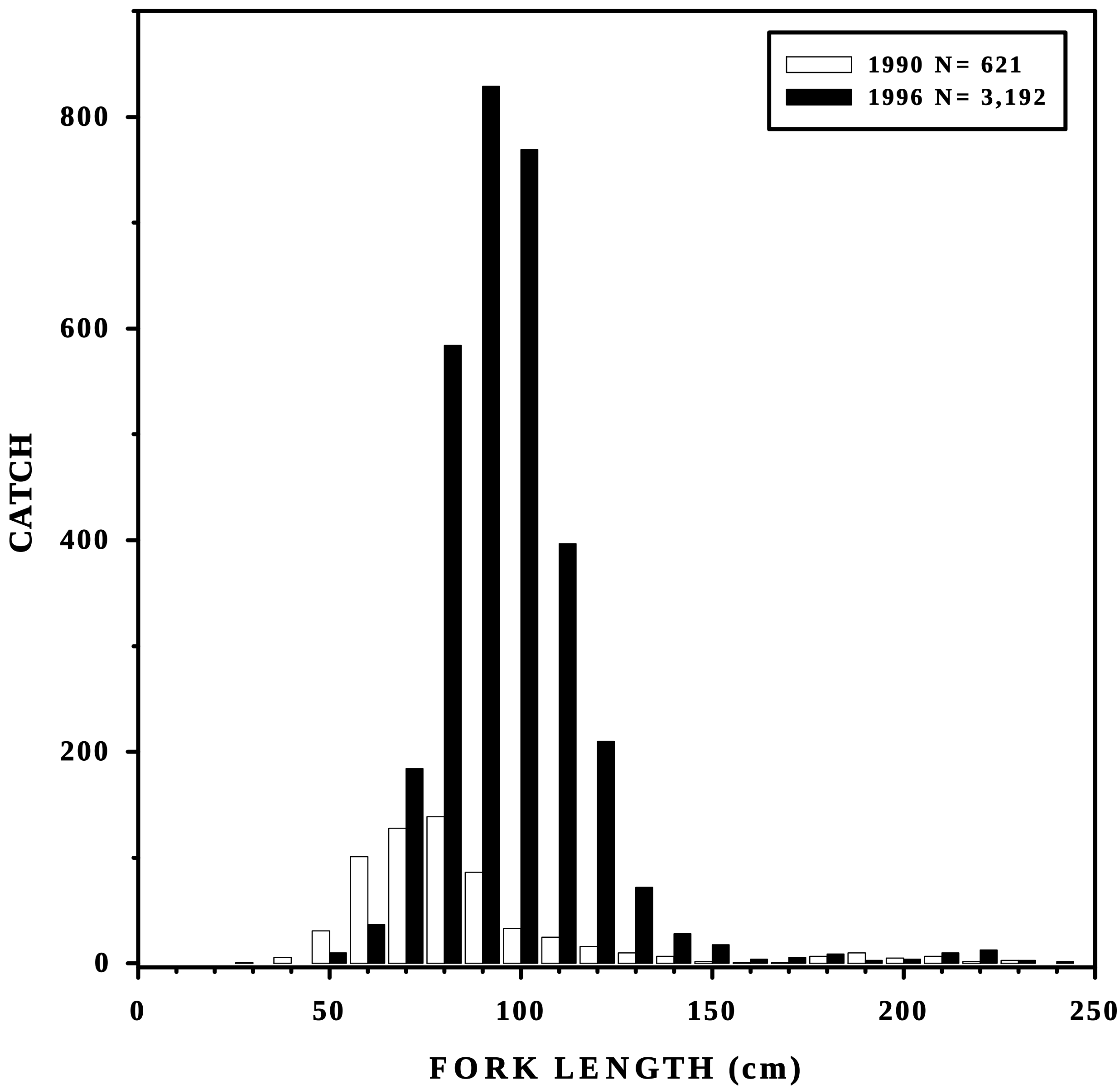

Figure 2. Frequency of catch of white sturgeon collected with setlines by Oregon Department of Fish and Wildlife in John Day Reservoir, April through September 1996. (1990 data are included for comparison).

Table 3. Mean catch of white sturgeon (all lengths) per setline day by month in John Day Reservoir, April through September 1996 (1990 data are included for comparison). A "-" indicates sampling was not conducted.

Year: bait type Month	Sampling section[a] 1	2	3	4	5	6	7	8	9	10	11	Total
1990: Pacific lamprey												
April	-	-	-	-	-	-	0.2	0.5	-	0.0	0.0	0.3
May	0.0	0.1	0.0	0.1	0.1	0.2	0.3	0.6	0.8	0.3	7.2	0.4
June	0.2	0.1	0.0	0.1	0.5	0.2	0.7	0.5	-	-	-	0.3
July	0.1	0.1	0.0	-	0.2	0.1	-	-	0.8	1.4	3.7	0.8
August	-	-	0.0	0.1	-	-	0.1	0.5	0.2	0.4	5.0	0.6
September	-	-	-	-	-	-	-	-	0.4	0.4	9.0	0.9
All months	0.1	0.1	0.0	0.1	0.3	0.2	0.2	0.5	0.5	0.8	4.6	0.5
1996: Pacific lamprey												
April	-	-	-	-	0.1	1.0	0.0	-	1.1	-	-	0.7
May	0.2	0.2	0.3	0.3	0.4	0.9	0.7	1.4	0.6	1.1	-	0.6
June	0.0	0.1	0.5	0.3	1.3	-	1.5	1.3	3.6	2.4	-	1.4
July	0.0	0.7	1.2	0.4	2.4	3.3	3.6	3.4	3.3	-	-	2.1
August	0.1	0.5	0.1	1.2	1.4	2.0	2.7	-	3.4	1.4	-	1.3
September	-	-	-	-	-	-	1.6	0.3	1.9	1.8	-	1.5
All months	0.1	0.3	0.4	0.5	1.1	1.6	1.9	1.7	2.3	1.7	-	1.2
1996: salted American shad												
April	-	-	-	-	0.1	0.6	-	-	-	-	-	0.4
May	0.0	0.0	0.6	0.2	1.0	1.7	1.6	2.0	2.0	1.9	-	1.2
June	0.2	0.0	0.2	0.2	-	-	1.6	1.5	3.7	2.3	-	1.2
July	0.9	1.1	1.6	0.8	1.6	8.6	6.7	7.4	-	-	-	3.8
August	0.0	0.2	0.2	0.1	2.3	4.2	-	-	3.0	1.0	-	1.3
September	-	-	-	-	-	-	2.4	1.1	1.0	0.5	3.0	1.4
All months	0.3	0.3	0.6	0.3	1.1	3.3	3.4	2.7	2.6	1.6	3.0	1.6
1996: pickled squid[b]												
July	1.9	4.1	6.9	8.4	5.4	14.0	19.8	20.1	8.7	-	-	10.3
August	0.7	2.8	4.7	2.9	12.5	14.4	9.0	-	8.1	2.5	3.0	6.2
September	-	-	-	-	-	-	10.0	13.2	12.4	5.9	12.3	10.8
All months	1.2	3.4	5.8	5.8	8.3	14.2	12.3	17.5	10.3	4.4	7.7	8.7

[a] Sampling sections: 1=John Day Dam forebay, 2=Rock Creek, 3=Sundale, 4=Arlington, 5=Willow Creek, 6=Crow Butte, 7=Boardman, 8=Blalock Islands, 9=Irrigon, 10=McNary Dam tailrace, 11=McNary Dam tailrace boat-restricted zone.

[b] Pickled squid was not used until July.

Table 4. Catches of white sturgeon by fork length (cm) interval with setlines in John Day Reservoir, April through September 1996 (1990 data are included for comparison).

Year Fork interval	Sampling section[a] 1	2	3	4	5	6	7	8	9	10	11	Total
1990												
21-40	0	0	0	0	0	0	0	1	0	0	0	1
41-60	0	0	0	0	0	0	1	1	17	16	44	79
61-80	1	3	0	6	9	7	14	32	45	45	112	274
81-100	1	0	1	2	6	3	9	21	27	26	63	159
101-120	2	0	0	0	2	1	2	8	11	9	16	51
121-140	2	0	1	0	0	2	1	2	1	2	7	18
141-160	1	0	0	0	0	0	0	0	0	0	2	3
161-180	0	2	0	0	0	0	1	1	0	1	0	5
181-200	1	3	0	1	1	1	1	2	0	2	3	15
201-220	2	0	0	0	3	1	0	1	1	1	3	12
221-240	0	0	0	0	0	0	1	0	0	1	2	4
Total	10	8	2	9	21	15	30	69	102	103	254[b]	623[b]
Percent	1.6	1.3	0.3	1.4	3.4	2.4	4.8	11.1	16.4	16.5	40.8	100
Setline sets	90	82	96	93	81	91	137	139	197	128	55	1,189
1996												
21-40	0	0	0	0	0	0	0	0	0	0	0	0
41-60	0	0	0	0	0	1	3	1	3	15	0	23
61-80	0	2	7	16	9	38	47	135	165	90	6	515
81-100	10	35	53	117	103	325	244	355	249	89	20	1,600
101-120	18	30	67	78	88	186	105	118	95	19	16	820
121-140	5	15	18	13	10	20	22	22	15	8	8	156
141-160	0	1	2	2	2	2	2	4	3	4	3	25
161-180	2	3	0	1	0	1	1	0	3	2	0	13
181-200	0	2	0	1	2	2	1	0	2	0	0	10
201-220	0	1	2	0	1	5	4	3	2	1	1	20
221-240	0	2	0	0	2	0	1	1	1	1	0	8
241-260	0	0	0	0	1	0	0	0	0	0	1	2
Total	35	91	149	228	218	580	430	639	538	229	55	3,192
Percent	1.1	2.8	4.7	7.1	6.8	18.2	13.5	20.0	16.9	7.2	1.7	100
Setline sets	96	103	105	131	99	108	103	123	132	115	9	1,124

[a] Sampling sections: 1=John Day Dam forebay, 2=Rock Creek, 3=Sundale, 4=Arlington, 5=Willow Creek, 6=Crow Butte, 7=Boardman, 8=Blalock Islands, 9=Irrigon, 10=McNary Dam tailrace, 11=McNary Dam tailrace boat-restricted zone.

[b] Total includes two fish that were captured in sampling section 11, but not measured.

Although our catch of white sturgeon >80 cm was substantially higher this year, we caught fewer fish <60 cm. Mean lengths of white sturgeon captured by gear were 85.3 cm for gill nets, 98.2 cm for setlines baited with Pacific lamprey, 98.0 cm for setlines baited with salted American shad, and 95.3 cm for setlines baited with pickled squid. Mean lengths of white sturgeon captured by bait type during the last two sampling periods when all baits were fished concurrently were 99.7 cm for setlines baited with Pacific lamprey, 98.5 cm for setlines baited with American shad, and 95.3 cm for setlines baited with pickled squid. These differences were significantly different (df=2, 2633; F=10.86; r=0.008; P≤0.0001).

Distribution and Movement

We captured white sturgeon throughout John Day Reservoir but fish were generally distributed farther downstream than in 1990 (Table 4). Catch rates averaged ≥4.1 white sturgeon per setline-day in sections 6 through 9 and 11, and ≤2.2 white sturgeon per setline-day in all other sections (1-5 and 10). There were significant differences in log-transformed catch rates among sampling sections (df=1130; F=25.71; r=0.185; P≤0.0001).

Most fish (72.5%) tagged by CRITFC and recaptured by ODFW had moved upstream (Table 5). Recaptures of fish tagged by ODFW showed nearly equal rates of upstream (53.7%) and downstream (46.3%) movement. Approximately 16% of fish tagged by CRITFC and 17% of fish tagged by ODFW were recaptured by ODFW within 1 km of the original tagging location. The average distance between capture and recapture locations was 15.0 km for fish tagged by CRITFC and 16.7 km for fish tagged by ODFW. We recaptured one white sturgeon tagged originally in 1989 in The Dalles Reservoir and two white sturgeon previously tagged above McNary Dam in 1995. Since 1987, we have recovered 4 fish in a reservoir upstream from where they were originally tagged and approximately 74 fish in downstream reservoirs.

Marking and Mark Recovery

The ODFW tagged or marked 2,814 white sturgeon (70-166 cm) including 44 recaptured-fish marked prior to 1996. We recaptured 130 of these fish and 98 additional fish (70-166 cm) previously tagged or marked by CRITFC from January through March 1996 (Table 6). We also recaptured five white sturgeon that were marked in 1996 and eight fish marked prior to 1996 that were not used in the abundance estimate due to their size (<70 cm or >166 cm). The abundance of white sturgeon (70-166 cm) was estimated to be 27,100 (95% confidence limits 23,800-30,800) using a Schnabel mark and recapture estimator based on combined CRITFC and ODFW 1996 mark and recapture data (Table 7) and 29,200 (95% confidence limits 22,000-38,700) using a Petersen estimator based on recaptures of fish marked prior to 1996. Excluding CRITFC data, we estimated an abundance of 21,900 (95% confidence limits 18,400-25,900) white sturgeon (70-166 cm) with a Schnabel estimator. We estimated 1.46 white sturgeon and 12.3 kg per hectare in John Day Reservoir.

The within-year retention rate for PIT tags was 98% for fish tagged by CRITFC and recaptured by ODFW and also for fish tagged by ODFW and recaptured by ODFW. We released 2,939 fish with PIT tags and recaptured 124, of which 3 had lost PIT tags. The CRITFC released 1,161 fish with PIT tags and we recaptured 98 of these fish. We checked 93 of these fish for PIT

Table 5. Number of white sturgeon (all lengths) tagged by agency and location in John Day Reservoir, January through September 1996, and location of recapture by Oregon Department of Fish and Wildlife (ODFW), April through September 1996. A "-" indicates sampling was not conducted.

Agency Tagging location	Number tagged	Recapture location[a]										
		1	2	3	4	5	6	7	8	9	10	11
ODFW												
1. John Day Dam forebay	34			1								
2. Rock Creek	86		1		1		1					
3. Sundale	140		1			1		2		1		
4. Arlington	207					2	2	1	2	2		2
5. Willow Creek	192				1	5		2	1	1		1
6. Crow Butte	540		1		5	4	13	6	5			1
7. Boardman	390			1	1	1	2	5	4	4		1
8. Blalock Islands	593					1	1	6	7	5		1
9. Irrigon	506				2				4	12	1	2
10. McNary Dam tailrace	222									1	5	
11. McNary Dam tailrace BRZ[b]	52			1								
Total	2,962		3	3	10	14	19	22	23	26	6	8
CRITFC[c]												
1. John Day Dam forebay	12											
2. Rock Creek	127		2	2	2					1		
3. Sundale	84		1	2	1	1		2				
4. Arlington	123			1	4	1	1	1	3			
5. Willow Creek	328		1	4	7	7	1	3	3			
6. Crow Butte	176				1	1	8	5	2			1
7. Boardman	203				1	2	4	2	12	1		
8. Blalock Islands	88				1			1	4			
9. Irrigon	14							1				
10. McNary Dam tailrace	-											
11. McNary Dam tailrace BRZ[b]	-											
Total	1,155		3	6	14	12	20	13	24	5		1

[a] To clarify trends, this table is not zero-filled.
[b] Boat-restricted zone (BRZ).
[c] Columbia River Inter-Tribal Fish Commission.

Table 6. Mark and recapture data for white sturgeon 70-166 cm fork length captured with setlines and gill nets and recovered from surveyed recreational and commercial fisheries in John Day Reservoir, April through September 1996.

Period	Number caught	Number marked[a]	Number recaptured	Number removed[b]		Number of marks at large
				Unmarked	Marked	
1/1-4/14[c]	1,201	1,144	0	465	11	0
4/15-5/26[d]	203	196	7	9	0	1,133
5/27-6/30[d]	289	280	9	9	1	1,329
7/1-8/11[d]	1,456	1,366	90	8	0	1,608
8/12-9/12[d]	1,094	972	122	9	0	2,974
Total	4,243	3,958	228	500	12	

[a] Includes recaptures of fish marked during previous years which are counted as new marks for population estimation.

[b] Includes estimated harvest in recreational and commercial fisheries sampled by Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife and estimated tribal subsistence harvest.

[c] Capture and marking of white sturgeon was conducted by Columbia River Inter-Tribal Fish Commission (Parker this report).

[d] Capture and marking of white sturgeon was conducted by Oregon Department of Fish and Wildlife.

Table 7. Estimated abundance (~N) of white sturgeon 70-166 cm fork length based on mark and recapture data and length-frequency distribution in John Day Reservoir, January through September 1996. Data for other areas of the Columbia River upstream from Bonneville Dam are included for comparison. Confidence intervals (95%) surrounding the abundance estimate are in parentheses. A "-" indicates data are not available.

Year	~N		Number of fish by fork length interval[a] 54-81	82-109	110-166	>166	Sum	Number/ ha	kg/ha
Bonneville Reservoir									
1989[b]	35,400	(27,500-45,400)	32,900	16,700	1,200	600	51,400	6.12	30.0
1994[c]	35,200	(24,800-66,000)	31,300	18,300	1,500	900	52,000	6.19	-
The Dalles Reservoir									
1987[b]	23,600	(15,700-33,600)	7,800	11,000	7,900	1,000	27,700	6.16	81.4
1988[b]	9,000	(7,300-11,000)	4,200	4,300	2,000	800	11,300	2.51	35.5
1994[c]	9,700	(7,500-14,000)	5,800	5,700	800	300	12,600	2.80	-
John Day Reservoir									
1990[b]	3,900	(2,300-6,100)	3,600	1,700	500	500	6,300	0.30	3.6
1996	27,100	(23,800-30,800)	5,800	19,700	4,400[d]	700	30,600	1.46	12.3
McNary Reservoir and the Hanford Reach									
1995[e]	5,200	(3,800-9,100)	1,100	2,100	2,500	800	6,500	0.35	6.6

[a] Abundance estimates for these fork length intervals are expanded from the mark and recapture abundance estimate (~N) based on the observed length frequency of white sturgeon >54 cm captured during each years sampling. Numbers are rounded to the nearest 100 for consistency. Fork length intervals approximate total lengths of 24-35, 36-47, 48-72, and >72 inches.

[b] Beamesderfer et al. 1995.

[c] North et al. 1996.

[d] Fork length interval 110-137 cm (~48-60 inches total length) = 4,040 fish.

[e] Rien et al. in press.

tags and found 2 PIT tags were lost. The within-year retention for wire-core spaghetti tags was 100% for fish tagged and recaptured by ODFW and 97% for fish tagged by CRITFC and recaptured by ODFW. We released 2,512 fish with spaghetti tags and recaptured 119, all with tags present. The CRITFC released 1,111 fish with wire-core spaghetti tags and we recaptured 92, of which 3 had lost spaghetti tags.

Age, Growth, and Morphometry

We assigned ages to 64 white sturgeon <110 cm (Table 8). Assigned ages ranged from 4-16 years. We collected fin-ray samples from 35 fish previously injected with OTC that will be used for age validation.

Paired samples of fork length and weight were sufficient to calculate a regression equation with high degrees of confidence ($W=3.168\ E\text{-}06xFL^{3.1941}$; df=575; F=18,302; r=0.97; P≤0.0001). The mean W_r of 98.4 for 576 fish weighed this year was not significantly different from the mean W_r of 100.2 for 451 fish weighed in 1990 (df=1, 1,026; F=2.29; r=0.002; P=0.131).

We calculated head to snout length ratios for 323 white sturgeon. Two-way ANOVA (type III sum of squares) showed mean head to snout ratios, classified by 20-cm length intervals, did not vary significantly among Bonneville, The Dalles, and John Day reservoirs and McNary Reservoir and the Hanford Reach (df=3, 1,130; F=0.58; r=0.097; P=0.628).

Stress and Genetic Analyses

We collected 55 blood plasma samples from white sturgeon for cortisol analyses and 157 whole blood samples for DNA analyses. None of these samples have been examined yet.

Reproduction

We surgically examined 35 white sturgeon (>150 cm) and collected paired gonad and blood plasma samples for laboratory analyses. Results of field, microscopic, and histologic examinations were inconsistent (Table 9). Many of the samples we collected from fish which were field-classified as male or unknown sex consisted of fat and non-germinal tissue which commonly surrounds male gonads. Female maturation stages determined from 13 ovary samples were: 2 pre-vitellogenic, 4 early vitellogenic, 4 late vitellogenic, 3 pre-vitellogenic with attritic oocytes, and 0 ripe fish. We have found no discernible pattern in mean egg diameters over time but a lack of samples collected from October through January complicates analysis (Figure 3). We have examined ovary samples of 1,756 maturing female white sturgeon (>79 cm fork length) recovered during ODFW research sampling and from sampling of recreational and commercial fisheries occurring between Bonneville and Priest Rapids dams from 1987 through 1996 (Table 10). We found 2.3% of these fish were ripe and were expected to spawn in the year of capture and 10.5% were in early or late stages of vitellogenesis and were expected to spawn the year following capture.

Table 8. Age-length frequency distribution of white sturgeon <110 cm fork length in John Day Reservoir, April through September 1996.

	Fork length interval (cm)[a]						
Age	40-59	60-79	80-99	100-109	Mean length	STD	N
1							0
2							0
3							0
4	3				55.7	3.1	3
5							0
6	2				56.0	4.2	2
7	4				53.7	4.3	4
8							0
9	5	3			61.1	8.0	8
10		5	1		73.3	7.2	6
11	1	4	1	2	78.1	17.8	8
12	1	4	8		82.3	8.3	13
13		4	3	2	86.2	15.4	9
14			3	3	99.7	4.9	6
15			2	2	96.3	9.3	4
16			1		88.0	-	1
N	16	20	19	9	77.6	17.2	64

[a] To clarify trends, this table is not zero-filled.

Table 9. Gender classification by three methods of 35 white sturgeon (>150 cm fork length) collected in John Day Reservoir, April through September 1996.

	Gender		
Examination method	Female	Male	Unknown
Field biopsy[a]	10	21	4
Microscopic[b]	13	0	22
Histology[c]	14	2	19

[a] Visual examination of gonads via surgical biopsy conducted by Oregon Department of Fish and Wildlife (ODFW) personnel.

[b] Microscopic examination of gonad samples collected during field biopsies. Examinations were conducted by experienced ODFW personnel.

[c] Histologic examination of gonad samples collected during field biopsies. Examinations were conducted by personnel at Oregon State University, Department of Fisheries and Wildlife.

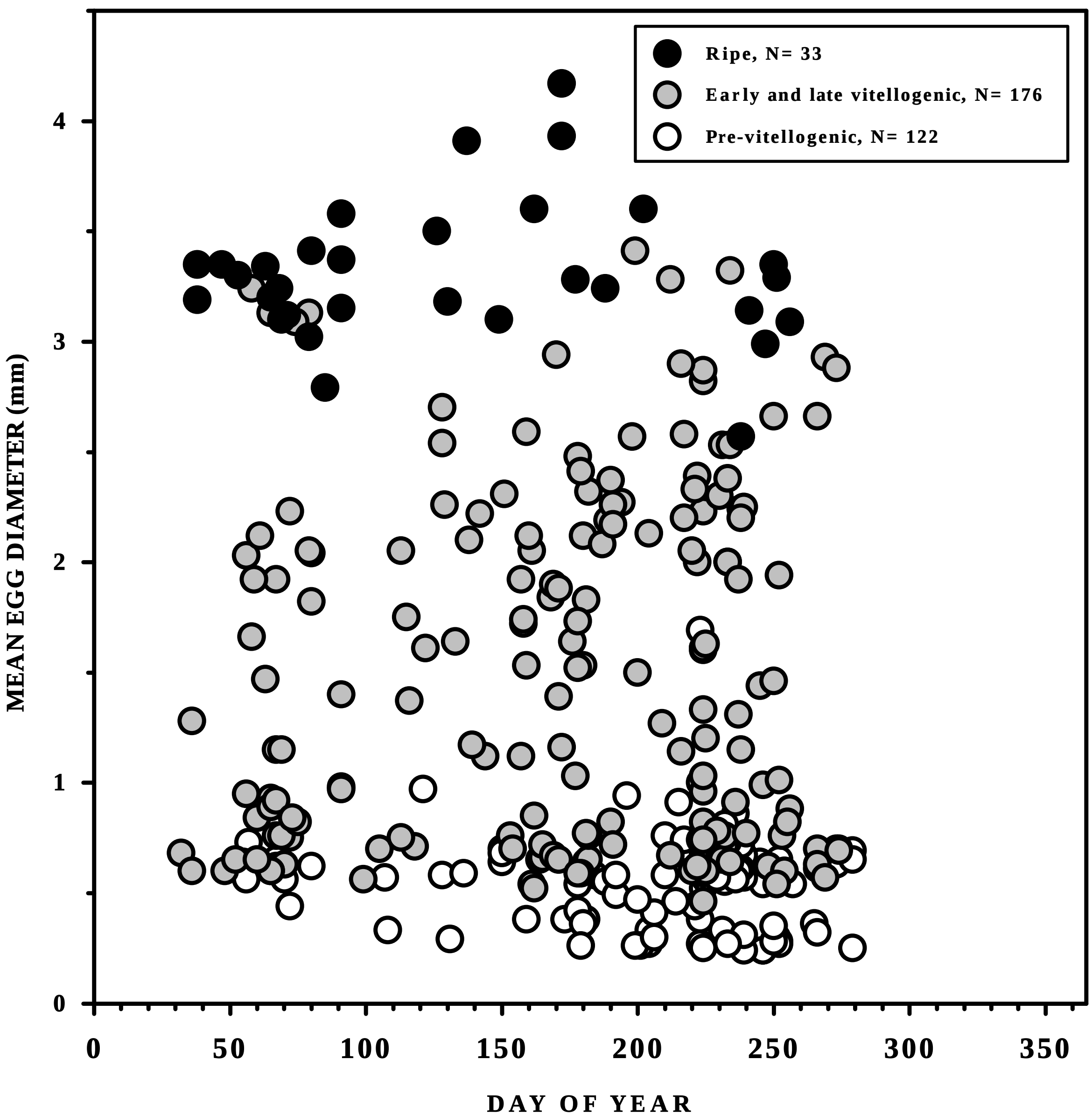

Figure 3. Mean egg diameter of pre-, late, and ripe vitellogenic female white sturgeon collected downstream from Priest Rapids Dam by day of the year, 1987-1996.

Table 10. Gonad developmental stage of female white sturgeon collected from the Columbia River between Bonneville and Priest Rapids dams, 1987-96. Fish were obtained from Oregon Department of Fish and Wildlife research sampling and from sampling of commercial and recreational fisheries.

Reservoir Fork length interval (cm)	Developmental stage[a] 1	2	3	4	5	6	Total	Expected spawning year[b] Year of capture	Year after capture	>one year post-capture
Bonneville:										
80-99	3	1	2	0	2	170	178	2	4	172
100-119	37	8	7	0	13	444	509	7	45	457
120-139	2	1	3	0	1	77	84	3	3	78
140-159	1	0	1	0	0	11	13	1	1	11
160-179	1	1	0	0	0	3	5	0	2	3
180-199	2	1	1	0	0	3	7	1	3	3
200-219	3	6	2	0	1	3	15	2	9	4
>219	7	10	5	2	2	2	28	5	17	6
Total (%)	56	28	21	2	19	713	839	21 (2.5)	84 (10.0)	734 (87.5)
The Dalles:										
80-99	0	0	0	0	0	14	14	0	0	14
100-119	4	1	0	0	0	240	245	0	5	240
120-139	5	3	0	0	3	198	209	0	8	201
140-159	12	5	4	0	2	90	113	4	17	92
160-179	6	5	1	0	1	16	29	1	11	17
180-199	3	2	0	0	1	3	9	0	5	4
200-219	5	0	2	0	0	1	8	2	5	1
>219	5	1	2	0	0	2	10	2	6	2
Total (%)	50	17	9	0	7	564	637	9 (1.4)	57 (9.0)	571 (89.6)
John Day:										
80-99	0	0	0	0	0	9	9	0	0	9
100-119	0	0	0	0	0	82	82	0	5	77
120-139	2	1	0	0	0	43	46	0	3	43
140-159	1	0	2	0	1	22	26	2	1	23
160-179	2	1	1	0	0	3	7	1	3	3
180-199	2	1	0	0	0	1	4	0	3	1
200-219	4	2	0	0	1	2	9	0	6	3
>219	4	1	1	0	2	1	9	1	5	3
Total (%)	15	6	4	0	4	163	192	4 (2.1)	26 (13.5)	162 (84.4)

(Continued)

Table 10 (continued). Gonad developmental stage of female white sturgeon collected from the Columbia River between Bonneville and Priest Rapids dams, 1987-96. Fish were obtained from Oregon Department of Fish and Wildlife research sampling and from sampling of commercial and recreational fisheries.

Reservoir	Developmental stage[a]							Expected spawning year[b]		
Fork length interval (cm)	1	2	3	4	5	6	Total	Year of capture	Year after capture	>one year post-capture
McNary Reservoir and the Hanford Reach[c]:										
110-119	0	0	0	0	0	0	0	0	0	0
120-139	0	0	0	0	0	0	0	0	0	0
140-159	0	1	0	0	0	1	2	0	1	1
160-179	1	1	2	0	0	6	10	2	2	6
180-199	0	2	0	0	1	2	5	0	2	3
200-219	0	1	0	0	0	1	2	0	1	1
>219	6	0	0	0	0	5	11	0	6	5
Total (%)	7	5	2	0	1	15	30	2 (6.7)	12 (40.0)	16 (53.3)
Unknown:										
80-99	0	2	0	0	0	0	2	0	2	0
100-119	1	0	1	0	0	31	33	1	1	31
120-139	1	0	2	0	0	11	14	2	1	11
140-159	0	1	1	0	0	4	6	1	1	4
160-179	1	0	0	0	0	1	2	0	1	1
180-199	0	0	0	0	0	0	0	0	0	0
200-219	0	0	0	0	0	0	0	0	0	0
>219	0	0	1	0	0	0	1	1	0	0
Total (%)	3	3	5	0	0	47	58	5 (8.6)	6 (10.3)	47 (81.1)

[a] 1=Early vitellogenic, 2=Late vitellogenic, 3=Ripe, 4=Spent, 5=Previtellogenic with attritic oocytes, and 6=Previtellogenic.

[b] Fish in stage 3 were expected to spawn in the year they were captured, fish in stages 1 and 2 were expected to spawn the year after they were captured, and fish in stages 4, 5, and 6 were not expected to spawn until two or more years after capture.

[c] White sturgeon <110 cm fork length (FL) were not available for examination due to the legal-size slot limit for the recreational fishery in this area and period. Fish 110-155 cm FL were unlikely to be sampled since commercial fisheries did not occur in this area and the recreational fishery was only sampled in 1994.

DISCUSSION

Our estimate of white sturgeon abundance in John Day Reservoir in 1996 was dramatically higher than our estimate from 1990. Several factors may have contributed to this difference including adoption of restrictive harvest guidelines (100 fish each for commercial and sport fisheries) in 1991, a reduction of the legal-size slot for the recreational fishery beginning in 1991, and increased precision of the 1996 estimate resulting from intensive sampling and increased catch. Corroboration among our 1996 estimates confirms white sturgeon abundance in John Day Reservoir is substantially higher than previously estimated. Although the current abundance estimate indicates an improved situation in John Day Reservoir, the scarcity of fish <60 cm is a concern. This may be the result of infrequent conditions required for successful spawning. Harvest managers should consider this variable recruitment in management decisions. However, limited sampling in the McNary Dam BRZ where small white sturgeon were common in 1990 may have reduced our catch of fish <60 cm. Also, these small fish are less vulnerable to our standard setline gear than larger fish are and gill nets, as currently deployed, have shown highly variable catch rates. Low catches probably increased the variance of our abundance estimate and may have reduced our estimate of white sturgeon 54-81 cm.

Retention of wire-core spaghetti tags appears to be very high. The within-year retention exceeded results observed for vinyl spaghetti tags, Carlin disk tags, and nylon-tipped dart tags previously used. The protective sheath which protects the numbering increases the legibility of recovered tags. We will continue to use this tag in 1997. Retention of PIT tags continues to be high. We cannot confirm whether lost tags were never applied, misread, expelled from the fish, malfunctioning, or were not detected. We suspect human, and not mechanical error is responsible for most lost tags. Passive integrated transponder tags provide us with an accurate and reliable means of identifying individual fish.

Setline catch rates with pickled squid were substantially higher than catch rates for setlines baited with either salted American shad or Pacific lamprey. Although the size of fish caught with each bait type was significantly different, they were very similar and the increased catch resulting from the use of pickled squid increased the precision of our estimate without apparent bias. We believe pickled squid may attract white sturgeon from a larger area than other baits do and reduce the need to deploy setlines precisely where fish are congregated and it may provoke non-feeding fish to feed. Two disadvantages we have found with squid are a need to frequently re-bait and a higher initial cost, both of which are outweighed by the superior catch rates. We plan to use this bait solely during future sampling provided it remains commercially available.

We caught very few white sturgeon with bottom gill nets this year; probably a result of our reduced ability to sample in the McNary Dam tailrace BRZ due to high flows. In 1990, 27% of our total catch was collected with gill nets which were used exclusively in this section. For this reason, ODFW gill-net catch rates do not provide a good indication of changes in abundance of small white sturgeon in John Day Reservoir since 1990. We continue to have limited success with our gill nets in areas outside tailrace BRZs. Increasing the duration of each set may improve catch rates since Parker (this report) reported catch rates for large-mesh gill nets deployed overnight averaged 1.5 fish per net.

The multi-agency mark and recapture sampling conducted this year was effective. The increased number of marked fish and subsequent recaptures provided us with the data needed to estimate adundance with a high degree of confidence. Pre- and within season coordination between CRITFC and ODFW reduced the potential for inconsistencies inherent with multi-agency sampling. The increased quantity of data collected did require substantially more time to enter, verify, and analyze. We plan to incorporate this coordinated approach during future sampling efforts whenever appropriate.

We have not found evidence of dimorphism in head shape for white sturgeon collected from the Columbia River between Bonneville and Priest Rapids dams. Our results indicate that head shape is most influenced by fish length and differences simply represent extremes of a normal distribution. We do not plan to continue measuring head morphology during future research.

Blood steroids may provide a means to determine sex and maturity of white sturgeon, but further work appears necessary (personal communication with Dr. Marty Fitzpatrick, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon). Differences in levels of testosterone and 11-ketotestosterone between sexes appear sufficient to determine the sex of legal-size white sturgeon in most cases, but variation in levels of these same steroids in mature fish and a lack of paired blood and gonad samples from male fish complicate analyses. Levels of estradiol measured in fish >150 cm were substantially higher than levels observed in smaller fish. Levels of this steroid may provide a means to determine if a female white sturgeon is mature, but do not appear to indicate the stage of maturity. We plan to continue collecting gonad and blood plasma samples from “over-size” fish during future sampling, but hope to eventually discontinue surgical biopsies and rely on blood chemistry analyses to determine sex and female maturation stage.

PLANS FOR NEXT YEAR

From April 1997 through March 1998 we will conduct mark and recapture sampling in The Dalles Reservoir to estimate survival of white sturgeon transplanted there from below Bonneville Dam in 1994 and 1995 as described in North et al. (in press) and estimate abundance of indigenous white sturgeon. We will coordinate with CRITFC who will contract with commercial fishers to capture, mark, and tag indigenous and transplanted white sturgeon in The Dalles Reservoir beginning in December 1996. We will also coordinate a genetics workshop in preparation for development of hypotheses and request bids for DNA analyses of white sturgeon blood samples collected while sampling Columbia River reservoirs between Bonneville and Priest Rapids dams, and Snake River reservoirs downstream from Little Goose Dam.

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Appendix A-1. Number and disposition of all fishes caught with setlines and gill nets in John Day Reservoir, April through September 1996.

	Setline		Gill net	
Species	Live	Dead	Live	Dead
White sturgeon (*Acipenser transmontanus*)	3,192	0	6	0
Common carp (*Cyprinus carpio*)	2	0	0	0
Peamouth (*Mylocheilus caurinus*)	0	0	1	0
Northern squawfish (*Ptychocheilus oregonensis*)	11	37	6	12
Largescale sucker (*Catostomus macrocheilus*)	0	0	38	8
Bullhead (*Ameiurus* spp.)	2	0	3	0
Channel catfish (*Ictalurus punctatus*)	40	0	3	0
Steelhead (*Oncorhynchus mykiss*)	0	0	0	1[a]
Sockeye salmon (*Oncorhynchus nerka*)	0	0	0	2[b]
Mountain whitefish (*Prosopium williamsoni*)	0	0	1	0
Smallmouth bass (*Micropterus dolomieu*)	1	0	1	0
Walleye (*Stizostedion vitreum*)	0	0	15	1

[a] Caught 8 August at river kilometer 467.9.
[b] Caught 24 June at river kilometer 464.4.

EFFECTS OF MITIGATIVE MEASURES ON PRODUCTIVITY OF WHITE STURGEON POPULATIONS IN THE COLUMBIA RIVER DOWNSTREAM FROM MCNARY DAM, AND DETERMINE THE STATUS AND HABITAT REQUIREMENTS OF WHITE STURGEON POPULATIONS IN THE COLUMBIA AND SNAKE RIVERS UPSTREAM FROM MCNARY DAM.

ANNUAL PROGRESS REPORT

APRIL 1996 - MARCH 1997

Report B

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

and

Describe the life history and population dynamics of subadult and adult white sturgeon upstream of McNary Dam and downstream from Bonneville Dam

This report includes: A survey of the 1996 recreational and commercial fisheries for white sturgeon between Bonneville and McNary dams, and a stock assessment of white sturgeon in the three lowermost reservoirs of the Snake River

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ABSTRACT

The Washington Department of Fish and Wildlife (WDFW) conducted a survey of the 1996 recreational fisheries on the Columbia River from Bonneville Dam upstream to McNary Dam to estimate white sturgeon *Acipenser transmontanus* harvest. Harvest and biological data were collected as a component of white sturgeon stock assessment work conducted by the Oregon Department of Fish and Wildlife (ODFW). Harvest monitoring was also used to evaluate the success of managing fisheries to protect and enhance white sturgeon populations between Bonneville and McNary dams (Zone 6 management unit of the Columbia River).

The WDFW and ODFW closed the Bonneville Reservoir recreational fishery to the retention of white sturgeon on April 1 and The Dalles and John Day recreational fisheries on May 1 when harvest was projected to exceed the guidelines. The Sturgeon Management Task Force recommended for 1996 to continue using the recreational fishery harvest guidelines in effect since 1991 of 1,350 fish for Bonneville Reservoir, 100 fish for The Dalles Reservoir, and 100 fish for John Day Reservoir. In 1996 anglers harvested an estimated 1,353 white sturgeon in Bonneville Reservoir, 80 white sturgeon in The Dalles Reservoir, and 60 white sturgeon in John Day Reservoir.

Treaty Indian commercial fishers landed 1,005 white sturgeon from Bonneville Reservoir (1,250 fish guideline) during gillnet and setline fisheries, 230 from The Dalles Reservoir (300 fish guideline), and 360 from John Day Reservoir (100 fish guideline). The Columbia River Inter-Tribal Fish Commission and the Yakama Indian Nation estimated an additional 490 fish were harvested during 1996 subsistence fisheries (260, 120, and 110 white sturgeon in Bonneville, The Dalles and John Day reservoirs, respectively).

White sturgeon stock assessment was conducted in the three lowermost reservoirs of the Snake River using setlines. The focus of 1996 work was in Ice Harbor Reservoir where we estimated 4,830 white sturgeon $\geq$54 cm fork length reside. A lack of younger fish led investigators to characterize the population as recruitment-limited. Future habitat assessments may shed light on whether limited available spawning habitat or some other mechanism is responsible for this result. Work in Lower Monumental and Little Goose reservoirs was designed to increase marked white sturgeon at large for 1997 stock assessments.

INTRODUCTION

This annual report describes work completed by the Washington Department of Fish and Wildlife (WDFW) as part of the Bonneville Power Administration (BPA) white sturgeon *Acipenser transmontanus* research project 86-50. The WDFW is responsible for portions of tasks related to Objective 1: to experimentally implement and evaluate the success of selected measures to protect and enhance white sturgeon populations and mitigate for effects of the hydropower system on the productivity of white sturgeon in the Columbia River downstream from McNary

Dam. These tasks include surveying the recreational fishery between Bonneville and McNary dams to estimate annual white sturgeon harvest and to evaluate management plans intended to regulate white sturgeon fisheries at optimum sustainable exploitation rates.

The WDFW also shares responsibility for tasks relating to Objective 3: to evaluate the need and identify potential measures for protecting and enhancing populations and mitigating for effects of the hydropower system on productivity of white sturgeon in the Columbia and Snake rivers upstream from McNary Dam. We intend to describe population characteristics and to estimate productivity of white sturgeon populations in the lower three reservoirs on the Snake River.

Specific activities reported include: 1) surveying the January through June 1996 recreational fishery in Bonneville Reservoir, the March through June 1996 recreational fishery in The Dalles Reservoir, and the March through May 1996 recreational fishery in John Day Reservoir; 2) monitoring 1996 Zone 6 treaty Indian commercial fishery landings of white sturgeon; and 3) May through September 1996 research setline sampling to assess the population dynamics of white sturgeon residing in Ice Harbor Reservoir.

METHODS

Recreational Fishery Survey

The 1996 recreational fishery survey was conducted throughout Bonneville and The Dalles reservoirs and between McNary Dam and Arlington, Oregon (River Kilometer (Rkm) 390) in John Day Reservoir (Figure 1). Methods were similar to those used in 1995 (James et al. 1996) and relied on angling pressure distribution data collected during surveys of Bonneville Reservoir from 1988-1990, The Dalles Reservoir from 1987-1989, and John Day Reservoir from 1989-1991 (Hale and James 1993). Sampling was conducted by two full-time creel samplers hired by ODFW, three full-time samplers hired by WDFW, and two staff from the WDFW Columbia River Anadromous Fish Division office. The survey was done only during legal angling hours for sturgeon (1 h before sunrise to 1 h after sunset).

Angling effort (angler hours and angler trips) was estimated by periodically counting anglers within representative index areas and expanding these counts to the entire reservoir using 1987-1991 aerial counts of angling pressure. 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 in 1994 and 1995 (James et al. 1996). Counts were made of all bank anglers and recreational 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. Total daily angling effort was then calculated by applying hourly

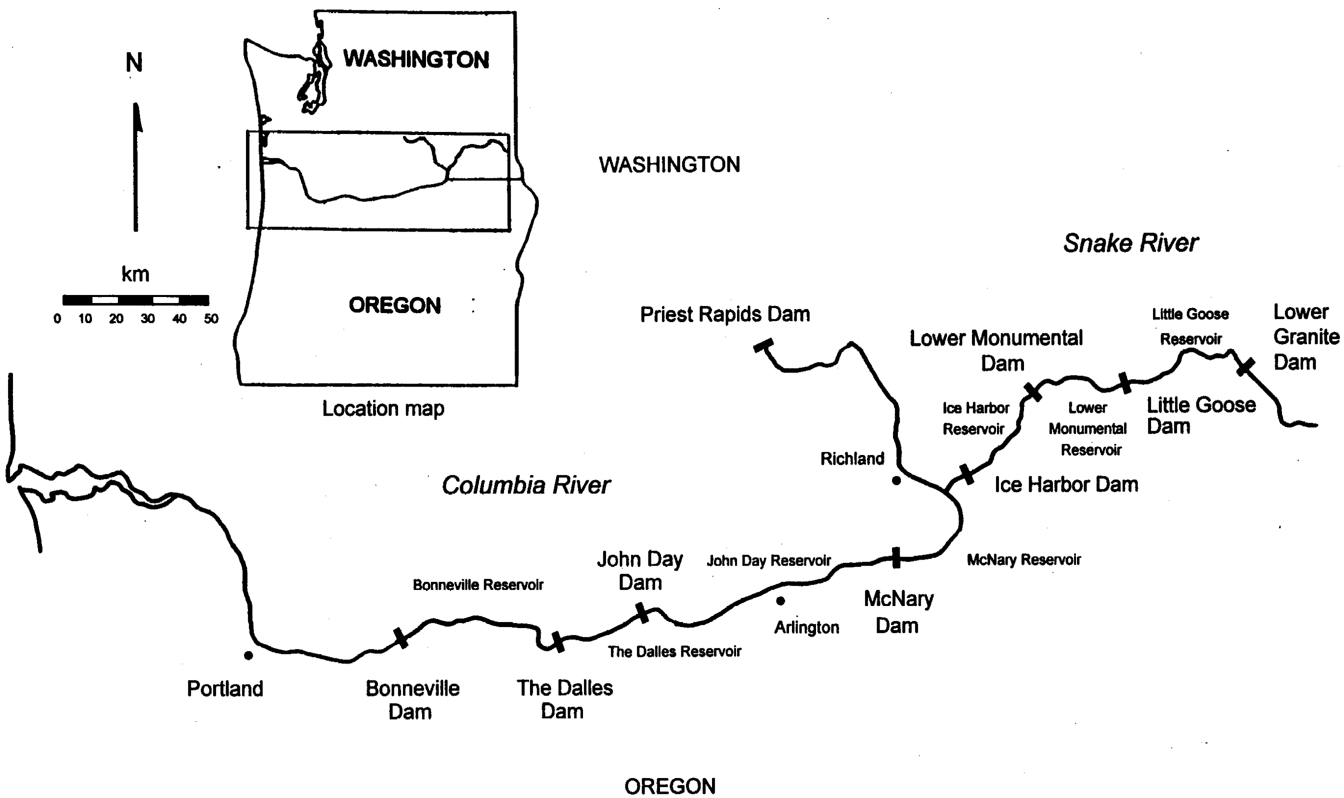

Figure 1. The Columbia River upstream to Priest Rapids Dam and the Snake River upstream to Lower Granite Dam.

angling pressure proportions obtained from prior years' surveys where systematic counts were made throughout the day. Index to non-index pressure distribution patterns were obtained from prior aerial survey data.

Catch per effort data were collected by interviewing anglers throughout the day and examining catches. Samplers interviewed anglers at bank fishing sites and boat ramps to determine angler type (target species) and catch per hour of effort for each species in the creel. Samplers collected data from both incomplete and complete angler trips. Interview data collected included angling method (bank or boat), target species, hours fished, number of anglers in the party, fishing location, state of residence, species, number of fish caught, number released, fork length (FL) of all retained fish, and presence of marks for white sturgeon, salmonids, and walleye. Samplers did not differentiate between smallmouth and largemouth bass. Anglers were also asked if they had registered with the northern squawfish sport reward program and, if so, the station where they registered. Anglers participating in walleye and bass tournaments were not sampled, however, summaries of catch and effort provided by tournament operators were used.

Harvest estimates for bank anglers fishing Bonneville Reservoir and for boat anglers in all reservoirs were calculated by multiplying the observed catch per hour for each angling method within a reservoir subsection by the total estimated effort for each angling method for that subsection. White sturgeon harvest by bank anglers in The Dalles and John Day reservoirs was calculated in a different manner since successful bank anglers may have been missed due to the one fish daily bag limit in these areas. The ratio of bank vs. boat harvest per angler hour was determined for years when the daily limit was two fish. This ratio was applied to the 1996 boat harvest per angler hour rate to estimate 1996 bank harvest per angler hour. The 1996 bank harvest rate was then applied to the 1996 estimate of bank angling effort for white sturgeon.

Effort and catch data were stratified by angling method (bank/boat), reservoir subsection, and weekend and weekday type to account for differential catch and sampling rates. Harvest and angling effort estimates were derived weekly and are reported monthly. Annual harvest estimates were calculated from survey period estimates by applying monthly harvest proportions based on 1987-1995 Washington and Oregon sturgeon catch record card reports.

Treaty Indian Commercial and Subsistence Harvest

Numbers of white sturgeon harvested in Zone 6 treaty Indian commercial fisheries were estimated from weights reported on fish receiving tickets for each gear type. Weights 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 122-183 cm (48-72 in) total length (TL). Treaty Indian subsistence harvest of white sturgeon was estimated by the Columbia River Inter-Tribal Fish Commission (CRITFC) and the Yakama Indian Nation (YIN) from interviews with treaty Indian fishers.

Lower Snake River White Sturgeon Stock Assessment

Sampling closely follows the methods developed and used since 1987 by the Oregon Department of Fish and Wildlife (ODFW) on the Columbia River reservoirs (Rien et al. 1993). Impounded white sturgeon residing in the lowermost three impoundments of the Snake River (Figure 1) were captured using 600 ft setlines consisting of 1/4 in nylon mainline with 40 detachable gangions snapped on every 15 ft. Gangions were 18 in long and consisted of a 5/16 in stainless steel snap attached to a 4/0 or 6/0 swivel and a #42 or #72 braided nylon gangion line attached to a circle halibut hook. Hook sizes were 12/0, 14/0, and 16/0. Each setline had 13 hooks of 2 sizes and 14 hooks of the third size. The size with 14 hooks was chosen randomly when setlines were deployed. Hooks were baited with chunks of pickled squid *Loligo* spp. and salted shad *Alosa sapidissima* with only one bait type being used per setline. Setlines were deployed both parallel to the current and cross-current and set 2 per 1.6 km.

Ice Harbor Reservoir was stratified into four sampling areas which were systematically fished weekly. A total of four passes were made through each sampling area between May 20 and September 6. Sampling was also done in Lower Monumental and Little Goose reservoirs for one week at the end of the season to mark white sturgeon in anticipation of 1997 stock assessment.

Captured white sturgeon were immediately placed in a live well or, for fish >183 cm (>72 in) TL, tied alongside the boat. Stressed fish and large fish were examined first and stressed fish were allowed to recover in a live well prior to release. All white sturgeon were examined for previously applied tags, tag scars, pectoral fin marks, and lateral scute marks. White sturgeon were measured to the nearest cm FL and weighed to the nearest 0.1 kg. White sturgeon ≤ 109 cm FL or ≥ 155 cm FL (white sturgeon outside the harvestable size slot) were injected with oxytetracycline (OTC) for aging verification (Leaman and Nagtegaal 1987) and externally marked by removal of the second right lateral scute. Passive Integrated Transponder (PIT) tags were injected behind and beneath the bony plates of the head of captured white sturgeon. The second left lateral scute was removed on all fish receiving PIT tags. PIT tag injection needles were sterilized in a solution of chlorhexidine prior to each tag injection.

Sequentially coded wire core spaghetti tags were applied to all captured fish in the dorsal musculature ventral to the dorsal fin rays. All fish were also marked by removal of the seventh left lateral scute.

Abundance of white sturgeon was estimated using a modified Schnabel multiple mark-recapture population estimator (Overton 1965). Numbers of fish captured were adjusted for setline gear size selectivity by estimating the ratio of recaptures to marked fish at large for the 50-109, 110-209, and >209 cm FL intervals (Hamley 1975; Lagler 1978; Beamesderfer and Rieman 1988). Recapture rates for the 50-109 and >209 cm FL size classes were divided by the rate calculated for the 110-209 cm FL size class which was considered the size class most vulnerable to our gear. Abundance was calculated for the 110-209 cm FL size class and extrapolated for the entire population using length frequencies adjusted for gear size selectivity. A 95% confidence interval was calculated for the estimated abundance of the 110-209 cm FL size class by assuming random mixing and treating recaptures in this size class as a Poisson variable (Ricker 1975).

A section of either the leading right or left pectoral fin ray was removed for aging purposes. Fin ray sections were removed using a hacksaw blade. A left pectoral fin ray sample was taken when fish had a damaged or deformed right pectoral fin ray. A 2 cm section was removed from approximately ½ cm distal to the articulation of the leading pectoral fin ray with particular care to avoid the blood vessel under the ray. Nexaband, an antiseptic surgical adhesive, was applied with a sterile cotton ball to stop any bleeding. Twenty pectoral fin ray samples per 20-cm length interval was the target sample for characterizing the age structure. Age at length data were fitted to a von Bertalanffy growth function. Parameters were fit using nonlinear least squares regression (SAS 1988).

Length and weight data were fitted to an exponential function using non-linear least squares regression. Relative condition was determined by estimating mean relative weight of the population and comparing it to a standard weight determined for white sturgeon (Beamesderfer 1993).

Gender and stage of maturity information was collected for fish ≥152 cm FL. Determination of gender and maturity were made by first trying to express eggs or milt from the vent by manual stripping. If the manual stripping method failed, the information was collected by surgical biopsy according to the procedures outlined by Beamesderfer et al. (1989). Gonad (<1 g) and blood plasma samples (approximately 4 ml) were collected from females and fish of undetermined gender. These samples were used for gender and maturity determinations and to assist Oregon State University researchers in the development of a plasma steroid assay for non-invasive white sturgeon gender and maturity determinations. Blood samples were collected from the caudal vein using sterile needles and vacutainers. Blood plasma was separated from whole blood with a centrifuge within 1 h of collection. Blood tissue was also collected for genetic analysis. Blood and plasma samples were preserved by freezing. Gonad samples were preserved in 10% buffered formalin. Ova diameters were measured in gonad samples and maturity was determined according to the procedures outlined in Chapman (1989).

RESULTS

Recreational Fishery Survey

Bonneville Reservoir

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

Anglers fished an estimated 56,736 hours (11,944 trips) in Bonneville Reservoir from January through June (Table 1). Angling effort for white sturgeon comprised 48% (5,708 trips) of the total estimated effort. The number of angler trips estimated by target species were as follows: 136 (1%) for anadromous salmonids, 1,979 (16%) for American shad *Alosa sapidissima*, 653 (5%) for walleye, 1,384 (12%) for bass, 1,503 (13%) for northern squawfish, 494 (4%) for other resident fish, and 87 (< 1%) for anglers participating in tournaments.

Anglers harvested an estimated 1,353 white sturgeon during 5,076 trips for sturgeon between January 1 and March 31 and no white sturgeon during 632 trips for sturgeon from April 1 through June 30 when retention was not allowed (Tables 2 and 3).

The fishery for white sturgeon encompassed the entire reservoir although most of the harvest occurred downstream of Hood River, OR (Rkm 271). Harvest per angler trip improved each month prior to closure, peaking in March at 0.30 fish per trip and averaging 0.26 fish per trip for bank anglers and 0.28 fish per trip for boat anglers during the retention fishery (Table 3). Angling effort for white sturgeon decreased by more than 90% from March levels during the catch and release fishery. Approximately 21% of the estimated bank effort (angler hours) and 23% of the estimated boat effort for white sturgeon during the survey period were accounted for by the 1,470 sturgeon anglers interviewed (Table 4).

Anglers fished January through March with a daily bag limit regulation allowing one fish 107 to < 122 cm (42 to < 48 in) TL and one fish 122-168 cm (48-66 in) TL which contributed to anglers releasing 13% of the reported catch of legal-sized fish (Table 4). The percentage sublegal (< 107 cm, < 42 in) TL, legal (107-168 cm, 42-66 in, both kept and released) TL, and oversize (> 168 cm, > 66 in) TL white sturgeon in the January through June reported catch was 84%, 16%, and < 1%, respectively (Table 4). The length distribution of the sampled harvest is presented in Table 5. Harvest per trip of 107-168 cm (42-66 in) TL fish by bank anglers has increased each year since 1993 (Table 6). Harvest per trip by boat anglers decreased from 1995 levels.

Table 1. Combined Washington and Oregon recreational fishery angling effort estimates for Bonneville Reservoir, January through June 1996; The Dalles Reservoir, March through June 1996; and John Day Reservoir, March through May 199

Species Method	Bonneville Hours	Bonneville Trips	The Dalles Hours	The Dalles Trips	John Day Hours	John Day Trips
Sturgeon [a]						
Bank	19,158	3,744	5,904	731	7,912	1,605
Boat	8,078	1,964	2,725	322	7,677	1,532
Total	27,236	5,708	8,629	1,053	15,589	3,137
Salmonid						
Bank	481	67	418	37	2,053	429
Boat	140	69	0	0	13	3
Total	621	136	418	37	2,066	432
Shad						
Bank	9,945	1,979	5,467	833	0	0
Boat	0	0	0	0	0	0
Total	9,945	1,979	5,467	833	0	0
Walleye						
Bank	6	20	1,202	170	96	26
Boat	2,638	633	20,703	3,286	22,447	4,255
Total	2,644	653	21,905	3,456	22,543	4,281
Bass						
Bank	1,434	404	1,196	247	2,084	587
Boat	4,919	980	2,659	509	15,406	3,239
Total	6,353	1,384	3,855	756	17,490	3,826
Squawfish						
Bank	3,883	882	8,712	915	94	18
Boat	3,181	621	9,584	1,465	28	13
Total	7,064	1,503	18,296	2,380	122	31
Other						
Bank	1,085	333	1,172	262	6,943	1,539
Boat	999	161	342	159	3,031	683
Total	2,084	494	1,514	421	9,974	2,222
Tournament						
Bank	0	0	0	0	0	0
Boat	789	87	205	21	4,356	482
Total	789	87	205	21	4,356	482
Combined total						
Bank	35,992	7,429	24,071	3,195	19,182	4,204
Boat	20,744	4,515	36,218	5,762	52,958	10,207
Total	56,736	11,944	60,289	8,957	72,140	14,411

[a] White sturgeon retention allowed January through March in Bonneville Reservoir and Januar through April in The Dalles and John Day reservoirs.

Table 2. Combined Washington and Oregon recreational fishery harvest, and catch and release estimates for Bonneville Reservoir, January through June 1996, The Dalles Reservoir, March through June 1996, and John Day Reservoir, March through May 1996

Species	Bonneville	The Dalles	John Day
White sturgeon [a]			
Legals kept	1,353	60	50
Sublegals released	9,259	2,174	1,107
Legals released	311	116	14
Oversize released	29	30	16
Total	10,952	2,380	1,187
Chinook salmon [b]			
Adults kept	0	0	0
Jacks kept	0	0	0
Total kept	0	0	0
Released	0	0	0
Coho salmon [b]			
Adults kept	0	0	0
Jacks kept	0	0	0
Total	0	0	0
Steelhead [c]			
Kept	0	0	138
Released	0	0	63
American shad			
Kept	1,299	5,175	0
Released	364	2,001	0
Walleye			
Kept	288	1,616	1,092
Released	118	1,342	736
Bass			
Kept	767	643	1,686
Released	2,041	1,678	2,571
Northern squawfish kept	3,397	12,151	205
Other resident fish kept	212	210	1,082

a White sturgeon retention allowed January through March in Bonneville Reservoir and January through April in The Dalles and John Day reservoirs.

b Chinook and coho seasons were closed to retention January 1 - July 31.

c Steelhead season was closed to retention April 1 - June 15.

Table 3. Estimates of recreational fishery angler trips for white sturgeon, white sturgeon harvest, and harvest per angler trip (HPUE) for Bonneville Reservoir, January through June 1996; The Dalles Reservoir, March through June 1996; and John Day Reservoir, March through May 1996

Month / Method	Bonneville			The Dalles			John Day		
	Trips	HPUE	Harvest	Trips	HPUE	Harvest	Trips	HPUE	Harvest
January									
Bank	334	0.04	15						
Boat	434	0.24	104						
Total	768	0.15	119						
February									
Bank	544	0.26	143						
Boat	223	0.12	27						
Total	767	0.22	170						
March									
Bank	2,463	0.29	708	420	0.03	14	1,056	0.01	13
Boat	1,078	0.33	356	76	0.29	22	655	0.02	13
Total	3,541	0.30	1,064	496	0.07	36	1,711	0.02	26
April									
Bank	151	0.00	0	235	0.05	11	468	0.01	6
Boat	67	0.00	0	175	0.07	13	741	0.02	18
Total	218	0.00	0	410	0.06	24	1,209	0.02	24
May									
Bank	112	0.00	0	35	0.00	0	63	0.00	0
Boat	92	0.00	0	0	0.00	0	136	0.00	0
Total	204	0.00	0	35	0.00	0	199	0.00	0
June									
Bank	140	0.00	0	41	0.00	0	18	0.00	0
Boat	70	0.00	0	71	0.00	0	0	0.00	0
Total	210	0.00	0	112	0.00	0	18	0.00	0
Combined									
Bank	3,744	0.26 [a]	866	731	0.04 [a]	25	1,605	0.01 [a]	19
Boat	1,964	0.28 [a]	487	322	0.14 [a]	35	1,532	0.02 [a]	31
Total	5,708	0.27 [a]	1,353	1,053	0.07 [a]	60	3,137	0.02 [a]	50

[a] White sturgeon retention allowed January through March in Bonneville Reservoir and January through April in The Dalles and John Day reservoirs. Harvest per angler trip calculated for the period when retention was allowed.

Table 4. Numbers of sturgeon anglers interviewed and numbers of white sturgeon kept and released reported during sampling of recreational fisheries in Bonneville Reservoir, January through June 1996; The Dalles Reservoir, March through June 1996; and John Day Reservoi March through May 1996.

Reservoir Method/Month	Anglers checked	Hours fished	Sublegal released	Legal released	Legal kept	Oversize released
Bonneville						
Bank						
January	84	333	18	0	7	0
February	135	426	114	0	23	0
March	802	3,050	766	12	169	1
April	35	80	24	0	0	0
May	24	43	56	4	0	0
June	28	64	85	4	0	0
Bank total	1,108	3,996	1,063	20	199	1
Boat						
January	31	208	50	0	7	0
February	23	124	17	0	2	0
March	280	1,422	588	19	91	1
April	19	90	22	2	0	0
May	6	33	6	0	0	0
June	3	18	25	5	0	1
Boat total	362	1,895	708	26	100	2
Combined total	1,470	5,891	1,771	46	299	3
The Dalles						
Bank						
January	--	--	--	--	--	--
February	--	--	--	--	--	--
March	168	678	86	0	3	0
April	137	721	109	0	4	0
May	15	63	34	0	0	0
June	18	82	21	1	0	0
Bank total	338	1,544	250	1	7	0
Boat						
January	--	--	--	--	--	--
February	--	--	--	--	--	--
March	17	143	39	5	4	0
April	33	290	99	0	4	0
May	0	0	0	0	0	0
June	2	12	22	3	0	1
Boat total	52	445	160	8	8	1
Combined total	390	1,989	410	9	15	1

continued

Table 4. Continued

Reservoir Method/Month	Anglers checked	Hours fished	Sublegal released	Legal released	Legal kept	Oversize released
John Day						
Bank						
January	--	--	--	--	--	--
February	--	--	--	--	--	--
March	291	794	85	1	3	0
April	130	327	22	0	4	0
May	28	61	5	0	0	0
June	--	--	--	--	--	--
Bank total	449	1,182	112	1	7	0
Boat						
January	--	--	--	--	--	--
February	--	--	--	--	--	--
March	144	642	134	1	6	1
April	208	1,108	188	2	6	4
May	34	197	26	2	0	3
June	--	--	--	--	--	--
Boat total	386	1,947	348	5	12	8
Combined total	835	3,129	460	6	19	8

Table 5. Length frequencies of harvested white sturgeon measured during sampling o recreational fisheries in Bonneville Reservoir, January through June 1996; The Dalles Reservoir, March through June 1996; and John Day Reservoir, March through May 1996. N all sampled fish were measured.

Fork length (cm)	Bonneville	The Dalles	John Day	Fork length (cm)	Bonneville	The Dalles	John Day
90				130			
91				131			1
92	1			132	1		
93	2			133	1		
94	12			134		2	1
95	13			135	1		
96	18			136			
97	22			137			
98	22			138			
99	19			139	1		
100	15	1		140			
101	17			141	1		
102	12			142	1		
103	16			143			
104	22			144			
105	9		1	145		1	
106	6	2		146			
107	13		1	147			1
108	10			148			
109	7			149			
110	9	2		150			
111	8		3	151			
112	6	2	1	152			
113	2		1	153			
114	5	1		154			
115	4		3	155			
116	1		1	156			
117	3	1	1	157			
118	4			158			
119	6	1		159			
120			1	160			
121	1	1		161			
122	2			162			
123	2	1		163			
124	1			164			
125	2			165			
126				166			
127	1	2		167			
128			1				
129				Total	299	17	17

Table 6. Estimated angling effort, harvest, and harvest per angler trip (HPUE) of white sturgeon from Bonneville, The Dalles, and John Day reservoirs, 1987 through 1996.

Reservoir Year	Period	Bank anglers Trips	Harvest	HPUE	Boat anglers Trips	Harvest	HPUE
Bonneville (107-167 cm total length interval)							
1987	-- a						
1988	Mar-Oct	5,653	532	0.094	4,776	688	0.144
1989	Mar-Oct	8,028	1,316	0.164	5,792	1,099	0.190
1990	Mar-Oct	7,213	719	0.100	7,349	1,055	0.144
1991	-- a						
1992	-- a						
1993	Mar-Oct	7,599	678	0.089	6,747	736	0.109
1994	Mar-Oct	7,821	1,024	0.131	5,329	1,089	0.204
1995	Feb-Apr	2,541	456	0.180	1,750	857	0.490
1996	Jan-Mar	3,341	823	0.246	1,735	463	0.267
The Dalles (122-167 cm total length interval)							
1987	Jun-Oct	5,019	465	0.093	3,618	339	0.094
1988	Mar-Oct	5,043	257	0.051	2,566	170	0.066
1989	Mar-Oct	3,659	119	0.033	1,760	99	0.056
1990	-- a						
1991	-- a						
1992	-- a						
1993	Mar-Oct	2,058	46	0.023	1,902	61	0.032
1994	Mar-Oct	3,124	75	0.024	1,863	68	0.037
1995	Mar-May	957	28	0.029	510	18	0.035
1996	Mar-Apr	655	21	0.031	251	29	0.115
John Day (122-167 cm total length interval)							
1987	-- a						
1988	-- a						
1989	May-Jul	3,572	22	0.006	3,401	34	0.010
1990	Mar-Dec	3,806	33	0.009	3,063	82	0.027
1991	Apr-Sep	1,977	36	0.018	2,463	73	0.030
1992	-- a						
1993	Mar-Oct	3,208	56	0.018	4,466	111	0.025
1994	Mar-Oct	3,221	42	0.013	6,860	164	0.024
1995	Mar-May	1,891	12	0.006	2,407	30	0.013
1996	Mar-Apr	1,524	17	0.011	1,396	27	0.020

a Minimal or no sampling.

Approximately 22% of the estimated recreational fishery harvest of white sturgeon from Bonneville Reservoir was examined for marked fish (Table 7). Five white sturgeon marked by ODFW during previous studies were observed in the creel and four white sturgeon with scute marks but no tags or tag scars were also observed. Anglers sent in information on an additional eight tagged fish.

The Dalles Reservoir

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

Anglers fished an estimated 60,289 hours (8,957 trips) in The Dalles Reservoir from March through June 1996 (Table 1). Angling effort for white sturgeon comprised 12% (1,053 trips) of the total estimated effort. The number of angler trips estimated by target species were as follows: 37 (< 1%) for anadromous salmonids, 833 (9%) for American shad, 3,456 (39%) for walleye, 756 (8%) for bass, 2,380 (26%) for northern squawfish, 421 (5%) for other resident fish, and 21 (< 1%) for anglers participating in tournaments.

Anglers harvested an estimated 60 white sturgeon during 906 trips for sturgeon between March 1 and April 30 and no white sturgeon during 147 trips for sturgeon from May 1 through June 30 when retention was not allowed (Tables 2 and 3). We estimated that an additional 20 white sturgeon were harvested in January and February prior to our survey based on the monthly harvest distribution reported on previous sturgeon catch report cards.

The primary recreational fishery for white sturgeon extended from the John Day Dam tailrace downstream to Miller Island (Rkm 327). More white sturgeon anglers fished from the bank than from boats. The average harvest per trip was 0.04 for bank anglers and 0.14 for boat anglers targeting white sturgeon during the retention fishery. Approximately 26% of the estimated bank effort (angler hours) and 16% of the estimated boat effort for white sturgeon were accounted for by the 390 white sturgeon anglers interviewed (Table 4).

The percentage sublegal (< 122 cm, < 48 in) TL, legal (122-168 cm, 48-66 in) TL, and oversize (> 168 cm, > 66 in) TL white sturgeon in the March through June sampled catch was 97%, 3%, and 0%, respectively (Table 4). The length distribution of the sampled harvest is presented in Table 5. Harvest per trip of 122-168 cm (48-66 in) TL fish by bank anglers has increased each year since 1993 (Table 6). Harvest per trip by boat anglers was substantially above 1993-1995 levels.

Table 7. Tag numbers of harvested marked white sturgeon and numbers of unmarked white sturgeon observed by samplers examining the recreational fishery creel (in-sample information) for Bonneville, The Dalles, and John Day reservoirs, 1996. Also presented are the tag numbers of caught and released marked white sturgeon reported during interviews and tag numbers of harvested marked white sturgeon not part of the sampled creel (tags voluntarily returned to Washington Department of Fish and Wildlife by anglers).

Reservoir Period	Recovery method	Proportion of harvest examined	Non-marked, kept	1996 mark Kept	1996 mark Released	Pre-1996 mark Kept	Pre-1996 mark Released
Bonneville							
1/1 - 6/30	In-sample	0.221	289	0	0	BO62577 BO61941 JD70241 JD70386 scar/scute [a]	0
	Volunteer			0	0	70420 [b] 75463 [b] JD71679 [c] JD74777 [c] BO60819 [d]	BO62253 JD72051 72028 BO61027 74788
The Dalles							
3/1 - 6/30	In-sample	0.233	14	0	0	TD53131	0
	Volunteer			0	0	0	62770
John Day							
3/1 - 5/31	In-sample	0.360	18	77944	0	0	scar/scute
	Volunteer			0	0	0	0

a *Four secondary marked sturgeon without tags or tag scars were examined with these scute mark patterns (2nd & 3rd right; 2nd right & 5th left; 2nd right, 2nd & 5th left; 10th, 11th, & 12th left).*

b *These tags were from the same fish.*

c *These tags were from the same fish.*

d *One angler reported a tag discarded with the fish carcass.*

Approximately 23% of the estimated recreational harvest of white sturgeon from The Dalles Reservoir was examined for marked fish (Table 7). One white sturgeon previously marked by ODFW was observed in the creel.

John Day Reservoir

The retention season for white sturgeon in John Day Reservoir opened January 1 and was scheduled to run through June 30. We began our survey of the fishery on March 1 and continued sampling it through May 31. State fishery managers closed the fishery to retention of white sturgeon on May 1 based on our projection that harvest would reach the guideline by that date.

Anglers fished an estimated 72,140 hours (14,411 trips) in John Day Reservoir from March through May (Table 1). Angling effort for white sturgeon comprised 22% (3,137 trips) of the total estimated effort. The number of angler trips estimated by target species were as follows: 432 (3%) for anadromous salmonids, 0 (0%) for American shad, 4,281 (30%) for walleye, 3,826 (27%) for bass, 31 (< 1%) for northern squawfish, 2,222 (15%) for other resident fish, and 482 (3%) for tournament anglers.

Anglers harvested an estimated 50 white sturgeon during 2,920 trips for sturgeon between March 1 and April 30 and no white sturgeon during 217 trips in May when retention was not allowed (Tables 2 and 3). An additional 10 white sturgeon were harvested in January and February prior to our survey based on the monthly harvest distribution reported on previous sturgeon catch report cards.

The recreational fishery for white sturgeon was concentrated from McNary Dam downstream past Irrigon, Oregon (Rkm 449), with some additional boat effort out of Boardman, Oregon (Rkm 434), and at Crow Butte Island (Rkm 426). Effort for white sturgeon was greatest in March and declined by over 90% during the catch and release period (Table 3). The average harvest per trip was 0.01 for bank anglers and 0.02 for boat anglers during the retention fishery. Approximately 15% of the estimated bank effort (angler hours) and 25% of the estimated boat effort for white sturgeon were accounted for by the 835 sturgeon anglers interviewed (Table 4).

The percentage sublegal (< 122 cm, < 48 in) TL, legal (122-168 cm, 48-66 in) TL, and oversize (> 168 cm, > 66 in) TL white sturgeon in the reported catch was 93%, 5%, and 2%, respectively (Table 4). The length distribution of the sampled harvest is presented in Table 5. Harvest per trip of 122-168 cm (48-66 in) TL fish increased from 1995 levels but remained below 1994 levels (Table 6).

Approximately 36% of the estimated recreational harvest of white sturgeon from John Day Reservoir was examined for marked fish (Table 7). One white sturgeon previously marked by ODFW was observed in the creel.

Treaty Indian Commercial and Subsistence Harvest

The 1996 treaty Indian commercial harvest estimates for Zone 6 were 1,005 white sturgeon from Bonneville Reservoir, 230 white sturgeon from The Dalles Reservoir, and 360 white sturgeon from John Day Reservoir (Table 8). Most of the harvest (900 fish) was landed in the spring setline fishery (April 1-May 31) with 505 fish harvested in the winter gillnet fishery (February 1- March 16), 180 fish harvested in the January setline fishery (January 1-31), and 10 fish landed in the fall gillnet fishery. The treaty Indian Zone 6 subsistence white sturgeon harvest estimated by CRITFC and YIN was 260 fish from Bonneville Reservoir, 120 fish from The Dalles Reservoir, and 110 fish from John Day Reservoir (Table 8).

Lower Snake River White Sturgeon Stock Assessment

A total of 879 overnight setline sets were made to capture white sturgeon in Ice Harbor Reservoir (Table 9). Total catch (including recaptures) of white sturgeon was 1,231 (Table 10). Catch rates were greatest in the lowermost sections of Ice Harbor Reservoir (Table 11).

A total of 1,071 white sturgeon were captured, marked with PIT and spaghetti tags, and released back into Ice Harbor Reservoir. The setline gear captured white sturgeon ranging in length from 58 to 243 cm FL (mean = 115 cm FL). Recapture rates of marked white sturgeon were highest for fish 110-209 cm FL; we caught 629 white sturgeon within this size class (Table 12). We recaptured 160 marked fish, with 92 recaptures from the 110-209 cm FL size class. We relied on anglers voluntarily returning tags on harvested marked fish to estimate removals of marked fish. We estimated one marked fish was harvested in the recreational fishery during the third mark-recapture period.

Abundance of the 110-209 cm FL size class was estimated with a modified Schnabel estimator at 1,460 fish with a 95% confidence interval of 1,090-2,190 fish. Expanding catches of all size classes $\geq$54 cm FL by adjusting for gear size selectivity resulted in a total population estimate of 4,830 fish (Table 13). Given a calculated surface area of 3,198 hectares (ha) for Ice Harbor Reservoir, the density of white sturgeon $\geq$54 cm FL was 1.51 sturgeon/ha.

There were 101 length-at-age assignments made for Ice Harbor white sturgeon, ranging from 5 years (59 cm FL) to 47 years (199 cm FL). The von Bertalanffy growth equation, $L_t = 477.8\,(1-e^{-0.0122\,(t+3.3749)})$, best described these data (Figure 2).

Lengths and weights were obtained from 1,070 white sturgeon that ranged from 59-241 cm FL and 1.2-108.0 kg. The exponential equation that best fit these data was $W = 6.853 * 10^{-6}\,(FL^{3.0224})$, (Figure 3A). Mean relative weight for the population was 92% of the standard weight for white sturgeon derived by Beamesderfer (1993) (Figure 3B).

Table 8. Sturgeon Management Task Force (SMTF) harvest guidelines and estimated harvest of white sturgeon from Bonneville, The Dalles, and John Day reservoirs, 1991 through 1996.

Fishery Guideline/Harvest Year	Bonneville Reservoir	The Dalles Reservoir	John Day Reservoir	Unspecified reservoir	Total
Recreational					
Guideline	1,350	100	100		1,550
Harvest					
1991	2,270	199	150	0	2,619
1992	1,717	139	147	0	2,003
1993	2,307	158	144	0	2,609
1994	2,223	154	234	0	2,611
1995	1,370	50	53	0	1,473
1996	1,353	80	62	0	1,495
Indian commercial					
Guideline	1,250	300	100		1,650
Harvest					
1991	999	457	39	0	1,495
1992	1,146	431	23	0	1,600
1993	1,415	579	12	0	2,006
1994	1,176	309	117	0	1,602
1995	1,421	312	308	0	2,041
1996	1,005	230	360	0	1,595
Combined fisheries					
Guideline	2,600	400	200		3,200
Harvest					
1991	3,269	656	189	0	4,114
1992	2,863	570	170	0	3,603
1993	3,722	737	156	0	4,615
1994	3,399	463	351	0	4,213
1995	2,791	362	361	0	3,514
1996	2,358	310	422	0	3,090
Indian subsistence					
Expectation [a]	--	--	--	--	300
Harvest					
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

[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 1996.

[b] Not available.

Table 9. Sampling effort (number of overnight setline sets) by sampling location and week for white sturgeon in Ice Harbor Reservoir, May 20 through September 6, 1996.

Week	Location (river kilometer)					Total
	16.4-27.3 [a]	27.4-40.1	40.2-53.0	53.1-66.2	66.3-66.6 [b]	
May 20 - May 23	42	--	--	--	--	42
May 28 - May 31	--	--	18	--	--	18
Jun 3 - Jun 6	--	49	--	--	--	49
Jun 10 - Jun 13	--	--	--	48	--	48
Jun 17 - Jun 20	45	--	--	--	--	45
Jun 24 - Jun 27	--	--	67	--	--	67
Jul 1 - Jul 4	--	63	--	--	--	63
Jul 8 - Jul 11	--	--	--	65	4	69
Jul 15 - Jul 18	68	--	--	--	--	68
Jul 22 - Jul 25	--	--	66	--	--	66
Jul 29 - Aug 1	--	66	--	--	--	66
Aug 5 - Aug 8	--	--	--	47	5	52
Aug 12 - Aug 15	65	--	--	--	--	65
Aug 19 - Aug 22	--	--	60	--	--	60
Aug 26 - Aug 29	--	56	--	--	--	56
Sep 3 - Sep 6	--	--	--	41	4	45
Total	220	234	211	201	13	879

[a] The boat-restricted zone (Rkm 15.6-16.3) of the forebay at Ice Harbor Dam was not sampled.

[b] The tailrace boat-restricted zone at Lower Monumental Dam.

Table 10. Catches of white sturgeon with setlines by sampling location and week in Ice Harbor Reservoir, May 20 through September 6, 1996.

Week	Location (river kilometer)					Total
	16.4-27.3 [a]	27.4-40.1	40.2-53.0	53.1-66.2	66.3-66.6 [b]	
May 20 - May 23	66	--	--	--	--	66
May 28 - May 31	--	--	5	--	--	5
Jun 3 - Jun 6	--	75	--	--	--	75
Jun 10 - Jun 13	--	--	--	7	--	7
Jun 17 - Jun 20	62	--	--	--	--	62
Jun 24 - Jun 27	--	--	74	--	--	74
Jul 1 - Jul 4	--	127	--	--	--	127
Jul 8 - Jul 11	--	--	--	21	5	26
Jul 15 - Jul 18	145	--	--	--	--	145
Jul 22 - Jul 25	--	--	125	--	--	125
Jul 29 - Aug 1	--	105	--	--	--	105
Aug 5 - Aug 8	--	--	--	66	2	68
Aug 12 - Aug 15	168	--	--	--	--	168
Aug 19 - Aug 22	--	--	74	--	--	74
Aug 26 - Aug 29	--	69	--	--	--	69
Sep 3 - Sep 6	--	--	--	27	8	35
Total	441	376	278	121	15	1,231

[a] The boat-restricted zone (Rkm 15.6-16.3) of the forebay at Ice Harbor Dam was not sampled.

[b] The tailrace boat-restricted zone at Lower Monumental Dam.

Table 11. Mean catch per setline set by sampling location and week for white sturgeon in Ice Harbor Reservoir, May 20 through September 6, 1996.

	Location (river kilometer)				
Week	16.4-27.3 [a]	27.4-40.1	40.2-53.0	53.1-66.4	66.3-66.6 [b]
May 20 - May 23	1.57	--	--	--	--
May 28 - May 31	--	--	0.28	--	--
Jun 3 - Jun 6	--	1.53	--	--	--
Jun 10 - Jun 13	--	--	--	0.15	--
Jun 17 - Jun 20	1.38	--	--	--	--
Jun 24 - Jun 27	--	--	1.10	--	--
Jul 1 - Jul 4	--	2.02	--	--	--
Jul 8 - Jul 11	--	--	--	0.32	1.25
Jul 15 - Jul 18	2.13	--	--	--	--
Jul 22 - Jul 25	--	--	1.89	--	--
Jul 29 - Aug 1	--	1.59	--	--	--
Aug 5 - Aug 8	--	--	--	1.40	0.40
Aug 12 - Aug 15	2.58	--	--	--	--
Aug 19 - Aug 22	--	--	1.23	--	--
Aug 26 - Aug 29	--	1.23	--	--	--
Sep 3 - Sep 6	--	--	--	0.66	2.00
Total	2.00	1.61	1.32	0.60	1.15

[a] The boat-restricted zone (Rkm 15.6-16.3) of the forebay at Ice Harbor Dam was not sampled.

[b] The tailrace boat-restricted zone at Lower Monumental Dam.

Table 12. Mark and recapture data used to estimate the abundance of 110-209 cm FL whit sturgeon in Ice Harbor Reservoir in 1996 using a modified Schnabel estimator.

Pass	Dates	Total catch	Number unmarked	Recaptures	Number marked and released	Marked fish harvested	Number of marks at large
1	May 20 - Jun 13	97	97	0	97	0	0
2	Jun 17 - Jul 11	140	132	8	132	0	97
3	Jul 15 - Aug 8	229	189	40	189	1	229
4	Aug 12 - Sep 6	163	119	44	119	0	417
	Totals	629	537	92	537	1	536
	Modified Schnabel estimate		1,457				
	95% confidence interval		1,093 - 2,188				

Table 13. Abundance of white sturgeon in Ice Harbor Reservoir based on 1996 mark and recapture estimates and length frequency distributic

Fork length (cm)	Estimated abundance	Density (No./hectare)
54-81	152	0.05
82-91	400	0.13
92-166	4,160	1.30
>166	120	0.04
Total	4,832	1.51

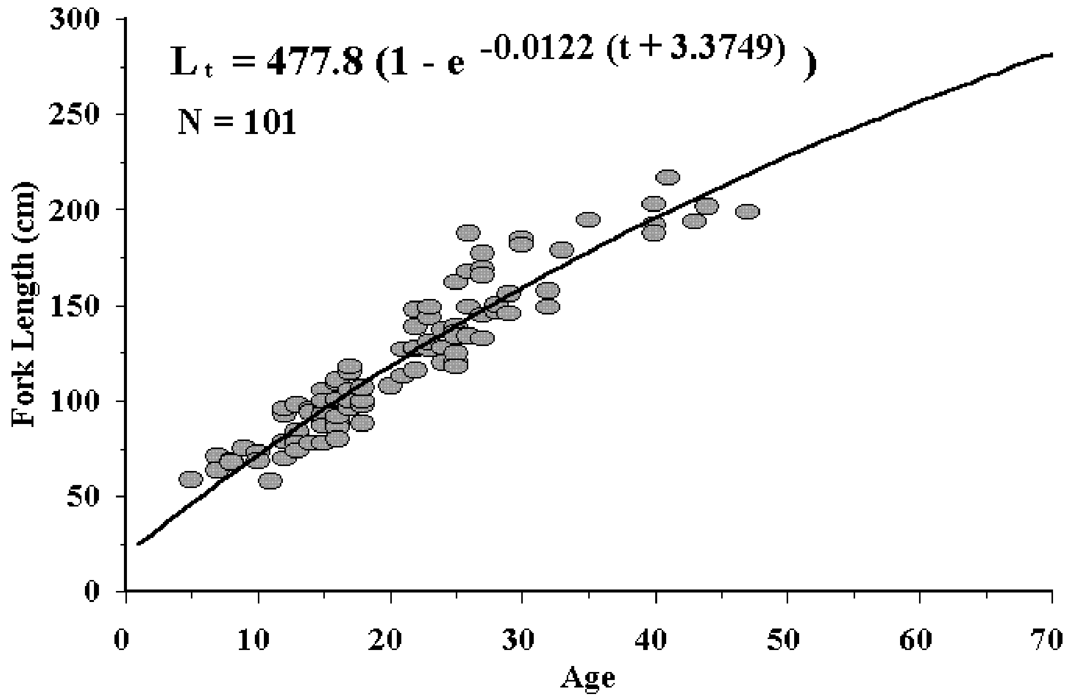

Figure 2. Length-at-age data and von Bertalanffy growth function for white sturgeon in Ice Harbor Reservoir, May through September, 1996.

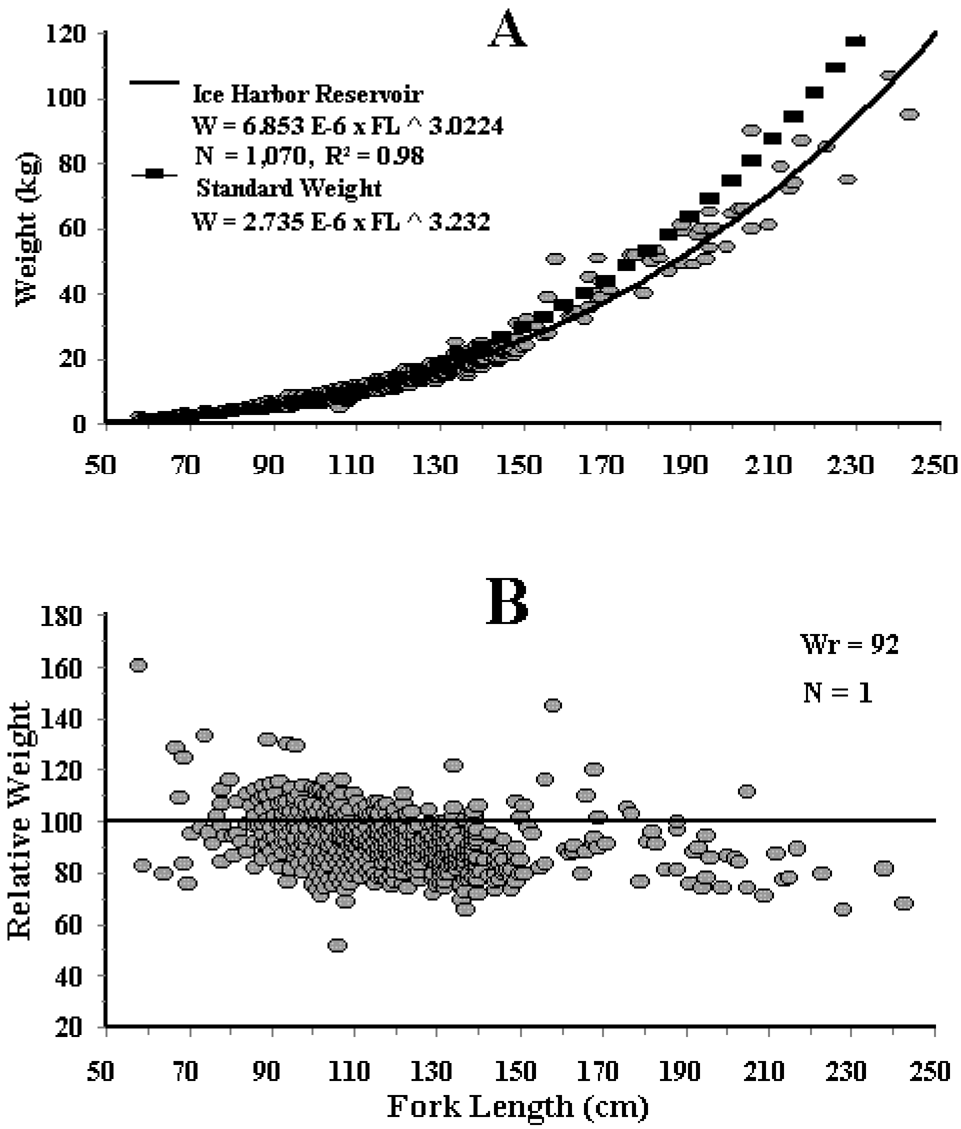

Figure 3. Length-weight relationship (A) and mean relative weight (B) of white sturgeon sampled in Ice Harbor Reservoir, May through September, 1996.

Thirty six of the 52 white sturgeon $\geq$152 cm FL caught in Ice Harbor Reservoir were surgically biopsied to determine gender and stage of maturity (Table 14). Twenty-four gonad samples were collected and examined histologically. Twelve (33%) of the 36 fish were determined to be male, 19 (53%) were female, and 5 (14%) were of unknown sex. Of the gonad samples determined to be ovarian, 14 (74%) were previtellogenic, 1 (5%) was previtellogenic with attritic oocytes, 3 (16%) were early vitellogenic, none (0%) were late vitellogenic, 1 (5%) was ripe, and none (0%) were spent.

DISCUSSION

Recreational Fishery Survey

Harvest management of Columbia River white sturgeon fisheries during 1996 was coordinated through the Sturgeon Management Task Force (SMTF), consisting of representatives from WDFW, ODFW, and the Columbia River treaty Indian tribes. The SMTF recommended 1996 harvest guidelines of 1,350 recreational and 1,250 commercial white sturgeon from Bonneville Reservoir, 100 recreational and 300 commercial from The Dalles Reservoir, and 100 recreational and 100 commercial from John Day Reservoir. Recreational white sturgeon harvest had exceeded the guidelines in all years since 1991-94 despite a series of regulatory harvest reduction actions implemented from 1992 through 1994 (Table 15). The WDFW and ODFW further restricted fisheries beginning in 1995 by adopting a January 1 through June 30 season for retention of white sturgeon and allowing catch and release angling opportunity during the remainder of the year. Despite this management action, in-season closures prior to June 30 were needed to stay within SMTF guidelines in 1995 and 1996.

We were asked by fishery managers to provide periodic updates of estimated 1996 white sturgeon harvest and to project future weekly harvest. We projected that the recreational white sturgeon harvest in Bonneville Reservoir would exceed the guideline set for the reservoir by the end of March. We also projected that harvests from The Dalles and John Day reservoirs would approach their guidelines by the end of April. As a result, WDFW and ODFW closed the Bonneville Reservoir recreational fishery to the retention of white sturgeon from April 1 through the end of the year and The Dalles and John Day recreational fisheries from May 1 through the remainder of the year. Catch and release fishing for white sturgeon was allowed to continue during the closure. Annual harvest stayed within the guidelines for all three reservoirs for the second year in a row.

Restoration of white sturgeon populations in Zone 6 mediated through implementation of harvest guidelines has shown some success. Catch rates of legal sized white sturgeon in recreational fisheries in Bonneville and The Dalles reservoirs has increased most years since implementation of the guidelines in 1991, indicating that these populations are beginning to recover. Recreational fishery catch rates in John Day Reservoir have not shown the same

Table 14. Sex and female maturity stage of white sturgeon from Ice Harbor Reservoir, M
through September 1996, as determined by biopsies.

Gender Maturity	Number	Size range (cm FL)	Percent of samples: Female samples	Percent of samples: All samples
Unknown	5	156-203		14%
Female				
Previtellogenic	14	146-223	74%	39%
Previtellogenic (attritic oocytes)	1	202	5%	3%
Early vitellogenic	3	166-238	16%	8%
Late vitellogenic	0	--	0%	0%
Ripe	1	205	5%	3%
Spent	0	--	0%	0%
Total female	19			53%
Male	12	158-217		33%
Total samples	36			

Table 15. Recreational sturgeon fishery regulations for Bonneville, The Dalles, and John Day reservoirs, 1992-1996.

Year	Daily bag limit	Size limit	Other
1992	1/1	40-72"	Oregon - No change from 1991 regulations for waters downstream of The Dalles Dam.
	1	48-66"	Oregon - No change from 1991 regulations for waters upstream of The Dalles Dam.
	1/1	40-60"	Washington - Size limit change effective April 16, 1992 for waters downstream of The Dalles Dam.
	1	48-60"	Washington - Size limit change effective April 16, 1992 for waters upstream of The Dalles Dam.
1993	1/1	40-72"	Oregon - No change from 1991 regulations for waters downstream of The Dalles Dam.
	1	48-66"	Oregon - No change from 1991 regulations for waters upstream of The Dalles Dam.
	1/1	40-72"	Washington - Size limit change effective April 16, 1993 for waters downstream of The Dalles Dam.
	1	48-66"	Washington - Size limit change effective April 16, 1993 for waters upstream of The Dalles Dam.
1994	1/1	42-66"	Oregon and Washington - Size limit effective January 1, 1994 for waters downstream of The Dalles Dam. Annual limit 10 fish. Closed to the retention of sturgeon September 16 - December 31.
	1	48-66"	Oregon and Washington - No size limit change from 1993 regulations for waters upstream of The Dalles Dam. Annual limit 10 fish. Closed to the retention of sturgeon September 16 - December 31.
1995	1/1	42-66"	Oregon and Washington - No size or bag limit change from 1994 for waters downstream of The Dalles Dam. Closed to the retention of sturgeon April 24 - December 31.
	1	48-66"	Oregon and Washington - No size or bag limit change from 1994 for waters upstream of The Dalles Dam. Closed to the retention of sturgeon June 1 - December 31.
1996	1/1	42-66"	Oregon and Washington - No size or bag limit change from 1995 for waters downstream of The Dalles Dam. Closed to the retention of sturgeon April 1 - December 31.
	1	48-66"	Oregon and Washington - No size or bag limit change from 1995 for waters upstream of The Dalles Dam. Closed to the retention of sturgeon May 1 - December 31.

increasing trend, however stock assessment conducted by the ODFW in 1996 indicates that abundance of white sturgeon has increased there as well (see Report A).

Treaty Indian Commercial and Subsistence Harvest

The treaty Indian commercial winter gillnet season was less productive in 1996 relative to recent years due to extreme flooding in February. The tribes therefore elected to conduct a spring setline fishery from April 1-May 31. All three Zone 6 reservoirs were opened to spring setlining despite the fact that the 100 fish guideline had already been exceeded in John Day Reservoir. Therefore, the John Day guideline was exceeded by almost fourfold in 1996 commercial fisheries. The combined Zone 6 commercial guideline was not exceeded. However, the tribes elected not to open the fall gillnet fishery to white sturgeon sales. The estimated treaty Indian subsistence harvest of 490 fish was also greater than the 300 fish expectation for annual subsistence harvest.

Lower Snake River White Sturgeon Stock Assessment

Distribution of adult white sturgeon in Ice Harbor Reservoir was similar to what ODFW reported for the McNary Reservoir-Hanford Reach white sturgeon population but dissimilar from what they found in Bonneville, The Dalles and John Day reservoirs (North et al. 1993). The ODFW reported highest concentrations of white sturgeon in tailrace areas downstream of each lower Columbia River dam while our highest average catch per set occurred in the middle and forebay areas of Ice Harbor Reservoir.

Our estimate of white sturgeon density, growth, and fitness in Ice Harbor Reservoir were less than that described for other Columbia Basin white sturgeon populations (Beamesderfer et al. 1995; DeVore et al. 1995). The relative lack of juvenile fish less than 58 cm FL and a skewed age structure with proportionally more older individuals may indicate recruitment problems (Figure 4). We do not believe that spawner abundance limits recruitment in Ice Harbor Reservoir since we observed a relatively high catch rate of mature and maturing females in our stock assessment. Extensive hydroelectric development in the Snake River Basin since the late 1950's may likely have caused a reduction in spawning and recruitment as reported by Parsley and Beckman (1994) for lower Columbia River impoundments.

Other factors may also contribute to reduced productivity of Ice Harbor white sturgeon. The slower growth rates and poorer condition factor observed in these fish may indicate problems with the forage base or available rearing habitat. The density of the population is low relative to other Columbia Basin populations studied (Beamesderfer et al. 1995, DeVore et al. 1995). It may be that ecosystem productivity has declined due to a combination of hydroelectric and agricultural development in the region. It is clear that anadromous prey has declined with time and other food resources available to other impounded Columbia Basin white sturgeon populations may not be found in Ice Harbor Reservoir.

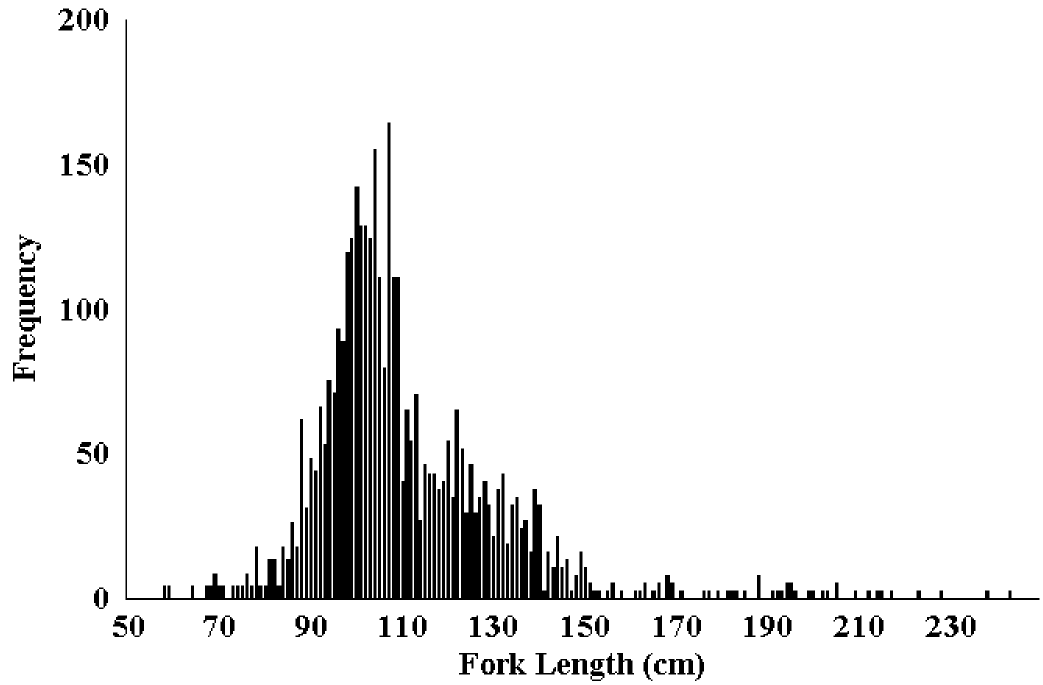

Figure 4. Length frequency distribution of white sturgeon in Ice Harbor Reservoir, May through September, 1996.

Plans for 1997

We plan to conduct stock assessment setline sampling in Lower Monumental and Little Goose reservoirs. We will continue monitoring 1997 Zone 6 recreational and treaty Indian commercial fisheries. Publication of "A Review of Alternatives for the Restoration and Management of White Sturgeon Populations and Fisheries in the Columbia River between Bonneville and McNary Dams (Zone 6)" is also scheduled for 1997.

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EFFECTS OF MITIGATIVE MEASURES ON PRODUCTIVITY OF WHITE STURGEON POPULATIONS IN THE COLUMBIA RIVER DOWNSTREAM FROM MCNARY DAM, AND DETERMINE THE STATUS AND HABITAT REQUIREMENTS OF WHITE STURGEON POPULATIONS IN THE COLUMBIA AND SNAKE RIVERS UPSTREAM FROM MCNARY DAM.

ANNUAL PROGRESS REPORT

APRIL 1996 - MARCH 1997

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 sturgeons and quantify the extent of habitat available in the Columbia River between Bonneville and Priest Rapids dams

This report includes: Investigations on seasonal habitat use and movements of white sturgeons in McNary Reservoir and the Hanford Reach, spawning habitat downstream from lower Columbia River dams, and recruitment to young of year in Bonneville Reservoir

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ABSTRACT

Investigations on the seasonal habitat use and movements of white sturgeons *Acipenser transmontanus* in the Columbia and Snake rivers between Priest Rapids, Ice Harbor, and McNary dams were begun. Acoustic transmitters were attached to 52 white sturgeons, which were subsequently relocated 292 times. Some fish were sedentary, while others made extensive movements up and down the river.

Indices of spawning habitat from four known spawning areas downstream from McNary, John Day, The Dalles, and Bonneville dams indicated that environmental conditions were favorable for spawning in 1996.

The Bonneville Reservoir was sampled with a bottom trawl to determine if recruitment to young of year occurred. We captured 490 juvenile white sturgeons, of which 419 were young of year.

INTRODUCTION

This annual report describes the progress of the U.S. Geological Survey's Columbia River Research Laboratory from 1 April 1996 through 31 March 1997 toward meeting the objectives of Bonneville Power Administration's Project 86-50. The primary goals of the U.S. Geological Survey under this project are to investigate the reproduction and life history of white sturgeons *Acipenser transmontanus*. Our tasks for this period were to:

1) Describe the habitat use and movements of juvenile and adult white sturgeons in the Columbia River between Priest Rapids and McNary dams, and downstream from Ice Harbor Dam on the Snake River and continue to quantify spawning and rearing habitat for white sturgeons in McNary Reservoir.

2) Conduct laboratory experiments to describe the effects of dissolved gas supersaturation on white sturgeon larvae.

3) Determine if recruitment of young of year (YOY) white sturgeons occurred in the Bonneville Reservoir.

4) Estimate the availability of spawning habitat for white sturgeons downstream from Bonneville, The Dalles, John Day, and McNary dams.

In addressing these tasks, we provide two manuscripts as appendices to this progress report. The first manuscript reports on the effects of dissolved gas supersaturation on larval white sturgeons (Appendix C-1). The second manuscript examines the statistical properties of YOY catch-per-unit-effort (CPUE) distributions from bottom trawling in Bonneville Reservoir and proposes the use of a presence-absence index with CPUE to index the relative abundance of YOY white sturgeons (Appendix C-2).

METHODS

Habitat use and movements of juvenile and adult white sturgeons were investigated by using acoustic underwater biotelemetry methods (Winter 1996). Ultrasonic transmitters and receivers were purchased from Sonotronics Inc.[1]. We used 2, 3, and 4-digit coded transmitters at frequencies of 74 and 76 kHz and depth-indicating transmitters at frequencies of 32, 34, 36, 38, and 40 kHz to identify individual fish.

White sturgeons were captured by fishing baited longlines with 20-40 circle hooks per line.

[1] Mention of trade names does not imply endorsement by the U.S. Geological Survey.

Hook sizes used were 10/0, 12/0, 14/0, and 16/0. Baits used included pickled roll mop herring, salted shad, frozen squid, and pickled squid. The longlines were fished for up to 24 hours, and fishing efforts were dispersed along the length of the study area in an attempt to release transmittered fish throughout the study area. Additional fish were captured for use as transmitters neared their expiration dates.

All transmitters were attached externally (Table 1). The transmitters, except the MT-95-2 transmitters, had a hole at each end for attachment. The transmitters were attached by passing a multi-stranded stainless steel wire (American Fishing Wire; 58.8 kg test) through the two holes on either end of the transmitter and then through the musculature ventral to the dorsal fin of the fish. The tag ends of the wires were then passed through a backing plate made of polyvinyl chloride plastic (PVC) and the tag ends were crimped with copper sleeves (American Fishing Wire # 4DB). The tag ends were then trimmed and the attachment area was bathed with a solution of nitrofurazone to reduce infections. The fish was then released. For the MT-95-2 transmitters, we attached two copper wires (22 gauge) to the transmitters with a clove hitch and cyanoacrylate glue and attached the transmitter as described above. It is common practice that the weight of a transmitter in water should not exceed 1.25% of the weight of the fish out of water (Winter 1996). We used the weight/length relation developed by North et al. (1995) for fish from our study area to find the minimum size of fish each transmitter model could be used on (Table 1).

White sturgeons with ultrasonic transmitters were located by using mobile tracking via boats. Tracking was confined to three periods of the year: spring, late summer, and winter. The spring season was defined as that time of the year when water temperatures are increasing (April, May, and June). The summer season is characterized by relatively stable warm water temperatures (August and September), and the winter season is characterized by relatively stable but cold water temperatures (January and February). Tracking was generally done once each week during each season from upstream to downstream. The boat was stopped at approximately 0.8 km intervals to listen for transmitters, with more frequent stops made around islands and in areas with a complex channel structure. Fish were generally located not more than once each week to reduce autocorrelation in the habitat use data.

When fish were found, the latitude and longitude were noted with a Rockwell PLGR+ Global Positioning System (GPS) receiver using the Precise Positioning Service[2], and a variety of habitat descriptors were usually measured. The North American Datum of 1927 (NAD27) was used as the datum for all recorded positions. The positions were converted to state plane coordinates (Washington South Zone) for use in a geographic information system. Water temperatures, and current velocities where fish were located and across the river channel were measured with an acoustic Doppler current profiler. This instrument was shared with the U.S. Fish and Wildlife Service (USFWS; Report D) and was not always available for our use. Water depths where fish

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[2]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 of 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.

Table 1. Physical characteristics, expected transmitter life, and the size range of white sturgeon (mm FL) each model of transmitter was used on.

Transmitter Model	Dimensions (diameter x length)	Transmitter weight in water (g)	Expected life	Smallest fish each transmitter could be used on[c]		Size of fish each model was used on (mm FL)
				Weight (g)	Fork Length (mm)	
MT-95-2	9 mm x 35 mm	3	47 d	240	320	562 - 776
PRG-94-HP/M	18 mm x 70 mm	8	7 months	640	435	926 - 1748
PRG-94-HP-L/M	18 mm x 90 mm	12	12 months	960	490	1152 - 2530
DT-88	18 mm x 80 mm	12	28 d	960	490	1803 - 1905
DT-96-L	18 mm x 95 mm	14	12 months	1,120	515	1720 - 2310

[c]The minimum fish weight is that which the weight of the transmitter (in water) is equal to 1.25% of the fish weight. Fork lengths corresponding to these weights were calculated from the weight-length relation $W_{kg}=2.83x10^{-6}(FL_{cm})^{3.27}$

were found were measured with an analog chart recorder. Turbidity near the surface was measured with a Hach model 2100 turbidity meter.

We fished a 6.2-m high-rise shrimp trawl (Palmer et al. 1988; Parsley et al. 1989) on the bottom to capture juvenile white sturgeons to determine if recruitment to young of year occurred in the Bonneville Pool. We fished the high-rise trawl on 12 consecutive days (excluding weekends) from 16 September to 1 October 1996. We trawled at 11 sites where young-of-year white sturgeons had been collected in previous years. Logistically, the 11 sites could not be trawled in one day; therefore, six sites upstream from the bridge at Hood River, Oregon, were trawled on one day and the remaining five sites downstream from the bridge were trawled the next day. On any given day, the direction that sampling was done (i.e., the furthest upstream site first, then moving downstream, or vice versa) was randomly chosen. Catch per unit effort (CPUE) of white sturgeon was expressed as the number of fish caught per hectare sampled with the high-rise trawl. We measured the total length (TL) to the nearest mm on all young-of-year and measured the fork length (FL) and TL to the nearest mm on other juvenile white sturgeons. The fish were each weighed on a Pesola hanging scale. Usually, young-of-year white sturgeons were weighed to the nearest 1 or 5 g, and larger juveniles were weighed to the nearest 10 g. 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 1/4 channel width increments from left to right while facing upstream. Digits preceding the last number represent river miles (RM) to the nearest 0.1 mile from the mouth of the Columbia or Snake rivers. For example, a site coded as 34753 says that the location is near river mile 347.5 and in the third quadrant of the river from the left bank (looking upstream). With the GPS receiver described above, we noted the latitude and longitude of the start and end points of each site we trawled, and we also used this receiver to navigate the trawling vessel during each tow. Speed-over-ground during each tow was maintained at approximately 3 km/h.

The methods and data described in Parsley and Beckman (1994) were used to model the availability of spawning habitat for white sturgeons downstream from McNary, John Day, The Dalles, and Bonneville dams. Parsley and Beckman (1994) presented the results of hydraulic simulations of the physical habitat downstream from these dams in response to river discharges. The results from that paper were used with river discharges and water temperatures that occurred during 1996 to create a daily index of spawning habitat for the four areas. Mean daily river discharges that occurred at the dams during May through July were obtained from the Fish Passage Center (Portland, Oregon). Water temperatures were automatically recorded every 2 h with Ryan Tempmentor thermographs placed on the river bottom at river kilometers 307.0, 346.5, and 467.6 in the Columbia River.

RESULTS

Habitat Use and Seasonal Movements

Transmitters were attached to 52 white sturgeons (Table 2) ranging in length from 562 mm FL to 2,310 mm FL. The sturgeons were captured and released throughout the study area (Figure 1), but no fish smaller than 800 mm FL was captured downstream from river km 580.

The fish were found 292 times (Figure 2). Some fish were never found after they were released, while others were found many times (Table 2). Water depths where the fish were found ranged from 1.8 to 27.4 m (mean 9.4 m). Velocity measurements were obtained at 200 locations; the data are being summarized.

Young-of-Year Indexing in Bonneville Reservoir

Recruitment to young of year occurred in the Bonneville Reservoir in 1996. We captured 490 juvenile white sturgeons with the high-rise trawl during our sampling in the Bonneville Reservoir; 419 (86%) of these fish were young of year. Young-of-year white sturgeons were captured at all 11 sites (Table 3). The young of year ranged in length from 70 to 261 mm TL and weighed 1.8 to 77 g. The mean length of young of year captured was 178 mm TL and the mean weight was 27.2 g. Older juvenile white sturgeons were captured at 7 of the 11 sites trawled. The older juvenile white sturgeons measured 342 to 912 mm FL and weighed 0.265 to 4.5 kg.

The CPUE with the bottom trawl varied from 7.63 to 54.30 young of year per hectare sampled at the 11 sites and from 7.63 to 63.47 fish per hectare sampled for all white sturgeons caught (Table 3). The CPUE for all sites combined was 27.29 young of year per hectare sampled and 31.92 fish per hectare sampled for all juvenile white sturgeons.

Availability of Habitat

Bonneville, The Dalles, John Day, and McNary Dam Tailraces

Monthly estimates of the index of spawning habitat for white sturgeons showed that the availability of habitat for spawning peaked in June, and the estimates were much higher for this month than the average of the estimates made since 1985 (Figure 3; Appendix C-3). Annual estimates of indices of white sturgeon spawning habitat (temperature conditioned weighted usable area) for 1996 were the highest calculated to date (Figure 4; Appendix C-3). The estimates for 1996 were outside one standard deviation of the average for each spawning area.

McNary Reservoir

Table 2. Characteristics of white sturgeons fitted with ultrasonic transmitters from May 1996 through February 1997.

Tag Code[a]	Date captured YY	MM	DD	Transmitter model	FL (mm)	TL (mm)	Location where captured[b c] Latitude	Longitude	Number of times relocated
76.285	96	5	1	PRG-94HP/M	970	1115	46 12 26.51	-119 03 39.17	14
76.276	96	5	1	PRG-94HP/M	940	1100	46 12 26.51	-119 03 39.17	13
76.2345	96	5	1	PRG-94HP/M	995	1165	46 12 26.51	-119 03 39.17	15
76.348	96	5	7	PRG-94HP/M	820	938	46 12 26.36	-119 03 42.48	6
76.2246	96	5	8	PRG-94HP/M	1245	1435	46 12 53.74	-119 06 10.71	11
76.2273	96	5	8	PRG-94HP/M	1060	1205	46 12 53.74	-119 06 10.71	4
76.258	96	5	9	PRG-94HP/M	814	926	46 40 29.05	-119 27 30.97	15
76.2237	96	5	9	PRG-94HP-L/M	1000	1152	46 40 29.05	-119 27 30.97	13
76.357	96	5	10	PRG-94HP/M	865	1005	46 35 21.92	-119 22 52.52	8
76.2255	96	5	14	PRG-94HP-L/M	1562	1753	46 38 15.95	-119 39 13.27	12
76.294	96	5	14	PRG-94HP/M	957	1073	46 37 31.68	-119 52 02.10	17
76.2336	96	5	14	PRG-94HP-L/M	2057	2261	46 43 21.11	-119 31 57.22	4
76.2327	96	5	15	PRG-94HP-L/M	1727	1905	45 55.612	-119 13.315	5
76.249	96	5	15	PRG-94HP/M	1212	1334	45 55.343	-119 10.272	0
76.2354	96	5	15	PRG-94HP-L/M	1651	1854	45 55 58.23	-119 15 41.09	5
76.267	96	5	15	PRG-94HP/M	1334	1524	45 55.343	-119 10.272	6
76.2228	96	5	15	PRG-94HP-L/M	1854	2083	45 55.612	-119 13.315	10
76.384	96	5	15	PRG-94HP/M	1549	1748	45 55.343	-119 10.272	4
40	96	5	22	DT-88	1702	1803	46 39 03.01	-119 36 32.81	2
40	96	5	29	DT-88	1753	1905	45 55 19.35	-119 11 29.34	2
74.97	96	7	31	MT-95-2	735	821	46 39.215	-119 36.071	0
74.2444	96	7	31	PRG-94HP/M	1040	1190	46 37.550	-119 51.966	9
74.106	96	7	31	MT-95-2	605	695	46 37.550	-119 51.966	0
32	96	8	1	DT-96-L	1590	1750	46 43.424	-119 31.829	8
74.88	96	8	1	MT-95-2	598	692	46 40.492	-119 27.381	8
74.3335	96	8	1	PRG-94HP/M	982	1102	46 43.424	-119 31.829	7
74.2435	96	8	1	PRG-94HP/M	885	1020	46 12.248	-119 01.999	8
74.2426	96	8	2	PRG-94HP/M	950	1005	46 12.248	-119 01.999	7
74.2525	96	8	2	PRG-94HP/M	1010	1017	46 12.248	-119 01.999	9
74.2534	96	8	2	PRG-94HP/M	1160	1320	46 31.802	-119 16.985	7
36	96	8	6	DT-96-L	1870	2050	46 37.608	-119 52.180	9
74.2543	96	8	7	PRG-94HP/M	1280	1420	45 55.859	-119 14.080	6
34	96	8	7	DT-96-L	1560	1720	45 55.859	-119 14.080	6
38	96	8	7	DT-96-L	1910	2110	45 55.320	-119 10.243	6
74.2633	96	8	7	PRG-94HP/M	1540	1700	45 55.565	-119 07.021	4
74.2453	96	8	7	PRG-94HP/M	1040	1180	45 58.056	-119 03.083	7
76.2354[c]	96	8	13	PRG-94HP-L/M	1270	1395	46 39.232	-119 36.127	6

Table 2. Continued

Tag Code[a]	Date captured YY	MM	DD	Transmitter model	FL (mm)	TL (mm)	Location where captured[b] Latitude	Longitude	Number of times relocated
76.338	97	1	7	PRG-94HP/M	1010	1140	45 55.467	-119 10.193	1
76.447	97	1	7	PRG-94HP/M	1160	1280	45 55.491	-119 11.325	1
74.3444	97	1	8	PRG-94HP-L/M	2270	2460	45 55.255	-119 10.867	0
74.2227	97	1	8	PRG-94HP-L/M	2100	2370	45 55.580	-119 09.243	1
74.2555	97	1	8	PRG-94HP-L/M	2270	2510	45 55.580	-119 09.243	0
76.266	97	1	9	PRG-94HP/M	1140	1220	45 55.571	-119 09.248	0
74.3456	97	1	9	PRG-94HPL	1870	2040	45 55.445	-119 11.732	0
76.347	97	1	14	PRG-94HP/M	977	1130	46 37.577	-119 52.174	2
76.456	97	1	14	PRG-94HP/M	1125	1265	46 38.276	-119 39.199	1
74.69	97	1	14	MT-95-2	562	639	46 39.022	-119 36.467	2
74.2245	97	1	15	PRG-94HP-L/M	2310	2530	46 42.434	119 32.171	2
74.55	97	1	15	MT-95-2	674	776	46 40.658	-119 27.346	3
76.257	97	1	16	PRG-94HP/M	1030	1130	46 35.423	-119 22.899	2
40	97	1	16	DT-96-L	1630	1800	46 42.375	-119 32.198	2
74.47	97	1	16	MT-95-2	590	675	46 40.658	-119 27.346	3

[a]Digits preceeding the decimal point are the frequency in kHz. Digits after the decimal point indicate the code used to identify individual transmitters. Transmitters listed without a decimal point following the frequency (e.g. 34) are depth-indicating transmitters, which vary the pulse interval with changes in depth.

[b]Locations were obtained with a global positioning system receiver using the Precise Positioning Service and the North American Datum of 1927.

[c]Locations (latitude and longitude) were recorded in either decimal minutes or decimal seconds.

[d]The fish this transmitter was originally fitted with was captured by an angler who returned the transmitter. The transmitter was then re-deployed.

Table 3. Effort expended and catch of white sturgeons with a high-rise trawl at 11 sites in the Bonneville Pool between 16 September and 1 October 1996.

Site	Time trawled (min)	Area sampled (ha)	Number of white sturgeon captured		Catch/ha sampled	
			All ages	Young of year	All ages	Young of year
15052	60	1.442	11	11	7.63	7.63
15734	60	1.468	23	21	15.67	14.31
15951	60	1.369	41	41	29.95	29.95
16522	60	1.202	10	10	8.32	8.32
16851	60	1.457	72	72	49.42	49.42
17063	60	1.418	31	26	21.86	18.34
17374	60	1.418	90	77	63.47	54.30
17652	60	1.428	34	31	23.81	21.71
17911	60	1.435	72	62	50.17	43.21
18351	60	1.409	52	30	36.91	21.29
18523	60	1.304	54	38	41.41	29.14
Totals	660	15.35	490	419	31.92	27.29

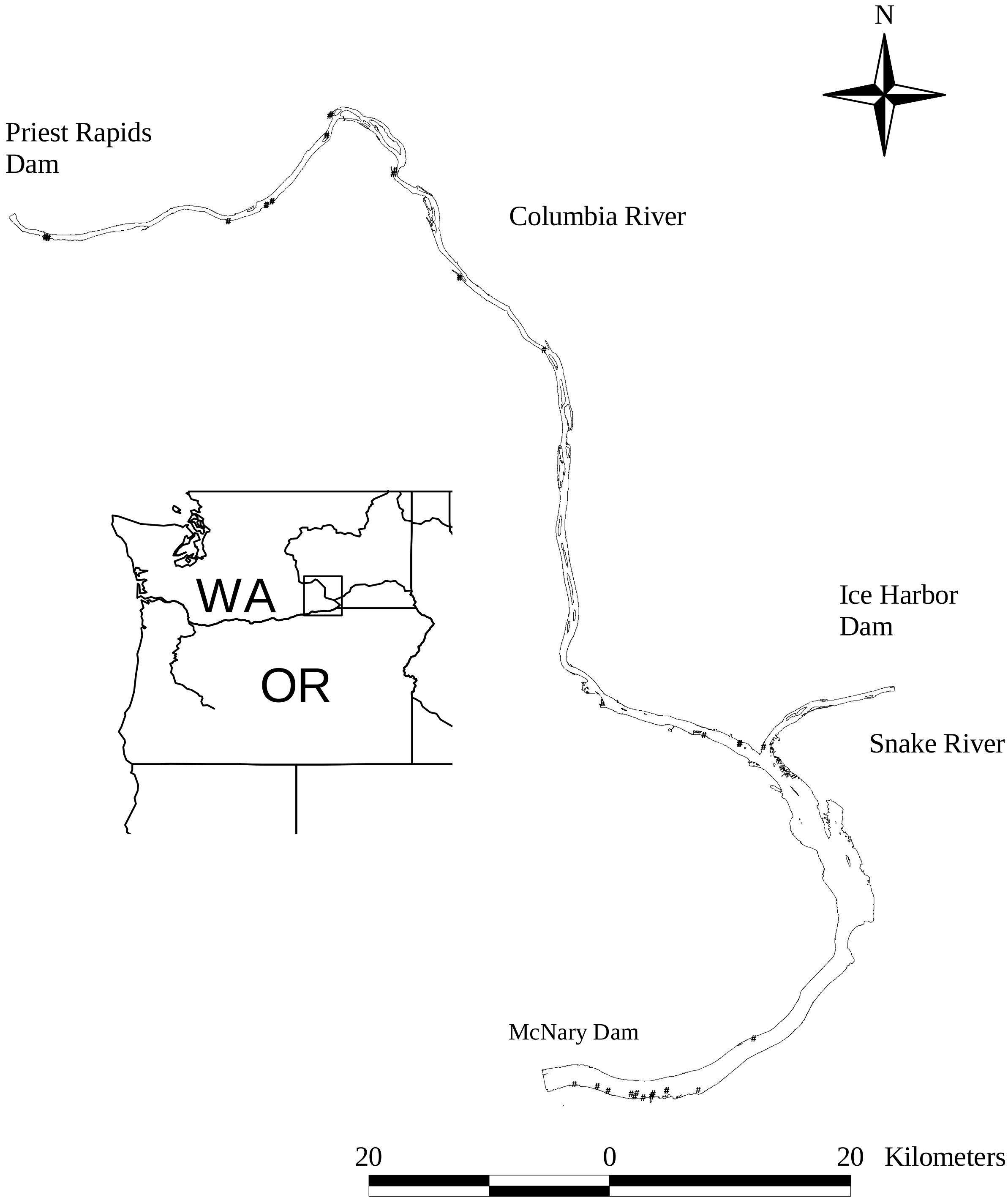

Figure 1. Locations (indicated by dots where 52 white sturgeons were captured and released in the Columbia and Snake rivers from May 1996 through February 1997. Several fish were captured and released at the same location.

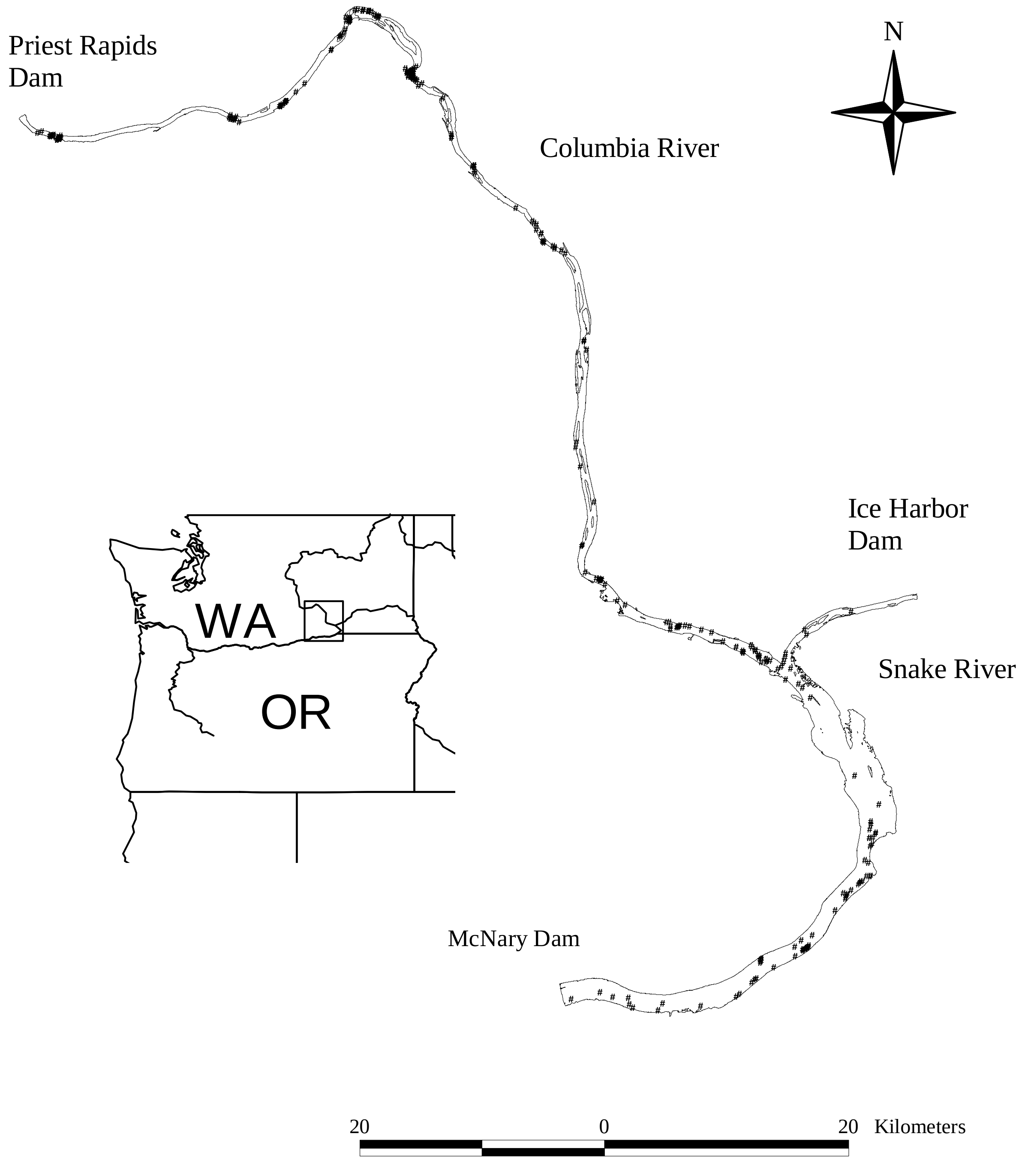

Figure 2. Locations (indicated by dots) where 45 white sturgeons were relocated in the Columbia and Snake rivers from May 1996 through February 1997.

The quantification of habitats for spawning and rearing within the McNary Reservoir, which includes the free-flowing Columbia River downstream from Priest Rapids Dam and the Snake River downstream from Ice Harbor Dam, will be completed when the suitability index curves describing habitat use are constructed from the telemetry study described above.

DISCUSSION

A variety of habitats are available for white sturgeons that reside in the Columbia and Snake rivers between McNary, Priest Rapids, and Ice Harbor dams (Figure 1). The Columbia River downstream from Priest Rapids Dam (river km 639) is considered free-flowing for approximately 84 km until backwater effects from McNary Dam (river km 470) reduce the water surface gradient and slow the water velocities. The reservoir created by McNary Dam is approximately 85 km in length, and the Snake River enters the reservoir at river km 523.

Habitat use by juvenile white sturgeons in reservoirs was previously investigated by Parsley et al. (1993) who used bottom trawls to capture fish. However, this gear does not capture adult fish, and proved to be ineffective in capturing juvenile fish from areas upstream from McNary Dam (Counihan et al. 1995). Thus, in 1996 we began a two-year study to determine the seasonal habitat use and movements of juvenile and adult white sturgeons residing in the Columbia and Snake rivers between Priest Rapids, Ice Harbor, and McNary dams. The study is still underway, and the results will be presented in a draft manuscript at a later date.

The bottom trawling for juvenile white sturgeons revealed that recruitment occurred in the Bonneville Reservoir. The majority (86%) of the white sturgeons captured were young of year; a larger percentage than that seen during the sampling in 1995 (59%; Parsley et al. in press). In 1996, young of year were captured at all 11 sites, but older juveniles were captured at only 7 of the 11 sites. A manuscript on the use of two methods to index the relative abundance of young-of-year white sturgeons is presented in Appendix C-2.

Plans for 1997

In 1997, the Biological Resources Division will continue to study the movements and habitat use by juvenile and adult white sturgeons in the McNary Pool study area. Additional white sturgeons will be fitted with transmitters as older transmitters expire, and tracking will occur during winter, spring, and summer. The methods will be similar to those used in 1996.

The Biological Resources Division will also initiate three new studies in 1997. One study will investigate the timing and duration of spawning by white sturgeons downstream from Lower Granite, Little Goose, and Lower Monumental dams on the Snake River. This study will use artificial substrates (McCabe and Beckman 1990) to attempt to collect eggs. The substrates will be fished during May, June, and July, or until water temperatures reach 20C.

The second study will investigate the timing of the development of white sturgeon eggs from broodstock from the lower Columbia, Snake, and Kootenai rivers. Fisheries professionals have been using relations developed by Wang et al. (1985) to back-calculate the time of spawning from eggs collected in the rivers, but the work done by Wang et al. (1985) was not intended to be used for this purpose. Though the authors give estimates of the time necessary to reach a particular developmental stage, they did not characterize the variability among samples used to derive the estimates. Also, the work done by Wang et al. (1985) was based on the development of embryos from broodstock taken from the Sacramento River, which may differ in developmental time from broodstock from the Columbia River basin.

A third study will investigate the effects of external transmitter placement on the swimming performance of small white sturgeons. We will conduct experiments with a swimming tunnel to determine if the weight and placement of transmitters hinder swimming performance.

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APPENDIX C-1

The Effects of Dissolved Gas Supersaturation on White Sturgeon Larvae

by

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This manuscript has been published in the journal *Transactions of the American Fisheries Society*. Therefore, we have elected to not reproduce the text here. Please contact the authors at the address listed above for a reprint of the original journal article.

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APPENDIX C-2

Indexing the Relative Abundance of Young-of-the-Year White Sturgeon in an impoundment of the Lower Columbia River from Highly Skewed Trawling Data

by

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The citation is:

Counihan, T.D., A.I. Miller, and M.J. Parsley. In press. Indexing the relative abundance of age-0 white sturgeon in an impoundment of the lower Columbia River from highly-skewed trawling data. North American Journal of Fisheries Management.

APPENDIX C-3

Monthly and annual indices of white sturgeon spawning habitat. The indices are temperature conditioned weighted usable areas (hectares) and were derived following the methodology used by Parsley and Beckman (1994).

Bonneville Dam Tailrace

Month	Year											
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
April	10.35	5.77	17.19	14.42	30.64	22.76	7.02	29.17	9.03	32.33	53.55	18.32
May	105.83	77.42	140.80	113.42	149.39	99.85	83.87	128.05	143.04	129.67	129.31	106.80
June	65.09	51.40	48.36	74.90	46.23	138.61	156.17	19.82	97.70	53.24	35.74	156.71
July	0.12	0.34	0.00	2.28	1.09	9.04	3.77	0.00	11.41	3.20	0.00	5.78
Sum	181.39	134.93	206.35	205.02	227.35	270.26	250.83	177.04	261.18	218.44	218.60	287.61
Annual mean	45.47	33.82	51.90	51.36	57.14	67.35	62.40	44.58	65.49	54.81	54.81	71.65
Standard deviation	57.92	47.73	62.07	56.39	63.63	64.39	69.69	52.61	69.55	53.61	58.50	70.34
Coef. var	1.27	1.41	1.20	1.10	1.11	0.96	1.12	1.18	1.06	0.98	1.07	0.98

APPENDIX C-3 continued.

The Dalles Dam Tailrace

Month	Year											
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
April	6.70	4.97	4.32	2.06	11.98	10.89	1.85	7.07	1.65	6.77	5.35	5.05
May	54.77	58.36	72.81	42.60	89.10	46.63	61.90	51.49	109.77	53.49	73.66	73.30
June	22.76	30.94	17.18	26.49	26.83	112.71	107.84	6.13	55.80	30.20	77.98	169.67
July	0.05	0.14	0.01	0.11	0.28	4.48	5.92	0.00	2.45	0.48	1.52	6.54
Sum	84.28	94.41	94.32	71.26	128.19	174.71	177.51	64.69	169.67	90.94	158.51	254.56
Annual mean	21.17	23.69	23.79	17.87	32.25	43.38	44.20	16.33	42.64	22.81	39.59	63.25
Standard deviation	27.74	37.45	34.19	24.32	40.24	52.24	51.39	22.64	58.23	24.23	44.11	74.94
Coef. var	1.31	1.58	1.44	1.36	1.25	1.20	1.16	1.39	1.37	1.06	1.11	1.18

APPENDIX C-3 continued.

John Day Dam Tailrace

Month	Year											
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
April	9.25	1.44	4.63	1.16	14.43	16.38	3.14	8.81	1.84	11.35	6.09	4.88
May	93.29	75.43	118.25	65.26	127.92	76.66	108.81	88.28	195.73	99.08	123.00	115.81
June	41.60	79.12	28.75	41.10	50.63	200.49	188.32	10.79	96.93	55.55	152.23	296.08
July	0.20	1.40	0.17	0.24	0.15	9.16	11.98	0.00	3.53	0.64	4.25	14.02
Sum	144.34	157.39	151.80	107.76	193.13	302.69	312.25	107.88	298.03	166.62	285.57	430.79
Annual mean	36.26	39.33	38.30	27.04	48.54	75.13	77.77	27.25	74.92	41.79	71.27	107.00
Standard deviation	49.57	66.44	57.77	41.28	61.80	92.72	90.21	39.10	104.12	45.36	80.21	127.57
Coef. var	1.37	1.69	1.51	1.53	1.27	1.23	1.16	1.43	1.39	1.09	1.13	1.19

APPENDIX C-3 continued.

McNary Dam Tailrace

Month	Year											
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
April	12.70	3.36	3.57	0.91	9.99	11.26	2.07	6.23	1.48	8.22	4.83	4.52
May	92.46	99.49	102.39	43.73	114.66	81.20	105.19	81.37	205.26	86.00	137.37	115.19
June	56.47	138.72	27.46	25.00	59.62	247.90	228.91	16.47	124.67	67.54	196.16	385.34
July	0.06	0.17	0.00	0.00	0.05	15.73	20.77	0.00	4.87	0.72	4.67	22.91
Sum	161.69	241.74	133.42	69.64	184.32	356.09	356.94	104.07	336.28	162.48	343.03	527.96
Annual mean	40.52	60.26	33.65	17.48	46.27	88.36	88.80	26.26	84.42	40.67	85.52	130.96
Standard deviation	54.48	103.89	55.68	29.85	59.60	115.08	104.21	38.94	117.56	45.51	101.22	162.28
Coef. var	1.34	1.72	1.65	1.71	1.29	1.30	1.17	1.48	1.39	1.12	1.18	1.24

EFFECTS OF MITIGATIVE MEASURES ON PRODUCTIVITY OF WHITE STURGEON POPULATIONS IN THE COLUMBIA RIVER DOWNSTREAM FROM MCNARY DAM, AND DETERMINE THE STATUS AND HABITAT REQUIREMENTS OF WHITE STURGEON POPULATIONS IN THE COLUMBIA AND SNAKE RIVERS UPSTREAM FROM MCNARY DAM.

ANNUAL PROGRESS REPORT

APRIL 1996 - MARCH 1997

Report D

Describe reproductive and early life history characteristics of white sturgeon in McNary Reservoir and downstream from Bonneville Dam

This report includes: Investigations on juvenile and young-of-year white sturgeon downstream from Bonneville Dam

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February 1998

CONTENTS

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Lawrence Davis and Dennis Umphfres assisted in the field sampling.

ABSTRACT

In September 1996, the National Marine Fisheries Service (NMFS) sampled juvenile white sturgeon (*Acipenser transmontanus*) in the Columbia River downstream from Bonneville Dam (River Mile (RM) 145). We collected 170 juvenile white sturgeon, including 60 young-of-the-year (YOY), with a 7.9-m (headrope length) semiballoon shrimp trawl between RM 28 and 132. The distribution of juvenile white sturgeon was patchy. The YOY white sturgeon comprised about 35% of the total catch of juvenile white sturgeon. Densities of YOY white sturgeon at 13 index sampling stations averaged 6.7 fish/hectare during the first survey (3-10 September) and 11.7 fish/hectare during the second survey (16-19 September); the mean for both surveys combined was 9.2 fish/hectare.

INTRODUCTION

Under an agreement with the Oregon Department of Fish and Wildlife (ODFW), the National Marine Fisheries Service (NMFS) conducted research to describe the reproductive and early life history characteristics of white sturgeon downstream from Bonneville Dam. This reach was used as a control area for Phase I of the White Sturgeon Study (1986-1992) and is being used in a similar manner for Phase II (1992-1997). Data collected in the control area will be used in conjunction with data from upstream impoundments to help determine the effects of the development and operation of the hydroelectric system on white sturgeon spawning and recruitment. The specific goal for 1996 was to estimate the relative success of young-of-the-year (YOY) white sturgeon recruitment in 1996 in the Columbia River downstream from Bonneville Dam. This report describes progress on NMFS studies that were conducted from 1 April 1996 through 31 March 1997.

METHODS

Juvenile Sampling

A 7.9-m (headrope length) semiballoon shrimp trawl, identical to that used from 1987 through 1995, was used to collect juvenile white sturgeon, including YOY. Mesh size in the trawl was 38 mm (stretched measure) in the body; a 10-mm mesh liner was inserted in the cod end of the net. Shrimp trawl efforts were usually 5 to 7 min in duration in an upstream direction. The trawling effort began when the trawl and the proper amount of cable were deployed, and the effort was considered ended when 5 to 7 min had elapsed. We estimated the distance the net fished during each sampling effort using a radar range-finder.

Trawling was conducted during two surveys in September at 36 sampling stations established during Phase I of the White Sturgeon Study in the lower Columbia River between River Mile (RM) 28 and 132. The sampling stations were originally selected primarily to determine habitat use by juvenile white sturgeon; no attempt was made to randomly select the stations. In some areas, two or three trawling efforts were completed along parallel transects. Transect 1 was closest to the Washington shore, Transect 2 was the middle transect, and Transect 3 was closest to the Oregon shore. Thirteen of the 36 sampling stations were selected as index sites for estimating YOY white sturgeon densities in the lower Columbia River (Figure 1).

Fishes captured in the shrimp trawls were identified and counted. White sturgeon from each sampling effort were measured (total and fork lengths (mm)) and weighed (g). Small YOY sturgeon (those less than about 150 mm fork length) do not have distinct forks in their tails; therefore I estimated their fork lengths to ensure consistency in data analysis. In previous years, all length comparisons of older juveniles were done using fork lengths, since natural total lengths are much less accurate. On older juvenile sturgeon (those with a fork in their tails), I observed that the distal end of an imaginary line, extended along the lateral row of scutes (before it turns upward) onto the caudal fin, approximated the location of the fork. I routinely examined juvenile white sturgeon longer than 174 mm fork length for the nematode parasite *Cystoopsis acipenseri*

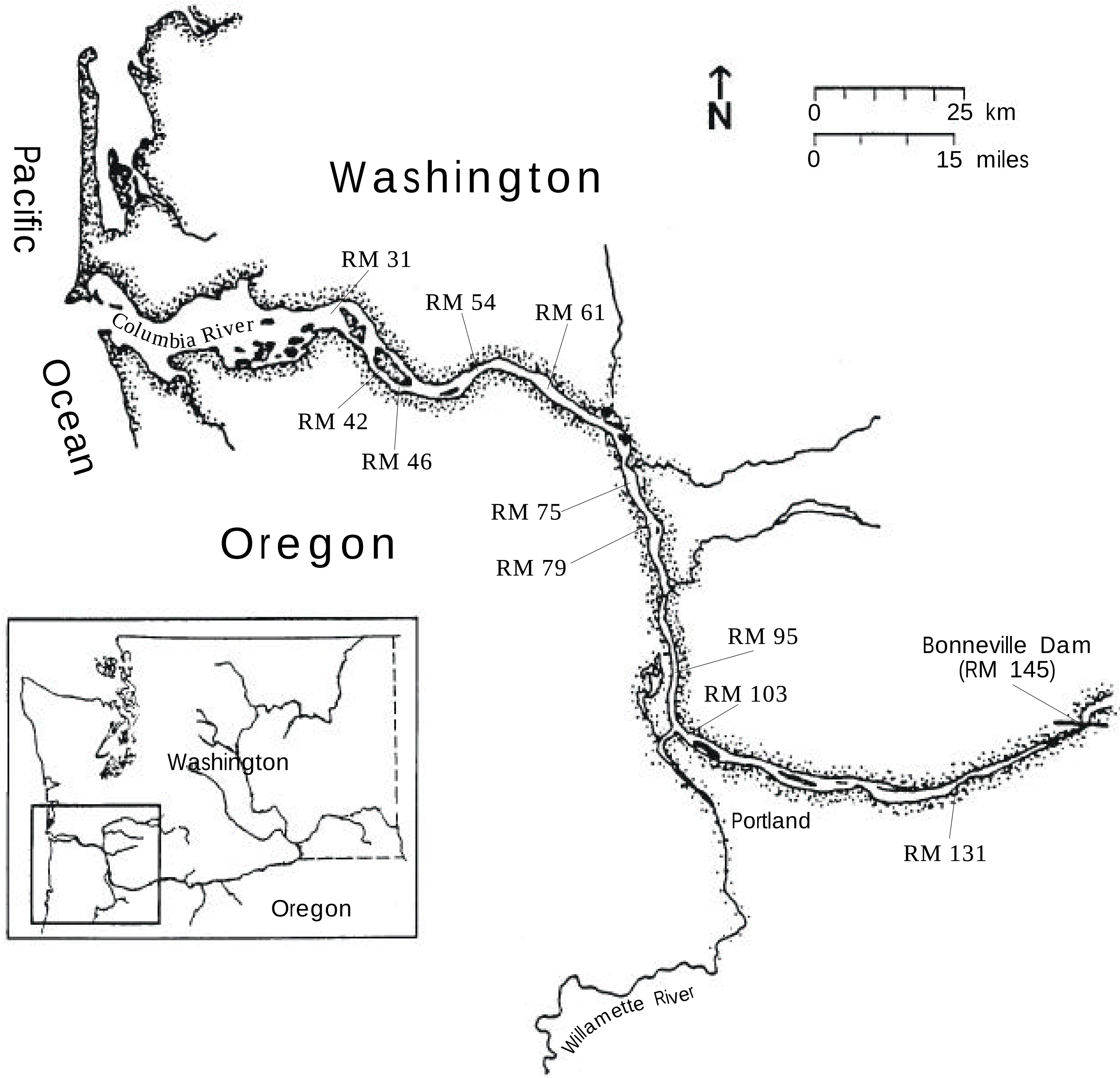

Figure 1. Location of the white sturgeon study area in the Columbia River downstream from Bonneville Dam. The specific locations of the thirteen index trawling stations are shown; at RMs 79, 95, and 131 two stations were sampled. No sampling was done at RM 145.

(Chitwood and McIntosh 1950; McCabe 1993). When present, the parasite is encased in blister-like cysts under the skin.

Physical Conditions

The following physical parameters were measured in conjunction with juvenile sturgeon sampling in September 1996: bottom depth (m) (minimum and maximum), bottom-water temperature (°C), and bottom-water turbidity (NTU). Depth was measured with an electronic depth sounder. A Van Dorn water bottle was used to collect water samples just above the bottom. The water temperature of each sample was measured immediately after collection, and a subsample of water was removed and placed in a glass bottle. The turbidity of the sample was determined in the laboratory using a Hach Model 2100A Turbidimeter[1]. All physical and accompanying fish catch data are available upon request from NMFS, Northwest Fisheries Science Center, Point Adams Biological Field Station, P.O. Box 155, Hammond, Oregon 97121.

Data Analyses

Physical and biological data collected during September 1996 were entered into computer files following formats agreed to by the original cooperating agencies involved in the White Sturgeon Study: Biological Resources Division (U.S. Geological Survey), ODFW, NMFS, and the Washington Department of Fish and Wildlife.

Using the distance fished during a shrimp trawl effort and the estimated fishing width of the net (5.3 m), I calculated the area fished for each effort. Fish densities (by species) for each effort were calculated and expressed as number/hectare (10,000 m^2).

The YOY white sturgeon were distinguished from older juvenile sturgeon using length frequencies.

RESULTS

In September 1996, 170 juvenile white sturgeon were collected between RM 28 and 132. Distribution of juvenile white sturgeon in this section of the river was patchy. The YOY group was the only age group that was easily discernible in a length-frequency histogram, as there was overlap in the lengths of the older age groups (Figure 2). The mean fork length ($\pm$ SD) and weight ($\pm$ SD) of 60 YOY white sturgeon collected were 147 mm ($\pm$ 36 mm) and 26 g ($\pm$ 16 g), respectively. Variations in the lengths and weights of YOY were considerable--lengths ranged from 70 to 220 mm and weights ranged from 3 to 70 g.

[1] *Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.*

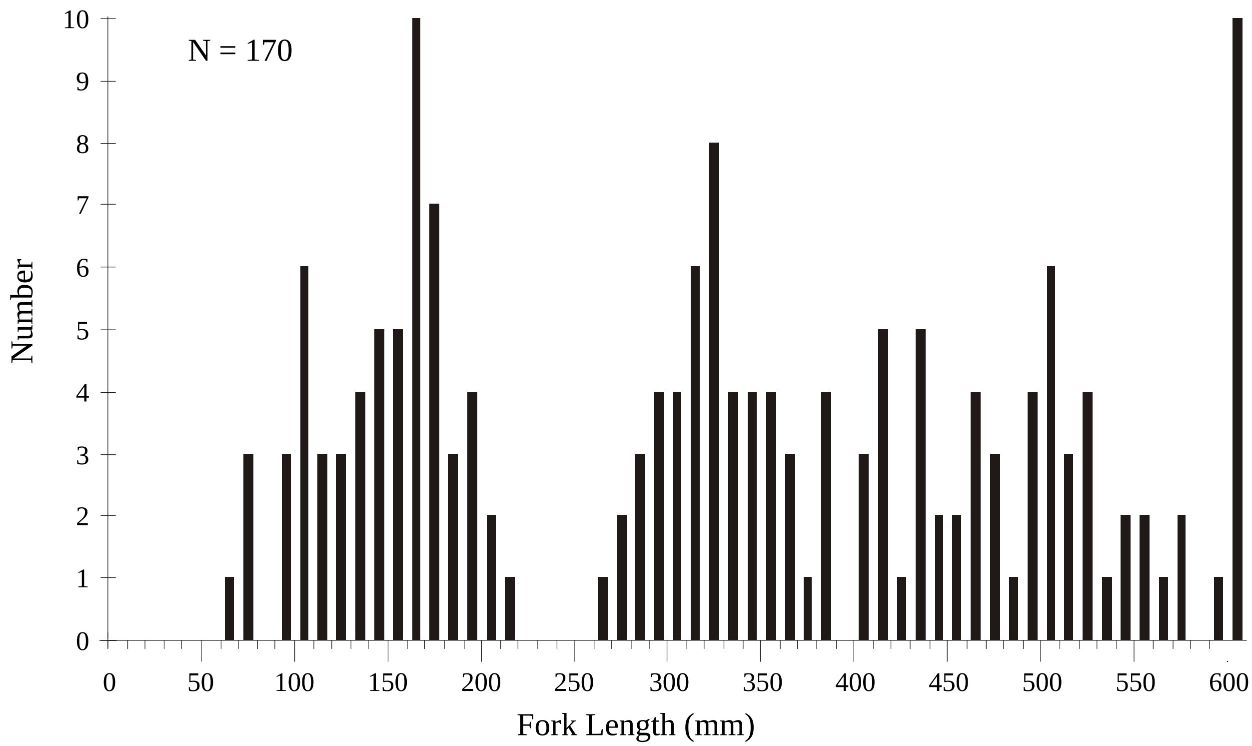

Figure 2. Length-frequency histogram for juvenile white sturgeon collected in the Columbia River downstream from Bonneville Dam, 1996. White sturgeon longer than 600 mm are included in the 600-mm interval.

In 1996, 60 YOY white sturgeon were collected between RM 28 and 132; YOY comprised about 35% of the total catch of juvenile white sturgeon. Densities of YOY white sturgeon at 13 index sampling stations averaged 6.7 fish/hectare during the first survey (3-10 September) and 11.7 fish/hectare during the second survey (16-19 September); the mean for both surveys combined was 9.2 fish/hectare (Table 1).

Twenty eight (22%) of 126 juvenile white sturgeon were infected with the nematode parasite *Cystoopsis acipenseri*. The mean fork length of infected fish was 318 mm, with a range from 266 to 361 mm.

DISCUSSION

Young-of-the-Year

Densities (number/hectare) of YOY white sturgeon at 13 index trawling stations in mid September 1996 (second survey) were not significantly different (Kruskal-Wallis, $P = 0.32$) from densities at the same sites in mid to late September of 1991, 1993, 1994, and 1995. No sampling was conducted in September 1992. Densities at the 13 stations averaged 6.7, 9.0, 2.3, 11.0, and 11.7 YOY/hectare in 1991, 1993, 1994, 1995, and 1996, respectively (Table 2). In all years, catches at 31% or more of the stations were zero. Young-of-the-year white sturgeon were collected over a similar geographic area in September 1996 as in September 1991, 1993, and 1995 (includes all sampling data from September of all years). In September of 1991, 1993, 1995, and 1996, YOY white sturgeon were collected between RM 28 and 131/132. However, in 1994, YOY white sturgeon were only collected between RM 61 and 132. In 1996, as in 1991, 1993, and 1995, the side channel near Goble, Oregon (RM 75), was a productive sampling site for YOY white sturgeon. No YOY white sturgeon were captured at this site in September 1994. The lower catches of YOY white sturgeon in mid to late September and the smaller area of capture in 1994 (all September sampling) compared to 1991, 1993, 1995, and 1996 may have been due to lower river flows in 1994 during the larval life stage (Table 3). After hatching, white sturgeon larvae are dispersed out of the spawning and egg incubation areas by river currents. In the Sacramento-San Joaquin Delta, California, Stevens and Miller (1970) observed a direct relationship between river flow into the Delta and catches of white or green sturgeon (*Acipenser medirostris*) larvae, or both.

The mean fork length of YOY white sturgeon collected in September 1996 was significantly shorter than those of YOY collected in September of 1993, 1994, and 1995 (two sample t-test, $P = 0.00$). It is uncertain why YOY white sturgeon were shorter in 1996 than in the three previous years. Possible causes of the shorter mean length observed in 1996 include one or more of the following: 1) later spawning in 1996, 2) slower growth during the larval and postlarval stages, and 3) unsuccessful recruitment from eggs spawned during the early part of the spawning period. No sampling was conducted for white sturgeon eggs and larvae during the spawning period in 1996. However, the water temperature at Bonneville Dam reached 10°C by 16 April. Spawning of white sturgeon downstream from Bonneville Dam occurs at water temperatures ranging from 10 to 19°C, with the spawning period extending from late April or early May through late June or early July (McCabe and Tracy 1994). In 1996, water temperatures during the

Table 1. Catches of young-of-the-year white sturgeon in September 1996 at 13 sampling stations in the Columbia River downstream from Bonneville Dam. Each value represents the results from one trawling effort. Location is shown in River Miles (RM) and in some instances a transect number is shown when parallel trawling efforts were done at the same RM.

Location (RM)	3-10 September		16-19 September	
	Number	Number/hectare	Number	Number/hectare
31	4	19	5	23
42	2	10	1	5
46	2	9	0	0
54	1	5	4	17
61	0	0	0	0
75	3	15	9	102
79-1	1	5	0	0
79-2	0	0	0	0
95-1	1	4	0	0
95-2	0	0	0	0
103	5	20	0	0
131-1	0	0	0	0
131-2	0	0	1	5
Mean	1.5	6.7	1.5	11.7

Table 2. Densities (number/hectare) of young-of-the-year white sturgeon in mid to late September of 1991 and 1993-1996 at 13 sampling stations in the Columbia River downstream from Bonneville Dam. Each value represents the results from one trawling effort. Location is shown in River Miles (RM) and in some instances a transect number is shown when parallel trawling efforts were done at the same RM.

Location (RM)	1991	1993	1994	1995	1996
31	12	0	0	10	23
42	0	0	0	0	5
46	0	6	0	4	0
54	0	15	0	0	17
61	6	5	6	14	0
75	48	18	0	77	102
79-1	5	35	0	8	0
79-2	8	9	0	4	0
95-1	4	0	4	0	0
95-2	0	0	4	0	0
103	0	5	12	26	0
131-1	0	15	4	0	0
131-2	4	9	0	0	5
Mean	6.7	9.0	2.3	11.0	11.7

Table 3. Summaries of river conditions at Bonneville Dam from April through August, 1993-1996 (U.S. Army Corps of Engineers, Portland District). Each value is an average for the specific month shown.

Year	April	May	June	July	August
			Water temperature (°C)		
1993	11.4	13.8	16.6	19.0	20.8
1994	10.7	14.7	16.8	20.4	22.0
1995	10.1	13.8	16.9	20.3	20.9
1996	9.4	12.4	15.7	19.7	20.9
			Bonneville Dam discharge (m^3/s x 1,000)		
1993	4.61	8.45	6.46	4.73	3.41
1994	4.36	6.00	5.52	4.31	2.68
1995	5.28	7.54	8.02	5.72	4.17
1996	9.36	9.94	10.90	7.02	5.35

spawning period were generally slightly colder than those during the three previous years (Table 3). The lower water temperatures in 1996 (April-July) may have delayed peak spawning and slowed the growth of white sturgeon larvae and postlarvae. In 1996, river flows throughout the spawning and larval dispersal periods were higher than those during 1993, 1994, and 1995 (Table 3). Food resources for postlarval sturgeon may have been less abundant in 1996 than in the previous years. Possibly, the higher river flows in 1996 reduced the abundance of benthic invertebrates, the primary prey of YOY white sturgeon (Muir et al. 1988), in rearing areas by scouring more benthic invertebrates out of rearing areas than in 1993, 1994, and 1995.

Plans for 1997

In 1997, NMFS will replicate the sampling done in 1996 to estimate the relative success of YOY-white sturgeon recruitment in the Columbia River downstream from Bonneville Dam.

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EFFECTS OF MITIGATIVE MEASURES ON PRODUCTIVITY OF WHITE STURGEON POPULATIONS IN THE COLUMBIA RIVER DOWNSTREAM FROM MCNARY DAM, AND DETERMINE THE STATUS AND HABITAT REQUIREMENTS OF WHITE STURGEON POPULATIONS IN THE COLUMBIA AND SNAKE RIVERS UPSTREAM FROM MCNARY DAM.

ANNUAL PROGRESS REPORT

APRIL 1996 - MARCH 1997

Report E

Quantify physical habitat used by spawning and rearing white sturgeon in the free-flowing portion of the Columbia River between McNary Reservoir and Priest Rapids Dam and in the free-flowing portion of the Snake River between McNary Reservoir and Ice Harbor Dam

This report includes: Physical habitat measurements at various river discharges in free-flowing portions of the lower Columbia and Snake rivers

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CONTENTS

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ABSTRACT

The U.S. Fish and Wildlife Service revisited all 129 main channel cross sections in the Columbia River between White Bluffs and Priest Rapids Dam, and in the lower Snake River between McNary Reservoir and Ice Harbor Dam during 1996 for white sturgeon (*Acipenser transmontanus*) habitat quantification. Stage-discharge work included measurement of 231 data pairs for 117 cross sections in the Columbia River at discharges ranging from 1,459 to 7,593 m^3/s. Stage-discharge data pairs were also collected for the seven Snake River main channel cross sections at discharges ranging from 567 to 2,833 m^3/s. In-river substrate was characterized on all cross sections in the study area using an underwater video camera. Global Positioning System (GPS) coordinates were collected for substrate locations on a subset of cross sections. Additional bank points were surveyed to accommodate hydraulic modeling for discharges up to 14,164 m^3/s in the Columbia River and 11,300 m^3/s in the Snake River. Stage-discharge data pairs, substrate data, and new bank profiles were added to cross section data files and hydraulic model calibration was partially completed. Reconnaissance surveys were conducted in the Columbia River between Coyote Rapids and White Bluffs, within the White Bluffs Island Complex, at individual islands in the Snake River downstream from Ice Harbor Dam, and in the tailrace areas downstream from Lower Monumental, Little Goose, and Lower Granite dams to characterize river channel morphology and determine cross section placement for field data collection in 1997. We assisted Thomas R. Payne and Associates with programming enhancements to the import subroutine for hydraulic data files. Velocity processing algorithms were refined to produce a more accurate representation of mean column velocity and to normalize velocities to the cross section. Resulting discharge calculations tracked Acoustic Doppler Current Profiler (ADCP) field measurements more accurately and consistently.

INTRODUCTION

This report describes work conducted by the U.S. Fish and Wildlife Service (USFWS) from 1 April 1996 to 31 March 1997 as part of white sturgeon (*Acipenser transmontanus)* studies under the Bonneville Power Administration's Project 86-50 on the mainstem Columbia and Snake rivers. The U.S. Fish and Wildlife Service is cooperating with the Biological Resources Division (BRD) of the U.S. Geological Survey on studies designated under Goal 3, Objective 3 of the program. The purpose of Goal 3 is to evaluate the need and identify potential measures for protecting and enhancing white sturgeon populations and mitigating for effects of the hydropower system on productivity of white sturgeon in the Columbia and Snake rivers upstream from McNary Dam. Under Objective 3, USFWS is responsible for quantification of physical habitat for white sturgeon in the following areas upstream from McNary Dam:

1) Spawning and rearing habitat in the free-flowing portion of the Columbia River between the White Bluffs boat ramp and Priest Rapids Dam (Hanford Reach);

2) Spawning and rearing habitat in the free-flowing portion of the Snake River between the confluence with the Columbia River and Ice Harbor Dam;

3) Spawning and rearing habitat in the tailrace areas downstream from Lower Monumental, Little Goose, and Lower Granite dams.

Specific tasks conducted by USFWS during this period were:

1) Measurement of horizontal and vertical cross section profiles to accommodate modeling of high flows which occurred during the period of record (time period for which streamflow records have been recorded) for main channel portions of the Columbia River between the White Bluffs boat ramp and Priest Rapids Dam, and for main channel portions of the Snake River between the confluence with the Columbia River and Ice Harbor Dam;

2) Measurement of cross section water surface elevation (stage)-discharge data pairs for Columbia and Snake river main channel cross sections;

3) Determination of geographic locations for cross section headpins, reference marks, and some substrate locations using Global Positioning System (GPS) receivers in the area described in Task 1;

4) Characterization of in-river substrate using underwater video for the area described in Task 1;

5) Reconnaissance and study design for islands and island complexes in the area described in Task 1, as well as in the tailrace areas downstream from Lower Monumental, Little Goose, and Lower Granite dams;

6) Data reduction and import of Acoustic Doppler Current Profiler (ADCP) raw data files into hydraulic modeling programs, integration of survey data and substrate characteristics

with hydraulic data for the Columbia River, and continued stage-discharge data entry for the Snake River;

7) Hydraulic model calibration and hydraulic modeling for the Columbia River.

METHODS

Field Data Collection

The sampling program was designed to acquire field data for analysis using the Physical Habitat Simulation System (PHABSIM), which was developed as part of the Instream Flow Incremental Methodology (IFIM; Bovee 1982). Within the PHABSIM, field measurements of depth, water column velocity, water elevation, river gradient, and river discharge are used to calibrate hydraulic models for simulation of depths and velocities at unmeasured discharges (Bovee and Milhous 1978; Milhous et al. 1989). Outputs from the hydraulic models along with substrate or cover characteristics and any relevant water quality parameters (usually water temperature) are then compared to habitat suitability criteria for the species/lifestage of interest to predict habitat quality and quantity over a range of river discharges. Hydraulic and habitat modeling algorithms and other data processing functions have been re-programmed into a user-friendly, menu-driven software package known as Riverine Habitat Simulation (RHABSIM)[1]. RHABSIM is fully compatible with PHABSIM and provides the same capabilities in addition to many enhancements, particularly graphics (Payne 1994). The RHABSIM system was used in place of PHABSIM for data entry and initial hydraulic model calibration, and will continue to be used throughout the remainder of this analysis for hydraulic and habitat modeling.

Hydraulic data collection, which began in 1994, was completed during 1996 for main channel sections of the Columbia River between the White Bluffs boat ramp near river mile (RM) 368 and Priest Rapids Dam (RM 397). Data collection continued for main channel cross sections in the Snake River between McNary Pool (RM 4.5) and Ice Harbor Dam (RM 10) (Figure 1). River segmentation and cross section placement were based on a sensitivity analysis conducted in early 1994 and are discussed in greater detail in the 1993 and 1994 Annual Reports (Anglin 1995, Anglin 1996). Cross sections were marked on each riverbank above the high water mark with painted lath and rebar capped with labeled plastic surveying markers. A reference mark was established near each cross section on a stationary object (usually a large boulder) to be used as a relative datum for cross section profile and water surface elevation surveys.

An electronic total station was used to measure riverbank profiles and water surface elevations, and an ADCP was used to measure depths, water column velocities, and discharge on

[1] Reference to trade names does not imply endorsement by the U.S. Fish and Wildlife Service, DOI.

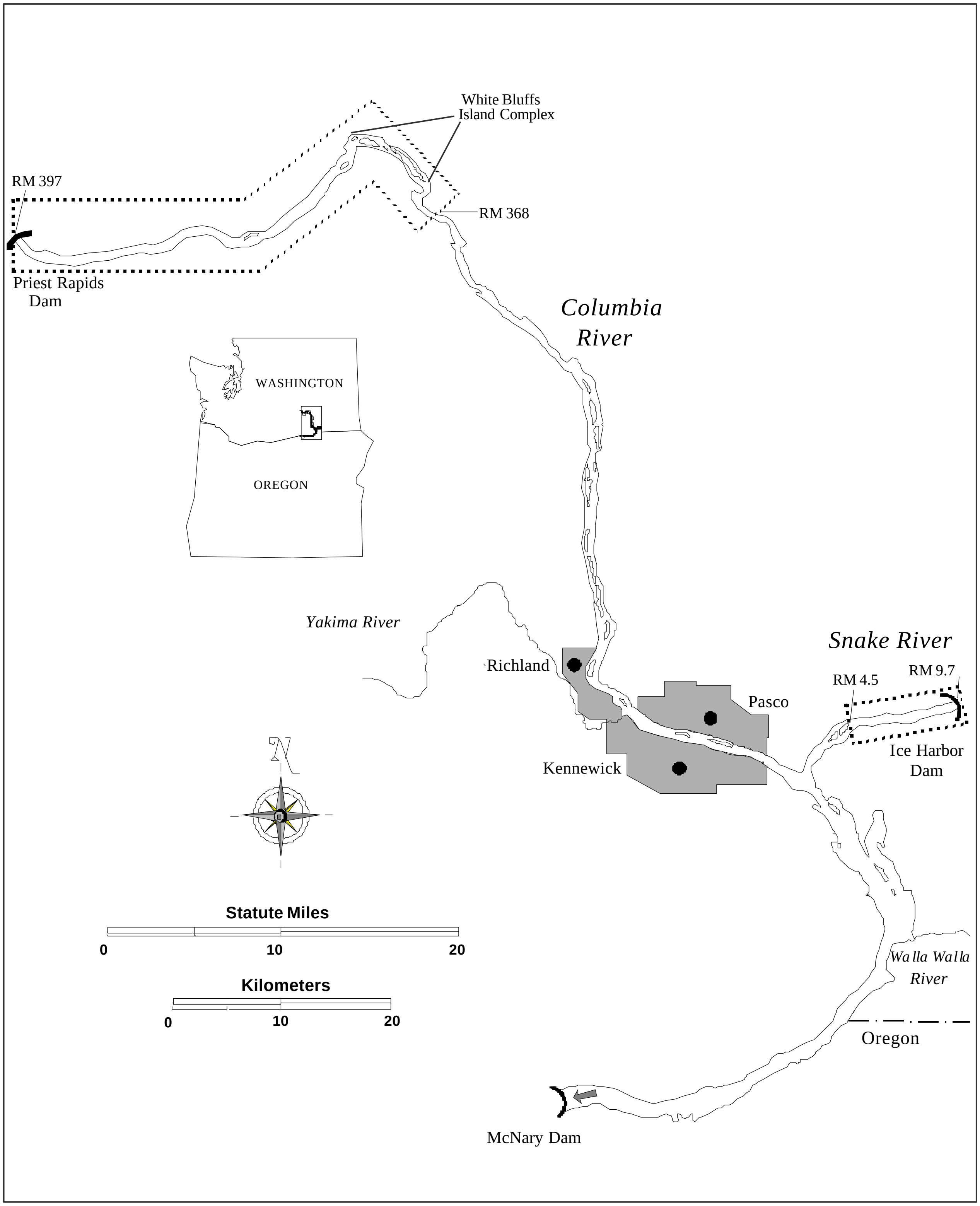

Figure 1. Location of study area between White Bluffs and Priest Rapids Dam on the Columbia River and downstream from Ice Harbor Dam on the Snake River.

each cross section. An electronic total station uses laser technology to measure distance while electronically compensating for atmospheric conditions and curvature of the earth. Horizontal and vertical angles are measured electronically and combined with distance measurements to provide slope distance, horizontal distance, and vertical difference (elevation). The ADCP uses the Doppler effect (the apparent change in the frequency of a wave resulting from relative motion of the source and the receiver) to measure the motion, direction, and depth of water from the returning echoes of four acoustic beams (RD Instruments 1989).

River bank profiles consisted of horizontal distance (between cross section endpoints) and elevation (relative to the cross section reference mark) for a variable number of points down to the water's edge for description of the bank contour. Additional bank points were surveyed and added to each data file to accommodate the elevations necessary for modeling the relatively high discharges which occurred during the period of record for the Columbia and Snake rivers.

Velocity distributions were collected for a single discharge on each cross section and relative water surface elevations (stages) were collected for up to four additional discharges (stage-discharge pairs) on each cross section in the Columbia River. Stage-discharge work is ongoing in the Snake River. A larger data set with more complete coverage of the entire flow range is required to describe the backwater effect from McNary Pool on Snake River cross sectional area and resulting velocity simulations. Velocity distributions were comprised of up to 125 measurements of water column velocity for depth cells or bins ranging from 25 to 50 cm in size, from approximately 0.6 m below the water surface to approximately 0.5 m above the river bottom. Portable electromagnetic flowmeters were used to collect velocity data from near shore areas which were too shallow for ADCP data collection (Figure 2).

Velocity distributions were measured by slowly traversing a cross section normal to the direction of flow. ADCP runs were started near the cross section headpin at a depth of approximately 1 m and were terminated on the opposite side of the river at a depth of 0.5-1.0 m, depending on bank slope. At least two runs were made in opposite directions at each cross section. Software that is used to configure and operate the ADCP allows the user to view data collection in real time, thus providing some assurance that the data is valid, or at least reasonable. Various aspects of the data can be viewed in different formats. The shiptrack plot (Figure 3) shows the course followed for the cross section run based on navigation data from the GPS receiver. Latitude and longitude, boat speed across the river bottom, and course referenced to navigation data from the GPS receiver for the current data point (termed “data ensemble”) are shown on the right side of the screen under the “Vessel (Nav)” heading. Since the runs start and end near the cross section headpins, the shiptrack plot shows the deviation of the run relative to the desired straight line course. The shiptrack plot also shows velocity magnitude and direction for each data ensemble in user-selected depth cells. Irregular or erratic patterns of either velocity magnitude or velocity direction across the channel may indicate configuration modifications are needed for the ADCP to more effectively measure the observed non-laminar flow conditions, as well as serving as a visual quality control check for obvious errors or problems.

Tabular velocity output (Figure 4) is also monitored during data collection to evaluate the numerical details of the velocity vector data. The east and north vectors represent the horizontal

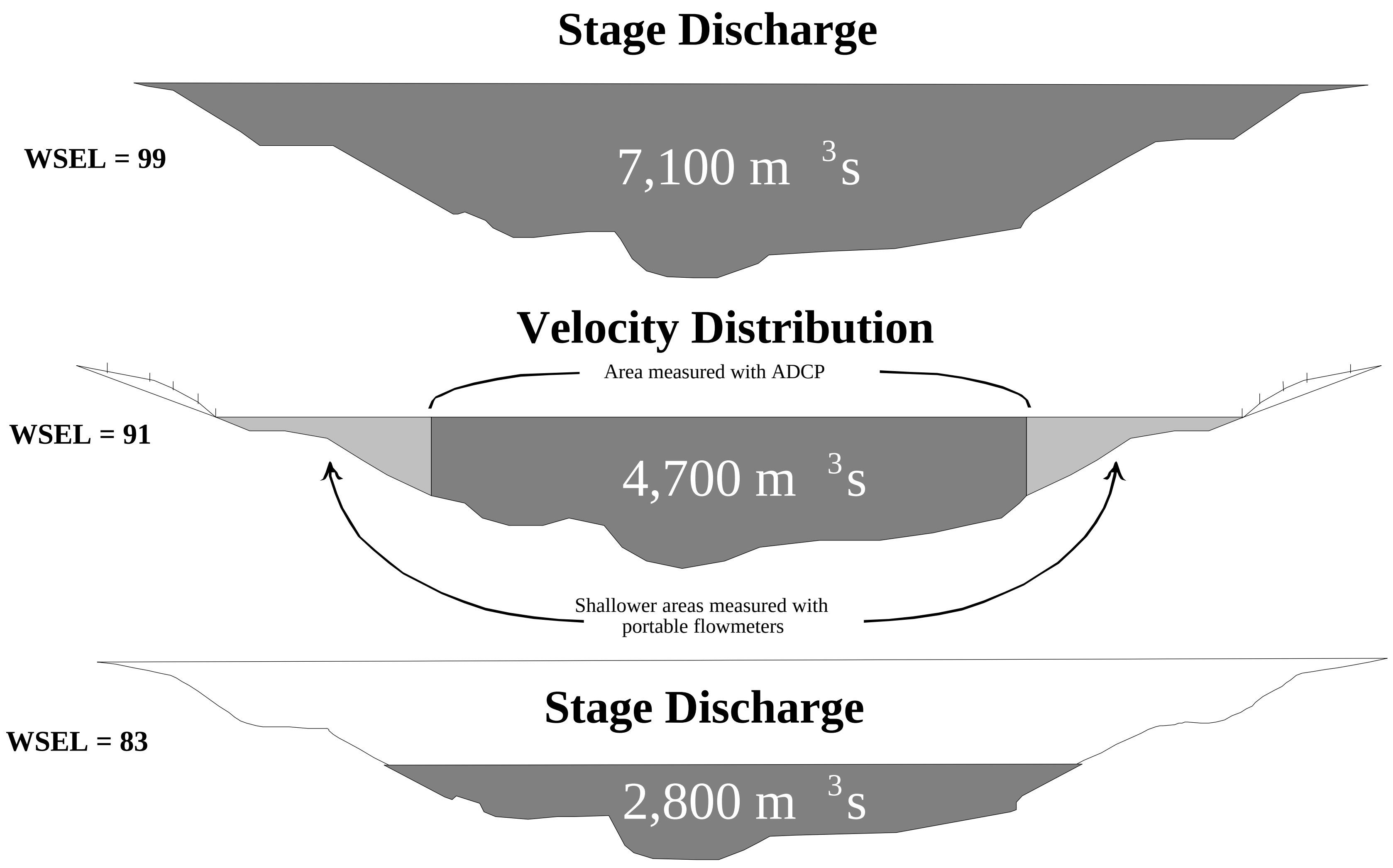

Figure 2. Sample cross section showing velocity distribution with location of ADCP and flowmeter measurements, bracketed by a higher and lower stage-discharge point.

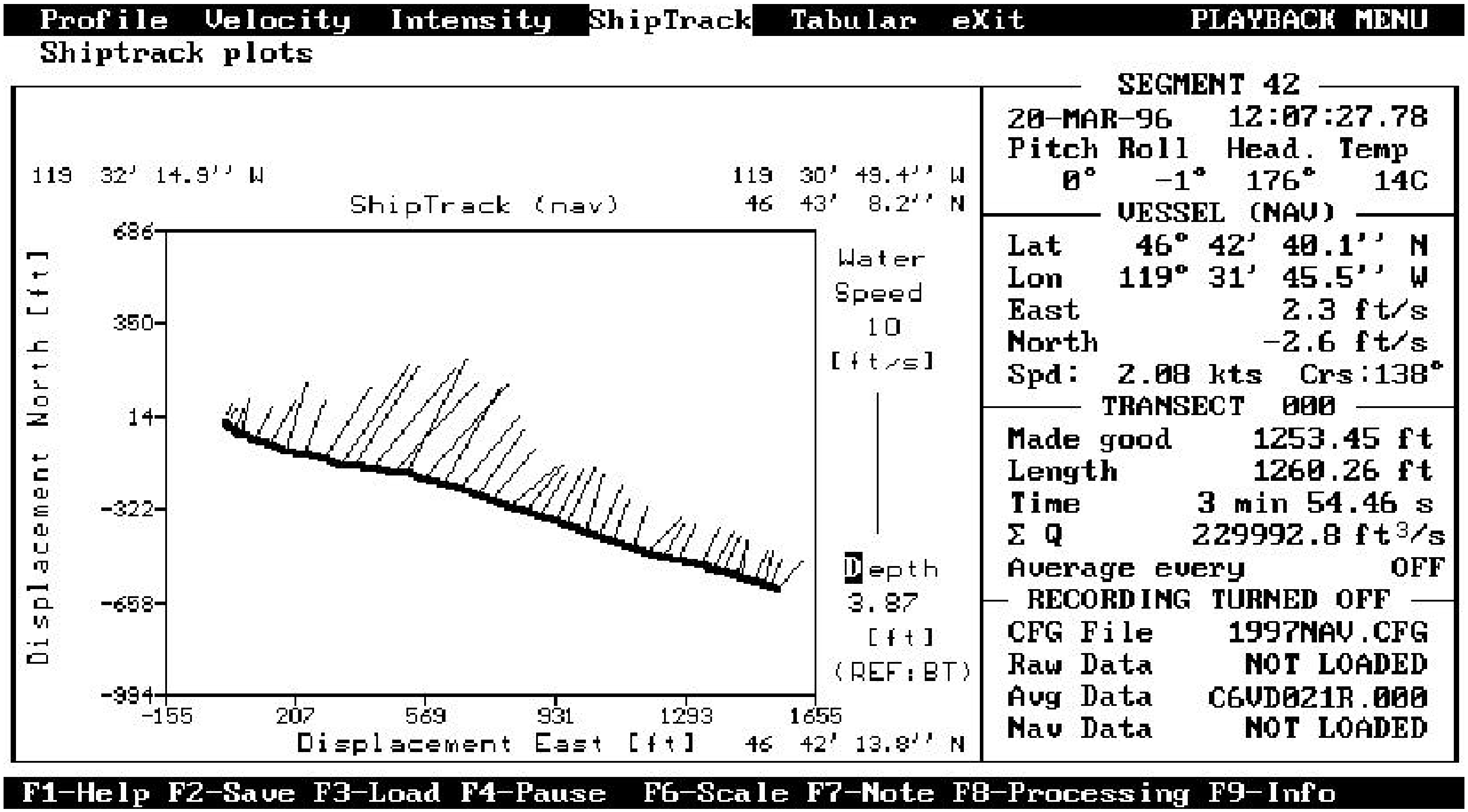

Figure 3. Shiptrack plot from the ADCP showing boat course across the river channel. Velocity vectors indicate magnitude and direction of water velocity for each data ensemble in the depth cell located at 3.87 feet.

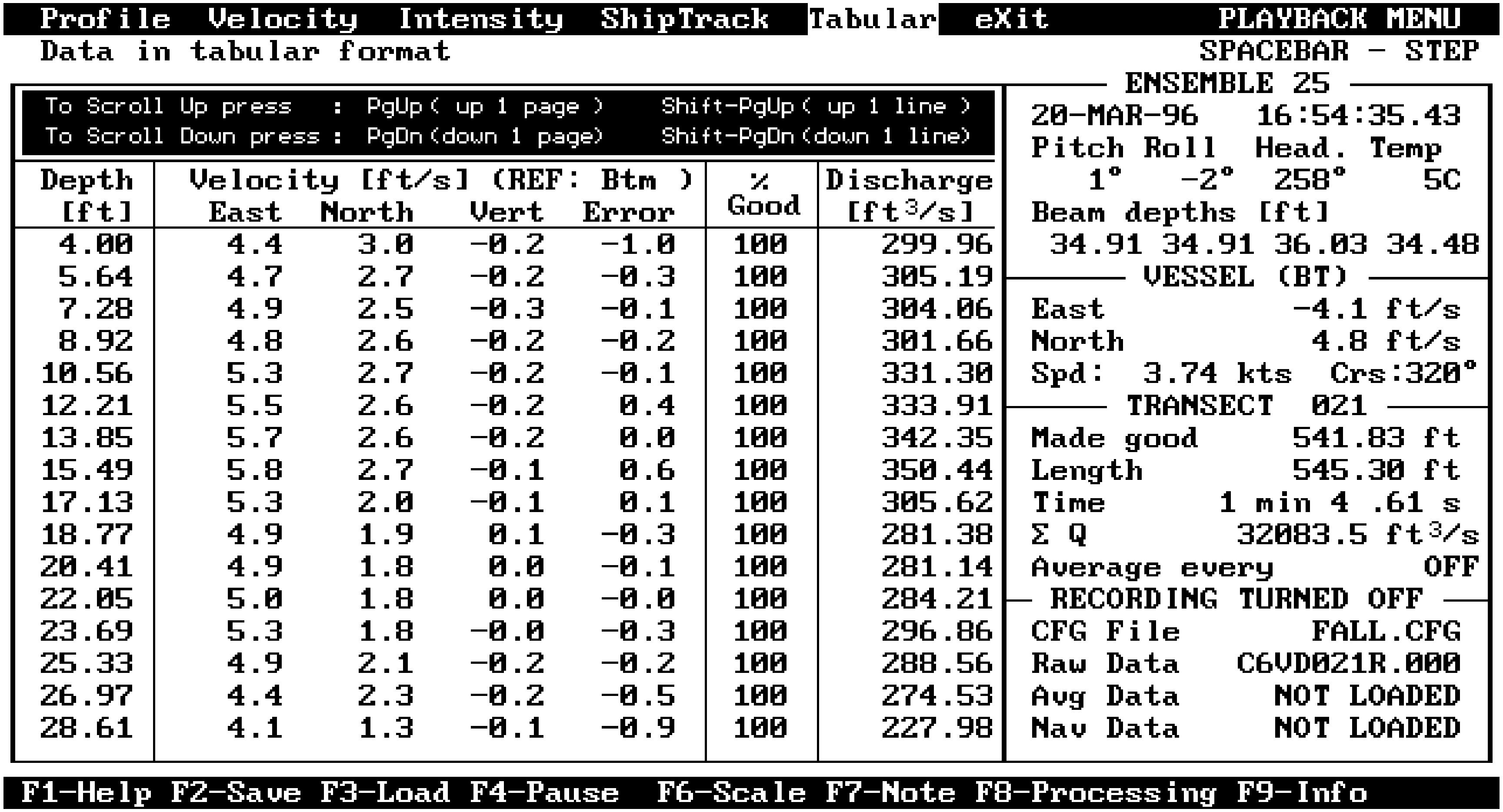

Figure 4. Tabular velocity data from ADCP showing the velocity vector components, percent of valid measurements and calculated discharge for each depth cell.

(usually downstream) velocity magnitude, and the vertical vector represents the upward velocity component. The error vector is an additonal, redundant, measurement of the vertical velocity component. The ADCP compares the vertical and error vectors to determine if the data for each depth cell is valid. Excessive variation from surface to bottom in either the vertical or error vectors can indicate a configuration change or larger sample size is needed to improve data quality. Consistently large differences between the magnitudes of the vertical and error vectors for each depth cell can also indicate a problem. The "% Good" column displays the percentage of samples or acoustic pings the ADCP determined were valid. When values decrease below 75%, standard deviation of the velocity data for each depth cell increases and may become a concern, indicating a configuration change may be needed. The discharge for each depth cell is shown in the last column for the current data ensemble. Excessive variation from one depth cell to the next, or from surface to bottom can indicate a configuration change or larger sample size is needed to improve data quality.

Velocity contour plots (Figure 5) display a visual, color-coded representation of the velocity profile for the cross section as it is measured. Each block represents the location and area of a depth cell. Velocity plots display cumulative data for the entire cross section through the current data ensemble and are used to monitor for irregular flow patterns and missing data. The white vertical bar near the right side of the velocity profile in Figure 5 represents a data ensemble with no measured depth cell velocities. The absence of depth cell velocities could have been caused by loss of bottom track data for referencing velocity measurements, excessive turbulence around the transducer heads or in the water column, or entrained air that is sometimes encountered downstream from the mainstem dams when spill is occurring. This plot allows data for the entire cross section to be viewed during or after data collection, thus informing the user if data collection has been interrupted. An additional run can then be made to assure that a full data set has been collected.

Figures 4 and 5 show data output referenced to bottom track from the ADCP, rather than being referenced to navigation data from the GPS receiver. As a result, data shown for the current ensemble under the "Vessel (BT)" heading do not include a geographic location. Boat speed and course are derived from bottom track data and the internal flux gate compass.

Horizontal distance and relative elevation were measured for bank points, and depth and water column velocities were measured for points between the water edges, for a total of 50-200 data points or cells along each cross section. Although water column velocities from discharge measurements associated with stage-discharge data collection were not used as the primary data set for velocity calibration and simulation, these data were collected on each cross section line and were used to evaluate velocity simulations over the range of measured flows.

Extensive field testing of configuration parameters for the ADCP was conducted during early spring in preparation for spring and summer field work. Our goal was to determine configurations that would enhance data quality, quantity, and resolution for the wide range of conditions encountered between spring high flows and summer low flows. Configurations that would allow quality data collection in shallow water (<1.0 m), turbulent water, and high velocity laminar flow were field tested in the Columbia and Lewis rivers under various conditions. We

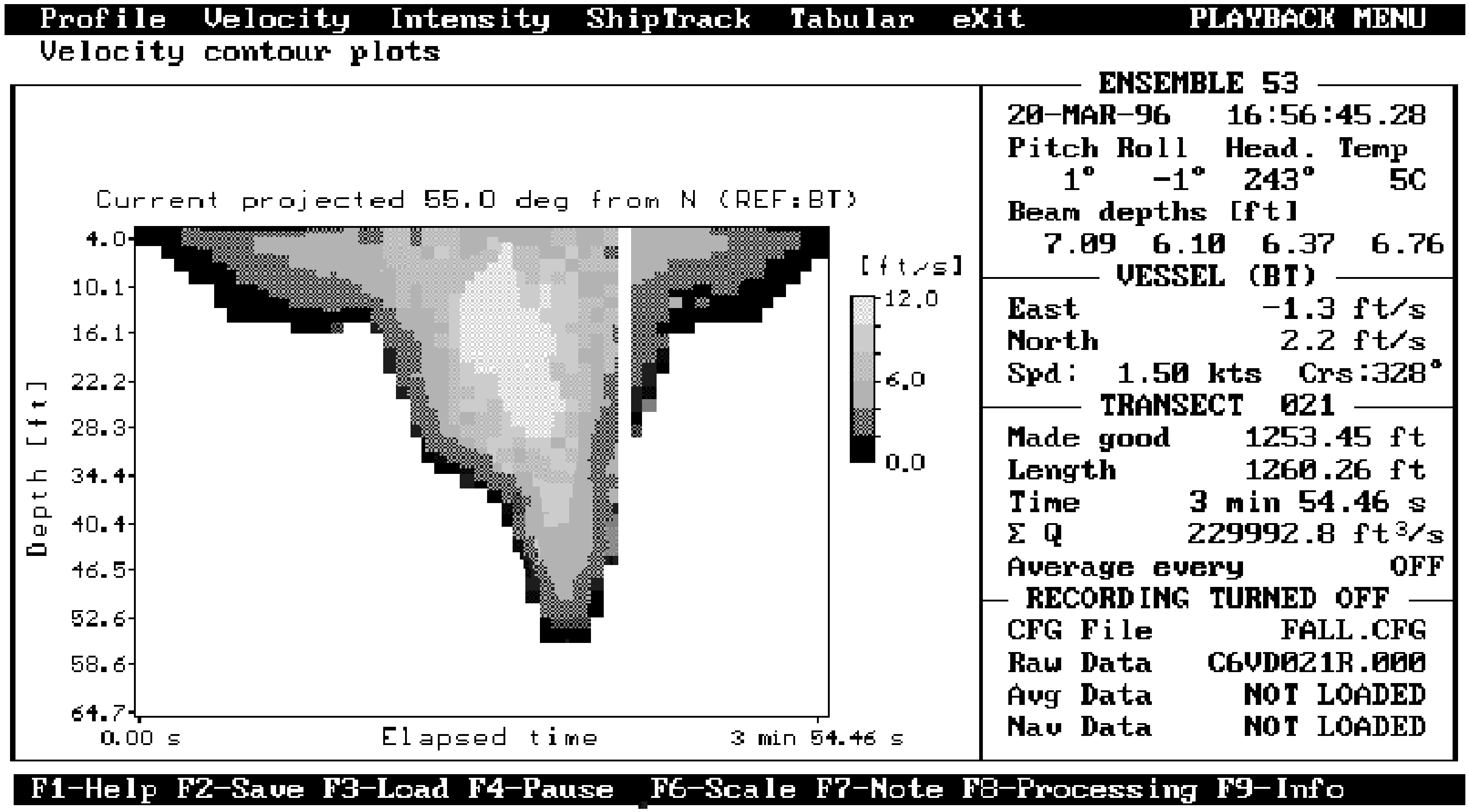

Figure 5. Velocity contour plot showing velocity magnitude for each measured depth cell. The white bar near the right side of the profile indicates missing depth cell velocities and loss of bottom track.

also tested navigation hardware, software, and data collection protocols to prepare for integration of geospatial data (latitude/longitude) with the ADCP raw data files.

Precision Lightweight GPS Receivers were used to collect waypoints (latitude and longitude) for all cross section headpins, a subset of reference marks, and some substrate sampling locations. They were also used (beginning in May 1997) to collect and output data for integration with ADCP raw data files following the testing discussed above. The receivers were purchased under a U.S. Air Force military contract and have the ability to utilize the Precise Positioning Service (PPS) of the NAVSTAR Global Positioning System. The PPS enables horizontal positions to be determined within ±4 m autonomously, in real-time without the need for post-processing.

River bed substrates along each cross section were characterized visually for bank points and with an underwater video camera between the left and right water edges. Bank substrate was described from the headpin to the water edge on each side of the river, and an electronic total station was used to locate the data, horizontally, on the cross section line. Underwater substrate was characterized at 30- to 45-m intervals across the river channel and where sharp changes in the cross section profile occurred. Locations for each underwater substrate data point were determined by noting the distance from the headpin as measured by the GPS receiver. The underwater video camera was mounted on a welded aluminum carriage weighted with two 22.7 kg lead sounding weights and deployed from the bow of a 6.4 m jet boat using a 24-volt electric hoist/davit system (Figure 6). One crew member was responsible for driving the boat along the cross section line and operating the GPS receiver, and a second member operated the winch, viewed the video camera monitor, classified substrate, and recorded data (GPS waypoints, substrate type, depth, and distance from the headpin). A third crew member assisted with deployment of the camera and camera cable, attaching and detaching clips to hold the camera cable to the winch cable as the camera was raised or lowered. Substrate images were recorded for most of the data points with a VHS video cassette recorder, and GPS waypoints were collected for a subset of the data points. Waypoints for the remainder of the substrate data points were interpolated by distance, from waypoints for the cross section headpins.

Data were then compiled and entered into the RHABSIM field data spreadsheet using numeric codes which designated the following substrate types (Parsley et al. 1993):

Substrate Type	**Particle Size (mm)**
Organic Debris	N/A
Hard Clay	0.00024-<0.004
Mud/Silt	0.004-<0.062
Sand	0.062-<2
Gravel	2-<64
Cobble	64-<250
Boulder	250-4,000
Bedrock	N/A

Figure 6. Deployment system for the underwater video camera. Hoist, davit and camera carriage are shown in the top photo and a closeup of the camera carriage is shown below.

A computer sonar unit with chart recorder was used to conduct reconnaissance surveys and to collect hard copy cross section profiles of the river channel in the tailrace areas of Lower Monumental, Little Goose, and Lower Granite dams. The chart recorder was also used to collect cross section profiles around islands in the White Bluffs island complex (RM 371-377) in the Hanford Reach of the Columbia River. Profiles were reviewed for each area to evaluate the variation in channel morphology. Results of the evaluation together with hydraulic characteristics observed in the field, were used to determine the level of effort and approximate location of cross sections necessary for an adequate description of physical habitat in the new areas.

We assisted BRD with the maintenance of digital thermographs for collection of continuous water temperature data in the Columbia River near Richland, Washington (RM 340.3) and in the Snake River below Ice Harbor Dam (RM 6.3).

Data Analysis

Hydraulic field data collected by the ADCP were converted from binary format to ASCII format and imported into the RHABSIM field data spreadsheet. The import program used by RHABSIM extracts data from the appropriate ADCP data fields and calculates horizontal distance, depth, and mean column velocity. Horizontal distance and elevation for surveyed bank points, the water edges, and water surface elevations were then combined with the ADCP data, and near shore depths and velocities were entered at the correct distances from the water edges. Water surface elevations and the corresponding discharges were entered into the spreadsheet as the data pairs were collected. Cross section profiles, water surface elevations, velocity distributions, and stage-discharge pairs were then viewed graphically (Figure 7) and examined for errors.

Calibration of hydraulic models for each of the cross sections was a two-step process. Determination of the best possible simulation of cross-sectional area for each calibration discharge was the goal of the first step. This was accomplished using one of five different models to simulate water surface elevations. We tested simulations using all measured calibration data as well as subsets of the entire data set to determine the specific combination of measured field data points that would produce the best overall simulation. Simulated water surface elevations from each test were reviewed to determine the best fit to measured data, as well as how realistic the simulations were for relatively low and high flows from the period of record (708 to 14,164 m^3/s for the Columbia River). Calibration of simulated velocities to the measured field data was the goal of the second step. Velocity calibration and simulation was accomplished using Manning's equation (Chow 1959). Manning's equation relates mean column velocity (*v*), slope (*S*), roughness (*n*), and hydraulic radius (*r*) for each point across the cross section as follows:

$$v = \frac{1.49}{n} r^{2/3} S^{1/2}$$

Initial roughness values were calculated using measured velocities, calculated hydraulic radius, and measured slope for each data point at the calibration discharge (velocity distribution data set).

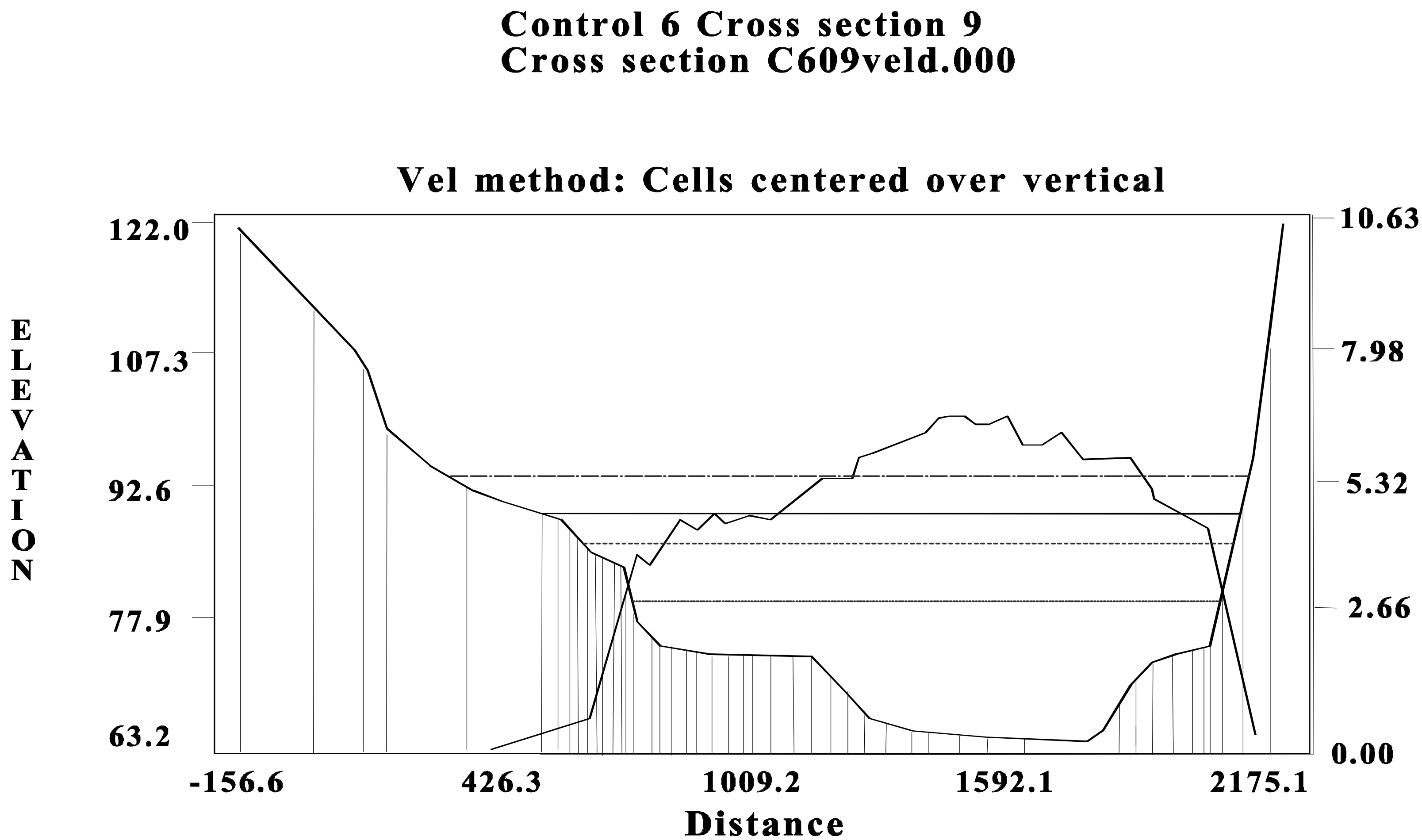

Figure 7. Graphic representation of measured field data including cross section profile, velocity distribution and water surface elevation for a flow of 5120 m^3/s (bold lines). Vertical lines show locations of data points. Three stage discharge points are shown for 2,900, 4,450, and 6,700 m^3/s. The x:y ratio for distance and elevation was exaggerated from 1:1 to 40:1 to illustrate cross sectional detail.

Calibration roughness values were then used to simulate velocities for the calibration discharge. Simulated velocities were compared to measured velocities (Figure 8) and roughness values were adjusted if needed, for the best overall fit. Simulated velocities for the stage-discharge flows were then compared to the actual measured velocities from the stage-discharge data files and the calibration roughness values were adjusted if needed. Finally, velocities were simulated for low and high flows from the period of record (listed above) and the pattern was reviewed across the range of flows for obvious errors or anomalies (Figure 9). The goal of this step was to achieve a balance between acceptable error at the calibration discharge and reasonable simulated velocities over the range of modeled flows. If the velocity pattern was reasonable, velocity magnitudes for each simulated discharge and the resulting discharge calculations were compared to determine if roughness values should remain constant or if they should vary with discharge. Divergence of simulated discharges and the corresponding discharge calculated from the simulated velocities at low or high flows, was an indication that constant roughness values might not be appropriate, and a variable roughness algorithm was used to describe an inverse relationship between water depth at each discharge and roughness. The algorithm adjusts roughness values for each data point as a function of depth at each flow, and Manning's equation is then solved to determine the new velocities across the range of flows to be modeled. Simulated velocities and resulting calculated discharges were reviewed again to evaluate the effect of the variable roughness function. If velocities and calculated discharges did not improve, the original constant roughness values were used, and velocity calibration was complete.

Hydraulic modeling was conducted following completion of the velocity calibration process to determine depths and velocities for each discharge to be simulated over the range of flows required for habitat and time series analysis.

RESULTS

Field Data Collection

Cross section locations and distribution were based on the results of the sensitivity analysis cited previously, in the "Methods" section of this report. A total of 122 main channel cross sections were distributed among five hydraulically controlled (pool/run), four uncontrolled (riffle), and one tailrace segment in the Columbia River between RM 368 and the Priest Rapids Dam tailrace (Figure 10). Controlled river segments ranged from 3,000 to 6,500 m in length and uncontrolled segments ranged from 1,500 to 3,200 m in length. The tailrace segment was approximately 1,600 m in length. Cross section widths ranged from 402 to 919 m. Cross sections in the Snake River between RM 4.5 and Ice Harbor Dam were selected at various locations to characterize observed hydraulic and habitat conditions. Cross section widths ranged from 402 to 641 m.

Cross section distance and elevation profiling was completed with the measurement of additional river bank points approximately 3 m in elevation above the visible high water mark at approximately 8,496 m^3/s. Preliminary rating curve analysis indicated the additional 3 m would

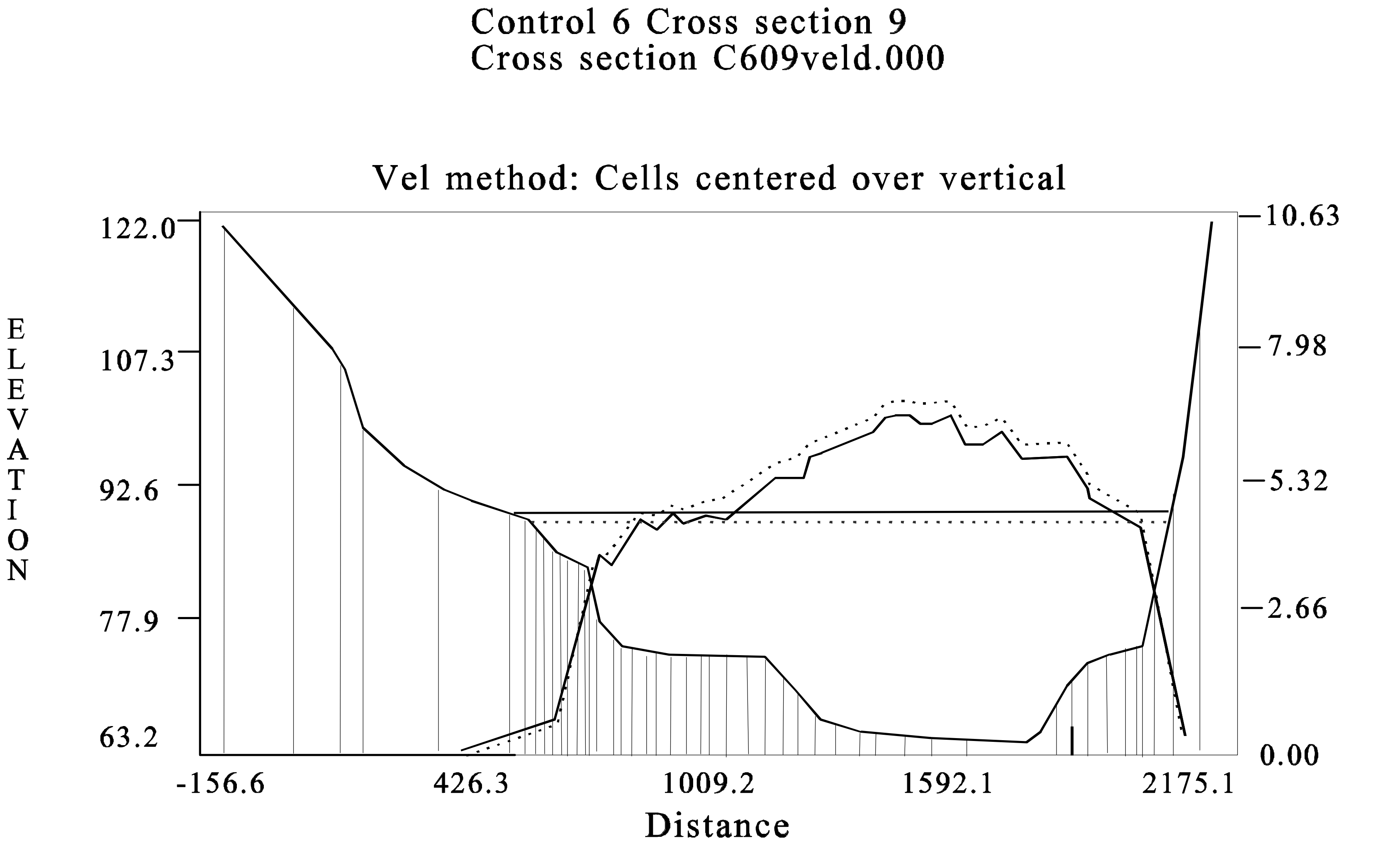

Figure 8. Measured (bold lines) and simulated velocity distributions and water surface elevations for the calibration discharge of 5,120 m^3/s.

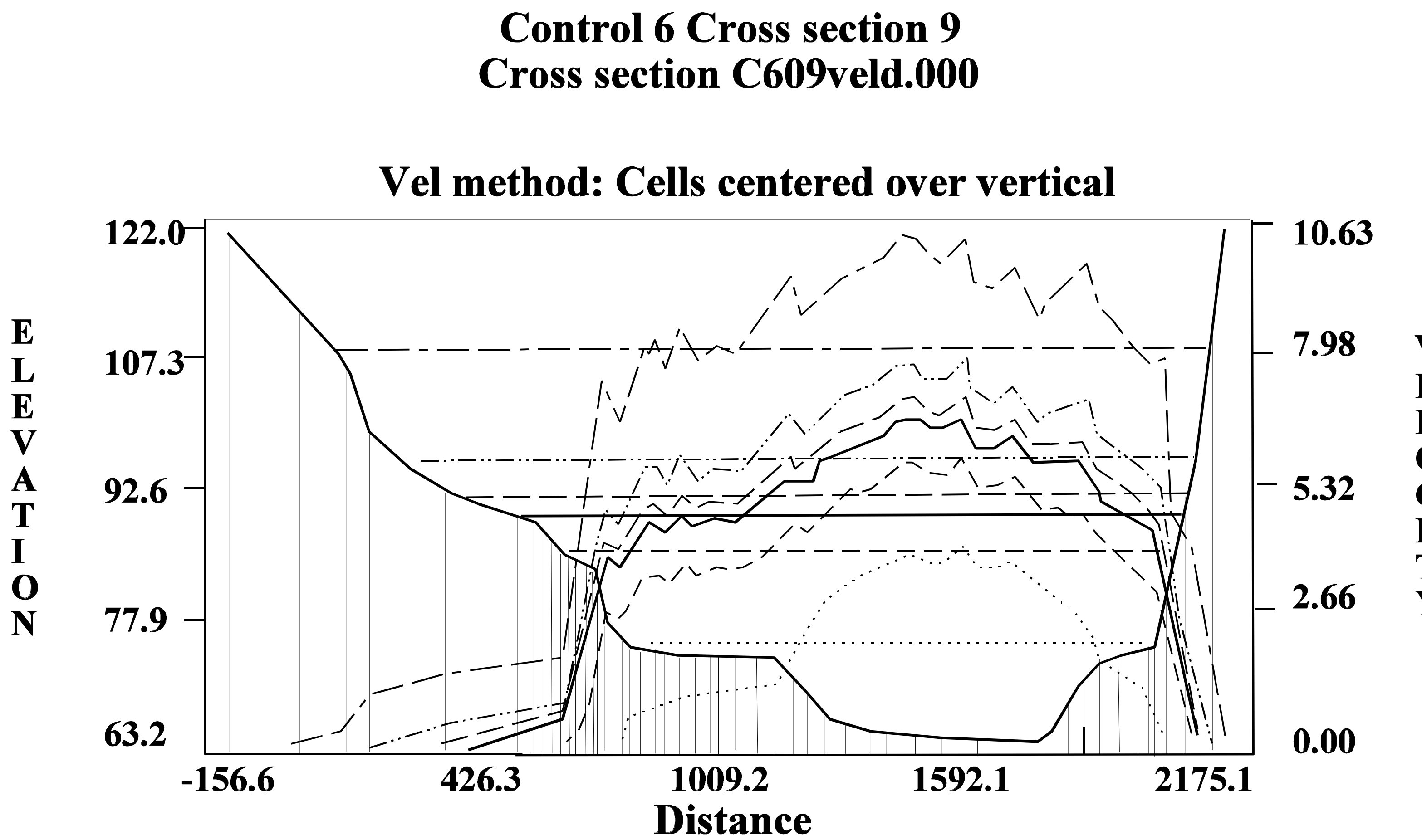

Figure 9. Simulated velocity distributions and water surface elevations for the calibration discharge of 5,120 m^3/s (bold lines), three stage-discharge points, and low and high flows from the period of record.

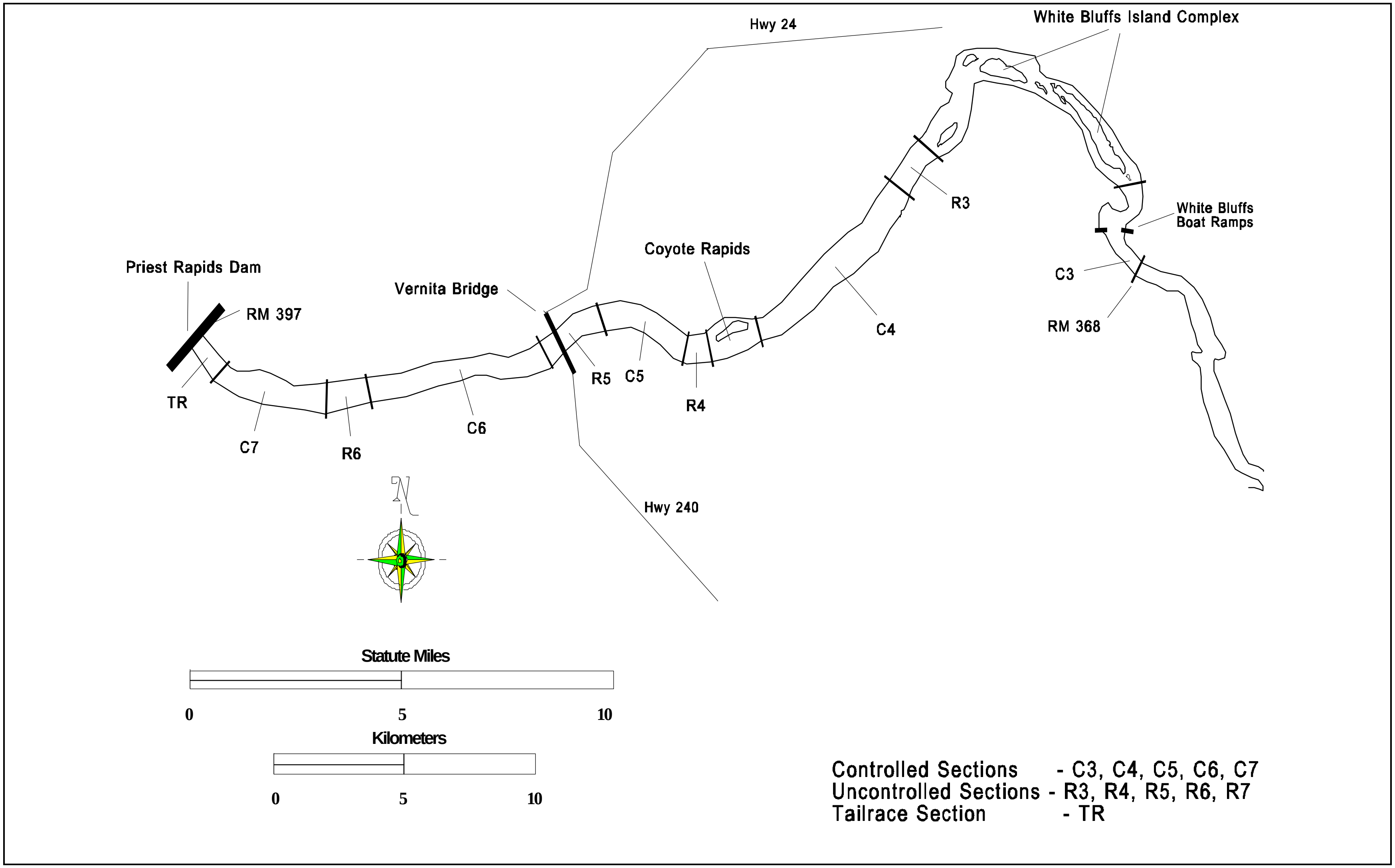

Figure 10. River segment location in the Columbia River portion of the study area.

accommodate modeling for discharges up to 14,164 m^3/s in the Columbia River and 11,300 m^3/s in the Snake River which will be required for time series analysis.

Measurement of 231 stage-discharge pairs completed hydraulic data collection for main channel cross sections in the Columbia River. Stage-discharge data were measured at river flows ranging from 1,459 to 7,593 m^3/s for 117 cross sections. Approximately 500 stage-discharge data pairs have been collected for calibration of hydraulic models. Data collection continued for the Snake River with the addition of 14 stage-discharge pairs for the main channel cross sections at river flows of 567 and 2,833 m^3/s.

Results from testing of configuration parameters for the ADCP allowed us to improve the quality and precision of hydraulic field data. Adjustments for various types of conditions were made using four primary parameters: blanking distance, depth cell size, lag interval, and navigation configuration. Blanking distance refers to the portion of the water column directly below the four ADCP transducers where data cannot be collected with the necessary accuracy or precision. We found that we could reduce blanking distance from 30 cm to as low as 10 cm when velocity and turbulence were not excessive, with no effect on data quality. The reduced blanking distance allows us to collect valid velocity data in shallower water and further inshore on each bank, thus reducing the area and time required for manual data collection. Depth cell size refers to the vertical size of the bins in the water column used for velocity measurement. We found that we could reduce the bin size from 50 to 25 cm when conditions were appropriate for higher resolution velocity data. The smaller bin size also allowed data collection in shallower, near shore areas. The lag interval refers to the structure of the acoustic pings the ADCP uses to measure velocity. A shorter interval allows velocities to be measured closer to the transducer head, thus enabling data collection in shallower areas. Following the addition of hardware and software for collection and recording of navigation data (latitude and longitude) from the GPS receiver, we were able to integrate those data with the ADCP data files during data collection. Summary reports are now produced when ADCP data files are imported into the hydraulic modeling software, that include latitude and longitude, horizontal distance, depth, elevation, and velocity for each measurement point across the channel (Figure 11). This ASCII report is suitable for use in a GIS database. We are currently working on the format for a similar report which will include the simulated depths and velocities as well as the measured data.

Approximately 500 waypoints were collected for cross section headpins, reference marks, and substrate locations with the GPS receiver. The waypoints were extremely useful for relocating cross sections and reference marks during data collection. Waypoints for substrate characterization will allow the data to be used in a GIS database for additional analysis. We began integration of latitude/longitude and the binary, ADCP hydraulic data files in the field on a regular basis.

Underwater substrate characterization was completed with the collection of data at 1,124 locations (300 with GPS waypoints) with the video camera for the main channel cross sections in the Columbia River. Substrate characterization was also completed for the Snake River main channel cross sections with the collection of 73 data points, all of which have corresponding GPS waypoints.

Bearing of Cross Section: 221.907°
Bearing of Channel: 131.907°
Water Surface Elevation: 100.00 feet

Point	Latitude	Longitude	Offset	Depth	Elevation	Velocity
1	46.6684642	-119.4541631	11.580	3.948	96.053	0.788
2	46.6684792	-119.4541667	14.340	2.983	97.018	-0.181
3	46.6684944	-119.4541639	16.300	3.503	96.498	-0.571
4	46.6685500	-119.4541194	16.300	0.000	100.000	0.000
5	46.6686167	-119.4539625	45.850	17.318	82.683	5.985
6	46.6686667	-119.4538708	70.850	21.920	78.080	7.376
7	46.6687111	-119.4537861	100.880	24.813	75.188	6.595
8	46.6687778	-119.4536667	137.280	29.695	70.305	6.773
9	46.6688478	-119.4535064	190.600	38.093	61.908	7.875
10	46.6688917	-119.4533500	224.440	44.935	55.065	8.745
11	46.6689333	-119.4532222	258.270	49.733	50.268	8.912
12	46.6689750	-119.4530833	297.250	52.783	47.218	7.870
13	46.6690333	-119.4529361	338.340	55.628	44.373	8.352
14	46.6690917	-119.4528000	379.970	57.933	42.068	8.144
15	46.6691556	-119.4526556	422.290	58.915	41.085	8.608
16	46.6692167	-119.4525056	468.430	59.195	40.805	8.231
17	46.6692972	-119.4523750	511.010	59.018	40.983	7.745
18	46.6693722	-119.4522806	546.660	55.243	44.758	7.238
19	46.6694417	-119.4521917	579.000	51.322	48.678	6.895
20	46.6695222	-119.4520722	621.850	46.983	53.018	6.847
21	46.6696194	-119.4519528	664.800	41.828	58.173	7.019
22	46.6697167	-119.4518500	707.860	37.590	62.410	6.476
23	46.6698194	-119.4517333	750.940	33.958	66.043	6.388
24	46.6699167	-119.4516333	794.750	30.143	69.858	5.402
25	46.6700139	-119.4515361	837.570	26.263	73.738	5.136
26	46.6701306	-119.4514333	880.470	22.983	77.018	4.930
27	46.6702667	-119.4513000	945.710	19.538	80.463	4.130
28	46.6703875	-119.4511833	990.990	16.840	83.160	3.846
29	46.6704833	-119.4510750	1033.450	14.928	85.073	3.023
30	46.6705750	-119.4509500	1071.110	13.535	86.465	2.364

Figure 11. Summary report produced from import of ADCP data file.

Cross section profiles were characterized with the chart recorder at 50 locations in the tailrace areas of Lower Monumental, Little Goose, and Lower Granite dams (Figure 12). Following our review of the paper traces for each of the areas, we selected 37 cross sections for data collection. Cross section profiles were characterized at 60 locations in the White Bluffs island complex in the Hanford Reach of the Columbia River. We selected 45 cross sections for data collection (Figure 13).

Data Analysis

Following the addition of new bank profile data, stage-discharge pairs, and substrate codes to the existing data files, cross section plots with measured water surface elevations, and summary rating curve statistics were produced (Figure 14) and reviewed for errors. We selected the water surface elevation model for each cross section with the best simulation of our measured field data and the most reasonable simulation of cross sectional area across the range of unmeasured flows. Calibration of simulated velocities to measured velocities at the calibration discharge, and comparison of measured velocities from the stage-discharge data files to the corresponding simulated velocities is ongoing for the Columbia River cross sections. We also began velocity simulations for the range of low to high flows discussed previously, using the variable roughness algorithm where appropriate and adjusting individual cell velocity simulations where needed. Hydraulic simulations have been conducted for a subset of cross sections, and habitat modeling will begin when habitat suitability criteria have been finalized and are available.

DISCUSSION

Field Data Collection

The spring and summer of 1996 were characterized by relatively high flow conditions in the Columbia and Snake rivers. We had completed velocity distribution data collection and were able to take full advantage of the high flows following delivery of our new ADCP. We completed an extraordinary volume of stage-discharge work as a result of having an ADCP at our disposal. We filled data gaps on various cross sections with high, intermediate, and low flow data points, and were able to complete data collection for the Columbia River main channel areas. We were also able to work with various configurations of the ADCP that allowed us to collect data under most types of conditions with the exception of tailrace areas when spill was occurring. The entrained air bubbles from the physical action of the spill created interference with the returning acoustic beams. For stage-discharge work in the tailrace areas, we were able to use discharges measured by the dam along with water surface elevations measured at each cross section when spill was occurring. We were also able to begin the automatic collection and integration of latitude and longitude data with ADCP data files. The summary reports discussed previously (Figure 11), as well as other more detailed formats will provide the opportunity to efficiently transfer large volumes of geo-referenced physical and hydraulic data to a GIS for further analysis or display.

The underwater video equipment and hardware for deployment worked well, as it allowed us to characterize substrates at approximately 1,200 locations in the Columbia and Snake

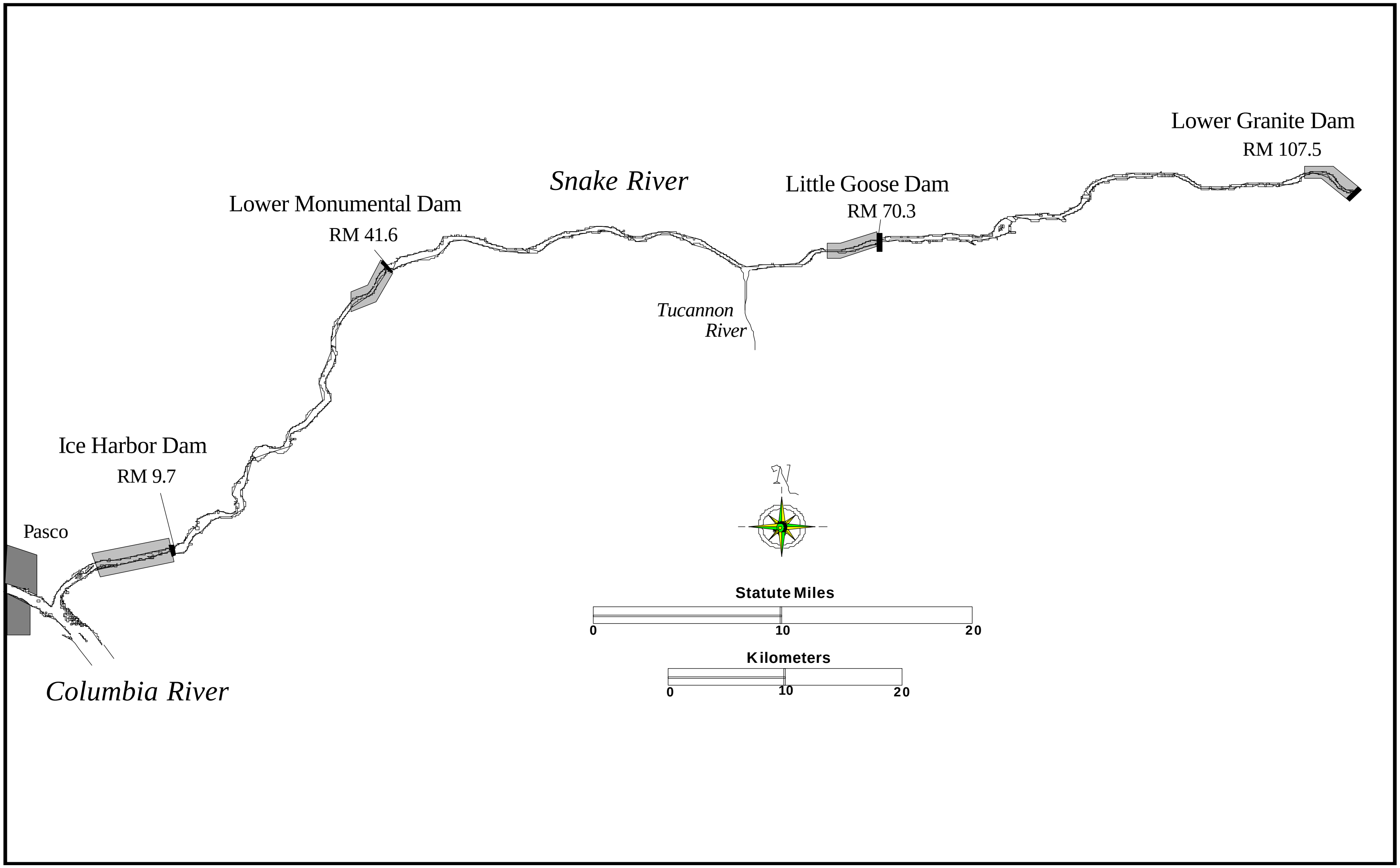

Figure 12. Lower Snake River with tailrace study areas indicated.

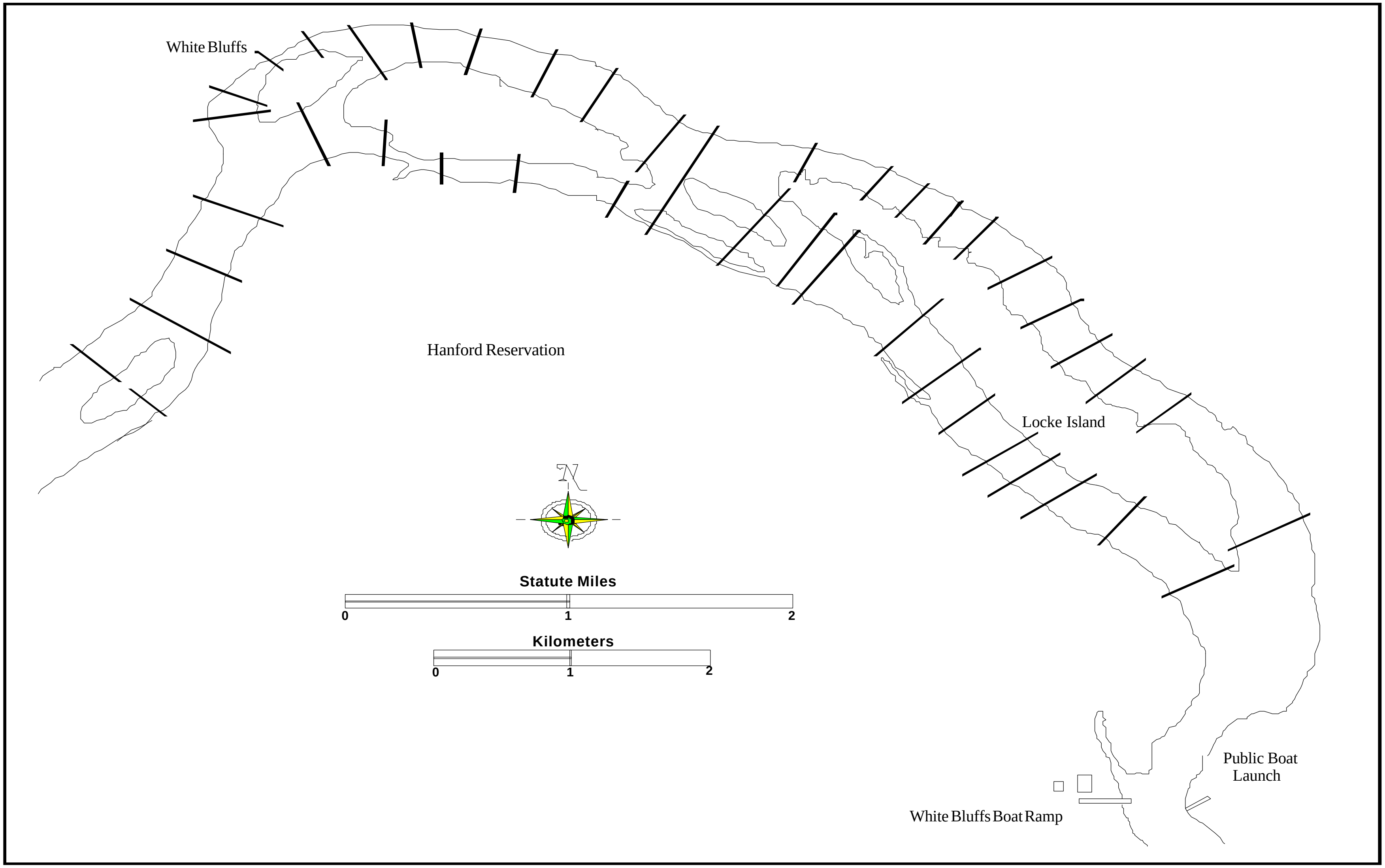

Figure 13. Cross section locations for data collection in the White Bluffs island complex of the Hanford Reach of the Columbia River.

C:\RHABSIM\DATA\IFG-REG.TXT

Stage/Flow Regression Statistics

XS	Name	N	A	B	MeanErr(%)	Variance	Std.Dev
1	C412VELD.000	4	0.8737	3.5050	3.8949	8.0899	2.84428

REGRESSION RESULTS:

XSEC # 1 C412VELD.000
SZF = 62.615

Log/log Functions (Given Flows):

```
  FLOW = 0.87371 * (Stage - 62.6150) ** 3.50497
 STAGE = 1.03927 * Flow ** 0.28531 + 62.6150
```

GivenFlow	Predicted	Ratio
162402.100	163777.300	0.9916
103806.000	95946.200	1.0819
49047.000	51192.990	0.9581
210896.000	216771.600	0.9729

Control 4 - Cross Section 12

CROSS-SECTION C412VELD.000

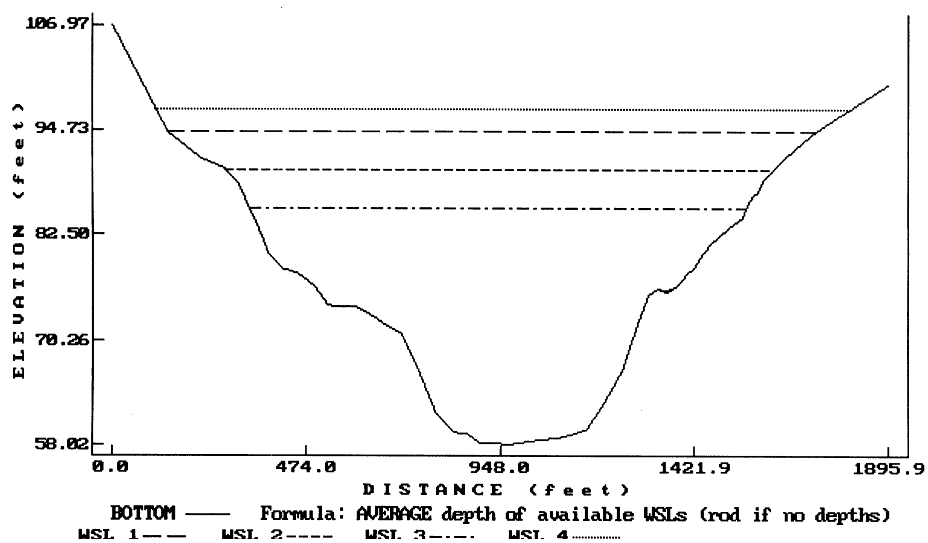

Figure 14. Cross section plot with measured water surface elevations and rating curve statistics.

rivers. The system was efficient and data collection was completed without any problems and in a relatively short period of time.

Reconnaissance of the new study areas in the lower Snake River and the White Bluffs island complex in the Columbia River provided the information required to set up the new areas in a timely manner and begin data collection immediately. The surveys also provided insight into the hydraulics and flow patterns associated with each area.

Data Analysis

Data input has been completed for the main channel section of the Columbia River and the hydraulic modeling is progressing toward completion. Model calibration has been efficient and water surface models and velocity simulations are working extremely well. Use of the relatively new technology associated with the ADCP and GPS equipment has made hydraulic modeling of large rivers such as the Columbia and Snake possible and efficient.

Plans for 1997

We plan to initiate hydraulic data collection during 1997 for the White Bluffs island complex, individual islands in the Columbia and Snake rivers within the current study area, and in the tailrace areas of Lower Monumental, Little Goose, and Lower Granite dams for quantification of white sturgeon spawning and rearing habitat. We also plan to initiate substrate characterization in those areas. We will continue accumulating stage-discharge data in the Snake River below Ice Harbor Dam to describe the backwater effect from McNary Pool. The type of water year and hydrograph will ultimately determine to what extent we are able to complete data collection. Field data will be reduced, converted to ASCII format, and entered into our hydraulic modeling programs.

We plan to purchase a new underwater video camera, hardware, and software to increase the efficiency and quality of substrate characterization. We also plan to include a laser calibration system for more efficient size determination of the substrate components.

Hydraulic modeling for the majority of cross sections in the main channel areas of the Hanford Reach study area should be complete. Habitat quantification and time series analysis will begin when habitat use studies being conducted by BRD are complete and suitability curves are available. Hydraulic modeling for the Snake River tailrace areas and the White Bluffs island complex will begin as data sets are compiled.

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EFFECTS OF MITIGATIVE MEASURES ON PRODUCTIVITY OF WHITE STURGEON POPULATIONS IN THE COLUMBIA RIVER DOWNSTREAM FROM MCNARY DAM, AND DETERMINE THE STATUS AND HABITAT REQUIREMENTS OF WHITE STURGEON POPULATIONS IN THE COLUMBIA AND SNAKE RIVERS UPSTREAM FROM MCNARY DAM.

ANNUAL PROGRESS REPORT

APRIL 1996 - MARCH 1997

Report F

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

and

Identify and evaluate approaches to supplement recruitment of wild populations of white sturgeon downstream from McNary Dam

This report includes: Tagging efforts in John Day Reservoir to assist with an update of white sturgeon life history parameters and population dynamics, and a study of the feasibility and effectiveness of using a fin clip to permanently mark young-of-year hatchery-reared white sturgeon

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February 1998

CONTENTS

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For white sturgeon tagging in John Day Reservoir, my appreciation goes to Yakama Indian Nation (YIN) fisheries technicians Roger Begay, Charles "Chuck" Gardee, Cecil James, James Kiona, and Evans Lewis, Jr. for their dedication during data collection. Steve Parker of YIN fisheries staff assisted with project coordination and management. In addition, I thank contract fishers Robert Brigham, Virgil Hunt, and Babtist "Butch" Lumley, Jr. for their diligent efforts during adverse weather conditions. Ruth Farr, John North, and Ron Reeves from the Oregon Department of Fish and Wildlife provided valuable contributions in data entry, verification, and analysis.

I thank the staff at the United States Fish and Wildlife Service (USFWS) Abernathy Salmon Technology Center for their assistance and the use of their facilities during the fin-removal mark investigations. Brian Hickson and Mark Hack provided additional assistance with fish care, data collection, analysis, and interpretation. Columbia River Inter-Tribal Fish Commission (CRITFC) technicians Laura Gramann, Jack McCormack, and Mike Wakeland assisted with fish care and data collection. Reviewers Tim Counihan, George McCabe, Jr., John North, Mike Parsley, and Tom Rien provided useful comments on this report.

ABSTRACT

I report on white sturgeon tagging efforts conducted on John Day Reservoir from January through March 1996. This work was done in cooperation with the Oregon Department of Fish and Wildlife (ODFW) and the Yakama Indian Nation (YIN) to increase the number of tagged white sturgeon in the population, with the intent of increasing the precision of the population estimate. Three tribal commercial fishers were contracted to capture white sturgeon and to assist YIN fishery technicians with tagging and data collection. A total of 804 diver (i.e. anchored) gillnet sets caught 1,212 white sturgeon. Fishers and technicians applied 1,161 PIT (passive integrated transponder) tags and 1,111 wire core spaghetti tags to white sturgeon (65 to 245 cm fork length). Fifty-five of these marked fish were recaptured during our tagging efforts.

The fin removal mark study focused on the feasibility and effectiveness of using a fin clip to permanently mark small (mean weight 6 g) young of the year hatchery reared white sturgeon. After five months, mean regeneration rates for anal and pelvic fin clipped fish were 93% and 75%, respectively. Sturgeon did not differ significantly between treatments and controls with respect to length and weight (MANOVA, Repeated Measures Design, P = 0.745), although significant differences existed within replicates for treatments and controls (MANOVA, Repeated Measures Design, P = 0.038).

INTRODUCTION

This report documents tasks completed by the Columbia River Inter-Tribal Fish Commission (CRITFC) from November 1995 through June 1996. The first task, white sturgeon tagging in John Day Reservoir was from part of Objective 1 from the Bonneville Power Administration Project 86-50. Objective 1 states: Evaluation of the success of developing and implementing a management plan for white sturgeon in reservoirs between Bonneville and McNary dams in enhancing production. The deliverable associated with Objective 1 task was marked white sturgeon in John Day Reservoir. The objective was to increase the marks-at-large in this population to complement stock assessment work being done by the Oregon Department of Fish and Wildlife (ODFW).

The second task, the fin removal mark study, was part of Objective 3: Identify and evaluate approaches to supplement recruitment of wild populations of white sturgeon downstream from McNary Dam. Specifically, the CRITFC describes the use of a marking technique (fin clip) that may be useful in identifying hatchery reared white sturgeon from naturally reared white sturgeon years after release into the wild.

METHODS

John Day Reservoir White Sturgeon Tagging Efforts

Three contract tribal fishers sampled white sturgeon in John Day Reservoir (Figure 1) using their boats and commercial gillnets. Fishers used commercial diver gillnets similar to those described in Parker (in press). Fishers were paid a daily boat lease rate of $75.00 and an additional $10.00 for each sturgeon recorded on data sheets, including recaptures. A Yakama Indian Nation (YIN) fisheries technician accompanied each fisher on all sets to record data. I trained fishers, their crews, and YIN technicians in collection of biological data and the procedures for application of tags and marks. Sampling began on January 29, 1996, but due to a sudden and severe cold spell (e.g., night time lows exceeded minus 23^{o} C) was restricted to a single day's effort. Field operations were stopped for several weeks until warmer temperatures and higher flows sufficiently melted shoreline ice to allow access at boat launches. All sampling was conducted using overnight sets of diver gillnets, although some sets were unavoidably extended to several days due to inclement weather or net movement from high flows.

Sampling effort varied by section throughout the reservoir (Table 1). Specific set data collected included river width (e.g. distance from bank), depth, and river kilometer. Effort and catch data from CRITFC sampling were linked to sampling sections used by ODFW with river kilometer data (North, this report). To maximize sampling effort and catch, fishers were not required to sample in all sections, but were self motivated to move and actively search for concentrations of white sturgeon, since they were paid by the fish. High runoff conditions, combined with abundant quantities of organic debris restricted sampling efforts to back eddies and other areas with reduced water velocities during much of the field season.

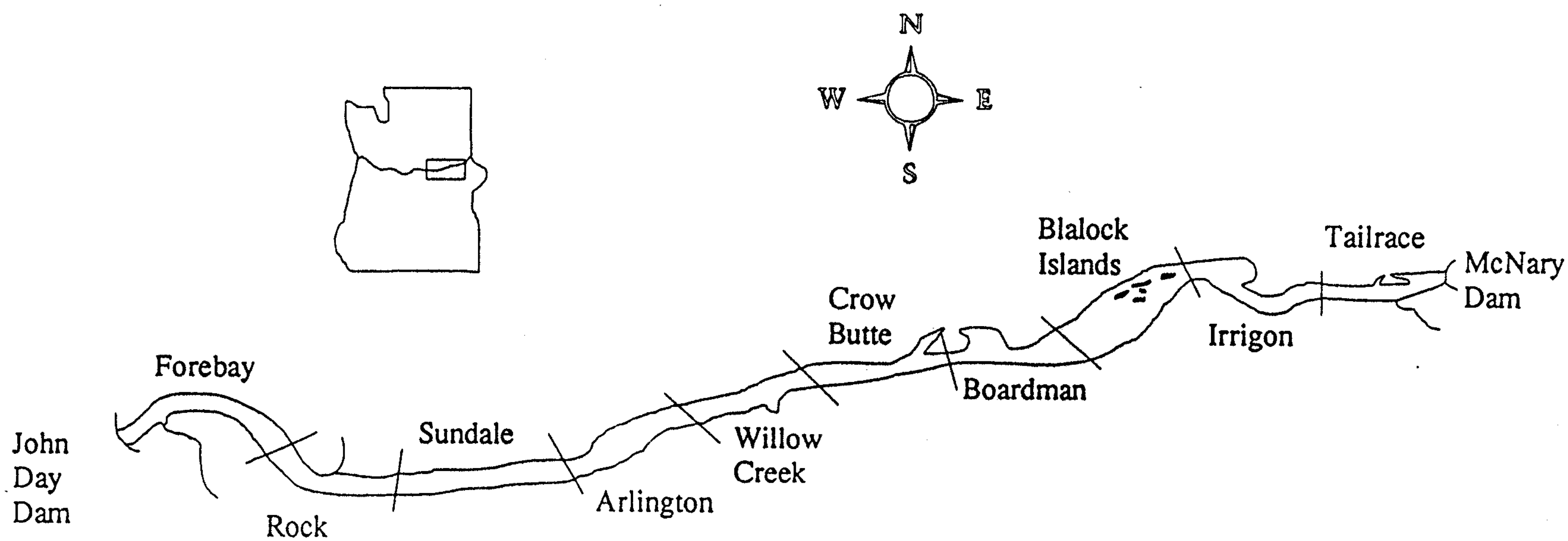

Figure 1. Sampled sections on John Day Reservoir on the Columbia River. The map is not drawn to scale.

White sturgeon were measured to the nearest cm fork length (FL) and weighed to the nearest 0.1 kg. All white sturgeon were examined for tags, tag scars, missing scutes, pectoral fin scars, and missing barbels. White sturgeon with missing scutes or tag scars were scanned with a PIT (passive integrated transponder) tag detector. Fish not previously captured were injected with a PIT tag under the posterior area of the head, just off the dorsal midline. Untagged white sturgeon greater than 80 cm FL were tagged with a wire core spaghetti tag near the middle of the dorsal fin, approximately 2-3 cm ventral to the base of the dorsal fin. The seventh left lateral scute was removed to indicate the year of capture. The second left lateral scute was removed to indicate the presence of a PIT tag (Rien et al. 1994).

Initially, white sturgeon (< 82 cm FL or > 166 cm FL) not previously captured were injected with 100 mg/ml oxytetracycline (OTC) to aid in age validation studies. The OTC dosage was administered at 25 mg/kg of body weight into the red muscle under lateral scutes. The size range for OTC injections was adjusted (<109 cm FL or >166 cm FL), following a regulation change in the treaty Indian subsistence fishery (February 1, 1996) that increased the minimum length for subsistence harvest of white sturgeon from 92 cm to 122 cm total length (TL). The second right lateral scute was removed to identify OTC injected fish. Pectoral fin ray sections and gonad samples were not collected.

Fin-Removal Mark Investigations

These investigations were conducted at the United States Fish and Wildlife Service (USFWS) Abernathy Salmon Culture Technology Center (ASCTC) located near Longview, Washington, from November 1995 through June 1996. Young of year white sturgeon from the 1995 brood year spawned at Pelfry's Sturgeon Hatchery were used in these investigations. The study was designed to evaluate the fin removal mark on small young of the year fish (< 10 g each).

The study design used two experimental treatments and one control treatment; each treatment was replicated three times using 30 fish per replicate. Experimental groups were characterized by the removal of either the left pelvic fin or the anal fin. Study fish had been previously graded as "smalls" by ASCTC staff and were netted at random from a circular rearing tank (diameter of 1.2 m, volume 576 L). Fish with known deformities (e.g., missing or damaged fins) or poor condition (e.g., pinched stomachs and disproportionately sized heads) were not included in the study. Acceptable fish were weighed to the nearest 0.1 g and randomly placed into one of nine holding tanks. Biomasses between groups were equalized by substituting large and small fish between groups until the coefficient of variation between groups was less than 2%.

Fish were held overnight prior to fin removal. Fish were anesthetized with a solution of 0.075 g/L MS-222, total lengths were measured to the nearest millimeter, and weights recorded to 0.1 g. Left pelvic and anal fins were removed using surgical scissors sterilized in a full strength iodine solution (Argentine, Argent, Inc.) Control fish were sham-clipped to approximate the handling stress the experimental fish received during fin removal. Fish were then returned to the holding tank and allowed to recover overnight. Fish were treated with a mild antiseptic salt bath (0.25% solution) for 30 min several times a week following fin removal, then weekly during the remainder of the study.

Fish were held in nine separate parallel tanks in an enclosed unheated building. Illumination was provided by overhead fluorescent lighting set to natural photoperiod using a photosensor on the north side of the building. Pathogen-free well water was supplied to the tanks at an average rate of 7.6 L per minute. Water temperatures varied seasonally and ranged from 9.5 to 11.5°C during the study. Dissolved oxygen ranged from 10.3 to 10.5 ppm. Individual tank volumes were initially set at about 169 L, but were later reduced to 89 L by shortening the standpipes to increase the exchange rate and the removal of waste materials. Individual tank flows and temperatures were generally measured and recorded weekly and dissolved oxygen monthly.

Automatic cartridge type feeders (Rondomatic, Grasslin Inc., Mahwah, NJ) were used to present 15 equal weight feedings over a 24 h period. All rations were calculated as a percentage of body weight (BWD). Daily rations for fingerlings were estimated using a computer generated growth program with feeding levels adjusted for growth daily and mortality weekly. Biweekly adjustments to the feeding program were made based on actual growth rates determined from weight samples. Specific growth rates (SGR) for each treatment were calculated by averaging the SGRs for the three replicates in each treatment. Rations were initially set at 2.5% BWD and were reduced as required reaching 1.5% BWD at the end of the study. Fish were starved for 24 h prior to the biweekly biomass (i.e. all fish weighed together) weighing. The initial diet was the Abernathy dry salmon diet which was later changed the Abernathy moist salmon diet. The diet change was necessary since many fish rejected the Abernathy dry salmon diet and were declining in condition factor. The change to the moist ration reversed the declining condition factors, but losses continued through the remainder of the study.

Individual fish were weighed, measured, and examined for regeneration on a monthly basis. Regeneration at fin clip sites was ranked at three levels. The first level was a complete clip (C), meaning no fin regeneration had occurred. Partial regeneration (PR) closely resembled an unclipped fin in appearance, but smaller in size than an unclipped fin. The final level was a fully regenerated fin (FR). At this level the clipped fin had fully regenerated and was similar in shape and size to an unclipped fin.

Regeneration, growth, and mortality data were summarized and statistically analyzed for significance. Tests used included MANOVA, Repeat Measures Design and multiple comparison for proportions test (Zar, 1984).

RESULTS

John Day Reservoir White Sturgeon Tagging Efforts

Effort and White Sturgeon Catch

Fishers caught 1,212 white sturgeon in 804 sets. Fish ranged in length from 65 cm FL to 245 cm FL, with 90.5% of the catch less than 100 cm FL (Figure 2). Catch per unit effort varied substantially between sections and ranged from 0.50 - 2.08 white sturgeon per set, with an average of 1.5 fish per set (Table 1). Gillnets caught white sturgeon of similar size range as setlines (Figure 2), although the commercial gillnets used in this study may have been less effective on those white sturgeon with fork lengths < 60 and >140 cm, compared to setlines used by ODFW.

Marking and Mark Recovery

A total of 1,212 white sturgeon were caught, with 1,201 of these fish between the 70 cm and 166 cm fork length, the size range used to estimate population abundance (North, this report). Fishers and technicians applied 1,116 PIT tags and 1,111 spaghetti tags for a total of 1,155 marked fish, with 1,144 of the marked fish between the 70 and 166 cm fork length. A total of 55 tagged fish were recaptured during the January through March 1996 sampling period. Abundance estimates and tag retention rates for fish tagged and recaptured by ODFW are reported by ODFW (North, this report). Recapture rates of CRITFC tagged fish by ODFW exhibited a similar recapture pattern as those marked and recaptured by ODFW (Figure 3), confirming that fish captured with gillnets were distributed similarly to those captured and marked using setlines.

Incidental Catch

Incidental fish species caught during the tagging effort included common carp *Cyprinus carpio* (N=30), walleye *Stizostedion vitreum* (N=11), channel catfish *Ictalurus punctatus* (N=3), and steelhead trout *Oncorhynchus mykiss* (N=3).

Fin-Removal Mark Investigations

Mark Retention

Removal of the left pelvic fin or anal fin did not result in a satisfactory mark. Anal fins regenerated at an average of 93% (for surviving fish), and left pelvic fins regenerated at an average rate of 75% (for surviving fish). Regeneration of fin tissue began within one month after clipping, although at very low levels (3% for each experimental treatment). Two months after clipping, regeneration rates increased substantially, with 72% of the pelvic and 89% of the anal fin clip treatments exhibiting partial regeneration. Fin growth varied little for the next 4 months. Three fish with clipped anal fins fully regenerated their clipped fin by the end of the study. No fish with left pelvic clipped fins fully regenerated their clipped fin during the study.

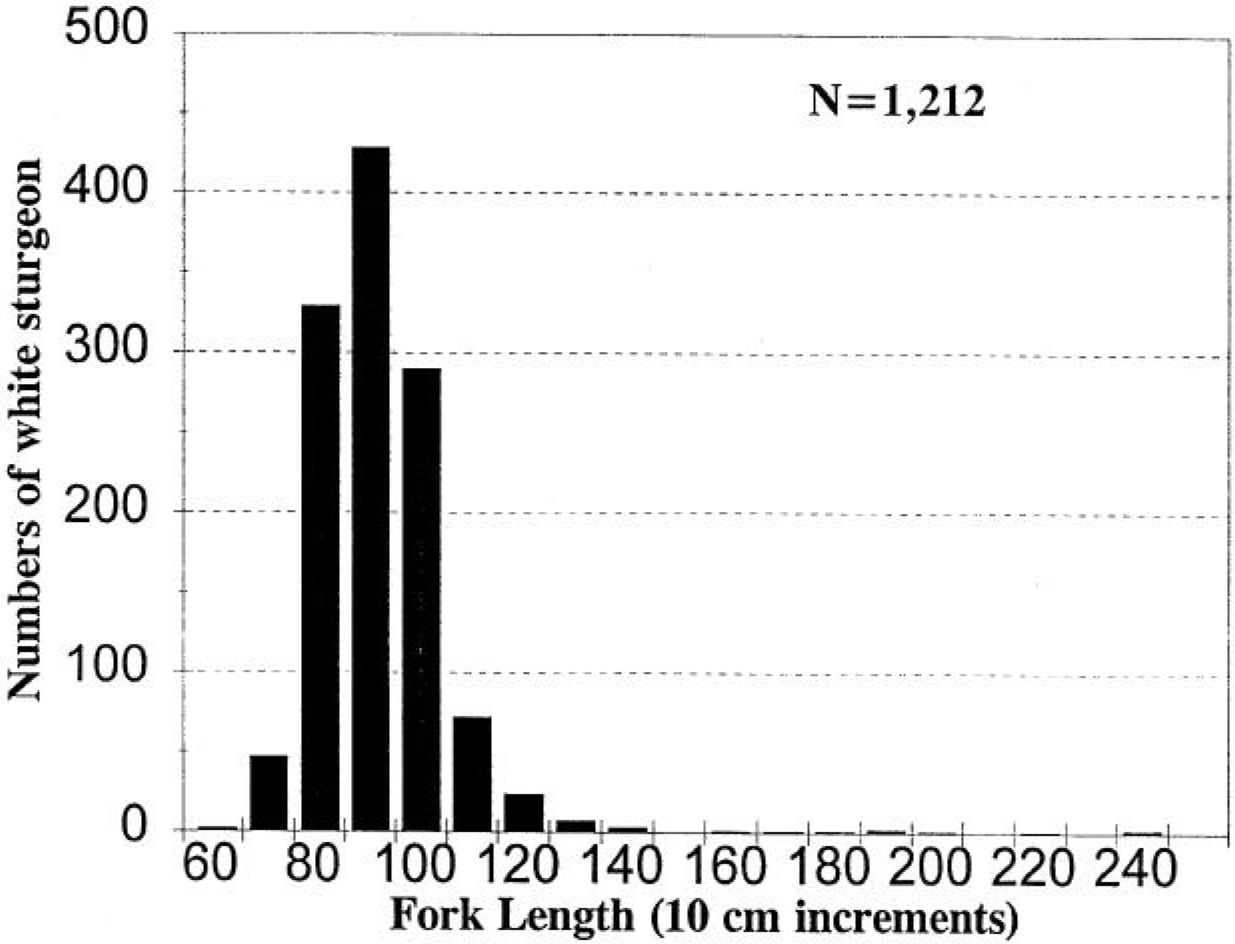

Figure 2. Length-frequency distribution (10 cm increments) for white sturgeon collected in John Day Reservoir January through March 1996.

Table 1. Effort, catch, and marks applied for white sturgeon sampling in John Day Reservoir, January through March, 1996. high flows did not permit sampling in Sections 10 and 11. Numbers within parentheses are for white sturgeon in the 70-166 cm size class.

Section	No. of sets	Catch	CPUE	No. marked
1	24	12 (12)	0.50	12 (12)
2	133	135 (135)	1.02	127 (127)
3	76	85 (83)	1.12	84 (82)
4	84	124 (123)	1.48	123 (122)
5	169	352 (351)	2.08	328 (327)
6	106	191 (190)	1.80	176 (175)
7	116	211 (210)	1.82	203 (202)
8	81	88 (83)	1.09	88 (83)
9	16	14 (14)	0.88	14 (14)
10	--	--	--	--
11	--	--	--	--
Total	805	1,212 (1,201)	--	1,155 (1,144)
Mean CPUE	--	--	1.50 (1.49)	--

[a] Sample sections: 1 = John Day Dam Forebay, 2 = Rock Creek, 3 = Sundale, 4 = Arlington, 5 = Willow Creek, 6 = Crow Butte, 7 = Boardman, 8 = Blalock Islands, 9 = Irrigon, 10 = McNary Dam Tailrace, 11 = McNary Dam Tailrace boat-restricted zone.

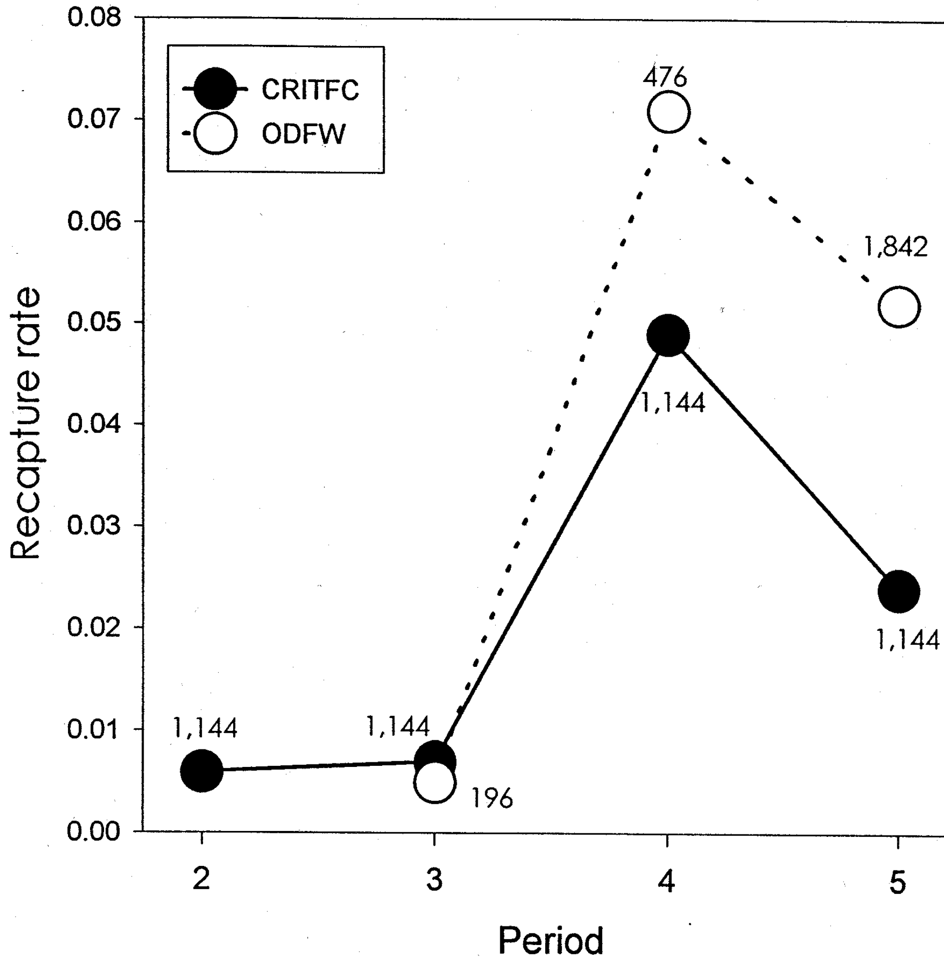

Figure 3. Recapture rates of white sturgeon tagged by CRITFC and ODFW crews in John Day Reservoir and recaptured by ODFW in 1996.

Growth

Growth rates (i.e., increases in length and weight) were not significantly affected by the treatments (MANOVA, Repeated Measures Design, P = 0.745) (Figure 4). Growth within treatments (between replicates) varied significantly (MANOVA, Repeated Measures Design, P = 0.038). Replication and the number of fish (initially N=30) per replication may have contributed to the stability between treatments. High variability regarding growth was the norm for all replicate tanks. Differences in mean daily growth rates began the first month and continued throughout the study (Figure 4). These differences may have been compounded by the diet conversion problem which occurred during the first month of the study.

Mortality

No short-term (i.e., one week) mortality occurred in the study. Generally, very little bleeding was observed at the site of the removed fin. After the first month, decreased condition factors and poor physical appearance (e.g., disproportionately large heads, shrunken abdomens, backward "C" resting positions) supported a diet conversion back to a semi-moist diet. The first mortality occurred two months after the study began, with peak losses occurring during the fourth and fifth months (Figure 5). Losses of one to three fish per month continued until the end of the study. Total losses were similar between treatments, with the highest loss occurring in the left pelvic fin clip treatment group (N=26) and the lowest in the control group (N=21). These differences were not significant when tested using the multiple comparison for proportions test (0.75 < P < 0.50). All mortalities had the same appearance of disproportionately large heads and shrunken bodies prior to death.

DISCUSSION

John Day Reservoir White Sturgeon Tagging Efforts

Late winter tagging efforts using gillnets successfully increased the number of marked white sturgeon in John Day Reservoir. The additional numbers of marked white sturgeon nearly doubled (98 of 228) the number of recaptures by ODFW (North, this report). The additional efforts by CRITFC provided a finer level of resolution regarding the population estimate of white sturgeon in John Day Reservoir, resulting in tighter confidence limits, than those report for other white sturgeon populations (North, this report).

Gillnets were effective in catching white sturgeon in the 70 to 166 cm size range used by ODFW to estimate population abundance. The numbers of white sturgeon < 60 cm FL in our catch might be improved in future marking efforts by using gillnets with smaller mesh sizes (e.g. 10.16 to 15.24 cm stretched mesh). Similarly, larger mesh (25.4 to 30.48 cm) might improve the catch of larger fish (> 166 cm FL).

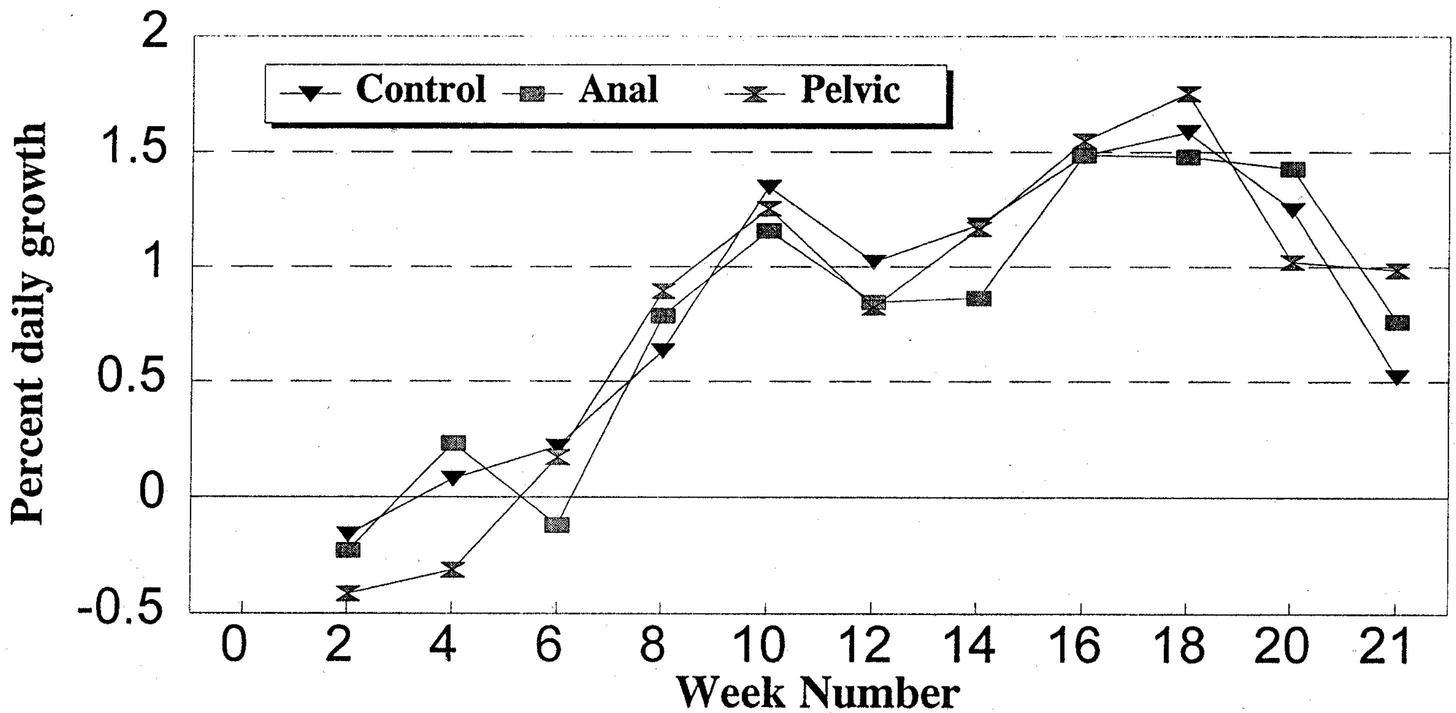

Figure 4. Mean daily growth rates (gms/day) of captive juvenile white sturgeon, plotted biweekly, for control and treatments, November 1995 through April 1996 (project initiated November 6, 1995, week 0).

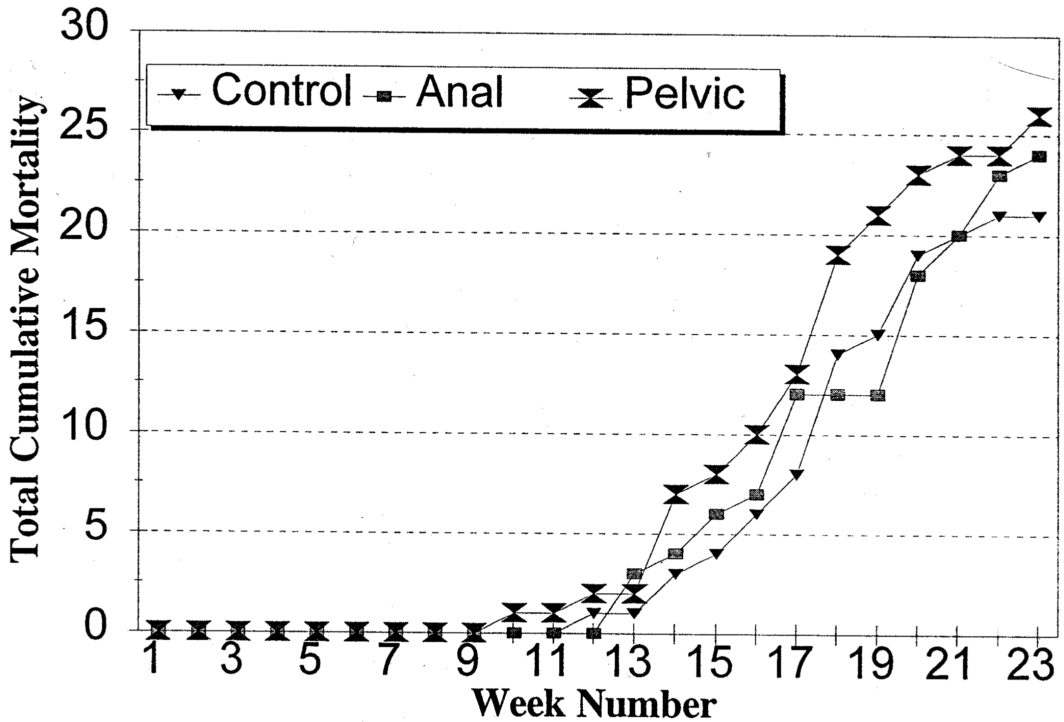

Figure 5. Total cumulative mortality of juvenile white sturgeon pooled by treatment and control replicates, November 1995 through April 1996 (project initiated November, 6, 1995, week 0).

Fin-Removal Mark Investigations

The goal of the research was to determine the usefulness of fin removal as a permanent mark for white sturgeon. Numerous studies have investigated a variety of marks for white sturgeon. Most marks are recognizable at best for several years or less (Cochnauer et al. 1985; Smith et al. 1990; Rien et al. 1994). I determined that fin removals applied to small (< 10 g) hatchery reared white sturgeon were not useful for a permanent mark.

This study incurred problems regarding the sensitivity of juvenile white sturgeon to changes in diet and habitat. These sensitivities imparted "noise" to the results, but probably did not affect whether fins were regenerated at different rates from what was recorded. Fish that declined in condition and eventually died also regenerated their fins, as did fish with higher condition factors.

Plans for 1997

We will coordinate with ODFW and other Project 86-50 cooperators to contract with selected tribal fishers and trained tribal fishery technicians to capture, tag, and release white sturgeon in The Dalles Reservoir in 1997 in conjunction with the trawl and haul evaluation and The Dalles Reservoir stock assessment. Modifications to our methods will likely include using a series of experimental gillnets with smaller mesh sizes (e.g., 10.16 to 15.24 cm stretched mesh) in attempt to maximize catches of trawl and haul white sturgeon and an earlier start time to avoid inclement weather. Efforts to identify a suitable permanent mark will continue in fiscal year 1997. In addition, I will assist with completion of the comprehensive strategic framework plan for the management and enhancement of white sturgeon in Zone 6.

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EFFECTS OF MITIGATIVE MEASURES ON PRODUCTIVITY OF WHITE STURGEON POPULATIONS IN THE COLUMBIA RIVER DOWNSTREAM FROM MCNARY DAM, AND DETERMINE THE STATUS AND HABITAT REQUIREMENTS OF WHITE STURGEON POPULATIONS IN THE COLUMBIA AND SNAKE RIVERS UPSTREAM FROM MCNARY DAM.

ANNUAL PROGRESS REPORT

APRIL 1996 - MARCH 1997

Report G

Evaluate the need and identify potential measures for protecting and enhancing populations and mitigating for effects of the hydropower system on productivity of white sturgeon in the Columbia and Snake rivers upstream from McNary Dam

This report includes: A summary of a biological risk assessment of rebuilding white sturgeon populations in the Snake River between Lower Granite and Hells Canyon dams.

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February 1998

CONTENTS

ACKNOWLEDGMENTS

The Upper Snake River White Sturgeon Biological Risk Assessment was the result of a team effort. We would like to thank Dave Bennett, Rudy Carter, Jim Chandler, Tim Cochnauer, John DeVore, Ken Lepla, Ron McMullin, Randy Osborne, Mike Parsley, Tom Rien, Art Seamans, and David Statler for their valued contributions to the Upper Snake River White Sturgeon Biological Risk Assessment. We would also like to thank Lars Mobrand and his staff, Rich Carmichael and Larry Lestelle, from Mobrand Biometrics Inc. for their work in facilitating the biological risk assessment process and compiling the findings.

ABSTRACT

A biological risk assessment team (BRAT) was assembled in 1996 to identify critical uncertainties that, unless resolved, result in risk of failure of mitigation/enhancement strategies due to lack of knowledge. BRAT participants included a wide range of professionals from a variety of federal, state, and private agencies that are knowledgeable about white sturgeon (*Acipenser transmontanus*) ecology and the Snake River system. The *Upper Snake River White Sturgeon Biological Assessment* was successful in compiling a consensus of the BRAT participants views of 1) important regional management objectives, 2) the perceived status of the Snake River system and the white sturgeon population, 3) potential mitigative actions to achieve regional objectives, and 4) the associated risks and uncertainties associated with their implementation. A multi-year research effort based on these findings has been initiated to collect specific biological and environmental data that will allow prioritization of potential mitigative actions and scientifically sound recommendations of implementation of mitigative actions designed to restore, protect, and enhance the white sturgeon population between Hells Canyon and Lower Granite dams.

The *Upper Snake River White Sturgeon Biological Assessment* (Carmichael et al. 1997) is available upon request from the Nez Perce Tribe, Dept. of Fisheries Management, P.O. Box 365, Lapwai, ID 83540, or by calling (208) 843-7320.

BIOLOGICAL RISK ASSESSMENT

Introduction

In 1996 the Nez Perce White Sturgeon Research Project conduct a biological risk assessment in response to measure 10.4A.4 of the Northwest Power Planning council 1995 Fish and Wildlife Program that calls for the Bonneville Power Administration to A...fund an evaluation, including a biological assessment (Section 7.3B.1) of potential means of rebuilding white sturgeon populations in the Snake River between Lower Granite and Hells Canyon dams@. The objective of this risk assessment was to review existing data on white sturgeon concerning: 1) reproduction and early life history of white sturgeon in the Snake River between Lower Granite and Hells Canyon dams, 2) life history and population dynamics of subadult and adult white sturgeon between Lower Granite and Hells Canyon dams, along with the effects of subadult white sturgeon emigration downstream from Lower Granite Dam, 3) spawning and rearing habitat use between Lower Granite and Hells Canyon dams, including habitat use in the contiguous Salmon River; and 4) determine if existing data are adequate for identifying potential measures to protect and enhance populations and to mitigate for the effects of hydropower systems on white sturgeon productivity.

An Ecosystem Diagnosis and Treatment process (EDT; Lestelle et al. 1996) was used to identify 1) a set of mitigation or management actions with the intent of restoring white sturgeon populations to pre-impoundment conditions, 2) the associated risks and benefits of implementation of management actions in the Snake River between Lower Granite and Hells Canyon dams, and 3) information that is currently lacking and required to assess effects of management actions. A series of three workshops were held where participants:

1) synthesized management actions conducive with the restoration of white sturgeon populations and identified other regional cultural and societal values derived from white sturgeon and associated with the Snake River system that could be affected by white sturgeon management actions;

2) organized available information describing white sturgeon life stages, key habitat requirements, life history, plus a set of environmental quality and quality attributes that may affect white sturgeon productivity and capacity at each life stage in an EDT format; and

3) conducted a >patient-template analysis=, synthesized action alternatives and conducted a benefit-risk analysis for white sturgeon populations between Hells Canyon and Lower Granite dams.

Because specific information concerning current status of white sturgeon stocks, or quantity and quality of habitat, between Hells Canyon and Lower Granite dams is not generally available or limited, the risk analysis was based on information generated by BRAT participants. BRAT participants were regional experts knowledgeable about life history-habitat relationships of white sturgeon as well as the Snake River between Lower Granite and Hells Canyon dams and included members of the Nez Perce Tribe, Washington Department of Fish and Wildlife, Idaho Department of Fish and Game, Oregon Department of Fish and Wildlife, U.S. Forest Service, Idaho Power Company, University of Idaho, U.S. Geological Service, and Hells Canyon Alliance.

Management Objectives and Regional Cultural and Societal Values

Various white sturgeon management objectives of concern to federal, state, tribal, and local agencies were identified by BRAT participants. Following is a summary of those objectives identified concerning white sturgeon in the Snake River system:

- To ensure the existence of white sturgeon in the Snake River between Hells Canyon and Lower Granite dams.
- To restore a sustainable tribal subsistence fishery.
- To sustain catch-and-release and restore consumptive recreational fishing opportunities.
- To preserve genetic stock identity and maintain genetic stock diversity.

In addition, other cultural and societal values and objectives associated with the Snake River system that may be affected by the implementation of potential white sturgeon management actions needed to achieve white sturgeon objectives listed above were identified. Societal values and regional objectives identified by BRAT members included:

- Maintaining the sustainability of other fishes and fisheries including fall chinook salmon natural production, summer steelhead, trout recreational fisheries, and other recreational fisheries (smallmouth bass, catfish, etc.) in the Snake River.
- Maintaining hydropower, flood control, shipping, guiding and outfitting, boat building, wood products industry, waste water operations, recreational use, and educational and scientific uses associated with and along the Snake River corridor.
- Protecting the scenic and aesthetic value of the Snake River area along with tribal cultural values and customs of native peoples.

Patient-Template Analysis

The Patient-Template Analysis (PTA) compares the existing conditions (patient) with sustainable, healthy conditions (pre-dam; template). A comparison of the patient and template was used to identify the factors or functions that are preventing the realization of objectives. The analysis is both quantitative and qualitative in nature. Life history and environmental data used in the PTA were considered within spatial and temporal scales consistent with the range of life histories of white sturgeon in the Snake River between Hells Canyon and Lower Granite dams. Seven life stages were identified: egg incubation, larval, young-of-the-year (YOY), small juvenile (<70 cm fork length), large juvenile (>70 cm fork length), adult, and spawning adult. The Snake River was divided into eight reaches on the basis of natural stream drainage system and habitat distinctions between Lower Granite Dam and the free-flowing river. Snake River reaches used for PTA analysis were from Hells Canyon Dam to Sheep Creek, Sheep Creek to West Creek, West Creek to Salmon River, Salmon River to Grande Ronde River, Grande Ronde River to Asotin Creek, Asotin Creek to Clearwater River, Clearwater River to Alpowa Creek, and Alpowa Creek to Lower Granite Dam. Comparisons of patient and template were made for each life stage for each river section.

Little change in habitat quality between the template and patient was found in the upper river (Hells Canyon Dam to Asotin Creek) that affects either white sturgeon egg or larval life stages. The effects of changing flow patterns were considered minimal and only a small change resulted from the increase in predators on eggs or larval white sturgeon between the Salmon River and Asotin Creek. However, severe reductions in habitat quality, considered lethal for eggs and larval white sturgeon, were apparent in lower river reaches (downstream from Asotin Creek). Lethal effects, primarily increased bedloads and changes in substrates and velocities in the lower river reaches, were directly attributed to the conversion of the free-flowing river to a reservoir. Also, adverse effects due to predation and toxicity for both eggs and larval white sturgeon, and loss of cover and habitat diversity for larval white sturgeon were found in the lower reaches.

Habitat quality for the YOY, small juvenile, large juvenile, adult, and spawning adult white sturgeon appears to have changed very little between Hells Canyon and Lower Granite dams. Only a small effect of chemical contamination, increased temperatures, and competitors on these life stages were apparent below the confluence of the Clearwater. However, effects of the catch-and-release fishery on large juveniles and adults were considered to range from low to moderate, depending on river reach and season. Impacts due to stress were thought to increase substantially during summer months when water temperatures peaked.

Changes in quantity of key habitat used by each life stage were also analyzed. Key habitat for spawning and egg incubation was described as riffles, glides, and tailouts with flow velocities $\geq$ 0.8 m/sec over boulders or cobbles. Key habitat for larval fish consists of riffles, glides, tailouts, or pools with areas of low velocity over substrate providing cover. Young-of-the-year use pools and glides with moderate to deep depths of low velocity with small diameter substrate, primarily sand and gravel. Small and large juveniles use pools and glides with moderate velocities (<1.25 m/sec), with the smaller juveniles occupying shallower pools with depths exceeding 3 m, and larger juveniles occupying pools with depths ranging from 5 to 25 m or greater. Key habitat for adults included pools and glides of all depths and velocities.

There was little or no change between template and patient in the quantity of key habitat for all life stages in the free flowing reaches upstream from Asotin Creek. However, the quantity of key habitat increased for larval, YOY, and both juvenile and adult life stages in the reservoir. In contrast, the quantity of key habitat for egg incubation and spawning decreased relative to increased wetted area and alteration of bottom substrates.

The effects of relative value of food resources were also analyzed. There was a dramatic change in the relative value of food resources throughout most of the system for all life stages between pre- and post-dam periods. This change was attributed to the reduction in anadromous salmonids and lamprey as well as the shift in fish community composition that resulted in an increase in competition between white sturgeon and other fish species found between Hells Canyon and Lower Granite dams.

Finally, changes in productivity and capacity were explored using PTA. Productivity was defined as reproductive success, or the number of eggs produced by the offspring of one spawner. Capacity for each life stage was defined as a product of the amount of key habitat and food availability and the density of the specific life stage being considered. Habitat and food availability were derived from the consensus of BRAT participants, while density was calculated from fish size information reported by Cochnauer (1983). Because information concerning white sturgeon habitat use is limited, production and capacity changes were analyzed using three different assumptions of habitat selection and utilization. The first analysis assumed that white sturgeon select habitat with the highest productivity value, that is, they are able to find and select habitat with the highest quality. The second analysis assumed that white sturgeon select habitat with highest abundance of food. The third assumed that habitat selection and use is random.

The first analysis found that changes in production for all life stages were minor. Only the production of adults and spawning life stages were slightly affected. Catch-and-release mortality during the summer in the upper reaches, and the compounding effects of chemicals, competitors, fishing, and temperature in the lower reaches, reduced productivity of these life stages. The loss in capacity, was approximately 70% for all life stages, except egg incubation, larval, and YOY. With little or no change in quantity of key habitat in the upper river, and the increase in quantity of key habitat in the lower river, the reduction in capacity was considered primarily a result of the reduction of food resources throughout the system.

The second analysis found that the loss in productivity approximated 60%. A slight decrease in productivity for both juvenile stages, and a substantial decrease in adult and spawning life stage production was found. Decreases in productivity in the upper river were attributed to mortality associated with catch-and-release fishing during summer months and in the lower river were attributed to the cumulative effects of chemical contamination, competitors, and the morality associated with catch-and-release fishing. The loss in cumulative capacity was also substantial, approximately 75%. Slight reductions in habitat for YOY, large juvenile, adult and spawning stages contributed to capacity losses, but the majority of the loss was attributed to reduced productivity and value of food resources. Reduction in food resources was found to be substantial for fish larger than 70 cm in the upper reaches of the Snake River, with food resources declining substantially above the Grande Ronde River.

The third analysis indicated that productivity was reduced approximately 80%. The majority of the change in production was found in adult and spawning life stages, while only minor changes in productivity were found in egg incubation, larval, and large juvenile life stages. Minor changes in productivity of the egg incubation stage occur in the impounded reaches and were attributed to an increase in bedload sediments, decrease in substrate sizes, and the increased effects of predation. Minor changes in production in larval white sturgeon were attributed to changes in depth, cover, and abundance of predators. The minor reduction in production of large juveniles and major reductions in adult and spawning life stages were attributed primarily to mortality associated with catch-and-release fishing. Loss of cumulative capacity was 36%. Although a greater quantity of key habitat was found in the patient (current conditions), a substantial reduction in food resource values for all life stages and a reduction in adult and spawning productivity appeared responsible for the decreases in cumulative capacity.

Potential Management Actions and Alternatives

Considering the results of the PTA, BRAT participants identified various potential management actions intended to achieve the management objectives outlined above. Potential management actions identified and considered effective measures to meet white sturgeon management objectives, assuming white sturgeon select and use habitat to maximize productivity, are:

1. Increase the food resources value (abundance and diversity) for all life stages from juveniles through spawning adults in all reaches.
    a. Enhance and restore Snake River anadromous salmonid and lamprey populations between Hells Canyon and Lower Granite dams.
    b. Supplement the food resource base with the planting of salmonids and/or shad carcasses throughout the system.
    c. Reduce power peaking generation at Hells Canyon Dam to maintain flow stability and eliminate drastic water level fluctuations to increase primary and secondary productivity.
    d. Restore river flow pattern to natural hydrograph while maintaining Lower Granite pool at the present elevation.

2. Restore white sturgeon passage at Lower Snake River and Idaho Power dams to allow utilization of additional areas for foraging.

3. Reduce chemical and contaminant loading in Lower Granite Reservoir.

The following management actions identified to effectively meet management objectives for white sturgeon assuming white sturgeon select and use habitat to gain maximum food, were:

1. Reduce the impact of the catch-and-release fishery, particularly during the summer when high water temperatures may cause increased stress.

2. Increase the food resource value (abundance and diversity) for all life stages from juveniles through spawning in all reaches (see above).

3. Enhance abundance of existing populations through supplementation.
    a. Collect adult white sturgeon from other populations in the Snake or Columbia rivers and release into the Snake River between Hells Canyon and Lower Granite dams.
    b. Collect juvenile white sturgeon from other populations in the Snake and Columbia rivers and release into the Snake River between Hells Canyon and Lower Granite dams.
    c. Produce adult white sturgeon in a hatchery and release into the Snake River between Hells Canyon and Lower Granite dams.
    d. Produce juvenile white sturgeon in a hatchery and release into the Snake River between Hells Canyon and Lower Granite dams.

There were no additional management actions proposed based on the random movement assumption. However, BRAT participants identified two other management actions for consideration in the benefit-risk analysis:

1. No action (i.e., do not implement any actions).

2. Reservoir drawdown to natural river levels that may occur for salmon restoration efforts.

Benefit-Risk Analysis

The benefit-risk process analyzed the effects of the potential management actions identified above relative to the white sturgeon management and other regional objectives that were identified. Both the perceived effectiveness and risk of each potential management action were analyzed. The perceived effectiveness of each management action was rated by BRAT participants, while the risk was addressed using the following questions:

a. How would white sturgeon productivity and capacity be affected by the management action?

b. How would the accomplishment of white sturgeon management objectives be affected by the action?

c. How would other societal values be affected by the treatment?

The BRAT found that white sturgeon productivity would be improved by enhancing and restoring the anadromous salmonid and lamprey populations or supplementing the food resource in the Snake River between Hells Canyon and Lower Granite dams. This action may increase white sturgeon spawning and growth rates. Increased food value and availability may increase capacity as well. This action was considered to have moderate potential for achieving white sturgeon management objectives. This action may lead to eventual increases in the abundance of juvenile and adult white sturgeon, although the magnitude of increases is unknown. The effects on other regional objectives are dependent on how this action would be implemented.

Only a small increase in white sturgeon productivity and a minimal increase in capacity may occur as a result of improved spawning habitat if power peaking generation at Hells Canyon Dam was reduced to maintain stable flows and water levels. This action may only have minimal effect in achieving white sturgeon management objectives and a large negative impact on power generation, but could have a positive impact on recreational use and aesthetic values.

The BRAT found that white sturgeon production may improve slightly if the natural hydrograph could be restored while maintaining Lower Granite pool at the present elevation. This action may improve egg and larval dispersal and survival but would not significantly affect capacity. This action would only be slightly effective in achieving white sturgeon objectives primarily because the present hydrograph is similar to the historical natural hydrograph with the exception of peak flow periods. However, this action could significantly affect power generation and irrigation.

Restoration of white sturgeon passage upstream and downstream past Lower Snake River and other Idaho Power dams would increase the amount of foraging areas available in the system, and thus could improve white sturgeon productivity and capacity. Growth rates and reproductive potential of those fish that seek superior foraging outside the reach could improve. This action could be highly effective in achieving the white sturgeon management objectives identified, but it would be expensive and have a large negative effect on power generation.

The potential effectiveness and risks associated with reducing contaminants in Lower Granite Reservoir were not addressed by BRAT participants. Little is known about the types and levels of contaminants in Lower Granite Reservoir or their effect on white sturgeon population dynamics.

If catch-and-release fishing is restricted, reductions in mortality rates of juvenile and adult life stages would increase productivity if carrying capacity was not exceeded, but would have no effect on capacity. Although this action could increase white sturgeon sustainability and the opportunity for tribal harvest it could reduce recreational fishing opportunities for white sturgeon.

Supplementation using white sturgeon from other populations in the Snake or Columbia Rivers or hatchery raised white sturgeon would increase productivity. Fish that die due to natural or man-induced factors could be replaced, but the capacity of the system would not be affected. This action could improve the likelihood of restoring the white sturgeon population to levels that would allow tribal and recreational harvest and potentially increase the genetic diversity of the population if the effective breeding population size was increased. However, it could be detrimental to the natural scientific value of treating this population as a control and observing natural recovery.

If no action is taken than no significant improvement in productivity or capacity would occur. The population would likely remain stable if mortality related to the catch-and-release fisheries is low. The population could be used to track natural recovery, but it would be unlikely that the population would reach a level where all white sturgeon objectives would be achieved.

A reservoir drawdown to natural river levels could act to increase productivity by improving egg dispersal and survival, and spawning habitat quality. Capacity of the system could increase for egg incubation and spawning life stages. However, capacity may decrease for other life stages, primarily by reducing rearing habitat for YOY and juveniles. This action could also increase the rate of entrainment (an emigration loss) below Lower Granite Dam. To create viable habitat for spawning and egg incubation in Lower Granite Reservoir accumulated sediments would have to be scoured. Overall, the negative effects of this action could outweigh the benefits.

Critical Uncertainties

Critical uncertainties or unknowns concerning the effectiveness of potential management actions were also identified by BRAT participants. These uncertainties need to be resolved before the potential effectiveness of the mitigative action can be fully evaluated. For example, before the effectiveness of mitigative actions formulated to enhance and restore the quantity and quality of food resources can be fully assessed four uncertainties need to be clarified. Unless it is determined what percentage of food supplemented would go to white sturgeon, how food could be distributed throughout the system, how white sturgeon would directly or indirectly benefit, and how much increase in prey abundance is needed these actions can not be fully assessed.

Before recommendations to alter power peaking generation at Hells Canyon or flow patterns in the river can be made, or the effectiveness of proposed flow changes assessed, uncertainties concerning how the hydrograph affects the quantity and quality of white sturgeon spawning habitat, secondary production/food resources, and white sturgeon habitat need to be determined.

In order to successfully restore white sturgeon passage upstream and downstream past the Snake River dams and assess the potential effectiveness of restored passage, we first need to determine whether the physical challenges allowing passage can be resolved. Then we will need to determine: 1) how many fish and of which life stages would move in and out of the reach, 2) for which dams, upstream and downstream, could passage be provided, and 3) if the expanded range for white sturgeon will actually increase capacity and productivity.

We need to quantify the mortality resulting from catch-and-release fishing before the effectiveness of potential management actions designed to reduce the effects of this fishery can be assessed, We also need to determine if all fisheries would need to be closed to decrease the incidental catch of white sturgeon, or if mortality could be sufficiently reduced by eliminating only white sturgeon fishing.

The primary uncertainty associated with supplementation of the white sturgeon population between Hells Canyon and Lower Granite dams concerns our lack of knowledge of whether the current white sturgeon population in the Upper Snake River basin is at equilibrium or whether there is under-utilized capacity. We also do not know if 1) supplementation will accelerate the rate at which the population will reach equilibrium, 2) potential donor populations are genetically compatible and adapted for Snake River conditions, 3) white sturgeon can be collected, handled, and released with acceptable levels of mortality, 4) released fish will remain in the river reach and disperse normally, 5) fish will survive, grow, and reproduce, and 6) hatchery fish can successfully and economically be produced in a hatchery environment.

Even if no action is taken, assuming that the population is allowed to recover naturally, we still need to determine if mortality occurs as a result of current recreational fisheries practices, and if so what level of fishing mortality can the population sustain. In addition, we are also unaware of 1) the status and prognosis of the population, 2) how available habitat is used by various life stages, 3) what the long-term potential for harvest is, 4) whether the population currently is at equilibrium, and 5) how isolation by damming is affecting white sturgeon population dynamics. Until these uncertainties are resolved, it is impossible to determine what the effect of taking no action could be on the white sturgeon population.

Finally, if Lower Granite Reservoir is drawn down for salmon restoration it is assumed that downstream entrainment would occur, but we are uncertain of the extent and what the effect on the population would be. We also assume scouring would occur, but we do not know whether scouring resulting from the drawdown would be sufficient to restore suitable habitat for spawning and egg incubation and whether the resulting habitat will be used by other life stages. It is unknown whether the benefits of increased spawning habitat would offset the losses due to entrainment and of rearing habitat for YOY and juveniles.

Informational Needs

Until the uncertainties associated with each of the potential management actions can be resolved, the effectiveness of their implementation can not be fully assessed. BRAT participants identified a broad array of information needs that are fundamental to evaluating the full effectiveness of any potential management action (Carmichael et al. 1997). Pertinent information concerning the Upper Snake River white sturgeon populations that is lacking or limited includes:

- The effect of catch-and-release fishery on productivity;
  - a. An estimate of mortality by life stage and identification of the sources of mortality.
  - b. An evaluation of physiological responses to the stress of catch and release and its impact on productivity of individuals and populations.

- The health and status of the white sturgeon population;
  - a. Abundance estimates throughout the entire reach.
  - b. Density by habitat type and reach.
  - c. Age specific growth rates (length and weight) by sex.
  - d. Sex ratios by age.
  - e. Age specific fecundity (either from this stock or surrogate stock).
  - f. Age at maturity for females.
  - g. Spawning periodicity for females.
  - h. Total mortality by age.
  - i. Physiological measures of health-developmental condition factors.
  - j. Food habits.

- Determining specific life history attributes;
  - a. Spawning locations and timing.
  - b. Egg and larva distribution patterns.
  - c. Young-of-the-year movement and rearing patterns.
  - d. Adult movement and rearing patterns.

- The effects of contaminants.

- Genetic characterization and comparison with other Columbia basin stocks.

- Degree and effects of entrainment and recruitment from upstream;
  - a. Magnitude by life stage.
  - b. Timing.

DISCUSSION

Biological Risk Assessment

Because quantitative information concerning white sturgeon populations between Hells Canyon and Lower Granite dams is not generally available, the Ecosystem Diagnosis and Treatment (EDT) process that relied on the knowledge of regional experts was successful in identifying life history and environmental relationships for white sturgeon that otherwise would not be available. As a result, the Biological Risk Assessment was able to identify important regional management objectives, potential mitigative and management actions needed to achieve these objectives, and the risks (potential effects and uncertainties) associated with the implementation of these actions.

The Biological Risk Assessment also identified the need for basic research to determine baseline conditions concerning the effects of catch-and-release fisheries, the status and health of the population, basic life history and genetic characteristics of the population, effects of contaminants, and rates and effects of entrainment and recruitment. Without this information the effects of management actions on the white sturgeon population and their success in achieving management objectives can not be evaluated. Although informational needs were not prioritized by BRAT participants, we feel it is important that research be conducted in order to be able to assess success of management actions in protecting and enhancing populations while attempting to mitigate the effects of hydropower systems on white sturgeon productivity in the Snake River between Hells Canyon and Lower Granite dams.

Plans for 1997

In response to the data needs identified by the Biological Risk Assessment we are in the process of formulating a multi-year study plan designed to obtain the necessary data that will allow us to determine the need for, and assess the effects of, potential management actions, if their implementation is deemed necessary. In 1997 we will begin to determine the status of the white sturgeon population between Hells Canyon and Lower Granite dams by estimating the abundance of age classes throughout the entire reach. To begin assessing the status of the white sturgeon population between Hells Canyon and Lower Granite white sturgeon will be captured using diver/gill nets, setlines, and hook-and-line sampling at random locations in the Snake River. Captured white sturgeon will be marked, weighed and measured. Not all of the proposed sampling methods can be used in all of the river reaches within the study area. One method may be more efficient than another within a single sampling reach depending on flow conditions. Nets, although found to be highly efficient at capturing white sturgeon in Lower Granite Reservoir (Lepla 1994), can only be used in low velocities. Setlines can be used in the majority of the river reaches if they are accessible by boat. Hook-and-line sampling can be conducted at all accessible sites, but is generally less efficient than nets and setlines Multiple methods will be used within a reach so valid comparisons of catch rates can be made between reaches and the total population throughout the study area can be estimated. Experimental design, methodology, and costs to fully assess the health and status of the population and characterize spawning and rearing habitat will be addressed in the 1997 multi-year research plan. Other study plans will be developed to address additional informational needs identified by the BRAT as funds become available.

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