REPORT D

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

2. Evaluate growth, mortality, and contributions to fisheries of juvenile white sturgeon transplanted from areas downstream from The Dalles Dam to areas in The Dalles and John Day Reservoirs.

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CONTENTS

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Lawrence Davis, Roy Pettit, Dennis Umphfres, and Washington Department of Fish and Wildlife (WDFW) personnel assisted in the field sampling. The WDFW 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 1993, the National Marine Fisheries Service sampled white sturgeon *Acipenser transmontanus* eggs, larvae, and juveniles in the Columbia River downstream from Bonneville Dam (River Mile (RM) 145). In conjunction with the Washington Department of Fish and Wildlife, 3,048 white sturgeon eggs were collected with plankton nets and artificial substrates between RM 120 and 145. Viable white sturgeon eggs were collected first on 27 April, and last on 14 July. The sampling site near Ives Island (RM 143) was used as the primary index station to monitor white sturgeon spawning throughout the season. Between 27 April and 14 July, white sturgeon egg densities near Ives Island (in plankton nets) ranged from 0.0 to 274.1 eggs/1,000 m^3 of water sampled, with the highest density on 27 April. Based on egg collections, we estimated that white sturgeon spawned on at least 46 days in 1993, beginning on 26 April and ending on 13 July. Spawning was estimated to have occurred at Bonneville Dam discharges (mean hourly discharge by day) ranging from 3,962 to 11,139 m^3/s, and water temperatures ranging from 11 to 18°C. A total of 170 white sturgeon larvae was collected in plankton nets between RM 120 and 145. Larvae were first collected on 10 May, and last collected on 6 July. Densities of larvae near Ives Island ranged from 0.0 to 4.8 larvae/1,000 m^3.

In September 1993, 210 juvenile white sturgeon were collected with a 7.9-m (headrope length) semiballoon shrimp trawl between RM 28 and 132 in the Columbia River downstream from Bonneville Dam. Distributions of juvenile white 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. We collected 55 young-of-the-year (YOY) white sturgeon between RM 28 and 131; YOY comprised about 26% of the total catch of juvenile white sturgeon. Densities of YOY white sturgeon at 13 index sampling stations averaged 2.9 fish/hectare during the first survey (7-10 September) and 9.0 fish/hectare during the second survey (20-24 September); the mean for both surveys combined was 5.9 fish/hectare.

INTRODUCTION

Under an agreement with the Oregon Department of Fish and Wildlife (ODFW), the National Marine Fisheries Service (NMFS) is responsible for segments of two objectives of the White Sturgeon Study. The first objective is to describe reproductive and early life history characteristics of white sturgeon in McNary Reservoir and downstream from Bonneville Dam. The second objective is to evaluate growth, mortality, and contributions to fisheries of juvenile white sturgeon transplanted from areas downstream from The Dalles Dam to areas in The Dalles and John Day Reservoirs. The NMFS's research is conducted in the Columbia River downstream from Bonneville Dam. This lower reach of the river was used as a control area for Phase I of the White Sturgeon Study (1986-1992) and will be used in a similar manner for Phase II (1992-1997). Data collected in the control area will be used to determine the effects of the development and operation of the hydropower system and assess the effects of recommended flow and project operations on white sturgeon spawning and recruitment in the impoundments upstream from Bonneville Dam.

Specific research goals for 1993 were 1) to determine the timing of spawning in the Columbia River downstream from Bonneville Dam; 2) to estimate the effects of river flow, water velocity, and water temperature on white sturgeon spawning; 3) to estimate the success of young-of-the-year (YOY) white sturgeon recruitment in 1993; and 4) to collect juvenile white sturgeon in selected areas of the Columbia River downstream from Bonneville Dam for an ODFW evaluation on the feasibility of transporting juvenile white sturgeon from fully-seeded habitats (e.g., the river downstream from Bonneville Dam) to under-seeded habitats upstream from The Dalles Dam. This report describes progress on NMFS studies from March 1993 to March 1994.

METHODS

Egg and Larval Sampling

In 1993, NMFS and the Washington Department of Fish and Wildlife (WDFW) sampled for white sturgeon eggs and larvae in the Columbia River downstream from Bonneville Dam. Sampling began in April and ended in July; generally, sampling was conducted weekly. 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 eight lead weights (4.5 or 9.1 kg each) were attached to two corners of 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. Substrates were cut into 76 X 91-cm sections and secured to an angle iron frame. Two sections of artificial substrate were placed back to back in each frame.

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

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 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 or larval sampling was done at various stations in the lower Columbia River from River Mile (RM) 120 to 145 (Table 1, Figure 1). Four of the stations (RM 120, 139, 140, and 143) had been routinely occupied during Phase I of the White Sturgeon Study. Sampling stations at RM 122 and 145 were newly established in 1993. The sampling station near Ives Island (RM 143), which has been routinely sampled in past years by WDFW and NMFS, was considered the primary index station for monitoring white sturgeon spawning in the Columbia River downstream from Bonneville Dam.

White sturgeon eggs and larvae were fixed in an approximately 4% buffered formaldehyde solution and transferred to WDFW.

Juvenile Sampling

A 7.9-m (headrope length) semiballoon shrimp trawl, identical to that used from 1987 through 1991, was used to collect juvenile white sturgeon, including YOY. Mesh size in the trawl was 38 mm (stretched measure) in the body; a 10-mm mesh liner was inserted in the cod end of the net. Shrimp trawl efforts were 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. We estimated the distance the net fished during each sampling effort using a radar range-finder.

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

Fishes captured in the bottom trawls were identified and counted. All white sturgeon from each sampling effort were measured (total and fork lengths (mm)) and weighed (g). Small YOY sturgeon do not have a distinct fork in their tails; therefore we estimated the fork lengths of small YOY sturgeon (less than 150 mm fork length) to ensure consistency in data analysis. In previous years, all length comparisons of older juveniles were done using fork lengths, since natural total lengths are much less reliable. On older juvenile sturgeon (those with a fork in their tails), we observed that the distal end of an imaginary line, extended along the lateral row of scutes (before it turns upward) onto the caudal fin, approximated the location of the fork. We routinely examined juvenile white sturgeon for the nematode parasite *Cystoopsis acipenseri* (Chitwood and McIntosh 1950). When present, the parasite is encased in blister-like cysts under the skin.

Table 1. Numbers of sampling efforts for white sturgeon eggs, larvae, and young-of-the-year in the Columbia River downstream from Bonneville Dam, 1993. When two plankton nets were fished simultaneously, the data were combined and considered as one sampling effort. Location is shown in River Miles (RM).

Location	Apr	May	Jun	Jul	Aug	Sep	Total
Plankton net							
RM 120-122	3	7	10	6	0	0	26
RM 139-140	6	8	10	6	0	0	30
RM 143-145	6	8	10	6	0	0	30
Artificial substrate							
RM 143	2	5	10	6	0	0	23
RM 145	0	1	0	0	0	0	1
Shrimp trawl							
RM 28-60	0	0	0	0	0	22	22
RM 61-90	0	0	0	0	0	28	28
RM 91-120	0	0	0	0	0	15	15
RM 121-132	0	0	0	0	0	14	14

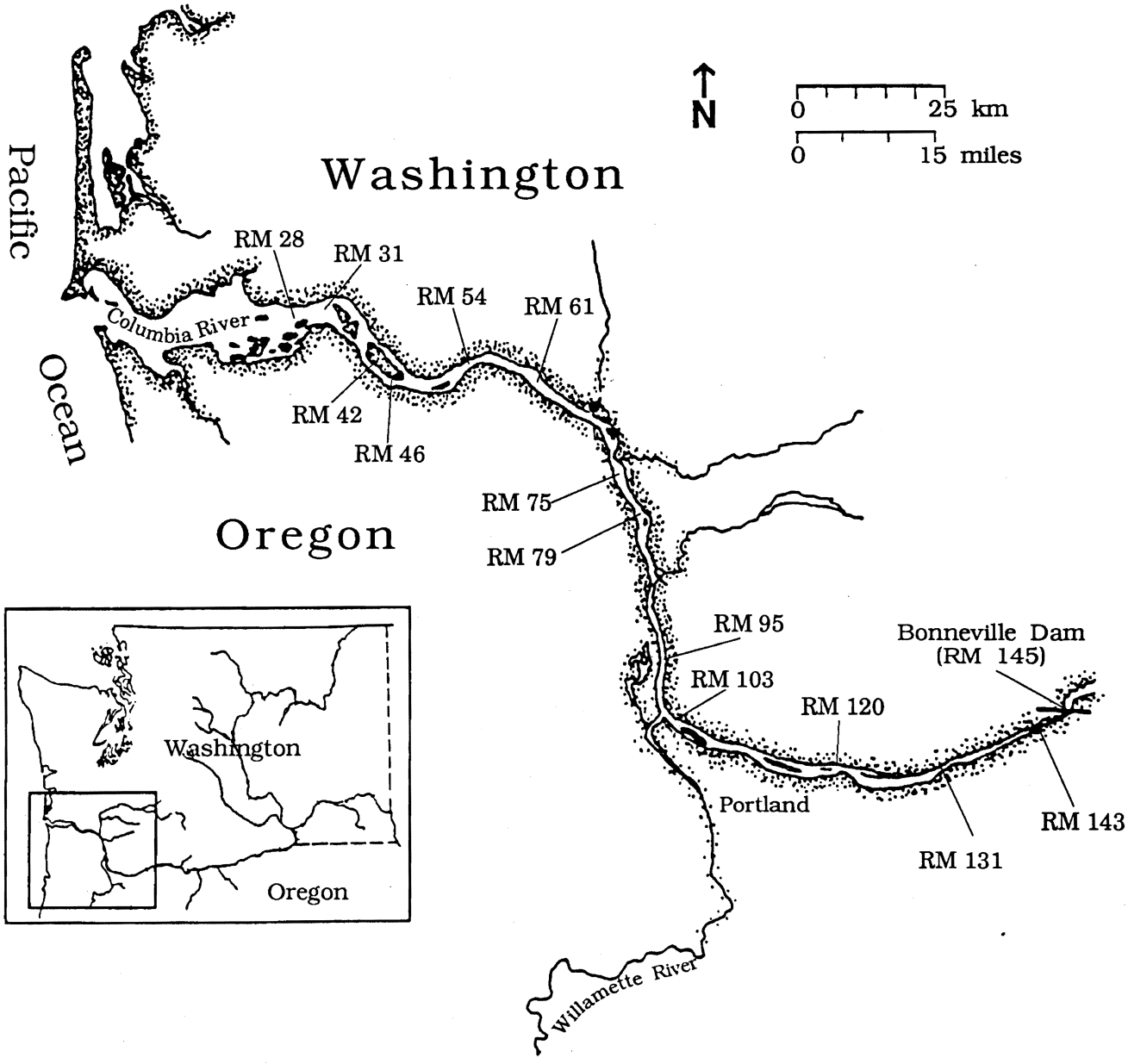

Figure 1. Location of white sturgeon study area in the Columbia River downstream from Bonneville Dam.

From 25 to 27 October, NMFS assisted ODFW in collecting juvenile white sturgeon between RM 131 and 132 with the 7.9-m shrimp trawl described above. The ODFW is evaluating the feasibility of collecting juvenile white sturgeon in the Columbia River downstream from Bonneville Dam and transporting them to impoundments upstream from The Dalles Dam (see Report A for further details and results of the ODFW study).

Physical Conditions

The following physical parameters were measured in conjunction with biological sampling: bottom 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 water velocities measured at 0.2 and 0.8 of the total depth, we calculated a mean water-column velocity (Buchanan and Somers 1969). Water velocities were measured only during egg and larval sampling. Depth was measured with electronic depth sounders, and velocity with a Price Type "AA" current meter attached to a 45.4-kg lead fish. A Van Dorn water bottle was used to collect water samples just above the bottom. The water temperature of each sample was measured immediately after collection, and a subsample of water was removed and placed in a glass bottle. The turbidity of the sample was determined in the laboratory using a Hach Model 2100A Turbidimeter.

Data Analyses

Physical and biological data collected during the field season were entered into computer files following formats agreed to by the four cooperating agencies involved in the White Sturgeon Study: the National Biological Survey (NBS), ODFW, NMFS, and WDFW.

Developmental stages of white sturgeon eggs and larvae were determined by WDFW, based on descriptions by Beer (1981). Timing of egg deposition was estimated using developmental stages of eggs and temperature-egg developmental data from Wang et al. (1985). Water temperature at the time of egg collection was used in making estimates of timing of egg deposition, and a daily index of spawning activity was calculated based on these estimated spawning dates. The index of spawning activity was treated as a dichotomous variable: spawning occurred or did not occur on a particular day. The WDFW'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.

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

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

RESULTS

Egg and Larval Sampling

In 1993, 3,048 white sturgeon eggs were collected between RM 120 and 145 (Table 2); 1,315 eggs were collected with plankton nets and 1,733 eggs were collected with artificial substrates. Viable white sturgeon eggs were first collected on 27 April at RM 140 and near Ives Island (RM 143) and were last collected on 14 July at RM 139, RM 140, and near Ives Island. In 1993, less than 1% of white sturgeon eggs collected in plankton nets were infected with fungus; fungus infection indicated infertile or dead eggs (Table 2).

The sampling station near Ives Island was used as the primary index station to monitor white sturgeon spawning during 1993 (Table 3). White sturgeon eggs were collected at this station on 10 of the 12 sampling days from 27 April to 14 July. The abundance (density) of white sturgeon eggs at Ives Island was highest on 27 April (274.1 eggs/1,000 m^3). At Ives Island, stage 2 (freshly fertilized) eggs represented 80% of the total eggs collected in plankton nets and were collected on 5 of the 10 sampling days when eggs were collected at this location (Table 4). Stage 2 eggs were first collected on 27 April and last collected on 25 May.

In areas downstream from Ives Island, only 8% of the total eggs collected in plankton nets were stage 2 eggs (Table 4). No stage 2 eggs were collected downstream from RM 139. A small number of stage 2 eggs was also collected in plankton nets upstream from Ives Island, representing 6% of the total eggs collected in plankton nets in this area. These data suggest that spawning intensity was greater in the area near or just upstream from Ives Island than in the other areas sampled.

Artificial substrates placed along Ives Island, just upstream from Ives Island, and about 600 m downstream from the spillways at Bonneville Dam (at the lower boundary of the restricted zone) collected white sturgeon eggs. Total egg collections using substrates at these stations were 1,239 eggs for Ives Island, 491 eggs for the site just upstream from Ives Island, and 3 for the site downstream from the spillways. Sampling effort was much less at the station downstream from the spillways than at the other two stations. Collection of white sturgeon eggs near the spillways indicated that the upper boundary of sturgeon spawning in the Columbia River downstream from Bonneville Dam is very close to the dam.

Based on back calculations using the developmental stages of eggs, we estimated spawning began on 26 April and ended on 13 July. During this period, spawning was estimated to have occurred on at least 46 days: 5 days in late April, 23 days in May, 14 days in June, and 4 days in July. Spawning was estimated to have occurred at water temperatures ranging from 11 to 18°C and Bonneville Dam discharges (mean hourly discharge by day) ranging from 3,962 to 11,139 m^3/s (Figure 2).

In 1993, 170 white sturgeon larvae were collected in plankton nets between RM 120 and 145 (Table 2). Larvae were first collected on 10 May at RM 139, 140, and Ives Island, and last collected on 6 July at RM 139 and 140. Overall, 61% of the larvae that were staged were classified as post hatch or stage 1 (Table 5). Densities of larvae near Ives Island ranged from 0.0 to 4.8 larvae/1,000 m^3 (Table 3).

Table 2. Numbers of white sturgeon eggs and larvae collected in the Columbia River downstream from Bonneville Dam, 1993; plankton nets and artificial substrates were used to collect eggs, and plankton nets were 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 River Miles (RM).

Sampling period	Eggs			Larvae	
	Area (RM)	Net	Substrate	Area (RM)	Net
13-30 Apr	140-143	349	73	-	0
1-15 May	120-145	247	789	120-143	15
16-31 May	139-145	457 (1)	167	122-145	7
1-15 Jun	120-145	226 (2)	649	120-145	118
16-30 Jun	139-145	24 (1)	29	139-145	27
1-15 Jul	139-143	11 (2)	26	139-140	3
16-27 Jul	140	1 (1)	0	-	0
TOTAL		1,315 (7)	1,733		170

Table 3. White sturgeon egg and larval catches near Ives Island (RM 143) in the Columbia River downstream from Bonneville Dam, 1993. Water temperatures were measured just above the bottom; Bonneville Dam flows were average hourly discharges (for each day). Generally, 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			
13 Apr	9	1.7	1.1	4.73	0.0	0.0
19 Apr	10	1.7	0.9	4.32	0.0	0.0
27 Apr	11	1.7	1.0	4.77	274.1	0.0
3 May	12	2.0	1.1	5.46	21.2	0.0
10 May	13	2.1	1.4	7.33	103.5	1.1
17 May	14	2.7	1.5	10.92	193.0	0.0
25 May	14	2.7	1.9	9.74	2.3	0.3
1 Jun	15	2.4	1.6	7.89	17.5	0.0
7 Jun	15	2.1	1.6	6.61	3.0	4.8
14 Jun	16	2.1	1.5	6.65	4.4	0.0
21 Jun	17	1.6	1.0	5.63	0.0	0.0
28 Jun	17	1.5	1.2	4.89	3.0	0.8
6 Jul	17	1.6	1.1	4.99	0.0	0.0
14 Jul	18	1.6	1.0	4.82	2.8	0.0
26 Jul	19	1.2	0.9	4.55	0.0	0.0

Table 4. Numbers of white sturgeon eggs (by developmental stage) collected with plankton nets in three areas downstream from Bonneville Dam, 1993. 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																		
17 May (145)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
25 May (145)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	9	0	11
1 Jun (145)	3	3	0	0	7	2	8	4	6	2	5	3	0	1	0	0	0	44
7 Jun (145)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4
14 Jun (145)	1	0	0	0	2	2	0	0	2	1	1	0	0	0	0	0	0	9
28 Jun (145)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Total	4	3	0	0	10	4	8	4	8	3	6	3	0	2	2	13	0	70 [a]
IVES ISLAND																		
27 Apr	328	0	0	0	9	9	0	0	0	0	0	0	0	0	0	0	0	346
3 May	28	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	31
10 May	176	0	0	0	0	0	0	0	0	0	0	0	0	0	6	3	0	185
17 May	265	0	0	0	0	38	38	0	0	0	0	19	0	0	0	19	0	379
25 May	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0	6
1 Jun	0	0	0	0	1	5	6	1	3	1	6	4	2	0	0	1	0	30
7 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4
14 Jun	0	0	0	1	1	3	0	1	0	0	1	0	0	0	0	0	0	7
28 Jun	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	0	0	4
14 Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3
Total	799	1	0	1	11	56	45	2	3	1	7	25	3	1	7	33	0	995 [b]
DOWNSTREAM																		
27 Apr (140)	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
3 May (139)	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	2
3 May (140)	1	0	0	0	0	0	1	1	1	0	2	6	2	1	1	0	0	16
10 May (140)	5	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0	0	9
11 May (120)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
17 May (139)	3	1	0	0	1	4	7	1	2	1	2	3	1	0	4	3	0	33
17 May (140)	0	0	0	0	4	5	1	0	1	1	1	3	0	2	3	2	0	23
1 Jun (140)	5	5	0	3	5	9	3	3	4	7	6	13	11	5	13	0	0	92
2 Jun (120)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
7 Jun (140)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
8 Jun (120)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
14 Jun (139)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
14 Jun (140)	4	0	0	0	1	2	1	1	4	1	3	7	2	1	0	0	0	27
28 Jun (139)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
28 Jun (140)	0	0	0	0	0	0	1	0	0	0	0	10	3	1	0	0	0	15
14 Jul (139)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
14 Jul (140)	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2	1	0	5
Total	18	9	1	3	11	20	15	6	12	10	17	45	21	12	24	8	0	232 [c]

[a] *Does not include 1 egg of unknown developmental stage.*
[b] *Does not include 5 eggs of unknown developmental stages.*
[c] *Does not include 12 eggs of unknown developmental stages.*

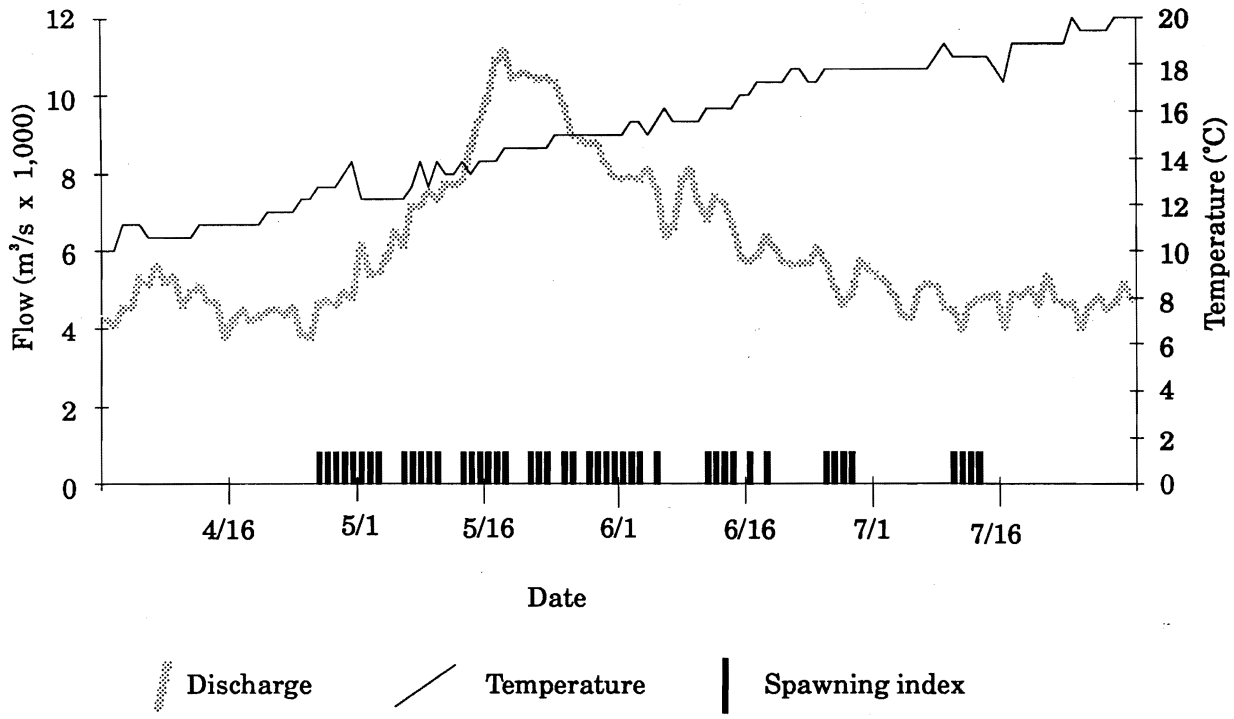

Figure 2. Water temperatures (°C) and Bonneville Dam discharges (mean hourly water discharges by day) from 1 April through 31 July 1993; discharge is shown as m^3/s x 1,000. Water temperatures were measured at Bonneville Dam. The spawning index shows the days on which we estimated that white sturgeon spawned.

Table 5. Numbers of white sturgeon larvae (by stage) collected with plankton nets downstream from Bonneville Dam, 1993.

Date (RM)	Larval stage								
	Post hatch	1	2	3	4	5	6	7	Total
IVES ISLAND									
10 May	1	1	0	0	0	0	0	0	2
25 May	1	0	0	0	0	0	0	0	1
7 Jun	3	4	1	0	0	0	0	0	8
28 Jun	0	0	0	0	0	0	0	1	1
Total	5	5	1	0	0	0	0	1	12
OTHER LOCATIONS									
10 May (139)	2	0	0	0	0	0	0	0	2
10 May (140)	4	3	0	0	0	0	0	0	7
11 May (120)	2	1	0	0	0	0	0	0	3
11 May (122)	0	1	0	0	0	0	0	0	1
17 May (139)	1	0	0	0	0	0	0	0	1
25 May (145)	4	0	0	0	0	0	0	0	4
26 May (122)	0	1	0	0	0	0	0	0	1
7 Jun (139)	1	6	2	0	0	0	0	0	9
7 Jun (140)	5	41	27	0	0	0	0	0	73
7 Jun (145)	1	3	2	0	0	0	0	0	6
8 Jun (120)	1	7	7	0	0	0	0	1	16
8 Jun (122)	0	2	2	0	0	0	0	0	4
14 Jun (140)	0	0	0	0	0	1	0	0	1
21 Jun (139)	0	0	0	2	0	0	0	0	2
21 Jun (140)	1	0	6	1	1	0	0	0	9
21 Jun (145)	0	6	7	0	0	0	0	0	13
28 Jun (139)	0	0	0	0	0	0	0	2	2
6 Jul (139)	0	0	0	0	0	0	0	1	1
6 Jul (140)	0	0	0	0	1	1	0	0	2
Total	22	71	53	3	2	2	0	4	157[a]

[a] *Does not include one larva of an unknown stage.*

Physical conditions under which eggs and larvae were collected were generally similar. Bottom-water temperatures at sites where eggs (not including a fungus-infected egg collected on 26 July) were collected in plankton nets ranged from 11 to 18°C. Bottom-water turbidities at these sites ranged from 2.7 to 13.0 NTU, and mean water-column velocities ranged from 1.0 to 2.7 m/s. Water velocities about 0.6 m above the bottom ranged from 0.7 to 2.4 m/s, and depths ranged from 3.4 to 21.9 m. White sturgeon larvae were captured where bottom-water temperatures ranged from 12 to 17°C, bottom-water turbidities ranged from 2.7 to 13.0 NTU, and mean water-column velocities ranged from 1.0 to 2.7 m/s. Water velocities about 0.6 m above the bottom ranged from 0.7 to 1.9 m/s, and depths ranged from 3.4 to 21.9 m.

Juvenile Sampling

In September 1993, 210 juvenile white sturgeon were collected in 79 trawling efforts between RM 28 and 132. Distribution of juvenile white sturgeon in this section of the river was patchy. There were differences in catches among different areas of the river and among parallel transects at the same river mile.

The YOY group was the only age group that was easily discernible in a length-frequency histogram, as there was considerable overlap in the lengths of the older age groups (Figure 3). The mean fork length ($\pm$ SD) and weight ($\pm$ SD) of 55 YOY white sturgeon collected were 182 mm ($\pm$ 27 mm) and 47 g ($\pm$ 18 g). Variations in the lengths and weights of YOY were considerable--lengths ranged from 87 to 223 mm and weights ranged from 5 to 90 g. At times, there was considerable variation in the lengths and weights of YOY collected on the same day.

In 1993, 55 YOY white sturgeon were collected between RM 28 and 131; YOY comprised about 26% of the total catch of juvenile white sturgeon. Densities of YOY white sturgeon at 13 index sampling stations averaged 2.9 fish/hectare during the first survey (7-10 September) and 9.0 fish/hectare during the second survey (20-24 September); the mean for both surveys combined was 5.9 fish/hectare (Table 6, Figure 1).

Only 23 (11.9%) of 193 juvenile white sturgeon were infected with the nematode parasite *Cystoopsis acipenseri*. The mean fork length of infected fish was 373 mm, with a range from 313 to 451 mm.

Publication Status of Phase I Manuscripts

Five manuscripts that were prepared as part of the Phase I work in the two-volume 1993 final report have been published or accepted for publication in professional journals (Table 7).

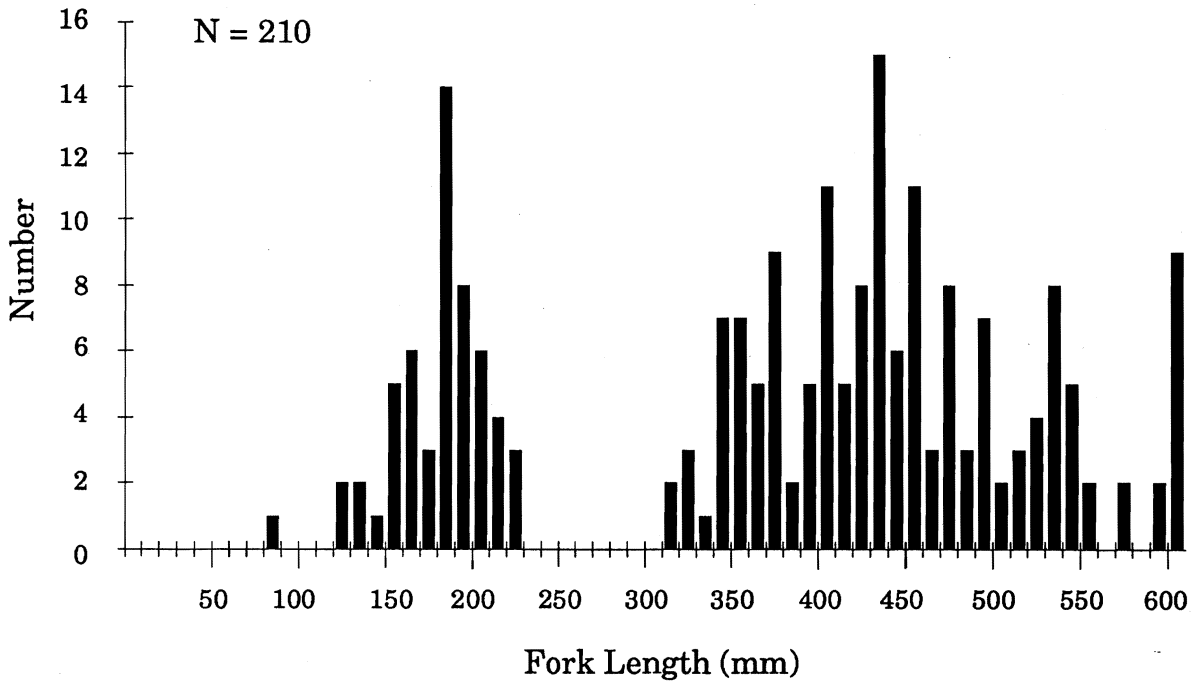

Figure 3. Length-frequency histogram for juvenile white sturgeon collected in the Columbia River downstream from Bonneville Dam, 1993. Sturgeon longer than 600 mm are included in the 600-mm interval.

Table 6. Catches of young-of-the-year white sturgeon in September 1993 at 13 sampling stations in the Columbia River downstream from Bonneville Dam. Location is shown in River Mile (RM) and in some instances a transect number is shown when parallel trawling efforts were done at the same RM.

Location (RM)	7-10 September		20-24 September	
	Number	Number/hectare	Number	Number/hectare
31	0	0.0	0	0.0
42	2	10.7	0	0.0
46	1	4.1	1	5.7
54	0	0.0	3	14.5
61	0	0.0	1	5.1
75	2	9.3	4	17.7
79-1	0	0.0	8	35.4
79-2	0	0.0	2	8.9
95-1	0	0.0	0	0.0
95-2	0	0.0	0	0.0
103	1	3.8	1	4.6
131-1	0	0.0	3	15.3
131-2	2	10.2	2	9.3
Mean	0.6	2.9	1.9	9.0

Table 7. Publication status of manuscripts prepared as part of Phase I work in the 1993 white sturgeon final report.

McCabe, G. T., Jr., and L. G. Beckman. 1990. Use of an artificial substrate to collect white sturgeon eggs. California Fish and Game 76:248-250.
McCabe, G. T., Jr. 1993. Prevalence of the parasite *Cystoopsis acipenseri* (Nematoda) in juvenile white sturgeons in the lower Columbia River. Journal of Aquatic Animal Health 5:313-316.
McCabe, G. T., Jr., R. L. Emmett, and S. A. Hinton. 1993. Feeding ecology of juvenile white sturgeon (*Acipenser transmontanus*) in the lower Columbia River. Northwest Science 67:170-180.
McCabe, G. T., Jr., and C. A. Tracy. Spawning and early life history of white sturgeon *Acipenser transmontanus* in the lower Columbia River. Accepted for publication in Fishery Bulletin.
Parsley, M. J., L. G. Beckman, and G. T. McCabe, Jr. 1993. Spawning and rearing habitat use by white sturgeons in the Columbia River downstream from McNary Dam. Transactions of the American Fisheries Society 122:217-227.

DISCUSSION

Egg and Larval Sampling

White sturgeon successfully spawned in the Columbia River downstream from Bonneville Dam in 1993, as evidenced by egg, larval, and YOY collections. Timing of spawning in 1993, which was estimated to have begun on 26 April and ended on 13 July, was similar to that observed in 1988-1991 (McCabe and Tracy 1993). In 1988, the spawning period was estimated to have extended from 22 April to 22 June; in 1989, from 22 April to 2 July; in 1990, from 23 April to 14 July; and in 1991, from 5 May to 14 July. From 1988 through 1991, spawning was estimated to have occurred on 38 to 48 days each year; in 1993, we estimated spawning occurred on at least 46 days.

Spawning in 1993 occurred during water temperature regimes suitable for incubation. Successful white sturgeon egg incubation occurs at temperatures between 10 and 18°C, with highest survival and uniform hatching between 14 and 16°C (Wang et al. 1985). In 1993, we estimated that spawning occurred at water temperatures of 11 to 18°C; however, water temperatures on more than 90% of the days on which spawning was estimated to have occurred were less than 18°C. Survival of the eggs spawned at a water temperature of 18°C was probably less than for eggs spawned at lower water temperatures. Wang et al. (1985) observed that substantial white sturgeon egg mortalities may occur at water temperatures of 18 to 20°C, and that temperatures greater than 20°C are clearly lethal. Based on larval collections of white or green sturgeon *Acipenser medirostris*, Kohlhorst (1976) estimated sturgeon in the Sacramento River spawned at water temperatures ranging from 7.8 to 17.8°C, with peak spawning at 14.4°C.

White sturgeon spawning in 1993 was estimated to have occurred over a wide range of Bonneville Dam discharges (daily). Apparently, water velocities, which are directly related to dam discharge, did not limit white sturgeon spawning downstream from Bonneville Dam in 1993. Based on computer simulations by Parsley and Beckman (1993) and daily Bonneville Dam discharges in 1993, more than 140 hectares of usable spawning habitat should have been present from April through July, even at the lowest discharges.

Young-of-the-Year

Catches (number/hectare) of YOY white sturgeon at eight index trawling stations in September 1993 were not significantly different (Kruskal-Wallis, $P > 0.05$) than catches at the same sites in September of 1990 and 1991. Catches at the eight sites averaged 6.4, 8.0, and 5.3 YOY/hectare in 1990, 1991, and 1993, respectively. In all years, catches at 50% or more of the stations were zero.

Plans for 1994

Plans for 1994 include sampling for white sturgeon eggs, larvae, and juveniles downstream from Bonneville Dam. Specifically, we plan to use plankton nets, artificial substrates, and bottom trawls to study the spawning and early life history of white sturgeon in the Columbia River downstream from Bonneville Dam. These data collected downstream

from Bonneville Dam, an area designated as a control for the overall White Sturgeon Study, will be provided to NBS, which is conducting similar research in impoundments upstream from Bonneville Dam. As in previous years, physical measurements will be made in conjunction with the biological sampling.

REFERENCES

Beer, K. E. 1981. Embryonic and larval development of white sturgeon (*Acipenser transmontanus*). Masters thesis. University of California, Davis.

Buchanan, T. J., and W. P. Somers. 1969. Discharge measurements at gaging stations. U.S. Geological Survey, Water Resources Investigations, Book 3, Chapter A8, Washington D.C.

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

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

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

McCabe, G. T., Jr., and C. A. Tracy. 1993. Spawning characteristics and early life history of white sturgeon *Acipenser transmontanus* in the lower Columbia River. Pages 19-46 *in* R. C. Beamesderfer and A. A. Nigro, editors. Status and habitat requirements of the white sturgeon populations in the Columbia River downstream from McNary Dam. Final report to Bonneville Power Administration (Project 86-50), Volume I, Portland, Oregon.

Parsley, M. J., and L. G. Beckman. 1993. An evaluation of spawning and rearing habitat for white sturgeon in the lower Columbia River. Pages 231-261 *in* R. C. Beamesderfer and A. A. Nigro, editors. Status and habitat requirements of the white sturgeon populations in the Columbia River downstream from McNary Dam. Final report to Bonneville Power Administration (Project 86-50), Volume I, Portland, Oregon.

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