STATUS AND HABITAT REQUIREMENTS OF WHITE STURGEON POPULATIONS IN THE COLUMBIA RIVER DOWNSTREAM FROM MCNARY DAM

Annual Progress Report

April 1988 - March 1989

Edited By

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EXECUTIVE SUMMARY

We report on our progress from April 1988 through March 1989 on determining the status and habitat requirements of white sturgeon populations in the Columbia River downstream from McNary Dam. The study is a cooperative effort by the Oregon Department of Fish and Wildlife (ODFW), Washington Department of Fisheries (WDF), U.S. Fish and Wildlife Service (FWS) and National Marine Fisheries Service (NMFS). Study objectives addressed by each agency are

1. ODFW (Report A): Describe the life history and population dynamics of subadults and adults between Bonneville and McNary dams and evaluate the need and identify potential methods for protecting, mitigating and enhancing populations downstream from McNary Dam.

2. WDF (Report B): Describe the white sturgeon recreational fishery between Bonneville and McNary dams, describe some reproductive and early life history characteristics downstream from Bonneville Dam and describe life history and population dynamics of subadults and adults downstream from Bonneville Dam.

3. FWS (Report C): Describe reproduction and early life history characteristics, define habitat requirements for spawning and rearing and quantify extent of habitat available between Bonneville and McNary dams.

4. NMFS (Report D): Describe reproduction and early life history characteristics, define habitat requirements for spawning and rearing and quantify extent of habitat available downstream from Bonneville Dam.

Our approach is to work concurrently downstream and upstream from Bonneville Dam[1]. Upstream from Bonneville Dam we began work in The Dalles Reservoir in 1987, expanded efforts to Bonneville Reservoir in 1988 and plan to include John Day Reservoir in 1989.

Highlights of results of our work in The Dalles and Bonneville reservoirs are

1. Using setlines, we caught 1,586 sturgeon in The Dalles Reservoir and 484 sturgeon in Bonneville Reservoir in 1988. Fork length of fish caught ranged from 34 cm to 274 cm. Of the fish caught we marked 1,248 in The Dalles Reservoir and 341 in Bonneville Reservoir. Of the fish marked in 1988, we recaptured 82 in The Dalles Reservoir and none in Bonneville Reservoir. We recaptured 89 fish marked in 1987 in The Dalles Reservoir. Anglers recaptured 35 fish marked in 1988 and 16 fish marked in 1987 in The Dalles Reservoir. Anglers recaptured 2 sturgeon marked in 1988 in Bonneville Reservoir.

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[1] *ODFW, WDF, FWS and NMFS. 1987. Status and habitat requirements of white sturgeon populations in the Columbia River downstream from McNary Dam. Annual Progress Report to the Bonneville Power Administration, Portland.*

2. Catch rates of sturgeon in setlines were 2.35 per overnight set in The Dalles Reservoir and 2.85 per overnight set in Bonneville Reservoir. Catch rates in the boat-restricted zones downstream from John Day and The Dalles dams were 6 and 4 times greater than elsewhere in The Dalles or Bonneville reservoirs.

3. Sturgeon moved throughout the reservoir; some recaptured fish moved up to 37 km and almost half moved at least 6 km from where tagged. No marked fish moved between reservoirs.

4. Ages of sturgeon sampled ranged from one to 46 years, although comparisons of paired readings showed only 65% agreement, indicating ages were uncertain. Two to four percent of sturgeon caught in 1987 and 1988 had developing or ripe eggs. Fecundity increased exponentially with length.

5. We interviewed 7,475 recreational anglers in The Dalles Reservoir and 4,654 recreational anglers in Bonneville Reservoir in 1988. Our estimates of angling effort for sturgeon were 64,692 hours in The Dalles Reservoir and 41,643 hours in Bonneville Reservoir. We estimated harvest by the recreational fishery to be 863 sturgeon from The Dalles Reservoir and 1,135 sturgeon from Bonneville Reservoir in 1988. Catch per hour averaged about 0.01 sturgeon in both reservoirs; boat anglers having twice the success of bank anglers.

6. Average lengths of recreationally harvested sturgeon before the minimum length limit was changed from 91 cm to 102 cm were 113 cm in The Dalles Reservoir and 96 cm in Bonneville Reservoir. After the minimum length limit was changed, average lengths harvested were 118 cm in The Dalles Reservoir and 103 cm in Bonneville Reservoir. Recreational anglers handled an estimated 5 sublegal-sized sturgeon for every legal-sized sturgeon handled in both reservoirs. Recreational anglers handled an estimated 5 legal-sized sturgeon for each overlegal-sized sturgeon handled in The Dalles Reservoir and 2 legal-sized for each overlegal-sized in Bonneville Reservoir.

7. The tribal commercial fishery harvested an estimated 4,141 sturgeon from all three reservoirs between Bonneville and McNary dams in 1988. Most of the harvest (3,786 sturgeon) was caught by set nets between February 1 and March 21, June 22 and July 9, and August 10 and September 3. Average lengths of commercially harvested sturgeon were 127 cm in The Dalles Reservoir and 114 cm in Bonneville Reservoir.

8. We caught 25 sturgeon eggs and 14 sturgeon larvae in John Day Dam tailrace from June 13 through July 14, 1988. We caught 156 eggs and 13 larvae in The Dalles Dam tailrace from May 25 through July 19, 1988. Eggs were collected in water up to 27 m deep. Larvae were collected in water up to 20 m deep. Eleven of the eggs (44%) in the John Day Dam tailrace were dead and covered with fungus. Developmental stages of eggs ranged from early gastrula to prehatch. Larvae were mostly one-day posthatch (11 to 13 mm TL); one was three-day posthatch (15 mm TL). Eggs were collected in both reservoirs at times when water temperatures were reported by others to be lethal to sturgeon eggs.

9. Based on back-calculated ages of eggs and larvae, spawning in The Dalles Reservoir in 1988 probably occurred May 30 to June 3, June 8, July 6 and July 11 to 12. Spawning in Bonneville Reservoir in 1988 probably occurred between May 25 and July 19. We observed spawning activity in Bonneville Reservoir downstream from The Dalles Dam spillway on June 3. Spawning behavior appeared to involve breaching and rolling of individuals near shore and occurred between the hours of 1200 and 1345 when daily discharge from The Dalles Dam was highest.

10. We caught 484 sturgeon in The Dalles Reservoir and 860 sturgeon in Bonneville Reservoir with trawls. Fork lengths ranged from 22 to 86 cm. We caught no post-larval young-of-year or age 1 sturgeon in either reservoir. Sixty percent of our catch in The Dalles Reservoir and 85 percent of our catch in Bonneville Reservoir was at sites with maximum depths greater than 17 m. We observed no apparent relationship between numbers of benthos and numbers of juvenile sturgeon sampled at various sites in The Dalles and Bonneville reservoirs.

11. The length-weight relationship of juvenile sturgeon was described as $\log W = 3.10(\log FL) - 5.42$ in The Dalles Reservoir and $\log W = 3.01(\log FL) - 5.19$ in Bonneville Reservoir; where W is weight in g and FL is fork length in mm. Mean fork length at age was 37 cm at age 2, 41 cm at age 3, 47 cm at age 4, 56 cm at age 5, 63 cm at age 6, and 68 cm at age 7 in The Dalles Reservoir and 38 cm at age 2, 44 cm at age 3, 47 cm at age 4, 51 cm at age 5, and 55 cm at age 6 in Bonneville Reservoir.

Highlights of results of our work downstream from Bonneville Dam are

1. We caught 3,044 sturgeon in 1988 working with commercial fishermen. We tagged 2,661 sturgeon. We examined for marks 9,845 sturgeon caught by the recreational fishery and 1,802 sturgeon caught by the commercial fishery. Of fish tagged in 1988, 63 were observed in our sample of recreationally caught fish and 4 were observed in our sample of commercially caught fish. Of fish tagged in 1983 through 1987, we observed 242 in our recreational fishery sample and 43 in our commercial fishery sample. From the mark-recapture ratios we observed we estimated abundance of harvest-size sturgeon in 1986 through 1988 to range from 121,000 to 216,000. We estimated harvest in 1986 through 1988 to range from 50,000 to 72,000.

2. We collected 1.404 sturgeon eggs and 90 sturgeon larvae between April 25 and June 20, 1988. We collected 719 eggs with nets and 685 eggs with artificial substrates. Most eggs and larvae were collected at the Ives Island sampling station, although 84 eggs were collected on artificial substrates placed just downstream from Bonneville Dam spillway. No eggs were collected on artificial substrates placed just downstream from Bonneville Dam second powerhouse. Developmental stages of eggs ranged from unfertilized to prehatch. Larval ages ranged from one to nine days posthatch; although most were one-day posthatch. We estimated spawning period, back-calculated from egg and larval stages in samples, to extend from April 19 to June 20.

3. Examination of substrate where eggs were collected revealed smooth cobble and rock. Bottom temperatures ranged from 10 to 16 C. Turbidities ranged from 2.6 to 6.5 NTU. Mean water column velocities were 1.2 to 2.8 m/s. Substrate samples indicated that some cobble occurs throughout the 7-mile stretch of river downstream from Bonneville Dam. This may represent the extent of preferred spawning habitat present between Bonneville Dam to the estuary.

4. We collected 2,633 juvenile sturgeon with trawls in 1988; 11 that were post-larval young-of-year. We tagged 1,494 juvenile sturgeon. We recaptured 16 sturgeon tagged in 1988 and 19 tagged in 1987. Distribution of juveniles was patchy and varied over the length and width of the study area. Juvenile sturgeon did not appear to move much; 91 percent of tagged fish were recovered where released. Minimum and maximum depths sampled were poor predictors of juvenile sturgeon densities, although mean densities were highest at sites with maximum depths greater than 18.3 m. We observed a poor relationship between juvenile sturgeon densities and benthic invertebrate densities or substrate sediment structure.

5. The length-weight relationship of juvenile sturgeon was described as $\log W = 3.11(\log FL) - 5.46$; where W is weight in g and FL is fork length in mm. Stomach content analyses from 100 of 292 samples collected showed the tube dwelling amphipod, *Corophium salmonis*, had the highest index of relative importance of all juvenile sturgeon food items. Eulachon eggs were an important food item at some locations.

REPORT A

1. Description of the life history and population dynamics of subadult and adult white sturgeon in the Columbia River between Bonneville and McNary Dams.

2. Evaluation of the need and identification of potential methods for protecting, mitigating, and enhancing white sturgeon populations in the Columbia River downstream from McNary Dam.

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ABSTRACT

We report on our effort from April 1988 to March 1989 to describe the life history and dynamics of white sturgeon *Acipenser transmontanus* in The Dalles and Bonneville reservoirs. We set 674 setlines in The Dalles Reservoir and 170 setlines in Bonneville Reservoir. We caught 1,586 white sturgeon in The Dalles Reservoir and 484 in Bonneville Reservoir. Catch per unit effort varied among areas of the reservoir. Our setlines were size selective. We recaptured 89 fish released in 1987 and 82 fish released in 1988. Spaghetti tags and barbel clips were the most persistent marks we examined. Extensive movements within the reservoir were observed for marked sturgeon. We aged fish as old as 46 and report on the uncertainty of our aging method. We estimated parameters in a length weight equation. Approximately 2.4% of the white sturgeon we examined were females that contained developing eggs.

INTRODUCTION

We began our study of white sturgeon *Acipenser transmontanus* life history and population dynamics in July 1986. We reported our progress through March 1988 in two reports: Rieman et al. (1987) and Nigro et al. (1988). In this report we describe our activities and results from April 1988 through March 1989. Previous work and reports focused on developing methods to effectively sample and mark subadult and adult white sturgeon. In this report, we summarize progress in applying those methods toward study objectives and intermediate results upon which analyses satisfying study objectives will be based.

METHODS

We sampled white sturgeon from May through July 1988 in The Dalles Reservoir and in August 1988 in Bonneville Reservoir to estimate population statistics. We divided The Dalles Reservoir into six sections and Bonneville Reservoir into eight sections (Figure 1). Sections were approximately 4 river-miles long in The Dalles Reservoir and 6 river-miles long in Bonneville Reservoir. We report results for the boat-restricted zones (BRZ) adjacent to and downstream from John Day and The Dalles Dams separate from other sections in each pool because the BRZs were unique habitats. BRZs were less than one-half mile long.

We attempted to distribute sampling effort equally among and within sections to representatively sample the population. We sampled all sections in The Dalles Reservoir once every 3 weeks and all sections within Bonneville Reservoir in a 4-week period. In The Dalles Reservoir we sampled each section on at least 4 occasions and in Bonneville Reservoir we sampled each section once (Table 1).

We sampled exclusively with setlines because they provide the greatest catch rate and are less size selective than other gears (Nigro et al. 1988). Lines were fished overnight for 13 to 38 hours. We used 12/0, 14/0, and 16/0 hooks baited with pieces of Pacific lamprey *Lampetra tridentata*. Each line had 40 hooks.

We measured fork length and examined each white sturgeon caught for tags, tag scars, tattoos, fin marks, barbel clips, and scute marks. We tagged all untagged white sturgeon with a fork length between 70 and 90 cm with one spaghetti tag and all white sturgeon longer than 90 cm with two spaghetti tags. Tagged white sturgeon were also marked by removing the third lateral scute on the right side to help identify tag loss. In addition, every other fish was secondarily marked by removing the right barbel so to evaluate effects of barbel removal. We weighed and measured total length, pectoral girth, and pelvic girth of all white sturgeon from The Dalles Reservoir with fork length greater than 150 cm to supplement samples collected in 1987. We weighed all white sturgeon collected in Bonneville Reservoir.

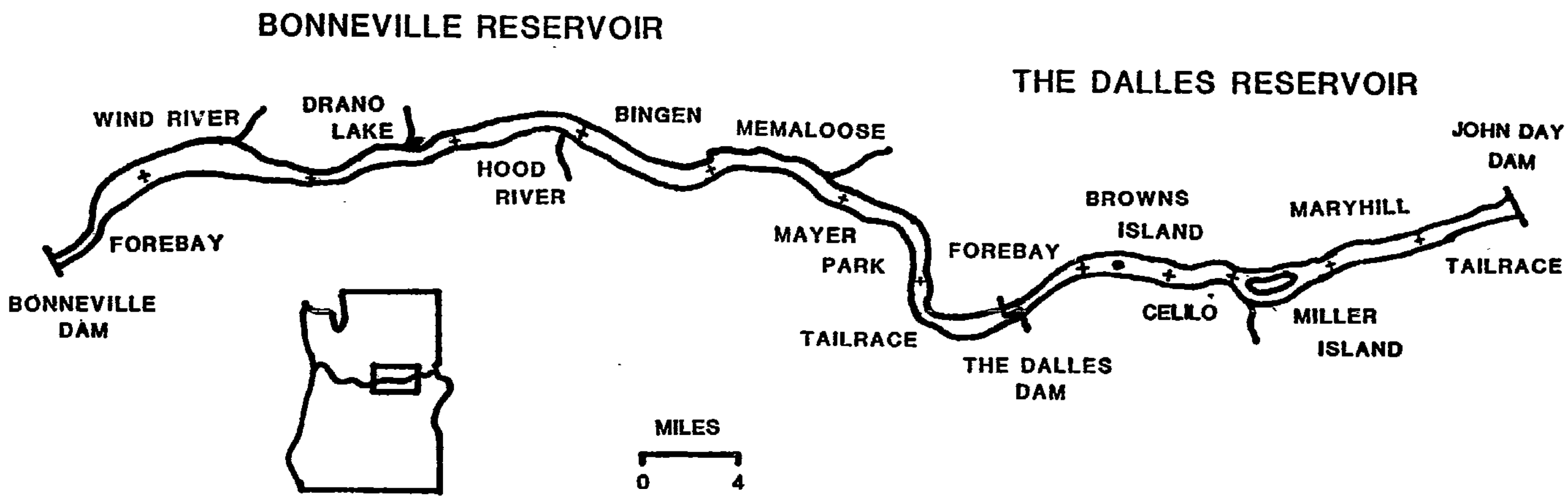


Figure 1. Sampling areas in Bonneville and The Dalles reservoirs on the Columbia River.

Table 1. Sampling effort (number of setline sets) for white sturgeon in Bonneville and The Dalles reservoirs, March through August 1988.

Reservoir, Julian week	Location[a]								
	1	2	3	4	5	6	7	8	9
Bonneville									
32	--	--	--	--	--	--	27	12	4
33	--	--	--	--	24	23	--	--	--
34	24	24	--	--	--	--	--	--	--
35	--	--	12	20	--	--	--	--	--
The Dalles									
17	--	--	--	--	--	1	2	--	--
18	7	1	--	--	--	--	--	--	--
19	--	--	--	--	12	23	6	--	--
20	--	--	19	23	--	--	--	--	--
22	24	18	--	--	--	--	--	--	--
23	--	--	30	30	--	--	--	--	--
24	30	30	--	--	--	--	--	--	--
25	--	--	--	--	30	24	6	--	--
26	35	23	--	--	--	--	--	--	--
27	--	--	--	--	30	24	6	--	--
28	--	--	30	30	--	--	--	--	--
29	--	--	--	--	33	21	6	--	--
30	--	--	30	30	--	--	--	--	--
31	30	30	--	--	--	--	--	--	--

[a] *In Bonneville Reservoir: 1 = Forebay, 2 = Wind River, 3 = Drano Lake, 4 = Hood River, 5 = Bingen, 6 = Memaloose, 7 = Mayer Park, 8 = Tailrace, 9 = The Dalles BRZ. In The Dalles Reservoir: 1 = Forebay, 2 = Browns Island, 3 = Celilo, 4 = Miller Island, 5 = Maryhill, 6 = Tailrace, 7 = John Day BRZ.*

We collected a section of the right pectoral fin ray from each white sturgeon longer than 150 cm captured in The Dalles Reservoir and every other sturgeon captured in Bonneville Reservoir to determine age (Appendix A-1). We also injected 822 white sturgeon with tetracycline to mark fin rays so that we can test the validity of our interpretation of age from fin sections of fish we recapture in future years. We injected 50, 100, or 200 mg/ml tetracycline into the red muscle under the dorsal scutes just behind the head. We adjusted doses such that each fish received about 25 mg/kg of body weight. We injected white sturgeon shorter than 86 cm and longer than 185 cm so that anglers who can legally keep fish between 91 and 183 cm in length would not risk eating flesh from an injected fish within the 15-day period directed by the Food and Drug Administration.

We examined the gonads of every white sturgeon longer than 150 cm to determine sex and stage of maturity (Appendix A-2). Small (1-2 cm) incisions were made on the ventral surface anterior to the vent. Otoscopes were inserted into the incisions and gonad condition was visually estimated according to criteria outlined in Nigro et al. (1988). Samples (3-5 g) of the gonad of females in which eggs were visible were removed with biopsy forceps and preserved in formalin. Incisions were closed with sutures and sealed with a surgical adhesive. We released all live fish after handling. We also examined samples of gonads from the catch in recreational and commercial fisheries in Bonneville, The Dalles, and John Day reservoirs, supplied by Washington Department of Fisheries (WDF).

We determined the relative efficiency of our sampling gear by examining length-frequency distributions of fish captured and recapture-to-at-large ratios of different sized fish so that we could correct analyses for gear biases. In preparation for estimating abundance and mortality rates of white sturgeon, we summarized number of white sturgeon marked and number recaptured in our sampling and by anglers who voluntarily returned tags. We also compared loss rates of tags and secondary marks to help select persistent marks and calculate correction factors in recapture rates.

We examined the distribution of white sturgeon by comparing catch rate among areas. We compared sites and dates of release and recapture of marked fish to determine the extent and timing of movement within each reservoir and to determine whether populations in each reservoir mixed.

We estimated age of white sturgeon from thin cross sections of pectoral fin rays (Appendix A-1) and summarized this information in preparation for estimating growth and age composition of white sturgeon populations. Each fin ray section was aged by at least two persons. We also examined the potential for variation in assigned age resulting from two extreme interpretations of banding patterns. At one extreme every band in a fin ray section was counted and at the other extreme only very distinct bands were counted. We assumed these alternative counts represented the oldest and youngest ages that could potentially be assigned.

We quantified the relationship between length and weight. We measured the diameter of eggs from ovarian samples to help determine the period of development so that we could estimate the proportion of the population that are females that will spawn each year. Number of females spawning this year was estimated to include ripe and spent fish. Number spawning next year was estimated to include early and late vitellogenic eggs.

RESULTS

Catch

We caught 1,586 white sturgeon in The Dalles Reservoir (2.35 per setline set) and 484 white sturgeon in Bonneville Reservoir (2.85 per set) in 1988 (Table 2). Our gear sampled fish between 34 and 274 cm fork length (Figure 2), although some sizes of fish appeared more vulnerable to capture (Figure 3).

Marking and Mark Recovery

We marked 1,248 white sturgeon in The Dalles Reservoir in 1988 and subsequently recaptured 82 of those marked fish, including 8 individuals that we recaptured twice (Table 3). We also recaptured 89 fish that were marked and released in The Dalles in 1987 (Table 4). We marked 341 sturgeon in Bonneville Reservoir. During 1988, at least 16 fish marked in 1987 and 35 fish marked in 1988 were caught by fishermen (Table 5). Spaghetti tags in the posterior position and barbel clips were the most persistent of the marks we tested (Table 6).

Distribution and Movement

White sturgeon were not evenly distributed and moved freely throughout The Dalles or Bonneville reservoirs. Densities in BRZs (inferred from catch per unit effort) were six times greater in The Dalles Reservoir and four times greater in Bonneville Reservoir than in the rest of the respective reservoirs (Table 7). White sturgeon were often recaptured in areas other than where released both in the year of release (Table 8) and in the year following release (Table 9). Movement of up to 37 km was observed, and 43% of the fish recaptured in the year of release had moved 6 or more km (Figure 4). We saw no movement of marked white sturgeon outside of the reservoir where marked. One white sturgeon marked by WDF below Bonneville Dam (unreadable tag) was recaptured in The Dalles Reservoir in 1987.

Table 2. Catches of white sturgeon in Bonneville and The Dalles reservoirs, March through August 1988.

Reservoir, Julian week	Location[a]								
	1	2	3	4	5	6	7	8	9
Bonneville									
32	--	--	--	--	--	--	92	57	46
33	--	--	--	--	85	51	--	--	--
34	24	26	--	--	--	--	--	--	--
35	--	--	46	57	--	--	--	--	--
The Dalles									
17	--	--	--	--	--	6	40	--	--
18	6	1	--	--	--	--	--	--	--
19	--	--	--	--	12	50	36	--	--
20	--	--	29	41	--	--	--	--	--
22	26	28	--	--	--	--	--	--	--
23	--	--	32	35	--	--	--	--	--
24	40	50	--	--	--	--	--	--	--
25	--	--	--	--	103	67	79	--	--
26	77	29	--	--	--	--	--	--	--
27	--	--	--	--	92	51	79	--	--
28	--	--	43	71	--	--	--	--	--
29	--	--	--	--	97	65	56	--	--
30	--	--	62	88	--	--	--	--	--
31	40	55	--	--	--	--	--	--	--

[a] *In Bonneville Reservoir: 1 = Forebay, 2 = Wind River, 3 = Drano Lake, 4 = Hood River, 5 = Bingen, 6 = Memaloose, 7 = Mayer Park, 8 = Tailrace, 9 = The Dalles BRZ. In The Dalles Reservoir: 1 = Forebay, 2 = Browns Island, 3 = Celilo, 4 = Miller Island, 5 = Maryhill, 6 = Tailrace, 7 = John Day BRZ.*

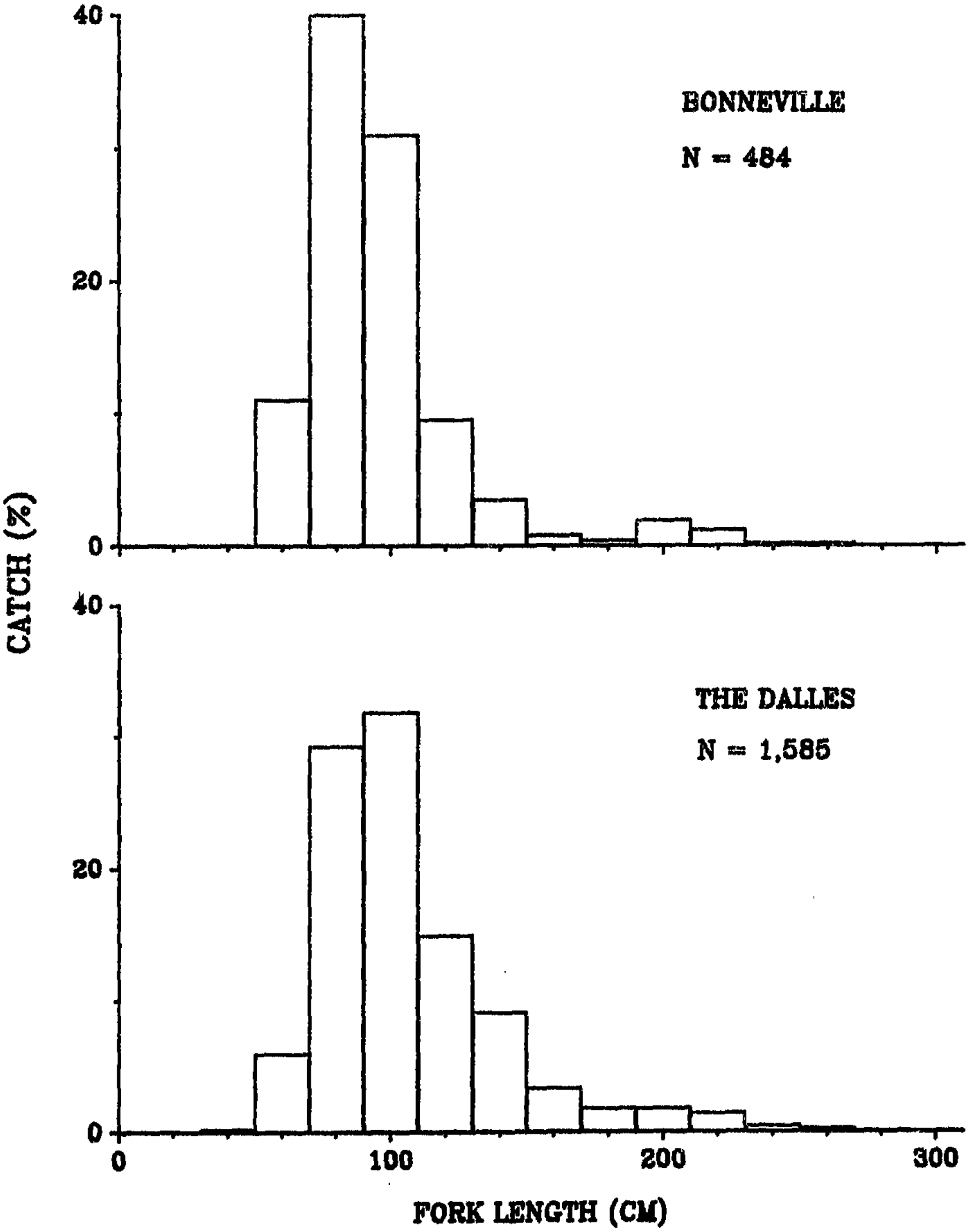


Figure 2. Length-frequency distributions of white sturgeon collected in Bonneville and The Dalles reservoirs, 1988.

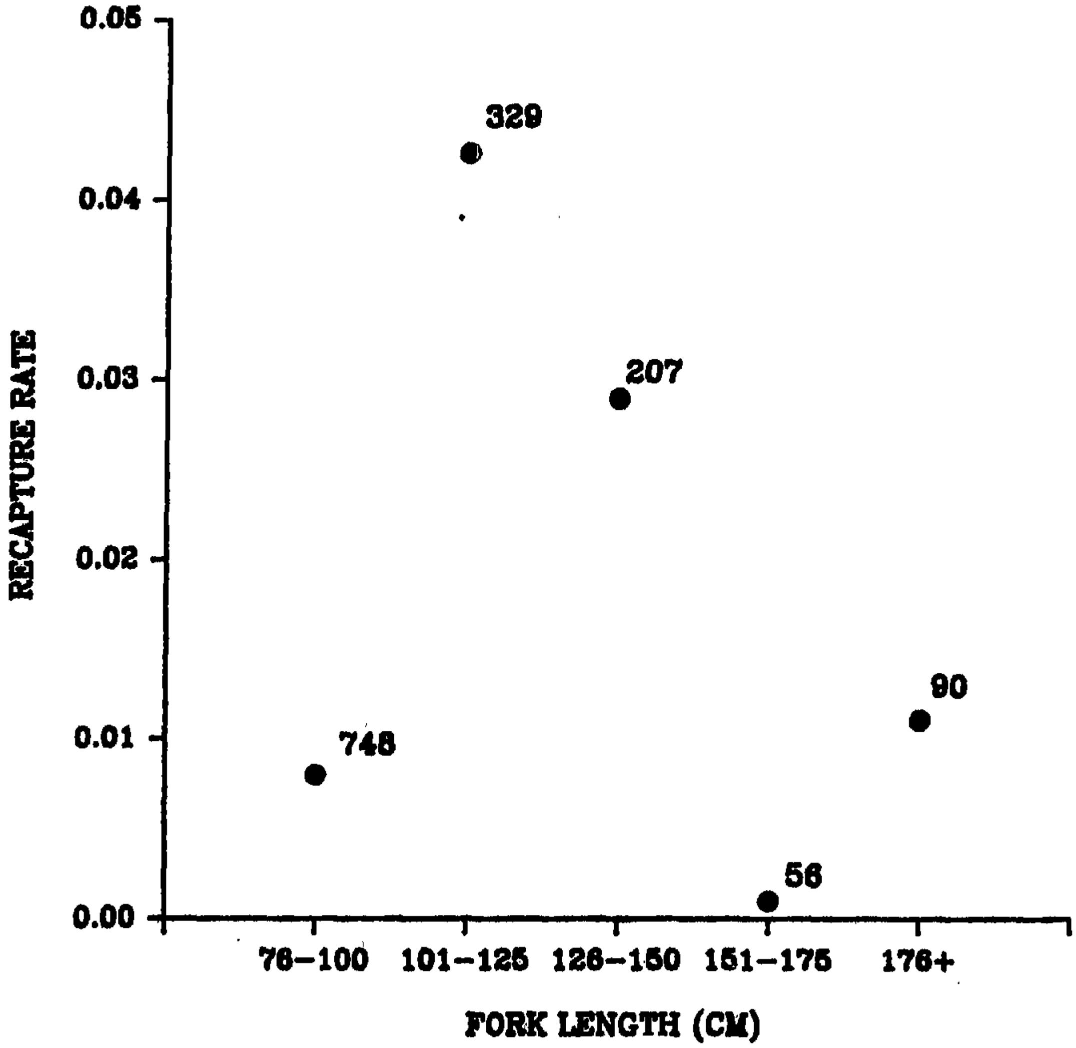


Figure 3. Recapture rate of white sturgeon by length interval, 1988. Number of marked fish at large, summed for four, 1-month periods is shown for each data point.

Table 3. Mark and recapture data for white sturgeon marked and recaptured in 1988.

Reservoir, month	Number caught	Number Recaptured	Number marked	Number removed[a]		Number marks at large
				Unmarked	Marked	
Bonneville:						
August	566	0	341	0	0	0
The Dalles:						
April	98	0	50	46	0	0
May	182	0	157	21	0	50
June	402	12	326	59	4	207
July	452	25	358	61	4	529
August	407	37	357	10	3	883
Total	1,541	74	1,248	197	11	

[a] *Includes observed catch by recreational and commercial fishermen from sampling by Washington Department of Fisheries.*

Table 4. Mark and recapture data from The Dalles Pool for white sturgeon recaptured in years subsequent to the year of marking.

Year	Number caught	Number recaptured	Number marked	Number removed[a]		Number marks at large
				Unmarked	Marked	
1987	1,604	0	770	749	48	0
1988	1,689[b]	89	1,248	339	35	722
Total	3,293	89	2,018	1,088	83	

[a] *Includes observed catch by recreational and commercial fishermen from sampling by Washington Department of Fisheries.*
[b] *Includes fish collected from January through December.*

Table 5. Recovery of sturgeon tags by recreational and commercial fishermen in Bonneville and The Dalles reservoirs, 1988.

Reservoir, release year, source	Month of recapture							
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bonneville:								
1988:								
recreational voluntary	--	--	--	0	0	0	0	2
recreational sample[a]	--	--	--	0	0	0	0	0
commercial voluntary	--	--	--	0	0	0	0	0
commercial sample[a]	--	--	--	0	0	0	0	0
The Dalles:								
1987:								
recreational voluntary	2	3	1	0	1	1	0	1
recreational sample	0	3	1	2	0	0	0	0
commercial voluntary	0	0	0	1	0	0	0	0
commercial sample	0	0	0	0	0	0	0	0
1988:								
recreational voluntary	0	2	3	2	4	3	2	4
recreational sample	0	3	1	2	0	3	0	0
commercial voluntary	0	0	0	2	1	0	0	0
commercial sample	0	0	0	1	0	0	0	0

[a] *Refers to recoveries during subsampling of the catch of recreational or commercial fishermen for biological information.*

Table 6. Retention of marks by white sturgeon recaptured with setlines. All reservoirs and sample years are combined.

Mark type, retention	Years since release	
	<1	1
Spaghetti tag (anterior):		
Retained	91	52
Lost	2	10
Spaghetti tag (posterior):		
Retained	57	37
Lost	0	0
Tattoo:		
Retained	3	0
Lost	4	28
Barbel clip:		
Retained	49	60
Lost	0	1
Fin-ray section:		
Retained	5	9
Lost	1	9
Scute mark:		
Retained	70	--
Lost	10	--

Table 7. Catch per setline day (40 hooks) of white sturgeon in areas of Bonneville and The Dalles reservoirs. All years of sampling are combined and weighted equally.

Reservoir, month	Location[a]								
	1	2	3	4	5	6	7	8	9
Bonneville:[b]									
August	1.50	1.63	3.92	3.10	3.63	2.43	3.52	4.83	11.50
The Dalles:[c]									
May	1.49	1.75	1.87	2.36	1.46	4.20	14.38	--	--
June	2.86	4.08	1.57	1.67	3.47	2.96	13.17	--	--
July	2.09	1.21	2.45	3.05	3.15	2.94	13.38	--	--
All	2.15	2.35	1.96	2.36	2.69	3.37	13.64	--	--

[a] *In Bonneville Reservoir: 1 = Forebay, 2 = Wind River, 3 = Drano Lake, 4 = Hood River, 5 = Bingen, 6 = Memaloose, 7 = Mayer Park, 8 = Tailrace, 9 = The Dalles BRZ. In The Dalles Reservoir: 1 = Forebay, 2 = Browns Island, 3 = Celilo, 4 = Miller Island, 5 = Maryhill, 6 = Tailrace, 7 = John Day BRZ.*

[b] *1988 sampling.*

[c] *1987-88 sampling.*

Table 8. Number of white sturgeon marked and recovered during the year of marking, by location in The Dalles Reservoir, 1987-88 combined.

Tagging location	Number tagged	Recapture location						
		1	2	3	4	5	6	7
1. Forebay	335	9	0	4	2	0	5	1
2. Browns Island	269	0	3	2	3	1	3	0
3. Celilo	225	1	0	3	5	0	1	0
4. Miller Island	257	0	0	1	6	5	4	3
5. Maryhill	278	0	2	2	2	11	5	2
6. Tailrace	317	0	0	3	3	0	14	4
7. John Day BRZ	469	0	0	2	3	3	24	11
8. Other	418	0	0	0	0	0	0	0

Table 9. Number of white sturgeon marked and recovered at least one year following marking by location in The Dalles Reservoir. Fish marked in 1987 and recaptured in 1988 are included.

Tagging location	Number tagged	Recapture location						
		1	2	3	4	5	6	7
1. Forebay	162	8	1	0	0	1	1	1
2. Browns Island	122	1	3	0	0	0	2	0
3. Celilo	90	0	2	3	0	1	1	0
4. Miller Island	65	0	1	0	2	0	0	0
5. Maryhill	26	0	0	0	0	1	0	0
6. Tailrace	124	0	0	0	3	3	2	2
7. John Day BRZ	241	1	0	4	0	6	10	13
8. Other	0	0	0	0	0	0	0	0

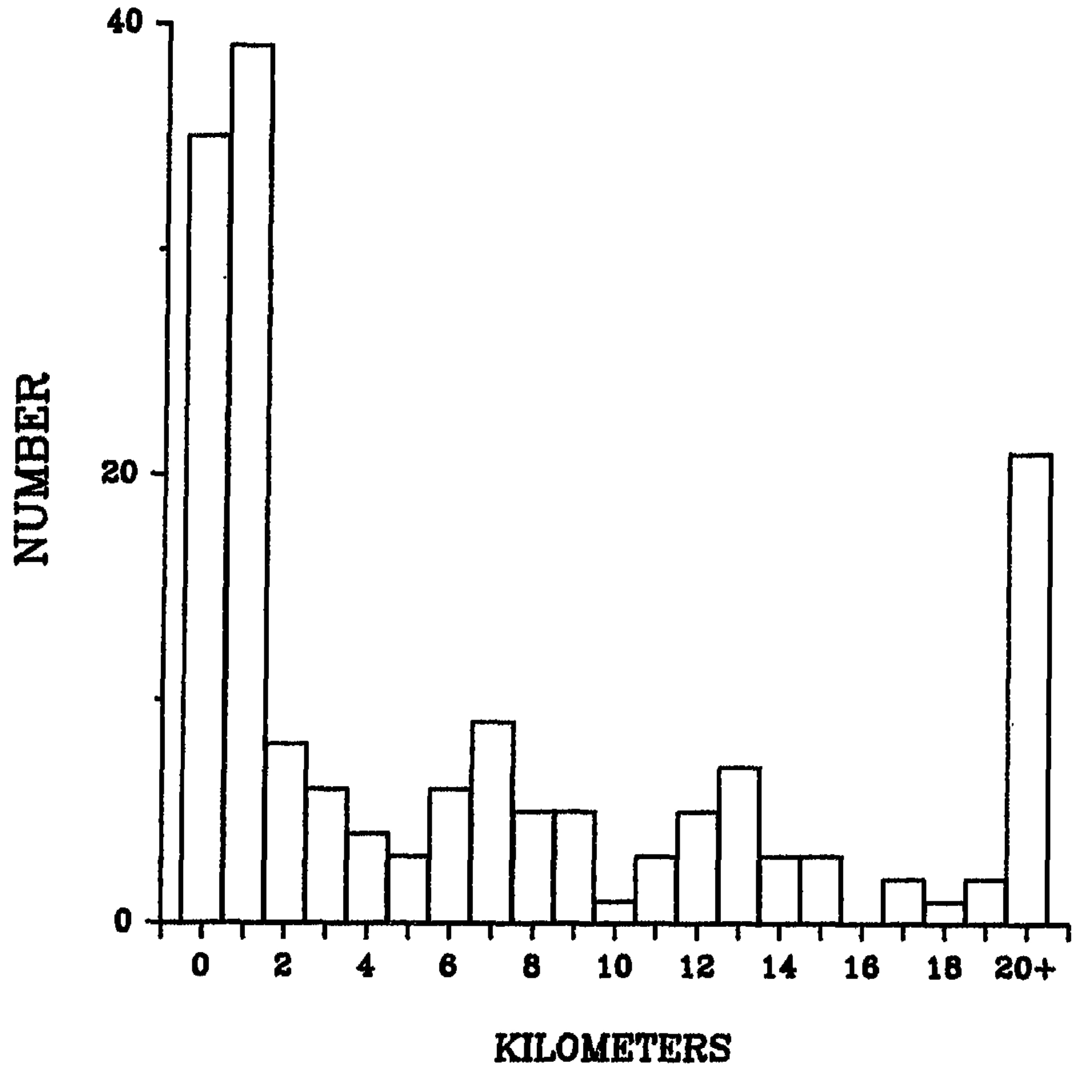


Figure 4. Distances traveled between release and recapture locations of white sturgeon recaptured within one year of marking in The Dalles Reservoir, 1987-88.

Age, Growth, and Morphometry

We assigned ages from 1 to 46 years to 499 white sturgeon collected in The Dalles Reservoir in 1987-88 (Table 10). Supplementation of 1987 samples with samples from large fish caught in 1988 has allowed us reach our target sample size of 30 fish per 20 cm length interval for all lengths up to 179 cm for The Dalles Reservoir population. Independent estimates of age from pectoral fins agreed for only 65% of the paired readings (Table 11). The potential for assigning different ages to a sample was great. We estimated an uncertainty of ±2 years in the age that could be assigned to fish just 5 years old depending on how banding patterns on fin ray sections are interpreted (Figure 5). The error appeared random, i.e. not consistently over- or underestimated. Paired samples of fork length and weight from sturgeon in The Dalles and Bonneville reservoirs were sufficient to calculate regression equations with high degrees of confidence (Figure 6).

Reproduction

We examined gonads of 2,182 sturgeon (FL > 80 cm) in 1987 and 1988 and found 2.4% contained developing or ripe eggs (stages 1 to 3; Table 12). We saw a wide range of egg diameters among female sturgeon collected during summer months. We had few samples from winter months (Figure 7), which made it difficult to draw conclusions about the duration of the developmental period of gonads in females and how many years of spawners were represented by the females with developing eggs. We had to pool samples from three reservoirs to estimate a length-fecundity relationship (Figure 8).

DISCUSSION

We completed collection of most of the data we need to estimate population statistics and potential production of white sturgeon in The Dalles Reservoir. Sample sizes appear adequate to estimate growth rate, mortality rate, and abundance within acceptable degrees of confidence. We will sample in The Dalles Reservoir for one month in 1989 to supplement samples of large (> 170 cm) white sturgeon where information on growth and reproduction is insufficient. This sampling will also allow us to examine potential biases in abundance estimates related to poor mixing of marked and unmarked fish and will allow us to recapture fish which we injected with tetracycline to validate our aging techniques. We will report preliminary estimates of population statistics and potential production of white sturgeon in The Dalles Reservoir in our next annual report.

Sampling in Bonneville Reservoir was sufficient to explore and select potential sampling sites, locate access points and hazards, and test the feasibility of our approach in a reservoir larger than The Dalles. In 1989 we will concentrate our sampling in Bonneville Reservoir and attempt to complete collection of most of the information we need to estimate population statistics there.

Table 10. Age-length-frequency distributions for white sturgeon in The Dalles Reservoir, 1987.

	Fork length group (cm)												
Age	20 -39	40 -59	60 -79	80 -99	100 -119	120 -139	140 -159	160 -169	180 -199	>199	Mean	SD	*N*
1	2										26.9	9	2
2	32	15									36.8	47	47
3	6	29									44.4	60	35
4	1	37	7								52.2	69	45
5		4	15								65.5	79	19
6			12	1							69.7	70	13
7			7	1							71.8	71	9
8			4	5							80.1	95	9
9			0	6	1						90.3	74	7
10			7	12	2						84.5	110	21
11			2	8	1						88.7	96	11
12			1	8	9	1					98.9	137	19
13			2	5	7	1	1				101.4	171	16
14			0	5	7	4	0				107.4	136	16
15			0	2	7	2	2				114.1	175	13
16			1	5	8	9	2	2			120.9	213	27
17				0	6	7	5	0			128.6	152	18
18				1	4	13	5	2	1		134.5	200	26
19				1	3	10	6	7	0		141.0	243	27
20					1	5	12	3	3		151.8	210	24
21					2	6	6	3	1		143.9	185	18
22						0	3	2	5	3	180.1	215	13
23						0	2	4	0	1	168.4	164	7
24						1	3	6	1	1	166.1	234	12
25						0	1	2	0	0	158.0	142	3
26						1	0	2	0	3	183.0	396	6
27						0	0	4	1	4	187.0	226	9
28						1	0	2	2	0	170.8	205	5
29							1	0	1	2	194.8	368	4
30+							3	2	2	11	--	--	18
N	41	85	58	60	58	61	52	37	17	25	--	--	499

Table 11. Agreement of independent readings of age from fin-ray sections from white sturgeon collected from The Dalles Reservoir, 1987.

		Years difference (% of observations)						
Final age	*N*	Same	One greater	One less	Two greater	Two less	>Two greater	>Two less
1	4	100	--	--	--	--	--	--
2	137	93	6	--	1	--	--	--
3	103	78	19	2	--	--	1	--
4	129	74	12	13	--	1	--	--
5	51	67	20	12	2	--	--	--
6	37	81	5	11	--	--	3	--
7	25	68	12	20	--	--	--	--
8	22	73	18	--	9	--	--	--
9	19	68	5	21	5	--	--	--
10	50	66	18	12	2	--	2	--
11	27	59	22	15	4	--	--	--
12	52	71	17	10	2	--	--	--
13	40	55	18	15	2	5	5	--
14	40	55	18	12	10	5	--	--
15	35	63	23	8	--	3	3	--
16	71	62	11	13	7	3	3	1
17	49	47	19	18	2	6	6	2
18	68	53	24	16	4	3	--	--
19	64	61	14	14	5	1	2	3
20	63	52	13	22	3	5	--	5
21	43	44	19	23	2	7	2	2
22	27	52	19	22	--	7	--	--
23	17	47	18	29	--	6	--	--
24	26	35	31	19	4	8	3	--
25	7	43	29	28	--	--	--	--
26	14	71	14	7	--	7	--	--
27	20	60	25	5	--	--	--	10
28	11	36	18	9	18	9	--	9
29	8	25	13	25	12	13	--	12
30+	38	37	26	18	3	10	5	--
	1,297	65	16	12	3	2	1	1

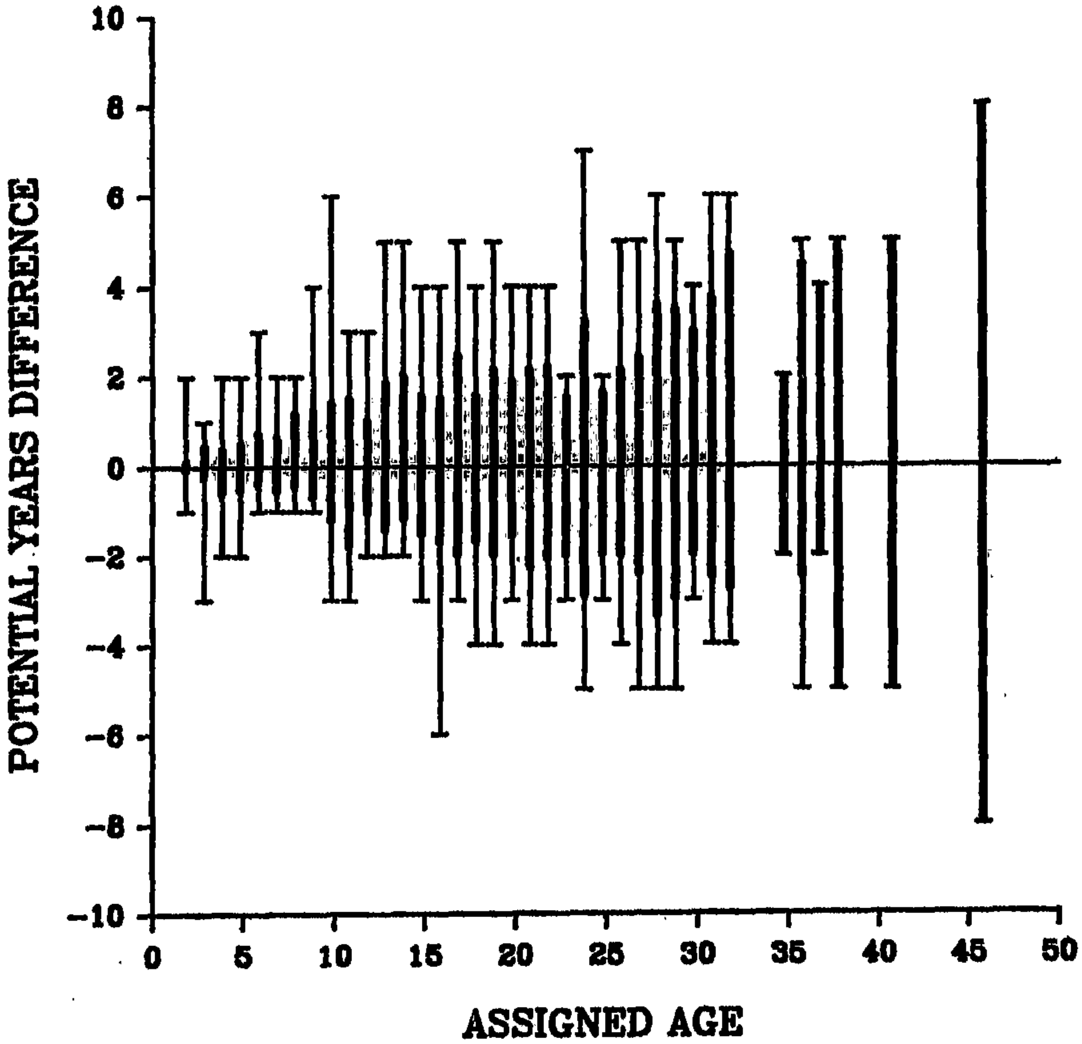


Figure 5. Uncertainty in aging of white sturgeon from sections of pectoral fin rays based on two extreme interpretations of banding patterns. Range refers to minimum and maximum ages assigned to any fish of a given age. Wide bars refer to the standard deviation in minimum and maximum ages assigned to all fish of a given age.

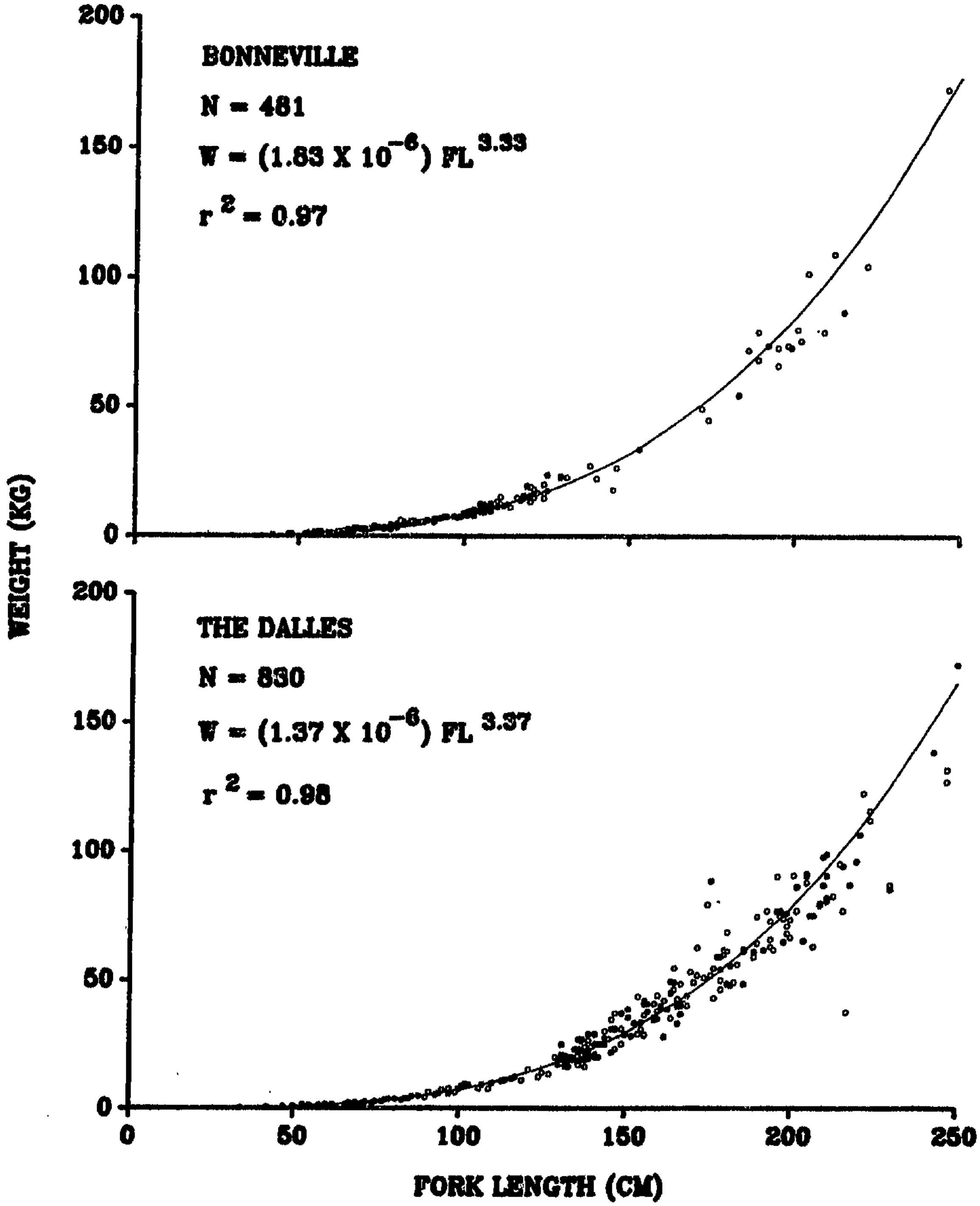


Figure 6. Weight-length relationships for white sturgeon collected in Bonneville and The Dalles reservoirs, 1987-88.

Table 12. Developmental stage of gonads of female white sturgeon, 1987-88.

Reservoir, length group (cm)	N[a]	Developmental stage[b]						Spawning year		Females spawning annually (%)
		1	2	3	4	5	6	This	Next	
Bonneville:										
80-99	126	0	0	0	0	0	34	0	0	0
100-119	348	10	3	2	0	2	123	2	13	3.7
120-139	79	1	0	1	0	0	25	1	1	1.3
140-159	9	0	0	1	0	0	4	1	0	0
160-179	4	0	0	0	0	0	1	0	0	0
180-199	8	0	0	0	0	0	0	0	0	0
200-219	6	0	3	0	0	0	0	0	3	50.0
>219	2	1	1	0	0	0	0	0	2	100
The Dalles:										
80-99	180	1	0	0	0	0	4	0	1	0.6
100-119	511	1	0	0	0	0	95	0	1	0.2
120-139	314	3	1	0	0	1	69	0	4	1.3
140-159	120	4	3	1	0	1	25	1	7	5.8
160-179	39	0	1	0	0	1	9	0	1	2.6
180-199	11	2	2	0	0	0	2	0	4	36.4
200-219	12	2	0	1	0	0	1	1	2	16.7
>219	9	2	1	0	0	0	3	0	3	33.3
John Day:										
80-99	0	0	0	0	0	0	0	0	0	--
100-119	212	0	0	0	0	0	51	0	0	0
120-139	128	0	1	0	0	0	31	0	1	0.8
140-159	53	2	0	1	0	0	12	1	2	3.8
160-179	11	0	1	0	0	0	0	0	1	9.1
180-199	0	0	0	0	0	0	0	0	0	--
200-219	0	0	0	0	0	0	0	0	0	--
>219	0	0	0	0	0	0	0	0	0	--

[a] *Includes all fish (both sexes) whose gonads were randomly examined.*
[b] *Stages are: 1 = Early vitellogenic, 2 = Late vitellogenic, 3 = Ripe, 4 = Spent, 5 = Previtellogenic with attritic oocytes, and 6 = Previtellogenic.*

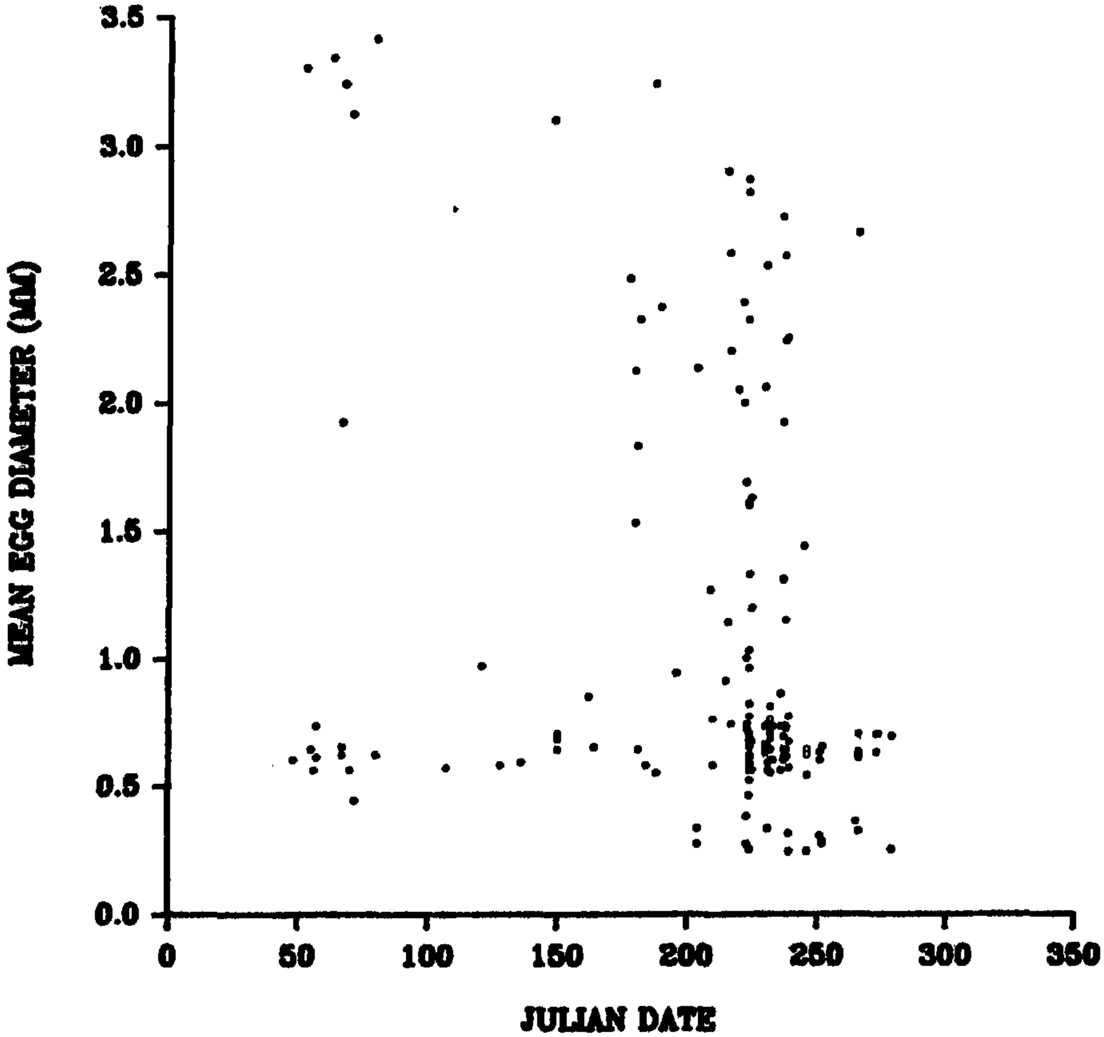


Figure 7. Mean diameter of developing eggs from ovaries of white sturgeon collected in Bonneville and The Dalles reservoirs, 1987-88.

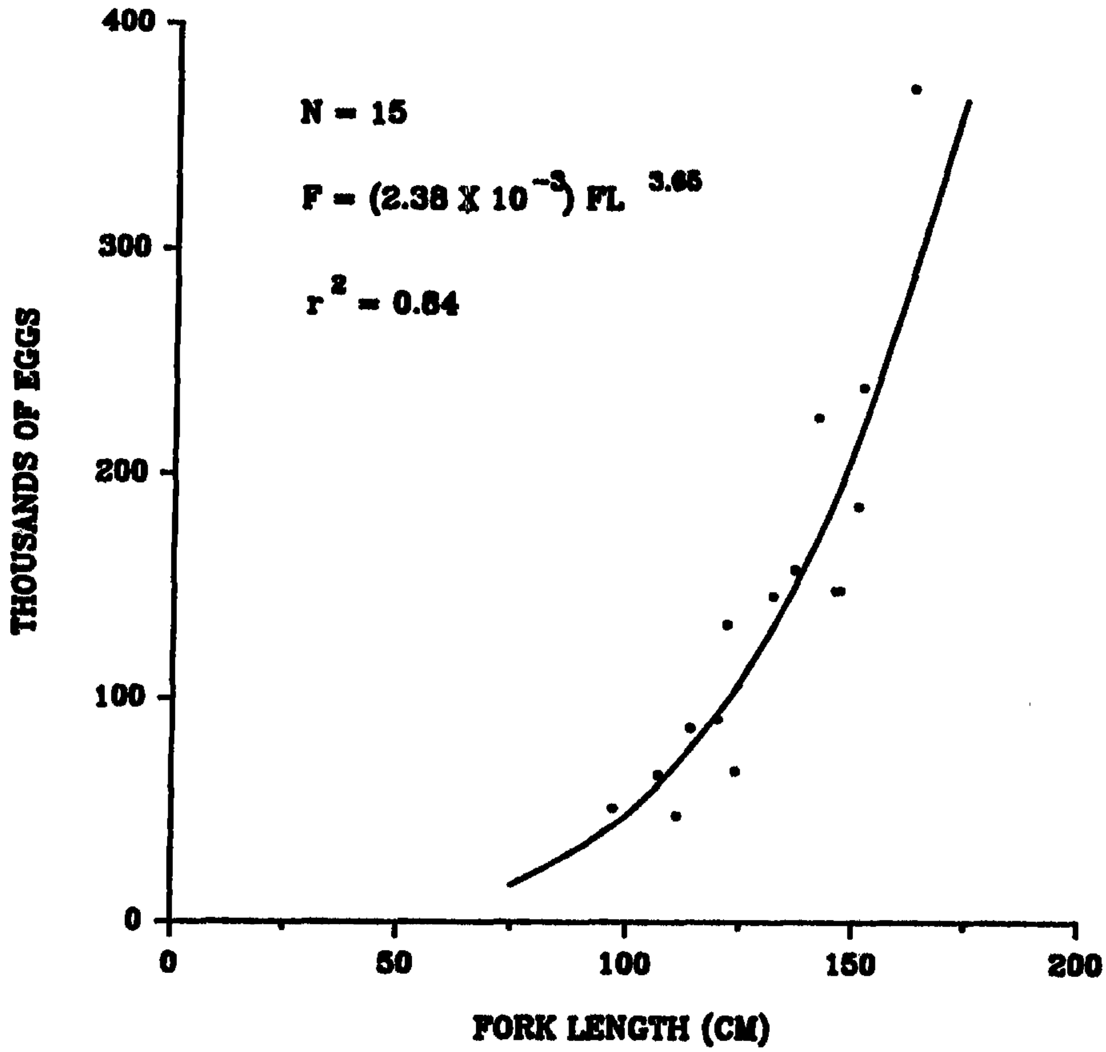


Figure 8. Fecundity versus length of white sturgeon collected in Bonneville, The Dalles, and John Day reservoirs, 1986-88.

Our surgical method for examining gonad condition in large fish was effective; however, we caught relatively few large fish so our sample sizes remain small. We ultimately may have to pool samples from all reservoirs above Bonneville Dam to estimate spawning proportions of the population. In addition we obtained few samples during winter, with which to define the duration of egg development, and few samples of whole gonads from which we could estimate fecundity. We will work with Washington Department of Fisheries to obtain samples of gonads from fish caught and killed in commercial and recreational fisheries throughout the year. We will also make arrangements with Oregon State Police and Washington Fisheries Patrol to obtain gonad samples from illegally harvested fish.

REFERENCES

Nigro, A.A., B.E. Rieman, J.C. Elliott, and D.R. Engle. 1988. Pages 5 to 57 *in* A.A. Nigro, editor. Status and habitat requirements of white sturgeon populations in the Columbia River Downstream from McNary Dam. Annual Progress Report to Bonneville Power Administration, Portland, Oregon.

Rieman, B.E., J.C. Elliott, and A.A. Nigro. 1987. Pages 7 to 24 *in* Status and habitat requirements of white sturgeon populations in the Columbia River downstream from McNary Dam. Annual Progress Report to Bonneville Power Administration, Portland, Oregon.

APPENDIX A-1

Methods for Aging White Sturgeon Using Pectoral Fin Rays

INTRODUCTION

This appendix details the methods and procedures we use to collect, prepare, and read the leading pectoral fin rays and to assign ages to white sturgeon from the Columbia River. Criteria developed by readers of fin ray sections to distinguish, count, and record number of annuli are described. These criteria are a guide for readers when deciding whether or not to call a mark an annulus. Aging data will be used to generate age at length keys and mean length at age.

COLLECTING FIN RAYS

We collect pectoral fin ray samples from white sturgeon using two methods. From live fish, a piece of one of the leading pectoral fin rays is removed. Two cuts are made with a hacksaw, the first within 5 mm from the articulation (knuckle) of the fin, and the second approximately 10 mm distal to the first cut (Appendix Figure A-1.1). Care is taken to avoid cutting the fin artery close to the fin ray articulation. The fin ray piece is then twisted free from the fin with pliers. Sometimes a knife must be used to help separate the piece, especially on larger fish. Excess flesh and skin are trimmed and the sample is placed in a coin envelope along with a completed label.

The entire leading pectoral fin ray, including knuckle, is removed from one or both sides of dead fish (Appendix Figure A-1.1). The leading ray is separated from the fin by running a knife between the ray and the rest of the fin. The ray is pressed anteriorly until the knuckle pops free of its socket. The ray is then cut free from the socket. Excess flesh and skin are removed, the ray is placed in a plastic bag, along with a label, and frozen. Included in the label are sample number, fish number, agency, record type, date, fork length, and reservoir.

PREPARING FIN RAY SECTIONS

The leading ray is separated from any other attached rays, is cleaned of excess skin and flesh, and is then air or oven dried.

Transverse sections of the ray are made using one of two methods. In the preferred method, the ray or a piece is clamped in a chuck and attached to the specimen arm of a Buehler Isomet low speed saw (bone saw). A minimum of three transverse sections, ranging from

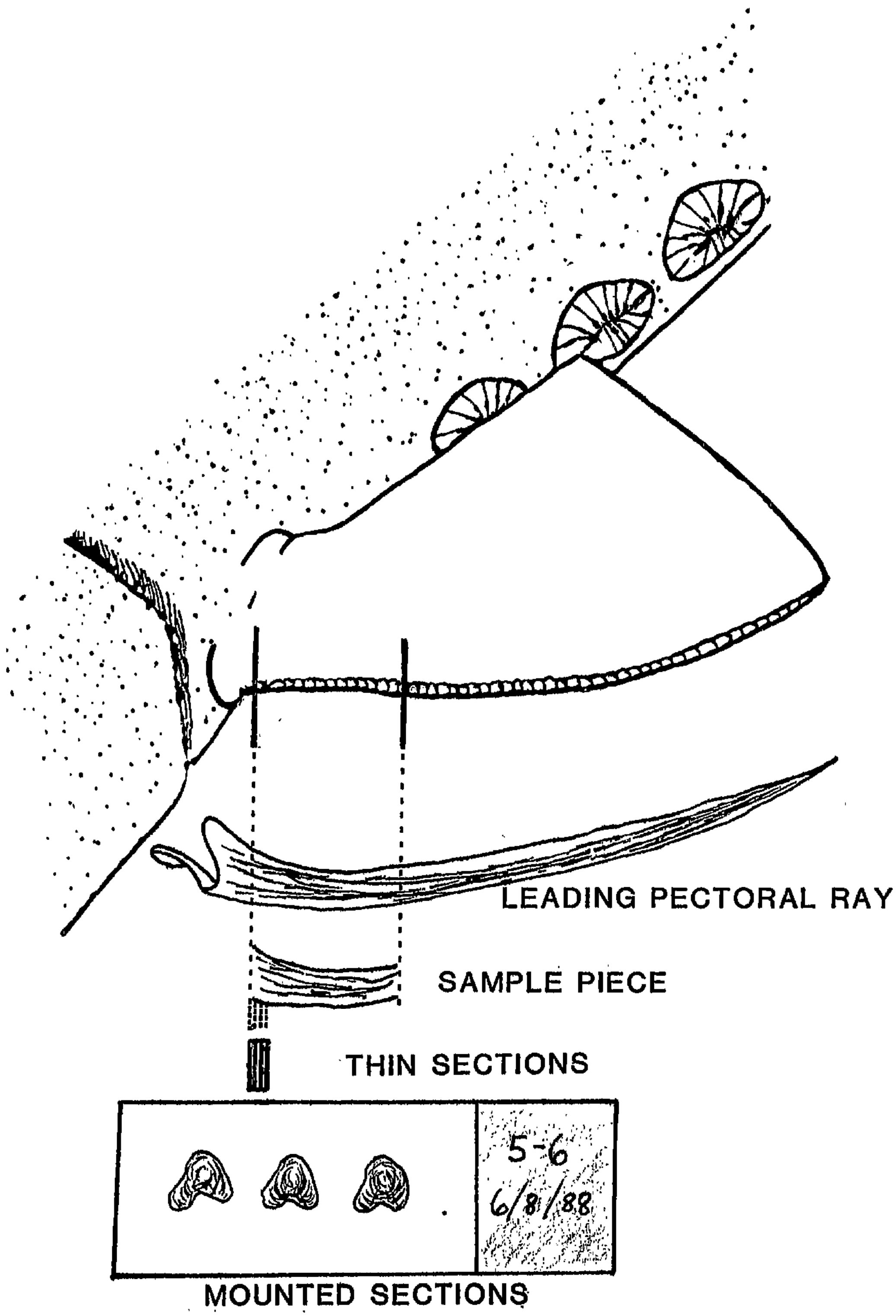


Figure A-1.1. Location of samples of pectoral fins of white sturgeon collected for age analysis.

0.3 to 0.6 mm thick, are made using two, closely spaced, diamond wafering blades. The weight attached to the specimen arm and the speed of the cut are adjusted to produce sections of the desired quality. Sections are taken from the proximal end of ray sections and from a similar distance from the articulation for whole rays (Appendix Figure A-1.1). The first pass with the saw cuts a single 0.3 mm section between the two blades, while subsequent passes produce a section between the two blades and a section between the end of the section and the section between the two blades.

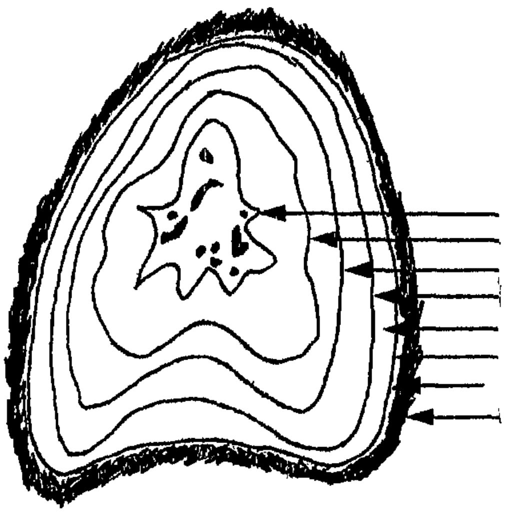
If a bone saw is not available, sections are made by clamping the ray or piece in a small bench vise and carefully making transverse cuts with a single-blade jeweler's saw. These sections may need to be polished with fine grit sand paper to achieve the desired thickness.

Sections are next examined for readability. Sections are washed in tap water and examined under a dissecting or compound microscope. Readable sections must be of a uniform thickness so that when light is transmitted through or reflected off sections, all periodic rings and other features are discernable from the center to the edge. If any damage, regeneration, or inclusion of the second ray within the leading ray has occurred, it must not preclude the ability to accurately identify periodic rings. If samples are unreadable, another section is prepared, or the sample is rejected and replaced. Readable sections are mounted on a glass microscope slide with clear fingernail polish, leaving the exposed side without a coating of polish. The proximal end section is mounted nearest the frosted end of the slide. Identification numbers are recorded on the frosted portion of the slide (Figure A-1.1).

READING FIN RAYS

Fin ray sections are read with a dissecting microscope using magnifications of 1.5X to 4X. Transmitted or reflected light may be used depending which gives the best resolution of the growth marks. Sections may be immersed in a water bath for 30 to 60 seconds and subsequently brushed with a thin film of mineral oil to further clarify periodic rings and edges. Samples are independently aged by two readers. The best section to be used for reading will be determined by the first reader and identified on the data sheet. Sections are labeled sequentially with the most proximal section always labeled number 1. Second readers will use the designated section for their readings but may refer to other sections to assist in interpretations.

Both readers will count annuli in each sample at least twice and will come to their own final age determination before comparing their age reading with that of the other reader. Each reader will keep a record of first and subsequent readings and any remarks in addition to entering his final aging on the data sheet. The first reader also determines whether rings show "banding" or "edge" characteristics a.)



b.)

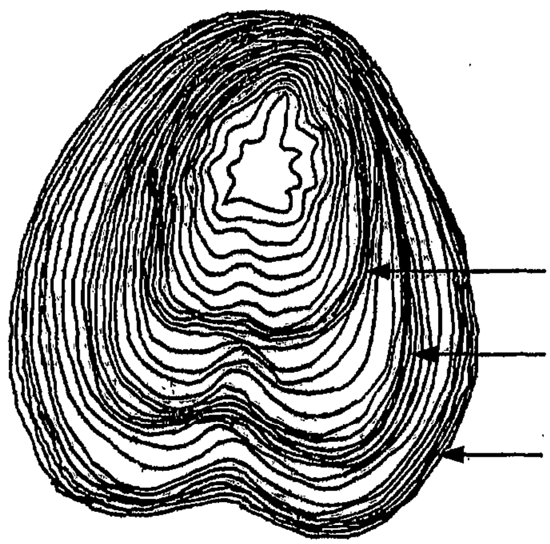


Figure A-1.2. Pectoral fin ray sections of white sturgeon demonstrating (a) opaque growth subsequent to the last translucent periodic ring and (b) banding and annuli stacked near the edge of the section.

(Appendix Figure A-1.2) and enters the appropriate codes on the data sheet.

RECOGNIZING ANNULI

1. Each year of growth is indicated by an opaque (white) periodic ring followed by a translucent (clear) periodic ring (annulus).

2. The first year of growth is indicated by the clear ring surrounding the focus of the section (central star: Appendix Figure A-1.2). Occasionally, this annulus may be obscured by regeneration or what appears to be constant growth during the first winter. Also, sections taken more distal from the articulation may not show the central star. We have developed criteria to assist in determining if the first visible annulus represents the fish's first or second winter. Generally, the area within the second annulus is much greater than that which would have been found within the first annulus. This area will decrease as the section is taken farther away from the articulation. The existence of a first annulus, in this case, may be indicated by the presence of spots with a translucent appearance in the area where the central star would be expected. When any of the above happens, the first clear ring may be the second "winter" and will more closely resemble subsequent annuli. If readers agree that this has occurred, this annulus is recorded as year 2 and a comment is made that the first or innermost annulus corresponding to 1 year of age (A1) was missing.

3. Annuli must be clear and distinct around the entire section except as indicated in (2) or:

   a. Annulus is distinct in the lobes but merges with another annulus in the dorsal and ventral sides. This is especially true among older fish for annuli near the section edge.

   b. Annulus is distinct in the dorsal and ventral areas but becomes indistinct in the lobes and there is evidence that the annulus was "squashed" by inclusion of second rays.

   c. Annulus is continuous except for some irregularity in ray growth and damage to the ray.

4. The last annulus counted must be distinct from the membrane or "fleshy" zone surrounding the hardened portion of the ray. This annulus may be counted even if only a portion of it exists.

5. A secondary clear ring or zone is distinguished from an annulus in that the mark is not continuous or distinct. It may be distinct in one lobe or area but not in another, may be a split of an annulus or may be a faint or grey zone.

COUNTING ANNULI

1. The first annulus is the central star (Age 1).

2. If the central star is missing, the first annulus is counted as Age 2.

3. Each subsequent annulus increases the age by one.

4. The last annulus visible establishes the final count of annuli.

5. "Plus" growth is indicated if an opaque ring is observed beyond the final counted annulus (Appendix Figure A-1.2a), and the reader believes another annulus would have been visible had the section been taken later that same year.

   Annuli generally become visible near the edge of a section around June or July. If the fish in Appendix Figure A-1.2a was collected in March 1988, the amount of growth past age 4 would indicate an annulus was forming (age 5) and so a "+" would be recorded on the data sheet. This fish would have been hatched in 1983. A fish from the same cohort captured in August, with an annulus visible near the edge would be recorded as age 5. Still later in the year, an opaque ring or plus growth may be visible after the age 5 annulus. A fish with plus growth after the age 5 annulus would be recorded as a 5 with no "+" until January 1. After this date and until the age 6 annulus is observed, a fish from this cohort would be recorded as a 5+. This system lumps fish of the same year class together for analyses.

6. "Bands" or groups of annuli and secondary marks (Appendix Figure A-1.2b) often occur in sections from fish collected above Bonneville Dam and less often in samples from fish below Bonneville Dam. At the present time, we are unsure whether the clear and distinct rings in these bands are annual events or whether more than one are laid down in one year. However, to provide consistent readings, we are counting each clear and distinct ring as an annulus. The first reader notes fish with banding in column 41 of the data sheet and also indicates how many years this reader feels age could be overestimated.

7. Annuli that occur near the edge may be stacked and obscure (Appendix Figure A-1.2b). Special attention is necessary to accurately count the number of annuli in this area. We note fish with stacked annuli on the edge on the data sheet (first reader only). The first reader also records the number of marks that were not counted as annuli to estimate the potential for underestimating age based on interpretation of fin ray sections.

ESTABLISHING FINAL AGE

After two readers have independently read and assigned ages to the collection, the first reader compares the two ages. Samples with identical ages are entered as the final age. Samples with different ages are reread by the first reader. If the first reader agrees with the age assigned by the second reader, this age is entered as the final age. If the first reader is unable to agree with the second reader, the sample is jointly re-examined by both readers. If both readers still cannot agree, a third reader may be used as a tie breaker. If the third reading differs from the first two readings, the sample is rejected or an average age is assigned. Rejected samples are replaced if additional samples in the same size category are available.

APPENDIX A-2

Methods for Sampling and Estimating Stage of Maturity of Gonads from White Sturgeon

SURGERY

After capture the fish is held in the live well or tied to the boat until the necessary equipment and surgical items (Appendix Table A-2.1) are prepared. Once this is done, the fish is transferred to a hooded stretcher and positioned on it's back on the deck or a convenient beach. The hood is flooded and continually flushed with fresh water to aerate the gills. The remainder of the fish is covered with wet burlap to keep the fish cool and the skin moist. Care should be taken to keep surgical instruments and hands sterile to avoid contamination of the fish. Hands should be washed with Betadyne or sterile latex gloves should be worn.

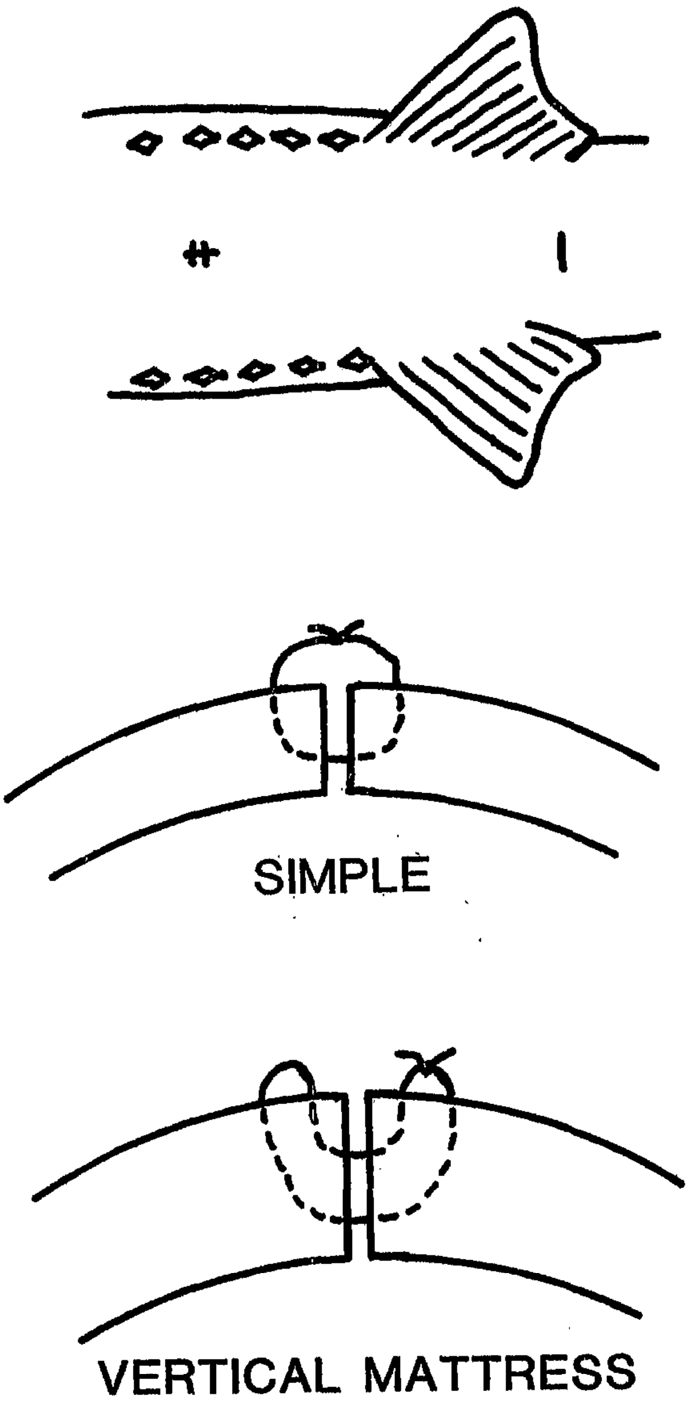
The abdominal area, three lateral scutes anterior to the genital pore, is swabbed with cotton soaked with zephiran chloride to disinfect. A 1.0 to 1.5 cm incision is made with a scalpel through the body wall just off the mid-line, being careful not to cut any internal organs. The gonads are located along the dorsal and ventral sides of the body cavity. It may be necessary to raise the tail end of the fish to drain body fluids towards the head in order to observe the gonad. Advanced and mature female gonads will be quite large and are often readily seen through the incision. Gonads that are immature or in early stages of maturation are small and difficult to find. If the gonad is not visible, the speculum of the otoscope is inserted into the opening to examine the condition of the gonads. The incision may need to be enlarged to 2.0 to 2.5 cm to fit the otoscope speculum.

Once the gonad is identified, a small sample up to 10 g is removed with the tissue forceps, placed in a small vial, and preserved with 10% formalin. The sample number and date from the data sheet for the fish are recorded on the vial. Comments on gonad condition and the surgical process are recorded in the remarks column or on the back of the data sheet. Then we inject 200 mg of oxytetracycline (4 cc of 50 mg/ml, or 2 cc of 100 mg/ml concentration) through the incision into the body cavity.

The incision is closed by using a half circle, reverse cutting edge needle, size CP-2 swedged with PDS (polydioxanone) suture. When the body wall is thick (greater than 0.5 cm) a vertical mattress stitch is used. When the body wall is thinner, a simple stitch is used (Appendix Figure A-2.1). The sutures should be no more than one cm apart. They should pull the edges together but not too tightly. This will prevent cutting by the sutures during swelling in the healing process. The incision is then swabbed with zephiran chloride and dried. A surgical adhesive (Naxaband or Vetbond) is applied to cover the incision and the sutures to protect the area for a short

Appendix Table A-2.1. List of surgical equipment and supplies needed to sample gonads from live white sturgeon.

Sealable container for instruments
Scalpel and blades
Forceps, angled and straight
Hemostats
Surgical scissors
Syringes
Otoscope and speculums
Surgical needles and sutures (Ethicon CP-2, 3-0 PDS)
Sterile surgical latex gloves
Cotton balls
Betadyne
Nolvosan, short-term sterilant
Alcohol
Zephiran chloride
Oxytetracycline
Formalin 10%
Surgical adhesive (Naxaband or Vetbond)
Sample vials
Hooded stretcher
Burlap



Appendix Figure A-2.1. Stitches used to close surgical incisions in the abdominal wall of white sturgeon.

period of time. The fish is released and the instruments, including speculum, are cleaned with alcohol and stored in the Nolvosan solution.

ESTIMATING STAGE OF EGG MATURITY

Samples are processed under a ventilated hood or in a well ventilated area to avoid breathing the formalin fumes. Gloves are worn.

Size and color are used to classify eggs or oocytes by stage of maturity (Appendix Table A-2.2). Individual eggs or oocytes are separated from the ovarian tissue and placed on a slide for measurements. Each measurement is made through the center of the oocyte. Soaking a sample of gonad in household bleach for approximately one minute helps free the oocytes from the connective tissue.

Samples containing previtellogenic oocytes are measured to the nearest mm using a microfiche and a metric ruler. Twenty oocytes from each sample are measured because a wide range of oocyte sizes are observed in these samples. The average measurement for the sample is then divided by the magnification of the microfiche (41.3) to give the average diameter of the oocytes to the nearest 0.01 mm.

Early vitellogenic, late vitellogenic, and ripe eggs are measured with a micrometer in a dissecting scope set at 1.5X. Samples are prepared in a similar manner as before, except only ten oocytes are measured from each sample because the observed variation is minimal and precision is not increased with a larger sample size. Eggs are measured to the smallest micrometer unit with each unit counting as one. The average measurement for the sample is then multiplied by the correction factor (0.06) to give the average diameter of the eggs to the nearest 0.01 mm.

Table A-2.2. Categories of egg maturity.

Category number	Category	Description of category
1	Early vitellogenic	Eggs are clear, cream to grey and have an average diameter from 0.6 mm to 2.1 mm.
2	Late vitellogenic	Eggs are pigmented and attached to ovarian tissue. Eggs have an average diameter from 2.2 mm to 2.9 mm.
3	Ripe	Eggs are fully pigmented and detached from ovarian tissue. Eggs have an average diameter from 3.0 mm to 3.4 mm.
4	Spent	Gonads are flaccid and contain some residual fully pigmented eggs.
5	Previtellogenic with attritic oocytes	Gonads do not show visual signs of vitellogenesis. Eggs are present but have an average diameter less than 0.5 mm. Dark pigmented tissue are present that may be reabsorbed eggs.
6	Previtellogenic	Gonads do not show visual signs of vitellogenesis. Eggs are present but have an average diameter less than 0.5 mm.

APPENDIX A-3

Comparison of Efficiency and Selectivity of Three Gears Used to Sample White Sturgeon in a Columbia River Reservoir

INTRODUCTION

White sturgeon *Acipenser transmontanus* is a valuable resource along the Pacific Coast of North America (Pycha 1956; Semakula and Larkin 1968; Kohlhorst 1980; Cochnauer 1983; Oregon Department of Fish and Wildlife 1988). In the Columbia River, white sturgeon support recreational, commercial, and tribal fisheries (Galbreath 1985). With the decline of anadromous salmonid fisheries (Raymond 1988), white sturgeon fisheries have rapidly increased in importance. Effort by recreational white sturgeon anglers now exceeds effort by recreational salmon anglers below Bonneville Dam (River kilometer 223) in the Columbia River (Hess and King 1988). Landings by commercial and tribal fisheries have in some cases increased fivefold (Oregon Department of Fish and Wildlife 1988).

The status of white sturgeon populations differs throughout the Columbia River basin. Although the population below Bonneville Dam has supported a harvest of over 50,000 fish annually in recent years, populations in the Snake and Kootenai rivers (Columbia River tributaries) have diminished to the point where no harvest is allowed. Several factors may be causing the differences in white sturgeon populations. White sturgeon migration has been blocked by the construction and operation of hydroelectric dams (Bajkov 1951; Lukens 1981). Habitat has been altered by the creation of the reservoirs formed by these dams (Coon et al. 1977; Haynes et al. 1978; Lukens 1981). Flow and temperature have been modified (Coon et al. 1977). The food supply or the accessibility to different food supplies has changed (Bajkov 1951; Lukens 1981). Other biological and physical factors such as predation and the level of pesticides may also be different (Bosley and Gately 1981).

We wanted to investigate the dynamics of the different white sturgeon populations so that we could evaluate the effects of dam construction and operation and design management strategies to optimize yield (Rieman et al. 1987). To estimate population statistics, we needed a gear with which we could collect a large, random sample of white sturgeon unharmed. Estimators of abundance and mortality require marking, releasing and recapturing of fish (Ricker 1975; Seber 1983). We needed to sample efficiently to minimize costs. The cost of sampling hundreds of kilometers of river could be prohibitive without efficient sampling. Lastly, we needed a sample of white sturgeon representative of the population. Size selectivity of gear is a widely documented problem and may bias estimates of population statistics (Beamesderfer and Rieman 1988).

The objective of this analysis was to select the most effective gear for capturing subadult and adult white sturgeon unharmed while minimizing size selectivity, which might bias representation of the population.

STUDY AREA

We selected The Dalles Reservoir, a mainstem impoundment of the Columbia River, for our gear analysis because it was relatively small compared with the other impoundments in the Columbia River, access to all parts of the reservoir was good, and we had evidence that all life stages were present. The reservoir is located between The Dalles and John Day dams (river kilometer 308 to 347). It was formed in 1957 with the closure of The Dalles Dam, a U.S. Army Corps of Engineers (USACE) hydroelectric, navigation, and flood control project. At mean operating level, the reservoir has a surface area of 3,800 hectares, water elevation of 48.2 m above mean sea level, and depth as great as 61 m. The upper reservoir is riverine, and measurable current exists throughout the reservoir. Average daily inflow and outflow ranges from 100,000 to over 400,000 cfs.

METHODS AND MATERIALS

We chose setlines, gillnets, and angling as potential gears to collect white sturgeon. We sampled white sturgeon in The Dalles Reservoir from March through September, 1987. Effort of each gear was evenly distributed throughout the reservoir.

Setlines consisted of a 182-m long mainline, of 64 mm diameter nylon rope, along which 40 hook lines (gangions) were equally spaced. Each gangion consisted of a removable, spring-loaded snap attached to a 0.5-m length of woven nylon cord by a swivel, with a circle hook attached to the other end of the cord. Each setline included 10 each of size 10/0, 12/0, 14/0 and 16/0 circle hooks. Each end of a setline was held in place by a 15 to 20 kilogram anchor. Each anchor was also attached to a buoy with rope identical to the mainline. Lines were set for 4 to 48 hours in depths from 3 to 50 m. Hooks were baited with 1- to 2-inch long cross-section slices of adult pacific lamprey *Entosphenus tridentatus* or 1- to 4-square-inch pieces of adult coho salmon *Oncorhynchus kisutch* carcass with skin attached. Only one bait type was used on each line. Setlines were deployed and retrieved from a 22 ft Boston Whaler equipped with a hydraulic pot hauler.

Gillnets were sinking type and set stationary. Each net was 45.6-m long and consisted of six, equal length, alternating panels of 5.1-cm, 8.3-cm and 11.4-cm bar mesh. Net panels were constructed from multifilament and cable nylon. Each panel was hung with 4.6-m deep mesh on a framework with 3-m long vertical slacker lines attached to the float and leadline at 3.8-m intervals along the length of the net. Gillnets were held in place by 4.5 to 20 kg anchors depending on current. A buoy marked each anchor. Gillnets were fished for 1 to 4 hours in depths from 3 to 35 m. Nets were deployed and retrieved by hand from the boat.

Angling gear consisted of a medium heavy action rod with a sensitive tip, a bait casting reel with 18-kg monofilament line and 7/0 or 9/0 J-type hooks. Rods were closely attended and hooks actively set. Hooks were baited with Pacific lamprey slices, coho salmon pieces, whole adult eulachon *Thaleichthys pacificus*, whole juvenile coho salmon and pickled herring. We fished from an anchored boat for durations of 1/2 to 3 hours in depths from 15 to 45 m.

We measured fork length of captured white sturgeon to the nearest centimeter. Hook size and bait type were recorded for fish caught in setlines.

We evaluated gear based on harm caused to the fish, sampling efficiency and size selectivity. Harm was evaluated by the percent of dead white sturgeon in the catch by gear. Sampling efficiency was evaluated by comparing catch per unit effort (CPUE) among gear. We standardized CPUE of gear by calculating mean catch per crew week (40 hours of sampling by a particular gear deployed by a three-person crew) based on 13.4 crew weeks of setlining, 3.7 crew weeks of gillnetting and 0.9 crew weeks of angling. We evaluated size selectivity of gear by comparing length-frequency distributions of catch among gear. We assumed size selectivity was least where the range of lengths sampled was greatest. Statistical differences in lengths of fish captured among gears were identified with chi-square tests ($p < 0.05$). We also used chi-square analysis to examine the selectivity associated with hook size and bait type used while setlining.

RESULTS

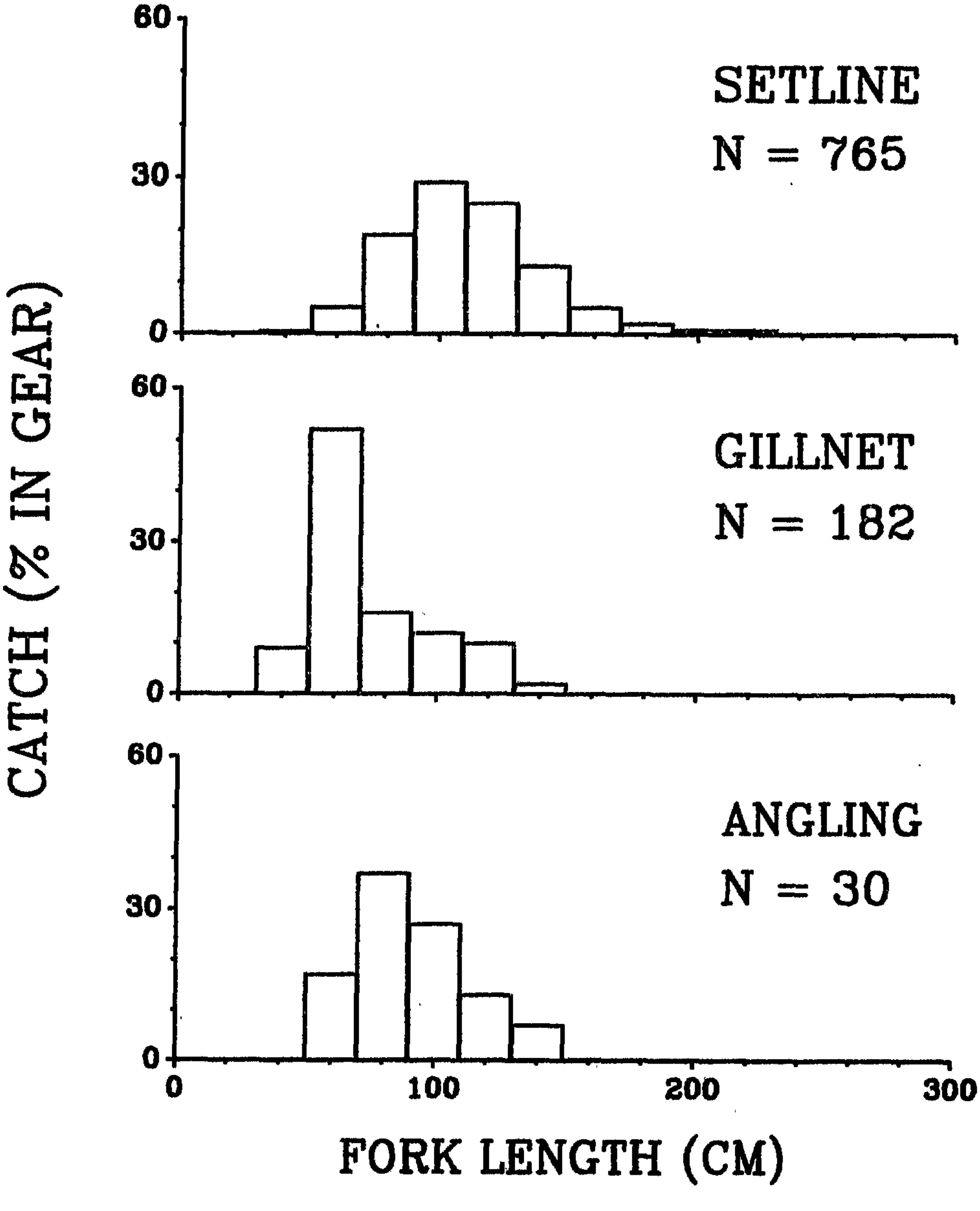
All three gears sampled white sturgeon unharmed. Direct mortality caused by gear was only 1 fish for each gear. Setlines were our most productive gear (Appendix Table A-3.1). Catch per crew week with setlines was 1.24 times catch with gillnets and 1.78 times catch while angling.

Different gear caught different sizes of fish (Appendix Figure A-3.1) and differences were significant between setlines and gillnets ($X^2 = 340.7$; df = 7; $p < 0.01$). Setlines captured white sturgeon over a much wider range of lengths and fish of a greater length than gillnets. Sample sizes from angling were inadequate to compare length distribution differences with other gears.

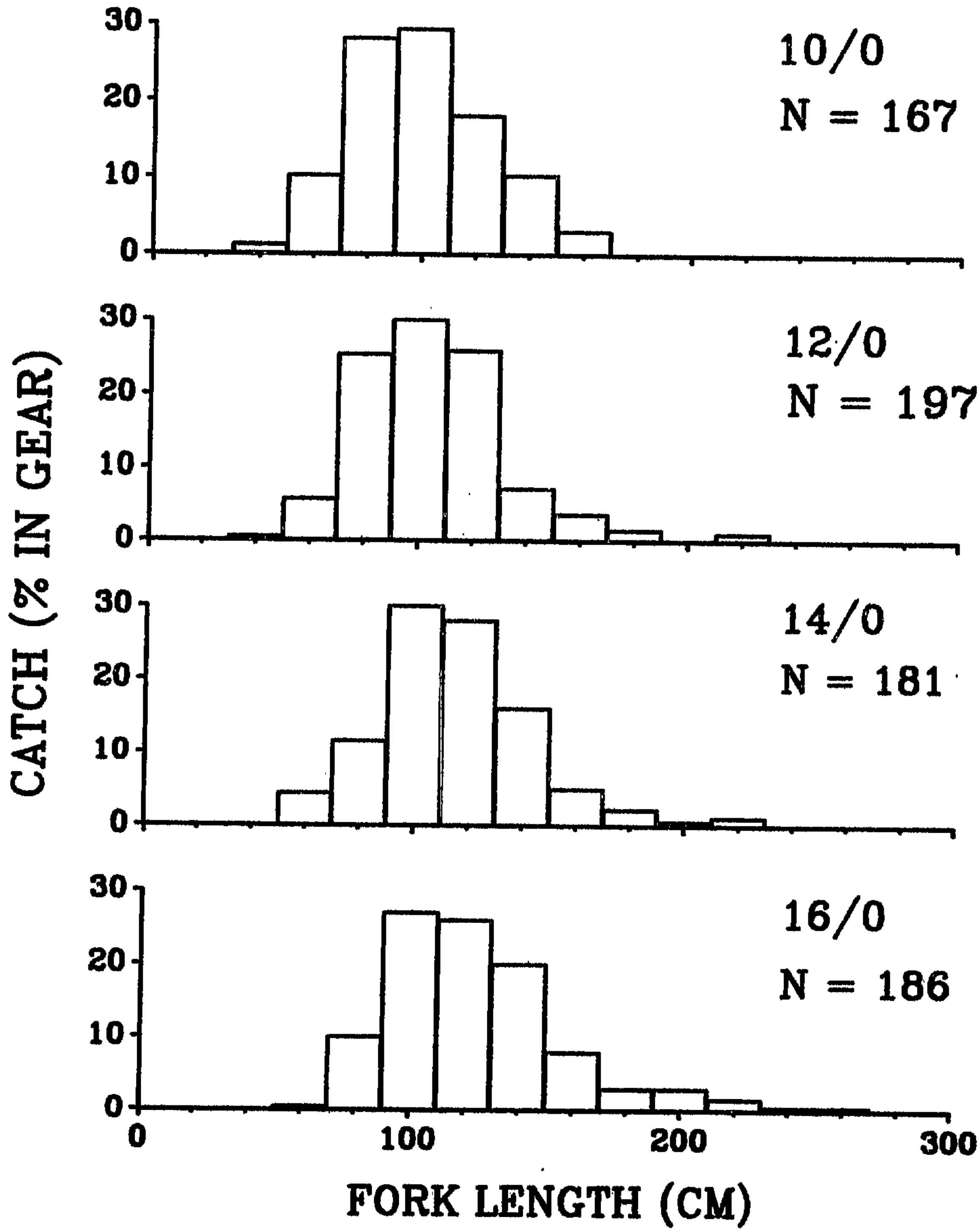
White sturgeon appeared fully recruited to all hook sizes for fish greater than 90 cm fork length. Differences in length-frequency distributions were significant for white sturgeon captured by various hook sizes ($X^2 = 88.3$; df = 18; $p < 0.01$) (Appendix Figure A-3.2). Larger hooks took larger fish and fish over a wider range of fork lengths. No significant difference in length-frequency distributions was detected between bait types ($X^2 = 5.2$; df = 5; $p = 0.389$).

Appendix Table A-3.1. Summary of white sturgeon effort and catch in The Dalles Reservoir, 1987.

Gear	Number of Observations	Crew hours	Catch	Catch per 40 crew hours
Setline	233	538	826	61.4
Gillnet	87	149	184	49.4
Hook and line	25	36	31	34.4



Appendix Figure A-3.1. Length-frequency distributions of white sturgeon collected in The Dalles Reservoir of the Columbia River, 1987.



Appendix Figure A-3.2. Length-frequency distributions of white sturgeon collected with various hook sizes on setlines in The Dalles Reservoir of the Columbia River, 1987.

DISCUSSION

We concluded that setlines were the best available gear for our study. Setlines returned more white sturgeon, in good condition, per crew hour than the other gears we tested. It was the most versatile gear. We were able to set it in almost any habitat in the study area and set and retrieve it under almost any weather condition. Setlines were easy to use, placing less physical demands on personnel because the hydraulic system did most of the work. Setlines also caught almost exclusively white sturgeon. Additionally, original cost of a setline was no greater than that for a gillnet, but a setline could be expected to last two or three seasons, whereas the life expectancy of a gillnet was less than one season. Damage to setlines could normally be repaired quickly at little or no cost or downtime.

Further, we were primarily concerned with white sturgeon 90 cm and larger, corresponding to lengths harvested in the fisheries, and the reproductive stock (fish longer than 183 cm, the maximum legal length limit). We believe that our setlines best represented the population of white sturgeon over 90 cm based on length-frequency distributions of catches.

The gillnets we used had many drawbacks and few advantages over setlines. Whereas mortality for white sturgeon was low for gillnets, they captured fish other than sturgeon, often with a substantial mortality rate. This limited use of gillnets to areas and times where adult salmon and steelhead were not present. Gillnets were further limited in application to areas with no or low current velocity and relatively smooth bottom contours. Finally, gillnets captured white sturgeon from a much narrower range of length than did setlines, and much of the catch consisted of fish under 90 cm fork length.

Angling was also inferior to setlines. Although mortality was low, the cost per fish was much higher for angling. Also, setlines could be deployed in almost any area we could fish with hook and line. Finally, the length range of white sturgeon captured with hook and line fell within that captured by setlines.

We will only sample with setlines for the remainder of the study. However, we have made a few modifications to address the efficiency and selectivity of our setlines. We are discontinuing using 10/0 hooks for the following reasons: (1) they required more crew hours to use because they were harder to sharpen and bait and required more frequent replacement; (2) the white sturgeon they captured were within the range of those captured with 12/0 hooks; and (3) they were often straightened out or snapped off, apparently unable to hold larger fish. Setlines will still consist of 40 hooks, divided among the three remaining hook sizes. Also, we will only use 300 lb test gangions because of the number of broken, 150 lb test gangions observed.

Finally, we will only be using pacific lamprey for bait. Pacific lamprey slices appear to be an attractive bait for white sturgeon for more than a day. Coho salmon pieces often fell apart within 24 hours. Further, Pacific lamprey is relatively easy to obtain and it reduces preparation and gear deployment time.

REFERENCES

Bajkov, A.D. 1951. Migration of the white sturgeon *Acipenser transmontanus* in the Columbia River. *Fish Commission of Oregon* Research Briefs 3(2):8-21.

Beamesderfer, R.C., and B.E. Rieman. 1988. Size selectivity and bias in estimates of population statistics of smallmouth bass, walleye, and northern squawfish in a Columbia River reservoir. North American Journal of Fisheries Management 8:505-510.

Bosley, C.E. and G.F. Gately. 1981. Polychlorinated biphenyls and chlorinated pesticides in Columbia River white sturgeon *Acipenser transmontanus*. U.S. Fish and Wildlife Service, Marrowstone Field Station, Nordland, Washington. Unpublished report.

Cochnauer, T.C. 1983. Abundance, distribution, growth and management of white sturgeon *Acipenser transmontanus* in the middle Snake River, Idaho. Doctoral dissertation. University of Idaho, Moscow.

Coon, J.C., R.R. Ringe, and T.C. Bjornn. 1977. Abundance, growth, distribution and movements of white sturgeon in the mid-Snake River. Water Resources Research Institute, Research Technical Completion Report, Project B-026-IDA. University of Idaho. Moscow.

Galbreath, J. 1985. Status, life history, and management of Columbia River white sturgeon, *Acipenser transmontanus*. Pages 119 to 126 in F.P. Binkowski and S.I. Doroshov, editors. North American sturgeons. Dr. W. Junk, Dordrecht, The Netherlands.

Haynes, J.M., R.H. Gray, and J.C. Montgomery. 1978. Seasonal movements of white sturgeon (*Acipenser transmontanus*) in the mid-Columbia River. Transactions of the American Fisheries Society 107:275-280.

Hess, S.S., and S.D. King. 1988. The 1987 lower Columbia River (Bonneville to Astoria) and estuary salmon (buoy 10) recreational fisheries. Oregon Department of Fish and Wildlife, Portland. Unpublished report.

Kohlhorst, D.W. 1980. Recent trends in the white sturgeon population in California's sacramento-San Joaquin Estuary. California Fish and Game 66:210-219.

Lukens, J.R. 1981. Snake River Sturgeon Investigations (Bliss Dam Upstream to Shoshone Falls). Idaho Department of Fish and Game Report to Idaho Power Company.

Oregon Department of Fish and Wildlife. 1988. Columbia River fish runs and fisheries, 1960-87. Portland.

Pycha, R.L. 1956. Progress report on white sturgeon studies. California Fish and Game 42:23-35.

Raymond, H.L. 1988. Effects of hydroelectric development and fisheries enhancement on spring and summer chinook and steelhead in the Columbia River basin. North American Journal of Fisheries Management 8:1-24.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191.

Rieman B.E., J.C. Elliott, and A.A. Nigro. 1987. Appendix A. Pages 7-24 *in* Status and habitat requirements of white sturgeon populations in the Columbia River downstream from McNary Dam. Bonneville Power Administration, Annual Progress Report, Portland, Oregon.

Seber, G.A.F. 1983. The estimation of animal abundance and related parameters. Charles Griffin, London.

Semakula, S.N., and P.A. Larkin. 1968. Age, growth, food and yield of the white sturgeon (*Acipenser transmontanus*) of the Fraser River, British Columbia. Journal of the Fisheries Research Board of Canada 25:2589-2602.

REPORT B

1. Description of reproduction and early life history characteristics of white sturgeon populations in the Columbia River downstream from Bonneville Dam.

2. Description of the white sturgeon recreational fishery in the Columbia River between Bonneville and McNary dams.

3. Description of the life history and population dynamics of subadult and adult white sturgeon in the Columbia River downstream from Bonneville Dam.

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CONTENTS

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ABSTRACT

Washington Department of Fisheries (WDF) censused the recreational fishery in Bonneville and The Dalles reservoirs for mark recovery, biological samples, and harvest data on white sturgeon *Acipenser transmontanus* from March through October of 1988. Total harvest of white sturgeon was 1,135 in Bonneville Reservoir and 863 in The Dalles Reservoir during this period. Samplers interviewed 4,654 anglers in Bonneville Reservoir and 7,748 anglers in The Dalles Reservoir. Biological sampling was conducted on 19.9% of the harvest in Bonneville Reservoir and 28.2% in The Dalles Reservoir. Samplers examined 255 harvested white sturgeon for marks during the Bonneville Reservoir census and none had been marked/tagged by Oregon Department of Fish and Wildlife. During The Dalles Reservoir census, 241 harvested white sturgeon were examined of which 19 were marked.

WDF continued efforts towards describing the population dynamics of white sturgeon downstream of Bonneville Dam. Field work was conducted through separate state-funded programs and primarily involved spaghetti tagging white sturgeon and sampling recreational and commercial fisheries. Using a simple Peterson mark-recapture method, abundance estimates of 3-6 foot white sturgeon ranged from about 122,000 to 216,000 for nine tag groups in 1986-88.

WDF assisted National Marine Fisheries Service in assessing reproduction and early life history of white sturgeon downstream of Bonneville Dam. WDF processed and staged samples of eggs and larvae collected in 1988. Ives Island, a primary spawning area about 2.5 miles downstream of Bonneville Dam, was recommended as a site to concentrate field sampling in order to identify critical environmental factors affecting early life history of white sturgeon.

INTRODUCTION

As part of the study funded by Bonneville Power Administration on Columbia River white sturgeon, the primary responsibility of the Washington Department of Fisheries (WDF) is to describe the population dynamics of white sturgeon downstream of Bonneville Dam. Additional responsibilities include providing the Oregon Department of Fish and Wildlife (ODFW) with mark recovery data and biological samples from fisheries between Bonneville and McNary dams.

WDF also contributes to this study through sturgeon research programs in the Columbia River which are partially or entirely state funded. Examples of this participation include assisting the National Marine Fisheries Service (NMFS) in the collection and analysis of white sturgeon eggs and larvae collected downstream of Bonneville Dam and collecting data on subadult and adult white sturgeon downstream of McNary Dam.

This annual report--third in the series--focuses on activities and information from the 1988 field season. Some data is presented from sampling in previous years as well. The report contains the following sections:

1) overview of eggs and larvae sampling downstream of Bonneville Dam;

2) catch and effort information from censusing the recreational sturgeon fishery in Bonneville and The Dalles reservoirs;

3) landings in the tribal commercial fishery;

4) summaries of mark recovery and biological data collected from recreational and commercial fisheries between Bonneville and McNary dams; and

5) progress on describing the yield or production of white sturgeon downstream of Bonneville Dam.

METHODS

Eggs and Larvae Analysis

A thorough discussion of sampling gear and techniques is presented by NMFS in REPORT D of this document. Refer to Tracy (1989) for additional information.

Sampling for white sturgeon eggs and larvae occurred at a variety of locations from Bonneville Dam downstream to the Interstate 5 Bridge. Most of the sampling was conducted at an index site that had been established at Ives Island (RM 143) about 2.5 miles downstream of Bonneville Dam. There were four sites upstream of the index and 11 sites downstream. Sampling at Ives Island in 1988 occurred from March 23 to August 3 but was conducted weekly from April 25 to July 5. Sampling usually occurred during daylight hours only, but one 12-hour overnight trip was made at Ives Island starting at 1643 hours May 25, 1988. Samples were collected using D-ring plankton nets set behind the NERKA, a 40 ft. research vessel operated by NMFS. Each set used 1-3 nets. Sets were 30 minutes per sample, except during the overnight trip when the sampling sets were 60 minutes.

Corresponding to each of the netted samples, volume of water passed and physical factors such as water temperature, depth, and water velocity were measured. Samples were preserved in buffered 10% formalin.

In the laboratory, contents of the sample jars were examined for eggs and larvae. Any eggs and larvae were counted, aged, and preserved in 10% methanol. Eggs were staged and larvae aged according to Beer (1980). Spawning dates were back-calculated using the method of Wang et al. (1984).

Recreational Fishery Census

In 1988, the recreational fishery census was conducted in Bonneville and The Dalles reservoirs from March through October (hereafter referred to as the census period) (Figure 1). The census occurred in order to estimate harvest of marked white sturgeon and collect biological samples from the catches examined.

The method used to estimate total catch and effort was similar to the procedure used in the 1987 census in The Dalles Reservoir (Kreitman and James 1988). In 1988, boats were counted instead of boat trailers and the index area for The Dalles Reservoir was modified slightly.

Index areas for angler counts were established at popular fishing locations or vantage points in both reservoirs (APPENDIX B-1). Angler effort was estimated from aerial counts of bank and boat anglers within each reservoir, plus simultaneous ground counts within an index area. On flight days, an index area count was made every three hours throughout the day including a simultaneous count during the time of the flight. Index counts began within three hours of sunrise, continued until sunset, and consisted of bank rod counts to determine bank effort, and boat counts to determine boat angler effort. Index counts were considered instantaneous. From the aerial count data, the proportion of the total effort represented by the index area counts was determined from a comparison of the two simultaneous counts. This proportion was applied to the index counts during nonflight hours to yield an estimate of the total angling effort that occurred on the flight day. On nonflight days, a single ground index count occurred at variable hours.

Samplers interviewed anglers at bank fishing sites and boat ramps to determine angler type and catch per hour of effort for each species in the catch. Interviews took place between effort counts and on nonflight days.

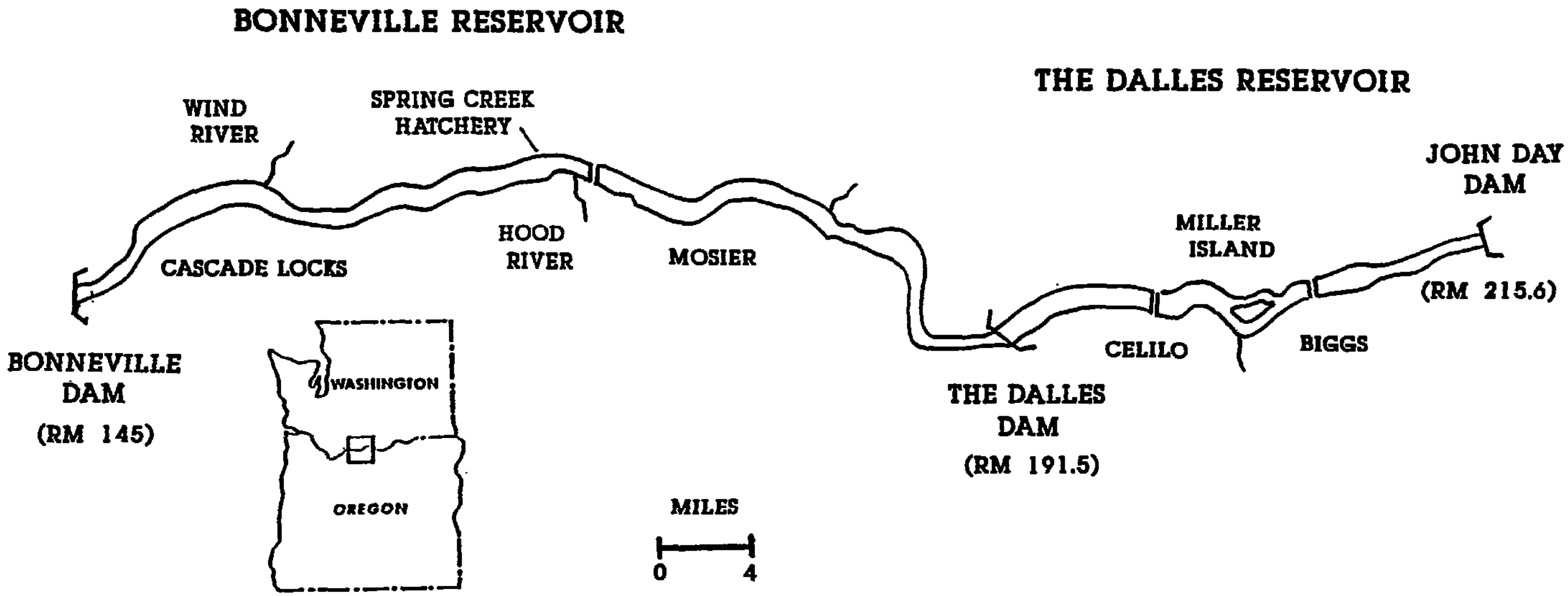


Figure 1. Location of Bonneville and The Dalles reservoirs on the Columbia River.

Both effort and catch sampling data was stratified by bank and boat angler types, and river subsection (APPENDIX B-1), as well as weekday and weekend effort to account for differences in catch rates. White sturgeon harvest was estimated for two week periods (a statistical week was Monday through Sunday numbered from the start of the year). If no anglers were interviewed within a subsection for a period when effort was observed, then data from successive periods were combined until a catch rate could be derived. Harvest was calculated by multiplying the observed harvest per hour for each angler type by the total estimated effort for each angler type for that period. Removal of marked white sturgeon was estimated by dividing the number of marked fish observed by the mark sampling rate. The mark sampling rate was the number of fish examined for marks divided by the total harvest.

Tribal Commercial Fishery Landings

Number of white sturgeon landed in Columbia River commercial fisheries was estimated from poundages reported on fish receiving tickets for each gear type. Pounds of white sturgeon landed were converted to number of fish by applying an average weight per fish obtained during biological sampling by field crews. Average weights were calculated by statistical week and applied to the total poundage for each week. If the sample size was less than 30 for the week, then data from successive weeks were combined until the sample size of at least 30 was obtained.

Landings by commercial fishing zone were estimated from the catch area reported on the fish tickets. There are five zones in the mainstem Columbia River downstream of Bonneville Dam. The tribal commercial fishery occurs in the area between Bonneville and McNary dams commonly referred to as Zone 6. In 1988, Washington required that fish tickets report the catch location according to specific reservoir. Oregon did not have the same provision in Zone 6 until late in the 1988 commercial season. Consequently, harvest stratified by reservoir is only available for Washington landings.

A tribal subsistence fishery for white sturgeon also occurred but the harvest was unknown.

Mark Recovery and Biological Sampling

Mark recovery and biological samples were collected from the recreational fishery in Bonneville and The Dalles reservoirs and from the tribal commercial fishery in Zone 6. Sampling of the recreational catch occurred as part of the angler interview. Commercial fishery catches were examined at the fish buying facilities. Samples from the tribal commercial fishery were segregated by reservoir whenever possible. Collection methods and handling of samples were similar in both fisheries.

Samples were classified as random or "in-sample" vs. nonrandom which were usually voluntary reports of spaghetti tagged fish. In general, if the field sampler would have examined the catch as part of that days activities then the samples were considered randomly collected (in-sample).

Voluntary returns of tagged white sturgeon were solicited: signs were posted at access areas and at popular fishing locations (APPENDIX B-2). Drop boxes for voluntary returns of spaghetti tags were established at locations convenient to the anglers. Field samplers often received voluntary information on tagged fish caught. Occasionally, nonrandom "select" samples were collected from examining recreational catches made on previous days which were being held (e.g. tethered) for later processing.

All available legal size catches were sampled and examined for identifying marks (spaghetti tags, clipped barbels, scutes and fin rays, or Monel bands). Biological data collected from legal size catch included fork length (FL), total length (TL), weight, sex, pectoral fin ray, and ovary samples. Pectoral fin rays were packaged unpreserved. Ovary samples were preserved in formalin. Both were transferred to ODFW for further processing.

Population Dynamics Downstream of Bonneville Dam

For modeling the white sturgeon population downstream of Bonneville Dam, data on abundance, total and fishing mortality, age, growth, and reproduction were collected during sampling recreational, commercial, and research fisheries in 1988. Information from previous years was also analyzed.

Estimates of the abundance of white sturgeon downstream of Bonneville Dam were made using a Peterson mark-recapture model, unadjusted for migration or gear bias. Marking of white sturgeon occurred by contracting with commercial fishermen to capture fish using drift gillnets. The gillnets were conventional commercial type gear rigged with a single mesh size of 6 1/4 to 8 inch stretch measure. Sequentially numbered spaghetti tie tags were inserted through the base of the dorsal fin to identify marked fish. White sturgeon larger than 70 cm TL were tagged with one or two tags. Double tagging was used to later estimate tag loss based on recovery data (Eberhardt et al. 1979). Most of the white sturgeon marking activities occurred in the Columbia River estuary (RM 5-22), although some marking occurred at four other sites scattered throughout the lower Columbia River (Figure 2). The intent of the marking program was to capture and tag as many white sturgeon as possible while reducing the number of salmonids that were incidentally handled. Sampling recreational and commercial fisheries was the primary method of recovering marked fish.

Fishery sampling procedures similar to those upstream of Bonneville Dam were used to collect information on adult and subadult white sturgeon downstream of Bonneville Dam. State funded programs by WDF and ODFW collected information and samples on this population. WDF processed samples of pectoral fin rays and ovaries from sturgeon examined from fisheries downstream of Bonneville Dam. Fin ray

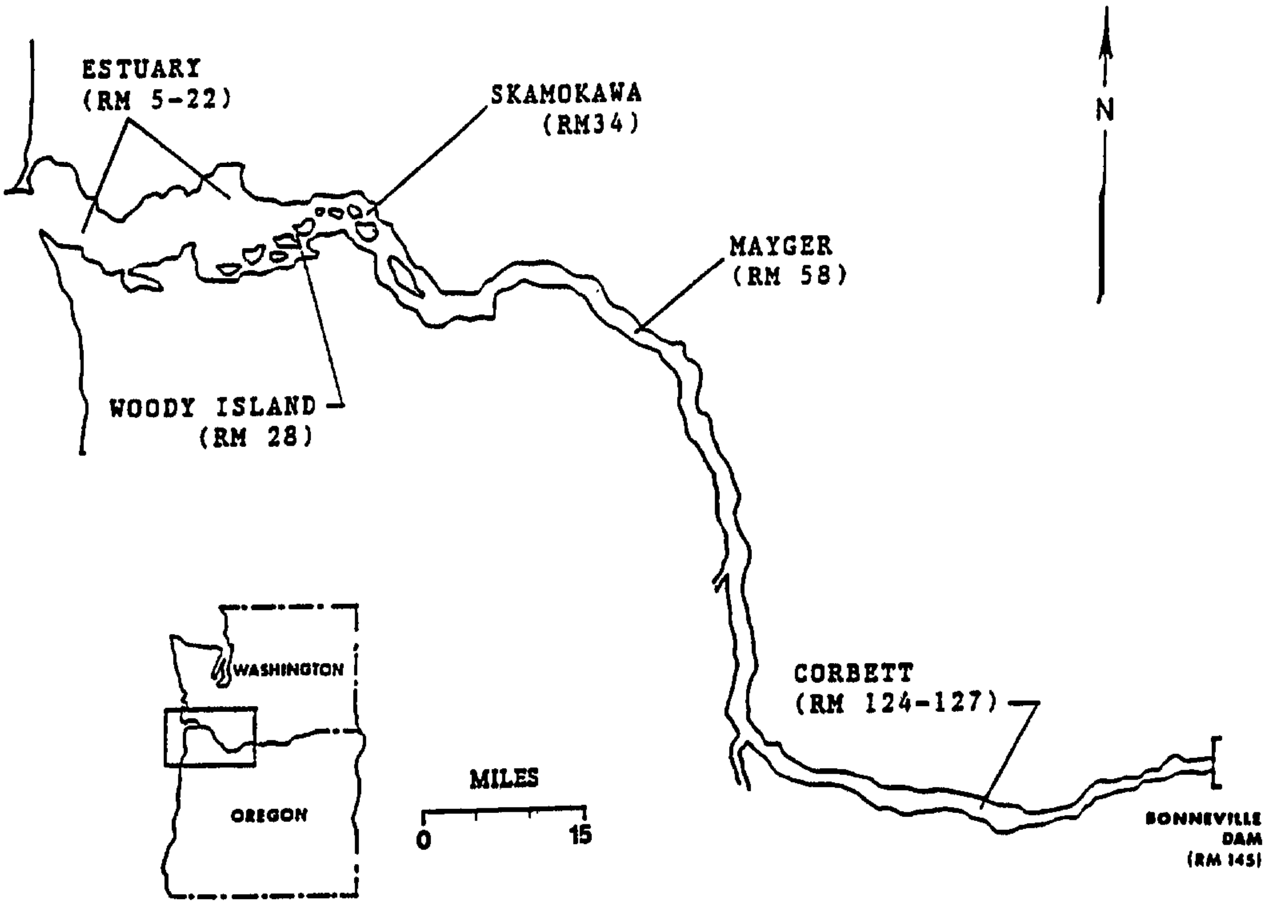


Figure 2. Locations on the Columbia River below Bonneville Dam where white sturgeon were captured and marked in 1988.

samples were aged following the method in Brennan (1987). Developmental stage of ovaries were classified according to the method used by ODFW for samples collected upriver.

Size selectivity was investigated for the hook and line gear in the recreational fishery and for the gillnets used to capture white sturgeon for marking (Hamley 1975). The purpose was to determine the effect of mesh size in the gillnet gear and whether the recreational catch may be biased towards certain sizes within the legal size. The rate of recapture of marks at-large for the two gear types was determined for different size groups. In the recreational fishery, recaptures up to nine months following release were compared by size group. In the gillnet analysis, recaptures up to five months following release were compared.

RESULTS

Eggs and Larvae Analysis

Sampling for white sturgeon eggs and larvae occurred on 21 days between March 23 and August 3, 1988 (APPENDIX B-3). The Ives Island index site was sampled 15 days during regular daytime sampling. In addition a 12 hour overnight trip was made at the index site. A total of 61 plankton net sets were made in 1988 including 11 sets during the Ives Island overnight trip.

A total of 719 eggs and 90 larvae were captured, mostly from the Ives Island index site. During regular daytime sampling 271 eggs were captured at the Ives Island index site and 84 eggs at other locations (Table 1). Eggs ranged from stage 1 (unfertilized) to stage 18 (prehatch). Stage 2 eggs, which are fertilized but have not experienced first cleavage, were the most common comprising 73% of the eggs collected at the Ives Island index site (Figure 3).

Upstream of Ives Island, 22 eggs were collected from April 25 and June 8. Eleven (50%) of the eggs collected above the index site were stage 2. At sites downstream of Ives Island, 59 eggs were collected between the first day of sampling on May 5 and June 20 (Table 1). Below the index site older eggs were more abundant with stage 16 comprising the largest single group (34%) (Figure 3).

A total of 12 larvae were caught during regular daytime sampling at Ives Island between May 5 and June 2. One larvae was captured above and 12 below the index site. Most of the larvae were aged as one day post hatch (Table 2). The average length of the larvae were 13.74 mm at the index site and 12.81 mm below the index site.

During the overnight trip at the Ives Island index site 364 eggs were collected. Again, most of the eggs (67%) were classified as stage 2 (Table 3). Peak periods of collection were at 2206, 0128 and 0445 hours (Figure 4).

During the overnight trip 65 larvae were captured and 49% were aged as one day post hatch (Table 4). The average length was 12.3 mm.

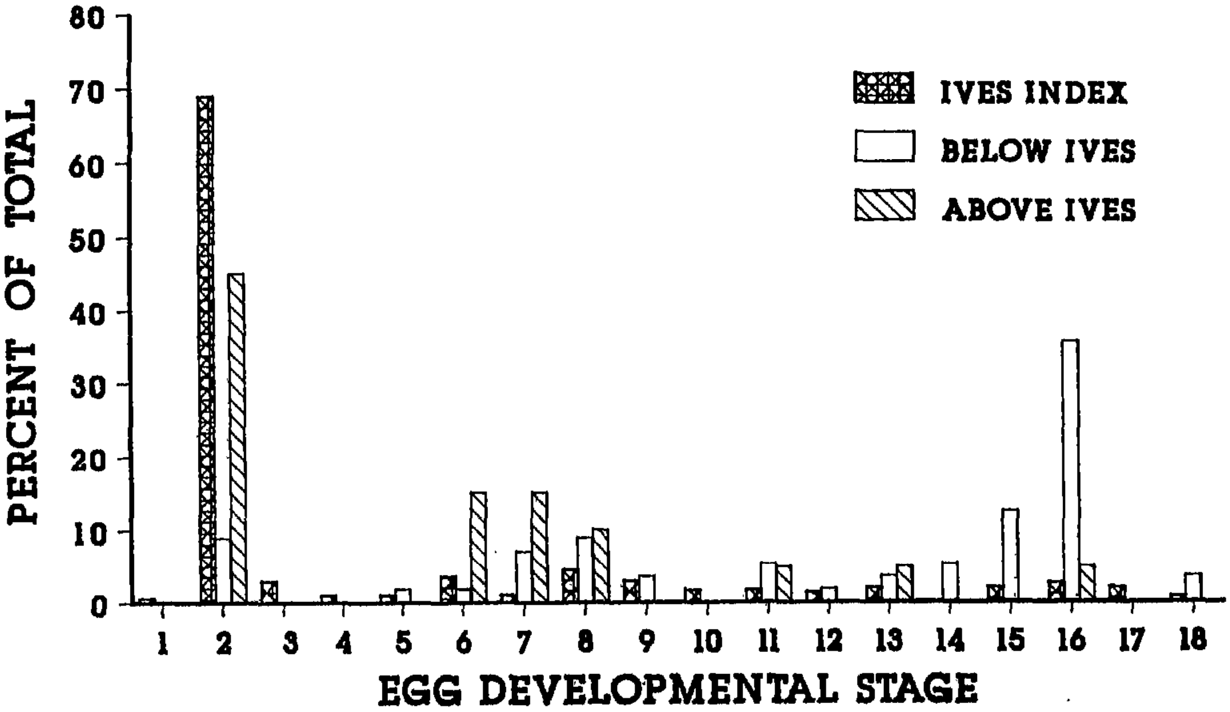


Figure 3. Developmental stage of white sturgeon eggs collected in the Columbia River downstream from Bonneville Dam, April through June, 1988.

Table 1. Numbers of white sturgeon eggs by developmental stage collected below Bonneville Dam during regular daytime sampling, 1988.

Location Date	(RM)	Egg developmental stage 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
Above Ives Island																				
Apr 25	144		1																	1
May 5	145		1																	1
May 10	144		1																	1
May 23	144						2					1					1			4
May 23	145													1						1
Jun 8	145		8				1	3	2											14
Total		0	11	0	0	0	3	3	2	0	0	1	0	1	0	0	1	0	0	22
Ives Island index																				
Apr 25	143		3	1			1		3	4	2	2	2							18
May 5	143		39		1				1	1	1	1						3		47
10	143	2	81		2	2	9									5				101
18	143		5							1		1				1				8
23	143		11				1	1	4	3	1	1	1						2	25
Jun 2	143		18	1		1	1	3												24
8	143		24								1		1				2			28
20	143		10	1																11
Total		2	191	3	3	3	12	4	8	9	5	5	4	0	0	6	2	3	2	262[a]
Below Ives Island																				
May 5	142		7						3	1		1								12
Jun 8	141					1			1	1		2	1	2	3	7	20	1	2	41
Jun 20	141						1	4	1											6
Total		0	7	0	0	1	1	4	5	2	0	3	1	2	3	7	20	1	2	59[b]

[a] *Does not include 9 eggs of unknown developmental stage.*
[b] *Does not include 3 eggs of unknown developmental stage.*

Table 2. Numbers of white sturgeon larvae by age captured below Bonneville Dam during regular daytime sampling, 1988.

Location Date	(RM)	Number of days post hatch								
		Post hatch	1	2	3	4	5	8	9	Total
Ives Island index										
May 5	143		2	1						3
10	143		2		1					3
23	143		1	2						3
Jun 2	143						1		1	2
Total		0	5	3	1	0	1	0	1	11
Other locations										
May 5	142		3		1	1				5
23	144			1						1
27	120			1						1
Jun 2	120			1						1
15	120					1				1
15	113	1								1
16	141		1			1		1		3
Total		1	4	3	1	3	0	1	0	13

Table 3. Numbers of white sturgeon eggs by developmental stage collected below Bonneville Dam at Ives Island overnight on May 25-26, 1988.

Time	Set Time (min)	Egg developmental stage 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
1843	60		4					1	3	1		3				1	1	1		15
1951	60		4					1	2	1	1				1					10
2100	60		0						1	1			3				3		1	9
2206	60		108						6											114
2314	60		9						2	1		2	4	1			1	1		21
0020	60		27						2	2				6						37
0128	60		34	5	3	2			3					3		3				53
0234	60		3				1		2			1		1			1	1		10
0340	60		1					1	1	1										4
0445	60		31	6					6					6			6	3		58
0553	30		19	1					3	1	1			1						26
Total		0	240	12	3	2	1	3	31	8	2	6	7	18	1	4	12	6	1	357[a]

[a] *Does not include 7 eggs of unknown developmental stage.*

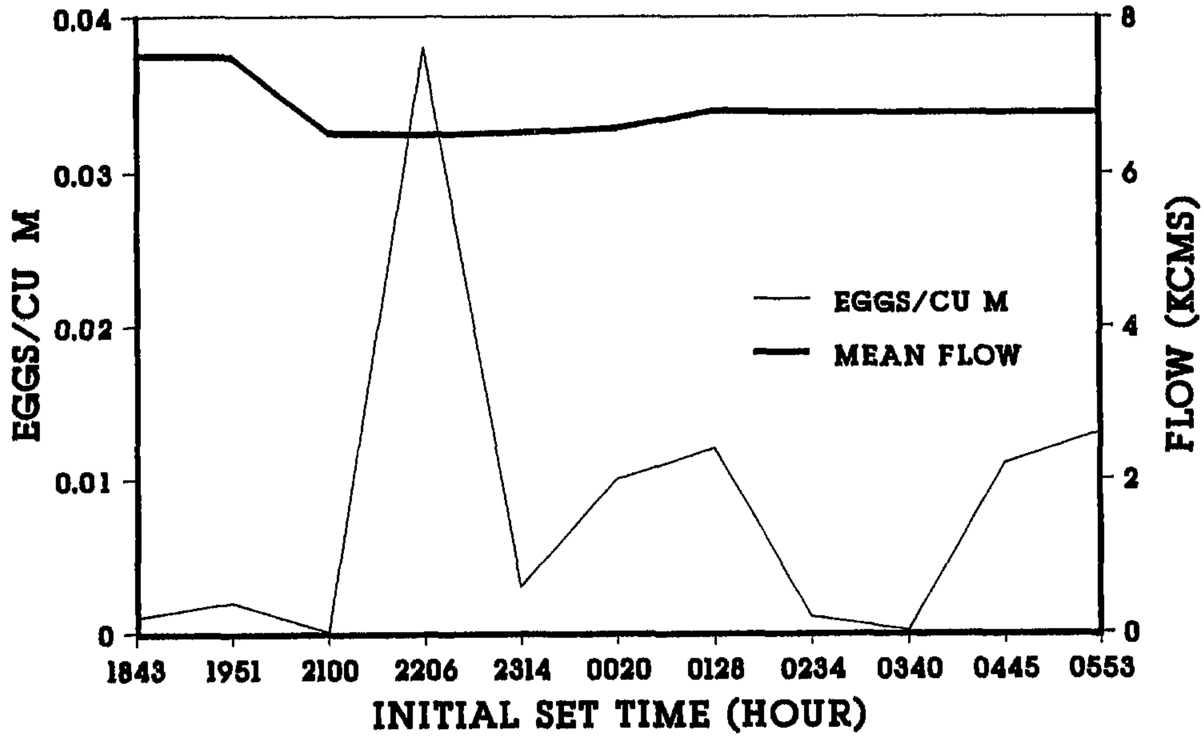


Figure 4. Mean hourly flow and stage 2 white sturgeon eggs collected per set during overnight sampling at Ives Island on May 25-26, 1988.

Table 4. Number of white sturgeon larvae by age captured below Bonneville Dam at Ives Island overnight on May 25-26, 1988.

		Number of days post hatch							
Time	Set time (min)	Post hatch	1	2	3	4	5	6	Total
1843	60		5		3				8
1951	60								0
2100	60	1	3			1			5
2206	60	3	3	1					7
2314	60	1	3	2	2	1			9
0020	60		4	2	1			2	9
0128	60	1	2						3
0234	60	2	2	2	1				7
0340	60	1	4	1	1		1		8
0445	60		1						1
0553	30	1	4		1				6
Total		10	31	8	9	2	1	2	63[a]

[a] *Does not includes 2 larvae of unknown age.*

At sites upstream of Ives Island, CPUE for eggs and larvae were significantly lower than the index area value. At sites up to two miles downstream of Ives Island, CPUE was lower for eggs and higher for larvae (Table 5).

A spawning index was established by back-calculating spawning dates from eggs and larvae. The index indicates only that there was evidence that spawning occurred on that date. Spawning commenced April 19 and extended to June 20. Spawning activity began 10 days after the water temperature exceeded 10°C and nine days after mean flows rose to about 4.25 thousand cubic meters per second (kcms) (Figure 5). Evidence of spawning activity was fairly continuous between May 1 and June 8 except when flows dropped from 6.49 kcms to 4.28 kcms during May 26 to May 31. Spawning activity was not evident immediately after a rapid drop in flows to about 4.25 kcms on June 9.

Recreational Fishery Census

Angler effort was counted on 211 days in Bonneville Reservoir and 230 days in The Dalles Reservoir during the census period of 245 days (Table 6). Samplers interviewed 4,654 anglers in Bonneville Reservoir and 7,475 anglers in The Dalles Reservoir (Table 7). These interviews include anglers at the mouths of the Deschutes and White Salmon rivers which were sampled by ODFW district personnel and the Washington Department of Wildlife. Anglers in Bonneville Reservoir fished 41,643 hours for white sturgeon and 89,751 hours for other species (Table 8). In The Dalles Reservoir, angling effort for white sturgeon was 64,692 hours compared to 94,361 hours for other species (Table 8). Angler effort for white sturgeon was fairly constant throughout the census period in Bonneville Reservoir but showed a strong peak in late May to early June (week 22-29) in The Dalles Reservoir.

Recreational harvest of white sturgeon was estimated to be 1,135 in Bonneville Reservoir and 863 in The Dalles Reservoir during the census period (Table 9). Legal size changed during the census period. Legal size was 36-72 inches TL (91-183 cm TL) through April 29 (week 18); thereafter, legal size was 40-72 inches TL (102-183 cm TL). Included in the harvest were a minor number of sublegal and slightly oversize fish.

During the census period, the ratio of sublegal:legal:oversize white sturgeon handled was about 10:2:1 in Bonneville Reservoir and about 23:5:1 in The Dalles Reservoir (Table 10). In Bonneville Reservoir, 15 oversize white sturgeon were handled by boat anglers compared to none by bank anglers. The converse situation occurred in The Dalles Reservoir where bank anglers handled 43 oversize fish compared to only three by boat anglers.

White sturgeon catch per angler hour reached a peak of 0.032 fish/hour during late May to early June (week 22-23) in Bonneville Reservoir (Table 11). In The Dalles Reservoir, the peak catch rates of 0.034 fish/hour and 0.036 fish/hour occurred later in the season during late September and early October (week 40-41) and in late

Table 5. Average catch of white sturgeon eggs and larvae per cubic meter and per minute below Bonneville Dam, April 25 - June 20, 1988.

Area	Eggs/m^3	Eggs/min	Larvae/m^3	Larvae/min
Ives Is. index	0.0100	0.4738	0.0004	0.0209
Ives Is. down to Warrendale	0.0082	0.2583	0.0011	0.0333
Ives Is. up to Bradford Is.	0.0012	0.0244	0.0001	0.0011
Warrendale to I-5 bridge	0.0000	0.0000	0.0001	0.0039
Ives Is. overnight trip	0.0123	0.5778	0.0022	0.1031
Period average	0.0065	0.2457	0.0008	0.0308

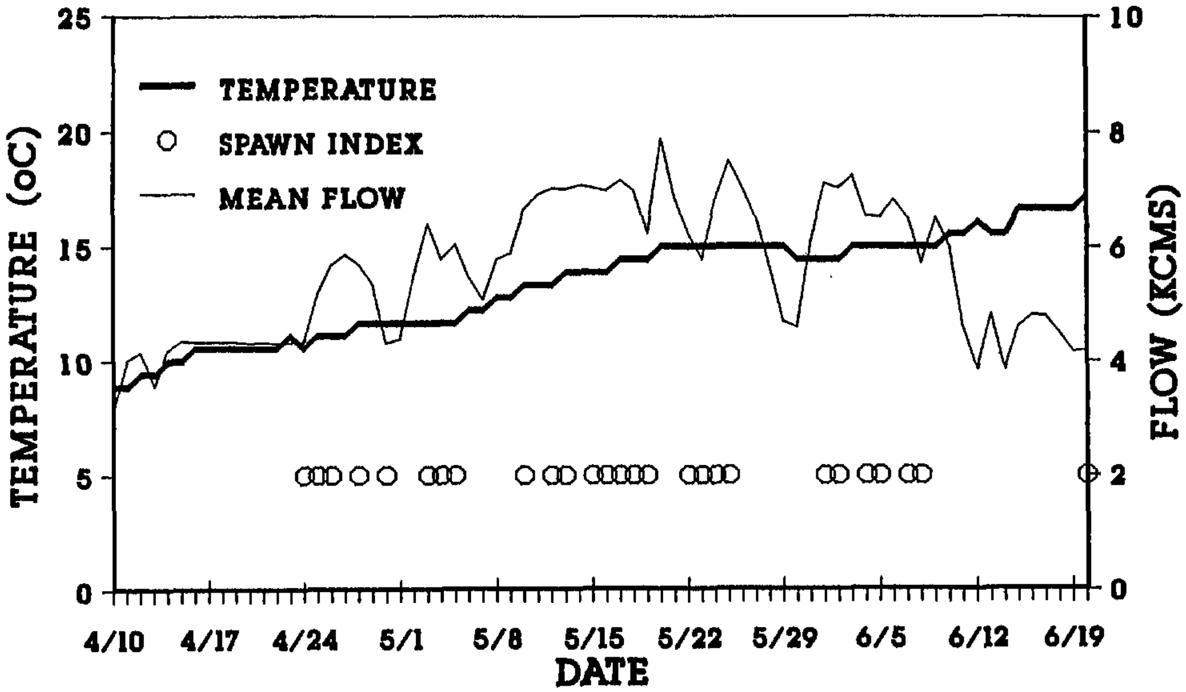


Figure 5. Temperature, mean daily flow and spawn index for white sturgeon egg and larval sampling in the Columbia River downstream from Bonneville Dam, April through June, 1988.

Table 6. Numbers of days angler effort was counted in Bonneville and The Dalles reservoirs, March-October, 1988.

Reservoir Week	Effort count type Flight	 Sunrise-sunset index	 Once through index
Bonneville			
10-11	4	4	7
12-13	4	4	7
14-15	4	4	7
16-17	4	4	7
18-19	4	4	8
20-21	4	4	8
22-23	4	4	7
24-25	4	4	10
26-27	4	4	8
28-29	4	4	8
30-31	3	4	9
32-33	4	4	7
34-35	4	4	10
36-37	4	4	8
38-39	4	4	9
40-41	4	4	9
42-43	4	4	6
44-45	4	4	4
Total	71	72	139
The Dalles			
10-11	4	4	3
12-13	4	4	7
14-15	4	4	9
16-17	4	4	9
18-19	4	4	10
20-21	4	4	10
22-23	4	4	9
24-25	4	4	10
26-27	4	4	9
28-29	4	4	9
30-31	3	4	10
32-33	4	4	10
34-35	4	4	10
36-37	4	4	8
38-39	4	4	8
40-41	4	4	9
42-43	4	4	10
44-45	4	4	8
Total	71	72	158

Table 7. Numbers of anglers interviewed on Bonneville and The Dalles reservoirs, March-October, 1988.

Reservoir Week	Boat		Bank	
	Sturgeon	Other	Sturgeon	Other
Bonneville				
10-11	25	15	99	32
12-13	35	17	102	41
14-15	21	39	75	35
16-17	2	0	58	16
18-19	24	11	59	13
20-21	73	63	81	18
22-23	31	4	119	12
24-25	69	14	184	122
26-27	33	27	103	82
28-29	43	23	108	129
30-31	64	28	67	272
32-33	22	16	77	208
34-35	67	177	72	227
36-37	39	185	71	198
38-39	33	99	49	131
40-41	22	73	35	55
42-43	39	43	65	95
44-45	11	16	40	1
Total	653	850	1,464	1,687
The Dalles				
10-11	10	167	54	43
12-13	36	207	98	48
14-15	21	143	109	38
16-17	16	93	106	10
18-19	9	20	136	42
20-21	24	49	180	70
22-23	21	18	334	165
24-25	45	31	458	210
26-27	47	13	518	74
28-29	41	59	242	93
30-31	29	57	116	71
32-33	6	119	119	171
34-35	28	403	128	119
36-37	20	304	123	169
38-39	9	522	114	187
40-41	25	94	57	208
42-43	8	127	65	112
44-45	17	49	12	62
Total	412	2,475	2,969	1,892

Table 8. Estimated hours of angler effort in Bonneville and The Dalles reservoirs, March-October, 1988.

Reservoir Week	Sturgeon anglers Boat	Sturgeon anglers Bank	Sturgeon anglers Combined	Other anglers Boat	Other anglers Bank	Other anglers Combined
Bonneville						
10-11	1,668	608	2,276	829	267	1,096
12-13	1,854	1,297	3,151	1,181	317	1,498
14-15	628	939	1,567	481	774	1,255
16-17	274	616	890	312	335	647
18-19	468	1,863	2,331	564	195	759
20-21	799	1,240	2,039	1,513	109	1,622
22-23	561	2,536	3,097	303	142	445
24-25	992	2,087	3,079	522	1,759	2,281
26-27	598	2,609	3,207	903	2,445	3,348
28-29	894	2,663	3,557	974	4,069	5,043
30-31	1,137	1,178	2,315	1,836	8,349	10,185
32-33	1,493	1,013	2,506	950	10,751	11,701
34-35	1,277	1,815	3,092	4,572	10,287	14,859
36-37	631	2,754	3,385	6,673	8,255	14,928
38-39	814	1,141	1,955	2,489	5,341	7,830
40-41	922	656	1,578	4,798	3,609	8,407
42-43	584	654	1,238	1,035	2,277	3,312
44-45	231	149	380	502	33	535
Total	15,825	25,818	41,643	30,437	59,314	89,751
The Dalles						
10-11	165	560	725	2,271	423	2,694
12-13	515	1,227	1,742	3,445	298	3,743
14-15	326	2,292	2,618	2,340	495	2,835
16-17	219	1,883	2,102	688	5,155	5,843
18-19	496	1,892	2,388	396	4,449	4,845
20-21	527	3,187	3,714	1,037	1,281	2,318
22-23	470	6,198	6,668	763	2,269	3,032
24-25	1,450	10,068	11,518	366	3,553	3,919
26-27	2,500	8,966	11,466	649	497	1,146
28-29	931	3,622	4,553	2,468	746	3,214
30-31	1,990	1,664	3,654	2,630	800	3,430
32-33	133	2,466	2,599	4,307	2,382	6,689
34-35	911	1,997	2,908	11,224	1,132	12,356
36-37	850	1,935	2,785	12,747	2,914	15,661
38-39	772	1,980	2,752	9,839	3,418	13,257
40-41	523	756	1,279	2,323	2,453	4,776
42-43	226	447	673	1,612	1,226	2,838
44-45	241	307	548	1,090	675	1,765
Total	13,245	51,447	64,692	60,195	34,166	94,361

Table 9. Estimated recreational fishery harvest of white sturgeon in Bonneville and The Dalles reservoirs, March-October, 1988.

Reservoir Week	Sturgeon anglers Boat	Sturgeon anglers Bank	Other anglers Boat	Other anglers Bank	Combined
Bonneville					
10-11	48	7	0	0	55
12-13	9	32	0	0	41
14-15	32	13	0	0	45
16-17	15	11	0	0	26
18-19	12	31	0	0	43
20-21	10	14	0	0	24
22-23	30	84	4	1	119
24-25	64	23	0	0	87
26-27	41	112	0	0	153
28-29	16	84	0	0	100
30-31	37	2	0	0	39
32-33	110	23	0	0	133
34-35	55	17	0	0	72
36-37	39	0	0	0	39
38-39	11	38	0	0	49
40-41	38	19	0	0	57
42-43	24	13	0	0	37
44-45	13	2	0	1	16
Total	604	525	4	2	1,135
The Dalles					
10-11	0	0	0	0	0
12-13	9	4	0	0	13
14-15	4	29	0	0	33
16-17	8	33	0	0	41
18-19	5	19	0	0	24
20-21	7	16	2	0	25
22-23	5	44	1	0	50
24-25	9	95	1	0	105
26-27	58	143	4	0	205
28-29	7	26	1	0	34
30-31	16	28	2	0	46
32-33	23	29	1	0	53
34-35	14	23	3	0	40
36-37	12	29	1	0	42
38-39	65	11	1	0	77
40-41	33	10	1	0	44
42-43	3	6	2	0	11
44-45	17	3	0	0	20
Total	295	548	20	0	863

Table 10. Numbers of white sturgeon, by size group, reported in the sampled recreational fishery catch in Bonneville and The Dalles reservoirs, March - October, 1988.

Reservoir Week	Boat Sub legal	Boat Legal rel.	Boat Legal kept	Boat Over-size	Bank Sub legal	Bank Legal rel.	Bank Legal kept	Bank Over-size
Bonneville								
10-11	10	2	10	0	9	1	3	0
12-13	39	0	2	0	25	0	6	0
14-15	39	0	4	0	14	2	3	0
16-17	1	0	1	0	7	0	4	0
18-19	11	0	12	0	21	0	4	0
20-21	87	8	9	2	54	0	5	0
22-23	19	0	14	0	28	0	20	0
24-25	87	1	25	6	77	2	17	0
26-27	28	0	9	1	71	1	14	0
28-29	66	0	6	1	48	0	13	0
30-31	66	0	10	3	25	0	2	0
32-33	24	0	9	0	61	2	11	0
34-35	114	6	13	0	65	0	2	0
36-37	51	2	5	1	31	0	0	0
38-39	41	0	2	0	20	0	8	0
40-41	110	0	7	1	16	1	5	0
42-43	67	3	12	0	51	0	5	0
44-45	6	0	2	0	22	0	5	0
Total	866	22	152	15	645	9	127	0
The Dalles								
10-11	2	0	0	0	6	0	0	0
12-13	10	0	3	0	3	0	2	0
14-15	23	0	1	1	17	0	4	0
16-17	7	0	1	0	16	2	7	1
18-19	0	0	2	0	28	5	6	3
20-21	12	0	0	0	19	0	6	3
22-23	12	0	0	0	38	0	17	9
24-25	41	0	2	0	76	1	36	10
26-27	56	0	10	0	100	2	58	9
28-29	47	0	2	0	82	0	11	1
30-31	44	1	3	0	29	0	4	0
32-33	0	0	2	0	67	1	11	0
34-35	56	0	3	0	81	1	7	1
36-37	25	0	2	0	63	3	11	1
38-39	11	1	4	0	12	1	2	0
40-41	47	0	11	0	9	0	5	0
42-43	29	0	2	1	23	0	7	2
44-45	65	0	9	1	11	0	1	3
Total	487	2	57	3	680	16	195	43

Table 11. White sturgeon harvest per hour of angling effort in Bonneville and The Dalles reservoirs, March-October, 1988.

Reservoir Week	Sturgeon anglers Boat	Sturgeon anglers Bank	Sturgeon anglers Combined	Other anglers Boat	Other anglers Bank	Other anglers Combined
Bonneville						
10-11	0.019	0.008	0.016	0.000	0.000	0.000
12-13	0.003	0.020	0.009	0.000	0.000	0.000
14-15	0.029	0.008	0.016	0.000	0.000	0.000
16-17	0.026	0.012	0.017	0.000	0.000	0.000
18-19	0.012	0.015	0.014	0.000	0.000	0.000
20-21	0.004	0.010	0.007	0.000	0.000	0.000
22-23	0.035	0.031	0.032	0.013	0.007	0.011
24-25	0.042	0.006	0.016	0.000	0.000	0.000
26-27	0.027	0.022	0.023	0.000	0.000	0.000
28-29	0.009	0.012	0.012	0.000	0.000	0.000
30-31	0.012	0.000	0.003	0.000	0.000	0.000
32-33	0.045	0.002	0.009	0.000	0.000	0.000
34-35	0.009	0.001	0.004	0.000	0.000	0.000
36-37	0.005	0.000	0.002	0.000	0.000	0.000
38-39	0.003	0.006	0.005	0.000	0.000	0.000
40-41	0.007	0.004	0.006	0.000	0.000	0.000
42-43	0.015	0.004	0.008	0.000	0.000	0.000
44-45	0.018	0.011	0.016	0.000	0.030	0.002
Average	0.013	0.006	0.009	< 0.001	< 0.001	< 0.001
The Dalles						
10-11	0.000	0.000	0.000	0.000	0.000	0.000
12-13	0.017	0.003	0.007	0.000	0.000	0.000
14-15	0.012	0.013	0.013	0.000	0.000	0.000
16-17	0.037	0.018	0.020	0.000	0.000	0.000
18-19	0.010	0.010	0.010	0.000	0.000	0.000
20-21	0.013	0.005	0.006	0.001	0.000	0.000
22-23	0.011	0.007	0.007	0.001	0.000	0.000
24-25	0.006	0.009	0.009	0.003	0.000	0.000
26-27	0.023	0.016	0.018	0.006	0.000	0.003
28-29	0.008	0.007	0.007	0.000	0.000	0.000
30-31	0.008	0.017	0.012	0.001	0.000	0.001
32-33	0.173	0.012	0.020	0.000	0.000	0.000
34-35	0.015	0.012	0.013	0.000	0.000	0.000
36-37	0.014	0.015	0.015	0.000	0.000	0.000
38-39	0.084	0.006	0.028	0.000	0.000	0.000
40-41	0.063	0.013	0.034	0.000	0.000	0.000
42-43	0.013	0.013	0.013	0.001	0.000	0.001
44-45	0.071	0.010	0.036	0.002	0.000	0.001
Average	0.022	0.011	0.013	< 0.001	< 0.001	< 0.001

October and early November (week 44-45)(Table 11). In both reservoirs catch per hour for boat anglers was about twice that of bank anglers.

Tribal Commercial Fishery Landings

A preliminary estimate of 4,141 white sturgeon were harvested in the 1988 tribal commercial fisheries. Most of this harvest (3,786) occurred during the setnet season. Sale of setnet caught white sturgeon was allowed during 49 days in the winter season (February 1 - March 21), 14 days in the sockeye season (June 22 - July 9) and during the first 16 days (August 10 - September 3) of the fall season. Setline seasons were shortened from those in previous years. The setline season occurred from January through April whereas only May and June had been closed previously. Additionally, less than 50 white sturgeon were commercially harvested by hook and line during open commercial periods in the setline and setnet fishery.

Mark Recovery and Biological Sampling

During examination of the recreational fishery harvest, 255 white sturgeon from Bonneville Reservoir and 241 white sturgeon in The Dalles Reservoir were checked for marks (Table 12). Mark sampling rates were 0.22 and 0.28 in Bonneville and The Dalles reservoirs respectively. No ODFW in-sample marks were observed in the Bonneville Reservoir fishery; consequently, the estimated harvest of marked fish was zero. Nineteen in-sample marks were observed in The Dalles Reservoir fishery. An estimated 68 ODFW marked white sturgeon were harvested from The Dalles Reservoir. Twenty ODFW marked fish were voluntarily reported to WDF during 1988. Information on four sublegal released ODFW marked fish was obtained also.

Fork lengths were measured on 226 and 238 recreationally harvested white sturgeon from Bonneville and The Dalles reservoirs respectively (Figure 6). In Bonneville Reservoir, average FL of harvested white sturgeon was 96 cm when the legal size was 36-72 inches TL, compared to 103 cm after the minimum legal size increased to 40 inches TL. During the entire census in Bonneville Reservoir, harvested white sturgeon ranged from 84 cm to 145 cm FL. White sturgeon harvested from The Dalles Reservoir recreational fishery averaged 113 cm FL prior to the increase in minimum size and 118 cm FL thereafter. Range was 83cm to 174 cm FL.

A total of 114 ovary and 171 fin ray samples were collected in the recreational fisheries.

During sampling of the tribal commercial fishery, 300 of the 1,924 white sturgeon landed in Washington were examined for marks (Table 13). One in-sample ODFW mark was recovered from the 801 white sturgeon harvested in The Dalles Reservoir and two marks from landings where the reservoir was unknown. An estimated 28 ODFW marked white sturgeon from The Dalles Reservoir were landed in

Table 12. Estimated recreational fishery harvest of ODFW marked white sturgeon from Bonneville and The Dalles reservoirs, March-October, 1988.

Reservoir Week	Estimated harvest	Number examined for marks	Mark sample rate	Observed marks	Estimated mark harvest
Bonneville					
10-11	55	13	0.24	0	--
12-13	41	8	0.20	0	--
14-15	45	7	0.16	0	--
16-17	26	5	0.19	0	--
18-19	43	16	0.37	0	--
20-21	24	12	0.50	0	--
22-23	119	31	0.26	0	--
24-25	87	39	0.45	0	--
26-27	153	16	0.10	0	--
28-29	100	17	0.17	0	--
30-31	39	12	0.31	0	--
32-33	133	20	0.15	0	--
34-35	72	13	0.18	0	--
36-37	39	5	0.13	0	--
38-39	49	8	0.16	0	--
40-41	57	12	0.21	0	--
42-43	37	14	0.38	0	--
44-45	16	7	0.44	0	--
Total	1,135	255	0.22	0	0
The Dalles					
10-11	0	0	0.00	0	--
12-13	13	5	0.38	0	--
14-15	33	5	0.15	0	--
16-17	41	8	0.20	0	--
18-19	24	8	0.33	0	--
20-21	25	5	0.20	0	--
22-23	50	17	0.34	1	--
24-25	105	36	0.34	4	--
26-27	205	66	0.32	6	--
28-29	34	13	0.38	1	--
30-31	46	7	0.15	1	--
32-33	53	13	0.25	1	--
34-35	40	9	0.23	2	--
36-37	42	12	0.29	0	--
38-39	77	6	0.08	0	--
40-41	44	16	0.36	3	--
42-43	11	5	0.45	0	--
44-45	20	10	0.50	0	--
Total	863	241	0.28	19	68

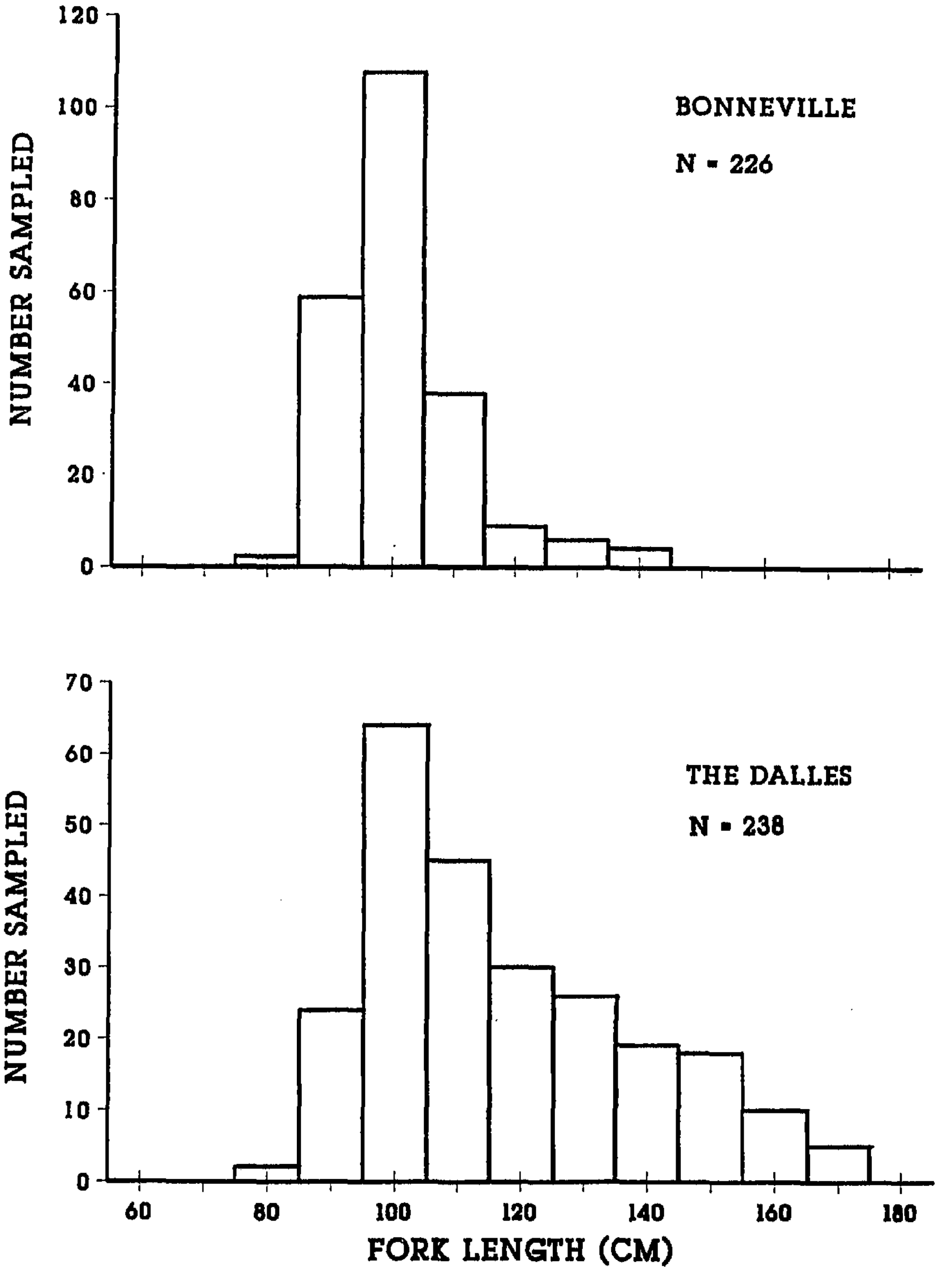


Figure 6. Length-frequency distributions of harvested white sturgeon sampled from the March through October, 1988, recreational fishery for Bonneville and The Dalles reservoirs.

Table 13. Estimated harvest of ODFW marked white sturgeon landed in Washington from commercial fisheries between Bonneville and McNary dams in 1988.

Week	Washington Landings		Number examined for marks			Observed marks		Estimated mark harvest
	The Dalles	Bonneville and John Day	The Dalles	Unknown pool	Bonneville and John Day	The Dalles	Unknown pool	
1-15	468	479	28	20	78	0	0	--
16-17	22	8	6	0	3	0	0	--
18-19	30	12	6	0	6	0	0	--
20-21	0	0	0	0	0	0	0	--
22-23	0	0	0	0	0	0	0	--
24-25	0	0	0	0	0	0	0	--
26-27	30	34	4	9	0	0	0	--
28-29	37	32	6	2	0	0	0	--
30-31	0	3	0	0	0	0	0	--
32-33	80	161	2	0	22	1	0	--
34-35	100	303	20	10	66	0	2[a]	--
36-37	31	91	1	0	11	0	0	--
38-52	3	0	0	0	0	0	0	--
Total	801	1,123	73 (85)[b]	41	186 (215)[b]	1 (3)	2	(28)[c]

[a] *Includes one fish with two tag scars at the base of the dorsal fin but no secondary marks.*

[b] *Fish sampled where the pool was not identified were distributed between The Dalles and Bonneville-John Day pools based on the ratio of known samples.*

[c] *The two mark recoveries where the pool was not identified were assigned to The Dalles pool to calculate mark harvest.*

Washington.

In the tribal commercial fishery landings in Oregon, 335 of the 2,217 white sturgeon landed were examined for marks (Table 14). Only one in-sample ODFW marked white sturgeon was recovered, originating from an unknown quantity of landings from The Dalles Reservoir. An estimated seven ODFW marked white sturgeon were landed in Oregon.

Fork lengths were measured on 251 and 104 white sturgeon commercially harvested from Bonneville and The Dalles reservoirs respectively (Figure 7). In Bonneville Reservoir, FL averaged 114 cm with a range of 101 cm to 165 cm. Fish harvested from The Dalles Reservoir averaged 127 cm FL and ranged from 104 cm to 166 cm FL.

A total of 248 ovary and 607 fin ray samples were collected in the tribal commercial fishery.

Refer to ODFW REPORT A in this document for additional information on mark recoveries and biological samples from the recreational and commercial fisheries between Bonneville and McNary dams.

Population Dynamics Downstream of Bonneville Dam

Field activities in 1988 focused on continued marking of white sturgeon and examining recreational and commercial fishery catches for mark recoveries and biological samples. A total of 3,044 white sturgeon were captured and 2,661 were marked with spaghetti tags during sturgeon and salmon research by WDF and ODFW. Of this total, 1,477 were marked and released in the Columbia River estuary, 601 at Woody Island, 76 at Skamokawa, 26 at Mayger and 481 at Corbett. An additional 35 white sturgeon were tagged during other research activities.

Mark sampling by WDF and ODFW was conducted on 9,845 white sturgeon harvested in the recreational fishery and 1,802 in the commercial fishery in 1988. Of the white sturgeon marked in 1988, 63 were recovered from the recreational fishery and four from the commercial fishery (Table 15). An additional 285 fish marked prior to 1988 were observed in the harvest from both fisheries.

Retention of marks on white sturgeon double tagged in 1986-88 showed spaghetti tags placed anterior in the dorsal fin were retained longer than tags in the posterior position (Table 16).

The size of white sturgeon caught by the gillnet gear used to capture fish for marking ranged from 29 cm to 217 cm FL (Figure 8). Of these, 76 were recaptured with the same gear but only two were greater than 120 cm FL. The combination of mesh sizes used to capture sturgeon was primarily selective for fish 80 cm to 100 cm FL.

Size selectivity of hook and line gear was investigated using data from 344 marked white sturgeon sampled in the recreational fishery since 1986. Comparing recapture rates to marks at-large

Table 14. Estimated harvest of ODFW marked white sturgeon landed in Oregon from commercial fisheries between Bonneville and McNary dams in 1988.

Week	Oregon Landings	Number examined for marks: The Dalles	Number examined for marks: Unknown pool	Number examined for marks: Bonneville and John Day	Observed Marks	Estimated mark harvest
1-15	828	3	3	21	0	--
16-17	60	0	0	0	0	--
18-19	51	0	0	0	0	--
20-21	7	0	0	0	0	--
22-23	0	0	0	0	0	--
24-25	0	0	0	0	0	--
26-27	54	0	0	16	0	--
28-29	22	0	0	2	0	--
30-31	0	0	0	0	0	--
32-33	521	3	0	125	0	--
34-35	593	24	17	102	1	--
36-37	81	3	13	3	0	--
38-52	0	0	0	0	0	--
Total	2,217 (242)[a]	33 (37)[b]	33	269	1	(7)

[a] *The ratio of known pool samples was applied to total Oregon landings to estimate The Dalles pool landings.*

[b] *Fish sampled where the pool was not identified were distributed between The Dalles and Bonneville-John Day pools based on the ratio of known samples.*

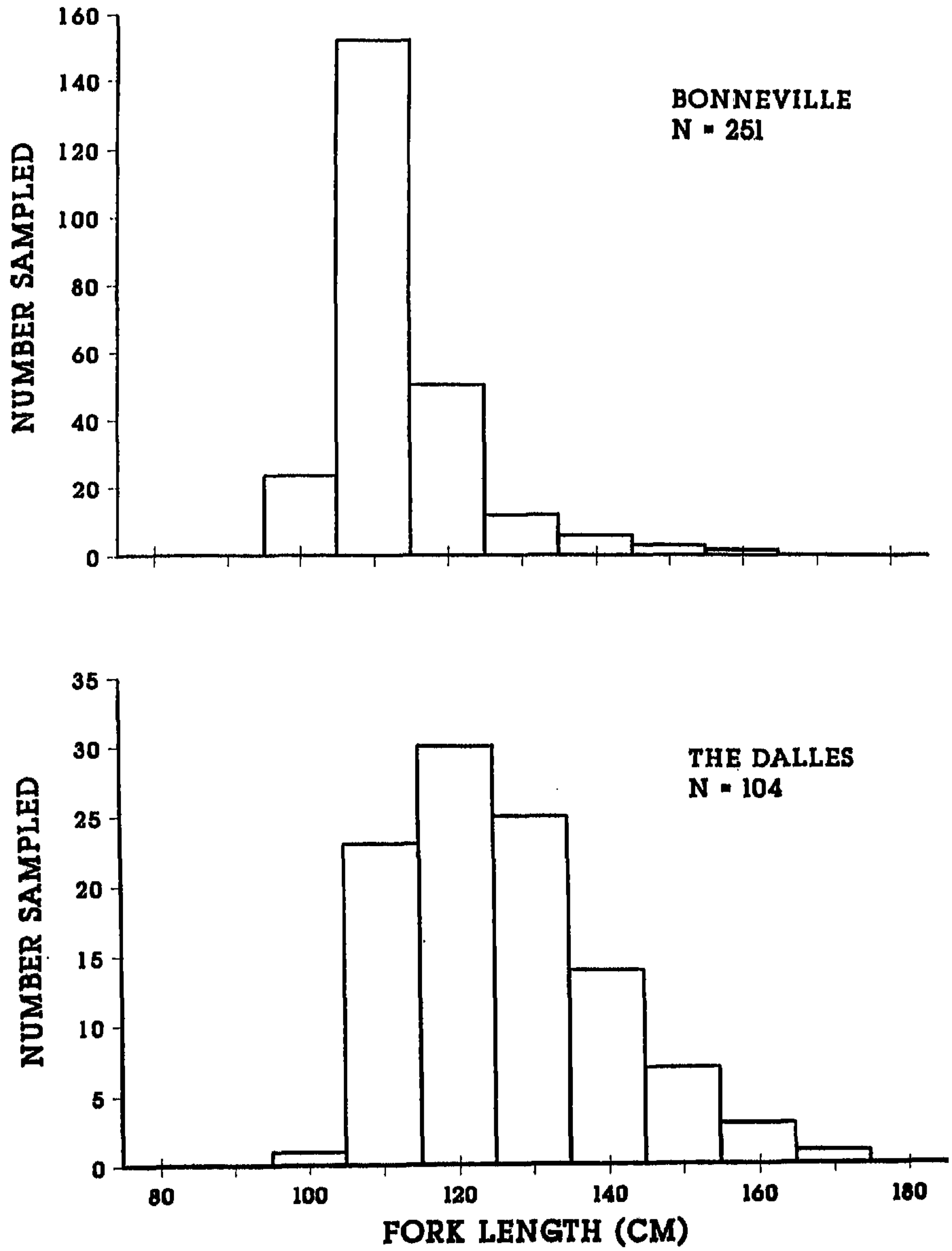


Figure 7. Length-frequency distributions of harvested white sturgeon sampled from 1988 commercial fisheries for Bonneville and The Dalles reservoirs.

Table 15. Recovery of tagged white sturgeon harvested from 1988 sport and commercial fisheries on the Columbia River downstream from Bonneville Dam.

Release Year	Insample		Voluntary	
	Sport	Commercial	Sport	Commercial
1988	63	4	122	8
1987	104	23	188	11
1986	114	17	141	23
1985	18	2	14	3
1984	2	0	5	1
1983	4	1	3	0
1982	0	0	1	0
Total	305	47	474	46

Table 16. Retention of spaghetti tags by white sturgeon double tagged in 1986 through 1988 and recovered in subsequent tagging activities and through sampling sport and commercial fisheries on the Columbia River downstream from Bonneville Dam.

Months out	Both tags retained	Posterior retained, anterior lost	Anterior retained, posterior lost
0-5	364	11	9
6-11	79	11	13
12-17	183	14	36
18-23	27	5	13
24-29	36	3	20
30-35	0	1	3
36-41	2	0	2

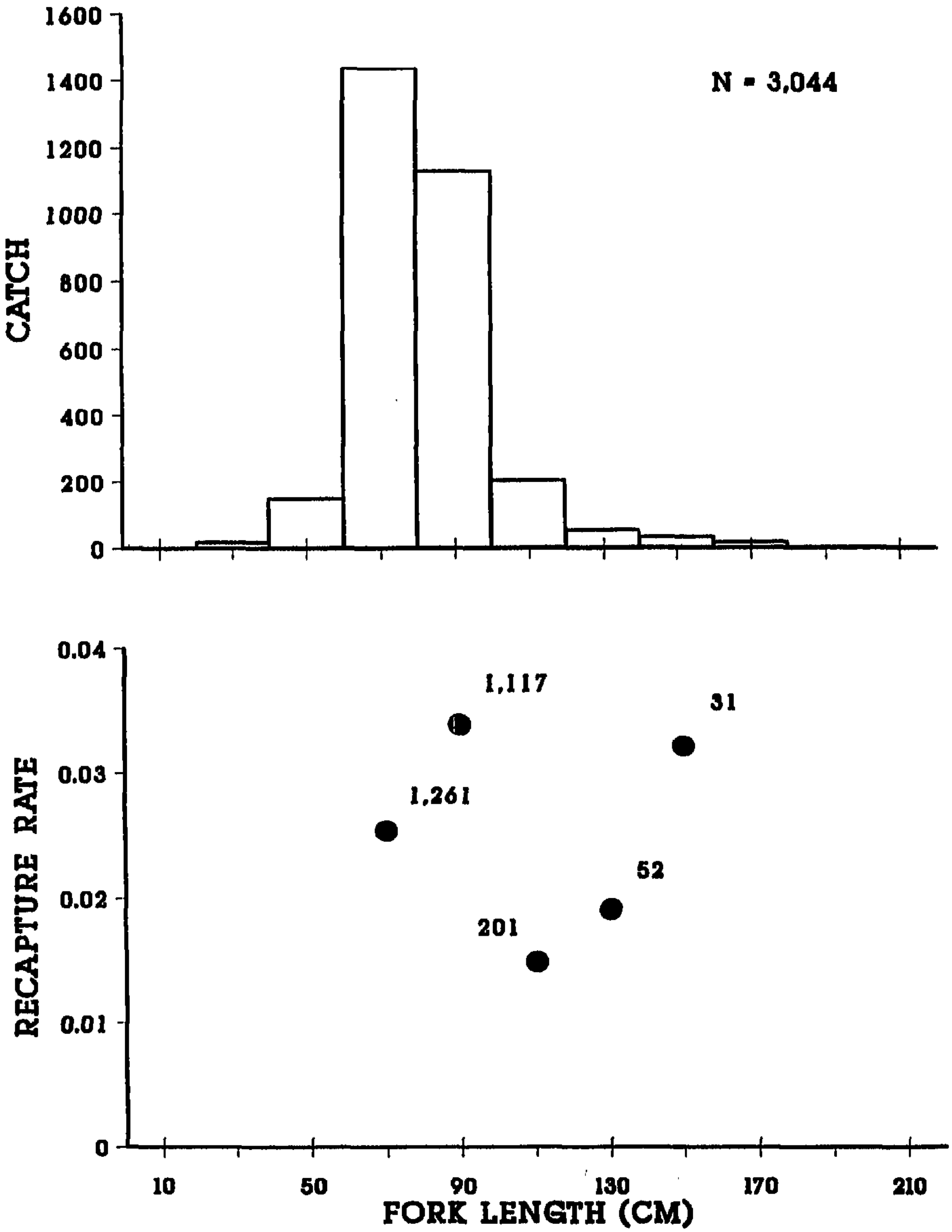


Figure 8. Length-frequency distribution of white sturgeon collected in the Columbia River downstream from Bonneville Dam with gillnet gear in 1988 and subsequent recapture rates of tagged fish at large for the same gear. Not all captured fish were tagged. Numbers of fish tagged in 1988 are shown for each length interval.

indicated this fishery was selective for fish approximately 90 cm FL and dropped as size increased (Figure 9).

Biological information was collected by WDF and ODFW during routine sampling of the 1988 fisheries. FL measurements averaged 95 cm from a sample of 4,363 white sturgeon harvested in the recreational fishery (Figure 10). In the commercial fishery, white sturgeon averaged 117 cm FL. Pectoral fin ray samples were collected from 21 white sturgeon in the recreational fishery and 1,079 in the commercial fishery. Ovary samples were obtained from 450 commercially harvested white sturgeon. Fin ray aging and ovary maturity analysis of the 1988 samples were not completed.

For nine groups of white sturgeon marked in 1986-88, point estimates of the abundance of 3-6 foot fish averaged 183,837 in 1986; 161,169 in 1987; and 155,232 in 1988 (Table 17). Range for all nine estimates (three each year) was 121,588 to 216,077 for the groups marked in April through June of 1986-88 and recovered from one to two months after the month of release.

Recreational and commercial fishery harvest of 3-6 foot white sturgeon downstream of Bonneville Dam was estimated to be 61,400 in 1986, 72,100 in 1987, and 50,000 in 1988 (ODFW and WDF 1989).

Discussion

Significant accomplishments in 1988 towards study objectives resulted from analysis of eggs and larvae collected downstream of Bonneville Dam and on continued population assessment of white sturgeon in the lower Columbia River. Additionally, sampling the recreational and commercial fisheries between Bonneville and McNary dams for mark recovery and biological information can provide indirect benefits for harvest management. Using the data collected on harvest and exploitation, managers can assess the effectiveness of different restrictive actions in the recreational and tribal commercial fisheries.

Analysis of white sturgeon eggs and larvae collected at several site downstream of Bonneville Dam showed the importance of the Ives Island area as the primary spawning reach in the lower Columbia River. Catches of eggs and larvae at sites above Ives Island were younger and fewer in number. Below Ives Island, catches of larvae were greater and eggs were older presumably because of downriver drift from the Ives Island area. The sharp peaks in newly fertilized eggs during the overnight trip suggests that single spawning events may have been detected.

Population dynamics investigations in 1988 included: 1) deriving crude estimates of abundance based on white sturgeon marked during 1986-88, 2) determining mark loss for spaghetti tags placed during 1986-88, and 3) profiling the size selectivity of gillnet gear used in 1988 for capturing white sturgeon for tagging and of the recreational gear used to recover tagged fish. Abundance estimates of about 122,000-216,000 3-6 foot white sturgeon downstream of

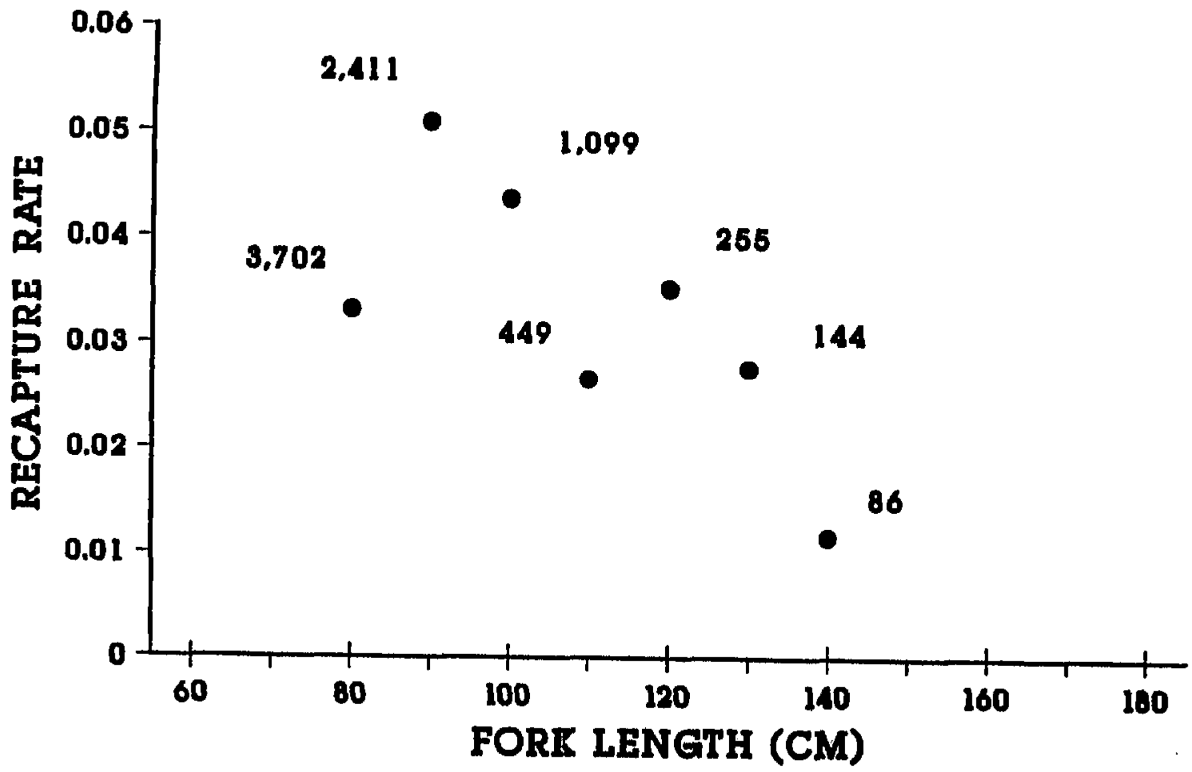


Figure 9. Recapture rates of tagged white sturgeon sampled from the recreational fishery on the Columbia River downstream from Bonneville Dam, pooled for 1986 through 1988. Only fish released and recaptured in the same year are included. The number of tagged fish at large are shown for each length interval.

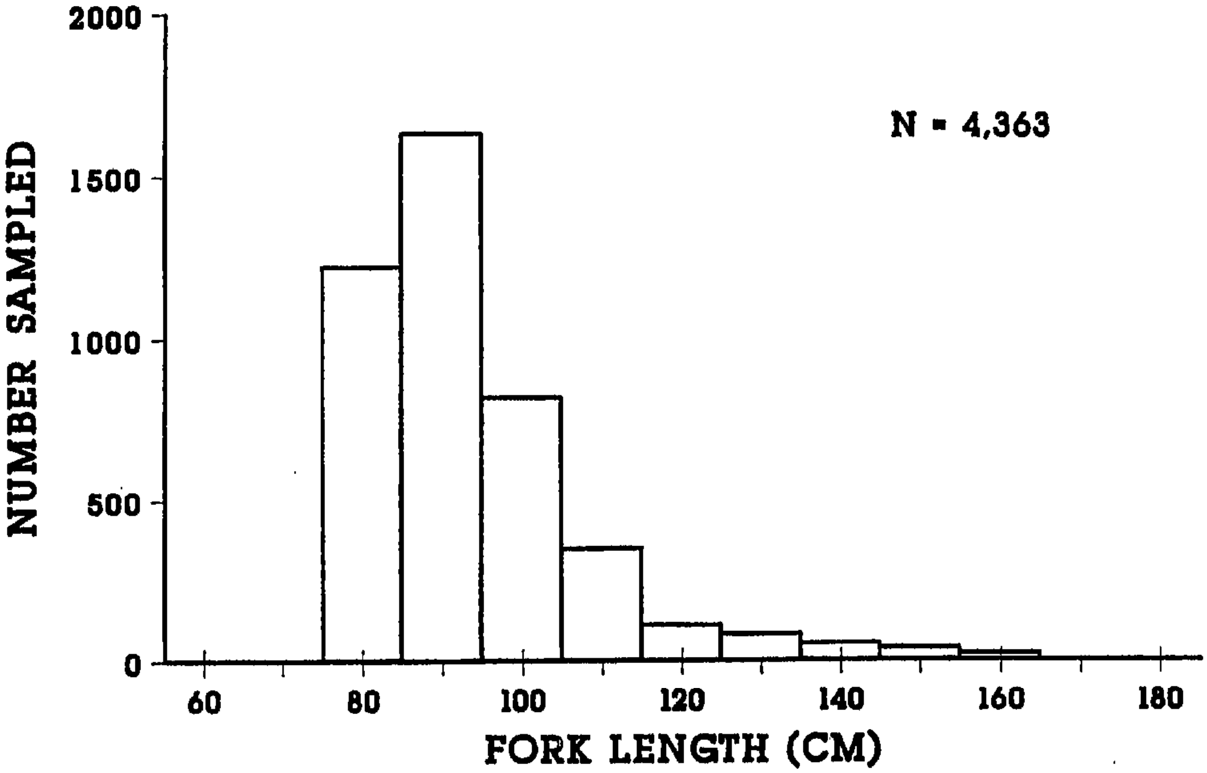


Figure 10. Length-frequency distribution of harvested white sturgeon sampled from the 1988 recreational fishery in the Columbia River downstream from Bonneville Dam.

Table 17. Estimates of 3-6 foot white sturgeon abundance for the Columbia River below Bonneville Dam.

Tagging period						95% Confidence limits	
Year	Month	Tags at-large[a]	Number examined for tags[b]	Tags Observed[b]	Abundance[c]	Lower	Upper
1986	April	694	6,227	20	216,077	129,819	334,055
	May	617	7,676	29	163,314	107,936	234,437
	June	687	3,257	13	172,120	89,502	297,595
	Average				183,837		
1987	April	241	5,173	9	138,521	61,711	270,532
	May	1,211	5,645	50	136,722	100,832	179,447
	June	586	3,554	10	208,264	97,468	391,537
	Average				161,169		
1988	April	423	5,181	15	146,104	79,992	243,263
	May	583	6,453	19	198,005	117,152	309,621
	June	284	3,425	8	121,588	51,164	249,011
	Average				155,232		

[a] *Tags at-large include all 3-6 foot white sturgeon tagged and released during the month indicated.*

[b] *Number examined for tags and tags observed came from sampling the sport fishery the two months following the month of tagging.*

[c] *Abundance = (Tags at-large x Number examined for tags)/Tags observed.*

Bonneville Dam were probably low. These estimates were subject to the problems associated with the adequate mixing of marked and unmarked white sturgeon, and with the exchange of fish between the ocean and the river during the marking or recapture period. Mark loss differed according to the placement on the dorsal fin. Anteriorly placed tags were retained longer. Size selectivity was evident with gillnet and hook and line gear.

Major investigative efforts in 1989 on white sturgeon downstream of Bonneville Dam will be directed towards continued sampling of eggs and larvae and towards addressing the problems associated with open-system population assessment. Intensified sampling at Ives Island, including additional overnight or multi-hour trips, will be valuable for identifying specific habitat and hydrological factors important to early life survival. Sampling during dramatic changes in river flows should be emphasized. Population modeling activities in 1989 will include investigating other abundance estimating methods and attempting to measure the bias with the present estimating procedures. Other population parameter related tasks for 1989 include: 1) processing 1988-89 fin ray samples, 2) determining growth rates, 3) injecting oxytetracyline into marked white sturgeon for subsequent fin ray age verification, 4) identifying spawning periodicity of harvestable size fish, and 5) incising white sturgeon larger than 150 cm FL for sex and maturity level.

General field activities in 1989 will include sampling of the recreational and commercial fisheries both above and below Bonneville Dam. Comprehensive creel censuses will occur in Bonneville and The Dalles reservoirs from March through October and in John Day Reservoir during May through July, 1989.

REFERENCES

Beer, K. 1980. Embryonic and larval development of white sturgeon. Master's Thesis. University of California at Davis.

Brennan, J.S. 1987. Age determination and verification of California white sturgeon, *Acipenser transmontanus*: a comparative analysis. Master's Thesis. San Jose State University, San Jose, California.

Eberhardt, L.L., D.G. Chapman, and J.R. Gilbert. 1979. A review of marine mammal census methods. Wildlife Monographs Number 63.

Hamley, J.M. 1975. Review of gillnet selectivity. Journal of the Fisheries Research Board of Canada. 32:1943-1969.

Kreitman, G. and B. James. 1988. Appendix B. Pages 58-88 *in* Status and habitat requirements of white sturgeon populations in the Columbia River downstream from McNary Dam. Oregon Department of Fish and Wildlife, Washington Department of Fisheries, U.S. Fish and Wildlife Service and National Marine Fisheries Service, Annual Progress Report to the Bonneville Power Administration, Portland, Oregon.

Oregon Department of Fish and Wildlife and Washington Department of Fisheries. 1989. Columbia River fish runs and fisheries, 1960-88, Status Report. Oregon Department of Fish and Wildlife, Portland, Oregon.

Tracy, C.A. 1989. Sturgeon larval sampling results 1988, Progress Report 89-9. Washington Department of Fisheries, Battle Ground, Washington.

Wang, Y.L., F.P. Binkowski, and S.I. Doroshov. 1985. Effect of temperature on early development of white and lake sturgeon, *Acipenser transmontanus* and *A. fulvescens*. Environmental Biology of Fishes 14(1):43-50.

APPENDIX B-1

Angler Effort Count Index Areas

Bonneville Reservoir

Boat

Bridge of the Gods at Cascade Locks, OR (RM 148.4) upstream past the mouth of the Wind River (RM 155.0).

West of Spring Creek Hatchery (RM 166.0) upstream to Mosier, OR (RM 175.5).

West end of The Dalles, OR (RM 188.6) upstream to Hwy 197 bridge at The Dalles (RM 191.5).

Bank

The old lock structure on the Oregon shore at Cascade Locks (RM 149.0).

The Washington shore east of the mouth of the Wind River (RM 155.0) upstream to Spring Creek Hatchery (RM 167.0).

The Oregon shore east of Hood River (RM 171.0) upstream to Mosier (RM 175.0).

The Washington shore across from Mosier (RM 175.1 - RM 176.0).

The Oregon and Washington shore at The Dalles (RM 188.6 - RM 189.5).

The Dalles Reservoir

Boat

The lower end of Miller Island (RM 203.2) upstream to John Day Dam (RM 215.6).

Bank

The Washington shore east of Maryhill, WA (RM 211.6) upstream to the base of John Day Dam (RM 215.5).

The Oregon shore east of Rufus, OR (RM 214.2) upstream to John Day Dam (RM 215.6).

Catch per Effort Analysis River Subsections

Catch per effort per angler type data were grouped by the following river subsections:

Bonneville Reservoir

Bonneville Dam (RM 145.0) upstream to the mouth of Wind River (RM 155.0).

The mouth of Wind River (RM 155.0) upstream to Hwy. 35 bridge at Hood River (RM 174.6).

Highway 35 bridge at Hood River (RM 174.6) upstream to The Dalles Dam (RM 191.5).

The Dalles Reservoir

The Dalles Dam (RM 191.5) upstream to the railroad bridge at Celilo (RM 201.1).

The railroad bridge (RM 201.1) upstream to Hwy. 97 bridge at Biggs (RM 209.1).

Hwy. 97 bridge at Biggs (RM 209.1) upstream to John Day Dam (RM 215.6).

APPENDIX B-2

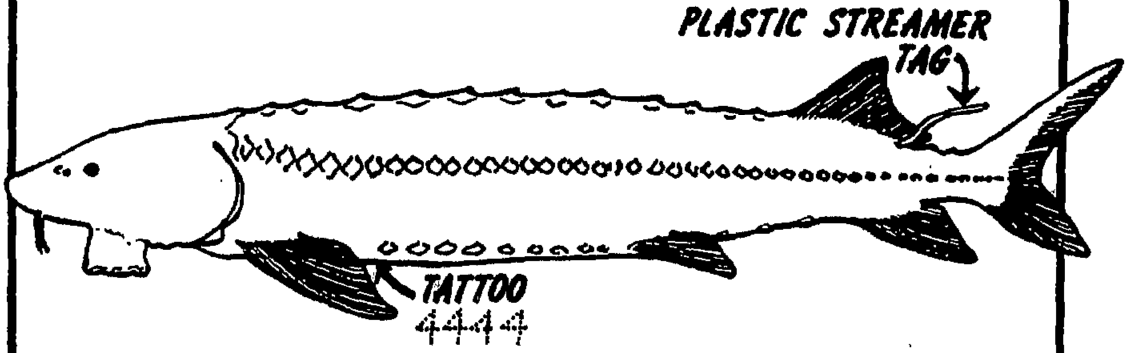
Poster Provided by ODFW Requesting Recovery Information
on Marked White Sturgeon

STURGEON ANGLERS

We need information on tagged STURGEON

▶Please examine your catch for two types of marks◀

(a plastic numbered tag or tattoo on the underside)



We need to know:

1. ***Where you caught the fish***
2. ***Tag or tattoo number and color***
3. ***Date caught***
4. ***Kept or released***
5. ***Your name and address if you would like information on your fish***

▶Please do not remove tags from fish to be released◀

Mail information to:

STURGEON TAGS
Oregon Dept. of Fish and Wildlife
17330 S.E. Evelyn St.
Clackamas, Or. 97015

STURGEON TAGS
Washington Dept. of Fisheries
P.O. Box 999, MS S-13
Battleground, Wa. 98604

Or leave information at:

Maier's Market
208 E. 2nd
The Dalles, Or.

Rufus General Store
Rufus, Or.

The Home & Sport Shop
126 West Main
Goldendale, Wa.

Your help with information on marked STURGEON will assist us in better understanding numbers, movement and death rates of these fish

APPENDIX B-3

White Sturgeon Egg and Larvae Data From Net Sets

Date	Location	Sampling time	Secchi (cm)	Depth (m)	Water Temp Site (°C)	Water Temp Bonn[a] (°C)	Flow[b] (m^3/s)	Volume sampled (m^3)	Catch Eggs	Catch Larvae
Mar 23	Hamilton Is	1132-1202	176.8	8.5	6.8	7.8	3519	627.1	0	0
23	Ives Is	1221-1253	176.8	4.9	6.8	7.8	3519	976.1	0	0
Apr 4	Ives Is	1052-1125	134.1	4.6	8.0	8.3	3805	1017.5	0	0
4	Hamilton Is	1206-1238	134.1	8.2	7.6	8.3	3805	1245.3	0	0
25	Ives Is	1050-1124	115.8	4.9	10.1	11.1	4275	2268.7	18	0
25	Hamilton Is	1208-1328	115.8	21.4	10.1	11.1	4275	1471.6	1	0
May 5	Ives Is	1054-1358	106.7	5.8	11.3	11.7	5376	4051.1	48	3
5	Bradford Is	1217-1247	106.7	9.4	11.3	11.7	5376	940.7	1	0
5	Pierce Is	1436-1515	106.7	6.7	11.3	11.7	5376	2455.3	12	5
10	Ives Is	1003-1031	85.3	5.5	12.8	13.3	5883	2812.9	101	3
10	Moffet Ck	1117-1149	85.3	14.3	12.3	13.3	5883	3648.8	1	0
10	Hamilton Is	1209-1240	85.3	12.8	12.3	13.3	5883	1774.0	0	0
10	Prindle Is	1353-1425	85.3	16.5	12.7	13.3	5883	1118.5	0	0
10	Lady Is	1648-1716	85.3	18.0	13.0	13.3	5883	1931.0	0	0
18	Lady Is	0901-0929	61.0	18.3	13.4	14.5	6373	2033.3	0	0
18	Ives Is	1157-1228	61.0	5.8	13.3	14.5	6373	3709.8	8	0
18	Hamilton Is	1310-1343	61.0	15.9	13.3	14.5	6373	3007.8	0	0
23	Lady Is	0854-0928	91.4	17.1	14.3	15.0	5410	898.8	0	0
23	Hamilton Is	1224-1256	91.4	14.0	14.3	15.0	5410	3032.0	4	1
23	Tanner Ck	1338-1408	91.4	12.2	14.3	15.0	5410	1377.0	1	0
23	Ives Is	1442-1514	91.4	4.9	14.3	15.0	5410	2957.2	28	4
25-26	Ives Is	1843-0623	88.4	4.3	14.1	15.0	6489	29681.7	364	65
27	Lady Is	0729-0801	67.1	20.1	14.1	15.0	6138	2376.3	0	1
27	I-205 Bridge	0859-0931	67.1	12.5	14.1	15.0	6138	1821.5	0	0
27	Hayden Bay	1006-1037	67.1	9.5	14.2	15.0	6138	1762.4	0	0
June 2	Lady Is	0849-0922	85.3	20.4	13.9	14.5	6775	2772.0	0	1
2	I-205 Bridge	1021-1053	85.3	10.4	13.9	14.5	6775	2018.8	0	0
2	Ives Is	1439-1512	85.3	5.5	14.1	14.5	6775	3331.8	28	2
6	Tunnel Pt	1437-1509	97.5	17.4	14.3	15.0	6084	1810.8	0	0
8	Lady Is	0755-0828	97.5	20.1	14.0	15.0	5455	2351.8	0	0
8	Bradford Is	1215-1245	97.5	13.1	14.3	15.0	5455	1293.5	14	0
8	Ives Is	1325-1337	97.5	4.6	14.3	15.0	5455	2902.8	28	0
8	Warrendale	1454-1528	97.5	16.2	14.3	15.0	5455	2420.6	42	0
15	Lady Is	1129-1240	137.2	19.8	15.4	16.7	4445	2546.5	0	1
15	I-205 Bridge	1334-1405	137.2	10.1	16.0	16.7	4445	1437.0	0	1
15	I-5 Bridge	1445-1516	137.2	6.7	16.5	16.7	4445	925.8	0	0
16	Ives Is	1008-1040	137.2	4.6	15.7	16.7	4598	2595.3	0	0
16	Warrendale	1136-1208	137.2	16.5	15.7	16.7	4598	1766.1	0	3
20	Lady Is	0846-0917	149.4	18.6	16.1	17.2	4085	1363.1	0	0
20	Ives Is	1231-1303	149.4	4.3	16.2	17.2	4085	2492.8	12	0
20	Warrendale	1340-1412	149.4	13.4	16.2	17.2	4085	881.4	8	0
20	Marker 84	1510-1543	149.4	12.5	16.5	17.2	4085	396.4	0	0
21	Cape Horn	1201-1233	158.5	20.4	16.8	17.2	4003	517.3	0	0
23	Marker 85	0955-1027	121.9	15.3	17.0	17.8	4750	735.3	0	0
29	Lady Is	0833-0904	131.1	20.4	16.9	18.9	4207	728.4	0	0
29	Ives Is	1120-1151	131.1	4.6	17.4	18.9	4207	2653.3	0	0
29	Warrendale	1221-1253	131.1	14.3	17.3	18.9	4207	814.3	0	0
July 5	Lady Is	0839-0911	152.4	17.7	18.0	18.9	2670	1183.1	0	0
5	Ives Is	1133-1204	152.4	4.3	18.0	18.9	2670	1835.9	0	0
19	Ives Is	1158-1229	146.3	3.7	19.5	19.5	3244	2404.9	0	0
Aug 3	Ives Is	1150-1222	146.3	2.7	20.6	21.7	2650	1217.8	0	0
Total									719	90
Average			114.7	11.8	14.3	15.2	5082	2487.9		

[a] *Average daily temperature taken at Bonneville Dam.*
[b] *Average daily flow at Bonneville Dam on day sampled.*

Report C

1. Describe reproduction and early life history characteristics of white sturgeon populations in the Columbia River between Bonneville and McNary dams.

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

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ABSTRACT

White sturgeon spawning occurred in the tailraces of John Day and The Dalles dams in 1988, though recruitment to young-of-the-year appears to have failed in both pools. Spawning behavior downstream from The Dalles Dam was observed and verified on 3 June by the collection of adhesive eggs immediately downstream from the area of activity.

We collected 25 eggs and 14 larvae of white sturgeon from 13 June through 14 July from the John Day Dam tailrace and 156 eggs and 13 larvae from 25 May through 29 July from The Dalles Dam tailrace. Spawning probably occurred on at least 4 days in the John Day Dam tailrace and on at least 25 days in The Dalles Dam tailrace based on back-calculated ages of eggs and larvae collected.

No post-larval, young-of-the-year, or age I white sturgeon were captured from either pool despite intense effort with the trawls. We captured 484 white sturgeon (265 - 960 mm FL) with trawls in The Dalles Pool and 860 white sturgeon in Bonneville Pool (306-850 mm FL). Catches in both pools varied spatially and temporally. We also captured 62 white sturgeon (480 - >900 mm FL) from backwater areas of Bonneville Pool with gill nets as part of an expanded effort to estimate habitat use by white sturgeon.

Availability of suitable microhabitats for spawning and embryo incubation may affect year-class strength. We speculate that water velocities, a function of discharge and channel morphology, may cue spawning and/or influence survival of yolk sac larvae. Younger age groups of white sturgeon, though, appear to be generalists in their habitat requirements.

INTRODUCTION

The U.S. Fish and Wildlife Service (FWS) is responsible for parts of study Objectives 1 and 3 (Beckman et al. 1987). Objective 1 requires us to describe reproduction and early life history of white sturgeon populations and Objective 3 to define habitat requirements for spawning and rearing and to quantify available habitat. Sub-objectives for 1988 specified in the 1987 annual report (Palmer et al. 1988) were to:

1) Continue sampling in The Dalles Pool for eggs, larvae and juvenile white sturgeon.

2) Begin exploratory sampling in Bonneville Pool to locate suitable sampling sites.

3) Initiate efforts to define habitat use by spawning and rearing white sturgeon in The Dalles and Bonneville pools.

4) Begin exploring approaches to modeling effects of hydropower development and operation on white sturgeon populations.

5) Initiate work to develop methods to quantify available habitat.

6) Delineate food availability as a biological indicator of habitat use.

The purpose of this report is to describe our progress during April 1988 - March 1989 towards meeting these sub-objectives and study Objectives 1 & 3.

METHODS

Field Sampling

Sampling for early life stages and younger age groups of white sturgeon was conducted in The Dalles Pool from 30 March to 17 November and in Bonneville Pool from 13 April to 29 November. Gears and techniques used were similar to those used in 1987 (Palmer et al. 1988) with the following exceptions. We replaced the 0.5 m diameter larval nets with D-shaped larval nets identical to those used by the National Marine Fisheries Service (NMFS) and Washington Department of Fisheries (WDF). The high-rise trawl was fished with 1.59 and 2.38-mm knotless nylon cod end liners and we removed the tickler chain because it frequently snagged on the bottom and didn't appear to enhance catches. The height of the 3.0-m wide beam trawl was reduced to 0.5-m. The beam trawl was fitted with a 1.59-mm knotless cod end liner and the tickler chain was removed. The high-rise and beam trawls have effective fishing widths of 4.4-m and

3.0-m, respectively (Normandeau Associates, Inc. 1985).

Catch of white sturgeon per unit of effort was expressed as number/15 min tow (CPT) and number/hectare (CPHA) for the high-rise trawl, number/15 min tow for the beam trawl and number of eggs or larvae/1000m^3 of water filtered for the D-shaped larval nets. We installed radar range finders on the trawling vessels to determine the length of each tow.

In The Dalles Pool, we routinely sampled seventeen locations throughout the pool with the high-rise trawl (Figure 1); above river mile (RM) 208 we sampled eleven locations with the D-shaped larval nets and the beam trawl (Figure 2). We sampled other locations or duplicated our efforts at these locations as time and weather allowed.

Sampling locations in both pools were designated by a five digit numeral. The first four digits indicate the river mile to the nearest tenth as described by the Hydrology Subcommittee, Columbia River Basin Inter-agency Committee. The last digit indicates the cross-channel position where the effort took place. We divided the river channel into four sections, using 1 to indicate the quarter nearest the Washington shore, 2 and 3 to indicate the middle quarters, and 4 to designate the quarter closest to the Oregon shore; 0 and 5 designated efforts that occurred in backwaters on the Washington and Oregon shores.

Sampling efforts in Bonneville Pool (Figure 3) during this first year were exploratory. High-rise trawl efforts occurred throughout the pool and sampling with the 3.0-m beam trawl and D-shaped larval nets occurred above RM 184.8.

Sampling in both pools was generally conducted weekly during May through July, biweekly during April, August and September, and once during October and November. Sampling with the D-shaped larval nets was discontinued after 18 July in The Dalles Pool and after 29 July in Bonneville Pool.

Egg and larval collections were preserved in 10% unbuffered formalin tinted with phloxine B. Larval white sturgeon were weighed (nearest 0.001 g) and their total length (nearest mm) was measured. Fork lengths (mm) and weights (nearest 10 g) were obtained from most white sturgeon captured. All white sturgeon were examined for previous marks and external parasites. Anterior pectoral fin rays were removed from most fish collected in April-June for aging to provide information on year-class strength. Most juvenile white sturgeon were tagged with an individually numbered monel metal bird banding tag placed around the anterior ray of the right pectoral fin. A 6.4-mm hole was punched in the right pelvic fin as a secondary mark to evaluate tag retention. Each tag has a letter code to indicate the pool the fish was originally captured in.

In May we began injecting all white sturgeon less than 800 mm fork length with oxytetracycline hydrochloride (OTC) to verify the ageing technique. Fish were injected at a dosage of 25 mg OTC per kg of weight. To identify injected fish in future years we removed the 2nd and 3rd scutes along the lateral line on the right side of the sturgeon. All incidental fish species were enumerated and released. Common and scientific names of all species collected are presented in Appendix C-1.

On 8 and 9 June, hourly sampling for eggs and larvae was conducted for 24 hours below The Dalles Dam to evaluate diel variations in abundance.

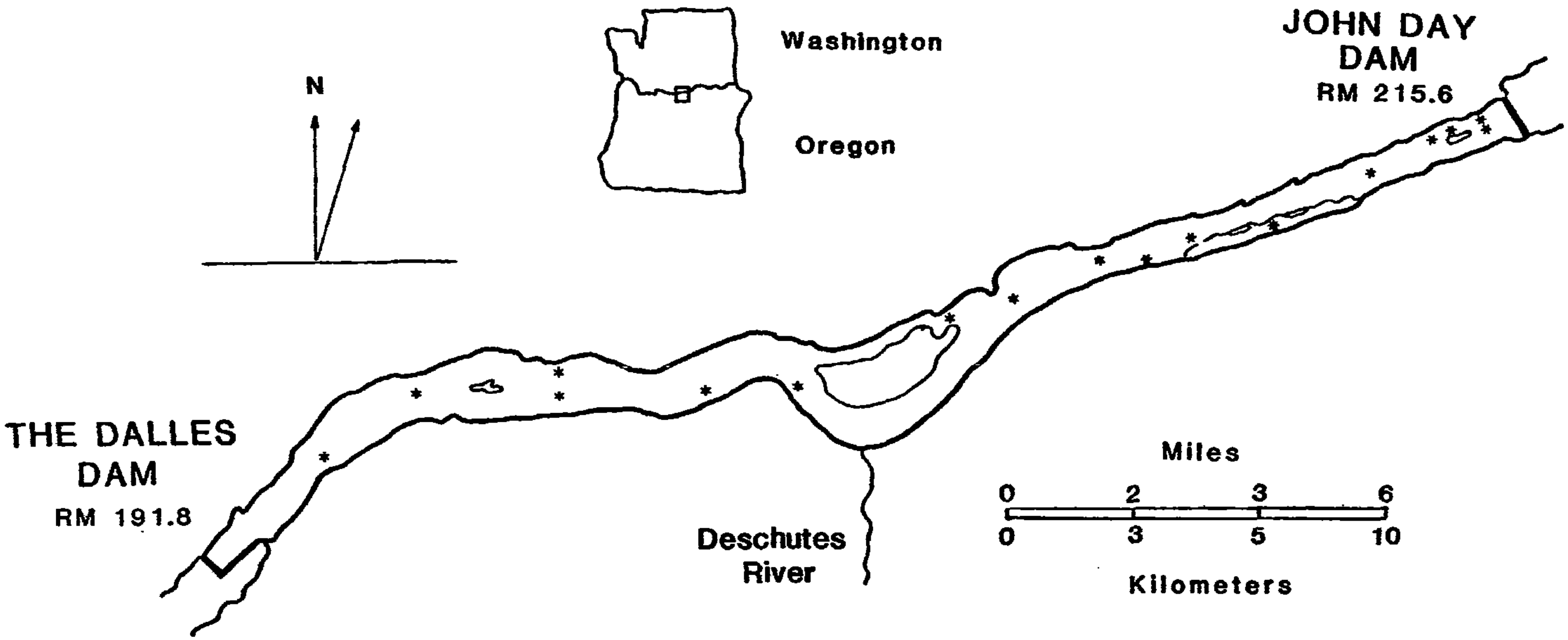

Figure 1. Locations (*) routinely sampled with the high-rise shrimp trawl on The Dalles Pool.

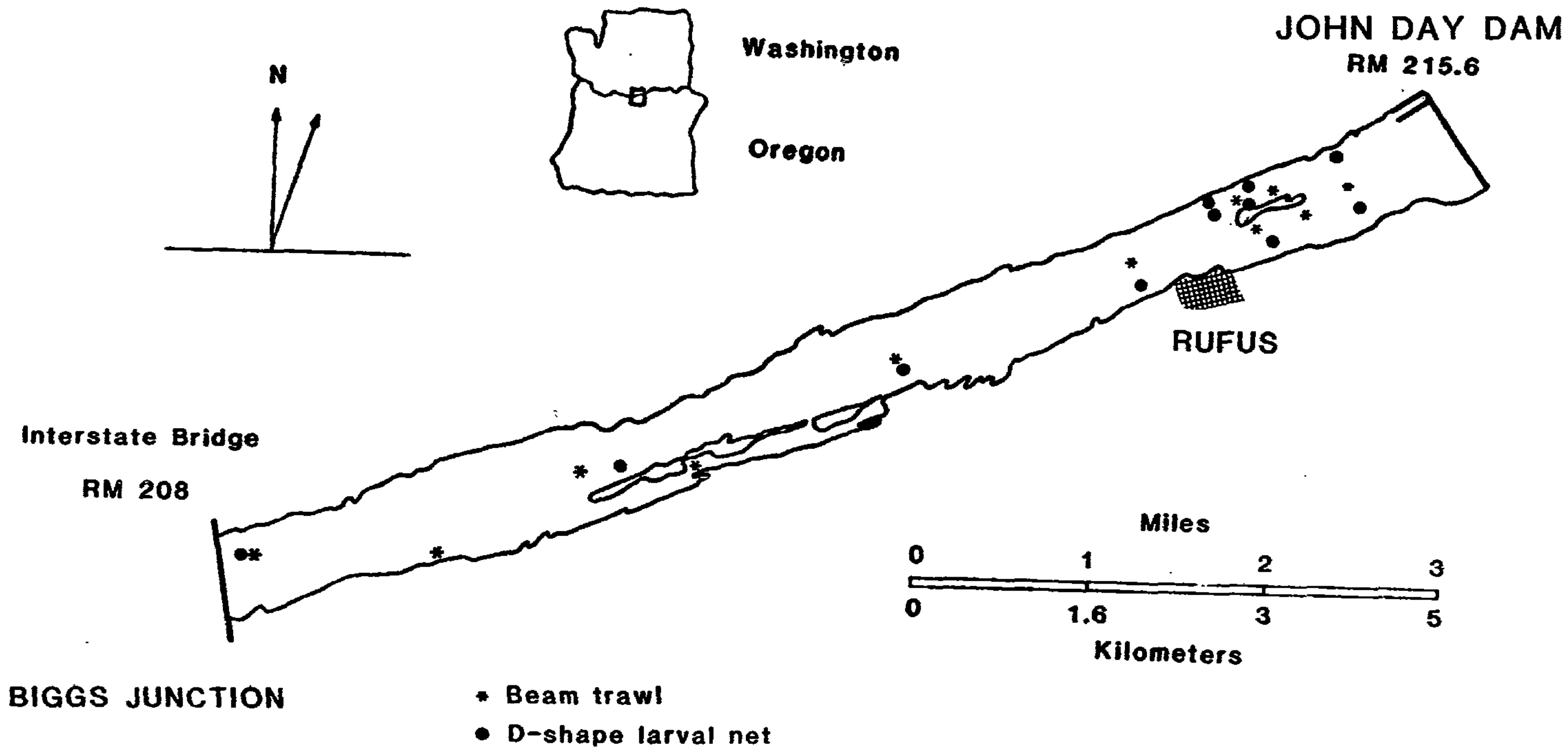

Figure 2. Locations routinely sampled with the beam trawl and the D-shaped larval nets.

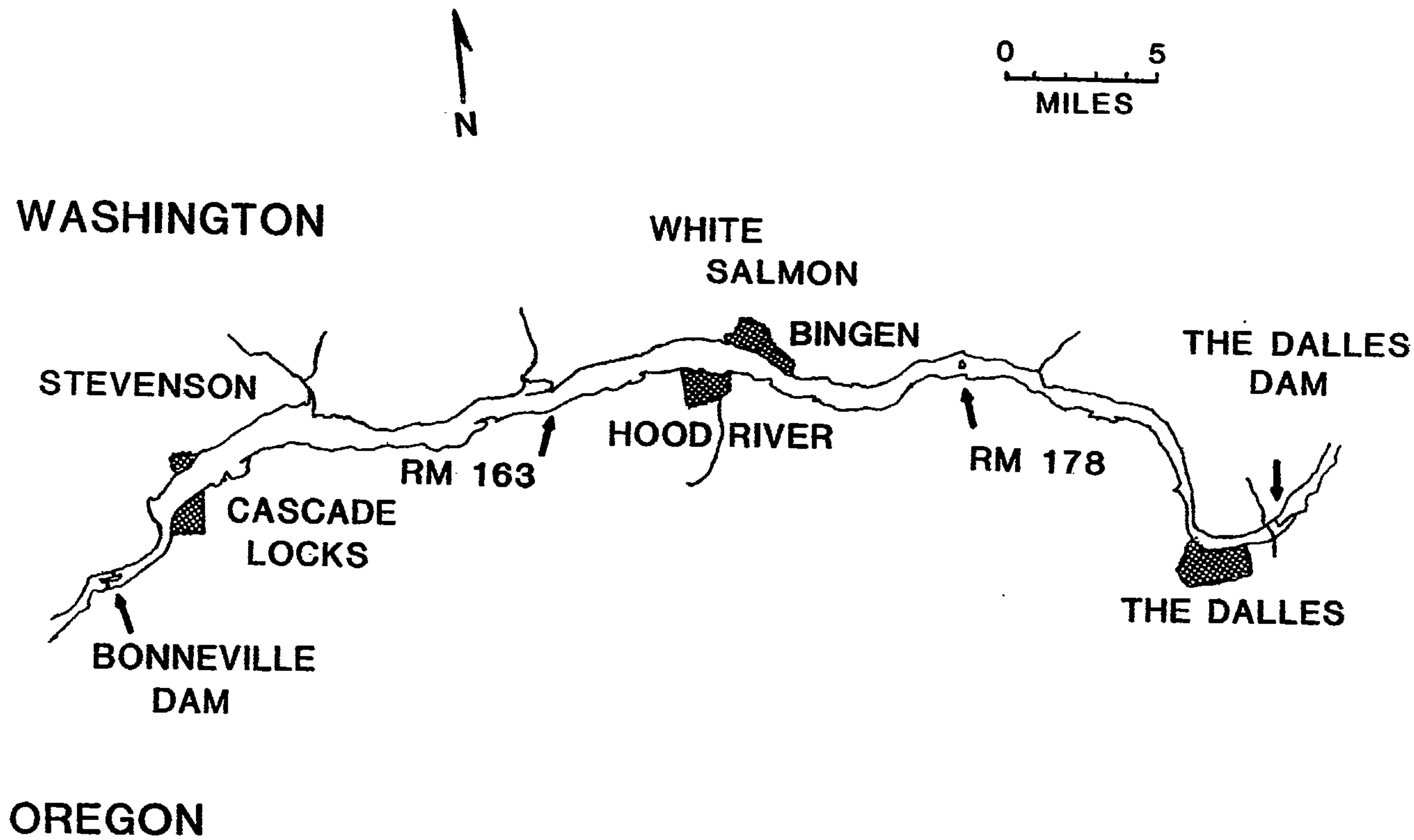

Figure 3. Bonneville Pool with adjacent communities and river miles separating the lower, middle and upper divisions.

We fished the 3.0-m beam trawl and a single D-shaped larval net from two boats anchored near RM 190. Water velocities were measured hourly, beginning with the first sampling period at 0600 hrs. on 8 June. Each sampling effort was approximately 50 min. in duration.

Three backwater areas in Bonneville Pool were sampled during October with variable mesh gill and fyke nets to estimate young-of-the-year and subadult white sturgeon use of this habitat type. Backwaters sampled were Salisbury Slough (Mayer State Park, RM 181) on the Oregon side of the river and Ashes Lake (RM 149) and Chamberlain Lake (RM 180) on the Washington side.

Habitat Measurements

The environmental and physical parameters being addressed are water temperature, turbidity, discharge at each dam, water velocities, water depth, and substrate composition. Water temperatures in known or suspected white sturgeon spawning areas were recorded with Ryan Model "J"[1] thermographs. One thermograph, anchored on the substrate, was placed below each dam at RM's 191.8 and 214.0. Water turbidity was measured approximately 2 m above the substrate with a Hach Model 16800 Turbidimeter. Measurements, in Nephlometric Turbidity Units (NTU's) were taken concurrent with most D-shaped larval net efforts beginning in mid May.

Mean water column velocity (an average of the velocity measured at 0.2 and 0.8 of the depth of the water) and bottom velocity (0.6 m from the substrate) were measured with a cable-suspended Price type "AA" sensor connected to a Swoffer Instruments Model 2200 direct reading current velocity meter. Measurements were taken prior to most efforts with the D-shaped larval nets.

Water velocities at routinely sampled trawling locations were determined by periodically measuring velocities at about one-third and two-thirds of the length of each trawl tow. Substrate composition was also determined at these points. We used a Van Veen grab sampler to collect substrates and noted substrate particle sizes (Table 1) present along each tow. Using the same sampler, we attempted to obtain benthic invertebrate samples from each location. Five grabs from each of the two points along seven of the transects were obtained; other locations were too rocky to sample. Samples were collected during early May and September for processing in the laboratory.

Depth preference of younger age groups of white sturgeon in each pool is being determined by comparing the depths at which we captured white sturgeon and the depths at which high-rise trawl efforts occurred.

Quantification of the extent of habitat available for spawning and rearing will result from a culmination of all the aforementioned efforts over the entire study period. Habitat available for each life stage will

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[1]Use of trade names does not imply endorsement by the U.S. Fish and Wildlife Service.

Table 1. Substrate particle size classifications used in this study.

Class	Particle size (mm)
Boulder	>250 - 4000
Rubble/cobble	64 - 250
Gravel	2 - 64
Sand	0.062 - 2
Mud/silt	0.004 - 0.062
Clay	0.00024 - 0.004
Organic debris[a]	

[a] Organic debris was not classified by particle size.

be expressed as a surface area, encompassed by one or more environmental characteristics we estimate to be limiting.

Laboratory

Egg and Larvae Sorting and Identification

Samples preserved in the field were sorted in the laboratory. All larval fish were identified to the lowest taxonomic level possible and enumerated. Eggs and larvae of white sturgeon were assigned developmental stages based on criteria established by Beer (1981) (Appendix C-2). The time of fertilization was estimated with the relationship developed by Wang et al. (1985) which uses the stage of embryonic development and incubation temperature. Temperature was assumed to be constant during incubation so temperatures at the time of collection were used in the relationship.

Age and Growth

Pectoral fin rays of white sturgeon were sectioned using a saw powered by a DREMEL tool fitted with a fine-toothed saw blade 0.127 mm in thickness. Fin rays were secured in a vise and the proximal (knuckle) end removed near the basal recess. Three to six transverse sections were cut to a thickness of 0.3 to 0.7 mm. Sections were cleared with xylene, ethyl alcohol, or water and mounted on microscope slides using clear fingernail polish. Growth rings were counted with the aid of a binocular dissecting scope. Sections were independently aged by two persons following criteria described by J.C. Elliott (memorandum dated October, 1988: ODFW, Dam and Hydro Programs, Clackamas, OR).

Annual relative rates of growth (h) and instantaneous population growth rates (G) (Ricker 1975) were determined for younger ages of white sturgeon captured in The Dalles Pool, Bonneville Pool, and from below Bonneville Dam; data from below Bonneville Dam were provided by NMFS (see Report D). Growth among pools was also compared by plotting mean fork length at age.

Weight-length relationships and condition factors were determined for early age groups of white sturgeon from both pools. Condition factors were determined using the formula $C = (W/L^3)10^5$.

Food Habits

Food items were recovered, using hydrogen peroxide as an emetic, from juvenile white sturgeon captured in The Dalles Pool from April through August. We collected ten sturgeon during August from Bonneville Pool to determine if the emetic caused complete regurgitation of the stomach contents. Food items were first recovered from these fish by using the emetic and the fish were then sacrificed and their digestive tracts were removed and examined for additional items.

Benthic Invertebrate Analysis

Preserved benthic invertebrate samples were sorted in the laboratory, identified, and enumerated. We identified oligochaetes to class, and all other invertebrates to genus or when practical to species. Some insects were also characterized by life stage. When a sample was too large to sort expediantly, a subsampling apparatus and process was used to split the sample into ten subsamples (Waters 1969). We then estimated what was present in the entire sample by processing three subsamples.

RESULTS

The Dalles Pool

Spawning Characteristics

During 1988, 25 eggs and 14 larvae of white sturgeon were collected from 13 June through 14 July in the John Day Dam tailrace area (Table 2). Most of the eggs and larvae were collected between RM 213.8 and RM 215.1 from the southern side of the river; egg catches in 1987 came primarily from the Washington side of the river between RM 212.3 and RM 214.7. White sturgeon eggs were collected on 4 of the 16 sampling dates during the period at depths of 5 to 15 m with 11 (44%) dead and covered with fungus. Mean water column and bottom velocities ranged from 0.88 to 1.40 m/s and 0.45 to 1.00 m/s, respectively. Larvae were collected only on 16 June at depths of 12 to 14 m with the mean water column and bottom velocities ranging from 0.88 to 1.61 m/s and 0.52 to 0.85 m/s, respectively.

Environmental Conditions

Water temperatures during April through July increased gradually (Figure 4), attaining 10°C on 20 April. White sturgeon have commenced spawning below Bonneville Dam at this temperature in previous years. Temperatures considered optimal for spawning, 14 to 17°C (Wang et al. 1985) occurred between 27 May and 21 June.

Discharge of water through John Day Dam during April through July ranged from 1.45 to 8.15 thousand cubic meters per second (kcms) (Figure 5) and fluctuated widely during each day. Mean daily turbidities ranged from 4.0 to 6.5 NTU (Figure 6) with the highest turbidities occuring during the period of grestest discharge.

Egg Deposition

At least four white sturgeon spawning episodes were estimated to have occurred in The Dalles Pool during 1988. Based on back-calculated ages of eggs and larvae collected, spawning probably occurred 30-31 May, 8 June, 6 July, and 11-12 July; no newly spawned adhesive eggs were collected.

Table 2. Number and catch of white sturgeon eggs and larvae collected in The Dalles Pool with D-shaped larval nets, beam trawl and high-rise trawl between RM 212.3 and 215.1 from 13 June through 14 July, 1988.

Gear/Catch	Egg			Larvae
	Viable	Fungused	Total	
D-shaped larval net				
Number	3	6	9	14
Catch/1000m^3	0.158	0.315	0.473	3.72
Beam trawl				
Number	9	5	14	0
CPT	0.178	0.099	0.278	0
High-rise trawl				
Number	2	0	2	0
CPT	0.101	0	0.101	0
CPHA	0.423	0	0.423	0
All gears				
Number	14	11	25	14

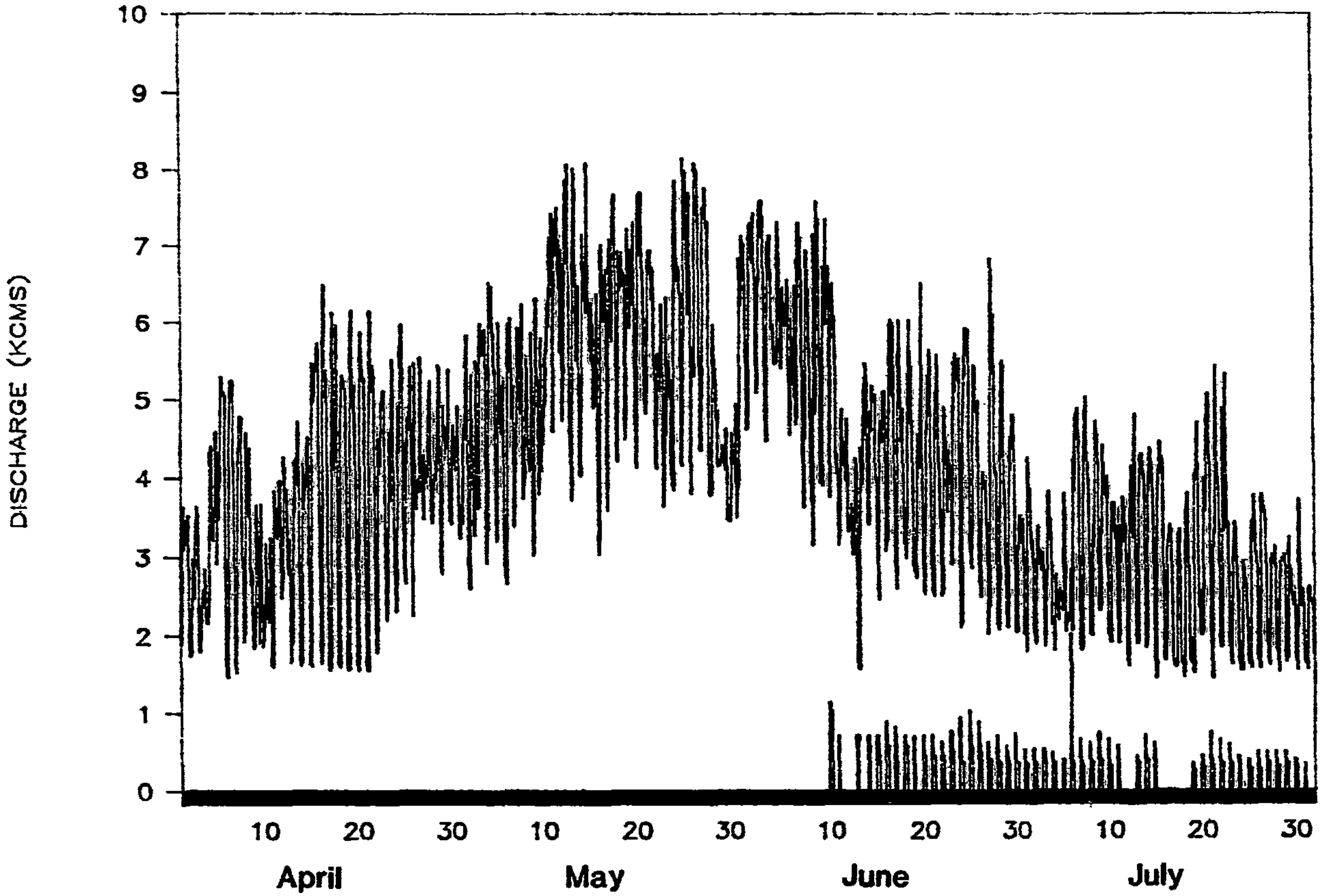


Figure 4. Hourly discharges through John Day Dam, April - July, 1988. The upper line indicates total discharge, the lower line indicates spill discharge.

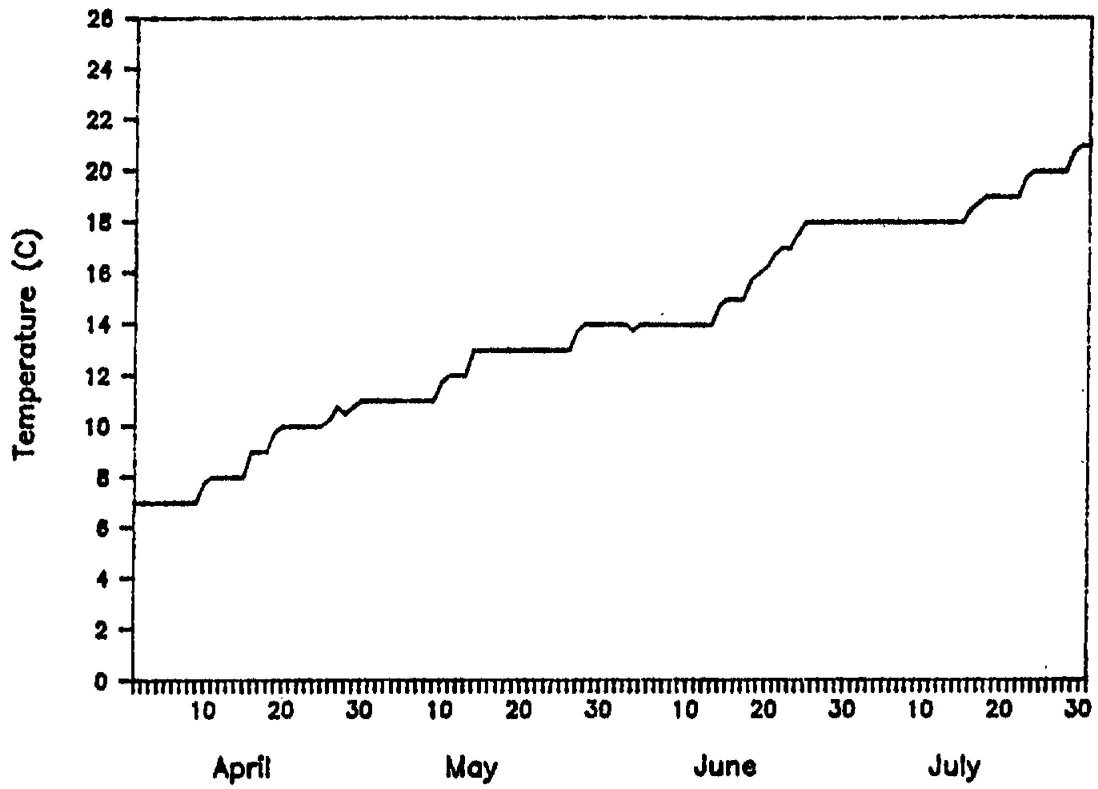


Figure 5. Mean daily water temperature below John Day Dam (RM 214.3, April through July, 1988.

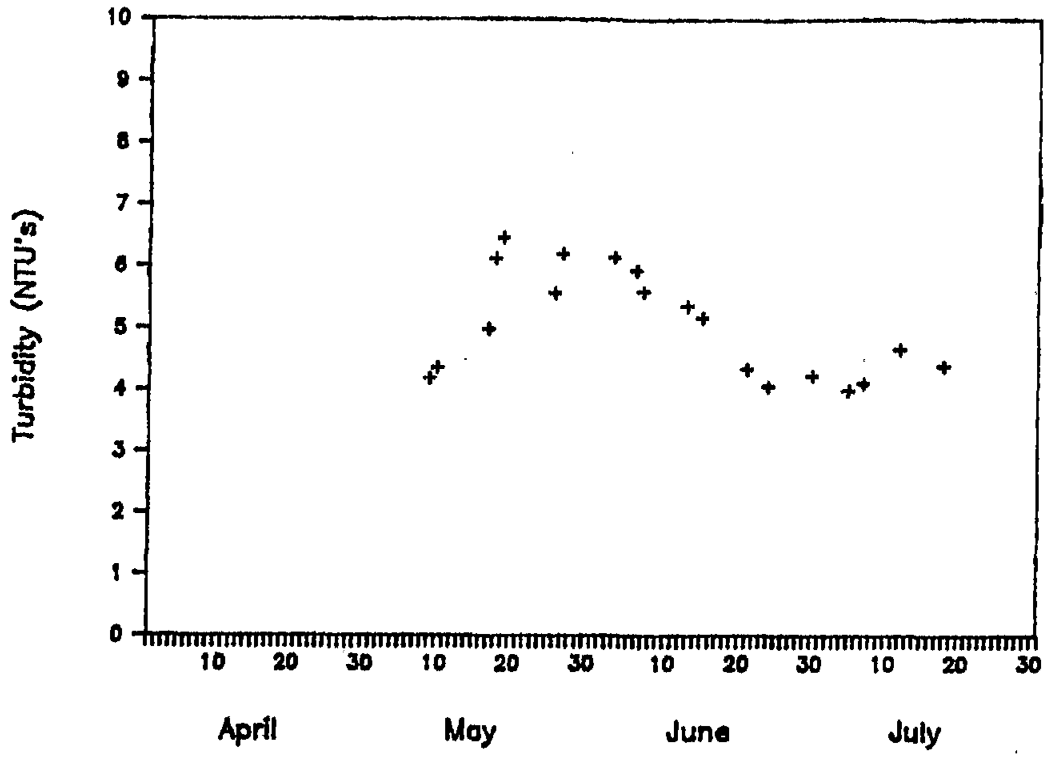


Figure 6. Daily mean turbidity measured in The Dalles Pool, from 9 May through 19 July, 1988.

Developmental stages of the 14 viable eggs collected ranged from early gastrula (about 27 hours old, water temperature 15°C) to prehatch (about 145 hours old, water temperature 15°C).

Larvae

White sturgeon larvae were collected on 16 June in The Dalles Pool. On this day, we collected 14 white sturgeon larvae with the D-shaped larval nets from the southern channel near the island at RM 214; only two of eleven larvae collected during 1987 were collected from this area. Eleven were staged as posthatch, indicating hatching occurred within the previous 24 hours. These larvae ranged from 11-13 mm in total length. The other three larvae collected were too mutilated to stage or measure, but probably were the same stage.

Early Age Groups

We captured 484 white sturgeon in The Dalles Pool with trawls. No post-larval young-of-the-year or age I (1987 year class) white sturgeon were captured. Fork lengths (FL) of white sturgeon captured ranged from 265 to 831 mm (Table 3). We tagged 469 sturgeon with monel bands and injected 355 with OTC. We recaptured 10 (2%) of the tagged fish, one of which had shed its tag. Five of the nine fish with tags had previously been injected with OTC. The number of days at-large for the recaptured fish ranged from 6 to 56 days (mean 34 days). Cross sections of pectoral fin rays from fish previously injected with OTC showed a thin band of fluorescent tissue near the outer margin when viewed under untraviolet light. All were recaptured within the area of original capture.

The nematode parasite Cystoopsis acipenser was observed on 32 (6.6%) of the white sturgeon examined in The Dalles pool. Smaller white sturgeon seemed more susceptible to infestation. Infected fish ranged from 283 to 650 mm FL, (mean = 367 mm) with 27 (84%) of the infected fish smaller than 385 mm FL.

Distribution

White sturgeon catches at each of the 17 routinely trawled locations exhibit a patchy distribution both spatially and temporally (Table 4). Catches from two locations, RM 205.3 and RM 209.0, accounted for 47% of the entire high-rise trawl catch (23% and 24%, respectively); no white sturgeon were captured at three locations. Fewer than 10 fish were caught at each of four locations with total catches at the remaining locations ranged from 10 to 54 fish (2% to 12%).

Generally, catches at all locations where we caught white sturgeon were highest during either May or June, with catches at some locations showing a great degree of variation within and between months. For example, on 25 May a tow at location 20531 yielded 51 white sturgeon (11.3% of our entire catch), whereas three other tows during May at this location yielded only

Table 3. Length frequencies (in mm) of white sturgeon collected in The Dalles Pool with trawls during April through November 1988.

Fork	Month							
Length	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
201-210								
211-220								
221-230								
231-240								
241-250								
251-260								
261-270		1						
271-280								
281-290		1	2					
291-300	1							
301-310	2	3	2	1				
311-320		3	1	2				
321-330	4	2	4	4	2			
331-340	2	5	9	6	1			
341-350	6	8	4		2			1
351-360	4	8	8	3				
361-370	6	10	7	2				
371-380	4	7	7	5				
381-390	7	8	7	11	2			
391-400	9	6	8	2	1			
401-410	3	10	4	4		3	1	
411-420	7	6	5	3	1			
421-430	9	4	2	3	2	1		1
431-440	2	6	3	1		1		
441-450	4	7	5	2		2		
451-460	7	9	3				1	
461-470	6	5	7			1	2	
471-480	2	7	2	1			2	1
481-490	2	6	2	1	2	1	1	
491-500	1	7	4	1	1			
501-510	2	3	2		1		2	
511-520	2	2	1	1	2			
521-530	2	3	4	1				
531-540		1	2	3	1			
541-550	1		2	1		1		
551-560	1		2	1				
561-570	1	2		1				1
571-580		2						
581-590		2	3	1		1		
591-600	2	2	1					
>601	2	5	9	3	2	2		
Totals	101	151	122	64	20	13	9	4

Table 4. Number, mean monthly catch per 15 minute tow (CPT) and mean monthly catch per hectare (CPHA) of white sturgeon captured with high-rise trawls at 17 routinely sampled locations in The Dalles Pool, 1988.

Location	Month								Total number	Mean CPUE
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		
19433										
Number	2	0	5	0	1	1	0	1	10	
CPT	0.67	0.00	1.88	0.00	0.50	0.75	0.00	1.50		0.67
CPHA	1.49	0.00	4.15	0.00	1.21	1.59	0.00	3.61		1.59
19633										
Number	3	4	13	5	1	4	0	0	30	
CPT	1.32	1.62	4.88	2.50	0.50	2.00	0.00	0.00		2.13
CPHA	2.97	4.50	11.15	6.32	1.38	6.37	0.00	0.00		5.19
19901										
Number	10	12	11	6	6	1	8	0	54	
CPT	3.33	3.60	4.13	3.00	3.00	0.75	12.00	0.00		3.45
CPHA	7.30	11.59	11.16	7.22	7.08	2.01	29.80	0.00		8.78
19903										
Number	0	0	0	0	0	0	0	0	0	
CPT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00
CPHA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00
20124										
Number	0	0	1	0	0	0	0	0	1	
CPT	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00		0.07
CPHA	0.00	0.00	4.35	0.00	0.00	0.00	0.00	0.00		0.20
20244										
Number	1	0	1	0	0	0	0	0	2	
CPT	0.52	0.00	0.39	0.00	0.00	0.00	0.00	0.00		0.15
CPHA	1.29	0.00	1.36	0.00	0.00	0.00	0.00	0.00		0.47
20531										
Number	11	81	10	0	0	0	0	0	102	
CPT	4.34	30.38	3.75	0.00	0.00	0.00	0.00	0.00		7.35
CPHA	9.98	91.20	9.90	0.00	0.00	0.00	0.00	0.00		18.08

Table 4. continued

Location	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total number	Mean CPUE
20652										
Number	1	3	7	4	1	0	0	0	16	
CPT	0.27	1.13	2.63	1.50	0.38	0.00	0.00	0.00		0.94
CPHA	0.73	4.14	8.26	4.34	0.97	0.00	0.00	0.00		2.73
20822										
Number	0	0	0	0	0	0	0	0	0	
CPT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00
CPHA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00
20904										
Number	47	32	16	10	3	0	1	1	110	
CPT	15.67	16.00	4.80	3.75	1.50	0.00	1.50	1.50		7.02
CPHA	41.18	50.34	16.10	11.10	4.38	0.00	4.23	3.15		20.45
20983[a]										
Number	3	3	11	26	2	5	0	0	50	
CPT	1.41	2.25	3.30	4.53	0.79	3.75	0.00	0.00		2.82
CPHA	3.66	6.94	11.25	16.74	2.82	9.74	0.00	0.00		9.21
21075										
Number	3	1	6	1	0	0	0	0	11	
CPT	1.50	0.50	1.80	0.50	0.00	0.00	0.00	0.00		0.83
CPHA	2.77	1.15	3.80	1.15	0.00	0.00	0.00	0.00		1.78
21302										
Number	2	1	23	5	2	1	0	2	36	
CPT	0.67	0.50	6.90	2.50	1.00	0.75	0.00	3.00		2.40
CPHA	2.00	1.98	28.81	8.64	3.36	2.41	0.00	9.43		8.34
21401[a]										
Number	0	0	0	0	0	0	0	0	0	
CPT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00
CPHA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00

Table 4. continued

Location	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total number	Mean CPUE
	Month									
21451[a]										
Number	0	0	0	0	1	0	0	0	1	
CPT	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00		0.50
CPHA	0.00	0.00	0.00	0.00	2.79	0.00	0.00	0.00		0.30
21501										
Number	8	9	7	1	1	0	0	0	26	
CPT	7.05	5.00	3.00	0.75	0.50	0.00	0.00	0.00		2.45
CPHA	17.87	20.85	9.23	2.85	1.81	0.00	0.00	0.00		8.20
21502										
Number	0	0	0	0	1	0	0	0	1	
CPT	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00		0.11
CPHA	0.00	0.00	0.00	0.00	2.04	0.00	0.00	0.00		0.40
All locations										
Number	91	146	111	58	19	12	9	4	450	
Mean CPT	2.33	3.76	2.22	1.40	0.52	0.60	0.79	0.36		1.81
Mean CPHA	5.58	12.99	6.86	4.54	1.60	1.72	2.14	0.97		5.42

[a] Catches and efforts were combined from two adjacent locations due to their similar habitats and close proximity.

30 fish. Only 20 white sturgeon were captured at this location during all of April and June and no white sturgeon were captured here after June.

Catch per hectare with the high rise trawl decreased from the upper portion of the pool to the lower portion of the pool (Table 5) Combined catches were highest during May for the entire pool, due mainly to the highest catch per tow on 25 May in the middle portion. No white sturgeon were captured in the middle portion during September through November.

It doesn't appear that catches of white sturgeon at seven locations were related to the total number of benthic invertebrates present at those locations (Figure 7). Mean numbers of benthic invertebrates per m^2 ranged from 3698 to 31,833 during the April sampling and from 6204 to 38519 during the September sampling at the seven locations (Appendix C-3). Four taxa dominated the collections. They were members of the class Oligochaeta, family Hydrobiidae of the class Gastropoda, genus *Corbicula* of the class Bivalvia, and genus *Corophium* of the class Crustacea.

Depth Preference

Early age groups of white sturgeon in The Dalles Pool were most likely to be captured in the deeper areas of the pool. Sixty percent of the fish were captured at depths exceeding 17 m although only 26% of the high-rise trawling effort was at these depths (Figure 8). The skewed distribution of sampling effort towards shallower depths was a result of our routinely sampling the same locations and may not represent the proportion that those depths occur in the reservoir.

Weight-Length Relation and Condition Factor

A weight-length relationship was calculated from a sample of 483 white sturgeon captured in The Dalles Pool from April through November, 1988. They ranged from 265 to 831 mm FL. The weight-length relationship is described by the equation $\log W = \log FL\ (3.10) - 5.425$ ($r = 0.95$) where W is the weight in grams and FL is the fork length in millimeters. Mean condition factor of these fish was determined to be 0.698 (Sd = 0.089; N = 482).

Age and Growth

We sectioned fin rays from 318 white sturgeon collected in The Dalles Pool from April through June, 1988. Ages were determined for 269 (85%) of these white sturgeon ranging in FL from 265 to 780 mm. Ages could not be assigned to 49 (15%) of the sectioned fin rays because of reader disagreement and poor quality sections. Mean FL was 366, 414, 474, 558, 629, and 685 mm for ages II - VII, respectively (Appendix C-4).

Growth of white sturgeon of ages II through V from the Dalles Pool was greater than growth of the same aged fish from below Bonneville Dam (Appendix C-5 and C-6). Annual relative growth rates and instantaneous

Table 5. Number, catch per 15 minute tow (CPT) and catch per hectare (CPHA) of juvenile white sturgeon captured with high-rise trawls at lower (RM 191.5-200), middle (RM 200-208), and upper (RM 208-215.6) portions in The Dalles Pool, 1988.

Location	Month								Total	Mean
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	number	CPUE
Lower Reservoir										
Number	15	17	29	11	8	6	8	1	95	
CPT	1.19	1.38	2.18	1.03	0.80	0.90	2.4	0.3		1.31
CPHA	2.69	3.93	5.16	2.67	2.02	2.16	6.29	0.69		3.26
Middle Reservoir										
Number	18	85	19	5	2	0	0	0	129	
CPT	1.27	6.51	1.60	0.42	0.18	-	-	-		1.73
CPHA	3.12	21.64	4.80	1.23	0.50	-	-	-		4.91
Upper Reservoir										
Number	67	49	67	49	11	7	1	3	254	
CPT	3.20	2.39	2.04	1.58	0.46	0.58	0.15	0.5		1.65
CPHA	9.04	9.52	7.36	5.77	1.57	1.85	0.44	1.50		5.61
All locations										
Number	100	151	115	65	21	13	9	4	478	
Mean CPT	2.10	3.29	1.98	1.21	0.47	0.52	0.68	0.34		1.59
Mean CPHA	5.33	11.27	6.15	3.89	1.40	1.48	1.85	0.91		4.75

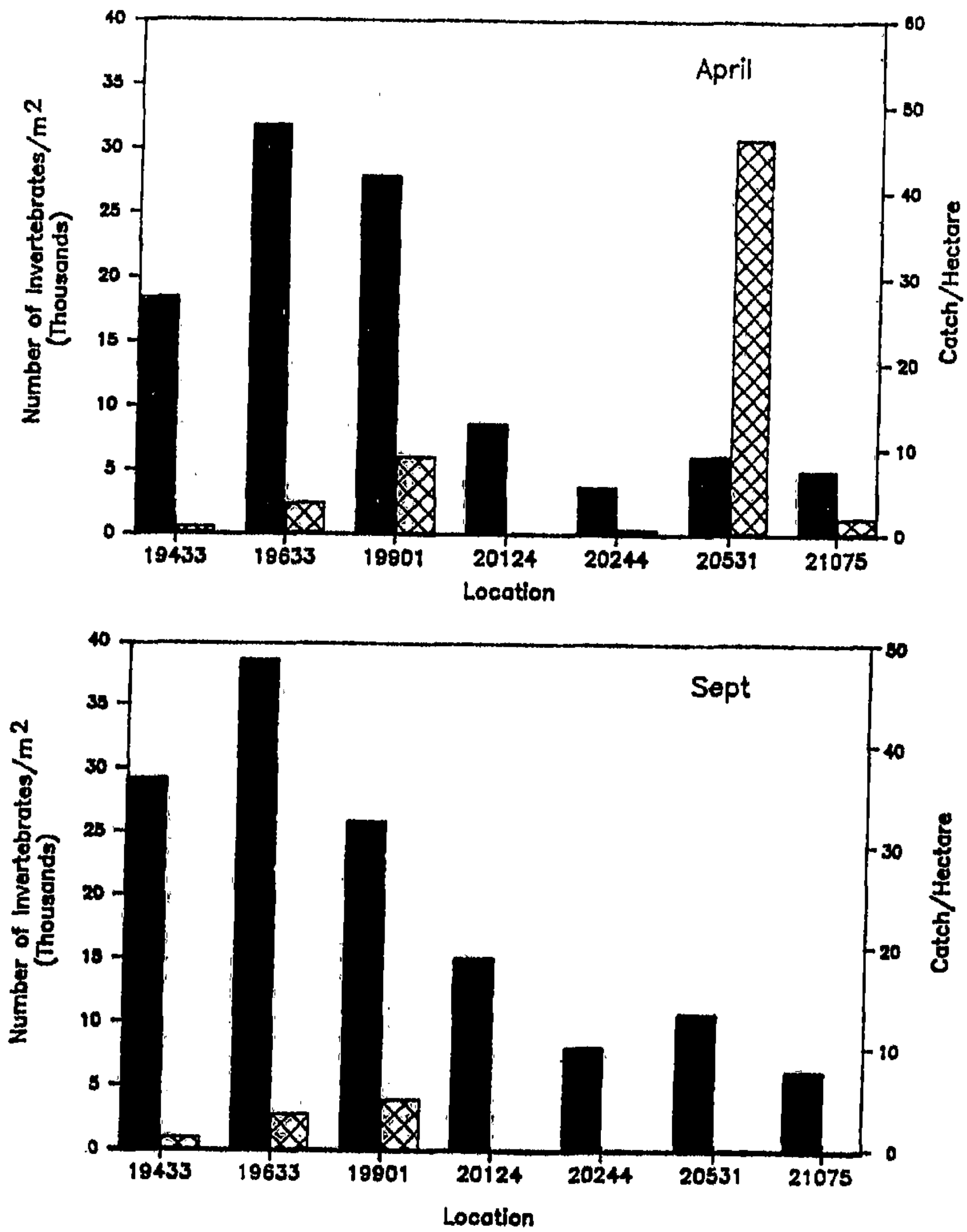


Figure 7. Numbers of invertebrates per m^2 and catch of white sturgeon per hectare at seven trawling locations in The Dalles Pool, April and September 1988.

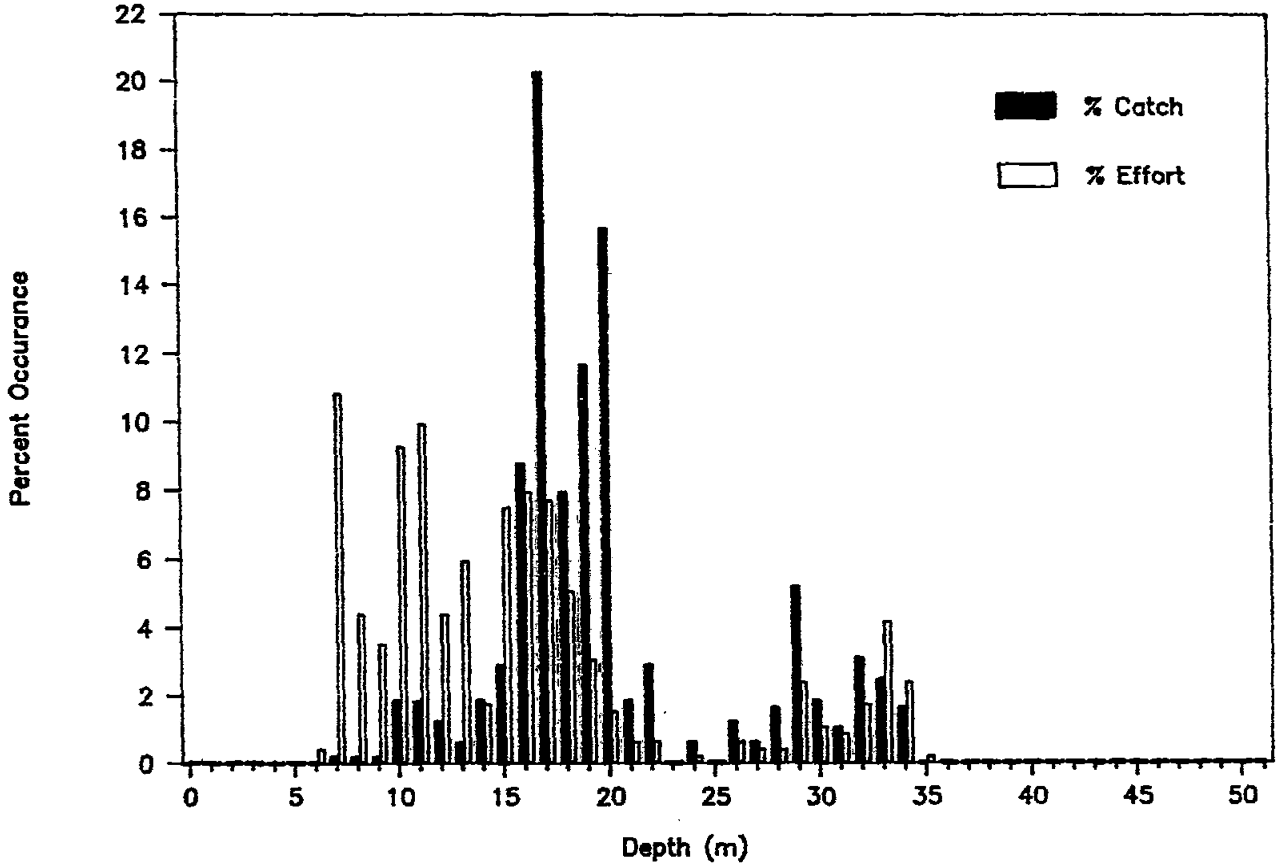


Figure 8. Percent of the catch of white sturgeon and the percent of the number of high-rise trawl tows at maximum depths encountered in The Dalles Pool, 1988.

population growth rates (G) were 45% (0.373), 53% (0.430), and 64% (0.494) for ages II through V respectively.

Catch of Other Fishes

Several species of fish other than white sturgeon were collected from The Dalles Pool during 1988 (Table 6). Trawl and net catches were dominated by young-of-the-year and older prickly sculpin. Other species commonly collected included American shad, carp, peamouth, northern squawfish, largescale sucker, channel catfish, sand roller, and walleye.

Physical Characteristics of Sampled Locations

Substrates; maximum depth, and water velocities estimated at locations routinely sampled to describe habitats are given in Table 7. We sampled a variety of habitats as evidenced by the variations in substrates, depths, and water velocities measured. Upper pool areas generally have higher water velocities and hence have coarser substrates than lower pool areas.

Bonneville Pool

Spawning Characteristics

White sturgeon eggs and larvae were collected downstream from The Dalles Dam between RM 189.4 and RM 191.6. A total of 156 eggs and 13 larvae were collected from 25 May to 19 July and 1 June to 29 July, respectively (Table 8). Most were captured alongside the navigation lock beneath the Highway 197 bridge. Eggs were collected at depths ranging from the water surface to 27 m; larvae were collected at depths ranging from 5.8 to 20 m. Mean water column velocities measured during most efforts that collected eggs or larvae ranged from 0.52 to 1.71 m/s.

Spawning activity of white sturgeon was observed in The Dalles Dam tailrace on 3 June, 1988 and verified by the collection of adhesive eggs at three locations in the tailrace area (Figure 9); one occurrence was subtle and the other quite aggressive. The first and subtle incident occurred between 1200 and 1230 hours near the south spillway fish entrance (Figure 9). The D-shaped larval nets had been deployed in a tow along the spill basin. During the tow a large white sturgeon (estimated 3 m in length) and several smaller fish (approximately 1.5 m in length) breached in front of the boat. A single newly spawned adhesive white sturgeon egg was collected.

The second, more aggressive incident occurred between 1300 and 1345 hours along the projection of rock fill separating the river channel and the navigation lock in water about 5 to 7 m deep. We were about 27 minutes into a stationary set with the D-shaped larval nets just above the Highway 197 bridge when we observed about 20-25 white sturgeon (estimated 1-3 m in length) breaching and rolling at the surface within an area about 15 m

Table 6. Number and catch of fishes excluding white sturgeon collected with high-rise and beam trawls and D-shaped larval nets in The Dalles Pool, April through November, 1988.

Taxon	High-rise trawl Number	CPT	CPHA	Beam trawl Number	CPT	D-shaped net Number	Catch/ $1000m^3$	Total Number
Pacific lamprey	17	0.06	0.17			1	0.01	18
American shad	245	0.80	2.44					245
Sockeye salmon	1	<0.01	0.01					1
Chinook salmon	318	1.04	3.16			10	0.12	328
Steelhead trout	1	<0.01	0.01					1
Mountain whitefish	3	<0.01	0.03					3
Chiselmouth	35	0.11	0.35	1	<0.01			36
Common carp	74	0.24	0.74	2	0.01			76
Peamouth	240	0.78	2.38					240
Northern squawfish	249	0.81	2.48					249
Redside shiner	1	<0.01	0.01					1
Unidentified cyprinid						11	0.13	11
Largescale sucker	230	0.75	2.29					230
Bridgelip sucker	118	0.39	1.17	1	<0.01			119
Unidentified sucker	2	<0.01	0.02	5	0.03	3	0.03	10
Channel catfish	196	0.64	1.95	9	0.05			205
Brown bullhead	1	<0.01	0.01	1	<0.01			2
Sand roller	31	0.10	0.31	3	0.02			34
Smallmouth bass	74	0.24	0.74	8	0.05			82
Unidentified crappie	767	2.51	7.63	173	0.99			940
Pumpkinseed	5	0.02	0.05					5
Walleye	203	0.66	2.02	7	0.04	1	0.01	211
Yellow perch	76	0.25	0.76	1	<.01			77
Prickly sculpin	3559	11.63	35.40	2228	12.74	84	0.98	5871
Unidentified larval fish	2	<0.01	0.02	5	0.03	7	0.08	14
Total number	6448			2444		117		9009

Table 7. Substrates, maximum depth and water velocities measured at routinely sampled locations in The Dalles Pool, 1988.

Location[a]	Substrates Present[b]						Maximum Depth(m)	Mean Water Velocity (m/sec)		
	C	O	M	S	G	R		Water Column	Bottom	N
19433	X	X	X	X	X	X	33	0.32	0.21	8
19633	X	X	X	X			31	0.28	0.18	8
19901	X	X	X	X			27	0.30	0.22	8
19903			X	X	X	X	10	0.43	0.34	8
20124	X	X	X	X	X		10	0.50	0.33	8
20244				X			12	0.67	0.38	8
20531	X	X	X				18	0.10	0.06	6
20652					X	X	14	0.71	0.48	8
20822					X	X	10	0.83	0.55	34
20904				X	X		18	0.57	0.40	8
20983					X	X	16	0.61	0.34	6
21004							12	0.61	0.39	27
21075	X	X	X	X	X	X	9	0.05	0.02	8
21163							11	0.81	0.58	24
21302					X	X	17	0.92	0.70	6
21303							12	0.91	0.62	27
21381							5	1.05	0.81	28
21383							13	0.76	0.54	30
21401					X	X	6	----	----	0
21402							6	1.04	0.71	4
21421					X	X	6	1.17	0.84	26
21422							5	1.25	0.92	26
21424							12	1.01	0.68	30
21451					X	X	6	----	----	0
21501					X	X	16	1.14	0.75	28
21502					X	X	8	----	----	0
21504							11	1.31	0.77	23

[a] The first 4 digits of the location refer to RM to the nearest tenth, the last digit refers to the cross-section quarter of the channel that the effort occurs in, with 1 indicating the quarter nearest the Washington shoreline.

[b] See Table 1 for a description of substrate classes; C = clay, O = organic matter, M = mud/silt, S = sand, G = gravel, R = rubble.

Table 8. Number and catch per unit effort of white sturgeon eggs and larvae collected with the D-shaped larval net (catch/1000m^3) and beam trawl (catch per 15 minute tow) in the Bonneville Pool between RM 189.4 and RM 191.6, 25 May through 29 July, 1988. (No eggs or larvae were collected with the high-rise trawl).

	Eggs			
Gear/catch	Viable	Fungused	Total	Larvae
D-shaped net				
Number	65	1	66	8
Catch/1000m^3	1.75	0.03	1.78	0.22
Beam trawl				
Number	76	14	90	5
CPT	0.41	0.08	0.49	0.03
All gears				
Number	141	15	156	13

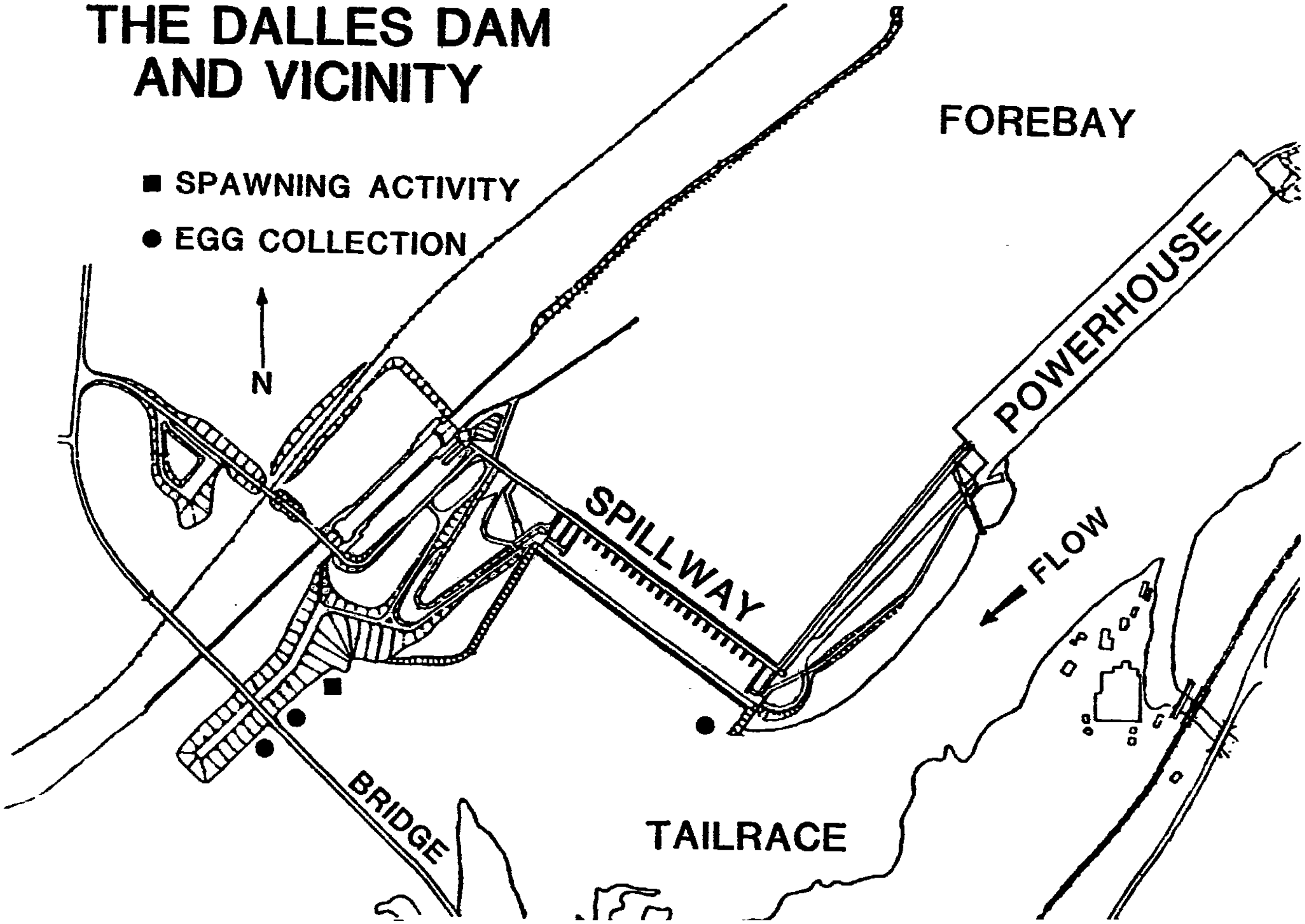


Figure 9. Locations where spawning activity was observed and adhesive eggs were collected below The Dalles Dam 3 June, 1988.

in diameter near the rip-rap shoreline. Suspecting that spawning was occurring, we moved the boat and nets to a point about 15 m downstream of the activity for the remaining 3 minutes of the set. During this 30 minute set, we collected 11 adhesive eggs. We immediately sampled for another 10 minutes just below the Highway 197 bridge and collected an additional 33 adhesive eggs. Discharges through The Dalles Dam during this period were at their highest for this day (about 7000 m^3/sec, Figure 10) causing turbulent upwelling that may have carried eggs to the surface where we collected them. Normally, we sample near the bottom, however, our nets would not submerge due to the upwelling. We estimated that we were sampling at depths of 0.3 to 3 m. We speculate that water velocities are an important cue for spawning. The fact that this spawning activity occurred while daily discharge was greatest supports our hypothesis.

Twenty-four hour sampling to estimate diel variability in catch of white sturgeon eggs and larvae was conducted on 8 and 9 June. During this 24 hour period, we collected 25 white sturgeon eggs with the beam trawl and 4 white sturgeon eggs with the D-shaped larval net; no larvae were collected. One egg was dead and covered with fungus and one was staged at first cleavage. The remaining 27 eggs were staged at heart formation to hatch in process.

Catch of eggs increased as discharge at the dam increased. Numbers of eggs caught/min. of effort from the beam trawl was highest between 1500 hrs and 2000 hrs when discharge peaked (Figure 11). We intended to sample hourly commencing at 0600 hrs with the beam trawl and a D-shaped larval net in The Dalles Dam tailrace. However, sampling with the beam trawl was not initiated until 1000 hrs due to difficulties in anchoring the boat fishing this gear.

Environmental Conditions

Water discharges, temperatures and turbidities below The Dalles Dam were similar to those below John Day Dam. Hourly discharges ranged from 1.31 to 9.48 kcms during April-July (Figure 12). Water temperature reached 10°C on 21 April and optimal temperatures for developing embyros (Wang et al. 1985) occurred between 27 May and 22 June (Figure 13). Water temperatures that occurred after June 22 are known to be sublethal or lethal to developing white sturgeon embryos (Wang et al. 1985). Mean daily turbidities ranged from 2.8 to 7.2 NTU (Figure 14).

Egg Deposition

White sturgeon spawning occurred more frequently in The Dalles Dam tailrace than in the John Day Dam tailrace during 1988. Eggs at various developmental stages were collected on 16 of 26 sampling dates between 25 May and 19 July. Egg deposition, based on back-calculated ages of eggs, was estimated to have occurred on at least 25 days between 25 May and 19 July. Adhesive eggs, evidence that spawning occurred during the previous 3 hours, were collected on 11 days.

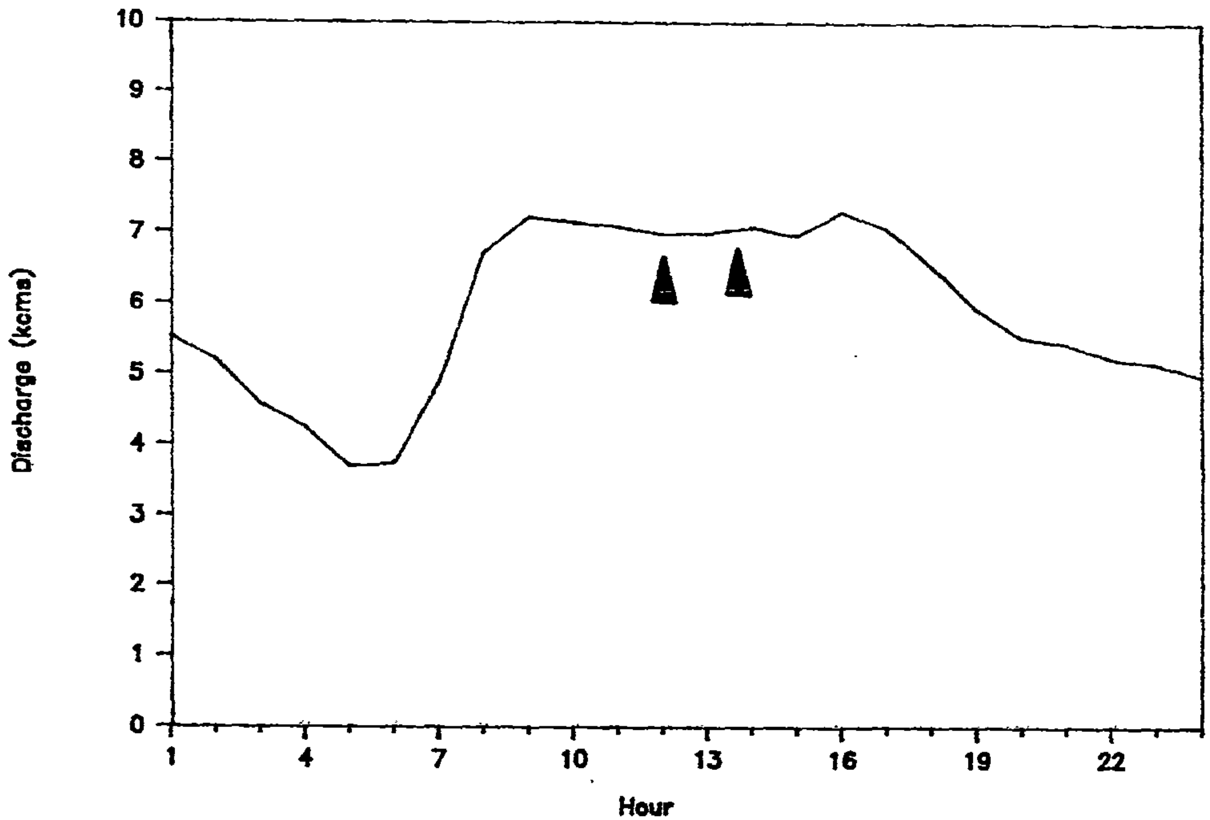


Figure 10. Hourly discharges of water through The Dalles Dam on 3 June, 1988. Spawning activity of white sturgeon was observed during the time period indicated by the arrows.

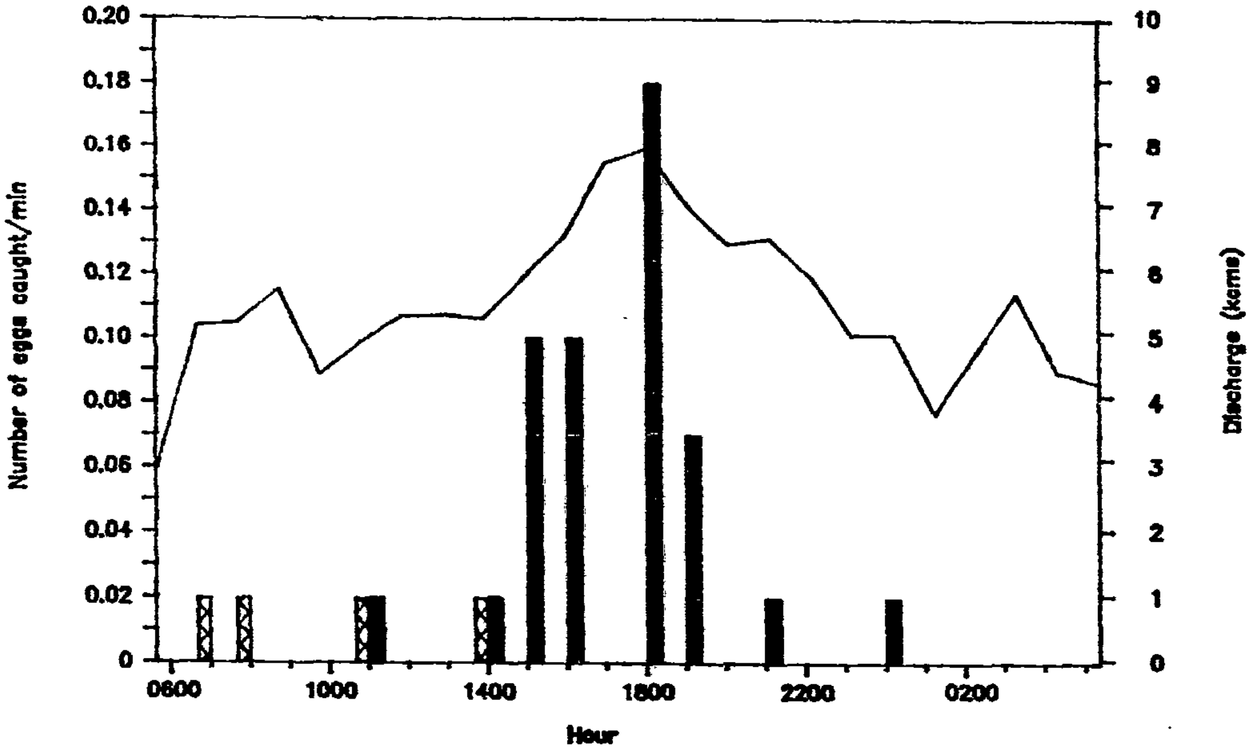


Figure 11. Number of white sturgeon eggs collected per minute with D-shaped larval nets (cross-hatched bars) and the beam trawl (solid bars) and hourly discharge at The Dalles Dam, 8 and 9 June, 1988. Effort with the beam trawl commenced at 1000 hrs.

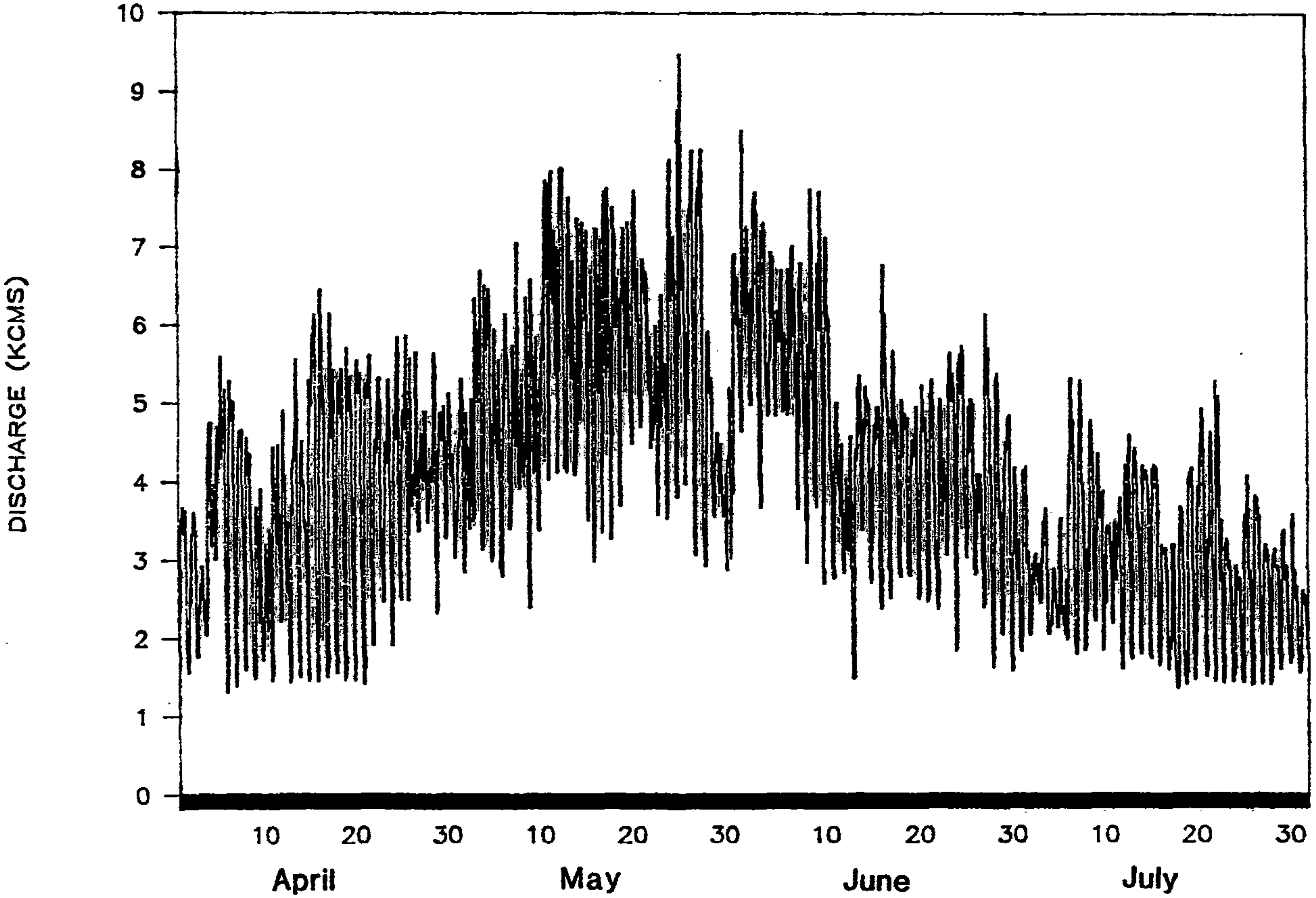


Figure 12. Hourly discharges through The Dalles Dam, April - July, 1988.

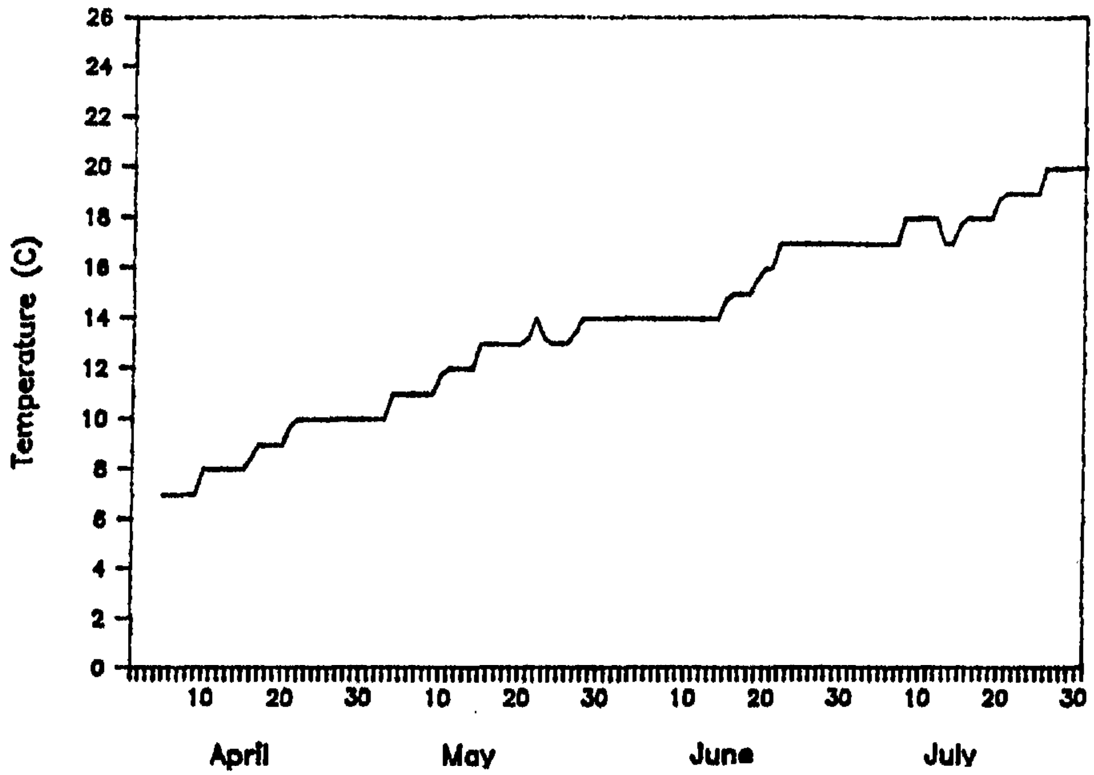


Figure 13. Mean daily water temperatures recorded at RM 191.8 below The Dalles Dam, 4 April through July, 1988.

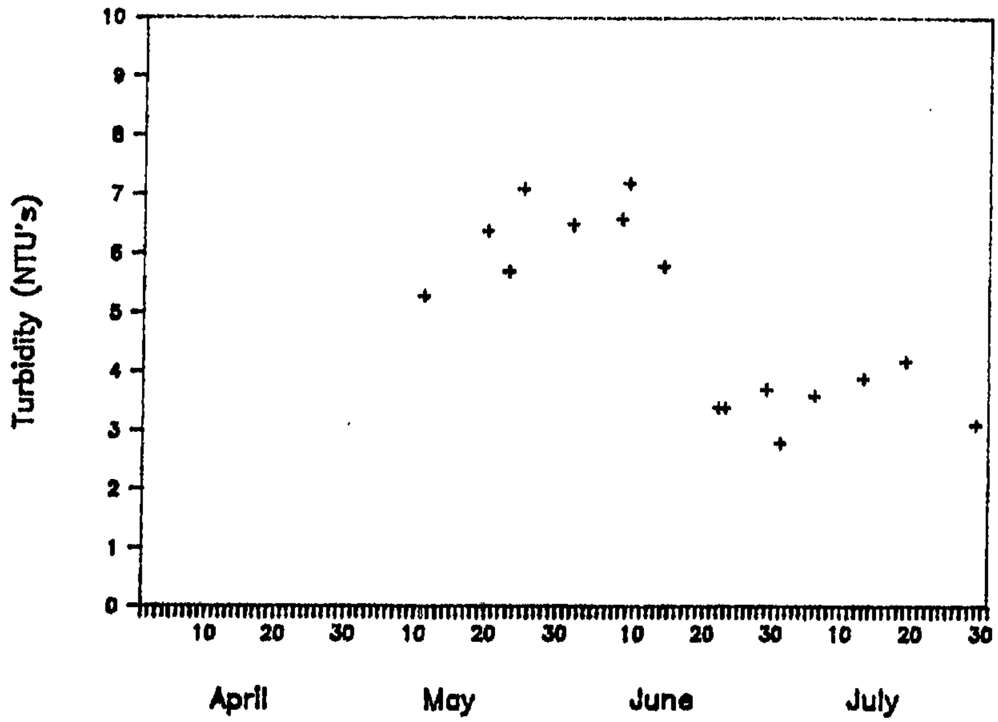


Figure 14. Turbidities measured in Bonneville Pool, April through July, 1988. Each point represents the average of the measured turbidities for that day.

Larvae

White sturgeon larvae were captured on 10 days between 31 May and 29 July. Developmental stages collected included post-hatch to three-day post-hatch. The three-day post-hatch larvae is the oldest young-of-the-year white sturgeon collected to date in either The Dalles or Bonneville pools. The post-hatch larvae ranged from 11 to 13mm in total length (TL) and the three-day post-hatch larvae was 15 mm TL. All larvae appeared to be in good condition, with some observed swimming in the collection jars.

Early Age Groups

We captured 860 white sturgeon in Bonneville Pool with trawls. No post-larval young-of-the-year or age I (1987 year-class) fish were captured in Bonneville Pool during 1988. Fork lengths of captured fish ranged from 306 to 850 mm FL (Table 9). We injected 707 with OTC, and 821 were tagged with monel bands. One tagged fish, previously injected with OTC, was recaptured 87 days after its initial capture and 3.5 km from the initial capture site. Exposure of a sectioned fin ray from this fish to ultra-violet light revealed that a thin band of fluorescent cartilage was deposited near the outer margin of the ray.

Distribution

Catches of white sturgeon varied spatially and temporally (Table 10). Partitioning the pool into three areas, lower, middle, and upper, revealed that catches with the high-rise trawl progressively decreased from the upper to the lower portion of the pool. Temporally, combined catches were highest during June, mainly because of a high catch in the upper portion of the pool. In the lower and middle area, catches were highest during May. Catches were lowest during October in the lower and middle portions, and lowest in August in the upper portion.

White sturgeon were captured in each of three backwater areas sampled in October, 1988. Nine fish greater than 900 mm FL were captured with gill nets in Ashes Lake, 45 fish 480-800 mm FL were captured with gill nets in Chamberlain Lake, and 8 fish 630-800 mm FL were captured with gill nets and fyke nets in Salisbury Slough. Although supporting fish, the importance of these backwaters as rearing areas for younger ages of white sturgeon remains unknown. White sturgeon immigration and emigration from these areas may be restricted by the size and/or depth of the outlets.

Depth Preference

Younger age groups of white sturgeon captured in Bonneville Pool with the high-rise trawl were most likely to be found in the deeper areas of the

Table 9. Length frequencies of white sturgeon collected in Bonneville Pool with trawls during 1988 (N= 852).

Fork length (mm)	Month							
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
201-210								
211-220								
221-230								
231-240								
241-250								
251-260								
261-270								
271-280								
281-290								
291-300								
301-310								
311-320				1	1			
321-330		2						
331-340		1	1	1		1		
341-350	2	1	1	1	1			
351-360		3	4	4	1	1		
361-370	3	2	12	4	1	1		2
371-380	3	1	11	5	1	2	1	
381-390	6	2	17	2	2	2		1
391-400	2	3	15	9	2	3		1
401-410	2	6	9	9	2	6	1	
411-420	1	3	14	6	4	6	2	
421-430	2	7	14	5	3	7	1	1
431-440	2	5	18	11	8	7	3	3
441-450	8	7	14	7	5	9	1	4
451-460	9	9	21	3	2	5		2
461-470	6	7	16	7	3	3	1	
471-480	3	3	16	5	6	5	1	2
481-490	1	8	23	5	2	6	2	
491-500	3	5	13	2	6	3	3	1
501-510	1	6	10	2	2	1		
511-520	2	8	4	6	2	2		
521-530		2	4	3	4	5	1	
531-540		12	9	1	1	2	1	
541-550	2	11	4	3	2	2		1
551-560	3	6	6	1	4	3	1	
561-570		3	2	6	3	1		
571-580	1	2	2	2				1
581-590	1	1	1	2	4	1		
591-600		6	2	3		1		
> 601	6	24	11	21	8	9	1	3
Total	69	156	274	137	80	94	20	22

Table 10. Number, catch per 15 minute tow (CPT) and catch per hectare (CPHA) of white sturgeon captured with the high-rise trawl at lower (RM 149-163), middle (RM 163-178), and upper (RM 178 - 191.5) portions of Bonneville Pool.

Location	Apr	Month May	Jun	Jul	Aug	Sep	Oct	Nov	Total Number	Mean CPUE
Lower Reservoir										
Number	0	6	5	11	5	3	1	2	33	
CPT	0	0.55	0.23	0.49	0.41	0.24	0.2	0.41		0.35
CPHA	0	1.26	0.54	1.13	1.01	0.57	0.54	0.99		0.82
Middle Reservoir										
Number	11	46	34	19	12	15	2	4	143	
CPT	1.6	2.19	1.47	1.23	1	1.03	0.25	1		1.36
CPHA	3.56	5.7	3.46	2.93	2.58	1.75	0.66	2.57		3.37
Upper Reservoir										
Number	58	102	225	103	79	76	17	16	676	
CPT	5.99	4.31	14.39	6.39	2.48	5.38	3.4	3.2		5.58
CPHA	15.31	19.92	39.39	15.84	6.65	13.4	8.21	9.67		14.96
All locations										
Number	69	154	264	133	96	94	20	22	846	
CPT	3.25	2.77	4.37	2.46	1.71	2.29	1.11	1.59		2.66
CPHA	7.40	7.44	10.65	5.85	4.42	5.33	2.88	4.20		6.61

pool. Eighty five percent of the fish were captured at depths exceeding 17 m, although only 56% of the high-rise trawling effort was at these depths (Figure 15). We captured white sturgeon with trawls at depths of 9 to 58 m. Though deeper areas exist, trawling depths were limited by cable capacity of the winches.

Weight-Length Relation and Condition Factor

We determined the weight-length relation from 848 white sturgeon (306 to 850 mm FL) collected from April through November. The relationship is described by the equation log W = Log FL (3.01) - 5.19 (r^2 = 0.96). The average condition factor of the fish was 0.723 (Sd = 0.075, N = 848).

Age and Growth

We sectioned pectoral fin rays from a sample of 305 white sturgeon captured between 13 April and 23 June. Ages were determined for 265 (87%) of these fish (Appendix C-3); age determinations were not made for 40 (13%) fish because of reader disagreement or poor quality sections. The white sturgeon aged ranged from 2 to 15 years. Mean fork lengths at age for ages II-VI (ages for which we had a sample size $\geq$ 18) were 380, 439, 470, 509, and 554 mm, respectively. There was considerable overlap in lengths of all age groups. For example, the largest age II fish was 48 mm longer than the smallest age VI fish.

Growth of white sturgeon aged II to VII from Bonneville Pool was greater than growth of fish from below Bonneville Dam (Appendix C-5). Annual relative growth and instantaneous population growth (G) rates for white sturgeon aged II to V were 55% (0.435), 23% (0.205), and 27% (0.240) respectively.

Catch of Other Fishes

Several species of fish other than white sturgeon were identified in our catch from Bonneville Pool during 1988 (Table 11). Trawl and net catches were dominated by young-of-the-year and older prickly sculpin. Other species commonly found included American shad, carp, peamouth, northern squawfish, largescale sucker, channel catfish, sand roller, and walleye.

Food Habits

The emetic hydrogen peroxide was successful in recovering some food items from white sturgeon collected during April through August; however, the technique was not suitable for a quantitative analysis of food habits.

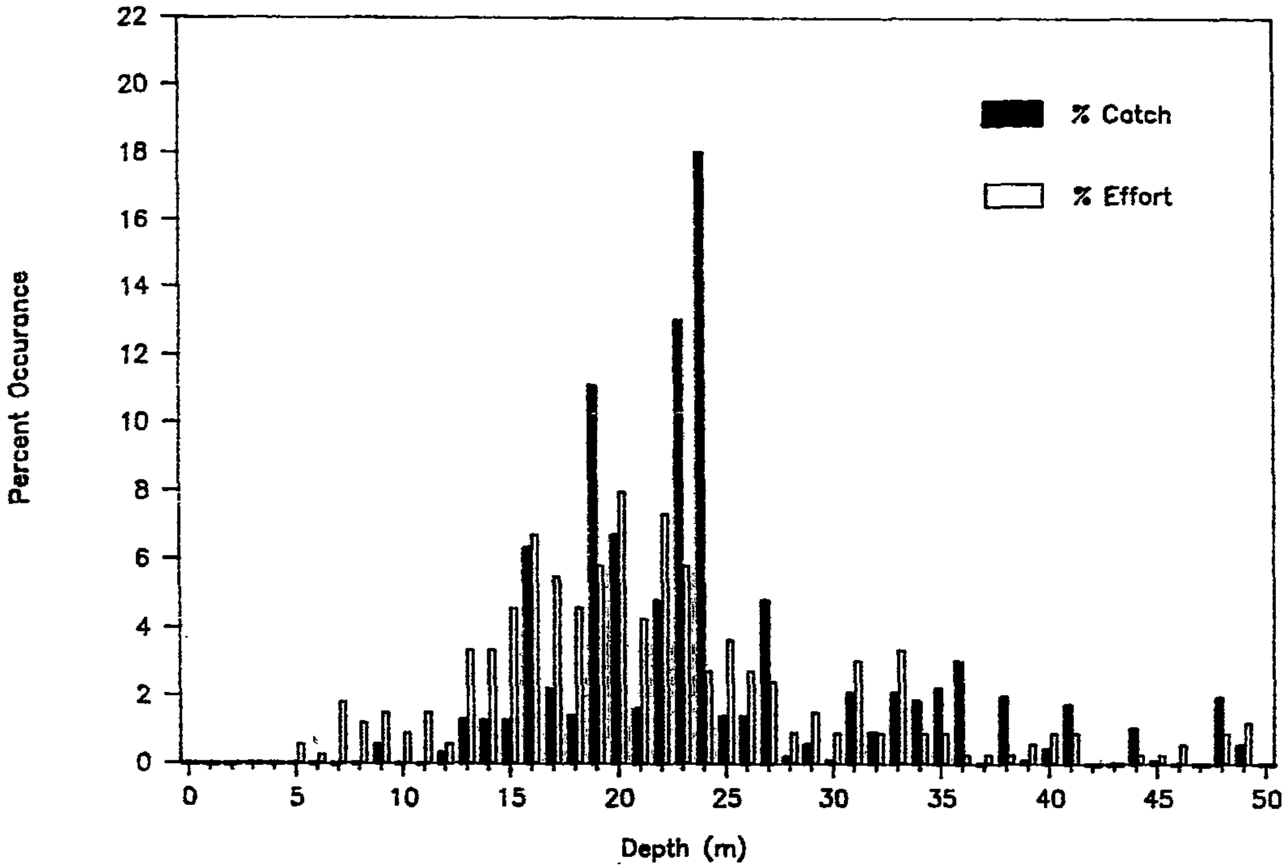


Figure 15. Percent of the catch of white sturgeon and the percent of the number of high-rise trawl tows at depthe we encountered in Bonneville Pool, 1988.

Table 11. Number and catch of fishes excluding white sturgeon collected with high-rise and beam trawls and D-shaped larval nets in Bonneville Pool, April through November, 1988.

Taxon	High-rise trawl Number			Beam Trawl Number		D-shaped larval net number		Total Number
	Number	CPT	CPHA	Number	CPT	number	1000^3	Number
Pacific lamprey	6	.02	.05	2	<0.01			8
American shad	59	.18	.46	2	<0.01			61
Chinook salmon	386	1.20	3.02					386
Mountain whitefish	2	<0.01	0.02	1	<0.01			3
Chiselmouth	1	<0.01	<0.01					1
Carp	7	0.02	0.05					7
Peamouth	472	1.47	3.69	1	<0.01			473
Northern squawfish	254	0.79	1.98					254
Redside shiner	171	0.53	1.34					171
Speckled dace	1	<0.01	<0.01					1
Unidentified cyprinid				1	<0.01	3	0.04	4
Largescale sucker	191	0.60	1.49					191
Bridgelip sucker	38	0.12	0.30					38
Unidentified sucker	16	0.05	0.13	18	0.08	14	0.18	48
Channel catfish	3	<0.01	0.02	1	<0.01			4
Sand roller	1023	3.19	7.99	22	0.09			1045
Smallmouth bass	30	0.09	0.23	2	<.01	1	0.01	33
Walleye	28	0.09	0.22					28
Three-spined stickleback	6	0.02	0.05					6
Prickly sculpin	6239	19.47	48.75	395	1.67	37	0.47	6671
Unidentified fish	3	0.09	0.22	10	0.04			13
Total number	8936			455				9391

For 10 white sturgeon collected during August, overall mean efficiency of hydrogen peroxide in recovering food items was 19.4% by weight. The efficiency of the emetic in recovering the two most common food items in the diet, *Neomysis mercedis* and *Corophium spp.*, was 7% and 55% by weight and 16% and 55% by number, respectively.

DISCUSSION

Spawning

White sturgeon spawning occurred downstream of both John Day and The Dalles dams in 1988, but occurred with greater frequency below The Dalles Dam. Spawning occurred in tailrace areas where water velocities were highest.

The 1988 spawning period was quite protracted, beginning in April below Bonneville Dam (see report D), and in late May below The Dalles and John Day dams and extended through July.

Egg deposition during 1987 and 1988 appears to have been far greater below Bonneville Dam than below the upriver dams. Increased spawning activity may be due to a greater abundance of reproductively active white sturgeon and/or more favorable spawning conditions (microhabitat) below Bonneville Dam. Spawning in 1987 and 1988 occurred as much as a month earlier below Bonneville Dam than below the upriver dams even though temperatures and turbidities were nearly identical on any given day below each dam. These variables, especially temperature, are two indicators of macrohabitat and define the time period in which spawning may occur. Mean daily discharges of flow through each dam were also nearly identical. However, the hourly patterns of discharge among the dams were quite different, and may affect the availability of suitable spawning microhabitats. For example, hourly discharges of water through Bonneville Dam were relatively constant each day during April through July, 1988 with the mean variation in hourly discharge within a given day of 22% (SD = 14.02). Variation in discharge at John Day and The Dalles Dams was much greater with discharges during each day at each of these dams varying 118% (SD 63.51). Because channel morphology differs below each dam, water velocities, which we suspect may cue spawning and effect survival of yolk-sac larvae, differ below each dam even though total discharges may be similar.

We hypothesize that breaching at this time of the year is associated with spawning. Our observations of breaching and subsequent collection of newly spawned eggs, which we believe to be the first observations of white sturgeon spawning in the natural environment, strengths our hypothesis. We do not know whether the eggs were actually extruded at the surface during breaching or deeper in the water column.

Early Age Groups

Abundance of early age groups (we hesitate to call them juveniles as our catches comprise of fish up to 15 years of age) of white sturgeon was greater in Bonneville Pool than in The Dalles Pool based on CPUE with the high-rise trawl. Catches in both pools were patchy, with wide variation in the numbers of fish collected at a given site during the sampling season.

Recruitment of white sturgeon to young-of-the-year or age I apparently did not occur in 1987 or 1988 in The Dalles or in Bonneville pools. Spawning occured below John Day Dam in 1987 and 1988 and below The Dalles Dams in 1988, but occurred with greater frequency below The Dalles Dam than below John Day Dam in 1988. Survival from the yolk-sac stage to young-of-the-year may be limiting recruitment. We collected newly hatched white sturgeon below both dams in 1988 and below John Day Dam in 1987 but have yet to capture a post larvae or age I white sturgeon from either pool despite intense sampling effort.

Currently, we can only speculate on the causes of the lack of recruitment of newly hatched white sturgeon. Two hypotheses include: (1) environmental conditions for survival of yolk-sac larvae were unfavorable; (2) bioaccumulation of toxic compounds in ovarian tissues caused mortality as the yolk-sac of white sturgeon was absorbed.

Greater discharges of water at The Dalles and John Day dams than those that occurred during the below normal years of 1987 and 1988 may provide larger areas of suitable microhabitat and a more favorable environment for incubation and survival of eggs and larvae of white sturgeon. The highest average daily discharge that occurred at The Dalles Dam in 1987 and 1988 was about 8300 m^3/s and 7000 m^3/s, respectively, while the highest average daily discharge in 1986, the youngest year-class of white sturgeon we collected, was about 11,500 m^3/s.

Bioaccumulation of toxins cause abnormalities in developing embryos of many animals. Though we are not currently investigating this hypothesis. Bosely and Gately (1981) reported increasing levels of organochlorine pesticides in fillets of white sturgeon collected from below Bonneville Dam to Lake Wallula (above McNary Dam). Polychlorinated biphenyl levels found in ovarian tissue of a white sturgeon from Bonneville Pool were at a level known to cause mortality in developing rainbow trout.

It appears that the younger age white sturgeon are generalists in their use of rearing habitat. We have captured fish in most habitat types and though we tend to capture them in deeper areas with the trawls, we also captured them in shallow (<3 m) backwaters with gill nets.

Younger ages of white sturgeon grew faster in the impounded reaches between Bonneville and John Day dams than fish from below Bonneville Dam (Appendixes C-4, C-5, and C-6). Densities of benthic invertegrates (per m^2) collected in The Dalles Pool were greater than densities found below Bonneville Dam (Report D), though we were unable to correlate catches of fish and invertebrate densities at individual sites in The Dalles Pool.

Plans for 1989

Study plans for the 1989 field season include continuation of the standardized sampling system used during 1988 in The Dalles Pool to collect eggs, larvae and younger age white sturgeon. Similar standardized sampling will commence in Bonneville Pool during 1989 based on 1988 exploratory activities that established suitable sampling locations. In addition, we will initiate exploratory sampling in John Day Pool.

The FWS will continue field efforts to define habitat use by spawning and rearing white sturgeon in The Dalles and Bonneville pools and initiate field efforts in John Day pool. We will begin constructing computerized habitat maps of each pool which should allow us to quantify the amount of habitat available for spawning and rearing. The maps will be digitized from existing navigational charts, modified with additional data, into a Geographic Information System. Cartographic modeling can then be used to determine the amounts of various types of habitat available. We will begin with The Dalles Pool, and extend into Bonneville Pool and John Day Pool as time permits.

REFERENCES

Beckman, L.G., D.E. Palmer, and M.J. Parsley. 1987. Appendix C *in* A.A. Nigro, editor. Status and habitat requirements of white sturgeon populations in the Columbia River downstream from McNary Dam. Annual Progress Report (Contract No. DE-AI79-86BP63584) to Bonneville Power Administration. Project No. 86-50.

Beer, K.E. 1981. Embryonic and larval development of white sturgeon, (*Acipenser transmontanus*). M.S. Thesis, UC Davis. 93 pp.

Bosely, C.E. and G.F. Gately. 1981. Polychlorinated biphenyls and chlorinated pesticides in Columbia River white sturgeon (*Acipenser transmontanus*). Unpublished report. U.S. Fish and Wildlife Service, Fisheries Assistance Office, Vancouver, Washington.

Normandeau Associates, Inc. 1985. Relative catch efficiency of a 3.0 m beam trawl, a 6.2 m high-rise trawl and a 1.0 m^2 epibenthic sled for sampling young-of-the-year striped bass and other fishes in the Hudson River estuary. Normandeau Associates, Inc. Bedford, New Hampshire. USA.

Palmer, D.E., M.J. Parsley, and L.G. Beckman. 1988. Appendix C *in* A.A. Nigro, editor. Status and habitat requirements of white sturgeon populations in the Columbia River downstream from McNary Dam. Annual progress report (Contract No. DE-AI79-86-BP63584), July 1987 - March 1988. Bonneville Power Administration, Portland, Oregon.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191: 382 p.

U.S. Fish and Wildlife Service (USFWS) 1980. Columbia River backwater study: Phase one. Fisheries Assistance Office, Vancouver, Washington, USA.

Wang, Y.L., F.P. Binkowski, and S.I. Doroshov. 1985. Effect of temperature on early development of white and lake sturgeon, *Acipenser transmontanus* and *A. fulvescens*. Environmental Biology of Fishes. 14(1): 43-50.

Waters, T.F. 1969. Subsampler for dividing large samples of stream invertebrate drift. Limnology and Oceanography 14: 813-815.

APPENDIX C-1

Common and scientific names of fishes collected in 1988.

Common name	Scientific name
Pacific lamprey	Lampetra tridentata
American shad	Alosa sapidissma
Coho salmon	Oncorhynchus kisutch
Sockeye salmon	Oncorhynchus nerka
Chinook salmon	Oncorhynchus tshawytscha
Rainbow trout	Oncorhynchus mykiss
Mountain whitefish	Prosopium williamsoni
Chiselmouth	Acrocheilus alutaceus
Common carp	Cyprinus carpio
Peamouth	Mylocheilus caurinus
Northern squawfish	Ptychocheilus oregonensis
Speckled dace	Rhinichthys osculus
Redside shiner	Richardsonius balteatus
Largescale sucker	Catostomus macrocheilus
Bridgelip sucker	Catostomus columbianus
Channel catfish	Ictalurus punctatus
Brown bullhead	Ictalurus nebulosus
Sand roller	Percopsis transmontana
Threespine stickleback	Gasterosteus aculeatus
Pumpkinseed	Lepomis gibbosus
Sunfishes	Lepomis spp.
Smallmouth bass	Micropterus dolomieui
Crappies	Pomoxis sp.
Yellow perch	Perca flavescens
Walleye	Stizostedion vitreum vitreum
Prickly sculpin	Cottus asper

APPENDIX C-2

White Sturgeon Egg and Larval Development Stages

Unfertilized Egg.
The egg is ovoid and grayish black in color.

Changing Pigmentation.
Animal pole is light with a dark center spot and facing upward. The vegetal pole is still darkly colored. The egg has enlarged and is adhesive.

First Cleavage.
The animal pole is divided into two equal blastomeres. The animal pole is light colored and the vegetal pole dark.

Second Cleavage.
The animal pole is divided into four equal blastomeres. The initial cleavage furrow continues into the vegetal pole.

Third Cleavage.
Two furrows develop parallel to the initial furrow. The blastomeres formed are not equal. The pigmentation is the same.

Fourth through Sixth Cleavage.
The lightly colored animal pole continues to divide, forming numerous micromeres. The smallest micromeres congregate at the top of the animal pole. The dark vegetal area is comprised of several macromeres.

Late Cleavage.
The animal pole has continued to divide into many small micromeres, creating a grainy appearance. A band of medium-sized micromeres forms the border of the two poles. More macromeres have formed in the vegetal pole.

Early Epithelial.
Micromeres in the animal pole are not separate, but still have the grainy appearance. The border of the two poles is a gradation of micromeres to macromeres.

Late Epithelial.
The animal pole is smooth and of light coloration. The vegetal pole is of a contrasting dark coloration. A dark furrow is forming at the border of the two poles.

Involution.
Gastrulation is initiated as the dark furrow (dorsal lip) increases. Epibolic growth of the animal area extends to the border of the two poles. The macromeres of the vegetal pole continue to divide.

Large Yolk Plug.
The dorsal lip forms a ring around the dark yolk plug. The light animal area covers over two-thirds of the egg.

Small Yolk Plug.
With gastrulation, the position of the embryo has changed to the dorsal side. As the yolk plug decreases, its lateral sides merge. From the dorsal side of the yolk plug, a faint band extends, representing the future embryonic axis.

Early Neurulation.
The yolk plug has submerged. A furrow is formed from the merging neural folds of the blastopore. The future cephalic area is at the anterior end of the furrow. The future trunk is lightly delineated on both sides of the neural folds.

Closure of the Neural Tube.
The neural folds converge forming the neurenteric canal. The trunk and tail protrude above the egg. The embryo extends around the yolk 160 degrees. The initial formations of the brain are seen in the cephalic region. The future pronephros are starting to extend form the foretrunk. Lateral somites have formed on the trunk.

Elongation of the Pronephros.
The pronephros continue to extend out from the foretrunk. The body of the embryo is elevated above the egg. The tip of the tail is undercut. The embryo extends around 200-300 degrees. The initial eye formations are seen in the cephalic area.

Formation of the Heart.
The embryo extends around 320-350 degrees. The tail is elevated above the yolk. The tail continues to separate from the yolk. The heart is a straight tube that eventually forms into an "S" tube anterior to the head. The tail is dorso-ventrally aligned with a fin fold. The primitive eye is seen deep in the head as a dark pigment in a light ring.

Prehatch.
The tip of the tail extends past the head and is turned 90 degrees. The head is elevated above the yolk. The entire tail is separated from the yolk. The fin fold is enlarging. The intestine is visible. The nares, eyes, and auditory vesicles are seen distinctly in the head.

Hatch in Process.
The tail hatches out first and then the trunk straightens out - see Larva Post-hatch for a more complete description.

Larval Development Stages

(POST-HATCH) The large, soft, round yolk is the prominent feature of the post-hatch larva. The yolk is white or developing a dark pigmentation dorsally. The head is slightly extended from the yolk with indistinct features and a few melanophores. The eye is a small distinct pigment spot. The nares are distinguished by small pits. The trunk is transluscent, with distinct body somites. The tail is elongate, narrowing at the tip. Fin folds extend dorsally and ventrally from mid-trunk to the tail. The intestine is spiral and darkly pigmented.

(1-DAY POST-HATCH) The pectoral fins are apparent as small swellings posterior to the defined pronephros. The yolk is increasing in pigmentation. As the gut develops, the yolk becomes more solid. The trunk is elongating, especially posterior to the intestine, and is quite transluscent. The fin folds are widening, particularly in the future caudal area. They are starting to separate at the anal area. The intestine is spiral and darkly pigmented. Rudimentary operculums are visible. The eye is distinguishable as a subsurface pigmentation within the developing optic cup. Otic vesicles protrude from the lateral portion of the brain.

(2-DAY POST-HATCH) The pectoral fins are quite distinct. The fin folds extend anterior along the dorsal trunk and ventrally from the yolk. The fin folds are widening and of uniform width around the elongating caudal area. The caudal region extends to a narrow tip. Slight pigmentation occurs in the future dorsal fin area. The yolk is starting to separate ventrally into the gut and the liver. The mouth is open with four barbel buds apparent. The operculums flare out from the head. The eye nears the surface as a dark spot within a lightly pigmented optic cup.

(3-DAY POST-HATCH) A fin fold protrudes at the future dorsal fin with pigmented striations radiating out from the trunk into it. The notochord tips up at the end. The caudal region of the tail is darkly pigmented. The mouth is open with barbel buds quite distinct. The opening of each nare is narrowing. The prominent eye is slightly subsurface with the lens inside a darkly pigmented optic cup. Melanophores are increasing on the head. The operculum is transparent as branchial arches with small gill filaments protrude slightly posterior to the operculum. The midgut is distinctly separate with the darkly speckled yolk dorso-anterior. The developing liver is white and anterior to the midgut on the ventral side of the yolk. A melanin plug is in the posterior intestine. The lateral line extends partially down the trunk.

(4-DAY POST-HATCH) Pigmentation increases over the entire larva especially in the snout area and the posterior portion of the trunk at future dorsal, anal, and caudal fin areas. The exception is the tip of the tail which has no pigmentation. Eyes are distinct with clear lenses in dark optic cups. Barbels are longer and the mouth is wider. The operculum is transparent with small, thick, gill filaments extending beyond it. Pectoral fins are larger and rounder. As the gut enlarges, the pectoral fins' position slowly moves ventrally. Pelvic fin buds are apparent just anterior of the anal slit in the fin fold. The fin folds narrow slightly at the future caudal peduncle area. The ventral fin fold elongates for the beginning of an heterocercal tail. The lateral line extends the full length of the trunk.

(5-DAY POST-HATCH) Pelvic fins are distinct. The fin fold narrows along the trunk except at future dorsal, anal, and caudal fin areas, where it widens. The fin fold is discontinuous at the anus. Pigmentation permeates future fin areas and the trunk area. Rays are forming in the dorsal fin area. The entire head has increasing pigmentation. The eyes are larger with transparent lenses in dark optic cups. Each nare narrows to form two ovoid pits. Barbels continue to lengthen and mouth parts are apparent. Long, thinner gill filaments extend past the operculum. The pectoral fins are larger, moving ventrally. Body somites extend down from the trunk as the yolk decreases. Ventrally, the heart is apparent, the liver dividing, and the midgut more transparent.

(6-DAY POST-HATCH) The pelvic fins are enlarging. The tail area is heavily pigmented with pigmentation streaming into the caudal, anal, and dorsal fin areas. Pigmented striations extend into the ventral caudal fin folds. Dorsal fin rays are visible extending into the dorsal fin fold. The fin fold continued to widen in the lower caudal area and narrows at the future caudal peduncle. The darkly pigmented head is distinguished by the enlarging eye. The midgut has yellow fluid. The pectoral fins continue to enlarge and move ventrally.

(8-DAY POST-HATCH) The tail is elongating. Pigmentation extends throughout the entire tail region and is especially heavy in the future lobes of the caudal fin. Fin folds continue to narrow at the future caudal peduncle. Rays are extending into the dorsal fin. Pelvic fins are larger and extend out from the trunk. Pectoral fins are moving ventrally and have fin rays. The body somites extend further down from the trunk over decreasing yolk. The head is developing its horny processes. Many long, thin, gill filaments extend past the operculum.

(9-DAY POST-HATCH) The dorsal portion of the caudal fin fold has narrowed and is completely discontinuous with the protruding dorsal fin fold. The ventral part of the caudal fin fold narrows at the future caudal peduncle and then widens into a deep lobe. The anal fin fold is now defined. Heavy pigmentation continues into the tail region, though more profuse in the ventral part of the caudal area. Dorsal fin rays are elongating. Anal fin rays are barely apparent. The round pelvic fins extend out from the trunk with elongating fin rays. The wide, rounded pectoral fins are ventral with rays extending into them. The head is elongating with many horny processes. The barbels are long, extending from the rostrum. Gill filaments still extend slightly past the operculum. The yolk sac is almost absorbed, and is barely protruding.

(10-DAY POST-HATCH) The same characteristics as the 9-DAY POST-HATCH except the caudal fin fold is completely discontinuous dorsally and ventrally. The anal fin rays are more visible, extending farther into the fin.

APPENDIX C-3

Benthic Invertebrate Sampling Results

Results of our benthic invertebrate sampling at seven locations in The Dalles Pool. Summarization of the data was conducted by NMFS. Community structure indices indicated on the last line of each table are calculated as follows:

Shannon-Weiner Diversity Index (H'; Krebs 1978);

$$H' = -\sum_{i=1}^{s} Pi \log_2 Pi$$

Pi = Xa/n (Xa equals the number of individuals of a particular species in a sample and n equals the total number of individuals in a sample)

S = number of species

Simpson Diversity Value (SDV; Simpson 1949);

$$SDV = 1 - \sum_{i=1}^{s} Pi^2$$

Species Richness (SR; Margalef 1958);

$$SR = (S-1)/\ln (n)$$

Evenness (J; Pielou 1966)

$$J = H/\log_2 S.$$

Station no: 19433 Date: 2 May 88 Sample size: 7

Taxa	Total number	Frequency occurr (%)	Mean number /m^2	Standard deviation /m^2
Nemertea	100	85.71	150.00	121.05
Hydra spp.	3	14.29	4.50	11.91
Polychaeta	1	14.29	1.50	3.97
Oligochaeta	708	85.71	1062.00	802.90
Hydrobiidae	4464	100.00	6696.00	3027.65
Corbicula manilensis	2516	100.00	3774.00	3221.44
Sphaeriidae	266	71.43	399.00	556.14
Ostracoda	61	71.43	91.50	81.27
Corophium spp.	4141	100.00	6211.50	4127.80

Number of taxa = 9.

Mean number per sample: 1751.43 Standard deviation: 732.36
Mean number /m^2: 18390.00 S.D. /m^2: 7689.81

H' = 1.98 SDV = 0.71 SR = 0.85 J = 0.63

Station no: 19433 Date: 2 Sep 88 Sample size: 6

Taxa	Total number	Frequency occurr (%)	Mean number /M^2	Standard deviation /M^2
Nemertea	467	100.00	817.25	706.13
Turbellaria	24	50.00	42.00	55.16
Polychaeta	3	50.00	5.25	5.75
Oligochaeta	1124	100.00	1967.00	1677.29
Gastropoda	1	16.67	1.75	4.29
Hydrobiidae	7843	100.00	13725.25	2833.85
Juga plicifera	28	100.00	49.00	47.27
Corbicula manilensis	6149	100.00	10760.75	1807.99
Sphaeriidae	514	100.00	899.50	1191.42
Corophium spp.	556	83.33	973.00	1241.32
Daphnia spp.	1	16.67	1.75	4.29

Number of taxa = 11.

Mean number per sample: 2785.00 Standard deviation: 519.03
Mean number /M^2: 29242.50 S.D. /M^2: 5449.83

H' = 1.80 SDV = 0.64 SR = 1.03 J = 0.52

Station no: 19633 Date: 2 May 88 Sample size: 7

Taxa	Total number	Frequency occurr (%)	Mean number $/m^2$	Standard deviation $/M^2$
Nemertea	57	71.43	85.50	77.02
Hydra sp.	20	28.57	30.00	54.37
Turbellaria	9	42.86	13.50	16.84
Polychaeta	29	57.14	43.50	47.51
Oligochaeta	2017	100.00	3025.50	641.29
Hydrobiidae	9502	100.00	14253.00	5112.17
Juga plicifera	1	14.29	1.50	3.97
Limpet	3	14.29	4.50	11.91
Corbicula manilensis	3066	100.00	4599.00	1680.34
Sphaeriidae	139	100.00	208.50	161.47
Ostracoda	113	57.14	169.50	194.60
Gammaridae amphipoda	3	14.29	4.50	11.91
Eogammarus spp.	7	14.29	10.50	27.78
Corophium spp.	6242	100.00	9363.00	3356.66
Cyclopoida	11	28.57	16.50	39.22
Chironomidae larvae	3	14.29	4.50	11.91

Number of taxa = 16.

Mean number per sample: 3031.71 Standard deviation: 474.04
Mean number $/M^2$: 31833.00 S.D. $/M^2$: 4977.46

H' = 1.92 SDV = 0.68 SR = 1.51 J = 0.48

Station no: 19633 Date: 2 Sep 88 Sample size: 7

Taxa	Total number	Frequency occurr (%)	Mean number $/M^2$	Standard deviation $/M^2$
Nemertea	327	100.00	490.50	278.51
Polychaeta	56	85.71	84.00	77.40
Oligochaeta	3533	100.00	5299.50	1903.15
Hirudinea	3	14.29	4.50	11.91
Hydrobiidae	13548	100.00	20322.00	4044.89
Juga plicifera	41	100.00	61.50	40.86
Limpet	2	28.57	3.00	5.12
Bivalvia	4	14.29	6.00	15.87
Corbicula manilensis	4928	100.00	7392.00	2728.75
Sphaeriidae	613	85.71	919.50	678.39
Ostracoda	4	42.86	6.00	8.26
Corophium spp.	2620	100.00	3930.00	1567.35

Number of taxa = 12.

Mean number per sample: 3668.43 Standard deviation: 690.19
Mean number $/M^2$: 38518.50 S.D. $/M^2$: 7246.99

H' = 1.92 SDV = 0.65 SR = 1.08 J = 0.54

Station no: 19901   Date: 2 May 88   Sample size: 6

Taxa	Total number	Frequency occurr (%)	Mean number $/M^2$	Standard deviation $/M^2$
Nemertea	154	100.00	269.50	93.13
Polychaeta	22	50.00	38.50	48.19
Oligochaeta	1985	100.00	3473.75	669.05
Hirudinea	1	16.67	1.75	4.29
Hydrobiidae	6521	100.00	11411.75	4222.58
Juga plicifera	6	33.33	10.50	16.27
Bivalvia	812	83.33	1421.00	1063.08
Corbicula manilensis	1255	100.00	2196.25	544.07
Sphaeriidae	158	16.67	276.50	677.28
Anodonta spp.	1	16.67	1.75	4.29
Ostracoda	16	66.67	28.00	27.11
Gammaridae amphipoda	3	16.67	5.25	12.86
Corophium spp.	4956	100.00	8673.00	2997.40
Trichoptera larvae	3	16.67	5.25	12.86

Number of taxa = 14.

Mean number per sample: 2648.83   Standard deviation: 683.71
Mean number $/M^2$: 27812.75   S.D. $/M^2$: 7178.98

H' = 2.10   SDV = 0.71   SR = 1.34   J = 0.55

Station no: 19901   Date: 2 Sep 88   Sample size: 6

Taxa	Total number	Frequency occurr (%)	Mean number $/M^2$	Standard deviation $/M^2$
Nemertea	189	83.33	330.75	331.16
Polychaeta	38	50.00	66.50	110.46
Oligochaeta	1995	100.00	3491.25	3909.90
Hirudinea	3	16.67	5.25	12.86
Gastropoda	3285	83.33	5748.75	5821.86
Hydrobiidae	2856	33.33	4998.00	8097.69
Juga plicifera	1	16.67	1.75	4.29
Physa spp.	3	16.67	5.25	12.86
Bivalvia	395	66.67	691.25	1445.81
Corbicula manilensis	3734	100.00	6534.50	1366.32
Sphaeriidae	261	16.67	456.75	1118.80
Ostracoda	3	16.67	5.25	12.86
Corophium spp.	2033	100.00	3557.75	1568.17

Number of taxa = 13.

Mean number per sample: 2466.00   Standard deviation: 1118.36
Mean number $/M^2$: 25893.00   S.D. $/M^2$: 11742.79

H' = 2.58   SDV = 0.81   SR = 1.25   J = 0.70

Station no: 20124 Date: 2 May 88 Sample size: 6

Taxa	Total number	Frequency occurr (%)	Mean number /M^2	Standard deviation /M^2
Nemertea	51	50.00	89.25	150.96
Polychaeta	13	33.33	22.75	42.22
Oligochaeta	2752	100.00	4816.00	1983.92
Hydrobiidae	68	100.00	119.00	131.93
Corbicula manilensis	324	100.00	567.00	273.73
Ostracoda	73	66.67	127.75	159.85
Corophium spp.	1471	100.00	2574.25	1466.90
Chironomidae larvae	180	83.33	315.00	205.54
Chironomidae pupae	10	33.33	17.50	30.19

Number of taxa = 9.

Mean number per sample: 823.67 Standard deviation: 137.74
Mean number /M^2: 8648.50 S.D. /M^2: 1446.27

H' = 1.71 SDV = 0.60 SR = 0.94 J = 0.54

Station no: 20124 Date: 2 Sep 88 Sample size: 6

Taxa	Total number	Frequency occurr (%)	Mean number /M^2	Standard deviation /M^2
Nemertea	536	83.33	938.00	1091.49
Polychaeta	1	16.67	1.75	4.29
Oligochaeta	2970	100.00	5197.50	5883.04
Hirudinea	7	16.67	12.25	30.01
Hydrobiidae	1554	100.00	2719.50	3652.19
Corbicula manilensis	1809	100.00	3165.75	1792.96
Sphaeriidae	311	83.33	544.25	685.95
Ostracoda	2	16.67	3.50	8.57
Corophium spp.	1411	100.00	2469.25	2017.64
Chironomidae larvae	1	16.67	1.75	4.29

Number of taxa = 10.

Mean number per sample: 1433.67 Standard deviation: 1197.87
Mean number /M^2: 15053.50 S.D. /M^2: 12577.59

H' = 2.31 SDV = 0.77 SR = 0.99 J = 0.70

Station no: 20244 Date: 2 May 88 Sample size: 6

Taxa	Total number	Frequency occurr (%)	Mean number $/M^2$	Standard deviation $/M^2$
Nemertea	4	33.33	7.00	12.72
Hydra sp.	1	16.67	1.75	4.29
Oligochaeta	77	83.33	134.75	192.29
Hydrobiidae	1	16.67	1.75	4.29
Corbicula manilensis	1623	100.00	2840.25	2823.68
Sphaeriidae	335	16.67	586.25	1436.01
Neomysis spp.	1	16.67	1.75	4.29
Corophium spp.	63	100.00	100.25	95.95
Cyclopoida	2	16.67	3.50	8.57
Chironomidae larvae	5	33.33	8.75	16.82
Trichoptera larvae	1	16.67	1.75	4.29

Number of taxa = 11.

Mean number per sample: 352.17 Standard deviation: 216.89
Mean number $/M^2$: 3697.75 S.D. $/M^2$: 2277.39

H' = 1.11 SDV = 0.38 SR = 1.31 J = 0.32

Station no: 20244 Date: 2 Sep 88 Sample size: 6

Taxa	Total number	Frequency occurr (%)	Mean number $/M^2$	Standard deviation $/M^2$
Nemertea	96	100.00	168.00	187.01
Hydra sp.	2	16.67	3.50	8.57
Polychaeta	2	33.33	3.50	5.42
Oligochaeta	158	83.33	276.50	382.91
Gastropoda	2	16.67	3.50	8.57
Hydrobiidae	161	83.33	281.75	578.91
Corbicula manilensis	3013	100.00	5272.75	8222.08
Sphaeriidae	50	33.33	87.50	209.23
Ostracoda	1	16.67	1.75	4.29
Gammaridae amphipoda	7	33.33	12.25	21.43
Corophium spp.	1090	100.00	1907.50	2366.30
Cyclopoida	8	33.33	14.00	21.69
Chironomidae larvae	7	33.33	12.25	25.21
Plecoptera	1	16.67	1.75	4.29

Number of taxa = 14.

Mean number per sample: 766.33 Standard deviation: 1065.19
Mean number $/M^2$: 8046.50 S.D. $/M^2$: 11184.51

H' = 1.48 SDV = 0.51 SR = 1.54 J = 0.39

Station no: 20531 Date: 2 May 88 Sample size: 6

Taxa	Total number	Frequency occurr (%)	Mean number /M^2	Standard deviation /M^2
Nemertea	80	100.00	140.00	127.68
Oligochaeta	1310	100.00	2292.50	1051.00
Gastropoda	4	16.67	7.00	17.15
Hydrobiidae	83	50.00	145.25	210.67
Corbicula manilensis	233	100.00	407.75	304.86
Ostracoda	35	83.33	61.25	57.67
Corophium spp.	1739	100.00	3043.25	1137.21
Bosmina longirostris	3	16.67	5.25	12.86
Daphnia spp.	1	16.67	1.75	4.29
Cyclopoida	1	16.67	1.75	4.29
Chironomidae larvae	4	33.33	7.00	12.72

Number of taxa = 11.

Mean number per sample: 582.17 Standard deviation: 106.15
Mean number /M^2: 6112.75 S.D. /M^2 1114.57

H' = 1.65 SDV = 0.61 SR = 1.23 J = 0.48

Station no: 20531 Date: 2 Sep 88 Sample size: 6

Taxa	Total number	Frequency occurr (%)	Mean number /M^2	Standard deviation /M^2
Nemertea	362	100.00	633.50	539.81
Nematoda	227	16.67	397.25	973.06
Polychaeta	12	83.33	21.00	16.27
Oligochaeta	2017	100.00	3529.75	2235.20
Gastropoda	625	50.00	1093.75	1923.51
Hydrobiidae	18	33.33	31.50	72.14
Corbicula manilensis	1657	100.00	2899.75	2707.57
Sphaeriidae	25	33.33	43.75	97.24
Ostracoda	6	33.33	10.50	16.27
Corophium spp.	1179	100.00	2063.25	1659.33
Chironomidae larva	2	16.67	3.50	8.57

Number of taxa = 11.

Mean number per sample: 1021.67 Standard deviation: 749.96
Mean number /M^2: 10727.50 S.D. /M^2: 7874.56

H' = 2.34 SDV = 0.77 SR = 1.15 J = 0.68

Station no: 21075   Date: 2 May 88   Sample size: 8

Taxa	Total number	Frequency occurr (%)	Mean number $/M^2$	Standard deviation $/M^2$
Nemertea	37	75.00	48.56	47.27
Turbellaria	1	12.50	1.31	3.71
Oligochaeta	2448	87.50	3213.00	2297.76
Hydrobiidae	3	25.00	3.94	7.81
Corbicula manilensis	595	100.00	780.94	646.78
Sphaeriidae	51	75.00	66.94	94.41
Ostracoda	4	50.00	5.25	5.61
Mysidacea	1	12.50	1.31	3.71
Neomysis spp.	1	12.50	1.31	3.71
Corophium spp.	297	75.00	389.81	459.79
Isopoda	1	12.00	1.31	3.71
Daphnia spp.	2	25.00	2.63	4.86
Cyclopoida	11	62.50	14.44	13.68
Chironomidae	14	12.50	18.38	51.97
Chironomidae larvae	315	87.50	413.44	358.49
Chironomidae pupae	5	25.00	6.56	12.47
Ephemeroptera	3	37.50	3.94	5.43
Hexagenia spp.	35	50.00	45.94	85.84
Hydracarina	16	50.00	21.00	34.60

Number of taxa = 19.

Mean number per sample: 480.00   Standard Deviation: 195.88
Mean number $/m^2$: 5040.00   S.D. $/M^2$: 2056.77

H' = 1.77   SDV = 0.56   SR = 2.18   J = 0.42

Station no: 21075   Date: 2 Sep 88   Sample size: 6

Taxa	Total number	Frequency occurr (%)	Mean number $/M^2$	Standard deviation $/M^2$
Nemertea	10	33.33	17.50	30.19
Turbellaria	3	16.67	5.25	12.86
Polychaeta	9	50.00	15.75	21.77
Oligochaeta	2469	100.00	4320.75	2584.49
Gastropoda	1	16.67	1.75	4.29
Corbicula manilensis	401	100.00	701.75	493.27
Sphaeriidae	23	33.33	40.25	93.54
Ostracoda	7	16.67	12.25	30.01
Corophium spp.	540	83.33	945.00	931.56
Cyclopoida	1	16.67	1.75	4.29
Chironomidae larvae	64	50.00	112.00	132.43
Chironomidae pupae	1	50.00	1.75	4.29
Ephemeroptera	1	16.67	1.75	4.29
Ephemeroptera larvae	15	50.00	26.25	45.41

Number of taxa = 14.

Mean number per sample: 590.83   Standard deviation: 312.47
Mean number $/M^2$: 6203.75   S.D. $/M^2$: 3280.99

H' = 1.40   SDV = 0.48   SR = 1.59   J = 0.37

APPENDIX C-4

Mean and range in fork length (FL) for white sturgeon ages I-VII captured with trawls from The Dalles Pool (N = 269), Bonneville Pool (N = 248) and from below Bonneville Dam (N = 174). Anterior pectoral spines from white sturgeon captured below Bonneville Dam were provided by NMFS.

The Dalles Pool	Age I	II	III	IV	V	VI	VII
Mean FL	-	366	414	474	558	629	685
Range	-	265-488	323-588	338-599	402-685	551-785	589-780
N	0	119	84	45	15	4	2

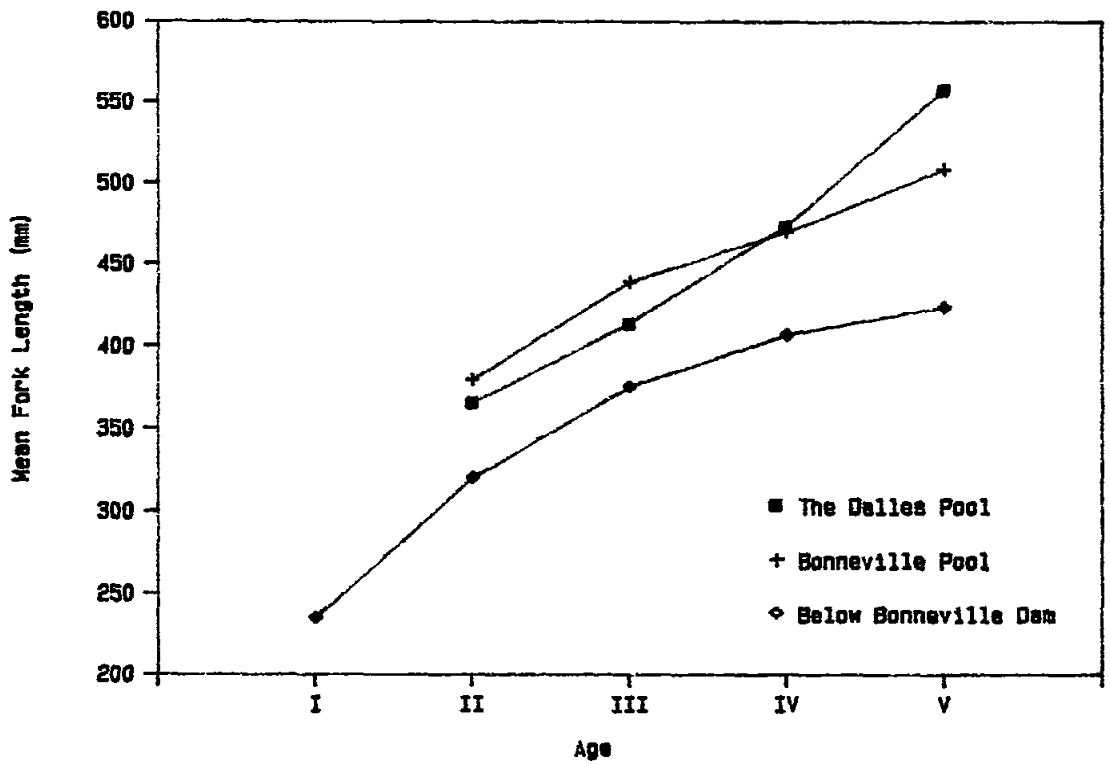
Bonneville Pool	Age I	II	III	IV	V	VI	VII
Mean FL	-	380	439	470	509	554	586
Range	-	315-475	360-543	397-554	372-604	427-714	477-745
N	0	61	44	84	32	18	9

Below Bonneville Dam	Age I	II	III	IV	V	VI	VII
Mean FL	235	320	376	407	424	438	483
Range	171-271	252-372	315-469	335-551	345-548	358-508	395-606
N	10	79	29	16	19	16	5

APPENDIX C-5

Relative (h) and instantaneous (G) population growth rates (Ricker 1975) for white sturgeon ages I-V captured with trawls from The Dalles Pool, Bonneville Pool and from below Below Bonneville Dam. Information used to calculate growth rates of white sturgeon below Bonneville Dam supplied by NMFS. Predicted weights were calculated from the weight-length relationship for each area.

Location	Age	Mean FL	Predicted Weight	h	G
The Dalles Pool	II	366	332		
				45	0.373
	III	414	482		
				53	0.430
	IV	474	741		
				64	0.494
	V	558	1215		
Bonneville Pool	II	380	376		
				55	0.435
	III	439	581		
				23	0.205
	IV	470	713		
				27	0.240
	V	509	906		
Below Bonneville	I	235	82		
				161	0.960
	II	320	214		
				65	0.503
	III	376	354		
				28	0.247
	IV	407	453		
				13	0.126
	V	424	514		



APPENDIX C-6. Mean fork length at age for younger ages of sturgeon captured in The Dalles Pool, Bonneville Pool, and below Bonneville Dam during 1988.

REPORT D

1. Description of reproduction and early life history characteristics of white sturgeon populations in the Columbia River downstream from Bonneville Dam.

2. Definition of habitat requirements for spawning and rearing of white sturgeon and quantification of extent of habitat available in the Columbia River downstream from Bonneville Dam.

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We thank Robert Emmett for writing or modifying computer programs for data entry and analysis. Lawrence Davis, Maurice Laird, and Roy Pettit assisted in the field sampling. The Washington Department of Fisheries provided summaries of the egg and larval sampling efforts. Some of the water discharge data for Bonneville Dam was provided by the Fish Passage Center.

ABSTRACT

During 1988, the National Marine Fisheries Service (NMFS) sampled white sturgeon *Acipenser transmontanus* eggs, larvae, and juveniles in the Columbia River downstream from Bonneville Dam. In conjunction with the Washington Department of Fisheries, 1,404 white sturgeon eggs were collected with plankton nets and artificial substrates between River Miles (RMs) 140 and 145. White sturgeon eggs were first collected with plankton nets on 25 April near Ives Island (RM 143) and at RM 144, and last collected in plankton nets on 20 June at RM 140 and near Ives Island. The sampling site near Ives Island was used as an index area to monitor white sturgeon spawning throughout the season. Stage 2 (freshly fertilized) eggs were collected on all sampling days that eggs were collected near Ives Island, indicating that spawning was occurring throughout the spring. Between 25 April and 20 June, white sturgeon egg densities near Ives Island (in plankton nets) averaged 10.22 eggs/1,000 m^3 of water sampled, with highest densities on 5 and 10 May (16.28 eggs/1,000 m^3 and 35.91 eggs/1,000 m^3, respectively). A total of 90 white sturgeon larvae were collected in plankton nets between RMs 113 and 144. Larvae were first collected on 5 May at RM 142 and near Ives Island, and last collected on 16 June at RM 140. Densities of larvae near Ives Island were low in 1988, ranging from 0.00 to 1.35 larvae/1,000 m^3. White sturgeon eggs were collected at bottom water temperatures ranging from 10 to 16°C, bottom water turbidities ranging from 2.6 to 6.5 NTU, water velocities (about 0.6 m above the bottom) ranging from 0.8 to 1.6 m/s, and water depths ranging from 3.0 to 21.3 m.

In 1988, a total of 2,633 juvenile white sturgeon were collected with trawls, primarily a 7.9-m (headrope length) semiballoon shrimp trawl, in the Columbia River downstream from Bonneville Dam. Most of the sampling for juvenile sturgeon was done in five index areas--RM 28, RMs 75-79, RMs 88-95, RM 114, and RMs 127-131--that were established as a result of 1987 research. Distributions of juvenile sturgeon were patchy; not only were there differences in catches among different areas of the river, but also differences in catches among parallel transects within the same area. Catches tended to be highest at RMs 95 and 131. The mean density of juvenile white sturgeon was highest at water depths (maximum) $\geq$18.3 m (167 $\pm$ 254 (SD) sturgeon/hectare) and lowest at depths <9.1 m (10 $\pm$ 16 sturgeon/hectare).

Since the white sturgeon is a demersal species, two benthic surveys were done in conjunction with the juvenile sampling to determine the relationships between sturgeon densities and the benthos (benthic invertebrates and the substrate). The relationship between white sturgeon densities and benthic invertebrate densities (total and individually important sturgeon prey taxa) was poor. The substrate in most of the sampling areas was primarily sand; like invertebrate densities, the relationship between white sturgeon densities and substrate texture was poor. The food of white sturgeon collected at RMs 95 and 131 was studied to determine the relationships between the benthic communities and sturgeon food. Stomach samples collected in May and June indicated that juvenile white sturgeon fed on organisms associated with the benthos; however, the relationship between primary prey items and densities of the organisms in the benthos was often poor. Overall, in May and June, the most important prey was the tube-dwelling amphipod *Corophium salmonis*. Other important prey included the bivalve *Corbicula manilensis* and eulachon *Thaleichthys pacificus* eggs.

A total of 1,494 juvenile white sturgeon were tagged with bird-banding

tags in 1988 and 35 tagged sturgeon were recaptured in NMFS trawls; 19 of the recaptures had been tagged by NMFS in 1987. About 91% of the tag recoveries were made in the same general area where the fish were originally tagged. Most of the tag recoveries were made at RM 131.

INTRODUCTION

Under the agreement with the Oregon Department of Fish and Wildlife (ODFW), the National Marine Fisheries Service (NMFS) is responsible for segments of Objectives 1 and 3 of the study. Objective 1 is to describe reproduction and early life history of white sturgeon populations, and Objective 3 is to define habitat requirements for all life stages of white sturgeon and to quantify available habitat. The NMFS's research is being done in the Columbia River downstream from Bonneville Dam--the Columbia River's only reach known to support all white sturgeon developmental stages in sufficient numbers to provide a control against which habitat availability and use between Bonneville and McNary dams can be compared. Also, under Objective 1, NMFS and the Washington Department of Fisheries (WDF) are attempting to determine the effect of variable flows at Bonneville Dam on the downstream displacement of white sturgeon eggs and larvae.

Specific research goals for 1988 were 1) to determine the spawning requirements of white sturgeon in the Columbia River downstream from Bonneville Dam; 2) to define the boundaries (based on substrate) of white sturgeon spawning areas in the Columbia River downstream from Bonneville Dam; 3) to determine the downstream distribution of white sturgeon larvae in the Columbia River downstream from Bonneville Dam; and 4) to determine the habitat requirements or preferences of juvenile white sturgeon in the Columbia River downstream from Bonneville Dam. This report describes progress on NMFS's studies from March 1988 to March 1989.

METHODS

Egg and Larval Sampling

In 1988, NMFS and WDF cooperatively sampled for white sturgeon eggs and larvae in the Columbia River downstream from Bonneville Dam. Sampling began in March and ended in August; generally, sampling was done either biweekly or weekly (during the spawning period). A D-ring type plankton net was used to collect white sturgeon eggs and larvae. The plankton net was 0.8 m wide at the bottom of the mouth opening and was constructed of 7.9-mesh/cm nylon marquisette netting (Kreitman 1983). Two lead weights (4.5 or 9.1 kg each) were attached to the net frame to hold the net on the river bottom. A digital flow meter (General Oceanics Model 2030[1]) was suspended in the mouth of the net to estimate the water volume sampled. Typically, two plankton nets were fished simultaneously for about 30 min from an anchored 12.2-m research vessel (Figure 1).

Artificial substrates constructed of latex-coated animal hair were also used to collect white sturgeon eggs. The substrates were cut into 76 X 91 cm sections and secured to an angle iron frame with strips of flat bar (Figure 2). The strips of flat bar were held in place with nuts and bolts, thus allowing fast removal of the substrate from the frame. Two sections of the artificial substrate were placed in each frame with the backs of each piece facing each other. Because two pieces were used in each frame, it made no

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

Figure 1. The 12.2-m research vessel used to collect physical and biological data in the Columbia River downstream from Bonneville Dam.

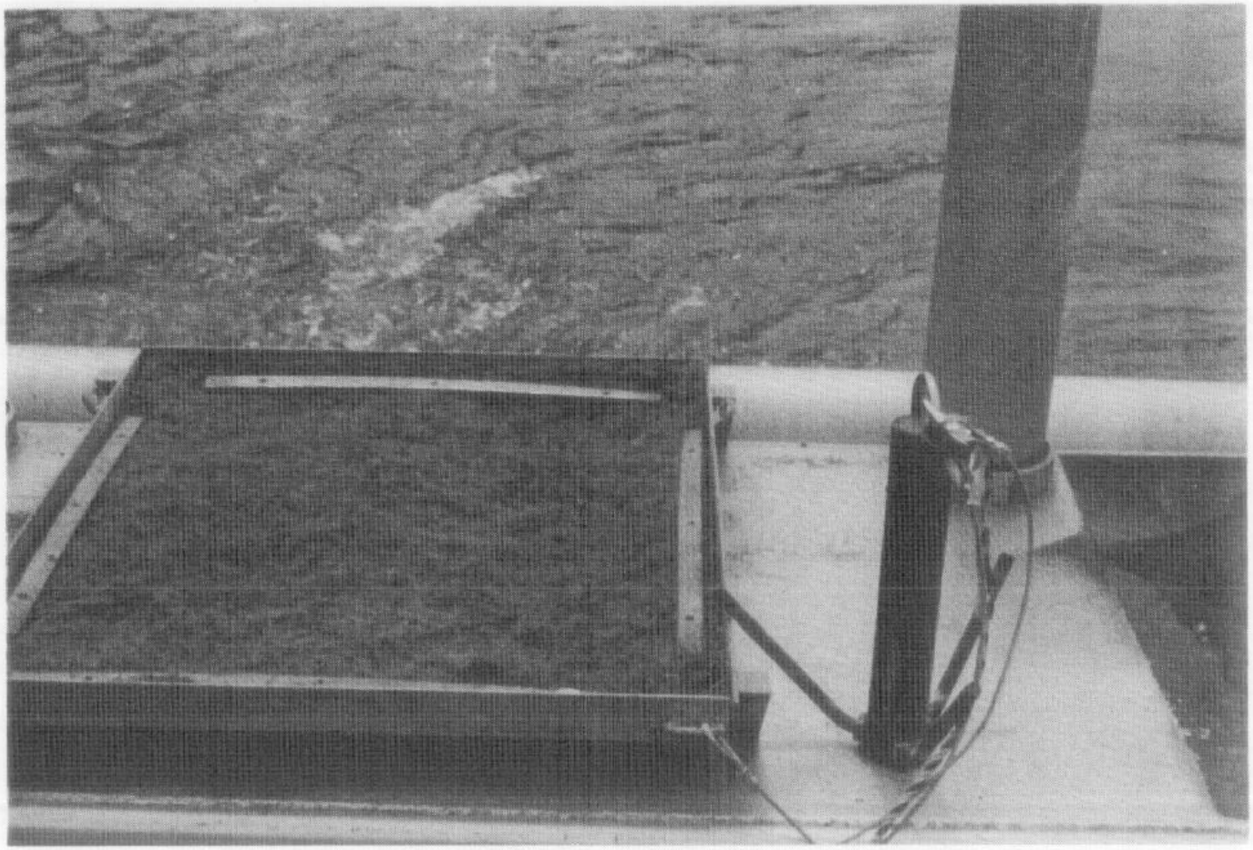

Figure 2. The artificial substrate used to collect white sturgeon eggs in the Columbia River downstream from Bonneville Dam; note anchor used to hold the substrate on the river bottom.

difference what side of the frame rested on the river bottom. Two short sections of cable were used to attach the frame to an anchor, which held the substrate in place on the bottom. A buoy line was attached to the anchor to allow retrieval of the substrate.

White sturgeon egg and larval sampling was done at various sites in the lower Columbia River from River Miles (RMs) 107 to 145 (Figure 3). Only the site near Ives Island (RM 143) was routinely sampled during the field season. The site near Ives Island, which has been routinely sampled in past years by WDF and NMFS, was considered an index area for monitoring white sturgeon spawning in the lower Columbia River. On 24 May, a team of NMFS scuba divers, using a diver sled (Swan 1989), attempted to examine the river bottom near Ives Island. In addition, a 12-h study using a plankton net was done at the Ives Island sampling site to determine if catches of white sturgeon and larvae changed during different light conditions. The 12-h study began at 1843 hours on 25 May and ended at 0623 hours on 26 May; one plankton net was normally fished for 1 h for each sampling effort. White sturgeon eggs and larvae were fixed in about a 4% buffered formaldehyde solution and transferred to WDF. Timing of egg deposition and hatching was estimated by WDF by examining the developmental stages of eggs and larvae. Some of the results from the egg and larval sampling are summarized by WDF in their annual report.

Juvenile Sampling

A 7.9-m (headrope length) semiballoon shrimp trawl, identical to the one used in 1987, was used to collect juvenile white sturgeon. 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. Infrequently, a 4.9-m semiballoon shrimp trawl was also used to sample for juvenile white sturgeon. Mesh size in the body of the 4.9-m trawl was 32 mm; a 10-mm mesh liner was inserted in the cod end of the net. Trawl efforts were normally 5 min in duration in an upstream direction. The trawling effort began when the trawl and the proper amount of cable were let out, and the effort was considered ended when 5 min elapsed. Using a radar range-finder, we estimated the distance the net fished during each sampling effort. Bottom trawling was done from late March through October. Trawling was done primarily in five index areas (RM 28, RMs 75-79, RMs 88-95, RM 114, and RMs 127-131) that were established as a result of 1987 research (Figure 3). The index sites were selected primarily to determine the habitat preferences or requirements of juvenile white sturgeon; no attempt was made to randomly select the sites. At RMs 75-79, trawling was done at RMs 75 and 79, and at RMs 88-95, trawling was done at RMs 88 and 95. Trawling at RMs 127-131 was done at RMs 127 and 131. At each RM, two or three trawling efforts were done 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. In certain river sections where only two transects were established, Transect 2 was closest to the Oregon shore. On 29 and 30 August, a 50-m variable mesh beach seine was used to sample backwaters and shoreline areas for juvenile white sturgeon. Mesh size in the seine ranged from 9.5 to 19.0 mm.

Fishes captured in the bottom trawls were identified and counted. Generally, all white sturgeon from a sampling effort were measured (natural total and fork lengths (mm)) and weighed (g). In instances when a large number of sturgeon was collected in a sampling effort, a subsample of at least

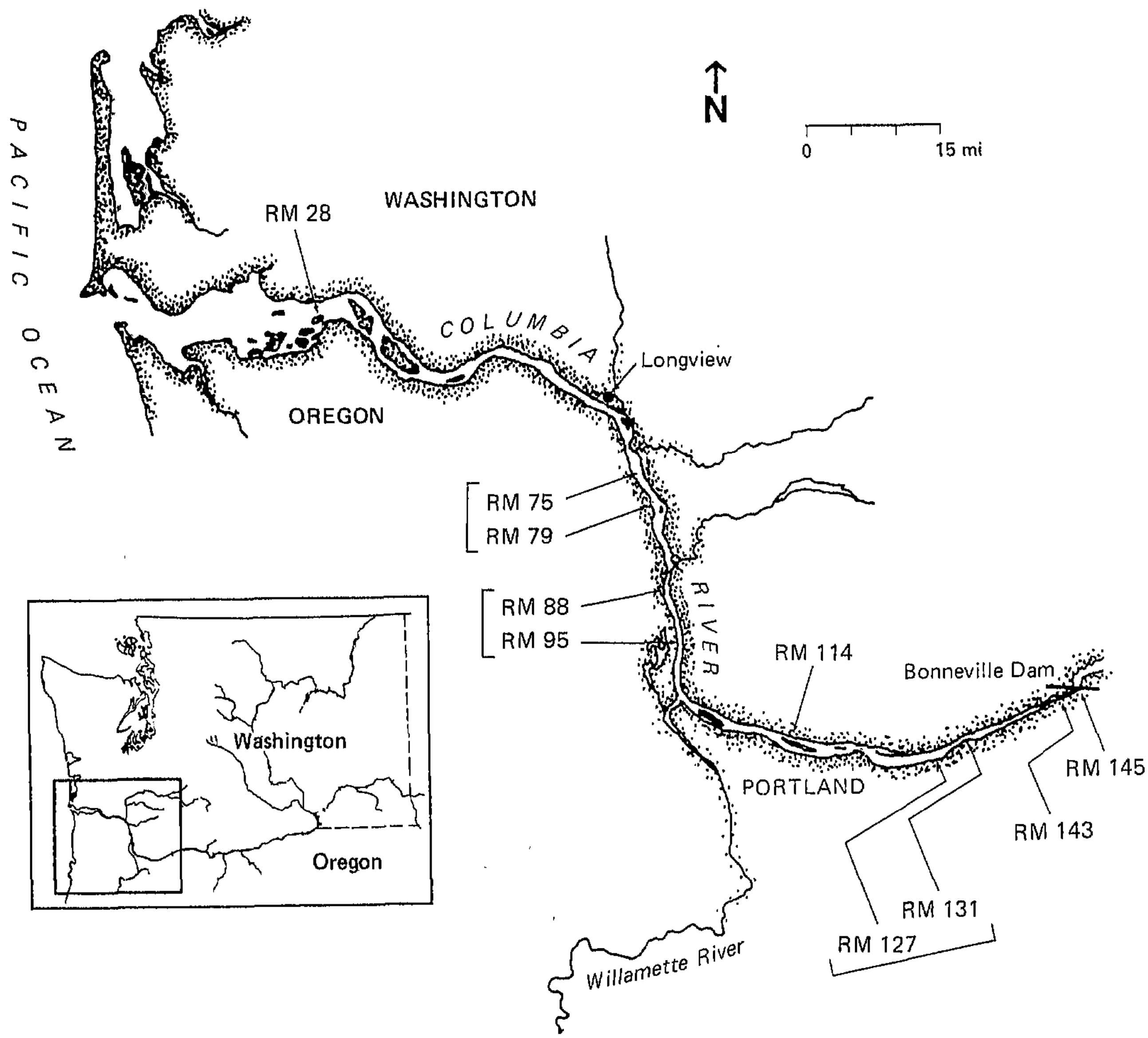

Figure 3. Lower Columbia River showing various white sturgeon sampling areas.

50 sturgeon was measured and weighed. White sturgeon were tagged to provide data on movement and growth. A bird-banding tag, constructed of monel metal, was placed around the anterior ray of the right pectoral fin. Also, we routinely examined juvenile white sturgeon for the nematode parasite *Cystoopsis acipenseri* (Chitwood and McIntosh 1950). When present, the parasite is contained in blister-like cysts under the skin. Throughout the field season, pectoral rays were removed from juvenile white sturgeon and given to the U.S. Fish and Wildlife Service (FWS) for age determinations. The anterior ray of the left pectoral fin was cut at or just distal to the fin articulation and removed from the fish.

Stomachs were collected from white sturgeon captured in two areas of the lower Columbia River (RM 95s and 131) to determine their food and the relationships between the benthic invertebrate communities and sturgeon food. The field season was divided into three time periods--1) May-June, 2) July-August, and 3) September-October. In each area, we tried to collect 25 stomachs from each of two size classes during each of the three time periods. The two size classes of sturgeon were 1) $\leq$350 mm fork length and 2) >350 mm fork length. Stomachs were removed from the sturgeon on board the sampling vessel and placed in individual vials containing a 7% buffered formaldehyde solution. The stomachs were later transferred to vials containing a 70% alcohol solution. Individual food items in each stomach were identified to the lowest practical taxonomic level, sorted, counted, and weighed to the nearest 0.0001 g.

Benthic Sampling

To help determine the habitat requirements or preferences of white sturgeon, benthic invertebrate and sediment samples were collected with a 0.1-m^2 Van Veen grab sampler (Word 1976, Figure 4) at the five index areas. Two benthic surveys were done in 1988--one in April and one in September. During each survey, a total of 240 grab samples were collected at 40 sampling stations. Five benthic invertebrate samples (replicates) and one sediment sample were collected at each sampling station; two stations were established along each bottom trawling transect--one near the beginning and the other near the end. When practical, each benthic invertebrate sample was sieved through a 0.5-mm screen and the residue preserved in a buffered formaldehyde solution ($\geq$4%) containing rose bengal, an organic stain. If it appeared that most of the material would not wash through the sieve, then the entire sample was preserved and sieved at a later time. Later the samples were washed with water and preserved in a 90% alcohol solution to prevent the destruction of calcareous invertebrate parts by formaldeyde. Each benthic invertebrate sample was sorted and the invertebrates were identified to the lowest practical taxonomic level and counted. Sediment samples were analyzed by the U.S. Army Corps of Engineers (North Pacific Division Materials Laboratory, Troutdale, Oregon) for sediment grain size and percent organic carbon (total volatile solids).

On 13 October, Van Veen grab samples were collected to determine the boundaries (based on substrate) of the white sturgeon spawning area downstream from Bonneville Dam. It was assumed that white sturgeon typically spawn in areas with a coarse sediment bottom (i.e., rock or cobble).

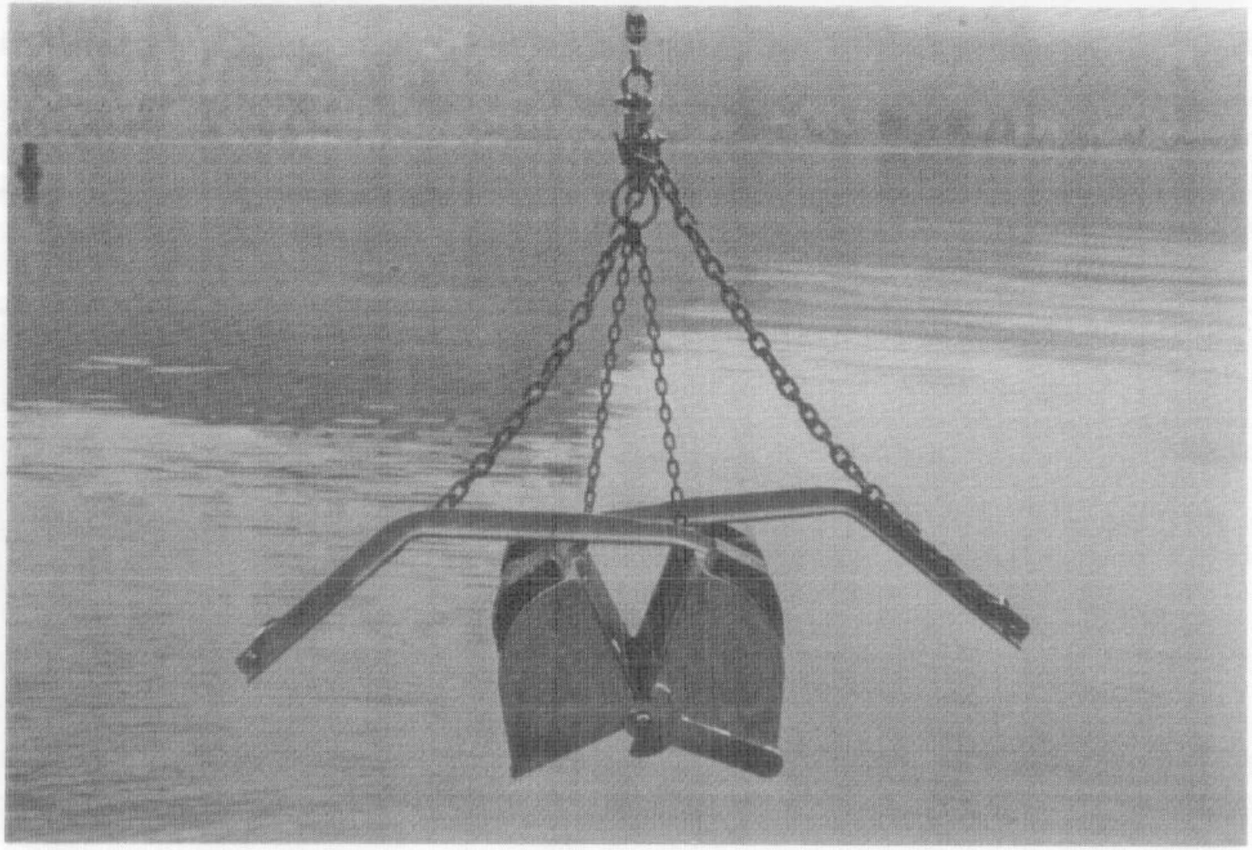

Figure 4. The 0.1-m² Van Veen grab sampler used to collect benthic samples in the Columbia River downstream from Bonneville Dam.

Physical Conditions

Various physical conditions, in addition to the sediment structure, were measured in conjunction with the biological sampling--depth (m) (minimum and maximum); bottom water temperature (°C); bottom water turbidity (NTU); and water velocities at 0.2 of the total depth, 0.8 of the total depth, and about 0.6 m above the bottom. By averaging the water velocities measured at 0.2 and 0.8 of the total depth, we calculated a mean water column velocity. Water velocities were routinely measured only during egg and larval sampling. Depth was measured with electronic depth sounders, and velocity was measured with a Gurley current meter that was attached to a 45.4-kg lead fish. Turbidity was determined in the laboratory using a Hach Model 2100A Turbidimeter.

Data Analyses

Physical and biological data collected during the season were entered into computer files following formats agreed to by the four agencies involved in the sturgeon study--FWS, ODFW, NMFS, and WDF. Various computer programs were used to analyze the data.

Using the distance fished during a trawl effort and the estimated fishing width of the net(s), we calculated the area fished for each effort. The fish densities (by species) for each effort were calculated and expressed as number/hectare (ha) (10,000 m^2). The estimated effective fishing widths of the 4.9- and 7.9-m semiballoon shrimp trawls were 3.3 and 5.3 m, respectively.

For data analysis, young-of-the-year (Y-O-Y) white sturgeon were separated from older juvenile sturgeon using length frequencies. For this report, a white sturgeon's birth date is assumed to be 1 January, although in reality the birth date is generally sometime later in the year.

Linear regression was used to compute the fork length-weight relationship for white sturgeon; the data were transformed ($\log_{10}$) prior to computing the relationship. A condition factor, C (Everhart and Youngs 1981), was computed for each white sturgeon using the formula:

$$C = (W/L^3) \times 10^5;$$

W = weight and L = length. Weight in grams and fork length in millimeters were used. A mean condition factor and standard deviation (SD) were calculated for all white sturgeon combined.

The relationship between white sturgeon density (number/ha) and depth was examined using linear regression. Sturgeon densities were transformed using $\log_{10}$ (number/ha + 1) prior to regression analysis. Also, densities of white sturgeon in three different depth ranges--$<$ 9.1, 9.1 to 18.2, and $\geq$18.3 m--were compared using the nonparametric Kruskal-Wallis test (Elliott 1977); the data were not transformed for this test.

Benthic invertebrate data were analyzed both by individual station and by combining various stations in an area. Output for each station(s) included the number of taxa, mean number/m^2 and a SD for each taxon, mean number of invertebrates/sample and SD, and total mean number of invertebrates/m^2 and SD.

The food of white sturgeon in each of two areas by time period was analyzed using two approaches. The importance of a prey taxon was determined using a modification of the Index of Relative Importance (IRI) described by Pinkas et al. (1971):

$$IRI = (N + W)\ F;$$

N = percent number of a prey item, W = percent weight of a prey item, and F = percent frequency of occurrence of a prey item. IRI values were then converted to percentages. To determine feeding intensity in each area, an Index of Feeding (IF) was calculated:

$$IF = \frac{Ws}{Wf} \times 100\%;$$

Ws = weight of stomach contents of a fish and Wf = weight of a fish.

RESULTS

Egg and Larval Sampling

In 1988, a total of 1,404 white sturgeon eggs were collected between RMs 140 and 145 (Table 1). Similar numbers of white sturgeon eggs were collected with plankton nets (n = 719) and artificial substrates (n = 685); however, one sampling effort with an artificial substrate in mid May yielded 423 white sturgeon eggs. White sturgeon eggs were first collected with plankton nets on 25 April near Ives Island (RM 143) and at RM 144. Eggs were last collected in plankton nets on 20 June at RM 140 and near Ives Island. The last eggs collected in 1988 were taken with an artificial substrate that was deployed near Ives Island on 20 June and retrieved on 23 June; however, 9 of the 16 eggs collected were either infected by fungi or had burst. None of the eggs collected on 23 June had been recently released (within a few hours).

The sampling site near Ives Island was used as an index area to monitor white sturgeon spawning during 1988 (Table 2). White sturgeon eggs were collected at this site on 8 of the 9 sampling days from 25 April (when eggs were first collected) to 20 June (when eggs were last collected). Stage 2 (freshly fertilized) eggs were collected on all sampling days that eggs were collected near Ives Island, indicating that spawning was occurring throughout the spring. Stage 2 eggs generally represented at least 30% of the eggs from an individual sampling effort. On 6 of the 8 days when eggs were collected, 53% or more of the eggs from individual sampling efforts were stage 2. Densities of white sturgeon eggs at Ives Island were highest on 5 and 10 May (16.28 eggs/1,000m^3 and 35.91 eggs/1,000m^3, respectively).

In 1988, a total of 90 white sturgeon larvae were collected in plankton nets between RMs 113 (I-205 Bridge) and 144 (Table 1). Larval sampling was done downstream from the I-205 Bridge; however, no larvae were collected in the downstream area. Larvae were first collected on 5 May at RM 142 and near Ives Island, and the last larvae were captured on 16 June at RM 140. Densities of larvae near Ives Island were low throughout the spring, ranging from 0.00 to 1.35 larvae/1,000 m^3 (Table 2).

Table 1. Numbers of white sturgeon eggs and larvae collected in the Columbia River downstream from Bonneville Dam, 1988; plankton nets and artificial substrates were used to collect eggs and plankton nets used to collect larvae. Fungus-infected eggs collected in plankton nets are shown in parentheses and are included in the numbers reported for the nets. Area refers to the geographic range in RMs.

Sampling period	Eggs			Larvae	
	Area (RMs)	Net	Substrate	Area (RMs)	Net
23 Mar-25 Apr	143-144	19	0	143-144	0
5-18 May	142-145	171 (1)	469	142-143	11
23-27 May	143-144	397 (10)[a]	116	120-144	71[b]
2-8 Jun	140-145	112 (5)	84	120-143	3
15-23 Jun	140-143	20 (1)	16	113-140	5
29 Jun-3 Aug	139-143	0	0	120-143	0
TOTAL		719 (17)	685		90

[a] *Includes 364 eggs collected during a 12-h study; see text for details.*
[b] *Includes 65 larvae collected during a 12-h study.*

Table 2. White sturgeon egg and larval catches near Ives Island (RM 143) in the Columbia River downstream from Bonneville Dam, 1988. Water temperatures were measured just above the bottom; Bonneville Dam flows were average hourly discharges (for each day). At least two plankton net samples were collected on each sampling day.

Date	Temp. (°C)	Velocity (m/s)		Bonneville Dam total discharge (1,000 m^3/s)	Eggs/ 1,000 m^3	Larvae/ 1,000 m^3
		Mean column	Bottom			
23 Mar	7	1.3	0.9	3.52	0.00	0.00
4 Apr	8	-	-	3.80	0.00	0.00
25 Apr	10	1.5	1.0	4.27	5.29	0.00
5 May	11	1.8	1.4	5.37	16.28	1.29
10 May	13	1.6	1.0	5.88	35.91	1.07
18 May	13	1.6	1.2	6.37	2.16	0.00
23 May	14	2.1	1.2	5.41	9.47	1.35
2 Jun	14	2.3	1.4	6.77	8.40	0.60
8 Jun	14	2.0	1.4	5.45	9.65	0.00
16 Jun	16	1.8	1.1	4.60	0.00	0.00
20 Jun	16	1.5	1.1	4.08	4.81	0.00
29 Jun	17	1.6	1.0	4.21	0.00	0.00
5 Jul	18	1.2	0.8	2.67	0.00	0.00
19 Jul	20	1.5	0.8	3.32	0.00	0.00
3 Aug	21	0.9	0.7	2.65	0.00	0.00

Results from the 12-h egg and larval study near Ives Island are presented in Table 3. Egg densities ranged from 1.40 eggs/1,000 m^3 (0340 to 0440 hours) to 40.06 eggs/1,000 m^3 (2206 to 2306 hours). Larval densities ranged from 0.00 larvae/1,000 m^3 (1951 to 2051 hours) to 4.62 larvae/1,000 m^3 (0553 to 0623 hours). Densities of eggs and larvae fluctuated throughout the 12-h study and did not follow any consistent pattern in relation to time of day (light or darkness) or Bonneville Dam discharge.

Examination of the river bottom near Ives Island by scuba divers on 24 May produced mixed results. Poor visibility in the river precluded viewing large areas of the bottom; however, the divers were able to collect a substrate sample. The substrate sample and their observations indicated that the bottom consisted of smooth cobble and rocks (about 65-300 mm in size) with smaller material ($\geq$5mm in size) and shells between the rocks.

Bottom water temperatures at sites where eggs were collected in plankton nets ranged from 10 to 16°C; bottom water turbidities ranged from 2.6 to 6.5 NTU; mean water column velocities ranged from 1.2 to 2.8 m/s; water velocities about 0.6 m above the bottom ranged from 0.8 to 1.6 m/s; and water depths ranged from 3.0 to 21.3 m. White sturgeon larvae were captured where bottom water temperatures ranged from 11 to 16°C; bottom water turbidities ranged from 3.4 to 6.5 NTU; mean water column velocities ranged from 1.1 to 2.3 m/s; water velocities about 0.6 m above the bottom ranged from 0.8 to 1.6 m/s; and water depths ranged from 4.3 to 20.4 m.

Artificial substrates placed downstream from the spillways at Bonneville Dam (at the boat deadline) collected 84 white sturgeon eggs, whereas artificial substrates placed downstream from the second powerhouse collected no white sturgeon eggs. Water velocities were not measured at these sites, but velocities appeared to be minimal downstream from the second powerhouse when the substrate was deployed and retrieved. Water velocities downstream from the spillways were relatively high when the spillways were being used.

Juvenile Sampling

Abundance and Distribution

In 1988, a total of 2,633 juvenile white sturgeon were collected with trawls in the Columbia River downstream from Bonneville Dam; the total includes 76 juvenile white sturgeon collected in conjunction with FWS during cooperative sampling. A total of 2,541 sturgeon were collected with the 7.9-m semiballoon shrimp trawl. No white sturgeon were collected with the beach seine. Distributions of juvenile white sturgeon in the Columbia River downstream from Bonneville Dam were patchy. Not only were there differences in catches among different areas of the river, but also differences in catches among parallel transects within the same area (Figure 5). Consistently, catches tended to be highest at RMs 95 and 131. The highest individual catches of the study were made at RM 131--182 juvenile white sturgeon (1,090/ha), 240 juvenile white sturgeon (1,164/ha), and 210 juvenile white sturgeon (822/ha) in March, September, and October, respectively.

Table 3. Summary of white sturgeon egg and larval collections during a 12-h study near Ives Island (RM 143) in the Columbia River downstream from Bonneville Dam. Sampling was done from 1843 hours on 25 May to 0623 hours on 26 May 1988 using a plankton net. Total discharge from Bonneville Dam was estimated by averaging hourly total discharges (two or three).

Sampling times (hours)	Bonneville Dam total discharge (1,000 m^3/s)	Eggs		Larvae	
		No.	No./1,000 m^3	No.	No./1,000 m^3
1843-1943	7.48	19	7.12	9	3.37
1951-2051[a]	7.00	11	4.37	0	0.00
2100-2200	6.51	9	3.16	5	1.76
2206-2306	6.48	114	40.06	7	2.46
2314-0014	6.49	21	7.35	9	3.16
0020-0120	6.53	38	13.47	9	3.19
0128-0228	6.67	53	17.94	3	1.02
0234-0334	6.77	11	3.86	7	2.46
0340-0440	6.76	4	1.40	8	2.80
0445-0545	6.77	58	19.65	1	0.34
0553-0623	6.81	26	17.15	7	4.62

[a] *Questionable sampling effort, net was damaged.*

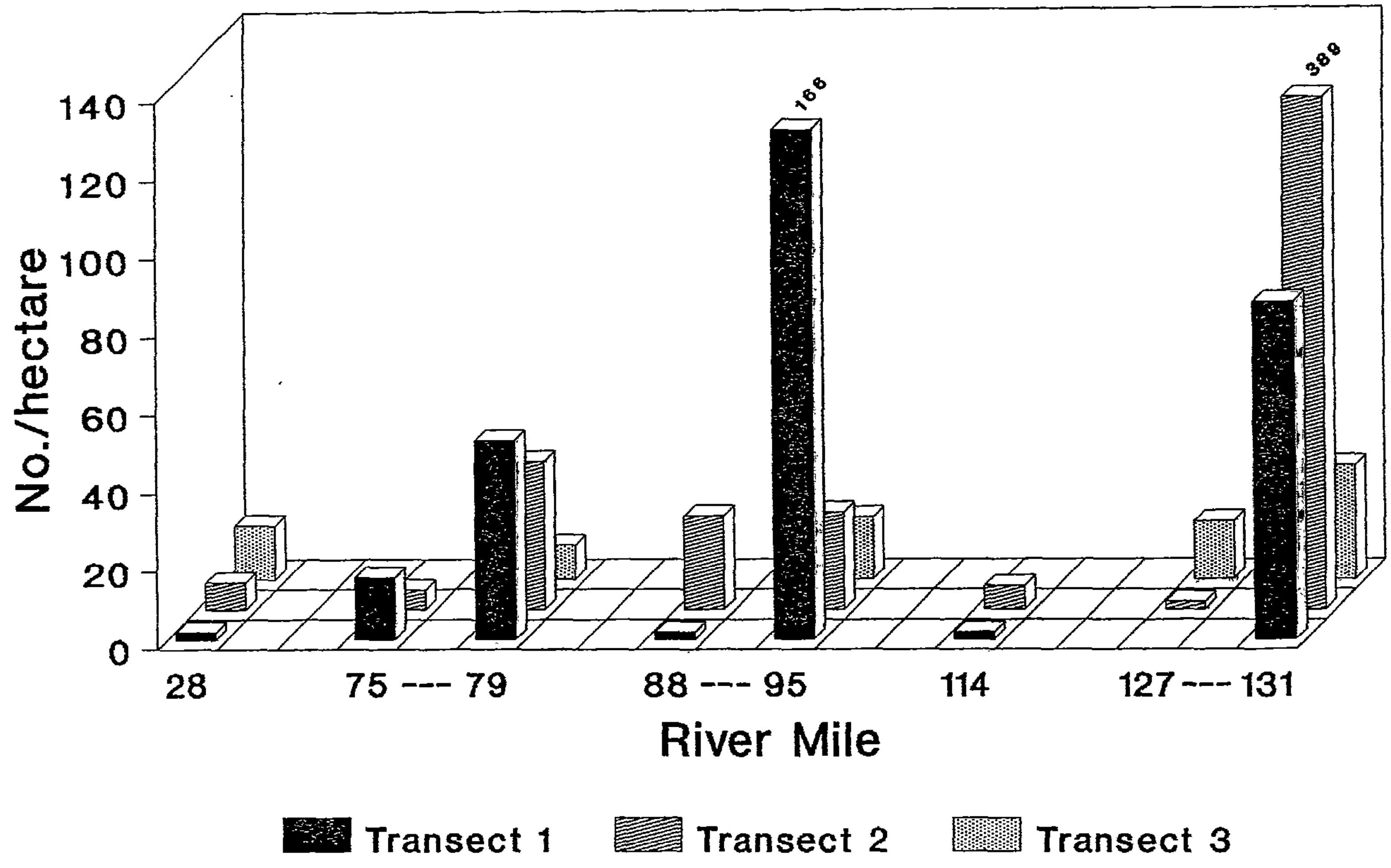

Figure 5. Estimated mean densities of juvenile white sturgeon at five index areas in the Columbia River downstream from Bonneville Dam, 1988.

Size-Class Structure

The monthly size ranges of white sturgeon captured in 1988 were similar, but the proportional abundances of various size groups changed (Figure 6). The Y-O-Y white sturgeon were first captured in July and were captured monthly through October, although catches were low (n = 11 for entire year). In general, the Y-O-Y group is the only age group that is easily discernible in the histograms, as there is considerable overlap in the lengths of the older age groups.

Species Associations

Juvenile white sturgeon were commonly captured with juvenile chinook salmon *Oncorhynchus tshawytscha*, peamouth *Mylocheilus caurinus*, northern squawfish *Ptychocheilus oregonensis*, leopard dace *Rhinichthys falcatus*, largescale sucker *Catostomus macrocheilus*, sand roller *Percopsis transmontana*, and sculpins (Cottidae) (Appendix D-1).

Tagging

A total of 1,494 juvenile white sturgeon were tagged in 1988 and 35 tagged sturgeon were recaptured in NMFS trawls (Table 4); 19 of the recaptures had been tagged by NMFS in 1987. Additional tagged fish were recovered by sport fishermen, but accurate lengths were not available. About 91% of the tag recoveries were made in the same general area where the fish were originally tagged. Most of the tag recoveries were made at RM 131; recaptures from this area frequently showed very slow or negative growth. Tag loss was noted on four white sturgeon that had been previously tagged.

Parasites

In 1988, a total of 1,824 juvenile white sturgeon were examined for the nematode parasite *Cystoopsis acipenseri*, and of this number, 148 (8%) were infected. The mean fork length of the infected fish was 326 mm, with a range from 252 to 433 mm; 147 of the infected fish were less than 400 mm long. The condition factor of infected fish was 0.6461 ± 0.0634, and the condition factor for non-infected sturgeon in the same length range was 0.6486 ± 0.0678.

Body Measurements and Conditon Factor

The regression equation for the length-weight relationship of juvenile white sturgeon was--$\log_{10}$weight (g) = -5.46 + 3.11 ($\log_{10}$fork length, mm); N = 1,824; $r^2 = 0.968$. The mean condition factor of 1,824 juvenile white sturgeon was 0.6562 ± 0.0689.

Physical Conditions

Sampling for juvenile white sturgeon with the 7.9-m trawl was done in depths ranging from 3.7 to 22.6 m. Minimum and maximum depths were poor predictors of juvenile white sturgeon densities (number/ha); less than 16% of

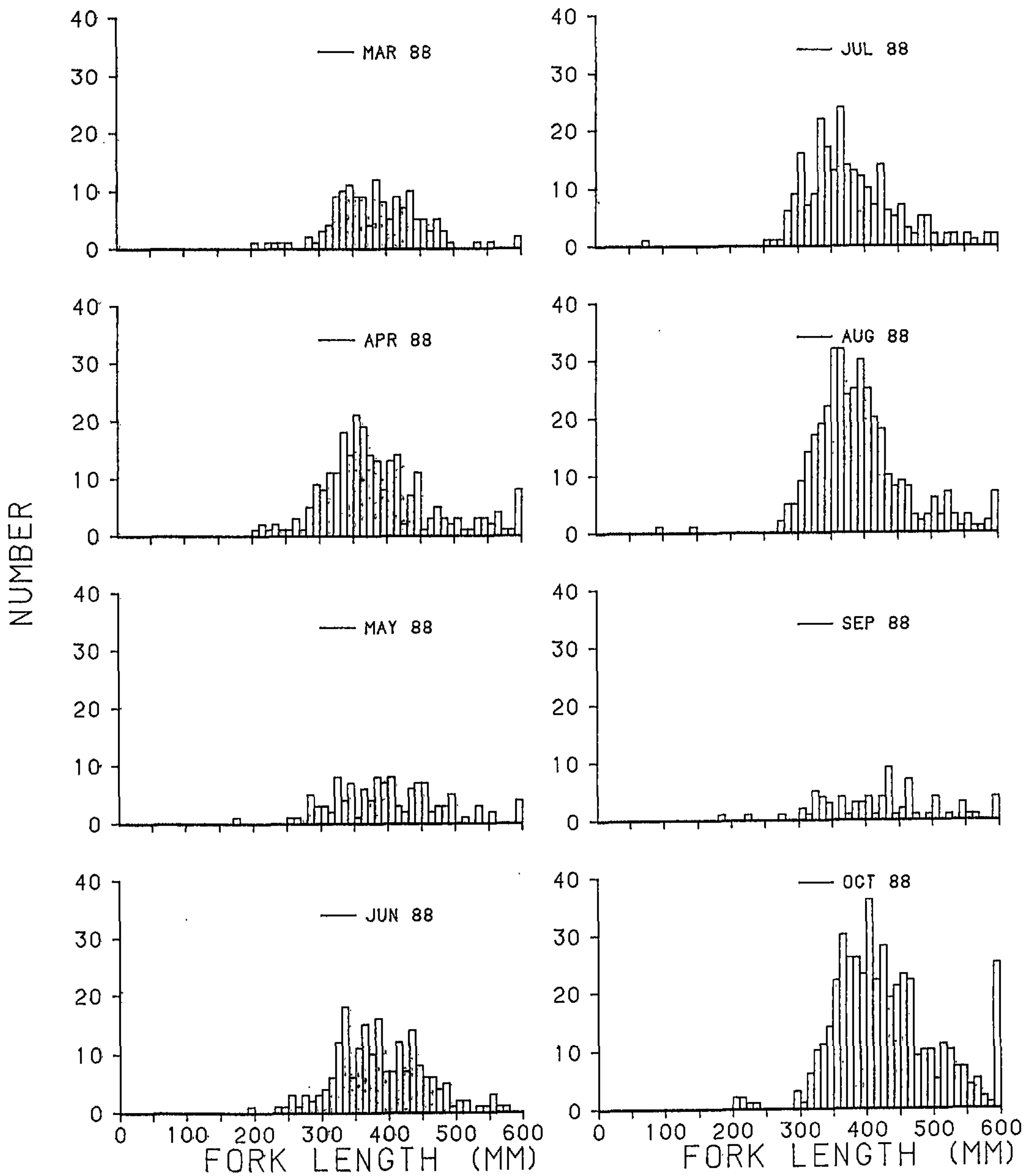

Figure 6. Length-frequency histograms for juvenile white sturgeon collected in the Columbia River downstream from Bonneville Dam, 1988. Sturgeon longer than 600 mm are included in the 600-mm interval.

Table 4. Recoveries (in 1988) of juvenile white sturgeon tagged in the Columbia River downstream from Bonneville Dam, 1987-88.

Location (RM)		Days at large	Change in fork length (mm)	Change in weight (g)
Tagged	Recaptured			
95	131	44	-4	-46
95	95	75	27	145
95	95	125	9	29
95	95	273	11	66
95	95	398	9	37
101	131	231	6	122
114	114	55	7	20
127	127	386	40	285
130	130	42	6	6
131	131	14	0	-8
131	131	14	1	-13
131	131	15	0	7
131	131	15	-1	-15
131	131	15	-11	-7
131	131	42	0	-4
131	131	43	-3	-73
131	131	58	1	14
131	131	103	7	28
131	131	116	3	21
131	131	147	17	46
131	131	237	-5	-38
131	131	243	-3	-24
131	131	251	3	16
131	131	252	-3	-10
131	131	254	-1	76
131	127	279	0	3
131	131	341	1	2
131	131	351	4	13
131	131	384	-22	-12
131	131	397	-33	-102
131	131	399	21	88
131	131	412	4	5
131	131	412	9	44
131	131	428	9	3
131	131	456	13	30

the variation was attributed to either the minimum or maximum depth. However, there was a significant difference in sturgeon densities when depths were separated into three ranges (maximum depth): <9.1, 9.1 to 18.2, and ≥18.3 m (Kruskal-Wallis, $P < 0.01$). The mean density was highest at depths ≥18.3 m (167 ± 254 sturgeon/ha) and lowest at depths <9.1 m (10 ± 16 sturgeon/ha); at depths from 9.1 to 18.2 m, the mean density was 23 ± 39 sturgeon/ha. Bottom water temperatures during juvenile white sturgeon sampling (7.9-m trawl samples) ranged from 6 to 22 °C.

Benthic Sampling

Benthic invertebrate densities varied temporally and spatially (Tables 5-9, Appendix D-2) in the Columbia River downstream from Bonneville Dam; eulachon (*Thaleichthys pacificus*) eggs are included in the tables because of their importance in the diet of white sturgeon (see stomach analysis section). When large numbers of eulachon eggs occurred in samples, their numbers were estimated. Densities varied among areas and among transects within the same RM. Mean densities (area totals) at areas RM 28 and RMs 75-79 were higher during Survey 2 than during Survey 1. If eulachon eggs are excluded, mean benthic invertebrate densities (area totals) for all of the areas, except the area from RM 88 to 95, were higher for Survey 2 than Survey 1. Major invertebrate taxa collected during the surveys included Turbellaria, Oligochaeta, *Corbicula manilensis, Corophium salmonis,* and Heleidae larvae. The relationship between white sturgeon densities and benthic invertebrate densities (total and individually important sturgeon prey taxa) was poor (Table 10).

Results from the sediment analysis indicated that the substrate in most of the sampling areas consisted primarily of sand (Table 11, Appendix D-3), although gravel and fines were also important at some stations. The substrate along some of the individual transects varied as indicated by the ranges shown in Table 11, and at some transects the substrate varied from Survey 1 to Survey 2. Organic matter at all stations was ≤3%. Like invertebrate densities, the relationship between white sturgeon densities and sediment structure was poor.

Samples collected with the Van Veen grab downstream from Bonneville Dam on 13 October indicated that at least part of the bottom substrate consisted of some cobble (≥64 mm) to locations about 6.7 miles downstream from the dam. Based on the substrate samples and assuming that white sturgeon typically spawn in areas with a coarse sediment bottom, it would appear that this is the lower boundary of the white sturgeon spawning area downstream from Bonneville Dam (if water velocities were appropriate for spawning). Substrate samples collected near the northern lower end of Bradford Island (Bonneville Dam) indicated a clay bottom, whereas farther upstream the bottom was rocky.

Stomach Contents Analysis

A total of 292 white sturgeon stomachs were collected from two areas of the lower Columbia River (RMs 95 and 131). One hundred stomachs collected during May and June were analyzed for this report. A detailed analysis of the stomachs collected in May and June, along with the analyses of the other stomachs will be presented in next year's annual report. At RM 95, the tube-

Table 5. Mean densities (no./m²) and standard deviations (SD) of major taxa collected during two benthic invertebrate surveys in the Columbia River downstream from Bonneville Dam (RM 28); Survey 1 was done in April 1988 and Survey 2 in September 1988. The total for each transect includes both major taxa and less important taxa not shown.

RM-transect	Taxon	Survey 1		Survey 2	
		Mean	SD	Mean	SD
28-1	Turbellaria	71	± 76	10	± 10
	Corbicula manilensis	34	± 33	195	± 296
	Corophium salmonis	63	± 73	690	± 638
	Heleidae larvae	190	± 208	2,220	± 1,683
	TOTAL	396	± 312	3,148	± 2,052
28-2	*Corbicula manilensis*	100	± 65	118	± 145
	Corophium salmonis	7,503	± 9,585	1,730	± 1,124
	Heleidae larvae	178	± 277	841	± 527
	TOTAL	7,931	± 9,447	2,764	± 1,617
28-3	*Neanthes limnicola*	19	± 43	140	± 88
	Oligochaeta	128	± 52	363	± 286
	Fluminicola spp.	277	± 329	568	± 439
	Lithoglyphys virens	81	± 148	0	± 0
	Corbicula manilensis	643	± 582	267	± 272
	Corophium spp.	0	± 0	86	± 222
	Corophium salmonis	1,194	± 662	5,212	± 763
	Heleidae larvae	195	± 163	35	± 41
	TOTAL	2,617	± 1,403	6,738	± 1,335
	AREA TOTAL[a]	3,500	± 6,016	4,216	±2,446

[a] *The mean density is the average of all samples taken in the area.*

Table 6. Mean densities (no./m²) and standard deviations (SD) of major taxa collected during two benthic invertebrate surveys in the Columbia River downstream from Bonneville Dam (RMs 75 to 79); Survey 1 was done in April 1988 and Survey 2 in September 1988. The total for each transect includes both major taxa and less important taxa not shown.

RM-transect	Taxon	Survey 1 Mean		Survey 1 SD	Survey 2 Mean		Survey 2 SD
75-1	Turbellaria	63	±	96	4	±	10
	Oligochaeta	111	±	151	249	±	202
	Corbicula manilensis	3	±	5	678	±	589
	Heleidae larvae	193	±	132	1,364	±	1,147
	Eulachon eggs	92	±	238	0	±	0
	TOTAL	497	±	265	2,338	±	1,829
75-2	*Corbicula manilensis*	131	±	159	417	±	526
	Corophium salmonis	99	±	123	78	±	108
	Heleidae larvae	141	±	158	870	±	1,147
	TOTAL	472	±	414	1,408	±	1,626
79-1	Turbellaria	104	±	145	6	±	11
	Oligochaeta	101	±	111	1,031	±	586
	Corbicula manilensis	4	±	7	612	±	973
	Corophium salmonis	2	±	4	56	±	61
	Heleidae larvae	244	±	214	606	±	417
	Eulachon eggs	60	±	103	0	±	0
	TOTAL	522	±	375	2,326	±	1,741
79-2	*Corbicula manilensis*	123	±	150	77	±	97
	Heleidae larvae	230	±	194	391	±	471
	Eulachon eggs	122	±	312	0	±	0
	TOTAL	513	±	547	517	±	573
79-3	*Corbicula manilensis*	400	±	293	407	±	226
	Corophium salmonis	85	±	36	360	±	150
	Heleidae larvae	77	±	82	39	±	33
	TOTAL	600	±	329	812	±	338
	AREA TOTAL[a]	521	±	383	1,480	±	1,522

[a] *The mean density is the average of all samples taken in the area.*

Table 7. Mean densities (no./m²) and standard deviations (SD) of major taxa collected during two benthic invertebrate surveys in the Columbia River downstream from Bonneville Dam (RMs 88 to 95); Survey 1 was done in April 1988 and Survey 2 in September 1988. The total for each transect includes both major taxa and less important taxa not shown.

RM-transect	Taxon	Survey 1			Survey 2		
		Mean		SD	Mean		SD
88-1	Oligochaeta	248	±	606	96	±	72
	Corbicula manilensis	202	±	122	242	±	348
	Corophium salmonis	264	±	263	19	±	21
	Heleidae larvae	427	±	252	474	±	389
	Eulachon eggs	70	±	154	0	±	0
	TOTAL	1,240	±	615	839	±	738
88-2	Turbellaria	228	±	174	2	±	4
	Oligochaeta	91	±	121	14	±	12
	Corbicula manilensis	250	+	172	526	±	476
	Heleidae larvae	1,023	±	782	264	±	134
	Eulachon eggs	80	±	176	0	±	0
	TOTAL	1,700	±	944	820	±	478
95-1	Oligochaeta	462	±	507	2,110	±	796
	Corbicula manilensis	1,367	±	1,660	244	±	175
	Heleidae larvae	731	±	1,249	492	±	350
	Eulachon eggs	153,352	±	37,978	0	±	0
	TOTAL	155,976	±	117,960	2,865	±	1,092
95-2	*Corbicula manilensis*	586	±	605	44	±	41
	Heleidae larvae	1,072	±	622	226	±	200
	TOTAL	1,827	±	1,197	299	±	236
95-3	*Corbicula manilensis*	488	±	422	78	±	139
	Corophium salmonis	444	±	325	622	±	299
	Chironomidae larvae	89	±	102	0	±	0
	Heleidae larvae	167	±	178	9	±	17
	TOTAL	1,311	±	913	715	±	431
	AREA TOTAL[a]	33,707	±	81,750	1,108	±	1,110

[a] *The mean density is the average of all samples taken in the area.*

Table 8. Mean densities (no./m^2) and standard deviations (SD) of major taxa collected during two benthic invertebrate surveys in the Columbia River downstream from Bonneville Dam (RM 114); Survey 1 was done in April 1988 and Survey 2 in September 1988. The total for each transect includes both major taxa and less important taxa not shown.

RM-transect	Taxon	Survey 1		Survey 2	
		Mean	SD	Mean	SD
114-1	*Corbicula manilensis*	230	± 167	333	± 242
	Chironomidae larvae	7	± 14	66	± 89
	Heleidae larvae	275	± 136	1,134	± 1,182
	Eulachon eggs	1,937	± 2,745	0	± 0
	TOTAL	2,461	± 2,874	1,620	± 1,391
114-2	*Corbicula manilensis*	201	± 179	754	± 717
	Corophium salmonis	10	± 10	78	± 80
	Heleidae larvae	801	± 982	887	± 1,000
	TOTAL	1,059	± 1,169	1,787	± 1,616
	AREA TOTAL[a]	1,760	± 2,253	1,704	± 1,470

[a] *The mean density is the average of all samples taken in the area.*

Table 9. Mean densities (no./m²) and standard deviations (SD) of major taxa collected during two benthic invertebrate surveys in the Columbia River downstream from Bonneville Dam (RMs 127 to 131); Survey 1 was done in April 1988 and Survey 2 in September 1988. The total for each transect includes both major taxa and less important taxa not shown.

RM-transect	Taxon	Survey 1 Mean		Survey 1 SD	Survey 2 Mean		Survey 2 SD
127-2	*Corbicula manilensis*	48	±	61	64	±	94
	Heleidae larvae	68	±	64	44	±	40
	TOTAL	193	±	125	121	±	94
127-3	*Corbicula manilensis*	653	±	756	783	±	635
	Chironomidae larvae	85	±	228	2	±	4
	Heleidae larvae	99	±	32	1,218	±	1,035
	Eulachon eggs	349	±	547	0	±	0
	TOTAL	1,221	±	1,044	2,057	±	1,579
131-1	Oligochaeta	15	±	28	89	±	57
	Corbicula manilensis	1,381	±	981	546	±	422
	Heleidae larvae	880	±	581	570	±	324
	Eulachon eggs	10,128	±	16,277	0	±	0
	TOTAL	12,474	±	16,010	1,273	±	634
131-2	Turbellaria	76	±	148	8	±	14
	Corbicula manilensis	621	±	1,037	284	±	289
	Heleidae larvae	343	±	533	502	±	440
	TOTAL	1,128	±	1,385	850	±	661
131-3	Oligochaeta	463	±	244	716	±	737
	Corbicula manilensis	255	±	247	80	±	57
	Ostracoda	67	±	107	5	±	9
	Corophium salmonis	353	±	164	252	±	96
	Chironomidae larvae	49	±	56	60	±	60
	Eulachon eggs	63	±	56	0	±	0
	TOTAL	1,302	±	375	1,162	±	927
	AREA TOTAL[a]	3,076	±	7,985	1,093	±	1,083

[a] *The mean density is the average of all samples taken in the area.*

Table 10. Summary of white sturgeon densities (no./ha) and benthic invertebrate densities (no./m²) at five index areas in the Columbia River downstream from Bonneville Dam. Benthic sampling for Survey 1 was done from 18-22 April and sampling for Survey 2 was done from 12-16 September. White sturgeon sampling for Survey 1 was done from 4-7 April and sampling for Survey 2 was done from 29 August-1 September.

RM-transect	Survey 1		Survey 2	
	Sturgeon density	Invertebrate density	Sturgeon density	Invertebrate density
28-1	0	396	10	3,148
28-2	6	7,931	17	2,764
28-3	24	2,617	5	6,738
75-1	0	497	27	2,338
75-2	0	472	13	1,408
79-1	251	522	10	2,326
79-2	48	513	25	517
79-3	8	600	5	812
88-1	0	1,240	0	839
88-2	23	1,700	6	820
95-1	561	155,976[a]	40	2,865
95-2	-	1,827	34	299
95-3	-	1,311	16	715
114-1	0	2,461	0	1,620
114-2	0	1,059	0	1,787
127-2	0	193	0	121
127-3	54	1,221	6	2,057
131-1	78	12,474[b]	27	1,273
131-2	531	1,128	162	850
131-3	0	1,302	9	1,162

[a] *Includes 153,352 eulachon eggs/m².*
[b] *Includes 10,128 eulachon eggs/m².*

Table 11. Summary of sediment characteristics at five sampling areas (juvenile white sturgeon) in the Columbia River downstream from Bonneville Dam, 1988; two samples were collected at different points along each transect. All sediment values, which are shown as ranges, are percents.

RM-trans.	Survey 1 (April)				Survey 2 (September)			
	Gravel[a]	Sand[b]	Fines[c]	Org.[d]	Gravel	Sand	Fines	Org.
28-1	1-2	98-99	0-<1	<1-1	4-5	94-96	<1	<1-1
28-2	<1-1	59-99	<1-41	1-3	2-3	97-98	<1	<1
28-3	<1	98->99	<1-2	1	<1-15	80-99	1-5	1
75-1	7	93	0-<1	1	3	97	0	1
75-2	8-20	80-92	<1	<1	1-3	97-99	<1	<1-1
79-1	5-29	70-95	<1	<1-1	3-14	86-97	0-<1	<1-1
79-2	2-18	82-98	0-<1	<1	<1-2	98-99	<1	<1-1
79-3	<1-1	99->99	0-<1	1	<1-2	98->99	<1	<1-1
88-1	<1-12	88->99	0-<1	1	0-<1	99->99	<1-1	1
88-2	1	99	0	1	1-2	98-99	0-<1	1
95-1	8-9	91-92	0-<1	1	2-5	95-97	<1	1
95-2	<1	>99	0	<1	<1-3	97->99	0-<1	1
95-3	10-15	85-90	<1	1	2-15	59-84	<1-39	1-3
114-1	10-12	88-90	0	1	6-16	84-94	0-<1	1
114-2	1-3	97-99	0-<1	<1	3-6	94-97	0-<1	<1-1
127-2	0-<1	>99	<1	1	0-1	99->99	<1	<1-1
127-3	<1-1	99->99	0	1	9-18	82-91	0-<1	1-2
131-1	6-16	84-94	0-<1	1-2	7-12	87-93	0-<1	1
131-2	<1-3	97->99	0-<1	1	3-19	81-97	0-<1	1
131-3	<1	94-97	2-6	1-3	0-1	96-97	3	1-2

[a] *Grain size* $\geq$*2 mm to <64 mm.*
[b] *Grain size 0.0625 to <2 mm.*
[c] *Grain size <0.0625 mm.*
[d] *Organic content.*

dwelling amphipod *Corophium salmonis* (82% total IRI), *Corophium spinicorne* (3%), and eulachon eggs (2%) were the most important identifiable prey items for white sturgeon ≤350 mm fork length (Size Class I); and *C. salmonis* (40%), eulachon eggs (12%), and the bivalve *Corbicula manilensis* (11%) were most important for sturgeon >350 mm (Size Class II). At RM 131, *C. salmonis* (59%) and eulachon eggs (26%) were the most important identifiable prey items for Size Class I sturgeon; and eulachon eggs (51%), *C. manilensis* (20%), *C. salmonis* (12%), and unidentified fish (3%) were most important for Size Class II sturgeon. At both RMs 95 and 131, sturgeon fed on eulachon eggs only in May. Index of Feeding (IF) values at RM 95 were 0.39 and 0.26% for Size Classes I and II, respectively. At RM 131, IF values were 0.29 and 0.34% for Size Classes I and II, respectively.

DISCUSSION

Egg and Larval Sampling

Catches of white sturgeon eggs in 1988 (n = 1,404) were considerably higher than catches in 1987 (n = 18) (McCabe and McConnell 1988). The increase in 1988 was in part due to increased sampling frequency during the spawning period, the use of two plankton nets simultaneously, and the use of artificial substrates. In addition, sturgeon egg production in 1988 may have been higher than in 1987. The mean catch of white sturgeon eggs in the plankton net near Ives Island (RM 143) between 21 April and 19 June 1987 was 2.09 eggs/1,000 m^3, but between 25 April and 20 June 1988, the mean catch was 10.22 eggs/1,000 m^3. In 1988, white sturgeon eggs were collected over a wider range than in 1987. Eggs in 1987 were collected between RMs 143 and 144, whereas in 1988, eggs were collected between RMs 140 and 145. In past studies by WDF, white sturgeon eggs have been collected as far downstream as RMs 118 (Kreitman 1983) and 136 (Kreitman 1983; Kreitman and Bluestein 1985).

Use of plankton nets and artificial substrates proved to be a good combination for collecting white sturgeon eggs in 1988. Each gear had its advantages and disadvantages. Data collected using the plankton net were more quantifiable than data collected with substrates. On the other hand, plankton nets could not be fished for long periods of time without the expense of many man-hours; artificial substrates could be deployed one day, then retrieved days later. Because artificial substrates could be fished for long periods, the chances of detecting spawning in an area were increased over that of only using plankton nets. If artificial substrates had not been used near the spillways at Bonneville Dam, we would not have discovered that spawning occurred that close to the spillways. However, artificial substrates are muchmore vulnerable to theft and loss to boat traffic (cutting of buoy line) than are plankton nets.

A total of 90 white sturgeon larvae were collected in 1988, compared to 40 collected in 1987 (McCabe and McConnell 1988). Considering the increase in larval sampling and the egg catches in 1988, one would have expected higher larval catches. From 21 April to 19 June 1987, the mean catch of larvae near Ives Island was 1.72 larvae/1,000 m^3, but during a similiar period in 1988, the mean catch near Ives Island was 0.48 larvae/1,000 m^3. The downstream distribution of white sturgeon larvae in 1988 was similiar to the distribution in 1987, with at least one larva being collected more than 30 miles downstream from Bonneville Dam.

In 1988, white sturgeon eggs and larvae were collected during the same general time period as in 1987 and past WDF studies. Based on sampling in 1988 and past years, it appears that white sturgeon spawn in the Columbia River downstream from Bonneville Dam from late April through early July (Kreitman 1985; Kreitman and Bluestein 1985; Bluestein 1986; McCabe and McConnell 1988).

White sturgeon eggs were collected at bottom water temperatures ranging from 10 to 16°C in both 1987 and 1988, and larvae were collected at temperatures ranging from 13 to 15°C in 1987 and 11 to 16°C in 1988. In the Sacramento-San Joaquin River system, California, white or green sturgeon *Acipenser medirostris* larvae were collected at water temperatures ranging from 14 to 22°C (Stevens and Miller 1970). Based on larval collections of white or green sturgeon in the Sacramento River, Kohlhorst (1976) estimated sturgeon spawn at water temperatures ranging from 7.8 to 17.8°C, with peak spawning at 14.4°C.

In both 1987 and 1988, white sturgeon larvae were collected more than 30 miles downstream from Bonneville Dam. It is not known precisely where the larvae collected downstream originated, but assuming that sturgeon spawn over a rock or cobble type bottom in high velocity areas, then the eggs were released in the area from Bonneville Dam to a point possibly about 6-7 miles downstream from the dam. River flow affects the downstream distribution of sturgeon larvae. Stevens and Miller (1970) noted a direct relationship between river flow and catches of white or green sturgeon larvae in the Sacramento-San Joaquin Delta, California. During low flows, fewer larvae were transported to the Delta by river flows. Brannon et al. (1985) found that the behavior of white sturgeon larvae was affected by current velocity. In laboratory experiments (Brannon et al. 1985), there was an inverse relationship between water velocity and the amount of time larvae spent in the water column. With continued larval sampling under different flow conditions, we should be able to better define the relationship between Columbia River flow and white sturgeon larval distribution in the river downstream from Bonneville Dam. River flows in both 1987 and 1988 were low in comparison to a normal flow year.

Size-Class Structure

Juvenile white sturgeon collected in the Columbia River downstream from Bonneville Dam showed considerable overlap in lengths for various age groups. Because of the overlaps, it was generally difficult to separate age groups other than Y-O-Y. Accurate ageing of most white sturgeon 1 year and older requires reading a cross section of a hard body part, such as a pectoral ray. Hess (1984), who aged white sturgeon using pectoral fin rays, found that white sturgeon collected in the lower Columbia River showed considerable variation in length for a specific age group. Virtually all the sturgeon aged by Hess were age 1 and older. Hess also noted that as the age increased, the length variation tended to increase. Results from the ageing of pectoral rays collected by NMFS in 1988 will be presented in FWS's annual report.

Young-of-the-Year

Catches of Y-O-Y white sturgeon were low in 1988, as in 1987. Theoretically, Y-O-Y white sturgeon should have represented a higher portion of the juvenile population than a specific older age group unless recruitment was poor in 1988. Assuming recruitment was normal in 1988, then there are at least three possible explanations for the low catches. The Y-O-Y white sturgeon were not vulnerable to capture in the trawls or beach seine, they were in areas where we did not sample, or they were widely dispersed. In June and July, many Y-O-Y white sturgeon may not have been fully vulnerable to capture, but by late September many should have been fully vulnerable based on their lengths. We feel that many Y-O-Y white sturgeon may seek refuge in close proximity to structures such as pile jetties, large rocks, and submerged logs. Bottom trawls and beach seines cannot effectively be used to sample around these types of structures. Another possible explanation for the low catches of Y-O-Y white sturgeon is that they may be more widely dispersed than older age groups, and thus less likely to be collected in large numbers.

Tagging

Recoveries of tagged sturgeon indicated negative or poor growth in many instances, particularly for fish recovered at RM 131. It is possible that the tag affected growth, but sturgeon recovered from areas other than RM 131 generally showed positive growth. The only accurate way to determine if the tag affects growth would be to do a laboratory experiment in which the growth rates of tagged and untagged sturgeon are compared. On the other hand, it is possible that juvenile sturgeon in at least certain areas of the Columbia River downstream from Bonneville Dam grew quite slowly.

Stomach Contents Analysis and Benthic Invertebrates

For the May-June period, juvenile white sturgeon at RMs 95 and 131 fed on organisms associated with the benthos; however, the relationship between primary prey items and densities of the organisms in the benthos was often poor. *Corophium salmonis* was an extremely important prey item at both RMs 95 and 131, yet their densities were less than $450/m^2$ during the April benthic invertebrate survey. For comparison, densities of *C. salmonis* in Cathlamet Bay, which is primarily a freshwater bay in the Columbia River estuary, ranged from 1,717 to $26{,}674/m^2$ in April 1984 (Emmett et al. 1986). In the present study, *C. salmonis* densities at RM 28 (upper estuary) were 1,194 and $7{,}502/m^2$ at two transects during the April benthic survey. Considering the relatively low densities of *C. salmonis* in the benthos at RMs 95 and 131, it seems likely that juvenile sturgeon are feeding on *C. salmonis* carried to them by the current or the sturgeon are moving to nearby areas with higher *C. salmonis* densities and feeding there. *Corophium* spp. have been observed in white sturgeon egg and larval samples collected with plankton nets, which are fished along the bottom, near Ives Island (RM 143). *Corophium volutator*, a related species, has been observed swimming above the bottom (Hughes 1988). If *C. salmonis* populations in freshwater sections of the lower Columbia River exhibit similiar behavior, then they would be dispersed by the river currents. During the early part of the field season we tried to sample the portion of the water column just above the bottom using an epibenthic sled (McCabe and McConnell 1988); however, we were unable to consistently collect good samples.

Often the epibenthic sled would fill with sand when towed along the bottom. Water velocities at RMs 95 and 131 are much lower than velocities near Ives Island; consequently, it requires more time to collect a good sample with a plankton net at the lower velocity areas than at Ives Island. The relationship between the importance of eulachon eggs in the diet of white sturgeon and their importance in the benthos was better than the relationship for *C. salmonis*. In 1988, eulachon eggs were an important part of the benthos and an important food item for juvenile white sturgeon in the Columbia River downstream from Bonneville Dam.

Based on benthic invertebrate samples collected at the five index areas, it is reasonable to assume that the diet of juvenile white sturgeon in freshwater areas of the Columbia River downstream from Bonneville Dam in May and June would be similiar to the feeding habits observed at RMs 95 and 131. Muir et al. (1988) found that *C. salmonis* was the most important prey item for white sturgeon <80 cm (total length); the juvenile sturgeon were collected in the Columbia River downstream from the mouth of the Willamette River and in the Columbia River estuary.

Results from the first year of combined juvenile sturgeon and benthic invertebrate sampling indicated that use of areas for rearing by juvenile white sturgeon could not be accurately predicted by benthic invertebrate densities. Areas with relatively higher invertebrate densities often were not used as heavily as other areas with lower densities. Based on 1988 research, it appears much of the river downstream from Bonneville Dam could serve as rearing habitat for juvenile white sturgeon, although there are preferred areas. Combined juvenile sturgeon and benthic invertebrate sampling in 1989 should increase our understanding of the relationship between juvenile sturgeon densities and the benthos.

Plans for 1989

Plans for 1989 include sampling for white sturgeon eggs, larvae, and juveniles downstream from Bonneville Dam. Specifically, we plan to use plankton nets and artificial substrates to study the spawning characteristics of white sturgeon in the lower Columbia River. These data collected downstream from Bonneville Dam, an area designated as a control for the overall sturgeon study, will be provided to FWS, who is doing similiar research in impoundments upstream from Bonneville Dam. Egg and larval data will also be used to determine the relationship between river flow and egg and larval catches. Hopefully, flows in 1989 will be closer to normal as compared to the two low-flow years of 1987 and 1988. Different flow conditions are needed to examine relationships between flow and egg and larval catches. As in 1987 and 1988, physical measurements will be made in conjunction with the egg and larval sampling.

Using biological and physical data collected in 1989, we will continue to examine the specific habitat preferences or requirements of juvenile white sturgeon. Bottom trawling and benthic sampling will be done in the five index areas sampled in 1988. Sampling stations include sites where white sturgeon are abundant and not abundant. Both types of sites are needed to determine habitat preferences.

Other activities planned for 1989 include continuation of the tagging of juvenile white sturgeon and examination of juveniles for the nematode parasite *Cystoopsis acipenseri*. Also, analysis of white sturgeon stomachs collected in 1988 will be completed.

REFERENCES

Bluestein, N. 1986. 1986 sturgeon larval sampling results. Washington Department of Fisheries memorandum to G. Kreitman, dated 27 August 1986, Battle Ground.

Brannon, E., S. Brewer, A. Setter, M. Miller, F. Utter, and W. Hershberger. 1985. Columbia River white sturgeon (*Acipenser transmontanus*) early life history and genetics study. University of Washington and U.S. National Marine Fisheries Service, Final Report to Bonneville Power Administration (Project 83-316), Seattle.

Chitwood, M. B., and A. McIntosh. 1950. An American host record for the Russian sturgeon nematode, *Cystoopsis acipenseri* Wagner, 1868. Journal of Parasitology 36(6-2):29.

Elliott, J. M. 1977. Some methods for the statistical analysis of samples of benthic invertebrates, scientific publication no. 25. Freshwater Biological Association, Ferry House, Ambleside, Cumbria, England.

Emmett, R. L., G. T. McCabe, Jr., T. C. Coley, R. J. McConnell, and W. D. Muir. 1986. Benthic sampling in Cathlamet Bay, Oregon--1984. National Marine Fisheries Service, Seattle, Washington.

Everhart, W. H., and W. D. Youngs. 1981. Principles of fishery science, 2nd edition. Cornell University Press, Ithaca, New York.

Hess, S. S. 1984. Age and growth of white sturgeon in the lower Columbia River, 1980-83. Oregon Department of Fish and Wildlife Report, Clackamas.

Hughes, R. G. 1988. Dispersal by benthic invertebrates; the *in situ* swimming behaviour of the amphipod *Corophium volutator*. Journal of the Marine Biological Association of the United Kingdom 68:565-579.

Kohlhorst, D. W. 1976. Sturgeon spawning in the Sacramento River in 1973, as determined by distribution of larvae. California Fish and Game 62:32-40.

Kreitman, G. 1983. 1983 sturgeon larvae sampling results. Washington Department of Fisheries memorandum to D. McIsaac, dated 8 December 1983, Vancouver.

Kreitman, G. 1985. 1985 sturgeon larval sampling results. Washington Department of Fisheries memorandum to D. McIsaac, dated 31 October 1985, Battle Ground.

Kreitman, G., and N. Bluestein. 1985. 1984 sturgeon larval sampling results. Washington Department of Fisheries memorandum to D. McIsaac, dated 26 March 1985, Battle Ground.

McCabe, G. T., Jr., and R. J. McConnell. 1988. Appendix D. Pages 114-140 *in* A. A. Nigro, editor. Status and habitat requirements of white sturgeon populations in the Columbia River downstream from McNary Dam. Report to Bonneville Power Administration (Project 86-50), Portland, Oregon.

Muir, W. D., R. L. Emmett, and R. J. McConnell. 1988. Diet of juvenile and subadult white sturgeon in the lower Columbia River and its estuary. California Fish and Game 74:49-54.

Pinkas, L., M. S. Oliphant, and I. L. K. Iverson. 1971. Food habits of albacore, bluefin tuna, and bonito in California waters. California Department of Fish and Game, Fish Bulletin 152, Sacramento.

Stevens, D. E., and L. W. Miller. 1970. Distribution of sturgeon larvae in the Sacramento-San Joaquin River system. California Fish and Game 56:80-86.

Swan, G. 1989. River diving techniques. Pages 227-232 *in* D. Graver, editor. Advanced diving technology and techniques. National Association of Underwater Instructors, Montclair, California.

Word, J. Q. 1976. An evaluation of benthic invertebrate sampling devices for investigating feeding habits of fish. Pages 43-55 *in* C. A. Simenstad and S. J. Lipovsky, editors. Fish food habits studies, 1st Pacific Northwest technical workshop. Washington Sea Grant WSG-WO 77-2, University of Washington, Seattle.

APPENDIX D-1

Summaries of individual trawling efforts for white sturgeon in the Columbia River downstream from Bonneville Dam, 1988 (not included in basic report, available upon request to NMFS, Point Adams Biological Field Station, P.O. Box 155, Hammond, OR 97121).

APPENDIX D-2

Summaries of benthic invertebrate studies (by station) done during April and September 1988 in the Columbia River downstream from Bonneville Dam (not included in basic report, available upon request to NMFS, Point Adams Biological Field Station, P.O. Box 155, Hammond, OR 97121).

APPENDIX D-3

Summaries of sediment studies (by station) done during April and September 1988 in the Columbia River downstream from Bonneville Dam (not included in basic report, available upon request to NMFS, Point Adams Biological Field Station, P.O. Box 155, Hammond, OR 97121).