KOOTENAI RIVER WRITE STURGEON INVESTIGATIONS AND EXPERIMENTAL CULTURE

Annual Progress Report FY 1990

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ABSTRACT

Setline and angling techniques were used to sample 332 sturgeon from the river between Kootenai Falls and Kootenay Lake during 1989 and 1990. Sturgeon were found in Montana within 4 km of Kootenai Falls and downstream from Bonners Ferry, Idaho to Kootenay Lake, British Columbia. Our data indicate there is a complete lack of recruitment of juveniles into the population. The youngest fish sampled was of the 1977 year class, and the population is estimated at 880 individuals with 95% confidence intervals of 638 to 1,211.

Culture of one pair of sturgeon in 1990 was of limited success. Less than 5% of eggs hatched with 50% initial mortality of fry. The contribution of contaminants found in eggs (aluminum, copper, zinc, lead, and organochlorides) toward this poor survival is unknown. Handling problems with the eggs at the time of spawning complicated our results.

An ongoing sonic telemetry study has revealed definite long distance movements. Sturgeon regularly move across the British Columbia-Idaho border and seek out deep holes or migrate to Kootenay Lake during late fall. Seasonal differences in use of depth and velocity parameters were found between sexes and among seasons. No relationships were found between sturgeon movement and month, water temperature, flow, and flow change. However, multiple regression analysis indicated that up to 30% of the variance in individual sturgeon movement was explained by the combination of the four variables.

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INTRODUCTION

The population of white sturgeon Acipenser transmontanus in the Idaho section of the Kootenai River was first surveyed in 1979 through 1982 (Partridge 1983). Recruitment of juvenile sturgeon to the population appeared to be insufficient to sustain the harvest of adult fish, forcing a closure on harvest beginning in 1984.

Current knowledge regarding habitat requirements of white sturgeon and our understanding of environmental influence ondistribution, movement, spawning, and juvenile survival is insufficient to allow us to determine how development and management of the Kootenai River has impacted this species.

This project, authorized by the Northwest Power Planning Council (1987) and funded by Bonneville Power Administration (BPA), is an effort to identify environmental factors limiting the white sturgeon population in the Kootenai River and to recommend effective mitigative actions to restore the wild population. Concurrently, BPA is providing the Kootenai Indian Tribe of Idaho with funding to develop an experimental white sturgeon culture facility on the Kootenai River. In November of 1988, the Idaho Department of Fish and Game (IDFG) and Kootenai Tribe began working cooperatively to meet the goal of restoring this population.

DESCRIPTION OF STUDY AREA

Geography

The Kootenai River originates in Kootenay National Park, British Columbia (B.C.), flowing south into Montana, then turning northwest at Jennings, the site of Libby Dam, at river kilometer (rkm) 352.4 (Figure I). Kootenai Falls, 50 km below Libby Dam, presents an impassable barrier to sturgeon. As the river flows through the northeast corner of Idaho, a definite reach change occurs at Bonners Ferry. Upstream from town, the river has an average gradient of 0.6 m/km, with velocities higher than 0.8 m/s. Downstream from Bonners Ferry the river slows to an average gradient of 0.02 m/km, deepens, and meanders through the Kootenai Valley back into B.C. into the south arm of Kootenay Lake. The river leaves the lake through the west arm to a confluence with the Columbia River at Castlegar. A natural barrier at Bonnington Falls, and now Corra Linn Dam, have isolated the Kootenai white sturgeon from other populations in the Columbia River basin for approximately 10,000 years (Northcote 1973). The basin drains an area of 49,987 km^2 (Bonde and Bush 1975).

Development

Spring floods were common prior to commencement of operation of Libby Dam in 1972. Constructed by the U.S. Army Corps of Engineers, Libby Dam provides flood control and hydropower generation and is part of the BPA network. Dam operation drastically alters natural flow levels by storing water during spring runoff, discharging power-peaking flows during late summer and fall, and drawing

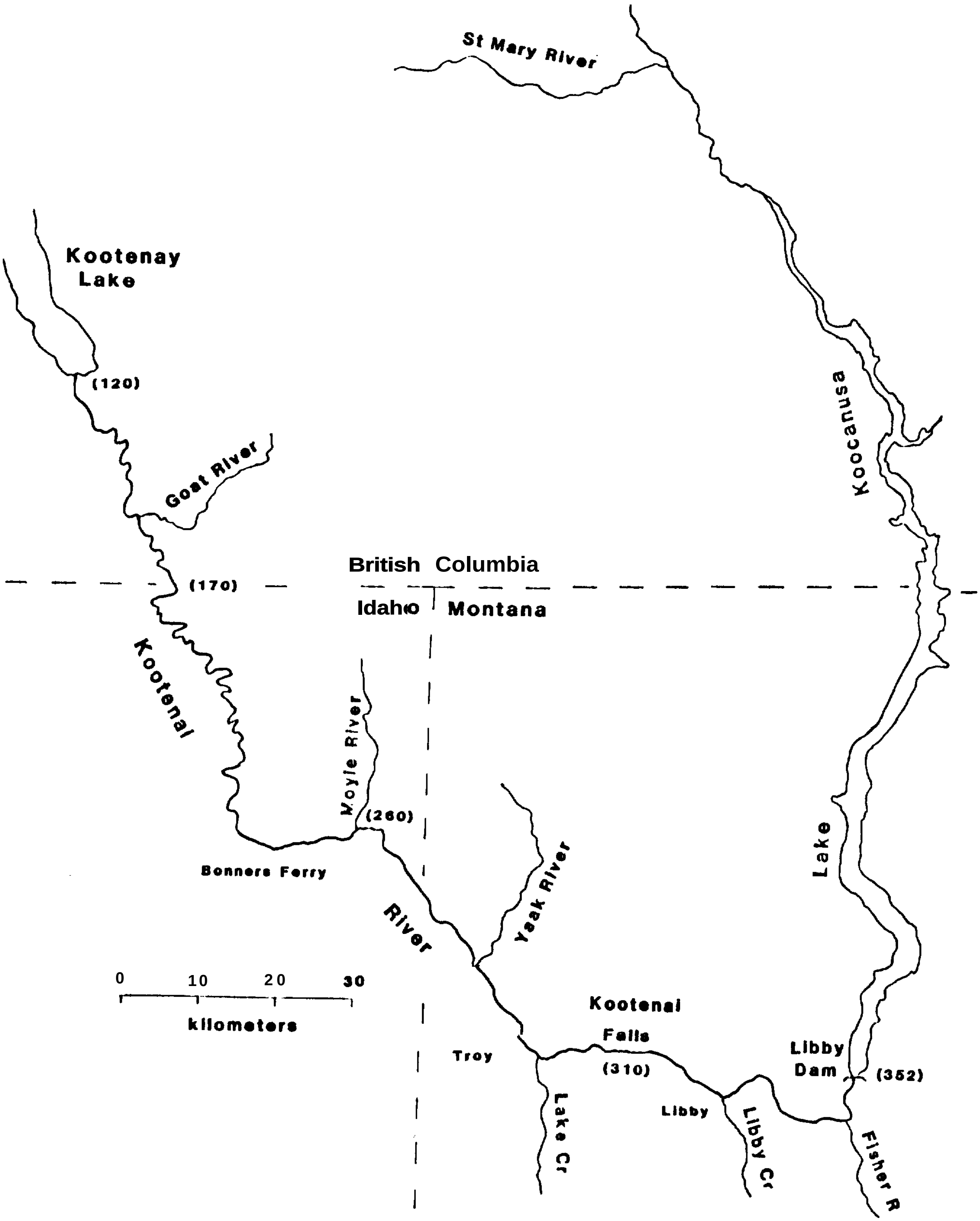

Figure 1. Map of the Kootenai River. Study area was from southern Kootenay Lake upriver to Kootenai Falls.

down the reservoir throughout winter. Corra Linn Dam effectively raises the mean level of Kootenay Lake 2.4 m, influencing the river level to Bonners Ferry.

To protect agricultural land between Bonners Ferry and Kootenay Lake, the riverbanks have been diked extensively since the 1920s, effectively removing most backwater and slough areas from the river system.

Contaminants

Prior to construction of Libby Dam, most point source pollution in the Kootenai River drainage came from a mine and fertilizer plant upriver on the St. Mary River (Bonde and Bush 1975). The ASARKO Mine (copper and silver) on Lake Creek near Troy, Montana is the only current mining operation in the drainage below the dam. The closed Snowshoe Mine on Snowshoe Creek (tributary to Libby Creek) was reclaimed in 1989 due to water quality problems.

Sturgeon Fishery

Idaho

Harvest of white sturgeon from the Kootenai River has been regulated in Idaho since 1944 when commercial fishing 'was prohibited. Increasingly restrictive statewide harvest limits and length restrictions were imposed over the years (Table 1). From 1944 through the mid-1970s, 10 to 20 fish were harvested per year; an estimated 43 to 50 sturgeon per year were harvested from 1979 through 1982. The first and only prior investigation of fisheries resources on the lower Kootenai River was conducted from 1979 through 1982 by Partridge (1983). Partridge found that only 13% of his sample of sturgeon were younger than age 15 and smaller than 92 cm total length, the legal size for harvest. Concluding that this lack of recruitment of juveniles was limiting the fishery, harvest of sturgeon was terminated in 1984.

Montana

Prior to 1972, harvest of white sturgeon was not restricted in Montana (Table 1). Harvest was restricted to 2 fish per year with a slot regulation of 102 to 183 cm total length for the next six years. Five to 18 sturgeon were legally harvested annually during that period. The fishery was completely closed in 1979 (Graham 1981). Montana officials have declared white sturgeon a "species of special concern" due to the very small number (an.estimated 5 fish) residing in the river in 1979.

British Columbia

Sturgeon harvest has been restricted in B.C. since 1952 (Table 1). From 1974 through 1989, anglers in B.C. were allowed to harvest one sturgeon per year with a minimum length restriction of 1 m. Beginning in 1989, setlining for white

Table 1. A history of fishing regulations for white sturgeon in the Kootenai River.

Year	Sturgeon fishing regulations		
	Idaho	Montana	British Columbia
1944	2 in possesion; no yearly limit; no carmercial harvest		
1948	1 setline; 1 in possession		
1949	1 setline; 1 in possession; 76 cm minimun size		
1952			setlines permitted; 1 per day: 92 cm minimum size
1955	1 setline; 1 in possession; 102 cm minimum size		
1957	1 setline; 2 per year; 1 in possession; 102 cm minimum size	setlines permitted for ling only	
1960	1 setline; 2 per year; 1 in possession; 92 - 183 cm length restriction		
1968		setline permitted for sturgeon February 15 through June 30	
1973		6 setlines with 6 hooks per line permitted February 15 through June 30; 2 per year; 102 - 183 cm length restriction	
1975		no setlines permitted; 2 per year; 102 - 183 an length restriction	
1978			100 can minimum size
1979	2 per year; 1 in possession; 92 - 183 cm length restriction: permit required	closed	
1981			1 per year: 100 cm minimum size
1982			Sturgeon declared a game fish
1983	setlines prohibited: season: July 1 through December 31; 1 per year: 92 - 183 cm length restriction		
1984	catch and release only; open all year		
1989			setlines prohibited
1990			catch and release only

sturgeon was prohibited, limiting method of harvest to angling. All harvest was prohibited in the Kootenai River beginning in 1990. Prior to this closure, 5 to 18 fish were harvested annually, and illegal harvest may have increased that estimate by 50% (Andrusak 1980). Since 1977, the B.C. Ministry of Environment tagged 180 sturgeon at the mouth of the Kootenai River where it enters the south arm of the lake. Several of those fish were recaptured in Idaho.

OBJECTIVES

1. Assess the status of white sturgeon in the Kootenai River between Kootenay Lake and Kootenai Falls with regard to distribution, population size, reproduction, and recruitment.
2. Describe weekly and seasonal movements of white sturgeon and describe the frequency of use of physical habitat parameters, including depth, focal point velocity, temperature, and turbidity.
3. Determine gamete viability by experimental culture of white sturgeon from the Kootenai River.
4. Test experimental culture as a means of recruiting sturgeon to the population.
5. Determine effects of pollutants on sturgeon reproduction by measuring levels of contaminants in sturgeon ova and offspring and in river sediments.
6. Determine if Kootenai River sturgeon are genetically different from other white sturgeon stocks by electrophoretic analysis.

METHODS

Population Status

Detailed methods for capture, handling, marking, and collecting habitat use information on white sturgeon are provided in Apperson and Anders (1990).

Sturgeon Egg and Larvae Sampling

On June 26 and 27, 1990, a crew from the Columbia River Field Station of the U.S. Fish and Wildlife Service sampled the Kootenai River for sturgeon eggs and larvae with a beam trawl. Detailed methodology and gear specifications are given by Parsley et al. (1989).

Analyses

Habitat Utilization and Seasonal Movement

Habitat suitability indices (HSI) and habitat parameter utilization frequency histograms were generated for focal point velocity, water depth, temperature, and turbidity (Macintosh Cricket Graph computer program, Abacus 1986; Bovee and Cochnauer 1977). A two-tailed, unpaired Student's t-test was used to test hypotheses that white sturgeon exhibited no significant differences in utilization of depth and velocity among seasons and between sexes.

Simple and multiple regressions were performed between sturgeon movement (change in sequential locations) and month, total fish length, water temperature, total discharge, and change in discharge. Regressions were performed for individuals, for each sex, and for all fish combined.

Population Estimate

Sturgeon sampling to develop a population estimate was conducted from mid-March through October 1989 and from July 25 through October 5, 1990. Four sampling passes were made between Kootenai Falls and Kootenay Lake in 1989, and a final pass was made in 1990 from Bonners Ferry to Kootenay Lake (Figure 1). Each pass took six to eight weeks to complete, and all sections of the river that were possible to fish were sampled. Any sturgeon caught and tagged superfluous to this sampling regiment were omitted from the population estimate. A modified Schnabel multiple mark recapture method was used to estimate the size of the sturgeon population (Bicker 1975). The following formulas were used:

$$\hat{N}=\frac{(C_t M_t)}{R_t+1}$$

Ninety-five percent confidence intervals were computed using a Poisson distribution:

$$R_t+1.92\pm1.96\sqrt{R_t+1}$$

where:

C_t=**total** sample taken during pass t,

M_t=**total** marked fish at the start of the t^{th} pass,

R_t=**number** of recaptures in the sample C_t.

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Culture Activities--l990

Collection of Broodstock

Setlines and angling were used from mid-April through mid-June 1990 to collect prospective broodstock. Sampling locations were identified by tracking movements of transmittered adults known to be in late reproductive stages. Sturgeon were held in the hooded stretcher and transported by boat to a net pen (6 m x 6 m x 4.5 m deep) set up offshore behind Smith Island at rkm 204.

Staging and Spawning Activities

Procedures for staging broodstock and inducing ovulation and spermiation are detailed in Conte et al. (1988), and were closely followed. Details of the treatment of individual sturgeon are presented in Appendix A.

Analysis of Contaminants

Levels of copper, zinc, lead, aluminum, strontium, and organochlorides in white sturgeon oocyte samples and in Kootenai River sediment samples were determined by Am Test, Inc. of Redmond, Washington. Metals were analyzed in accordance with Environmental Protection Agency (EPA) method 6010 (US EPA 19861, and organochlorides were analyzed according to Method PPB 12/83 (US EPA 1983). Copper, zinc, and strontium were chosenbecause previous water quality monitoring singled out these metals as being at potentially harmful levels (Bonde and Bush 1975). Aluminum was examined in 1990 samples because high levels were.found in preliminary well water quality tests at **a** proposed site for the culture facility adjacent to the river. Lead was examined because of its prevalence near silver and copper ore bodies being mined in the drainage. Organochlorides were measured because relatively high levels of DDT and its metabolites and polychlorinated biphenyl (PCB) were found in a sturgeon ova sample in 1982.

RESULTS

Population Structure

Population Estimate and Abundance

The population size was estimated at 880 individuals, with 95% confidence intervals of 638 to 1,211. This translates to an average abundance of seven sturgeon per km between Bonners Ferry and Kootenay Lake.

A total of 332 white sturgeon were captured from March 1989 through November 1990. All but two fish were marked with Floy tags, and 271 fish received PIT tags. Forty-seven sturgeon were recaptured, six of those were recaptured twice. Floy tags were lost from 11 sturgeon (7 of those were lost during the year of tagging), but PIT tags were secure in all recaptured fish. With one exception, all sturgeon were captured between rkm 244.5 (1 rkm downstream from the Highway 95 bridge at Bonners Ferry) and the Kootenay Lake delta at rkm 120. One sturgeon (105 cm FL) was caught in Montana at rkm 310.5 (2 rkm below Kootenai Falls). Fork length of white sturgeon in the sample ranged from 88 cm to 274 cm, with a mean of 150 cm (Figure 2). A weight-length relationship developed from 180 measurements showed weight = (5.895 x 10^{-7}) fork $length^{3.501}$ (Figure 3).

In 1989, overall catch rate in Idaho was double that in B.C.; however, in 1990, the catch rate in B.C. exceeded that in Idaho by 25% (Table 2). Small setlines (rigged with ten 10/O or smaller hooks) were fished for a total of 1,220 hours in 1989, capturing only 2 sturgeon (130 and 136 cm FL), and were fished for 525 hours in 1990 for 0 sturgeon. Overall catch rates were highest throughout the Idaho section below Bonners Ferry and near the mouth of the river (Figure 4). Weekly catch per setline hour was highest during summer when discharge was relatively low and temperature was high (Figure 5; Appendix A). Drastic fluctuations in discharge that began in late summer often fouled our overnight sets, and catch per unit effort declined throughout the fall.

Project angling effort was sporadic. Holes with historically higher densities of sturgeon were usually selected for angling effort, Angling effort totalled 716 rod hours to catch 24 fish in 1989 (0.03 fish/rod hour) and 109 rod hours for 6 fish in 1990 (0.06 fish/rod hour).

Gear Selectivity

We discontinued using J-type hooks on setlines after several fish straightened hooks and escaped. The J-type hooks were occasionally swallowed by sturgeon, whereas circle hooks always caught fish in the mouth, making release less stressful. Length frequencies of sturgeon captured on the three sizes of hooks are shown in Figure 6. **No** fish size to hook size selectivity could be identified from our sample.

Age and Growth

Average annual growth rate for 15 white sturgeon tagged in 1979 through 1982 and recaptured in 1989 and 1990 was 3.1 cm FL and 3.7 cm TL (Table 3). Those fish ranged from 100 to 158 cm FL in 1989. A comparison of seven old and new samples of pectoral fin-ray sections showed discrepancies between estimated age differences and actual time between collection of samples of up to 3 years with a mean difference of 1.6 years (Table 4). Annuli discrepancies occurred on the outer edges of fin-ray sections.

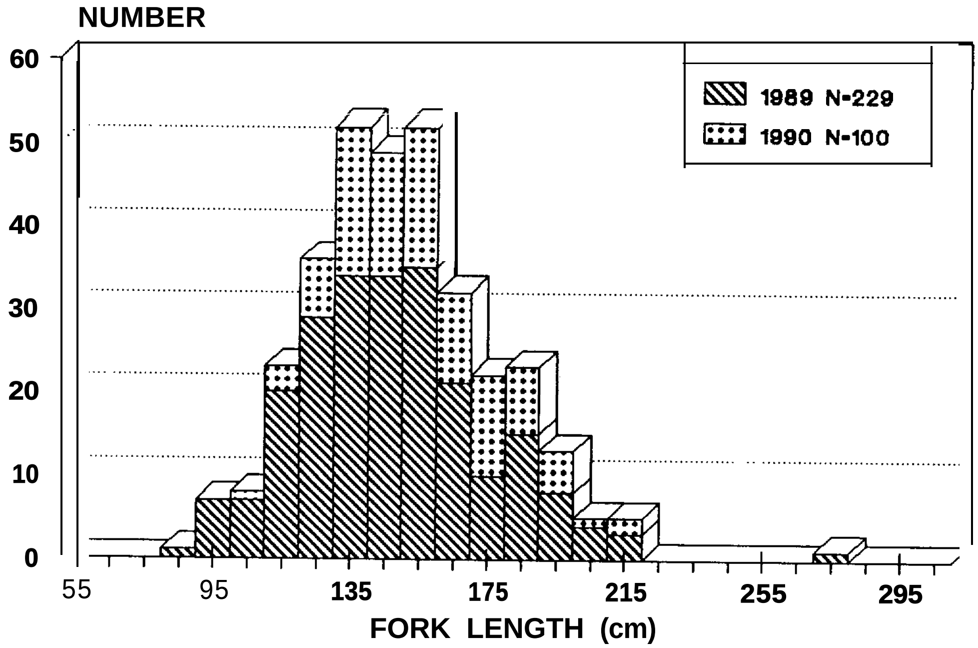


Figure 2. Length frequency of white sturgeon sampled from the Kootenai River, 1989 to 1990.

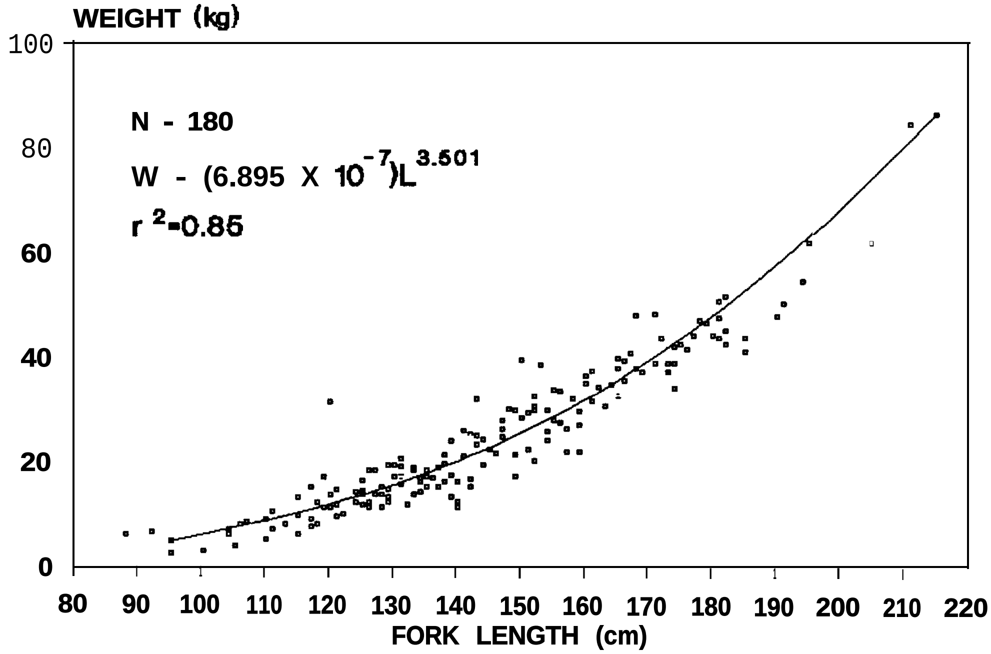


Figure 3. Weight-length relationship for white sturgeon sampled in the Kootenai River, 1989 to 1990.

Table 2. Capture of white sturgeon with setlines, Kootenai River, 1989 through 1990.

Year	River section	Setline hours[1]	Number of sturgeon captured	Sturgeon per hour
1989	British Columbia	4,548	53	0.012
1989	Idaho (lower river[2])	8,095	173	0.021
1989	Idaho (upper river[3])	690	0	0
1989	Montana	1,487	2	0.001
1990	British Columbia	3,515	47	0.013
1990	Idaho (lower river)	8,630	83	0.010
1990	Idaho (upper river)	67	0	0
1990	Montana	0	0	0

[1]setline hour = six hooks fished for one hour (hook sizes: 2 @ 12/0, 2 @ 14/0, and 2 @ 16/0)

[2]downriver from Bonners Ferry

[3]upriver from Bonners Ferry

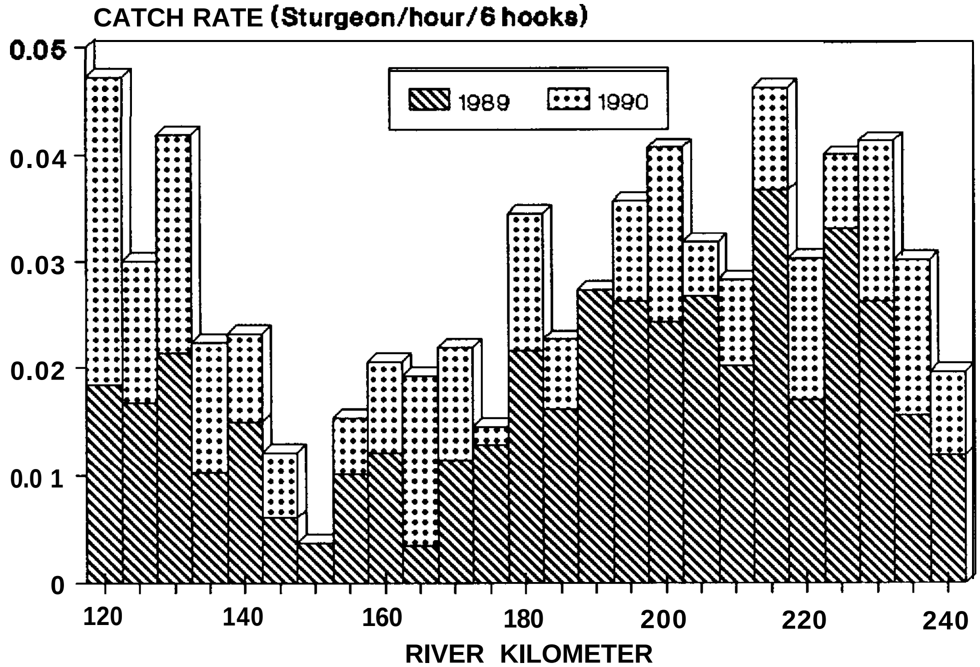
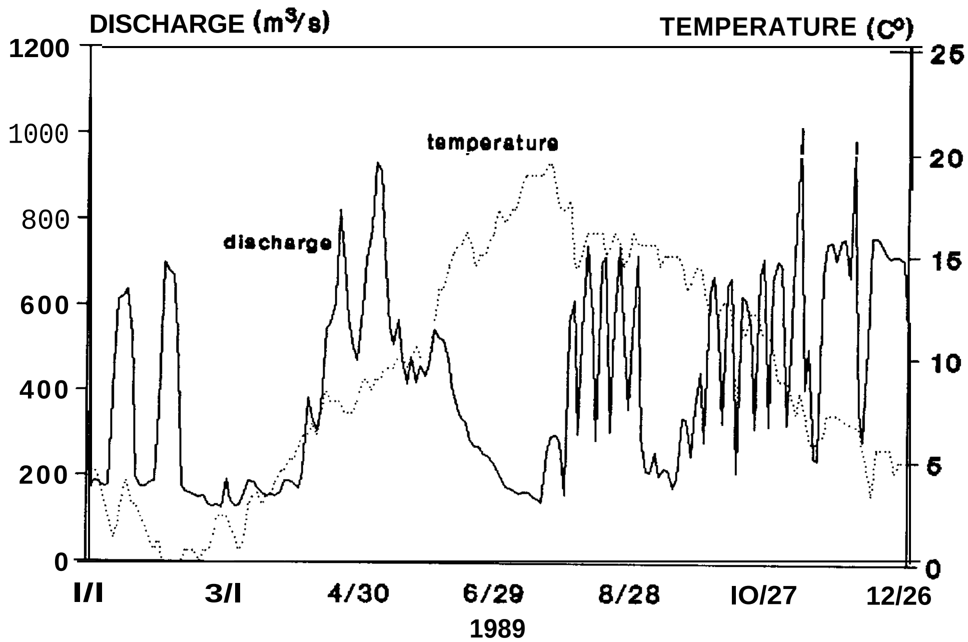


Figure 4. Catch rates of white sturgeon by river kilometer from Bonners Ferry, Idaho to Kootenay Lake, British Columbia, 1989 to 1990.



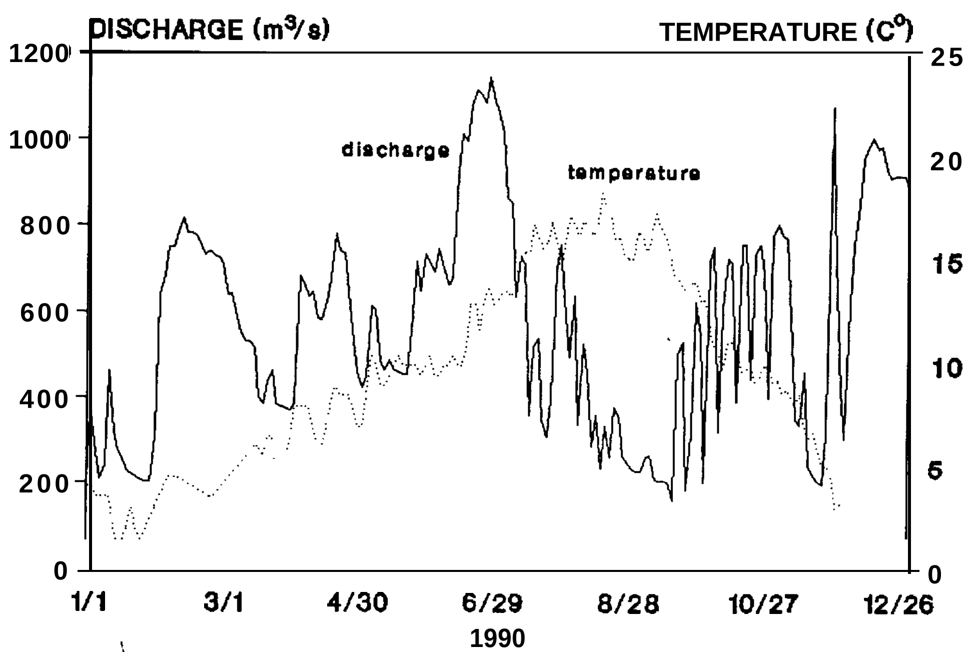


Figure 5. Kootenai River mean daily discharge and minimum daily temperature at Porthill, Idaho, 1989 and 1990.

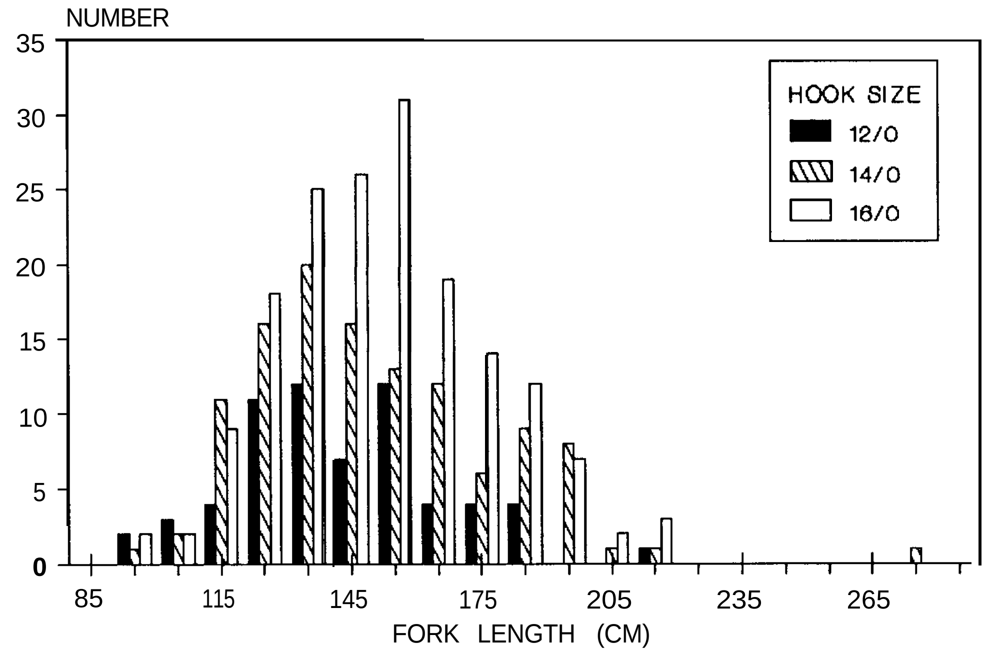


Figure 6. Length frequencies of white sturgeon captured by hook sizes used in the Kootenai River, 1989 to 1990.

Table 3. Growth rate of white sturgeon in the Kootenai River based on recaptured fish.

Old tag number	First capture			Recapture			Mean annual growth	
	Date (M/Y)	Length FL/TL (cm)	Weight (kg)	Date	Length FL/TL (cm)	Weight (kg)	Length FL[1]/TL[2] (cm)	Weight (kg)[3]
03871	11/80	117/127	12.3	4/89	138/154	21.0	2.5/3.2	1.0
G0648	8/81	112/125	11.8	5/89	144/158	--	4.1/4.3	--
00754	7/82	127/143	16.8	5/89	135/155	27.0	1.2/1.8	1.5
00652	8/81	92/102	5.9	9/89	130/145	19.0	4.8/5.4	1.6
00656	9/81	92/99	6.4	6/89	111/123	7.0	2.4/3.1	0.1
00663	9/81	129/145	17.7	6/89	155/178	--	3.3/4.2	--
00699	5/82	106/121	10.0	7/89	140/160	12.0	4.7/5.4	0.3
00748	6/82	111/127	11.4	9/90	128/147	13.5	2.1/2.5	0.3
00717	6/82	69/79	2.2	8/89	100/112	3.0	4.3/4.6	0.1
00671	10/81	113/127	13.9	9/89	129/146	--	2.0/2.4	--
00728	6/82	105/119	9.5	9/89	135/153	15.0	4.1/4.7	0.8
00753	7/82	118/125	12.3	9/89	135/143	27.0	2.3/2.5	2.0
03801	7/80	120/128	12.7	6/89	142/161	16.5	2.4/3.7	0.4
03817	7/80	117/130	12.3	7/82	---/136	13.6	---/3.0	0.7
03817	subsequent recapture			8/90	158/178	31.5	4.1/4.8	1.9
03715	5/80	101/112	7.3	5/81	---/117	8.6	---/5.0	1.3
03715	subsequent recapture			8/90	125/141	14.0	2.4/2.9	0.7

[1]FL: N=15; $\bar{x}$=3.11; s=1.14

[2]TL: N=17; $\bar{x}$=3.74; s=1.15

[3]Weight: N=14; $\bar{x}$=0.91; s=0.65

Table 4. Comparison of past and present estimated ages of individual white sturgeon in the Kootenai River.

Tag #	Past estimate		Current estimate		Estimated age difference	Actual years lapsed	Difference[1]
	Date (mm/yy)	Age	Date (mm/yy)	Age			
01085	8/81	15	6/89	24	9	8	1
01093	9/81	15	6/89	21	6	8	2
01114	7/80	16	6/89	24	8	9	1
01215	10/81	18	9/89	23	5	8	3
01027	8/81	19	5/89	26	7	8	1
01023	11/80	20	4/89	26	6	9	3
01543	5/80	17	8/90	27	10	10	0

'mean difference between estimated and actual age differences was 1.6 years

Reproductive Potential

Maturity

A total of 291 white sturgeon have been surgically examined to determine sex and stage of maturity. Of those, 75% were positively sexed (Table 5). We surmise that refinement of our techniques were responsible for the decrease in proportion of unsexable sturgeon from 1989 to 1990 and the increase in non-reproductive males between years. Also a factor was our disproportionate sampling during 1990 in the section of river where reproductive fish concentrated. Lengths of sturgeon at various reproductive stages is presented in Figure 7. The smallest ripe female in our sample was 135 cm FL and the smallest reproductive male was 115 cm FL.

Wild Spawning

Nineteen 5- to lo-minute beam trawl hauls conducted between rkm 229.5 and 249.5 failed to collect white sturgeon eggs or larvae. An apparent concentration of reproductive sturgeon at rkm 229 to 231 during May 1990 was the only evidence we have that spawning may have occurred (detailed in discussion of "Spawning-Related Behavior").

Culture Activities--l990

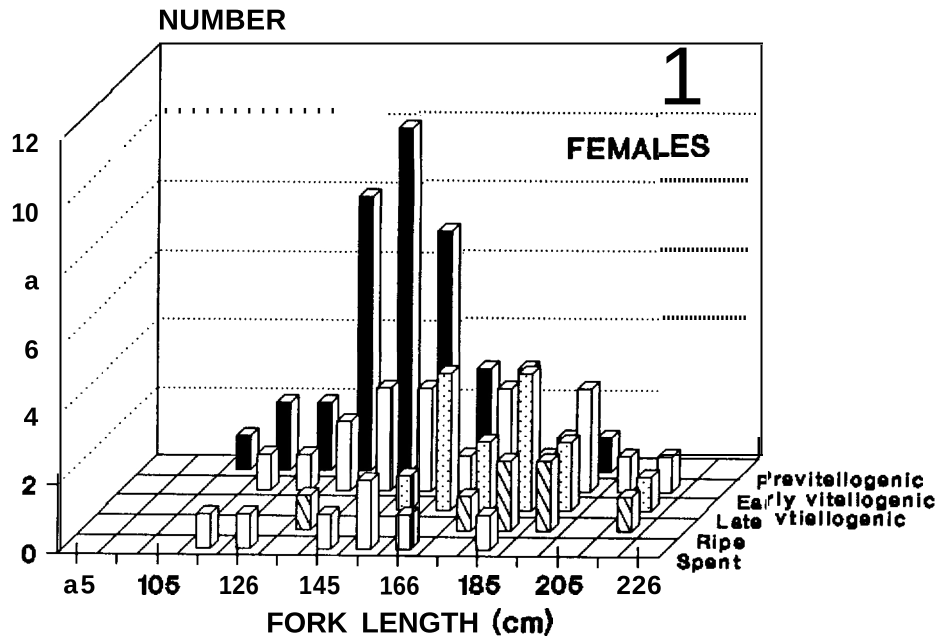
On July 18, 130 cc of semen was collected from one male (150 cm FL) 24 hours following an injection of luteinizing hormone releasing hormone analogue (LHRHa) and kept in oxygenated ziplock bags in an ice-filled cooler. Approximately 60,000 eggs were taken from one female (174 cm FL; 41.4 kg) on July 19 (from 0100 to 0230 hours). Sixty percent of the eggs were fertilized on site, de-adhesed with Fullers earth, and placed in oxygenated ziplock bags in ice-filled coolers, with eggs insulated from direct contact with ice (Treatment 1). An additional 25% of the eggs were kept unfertilized and placed in the coolers (Treatment 2). The remaining 15% of the eggs were subjected to a third treatment: eggs were fertilized and de-adhesed on site, then transported to a nearby spring and placed in two Heath trays in a makeshift incubator. This was an effort to rear some sturgeon within the Kootenai drainage. Treatment 3 did not fare well; some eggs did begin cleavage, but a fungus infected the entire treatment within three days. Effort to remove infected eggs proved futile and the treatment was abandoned.

Treatments 1 and 2 were flown to the College of Southern Idaho (CSI) hatchery in Twin Falls. Eight hours following spawning, Treatment 1 was equally distributed into two McDonald upwells. Treatment 2 was fertilized and de-adhesed then placed in one upwell. Flow rate was set at 4 gallons/min to keep eggs suspended but not rolling. Water temperature was 12.8°C.

Egg survival to initial cleavage differed drastically between treatments (Table 6). Only 10% of Treatment 1 eggs survived through first cleavage versus 35% initial survival of Treatment 2 eggs. Survival to hatching was similar

Table 5. Sexual development of white sturgeon sampled in the Kootenai River, 1989 and 1990.

Categories of sexual development			Percent of sample by year	
Category	Sex	Description of development	1989	1990
0	unknown	gonad undifferentiated or not seen	32.6	14.5
1	Female	Previtellogenic: no visual signs of vitellogenesis; eggs present but have average diameter <0.5 mm	13.8	11.8
2	Female	Early vitellogenic: eggs are cream to gray; average diameter 0.6 to 2.1 mm	6.6	7.3
3	Female	Late vitellogenic: eggs are pigmented and attached to ovarian tissue; average diameter 2.2 to 2.9 mm	5.0	4.5
4	Female	Ripe: eggs are fully pigmented and detached from ovarian tissue; average diameter 3.0 to 3.4 mm	2.2	2.7
5	Female	Spent: gonads are flaccid and contain some residual fully pigmented eggs	2.8	0.9
6	Female	Previtellogenic with attritic oocytes: eggs present but have an average diameter <0.5 mm; dark pigmented tissue present that may be reabsorbed eggs	1.7	0
7	Male	Non-reproductive: testes with translucent smokey pigmentation	3.3	27.3
8	Male	Reproductive: testes white with folds and lobes	32	28.2
9	Male	Ripe: milt flowing: large white lobular testes	0	2.7



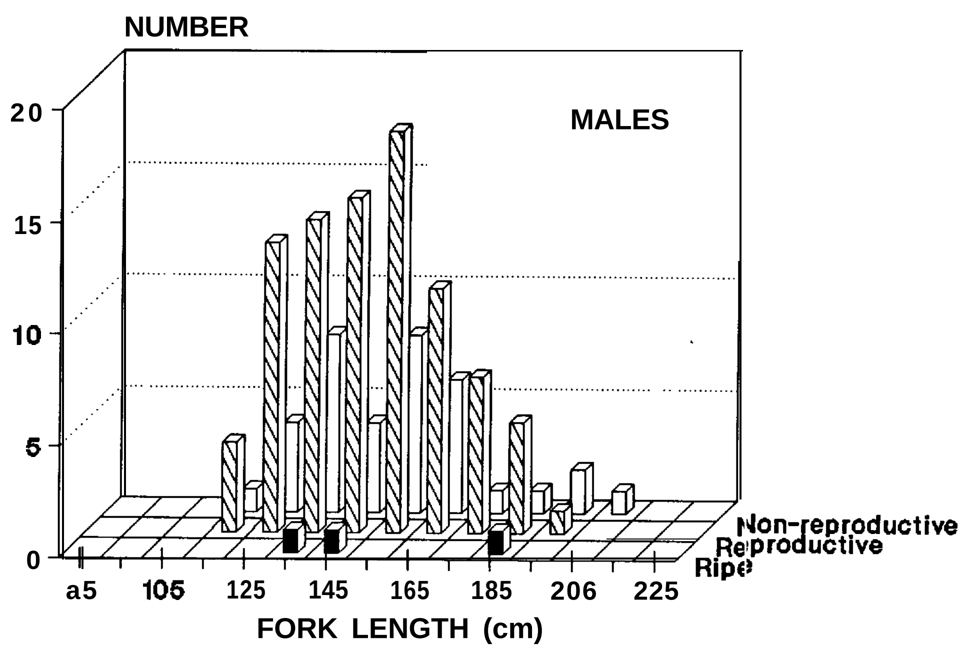


Figure 7. Length frequencies of reproductive stages of white sturgeon in the Kootenai River, 1989 to 1990. The spent female category includes previtellogenic fish with attritic oocytes.

Table 6. Survival of white sturgeon eggs from culture activities with one spawning pair, Kootenai River, 1990.

Date	Stage of development	Surviving white sturgeon eggs			
		Fertilized prior to air transport (Treatment 1)		Fertilized after air transport (Treatment 2)	
		Number	Percent	Number	Percent
7/l 9/90	Fertilization	35,000	100	15,000	100
7/20/90	First cleavage	3,500	10	5,200	35
7/25/90	Neurulation	1,000	3	1,500	10
8/02/90	Begin of hatch	850	2	1,350	9

following first cleavage. As eggs hatched, the larvae were flushed from the upwells to a common trough.

Approximately 2,200 eggs actually hatched, but half of the sac fry were severely deformed with curvature of the vertebral column and soon died (Table 7). Yolk sac absorption was complete 22 days post hatch, and all survivors were on feed by 40 days post hatch. Survival was good throughout feed initiation; more than 73% of the fry that absorbed their yolk sac successfully started feeding. Fry were segregated by size into two tanks on September 16 and resorted on January 12.

A sample of the fry were tested for presence of disease, including an iridovirus known to infect white sturgeon. The nonlethal test involved removing a small section of gill lamellae. **No** disease was detected in Kootenai River sturgeon (Keith Johnson, Fish Pathologist, Idaho Department of Fish and Game, personal communication).

Contaminants Analysis

Fifteen samples of sturgeon oocytes were examined for copper and zinc contamination. Levels of copper ranged from 1.18 to 3.2 µg/g, and zinc was found at concentrations of 17.8 to 32.8 µg/g (Tables 8, 9, and 10).

Organochloride compounds found in oocytes included DDT, DDD, DDE, and PCB (as Aroclor 1260); combined levels found ranged from 0.215 to 1.080 µg/g.

River sediment samples contained 1.62 to 12.8 µg/g copper and 22.4 to 70.6 µg/g zinc. Metal concentrations were considerably higher at the downriver site. No organochlorides were found in river sediments (Table 11).

Eggs, embryos, and larvae of the 1990 spawn contained detectable levels of copper, zinc, aluminum, lead, and some pesticides (Table 9). No PCBs were found. Higher levels of metals were found in the unfertilized eggs than in developing fish.

Movement and Habitat Use

Sampling efforts in Montana failed to capture any reproductively mature sturgeon for transmitter attachment. During 1989, 16 fish in the Idaho sections of the river and 4 fish in B.C. received transmitters. During 1990, six additional sturgeon were transmittered, one old transmitter was replaced, and one old transmitter was removed (Figure 8; Table 12).

Habitat Use

Focal Point Velocity-Sturgeon utilized measurable velocities ranging from 0.03 m/s to 0.61 m/s throughout the river, with a modal utilization of 0.24 m/s to 0.27 m/s (Figure 9). Velocities utilized in Kootenay Lake were less than 0.03 m/s, below the resolution of the Price AA current meter. Focal point velocities (fpv) were significantly lower for females than for males during winter ($P \leq 0.01$)

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Table 7. Survival and growth of white sturgeon from Kootenai River culture, 1990.

Date	Stage of development	Number of fish	Total weight (g)	Fish/ gram	Grams/ fish	Feed grams/ day
8/05/90	End of hatch	1,000	---	---	---	0
8/l 3/90		175	---	---	---	4
8/27/90	Yolk absorption complete	140	---	---	---	4
9/07/90		135	---	---	---	4
9/l 4/90	Feed intitiation complete	102	36.31	2.81	0.356	8
10/01/90		95	78.6	1.42	0.813	28
10/09/90		94	121.16	0.89	1.265	72
10/22/90		92	190.2	0.54	2.040	96
10/24/90		67'	---	---	---	---
11/08/90		65	255.69	0.28	3.840	128
11/21/90		65	282.80	0.24	4.275	112
12/13/90		65	395.70	0.17	6.010	248
12/20/90		65	417.80	0.16	6.365	87
01/02/91		65	510.00	0.13	7.825	195
01/10/91		65	532.4	0.12	8.160	105
01/20/91		64[2]	598.7	0.12	9.270	105
01/31/90		61[2]	728.2	0.09	11.675	198

[1]25 fish were sacrificed for genetic analyses

[2]mortalities due to cannibalism

Table 8. Contaminant levels found in white sturgeon oocyte samples, Kootenai River, 1989.

Tag #	1147	1154	1156	1157	1169	1172	1177	1243	----
FL (cm)	187	135	165	186	198	184	191	170	---
PCB's (µg/kg)[1]									
Arochlor-1260	732	732	732	300	330	<50	200	310	230
Pesticides (µg/kg)[1]									
Alpha BHC	< 4.0	< 4.0	< 4.0	< 3.5	< 3.5	< 3.5	< 3.5	< 3.5	< 3.5
Lindane	< 4.0	< 4.0	< 4.0	< 3.5	< 3.5	< 3.5	< 3.5	< 3.5	< 3.5
Heptachlor	< 3.0	< 3.0	< 3.0	< 3.5	< 3.5	< 3.5	< 3.5	< 3.5	< 3.5
Aldrin	< 4.0	< 4.0	< 4.0	< 3.5	< 3.5	< 3.5	< 3.5	< 3.5	< 3.5
Endosulfan I	< 5.0	< 5.0	< 5.0	<12	<12	<12	<12	<12	<12
ODE	100[3]	1003	100[3]	650	440	176	360	190	570
DDD	<10	<10	<10	<10	44	6	40	28	61
DDT	<20	<20	<20	<10	96	33	86	73	90
delta BHC		----	----	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3
Toxaphene	<1,000	<1,000	<1,000	<200	<200	<200	<200	<200	<200
Chlordane	<100	<100	<100	< 50	< 50	< 50	< 50	< 50	< 50
Methoxychlor	< 50	<50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
Metals (µg/g)[4]									
Copper	1.72	1.85	2.24	1.62	1.87	2.50	1.18	1.31	1.32
Zinc	32.8	22.3	23.1	21.5	23.3	18.8	20.4	21.6	15.3

[1] reported on an "as received" basis

[2] composite of three egg samples (1147,1154, and 1156)

[3] composite of three egg samples (1147, 1154, and 1156)

[4] reported on a "wet weight" basis

Table 9. Contaminant levels in white sturgeon eggs, embryos and larvae from one spawning pair, Kootenai River, 1990.

	Sample			
	Unfertilized eggs	Fertilized eggs	Embryos	Larvae
PCB's (µg/kg)[1]				
Arochlor 1016	< 120	< 70	< 70	< 70
Arochlor 1221	< 480	< 270	< 270	< 260
Arochlor 1232	< 120	< 70	< 70	< 70
Arochlor 1242	< 120	< 70	< 70	< 70
Arochlor 1248	< 120	< 70	< 70	< 70
Arochlor 1254	< 120	< 70	< 70	< 70
Arochlor 1260	< 120	< 70	< 70	< 70
Pesticides (µg/kg)[1]				
Alpha BHC	< 7	< 4	< 4	< 4
Lindane	< 7	< 4	< 4	< 4
Heptachlor	< 5	< 3	< 3	< 3
Aldrin	< 7	< 4	< 4	< 4
Beta BHC	< 10	< 5	< 5	< 5
Delta BHC	< 12	< 7	< 7	< 7
Heptachlor Epoxide	< 7	< 4	< 4	< 4
Endosulfan I	< 10	< 5	< 5	< 5
p,p'-DDE	< 10	6	6	6
Dieldrin	16	10	10	9
Endrin	< 12	< 7	< 7	< 7
p,p'-DDD	22	17	23	20
Endosulfan II	< 7	4	5	< 4
p,p'-DDT	< 24	< 13	< 13	< 13
Endrin Aldehyde	< 24	< 13	< 13	< 13
Endosulfan Sulfate	< 19	< 11	< 11	< 10
Methoxychlor	< 48	< 27	33	< 26
Toxaphene	<1,400	< 800	< 800	< 800
Chlordane	< 120	< 70	< 70	< 70

[1] reported on an "as received basis"

Table 9. Continued.

	Samples			
	Unfertilized eggs	Fertilized eggs	Embryos	Larvae
Metals (µg/g)[2]				
Copper	1.66	0.716	0.664	0.402
Zinc	17.8	3.69	3.32	1.39
Aluminum	24	7.9	4.6	4.6
Lead	0.552	0.322	0.100	0.080

[2] reported on a "wet weight" basis

Table 10. Metal levels found in white sturgeon oocyte samples, Kootenai River, 1990.

	Sample				
Tag #	1090	1530	1551	1565	9999
Length (FL cm)	211	165	196	214	---
Metals (µg/g)[1]					
Copper	2.1	2.5	3.2	1.6	2.0
Zinc	22.0	32.0	31.0	27.0	25.0
Lead	0.12	0.08	<0.01	0.16	1.6
Aluminum	1.2	1.7	5.3	1.6	3.9
Strontium	0.20	0.29	0.32	<0.16	0.20

'reported on an "as received" basis

Table 11. Contaminant levels found in Kootenai River sediments, 1989.

	Samples				
River km	239	215	179	165	126
PCB's (µg/kg)[1]					
Arochlor-1260	< 50	< 50	< 50	< 50	< 50
Pesticides (µg/kg)[1]					
Alpha BHC	< 3.5	< 3.5	< 3.5	< 3.5	< 3.5
Lindane	< 3.5	< 3.5	< 3.5	< 3.5	< 3.5
Heptachlor	< 3.5	< 3.5	< 3.5	< 3.5	< 3.5
Aldrin	< 3.5	< 3.5	< 3.5	< 3.5	< 3.5
Endosulfan I	< 12	< 12	< 12	< 12	< 12
DDE	< 3.5	< 3.5	< 3.5	< 3.5	< 3.5
DDD	< 10	< 10	< 10	< 10	< 10
DDT	< 10	< 10	< 10	< 10	< 10
Delta BHC	< 7.3	< 7.3	< 7.3	< 7.3	< 7.3
Toxaphene	<200	<200	<200	<200	<200
Chlordane	< 50	< 50	< 50	< 50	< 50
Methoxychlor	< 50	< 50	< 50	< 50	< 50
Metals (µg/g)[2]					
Copper	2.85	4.82	2.93	1.62	12.8
Zinc	22.4	47.4	41.4	51.7	70.6

[1] reported on an "as received" basis

[2] reported on a "dry weight" basis

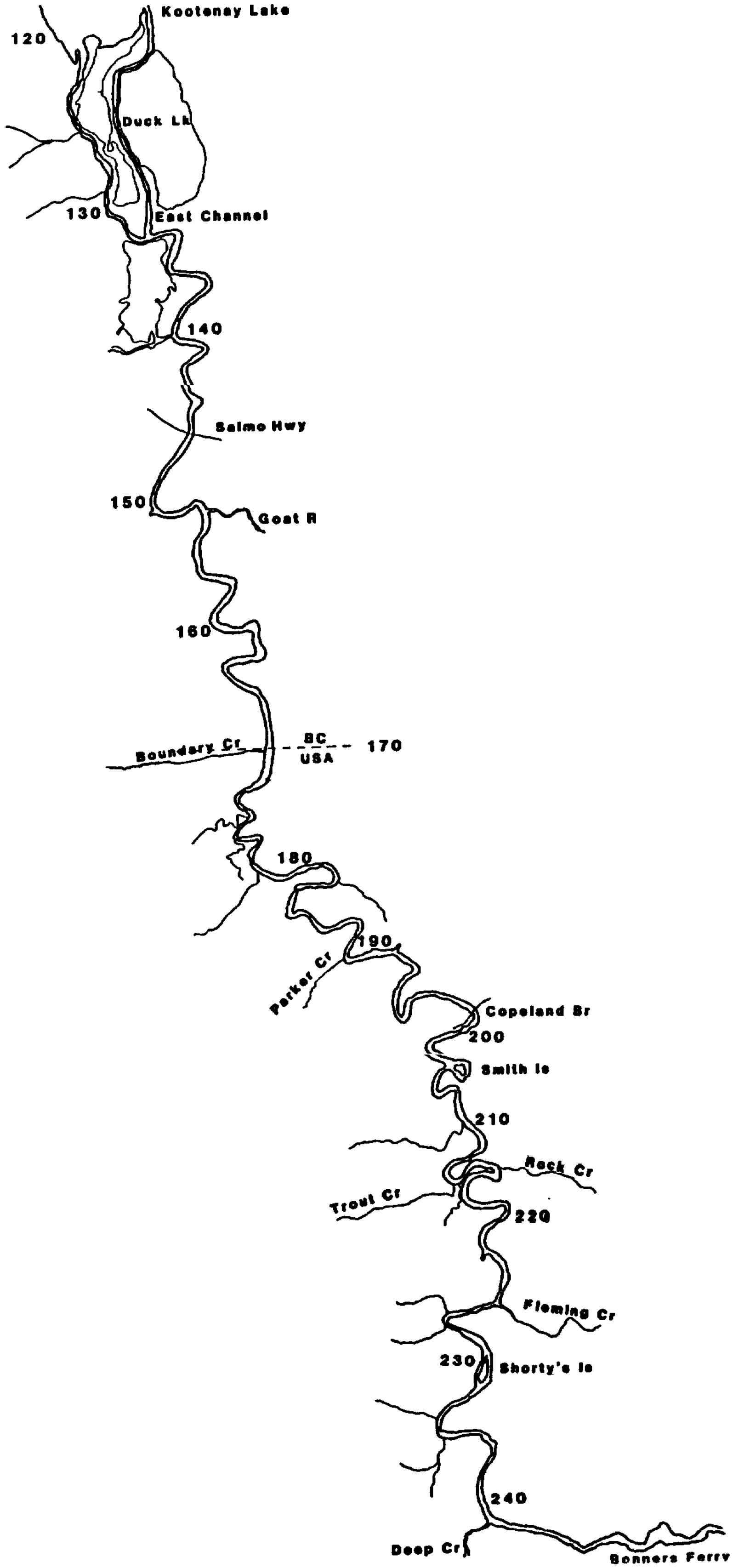


Figure 8. The lower Kootenai River with river kilometers.

Table 12. Specifications of white sturgeon tagged with ultrasonic transmitters in the Kootenai River, 1989 through 1990.

Sonic code	sex (stage)	Length (cm TL)	Initial capture		Last location	
			Date	rkm	Date	rkm
249	M(8)	158	5/17/89	237.7	11/07/90	215.9
258'	F(2)	155	5/17/89	234.5	10/31/90	235.7
276	M(8)	141	5/17/89	234.5	10/10/90	215.5
267	F(1)	123	5/31/89	225.1	10/11/90	120.0
294	M(8)	164	6/07/89	203.6	09/17/90	215.5
285	M(8)	169	6/09/89	199.5	07/24/90	140.0
339	F(2)	171	6/13/89	192.0	09/31/89	120.0
3572	M(8)	146	6/14/89	193.1	11/07/90	192.2
2228[3]	F(5)	215	6/14/89	193.1	11/16/90	212.5
366[4]	M(8)	164	6/14/89	191.0	04/25/90	211.2
348	M(8)	185	6/14/89	190.0	10/24/90	215.5
384	Unknown	151	6/23/89	154.2	06/21/90	230.0
2255[3]	F(2)	170	6/22/89	163.0	10/30/90	120.0
2246[3]	F(4)	207	6/28/89	140.0	11/16/90	209.7
456	M(8)	156	6/28/89	138.7	10/30/90	120.0
465	F(3)	220	7/20/89	205.5	10/30/90	120.0
375	F(3)	215	7/20/89	213.2	11/07/90	216.2
2264[3]	F(2)	143	8/31/89	228.7	10/25/90	228.4
2237[3]	F(6)	136	9/06/89	216.0	11/07/90	216.2
447	M(8)	170	9/26/89	215.2	10/11/90	120.0
88	F(3)	196	4/11/90	225.0	10/30/90	120.0

'replaced with transmitter #366 on 9/7/90

[2]not moved since 7/18/89; suspect. fish lost transmitter

[3]two-year transmitter

[4]taken to netpen on 4/25/90; released without transmitter on 7/17/90

Table 12. Continued.

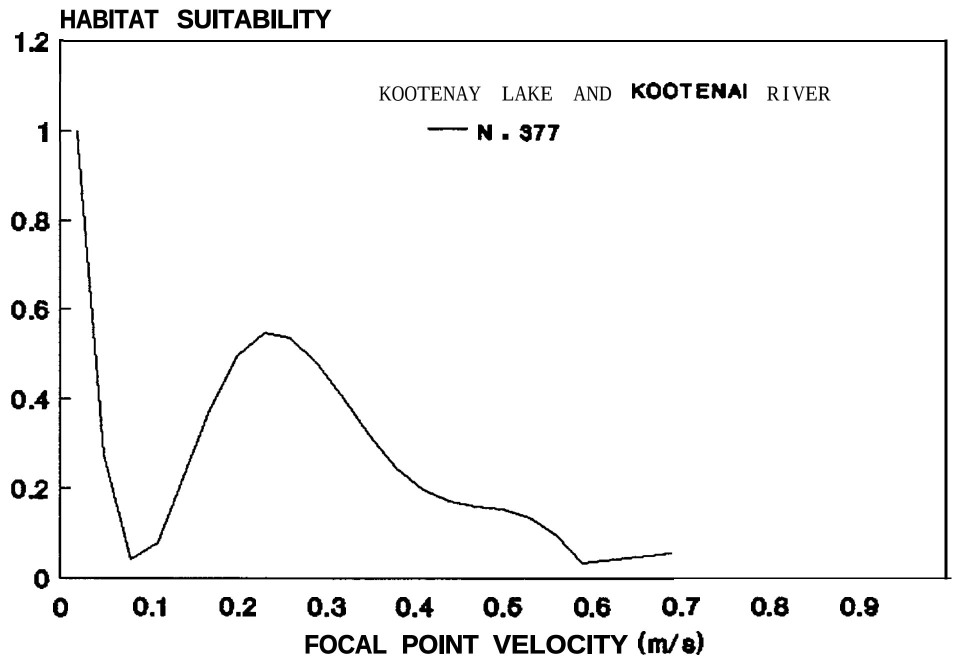
Sonic code	Sex (stage)	Length (cm TL)	Initial capture		Last location	
			Date	rkm	Date	rkm
1057[5]	M(9)	152	5/30/90	230.0	10/30/90	120.0
555[6]	F(4)	236	6/29/90	204.0	10/30/90	115.0
97[7]	F(3)	181	6/24/90	204.0	10/30/90	120.0
2273	F(2)	214	9/26/90	129.8	10/30/90	120.0
2327	F(4)	212	11/01/90	213.5	11/01/90	215.5

[5]transmitter not coded

[6]fish did not move since 9/18/90; suspect she died; was held in netpen from 6/8 - 6/29/90

[7]released from netpen; originally captured at rkm 231.3 on 6/3/90

A



B

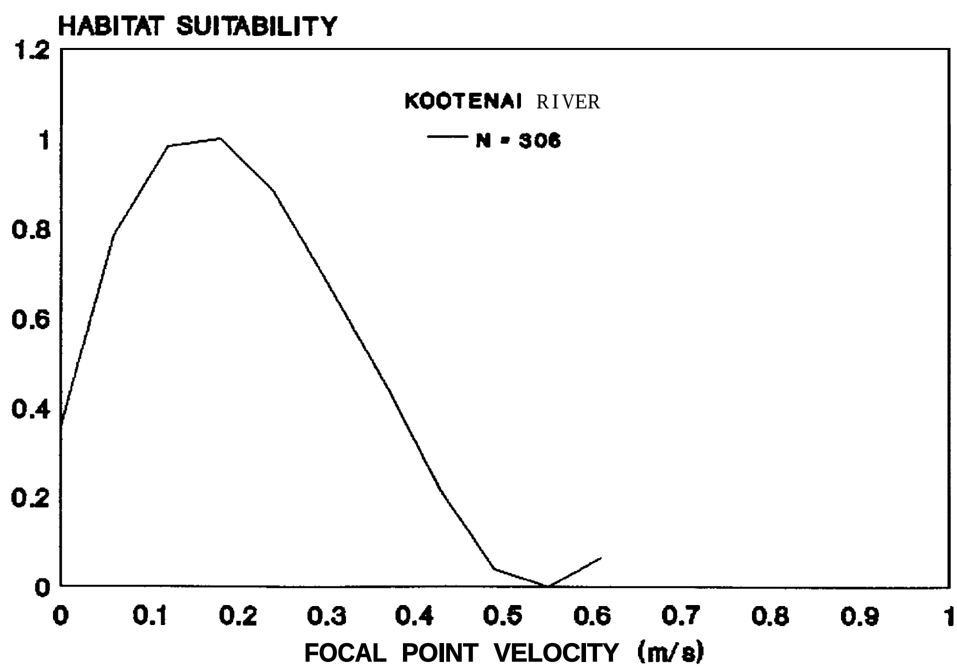


Figure 9. Habitat suitability indices for white sturgeon focal point velocity use in a) Kootenai River and Kootenay Lake, and in b) Kootenai River, July 1989 through July 1990.

and summer ($P \leq 0.05$) (Appendix C) (winter = January through March, spring = April through June, summer = July through September, and fall = October through December). Female fpv utilization was significantly lower in winter than in spring ($P \leq 0.01$) or summer ($P \leq 0.05$) (Appendix D). **No** significant differences in fpv utilization were found for male sturgeon between seasons (Appendix E).

Depth-Sturgeon utilized depths from 3 m to 30 m in Kootenai River, with an optimum of 9 m (Figure 1Oa). Utilized depths in Kootenay Lake ranged from 10 m to 100.5 m, with a bimodal optimum of approximately 55 m and 90 m (Figure 1 Ob). We rarely located sturgeon in shallow water in Kootenay Lake. Females used significantly ($P \leq 0.01$) deeper water than males during winter (Appendix F; Figure 1Oc). Females also used significantly deeper water in winter than in spring and summer ($P \leq 0.01$) (Appendix G). Males used significantly deeper water in winter than **in** spring or summer ($P \leq 0.01$) (Appendix H).

Temperature and Turbidity-The lower river was isothermic and had extremely homogeneous water turbidity. As a result, sturgeon utilization of those parameters reflected the only values available; therefore, we did not develop suitability indices for temperature and turbidity utilization.

Factors Affectins Sturqeon Movement-Simple regression analyses indicated no relationships between individual sturgeon movement (defined as distance moved) and month, water temperature, flow, and flow change; nor was a relationship observed between the combined movements of all transmittered fish and the same variables. However, multiple regression analyses ($df \geq 20$) indicated that as much as 30% of the variance in individual sturgeon movement was explained by the combination of the four variables. Multiple regressions performed with data from individual fish (df>5 and ≤ 20) indicated that as much as 73% of the variability in individual sturgeon movement was explained **by** the combination of month, water temperature, flow, and flow change. Multiple and stepwise regression analyses indicated no relationship between the movements of all sturgeon and month, sex, total length of fish, water temperature, flow, and flow change. Multiple and stepwise regressions also indicated no relationship between male or female sturgeon movement and month, total fish length, water temperature, flow, and flow change.

Seasonal Movement

Movements of 19 transmittered sturgeon were categorized into five general patterns according to duration of movement, seasonality of movement, and distance moved (Table 13). Sturgeon transmittered in 1990 were not tracked long enough to identify patterns of movement.

Pattern I-Five males and four females exhibited movement of less than 50 km from the tagging site (Figure 11; Figure 12). These fish remained in Idaho and moved back and forth among frequently used holes in the river, such as Fleming Creek, Rock Creek, and Smith Island. Two of the female sturgeon were in early reproductive stages, one was late vitellogenic, and one appeared to be spent.

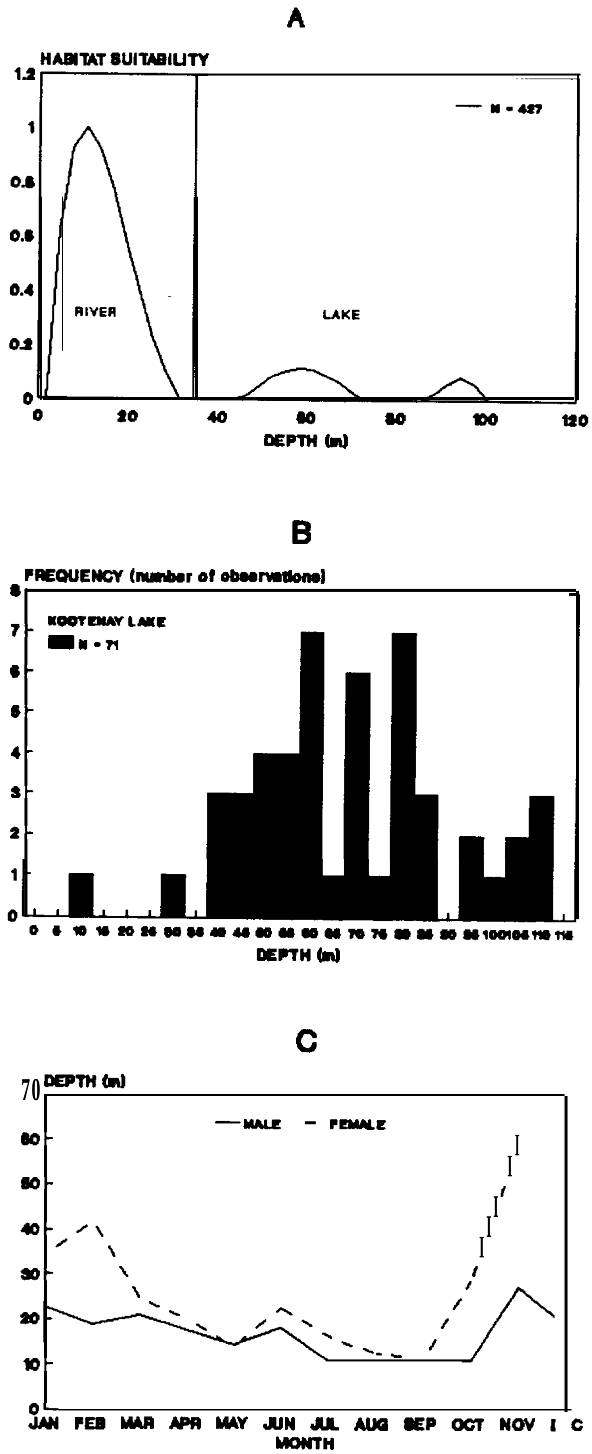


Figure 10. White sturgeon a) depth suitability in the Kootenai River system, b) depth utilization frequency in Kootenay Lake, and c) mean monthly depth utilization, June 1989 through July 1990.

Table 13. Seasonal movement patterns of white sturgeon in the Kootenai River system, Idaho and British Columbia, May 1989 through July 1990.

Movement pattern	Description of movement pattern	Sonic code	Sex (stage)
I	Distance from release site generally less than 30 km	249	M (8)
		348	M (8)
		276	M (8)
		294	M (8)
		366	M (8)
		258	F (2)
		2237	F (6)
		375	F (3)
		2264	F (2)
II	Tagged in Idaho upriver from rkm 200; moved downriver to Kootenay Lake in summer through fall, 1989 and remained	339	F (2)
		267	F (1)
		2255	F (2)
		285	M (8)
III	Tagged in British Columbia between rkm 135 and rkm 154; moved 49 to 57 km upriver and remained	456	M (8)
		465	F (3)
		384	Unknown
IV	Exhibited sustained downriver movement to Kootenay Lake from July to October, 1989; overwintered in lake: moved upriver from May through July 1990	447	M (8)
		2246	F (4)
V	Tagged in Idaho (rkm 193), moved to Kootenay Lake and back to tagging location in July, 1989; returned to lake to over-winter, then returned to tagging location in May, 1990	2228	F (5)

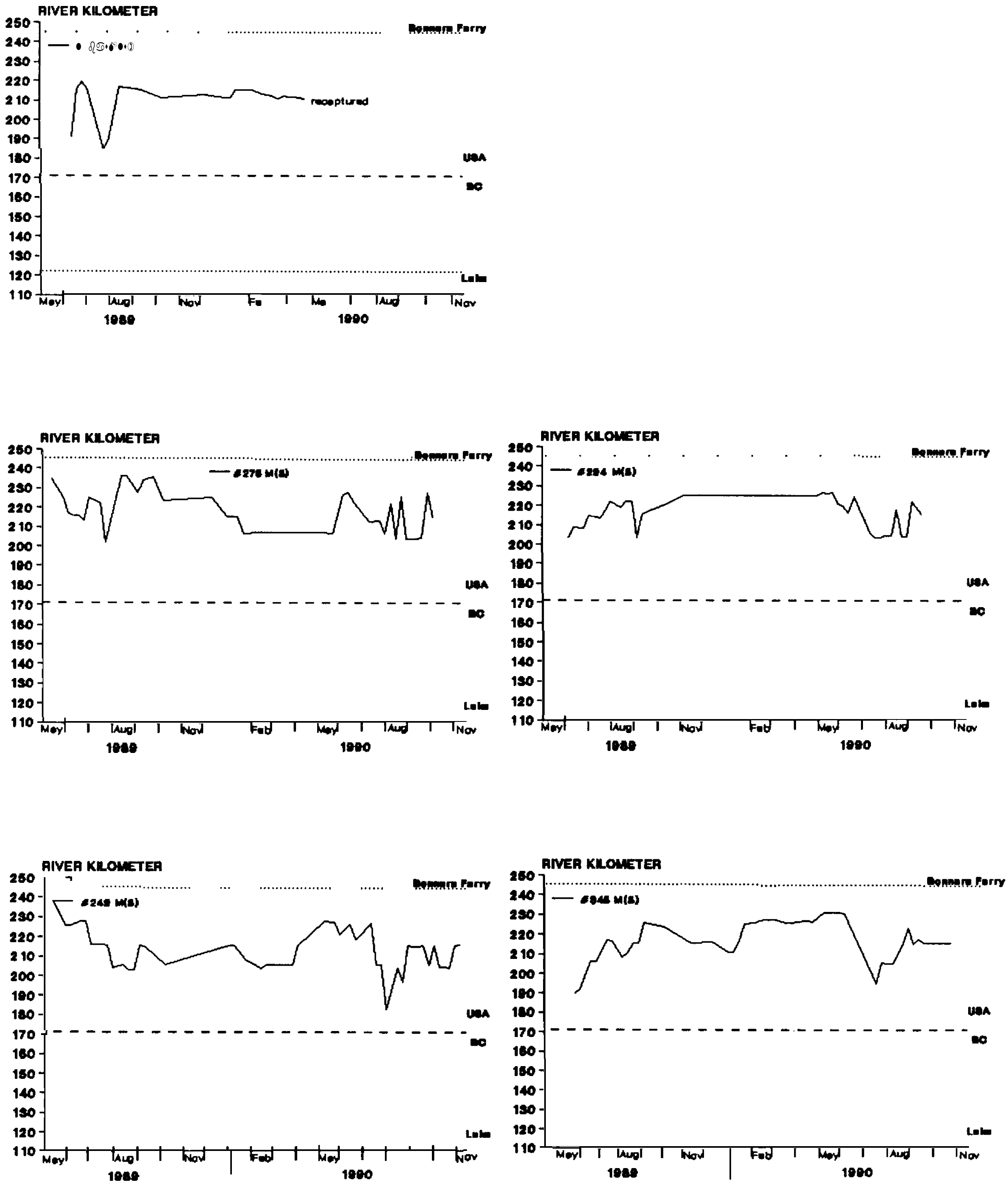


Figure 11. Locations of male white sturgeon exhibiting seasonal movement Pattern I, Kootenai River, 1989 to 1990.

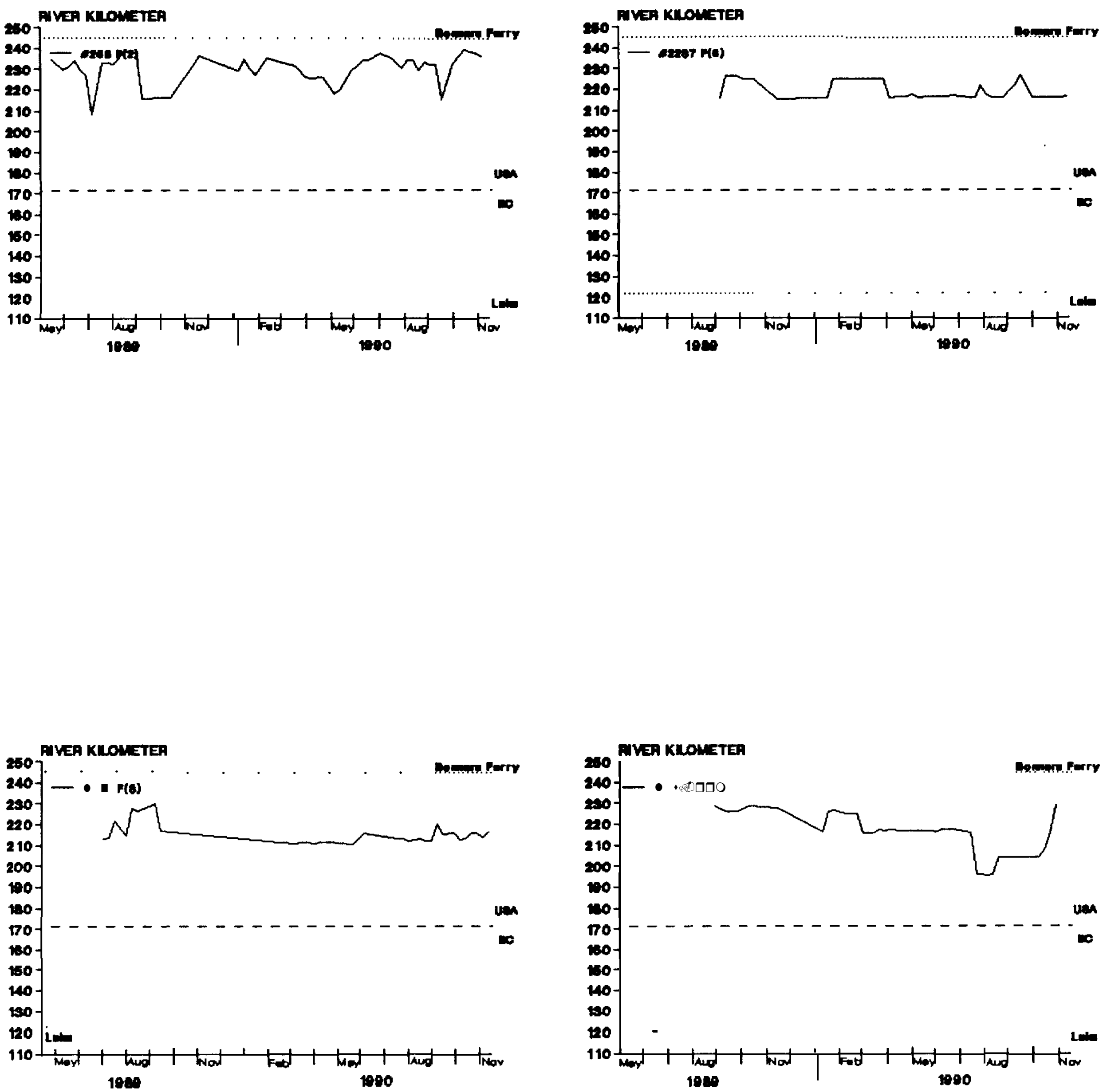


Figure 12. Locations of female white sturgeon exhibiting seasonal movement Pattern I, Kootenai River, 1989 to 1990.

Pattern II-A second pattern was **characterized by** sudden downstream movement of three females, all in early reproductive stages, and one male during late summer, 1989 (Figure 13). Two of these sturgeon remained at the south end of Kootenay Lake through 1990; the third female (one that may have recently spawned) was last located in the lake, disappearing presumably into the lake in September 1989. The male disappeared from the lower river in July, 1990.

Pattern III-Three sturgeon initially captured in the lower 35 km of the river, moved upstream into Idaho during summer 1989 and remained until late summer 1990, when two of the fish suddenly moved to the lake (Figure 14). One of these fish was a late vitellogenic female, the other a reproductive male. The third fish, a sturgeon of unknown sex (perhaps a non-vitellogenic female), was not located after June 1990.

Pattern IV-One male and one ripe female moved from Idaho to Kootenay Lake during autumn 1989, overwintered, then moved back upstream (Figure 15). The male was not actually located throughout the winter and we assumed he **travelled** into the lake. The female remained near the Rock Creek Hole through the latter part of 1990. the male made a fast migration back to the lake in late summer 1990.

Pattern V-One female that appeared spent exhibited a very abrupt migration from Idaho to the lake and back upriver during summer 1989 (Figure 16). The fish spent the remainder of the summer in Idaho, returned to the lake for winter, then returned upriver in spring 1990, and except for a **quick** trip downriver and back upriver, remained in Idaho.

A ripe male and a late vitellogenic female transmittered during spring 1990 both moved down to the lake by August and remained (Figure 17). A late vitellogenic female that was released from the net pen in late June also moved to the lake by August. An early vitellogenic female **was** transmittered near the lake in late September and remained through October. The female we attempted to spawn, but failed, was transmittered and released from the pen in late June. She moved directly to the lake, and her transmitter location remained in an unusual area approximately 10 km north of the south shore at a depth of 40 **m.** We believe this sturgeon died, as she **was** very stressed from our handling. The last sturgeon, a late vitellogenic female, was transmittered on November 1 at Rock Creek **(rkm** 215).

Point to Point Movement (Recaptures)

Recaptures of 45 fish provided information regarding gross movements and ranges of sturgeon. Five reproductive males were recovered from April through June 1990 in the section of river suspected of being a spawning area, having moved upstream since initial captures the previous summer (Figure 18). Two late vitellogenic females were recovered in June and September 1990 demonstrating similar upstream movements. Twice as many males as females were recaptured. The most dramatic of the movements was a 135 cm FL male that moved 73 km downstream in 10 days in late September-early October.

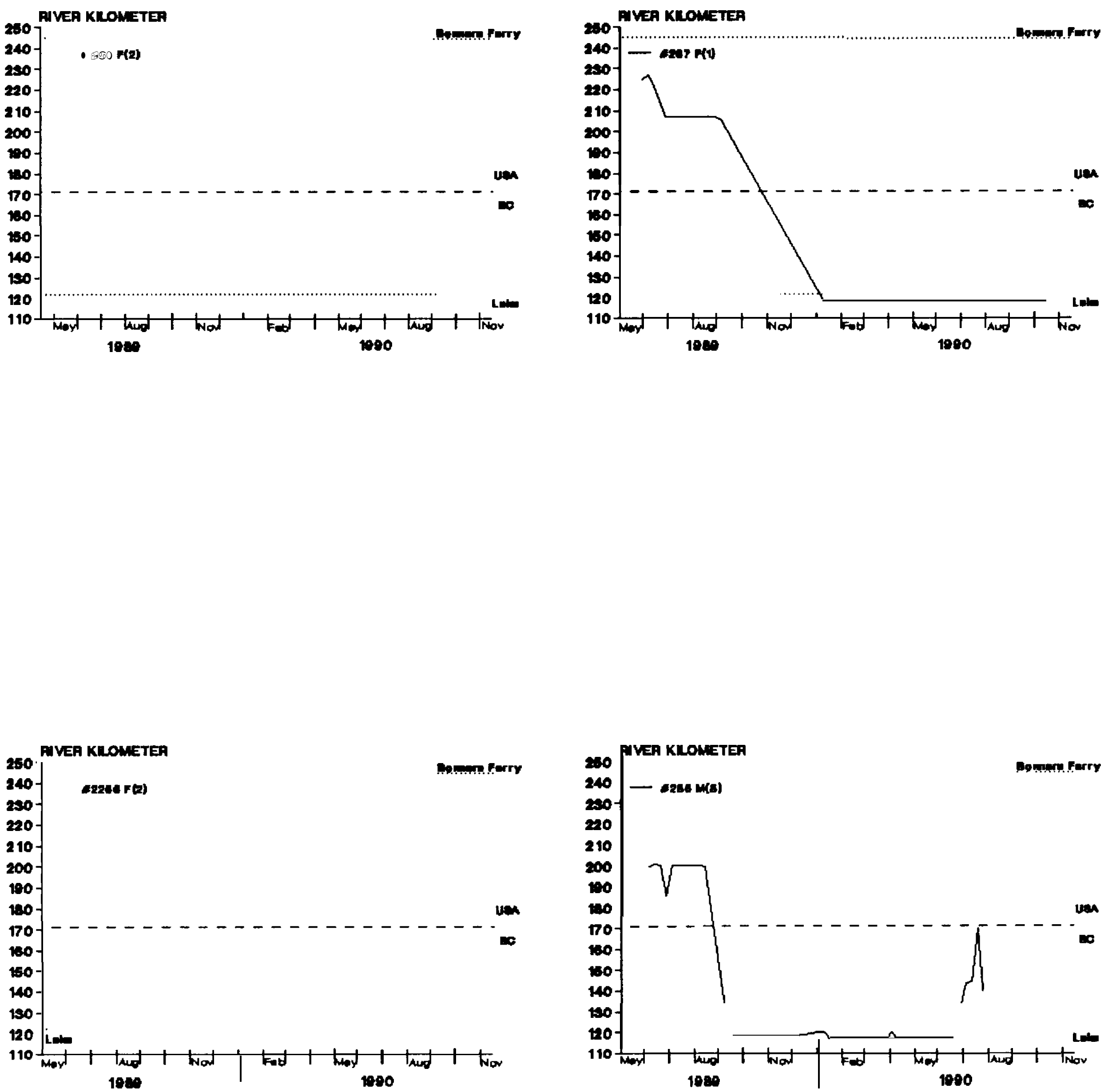


Figure 13. Locations of white sturgeon exhibiting seasonal movement Pattern II, Kootenai River, 1989 to 1990.

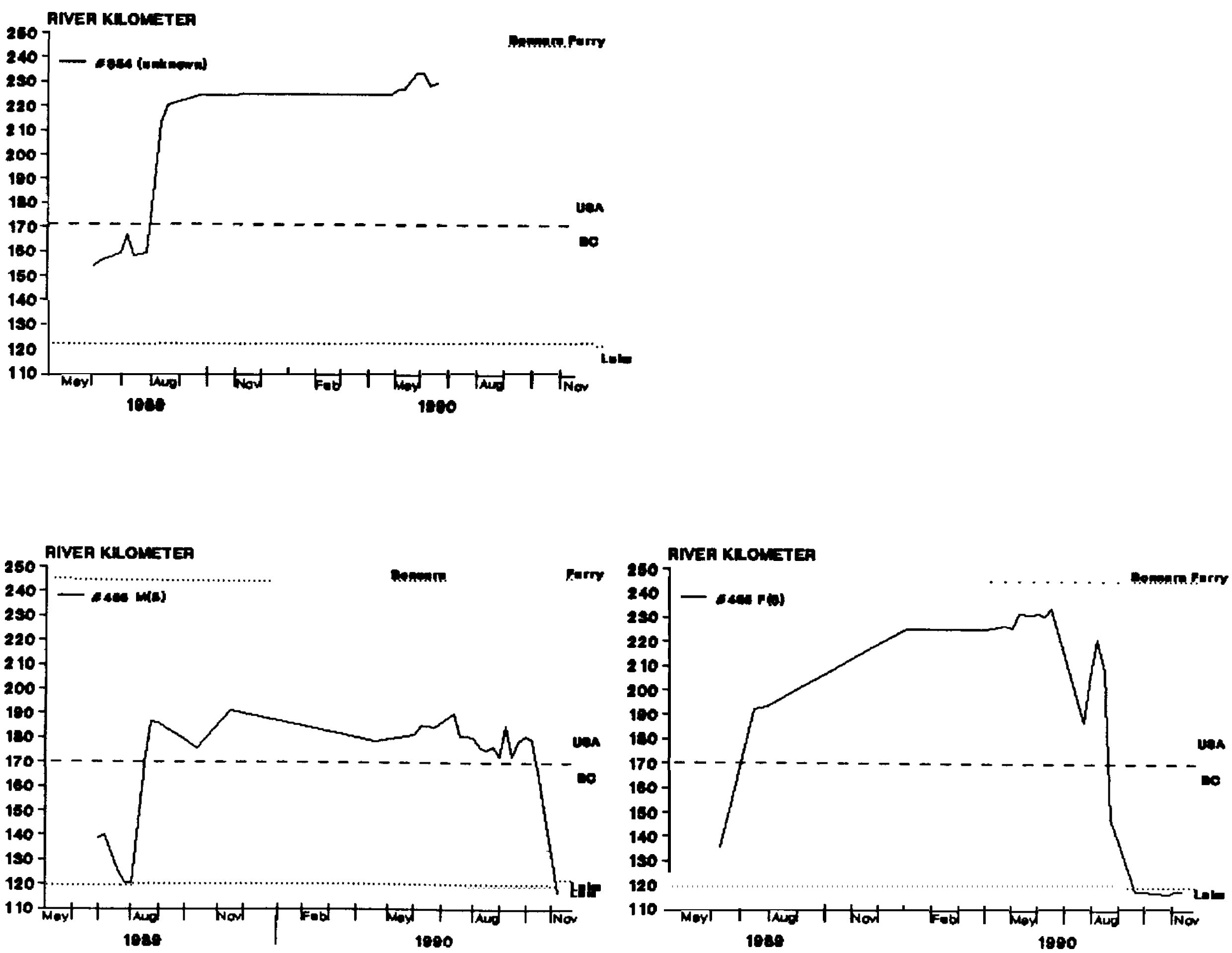
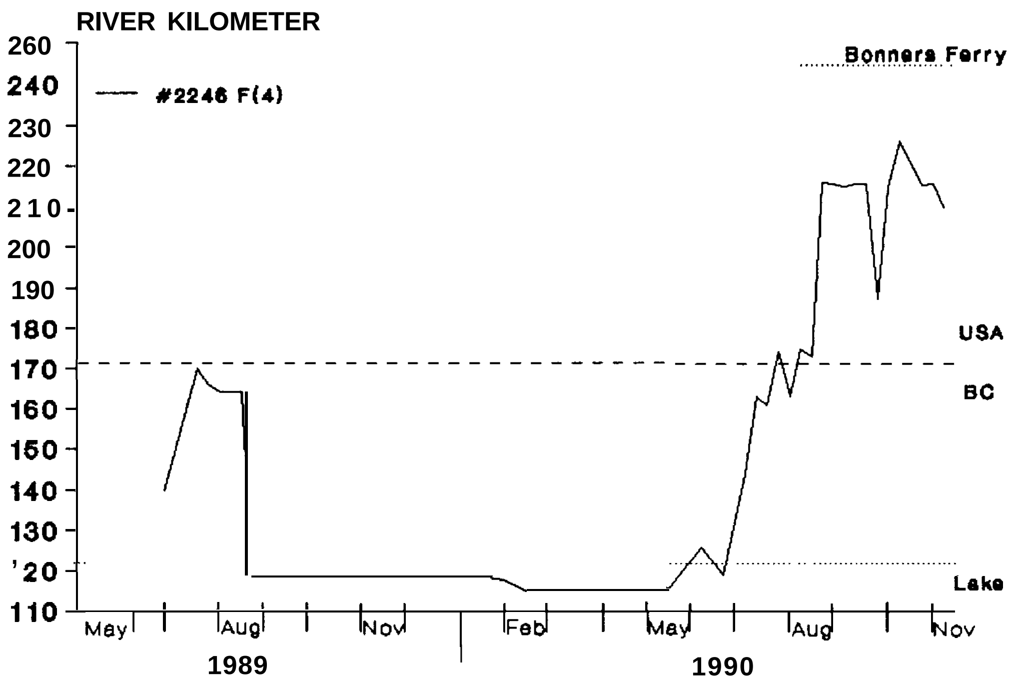


Figure 14. Locations of white sturgeon exhibiting seasonal movement Pattern III, Kootenai River, 1989 to 1990.



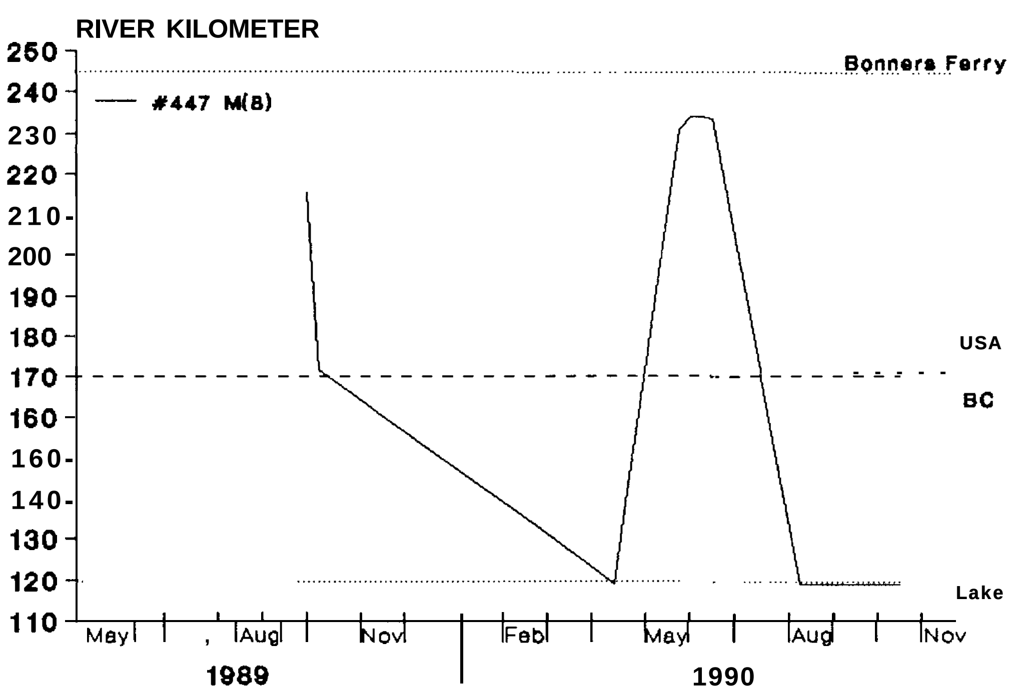


Figure 15. Locations of white sturgeon exhibiting seasonal movement Pattern IV, Kootenai River, 1989 to 1990.

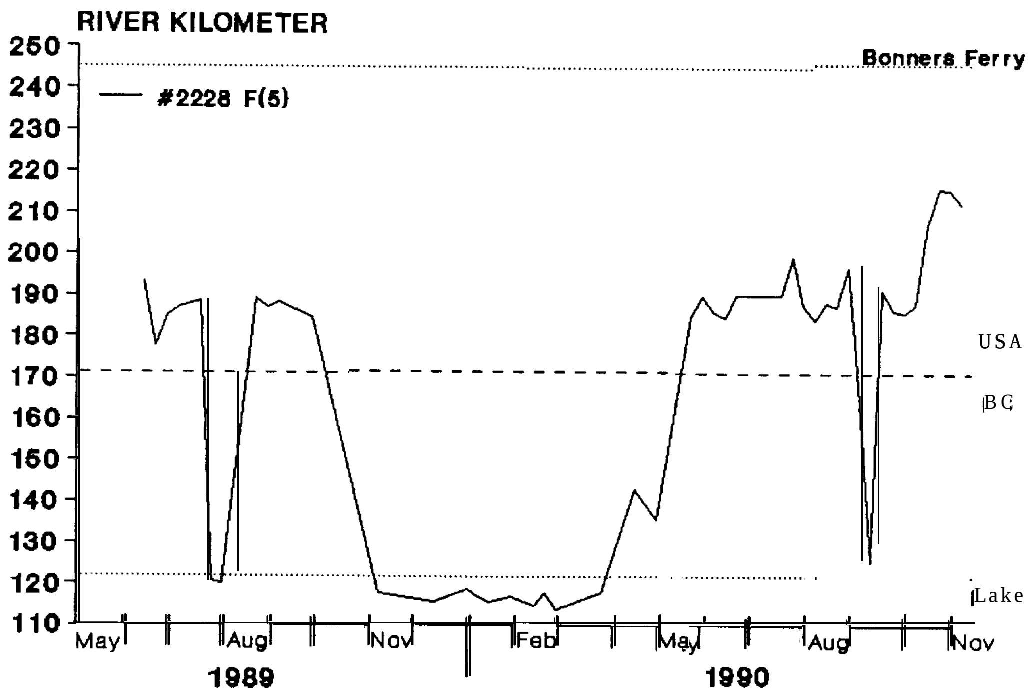


Figure 16. Locations of the white sturgeon exhibiting seasonal movement Pattern V, Kootenai River, 1989 to 1990.

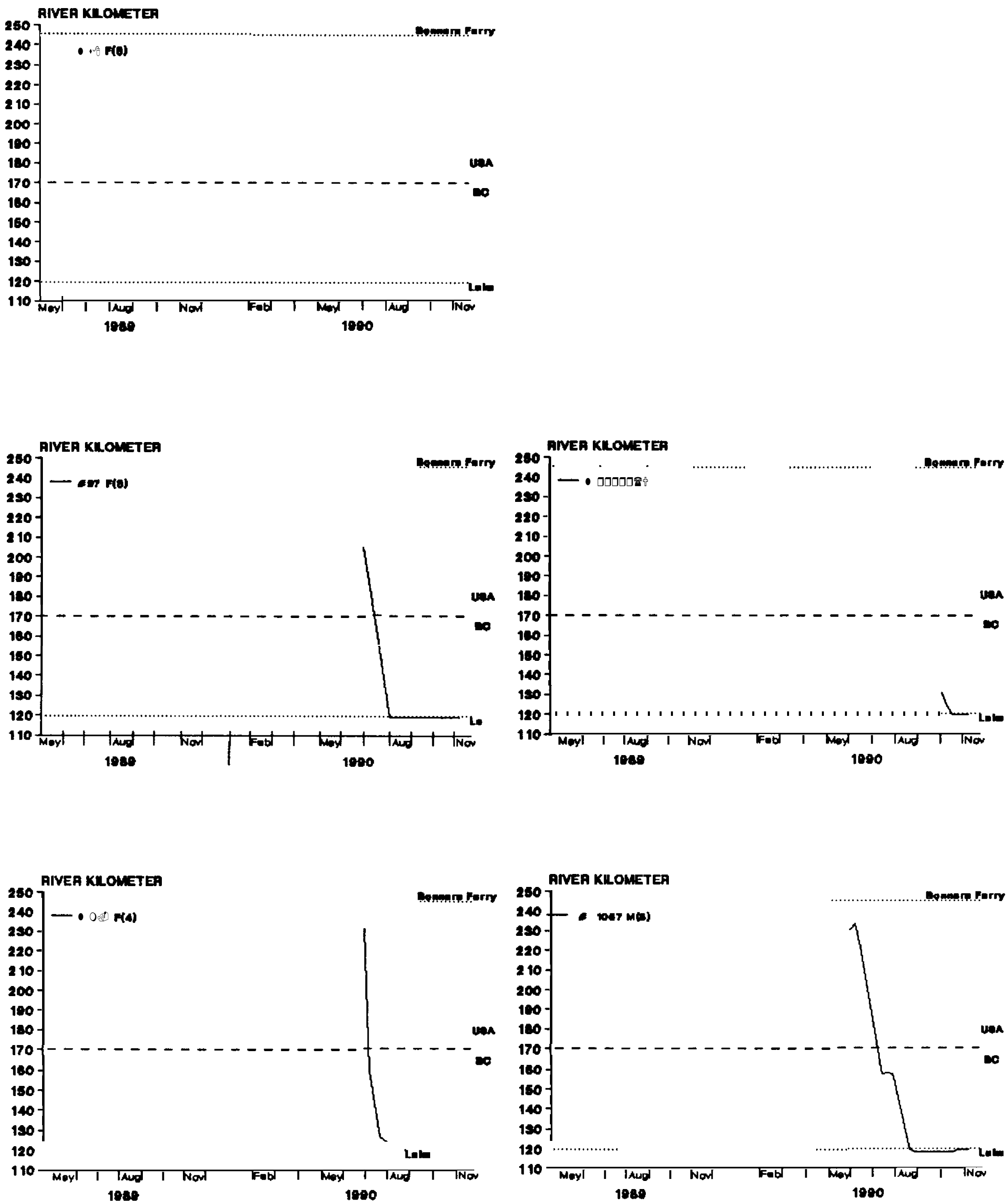


Figure 17. Movement of white sturgeon tagged with sonic transmitters in the Kootenai River during 1990.

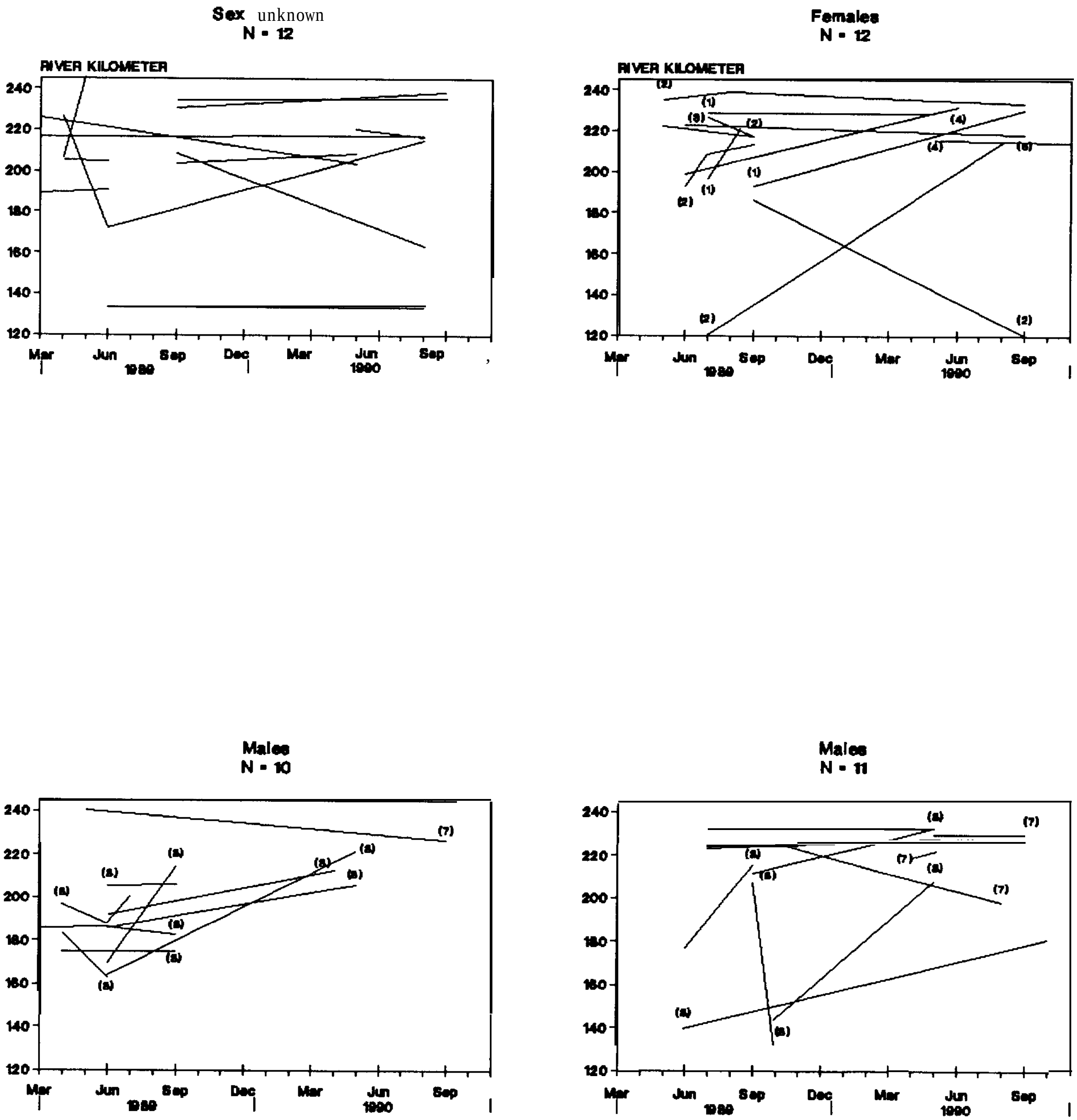


Figure 18. Movements of recaptured white sturgeon in the Kootenai River, 1989 to 1990. Reproductive stages appear in parentheses.

DISCUSSION

Population Structure and Reproductive Potential

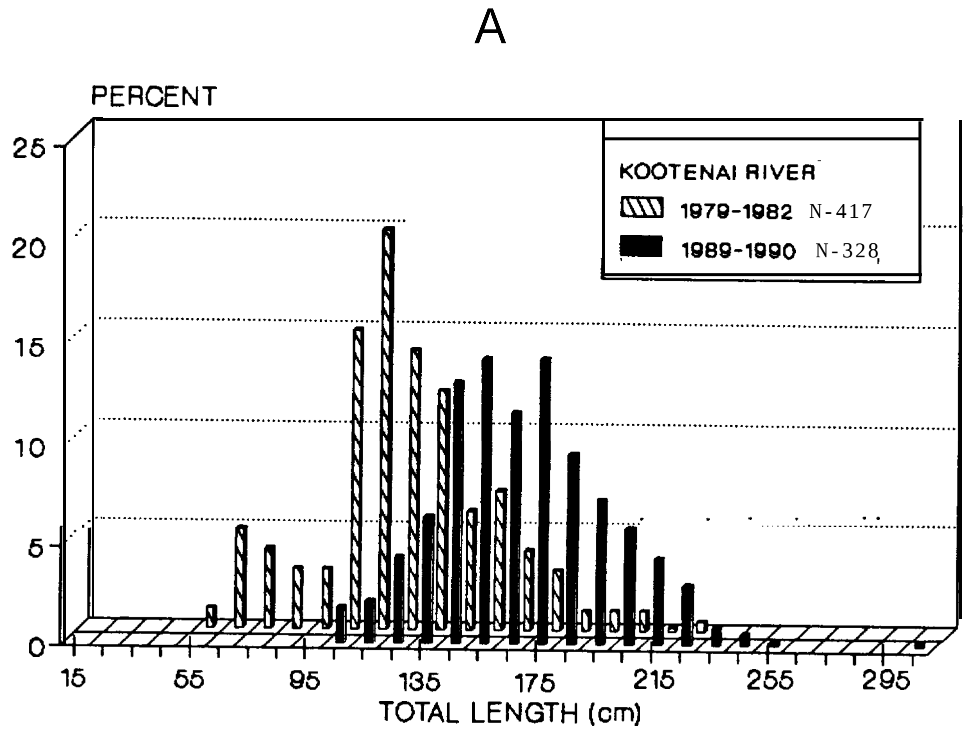
Except for a 40-cm shift toward larger fish, the pattern of the past and present length frequencies of sturgeon in the Kootenai River are very similar (Figure 19a). Lengths of 417 white sturgeon sampled from the Kootenai River in 1980 through 1982 ranged from 50 cm TL to 224 cm TL, with a mean TL of 122 cm (Partridge 1983). It appears from this and from growth rate data that the same individuals sampled 10 years ago have grown, with virtually no recruitment of juveniles into the population. We believe that our sample accurately represented the population. Recruitment of white sturgeon to setline gear has been evaluated by the Oregon Department of Fish and Wildlife in the lower Columbia River (Beamsderfer et al. 1989). Gear identical to ours fully recruited white sturgeon >90 cm FL and did catch fish as small as 50 cm with all hook sizes (Figure 19b). Though we did not capture white sturgeon smaller than 94 cm FL, we did hook many squawfish, especially on 10/O and 12/O circle hooks.

A comparison of Partridge's (1983) population estimate (1,194 sturgeon with 95% confidence intervals of 907 to 1,503) with our estimate would indicate an overall annual mortality rate of 0.03 for adult sturgeon. We do acknowledge that past and present estimates are not directly comparable because Partridge did not sample in British Columbia, and we found substantial movement of sturgeon between Canadian and U.S. sections of the river. Also, unknown rates of sturgeon movement into and from Kootenay Lake may **have** biased our population estimate. Regardless of discrepancies between the samples, it is apparent that without immediate steps toward producing new year classes, the Kootenai population of white sturgeon will become extinct. Approximately 80% of the population is over 20 years old and is reproductively mature. It is imperative that recruitment of juvenile sturgeon occurs during the next ten years to ensure maintenance of the population. **A** predictive model that focuses on the reproductive potential of the Kootenai sturgeon population will be developed.

The average abundance of seven sturgeon/rkm in the Kootenai River is comparable to the eight sturgeon/rkm of similar-sized fish found in the middle Snake River (Cochnauer 1983). However, in addition to adults, juveniles (60 to 91.5 cm TL) were found in the middle Snake River at an average abundance of 18 sturgeon/rkm. Similarly, in Hells Canyon of the Snake River, 5 sturgeon/rkm were found that were >91.5 cm TL and 20 **sturgeon/rkm** were found that were 46 to 91.5 cm TL (Lukens 1984).

The sex ratio and reproductive potential detected in the Kootenai population are comparable to other populations of white sturgeon. Dr. Serge Doroshov (University of California at Davis, personal communication) noted that consistently 10% of most white sturgeon populations are reproductive at any given time. In both 1989 and 1990, late reproductive females and reproductive males comprised 7% and 30% of the sample, respectively. Discrepancies in overall proportions of sturgeon developmental stages found between years have two likely explanations. Our techniques for identifying early reproductive stages improved with time, and in 1990 we probably sampled a disproportionate number of sturgeon that were reproductively active.

Extensive aging of sturgeon from fin-ray sections has been recently conducted with lower Columbia River fish (Beamsderfer et al. 1989). Fin-ray



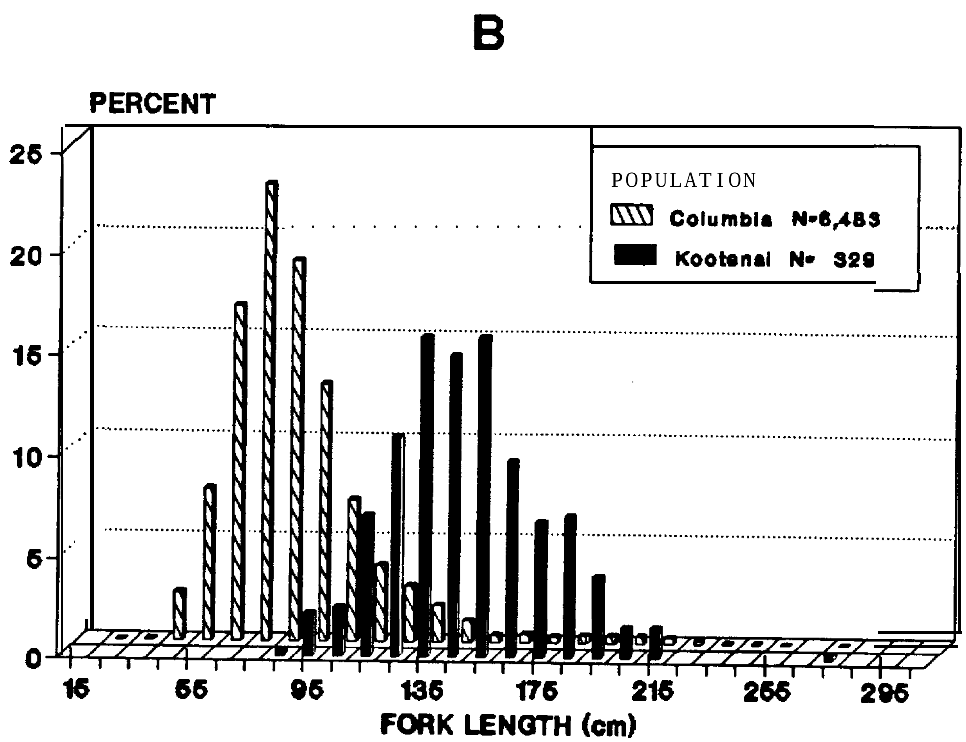


Figure 19. a) **Comparison** of past (Partridge 1983) and current length frequencies of white sturgeon in the Kootenai River.
b) Comparison of current length frequencies of white sturgeon sampled by setline in the Kootenai River and lower Columbia River (Beamsderfer et al. 1990).

sections were read independently by at least two people, and identical ages were assigned 35% to 62% of the time for fish 15 to 25 years of age and declined for older fish. However, most discrepancies were only one or two years. As we recapture fish marked with OTC, we hope to validate our aging techniques, if only to develop degrees of confidence for estimating age within given age groups. Refinement of aging techniques will assist with determination of both mortality rates and ages of reproductive maturity.

Sturgeon Enhancement

Though the 1990 culture efforts produced very few progeny, we did meet our primary objective documenting that Kootenai sturgeon gametes are viable. The conditions we were forced to work with through spawning were very rudimentary and undoubtedly inflicted stress upon the eggs. The brood female was spawned in fairly warm water of 19°C (3°C higher than recommended), had been held in the netpen for six weeks, and ova in one ovary were obviously of poor quality. We may have fertilized Treatment 1 eggs prematurely, before they were fully ovulated, which would explain the higher initial survival of Treatment 2 which was fertilized five hours later. Fertility rates above 80% were considered good (Joel Van Eenennaam, University of California at Davis, personal communication). We lost half of the fry upon hatching. Only 5% hatching mortality typically occurs in white sturgeon culture (Joel Van Eenennaam, University of California at Davis, personal communication); occurring mostly among late hatching eggs. Overall poor egg quality may be blamed. If, under ideal conditions, we can approach success comparable to that of other culture programs, we may de-emphasize the threat to gamete viability from contaminants. After mortalities through hatching, survival through feed initiation was quite good.

Given that the Kootenai white sturgeon is a population with the potential for reproduction, but with an inherent reduced genetic variability (Setter and Brannon 1990), we must exercise caution as supplementation efforts are begun. With the facilities to use gametes from a limited number of brood fish, we must limit the number of offspring stocked into the river. Incorporating mortality rates of various age groups from the Snake River populations (Cochnauer 1983; Lukens 1984), we estimated that an annual stocking of 7,000 to 10,000 yearling sturgeon would be required to maintain the current numbers of adults in the population. Population dynamics modeling exercises will be used to predict responses to varying stocking regimes. The 1990 progeny appeared disease-free, and individuals are growing well. Surviving juveniles may be stocked into the Kootenai River.

Intensive setlining near Shorty's Island in spring of 1990, where we located the concentration of reproductive sturgeon, produced a sample of over three times more males than females. The following sampling pass made throughout the lower river (August through mid-September) produced almost two times more males than females. This may indicate that pre-spawning and post-spawning females are less recruitable to setline gear than nonreproductive females or male sturgeon. It may be advisable to schedule future female broodstock collections for late summer through fall.

We must emphasize that hatchery supplementation of Kootenai River white sturgeon without natural reproduction should not be a goal. Experimental culture will be used to isolate factors currently limiting recruitment and to stock some sturgeon to preserve the population. A hatchery program may be unable to maintain the population's genetic diversity because very limited numbers of broodstock can be collected and spawned annually.

We have observed adult movement which may be for reproductive purposes. We recommend increased spring flows to determine if adequate spawning conditions can be provided that may produce some natural recruitment.

Seasonal Movement and Migration

This research identified seasonal movement and migration patterns between different habitats in the Kootenai River system by over half of the tracked sturgeon tagged in 1989. The remaining fish did not migrate. Movements of non-migrants were generally less than 30 km, and appeared random. Because the sturgeon that were tracked exhibited nearly a continuum of distances moved, distinction between seasonal movement and migration may appear somewhat artificial as applied to certain fish. Migration is a difficult concept to define due to the gradations of most parameters that characterize it (McKeown 1984). Migrations occur because reproductive habitats may not be adequate for other activities such as feeding or overwintering; seasonal changes in habitat quality and changes in the internal environment of a fish may also trigger migration. We defined migration as: a class of sustained, unidirectional movement (50 to 115 km) for the purposes of reproduction or overwintering, usually by more that one individual, simultaneously or during the same l- to 3-month period.

A sturgeon migration pattern specific to females in the Kootenai River, supported from an energetic perspective, may be one of vitellogenic females overwintering near areas thought to be used for spawning. Of the eight sturgeon which congregated near Shorty's Island, six overwintered less than 21 km from this area; the seventh was a male which migrated at least 91 km upstream from Kootenay Lake to join this aggregation. The remaining fish was tagged in the spring of 1990, prohibiting collection of overwintering data. Conversely, recently spawned females migrated downriver and overwintered in Kootenay Lake. Females utilized areas of significantly lower current velocity during the winter. The need to recover following the metabolic drains of spawning and migration may explain such behavior by recently spawned females.

Fifty-seven percent of the males tagged in 1989 did not migrate and moved generally less than 30 km, but up to 46 km. Most of these males overwintered in the same general area in Idaho (rkm 200 - 240) as the vitellogenic females which congregated at Shorty's Island for, apparently, spawning related activities. If some observed migrations were for reproduction, 14 months of tracking was probably an insufficient period of time to observe migration of all tagged individuals because they would not all attempt to spawn annually.

All downstream migrations in late summer and fall, ending in Kootenay Lake, appeared to be for overwintering in the lake. At least 36% of sturgeon tracked through the winter of 1989 overwintered in Kootenay Lake following downriver migrations of 50 to 105 km. Only one male, however, made an upriver migration back to his initial location in the following spring, presumably to spawn.

Factors Affecting Sturgeon Movement

Month of the year, sex and total length of sturgeon, water temperature, river flow, and change in river flow were poor predictors of the movement and migration of sturgeon tagged with sonic transmitters. These variables, individually and collectively, did not statistically explain observed sturgeon movement and migration during 1989 and 1990 in the Kootenai River. Bajkov (1951) and Haynes and Gray (1981) suggested that sturgeon movements may be related to feeding. Haynes et al. (1978) reported that long distance sturgeon movements in the mid-Columbia River were related to temperature. Haynes and Gray (1981) noted complete cessation of sturgeon movement >0.5 km in autumn, which they felt was related to cold temperatures; movements >2 km all occurred at temperatures above 13°C. Sturgeon movement in the Kootenai River was not as severely curtailed by cold water temperatures during the winter. Six fish moved from 7.7 to 12.1 km during January and February in temperatures of 2°C to 4°C. One-third of this movement involved travel between Rock Creek and Fleming Creek holes in Idaho; areas highly utilized for overwintering.

As with sturgeon movement in the Kootenay River, Haynes and Gray (1981) reported that linear regression analyses comparing distances sturgeon moved in the mid-Columbia River with river flows produced scatter diagrams with regression coefficients approaching zero. They suggested the complex interaction of water temperature, feeding, urge to spawn, and other factors influence sturgeon movements in the mid-Columbia River. The large variability of sturgeon movement and the lack of a relationship between and among measured variables (month, sex, total length of fish, temperature, flow, flow change, and sturgeon movement) leads us to suggest that additional unmeasured biotic and abiotic factors may have influenced sturgeon movement. An alternate explanation may be that qualitative, quantitative, and temporal changes in biotic and abiotic conditions in the Kootenai River system, caused by the operation of Libby Dam, eliminated these measured variables as predictors of sturgeon movement. These variables, in their natural pre-dam coexistence, may have been able to predict sturgeon movement to a larger extent.

Another explanation of our observations may be that white sturgeon in the Kootenai River system are opportunistic in terms of habitat use, and that their movements (with the possible exceptions of specific feeding, overwintering, or reproductive migrations) may not be highly correlated with one or many biotic or abiotic environmental variables.

We will continue to monitor sturgeon in the Kootenai River with regard to habitat utilization and seasonal movements. Additional data and more extensive analyses will hopefully clarify how environmental factors may influence the health of this population.

No transmittered sturgeon moved upriver farther than Deep Creek (rkm 240); however, we know that some migration occurs between the more typical sturgeon habitat downstream from Bonners Ferry and higher gradient waters upstream into Montana. Two sturgeon tagged in Montana (rkm 311) in 1978 were recaptured by anglers near Bonners Ferry (rkm 246) in the spring of 1980 (Graham 1981). A sturgeon (approximately 120 cm) was illegally harvested in 1990 from the lower Yaak River, very near the confluence with the Kootenai River. We believe limited habitat exists for white sturgeon upriver from Bonners Ferry. We know that limited sampling opportunity exists throughout that section of river because of the high gradient.

Spawning-Related Behavior

Seven transmittered sturgeon moved from 5 km to 104 km upstream, congregating in an 8-km stretch of the river near Shorty's Island (rkm 227-235) throughout June 1990. This area was not commonly used by sturgeon during any other time of the year. We intensified broodstock collection efforts in that area, assuming fish were congregated for spawning, and sampled two ripe males and three late vitellogenic females. By mid-July, all except one transmittered fish had moved out of the area, most of them moving downriver 15 to 76 km. Timing of this migration and aggregation of reproductive sturgeon coincided with an increase in discharge in the lower river from approximately 700 to 1,150 m^3/s and an increase in water temperature from 8°C to 14°C.

Typically, the operation of Libby Dam drastically alters seasonal downriver discharge by storing natural spring runoff, providing more constant flows throughout the year, and providing late summer power peaking flows (Figure 20). Spring discharge in the lower river in 1990 was atypical for the post-Libby Dam period (Figure 5). Increasing and high flows coincided with increasing temperature through June 1990, instead of discharge declining through late spring as occurred in 1989 and most prior years under normal dam operation. The river channel at Shorty's Island was constricted and had slightly increased velocities approaching 0.6 m/s toward the lower end of ranges of sturgeon spawning velocities found in the lower Columbia. Mean water column velocities measured in sturgeon spawning areas below the lower three Columbia River dams ranged from 0.4 to 2.6 m/s (Nigro in preparation). Sturgeon in the lower Columbia River key into increasing discharge with increasing temperature for spawning.

Unfortunately, trawl efforts did not detect any sturgeon eggs. Sampling occurred during the last week in June when sturgeon began dispersing from the Shorty's Island area, and gear used may not have been able to recruit eggs and larvae at such low velocities. Therefore, if sturgeon were attempting to spawn in the lower Kootenai, we may not expect to detect it with the trawl.

Diel Movement

Based on die1 movement data recorded from six fish for 24 hours at hourly intervals during the summer, sturgeon appear to inhabit water deeper than 12 m when remaining relatively sedentary, while fish found in shallower water generally exhibited more sustained and extensive movements. Coon et al. (1977) recorded locations of two sturgeon (220 cm TL) equipped with sonic transmitters at approximately 2-hour intervals in the mid-Snake River between August 20 and 22, 1973. One of these fish moved only within a large eddy directly downstream of its release site. During both days and nights, this fish moved primarily into the shallower upstream end of the hole, and near daylight both days, it appeared to settle back near the area of maximum depth. However, during no 2-hour period did this fish appear to remain completely motionless. The second fish exhibited similar movements in a different eddy after moving downstream through a short rapids following its release. The locations of six sturgeon recorded hourly for 24-hour periods in the Kootenai River also suggests that these fish rarely remained completely motionless. Four of these fish also moved only within the holes of their initial location.

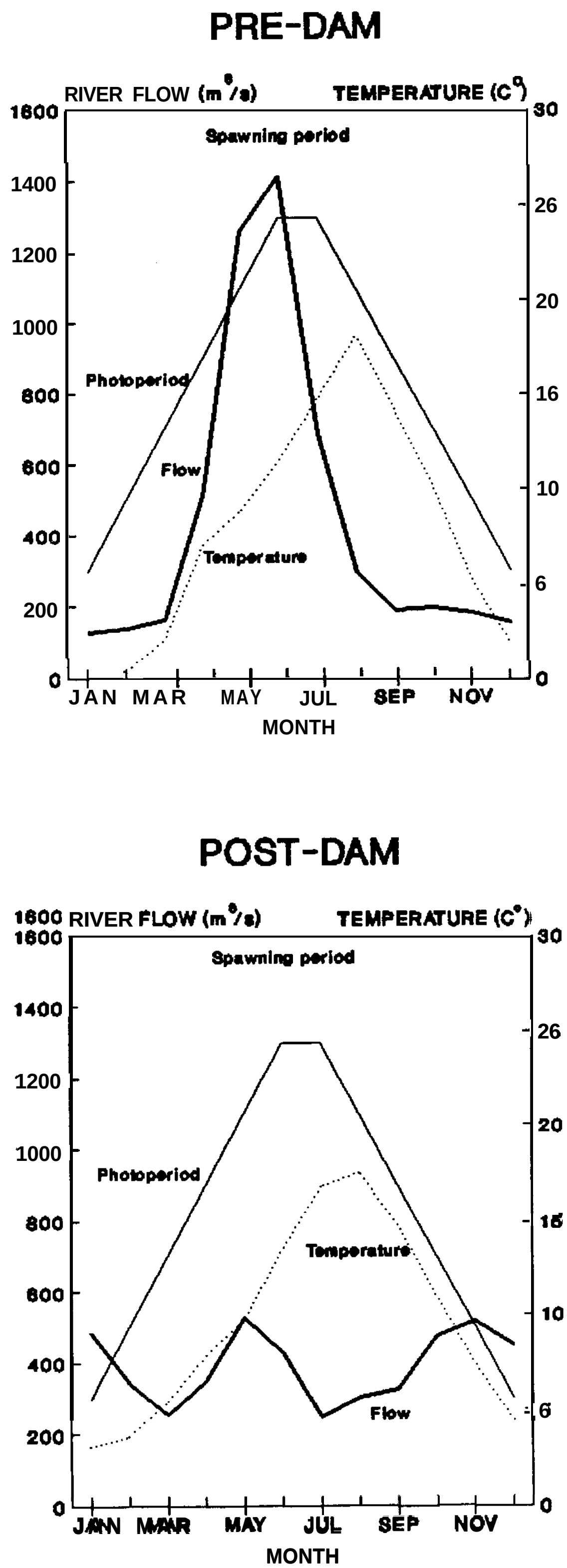


Figure 20. Mean monthly flow, water temperature, and photoperiod values in the Kootenai River at Porthill, Idaho before and after the operation of Libby Dam.

Haynes and Gray (1981) reported that die1 movements of sturgeon may be influenced by the light cycle and by feeding requirements. We observed no such die1 patterns of movement with respect to orientation in the river channel (ie., inshore versus offshore).

Contaminants

Concentrations of copper found in sturgeon oocytes potentially present the most severe contaminant effect on reproductive success. Water copper levels of only 9 µg/l appeared to inhibit yolk uptake in larval white sturgeon (Joel Van Eenennaam, University of California at Davis, personal communication). Copper levels in the Kootenai River at Porthill ranged from 2 to 12 µg/l (1983-1986, USGS records).

Nothing is known regarding the toxicity of zinc to white sturgeon. Current water quality criteria to protect freshwater aquatic life is 47 µg/l as a 24-hour average (U.S. Environmental Protection Agency 1984). Concentrations of dissolved zinc in the Kootenai River at Porthill ranged from 9 to 19 µg/l from 1983 through 1986.

Levels of DDT complex residues in Kootenai River white sturgeon oocytes were generally higher than levels found to damage rainbow trout Oncorhvnchus mykiss (Hogan and Brauhn 1975). Levels of PCBs were relatively low in the 1989 samples and were absent from the eggs used in culture. Rainbow trout eggs contaminated with 0.090 µg/g of a DDT complex and 2.70 µg/g of PCBs (as Aroclor 1242) resulted in 60-70% of the fry developing deformities and 75% cumulative mortality 25 days after hatching. Concentrations of organochlorides required to affect white sturgeon reproduction and egg and fry survival are not known, and scant information is available regarding contaminant levels in other populations of white sturgeon. Successful reproduction does occur in the lower Columbia River where ova samples from two sturgeon contained 0.16 and 0.45 µg/g PCB (as Aroclor 1254), 0 and 0.47 µg/g DDT, 0 and 0.71 µg/g DDD, and 0.07 and 1.75 µg/g DDE (Bosley and Gately 1981). Those levels generally spanned the range of concentrations found in Kootenai River sturgeon. Organochlorides will accumulate in tissues with high lipid content; therefore, reproductive organs will have higher concentrations than skeletal muscle. A concentration of PCB (as Aroclor 1260) in water of 0.002 µg/l resulted in a tissue residue in fathead minnow Pimephales promelas of 0.5 µg/kg (Nebeker 1976). More highly chlorinated PCB mixtures are bio-accumulated in lipids of fish than the lower chlorinated compounds (i.e. PCB as Aroclor 1260 is more chlorinated than Aroclor 1242). Water concentration of 1.8 µg/l PCB (Aroclor 1254) caused a 50% reduction in fathead minnow reproduction.

Additional analyses of contaminants in eggs of known viable populations of white sturgeon have been arranged and may help identify tolerance levels for egg and gamete viabilities.

RECOMMENDATIONS

1. Experimental culture of Kootenai sturgeon should be continued. If successful, 7,000 (and no more than 10,000) age 0 to age 1 offspring from Kootenai River broodstock should be released into the Kootenai River in 1992 to provide some artificial recruitment and year classes until natural recruitment is reestablished. Such limitation should provide protection to existing genetics. All hatchery offspring should be permanently marked with a PIT tag for individual identification.

2. Effects of regulated discharge on sturgeon spawning behavior and success should be evaluated. Increased spring flows of approximately 1,000 m^3/s should be released from Libby Dam, timed with natural flows to evaluate the effects of river discharge on spawning success, embryo survival, and ultimately, juvenile recruitment.

3. We recommend that broodstock collection be conducted during late summer, and that adults be held through winter at the experimental facility. Mature female sturgeon were captured less frequently relative to males during spring than other seasons.

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John Siple, project hatchery manager, supervised the experimental culture operation and provided survival and growth information on the 1990 year class of sturgeon.

Sturgeon culture would not have been possible without assistance from Terry Patterson of CSI. Terry provided expertise before and during the spawning operation, and he was responsible for rearing the 1990 progeny at CSI.

We thank Lance Beckman, U.S. Fish and Wildlife Service, for volunteering his crew and equipment to conduct egg and larvae trawling in the Kootenai River.

Mr. Ray Henthorn and Ms. Billy Krause were gracious enough to allow us access through their lands to tend the net pen and carry out spawning activities.

Technical assistance, as well as the velocity meter and turbidimeter, were provided by Al Scholz of Eastern Washington University.

Am Test, Inc. of Redmond, Washington analyzed contaminant content of samples.

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APPENDICES

Appendix A. Effort and catch of white sturgeon by river ki ometers and dates sampled, Kootenai River, 989 and 990.

River km	Pass 1 Effort (h)[2]	Pass 1 Catch (#)	Pass 2 Effort (h)	Pass 2 Catch (#)	Pass 3 Effort (h)	Pass 3 Catch (#)	Pass 4 Effort (h)	Pass 4 Catch (#)	Pass 5 Effort (h)	Pass 5 Catch (#)	Effort (h)	Catch (#)	Effort (h)	Catch (#)
120-129	71.8	0	144 5	7	476.1	1	659.5	9	0	0	514.5	20	423.7	7
130-139	60.0	1	212.0	9	110.0	2	535.0	1	0	0	411.0	9	343.5	3
140-149	59.5	1	166.0	7	88.0	0	505.0	1	0	0	449.5	4	370.0	2
150-159	200	0	245 5	6	161.5	1	640.0	0	0	0	233.5	1	550	0
160-169	0	0	219.0	5	167.5	1	375.5	0	0	0	430.5	5	0	0
170-179	17.0	1	239.5	4	65.5	0	41 .0	3	0	0	380	1	397.5	2
180-189	747.4	0	320.0	9	267.7	4	235.5	4	0	0	467 0	4	226.0	2
190-199	145.2	2	492.0	19	232.0	7	275.8	2	0	0	416.5	3	287.0	1
200-209	270.2	7	463.7	13	184.5	7	587.5	5	356.3	2	385.0	4	398.2	0
210-219	183.0	3	406.6	4	173.2	9	534.6	7	819.0	4	387.0	6	864.5	1
220-229	60.2	2	509.7	15	209.1	0	441.5	0	1,211.2	1	411.5	6	166.5	3
230-239	74.8	0	458.8	14	117.0	3	296.0	1	1,604.0	25	502.0	6	0	0
240-249	45.1	4	70.0	0	144.8	1	142.5	0	330.0	3	399.0	1	0	0

	Dates of Sampling	Purpose
Pass 1:	March 13 to May 1, 1989	Population estimate
Pass 2:	May 16 to June 3, 1989	Population estimate
Pass 3:	July 12 to August 3, 1989	Population estimate
Pass 4:	September 1 to October 2, 1989	Population estimate
Pass 5:	April 10 to June 14, 1990	Broodstock collection
Pass 6:	July 27 to September 14, 1990	Population estimate
Pass 7:	September 26 to November 5, 1990	Population estimate (aborted)

2 One hour = one setline with six hooks fishing for one hour.

Appendix B. Specific information regarding white sturgeon held for culture activities, Kootenai River, 1990.

Sturgeon ID		Size			Capture information		Sex	Treatment
Floy tag	PIT tag	FL (cm)	TL (cm)	Weight (kg)	Date	River km		
01090	7F7F402041	211	236	04.5	06/08/90	231.0	F	Biopsy on 6/8; injected with priming dose of 0.84 mg LHRHa at 2335 hr on 6/26; injected with resolving dose of 7.56 mg LHRHa 1135 hr on 6/27; showed signs of stress, could not maintain uprig position; did not ovulate within 48 hours of resolving dose; badl infected with Columnaris; releas on 6/29 with sonic transmitter #555.
01098	7F7F120E1B	141	160	20.7	04/25/90	211.1	M	Recaptured from 1989 with sonic transmitter #366 (removed); biopsies on 4/25, 6/5; no sperm motility in on 6/26; no sperm motility on 7/17 following injection of 0.7 mg LHRHa; released on 7/18.
01111	7F7F0E3261	160	184	40.5	05/17/90	220.5	M	Biopsy on 5/17; good sperm motility on 6/25; injected with 1.21 mg LHRHa on 6/27; used in first spawning attempt and first cryopreservation work; injected with 0.91 mg LHRHa on 7/17, but had very low sperm motility; released on 7/18.
01248[1]	7F7F117D29	150	170	---	04/27/90	216.0	M	Biopsies on 4/27, 6/4; good motility of semen on 6/25; injected with 1.54 mg LHRHa on 7/17; collected 130 cc of concentrated semen on 7/18; only semen used to fertilize eggs of #01290; released 7/20.
01290[1]	7F7F403874	174	199	41.4	05/30/90	231.0	F	Biopsies 5/30, 6/4, 6/25, 6/29; progesterone assay on 6/29: 3.5% GVBD, ova diameter 3.1 mm, ova free from left ovary, right ovar hard; progesterone assay on 7/17 50% GVBD, ova diameter 3.2 mm; initial dose of 0.41 mg LHRHa at 1300 hr on 7/17; resolving dose 3.73 mg LHRHa at 1300 hr on 7/18 ovulation at 2300 hr on 7/18; 50,000 eggs removed; released on 7/20 with sonic transmitter; fou carcass on 8/9 at rkm 134.
01296	7F7F40325A	181	203	---	06/03/90	231.3	F	Biopsies on 6/3, 6/5; egg diamet <3 mm; released on 6/24 with son transmitter # 97.

[1] gametes used in culture

Appendix B. Continued.

Sturgeon ID		Size			Capture information		Sex	Treatment
Floy tag	PIT tag	FL (cm)	TL (cm)	Weight (kg)	Date	River km		
01299	7F7F403525	190	218	47.3	06/14/90	231.1	M	Biopsy on 6/14; semen collected with syringe, but no sperm motility on 6/25; incision badly infected and fish stressed on 7/17; resutured and released on 7/17.
01298	7F7F403845	143	156	24.5	06/08/90	231.3	M	No biopsies, spermiating male with good sperm motility on 6/25; injected with 0.76 mg LHRHa on 6/27; sperm used in cryopreservation work; injected with 0.76 mg LHRHa on 7/17, but no sperm present: released 7/18.

Appendix C. White sturgeon seasonal focal point velocity (m/s) utilization in the Kootenai River system, Idaho and British Columbia, July 6, 1989 to July 24, 1990.

	Range	Mean	SD	(N)	df	t-statistic	significance
				Winter			
Male	0.0-0.54	0.26	0.24	50	100	2.88	0.005**
Female	0.0-0.54	0.14	0.16	54	100	2.88	0.005**
				Spring			
Male	0.0-0.42	0.25	0.16	43	112	1.14	0.256
Female	0.0-0.56	0.22	0.15	71	112	1.14	0.256
				Summer			
Male	0.0-0.51	0.25	0.11	65	120	2.57	0.012*
Female	0.05-0.56	0.20	0.11	57	120	2.57	0.012*
				Fall			
Female	0.0-0.27	0.13	0.13	3	8	0.30	0.773
Male	0.0-0.2	0.10	0.12	7	8	0.30	0.773

** Significant at $P \leq 0.01$ level.
* Significant at $P \leq 0.05$ level.

Appendix D. Female sturgeon seasonal focal point velocity (m/s) utilization in the Kootenai River, Idaho and British Columbia, July 6, 1989 to July 24, 1990.

	Winter	Spring	df	t-statistics	significance
Range	0.0-0.54	0.0-0.56			
Mean	0.14	0.22	123	-2.71	0.008**
SD	0.16	0.15			
(N)	54	71			
	Winter	**Summer**	**df**	**t-statistics**	**significance**
Range	0.0-0.54	0.05-0.56			
Mean	0.14	0.20	109	-2.18	0.013*
SD	0.16	0.11			
(N)	54	57			
	Winter	**Fall**	**df**	**t-statistics**	**significance**
Range	0.0-0.54	0.0-0.27			
Mean	0.14	0.10	59	0.59	0.560
SD	0.16	0.12			
(N)	54	7			
	Spring	**Summer**	**df**	**t-statistics**	**significance**
Range	0.0-0.56	0.05-0.56			
Mean	0.22	0.20	126	0.84	0.404
SD	0.15	0.11			
(N)	71	57			
	Spring	**Fall**	**df**	**t-statistics**	**significance**
Range	0.0-0.56	0.0-0.27			
Mean	0.22	0.10	76	1.90	0.061
SD	0.15	0.12			
(N)	71	7			
	Summer	**Fall**	**df**	**t-statistics**	**significance**
Range	0.05-0.56	0.0-0.27			
Mean	0.20	0.10	62	2.16	0.035"
SD	0.11	0.12			
(N)	57	7			

** Significant at $P \leq 0.01$ level.
* Significant at $P \leq 0.05$ level.

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Appendix E. Male sturgeon seasonal focal point velocity (m/s) utilization in the Kootenai River system, Idaho and British Columbia, July 6, 1989 to July 24, 1990.

	Winter	Spring	df	t-statistics	significance
Range	0.0-1.54	0.0-0.49			
Mean	0.26	0.25	91	0.10	0.922
SD	0.24	0.16			
(N)	50	43			

	Winter	Summer	df	t-statistics	significance
Range	0.0-1.54	0.0-0.51			
Mean	0.26	0.25	113	0.24	0.812
SD	0.24	0.11			
(N)	50	65			

	Winter	Fall	df	t-statistics	sicmificance
Range	0.0-1.54	0.0-0.26			
Mean	0.26	0.13	51	0.90	0.374
SD	0.24	0.13			
(N)	50	3			

	Spring	Summer	df	t-statistics	significance
Range	0.0-0.49	0.0-0.51			
Mean	0.25	0.25	106	0.15	0.884
SD	0.16	0.11			
(N)	43	65			

	Spring	Fall	df	t-statistics	significance
Range	0.0-0.57	0.0-0.26			
Mean	0.25	0.13	44	1.28	0.207
SD	0.16	0.13			
(N)	43	3			

	Summer	Fall	df	t-statistics	significance
Range	0.0-0.51	0.0-0.26			
Mean	0.25	0.13	66	1.81	0.074
SD	0.11	0.13			
(N)	65	3			

Appendix F. Male and female white sturgeon seasonal depth utilization (m) in the Kootenai River system, Idaho and British Columbia, June 22, 1989 to July 24, 1990.

	Male	Female	df	t-statistics	significance
		Winter			
Range	6.1-97.6	6.1-100.6			
Mean	21.27	34.93	104	-2.92	0.004**
SD	16.92	29.30			
(N)	52	54			
		Spring			
Range	5.5-94.5	3.1-77.7			
Mean	17.39	18.67	114	-0.40	0.689
SD	15.66	18.51			
(N)	58	58			
		Summer			
Range	3.7-27.4	4.3-97.6			
Mean	10.94	14.30	114	-1.61	0.109
SD	4.23	15.27			
(N)	58	58			
		Fall			
Range	5.4-54.3	5.1-64.0			
Mean	17.03	30.66	17	-1.45	0.164
SD	15.13	24.11			
(N)	9	10			

** Significant at the $P \leq 0.01$ level.

Appendix G. Female sturgeon seasonal depth (m) utilization in the Kootenai River system, Idaho and British Columbia, June 22, 1989 to July 24, 1990.

	Winter	Spring	df	t-statistics	significance
Range	6.1-100.6	3.1-77.7			
Mean	34.93	18.67	110	3.54	0.001**
SD	29.30	18.51			
(N)	54	58			

	Winter	Summer	df	t-statistics	significance
Range	6.1-100.6	4.3-97.6			
Mean	34.93	14.30	110	-4.72	0.000**
SD	29.30	15.27			
(N)	54	58			

	Winter	Fall	df	t-statistics	significance
Range	6.1-100.6	5.1-64.0			
Mean	34.93	30.66	62	0.43	0.666
SD	29.30	24.11			
(N)	54	10			

	Spring	Summer	df	t-statistics	significance
Range	3.1-77.7	4.3-97.6			
Mean	18.67	14.30	114	1.39	0.168
SD	18.51	15.27			
(N)	58	58			

	Spring	Fall	df	t-statistics	significance
Range	3.1-77.7	5.1-64.0			
Mean	18.67	30.66	66	-1.81	0.095
SD	18.51	24.11			
(N)	58	10			

	Summer	Fall	df	t-statistics	significance
Range	4.3-97.6	5.1-64.0			
Mean	14.30	30.66	66	-2.85	0.006**
SD	15.27	24.11			
(N)	58	10			

** Significant at the $P \leq 0.01$ level.
* Significant at the $P \leq 0.05$ level.

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Appendix H. Male white sturgeon seasonal depth (m) utilization in the Kootenai River system, Idaho and British Columbia, June 22, 1989 to July 24, 1990.

	Winter	Spring	df	t-statistics	significance
Range	6.1-97.6	5.5-94.5			
Mean	21.27	17.39	108	1.25	0.214
SD	16.92	15.66			
(N)	52	58			

	Winter	Summer	df	t-statistics	significance
Range	6.1-97.6	3.7-27.4			
Mean	21.27	10.94	108	4.50	0.000**
SD	16.92	4.23			
(N)	52	58			

	Winter	Fall	df	t-statistics	significance
Range	6.1-97.6	5.4-54.3			
Mean	21.27	17.03	59	0.70	0.484
SD	16.92	15.13			
(N)	52	9			

	Spring	Summer	df	t-statistics	significance
Range	5.5-94.5	3.7-27.4			
Mean	17.39	10.94	114	3.03	0.003**
SD	15.66	4.23			
(N)	58	58			

	Spring	Fall	df	t-statistics	significance
Range	3.7-27.4	5.4-54.3			
Mean	10.94	17.03	65	-2.57	0.013
SD	4.23	15.13			
(N)	58	9			

	Summer	Fall	df	t-statistics	significance
Range	5.5-94.5	3.7-27.4			
Mean	17.39	17.03			
SD	15.66	15.13			
(N)	58	9			

** Significant at the $P \leq 0.01$ level.
* Significant at the $P \leq 0.05$ level.

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