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

Annual Progress Report

April 1989 - March 1990

Edited By

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EXECUTIVE SUMMARY

We report on our progress from April 1989 through March 1990 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 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 and expanded efforts to Bonneville Reservoir in 1988 and John Day Reservoir in 1989.

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

1. Using setlines, we caught 232 sturgeon in The Dalles Reservoir and 3,378 sturgeon in Bonneville Reservoir in 1989. Fork length of fish caught ranged from 27 cm to 256 cm. Vulnerability to capture appeared to increase with size up to 125 cm fork length in Bonneville Reservoir. Of the fish caught we marked 147 in The Dalles Reservoir and 2,131 in Bonneville Reservoir. Of the fish marked in 1989, we recaptured none in The Dalles Reservoir and 65 in Bonneville Reservoir. We recaptured 13 fish marked in 1987 and 57 tagged in 1988 in The Dalles Reservoir. We recaptured 37 fish marked in 1988 in Bonneville Reservoir. We recovered

[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.*

87 tags from sport and commercial fisheries: 60 from The Dalles Reservoir and 27 from Bonneville Reservoir.

2. Approximately one percent of sturgeon marked with two spaghetti tags lost at least one by the end of the sampling season. After one year, 13 percent of tagged fish had lost at least one tag. Fish secondarily marked with a barbel clip were recaptured at a significantly lower rate than marked fish without barbel clips. There was no difference in recapture rates of fish secondarily marked by removing a section of the fin ray and fish not marked this way.

3. Catch rates of sturgeon in setlines averaged 3.31 per overnight set for 70 lines in The Dalles Reservoir and 4.36 per overnight set for 774 lines in Bonneville Reservoir. Catch rates in the boat-restricted zones downstream from John Day and The Dalles dams were 6 and 3 times greater than elsewhere in The Dalles or Bonneville reservoirs.

4. Sturgeon moved throughout both reservoirs; some recaptured fish moved up to 54 km and almost one quarter moved at least 10 km from where tagged. Four fish marked in The Dalles Reservoir in 1988 were recaptured in Bonneville Reservoir in 1989. Two sturgeon marked in Bonneville Reservoir in 1988 were recaptured by recreational anglers downstream from Bonneville Dam in 1989. Catch rate of white sturgeon 80 cm fork length and greater varied significantly among 3-m depth intervals in both reservoirs.

5. Ages of sturgeon sampled ranged from 1 to 38 years in Bonneville Reservoir and 1 to 48 years in The Dalles Reservoir. Of the 3,198 sturgeon captured from 1987 through 1989, 3.4 percent had developing or ripe eggs and were expected to spawn the year following capture. Fecundity increased exponentially with length.

6. We interviewed 7,757 recreational anglers in The Dalles Reservoir, 5,682 recreational anglers in Bonneville Reservoir and 1,867 recreational anglers in John Day Reservoir in 1989. Our estimates of angling effort for sturgeon were 45,684 hours in The Dalles Reservoir, 70,583 hours in Bonneville Reservoir and 43,650 hours in John Day Reservoir. We estimated harvest by the recreational fishery to be 499 sturgeon from The Dalles Reservoir, 2,619 sturgeon from Bonneville Reservoir and 282 sturgeon from John Day Reservoir in 1989. Catch per hour by sturgeon anglers averaged about 0.01 sturgeon in The Dalles Reservoir, 0.04 in Bonneville Reservoir and <0.01 in John Day Reservoir; boat anglers had almost twice the success of bank anglers.

7. Average lengths of recreationally harvested sturgeon were 116 cm in The Dalles Reservoir, 103 cm in Bonneville Reservoir and 102 cm in John Day Reservoir. Recreational anglers handled between 6 and 10 sublegal-sized sturgeon for every legal-sized sturgeon handled. Recreational anglers handled an estimated 15 legal-sized sturgeon for each overlegal-sized sturgeon handled in The Dalles Reservoir, 43 legal-sized for each overlegal-sized in Bonneville Reservoir and 5 legal-sized for each overlegal-sized in John Day Reservoir.

8. The tribal commercial fishery harvested an estimated 1,932 sturgeon from The Dalles Reservoir, 1,410 from Bonneville Reservoir and 165 from John Day Reservoir in 1989. Average lengths of commercially harvested sturgeon were 126 cm in The Dalles Reservoir and 115 cm in Bonneville Reservoir; one sturgeon sampled in John Day Reservoir was 117 cm fork length.

9. Samples of sturgeon from recreational and commercial fisheries were 45 percent female in The Dalles Reservoir and 58 percent female in Bonneville Reservoir; 1 of 4 fish sampled from John Day Reservoir was female.

10. We caught 104 sturgeon eggs and 73 sturgeon larvae in The Dalles Dam tailrace from May 19 through July 25, 1989; 25 eggs and 18 larvae in John Day Dam tailrace from June 5 through July 6, 1989; and 69 eggs and 6 larvae in McNary Dam tailrace from June 7 through June 22, 1989. Eggs were collected in water from 5 to 50 m deep. Larvae were collected in water from 6 to 58 m deep. Mean water column velocities where eggs were collected ranged from 0.39 to 1.89 m/sec; larvae were collected where velocities were 0.27 to 1.31 m/sec. Between 9 and 35 percent of the eggs in the three pool area were dead or covered with fungus. Developmental stages of eggs ranged from unfertilized to prehatch. Larvae ranged from posthatch to yolk-absorbed stages; 8 to 23 mm total length.

11. Based on back-calculated ages of eggs and larvae, spawning in 1989 probably occurred from May 11 to July 25 in Bonneville Reservoir, May 24 to July 3 in The Dalles Reservoir and June 6 to 13 in John Day Reservoir. Water temperatures on these dates ranged from 12.5 to 19.2 C.

12. Young-of-the-year (YOY) sturgeon were captured for the first time upstream from Bonneville Dam in 1989 in Bonneville Reservoir; no YOY sturgeon were collected in The Dalles or John Day reservoirs. Total lengths of 56 YOY sturgeon collected ranged from 20 mm in late June to 321 mm in late November.

13. We caught 627 juvenile sturgeon (age II or older) in Bonneville Reservoir, 260 in The Dalles Reservoir and 67 in John Day Reservoir in 1989. Fork lengths ranged from 32 to 96 cm. We marked 577 juvenile sturgeon in Bonneville Reservoir, 229 in The Dalles Reservoir and 65 in John Day Reservoir. Between 0 and 3 percent of marked fish at large were recaptured in 1989; some had shed their Monel bands. Oxytetracycline was injected in 580 sturgeon in Bonneville Reservoir, 234 in The Dalles Reservoir and 64 in John Day Reservoir as part of age validation experiments. About 81 percent of our catch in Bonneville Reservoir and 100 percent in The Dalles and John Day reservoirs were at sites with maximum depths 8 m or greater; some sturgeon were caught at a maximum depth of 6 m in Bonneville Reservoir.

14. The length-weight relationship of juvenile sturgeon was described as $\log W = 2.98(\log FL) - 5.09$ in Bonneville Reservoir, $\log W = 2.96(\log FL) - 5.03$ in The Dalles Reservoir and $\log W = 3.15(\log FL) - 5.54$ in John Day 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, 39 cm at age 3, 42 cm at age 4, 45 cm at age 5, 52 cm at age 6, and 62 cm at age 7 in Bonneville Reservoir; 37 cm at age 2, 42 cm at age 3, 46 cm at age 4, 48 cm at age 5, and 59 cm at age 6 in The Dalles Reservoir; and 44 cm at age 3, 46 cm at age 4, 51 cm at age 5, 61 cm at age 6, and 58 cm at age 7 in John Day Reservoir.

15. The emetic hydrogen peroxide was only 3.2 percent efficient by weight in recovering food items and was not suitable for quantitative analysis of juvenile sturgeon food habits. Food habit analyses of 24 YOY sturgeon ranging in total length from 35 to 276 mm and weight from 0.3 to 116.3 g indicated the amphipod *Corophium salmonis* was the most important food item, comprising 99 percent by weight of food ingested. Other prey items found in stomach samples were *Ramellogammarus oregonensis*, *Neomysis* spp., *Corbicula* spp., cladocerans and copepods. We observed predation on sturgeon eggs by largescale suckers, northern squawfish and common carp.

16. We surveyed habitat in The Dalles Reservoir and found approximately 80 percent of the surface area occupied by depths greater than 5.5 m. Substrate overlays for the whole reservoir and hydraulic simulations of water velocities are presently being completed.

Highlights of results of our work downstream from Bonneville Dam are

1. We caught 7,036 sturgeon in 1989 using gill nets. Of the fish we caught, we tagged 5,389 sturgeon; 4,273 of which were tagged in the Columbia River estuary. In addition to the fish we caught, we examined for marks 4,409 sturgeon caught by the recreational fishery and 1,960 sturgeon caught by the commercial fishery. Of fish tagged in 1989, 38 were observed in our recreational fishery samples, 14 were observed in our commercial fishery samples, and 125 were observed in our research samples. Of fish tagged in 1983 through 1988, we observed 98 in our recreational fishery samples, 52 in our commercial fishery samples and 151 in our research samples. Fork lengths of sturgeon caught in the recreational and commercial fisheries averaged 100 cm and 119 cm. Fork lengths ranged from 81 to 168 cm in the recreational fishery and 100 to 173 cm in the commercial fishery.

2. We collected 2,323 sturgeon eggs and 135 sturgeon larvae between April 27 and July 6, 1989. We collected 2,018 eggs with nets and 305 eggs with artificial substrates. Most eggs were collected at the Ives Island sampling station. Most of the eggs collected with artificial substrates were collected immediately downstream from Bonneville Dam; 256 downstream from the spillway, 2 downstream from the first powerhouse and none downstream from the second powerhouse. Freshly fertilized eggs made up over 70 percent of the eggs collected at Ives Island, but less than 15 percent of the eggs collected downstream from Ives Island or in Bonneville Dam tailrace, suggesting that spawning intensity was greatest near Ives Island. We estimated spawning period, back-calculated from egg stages in samples, to extend from April 22 to July 2.

3. The physical characteristics of sites where eggs and larvae were collected were similar. Bottom temperatures ranged from 12 to 18 C, turbidities from 3.3 to 10.0 NTU, mean water column velocities from 0.7 to 2.6 m/s, and depths from 4.6 to 22.6 m. Using multiple regression, 90 percent of the variation in catch of sturgeon eggs at Ives Island could be attributed to the combination of temperature, turbidity and mean water column velocity.

4. We collected 2,579 juvenile sturgeon with trawls in 1989; 111 that were post-larval young-of-the-year (YOY). We tagged 1,675 juvenile sturgeon. We recaptured 24 sturgeon; 2 tagged in 1987, 10 tagged in 1988 and 12 tagged in 1989. Distribution of juveniles was patchy and numbers caught varied greatly among sampling areas and transects within sampling areas. Juvenile sturgeon catches were highest in deeper (≥18.3 m) areas with sandy substrate. Juvenile sturgeon did not appear to move much; all of the fish recovered were released within a mile of where recaptured. We observed a poor relationship between juvenile sturgeon densities and benthic invertebrate densities or substrate sediment structure.

5. Size distributions of juvenile fish sampled were similar among months through June; 1989 was the only discernable year class and was recruited to our gear in July. Mean fork length of YOY sturgeon increased from 85 mm in July to 240 mm in November. The length-weight relationship of juvenile sturgeon was described as log W = 2.98(log FL) - 5.14; where W is weight in g and FL is fork length in mm. Stomach content analyses from 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 1989 to March 1990 to describe the life history and dynamics of white sturgeon *Acipenser transmontanus* in Bonneville and The Dalles reservoirs. We set 774 setlines in Bonneville Reservoir and 70 setlines in The Dalles Reservoir. We caught 3,378 white sturgeon in Bonneville Reservoir and 232 in The Dalles Reservoir. Catch per unit effort varied among areas of the reservoir. Our setlines were size selective. We recaptured 13 fish released in 1987, 94 fish released in 1988, and 65 fish released in 1989. Recapture rates of sturgeon that we barbel clipped were significantly lower than recapture rates of sturgeon from which no barbel was removed. We recaptured fish from which we took pectoral fin ray samples at similar rates to those from which no fin ray samples were taken. We observed extensive movements of marked sturgeon within the reservoirs. We aged fish as old as 48 years. Bone marks were observed on 45 of 48 fish previously injected with oxytetracycline and we examined the period of annulus formation. We estimated parameters in a length-weight equation. About 3.4% of the female white sturgeon we examined to date had early or late vitellogenic eggs and would be expected to spawn the following year.

INTRODUCTION

We began our study of white sturgeon *Acipenser transmontanus* life history and population dynamics in July 1986. We reported our progress through March 1989 in three reports: Rieman et al. (1987); Nigro et al. (1988); and Beamesderfer et al. (1989). In this report we describe our activities and results from April 1989 through March 1990, summarizing progress toward study objectives and intermediate results upon which we will base analyses satisfying study objectives.

METHODS

We sampled white sturgeon from April through August 1989 in Bonneville Reservoir and in June and July 1989 in The Dalles Reservoir (Lake Celilo) to estimate population statistics. We divided Bonneville Reservoir into eight sections and The Dalles Reservoir into six sections (Figure 1). Sections were about 6 river-miles long in Bonneville Reservoir and 4 river-miles long in The Dalles Reservoir. Results for the boat-restricted zones (BRZ) adjacent to and downstream from The Dalles and John Day dams are reported separately from other sections in each pool because the BRZs were unique habitats. BRZs were less than 1/2 mile long.

We distributed sampling effort equally among and within sections to obtain a representative sample of the population. All sections in Bonneville Reservoir were sampled every 4 weeks and each section was sampled at least 4 times, except in the BRZ where spill prevented sampling until July. In The Dalles Reservoir, we sampled each section once (Table 1).

Setlines were used exclusively for sampling because they provide the greatest catch rate and are less size selective than other gears (Elliott and Beamesderfer 1990). We fished lines overnight for 11 to 79 hours (average 24.4 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 (FL) to the nearest cm and examined each white sturgeon caught for tags, tag scars, fin marks, barbel clips, and scute marks. All untagged white sturgeon with a fork length over 64 cm were tagged with one spaghetti tag placed at the base of the anterior end of the dorsal fin. All white sturgeon longer than 84 cm were also tagged with a second spaghetti tag placed at the base of the posterior end of the dorsal fin. We removed the third left lateral scute from tagged white sturgeon to identify tag loss. We weighed to the nearest kg all white sturgeon from Bonneville Reservoir with fork lengths greater than 169 cm to supplement samples collected in 1988. We weighed all recaptured and surgically examined fish from Bonneville and The Dalles reservoirs.

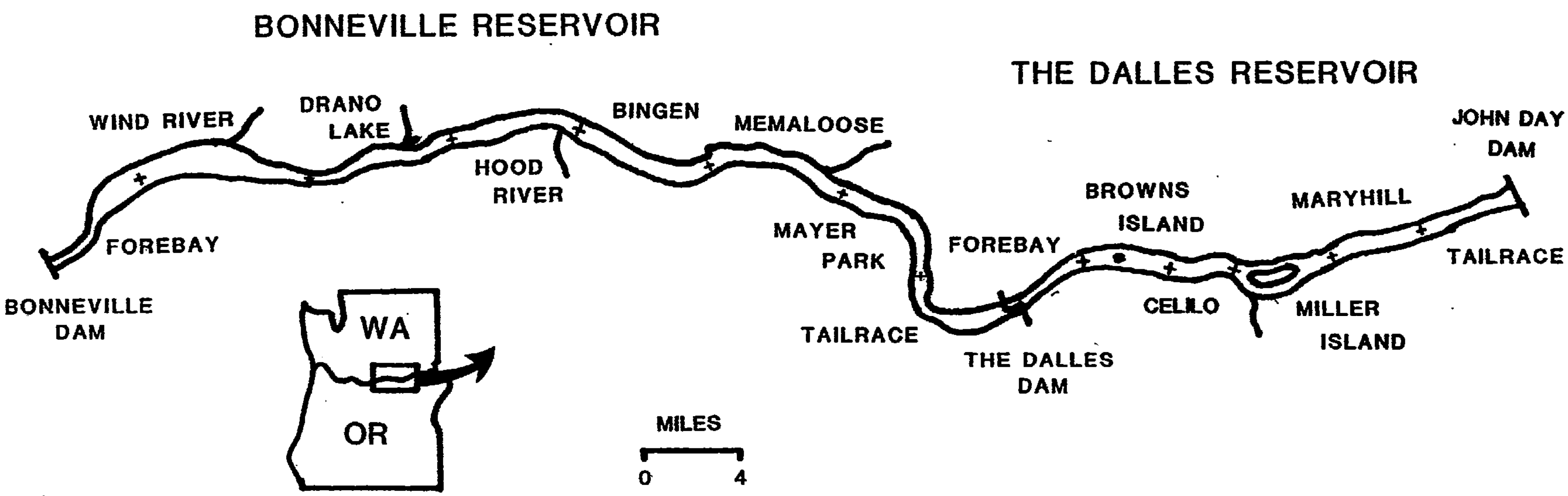

Figure 1. Columbia River from Bonneville Dam to John Day Dam. Boundaries of sampling areas are shown by +.

Table 1. Sampling effort (number of setline sets) for white sturgeon in Bonneville and The Dalles reservoirs, April through August 1989.

Reservoir, Week of year	Location[a]									
	1	2	3	4	5	6	7	8	9	Total
Bonneville:										
16	0	0	0	0	0	0	3	0	0	3
17	0	0	0	0	0	0	21	18	0	39
18	0	0	12	30	0	0	0	0	0	42
19	0	0	0	0	26	22	0	0	0	48
20	24	20	0	0	0	0	0	0	0	44
21	0	0	0	0	0	0	24	24	0	48
22	0	0	10	22	0	0	0	0	0	32
23	0	0	0	0	20	22	0	0	0	42
24	21	22	0	0	0	0	0	0	0	43
25	0	0	0	0	0	0	14	8	0	22
26	0	0	15	11	0	0	0	0	0	26
27	0	0	0	0	20	16	0	0	0	36
28	24	24	0	0	0	0	0	0	0	48
29	0	0	0	0	0	0	24	24	7	55
30	0	0	15	36	0	0	0	0	0	51
31	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	27	25	0	0	0	52
33	27	28	0	0	0	0	0	0	0	55
34	0	0	0	0	0	0	29	24	4	57
35	0	0	14	17	0	0	0	0	0	31
Total	96	94	66	116	93	85	115	98	11	774
The Dalles:										
23	15	15	0	0	0	0	0	--	--	30
24	0	0	8	12	0	0	0	--	--	20
29	0	0	0	0	6	10	4	--	--	20
Total	15	15	8	12	6	10	4	--	--	70

[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.*

Right pectoral fin-ray sections were collected to determine age. In Bonneville, we collected fin-ray samples from every other white sturgeon captured until we had at least 30 samples for each 20 cm fork length interval. In The Dalles Reservoir, we collected a fin-ray sample from each white sturgeon longer than 169 cm to supplement samples collected in 1987 and 1988.

We injected 2,590 white sturgeon with oxytetracycline (OTC) in 1989 in addition to 758 fish injected in 1988 to mark fin rays so we could test the validity of our age interpretations from fin sections using fish we recapture in future years. We injected 100 mg/ml OTC into the red muscle under the dorsal scutes just behind the head. Doses were adjusted such that each fish received about 25 mg/kg of body weight. Only white sturgeon with fork lengths less than 85 cm and longer than 185 cm were injected. In this way, anglers, who can legally keep fish with total lengths from 91 through 183 cm (40 through 72 inches), would not risk eating flesh from an injected fish within the 15-day period directed by the Food and Drug Administration. We removed the second right lateral scute from OTC injected fish to permit identification at recapture. We collected fin ray samples from 48 fish previously injected with OTC.

We examined the gonads of every white sturgeon longer than 169 cm to determine sex and stage of maturity following procedures outlined in Beamesderfer et al. (1989). We also examined samples of gonads, supplied by Washington Department of Fisheries (WDF), from the catch in recreational and commercial fisheries in Bonneville, The Dalles, and John Day reservoirs.

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 we can 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 compared loss rates of tags and secondary marks to help select persistent marks and calculate correction factors in recapture rates. Where possible, we compared recapture rates of white sturgeon with and without secondary marks to appraise effects of marking.

We examined distribution of white sturgeon by comparing catch rate among areas. We compared the sites and dates of release with those for recapture of marked fish to determine the extent and timing of movement within each reservoir and to determine whether populations in each reservoir mixed. Catch rates of setline sets at different depths were compared in an attempt to identify preferences.

Age of white sturgeon was estimated from thin cross sections of pectoral fin rays following procedures outlined in Beamesderfer et al. (1989). We 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 people. We examined fin-ray sections of OTC-injected fish to determine the validity of our aging technique. We examined the proximity of OTC marks to the annulus formed before injection to determine time of annulus formation.

We quantified the relationship between length and weight. We measured the diameter of eggs from samples of ovaries to help determine the period of development and estimate the proportion of the population that is females that will spawn each year. We included females with early and late vitellogenic eggs in our estimate of the number of females spawning next year. We examined mean egg diameter of individual sturgeon over time in an attempt to describe the duration of egg development in female sturgeon.

RESULTS

Catch

We set 774 setlines (Table 1) and caught 3,378 white sturgeon (Table 2) in Bonneville Reservoir (4.36 fish per setline set). In The Dalles Reservoir (Tables 1 and 2), we set 70 setlines and caught 232 white sturgeon (3.31 fish per set). Our gear sampled fish from 27 through 256 cm fork length (Figure 2). Vulnerability to capture appeared to increase with size up to 125 cm fork length in Bonneville Reservoir (Table 3).

Marking and Mark Recovery

We tagged 2,131 white sturgeon larger than 69 cm fork length in Bonneville Reservoir in 1989 (Table 4). We also recaptured 41 fish that were marked in 1988 that we are counting in this year's tagged population: 37 from Bonneville Reservoir (Table 5) and 4 from The Dalles Reservoir. We recaptured 65 fish tagged in Bonneville in 1989, including 3 that we recaptured in the same period in which they were tagged (Table 4). WDF personnel recovered four tagged fish while sampling recreational and commercial fisheries in Bonneville Reservoir. Recreational and commercial anglers voluntarily reported 23 tagged fish they harvested in Bonneville Reservoir (Table 6).

We tagged 147 white sturgeon larger than 69 cm fork length in The Dalles Reservoir in 1989 (Table 4). We recaptured 13 fish tagged in The Dalles Reservoir in 1987 and 57 fish tagged in 1988 (Table 5). WDF personnel recovered 20 tagged fish while sampling recreational and commercial fisheries in The Dalles Reservoir. Recreational and commercial anglers voluntarily reported 40 tagged fish they harvested in The Dalles Reservoir (Table 6).

Table 2. Catches of white sturgeon (all lengths) with setlines in Bonneville and The Dalles reservoirs, April through August 1989.

Reservoir, Week of year	Location[a]									
	1	2	3	4	5	6	7	8	9	Total
Bonneville:										
16	--	--	--	--	--	--	3	--	--	3
17	--	--	--	--	--	--	35	29	--	64
18	--	--	33	85	--	--	--	--	--	118
19	--	--	--	--	84	106	--	--	--	190
20	33	71	--	--	--	--	--	--	--	104
21	--	--	--	--	--	--	57	77	--	134
22	--	--	24	96	--	--	--	--	--	120
23	--	--	--	--	133	166	--	--	--	299
24	63	89	--	--	--	--	--	--	--	152
25	--	--	--	--	--	--	92	64	--	156
26	--	--	83	99	--	--	--	--	--	182
27	--	--	--	--	117	62	--	--	--	179
28	102	186	--	--	--	--	--	--	--	288
29	--	--	--	--	--	--	130	116	66	312
30	--	--	96	219	--	--	--	--	--	315
31	--	--	--	--	--	--	--	--	--	--
32	--	--	--	--	102	123	--	--	--	225
33	50	91	--	--	--	--	--	--	--	141
34	--	--	--	--	--	--	81	87	67	235
35	--	--	53	108	--	--	--	--	--	161
Total	248	437	289	607	436	457	398	373	133	3,378
The Dalles:										
23	19	37	--	--	--	--	--	--	--	56
24	--	--	9	30	--	--	--	--	--	39
29	--	--	--	--	34	41	62	--	--	137
Total	19	37	9	30	34	41	62	--	--	232

[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.*

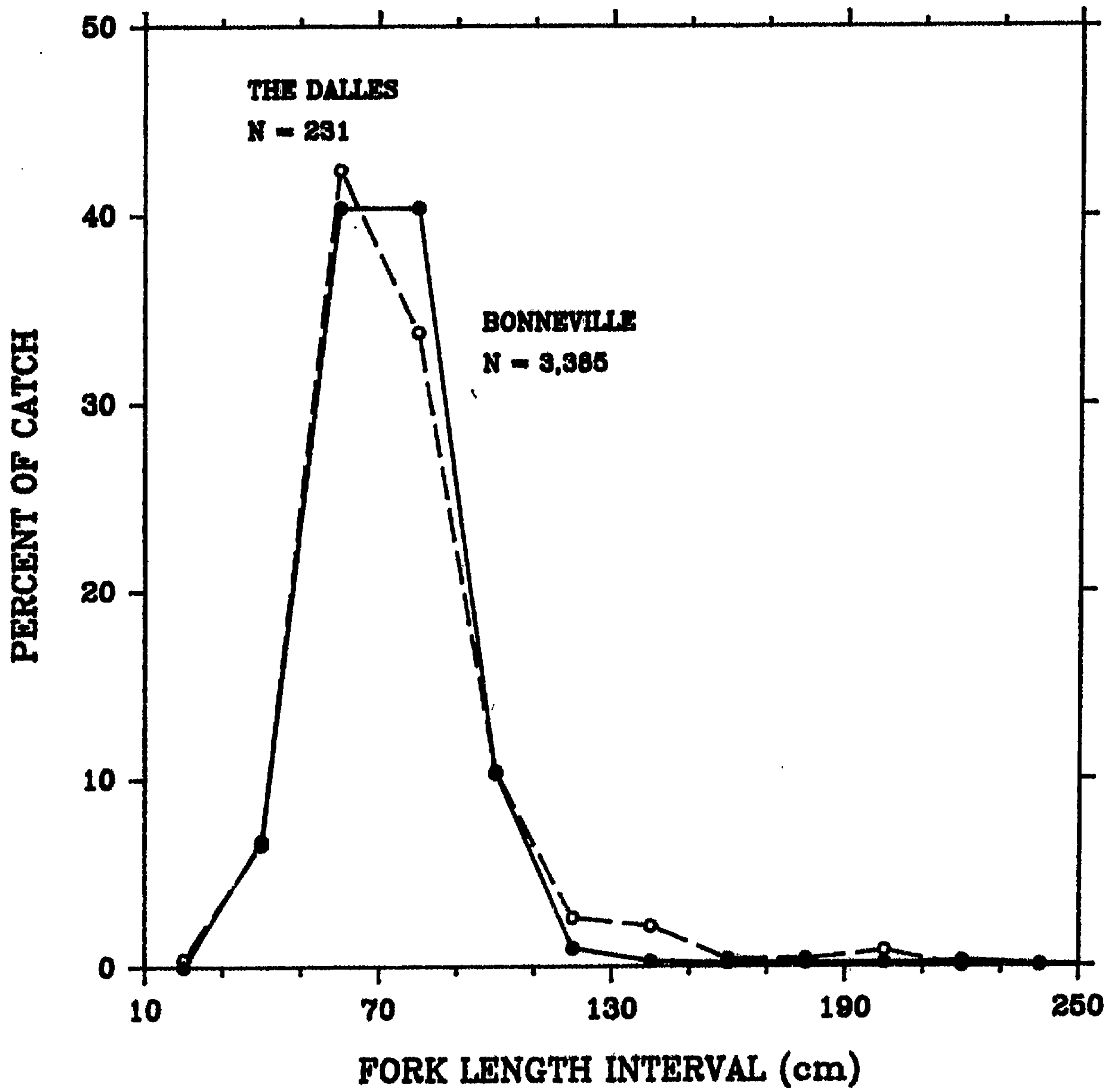

Figure 2. Length-frequency distribution of white sturgeon collected in Bonneville and The Dalles reservoirs, 1989.

Table 3. Recapture rate of white sturgeon in Bonneville Reservoir by length interval, 1989.

Fork length interval (cm)	Number of fish at large	Recapture rate
51-75	1,939	0.0103
76-100	2,656	0.0128
101-125	271	0.0148
126-150	37	0
151-175	6	0
>175	40	0.0250

Table 4. Mark and recapture data for white sturgeon (> 69 cm) captured with setlines and by surveyed anglers in 1989.

Reservoir, period	Number caught	Number marked[a]	Number recaptured	Number removed[b]		Number of marks at large
				Unmarked	Marked	
Bonneville:						
4/16-22	3	3	0	3	0	0
4/23-5/20	272	272	0	45	0	3
5/21-6/17	423	421	1	81	1	275
6/18-7/15	594	582	11	122	1	695
7/16-8/19	680	649	29	81	5	1,276
8/20-9/02	268	245	21	18	2	1,920
Total	2,240	2,172	62	350	9	
The Dalles:						
5/21-6/17	61	59	0	50	0	0
6/18-7/15	0	0	0	82	0	59
7/16-8/19	88	88	0	30	0	59
Total	149	147	0	193	0	

[a] *Includes recaptures of previous year marks which are counted as new marks for population estimation.*
[b] *Includes observed catch by recreational and commercial fishermen from sampling by Washington Department of Fisheries.*

Table 5. Mark and recapture data for white sturgeon (> 69 cm) captured in years following the year of tagging.

Reservoir, year marked	Number captured	Number marked	Number recaptured		Number removed[a]		Number of marks at large
			1988	1989	Unmarked	Marked	
Bonneville:							
1988	343	342	--	37	520	2	--
1989	2,240	2,172	--	--	707	16	340
Total	2,583	2,514	--	37	1,227	18	
The Dalles:							
1987	792	771	82	13	875	59	--
1988	1,333	1,243	--	57	377	34	712
1989	149	147	--	--	923	2	1,921
Total	2,274	2,161	82	70	2,175	95	

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

Table 6. Recovery of sturgeon tags by recreational and commercial fishermen in Bonneville and The Dalles reservoirs, 1989.

Release year, source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Month of recapture											
Bonneville Reservoir												
1988:												
Recreational voluntary	0	0	0	1	0	1	2	0	0	2	0	0
Recreational sample[a]	0	0	0	0	0	0	0	0	0	0	0	0
Commercial voluntary	1	0	0	0	0	0	0	0	0	0	0	0
Commercial sample[a]	0	1	1	0	0	0	0	0	0	0	0	0
1989:												
Recreational voluntary	0	0	0	0	0	2	2	3	3	2	1	2
Recreational sample[a]	0	0	0	0	0	0	0	1	1	0	0	0
Commercial voluntary	0	0	0	0	0	0	0	1	0	0	0	0
Commercial sample[a]	0	0	0	0	0	0	0	0	0	0	0	0
The Dalles Reservoir												
1987:												
Recreational voluntary	0	0	0	1	0	1	1	0	0	0	1	0
Recreational sample[a]	0	0	0	0	0	0	0	0	2	2	0	0
Commercial voluntary	0	1	2	2	0	0	0	0	0	0	0	0
Commercial sample[a]	0	0	2	0	0	0	0	0	0	0	0	0
1988:												
Recreational voluntary	1	0	2	1	0	8	4	0	0	0	0	0
Recreational sample[a]	0	0	0	0	0	1	7	0	0	1	0	0
Commercial voluntary	4	1	4	3	0	0	0	1	1	0	0	0
Commercial sample[a]	0	0	5	0	0	0	0	0	0	0	0	0
1989:												
Recreational voluntary	0	0	0	0	0	0	0	0	0	0	1	0
Recreational sample[a]	0	0	0	0	0	0	0	0	0	0	0	0
Commercial voluntary	0	0	0	0	0	0	0	0	0	0	0	0
Commercial sample[a]	0	0	0	0	0	0	0	0	0	0	0	0

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

We observed that spaghetti tags placed at the base of the dorsal fin were retained at a similar rate in anterior and posterior positions. The tag loss rate was about 1% among fish recaptured in the year of tagging. After 1 year, 13% of tags applied had been lost (Table 7). Barbel clips used in earlier years were the most persistent secondary mark (Table 7). However, we recaptured barbel-clipped sturgeon at a significantly lower rate than sturgeon that were not barbel clipped (Table 8). We recaptured fish from which we took pectoral fin ray samples at a rate similar to that for fish from which no fin-ray samples were taken.

Distribution and Movement

White sturgeon were not evenly distributed and moved widely within the reservoirs. Densities in BRZs (inferred from catch per unit effort) were three times greater in Bonneville Reservoir and six times greater in The Dalles Reservoir than in the rest of the respective reservoirs (Table 9). We often recaptured white sturgeon in areas other than where they were released (Tables 10 and 11). In Bonneville Reservoir we observed movement of up to 54 km, and 22% of the fish recaptured in the year of release had moved 10 km or more (Figure 3).

We recaptured four sturgeon in Bonneville Reservoir during 1989 that we originally marked in The Dalles Reservoir in 1988. Anglers recaptured two sturgeon below Bonneville Dam that we originally marked in Bonneville Reservoir in 1988.

Catch rate of white sturgeon longer than 80 cm FL varied significantly among 3-m depth intervals in Bonneville ($F = 2.74$, $df_1 = 12$, $df_2 = 578$, $P = 0.001$) and The Dalles ($F = 2.19$, $df_1 = 11$, $df_2 = 559$, $P = 0.014$) reservoirs. However, catch rate was not strongly related to average depth of set in Bonneville ($R^2 = 0.05$) or The Dalles ($R^2 = 0.11$) reservoirs. Catch rate of white sturgeon 80 cm FL and smaller did not vary significantly among 3-m depth intervals in Bonneville ($F = 1.54$, $df_1 = 13$, $df_2 = 677$, $P = 0.098$) or The Dalles ($F = 1.20$, $df_1 = 11$, $df_2 = 445$, $P = 0.282$) reservoirs (Figure 4).

Age, Growth, and Morphometry

We assigned ages from 1 to 38 years to 231 white sturgeon collected in Bonneville Reservoir in 1988-89 (Table 12). We assigned ages from 1 to 48 years to 445 white sturgeon collected in The Dalles Reservoir in 1987-89 (Table 13). Supplementation of earlier samples with samples from large fish caught in 1989 has allowed us to reach our target sample size of 30 fish per 20 cm length interval for all lengths up to 139 cm for Bonneville Reservoir population and up to 179 cm for The Dalles Reservoir population. Paired samples of fork length and weight from sturgeon in The Dalles and Bonneville reservoirs were

Table 7. Number of marked white sturgeon recaptured with setlines in Bonneville and The Dalles reservoirs, 1987-89.

Mark type, retention[a]	Years since release <1	1	2
Spaghetti tag (anterior):			
Retained	140	100	3
Lost	3	16	0
Spaghetti tag (posterior):			
Retained	74	63	0
Lost	0	8	0
Tattoo:			
Retained	3	0	0
Lost	3	25	0
Barbel clip:			
Retained	43	63	4
Lost	1	1	0
Fin-ray section:			
Retained	29	23	1
Lost	1	8	0
Scute mark:			
Retained	129	51	([b])
Lost	8	2	([b])

[a] *We determined tag loss from marks and tag scars on sturgeon at recapture. Retention or loss of other marks was determined from recaptures of tagged fish.*

[b] *We did not apply scute marks in 1987.*

Table 8. Recapture rate in setlines of white sturgeon marked with barbel clips and pectoral fin ray sections, 1987-89.

Mark, treatment	Marked (M)	Recaptured (R)	R/M	Contingency chi-square results		
				df	X^2	P[a]
Barbel clip:[b]						
Not marked	601	103	0.1714	1	6.78	0.009
Marked	690	77	0.1116			
Fin ray section:[c]						
Not marked	553	31	0.0561	1	0.25	0.620
Marked	580	38	0.0655			

[a] *$P \leq 0.05$ denotes a significant difference.*
[b] *We included fish tagged in The Dalles Reservoir in 1988.*
[c] *We applied pectoral fin-ray marks at different rates as our sample size needs for fin-ray sections were met. To account for this bias we include only fish tagged in Bonneville Reservoir from 1988 through 12 June 1989 with fork lengths of 50-124 cm.*

Table 9. Catch per setline day (40 hooks) by month for white sturgeon, 1987 through 1989.

Reservoir, month[b]	Location[a]								
	1	2	3	4	5	6	7	8	9
Bonneville:									
April	--	--	--	--	--	--	1.58	1.61	--
May	1.38	3.55	2.59	3.48	3.23	4.82	2.38	3.21	--
June	3.00	4.05	5.53	9.00	6.65	7.55	6.57	8.00	--
July	4.25	7.75	6.40	6.08	5.85	3.88	5.42	4.83	9.43
August	1.45	2.25	3.81	4.46	3.67	3.63	3.09	4.00	14.13
All months	2.27	3.92	4.29	4.88	4.45	4.70	3.45	3.91	11.93
The Dalles:									
April	1.00	1.29	--	--	0.00	2.94	17.50	--	--
May	1.03	1.45	1.64	2.09	1.10	3.35	12.70	--	--
June	2.17	2.66	2.05	1.55	3.43	2.79	13.17	--	--
July	--	--	1.75	2.91	3.28	3.02	13.80	--	--
August	1.44	1.50	--	--	--	--	--	--	--
All months	1.67	2.15	1.85	2.29	2.82	3.04	13.80	--	--

[a] *Locations: 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] *Months: April = Weeks 13 through 17, May = weeks 18 through 22, June = weeks 23 through 26, July = weeks 27 through 30, August = weeks 31 through 35, September = weeks 36 through 37.*

Table 10. Number of white sturgeon (fork length ≥ 65 cm) marked and recovered during the year of marking, by location in Bonneville (1988-89) and The Dalles (1987-89) reservoirs.

Reservoir, tagging location	Number tagged	Recapture location									
		1	2	3	4	5	6	7	8	9	10
Bonneville:											
1. Forebay	258	0	1	0	1	0	1	0	0	0	1
2. Wind River	419	0	1	2	0	0	0	0	0	0	4
3. Drano Lake	296	0	1	4	3	0	0	0	0	0	3
4. Hood River	579	0	2	0	6	1	0	0	0	0	1
5. Bingen	361	0	1	0	1	2	1	0	0	0	1
6. Memaloose	331	0	1	0	0	2	7	0	0	1	2
7. Mayer Park	281	0	0	0	0	0	0	3	2	0	0
8. Tailrace	257	0	3	0	1	0	0	2	24	1	2
9. The Dalles BRZ	144	0	0	0	0	0	0	0	0	0	0
The Dalles:											
1. Forebay	333	10	0	4	2	0	5	1	5	--	--
2. Browns Island	275	0	3	2	3	1	3	0	4	--	--
3. Celilo	212	1	0	3	5	0	1	0	4	--	--
4. Miller Island	265	0	0	1	7	5	4	3	0	--	--
5. Maryhill	290	0	2	2	2	11	5	2	0	--	--
6. Tailrace	328	0	0	3	3	0	14	4	0	--	--
7. John Day BRZ	502	0	0	2	3	3	25	11	9	--	--

Table 11. Number of white sturgeon (all lengths) marked and recovered at least 1 year following marking, by location in Bonneville and The Dalles reservoirs. Fish marked from 1987 through 1988 and recaptured from 1988 through 1989 are included.

Reservoir, tagging location	Number tagged	Recapture location									
		1	2	3	4	5	6	7	8	9	10
Bonneville:											
1. Forebay	24	0	0	0	0	0	0	0	0	1	0
2. Wind River	25	1	0	1	0	0	0	0	0	0	0
3. Drano Lake	45	0	0	0	0	0	0	0	0	0	1
4. Hood River	56	1	1	0	2	0	0	0	0	0	1
5. Bingen	71	0	1	0	2	3	0	1	0	0	2
6. Memaloose	36	0	0	0	0	1	4	1	0	0	0
7. Mayer Park	64	0	0	0	0	0	0	5	2	0	1
8. Tailrace	43	0	0	0	1	0	0	1	4	1	0
9. The Dalles BRZ	37	0	0	0	0	0	0	0	1	0	2
The Dalles:											
1. Forebay	319	9	1	0	1	1	2	1	6	--	--
2. Browns Island	248	1	4	0	0	0	3	1	5	--	--
3. Celilo	209	0	2	5	0	1	1	0	10	--	--
4. Miller Island	246	0	1	2	3	0	0	0	8	--	--
5. Maryhill	268	0	0	0	0	4	5	2	12	--	--
6. Tailrace	301	0	0	0	4	4	3	4	2	--	--
7. John Day BRZ	461	1	0	4	0	7	11	15	20	--	--

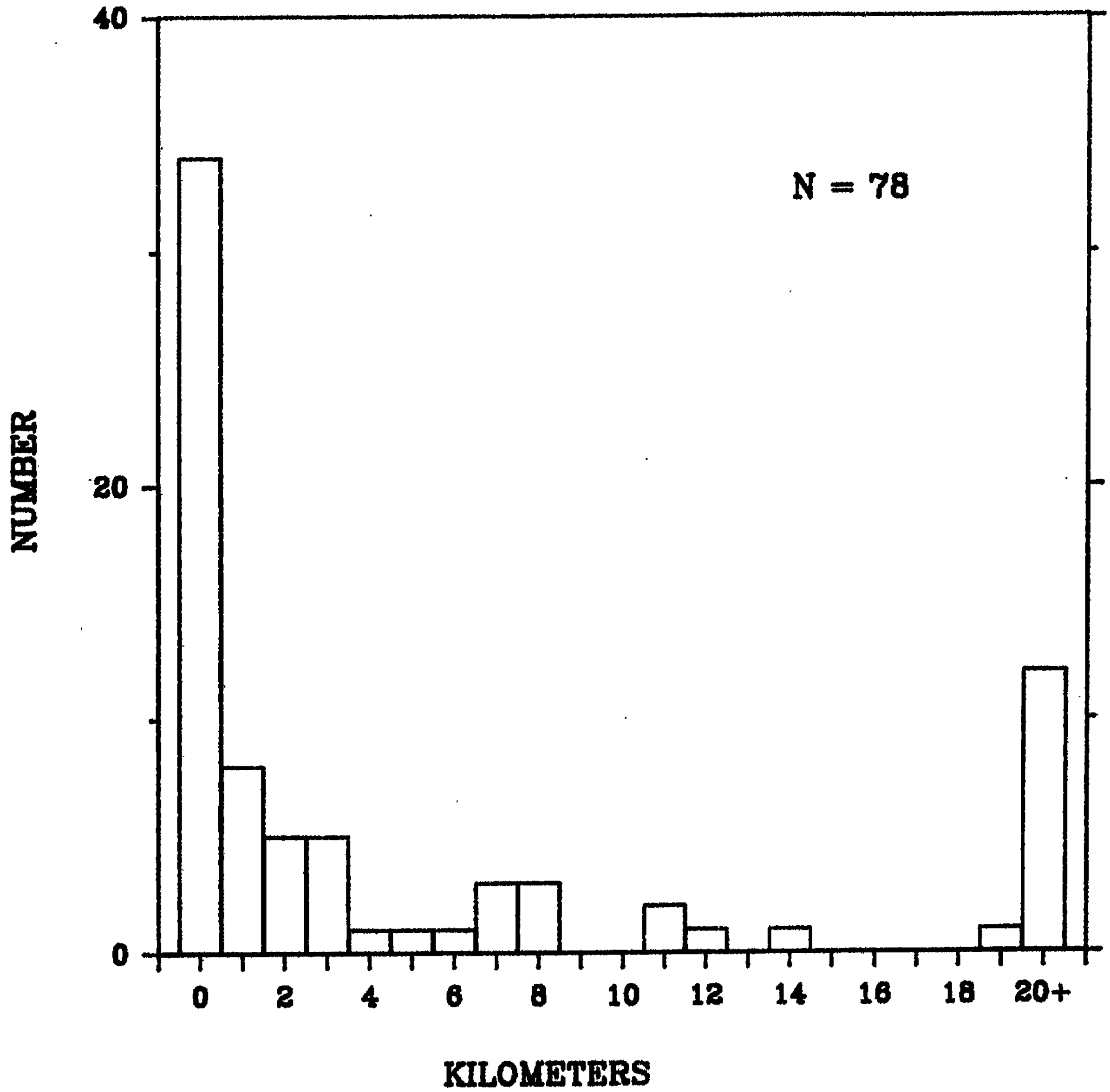

Figure 3. Distance traveled between release and recapture locations of white sturgeon recaptured within 1 year of marking in Bonneville reservoir, 1987-89.

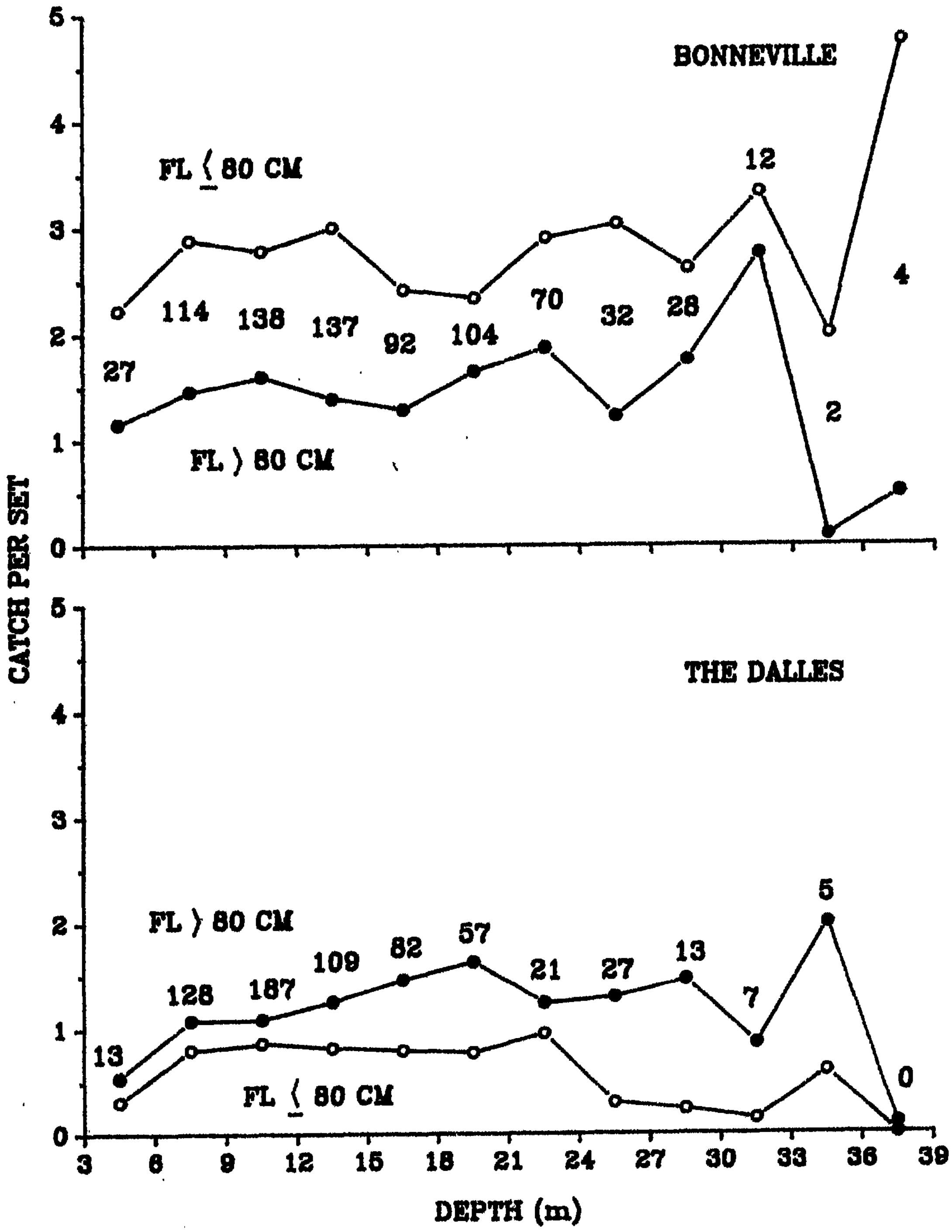

Figure 4. Catch per setline day (40 hooks) by 3 m depth interval for white sturgeon in Bonneville (1989) and The Dalles (1988) reservoirs. The number of setline days is indicated for each depth interval.

Table 12. Age-length-frequency distribution for white sturgeon collected in Bonneville Reservoir, April to June, 1988-89.

	Fork length interval (cm)											Fork length		
Age	0 -19	20 -39	40 -59	60 -79	80 -99	100 -119	120 -139	140 -159	160 -179	180 -199	>199	Mean	SD	N[a]
1	1	2										22.4	3.3	3
2		7										35.6	1.2	7
3		11	2									37.4	4.4	13
4		4	5									42.3	5.0	9
5		3	10									47.4	7.8	13
6		1	7	1								50.9	8.3	9
7			2	7								64.4	5.6	9
8			3	4	1							64.0	9.7	8
9			2	1	2							67.0	16.2	5
10			1	3	1							71.4	12.7	5
11			2	2	3	2						78.4	14.9	9
12			1	2	2	2						85.0	18.1	7
13			0	1	5	0						83.8	4.6	6
14			1	1	3	1						81.3	15.6	6
15				2	1	5	3					104.2	19.5	11
16				2	3	2						85.3	14.5	7
17				4	3	7	2	2				102.2	24.3	18
18				1	1	2	3	0				110.1	23.8	7
19					0	2	2	0				111.5	9.9	4
20					4	2	1	6				121.1	26.9	13
21					0	3	3	2	1		1	136.8	34.0	10
22					0	0	5	1	0		0	129.8	9.8	6
23					0	0	0	0	1		0	160.0	--	1
24					1	1	3	0	1		0	125.5	25.9	6
25						1	1	1	0	1	1	156.2	41.1	5
26						1	1	0	0	2	1	162.4	45.0	5
27							1	1	0	1	0	159.3	33.6	3
28							1	2	1	1	1	166.2	27.8	6
29							1	1	1	0	2	182.4	50.6	5
≥30							3	0	1	5	6	--	--	15
N	1	28	36	31	30	31	30	16	6	10	12	--	--	231

[a] *Includes samples from U. S. Fish and Wildlife Service trawl catch and Washington Department of Fisheries fishery surveys.*

Table 13. Age-length-frequency distribution for white sturgeon collected in The Dalles Reservoir, April to June, 1987-89.

	Fork length interval (cm)										Fork length		
Age	20 -39	40 -59	60 -79	80 -99	100 -119	120 -139	140 -159	160 -179	180 -199	>199	Mean	SD	N[a]
1	2										26.9	0.9	2
2	14	6									36.0	5.5	20
3	3	20									45.5	6.2	23
4		22	7								54.8	5.9	29
5		2	13								67.1	7.2	15
6		0	12	1							69.7	7.0	13
7		1	7	1							71.8	7.1	9
8			4	5							80.1	9.5	9
9			0	6	1						90.3	7.4	7
10			7	12	2						84.5	11.0	21
11			2	8	1						88.7	9.6	11
12			1	8	9	1					98.9	13.7	19
13			2	5	7	1	1				101.4	17.1	16
14			0	5	7	4	0				107.4	13.6	16
15			0	2	7	2	2				114.1	17.5	13
16			1	5	8	9	2	2			120.9	21.3	27
17				0	6	7	5	0			128.6	15.2	18
18				1	4	13	6	2	1		135.2	20.0	27
19				1	3	10	6	7	0		141.0	24.3	27
20					1	5	12	3	3		151.8	21.0	24
21					2	6	6	3	1		143.9	18.5	18
22						0	3	2	5	3	180.1	21.5	13
23						0	3	4	1	1	169.6	18-6	9
24						1	3	6	1	1	166.1	23.4	12
25						0	1	2	0	0	158.0	14.2	3
26						1	0	2	0	3	183.0	39.6	6
27						0	0	4	1	4	187.0	22.6	9
28						1	0	2	2	0	170.8	20.5	5
29							1	0	1	3	198.4	32.9	5
≥30							3	2	2	12	--	--	19
N	19	51	56	60	58	61	54	41	18	27	--	--	445

[a] *Includes samples from U. S. Fish and Wildlife Service trawl catch and Washington Department of Fisheries fishery surveys.*

sufficient to calculate regression equations with high degrees of confidence (Figure 5).

We saw OTC marks in bone in 45 of 48 pectoral fin ray sections from white sturgeon previously injected with OTC. Generally, the OTC marks were within or abutting the previous year's annulus when injected in May and June, and separate from the annulus when injected in July and August. However, more than 20% of the fish injected in August still had marks bordering the annulus (Table 14).

Reproduction

We have examined gonads of 3,198 sturgeon (FL >79 cm) collected from 1987 through 1989. We found 3.4% of these contained developing eggs (stages 2 and 3) which we would expect to be spawned the year following capture (Table 15). We saw three egg diameter groups from fish collected from February through April (Figure 6). After May, discrete groups were more difficult to discern. We had to pool samples from three reservoirs to estimate a fecundity-length relationship (Figure 7).

DISCUSSION

We completed collection of most of the data we need to estimate population statistics and potential production of white sturgeon in Bonneville Reservoir. Sample sizes appear adequate to estimate growth rate and abundance within acceptable degrees of confidence. However, preliminary estimates of total mortality using catch curves indicate fishing mortality has changed substantially over time, which means we need to use a cohort analysis among years to estimate mortality. We also need additional samples from large fish (>169 cm) to refine maturity-length and fecundity-length relationships.

We will sample in Bonneville, The Dalles, and John Day reservoirs in 1991 to estimate age structure in each reservoir and to supplement samples of large white sturgeon where information on reproduction is insufficient. This sampling will also allow us to recapture additional fish that we injected with OTC to improve validation of our aging technique.

In 1990 we will begin sampling John Day Reservoir. We intend to explore the reservoir, select sampling sites, and complete collection of most of the information we need to estimate population statistics and potential production.

In 1990 we will begin marking white sturgeon with fork lengths over 84 cm with a single disc tag and a single spaghetti tag. We will continue tagging fish with fork lengths from 65 through 84 cm with a single spaghetti tag. Studies of white sturgeon in the Sacramento

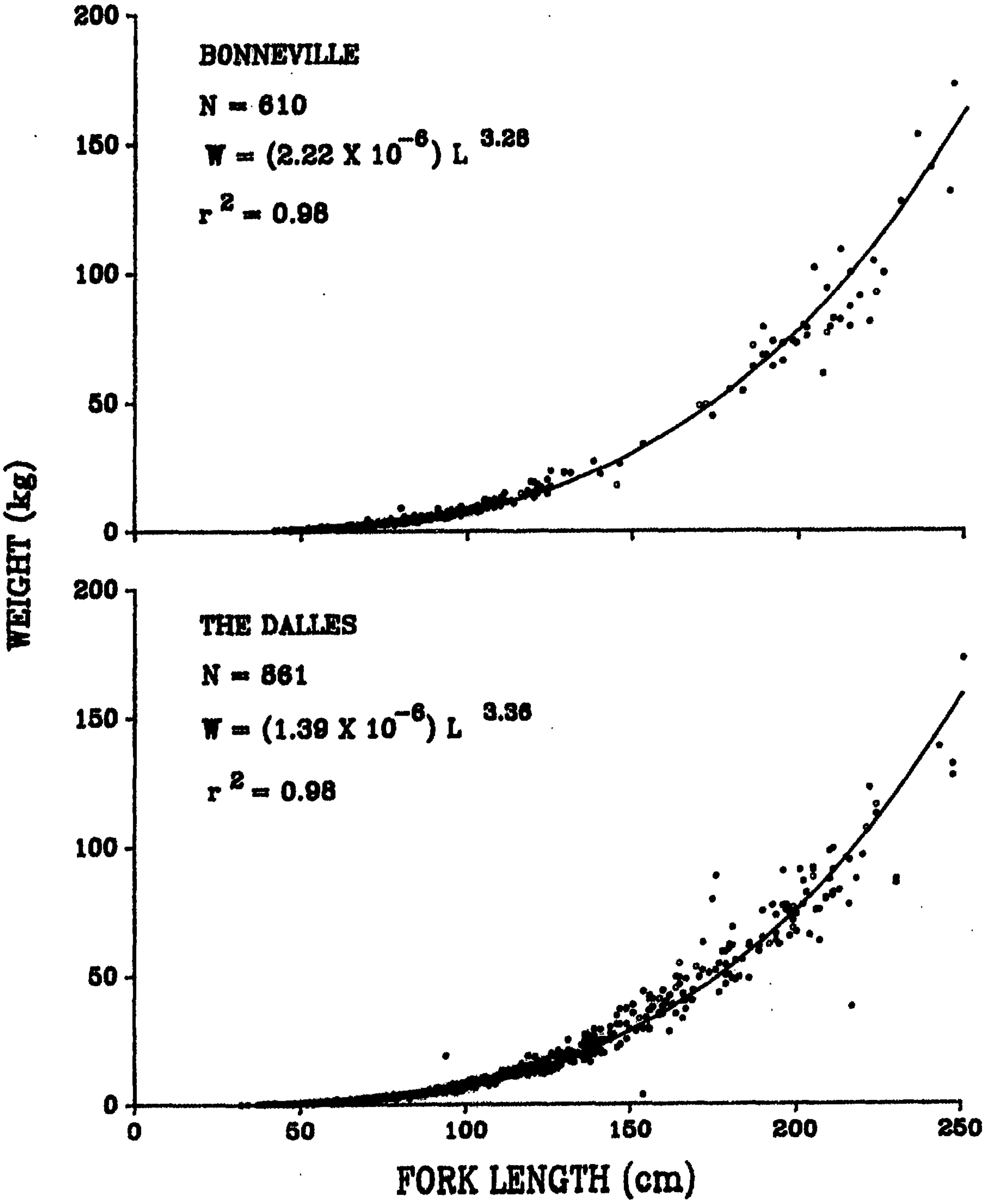

Figure 5. Weight-length relationships for white sturgeon collected in Bonneville and The Dalles reservoirs, 1987-89.

Table 14. Percent of pectoral fin ray samples showing a bone mark within or abutting the previous years annulus by month for white sturgeon previously injected with oxytetracycline in Bonneville and The Dalles reservoirs, 1988-89.

Month	*N*	Percent in or abutting annulus
May	1	100
June	9	78
July	8	37
August	19	21

Table 15. Developmental stage of gonads of female white sturgeon between Bonneville and McNary Dams, 1987-89.

Reservoir, length group (cm)	N[a]	Developmental stage[b]						Expected spawning year	
		1	2	3	4	5	6	Year captured	Year after capture
Bonneville:									
80-99	232	2	1	0	0	2	113	0	3
100-119	669	29	7	4	0	8	296	4	36
120-139	118	1	0	2	0	1	45	2	1
140-159	9	0	0	1	0	0	4	1	0
160-179	7	0	0	0	0	0	1	0	0
180-199	13	1	0	0	0	0	2	0	1
200-219	17	1	6	0	0	1	2	0	7
>219	12	1	7	0	0	0	1	0	8
The Dalles:									
80-99	55	0	0	0	0	0	14	0	0
100-119	551	4	1	0	0	0	191	0	5
120-139	437	5	2	0	0	3	163	0	7
140-159	183	7	3	1	0	2	65	1	10
160-179	46	5	5	0	0	1	14	0	10
180-199	12	2	2	0	0	1	2	0	4
200-219	13	3	0	1	0	0	1	1	3
>219	9	2	1	0	0	0	3	0	3
John Day:									
80-99	1	0	0	0	0	0	0	0	0
100-119	209	0	0	0	0	0	51	0	0
120-139	127	2	1	0	0	0	30	0	3
140-159	53	2	0	1	0	0	12	1	2
160-179	11	0	1	0	0	0	0	0	1
180-199	2	0	0	0	0	0	0	0	0
200-219	0	0	0	0	0	0	0	0	0
>219	1	1	0	0	0	0	0	0	1
Unknown:									
100-119	243	2	1	0	0	0	29	0	3
120-139	113	1	0	0	0	0	12	0	1
140-159	45	0	0	1	0	0	4	1	0
160-179	10	0	0	0	0	0	1	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.*

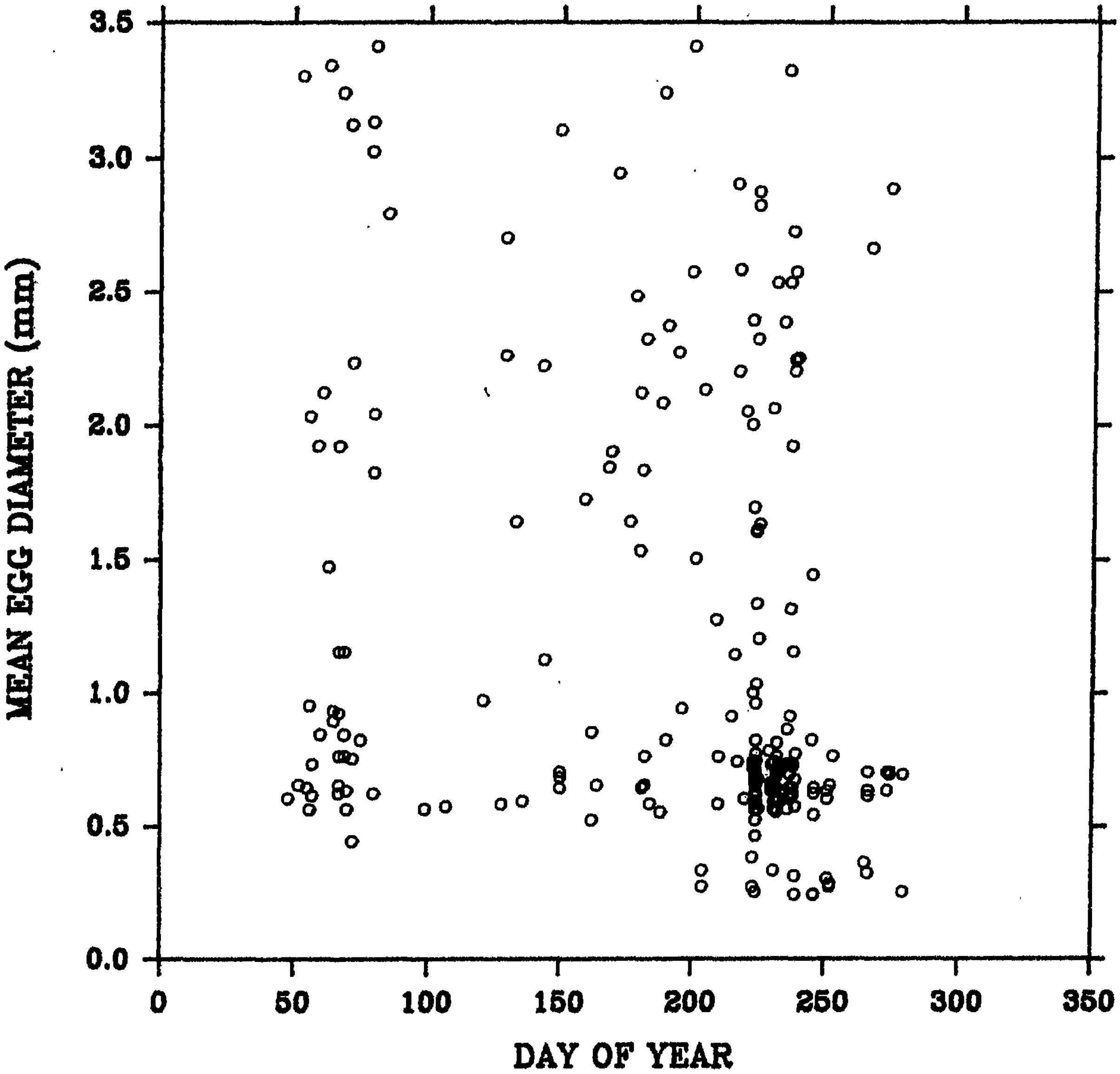

Figure 6. Mean diameter of developing eggs from ovaries of white sturgeon collected in Bonneville and The Dalles reservoirs, 1987-89.

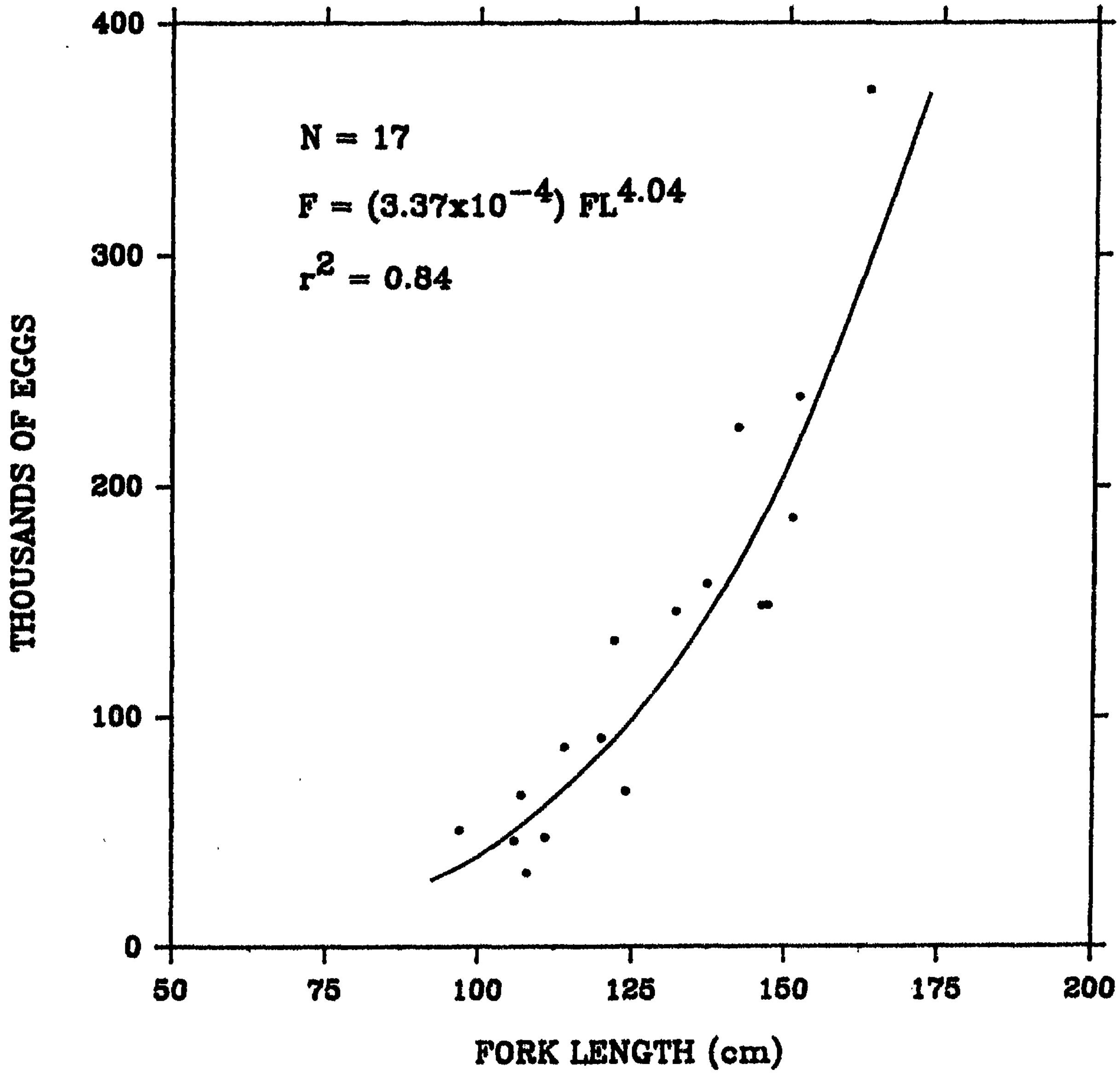

Figure 7. Fecundity-length relationship of white sturgeon collected in Bonneville, The Dalles, and John Day reservoirs, 1986-89.

River, California, indicate higher long-term tag retention using disc tags than we have seen with spaghetti tags (personal communication on 15 August, 1990, with David L. Kohlhorst, California Department of Fish and Game, Stockton, California).

We did not use barbel clips in 1989 as a secondary mark because we were concerned about the effect this may have on fish behavior and survival. Lower recapture rates for barbel-clipped white sturgeon imply barbel clips have an adverse effect.

Removing a section of the leading pectoral fin ray did not appear to affect survival, based on comparisons of recapture rates with unsectioned fish. Kohlhorst (1979) concluded that removal of the first pectoral fin ray resulted in substantial mortality of white sturgeon during the first year following removal. We believe the difference in mortality rate may be attributed to the techniques used: We remove a small (10 mm) section of the fin ray and leave most of the "knuckle" near the articulation, as well as the distal portion of the fin ray, intact. Kohlhorst (1979) removed the entire fin ray starting as close to the articulation as possible.

Examination of pectoral fin rays from fish injected with OTC appears to support our aging criteria. We have been interpreting each of several distinct but closely spaced translucent marks as annuli, but we were concerned that these marks might be false annuli. Several recaptures of fish injected 1 year earlier showed OTC marks between two closely spaced translucent marks at the outer edge of the fin ray. We believe this confirms our interpretation.

We had some difficulty during the extended period of annulus formation in differentiating the last annulus from a clear zone at the margin. The clear zone was observed on many but not all fin-ray samples. Fish are erroneously placed in the preceding year-class when the clear zone is mistaken for the current year's annulus. Fish are erroneously placed in the following year class when the current year's annulus is discounted as the clear zone. OTC marking indicated current year's growth could resume (and distinguish the annulus) any time from June through August. In 1990 we will complete collection of fin-ray samples before growth resumes in June. For those early samples, the last annulus and clear zone correspond and no distinction is required.

The three egg diameter groups observed in gonad samples collected from February through April may represent two groups of females with developing eggs that will spawn in different years and a third group of immature females. This pattern would be consistent with the 16-month period of maturation seen in hatchery sturgeon in California (personal communication, 7 March 1990, Serge I. Dorshov, Department of Animal Science, University of California, Davis). We need additional gonad samples, particularly from early in the year, to adequately describe the duration of egg development. To estimate the proportion of the population that are female spawners in any year, we need to know how many years of spawners are represented among females with developing eggs. We will continue working with WDF and Oregon State Police to obtain samples of whole gonads from fish caught and killed in recreational and commercial fisheries as well as illegally harvested fish to increase our sample size.

Problems with mortality estimates from catch curves have postponed our reporting of preliminary estimates of population statistics and potential production of white sturgeon in The Dalles Reservoir. These results will be included in our next annual report.

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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

The Washington Department of Fisheries (WDF) censused the recreational fisheries in Bonneville, The Dalles and John Day reservoirs for mark recovery, biological samples and harvest data on white sturgeon *Acipenser transmontanus*. Samplers interviewed 5,682 anglers in Bonneville Reservoir and 7,757 anglers in The Dalles Reservoir from March through October 1989 and 1,867 anglers in John Day Reservoir from May through July 1989. Harvest estimates of legal size white sturgeon for these time periods were 2,619, 499 and 282 in Bonneville, The Dalles and John Day reservoirs, respectively. Biological sampling was conducted on 18.4% of the Bonneville Reservoir sturgeon harvest, 36.9% of the sturgeon harvest in The Dalles Reservoir and 8.9% of the sturgeon harvest in John Day Reservoir during respective census periods. Of the 507 white sturgeon harvested and examined for marks/tags that were put out by the Oregon Department of Fish and Wildlife in Bonneville Reservoir, 2 marked sturgeon were observed. In The Dalles Reservoir, 186 sturgeon were mark sampled with 10 mark recoveries. The John Day Reservoir mark sample of white sturgeon was 29 examined with no mark recoveries.

Treaty commercial fishery landings were sampled for harvest, mark and biological information on white sturgeon. The estimated treaty commercial harvest of white sturgeon from Bonneville Reservoir in 1989 was 1,410, of which 8.1% was biologically sampled. The Bonneville mark sample from this fishery was 185 sturgeon, of which two were marked. The Dalles Reservoir treaty commercial harvest was 1,932 white sturgeon in 1989 with 27.1% of the harvest biologically sampled. There were 22 marks recovered from 664 sturgeon mark sampled from these fisheries. In John Day Reservoir, treaty commercial fishermen harvested 165 sturgeon in 1989. There was one unmarked sturgeon randomly sampled from these fisheries.

WDF assisted the National Marine Fisheries Service in assessing reproduction and early life history of white sturgeon downstream from Bonneville Dam. WDF processed and staged samples of eggs and larvae collected in 1989.

Population dynamics modeling of white sturgeon downstream from Bonneville Dam in 1989 included refinement of abundance and exploitation estimates and reproductive parameters. A total of 5,389 white sturgeon were tagged. Age validation techniques were furthered by injecting OTC and secondarily marking 244 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, biological samples and harvest estimates 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 the collection of data on subadult and adult white sturgeon downstream of McNary Dam.

This annual report focuses on activities and information from the 1989 field season. The report contains the following sections:

1) egg and larval analysis of samples collected downstream from Bonneville Dam by NMFS;
2) catch and effort information from censusing the recreational sturgeon fisheries between Bonneville and McNary dams;
3) landings in the tribal commercial fisheries between Bonneville and McNary dams;
4) summaries of mark recovery and biological data collected from recreational and commercial fisheries between Bonneville and McNary dams; and
5) progress in describing the yield or production of white sturgeon downstream of Bonneville Dam.

METHODS

Eggs and Larvae Analysis

Sturgeon eggs and larvae downstream from Bonneville Dam were collected by NMFS. A thorough discussion of sampling gear and techniques is presented by NMFS in REPORT D of this document. Refer to Tracy (1990) for additional information.

Initial processing of egg and larval samples was conducted by WDF. Eggs and larvae in the samples were enumerated, aged and preserved in 20% methanol. Eggs were staged and larvae aged according to Beer (1980). Spawning dates were back-calculated using the method of Wang et al. (1985).

Recreational Fishery Census

The 1989 recreational fishery census was conducted in Bonneville and The Dalles reservoirs from March through October and in John Day Reservoir from May through July (hereafter referred to as the census period) (Figures 1 and 2). The census occurred in order to estimate the harvest of marked white sturgeon and collect biological samples from the examined catches. The legal size slot for recreational fisheries between Bonneville and McNary dams was 40 to 72 inches total length in 1989.

Harvest was estimated as the product of effort and catch rate (LaVoy et al. 1989). There were slight modifications to the Bonneville Reservoir index areas in 1989 (Appendix B-1).

Index areas for angler counts were established at popular fishing locations and vantage points in all three reservoirs (Appendix B-1). Angler effort was estimated from aerial counts of bank and boat anglers within each reservoir. Flights of the entire sampling area were made on four of every six intensive index area count days while simultaneous ground counts were made within index areas. The intensive index area counts were conducted every three hours throughout the day on a twice weekly basis. Intensive counts within index areas 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. Rounds of index counts were considered instantaneous in the catch and effort estimates. The proportion of the total effort represented by the index area counts was determined by comparing counts within and outside the index areas using the aerial count data. This proportion was applied to the index counts during non-flight hours to yield an estimate of the total angling effort that occurred on the index count day. A single ground index count occurred at variable hours during most other days of the census period.

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 creel. Interviews took place between index effort counts and on non-flight days. Interviews in Bonneville Reservoir were supplemented by creel checks made by Washington Department of Wildlife samplers at the mouths of the Little White Salmon and White Salmon rivers.

White sturgeon harvest estimates were made for two statistical week intervals (statistical weeks are Monday through Sunday numbered sequentially from the start of the year). Effort and catch sampling data were stratified by bank and boat angler types, river subsections (Appendix B-1), week day and weekend day effort to account for differential catch rates. If no anglers were interviewed in a subsection for a period when effort was observed, then data from proximate periods were combined to derive a representative catch rate and applied to the effort estimate for that time period. Harvest estimates were calculated by multiplying the observed catch per hour of effort for each angler type within a river subsection by the total estimated effort for each angler type for that period and subsection. Removal of marked white sturgeon was estimated by dividing the number of marked fish examined by the mark sampling rate. The mark sampling rate is defined as the number of fish examined for marks divided by the total estimated harvest.

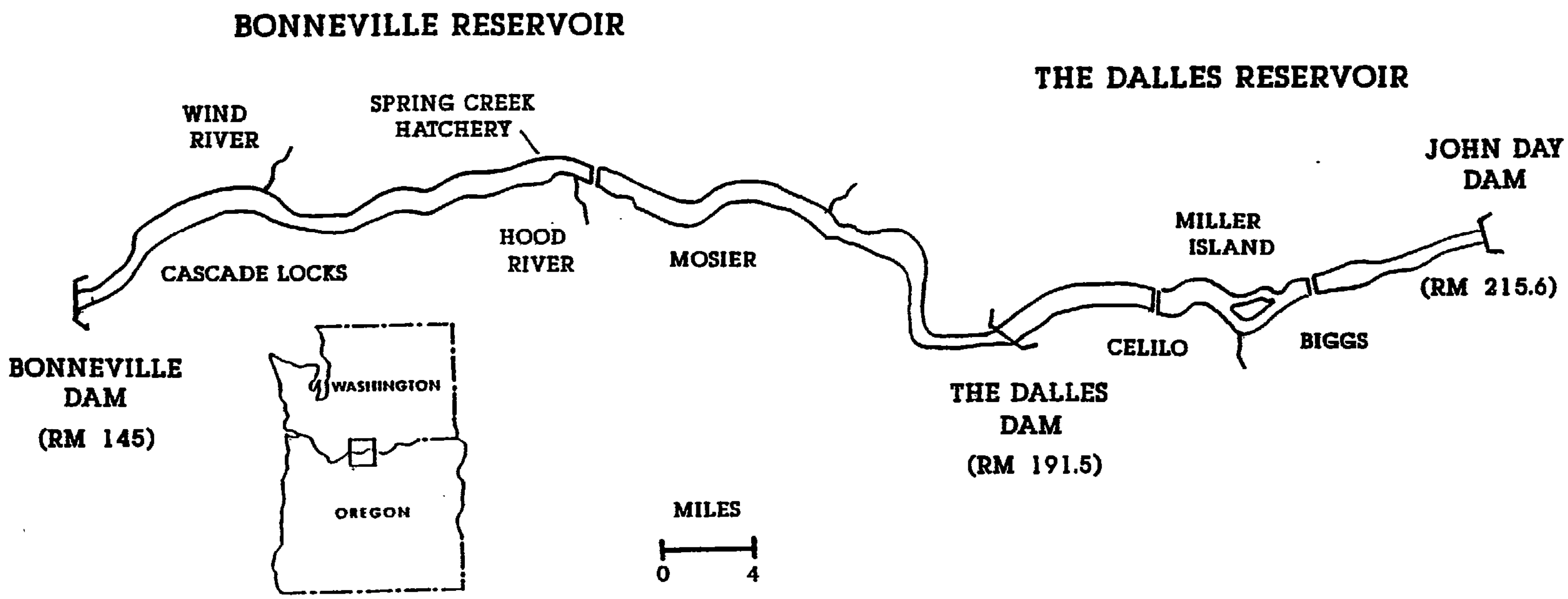

Figure 1. Location of Bonneville and The Dalles reservoirs on the Columbia River.

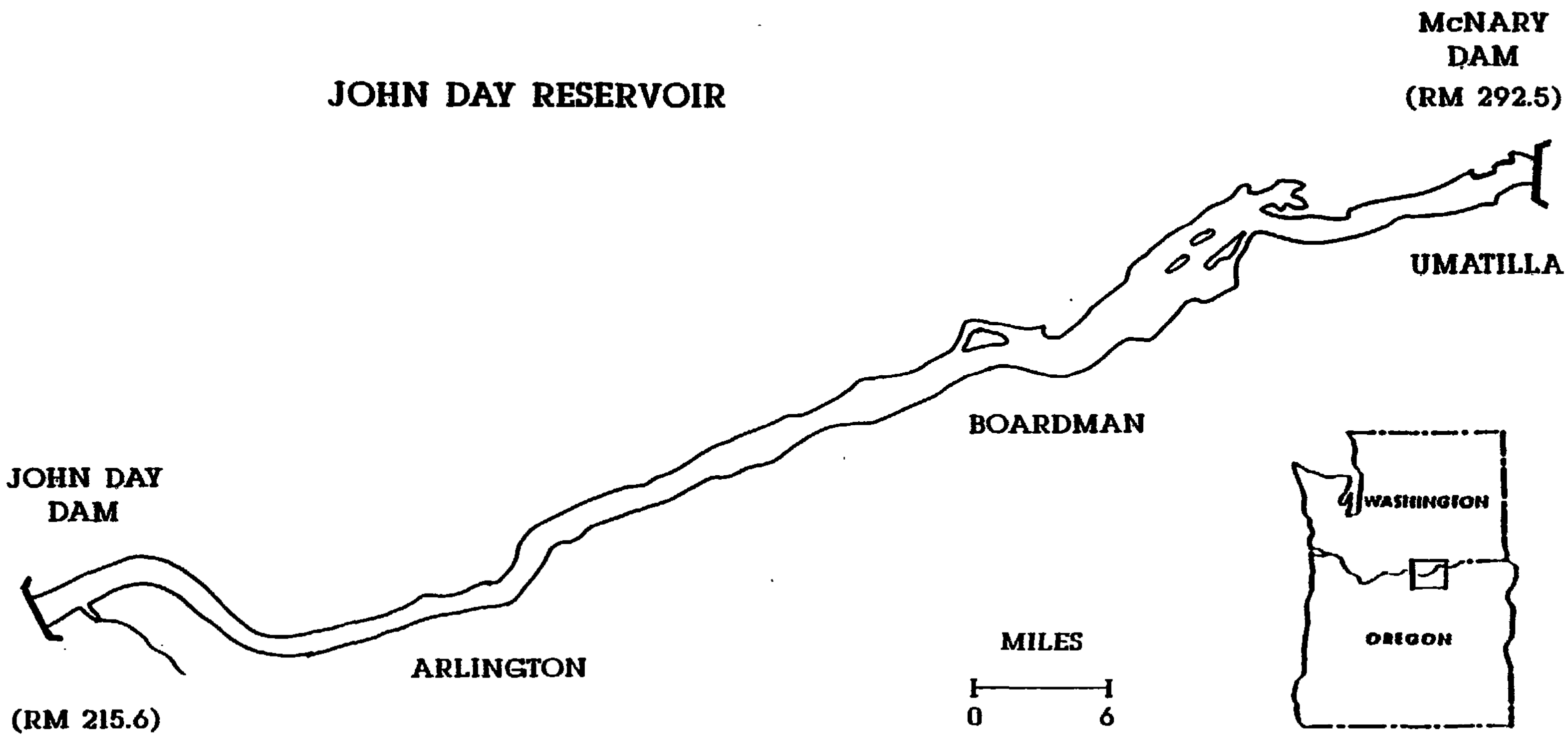

Figure 2. Location of John Day Reservoir on the Columbia River.

Tribal Commercial Fishery Landings

Numbers of white sturgeon harvested in Columbia River commercial fisheries were estimated from poundages reported on fish receiving tickets for each gear type. Poundages of white sturgeon were converted to numbers of fish by applying an average weight per fish obtained during random biological sampling by field crews. Average weights and the conversion of numbers from pounds of fish were calculated by statistical week.

Landings by commercial fishing zone were estimated from the catch area reported on fish receiving tickets. There are five commercial fishing zones in the mainstem Columbia River downstream from Bonneville Dam and one commercial fishing zone for tribal fisheries between Bonneville and McNary dams (Zone 6). Zone 6 is further stratified by reservoir on the fish receiving tickets, enabling a reservoir-specific harvest estimate. The legal commercial size slot for sturgeon was 48 to 72 inches in 1989.

Tribal ceremonial and subsistence fisheries for white sturgeon also occurred in 1989 and were sporadically sampled. Harvest estimates and catch accountability for these fisheries are unavailable.

Mark Recovery and Biological Sampling

Mark recovery and biological sampling data were obtained for white sturgeon from the recreational and commercial fisheries from all areas downstream from McNary Dam. Sampling of the recreational catch was obtained as part of the angler interview. Commercial fishery catches were sampled at the fish buying facilities. Samples from the tribal commercial fishery were segregated by reservoir whenever possible. Collection methods and handling of samples were consistent for all fisheries sampled.

Samples were classified as random or "in-sample" if they were obtained during the normal interview/sampling routine. Marked spaghetti-tagged sturgeon, voluntarily turned in by the fisherman outside the normal sampling routine, were classified as nonrandom.

Voluntary returns of tagged white sturgeon were solicited with signs posted at access points and at popular fishing locations. Drop boxes for voluntary returns of spaghetti tags were also 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 (eg. tethered) for later processing.

All available sturgeon catches were sampled and examined for identifying marks (spaghetti tags, clipped barbels, scutes and fin rays or Monel bands). Biological data collection included fork length (FL), total length (TL), weight, sex, pectoral fin ray and ovary samples. Pectoral fin rays were packaged unpreserved with identification labels.

Ovary samples were preserved in formalin. Both were transferred to ODFW for further processing.

Population Dynamics Downstream of Bonneville Dam

Data used in modeling the white sturgeon population downstream of Bonneville Dam include estimates of abundance, total and fishing mortality, age, growth and reproduction. Data were collected by an intensive white sturgeon marking program and by sampling recreational, commercial and research fisheries in 1989. Sampling methodology is described in King (1990) and Grimes (1990). Data collected in previous years were processed and analyzed.

White sturgeon were collected for marking by contracting with commercial fishermen. Commercial capture gear consisted of conventional diver and floater gillnets 200 fathoms in length 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 obtain an estimate of 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 in four other areas distributed throughout the lower Columbia River (RM 28-127) (Figure 3). The intent of the marking program was to capture and tag as many white sturgeon as possible throughout the year while minimizing the incidental handling of salmonids. The primary method of recovering marked white sturgeon was by sampling recreational and commercial fisheries downstream of Bonneville Dam.

Efforts to validate age determination techniques (Brennan 1987) were supplemented by oxy-tetracycline (100 mg/l OTC) injections in sublegal size sturgeon (70-95 cm TL) caught during research fisheries in 1989. OTC injections were accompanied by spaghetti tag marking and a year specific scute removal pattern (2nd right, 3rd left lateral in 1989). Subsequent OTC recoveries will be analyzed by cross sectioning pectoral fin ray samples. Periodic growth rings will be examined under ultraviolet light with a dissection scope. The number and distribution of rings and checks will be measured with respect to the fluorescent OTC ring. The identification of annuli in these sections will validate these aging techniques.

Developmental stages of ovaries collected from sturgeon downstream from Bonneville Dam were classified according to the method used by ODFW for samples collected between Bonneville and McNary dams.

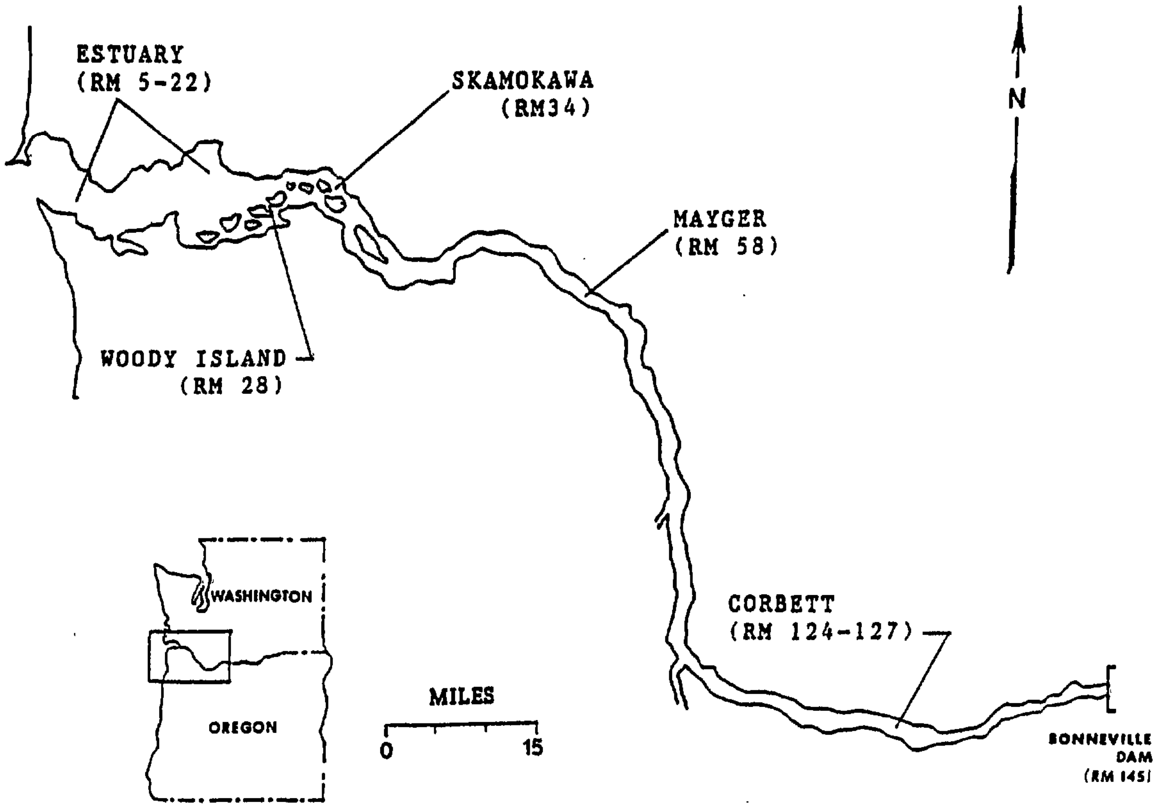

Figure 3. Locations on the Columbia River below Bonneville Dam where white sturgeon were captured and marked in 1989.

RESULTS

Eggs and Larvae Analysis

The results of the egg and larvae analysis for specimens collected downstream of Bonneville Dam are presented by NMFS in REPORT D of this document. Additional information can be obtained in Tracy (1990).

Recreational Fishery Census

Angler effort in the recreational fisheries in Bonneville and The Dalles reservoirs was estimated on 216 and 205 days, respectively, during the census period of 244 days (March through October) in 1989 (Table 1). Angler effort in the John Day Reservoir was counted on 81 days during the 1989 census period of 92 days (May through July) (Table 2). Samplers interviewed 5,682 anglers in Bonneville Reservoir, 7,757 anglers in The Dalles Reservoir and 1,867 anglers in John Day Reservoir during the respective 1989 census periods (Tables 3 and 4). Anglers in Bonneville Reservoir fished 70,583 hours for white sturgeon and 85,971 hours for other species during the census period (Table 5). The angling effort in The Dalles Reservoir during the census period totaled 45,684 hours for white sturgeon and 126,802 hours for other species (Table 5). John Day Reservoir anglers fished 43,650 hours for sturgeon and 71,961 hours for other species during the 1989 census period (Table 6).

Catch rates (harvested catch per angler hour) during the census period in Bonneville Reservoir peaked in late March (week 12-13) at 0.073 fish/hour (Table 7). In The Dalles Reservoir, the peak catch rate of 0.031 fish/hour occurred in early October (week 40-41). The John Day Reservoir fishery had a peak catch rate of 0.011 fish/hour in July (week 28-29) (Table 8).

Recreational harvest of legal size white sturgeon in Bonneville Reservoir during the 1989 census period was estimated to be 2,619, while The Dalles and John Day reservoir catches were estimated to be 499 and 282, respectively (Tables 9 and 10). There were a minor number of sublegal and slightly oversize sturgeon included in the recreational harvest.

The ratios of sublegal:legal:oversize white sturgeon handled during the 1989 census period were 270:43:1 in Bonneville Reservoir, 123:15:1 in The Dalles Reservoir and 53:5:1 in John Day Reservoir (Tables 11 and 12). In Bonneville Reservoir, 12 oversize white sturgeon were handled by boat anglers compared to one by bank anglers. The converse situation occurred in The Dalles and John Day reservoirs. Boat anglers in The Dalles Reservoir handled 3 oversize sturgeon while bank anglers handled 11. Boat anglers fishing in John Day Reservoir handled 2 oversize sturgeon while bank anglers handled 6 oversize sturgeon.

Table 1. Numbers of days angler effort was counted on Bonneville and The Dalles reservoirs, March-October, 1989.

Reservoir, statistical week	Effort count type		
	Flight	Sunrise-sunset index	Once through index
Bonneville			
10-11	2	2	6
12-13	3	4	9
14-15	3	4	10
16-17	2	4	9
18-19	3	4	10
20-21	2	4	9
22-23	3	4	8
24-25	3	4	9
26-27	2	4	9
28-29	2	4	8
30-31	3	4	7
32-33	2	4	10
34-35	3	4	7
36-37	3	4	8
38-39	2	4	9
40-41	3	4	9
42-43	2	4	8
44-45	2	2	3
Total	45	68	148
The Dalles			
10-11	2	2	1
12-13	3	4	5
14-15	3	4	7
16-17	2	4	10
18-19	3	4	10
20-21	2	4	9
22-23	3	4	9
24-25	3	4	8
26-27	2	4	10
28-29	2	4	7
30-31	3	4	9
32-33	2	4	9
34-35	3	4	8
36-37	3	4	7
38-39	2	4	9
40-41	3	4	9
42-43	2	4	7
44-45	2	2	3
Total	45	68	137

Table 2. Numbers of days angler effort was counted on John Day Reservoir, May-July, 1989.

Reservoir, statistical week	Effort count type		
	Flight	Sunrise-sunset index	Once through index
John Day			
19	0	1	0
20-21	2	4	10
22-23	3	4	9
24-25	3	4	10
26-27	2	4	10
28-29	2	4	8
30-31	3	3	10
32	0	0	0
Total	15	24	57

Table 3. Numbers of anglers interviewed on Bonneville and The Dalles reservoirs, March-October, 1989.

Reservoir statistical week	Boat		Bank	
	Sturgeon	Other	Sturgeon	Other
Bonneville				
10-11	30	11	72	8
12-13	48	7	190	21
14-15	92	21	325	10
16-17	58	101	148	16
18-19	54	63	146	17
20-21	84	72	136	25
22-23	116	47	134	15
24-25	91	20	95	68
26-27	113	13	110	81
28-29	93	15	100	174
30-31	24	29	154	214
32-33	70	35	107	201
34-35	36	106	92	152
36-37	30	160	49	172
38-39	65	176	23	234
40-41	21	40	46	152
42-43	31	55	26	78
44-45	6	9	28	21
Total	1,062	980	1,981	1,659
The Dalles				
10-11	9	13	7	2
12-13	5	47	64	7
14-15	32	58	53	6
16-17	24	180	81	6
18-19	13	270	112	12
20-21	5	159	101	26
22-23	21	173	229	114
24-25	66	170	348	388
26-27	114	157	467	163
28-29	15	60	258	49
30-31	45	84	219	66
32-33	25	176	130	170
34-35	16	368	109	117
36-37	24	501	138	120
38-39	7	212	101	286
40-41	23	99	60	196
42-43	26	128	31	123
44-45	7	17	7	42
Total	477	2,872	2,515	1,893

Table 4. Numbers of anglers interviewed on John Day Reservoir, May-July, 1989.

Reservoir, statistical week	Boat		Bank	
	Sturgeon	Other	Sturgeon	Other
John Day				
19	3	0	2	0
20-21	13	72	75	55
22-23	34	39	78	32
24-25	44	171	94	117
26-27	84	120	122	82
28-29	57	146	86	20
30-31	38	91	136	56
32	0	0	0	0
Total	273	639	593	362

Table 5. Estimated hours of angler effort in Bonneville and The Dalles reservoirs, March-October, 1989.

Reservoir, statistical week	Sturgeon anglers			Other anglers		
	Boat	Bank	Combined	Boat	Bank	Combined
Bonneville						
10-11	996	2,172	3,168	159	145	304
12-13	1,131	3,224	4,355	208	362	570
14-15	1,482	3,380	4,862	230	272	502
16-17	1,335	2,574	3,909	1,387	91	1,478
18-19	870	1,990	2,860	1,995	236	2,231
20-21	2,042	1,860	3,902	788	158	946
22-23	2,453	3,872	6,325	980	124	1,104
24-25	2,389	2,516	4,905	990	1,238	2,228
26-27	2,459	3,896	6,355	489	2,132	2,621
28-29	1,818	2,677	4,495	321	4,835	5,156
30-31	1,356	2,984	4,340	1,188	6,854	8,042
32-33	1,651	2,628	4,279	753	8,335	9,088
34-35	2,219	1,875	4,094	3,728	7,045	10,773
36-37	1,108	1,841	2,949	5,643	7,371	13,014
38-39	1,935	1,662	3,597	4,990	6,979	11,969
40-41	853	1,790	2,643	1,775	4,904	6,679
42-43	705	1,097	1,802	1,369	3,323	4,692
44-45	624	1,119	1,743	1,401	3,173	4,574
Total	27,426	43,157	70,583	28,394	57,577	85,971
The Dalles						
10-11	408	476	884	726	8	734
12-13	144	655	799	782	81	863
14-15	510	669	1,179	837	121	958
16-17	409	1,200	1,609	2,982	76	3,058
18-19	153	1,582	1,735	3,766	138	3,904
20-21	94	1,257	1,351	2,734	119	2,853
22-23	612	4,209	4,821	4,701	1,597	6,298
24-25	1,016	5,553	6,569	3,361	3,290	6,651
26-27	2,007	6,848	8,855	3,650	2,073	5,723
28-29	601	2,700	3,301	2,635	394	3,029
30-31	961	2,151	3,112	3,490	922	4,412
32-33	1,397	1,631	3,028	5,574	1,942	7,516
34-35	380	1,456	1,836	17,238	1,699	18,937
36-37	642	2,437	3,079	23,165	2,069	25,234
38-39	361	1,169	1,530	17,651	3,633	21,284
40-41	371	573	944	3,856	2,115	5,971
42-43	279	356	635	2,899	2,016	4,915
44-45	292	125	417	2,312	2,150	4,462
Total	10,637	35,047	45,684	102,359	24,443	126,802

Table 6. Estimated hours of angler effort in John Day Reservoir, May-July, 1989.

Reservoir, statistical week	Sturgeon anglers			Other anglers		
	Boat	Bank	Combined	Boat	Bank	Combined
John Day						
19	299	1,059	1,358	2,704	255	2,959
20-21	842	2,122	2,964	5,645	510	6,155
22-23	5,323	2,928	8,251	11,330	810	12,140
24-25	3,832	3,757	7,589	15,133	2,341	17,474
26-27	4,474	5,025	9,499	9,320	1,521	10,841
28-29	4,197	2,874	7,071	8,398	275	8,673
30-31	4,439	2,253	6,692	12,424	949	13,373
32	110	116	226	324	22	346
Total	23,516	20,134	43,650	65,278	6,683	71,961

Table 7. Numbers of white sturgeon, by size group, reported in the sampled recreational fishery catch in Bonneville and The Dalles reservoirs, March-October, 1989.

Reservoir, statistical week	Boat				Bank			
	Sub legal	Legal rel.	Legal kept	Over-size	Sub legal	Legal rel.	Legal kept	Over-size
Bonneville								
10-11	30	0	6	0	62	0	6	0
12-13	110	2	12	0	170	2	35	0
14-15	72	0	13	0	362	0	35	0
16-17	98	0	2	0	96	0	8	0
18-19	78	0	10	0	85	0	7	1
20-21	208	1	24	5	83	0	9	0
22-23	196	1	15	1	112	0	5	0
24-25	243	0	52	0	74	0	12	0
26-27	251	0	48	2	114	0	23	0
28-29	152	2	41	0	71	0	16	0
30-31	23	0	4	0	105	0	22	0
32-33	118	1	27	1	94	0	18	0
34-35	34	3	4	2	43	2	17	0
36-37	40	0	3	0	51	0	11	0
38-39	105	1	14	1	11	0	3	0
40-41	32	0	3	0	34	0	9	0
42-43	111	0	15	0	16	0	4	0
44-45	19	0	2	0	7	3	0	0
Total	1,920	11	295	12	1,590	7	240	1
The Dalles								
10-11	0	0	0	0	11	0	0	0
12-13	1	0	0	0	18	0	5	0
14-15	12	0	2	0	9	0	0	0
16-17	4	0	0	0	24	0	1	0
18-19	14	0	0	0	19	0	1	0
20-21	6	0	0	0	27	0	8	0
22-23	23	0	0	0	19	0	7	3
24-25	123	0	20	0	94	0	21	5
26-27	195	1	17	1	155	0	27	3
28-29	35	0	4	1	118	1	6	0
30-31	66	1	9	0	154	0	2	0
32-33	100	0	3	0	75	1	7	0
34-35	41	0	6	0	43	0	4	0
36-37	82	1	6	0	81	0	9	0
38-39	13	2	1	0	41	0	10	0
40-41	30	2	5	0	26	0	6	0
42-43	47	1	8	1	6	0	0	0
44-45	7	0	1	0	1	0	1	0
Total	799	8	82	3	921	2	115	11

Table 8. Numbers of white sturgeon, by size group, reported in the sampled recreational fishery catch in John Day Reservoir, May-July, 1989.

Reservoir, statistical week	Boat				Bank			
	Sub legal	Legal rel.	Legal kept	Over-size	Sub legal	Legal rel.	Legal kept	Over-size
John Day								
19	0	0	2	0	0	0	0	0
20-21	1	0	1	0	1	0	0	2
22-23	25	0	0	2	8	0	0	0
24-25	44	0	2	0	41	0	3	0
26-27	126	8	2	0	22	0	5	2
28-29	57	0	5	0	41	1	4	0
30-31	35	0	4	0	26	0	2	2
32	0	0	0	0	0	0	0	0
Total	288	8	16	2	139	1	14	6

Table 9. White sturgeon harvest per hour of angling effort in Bonneville and The Dalles reservoirs, March-October, 1989.

Reservoir, statistical week	Sturgeon anglers			Other anglers		
	Boat	Bank	Combined	Boat	Bank	Combined
Bonneville						
10-11	0.049	0.048	0.049	0.000	0.000	0.000
12-13	0.034	0.087	0.073	0.000	0.000	0.000
14-15	0.019	0.030	0.026	0.000	0.000	0.000
16-17	0.005	0.014	0.011	0.000	0.000	0.000
18-19	0.016	0.017	0.016	0.000	0.000	0.000
20-21	0.040	0.015	0.028	0.000	0.000	0.000
22-23	0.031	0.005	0.015	0.000	0.000	0.000
24-25	0.054	0.051	0.052	0.000	0.000	0.000
26-27	0.073	0.045	0.056	0.000	0.000	0.000
28-29	0.079	0.040	0.056	0.000	0.000	0.000
30-31	0.027	0.027	0.027	0.000	0.000	0.000
32-33	0.056	0.044	0.048	0.000	0.000	0.000
34-35	0.027	0.027	0.027	0.000	0.000	0.000
36-37	0.014	0.046	0.034	0.000	0.000	0.000
38-39	0.051	0.039	0.046	0.000	0.000	0.000
40-41	0.011	0.033	0.026	0.000	0.000	0.000
42-43	0.057	0.015	0.032	0.000	0.000	0.000
44-45	0.059	0.000	0.021	0.000	0.000	0.000
Average	0.041	0.034	0.037	0.000	0.000	0.000
The Dalles						
10-11	0.000	0.019	0.010	0.000	0.000	0.000
12-13	0.000	0.017	0.014	0.000	0.000	0.000
14-15	0.008	0.000	0.003	0.000	0.000	0.000
16-17	0.000	0.002	0.001	0.000	0.000	0.000
18-19	0.000	0.002	0.002	0.000	0.000	0.000
20-21	0.000	0.010	0.010	0.000	0.000	0.000
22-23	0.008	0.005	0.006	0.000	0.000	0.000
24-25	0.039	0.008	0.013	0.000	0.000	0.000
26-27	0.023	0.010	0.013	0.000	0.000	0.000
28-29	0.032	0.003	0.008	0.000	0.000	0.000
30-31	0.019	0.002	0.007	0.000	0.000	0.000
32-33	0.012	0.010	0.011	0.001	0.000	0.001
34-35	0.039	0.005	0.012	0.000	0.000	0.000
36-37	0.028	0.012	0.015	0.000	0.000	0.000
38-39	0.008	0.018	0.016	0.000	0.000	0.000
40-41	0.046	0.021	0.031	0.000	0.000	0.000
42-43	0.022	0.000	0.009	0.001	0.000	0.000
44-45	0.027	0.032	0.029	0.000	0.000	0.000
Average	0.020	0.008	0.011	0.000	0.000	0.000

Table 10. White sturgeon harvest per hour of angling effort in John Day Reservoir, May-July, 1989.

Reservoir, statistical week	Sturgeon anglers			Other anglers		
	Boat	Bank	Combined	Boat	Bank	Combined
John Day						
19	0.047	0.000	0.010	0.000	0.000	0.000
20-21	0.027	0.000	0.008	0.000	0.000	0.000
22-23	0.000	0.000	0.000	0.000	0.000	0.000
24-25	0.009	0.007	0.008	0.000	0.000	0.000
26-27	0.003	0.005	0.004	0.000	0.000	0.000
28-29	0.014	0.008	0.011	0.000	0.000	0.000
30-31	0.012	0.004	0.009	0.000	0.000	0.000
32	0.009	0.000	0.004	0.000	0.000	0.000
Average	0.008	0.004	0.006	0.000	0.000	0.000

Table 11. Estimated recreational fishery harvest of white sturgeon in Bonneville and The Dalles reservoirs, March-October, 1989.

Reservoir, statistical week	Sturgeon anglers		Other anglers		
	Boat	Bank	Boat	Bank	Combined
Bonneville					
10-11	49	105	0	0	154
12-13	39	280	0	0	319
14-15	28	100	0	0	128
16-17	7	35	0	0	42
18-19	14	33	0	0	47
20-21	81	28	0	0	109
22-23	77	19	0	0	96
24-25	129	128	0	0	257
26-27	180	177	0	0	357
28-29	144	108	0	0	252
30-31	36	81	0	0	117
32-33	92	115	0	0	207
34-35	59	50	0	0	109
36-37	15	84	0	0	99
38-39	99	65	0	0	164
40-41	9	59	0	0	68
42-43	40	17	0	0	57
44-45	37	0	0	0	37
Total	1,135	1,484	0	0	2,619
The Dalles					
10-11	0	9	0	0	9
12-13	0	11	0	0	11
14-15	4	0	0	0	4
16-17	0	2	0	0	2
18-19	0	3	0	0	3
20-21	0	13	0	0	13
22-23	5	22	0	0	27
24-25	40	43	0	0	83
26-27	46	66	0	0	112
28-29	19	9	0	0	28
30-31	18	5	0	0	23
32-33	17	17	8	0	42
34-35	15	7	0	0	22
36-37	18	29	0	0	47
38-39	3	21	0	0	24
40-41	17	12	0	0	29
42-43	6	0	2	0	8
44-45	8	4	0	0	12
Total	216	273	10	0	499

Table 12. Estimated recreational fishery harvest of white sturgeon in John Day Reservoir, May-July, 1989.

Reservoir, statistical week	Sturgeon anglers		Other anglers		
	Boat	Bank	Boat	Bank	Combined
John Day					
19	14	0	0	0	14
20-21	23	0	0	0	23
22-23	0	0	0	0	0
24-25	33	28	0	0	61
26-27	14	26	0	0	40
28-29	57	23	0	0	80
30-31	55	8	0	0	63
32	1	0	0	0	1
Total	197	85	0	0	282

Tribal Commercial Fishery Landings

The preliminary 1989 tribal commercial harvest estimate for Zone 6 (Bonneville to McNary dams) was 3,507 white sturgeon. Most of this harvest (3,074) occurred in the winter set-net fishery which took place from February 1 through March 21, 1989. The setline fishery, which ran from January 1 through April 30 in 1989, had a harvest of 433 sturgeon. The Dalles Reservoir was the primary tribal commercial catch area with 1,932 sturgeon harvested. There were 1,410 sturgeon harvested in Bonneville Reservoir by treaty commercial fishermen in 1989. There were 165 sturgeon harvested in John Day Reservoir commercial fisheries. There was no allowable sale of sturgeon in any of the other tribal fisheries in 1989. Incidentally caught sturgeon taken after April 30, 1989 during tribal fisheries were not allowed for sale, but were allowed to be taken for ceremonial and subsistence purposes. Ceremonial and subsistence harvest estimates are not available.

Mark Recovery and Biological Sampling

There were 507 white sturgeon examined for marks in the Bonneville Reservoir recreational fishery in 1989 for an overall mark sample rate of 0.19 (Table 13). There were 2 marks recovered while sampling the Bonneville recreational fishery for an estimated 10 marked sturgeon harvested in that pool. In The Dalles Reservoir, 186 sturgeon from the recreational fishery were examined for marks with 10 in-sample marks recovered. The mark sample rate of 0.37 in The Dalles reservoir resulted in an estimated harvest of 27 marked sturgeon. There were 29 sturgeon examined for marks in the John Day Reservoir recreational catch with no marks recovered (Table 14). The mark sample rate for this fishery was 0.10 and the estimated harvest of marked fish was zero. Eight ODFW marked sturgeon harvested in Bonneville Reservoir were voluntarily reported to WDF during 1989. Information on 2 released sublegal marked fish was also obtained from the Bonneville Reservoir fishery. There were voluntary recoveries of 13 ODFW marked sturgeon from The Dalles Reservoir fishery with information also obtained on 4 sublegal marked fish that were released. Additionally, four marked sturgeon were selectively sampled (eg. from prior day's catch) in The Dalles fishery with select information on one released sublegal sturgeon also acquired from this fishery. There were no recoveries of ODFW marked sturgeon from the John Day Reservoir fishery.

Fork lengths were measured on 482, 184 and 25 white sturgeon harvested in Bonneville, The Dalles and John Day reservoir recreational fisheries, respectively (Figures 4 and 5). The average FL of harvested white sturgeon in Bonneville Reservoir in 1989 was 103 cm and ranged from 89 to 166 cm FL. White sturgeon recreationally harvested in The Dalles Reservoir in 1989 averaged 116 cm FL with a range of 82 to 175 cm FL. The average FL in the John Day Reservoir recreational harvest was 102 cm with a range of 89 to 120 cm FL.

There were 185 sturgeon examined for marks in tribal commercial fisheries in Bonneville Reservoir in 1989 with 2 in-sample marks recovered (Table 15). With an estimated tribal commercial harvest of

Table 13. Estimated recreational fishery harvest of ODFW marked white sturgeon from Bonneville and The Dalles reservoirs, March-October, 1989.

Reservoir, statistical week	Estimated harvest	Number examined for marks	Mark sample rate	Observed marks	Estimated mark harvest
Bonneville					
10-11	154	12	0.08	0	--
12-13	319	47	0.15	0	--
14-15	128	45	0.35	0	--
16-17	42	10	0.24	0	--
18-19	47	16	0.34	0	--
20-21	109	32	0.29	0	--
22-23	96	17	0.18	0	--
24-25	257	61	0.24	0	--
26-27	357	62	0.17	0	--
28-29	252	54	0.21	0	--
30-31	117	25	0.21	0	--
32-33	207	44	0.21	1	--
34-35	109	19	0.17	0	--
36-37	99	14	0.14	0	--
38-39	164	17	0.10	1	--
40-41	68	12	0.18	0	--
42-43	57	18	0.32	0	--
44-45	37	2	0.05	0	--
Total	2,619	507	0.19	2	10
The Dalles					
10-11	9	0	0.00	0	--
12-13	11	5	0.45	0	--
14-15	4	2	0.50	0	--
16-17	2	1	0.50	0	--
18-19	3	1	0.33	0	--
20-21	13	8	0.62	0	--
22-23	27	7	0.26	0	--
24-25	83	39	0.47	0	--
26-27	112	40	0.36	0	--
28-29	28	10	0.36	2	--
30-31	23	9	0.39	3	--
32-33	42	10	0.24	0	--
34-35	22	10	0.45	0	--
36-37	47	13	0.28	0	--
38-39	24	11	0.46	1	--
40-41	29	11	0.38	3	--
42-43	8	7	0.88	1	--
44-45	12	2	0.17	0	--
Total	499	186	0.37	10	27

Table 14. Estimated recreational fishery harvest of ODFW marked white sturgeon from John Day Reservoir, May-July, 1989.

Reservoir, statistical week	Estimated harvest	Number examined for marks	Mark sample rate	Observed marks	Estimated mark harvest
John Day					
19	14	2	0.14	0	--
20-21	23	1	0.04	0	--
22-23	0	0	0.00	0	--
24-25	61	5	0.08	0	--
26-27	40	14	0.35	0	--
28-29	80	6	0.08	0	--
30-31	63	1	0.02	0	--
32	1	0	0.00	0	--
Total	281	29	0.10	0	0

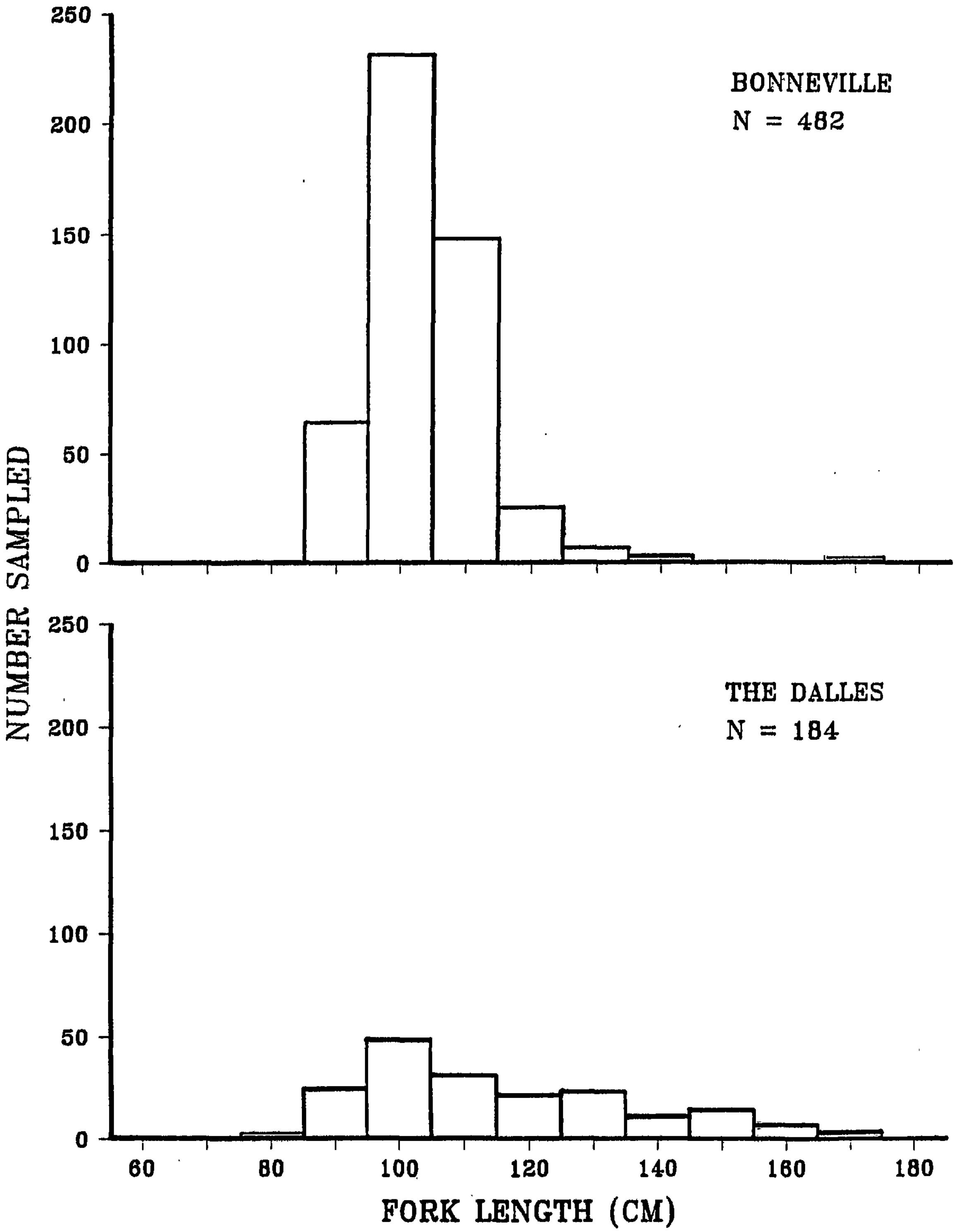

Figure 4. Length-frequency distributions of harvested white sturgeon sampled from the March through October, 1989, recreational fisheries for Bonneville and The Dalles reservoirs.

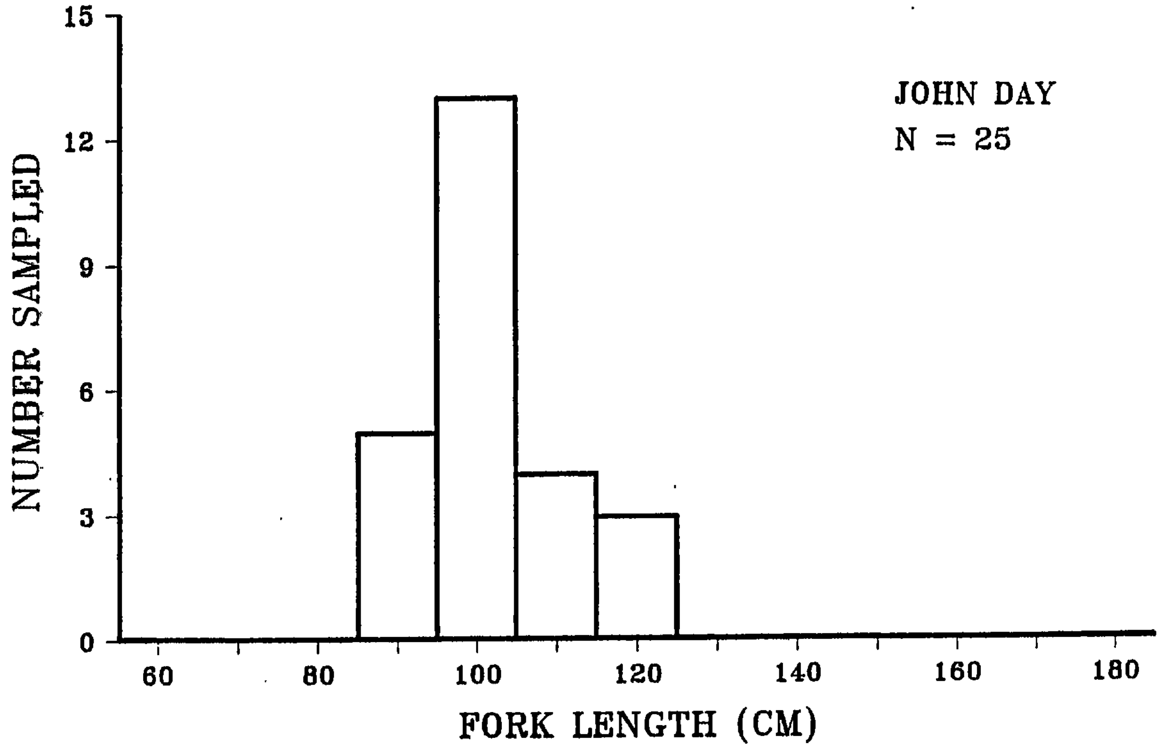

Figure 5. Length-frequency distribution of harvested white sturgeon sampled from the May through July, 1989, recreational fishery for John Day Reservoir.

Table 15. Estimated harvest of ODFW marked white sturgeon landed by commercial fisheries in Bonneville, The Dalles, and John Day reservoirs during 1989.

Reservoir, statistical week	Number landed	Number examined for marks[a]	Mark sample rate	Observed marks	Estimated mark harvest
Bonneville					
1- 2	2	0	0.000	0	--
3- 4	9	0	0.000	0	--
5- 6	9	0	0.000	0	--
7- 8	118	4	0.034	0	--
9-10	164	13	0.079	1	--
11-12	694	85	0.122	1	--
13-14	292	80	0.274	0	--
15-16	69	3	0.043	0	--
17-18	51	0	0.000	0	--
19-52	2	0	0.000	0	--
Total	1,410	185	0.131	2	15
The Dalles					
1- 2	2	0	0.000	0	--
3- 4	31	3	0.097	0	--
5- 6	27	2	0.074	0	--
7- 8	63	2	0.032	1	--
9-10	837	317	0.379	10	--
11-12	735	272	0.370	8	--
13-14	182	67	0.368	3	--
15-16	36	0	0.000	0	--
17-18	15	0	0.000	0	--
19-52	4	0	0.000	0	--
Total	1,932	663	0.343	22	64
John Day					
1- 2	0	0	0.000	0	--
3- 4	0	0	0.000	0	--
5- 6	2	0	0.000	0	--
7- 8	17	0	0.000	0	--
9-10	69	0	0.000	0	--
11-12	22	0	0.000	0	--
13-14	28	0	0.000	0	--
15-16	6	1	0.167	0	--
17-18	21	0	0.000	0	--
19-52	0	0	0.000	0	--
Total	165	1	0.006	0	0

[a] *The reservoir was unidentified for five mark sampled fish.*

1,410 sturgeon in Bonneville Reservoir, the mark sample rate for these fisheries was 0.13 and the estimated harvest of ODFW marked fish was 15. There were 663 sturgeon examined for marks from The Dalles Reservoir tribal commercial estimated harvest of 1,932 sturgeon (mark sample rate was 0.34). Twenty two marks were recovered from The Dalles commercial fisheries. The estimated harvest of ODFW marked sturgeon in The Dalles commercial fisheries was 64.

Fork lengths were measured on 114 and 518 sturgeon caught in Bonneville and The Dalles tribal commercial fisheries, respectively (Figure 6). The average FL from commercially harvested sturgeon from Bonneville Reservoir was 115 cm and ranged from 104 to 161 cm FL. Sturgeon commercially harvested in The Dalles Reservoir averaged 126 cm FL and ranged from 100 to 169 cm FL. The one sturgeon sampled from the John Day Reservoir tribal commercial fisheries measured 117 cm FL.

The sex ratio based on samples examined for sex in Bonneville Reservoir 1989 recreational and tribal commercial fisheries was 58% female (Table 16). There were 306 ovary samples collected from these Bonneville Reservoir fisheries. The sampled sex ratio for 1989 recreational and tribal commercial fisheries in The Dalles Reservoir was 45% female. There were 260 ovary samples obtained from these fish. Four sturgeon were examined for sex in John Day Reservoir fisheries in 1989. Three of these fish were males and a gonad sample was obtained from the one female sampled.

Fin ray samples were obtained from 547, 526 and 19 white sturgeon harvested in Bonneville, The Dalles and John Day reservoir fisheries, respectively in 1989 (Table 16). There were 5 pectoral fin ray samples taken from sturgeon harvested in unknown reservoirs.

Population Dynamics Downstream of Bonneville Dam

Field activities downstream of Bonneville Dam in 1989 focused on continued marking of white sturgeon and sampling recreational and commercial fisheries for mark recoveries and biological samples. A total of 7,036 white sturgeon were captured and 5,389 were marked with spaghetti tie tags during WDF and ODFW research fisheries in 1989. Total marks placed represents a record, surpassing the previous record of 4,581 sturgeon tagged and released in 1986. The mark and release effort was distributed as follows: 4,273 in the Columbia River estuary (RM 5-22), 812 at Woody Island (RM 28), 85 at Skamokawa (RM 34), 41 at Mayger (RM 58) and 178 at Corbett (RM 128). An additional 18 sturgeon were tagged and released during other tagging activities. There were 244 white sturgeon injected with OTC during 1989 research fisheries. These fish were also tagged and secondarily marked with a specific scute removal pattern. There were no recoveries of OTC-injected sturgeon from 1988 tagging efforts in 1989.

WDF and ODFW mark sampled 4,409 and 1,960 white sturgeon harvested in the lower Columbia River recreational and commercial fisheries, respectively in 1989 (Table 17). There were 38 recoveries of sturgeon marked in 1989 in recreational fisheries and 14 marks recovered from

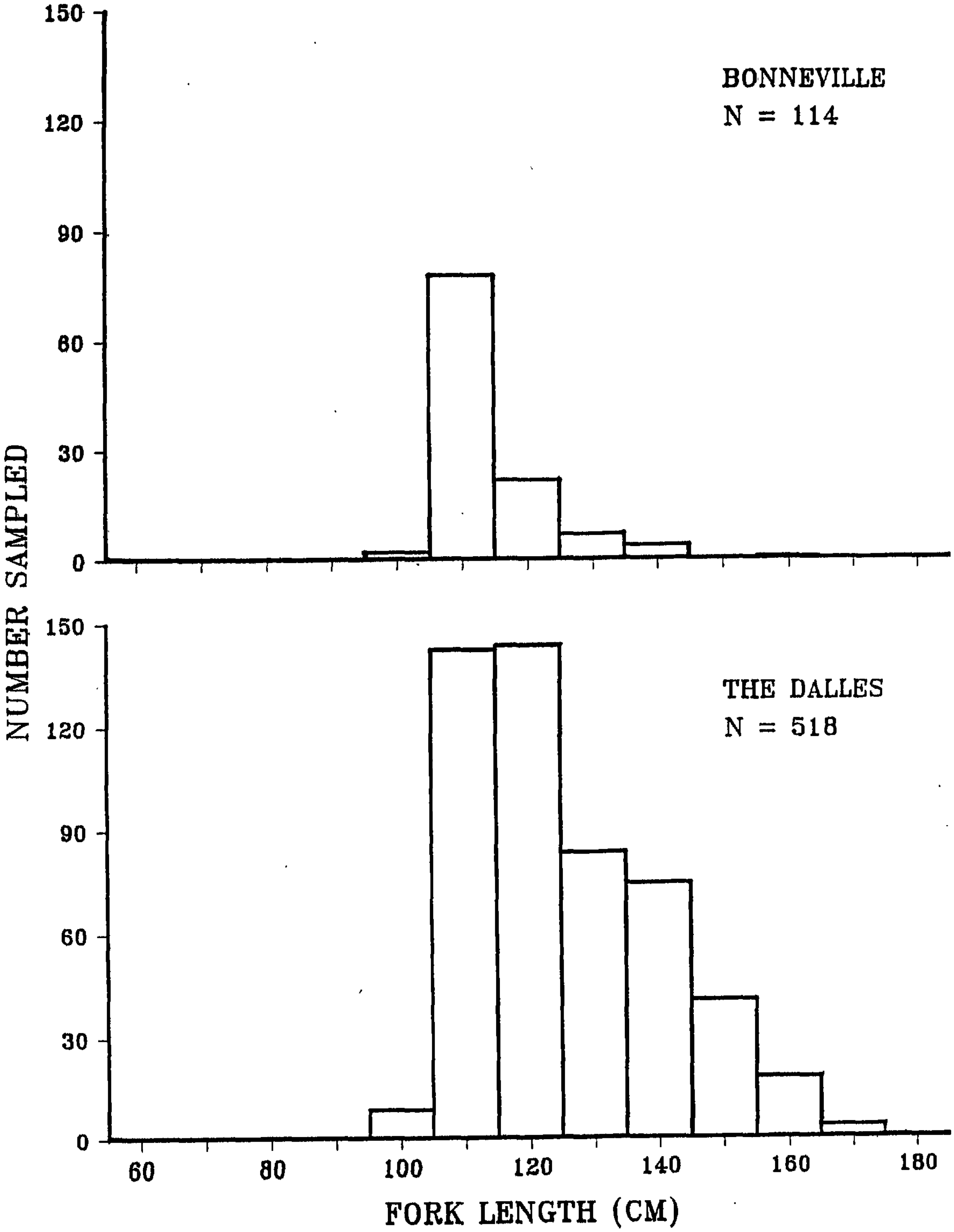

Figure 6. Length-frequency distributions of harvested white sturgeon sampled from 1989 commercial fisheries for Bonneville and The Dalles reservoirs.

Table 16. Numbers of white sturgeon measured, numbers examined to determine sex, and numbers of ovary and fin ray samples collected during sampling of 1989 recreational and commercial fisheries on Bonneville, The Dalles and John Day reservoirs.

Reservoir, fishery	Length measurement collected	Gonad examined			Ovary sample collected	Fin ray sample collected
		Unknown	Male	Female		
Bonneville						
Sport	482	0	187	252	249	433
Commercial	114	0	47	68	57	114
Total	596	0	234	320	306	547
The Dalles						
Sport	184	0	23	31	29	2
Commercial	524	0	293	231	231	524
Total	708	0	316	262	260	526
John Day						
Sport	25	0	2	1	1	18
Commercial	1	0	1	0	0	1
Total	26	0	3	1	1	19
Unidentified pool						
Sport	0	0	0	0	0	0
Commercial	5	0	2	3	3	5
Total	5	0	2	3	3	5

Table 17. Recovery of white sturgeon tags by commercial, recreational and research fisheries below Bonneville Dam, 1989.

Recovery type	Estimated harvest or catch	Number examined for tags	Number recovered: 1989 tag year		Number recovered: Pre-1989 tag year	
			In-Sample	Volunteer	In-Sample	Volunteer
Commercial	5,012	1,960	14	7	52	19
Recreational	25,380	4,409	38	54	98	170
Research[a]	7,036	7,036	125	--	151	--
Total	37,428	13,405	177	61	301	189

[a] *Specific gillnet fisheries to capture sturgeon for marking or to monitor salmon runs.*

this same tag group in commercial fisheries in 1989. Additionally, there were 150 recoveries from tag groups marked prior to 1989 in lower Columbia River harvests. There were also 125 and 151 in-sample mark recoveries of 1989 tag groups and pre-1989 tag groups, respectively in 1989 research fisheries.

Biological data on white sturgeon were collected by WDF and ODFW during routine sampling of 1989 fisheries downstream of Bonneville Dam. The recreational harvest sample of 3,842 white sturgeon averaged 100 cm FL with a range of 81 to 168 cm FL. Random samples of white sturgeon from the commercial harvest ranged from 100 to 173 cm FL with an average FL of 119 cm (n=754). Pectoral fin ray samples were collected from 100 white sturgeon in the recreational fishery and 791 white sturgeon in the commercial fishery. Ovary samples were obtained from 362 commercially harvested white sturgeon. Fin ray aging and ovary maturity analysis of 1989 samples have not been completed.

DISCUSSION

The goal of mark sampling 20% of the harvest was nearly achieved for recreational and commercial fisheries in Bonneville Reservoir and was surpassed for The Dalles Reservoir fisheries. Progress was made towards achieving biological sample requirements to estimate parameters of growth and reproductive potential for the reservoir populations.

Significant progress was made in the 1989 white sturgeon marking program downstream of Bonneville Dam. The goal of marking 5,000 white sturgeon during the year was surpassed. Injecting OTC as an age marker was incorporated as part of routine marking procedures for sublegal sturgeon. These efforts should help refine abundance estimates and associated bias, growth rates, gear selectivity, tag retention rates, migration and mortality parameters.

Efforts to define population dynamics parameters of white sturgeon downstream of Bonneville Dam were advanced but not completed. Data collected in 1989 are being processed, analyzed and incorporated into databases. Problems associated with adequate mixing of marked and unmarked individuals within an open system, and the exchange of white sturgeon between the Columbia River and the ocean during the marking and recapture period have not been resolved. Efforts will be made to identify subgroups within the population that are segregated temporally and spatially.

Major investigative efforts on white sturgeon downstream of Bonneville Dam in 1990 will be directed towards continued sampling of eggs and larvae, addressing the problems associated with open system population assessment and obtaining reproductive data on oversize fish that are not susceptible to legal harvest. WDF will continue to assist NMFS in collecting and analyzing sturgeon eggs and larvae. Indices of spawning obtained during hydrological periods that are markedly different than past years will help determine the importance of flow and current velocity in Columbia River white sturgeon spawning. Fin ray age validation efforts will be expanded by injecting OTC into sublegal size white sturgeon caught at various times of the year. Verification of circulus placement with respect to the OTC mark will determine when circuli were formed and whether they represent annular events. There will be a greater effort to obtain age and reproductive data from oversize white sturgeon. WDF will accompany brood stock collection efforts by private hatchery interests downstream from Bonneville Dam. A profile of sex and maturity of large fish during the critical spawning window of lower Columbia white sturgeon will be obtained.

General field activities in 1990 will include sampling of recreational and commercial fisheries below McNary Dam. Comprehensive creel censuses will be conducted in Bonneville and John Day reservoirs from March through October, 1990. Research fisheries will be conducted downstream of Bonneville Dam in 1990 to achieve marking and recovery objectives.

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APPENDIX B-1

Angler Effort Count Index Areas and Catch Per Effort Analysis River Subsections

INDEX AREAS

Bonneville Reservoir

Boat

Bridge of the Gods at Cascade Locks, OR (RM 148.4) upstream past Stevenson, WA (RM 151.7).

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).

Three access points along the Washington shore between Thirteenmile Point and Spring Creek Hatchery (RM 160.5, RM 165.2, and RM 166.7).

The Highway pullout on the Oregon shore just west of Mosier (RM 173.9).

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).

John Day Reservoir

Boat

West of Boardman, OR (RM 268.0) upstream past Glade Creek on the Washington shore (RM 273.0).

Irrigon, OR (RM 283.0) upstream to McNary Dam (RM 292.5).

Bank

The Oregon shore just west of Irrigon, OR (RM 279.1 to RM 279.3).

The Washington shore west of Plymouth, WA (RM 286.4).

The Oregon shore just upstream of Hwy. 82 bridge at Umatilla, OR (RM 291.0).

The Oregon shore just downstream of McNary Dam (RM 292.1).

RIVER SUBSECTIONS

Bonneville Reservoir

Boat

Bonneville Dam (RM 145.0) upstream past Spring Creek Hatchery (RM 167.0).

East of Spring Creek Hatchery (RM 167.0) upstream to Hwy. 35 bridge at Hood River (RM 169.6).

Hwy. 35 bridge at Hood River (RM 169.6) upstream to The Dalles Dam (RM 191.5).

Bank

The Oregon shore from Bonneville Dam (RM 145.0) upstream past Cascade Locks (RM 149.0).

The Oregon shore upstream of Cascade Locks (RM 149.0) to Hwy. 35 bridge (RM 169.6).

The Washington shore from Bonneville Dam (RM 145.0) upstream to Hwy. 35 bridge (RM 169.6).

Both the Oregon and Washington shore from Hwy. 35 bridge (RM 169.6) upstream to The Dalles Dam (RM 191.5).

The Dalles Reservoir

Boat and Bank

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

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

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

John Day Reservoir

Boat

John Day Dam (RM 215.6) upstream to Boardman (RM 268.0).

Boardman (RM 268.0) upstream past Patterson, WA (RM 279.0).

East of Patterson (RM 279.0) upstream to McNary Dam (RM 292.5).

Bank

Both the Oregon and Washington shore from John Day Dam (RM 215.6) upstream past Patterson (RM 279.0).

Both the Oregon and Washington shore east of Patterson (RM 279.0) upstream to Hwy. 82 bridge (RM 290.9).

Both the Oregon and Washington shore from Hwy. 82 bridge (RM 290.9) upstream to McNary Dam (RM 292.5).

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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ACKNOWLEDGEMENTS

We thank Steven Hirtzel, Richard Nelle, and Calvin Sprague for assisting with field sampling, laboratory analysis and data entry; Carol Rike typed the report. The National Marine Fisheries Service provided pectoral spine samples from white sturgeon captured below Bonneville Dam for age determination. Bill Nelson and Jim Peterson provided helpful editorial comments on this report.

ABSTRACT

The U.S. Fish and Wildlife Service (FWS) sampled white sturgeon (Acipenser transmontanus) eggs, larvae and juveniles in the three Columbia River pools between Bonneville (RM 146.5) and McNary dams (RM 291.5) from February through November, 1989. White sturgeon successfully spawned in all three pools, though there was considerable variation in numbers of eggs and larvae collected. Spawning occurred only in the tailrace areas of higher velocities; eggs were collected in the upper three river miles of each pool at water temperatures from 13 to 19° C. Initiation of spawning in each pool was progressively later upstream, starting 11 May, 24 May, and 06 June in Bonneville, The Dalles and John Day pools, respectively. Larvae were collected further downstream in Bonneville and The Dalles pools during 1989 than in 1988.

Post-larval and young-of-the-year white sturgeon were collected for the first time during the study but only in Bonneville Pool. Young-of-the-year white sturgeon were collected most often at depths ranging from 23 to 49 m and as far as 55 kilometers downstream from The Dalles Dam.

Juvenile white sturgeon were most abundant in Bonneville Pool; catch per effort there was similar to 1988. Catch per area of white sturgeon remained stable in Bonneville Pool during 1989 while catches declined 27 % in The Dalles Pool from 1988. The CPE was lowest in John Day Pool, with densities only 10 % and 16 % of those found in Bonneville and The Dalles pools, respectively. Based on 1989 catches, recruitment has been low in the three pools above Bonneville Dam since 1986. No age I white sturgeon were collected during 1989, with six and four age II white sturgeon collected in Bonneville and The Dalles Pool, respectively; no white sturgeon younger than age III were collected from John Day Pool. Growth of white sturgeon in the pools above Bonneville Dam was greater than in the lower river through age V. Considerable overlap in size range of each age group through age VII occurred.

Evidence of predation on white sturgeon eggs by largescale sucker, common carp and northern squawfish was observed in the McNary Dam tailrace; however predator collections were small and the level of egg predation was not determined.

White sturgeon consumed a wide variety of prey, mostly invertebrates associated with the benthos. Corophium salmonis was the dominant food item, accounting for 33% of the total diet by weight. Though our sample size was small (N = 29), findings were consistent with recent studies of food habits of lower Columbia River white sturgeon.

INTRODUCTION

As co-investigator of the Columbia River white sturgeon (Acipenser transmontanus) study, the U. S. Fish and Wildlife Service (FWS) is responsible for tasks associated with Objectives 1 and 3. Objective 1 is to describe reproduction and early life history characteristics of white sturgeon populations, and Objective 3 is to define habitat requirements for spawning and rearing of white sturgeon and quantify extent of habitat available between Bonneville and McNary dams.

Research efforts for 1989 were to: 1) continue sampling Bonneville and The Dalles pools for eggs, larvae and juvenile white sturgeon; 2) initiate exploratory sampling in John Day Pool to locate suitable sampling locations; 3) continue efforts to define important spawning and nursery habitat; and 4) begin constructing habitat maps for each pool to quantify amount of available habitat for spawning and rearing. This report describes our activities during the 1989 field season and progress from April 1989 through March 1990.

METHODS

Field Sampling

We sampled for white sturgeon early life stages, eggs through juveniles, in Bonneville, The Dalles and John Day pools during 1989 (Figure 1). Systematic sampling at standardized locations continued in The Dalles Pool and began in Bonneville Pool after exploratory efforts in 1988. Sampling in the John Day Pool was initially exploratory and resulted in establishment of permanent sampling locations.

Gears and techniques remained the same as those used during 1988 (Parsely et al. 1989) with the following exceptions. We enlarged the fine mesh liner (1.59-mm knotless nylon) in the beam trawl to the dimensions of the entire net and reduced high-rise trawl tow duration in Bonneville Pool to 10 min from the 15 min used during 1988 to match the length of tows in The Dalles Pool. We added a 10 kg weight to each side of the beam trawl frame when sampling in faster water. We also used the beam trawl to sample for post-larval and young-of-the-year stages which were not yet readily vulnerable to the larger mesh high-rise trawl. This sampling consisted of towing the beam trawl at low speed for 30 min.

Weekly sampling for sturgeon eggs and larvae began 4 April with beam trawls and 13 April with D-shaped larval nets (Table 1). In all three pools, permanent sampling sites were located in the upper seven river miles (Figures 2, 3, & 4).

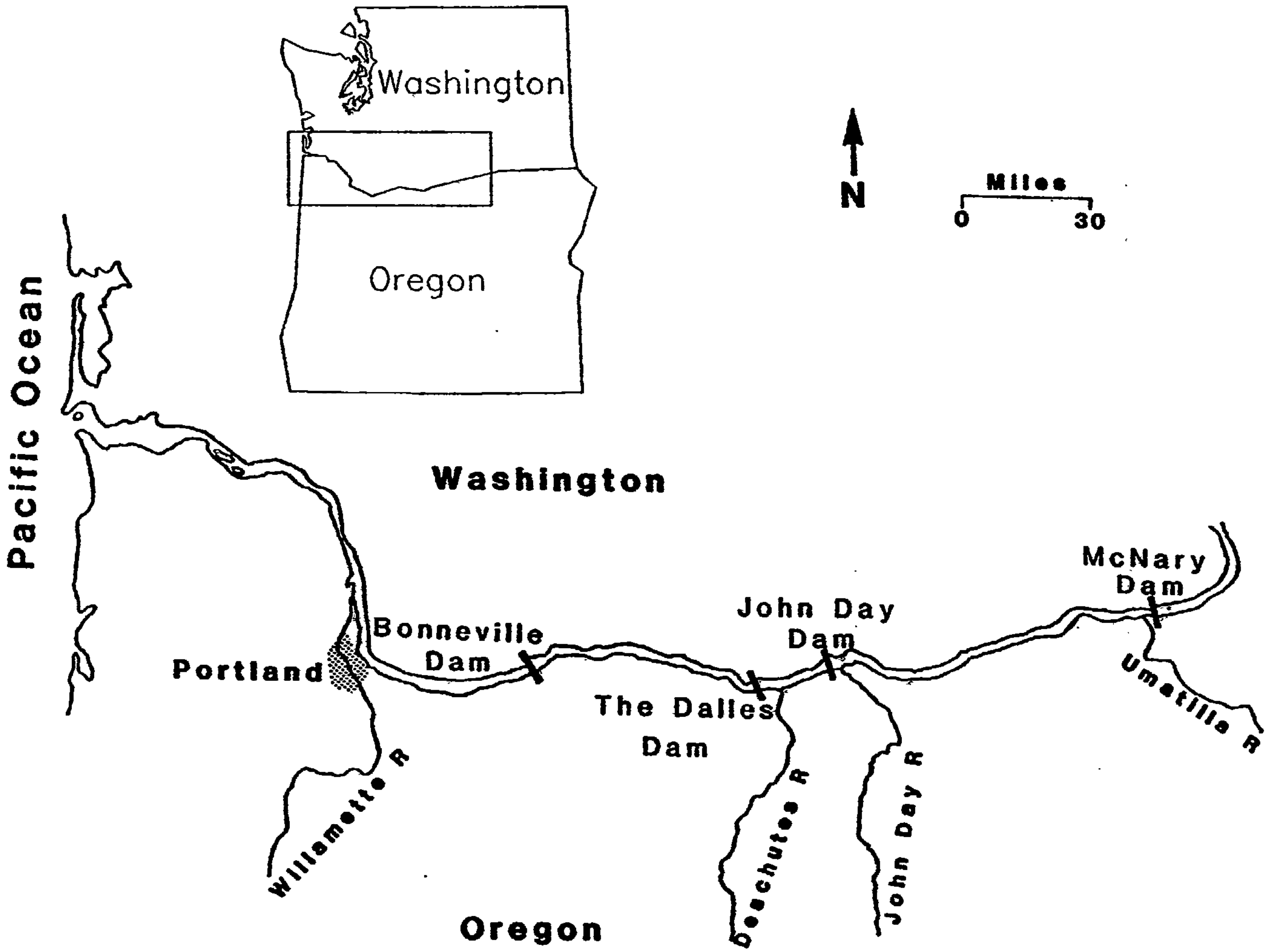

Figure 1. Location of study area between Bonneville and McNary Dams along the Columbia River.

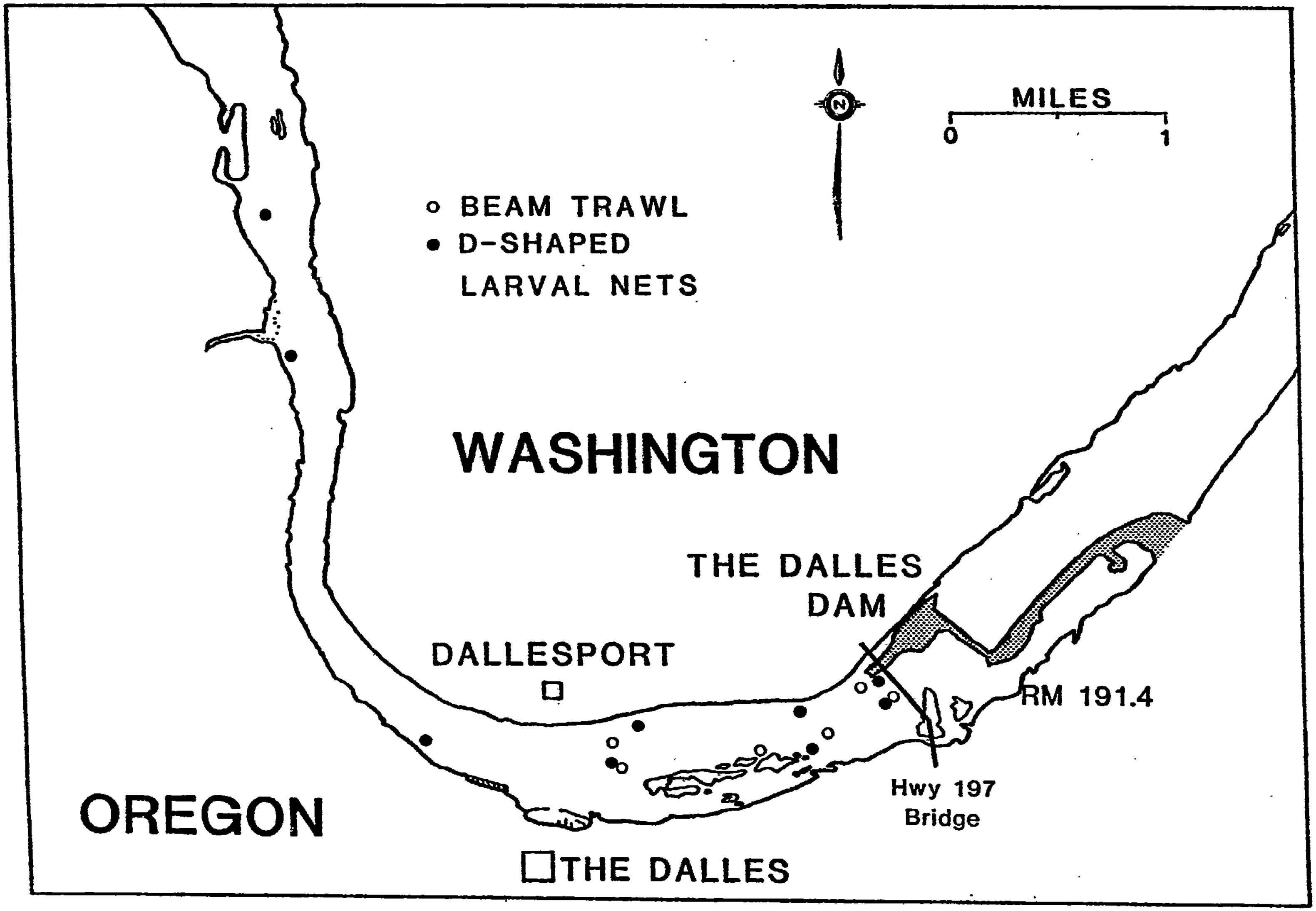

Figure 2. White sturgeon egg and larvae sampling areas in Bonneville Pool, 1989.

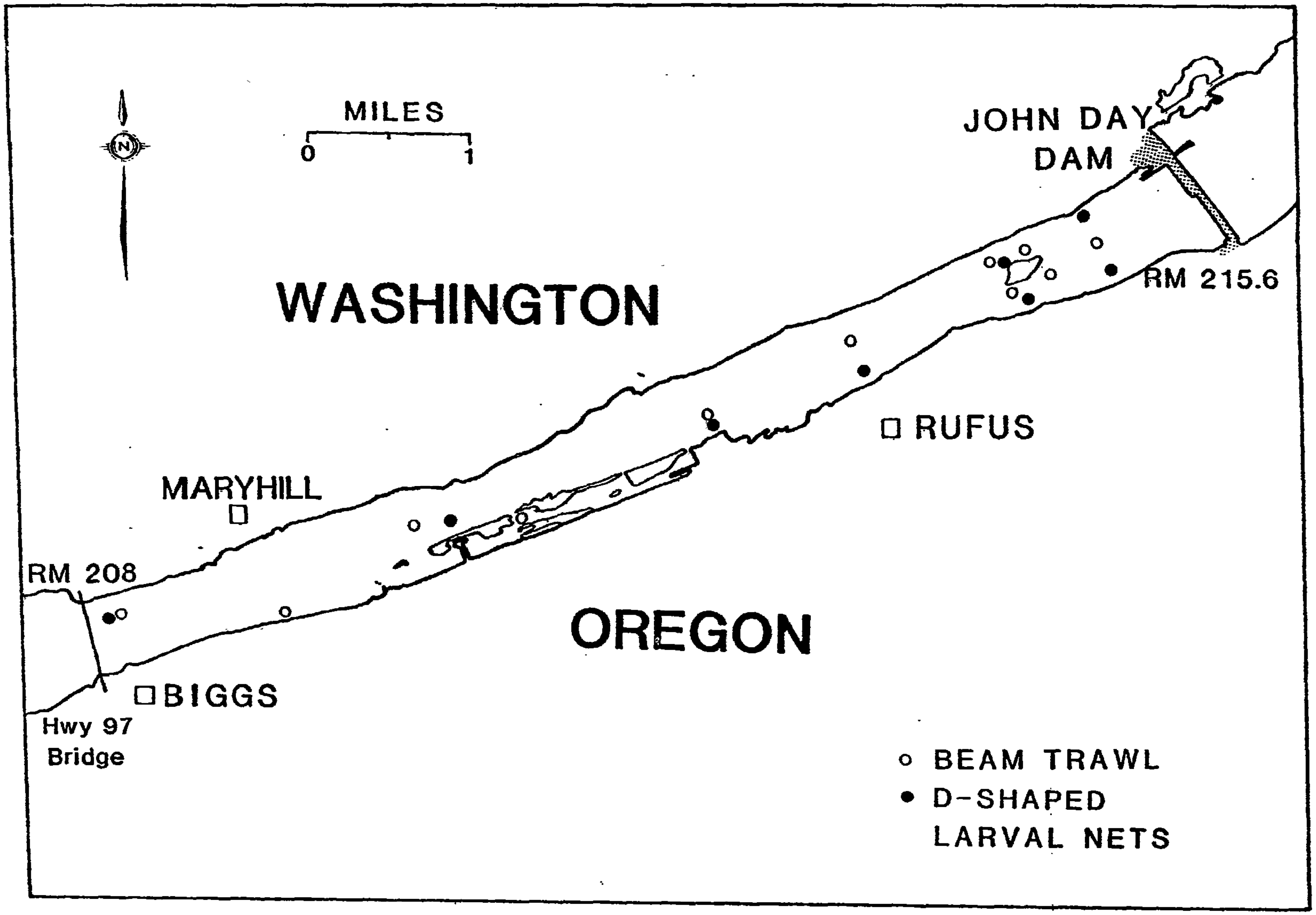

Figure 3. White sturgeon egg and larvae sampling areas in The Dalles Pool, 1989.

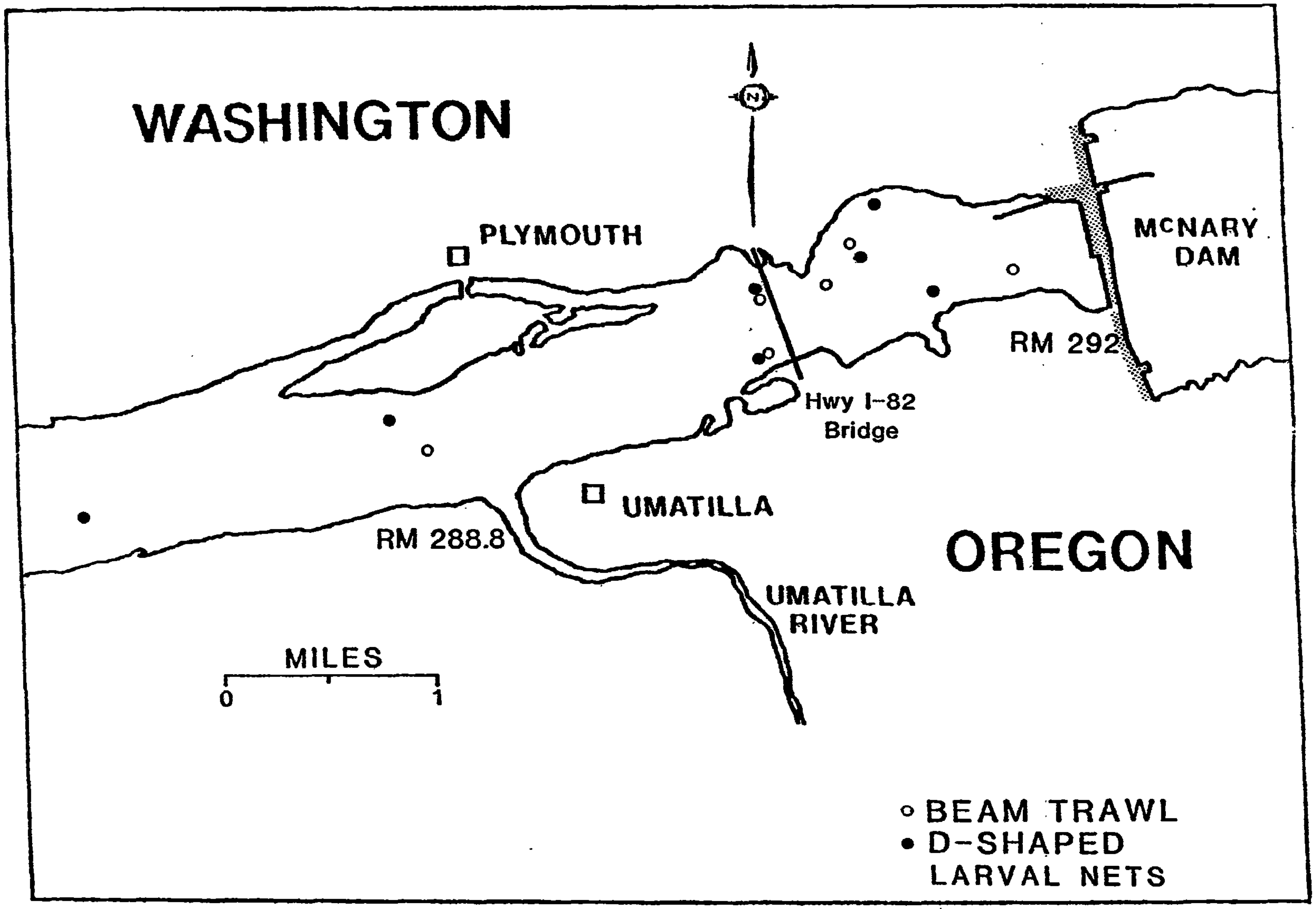

Figure 4. White sturgeon egg and larvae sampling areas in John Day Pool, 1989.

High-rise trawling efforts for young-of-the-year (YOY) and juvenile stages varied in each pool. In Bonneville Pool we sampled once during January, October and November, and bi-weekly from 10 April through 27 September; normally, 22 sites were sampled. In The Dalles Pool we sampled 17 sites weekly from 10 April through July and then bi-weekly through 19 September. Exploratory trawling in John Day Pool began 28 February and occurred bi-weekly until 18 September; numerous locations were fished to identify suitable sites (Table 1).

Sampling with the beam trawl for post-larval YOY was initiated in Bonneville Pool on 5 July. The technique proved effective so efforts were expanded into bi-weekly sampling of the other pools during August.

Catch per unit effort (CPE) of white sturgeon 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 and larvae/1000 m^3 of water filtered and catch/15 min set for the D - shaped larval net. Only effort from the day of first egg or larvae collection through the day of last collection in a pool was used to calculate CPE.

Egg and larval collections were preserved in 10% unbuffered formalin tinted with phloxine B. Larval and YOY sturgeon were measured to total length (mm) and weighed (nearest 0.001 g). Fork lengths (mm) and weights (nearest 10 g) were measured from most sturgeon collected. Pectoral finrays were removed for age determination with a target sample size of 100 finrays established per pool. All sturgeon less than 800 mm (FL) were injected with oxytetracycline hydrochloride (OTC) to verify the ageing technique. Fish were injected at a dosage of 25 mg OTC per kg. The second lateral scute (right side) and third lateral scute (left side) were removed to identify in future years when the fish had been injected with OTC. Most white sturgeon were tagged with a monel bird band to provide information on movement and growth. All sturgeon were examined for previous marks and the external parasite Cystoopsis acipenser. All other fish were identified, enumerated and released. Common and scientific names of all species collected are presented in Appendix C-1.

To determine if predation or scavenging on white sturgeon embryos occurred, various non-game fishes were collected from The Dalles and McNary dam tailrace areas during the spawning period. Digestive tracts were removed from largescale sucker, northern squawfish, common carp and sculpins collected below McNary Dam and from largescale sucker below The Dalles Dam. Digestive tracts were examined for sturgeon eggs, and eggs enumerated if present.

Food Habits

We collected 29 juvenile sturgeon from May through July in Bonneville and The Dalles pools (Target sample size: five fish per pool/month) to examine food habits and to determine if the emetic, hydrogen peroxide, caused complete regurgitation of the stomach contents. Food items were first recovered from sturgeon using 20 to 25 ml of the emetic. The fish were then sacrificed and their

Table 1. Sampling effort (number of sites sampled weekly) using D-shaped larval nets, beam and high-rise trawl gears in Bonneville, The Dalles, and John Day Reservoirs during 1989.

		Location		
Gear Type	Julian Week	Bonneville	The Dalles	John Day
D-shaped larval net	15	--	9	--
	16	7	9	6
	17	8	8	6
	18	7	8	8
	19	8	8	4
	20	8	6	7
	21	8	8	5
	22	8	8	7
	23	5	8	7
	24	8	8	6
	25	7	9	8
	26	9	9	7
	27	9	9	8
	28	6	8	8
	29	9	9	7
	30	9	8	7
Beam trawl	14	7	11	--
	15	7	11	--
	16	7	11	4
	17	7	11	--
	18	7	11	7
	19	7	11	8
	20	7	11	--
	21	7	11	6
	22	7	11	6
	23	7	11	6
	24	7	11	9
	25	7	11	6
	26	7	11	6
	27	7	11	6
	28	7	11	6
	29	7	11	6
	30	7	11	6
	31	6	--	--
	32	--	7	4
	33	6	--	--
	34	--	3	4
	35	5	--	--
	36	--	7	4
	37	8	--	--

Table 1. (continued)

Gear Type	Julian Week	Location: Bonneville	The Dalles	John Day
High-rise trawl	4	3	--	--
	9	--	--	7
	11	--	--	16
	12	--	--	7
	15	22	17	--
	16	--	17	11
	17	22	17	--
	18	--	17	17
	19	22	17	--
	20	--	17	6
	21	22	17	--
	22	--	17	18
	23	17	17	--
	24	--	17	21
	25	22	17	--
	26	--	17	18
	27	22	17	--
	28	--	17	19
	29	22	17	--
	30	--	17	19
	31	22	--	--
	32	--	14	15
	33	22	--	--
	34	--	17	17
	35	22	--	--
	36	--	17	17
	37	22	--	--
	38	--	17	18
	39	24	--	--

digestive tracts removed, preserved in 10 % formalin, and examined for additional items in the laboratory.

We also examined the food habits of 24 YOY white sturgeon collected in Bonneville Pool from July through October. The fish were sacrificed, and preserved whole in 10 % formalin. Digestive tracts were removed in the laboratory and examined for food items.

Habitat Use

Environmental and physical parameters addressed were water temperature, turbidity, discharge at each dam, water velocities, and water depth. Water temperatures, velocities and turbidity were measured prior to setting the D-shaped larval nets. Hourly discharge records of the four lower Columbia River dams were obtained from the Fish Passage Center for April through July. Water temperatures in known or suspected white sturgeon spawning areas were recorded hourly with Ryan Tempmentor thermographs[1]. Thermographs were placed on the substrate below each dam at RM's 190.8, 214.3, and 290.6 from late April through August or September. Water temperature was also measured with a Yellow Springs Instrument Co. Model 58 dissolved oxygen and temperature meter. Turbidity was measured with a Hach model 16800 Turbidimeter on samples collected approximately 0.2 m above the substrate with a vertical van Dorn sampler.

Mean water column velocity (an average of the velocity measured at 0.2 and 0.8 of the total depth) and bottom velocity (measured 0.6 m from the substrate) at sample sites was 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. Mean water column and bottom velocities were measured at permanent high-rise trawl locations in Bonneville Pool at one-third and two-thirds the distance of each trawl tow.

Laboratory

Egg and Larvae Samples

As during 1988, samples preserved in the field were sorted in the laboratory, identified to the lowest taxonomic level possible, and enumerated. Eggs and larvae of white sturgeon were assigned developmental stages based on the criteria described by Beer (1981). To back-calculate when eggs and larvae had been fertilized, we used the relationship developed by Wang et al. (1985). Water temperatures at the time of collection were used in the relationship and assumed to have been constant during incubation.

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

Age and Growth

Pectoral fin rays of white sturgeon were cross-sectioned and age estimated by counting growth rings (annuli). Fin ray sections were independently aged by two persons following criteria summarized by Beamsderfer et al. (1989).

Annual relative rates of growth (h) and instantaneous growth rates (G) (Ricker 1975) were determined for younger ages (II to V) of sturgeon captured in the three pools above Bonneville Dam, and also from below Bonneville Dam. Data from below Bonneville Dam was provided by National Marine Fisheries Service. Growth among pools was also compared by plotting mean fork length at age.

Weight-length relationships and condition factors were determined for juvenile white sturgeon for all three pools. Linear regression was used to compute the weight-length relationship using transformed (log 10) data. Condition factors were determined using the formula $C = (W/L^3)*10^5$.

Visual Implant Tagging

Visual implant (V I) tags were placed in white sturgeon during October at our laboratory, Hagerman State Fish Hatchery and the College of Southern Idaho Fish Hatchery, to determine their feasibility as a long term mark. Sturgeon were anesthetized with tricane methanesulfonate (MS-222) and their fork length was measured to the nearest 5 mm. The tags measure 1.5 x 3.5 x 0.1 mm, and consist of a filmlike material coded with three alphanumerics. The tags are intended to be externally readable, however we investigated several locations which may require the tag to be removed, read, and re-implanted into the fish (Personal Communication: Peter Bergman, Northwest Marine Technologies; Olympia, Washington 98502). Tags were implanted with a syringe in four locations: rostrum -anterior to the left barbel on the ventral portion of the rostrum; anterior mouth- at the anterior side of the mouth tube; posterior mouth- at the posterior side of the mouth tube; and scute- under the first right lateral scute.

Habitat Quantification

Surface areas of each pool that are comprised of specific depths and substrates, or a combination thereof, are being determined through the use of cartographic modeling with a geographic information system (GIS). Data are digitized from nautical charts (scale = 1:20,000 and 1:40,000) published by the National Oceanic and Atmospheric Administration. Alternate sources of information (field measurements, pre and post-impoundment aerial photographs) are used to add to or adjust the nautical charts as needed. Water velocities present at discharges during the spring when water temperatures are suitable for white sturgeon spawning are simulated downstream from each dam through the use of PHABSIM, a component of the Instream Flow Incremental Methodology that estimates physical habitat available in riverine systems at various discharges (Bovee 1982).

RESULTS

Bonneville Pool

Environmental Conditions

Hourly discharge of water through The Dalles Dam ranged from 1.27 to 10.10 1000 m^3/s (kcms) during April through July (Figure 5), and was characterized by wide daily fluctuations. Peak discharge was from late April to early June.

Water temperatures gradually increased from 9.2° C on 17 April to 19.5° C on 25 July (Figure 6). Due to the failure of the continuous recording thermograph placed below The Dalles Dam, water temperatures are reported for sampling dates only. On 24 April the water temperature was 10.7° C; white sturgeon have spawned at 10° C below Bonneville Dam in previous years. On 6 June the temperature reached 17° C, considered the upper temperature limit for optimal white sturgeon spawning (Wang et al. 1985).

Mean daily turbidities ranged from 9.6 NTU on 24 April to 3.6 NTU on 25 July (Figure 7).

Sturgeon egg collections

In the Dalles Dam tailrace we collected 104 eggs between RM 189.9 and RM 191.5 from 19 May to 25 July (Table 2). Eggs ranging from unfertilized to pre-hatch were collected on 17 of 22 sampling days during this period at depths ranging from 18 to 50 m. Mean water column and bottom velocities at sites sampled with D-shaped larval nets ranged from 0.50 to 1.51 m/s and 0.39 to 1.13 m/s, respectively. Back-calculating ages of eggs indicated spawning ocurred on at least 30 days from 11 May through 25 July. Adhesive eggs, evidence that spawning occurred during the previous three hours, were collected on seven sampling dates, water temperatures on these dates ranged from 12.5 to 19.2° C. Dead or fungused eggs comprised 35% of the catch.

Sturgeon larvae collections

We collected 73 white sturgeon larvae between RM 173.7 and RM 191.5 on 12 of 17 days sampled between 30 May and 18 July (Table 2). Developmental stages of larvae ranged from post-hatch through yolk absorption with total lengths ranging from 8 to 23 mm. Larvae appeared more numerous and widely distributed during 1989 than in 1988. Larvae older than four days post-hatch were more likely to be found at depths greater than 15 m, and were collected at maximum depths to 58 m. Generally, catches were highest at sampling sites with depths greater than 25 m. Mean water column and bottom velocities at sites sampled with D-shaped larval nets ranged from

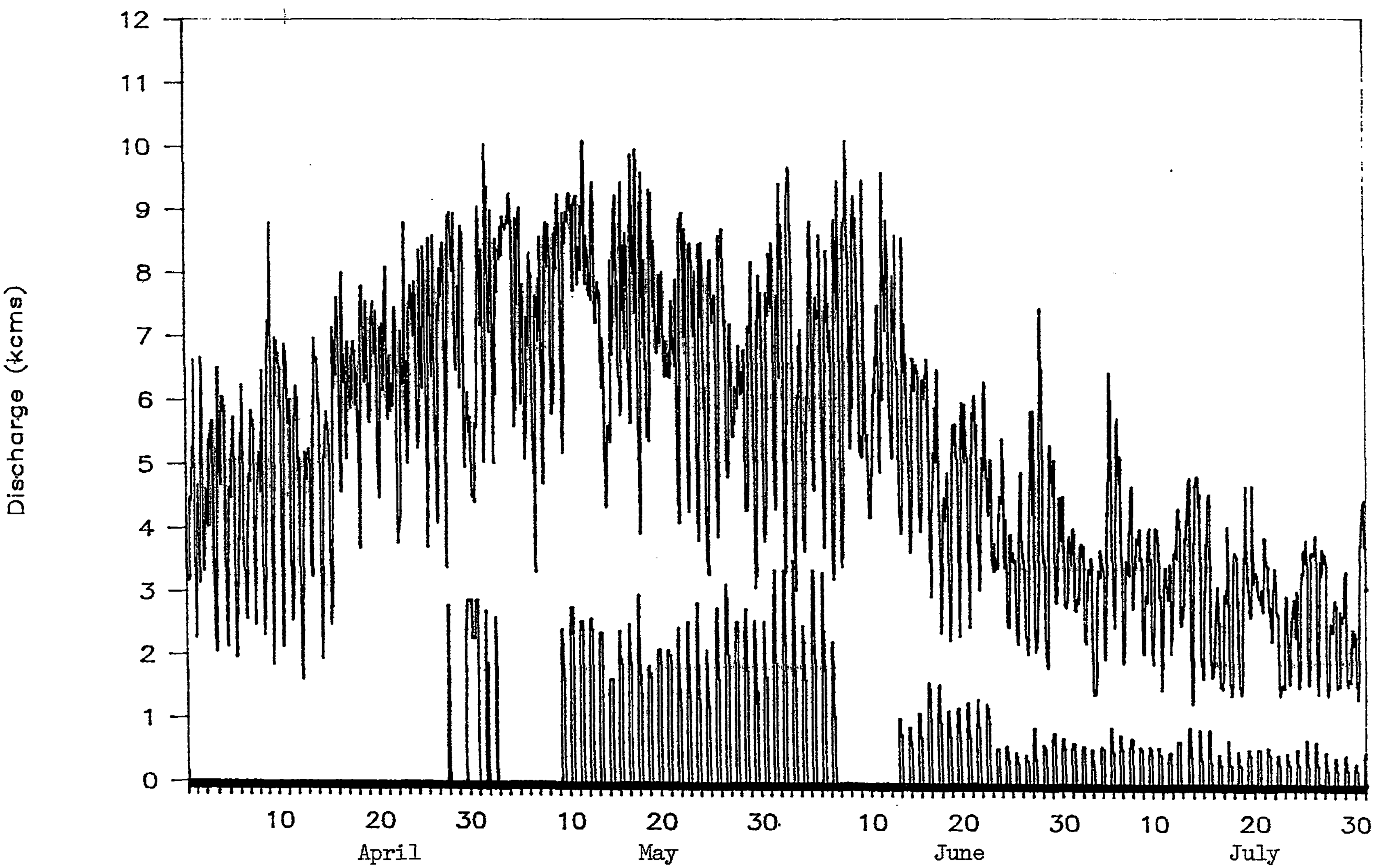

Figure 5. Hourly discharge through The Dalles Dam, April through July, 1989. The upper line indicates total discharge, the lower line indicates spill discharge.

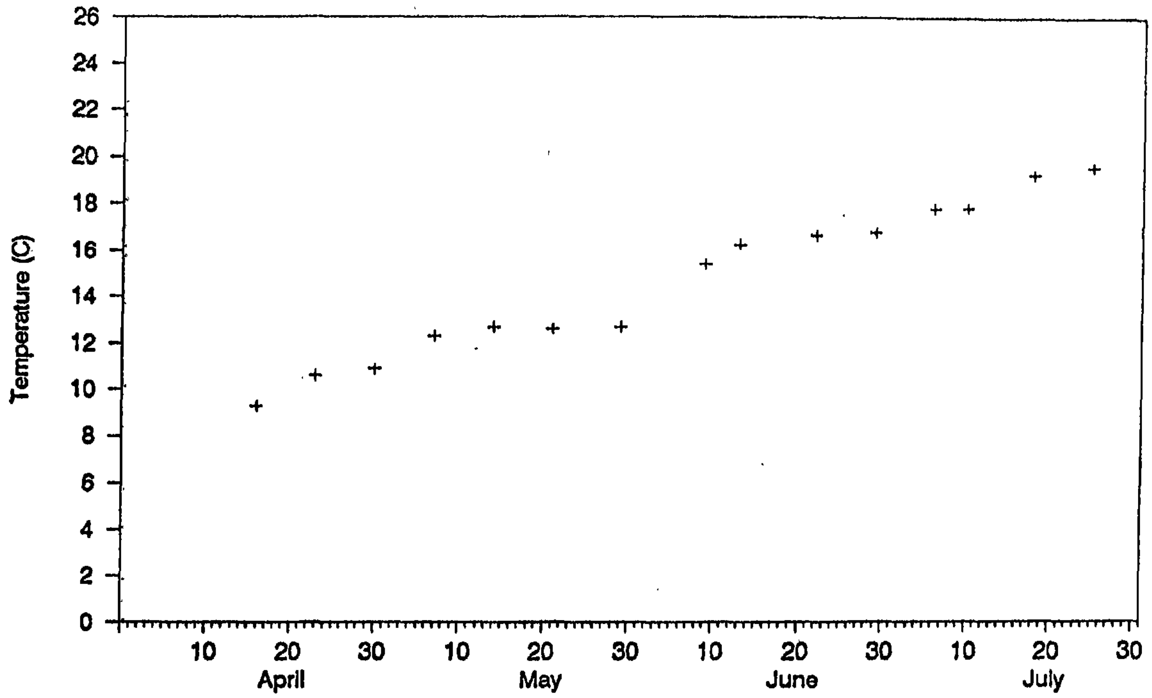

Figure 6. Weekly temperature at RM 190.2 in Bonneville Pool, April through July, 1989.

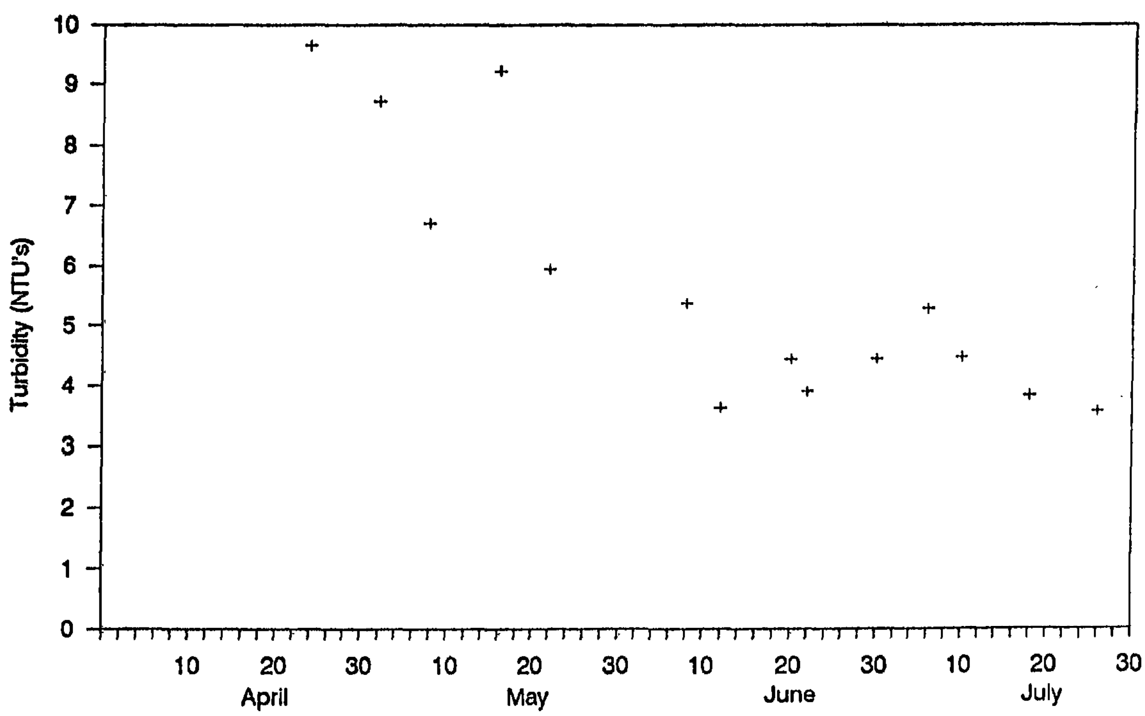

Figure 7. Mean turbidity measurements from RM 186.5 to 191.4 in Bonneville Pool from 24 April through 25 July, 1989.

Table 2. Number and catch per unit effort of white sturgeon eggs and larvae collected with the D-shaped larval net and beam trawl in Bonneville Pool between RM 189.3 and RM 191.6 from 22 May through 25 July, 1989. (No eggs or larvae were collected with the high-rise trawl).

	Eggs			Larvae
Gear	Viable	Fungused	Total	Total
D-Shaped larval net				
Number	24	16	40	16
Catch/1000 m^3	0.84	0.56	1.40	0.64
Catch/15 min	0.11	0.08	0.19	0.08
Beam trawl				
Number	44	20	64	57
Catch/15 min	0.51	0.23	0.74	0.74
Both gears				
Number	68	36	104	73

0.37 to 1.00 m/s and 0.27 to 0.85 m/s when larvae were collected. Criteria for assigning larvae through YOY stages are described in Appendix C-2.

Young-of-the-Year sturgeon collections

Young-of-the-year sturgeon were captured during 1989 for the first time during the study. We collected 56 YOY sturgeon ranging in TL from 20 mm on 29 June to 321 mm on 30 November (Table 3). Young-of-the-year sturgeon were collected from RM 183 downstream to RM 157 and all appeared healthy and active after capture. Beam trawl tows of 30 min duration at 0.45 to 0.80 m/sec were effective for collecting YOY ranging in length from 20 to 150 mm TL. High-rise trawl sampling became more effective than the beam trawl for YOY sturgeon larger than 150 mm TL.

Juvenile sturgeon collections

We captured 627 white sturgeon age II and older during 1989 in Bonneville Pool. No age I fish (1988 year class) were captured. Fork lengths (FL) ranged from 317 to 885 mm with mean FL 476 mm (Table 4). We applied monel bands to 577 fish and injected 580 sturgeon with oxytetracycline for age validation experiments. Seven (1.1%) sturgeon were recaptured, five from 1988 and two previously tagged during 1989, and all had shed their tags. The parasite _Cystoopsis acipenser_ was observed on eight (1.1%) of the sturgeon captured. Infected fish ranged from 317 to 714 mm FL (mean = 434 mm).

Distribution: Catches of white sturgeon in the high-rise trawl at each of the 22 permanent sampling locations in Bonneville Pool varied markedly, both spatially and temporally (Appendix C-3). The high variability in catch may indicate patchy distribution, changes in sturgeon vulnerability to gear and/or year-class availability. Catches at two locations, RM 179.1 and RM 190.0, accounted for 45% of the total 1989 catch; two or less white sturgeon were collected at seven trawl locations. Total monthly catches and CPE were highest during May, June and July. Catch per time and area was highest during May and declined markedly from August through October.

Catch per trawl and hectare was highest in the upper pool (Table 5), with CPE levels similar to 1988. Eighty percent of the juvenile sturgeon were caught in the upper one-third of the pool, 17% from the middle third, and only 3% from the lower third.

Depth preference: Depth preference of juvenile white sturgeon was less evident during 1989 than 1988. Seventy-seven percent of the fish were captured at maximum depths between 10 and 24 m where 53% of the high-rise trawl effort occurred. Sturgeon were caught as

Table 3. Length frequencies (total length) of young-of-the-year white sturgeon collected in Bonneville Pool during 1989 (N = 52). Fork length measured for two sturgeon collected during October.

Total Length (mm)	Month					
	Jun	Jul	Aug	Sep	Oct	Nov
1-25	4	10				
26-50		13				
51-75		2	4	1		
76-100		2	1			
101-125			3			
126-150			6			
151-175						
176-200			1			
201-225			1	1		
226-250						1
251-275						
276-300						2
301-325						
326-350						
Total	4	27	16	2		3

Table 4. Length frequencies of white sturgeon collected in Bonneville Pool during 1989 (N = 617). Sturgeon collected during November less than 280 mm FL are young-of-the-year.

Fork length (mm)	Month							
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
201-210								1
211-220								
221-230								
231-240								1
241-250								1
251-260								2
261-270								1
271-280								
281-290								
291-300								
301-310								
311-320		1						
321-330								
331-340	1	1			1			
341-350	1			3				
351-360	1	7	2	3				
361-370	5	4	1	1				
371-380	2	6		7	3			
381-390	3	4		5	1			
391-400	9	3	5	6	3			
401-410	7	14	5	8	7	2		
411-420	4	11	4	7	3	1		
421-430	6	7	8	16	3	1		
431-440	5	8	11	6	3	2		
441-450	2	13	5	7	6			1
451-460	5	9	7	6	7	1	1	
461-470	4	5	10	10	6	2		1
471-480	1	6	8	13	3	1		
481-490	2	8	7	11	3	1		1
491-500		8	10	7	2			
501-510	2	7	9	5	5	1		
511-520	2	1	4	5	1			
521-530	2	2	2	2				
531-540	2	3	5	1	2	1		
541-550	2	2	2	1			1	1
551-560	2	4	2	6	1	1	1	
561-570		1	1	2		1	1	
571-580		1		2			1	
581-590	1	2	2	5	2	1		
591-600	2	2	2	1	2		1	1
>601	10	10	3	6	7	5	1	7
Total	83	150	115	152	71	21	7	18

Table 5. Number, catch per 15 minute tow (CPT), catch per hectare (CPHA) and overall catch per unit of effort (CPE) by month of juvenile white sturgeon captured with the high-rise trawl at lower (RM 149 - 163), middle (RM 163 - 178), and upper (RM 178 - 191.5) locations in Bonneville Pool.

Location	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total Number	CPUE
Lower Reservoir										
Number	2	4	3	5	3	2	1		20	
CPT	0.21	0.43	0.50	0.36	0.32	0.19	0.21			0.32
CPHA	0.51	1.04	1.10	0.81	0.70	0.41	0.46			0.71
Middle Reservoir										
Number	20	9	9	26	17[1]	5	4	13	103	
CPT	1.88	0.84	0.84	1.98	1.20	0.45	0.66	1.65		1.23
CPHA	5.38	2.49	2.15	4.89	2.79	1.08	1.51	4.62		3.15
Upper Reservoir										
Number	61	133	102	117[2]	51	13	2		479	
CPT	6.10	14.25	10.93	9.86	3.64	1.30	0.43			6.81
CPHA	16.75	40.10	28.45	23.72	8.85	2.82	1.04			16.99
All Locations										
Number	83	146	114	148	71	20	7	13	602	
CPT	2.77	4.98	4.38	3.44	1.91	0.63	0.45	1.65		2.70
CPHA	7.36	13.57	10.86	7.98	4.43	1.41	1.04	4.62		6.59

[1] One sturgeon captured with no effort recorded, and was excluded in effort estimates.

[2] Twenty five sturgeon caught during a trawl/tow with no effort recorded and were excluded in calculating effort estimates.

shallow as 6 m, which was about the minimum depth trawled (Figure 8).

Weight-length relationship and condition factor: The weight-length relationship was calculated from a sample of 610 white sturgeon collected in Bonneville Pool from April through November, 1989. Sturgeon ranged from 317 to 780 mm FL. The weight-length relationship is described by the equation log W = log FL (2.978) - 5.086 (r = .96), where W is the weight in grams and Fl is the fork length in millimeters. Mean condition factor of juvenile white sturgeon was 0.722 (Sd = .0845; n = 608).

Age and growth: Ages were determined for 98 white sturgeon from sectioned pectoral fin rays collected from April through June, 1989. Fork lengths of aged sturgeon ranged from 340 to 745 mm (Table 6). No age I (1988 year-class) sturgeon were collected. Mean fork lengths at age were 358, 392, 424, 452, 521 and 624 mm for ages II through VII, respectively (Appendix C-5). Annual relative growth rates (h) and instantaneous population growth rates (G) were 31% (.269), 26% (.234), and 21% (.191) for ages II through V, respectively (Appendix C-6).

Other species

Young-of-the-year and older prickly sculpin dominated the trawl catches of fishes other than sturgeon in Bonneville Pool. Other species commonly collected included peamouth and YOY American shad (Table 7).

The Dalles Pool

Environmental conditions

Water discharges, temperatures, and turbidities in the John Day Dam tailrace were similar to those in The Dalles Dam tailrace. Hourly discharge ranged from 1.38 to 9.75 kcms during April through July (Figure 9). During the peak discharge period (late April - early June), virtually none of the discharge was spill, unlike at The Dalles Dam.

Mean daily water temperatures ranged from 6.6° C to 20.5° C, reaching 10° C on 19 April and 17° C n 26 June (Figure 10). Mean daily turbidities ranged from 9.7 NTU during early May to 3.4 NTU on 11 June (Figure 11).

Sturgeon egg collections

During 1989, we collected 25 eggs between RM 213.8 and RM 215.1 on 4 of 12 sampling dates from 5 June to 6 July (Table 8).

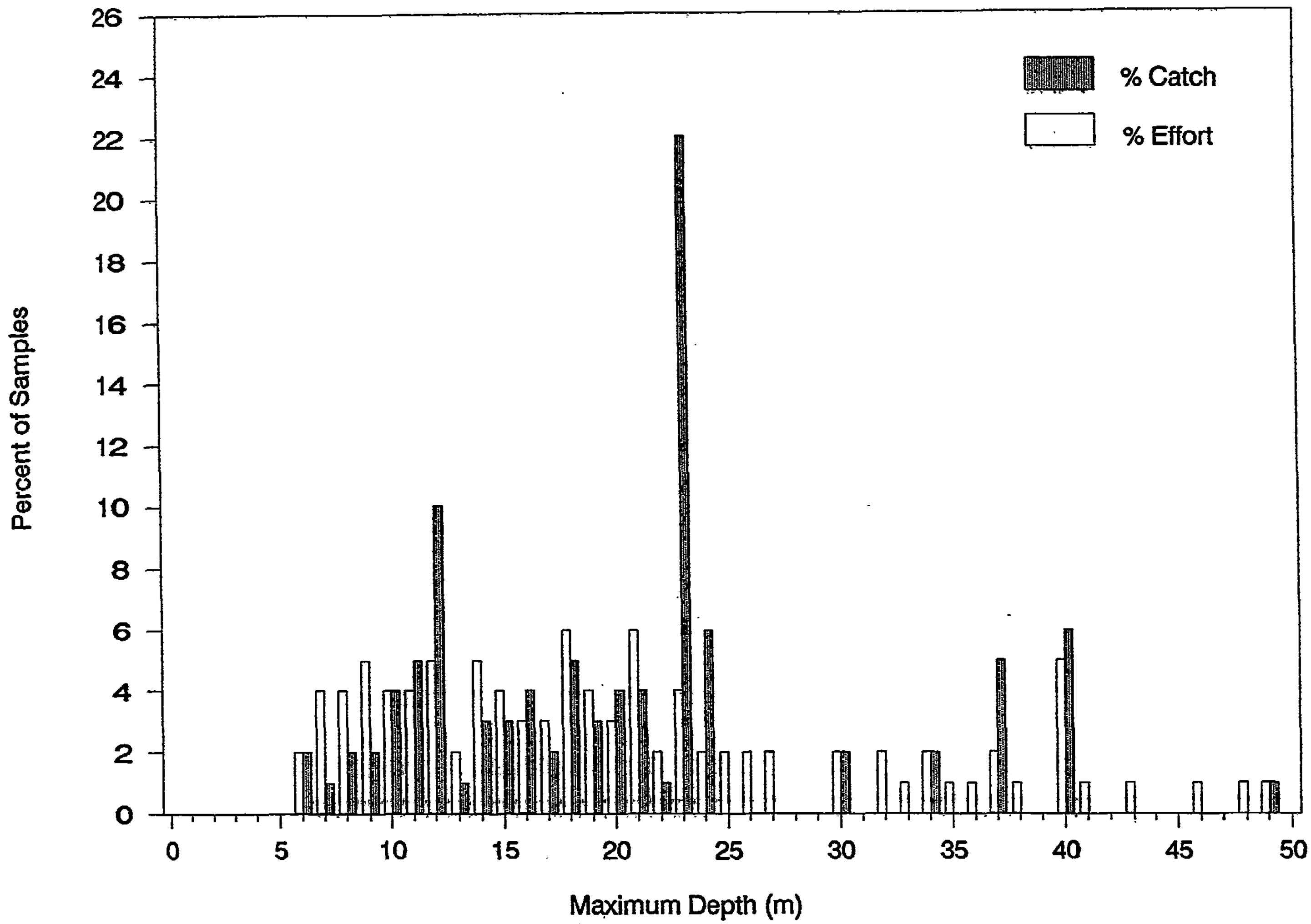

Figure 8. Percent of juvenile white sturgeon catch and the percent of high-rise trawling efforts at maximum depths in Bonneville Pool, 1989.

Table 6. Age distribution of white sturgeon by fork length group, Bonneville Pool, 1989.

Length group (mm)	No.	Age I	II	III	IV	V	VI
201-225							
226-250							
251-275							
276-300							
301-325							
326-350	1			1			
351-375	5		1	4			
376-400	12		5	5	1	1	
401-425	16			6	4	5	1
426-450	21			5	10	6	
451-475	12			5	4	3	
476-500	5					5	
501-525	2					1	1
526-550	6				2	1	3
551-575	3			1	1	1	
576-600	1					1	
601-625	1					1	
626-650							
651-675							
676-700							
>700	3					2	1

Table 7. Number and catch per unit of effort of fishes excluding sturgeon collected with high-rise (catch/15 minute tow (CPT) and catch/hectare (CPHA)), beam trawls (catch/15 minute tow (CPT) and D - shaped larval nets (catch/1000 m^3) in Bonneville Pool from April through November, 1989.

	High-rise trawl			Beam trawl		D - shaped larval net			Total
Species	No.	CPT	CPHA	No.	CPT	No.	CPT	CKM^3	No.
Pacific lamprey	11	0.05	0.13	8	0.04	1	<0.01	0.02	20
American shad	306	1.43	3.50	9	0.04	7	0.02	0.11	322
Chinook salmon	99	0.46	1.13	15	0.07	5	0.01	0.08	119
Common carp	4	0.02	0.05						4
Peamouth	522	2.45	5.97	3	0.01				525
Longnose dace	1	<0.01	0.01						
Northern squawfish	113	0.53	1.2	1	<0.01				114
Redside shiner	48	0.22	0.55	2	0.01				50
UID[a] cyprinid	3	0.01	0.03	134	0.59	9	0.02	0.14	146
Largescale sucker	95	0.45	1.09	1	<0.01				96
Bridgelip sucker	5	0.02	0.06						5
UID sucker	7	0.03	0.08	103	0.45	19	0.04	0.31	129
Channel catfish	5	0.02	0.06	2	0.01				7
Bullhead spp.	2	0.01	0.02						2
Sand roller	103	0.48	1.18	17	0.07				120
Smallmouth bass	31	0.15	0.35	3	0.01				34
Largemouth bass	1	<0.01	0.01						1
Walleye	24	0.11	0.27						24
Black crappie	1	<0.01	0.01						1
Three-spined stickleback				1	<0.01				1
Prickly sculpin	1962	9.19	22.45	753	3.31	40	0.09	0.64	2755
UID fish				2	0.01	1	<0.01	0.02	3
Total Number	3,343			1,054		82			4,479

[a] unidentified

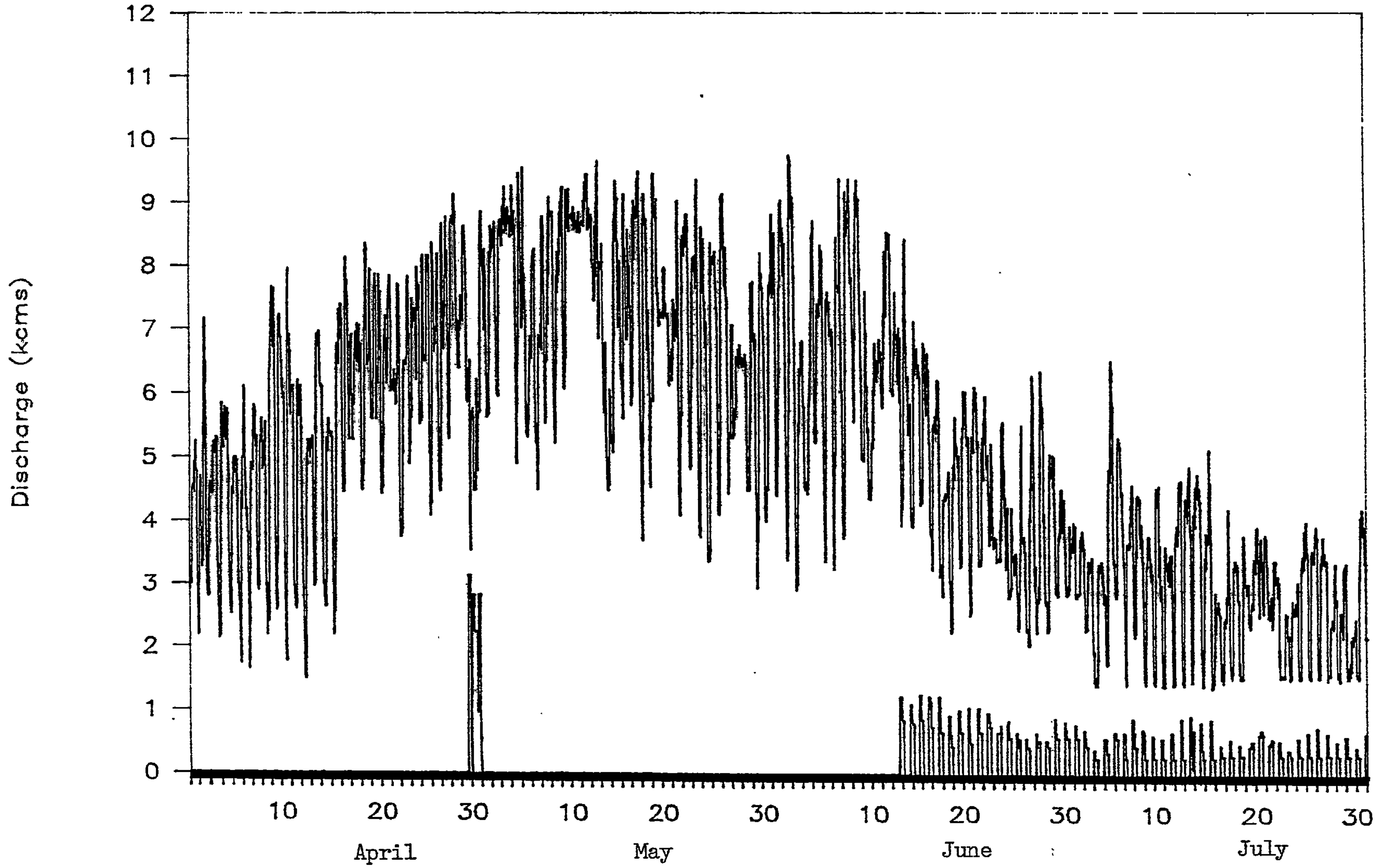

Figure 9. Hourly discharge through John Day Dam, April through July, 1989. The upper line indicates total discharge, the lower line indicates spill discharge.

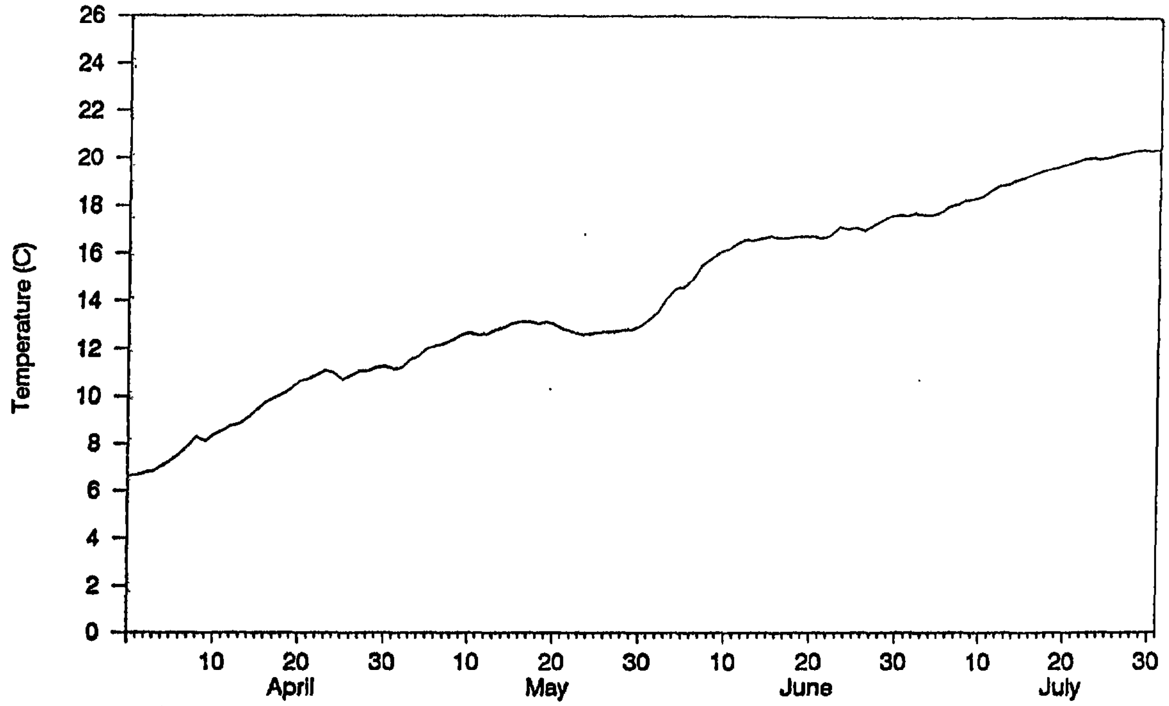

Figure 10. Mean daily water temperatures at RM 214.3 in The Dalles Pool, April through July, 1989.

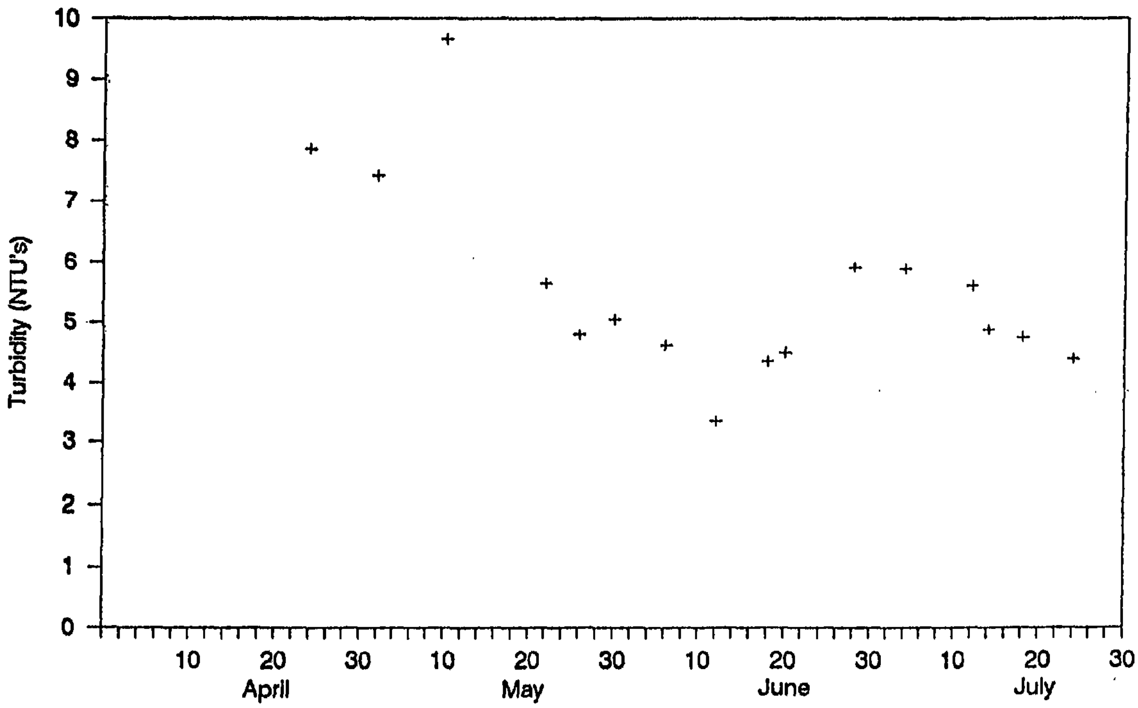

Figure 11. Mean turbidity measurements from RM 208.2 to 215.0 in The Dalles Pool from 25 April through 24 July, 1989.

Most eggs were collected along the Oregon or southern half of the river channel at depths ranging from 6 to 14 m. Water temperatures ranged between 12.6° C and 17.7° C during this period. Mean water column and bottom velocities during efforts that collected eggs ranged from 1.11 to 1.89 m/s and 1.11 to 1.25 m/s, respectively. Five (20%) of the eggs collected were dead and covered with fungus.

White sturgeon spawning occurred more frequently during 1989 than in 1988 in the John Day Dam tailrace. Based on back-calculated ages of eggs and larvae, spawning occurred on at least 11 days between 24 May and 03 July. The first estimated date of spawning, 24 May, occurred 12 days prior to when the first larvae was collected. Adhesive eggs, evidence that spawning occurred during the previous three hours, were collected on 12 June and 27 June between 1300 and 1530 hours. Developmental stages of the 20 viable eggs collected ranged from newly fertilized or adhesive eggs, (water temperature 16.5° C) to hatch in progress or emerging embryo (approximately 105 hours old, water temperature 17.8° C).

Sturgeon larvae collections

White sturgeon larvae were first collected 05 June and on 5 of 12 sampling dates during the observed spawning period (Table 8). All but 3 of the 18 larvae were collected along the Oregon side of the channel near the island above RM 213.8. All larvae collected during 1988 came from the Oregon side of the river. We also collected a single larvae at RM 209.8 on 07 June, five miles downstream from previous egg and larvae collections during 1987 and 1988. Larvae were collected at depths from 6 to 15 m, with mean water column and bottom velocities ranging from 0.76 to 1.25 m/s and 0.76 to 1.31 m/s, respectively. Developmental stages of larvae ranged from posthatch, indicating hatching occured within the previous 24 hours, to completion of yolk sac absorption. Total length of larvae collected ranged from 11 to 15 mm.

Juvenile sturgeon collections

We captured 260 juvenile white sturgeon in The Dalles Pool with trawls. This catch was nearly 47% less than 1988 catches although effort was similar both years. No YOY or age I (1988 year-class) fish were captured. Fork lengths (FL) of juveniles ranged from 320 to 831 mm (Table 9), with mean FL 482 mm. We applied monel tags to 229 sturgeon and injected 234 with OTC. Eight (3%) sturgeon were recaptured from 1988, one of which had lost its tag. Number of days at-large for recaptured fish ranged from 283 - 446 days (mean = 388 days), and maximum movement was 10 river miles (Table 10).

The nematode parasite Cystoopsis acipenser was observed on 12 (4.6%) of the white sturgeon captured in The Dalles Pool. Infected fish ranged from 370 to 765 mm (mean = 501 mm), with average number of parasitic cysts nine (ranging from 1 to 58). One sturgeon captured during 1988 with a Cystoopsis infection, exhibited no

Table 8. Number and catch per unit effort of white sturgeon eggs and larvae collected with the D-shaped larval net, beam trawl, and high-rise trawl in the The Dalles Pool between RM 209.8 and R. 215.1 from 5 June through 6 July, 1989.

	Eggs			Larvae
Gear	Viable	Fungused	Total	Total
D-Shaped larval net				
Number	16	2	18	10
Catch/1000 m^3	0.81	0.10	0.91	0.34
Catch/15 min	0.19	0.02	0.21	0.07
Beam trawl				
Number	4	2	6	8
Catch/15 min	0.08	0.04	0.13	0.11
High-rise trawl				
Number	0	1	1	0
Catch/15 min	0.00	0.09	0.09	0.00
Catch/hectare	0.00	0.21	0.21	0.00
All gears				
Number	20	5	25	18

Table 9. Length frequencies of white sturgeon collected in The Dalles Pool during 1989 (N = 257).

Fork length (mm)	Month					
	Apr	May	Jun	Jul	Aug	Sep
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		
321-330		1				
331-340	2					
341-350	1		1			
351-360	1	1	3			
361-370		2	2			
371-380	1	1		2		
381-390	2	2	1	1		
391-400	2	2	4			
401-410	3	2	4	2		
411-420	4	1	3	3		
421-430	4	3	5	5		
431-440	1	4	5	2	1	
441-450	2	4	4	1		1
451-460	5	2	5	4		
461-470	2	4	5	2	1	
471-480	5	3	2	6	1	
481-490	3	4	2	4		
491-500	1	4	4	9	1	
501-510		2	4	3	1	
511-520	2	2	3	4		2
521-530	1	2	1	3		
531-540	1	4	3	1	1	
541-550		1	1			
551-560		1		1	1	
561-570	2			2		
571-580		2				
581-590			1	1		
591-600				2		
> 601		9	5	10	2	
Total	45	63	68	69	9	3

Table 10. Recoveries (during 1989) of white sturgeon tagged in The Dalles Pool, 1989 (n = 7).

Location (RM) Tagged	Recaptured	1988 Length (mm)	1988 Weight (g)	Days at Large	Change in Fork Length (mm)	Change in Weight (g)
194.3	196.3	463	845	322	61	280
209.0	199.0	388	320	443	(FL and weight not measured)	
209.8	213.0	440	660	283	33	250
209.0[1]	199.0	337	235	414	148	725
199.0	199.0	451	537	446	43	343
209.0	209.0	355	300	420	110	450
196.3[2]	296.8	603	1560	269	27	240

[1] Sturgeon was parasitized by Cystoopsis acipenser during 1988, but not at recapture. Note the dramatic gain in length and weight.

[2] Information supplied by ODFW from fish recaptured on set line gear.

evidence of parasitism at recapture, and increased in length and weight.

Distribution: The total number, catch per trawl and catch per hectare of white sturgeon declined for the 17 permanent sampling locations from 1988 for all months sampled except July. Overall, mean catch per 15 min tow and catch per hectare declined 34% and 26%, respectively in 1989 from 1988.

Similar to 1988, catches of white sturgeon varied spatially and temporally (Appendix C-4 & Table 11). Catches at RM 199.0, RM 205.3; RM 209.0 and RM 213.0, accounted for 73% of the total catch. No sturgeon were collected at 5 locations and fewer than 10 fish were caught at 6 of the remaining 8 locations. Locations where no sturgeon were collected generally had maximum depths less than 10 m and substrates comprised mostly of gravel and rubble. Total monthly catches of white sturgeon were generally highest during May, June and July. Catch per time and area increased from April through June, were highest during July and declined dramatically during August and September.

Catch per hectare of white sturgeon with the high-rise trawl progressively decreased from the upper to the lower portion of the pool (Table 11); no white sturgeon were captured in the middle portion during August and September.

Depth preference: Similar to 1988 catches, juvenile white sturgeon were most often captured in the mid-depth areas sampled in The Dalles Pool (Figure 12). Approximately 91% of the sturgeon were captured at maximum depths greater than 16 m, though only 45% of high-rise trawl efforts occurred at these depths. We captured white sturgeon with trawls at depths ranging from 5 to 35 m.

Weight-Length relationship and condition factor: The weight-length relationship calculated from a sample of 257 white sturgeon collected in The Dalles Pool from April through September, 1989 is described by the equation $\log W = \log FL(2.965) - 5.034$ ($r = .97$). Fork lengths ranged from 320 to 857 mm. Mean condition factor of juvenile white sturgeon was determined to be 0.751 (Sd = 0.079; N = 257).

Age and growth: We sectioned 125 fin rays from white sturgeon collected in The Dalles Pool from April through mid-July, 1989. Ages were determined for 112 (89%) of these fish. Fork lengths of aged sturgeon ranged from 325 to 756 mm (Table 12). No age I (1988 brood year) sturgeon were observed. Mean fork lengths for ages II - VI were 371, 423, 458, 483, and 594 mm, respectively (Appendices C-5 & C-7). Annual relative growh rates (h) and instantaneous population growth rates (G) were 47% (.388), 27% (.236), and 17% (.157) for ages II through V (Appendix C-6).

Table 11. Number, catch per 15 minute tow (CPT) and catch per hectare (CPHA) of white sturgeon captured with the high-rise trawls at lower (RM 191.5 - 200), middle (RM 200 - 208), and upper (RM 208 -215.6) locations in The Dalles Pool during 1989.

Location	Apr	May	Jun	Jul	Aug	Sep	Total Number	CPUE
Lower Reservoir								
Number	4	6	17	18	4	2	51	
CPT	0.50	0.53	1.59	2.25	1.50	0.38		1.11
CPHA	1.41	1.48	4.36	5.89	3.90	0.92		2.99
Middle Reservoir								
Number	9	28	6	17	0	0	60	
CPT	1.13	2.47	0.56	2.13	0.00	0.00		1.28
CPHA	3.44	7.21	1.71	6.10	0.00	0.00		3.75
Upper Reservoir								
Number	30	26	45	33	4	1	139	
CPT	1.50	0.93	2.03	1.41	0.33	0.08		1.19
CPHA	5.61	4.18	8.48	5.34	1.17	0.25		4.60
All Locations								
Number	43	60	68	68	8	3	250	
CPT	1.19	1.17	1.57	1.73	0.43	0.14		1.19
CPHA	3.98	4.23	5.36	5.66	1.43	0.37		3.96

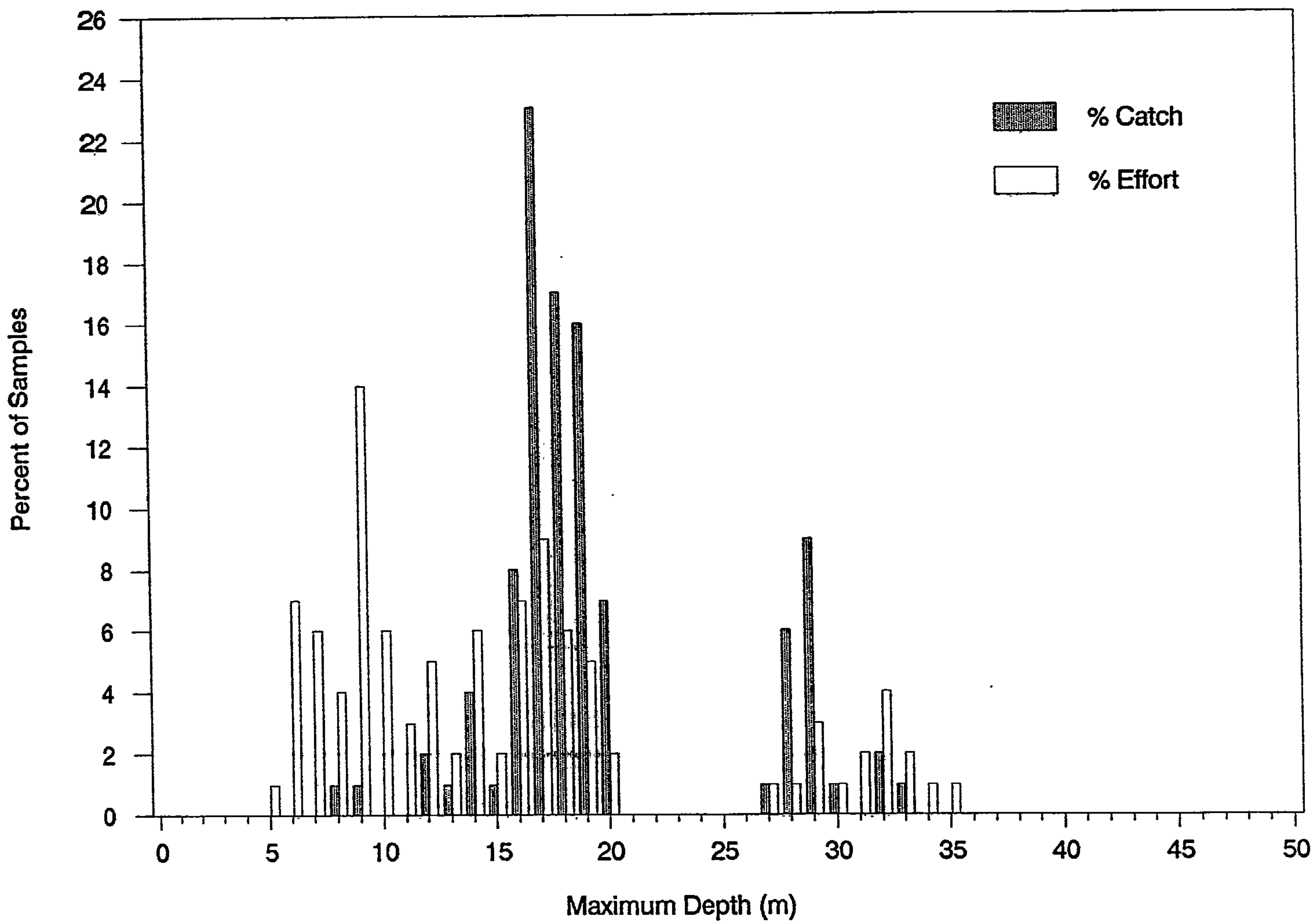

Figure 12. Percent of juvenile white sturgeon catch and the percent of high-rise trawling efforts at maximum sampling depths in The Dalles Pool, 1989.

Table 12. Age distribution of white sturgeon by fork length group, The Dalles Pool, 1989.

Length group (mm)	No.	Age I	Age II	Age III	Age IV	Age V	Age VI
201-225							
226-250							
251-275							
276-300							
301-325							
326-350	2			1		1	
351-375	3			3			
376-400	7		3	3	1		
401-425	11		1	6	4		
426-450	14			5	7	2	
451-475	16			10	6		
476-500	18			4	8	5	1
501-525	15			3	6	6	
526-550	10			1	3	5	1
551-575	5				1	3	1
576-600	4				1	1	2
601-625	2			1	1		
626-650							
651-675	1					1	
676-700							
>700	1					1	

Other species

Several species of fish other than white sturgeon were identified from catches in The Dalles Pool during 1989 (Table 13). Trawl catches were dominated by YOY and older prickly sculpin. Other species commonly collected included YOY American shad, largescale and bridgelip suckers, peamouth and smallmouth bass.

John Day Pool

Environmental conditions

Water temperatures, and turbidities in McNary Dam tailrace were similar to those in the John Day Dam and The Dalles Dam tailrace areas. Hourly discharge ranged from 1.49 to 10.75 kcms during April through July (Figure 13). During the peak discharge period (late April - early June), daily discharge patterns were similar to those at John Day and The Dalles dams, though hourly fluctuations were not as pronounced during the period of egg and larvae collections through mid-June. Spill patterns also differed somewhat from the other two dams in that some occurred from late April through mid-May, and little thereafter.

Mean daily water temperatures from April through July ranged from 6.4° C to 20.4° C, reaching 10° C on 18 April and 17° C on 24 June (Figure 14). Mean daily turbidity ranged from 8.1 to 3.5 NTU (Figure 15).

Sturgeon egg collections

During 1989, 69 eggs of white sturgeon were collected in the McNáry Dam tailrace area between 7 and 22 June using D-shaped larval nets and beam trawls (Table 14). White sturgeon eggs were collected between RM 291.2 and RM 291.6 along the Oregon shore, except for two eggs collected near mid-channel at RM 290.7 and RM 290.9. Eggs were collected at depths from 4.9 to 11.6 m with mean water column and bottom velocities ranging from 0.81 to 1.60 m/s and 0.58 to 1.28 m/s, respectively. Based on back-calculated ages of eggs and larvae, spawning occurred over eight consecutive days beginning 6 June through 13 June. Mean daily water temperatures ranged from 15.1 to 16.3° C during this period. The first estimated spawning episode of 6 June was one and six days prior to the first egg and larvae collections, respectively. Adhesive eggs were collected on 7, 9, and 12 June. Developmental stages of the 63 viable eggs ranged from newly fertilized (15.4° C) to prehatch (approximately 79 hours old at 16.2° C). Six (9%) of the eggs were dead and covered with fungus.

Sturgeon larvae collections

White sturgeon larvae were captured on 12 and 14 June (Table

Table 13. Number and catch per unit of effort of fishes excluding sturgeon collected with high-rise (catch/15 minute tow (CPT) and catch/hectare (CPHA)), beam trawls and D - shaped larval nets (catch/1000 m^3) in The Dalles Pool from April through September, 1989.

	High-rise trawl			Beam trawl		D - shaped larval net			Total
	No.	CPT	CPHA	No.	CPT	No.	CPT	CKM^3	No.
Pacific lamprey	60	0.28	0.94	21	0.08	3	0.01	0.03	84
American shad	1438	6.69	22.65	100	0.40	9	0.02	0.09	1547
Steelhead trout	4	0.02	0.06						4
Chinook salmon	97	0.46	1.53	10	0.04	6	0.01	0.06	113
Mountain whitefish	3	0.01	0.05						3
Chiselmouth	2	0.01	0.03						2
Common carp	39	0.18	0.61						39
Peamouth	114	0.54	1.80						114
Northern squawfish	76	0.36	1.20	7	0.03				83
Redside shiner	1	<0.01	0.02	1	<0.01				2
UID[a] cyprinid	1	<0.01	0.02	99	0.40	81	0.16	0.79	181
Largescale sucker	127	0.60	2.00	1	<0.01				128
Bridgelip sucker	18	0.09	0.28	1	<0.01				19
UID sucker	364	1.72	5.73	623	2.52	15	0.03	0.15	1002
Channel catfish	116	0.55	1.83	13	0.05				129
Bullhead spp.	6	0.03	0.09	2	0.01				7
Sand roller	25	0.12	0.39	7	0.03				32
Smallmouth bass	73	0.34	1.15	30	0.12				103
<u>Lepomis</u> spp.	1	<0.01	0.02						1
White crappie	4	0.02	0.06			1	<0.01	0.01	5
Black crappie	5	0.02	0.08						5
UID crappie	105	0.50	1.65	4	0.02				109
Walleye	48	0.23	0.76	1	<0.01				49
Yellow perch	39	0.18	0.61	4	0.02				43
Prickly sculpin	3880	18.32	61.10	5618	22.74	80	0.16	0.78	9578
UID fish				7	0.03	3	0.01	0.03	10
Total Number	6,646			6,549		198			13,393

[a] unidentified

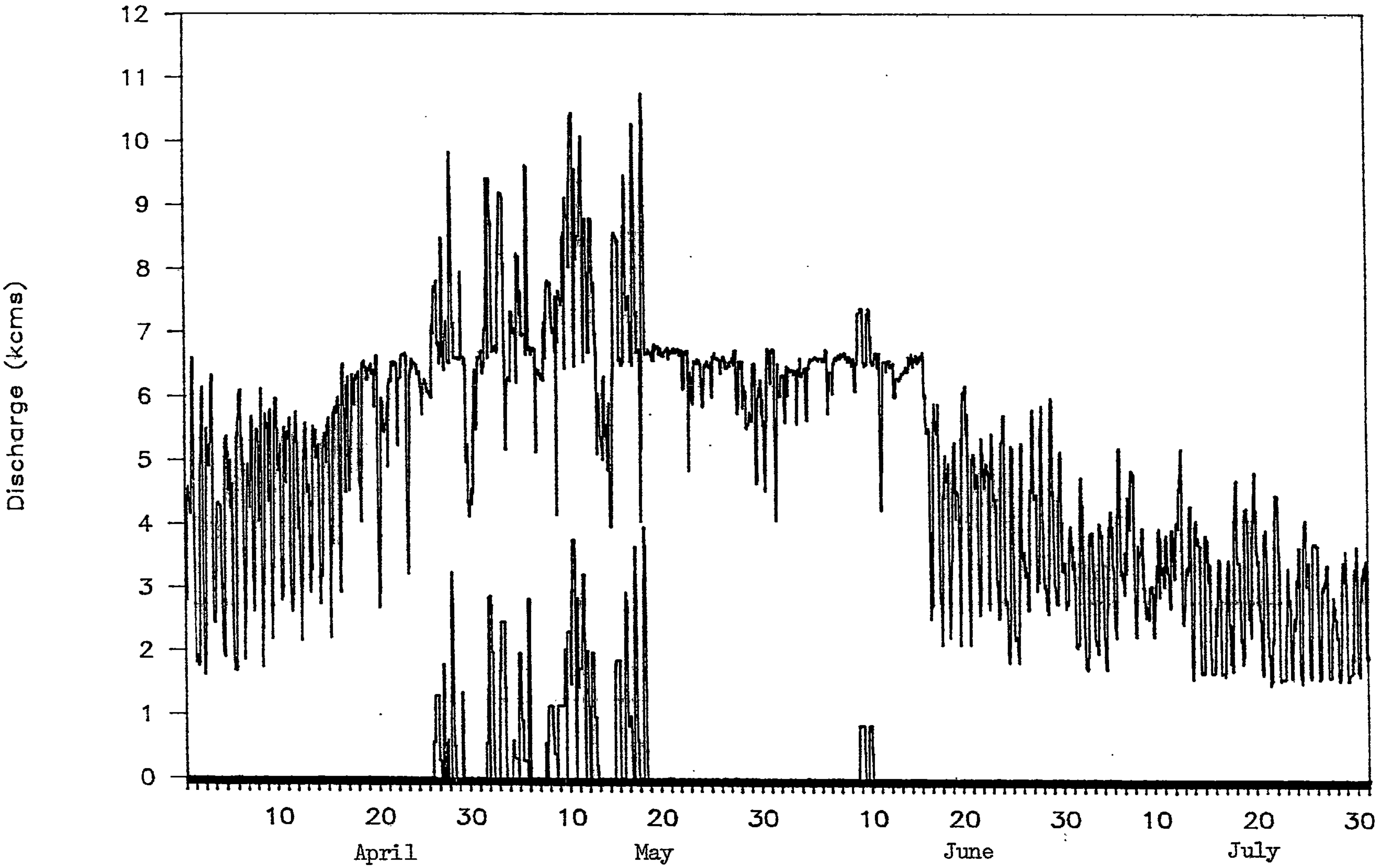

Figure 13. Hourly discharge through McNary Dam, April through July, 1989. The upper line indicates total discharge, the lower line indicates spill discharge.

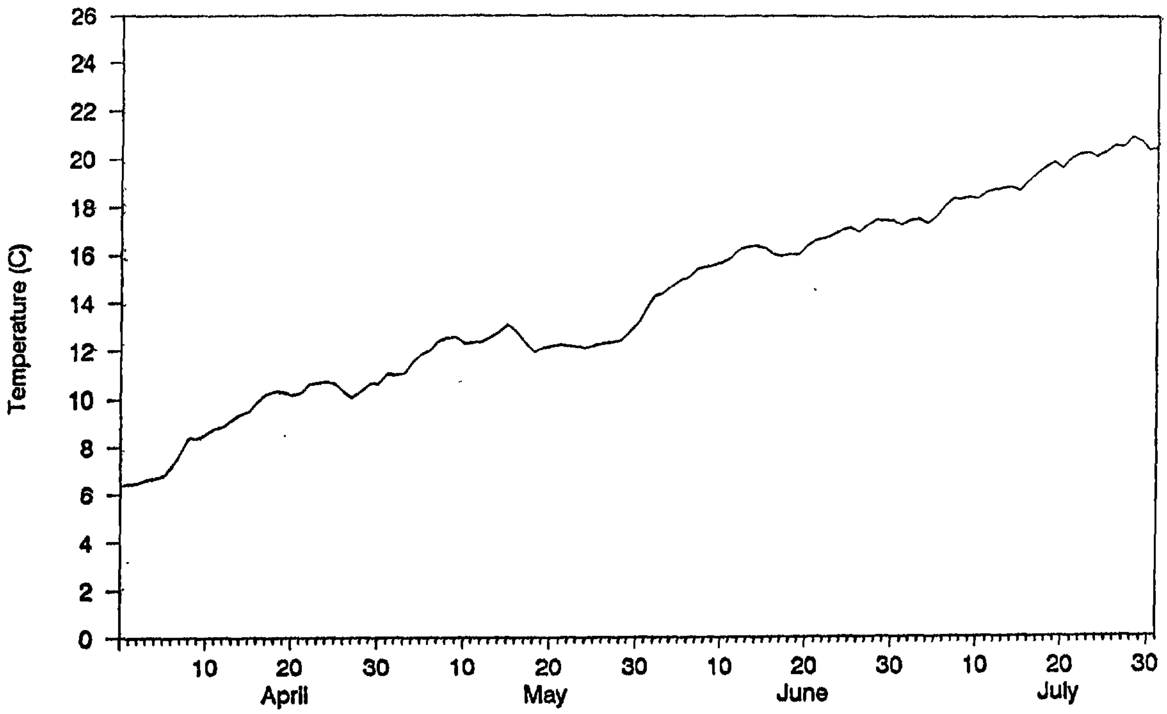

Figure 14. Mean daily water temperatures at RM 290.6 in John Day Pool, April through July, 1989.

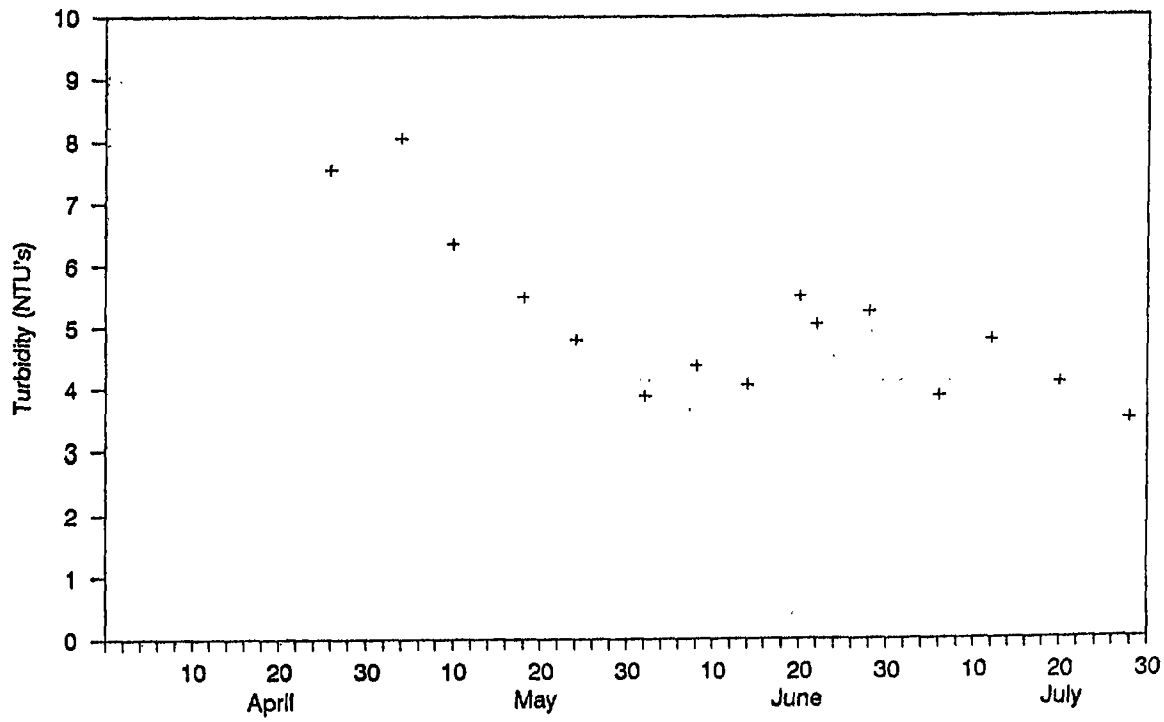

Figure 15. Mean turbidity measurements from RM 288.6 to 291.5 in John Day Pool, April through July, 1989.

Table 14. Number and catch per unit effort of white sturgeon eggs and larvae collected with the D-shaped larval net and beam trawl in the John Day Pool between RM 290.7 and R. 291.6 from 7 June through 22 June, 1989.

	Eggs			Larvae
Gear/catch	Viable	Fungused	Total	Total
D-Shaped larval net				
Number	11	2	13	3
Catch/1000 m^3	1.32	0.24	1.56	3.47
Catch/15 min	0.28	0.05	0.33	0.75
Beam trawl				
Number	52	4	56	3
Catch/15 min	2.36	0.18	2.54	1.73
All gears				
Number	63	6	69	6

14). All larvae (n = 6) were collected at RM 291.3 near the Oregon shore at a depth of 33 m. Developmental stage of one larvae was posthatch, indicating hatching occurred within the previous 24 hours, with the remaining five larvae staged as one day post hatch, indicating hatching occurred 24 to 48 hours previously. Total lengths of larvae ranged from 13 to 14 mm.

Juvenile sturgeon collections

We captured 67 juvenile white sturgeon in the John Day Pool, 2 with the beam trawl and 65 with the high-rise trawl. No YOY, age I (1988 year-class), or age II (1987 year-class) fish were captured. Fork lengths ranged from 317 to 955 mm (Table 15), with mean FL 528 mm. Monel bands were attached to 65 sturgeon and 64 were injected with OTC; none were recaptured.

The nematode parasite Cystoopis acipenser was observed on seven (10.4%) of the white sturgeon captured; infected fish ranged from 425 to 637 mm FL (mean = 504 mm).

Distribution: White sturgeon catches were highest in the upper portion of the reservoir and decreased progressively from the upper to the lower portions (Table 16). No sturgeon were captured from RM 218 to RM 239. Total sturgeon catch (catch/ha) was 52 (1.65), 11 (0.35) and 2 (0.06) in the upper, middle, and lower sections, respectively.

A strong temporal pattern of distribution was not evident, probably due to small sample size. Catches were highest during May, July, and September in the upper portion, and April in the middle section.

Depth preference: Juvenile white sturgeon were most often captured at intermediate depths in the John Day Pool. Approximately 65% of the sturgeon were captured at maximum depths between 18 and 25 m, where only 28% of high-rise trawl efforts occurred (Figure 16). At maximum depths from 8 to 12 m approximately 24% of the sturgeon were captured and 41% of the effort occurred. Eight percent of the catch and 30% of the effort occurred at depths over 30 m.

Weight-Length relationship and condition factor: The length-weight relationship calculated from 65 white sturgeon collected in the John Day Pool from February through September, 1989 is described by the equation Log W = Log FL(3.148) - 5.542 (r = 0.95). The sturgeon ranged from 317 to 721 mm FL. Mean condition factor was 0.728 (sd = 0.095; N = 65).

Age and growth: We aged 65 fin ray sections from sturgeon collected in the John Day pool from February through September,

Table 15. Length frequencies of white sturgeon collected in John Day Pool during 1989 (N = 67).

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

Table 16. Number, catch per 15 minute tow (CPT) and catch per hectare (CPHA) of white sturgeon captured with the high-rise trawl at lower (RM 218 - 244), middle (RM 244 - 268), and upper (RM 268 - 293) locations in John Day Pool.

Location	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total Number	CPUE
Lower Reservoir										
Number	-[1]	0	-[1]	0	2	0	0	0	2	
CPT	-	0.00	-	0.00	0.11	0.00	0.00	0.00		0.03
CPHA	-	0.00	-	0.00	0.25	0.00	0.00	0.00		0.07
Middle Reservoir										
Number	-[1]	3	3	2	0	2	1	0	11	
CPT	-	0.30	1.07	0.22	0.00	0.17	0.08	0.00		0.16
CPHA	-	0.66	2.33	0.52	0.00	0.35	0.18	0.00		0.35
Upper Reservoir										
Number	6	4	3[2]	11	5[3]	9	4	10	52	
CPT	1.20	0.57	0.14	0.59	0.45	0.76	0.33	0.83		0.75
CPHA	3.03	1.36	0.38	1.80	1.16	1.77	0.84	1.85		1.65
All Locations										
Number	6	7	6	13	7	11	5	10	65	
CPT	1.20	0.29	0.41	0.36	0.18	0.29	0.16	0.29		0.29
CPHA	3.03	0.68	1.02	1.00	0.41	0.64	0.35	0.59		0.66

1 No trawl effort during these months.

2 Effort not recorded for a sample with two sturgeon; they were included in total number, but not in calculation of catch per effort.

3 Effort not recorded for four samples with no sturgeon; recorded time not included in calculation of catch per effort.

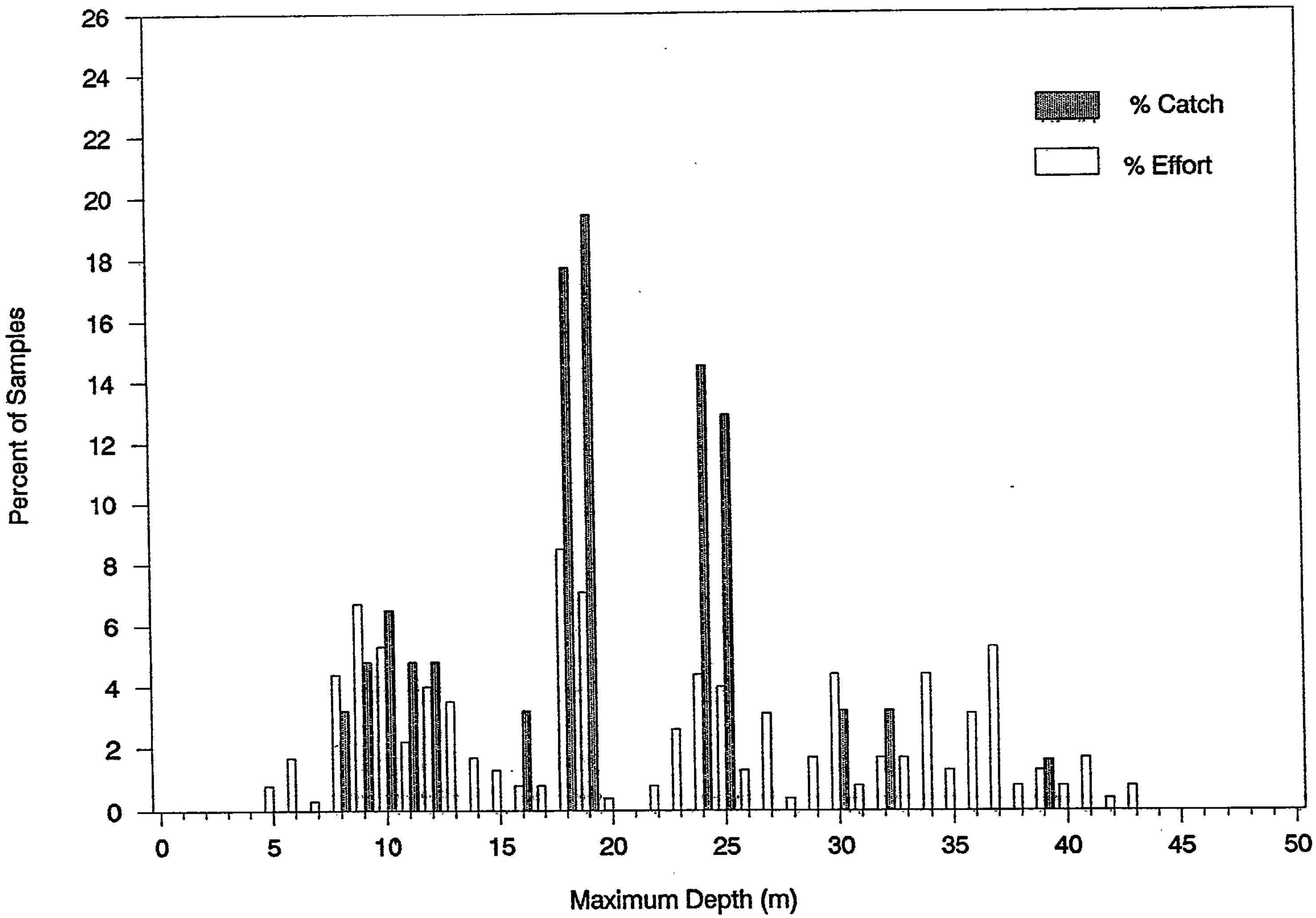

Figure 16. Percent of juvenile white sturgeon catch and the percent of high-rise trawling efforts at maximum sampling depths in John Day Pool, 1989.

1989; ages were determined for 54 (84%) of these sturgeon. Fork lengths of aged sturgeon ranged from 317 to 721 mm (Table 17). Mean fork lengths for ages III to VII were 445, 458, 515, 608, 577 mm, respectively (Appendices C-5 & C-7).

Mean FL at age was generally greater for white sturgeon in the John Day Pool than in other sampled pools. Annual relative growth rates (h) and instantaneous population growth rates (G) were 9% (0.090) and 45% (0.369) for ages III through V (Appendix C-6).

Other Species

Numerous species of fish were identified in our John Day Pool catches. Catches were dominated by prickly sculpin (59% of total non-sturgeon catch), with sand roller, YOY American shad, common carp, and largescale sucker also common (Table 18).

Food Habits

Emetic Efficiency

Similar to 1988, the emetic hydrogen peroxide was not suitable for a quantitative analysis of food habits. Twenty-nine white sturgeon (350 to 591 mm FL; mean = 471 mm) collected in Bonneville and The Dalles Pools from May through July were examined. Overall mean efficiency of hydrogen peroxide in recovering food items was 3.2% by weight. Combined food items recovered from 29 sturgeon are summarized in Appendix C-8.

Young-of-the-Year Food Habits

Food habits of 24 YOY white sturgeon ranging in total length from 35 to 276 mm (mean = 116) and weight from 0.286 to 116.3 g (mean = 17.4 g) were examined. Young-of-the-year sturgeon fed primarily on the amphipod *Corophium salmonis* (occasionally *C. spinicorne*) which was identified in all 24 stomachs examined and which comprised 98.9% by weight of prey taxa consumed. Percent occurrence of other prey consumed included *Ramellogammarus oregonensis* (17%), *Neomyis* spp. (21%), *Corbicula* spp. (8%), cladocera (8%), and copepods (8%).

Visual Implant Tagging

Visual implant (VI) tags were implanted into six white sturgeon held in our laboratory. Sturgeon were injected with tags at 4 locations and held in an indoor circular tank. One fish died and the remaining fish were evaluated for tag retention approximately 45 days later. Tags injected into the anterior

Table 17. Age distribution of white sturgeon by fork length group, John Day Pool, 1989.

Length group (mm)	No.	Age II	III	IV	V	VI	VII
201-225							
225-250							
251-275							
276-300							
301-325	1			1			
326-350							
351-375							
376-400	1				1		
401-425	3			3			
426-450	5		1	2	2		
451-475	7		2	3	1	1	
476-500	5		3	1	1		
501-525	4			4			
526-550	6			2	4		
551-575	5				3	1	1
576-600	6			1	3	1	1
601-625	4			1	2	1	
626-650	1					1	
651-675	4				1	1	2
676-700	1					1	
>701	1					1	

Table 18. Number and catch per unit of effort of fishes excluding sturgeon collected with high-rise (catch/15 minute tow (CPT) and catch/hectare (CPHA)), beam trawls and D - shaped larval nets (catch/1000 m^3) in John Day Pool from February through September, 1989.

Species	High-rise trawl No.	High-rise trawl CPT	High-rise trawl CPHA	Beam trawl No.	Beam trawl CPT	D - shaped larval net No.	D - shaped larval net CPT	D - shaped larval net CKM^3	Total No.
Pacific lamprey	10	0.05	0.12			1	<0.01	0.02	11
American shad	2136	11.10	25.86	29	0.15	63	0.17	1.02	2228
Chinook salmon	141	0.73	1.71	13	0.07	6	0.02	0.10	160
Mountain whitefish	3	0.02	0.04	2	0.01				5
Chiselmpouth	14	0.07	0.17						14
Common carp	896	4.66	10.85	4	0.02				900
Goldfish	70	0.36	0.85						70
Peamouth	14	0.07	0.17						14
Northern squawfish	27	0.14	0.33						27
UID[a] cyprinid	1	0.01	0.01	8	0.04	1	<0.01	0.02	10
Largescale sucker	597	3.10	7.23	1	0.04				598
Bridgelip sucker	27	0.14	0.33						27
UID sucker	9	0.05	0.11	45	0.24	11	0.03	0.18	65
Channel catfish	86	0.45	1.04	9	0.05				95
Bullhead spp.	53	0.28	0.64						53
Sand roller	2841	14.76	34.40	402	2.13				3243
Smallmouth bass	42	0.22	0.51	1	0.01				43
Pumpkinseed	30	0.16	0.36						30
Bluegill	5	0.03	0.06						5
White crappie	42	0.22	0.51						42
Black crappie	13	0.07	0.16						13
UID crappie	11	0.06	0.13						11
Walleye	23	0.12	0.28						23
Yellow perch	63	0.33	0.76						63
Prickly sculpin	9679	50.29	117.2	1360	7.22	23	0.06	0.37	11062
Total Number	16,833			1,874		105			18,812

[a] unidentified

portion of the mouth tube (anterior mouth) were most consistently retained and externally readable. Tags at the other three locations were readily lost and less readable.

At Hagerman State Hatchery, 100 white sturgeon were tagged at two locations, the Rostrum and Anterior Mouth. In addition, 36 white sturgeon were tagged under the left first lateral scute. Thirty-two fish had tags injected under the first right lateral scute and were injected with 0.30 oxytetracycline (50 mg/l) to help monitor post-handling stress and mortality. At the College of Southern Idaho Fish Hatchery, 95 sturgeon were tagged at two locations, the Rostrum and Anterior Mouth. Tag retention and readability will be evaluated in the future.

Predation/Scavenging upon Sturgeon Eggs

During June 1989, digestive tracts from 26 non-game fish collected below The Dalles and McNary Dams were examined for evidence of predation / scavenging on white sturgeon embryos. On 12 - 13 June at the McNary Dam tailrace, digestive tracts of 20 non-game fish were collected, with two largescale sucker, one northern squawfish and two common carp containing a total of 88 white sturgeon eggs. Though one largescale sucker (TL = 534 mm) collected at RM 291.3 contained 70 sturgeon eggs, 10 of the remaining suckers contained no sturgeon eggs. Two of the three common carp examined contained 5 and 6 sturgeon eggs, respectively. Of the four northern squawfish examined, one contained 2 sturgeon eggs. Digestive tracts of six largescale suckers collected on 20 June below The Dalles Dam were examined, but contained no white sturgeon eggs.

Habitat Quantification

The Dalles Pool

Approximately 80% of the surface area of The Dalles Pool is comprised of water depths greater than 5.49 m as determined from depth contours shown on navigation charts (pool elevation = 48.77 m) (Table 19). Substrate overlays for the entire pool and hydraulic simulation of water velocities between RM 210.4 and 214.8 at various discharge are currently being completed for The Dalles Pool.

Bonneville and John Day Pools

Habitat quantification efforts were not initiated for these pools in 1989.

Table 19. Surface areas of depth contours in The Dalles Pool. Areas were calculated from digitized navigation charts using a Geographic Information System.

Contours English ft	Contours Metric m	Area (hectares)	Percent Occurrence
0 - 6	0 - 1.83	195.07	5.36
6 - 12	1.84 - 3.66	139.22	3.83
12 - 18	3.67 - 5.49	336.13	9.24
18 - 30	5.50 - 9.14	896.00	24.63
30 - 60	9.15 - 18.29	1484.61	40.81
> 60	> 18.30	587.22	16.14
Total		3638.25	100.00

DISCUSSION

White sturgeon egg and larvae collections

White sturgeon successfully spawned during 1989 in the three pools above Bonneville Dam though numbers of eggs and larvae were low and quite variable among the different pools. Egg and larvae collections were highest downstream from The Dalles Dam (Bonneville Pool) and lowest below John Day Dam (The Dalles Pool). Collections of larvae were nearly 5.5 times those of 1988 below The Dalles Dam but egg and larvae catches below John Day Dam were very similar to 1988. As in 1987 and 1988, spawning occurred only in tailrace areas with high velocities and eggs were collected only in the upper three river miles of each reservoir.

The spawning period below The Dalles and John Day dams was similar to 1988, though spawning was initiated earlier in 1989. Spawning was estimated to first occur on 11 May below The Dalles Dam; 24 May below John Day Dam and 06 June below McNary Dam (Figure 17). Spawning was estimated to have occurred on at least 30 days below The Dalles Dam over the 76 day spawning period through 25 July. At least 11 spawning episodes were estimated to have occurred below John Day Dam from 24 May through 06 July and below McNary Dam, spawning episodes occurred daily from 06 June through 14 June.

Water temperatures associated with the white sturgeon spawning period in all pools ranged from 12.6° C to 20.1° C. Below the Dalles dam, spawning initially occurred at 12.7° C and concluded during late July at 20.1° C. Temperatures during the spawning period below John Day Dam and McNary Dam ranged from 12.6 to 18° C and 15.1 and 16.3° C, respectively. Sturgeon spawned at water temperatures ranging from 10 to 16° C below Bonneville Dam (McCabe et al 1989). White sturgeon in the Sacramento River spawned at temperatures ranging from 7.8 to 17.8° C with peak spawning at near 14.4° C (Kohlhorst 1976).

White sturgeon larvae were collected further downstream from The Dalles and John Day Dam spawning areas during 1989 than during 1988, with larvae collected 11.3 and 6.2 river miles downstream, respectively. Larval distribution is probably influenced by many factors, such as flow, behavior, and availablity of suitable microhabitats. Downstream dispersal and catches of larval white sturgeon were related to river flows in the Sacramento - San Joaquin Delta (Stevens and Miller 1970). Brannon et al (1985), in laboratory experiments, demonstrated that higher velocities increase downstream distribution but also cause larvae to return more rapidly to the substrate to seek cover. Larvae also preferred substrates "where cover was maximized". The higher flows of 1989 appeared to distribute sturgeon larvae further downstream, resulting in increased availability to capture.

Post larval YOY white sturgeon were collected during 1989 for the first time during the study and only in Bonneville Pool. Young-of-the-year sturgeon were widely dispersed and collected as far as 34.5 miles (RM 157.3) downstream from The Dalles Dam with most collected between RM 159.5 and 170.6. Young-of-the-year sturgeon were associated with deeper areas of Bonneville Pool, most often collected at depths ranging from 23 to 49 m.

Predation on sturgeon eggs in McNary tailrace by largescale sucker, carp and northern squawfish was observed. Further efforts are needed to determine the level and significance of egg predation on early life survival.

Juvenile white sturgeon collections

As in 1988, juvenile white sturgeon were more abundant in Bonneville Pool than in The Dalles Pool. Catches in John Day Pool were lower, with sturgeon densities only 10% and 16% of those found in Bonneville and The Dalles pools, respectively. Sturgeon CPE was similiar in Bonneville Pool in both years, but declined 27% in The Dalles Pool in 1989. Juvenile sturgeon catches during 1989 above Bonneville Dam indicate very weak year - classes have occurred since 1986. No age I sturgeon were collected in 1989, and only 6 and 4 age II sturgeon were collected in Bonneville and The Dalles pools, respectively; no sturgeon younger than age III were collected from John Day Pool.

Juvenile white sturgeon are widely distributed in the reservoirs, though densities are much greater in the upper portions. For example, in John Day Pool, only two sturgeon were collected in the lower 26 river miles of the reservoir, a stretch characterized by depths > 50 m, slow currents, and rocky substrates. Sturgeon were collected at most depths sampled, though they seemed to prefer deeper habitats at maximum depths ranging from 16 to 40 m. Additionally, juvenile sturgeon were collected over most substrate types, though seldom over gravel/cobble less than 9 m in depth.

Sturgeon exhibited limited but random patterns of movements in The Dalles Pool based upon tag recoveries. Movements of recaptured fish ranged up to 10 RM upstream and downstream, and 3 of 7 sturgeon were recovered at the intitial tagging location.

Juvenile sturgeon through age V were larger in the three pools above Bonneville Dam than sturgeon of the same age collected below Bonneville Dam, most likely due to faster growth through age II (Appendices C-5 & C-7). All recaptured tagged sturgeon from The Dalles Pool (Table 9) exhibited positive growth. Recoveries of several tagged sturgeon from below Bonneville Dam during 1988 revealed negative or poor growth (McCabe et al 1989), with general patterns of growth localized and area specific. White sturgeon collected between Bonneville and McNary dams during 1989 demonstrated considerable variation in size at each age through VII (Appendix C-7). This finding is consistent with white sturgeon growth studies on the lower Columbia (Hess 1984) and Sacramento-San Joaquin Estuary (Kohlhorst et al. 1980).

Food Habits

Juvenile white sturgeon < 600 mm Fl collected in Bonneville and The Dalles pools consumed a wide variety of prey species, mostly invertebrates associated with the benthos. The amphipod Corophium salmonis was the dominant food item, found in all (n = 29) of the stomachs examined and accounted for 33% by weight (Appendix C-5). Other prey common in the diet of juvenile sturgeon included the decapod Pacificatus spp., the amphipod Ramellogammarus oregonensis, the mysid Neomysis spp, and the bivalves Corbicula spp and miscellaneous hydrobiidae. These findings are similiar to recent lower Columbia River studies that showed juvenile white sturgeon fed primarily on small benthic invertebrates (Muir et al 1988; McCabe et al 1989). Young-of-the-year white sturgeon in Bonnville Pool fed almost exclusively on Corophium salmonis and Corophium spinicorne (98.9% by weight).

Plans for 1990

The 1990 study efforts include the continuation of the standardized sampling system in all three pools to collect eggs, larvae, young-of-the-year (YOY) and older juvenile age whte sturgeon. Egg and larval sampling with D-shaped larval nets and beam trawls will commence during the first week of May and continue thru July on a weekly basis. Sampling in the Bonneville pool for YOY and older juveniles with the high-rise trawl will follow the same bi-weekly schedule followed in 1989. Trawl efforts in The Dalles and John Day pools will occur once during April and then bi-weekly during August and SSeptember. Trawling in John Day downstream from Arlington, Oregon (RM 243) will be excluded from the regular schedule because no fish were caught there during 1989.

Field efforts to define habitat use by spawning and rearing white sturgeon will continue in all three pools in 1990. Construction of computerized habitat maps of each pool, which should allow us to quantify the amount of habitat available for spawning and rearing will be completed in 1990. The maps are being digitized from existing navigational charts, modified with additional data, into a Geographic Information System. Cartographic modeling will then be used to determine the amounts of various types of habitat available. These efforts will also include the spawning and rearing areas below Bonneville Dam.

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APPENDIX C-1

Common and scientific names of fishes collected between Bonneville and McNary Dams during 1989.

Common Name	Scientific name
Pacific lamprey	*Lampetra tridentata*
American shad	*Alosa sapidissima*
Chinook salmon	*Oncorhynchus tshawytscha*
Rainbow trout	*Oncorhynchus mykiss*
Mountain whitefish	*Prosopium williamsoni*
Chiselmouth	*Acrocheilus alutaceus*
Common carp	*Cyprinus carpio*
Goldfish	*Carassius auratus*
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 spp.*
Yellow perch	*Perca flavescens*
Walleye	*Stizostedion vitreum vitreum*
Prickly sculpin	*Cottus asper*

APPENDIX C-2

Criteria for assigning white sturgeon early life stages: larvae through YOY.

Larvae:	Post hatch sturgeon with yolk sac visible by external observation.
Post-Larvae:	Larval sturgeon with yolk sac not visible by external observation. Total length < 20 mm TL. (Usually occurs 7 to 10 days post hatch). Head region not fully developed.
YOY:	Young-of-the-year sturgeon $\geq$ 20 mm TL. Head region has developed all of the basic sensory and jaw structures of older sturgeon.

APPENDIX C-3

Number, monthly catch per 15 minute tow (CPT), monthly catch per hectare (CPHA) and overall monthly catch per unit of effort (CPE) of white sturgeon captured with high-rise trawls at 22 routinely sampled locations in Bonneville Pool during 1989.

Location	Month									Overall
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Number	CPUE
15052										
Number	0	1	0	1	0	0	0		2	
CPT	0.00	0.75	0.00	0.50	0.00	0.00	0.00			0.23
CPHA	0.00	1.89	0.00	0.97	0.00	0.00	0.00			0.50
15053										
Number	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
CPHA	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00
15242										
Number	1	0	0	1	0	0	0		2	
CPT	0.75	0.00	0.00	0.50	0.00	0.00	0.00			0.23
CPHA	1.89	0.00	0.00	1.18	0.00	0.00	0.00			0.54
15502										
Number	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
CPHA	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00
15734										
Number	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
CPHA	0.00	0.00	0.00	0.00	0.00	0.00	0.00			0.00
15951										
Number	1	0	0	0	2	2	1		6	
CPT	0.75	0.00	0.00	0.00	1.50	1.50	1.50			0.64
CPHA	1.88	0.00	0.00	0.00	3.61	3.27	3.32			1.53
16072										
Number	0	3	3	3	1	0	0		10	
CPT	0.00	2.25	2.25	1.50	0.79	0.00	0.00			1.08
CPHA	0.00	5.42	5.12	3.35	1.52	0.00	0.00			2.40

APPENDIX C-3 (continued)

Location	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Number	Overall CPUE
16403										
Number	1	0	0	0	0	0	0		1	
CPT	0.75	0.00	0.00	0.00	0.00	0.00	0.00			0.11
CPHA	1.86	0.00	0.00	0.00	0.00	0.00	0.00			0.24
16522										
Number	0	3	0	1	2	0	0		6	
CPT	0.00	2.25	0.00	0.50	1.50	0.00	0.00			0.64
CPHA	0.00	6.58	0.00	1.19	3.41	0.00	0.00			1.65
16851										
Number	1	2	0	0	1[1]	0	0		4	
CPT	0.75	1.50	0.00	0.00	0.00	0.00	0.00			0.33
CPHA	1.98	4.38	0.00	0.00	0.00	0.00	0.00			0.81
16903										
Number	3	1	1	3	0	0	0		8	
CPT	2.25	0.75	0.75	1.50	0.00	0.00	0.00			0.86
CPHA	6.69	2.50	2.27	3.65	0.00	0.00	0.00			2.23
17063										
Number	0	0	0	2[2]	4	3	3	13	25	
CPT	0.00	0.00	0.00	3.00	2.00	1.73	2.14	1.93		1.51
CPHA	0.00	0.00	0.00	7.22	4.96	4.57	4.84	5.56		4.16
17374										
Number	15	3	8	17	8	2	0		53	
CPT	11.25	2.25	6.00	12.75	4.00	1.50	0.00			5.68
CPHA	49.78	6.94	19.24	36.63	10.01	4.09	0.00			16.76
17442										
Number	0	0	0	1	0	0	1		2	
CPT	0.00	0.00	0.00	0.75	0.00	0.00	1.50			0.21
CPHA	0.00	0.00	0.00	1.70	0.00	0.00	3.51			0.48

APPENDIX C-3 (continued)

Location	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Overall Number	Overall CPUE
17652										
Number	0	0	0	2	2	0	0		4	
CPT	0.00	0.00	0.00	1.50	1.00	0.00	0.00			0.43
CPHA	0.00	0.00	0.00	3.56	2.45	0.00	0.00			1.09
17911										
Number	7	24	73	46	4	2	1		157	
CPT	5.25	18.00	54.75	34.50	2.00	1.50	1.50			16.82
CPHA	14.81	40.86	127.85	76.27	4.63	3.36	3.61			39.56
18351										
Number	2	5	2	6	34	9	1		59	
CPT	1.50	3.75	1.50	4.50	17.00	6.75	1.50			6.32
CPHA	4.30	12.79	4.16	11.33	42.14	15.55	4.23			16.92
18353										
Number	0	10	5	14	3	0	0		32	
CPT	0.00	7.50	3.75	10.50	1.50	0.00	0.00			3.43
CPHA	0.00	17.79	9.58	22.32	3.07	0.00	0.00			7.57
18502										
Number	7	44	11	8	4	0	0		74	
CPT	5.25	33.00	8.25	6.00	2.00	0.00	0.00			7.93
CPHA	13.22	93.04	20.15	13.26	4.63	0.00	0.00			18.42
18523										
Number	4	13	0	1	2	0	0		20	
CPT	2.00	9.75	0	0.75	1.00	0.00	0.00			2.00
CPHA	4.86	30.66	0	1.95	2.41	0.00	0.00			4.86
18982										
Number	0	7	7	4	3	0	0		21	
CPT	0.00	5.25	5.25	3.00	1.50	0.00	0.00			2.25
CPHA	0.00	22.04	15.61	8.05	4.33	0.00	0.00			6.78

APPENDIX C-3 (continued)

Location	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Overall Number	Overall CPUE
19005										
Number	41	30	4	38[3]	1	1	0		115	
CPT	30.75	22.50	3.00	9.75	0.50	0.75	0.00			9.64
CPHA	79.86	53.35	10.03	25.72	1.38	1.80	0.00			25.68
All locations										
Number	83	146	114	148	71	19	7	13	601	
CPT	2.77	4.98	4.38	3.44	1.91	0.64	0.45	1.65		2.70
CPHA	7.36	13.57	10.86	7.98	4.43	1.45	1.04	4.62		6.69

[1] One sturgeon captured with no effort recorded, and was excluded in effort estimates.

[2] Effort not recorded for one trawl tow (no sturgeon captured); and was excluded in effort estimates.

[3] Twenty five sturgeon caught during a trawl/tow with no effort recorded and were excluded in calculating effort catch per effort estimates.

APPENDIX C-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 permanent sampling locations in The Dalles Pool during 1989.

Location	Month						Total number	CPUE
	Apr	May	Jun	Jul	Aug	Sep		
19433								
Number	0	0	0	4	1	0	5	
CPT	0.00	0.00	0.00	2.0	1.50	0.00		0.42
CPHA	0.00	0.00	0.00	5.33	3.72	0.00		1.06
19633								
Number	1	1	2	0	1	0	5	
CPT	0.50	0.38	0.75	0.00	1.50	0.00		0.44
CPHA	1.38	1.05	2.10	0.00	3.96	0.00		1.16
19901								
Number	3	5	15	14	2	2	41	
CPT	1.50	2.50	5.63	7.00	3.00	1.50		3.84
CPHA	4.49	6.39	14.72	18.67	7.67	3.66		10.18
19903								
Number	0	0	0	0	0	0	0	
CPT	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
20124								
Number	40	4	0	0	0	0	4	
CPT	0.00	1.20	0.00	0.00	0.00	0.00		0.32
CPHA	0.00	3.43	0.00	0.00	0.00	0.00		0.89
20244								
Number	0	0	1	0	0	0	1	
CPT	0.00	0.00	0.38	0.00	0.00	0.00		0.09
CPHA	0.00	0.00	1.27	0.00	0.00	0.00		0.33
20531								
Number	7	22	2	17	0	0	48	
CPT	3.50	6.60	0.75	8.50	0.00	0.00		4.11
CPHA	8.59	14.83	1.87	21.07	0.00	0.00		9.93

APPENDIX C-4 (continued)

Location	Apr	May	Jun	Jul	Aug	Sep	Total number	CPUE
20652								
Number	2	2	3	0	0	0	7	
CPT	1.00	0.75	1.13	0.00	0.00	0.00		0.58
CPHA	3.46	2.96	4.05	0.00	0.00	0.00		1.92
20822								
Number	0	0	0	0	0	0	0	
CPT	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
20904								
Number	2	17	13	14	2	0	48	
CPT	1.00	5.10	4.87	5.25	1.50	0.00		3.60
CPHA	3.46	17.85	17.34	16.69	4.63	0.00		12.03
20983[1]								
Number	11	0	9	2	0	0	22	
CPT	3.30	0.00	3.37	0.75	0.00	0.00		1.44
CPHA	10.72	0.00	14.74	2.53	0.00	0.00		5.46
21075								
Number	0	1	0	1	0	0	2	
CPT	0.00	0.30	0.00	0.38	0.00	0.00		0.16
CPHA	0.00	0.70	0.00	1.01	0.00	0.00		0.38
21302								
Number	6	3	21	13	1	1	45	
CPT	3.00	0.90	7.87	4.87	0.75	0.75		3.38
CPHA	12.28	5.19	37.35	19.01	2.75	2.15		14.31
21401[1]								
Number	0	0	0	0	0	0	0	
CPT	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
21451[1]								
Number	0	0	0	0	0	0	0	
CPT	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

APPENDIX C-4 (continued)

Location	Month						Total number	CPUE
	Apr	May	Jun	Jul	Aug	Sep		
21501								
Number	11	5	2	3[2]	1	0	22	
CPT	5.50	1.88	1.00	1.50	1.00	0.00		2.03
CPHA	18.75	7.14	2.99	5.58	2.93	0.00		6.75
21502								
Number	0	0	0	0	0	0	0	
CPT	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
All locations								
Number	43	60	68	68	8	3	250	
CPT	1.22	1.17	1.57	1.73	0.43	0.14		1.19
CPHA	4.06	4.23	5.36	5.66	1.43	0.37		3.96

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

[2] One sturgeon was captured on a haul where effort was not recorded; hence it was not included in catch per effort calculations.

APPENDIX C-5

Mean and range in fork length (FL) for white sturgeon ages I-VII captured with trawls from Bonneville Pool (N = 92), The Dalles Pool (N = 111), John Day Pool (N = 54) and from below Bonneville Dam (N = 128). Anterior pectoral spines from white sturgeon captured below Bonneville Dam were provided by NMFS.

Bonneville Pool	Age						
	I	II	III	IV	V	VI	VII
Mean FL	-	358	392	424	452	521	624
Range	-	340-366	317-538	362-548	355-608	398-658	553-649
N	0	6	27	22	26	7	4

The Dalles Pool	Age						
	I	II	III	IV	V	VI	VII
Mean FL	-	371	423	458	483	594	-
Range	-	355-395	320-591	365-578	325-554	471-756	-
N	0	4	37	38	23	8	1

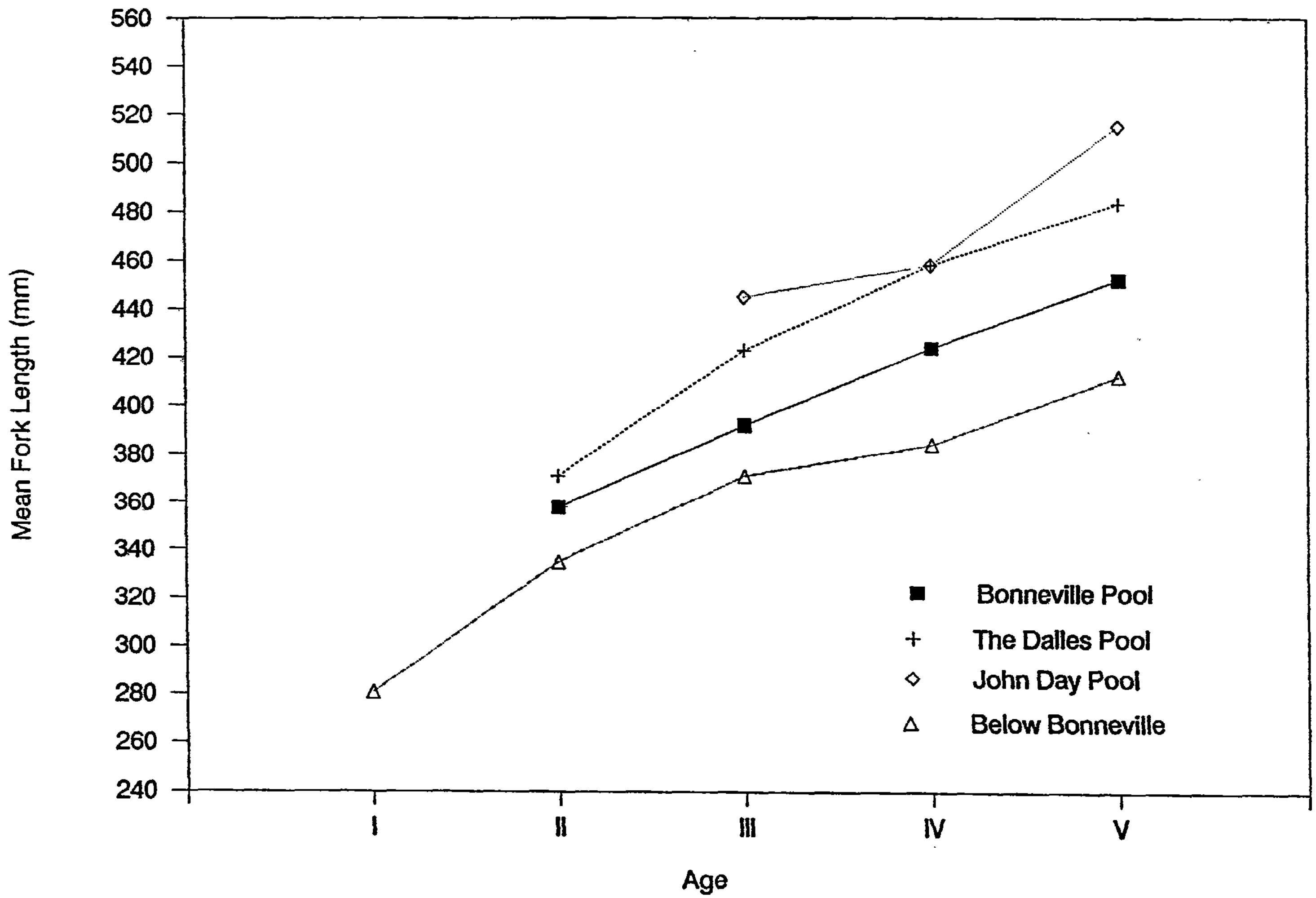
John Day Pool	Age						
	I	II	III	IV	V	VI	VII
Mean FL	-	-	445	458	515	608	577
Range	-	-	421-462	317-600	360-635	527-721	429-653
N	0	0	6	18	18	6	6

Below Bonneville	Age						
	I	II	III	IV	V	VI	VII
Mean FL	281	335	371	384	412	456	512
Range	264-294	285-404	294-436	320-457	348-471	358-519	416-704
N	2	19	30	22	28	15	12

APPENDIX C-6

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

Location	Age	Mean FL	Predicted Weight	h	G
Bonneville Pool	II	358	331		
	III	392	433	31	.269
	IV	424	547	26	.234
	V	452	662	21	.191
The Dalles Pool					
	II	371	384		
	III	423	566	47	.388
	IV	458	717	27	.236
	V	483	839	17	.157
John Day Pool					
	II	-	-		
	III	445	624		
	IV	458	683	9	.090
	V	515	988	45	.369
Below Bonneville					
	I	281	143		
	II	335	242	69	.526
	III	371	328	35	.304
	IV	384	363	11	.101
	V	412	445	22	.204



APPENDIX C-7. Mean fork length at age for white sturgeon age I - V captured in Bonneville, The Dalles, and John Day Pools, and from below Bonneville Dam during 1989.

APPENDIX C-8

Percent occurrence, range and mean number, and percent weight of food items recovered from juvenile white sturgeon (n = 29) from The Dalles and Bonneville Pools. Sturgeon ranged from 350 to 591 mm FL (mean = 471 mm).

Food Item	Percent Occurrence	Number Range	Number Mean	Percent Weight
Nematoda	6.9	-	-	-
Polychaeta	3.4	-	2	< 0.1
Oligochaeta	10.3	2 - 136	49	1.1
Arthropoda				
Crustacea				
Cladocera	3.4	-	12	< 0.001
Mysidacea				
Neomysis sp	51.7	1 - 48	12	2.7
Amphipoda				
Ramellogammarus oregonensis	41.4	1 - 75	12	3.3
Corophium salmonis & *spinicorne*	100.0	1 - 599	117	33.4
Decapoda				
Pacificatacus spp	17.2	1 - 17	3	26.5
Mollusca				
Pelecypoda				
Hydrobiidae	31.0	1 - 42	10	< 0.7
Corbicula sp	34.5	1 - 815	107	13.3
Sphaeridae	6.9	1 - 2	1.5	< 0.001
Insecta				
Diptera				
Chironomidae				
Larva/pupa	34.0	3 - 130	21	0.5
Tricoptera	17.2	2 - 5	3	< 0.2
Coleoptera (larva)	3.4	-	1	< 0.001

APPENDIX C-8 (continued)

Food Item	Percent Occurrence	Number Range	Number Mean	Percent Weight
Ephemeroptera				
Hexagenia sp	13.8	1 - 4	2	< 0.2
Osteichthyes				
Cottus asper	3.4	-	2	5.4
Oncorhynchus tshawystshaw	3.4	-	1	12.5
Miscellaneous Fish eggs	10.3	1 - 9	4	< 0.2
Plant Material	82.8	-	-	-

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 his assistance with data analysis. Lawrence Davis, Maurice Laird, and Roy Pettit assisted in the field sampling. The Washington Department of Fisheries determined the developmental stages of white sturgeon eggs and larvae and provided summaries of the egg and larval sampling efforts. The U.S. Army Corps of Engineers provided water temperature and water discharge information for Bonneville Dam.

ABSTRACT

During 1989, 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, 2,323 white sturgeon eggs were collected with plankton nets and artificial substrates between River Miles (RMs) 138 and 145. White sturgeon eggs were first collected with plankton nets on 27 April near Ives Island (RM 143), and last collected in plankton nets on 6 July at RM 140. 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 7 of the 10 days that eggs were collected near Ives Island, indicating that spawning was occurring throughout the spring. Between 27 April and 28 June, white sturgeon egg densities near Ives Island (in plankton nets) averaged 46.2 eggs/1,000 m^3 of water sampled, with the highest density on 17 May (171.3 eggs/1,000 m^3). We estimated that white sturgeon spawned on at least 43 days in 1989, beginning on 22 April and ending on 2 July. During the spawning period, Bonneville Dam discharge (mean hourly discharge by day) ranged from 3,348 to 8,872 m^3/s. White sturgeon eggs were collected at bottom-water temperatures ranging from 12 to 18°C, bottom-water turbidities ranging from 3.3 to 10.0 NTU, mean water-column velocities ranging from 0.7 to 2.6 m/s, and water depths ranging from 4.6 to 22.6 m. A total of 135 white sturgeon larvae were collected in plankton nets between RMs 108 and 144. Larvae were first collected on 8 May at RM 113, and last collected on 28 June near Ives Island and RM 140. From 27 April to 28 June, densities of larvae near Ives Island averaged 1.7 larvae/1,000 m^3 and ranged from 0.0 to 6.7 larvae/1,000 m^3.

In 1989, a total of 2,579 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. Much of the sampling for juvenile sturgeon was conducted in five index areas--RM 28, RM 75-79, RM 88-95, RM 114, and RM 127-131--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 (83 $\pm$ 284 (mean $\pm$ SD) sturgeon/hectare) and lowest at depths <9.1 m (9 $\pm$ 32 sturgeon/hectare). In 1989, a total of 111 young-of-the-year white sturgeon were collected between RMs 29 and 101. Young-of-the-year preferred deeper areas of the river (mean minimum and maximum depths were 14.7 and 22.6 m, respectively).

Since the white sturgeon is a demersal species, two benthic surveys were conducted in conjunction with the juvenile sampling to determine the relationships between sturgeon densities and the benthos (benthic invertebrates and the substrate). The relationships between white sturgeon densities and benthic invertebrate densities, specifically *Corbicula manilensis* (a bivalve) and *Corophium salmonis* (a tube-dwelling amphipod) densities (both important prey items), were 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 stomach contents of white sturgeon collected at RMs 95 and 131 were analyzed to determine what they were eating and relationships with the benthic invertebrate communities. Overall, the most important identifiable prey was

Corophium salmonis. Other important prey included *Corbicula manilensis*, *Neomysis* sp., *Corophium spinicorne*, Chironomidae larvae, and eulachon *Thaleichthys pacificus* eggs. Results from the stomach analysis indicated that food may be limited for juvenile sturgeon at RMs 95 and 131 in September-October.

A total of 1,675 juvenile white sturgeon were tagged with bird-banding tags in 1989. Twenty-four tagged sturgeon were recaptured in NMFS trawls; two of the recaptures had been tagged by NMFS in 1987 and ten had been tagged in 1988. All of the recaptures were made within a mile of where the fish were originally tagged.

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 conducted 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 spawning and the early life history of white sturgeon.

Specific research goals for 1989 were 1) to examine the spawning requirements of white sturgeon in the Columbia River downstream from Bonneville Dam; 2) to determine the downstream distribution of white sturgeon larvae in the Columbia River downstream from Bonneville Dam; 3) to determine the habitat requirements or preferences of juvenile white sturgeon in the Columbia River downstream from Bonneville Dam; and 4) to provide a detailed analysis of the food habits of juvenile white sturgeon in the Columbia River downstream from Bonneville Dam. This report describes progress on NMFS's studies from March 1989 to March 1990.

METHODS

Egg and Larval Sampling

In 1989, 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 either biweekly or weekly (during the spawning period). A D-ring plankton net was used to collect white sturgeon eggs and larvae. This 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). Depending upon the water velocity, two to four 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.

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. The strips were held in place with nuts and bolts, allowing fast removal of the substrate from the frame. Two sections of the artificial substrate were placed back to back in each frame. Because two pieces were used in each frame, it made no difference what side of the frame rested on the river bottom. Two short sections of cable were used to attach the frame to an

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

anchor, which held the substrate and frame in place on the bottom. A buoy line was attached to the anchor to allow retrieval of the substrate, frame, and anchor.

White sturgeon egg and larval sampling was done at various sites in the lower Columbia River from River Mile (RM) 95 to 145 (Figure 1). The most frequent sampling was done at a site near Ives Island (RM 143), which has been routinely sampled in past years by WDF and NMFS, and is considered an index area for monitoring white sturgeon spawning in the lower Columbia River. On 25 May, we also sampled with plankton nets in the Willamette River at Oregon City, Oregon; sampling was about 0.75 miles downstream from the falls at Oregon City.

White sturgeon eggs and larvae were fixed in an approximately 4% buffered formaldehyde solution and transferred to WDF. Egg and larval stages were determined by WDF based on descriptions developed by Beer (1981). The WDF's descriptions for larval stages 1-7 correspond to Beer's descriptions for his stages 1-day post hatch through 7-day post hatch. We were unable to estimate the number of days required to reach a specific larval stage because water temperatures in the Columbia River were not always comparable to laboratory temperatures in Beer's study. Timing of egg deposition was estimated using an equation developed by Wang et al. (1985); the water temperature at the time of egg collection was used in the equation.

Juvenile Sampling

A 7.9-m (headrope length) semiballoon shrimp trawl, identical to that used in 1987 and 1988, 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 conducted from 27 March to 1 November. Trawling was primarily in five index areas (RM 28, RM 75-79, RM 88-95, RM 114, and RM 127-131) established as a result of 1987 research (Figure 1). 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 RM 75-79, trawling was at RMs 75 and 79; at RM 88-95, trawling was at RMs 88 and 95. Trawling at RM 127-131 was at RMs 127 and 131. At each RM, two or three trawling efforts were completed along parallel transects. Transect 1 was closest to the Washington shore, Transect 2 was the middle transect, and Transect 3 was closest to the Oregon shore. In certain river sections where only two transects were established, Transect 2 was closest to the Oregon shore.

Fishes captured in the bottom trawls were identified and counted. Generally, all white sturgeon from a sampling effort were measured (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 50 sturgeon was measured and weighed. White sturgeon were tagged to provide data

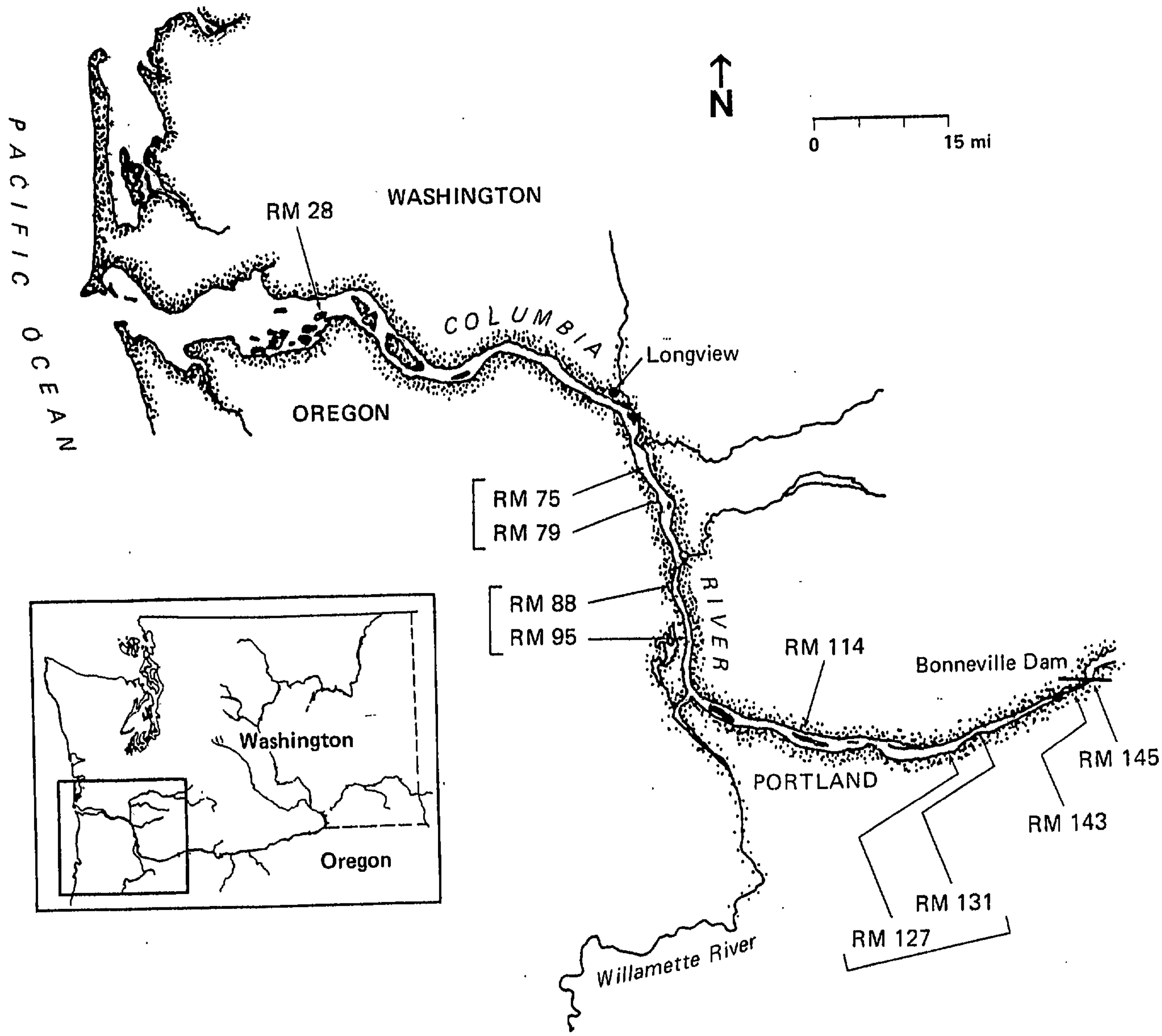

Figure 1. Lower Columbia River showing white sturgeon sampling areas.

on movement and growth. A monel metal bird-banding tag 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. A portion of the anterior ray of the left pectoral fin was removed by cutting at or just distal to the fin articulation.

In 1988, stomachs were taken from white sturgeon captured in two areas of the lower Columbia River (RMs 95 and 131) to determine what they were eating and the relationships between the benthic invertebrate communities and sturgeon food. Analysis of the stomach contents was not completed until 1989. Sturgeon stomachs were taken during three time periods--1) May-June, 2) July-August, and 3) September-October. In each area, we tried to take 25 stomachs from each of two size-classes of sturgeon during each of the three time periods. The two size-classes of sturgeon were 1) ≤350 mm fork length and 2) 351 to 725 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% ethyl alcohol solution. Individual food items in each stomach were identified to the lowest practical taxonomic level, sorted, counted, and weighed to the nearest 0.1 mg.

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) at the five index areas. Two benthic surveys were conducted in 1989--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 (≥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 formaldehyde. 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).

Physical Conditions

Selected physical parameters, 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 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. Selected computer programs were used to analyze the data.

Linear and multiple regressions were used to determine the relationships between measured physical parameters (water temperature, turbidity, water velocity, and Bonneville Dam discharge) and densities of white sturgeon eggs (stage 2) observed at Ives Island. Stage 2 eggs are freshly fertilized eggs and their presence indicates recent spawning. Egg densities, which were expressed as number/1,000 m^3 of water, were transformed to $\log_{10}$ of (number + 1) prior to analysis.

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 (g) and L = length (mm, fork length). A mean condition factor and standard deviation (SD) were calculated for all white sturgeon measured and weighed.

Densities of white sturgeon in three different depth ranges--$\leq$9.0, 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 stations in an area. Information calculated for each station included the number of taxa, mean number/m^2 and SD for each taxon, mean number of invertebrates/sample and SD, and total mean number of invertebrates/m^2 and SD. For the index areas, the relationships between white sturgeon densities and benthic invertebrate densities, specifically *Corbicula manilensis* and

Corophium salmonis, were examined using linear and multiple regressions. White sturgeon densities were transformed to $\log_{10}$ of (density + 1) and benthic invertebrate densities were transformed ($\log_{10}$) prior to analyses.

The food of white sturgeon in each of two areas during three time periods 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. Differences among IF values were statistically tested using the Mann-Whitney test (Elliott 1977).

RESULTS

Egg and Larval Sampling

In 1989, a total of 2,323 white sturgeon eggs were collected between RMs 138 and 145 (Table 1); 2,018 eggs were collected with plankton nets and 305 eggs were collected with artificial substrates. White sturgeon eggs were first collected with plankton nets on 27 April near Ives Island (RM 143). Eggs were last collected in plankton nets on 6 July at RM 140.

The sampling site near Ives Island was used as an index area to monitor white sturgeon spawning during 1989 (Table 2). White sturgeon eggs were collected at this site on all sampling days from 27 April (when eggs were first collected) to 28 June (when eggs were last collected). The density of white sturgeon eggs at Ives Island was highest on 17 May (171.3 eggs/1,000 m^3). At Ives Island, stage 2 (freshly fertilized) eggs represented 71% of the total eggs collected in plankton nets and were collected on 7 of the 10 sampling days that eggs were collected at this location, indicating that spawning was occurring throughout the spring. Stage 2 eggs also represented at least 30% of the eggs from an individual sampling effort on 6 of the 10 sampling days. Stage 2 eggs were first collected on 27 April and last collected on 8 June (Table 3).

In areas downstream from Ives Island, only 14% of the total eggs collected were stage 2 eggs; also, stage 2 eggs were not as frequently collected in these areas as at Ives Island (Table 3). These data indicate that spawning intensity was much greater in the area near Ives Island. Most of the stage 2 eggs collected upstream from Ives Island were collected on artificial substrate placed just downstream from the spillways (RM 145); stage 2 eggs were collected near the spillways on 10, 11, and 24 May.

Table 1. Numbers of white sturgeon eggs and larvae collected in the Columbia River downstream from Bonneville Dam, 1989; 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 RM.

Sampling period	Eggs			Larvae	
	Area (RM)	Net	Substrate	Area (RM)	Net
30 Mar-27 Apr	143	385	47	143	0
1-17 May	139-145	892 (7)	37	108-144	51
22 May-1 Jun	139-145	121 (15)	215	113-143	41
7-21 Jun	138-145	616 (9)	6	113-143	35
28 Jun-6 Jul	140-143	4 (3)	0	140-143	8
19 Jul-17 Aug	143	0	0	143	0
TOTAL		2,018 (34)	305		135

Table 2. White sturgeon egg and larval catches near Ives Island (RM 143) in the Columbia River downstream from Bonneville Dam, 1989. 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			
30 Mar	7	-	-	5.36	0.0	0.0
18 Apr	10	1.9	1.5	6.56	0.0	0.0
27 Apr	12	2.2	1.5	6.84	127.9	0.0
1 May	12	2.0	1.7	6.77	17.2	0.0
10 May	13	2.4	-	8.25	39.0	0.9
17 May	14	2.3	1.6	7.96	171.3	2.6
24 May	14	2.2	1.4	6.68	8.5	0.3
1 Jun	14	2.2	1.6	6.93	8.8	6.7
8 Jun	16	2.6	2.0	7.48	87.9	1.9
15 Jun	17	2.2	1.5	5.91	0.3	1.8
21 Jun	17	1.9	1.0	4.77	0.4	0.0
28 Jun	18	1.6	1.1	4.00	0.9	3.2
6 Jul	19	1.6	1.0	4.06	0.0	0.0
19 Jul	20	1.0	0.6	2.58	0.0	0.0
31 Jul	20	1.5	1.3	3.14	0.0	0.0
17 Aug	20	1.0	0.6	2.69	0.0	0.0

Table 3. Numbers of white sturgeon eggs (by developmental stage) collected with plankton nets in three areas downstream from Bonneville Dam, 1989. Upstream and downstream areas were defined in relation to Ives Island.

Date (RM)	Egg developmental stage																	
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
UPSTREAM																		
10 May (144)	1	0	0	0	1	2	4	1	0	2	0	0	0	0	0	1	0	12
IVES ISLAND																		
27 Apr (143)	348	0	0	0	6	9	3	0	0	16	3	0	0	0	0	0	0	385
1 May (143)	17	1	1	0	6	0	2	4	2	1	7	4	1	6	1	1	0	54
10 May (143)	70	6	0	3	10	0	9	3	0	3	13	0	0	0	3	7	0	127
17 May (143)	525	16	0	14	16	0	0	0	0	0	0	0	0	0	14	14	0	599
24 May (143)	18	0	1	0	1	0	2	2	2	1	0	0	0	0	0	0	0	27
1 Jun (143)	1	0	0	1	1	0	0	0	0	0	0	1	1	0	2	5	4	16
8 Jun (143)	99	8	0	8	24	12	81	13	24	14	0	0	0	0	0	0	0	283
15 Jun (143)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
21 Jun (143)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Total	1,078	31	2	26	64	21	97	22	28	36	24	5	2	6	20	27	4	1,493[a]
DOWNSTREAM																		
1 May (139)	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2
1 May (140)	1	0	0	0	5	8	9	3	1	5	0	5	1	1	0	0	0	39
10 May (140)	14	2	0	1	0	0	3	3	1	1	6	6	2	0	1	0	0	40
17 May (139)	0	0	0	0	0	0	1	1	0	0	0	1	0	1	1	7	0	12
24 May (139)	0	0	0	0	2	0	0	0	0	2	0	0	0	0	1	0	0	5
24 May (140)	6	1	5	5	1	5	11	1	1	7	4	6	1	0	0	0	0	54
1 Jun (139)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	0	4
8 Jun (139)	2	3	0	1	2	2	2	0	0	0	0	2	0	0	0	1	0	15
8 Jun (140)	48	0	17	0	34	15	98	30	35	6	6	9	0	0	0	0	0	298
21 Jun (140)	0	0	0	1	0	0	0	1	0	0	0	2	1	1	2	0	0	8
21 Jun (142)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
6 Jul (140)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Total	71	6	22	8	44	30	124	39	40	21	16	32	6	3	7	10	0	479[b]

[a] *Does not include 18 eggs of unknown developmental stages.*
[b] *Does not include 16 eggs of unknown developmental stages.*

Based on back calculations using the developmental stages of eggs, we estimated spawning began on 22 April and ended on 2 July. During this period, spawning was estimated to have occurred on at least 43 days--9 days in late April, 23 days in May, 10 days in June, and 1 day in early July. During the spawning period, water temperatures (measured at Bonneville Dam) ranged from 12 to 18°C and Bonneville Dam discharge (mean hourly discharge by day) ranged from 3,348 to 8,872 m^3/s (Figure 2).

Results of linear regression analyses indicated the following relationships among egg (stage 2) densities at Ives Island (from 27 April to 28 June) and temperature, turbidity, mean water-column velocity, and Bonneville Dam discharge: 1) 36% of the variation in catch could be attributed to temperature, 2) 73% of the variation to turbidity, 3) 33% of the variation to mean column velocity, and 4) 54% of the variation to Bonneville Dam discharge. Using multiple regression, 90% of the variation in catch could be attributed to the combination of temperature, turbidity, and mean column velocity.

Artificial substrates placed downstream from the spillways at Bonneville Dam (at the lower boundary of the restricted zone) collected 256 white sturgeon eggs (five successful sampling efforts); whereas, artificial substrates placed downstream from the Second Powerhouse turbines collected no white sturgeon eggs. Water velocities were not measured at these sites; however, velocities appeared to be low 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. Artificial substrates were also placed downstream from the First Powerhouse, but only two eggs were collected on one occasion.

In 1989, a total of 135 white sturgeon larvae were collected in plankton nets between RMs 108 and 144 (Table 1). Larval sampling was also conducted downstream from RM 108; however, no larvae were collected in this area. Larvae were first collected on 8 May at RM 113 (I-205 Bridge), and the last larvae were captured on 28 June near Ives Island and RM 140. Overall, 66% of the larvae that were staged were classified as post hatch or stage 1 (Table 4). Densities of larvae near Ives Island ranged from 0.0 to 6.7 larvae/1,000 m^3 (Table 2).

The physical conditions under which eggs and larvae were collected were very similar. Bottom-water temperatures at sites where eggs were collected in plankton nets ranged from 12 to 18°C; bottom-water turbidities ranged from 3.3 to 10.0 NTU; mean water-column velocities ranged from 0.7 to 2.6 m/s; water velocities about 0.6 m above the bottom ranged from 0.5 to 2.0 m/s; and water depths ranged from 4.6 to 22.6 m. White sturgeon larvae were captured where bottom-water temperatures ranged from 13 to 18°C; bottom-water turbidities ranged from 3.3 to 9.2 NTU; mean water-column velocities ranged from 0.7 to 2.6 m/s; water velocities about 0.6 m above the bottom ranged from 0.5 to 2.0 m/s; and water depths ranged from 4.6 to 22.6 m.

No white sturgeon eggs or larvae were collected in the Willamette River at Oregon City on 25 May.

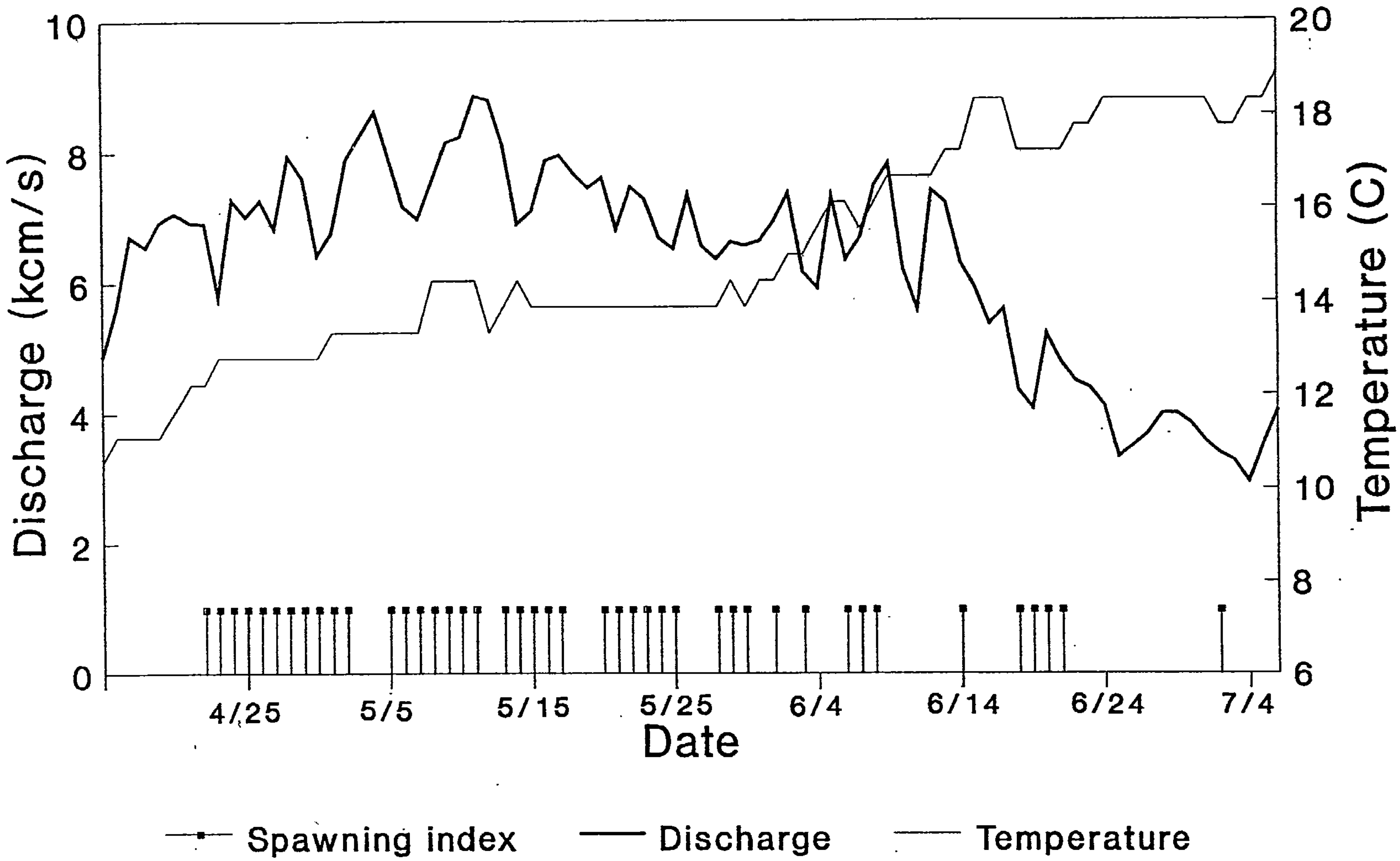

Figure 2. Water temperatures (°C) and Bonneville Dam discharges (mean hourly water discharges by day) from 15 April through 6 July 1989; discharge is shown as $m^3/s \times 1,000$. Water temperatures were measured at Bonneville Dam. The spawning index shows the days on which white sturgeon spawning was estimated to have occurred.

Table 4. Numbers of white sturgeon larvae (by stage) captured downstream from Bonneville Dam, 1989.

Date (RM)	Larval stage								
	Post hatch	1	2	3	4	5	6	7	Total
IVES ISLAND									
10 May (143)	2	1	0	0	0	0	0	0	3
17 May (143)	3	0	0	0	0	0	0	0	3
24 May (143)	0	1	0	0	0	0	0	0	1
1 Jun (143)	4	8	4	0	1	0	0	1	18
8 Jun (143)	1	0	0	2	2	1	0	0	6
15 Jun (143)	3	2	2	0	0	0	0	0	7
28 Jun (143)	0	6	1	0	0	0	0	0	7
Total	13	18	7	2	3	1	0	1	45[a]
OTHER LOCATIONS									
8 May (113)	1	1	1	0	0	0	0	0	3
9 May (108)	0	1	0	0	0	0	0	0	1
9 May (120)	2	2	0	0	0	0	0	0	4
10 May (139)	0	1	0	0	0	0	0	0	1
10 May (140)	1	1	2	0	0	0	0	0	4
10 May (144)	0	0	1	0	0	0	0	0	1
17 May (120)	2	2	0	0	0	0	0	0	4
17 May (139)	11	5	1	0	0	0	0	0	17
22 May (113)	0	0	0	0	0	0	0	1	1
24 May (120)	0	0	0	0	0	1	0	0	1
24 May (139)	1	0	0	2	0	0	0	0	3
24 May (140)	1	0	0	0	0	0	0	0	1
1 Jun (139)	4	5	2	0	0	1	0	0	12
8 Jun (120)	1	0	0	0	0	0	0	0	1
8 Jun (138)	0	0	0	1	0	0	1	0	2
8 Jun (139)	0	0	0	0	1	2	0	5	8
8 Jun (140)	0	0	0	1	0	1	0	0	2
15 Jun (139)	2	1	0	0	0	0	0	0	3
20 Jun (113)	1	0	0	0	0	0	0	0	1
21 Jun (120)	0	0	0	0	1	0	0	0	1
21 Jun (139)	0	0	0	0	0	0	0	2	2
21 Jun (142)	1	0	0	0	0	0	0	0	1
28 Jun (140)	0	1	0	0	0	0	0	0	1
Total	28	20	7	4	2	5	1	8	75[b]

[a] *Does not include 10 larvae of unknown stages.*
[b] *Does not include 5 larvae of unknown stages.*

Juvenile Sampling

Abundance and Distribution

In 1989, a total of 2,579 juvenile white sturgeon were collected with trawls in the Columbia River downstream from Bonneville Dam. Of this total, 2,558 were collected with the 7.9-m semiballoon shrimp trawl. Distribution of juvenile white sturgeon in the Columbia River downstream from Bonneville Dam was 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 3). Mean catches were highest at RM 95, Transect 1 (64 sturgeon/ha) and RM 131, Transect 2 (148 sturgeon/ha). The highest catch in 1989 was made at RM 132 on 23 October when 362 white sturgeon (2,458/ha) were collected in a 5-min trawling effort.

Size-Class Structure

The monthly size ranges of white sturgeon captured in 1989 were similar from March through June, prior to the appearance of Y-O-Y white sturgeon in July (Figure 4). 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.

Young-of-the-Year

In 1989, a total of 111 Y-O-Y white sturgeon were captured between RMs 29 and 101 (Table 5); Y-O-Y comprised 4% of the total catch of juvenile white sturgeon. The Y-O-Y were first collected on 7 July.

The Y-O-Y were collected during trawling efforts where the depths ranged from 4.0 to 37.5 m; mean minimum and maximum depths were 14.7 and 22.6 m, respectively. As indicated by the mean depths, Y-O-Y preferred deeper areas of the river. The bottom substrates over which Y-O-Y were found were predominantly sand.

White sturgeon Y-O-Y grew rapidly during the summer and fall; the mean fork length increased from 85 mm in July to 240 mm on 1 November. At times, there was considerable variation in the lengths and weights of Y-O-Y white sturgeon collected on the same day.

Species Associations

Juvenile white sturgeon were commonly captured with American shad *Alosa sapidissima*, juvenile chinook salmon *Oncorhynchus tshawytscha*, eulachon *Thaleichthys pacificus*, 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).

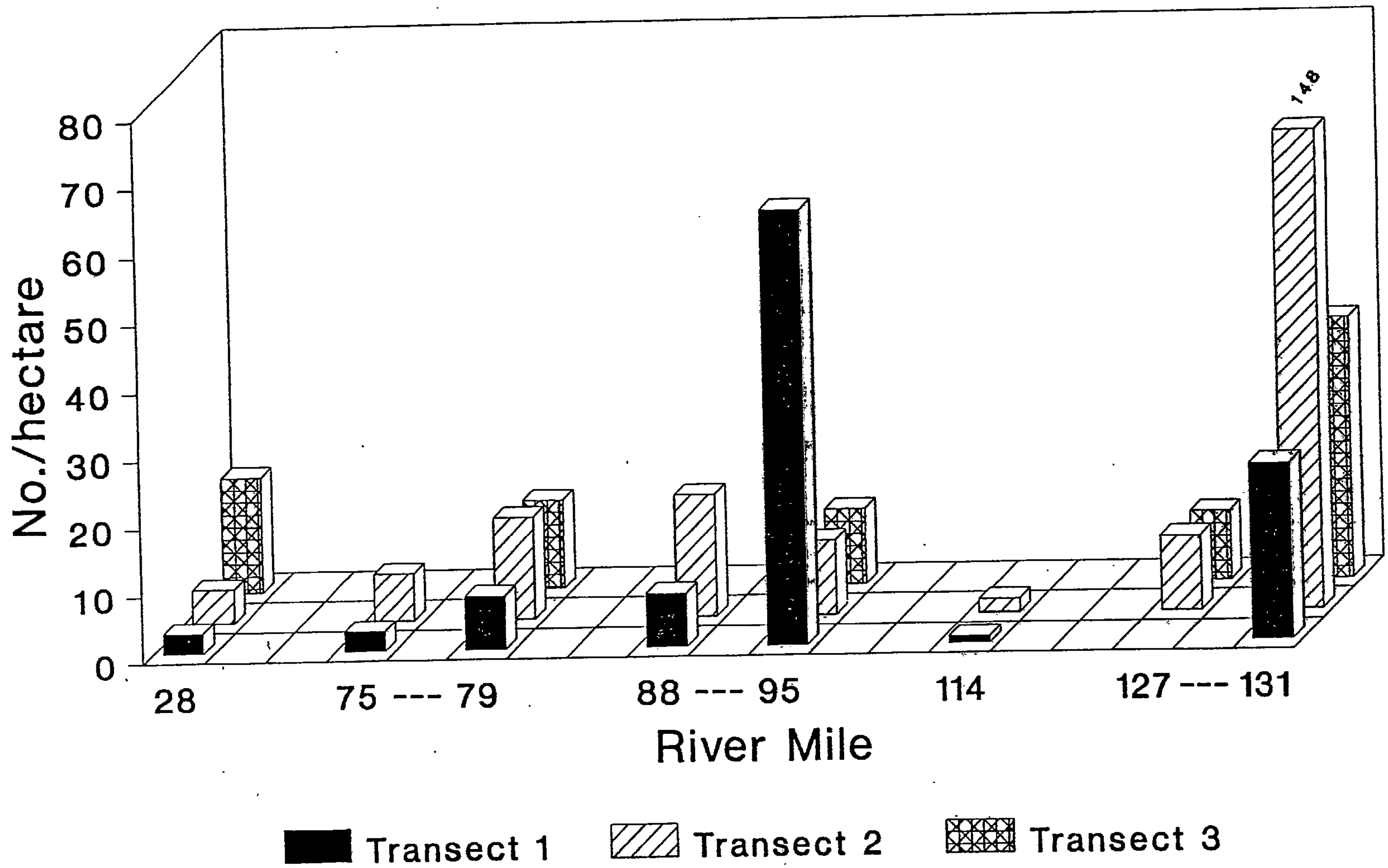

Figure 3. Estimated mean densities of juvenile white sturgeon at five index areas in the Columbia River downstream from Bonneville Dam, 1989.

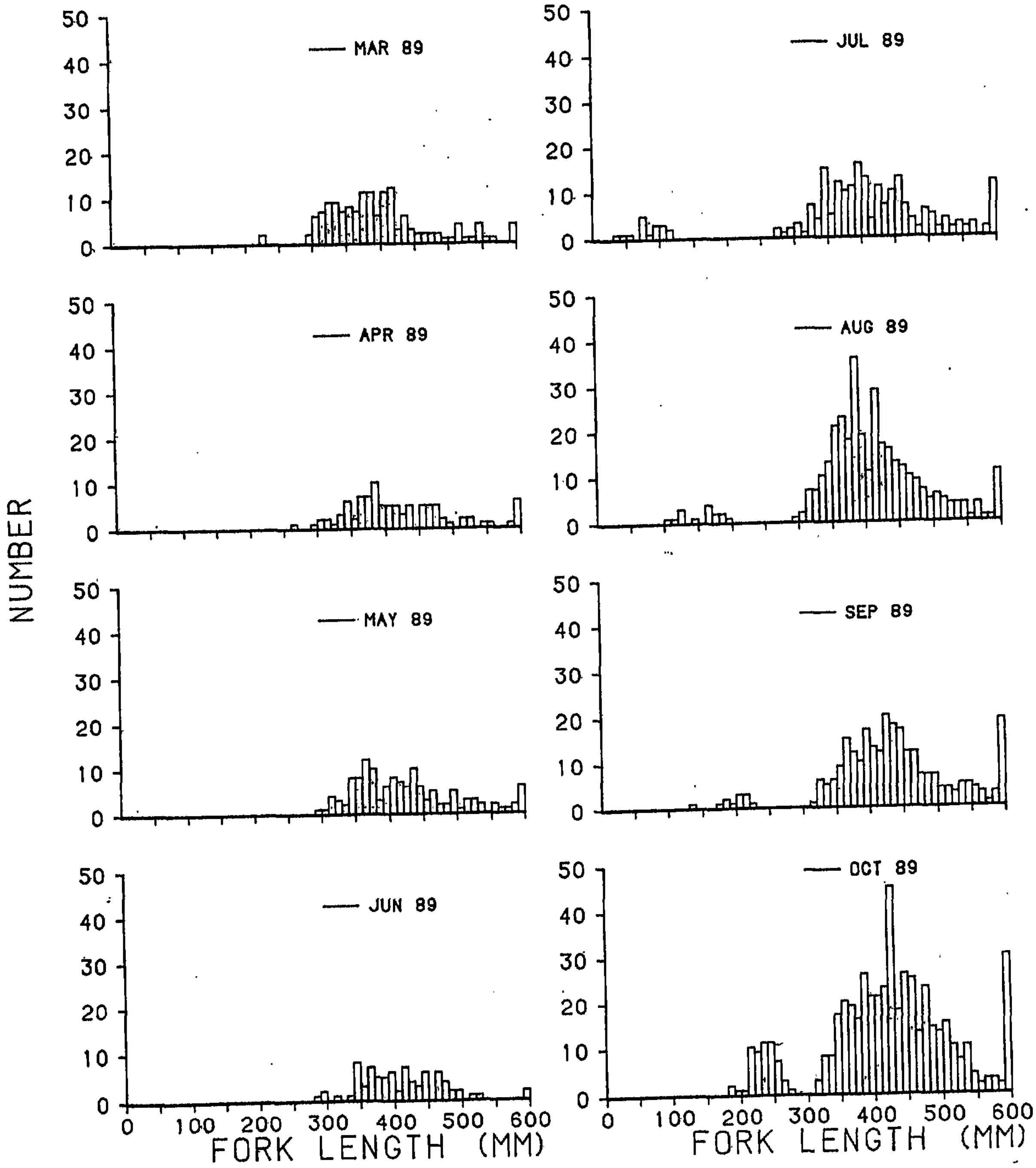

Figure 4. Length-frequency histograms for juvenile white sturgeon collected in the Columbia River downstream from Bonneville Dam, 1989. Sturgeon longer than 600 mm are included in the 600-mm interval.

Table 5. Summary of young-of-the-year white sturgeon catches in the Columbia River downstream from Bonneville Dam, 1989.

Month	Capture location (RM)	Number	Fork length (mm)		Weight (g)	
			Mean	SD	Mean	SD
Jul	30-95	17	84.6	±22.8	5.0	±3.1
Aug	30-95	15	154.9	±26.1	31.6	±13.5
Sep	29-95	12	197.5	±25.3	59.7	±18.7
Oct	30-101	56	233.6	±19.7	87.4	±18.5
Nov[a]	66-75	11	239.8	±13.9	90.5	±20.2

[a] *Sampling for November was conducted on 1 November.*

Tagging

A total of 1,675 juvenile white sturgeon were tagged in 1989. Twenty-four tagged sturgeon were recaptured in NMFS trawls (Table 6); 2 of the recaptures had been tagged by NMFS in 1987 and 10 had been tagged in 1988. All of the recaptures were made within a mile of where the fish were originally tagged. Sixteen of the tag recoveries were made at RM 131 to 132; recaptures from this area frequently showed negative growth.

Parasites

In 1989, a total of 1,822 juvenile white sturgeon were examined for the nematode parasite *Cystoopsis acipenseri*, and of this number, 24 (1%) were infected. The mean fork length of the infected fish was 337 mm, with a range from 294 to 405 mm; 23 of the infected fish were less than 400 mm long. The condition factor of infected fish was 0.6200 $\pm$ 0.0574, and the condition factor for non-infected sturgeon in the same length range was 0.6352 $\pm$ 0.0679.

Body Measurements and Condition Factor

The regression equation for the length-weight relationship of juvenile white sturgeon was $\log_{10}$weight, g = -5.14 + 2.98 ($\log_{10}$fork length, mm); N = 1,822; r^2 = 0.98. The mean condition factor of 1,822 juvenile white sturgeon was 0.6595 $\pm$ 0.0804.

Physical Conditions

Sampling for juvenile white sturgeon with the 7.9-m trawl was conducted in depths ranging from 2.7 to 37.5 m. There was a significant difference among sturgeon densities when grouped into three depth ranges (maximum depth): $\leq$9.0, 9.1 to 18.2, and $\geq$18.3 m (Kruskal-Wallis, $P < 0.01$). The mean density was highest at depths $\geq$18.3 m (83 $\pm$ 284 sturgeon/ha) and lowest at depths $\leq$9.0 m (9 $\pm$ 32 sturgeon/ha); at depths from 9.1 to 18.2 m, the mean density was 20 $\pm$ 51 sturgeon/ha. Bottom-water temperatures during juvenile white sturgeon sampling (7.9-m trawl samples) ranged from 6 to 21 °C.

Benthic Sampling

Benthic invertebrate densities varied temporally and spatially (Tables 7-11, Appendix D-2) in the Columbia River downstream from Bonneville Dam; eulachon eggs are included in the tables because of their importance in the diet of white sturgeon (see stomach contents analysis section). When large numbers of eulachon eggs occurred in samples, their numbers were estimated. Benthic invertebrate densities varied among areas and among transects within the same RM. Mean densities (area totals) for all areas, except RM 88-95, 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 were higher during Survey 2 than during Survey 1. Major invertebrate taxa collected during the surveys included Turbellaria, Oligochaeta, *Corbicula manilensis, Corophium salmonis,* Chironomidae larvae, and Heleidae larvae. The relationships between white sturgeon densities and densities of *Corbicula*

Table 6. Individual recoveries (in 1989) of juvenile white sturgeon tagged in the Columbia River downstream from Bonneville Dam, 1987-1989.

Location (RM)		Days at large	Change in fork length (mm)	Change in weight (g)
Tagged	Recaptured			
29	29	14	-2	5
95	95	28	0	-15
95	95	293	22	340
95	95	295	2	85
95	95	308	0	15
95	95	322	6	-54
95	95	336	15	52
95	95	693	63	67
131	131	11	1	-18
131	131	17	-2	-6
131	132	28	-9	-32
131	131	28	-5	-9
131	131	29	0	1
131	130	96	-2	-2
131	131	98	2	-1
131	132	109	4	15
131	131	124	-6	-23
131	132	152	11	28
131	131	284	0	-29
131	131	322	3	-40
131	131	334	0	-20
131	132	461	-7	-46
131	132	538	128	360
131	131	748	-1	-57

Table 7. Mean densities (number/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 in April 1989 and Survey 2 in September 1989. 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
28-1	Turbellaria	84	±	60	16	±	50
	Corbicula manilensis	40	±	50	72	±	65
	Corophium salmonis	12	±	17	1,505	±	2,020
	Heleidae larvae	106	±	54	332	±	264
	TOTAL	266	±	85	1,938	±	1,905
28-2	Turbellaria	52	±	59	0	±	0
	Corbicula manilensis	202	±	104	67	±	72
	Corophium salmonis	143	±	164	1,359	±	500
	Chironomidae larvae	36	±	28	2	±	4
	Heleidae larvae	642	±	289	299	±	177
	Invertebrate eggs	196	±	444	0	±	0
	Eulachon eggs	743	±	1,776	0	±	0
	TOTAL	2,046	±	1,855	1,743	±	514
28-3	*Neanthes limnicola*	62	±	34	103	±	77
	Oligochaeta	126	±	92	32	±	28
	Fluminicola spp.	689	±	773	151	±	157
	Corbicula manilensis	38	±	38	96	±	83
	Corophium spp.	0	±	0	15	±	25
	Corophium salmonis	604	±	321	3,272	±	1,232
	Chironomidae larvae	20	±	19	2	±	4
	Plecoptera	17	±	53	0	±	0
	TOTAL	1,572	±	1,117	3,677	±	1,337
	AREA TOTAL[a]	1,295	±	1,430	2,453	±	1,595

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

Table 8. Mean densities (number/m²) and standard deviations (SD) of major taxa collected during two benthic invertebrate surveys in the Columbia River downstream from Bonneville Dam (RM 75 to 79); Survey 1 was in April 1989 and Survey 2 in September 1989. 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	43	±	51	2	±	4
	Oligochaeta	56	±	61	61	±	68
	Corbicula manilensis	48	±	44	100	±	99
	Corophium salmonis	2	±	4	49	±	50
	Chironomidae larvae	14	±	10	0	±	0
	Heleidae larvae	489	±	312	326	±	328
	TOTAL	663	±	342	550	±	409
75-2	*Corbicula manilensis*	21	±	37	303	±	292
	Corophium salmonis	7	±	10	40	±	62
	Heleidae larvae	99	±	92	401	±	246
	TOTAL	148	±	118	760	±	414
79-1	Turbellaria	91	±	97	30	±	41
	Oligochaeta	238	±	471	464	±	386
	Corbicula manilensis	18	±	15	392	±	461
	Corophium salmonis	2	±	4	79	±	141
	Heleidae larvae	546	±	658	322	±	188
	TOTAL	902	±	837	1,295	±	773
79-2	*Corbicula manilensis*	26	±	29	366	±	398
	Corophium salmonis	1	±	3	41	±	21
	Heleidae larvae	219	±	198	341	±	263
	TOTAL	262	±	216	781	±	453
79-3	*Corbicula manilensis*	6	±	7	332	±	377
	Corophium salmonis	1	±	3	756	±	285
	Heleidae larvae	49	±	38	37	±	26
	TOTAL	68	±	38	1,146	±	619
	AREA TOTAL[a]	409	±	516	906	±	596

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

Table 9. Mean densities (number/m²) and standard deviations (SD) of major taxa collected during two benthic invertebrate surveys in the Columbia River downstream from Bonneville Dam (RM 88 to 95); Survey 1 was in April 1989 and Survey 2 in September 1989. 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
88-1	Oligochaeta	27	±	22	16	±	29
	Corbicula manilensis	14	±	21	105	±	77
	Corophium salmonis	62	±	137	1,059	±	493
	Heleidae larvae	100	±	107	63	±	40
	TOTAL	206	±	205	1,265	±	534
88-2	*Corbicula manilensis*	72	±	69	103	±	52
	Corophium salmonis	5	±	7	391	±	540
	Corophium spinicorne	0	±	0	54	±	86
	Heleidae larvae	275	±	338	47	±	59
	TOTAL	372	±	367	637	±	484
95-1	Oligochaeta	751	±	920	670	±	516
	Corbicula manilensis	699	±	848	174	±	213
	Corophium salmonis	33	±	49	41	±	27
	Heleidae larvae	271	±	285	88	±	126
	Eulachon eggs	7,359	±	16,331	0	±	0
	TOTAL	9,126	±	15,751	983	±	741
95-2	*Corbicula manilensis*	104	±	108	183	±	271
	Corophium salmonis	19	±	20	13	±	13
	Heleidae larvae	171	±	182	383	±	207
	TOTAL	308	±	232	635	±	400
95-3	Oligochaeta	22	±	18	12	±	13
	Corbicula manilensis	98	±	81	116	±	126
	Corophium salmonis	134	±	112	1,177	±	930
	Heleidae larvae	337	±	310	180	±	228
	TOTAL	600	±	330	1,518	±	709
	AREA TOTAL[a]	2,122	±	7,626	1,015	±	665

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

Table 10. Mean densities (number/m²) 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 in April 1989 and Survey 2 in September 1989. 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	Turbellaria	14	±	19	6	±	13
	Oligochaeta	2	±	4	15	±	20
	Corbicula manilensis	156	±	169	102	±	128
	Corophium salmonis	3	±	7	14	±	28
	Chironomidae larvae	43	±	38	2	±	4
	Heleidae larvae	275	±	155	256	±	139
	TOTAL	501	±	257	401	±	190
114-2	*Corbicula manilensis*	48	±	34	36	±	23
	Chironomidae larvae	4	±	5	14	±	36
	Heleidae larvae	155	±	158	408	±	269
	TOTAL	219	±	170	470	±	280
	AREA TOTAL[a]	360	±	256	436	±	235

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

Table 11. Mean densities (number/m²) and standard deviations (SD) of major taxa collected during two benthic invertebrate surveys in the Columbia River downstream from Bonneville Dam (RM 127 to 131); Survey 1 was in April 1989 and Survey 2 in September 1989. 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	*Corophium salmonis*	20	±	19	10	±	9
	Chironomidae larvae	3	±	5	64	±	67
	Heleidae larvae	24	±	17	315	±	175
	TOTAL	59	±	37	434	±	235
127-3	Oligochaeta	290	±	433	443	±	644
	Corbicula manilensis	35	±	56	648	±	998
	Heleidae larvae	343	±	341	506	±	278
	TOTAL	682	±	720	1,638	±	1,365
131-1	Oligochaeta	6	±	11	168	±	111
	Corbicula manilensis	68	±	55	302	±	233
	Corophium salmonis	5	±	7	80	±	93
	Heleidae larvae	105	±	67	392	±	216
	TOTAL	194	±	79	974	±	398
131-2	Oligochaeta	15	±	17	19	±	33
	Corbicula manilensis	52	±	44	26	±	22
	Corophium salmonis	54	±	30	198	±	185
	Chironomidae larvae	22	±	13	35	±	27
	Heleidae larvae	108	±	107	88	±	110
	TOTAL	252	±	153	374	±	150
131-3	Oligochaeta	1,078	±	1,081	261	±	124
	Corbicula manilensis	120	±	53	34	±	56
	Ostracoda	8	±	13	47	±	68
	Corophium salmonis	766	±	270	205	±	188
	Chironomidae larvae	89	±	67	71	±	59
	TOTAL	2,137	±	1,090	643	±	253
	AREA TOTAL[a]	665	±	957	812	±	785

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

manilensis and *Corophium salmonis*, two important prey items for juvenile sturgeon, were poor (Table 12). Results of linear regression indicated that less than 3% of the variation in sturgeon densities was explained by *Corbicula manilensis* densities; less than 12% of the variation was explained by *Corophium salmonis* densities. Results from multiple regression showed that no more than 12% of the variation in sturgeon densities was explained by using both *Corbicula manilensis* and *Corophium salmonis* densities as predictors.

Results from the sediment analysis indicated that the substrate in most of the sampling areas consisted primarily of sand (Table 13, Appendix D-3), although gravel and fines were present in relatively high proportions at some stations. The substrate along some of the individual transects varied as indicated by the ranges shown in Table 13, and at some transects the substrate varied from Survey 1 to Survey 2. With the exception of one station, total organic carbon associated with sediment at the stations was $\leq$2%. There was no apparent relationship between white sturgeon densities and sediment structure.

Stomach Contents Analysis

A total of 292 stomachs were taken from white sturgeon collected in two areas of the lower Columbia River (RMs 95 and 131) in 1988; however, analysis of the stomachs was not completed until 1989. Overall, the amphipod *Corophium salmonis* was the most important identifiable prey item at both RMs 95 and 131 (Table 14). During all three time periods in both areas, percent Index of Relative Importance (IRI) was higher for *Corophium salmonis* for Size Class I sturgeon ($\leq$350 mm fork length) than for Size Class II sturgeon (351 to 725 mm fork length), indicating that Size Class I sturgeon were preying more heavily on *Corophium salmonis* than were Size Class II sturgeon. The temporal importance of *Corophium salmonis* for Size Class I sturgeon at RM 95 remained relatively consistent, ranging from 75 to 82 %IRI during the three periods; whereas, at RM 131, the temporal importance of *Corophium salmonis* varied, ranging from 44 to 75 %IRI.

Size Class II sturgeon preyed heavily on *Corophium salmonis*, but they also preyed heavily on the bivalve *Corbicula manilensis*, Chironomidae larvae, and eulachon eggs at times. At both RMs 95 and 131, sturgeon fed on eulachon eggs only in May. At RM 95, the temporal importance of *Corophium salmonis* for Size Class II ranged from 38 %IRI in July-August to 51 %IRI in September-October. Also, eulachon eggs (12 %IRI) and *Corbicula manilensis* (11 %IRI) were important in May-June and *Corbicula manilensis* (19 %IRI) and *Corophium spinicorne* (7 %IRI) were important in July-August. At RM 131, the temporal importance of *Corophium salmonis* for Size Class II ranged from 12 %IRI in May-June to 24 %IRI in both July-August and September-October. Other important prey for Size Class II at RM 131 included eulachon eggs (51 %IRI) and *Corbicula manilensis* (20 %IRI) in May-June, *Corbicula manilensis* (35 %IRI) in July-August, and chironomids (22 %IRI) in September-October.

Other results from the stomach analysis indicated that food may be limited for juvenile sturgeon at RMs 95 and 131 in September-October. At RM 95, Index of Feeding (IF) for both size classes of sturgeon was significantly lower (Mann-Whitney test, $P < 0.05$) in September-October than in either May-June or July-August, indicating reduced in September-October; at RM 131, IF for Size Class II sturgeon was significantly lower in September-October than in either May-June or July-August (Table 15). The number of

Table 12. Summary of white sturgeon densities (number/ha) and benthic invertebrate densities (number/m²) at five index areas in the Columbia River downstream from Bonneville Dam. Densities are shown for the invertebrates *Corbicula manilensis* (Cm) and *Corophium salmonis* (Cs), which are important prey for juvenile sturgeon. Benthic sampling for Survey 1 was from 10-14 April and sampling for Survey 2 was from 11-15 September. White sturgeon sampling for Survey 1 was from 27-29 March and sampling for Survey 2 was from 28 August-1 September.

RM-transect	Survey 1			Survey 2		
	Sturgeon density	Invertebrate density		Sturgeon density	Invertebrate density	
		Cm	Cs		Cm	Cs
28-1	0	40	12	5	72	1,505
28-2	36	202	143	20	67	1,359
28-3	0	38	604	17	96	3,272
75-1	14	48	2	10	100	49
75-2	10	21	7	10	303	40
79-1	0	18	2	0	392	79
79-2	17	26	1	20	366	41
79-3	9	6	1	-	332	756
88-1	54	14	62	21	105	1,059
88-2	7	72	5	25	103	391
95-1	29	699	33	106	174	41
95-2	8	104	19	46	183	13
95-3	27	98	134	13	116	1,177
114-1	7	156	3	0	102	14
114-2	12	48	7	0	36	5
127-2	36	2	20	5	32	10
127-3	6	35	9	5	648	18
131-1	24	68	5	35	302	80
131-2	218	52	54	94	26	198
131-3	274	120	766	12	34	205

Table 13. Summary of sediment characteristics at five sampling areas (juvenile white sturgeon) in the Columbia River downstream from Bonneville Dam, 1989; two samples were collected at different points along each transect. Sediment values are percentages of total.

RM-trans.	Survey 1 (April)				Survey 2 (September)			
	Gravel[a]	Sand[b]	Fines[c]	Org.[d]	Gravel	Sand	Fines	Org.
28-1	2	97-98	<1	<1	<1-4	96->99	<1	1
28-2	<1-1	99	<1	<1-1	1-2	97-99	<1	1
28-3	0	92-97	<1-8	1-2	0	91-99	1-9	1-2
75-1	3-13	87-97	<1	1	4-11	89-96	<1	1
75-2	<1	>99	0-<1	<1-1	1-13	87-99	<1	1
79-1	2-18	82-98	0-<1	<1-1	12-17	83-88	<1	<1-1
79-2	1-6	94-99	0-<1	<1-1	2	98	0-<1	1
79-3	<1	>99	0-<1	<1-1	<1-1	98->99	<1	1
88-1	0	>99	<1	1	0-<1	>99	<1	1
88-2	<1-1	99->99	0-<1	1	0-<1	10-99	<1-90	1
95-1	6	94	0	1	2-12	88-98	<1	1
95-2	<1-1	99->99	0-<1	1	<1-1	99->99	0-<1	1
95-3	<1	>99	0-<1	1	0-3	96->99	<1-1	1
114-1	5-8	92-95	0-<1	1	2-19	81-98	<1	1
114-2	1	99	0-<1	<1-1	<1-1	98->99	<1	1
127-2	0-<1	>99	<1	<1-1	0	>99	<1	<1
127-3	12-35	65-88	<1	1	12-55	45-88	0-<1	1
131-1	6	94	0-<1	1	7-17	83-93	0-<1	1-5
131-2	0	>99	<1	<1-1	0-9	88->99	<1-3	1
131-3	0	97-98	2-3	2	<1	97-98	2-3	1-2

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

Table 14. Summary of white sturgeon diet studies from May through October 1988; numbers shown in the table are percents of total Index of Relative Importance (%IRI). Data are presented for two size-classes--Size Class I (≤350 mm fork length) and Size Class II (351-725 mm fork length)-- in two areas of the Columbia River, RMs 95 and 131. Only prey items with %IRI values greater than 1 (for at least one size-class and season) are shown.

RIVER MILE 95

Food category	May-Jun		Jul-Aug		Sep-Oct	
	Size I	Size II	Size I	Size II	Size I	Size II
Corbicula manilensis	<1	11	<1	19	0	3
Neomysis mercedis	0	0	4	<1	<1	<1
Corophium salmonis	82	40	75	38	75	51
Corophium spinicorne	3	2	4	7	5	3
Heleidae larvae	<1	<1	3	3	<1	<1
Eulachon eggs	2	12	0	0	0	0
Digested material	11	34	13	32	21	41

RIVER MILE 131

Food category	May-Jun		Jul-Aug		Sep-Oct	
	Size I	Size II	Size I	Size II	Size I	Size II
Corbicula manilensis	<1	20	<1	35	<1	<1
Neomysis sp.	0	0	<1	0	20	2
Neomysis mercedis	0	0	<1	<1	<1	1
Corophium salmonis	59	12	75	24	44	24
Corophium spinicorne	<1	<1	1	<1	<1	<1
Hemiptera	0	0	0	<1	<1	1
Chironomidae larvae	0	<1	4	2	11	18
Chironomidae pupae	<1	0	0	<1	<1	4
Heleidae larvae	<1	<1	2	1	0	0
Eulachon eggs	25	51	0	0	0	0
Fish (unidentified)	0	3	0	0	0	0
Digested material	16	13	17	35	23	49

Table 15. Comparisons of Index of Feeding (IF) for two size-classes of juvenile white sturgeon collected at RMs 95 and 131 in the Columbia River downstream from Bonneville Dam, 1988. Size Class I sturgeon were ≤350 mm fork length and Size Class II sturgeon were 351-725 mm fork length. Mean IF was calculated using only stomachs that contained food. The total number of stomachs collected and the number of empty stomachs are shown for each class.

RIVER MILE 95

Size Class	Time period: May-Jun	Jul-Aug	Sep-Oct
Size I			
a) mean IF	0.39	0.44	0.22[a]
b) total number	26	24	20
c) number empty	0	0	3
Size II			
a) mean IF	0.27	0.35	0.08[a]
b) total number	25	25	24
c) number empty	1	0	10

RIVER MILE 131

Size Class	Time period: May-Jun	Jul-Aug	Sep-Oct
Size I			
a) mean IF	0.31	0.23	0.20
b) total number	27	25	24
c) number empty	2	0	6
Size II			
a) mean IF	0.38	0.41	0.03[a]
b) total number	23	25	24
c) number empty	2	0	17

[a] *Mean IF for Sep-Oct was significantly less than IF for both May-Jun and Jul-Aug; Mann-Whitney test, P <0.05.*

empty stomachs for both size classes in both areas was highest in September-October, indicating reduced feeding.

DISCUSSION

Egg and Larval Sampling

Catches of white sturgeon eggs in 1989 (n = 2,323) were considerably higher than catches in 1988 (n = 1,404; McCabe et al. 1989). The mean catch of white sturgeon eggs in plankton nets near Ives Island (RM 143) between 25 April and 20 June 1988 was 10.2 eggs/1,000 m^3, but between 27 April and 28 June 1989, the mean catch was 46.2 eggs/1,000 m^3. In 1989, white sturgeon eggs were collected over a slightly wider range than in 1988. Eggs in 1988 were collected between RMs 140 and 145, whereas in 1989, eggs were collected between RMs 138 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).

The eggs collected just downstream from the spillways and First Powerhouse at Bonneville Dam were probably released by sturgeon spawning near the downstream section of the dam, and not by sturgeon spawning in the Bonneville Pool. The FWS sampled intensively in the Bonneville Pool in 1989 and collected sturgeon eggs between RMs 189.9 and 191.5 (Michael Parsley, FWS, Cook, Washington, personal communication); Bonneville Dam is at RM 145.6.

A total of 135 white sturgeon larvae were collected in 1989, compared to 90 collected in 1988 (McCabe et al. 1989). From 25 April to 20 June 1988, the mean catch of larvae near Ives Island was 0.5 larvae/1,000 m^3, but from 27 April to 28 June 1989, the mean catch of larvae near Ives Island was 1.7 larvae/1,000 m^3. The downstream distribution of white sturgeon larvae in 1989 was similar to the distributions in 1987 and 1988, with at least one larva being collected more than 30 miles downstream from Bonneville Dam. In 1989, a larva was collected at RM 108, which is 5 miles farther downstream than any location at which larvae were collected in 1987 and 1988. River flows in spring 1989 were higher than flows in spring 1987 and 1988.

In 1989, white sturgeon eggs and larvae were collected during the same general time period as in 1987 (McCabe and McConnell 1988), 1988, and past WDF studies. Based on sampling in 1989 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; McCabe et al. 1989).

White sturgeon spawning in 1989 was estimated to have occurred during a period when water temperatures (measured at Bonneville Dam) ranged from 12 to 18°C. Based on larval collections of white or green sturgeon *Acipenser medirostris*, Kohlhorst (1976) estimated sturgeon in the Sacramento River spawn at water temperatures ranging from 7.8 to 17.8°C, with peak spawning at 14.4°C.

It is not known precisely where the larvae collected downstream from Bonneville Dam originated, but assuming that sturgeon spawn over a rock or cobble 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; there was an inverse relationship between water velocity and the amount of time larvae spent in the water column.

Size-Class Structure

Juvenile white sturgeon collected in the Columbia River downstream from Bonneville Dam showed considerable overlap in lengths among 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 those 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 1989 will be presented in FWS's annual report.

Young-of-the-Year

Catches of Y-O-Y white sturgeon in 1989 (n = 111) were considerably higher than catches in both 1987 (n = 49; McCabe and McConnell 1988) and 1988 (n = 11; McCabe et al. 1989). Possible reasons for the higher catches in 1989 include increased sampling in selected deeper areas of the river or better recruitment to the Y-O-Y stage.

Based on Y-O-Y collections in 1989, it would appear that river currents dispersed white sturgeon larvae farther downstream than indicated by larval collections in plankton nets. All Y-O-Y collected in 1989 were captured downstream from the mouth of the Willamette River (RM 101); Y-O-Y white sturgeon were routinely collected in the upper Columbia River estuary (RM 31) beginning in early July. We assume that Y-O-Y, particularly the smaller ones, were carried by river currents as larvae to the general area where we subsequently captured them as Y-O-Y.

Tagging

Recoveries of tagged sturgeon indicated negative or poor growth in many instances, particularly for fish recovered at RM 131; similar results were noted in 1988 (McCabe et al. 1989). It is possible that the tag affected growth. However, the only accurate way to determine if this was the case would be a laboratory experiment comparing the growth rates of tagged and untagged sturgeon. On the other hand, it is possible that juvenile sturgeon in at least certain areas of the Columbia River downstream from Bonneville Dam grow quite slowly. These observations of slow growth are consistent with results from the benthic invertebrate analysis, stomach contents analysis, and age determinations done by FWS. The FWS noted that juvenile white sturgeon collected downstream from Bonneville Dam grew slower than juvenile sturgeon collected in the impoundments between Bonneville and John Day dams (Parsley et al. 1989).

Stomach Contents Analysis and Benthic Invertebrates

For May-October 1988, juvenile white sturgeon at RMs 95 and 131 fed on organisms associated with the benthos. *Corophium salmonis* was an extremely important prey item at both RMs 95 and 131, yet its densities were less than $450/m^2$ during the April 1988 benthic invertebrate survey (McCabe et al. 1989). For comparison, densities of *Corophium 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 1988, *Corophium salmonis* densities at RM 28 (upper estuary) were 1,194 and $7,503/m^2$ at two transects during the April benthic survey (McCabe et al. 1989). Considering the relatively low densities of *Corophium salmonis* in the benthos at RMs 95 and 131, it is possible that juvenile sturgeon are feeding on *Corophium salmonis* carried to them by the current or the sturgeon are moving to nearby areas with higher *Corophium salmonis* densities and feeding there. *Corophium* spp. have been observed in white sturgeon egg and larval samples collected with plankton nets fished along the bottom near Ives Island (RM 143). *Corophium volutator,* a related species, has been observed swimming above the bottom (Hughes 1988). If *Corophium salmonis* populations in freshwater sections of the lower Columbia River exhibit similar behavior, they would be dispersed by river currents. During the early part of the 1988 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. In May-June, 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 *Corophium 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 would be similar to the feeding habits observed at RMs 95 and 131. Muir et al. (1988) found that *Corophium salmonis* was the most important prey item for white sturgeon <800 mm (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 combined juvenile sturgeon and benthic invertebrate sampling in 1989 indicated that use of areas for rearing by juvenile white sturgeon could not be accurately predicted by benthic invertebrate densities. Based on 1988 and 1989 research, much of the river downstream from Bonneville Dam apparently could serve as rearing habitat for juvenile white sturgeon, although there are preferred areas.

Plans for 1990

Plans for 1990 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, which is conducting similar research in impoundments upstream from Bonneville Dam. As in previous years, physical measurements will be made in conjunction with the egg and larval sampling, to determine, among other relationships, the relationship between river flow and egg and larval catches.

Using biological and physical data collected in 1990, we will continue to examine the specific habitat preferences or requirements of juvenile white sturgeon. Bottom trawling will be done in various habitats downstream from Bonneville Dam, with much more emphasis on the area between RMs 28 and 75. Limited benthic sampling will be done at some sites.

In conjunction with FWS, we will begin quantifying spawning and rearing habitat available for white sturgeon in the Columbia River downstream from Bonneville Dam. Other activities planned for 1990 include continued tagging of juvenile white sturgeon and examination of juveniles for the nematode parasite *Cystoopsis acipenseri*.

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APPENDIX D-1

Summaries of individual trawling efforts for white sturgeon in the Columbia River downstream from Bonneville Dam, 1989 (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) conducted during April and September 1989 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) conducted during April and September 1989 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).