KOOTENAI RIVER WHITE STURGEON INVESTIGATION: KOOTENAI RIVER WHITE STURGEON SPAWNING AND RECRUITMENT EVALUATION

Period Covered: January 1, 1998 to December 31, 1998

Annual Progress Report 1998

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KOOTENAI RIVER WHITE STURGEON INVESTIGATION
ANNUAL PROGRESS REPORT

KOOTENAI RIVER WHITE STURGEON SPAWNING AND RECRUITMENT EVALUATION

Period Covered: January 1, 1998 to December 31, 1998

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ABSTRACT

Flows in the Kootenai River for white sturgeon *Acipenser transmontanus* spawning in 1998 were expected to be at a minimum because the snow pack in the basin was only about 79% normal, and local inflow was expected to be very low, <142 m^3/s (5,000 cfs). Flows in the Kootenai River at Bonners Ferry from late April through early May were at about 425 m^3/s (15,000 cfs) while water temperature ranged from about 8 to 10^{o}C (45 to 50^o F). Spawning and incubation flows from Libby Dam began on May 18 when flow at the dam was brought up to 765 m^3/s (27,000 cfs). Unusually frequent rains and several enormous storms brought peak flows at Bonners Ferry to over 1,175 m^3/s (41,500 cfs) on May 27, temperature ranged between 8 and 10.6^{o}C (45 to 51^o F). Flow gradually subsided at Bonners Ferry during June and was steady at 708 to 765 m^3/s (25,000 to 27,000 cfs) while temperature gradually rose to 14.4^{o}C (58^o F). Forty-seven adult white sturgeon were captured with 4,220 hours of angling and setlining effort between March 1 and April 15, 1998 by the Idaho Department of Fish and Game (IDFG). Sonic and radio tags were attached to four female and five male sturgeon during this effort. From April 1 through July 31, 1998, a total of 17 fish were monitored specifically for pre-spawn and spawning activities. White sturgeon spawning location, timing, frequency, and habitat were evaluated by sampling for eggs with artificial substrate mats. Four hundred and eighty-four eggs were collected, 393 eggs (81%) were collected on 60 standard mats, and 91 eggs (19%) were collected on seven experimental mats with drift nets. Ten eggs collected with experimental mats were found mixed with sand, suggesting eggs are moving in the lower water column with sand. The middle Shorty's Island reach (rkm 229.6 - 231.5) produced the most eggs (173) while the Deep Creek section (rkm 237.6 to 240.5) produced 112 eggs. No eggs were collected above the Deep Creek section (>rkm 240.5). Four hundred and twenty (87%) of the 484 white sturgeon eggs collected in 1998 were viable. Development ranged from stage 12 to 28 (1 h to 12 d old), with 95% of the viable eggs at stage 21 (about 2.4 days) or earlier. The oldest egg was estimated at 293 hours old or about 12 days. Based on ages of viable eggs and the dates of egg collection, we estimated that white sturgeon spawned during at least 20 days in 1998. The first spawning episode was estimated to have occurred on May 6. The next episode was estimated to have occurred May 7 with a gap in spawning until May 10. Thereafter, spawning occurred for the next three days with a second break. From May 22, spawning occurred nearly every day through June 6. Peak spawning appeared to occur between from May 23 through May 28. Juvenile sampling yielded 163 individual fish (several fish were recaptured) of which 160 were hatchery and three wild sturgeon recruited from flow test years. Food habit studies of hatchery age-3 sturgeon indicated Chironomids comprised about 36% of the total food items by number while the Ephemeropterans Ephemerellidae and Baetidae contributed 22%. Continuous seismic profiling of a 12-km (7.45 mi) reach of the Kootenai River (rkm 228 - 240) indicated the riverbed was comprised primarily of fine and coarse sand. There was no evidence to suggest pre-dam gravels were overlain with sand. Recommendations for the 1999 spawning season include coordinating the flow test with sturgeon behavior and river temperatures of 8 to 10^0 C (46 - 50^0 F), and discharge should be in increments of 57 m^3/s (2,000 cfs) per day to a minimum of 1,130 m3/s (40,000 cfs) at Bonners Ferry. We also recommend no load following.

OBJECTIVE

Determine environmental requirements for adequate spawning and recruitment of white sturgeon.

STUDY SITE

The Kootenai River originates in Kootenay National Park, British Columbia (BC). The river flows south into Montana and turns northwest at Jennings, the site of Libby Dam, at river kilometer (rkm) 352.4 (Figure 1). Kootenai Falls, 40 km (24.8 mi) below Libby Dam, is thought to be an impassable barrier to sturgeon. As the river flows through the northeast corner of Idaho, there is a gradient transition at Bonners Ferry. Upriver from Bonners Ferry the channel has an average gradient of 0.6 m/km (3.15 ft/mi) and the velocities are often higher than 0.8 m/s (2.6 ft/s). Downriver from Bonners Ferry the river slows with velocities usually less than 0.4 m/s (1.3 ft/s), average gradient is 0.02 m/km (0.1 ft/mi), the channel deepens and the river meanders north through the Kootenai River Valley. The river returns to BC at rkm 170 and enters the South Arm of Kootenay Lake at rkm 120. The river leaves the lake through the West Arm to its confluence with the Columbia River at Castlegar, BC. A natural barrier at Bonnington Falls (now a series of four dams) has isolated the Kootenai River 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 (19,300 mi^2) (Bonde and Bush 1975). Impounding the Kootenai River with Libby Dam reversed the natural hydrograph (Figure 2). However, since 1991 mitigative flows have further changed the hydrograph (Figure 2).

METHODS

Discharge and Water Temperature

Kootenai River discharge and water temperature data at Bonners Ferry and discharge from Libby Dam were obtained from the U. S. Army Corps of Engineers (USACE). The US Fish and Wildlife Service (USFWS) and USACE established operational guidelines for Libby Dam for the 1998 Kootenai River white sturgeon spawning season.

Adult White Sturgeon Sampling

Adult white sturgeon were captured with rod and reel or set lines from March 1, 1998 to April 15, 1998. Sampling was carried out in accordance to methods cited in Paragamian et al. (1996). Adult white sturgeon expected to spawn in 1998 were tagged with radio and sonic tags and monitored to determine movements during the spawning season (Paragamian et al. 1996).

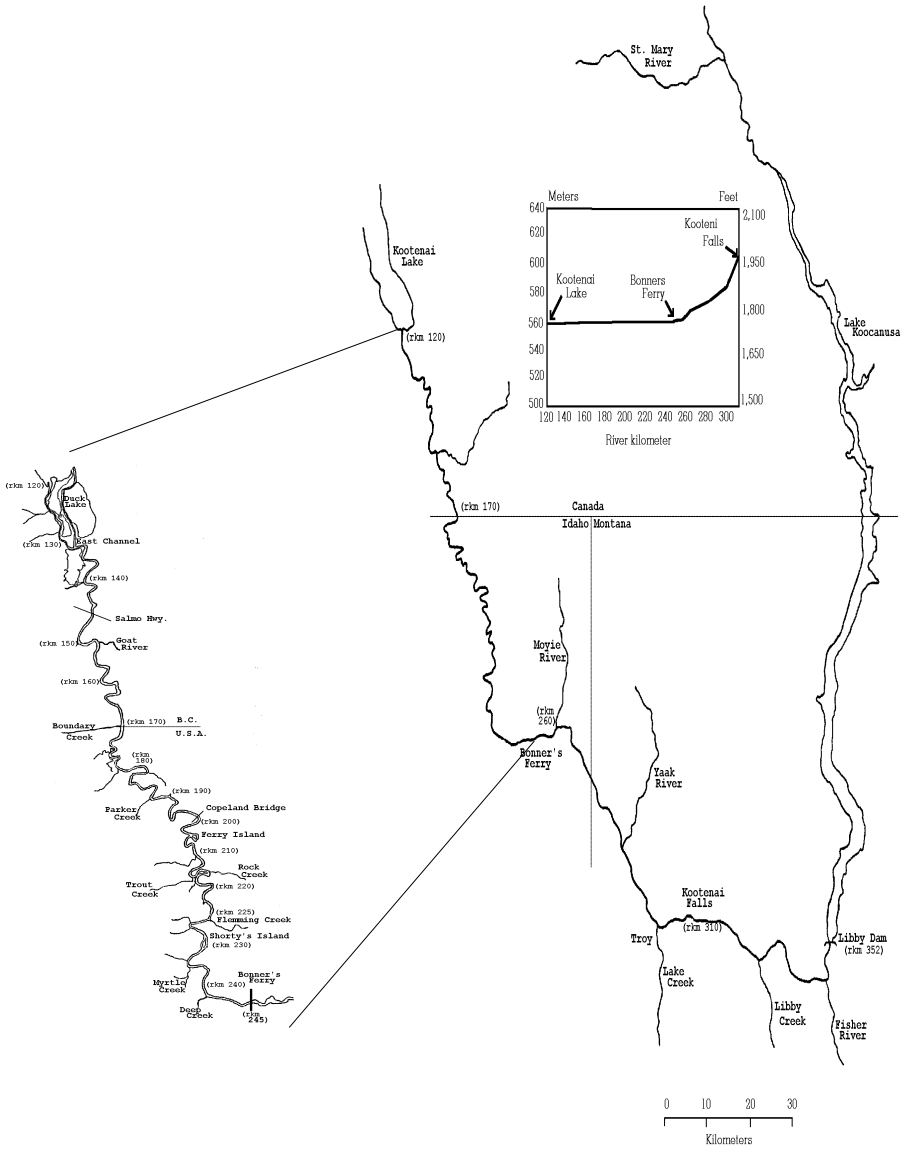


Figure 1. Map of the Kootenai River with a schematic of river reference from Bonners Ferry to Kootenay Lake. Complete study Kootenay Lake upriver to

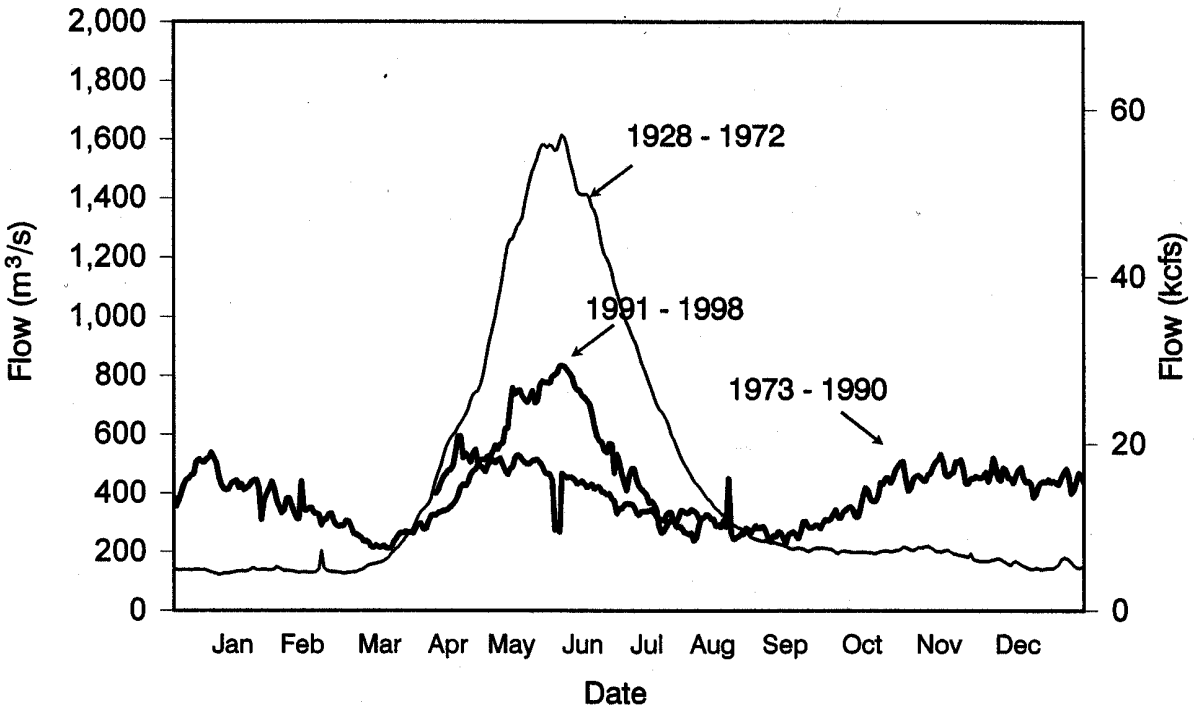


Figure 2. Mean monthly flow patterns in the Kootenai River at Bonners Ferry, Idaho from 1928 through 1972 (pre-Libby Dam), 1973 - 1990 (post-Libby Dam), and 1991 - 1998 (post-Libby Dam with augmented flows).

Adult White Sturgeon Telemetry

Movement and migration of adult white sturgeon fitted with sonic and radio transmitters were monitored monthly from the Kootenai River at Bonners Ferry into the river's delta at Kootenay Lake. The main objective was to locate late vitellogenic females and males migrating upstream to staging and spawning reaches. As sturgeon activity increased, monitoring effort increased. Each transmitter location was recorded to the nearest 0.1 rkm (0.061 mi). Surface water temperature was measured daily with a hand-held mercury bulb thermometer. Effort required to monitor sturgeon movement and activity varied with season. Less effort was required during winter months when most fish moved less frequently than in spring and fall. Increased activity of tagged fish during the pre-spawning and spawning seasons required more frequent monitoring. Reaches above Copeland (Figure 1) were monitored more intensively than downriver or Kootenay Lake, especially during the pre-spawning and spawning periods when mature sturgeon moved upstream.

Two fixed-location receivers (fr) were stationed upriver from the spawning reach (rkm 237.4 and 245.2) from late April through early July 1998. The position at rkm 237.4 was to detect fish movements above the Myrtle Creek spawning location (rkm 237.0) and the upriver Bonners Ferry location (rkm 245.2) was selected to detect fish movements above Ambush Rock (rkm 244.5). Radio frequencies of suspected spawners were programmed into the receivers, which were checked every other day.

Artificial Substrate Mat Sampling

White sturgeon spawning was documented with artificial substrate mats (McCabe and Beckman 1990). Egg mat densities in the spawning area were based on general densities of spawning sturgeon monitored by telemetry in previous years. Adult white sturgeon locations from previous years were assigned to high, medium, and low densities for sonic and radio tagged fish. These were based on telemetry observations: high- sturgeon were frequently located, medium- sturgeon were occasionally located, and low- sturgeon were seldom located. We set an average of 1.9 mats/0.1 km in the high density sections (25 mats), an average of 1.05 mats/0.1 km in the medium density sections (21 mats), and an average of about one mat/6.25 km in the low density sections (24 mats). A 1 km reach from rkm 230-231 was not sampled because it was a brood stock collection reach for the Kootenai Tribe of Idaho (KTOI). Some of the high and medium 0.1 km sites were sampled with two mats. The sites that were sampled with two mats were chosen randomly from all high or medium density sites.

Six additional experimental mats equipped with drift nets attached to the posterior were deployed at selected sites, between rkm 229.3 and rkm 241.8 to capture drifting eggs and larvae. Each drift net was 30.48 cm x 63.5 cm x 60.96 cm (12 x 25 x 24 in), 3 mm (0.1 in) mesh polyester netting with an 8.1 cm (3.19 in) diameter collecting bucket attached at the cod end. Eggs were collected, preserved in a formaldehyde solution, and staged according to Paragamian et al. (1996).

Juvenile White Sturgeon Sampling

Weighted multifiliment gill nets with 2.5 to 5 cm (1-2 in) mesh and benthic trawls were used to sample juvenile and young-of-the-year (YOY) sturgeon (Paragamian et al. 1996; Fredericks and Fleck 1996). Gill net and benthic trawl sampling were completed at randomly selected locations between rkm 170 and rkm 236. Gill nets were set during the day and checked every hour. Juvenile sturgeon were processed by methods cited in Paragamian et al. (1996).

Juvenile White Sturgeon Food Habits

We tested the food habits of hatchery white sturgeon in the Kootenai River by examining the stomach contents of fish recaptured during juvenile sampling. Only age-3 hatchery white sturgeon (1995-year class) were used for food habit analysis. The sacrifice of up to 25 hatchery white sturgeon was authorized in our Section 10 Permit. Hatchery fish captured during sampling that were evaluated for food habits were weighed and measured (TL and FL). An incision was made in the abdominal wall to insure preservation of the stomach and its contents, and then the fish was placed in a quart jar containing formalin. The date and location of the collection was noted. The stomach contents were identified to genus (if possible), enumerated, and dry weighed in the lab.

Age and Growth of White Sturgeon

Ages of adult and juvenile white sturgeon were determined by pectoral fin ray analysis (Marcuson et al. 1995; Paragamian et al. 1996). Age information was used to determine year class structure.

Larval Sturgeon Sampling

We used surface and midwater paired half-meter net tows, bottom-towed D-rings, and benthic trawling to search for larval white sturgeon in the Kootenai River. We used two techniques for paired half-meter net sampling. Nets were towed upstream, against the current, during daylight and dusk hours. Tows were made at randomly selected locations between rkm 170 and rkm 240.

Benthic trawls were carried out at randomly selected locations in the Kootenai River (rkm 170 through 240). The trawl was towed downstream with the current and sampling was performed during daylight hours from July through August 1998. The benthic trawl provided the opportunity to sample the bottom of the river with gear that would be selective for YOY and juvenile sturgeon.

Contaminants

Fifteen-gram egg samples were biopsied from stage-3 and -4 females (Appendix 1) captured during adult sampling. Samples were frozen in plastic vials that had been double rinsed in pesticide grade acetone. Eggs were frozen until they could be analyzed for pesticides, PCB's and metals.

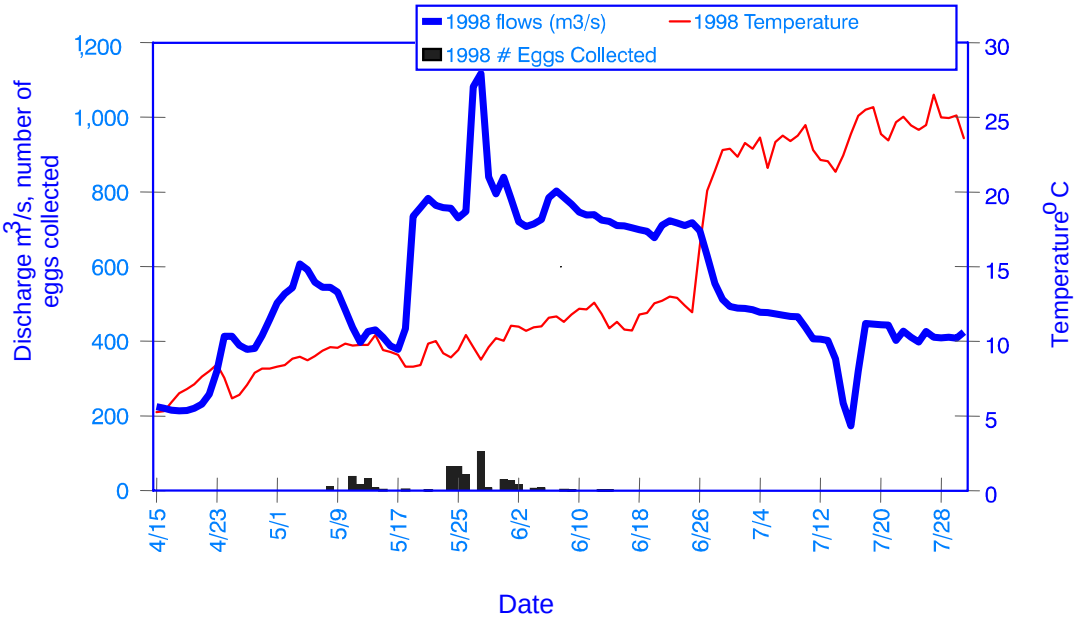
Acoustic Subbottom Profiles

Acoustic Subtotal Profiles (ASP) were made by following the thalweg of the Kootenai River from rkm 226 through rkm 246, the reach of river used by white sturgeon for spawning. ASP studies were a cooperative effort by the IDFG and the US Geological Survey under the supervision of Gary Barton. The objective was to identify any unique qualities in the thickness and layering of bed sediment that may be attributed to post-dam hydrology. Two passes were made through the study reach; the first with a low frequency transducer (12 kHz) and the second with a high frequency transducer (2-23 kHz). A continuous, high-resolution, single channel, seismic-reflection profiler recorded the texture and thickness of various substrates (Haeni 1986; and Reynolds and Williams 1968). This seismic reflection system consists of a single channel type with an analog recorder, an amplifier and filtering system, two 110v portable generators, a power supply for the acoustic source, an acoustic sound source (transducer) for high frequency and low frequency transducers, a reel-to-reel four track tape recorder, and a hydrophone array. The system operates by towing the transducer and hydrophones with a boat. The acoustic signals generated by the transducer are transmitted to the substrate of the riverbed. Sound waves are reflected by the interfaces with the substrates and depending on their density and depth in the profile (acoustic impedance), returned sound waves are intercepted by the hydrophone. The acoustic impedance is analyzed by the on-board electronic equipment including an amplifier filter and analog graph and tape recorders.

RESULTS

Discharge and Water Temperature

Flows for white sturgeon spawning in 1998 were expected to be at a minimum because the snow pack in the basin was about 79% normal, and local inflow was expected to be very low, (<142 m^3/s (5,000 cfs) (conversions to cfs are rounded to hundreds). Flows in the Kootenai River at Bonners Ferry from late April through early May were at about 425 m^3/s (15,000 cfs) while water temperature ranged from about 8 to 10^{o}C (45 to 50^o F) (Figure 3). Spawning and incubation flows from Libby Dam began on May 18 when flow was brought up to 765 m^3/s (27,000 cfs) (nearly two weeks after sturgeon began spawning). However, unusually frequent rains and several enormous storms in the basin brought peak flows in the Kootenai River at Bonners Ferry to over 1,175 m^3/s (41,500 cfs) on May 27 (Figure 3), but temperature continued to oscillate between 8 and 10.6^{o}C (45 to 51^o F). Flow gradually subsided at Bonners Ferry during June and was relatively steady at 708 to 765 m^3/s (25,000 to 27,000 cfs) while temperature gradually rose to 14.4^{o}C (58 ^{o} F).



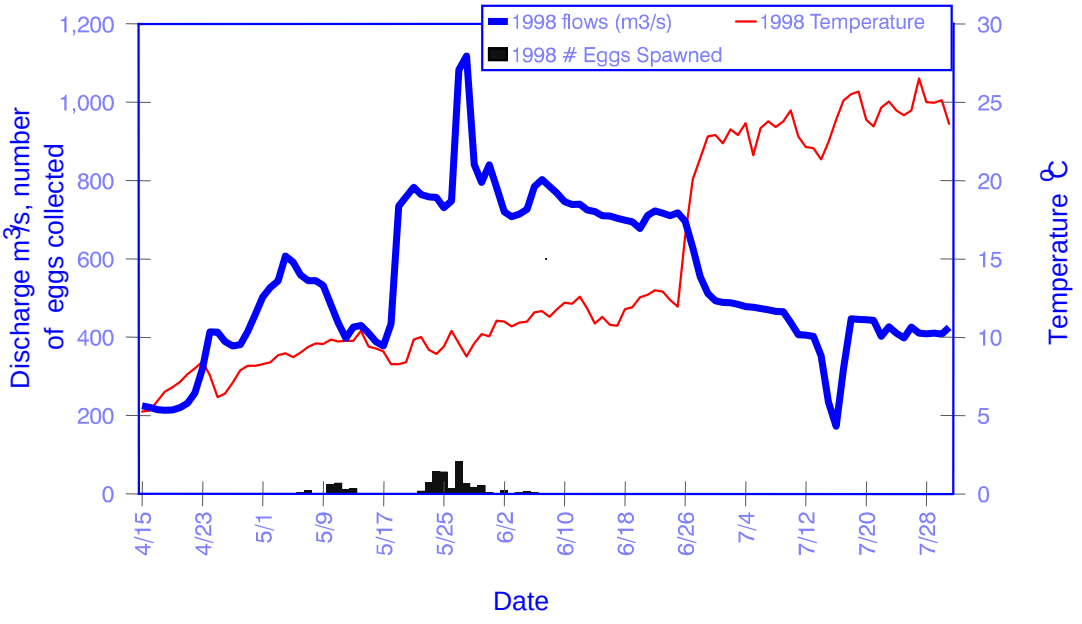


Figure 3. Top figure is collection date, number of eggs, temperature (^{o}C), and flow (m^3/s), Kootenai River at Bonners Ferry, Idaho, 1998. Bottom figure is spawn date, number of eggs, temperature (^{o}C), and flow (m^3/s).

Adult White Sturgeon Sampling

Forty-seven adult white sturgeon were captured with 4,220 hours of angling and setlining effort between March 1 and April 15, 1998 (Table 1). Thirty-one (66%) of the 47 sturgeon captured, were recaptures from previous years. None were recaptures of fish originally caught in 1998. An additional five adult sturgeon were incidentally captured in juvenile gill nets during July, 1998.

Catch per unit effort (CPUE) for adult white sturgeon caught by angling and setline gear were 0.15 and 0.01 fish/h, respectively. Catch per unit effort for adults captured in juvenile gillnets was 0.01 fish/h (Table 1).

Ninety-four biopsies were performed by the Idaho Department of Fish and Game (IDFG), British Columbia Ministry of Environment Lands and Parks (BC MELP), and the Kootenai Tribe of Idaho (KTOI) on adult sturgeon during 1998 to determine sexual maturity stage of ovaries and testes (24 females, 56 males, 14 unknown) (Appendix 1). Sonic and radio tags were attached to four female and five male sturgeon during this effort.

Adult White Sturgeon Telemetry

Forty-five white sturgeon with active transmitters were monitored with a total of 449.7 h of effort from September 1, 1997 to August 31, 1998 (Table 2, Figure 4, and Appendix 2 a-e). From April 1 through July 31, 1998, 18 of the 45 fish were monitored specifically for pre-spawn and spawning activities. Locations, river discharges, and temperatures during the migration and spawning period are displayed for these 18 suspected spawners (Appendix 2 a-e). One hundred trips were made throughout different sections of the study area to monitor radio and sonic tagged sturgeon during the pre-spawn and spawning period in 1998. Twenty-two trips targeted the section from the Kootenai River delta at Kootenay Lake to Porthill, 29 trips from Porthill to Copeland, 43 trips from Copeland to Bonners Ferry and 7 trips above Bonners Ferry. The fixed location receivers were deployed April 27 (rkm 237.4) and May 4 (rkm 245.2) and retrieved July 2 and 3, respectively.

Migration of Monitored Sturgeon in 1998

Twenty-one adult males, 22 females, and 2 white sturgeon of unknown sex carried transmitters in 1998 (Table 2). Five males, six females, and one of unknown sex remained in Kootenay Lake during the pre-spawn and spawning period. Of the above lake dwelling fish, one was tagged in 1994, two in 1995, seven in 1996 and two in 1997. Four males and seven females made brief movements out of the lake and into the lower river (rkm >122<203). An additional two males and two females went upriver as far as Flemming Creek (rkm 225) during the spawning period. We tracked the remaining nine males, eight females, and one of unknown sex to locations upstream of Flemming Creek. These 18 sturgeon migrated to spawning locations in the upper Kootenai River of which 16 were in locations where eggs were collected (Table 3), female 814 and 788 were the only exceptions. The furthest upriver location was at rkm 245.3 near Ambush Rock (1 female). Thirteen of the 18 suspected spawners had left the spawning area by June 30, 1998.

Table 1. Sampling effort and number of adult and juvenile white sturgeon caught by the Idaho Department of Fish and Game in the Kootenai River, Idaho, March 1, 1998 to August 31, 1998.

Gear type	Hours of effort	Number of juvenile sturgeon caught (No. individuals)	Number of adult sturgeon caught	Juvenile CPUE (fish/h)	Adult CPUE (fish/h)
Hoopnet	29,146.5	---	---	---	---
Gillnet (2.4-7.6 cm mesh)	592.8	175 (161)	5	0.30	0.01
Angling [a]	54.8	0	8	---	0.15
Setline [a]	4,164.9	2 (2)	39	0.0005	0.01
Benthic Trawl	16.04	---	---	---	---
TOTAL	33,975.0	177 (163 [b])	52		

[a] Gear targeting adult white sturgeon only.
[b] This includes 3 wild and 160 hatchery fish

Table 2. Upriver locations of 43 Kootenai River white sturgeon of known sex and two of unknown sex monitored for spawning activity from April 1,1998 to July 31, 1998.

Fish #		Tagging location (rkm)	Date tagged	Highest rkm (Date)			Last date located above rkm 225
Male	**Female**			**>122<203**	**>203<225**	**>225**	
---	36[a]	214.9	3/11/98	---	---	237.5(5/26)	8/10
124[b]	---	78.0	8/1/96	c	---	---	---
---	163	215.0	4/26/94	---	213.5	---	---
174[a]	---	215.4	3/9/98	---	---	237.5(4/29)	9/24
---	250[a]	215.1	9/11/96	---	---	242.2(5/28)	5/28
---	271[a]	215.4	3/18/98	---	---	245.3(6/14)	6/19
---	348	203.0	4/19/94	---	---	231.4(6/2)	6/6
407[a]	---	215.6	3/6/96	---	---	231.3(6/8)	9/24
---	436	207.8	4/27/93	131.4	---	---	---
---	560	204.9	3/18/94	---	204.8	---	---
565	---	193.0	3/19/94	186.7	---	---	---
---	617	215.6	3/17/97	190.1	---	---	---
621	---	215.0	3/20/95	---	215.5	---	---
---	625	215.4	3/24/95	c	---	---	---
---	629	215.0	3/29/95	128.0	---	---	---
635[a]	---	215.4	3/6/98	---	---	239.5(6/2)	6/30
---	649	205.0	4/12/95	175.3	---	---	---
---	714	205.0	3/5/96	169.8	---	---	---
---	716	215.8	3/5/96	126.5	---	---	---
---	718	215.5	3/5/96	c	---	---	---
720	---	215.6	3/6/96	c	---	---	---
722	---	215.5	3/7/96	133.7	---	---	---
---	730	215.0	3/12/96	c	---	---	---
779	---	215.7	3/4/97	c	---	---	---
781	---	215.5	3/10/97	c	---	---	---
785	---	215.7	3/13/97	---	212.6	---	---
787	---	215.6	3/18/97	161.9	---	---	---
---	788	215.6	3/18/97	---	---	239.8 (6/5)	---
811[a]	---	215.5	3/2/98	---	---	239.8(5/25)	6/4

Table 2 continued.

Fish #		Tagging location (rkm)	Date tagged	Highest rkm (Date)			Last date located above rkm 225
Male	**Female**			**>122<203**	**>203<225**	**>225**	
---	814 [a]	205.0	3/3/98	---	---	241.4(6/15)	6/23
---	818 [a]	215.5	3/16/98	---	---	236(6/2)	6/2
819[a]	---	215.1	3/17/98	---	---	238.4(5/13)	6/4
2057	---	215.0	3/29/95	c	---	---	---
---	2176	17.0	8/17/94	c	---	---	---
2194[ab]	---	83.0	8/6/94	---	---	241.9(5/26)	6/14
2202 [a]	---	215.1	3/17/98	---	---	234.0(5/24)	9/24
---	2286	17.0	8/1/96	162.5	---	---	---
---	2308	17.0	8/1/96	c	---	---	---
2313	---	17.0	10/8/96	122.0	---	---	---
2320	---	17.0	8/1/96	c	---	---	---
2334 [a]	---	17.0	9/6/96	---	---	239.8(6/14)	6/19
---	2335 [a]	17.0	9/17/96	---	---	240.3(5/28)	6/4
2336 [a]	---	17.0	10/8/96	---	---	239.9(6/19)	6/25
2337 [a]	---	17.0	10/29/96	---	---	236.4(5/31)	5/31
---	2338	17.0	10/9/96	c	---	---	---
n=12	n=16	Non-spawners (n=28)					
n=10	n=7	Spawners (n=17)					
n=22	n=23	Combined (n=45)					

[a]Suspected spawners in 1998
[b]These fish were not sexed prior to tagging
[c]These fish did not make any upriver movement out of Kootenay Lake in 1998

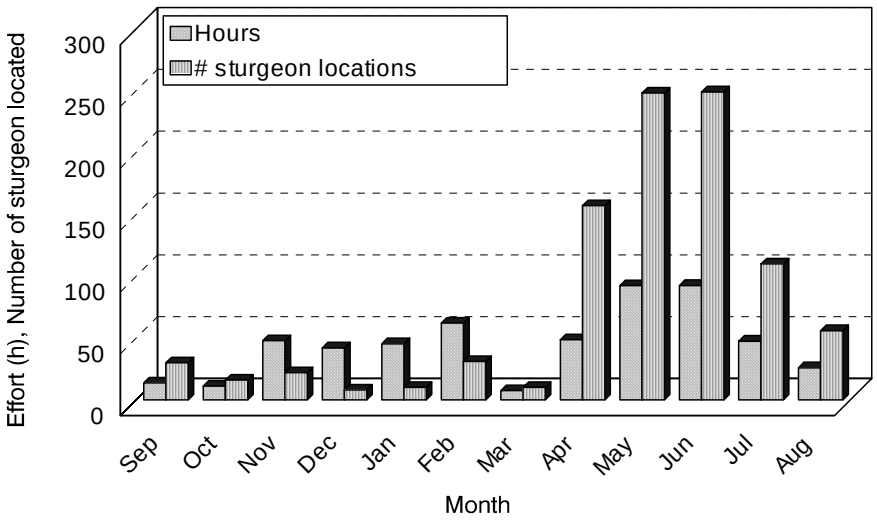


Figure 4. Telemetry effort (hours) and number of times white sturgeon were located monthly from September 1, 1997 to August 31, 1998, Kootenai River, Idaho.

Table 3. Fish tracked to sections of the Kootenai River, Idaho, where white sturgeon eggs were spawned (back-calculated to spawning date), within 24 hours preceding spawning date, 1998.

Location	Egg spawn date[b]	Fish #	
		Males	Females
Lower Shorty's Island (rkm 227-231.5)	May 6 and 7	174, 407, 2202, 2337	36, 818
	May 10-13	174, 407, 2337	818
	May 24-30	174, 407,635,819,2334,2337	36, 2335
	June 2	174, 407, 819	36, 271, 348
Myrtle Creek (rkm 233.5-234.7)	May 11		
	May 24	2202	
	May 30		
	June 2	811, 2334	2335
	June 5		2194[a]
Wildlife Refuge (rkm 234.8-237.5)	May 27-30	635, 819, 2334, 2336	
	June 4-6	635, 2336	250, 2194[a]
Deep Creek (rkm 237.6-240.5)	May 11-13	635, 819, 2334	2194[a]
	May 22-26	811, 2334, 2336	250, 2194[a]

[a]The sex of this fish is unknown

[b]This assumes that eggs were spawned in the same river reach where they were collected.

Fixed-Receiver Results

The fixed-receivers gave us more reliable results in 1998 than 1996 or 1997. There was only minor background noise interfering with the receivers' abilities to differentiate noise from actual radio frequencies 100% of the time. Only verified locations will be discussed here. The 3-element yagi antennas were able to detect the movements of six fish past the two fixed-receiver stations (fr 1 and 2). This included three females (#'s 36, 271, 818) and three males (#'s 174, 635, 819). The upriver movements were supported by previous and later locations of the same radio frequencies from boat and aerial tracking. Fixed-receiver locations at rkm 245.3 (fr 2) represent the highest known upriver locations for two fish (female 271 and male 635) in 1998. Female 271 was recorded at fr 2 several times between June 10 and June 15 and was detected by boat at least once during this period as well. She moved upriver to this point after being detected several times by boat and the downriver fixed receiver (fr 1, rkm 237.5) between 226.1 and 237.6 from May 31 and June 9. After June 15, she moved steadily downriver and was found at the lake July 15. Male 635 moved past fr 1 many times between June 1 and June 18, he was also located by boat in this area during the same period. On June 19, male 635 was recorded at fr 2 (rkm 245.3). He returned down-river to the location of fr 1 later that day, where he remained for the next 11 days. On June 30, he again made the upriver move to fr 2. On July 2 he began a steady downriver move and was detected near Kootenay Lake by August 5.

Male #174 came up to fr 1 (rkm 237.5) on April 30 from the lower Shorty's Island area (rkm 229). He returned downriver after spending several hours around 237.5. Fish #818, a female, came upriver to fr 1 from the Rock Creek-Turner Hill Hole (rkm 216) area on May 2. She moved back downriver to lower and then upper Shorty's Island. Female #36 was located by boat at rkm 239.6 on May 10. She was recorded several times on May 11 at fr 1 (rkm 237.5). This fish spent the next few weeks in the Myrtle Creek and Shorty's Island areas. On July 1 and 2 she was again recorded at fr 1, after which time she moved back to the Shorty's Island area. Male #819 was the last fish to move by fr 1 (237.5). He was recorded near the station on May 13, 14 and 15. He moved back downriver after this time and was eventually detected in Kootenay Lake July 7.

Aerial Telemetry Results

Fourteen different sturgeon were located on several occasions during 19.7 h of aerial telemetry. Flights occurred over the Kootenai River between Bonners Ferry (rkm 245.8) and Kootenay Lake, including the Creston Delta (rkm 121.0-113.0) from May 1 to June 2, 1998. In seven flights, 66 sturgeon locations were recorded. We were able to detect fish in the shallow water of the Creston Delta, but not in the deeper portions of Kootenay Lake. The addition of a second loop antenna (one off each wing strut) greatly improved signal strength, detection distance, and our ability to pinpoint the location of each fish.

Artificial Substrate Mat Sampling

We sampled a total of 3,908 mat days (a mat day is one 24 h set) in the Kootenai River during white sturgeon spawning in 1998. Sampling with regular mats began April 30 (May 12 for experimental mats equipped with drift nets) and ended June 29, 1998. Although we attempted to check all mats daily, high water conditions and debris in the river made it difficult to find all of the mats each day. Thus, some mats were set for several days before they could be relocated. The total sampling time for egg mats was 93,798 hours (including experimental mats with nets); 90,212 h (96%) were expended with the standard mats while experimental mats with drift nets added 3,586 h (4%). A total of 484 eggs were collected (Figure 3). Three hundred and ninety-three eggs (81%) were collected on 60 standard mats (not all mats collected eggs) (Table 4), 81 eggs (17%) were collected on six experimental mats with drift nets (449 h of effort for mats with eggs), and 10 additional eggs (2%) were found mixed with sand in three of the drift nets (Table 5).

Standard mats collected 393 white sturgeon eggs within five different geographic river sections (Table 4 and Appendix 3). The Middle Shorty's Island reach (rkm 229.6 - 231.5) produced the most eggs (173) with 483 mat days of effort while the Deep Creek section (rkm 237.6 to 240.5), with 401 mat days of effort, produced 112 eggs. No eggs were collected above the Deep Creek section (> rkm 240.5) with 718 mat days of effort.

Depth of artificial substrate mat placement ranged from 0.9 to 21.9 m (3 to 72 ft) for all mats. On several occasions, weather and river conditions made it hazardous to collect all habitat parameters at egg collection sites. For mats that collected eggs (standard and experimental mats combined) depth ranged from 7 to 18.3 m (23 to 60 ft) and averaged 11.4 m (37.5 ft) (Appendix 4 and 5). Surface velocities at 67 egg collection sites ranged from 0.29-1.10 m/s (0.95 to 3.61 ft/s) and averaged 0.69 m/s (2.27 f/s). Velocities near the river substrate at 67 of the egg collection sites ranged from 0.08 to 0.97 m/s (0.26 to 3.18 ft/s) and averaged 0.56 m/s (1.82 ft/s). Mid-column velocity ranged from 0.21 to 0.97 m/s (0.67 to 3.17 ft/s) and averaged 0.62 m/s (2.05 ft/s).

Four hundred and twenty (87%) of the 484 white sturgeon eggs collected in 1998 were viable. Development ranged from stage 12 to 28 (1 h to 12 d old), with 95% of the viable eggs at stage 21 (about 2.4 days) or earlier (Appendix 4 and 5). Eighty-two percent of the eggs were less than 48 h old, 11% were 48 to 72 hours old, and 7% were more than 72 hours old. The oldest egg was estimated at 293 hours old or about 12 days.

Based on ages of viable eggs and the dates of egg collection, we estimated that white sturgeon spawned on at least 20 days in 1998 (Figure 3). The first spawning episode was estimated to have occurred on May 6. The next episode was estimated to have occurred May 7 with a gap in spawning until May 10. Thereafter, spawning occurred for the next three days with a second break until May 22 when spawning occurred nearly every day through June 6 (Figure 3). Peak spawning appeared to occur from May 23 through May 28 (Figure 3). The three largest spawning events, based on our sampling, aging, and back calculation to spawn date took place: May 24 (57 eggs), May 25 (56 eggs) and May 28 (83 eggs) (Figure 3 and Appendices 4 and 5). The other spawning dates yielded from one to 30 eggs each.

Table 4. Location (rkm), depth (m), effort and white sturgeon egg catch by standard artificial substrate mats, Kootenai River, Idaho, 1998.

Geographical description	River location (rkm)	Depth range (m)	Total sample hours[a]	Number white sturgeon eggs
Lower Shorty's Island	228.0-229.5	5.18-21.25	14,179.2	39
Middle Shorty's Island	229.6-231.5	3.66-19.21	11,587.0	173
Upper Shorty's Island	231.6-233.4	4.57-18.29	9,861.1	0
Myrtle Creek	233.5-234.7	1.52-18.29	11,005.2	14
Refuge	234.8-237.5	4.88-21.04	16,728.8	55
Deep Creek	237.6-240.5	6.1-15.24	9,625.7	112
Hatchery	240.6-243.9	5.49-11.89	6,132.6	0
Ambush Rock	244.0-244.6	0	0	0
US 95	244.7-246.6	2.44-10.37	7,314.7	0
Upper Pump Station	246.7-247.7	.91-6.71	3,777.3	0
All Sections	**228.0-247.7**	**.91-21.95**	**90,211.6**	**393**

[a]One mat sample is equal to the time a mat is in the river before it is pulled and checked

Table 5. Location (rkm), depth (m), effort and white sturgeon egg catch by experimental artificial substrate mats equipped with drift nets (only mats that collected eggs), Kootenai River, Idaho, 1998.

River location[a] (rkm)	Depth (m)	Total sample hours[ab]	Number of eggs on mat	Number of eggs in net
229.0	14	47.5	2	0
230.8	9-12	165.8	7	4
230.9	7-18	143.0	70	5
233.8	11	44.3	1	0
233.9	12	23.4	1	0
239.4	8	24.8	0	1
Averages/Totals	**40.26**	**448.8**	**81**	**10**

[a] Experimental egg mats were set in locations where eggs were being collected by standard mats
[b] No CPUE was calculated

Juvenile White Sturgeon Sampling

We expended 593 hours of gill net sampling effort to capture 175 (161 individual) juvenile white sturgeon (Table 1). An additional two juvenile sturgeon were incidentally captured on adult setline gear. No juvenile sturgeon were captured with 29,147 h of hoopnet effort or 16.04 h of benthic trawl effort. However, in October 1998 a wild juvenile sturgeon of the 1997-year class was captured with hoopnets while sampling for burbot, during a companion study (Paragamian and Whitman, in progress). Catch per unit effort for juvenile sturgeon captured by gill net was 0.3 fish/h. Of the 163 individual juvenile sturgeon captured, three were wild and 160 were released from the Kootenai Tribal Hatchery (Appendix 6 and 7).

Juvenile White Sturgeon Food Habits

We examined the stomach contents of 24 age-3 hatchery white sturgeon captured in the Kootenai River. These hatchery sturgeon were released in May 1997 and were collected for food habit analysis during July through August 1998. All stomachs examined contained food items. Food items identified included three orders of insects: Diptera, Ephemeroptera, and Tricoptera as well as Plecopterans, Hydracarina, and fish and plant parts (Table 6). Dipterans comprised the largest portion of the diet, numerically contributing 36% of the items (3,533 items of a total of 9,818 examined). Chironomidae larvae comprised 13%, by number, of the stomach contents (N = 1,290), followed by Chironomidae pupae at 11% (N = 1,068). Other items in the diet that were nearly as common were the Ephemeropterans Ephemerellidae (N = 1,022) and Baetidae (N = 948) at 10% each, and the Tricopteran Hydropsychidae (N = 810) at 8%, while other food items were low in comparison (Table 6).

Age and Growth of White Sturgeon

Adults

Ages of all wild white sturgeon captured in 1998 ranged from 6 to 49 years (Figure 5). These fish are from year classes between 1949 and 1992.

Growth for recaptured sturgeon averaged 1.2 $\pm$2.5 cm (0.49$\pm$ 0.99 in) fork length (FL) and 1.9$\pm$5.0 cm (0.75$\pm$1.8 in) total length (TL) per year. Intervals between multiple captures ranged from 121 to 7,628 days. The maximum measurable annual growth of an adult was 14.2 cm (5.6 in) FL and 23.0 cm (9.1 in) TL.

We calculated relative weight (Beamesderfer 1993) for FL for 45 adult white sturgeon captured during the 1998 sampling. FL W_r for adult white sturgeon ranged from 44 to 114 and the mean was 82 (SD = 15.6).

Table 6. Food items in 24 age-3 hatchery white sturgeon captured in the Kootenai River, Idaho, 1998

Food Item	Total Number Of Items	Percent of Total Contents	Percent of Stomachs Containing Item	Total Dry Weight (g)
Diptera	**3533**		**96**	**1.5200**
Chironomidae larvae	1290	13	83	0.8873
Chironomidae pupae	1068	11	63	0.0811
Chironomidae adult	818	8	67	0.4853
Chironomidae parts	100	1	4	0.0233
Simulidae	27	0.5	4	0.0014
Empididae	230	2	17	0.0416
Ephemeroptera	**2202**		**63**	**0.3105**
Heptageniidae	232	2	13	0.0129
Baetidae	948	10	54	0.0950
Ephemerellidae	1022	10	54	0.2026
Tricoptera	**1088**		**50**	**0.2811**
Hydropsychidae	810	8	46	0.2499
Limnephilidae	135	1	8	0.0181
Hydrophilidae	59	1	4	0.0040
Brachycentridae	84	1	4	0.0091
Plecoptera	**500**		**21**	**0.0815**
Perlodidae	182	2	8	0.0414
Pteronarcyidae	208	2	8	0.0380
Plecoptera parts	110	1	4	0.0021
Hemiptera	**198**		**13**	**0.0049**
Corixidae	198	2	13	0.0049
Other	**2297**		**63**	**0.8174**
Unknown invertebrate parts	786	8	33	0.1830
Osteichthyes	251	3	8	0.0354
Plant parts‘	708	7	33	0.3364
Arachnida	70	1	8	0.0004
Coleoptera	296	3	21	0.0185
Pelecypoda	46	1	4	0.2430
Hirudinae	140	1.5	8	0.0007

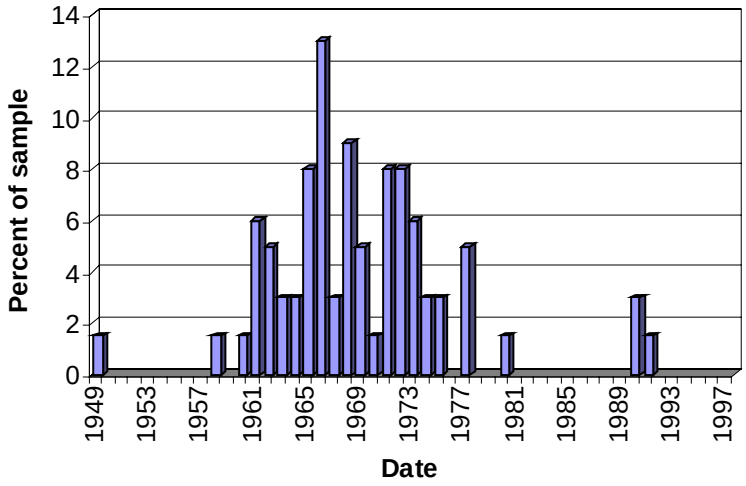


Figure 5. Age frequency histogram for Kootenai River white sturgeon captured and aged during 1998 (n=65).

Juveniles

Lengths of three wild juvenile white sturgeon captured between August 1, 1997 and August 31, 1998 were 47.6 (age 6), 58.6 (age 7), and 65.7 cm FL (age 7); or 55.1; 68.7; and 76 cm TL, respectively. Calculated growth for 188 recaptured hatchery reared and released juvenile sturgeon was 7.7±13.7 cm (3.1±5.4 in) FL and 8.8±3.5 cm (3.5±5.4 in) TL. Maximum measurable growth was 24.6 cm (9.7 in) FL and 27 cm (10.6 in) TL. Calculated growth for three wild juvenile sturgeon was 1.0±5.6 cm (0.41±2.2 in) FL and 2.2±0.0 cm (0.88±0.0 in) TL. Maximum measurable growth for wild juvenile sturgeon was 8.5 cm (3.3 in) FL and 9.3 cm (3.6 in) TL.

We calculated FL W_r for 99 juvenile white sturgeon of the 1995 brood year captured during the 1998 sampling period. Hatchery juvenile white sturgeon FL W_r ranged from 37 to 153 and the mean was 83 (SD = 21). FL W_r for the three juvenile wild white sturgeon ranged from 93 to 109 with a mean of 103 (SD = 6.6).

Larval Sturgeon Sampling

No larval sturgeon were captured during 1998. Between May 22 and July 10, we sampled 439,550 m^3 of water in 151.25 h with meter (17,319 m^3), dual half-meter (391,035 m^3) and D-ring nets (31,199 m^3) between rkm 172 and 244.5 in the Kootenai river. We sampled 391,035 m^3 of water with dual half-meter nets during surface (196,842 m^3) and subsurface (194,190 m^3) tows. Of the total volume of water sampled, 37,889 m^3 (10%) was sampled at night. Duration of tows ranged from 0.28-0.73 h. Although no larval sturgeon were collected in larval nets, other species collected include larval suckers *Catostomus sp.*, kokanee *Onchorhynchus nerka*, whitefish *Prosopium williamsoni*, and yellow perch *Perca flavescens*.

Contaminants

Eight ovarian tissue samples were collected in 1998. These eight samples were added to the nine collected in 1997 and were sent to AMTEST Inc. of Redmond, WA for chemical analysis. Four organochlorine pesticides (DDE, DDT, Dieldrin and Aldrin), one PCB (1260) and seven metals (arsenic, cadmium, copper, iron, lead, selenium, zinc) were detected in the tissues. Lipid content of ovarian tissues ranged from 2.3-12% total weight.

Acoustic Subbottom Profiles

Continuous seismic profiling of a 12-km (7.45 mi) reach of the Kootenai River (rkm 228 - 240) indicated the riverbed was comprised primarily of fine and coarse sand. Several pools were overlain with clay while no coarse substrates were recorded. The riverbed was characterized as an extensive series of dynamic sand dunes. The sand dunes increase in size in a downstream order from each pool (trench) (Figure 6). Seismic stratigraphy indicated each sand dune was approximately 2 m (6 ft) in height and about 10 m (31 ft) in length. Analysis of high frequency recordings indicated the dunes are in parallel layers to a depth of about 4 m (12.5 ft) (Figure 6). Below the layered sand dunes is a homogenous layer of sand or silt to a minimum depth of about 5.1 - 5.8 m (16 - 18 ft) (Figure 6).

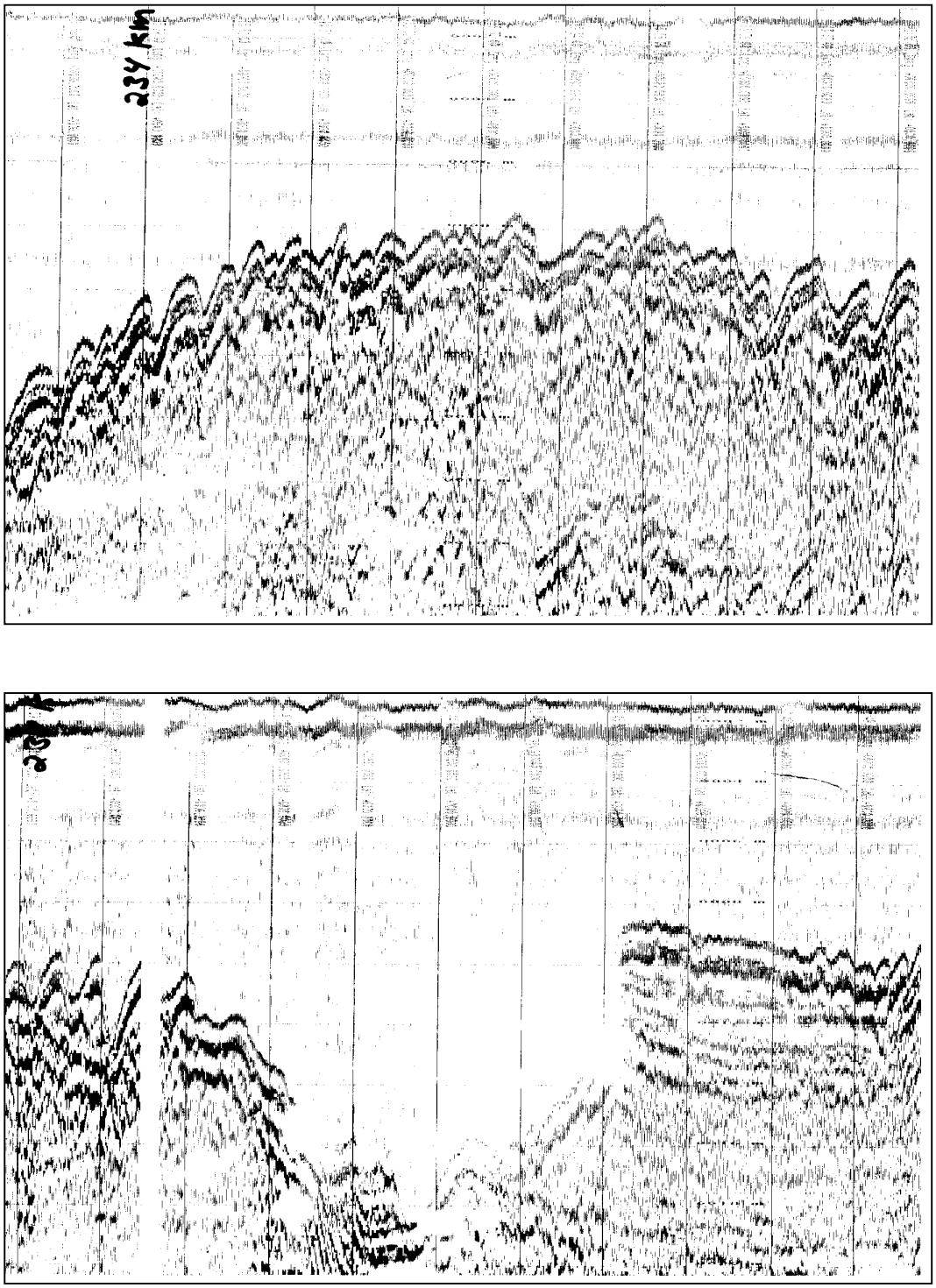


Figure 6. Seismic profiles of the Kootenai River, flow of the river is from left to right. The top figure is a seismic profile of rkm 234 showing the parallel layers of coarse sand, to a depth of about 6 m, and sand dunes. The sand dunes are approximately 2 m in height and about 10 m long. The bottom figure is of rkm 237 and is an example of a trench (pool). Note the collapse of material at the downstream end of the trench.

Seismic study recorded calving or slumping of the sand bed load into pools (Figure 6). Layers of sand were registered in locations where these large slumps were recorded but no gravel was measured on these open faces.

DISCUSSION

The principle objective of this investigation is to identify the minimum discharge necessary to produce sufficient recruitment of a white sturgeon year-class and to achieve recovery of the population. Seven years of study have resulted in a substantial number of eggs collected and the capture of wild sturgeon recruited from several flow test years. Flows provided in 1992 and 1993 were minimal mitigative measures and very little spawning occurred; more spawning occurred with the intermediate flows test of 1994 and 1995; and the 1996, 1997, and 1998 flows that were the results of high volumes of local inflow from exceptional snow pack and rainfall. It may be a minimum of eight years before the complete significance of each flow year is fully understood, when progeny are near adult life stages. It is evident from egg collections, stages of eggs, flow conditions, and the capture of wild sturgeon that flows in the range of 1,130 - 1,300 m^3/s (40,000 - 45,000 cfs) may provide for sturgeon recruitment, and have minimal impacts to agriculture in the Kootenai Valley. However, we believe test flows must be coordinated with behavior of female white sturgeon, which will be discussed later in this text. Thus, the test flow for 1999 should be similar in volume and discharge to that of 1997, should begin when local runoff begins to subside or when river temperature approaches 8 to 10^0 C (46 - 50^0 F), and ramping of discharge should be in increments of 57 m^3/s (2,000 cfs) per day to a minimum of 1,130 m^3/s (40,000 cfs) at Bonners Ferry.

White sturgeon spawning in 1998 was the earliest recorded since study began. Snow pack at the end of winter was about 79%, the lowest since this study began. The Kootenai River rose only gradually during the spring from local runoff; by early May it reached 608 m^3/s (21,442 cfs), and was relatively steady for about a week. Water temperature was also rising to about 8°C (46.4°F) and mature white sturgeon migrated to the spawning reach and began spawning. Flow gradually receded to about 428 m^3/s (15,000 cfs) prior to flow mitigation, and spawning ceased. Spawning flows were initiated on May 18 stimulating resumption in spawning soon afterward. Locally heavy rainfall and flow mitigation brought flows to a high of over 1,175 m^3/s (41,500 cfs) on May 27 but subsided to about 775 m^3/s (26,500 cfs) thereafter.

Because of the timing of mitigated flows in 1998 spawning reach, abandonment may have been avoided. Spawning of white sturgeon in 1998 occurred during local runoff and earlier than previously recorded, May 6. After local runoff subsided, spawning ceased but resumed soon after mitigated flows were released May 18. Tagged sturgeon abandoned the spawning reach in 1992 and 1993 when mitigated flows did not augment the drop in flow of local runoff. No eggs were collected in 1992 and only two in 1993.

Kootenai River white sturgeon eggs apparently are moving with sand near the river bottom. Six experimental mats, with drift nets attached to the end of the mats, collected ten white sturgeon eggs in addition to sand. The experimental drift nets were used to help test the hypothesis that sturgeon eggs are moving in the water column along with shifting sand rather than settling out on the riverbed. In nearly every instance when mats were checked, the drift nets were filled with sand, and on three occasion's sturgeon eggs were mixed with the sand. Only 3% of the total mat effort was expended with the experimental mats but the collection of 91 eggs with these mats contributed 19% of the total catch of eggs. It is very likely these experimental mats created a microenvironment by slowing the river velocity and eggs had a tendency to settle out on the mats or were captured in the drift nets rather than pass by. In addition, we tended to place experimental mats in the vicinity of spawners, which added to the bias. It is not known where in the water column white sturgeon spawn but they are thought to be broadcast spawners (Parsley et al. 1993). Prior to using experimental mats we were unsure if white sturgeon eggs settled out on the substrate and were subject to being buried by sand, resulting in mortality, or drifted with the current. Previous study suggested older eggs are found during years of higher flow (Paragamian et al. 1997) when eggs may be carried in the water column as opposed to being buried in the substrate, offering better survival when eggs are in suspension. These data also add credibility to earlier findings that some spawning episodes can be tracked downstream on successive days after spawning (Paragamian et al. 1996).

White sturgeon spawning over sand substrate appears to be a contradiction to a proposed survival strategy. White sturgeon have an adhesive egg that adheres to coarse substrates. Many of the eggs that we collected were coated in sand, although this did not appear to affect development (Paragamian et al. 1996 and 1997). Brannon (1984) believed the adhesion of eggs to coarse particles benefit survival of white sturgeon larvae by placing them in proximity to cover after hatching and prevented suffocation by fine sediments. Some researchers believe white sturgeon key on high current velocities for spawning and coarse substrates are the result of the sorting of particles by higher velocities (Parsley et al. 1993). Buckley and Kynard (1982) indicated water velocity and depth might be more important to spawning shortnose sturgeon *(A. brevirostrum*) than depth alone in determining specific spawning location and substrate.

Seismic studies of the Kootenai River subbottom indicated a homogenous layer of coarse sand and no evidence of gravel. These findings suggest Kootenai River white sturgeon spawn in the reach from rkm 228 through 240 for reasons other than the previous existence of spawning gravels or cobbles. Other researchers have documented white sturgeon eggs and possible spawning over sand substrate but in general it is not common. Kohlhorst (1976) found white sturgeon eggs and larvae over sand substrate in the Sacramento River. Parsley et al. (1993) and McCabe and Tracy (1994) also found some white sturgeon eggs in the Columbia River over sand substrate.

Our catch success and recapture ratio of hatchery reared white sturgeon suggests higher than anticipated survival, warranting a reduction in stocking numbers/family. About 2,588 hatchery reared white sturgeon have been released into the Kootenai River since 1992. In 1997 we captured 23 fish from the 1995 cohort with 535 h of gill net effort (Paragamian et al. 1997). In 1998 we captured 160 individual hatchery sturgeon from the 1995 cohort, of these 11 were recaptured during the same season. Recapture rates for hatchery fish in 1997 and 1998 were similar to the capture rates for other releases of

hatchery fish (Paragamian et al. 1995 and 1996). The Kootenai River White Sturgeon Recovery Plan (Kincaid Breeding Plan; Kincaid 1993) recommends stocking 1,000 individual sturgeon/family at age-1. We believe the number of hatchery fish released can be reduced to a maximum of 250 fish if released at age-2, based on survival estimates of wild juvenile white sturgeon (Paragamian et al. 1996). Our concern for the excess numbers of hatchery fish in the system is when these fish mature the high numbers of surviving siblings may cause genetic swamping and inbreeding or even intraspecific competition for food and space at young ages with wild or other hatchery fish.

We believe movement of larval sturgeon and rearing of wild sturgeon in Kootenay Lake, BC may have affected the outcome of our juvenile sampling. Kootenai River white sturgeon have a "short two-step migration pattern" and juveniles of sturgeon populations with this life history scheme usually rear in large lakes (Bemis and Kynard 1997). Sampling of juvenile sturgeon in the Kootenai River, Idaho from 1995 through 1998 has produced 17 wild sturgeon recruited from flow test years (1991 through 1998). Of that total at least ten were from 1991, three from 1992, and one from 1995. In addition, a wild sturgeon aged to the 1997 cohort was captured in a hoop net in October 1998 during burbot investigations. These totals are low in comparison to the numbers of hatchery fish that have been recaptured. We believe a substantial portion of young sturgeon produced during flow test years could be rearing in Kootenay Lake. Sampling for white sturgeon in Kootenay Lake has produced many unmarked sturgeon (BC MELP file records, Nelson, BC), some of which were wild sturgeon approaching maturity.

Relative weights (W_r) of adult and juvenile white sturgeon were low in comparison to that of other white sturgeon populations (Beamesderfer 1993). However, W_r is an index that should be used with caution because it usually has more value as an index of well-being for comparisons within a population. For example, it will be useful in the future for Kootenai River white sturgeon for contrasts between years, cohorts, wild vs hatchery fish, and for an individual fish captured several times over a period of years. It will therefore, provide a more meaningful use after more cohorts of hatchery fish are released and when we have more information on sturgeon food habits and food availability.

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RECOMMENDATIONS

1. Spawning migration of white sturgeon commences at temperatures above 6^{o} C (females at about 8^{o}C), any drop in flow or temperature could compromise spawning. Thus, flow and temperature must be maintained or allowed to increase to hold adults in the spawning reach. On or about 15 April (when water temperature is 7 - 8^{0}C (43 - 46^{0}F) maintain a minimum flow of 425 m^3/s (15,000 cfs).

2. Maximum flows (that do not jeopardize agricultural interests) are necessary for spawning white sturgeon and best survival of eggs and larval sturgeon. Flows from Libby Dam during white sturgeon spawning and egg development should be between 708 m^3/s (25,000 cfs) and 765 m^3/s (27,000 cfs) for 42 days when water temperatures approach 8 to 10^{0}C (46 - 50^{0} F), this would provide flows of about 1,130 m^3/s (40,000 cfs) at Bonners Ferry.

3. Storage of warm water for tests, followed by brief three-day releases, has not benefited spawning white sturgeon. Temperature tests could restrain spawning. By retaining warm water in Lake Koocanusa downstream river temperatures are reduced. Therefore, the storage of warm water in Lake Koocanusa for temperature tests should be discontinued.

4. Severe reductions in flow after white sturgeon spawn could strand invertebrates and larval fish in varial zones. Hence, a discharge of 311.5 m^3/s (11,000 cfs) for 30 additional days in July to early August should be provided to maintain sufficient habitat for rearing of larval sturgeon and maintain productivity.

5. Daily fluctuations in flows from Libby Dam, because of power peaking, could cause adult sturgeon to abandon the spawning reach. No eggs were collected in 1992 when flows in the Kootenai River were allowed to fall and sturgeon abandoned the spawning reach. The prohibition of power peaking must be maintained during the migration, spawning, and rearing seasons (April through September).

6. Release numbers of hatchery reared sturgeon should conform to protocols set in the Kootenai River White Sturgeon Recovery Plan. Maximum numbers of sturgeon per family should not exceed 250 if released at age 2+. Previous releases of hatchery sturgeon at age 2+ have been up to 1,000 fish per family. Test netting for wild sturgeon suggests hatchery fish have higher than expected survival.

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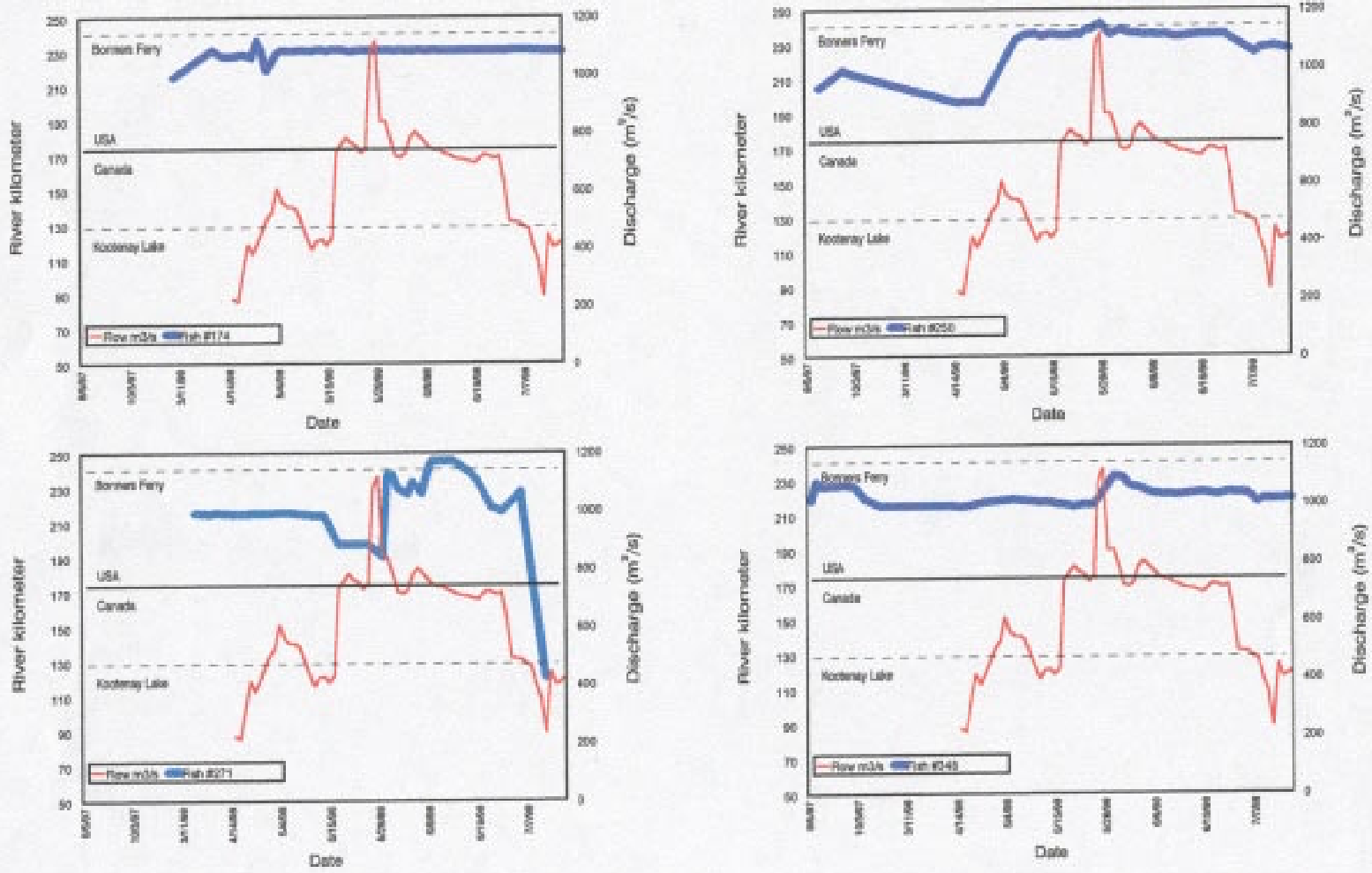
APPENDICES

Appendix 1. Sexual development of white sturgeon sampled by IDFG, KTOI and BC MELP in the Kootenai River, Idaho, 1989 through 1998.

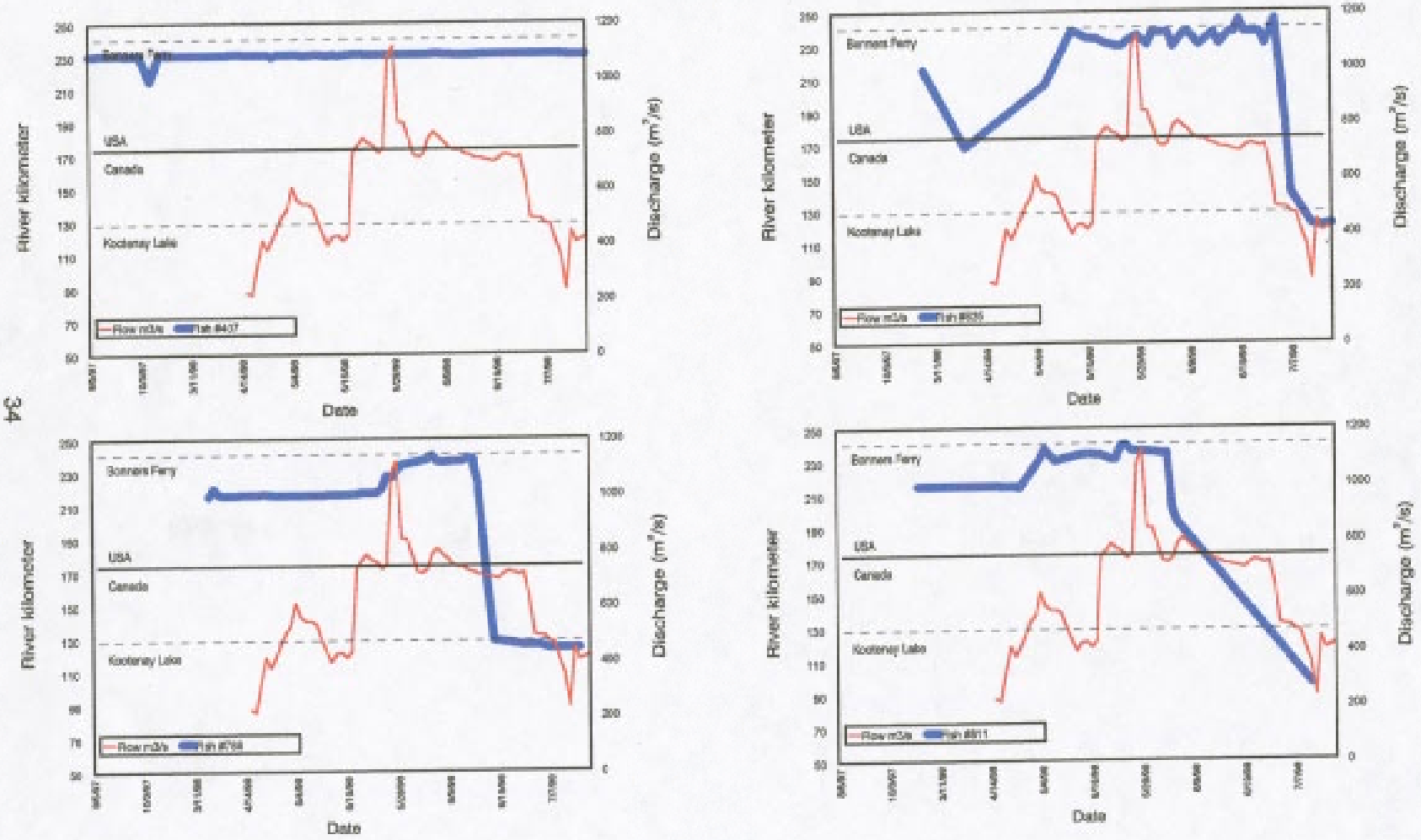
Categories of sexual development		Percent (number) of sample by year									
Category/Sex	**Description of development**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995[a]**	**1996[a]**	**1997**	**1998**
0/Unknown[b]	Gonad undifferentiated or not seen	32 (58)	14 (15)	6 (3)	2 (1)	0	24 (14)	0	45 (67)	19 (14)	15 (14)
1/Female	Previtellogenic: No visual signs of vitellogenesis; eggs present but have average diameter <0.5 mm	14 (25)	12 (13)	8 (4)	12 (5)	0	5 (3)	11 (3)	5 (7)	14 (10)	11 (10)
2/Female	Early vitellogenic: Eggs are cream to gray; average diameter 0.6-2.1 mm	7 (12)	7 (8)	4 (2)	2 (1)	5 (1)	2 (1)	0	4 (6)	0	9 (8)
3/Female	Late vitellogenic: Eggs are pigmented and attached to ovarian tissue; average diameter 2.2-2.9 mm	6 (10)	5 (5)	8 (4)	9 (4)	53 (10)	2 (1)	0	2 (3)	1 (1)	2 (2)
4/Female	Ripe: Eggs are fully pigmented and detached from ovarian issue; average diameter 3.0-3.4 mm	2 (3)	5 (5)	4 (2)	9 (4)	11 (2)	14 (8)	25 (7)	5 (7)	10 (7)	4 (4)
5/Female	Spent: Gonads are flaccid and contain some residual fully pigmented eggs	3 (5)	1 (1)	2 (1)	0	5 (1)	0	3.5 (1)	0	0	0
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	2 (3)	0	0	0	0	0	0	1 (2)	3 (2)	0
R/Female	Reabsorbing eggs	0	0	0	2 (1)	0	0	0	1 (1)	0	0
7/Male	Non-reproductive: Testes with translucent smokey pigmentation	3 (6)	27 (30)	29 (15)	26 (11)	0	19 (11)	36 (10)	13 (20)	24 (17)	19 (18)
8/Male	Reproductive: Testes white with folds and lobes	32 (58)	28 (31)	18 (9)	16 (7)	21 (4)	35 (20)	21 (6)	20 (31)	29 (21)	40 (38)
9/Male	Ripe: Milt flowing; large white lobular testes	0	3 (3)	14 (7)	21 (9)	5 (1)	0	0	2 (3)	0	0
S/Male	Spent: Testes flaccid; some residue of milt	0	0	8 (4)	0	0	0	3.5 (1)	2 (3)	0	0

[a] Surgeries done by IDFG and KITOI were carried out on fish that externally appeared to be candidates for spawning. Surgeries done by BCME and those done during previous years were more randomly distributed among fish >130cm.

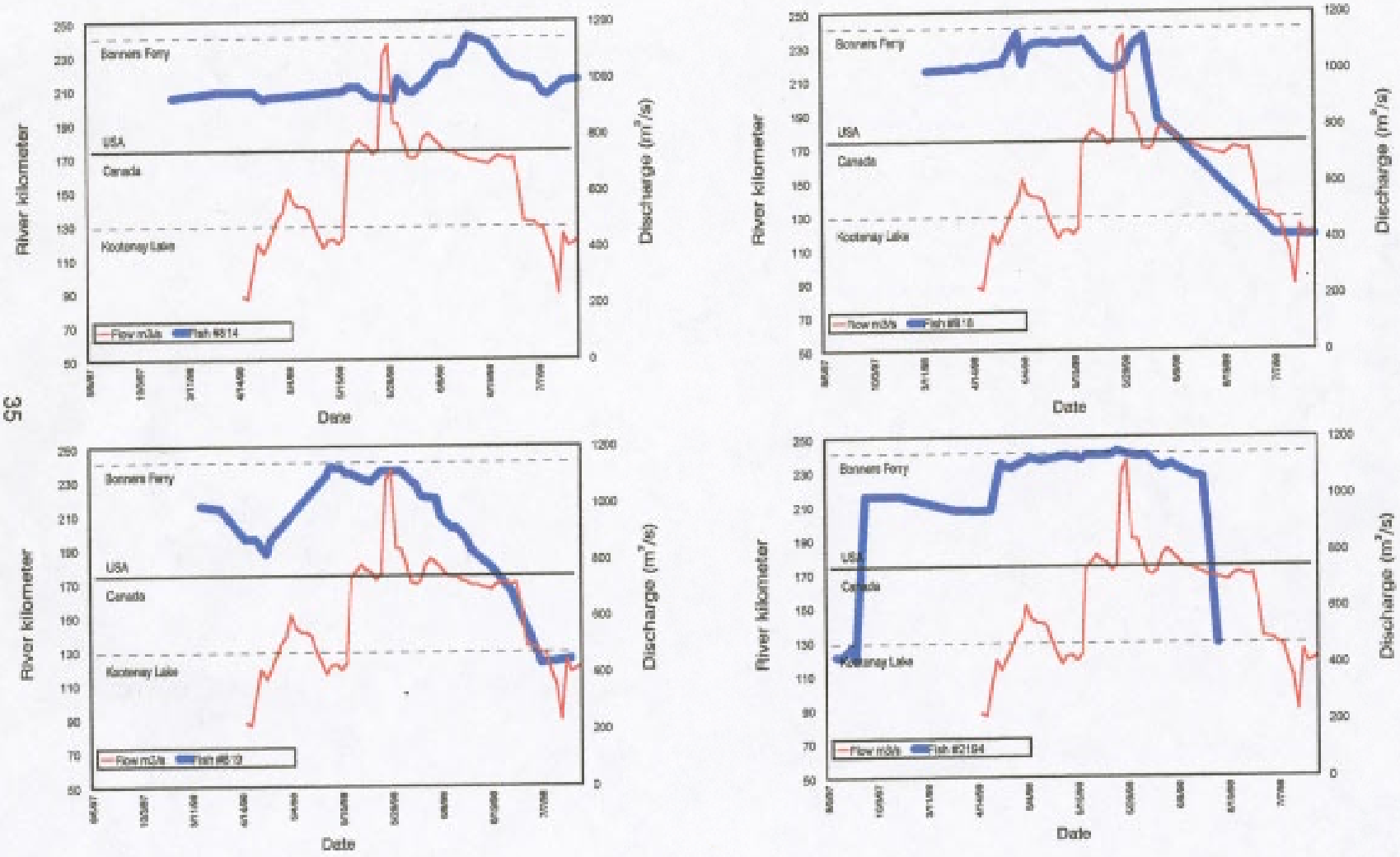
[b] Fish that we did not perform surgery on were placed in the unknown category



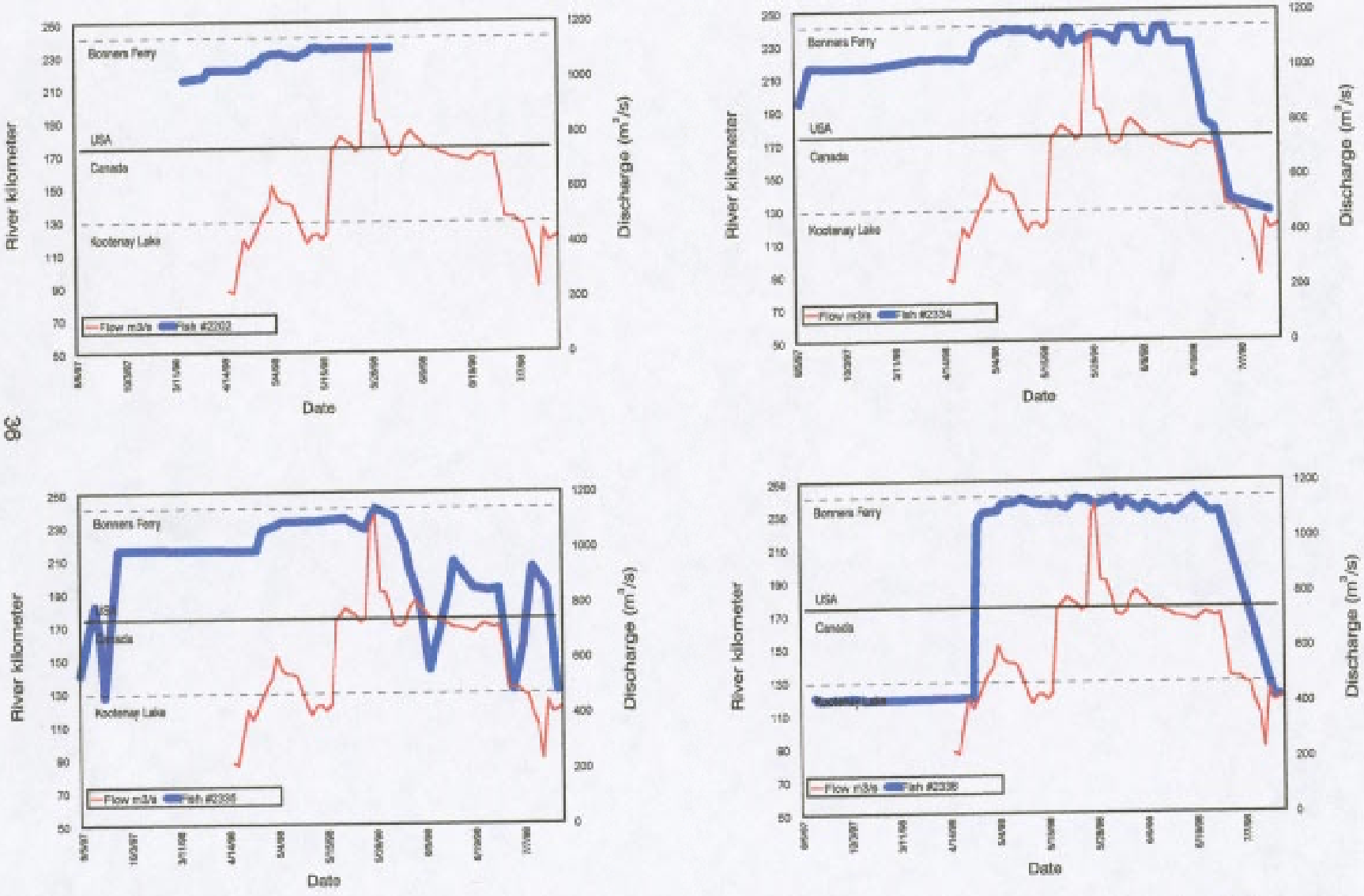
Appendix 2a. Migration and flow (m3/s) for adult white sturgeon that appeared to spawn in the Kootenai River, Idaho, in 1998.



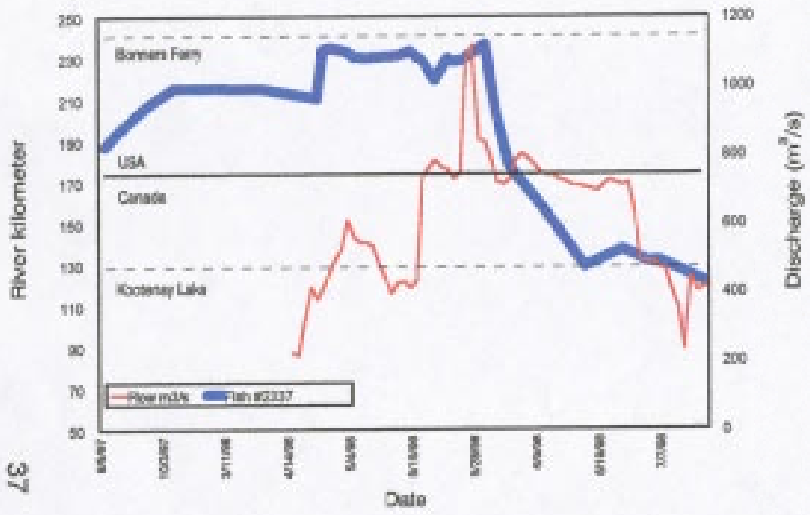
Appendix 2b. Migration and flow (m3/s) for adult white sturgeon that appeared to spawn in the Kootenai River, Idaho, in 1998 continued.

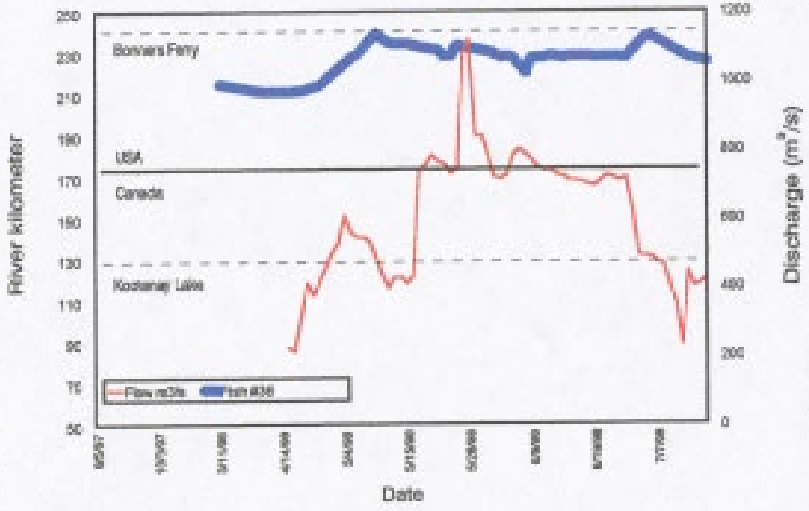


Appendix 2c. Migration and flow (m3/s) for adult white sturgeon that appeared to spawn in the Kootenai River, Idaho, in 1998 continued.



Appendix 2d. Migration and flow (m3/s) for adult white sturgeon that appeared to spawn in the Kootenai River, Idaho, in 1998 continued.





Appendix 2e. Migration and flow (m3/s) for adult white sturgeon that appeared to spawn in the Kootenai River, Idaho, in 1998 continued.

Appendix 3. River location (rkm), number of eggs, depth (m), temperature (°C) and velocity at sites (m/s) where white sturgeon eggs were collected, Kootenai River, Idaho, 1998.

River section (rkm)	No. Eggs[a]	No. Mats w/eggs	Depth range (m)	Mean depth (m)	0.2[a] Velocity (m/s)	0.8[b] Velocity (m/s)	Mean velocity (m/s)
238.0-229.5	39	8	34-46	40.4	0.71	0.45	0.58
229.6-231.5	173	23	23-54	35.8	0.71	0.57	0.64
233.5-234.7	14	3	30-38	34	0.74	0.58	0.66
234.8-237.5	55	15	29-57	46.4	0.64	0.56	0.60
237.6-240.5	112	11	25-31	27.9	0.65	0.49	0.57
All locations	**393**	**60**	**23-57**	**37.5**	**0.68**	**0.54**	**0.61**

[a]0.2 of total depth
[b]0.8 of total depth

Appendix 4. White sturgeon egg collection locations, habitat attributes and staging data for eggs collected during the 1998 sampling season on the Kootenai River, Idaho.

Date	Rkm	Depth	No. eggs	Flow 0 .2	Flow 0.8	Temp (C)	Discharge (m3/s)	Stage	Spawn Date
5-8-98	229.4	11	3	0.29	0.12	9.6	544	18	5/7
								Dead	
5-8-98	231	9	2	0.56	0.65	9.6	544	19	5/7
5-8-98	230.9	9	5	0.34	0.08	9.6	544	19	5/7
								20	5/6
5-11-98	229.7	10	36	0.60	0.51	9.72	437	17	5/10
5-11-98	231	7	1	0.73	0.4	9.72	437	23	5/7
5-11-98	239.5	8	2	0.79	0.43	9.72	437	12	5/11
								15	5/11
5-12-98	229.7	10	9	0.43	0.29	9.76	397	17	5/10
								18	5/10
								Dead	
5-12-98	239	8	4	0.49	0.43	9.76	397	14	5/12
5-12-98	239.6	8	2	0.37	0.27	9.76	397	12	5/12
								15	5/12
5-13-98	229.3	11	2	0.58	0.26	9.76	426	Dead	
5-13-98	229.6	10	1	0.5	0.4	9.76	426	21	5/11
5-13-98	231	9	1	0.53	0.42	9.76	426	12	5/13
5-13-98	233.9	9	11	0.58	0.45	9.76	426	21	5/11
5-13-98	239.5	8	12	0.41	0.33	9.76	426	16	5/13
								20	5/11
5-14-98	229.1	10	1	0.55	0.27	10.4	430	20	5/12
5-14-98	229.8	12	4			10.4	430	Dead	
				---	---			21	5/12
5-14-98	231	7	2	---	---	10.4	430	21	5/12
5-14-98	239	8	1	---	---	10.4	430	19	5/13
5-15-98	229.8	12	2	---	---	9.4	411	Dead	
								21	5/11
5-18-98	229.8	10	2	0.67	0.54	8.28	434	Dead	
5-18-98	236.4	13	1	0.41	0.4	8.28	434	Dead	
5-24-98	229.7	10	2	0.84	0.72	8.92	756	12	5/24
5-24-98	234	12	2	0.8	0.63	8.92	756	12	5/24
5-24-98	239.5	9	58	0.78	0.62	8.92	756	Dead	
								12	5/24
								14	5/24
								15	5/24
								16	5/23
								17	5/23
								18	5/23
								19	5/22
								20	5/22
								Shell	
5-25-98	229	14	22	0.83	0.52	9.4	730	Dead	
								18	5/24

Appendix 4. Continued.

Date	Rkm	Depth	No. eggs	Flow 0 .2	Flow 0.8	Temp (C)	Discharge (m3/s)	Stage	Spawn Date
5-25-98	229.5	14	1	0.86	0.52	9.4	730	17	5/24
5-25-98	229.7	14	37	0.79	0.66	9.4	730	12	5/25
								13	5/25
								14	5/25
								15	5/25
5-25-98	239.5	9	4	0.52	0.6	9.4	730	17	5/24
								19	5/23
5-25-98	239.6	9	1	0.73	0.36	9.4	730	19	5/23
5-26-98	229	14	2	0.89	0.82	10.4	747	19	5/24
5-26-98	229.7	11	12	0.79	0.68	10.4	747	16	5/25
								17	5/25
								18	5/25
								19	5/24
5-26-98	231	9	1	1.0	0.87	10.4	747	12	5/26
5-26-98	239.5	9	9	0.74	0.74	10.4	747	Dead	
								20	5/24
								21	5/24
5-26-98	240	9	19	0.93	0.53	10.4	747	Dead	
								14	5/26
								15	5/26
								16	5/25
5-28-98	229.6	10	1	0.91	0.74	8.76	1117	22	5/25
5-28-98	231	15	42	1.1	0.76	8.76	1117	15	5/28
								18	5/27
								19	5/27
								Dead	
5-28-98	231.2	15	2	0.98	0.9	8.76	1117	Dead	
								15	5/28
5-29-98	236.5	17	8	0.57	0.75	9.6	840	15	5/29
								16	5/29
								17	5/28
								18	5/28
5-31-98	231.1	12	3	0.9	0.84	10.04	839	Dead	
								23	5/27
6-1-98	234.3	14	5	0.62	0.63	11.04	782	Dead	
								16	5/30
6-1-98	236.4	14	4	0.68	0.52	11.04	782	21	5/29
6-1-98	236.5	14	14	0.69	0.68	11.04	782	Dead	
								21	5/30
								22	5/30
								24	5/29
6-1-98	235.5	16	1	0.78	0.57	11.04	782	21	5/29
6-1-98	235.6	9	3	0.78	0.57	11.04	782	Dead	
								18	5/30
								23	5/29
6-1-98	236	13	1	0.31	0.16	11.04	782	21	5/30

Appendix 4. Continued.

Date	Rkm	Depth	No. eggs	Flow 0 .2	Flow 0.8	Temp (C)	Discharge (m3/s)	Stage	Spawn Date
6-2-98	229.5	13	6	0.85	0.74	10.98	720	12	6/2
								13	6/2
6-2-98	235.9	12	2	0.7	0.56	10.98	720	Dead	
6-2-98	231	15	3	0.55	0.46	10.98	720	23	5/30
								25	5/28
6-2-98	236.4	17	5	.58	.51	10.98	720	Dead	
								22	5/30
								23	5/30
6-4-98	229.5	11	2	.86	.35	10.92	714	Dead	
6-4-98	229.6	9	4	.73	.35	10.92	714	Dead	
								21	6/2
6-4-98	230.9	16	1	.66	.55	10.92	714	24	5/31
6-5-98	236.5	16	8	.7	.51	10.99	727	Dead	
								12	6/5
								13	6/5
								14	6/5
6-8-98	236.5	15	2	.75	.69	11.3	785	20	6/6
								25	6/4
6-13-98	236	39	1	.84	.44	11.83	725	ND	
6-14-98	233.7	10	1	.84	.65	10.87	721	28	6/2

Appendix 5. White sturgeon egg staging data for eggs collected on experimental substrate mats equipped with drift nets during the 1998 sampling season on the Kootenai River, Idaho.

Date	Rkm	Depth	No. eggs in net	No. eggs on mat	Flow 0.2	Flow 0.8	Temp (C)	Discharge (m3/s)	Stage	Spawn Date
5-13-98	230.9	24	0	4	0.52	0.28	9.76	426	16	5/13
5-13-98	239.4	26	1	0	0.47	0.4	9.76	426	13	5/13
5-21-98	233.8	37	0	1	0.83	0.74	9.84	783	Dead	---
5-24-98	229.0	47	0	2	0.82	0.63	8.92	756	12	5/24
5-26-98	230.8	39	0	1	0.66	0.68	10.4	747	17	5/25
5-26-98	230.8	39	0	1	0.66	0.68	10.4	747	17	5/25
5-28-98	230.9	30	5	49	1.05	0.67	8.76	1117	Dead	---
									14	5/28
									15	5/28
									18	5/27
									19	5/27
									20	5/26
									21	5/26
5-31-98	230.8	30	4	5	.51	.85	10.04	839	Dead	---
									20	5/29
									21	5/29
									22	5/28
									23	5/27
5-31-98	230.9	60	0	17	.79	.8	10.04	839	Dead	---
									20	5/29
									21	5/29
									22	5/28
									23	5/27
6-9-98	233.9	38	0	1	.96	.97	11.78	767	24	5/29

Appendix 6. Year class, number captured, capture locations, fork length (cm), total length (cm) and weight (kg) of hatchery released juvenile sturgeon from the Kootenai River, Idaho, 1998.

Year class	No. captured	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)
1990	1	215.4	66.2	78.1	1.86
	1	225.1	65.8	77.7	0.195
1991	2	205	56.3-64	64.8-73.6	12.519
	1	215.4	64.2	75.4	0.215
	1	215.5	66.7	77.9	2.15
	3	215.6	49.6-57	58.2-66.2	.8-1.25
	1	225	52.1	60.1	0.95
	2	225.1	49.6-55.4	58-63.8	0.775-1.2
1992	1	182.5	51.5	59	0.78
	1	190.3	61.2	71	1.525
	1	204	59	69.5	1.5
	1	205	66.6	77.2	1.85
	1	210.5	66.3	75.6	1.8
	1	215.5	50.2	57.9	0.775
	1	215.6	59.5	68	1.4
	1	227.4	62	59.1	1
1995	1	176.3	24.7	40	0.15
	1	185	39.1	43.3	0.325
	1	190.3	27.2	31.7	0.15
	1	191.9	35.7	41.3	0.2
	1	192.1	36.1	42	0.25
	1	195.7	35.5	42	0.24
	1	203.4	33.2	38.5	0.25
	1	204	38	43.5	0.3
	2	205	33.9-38.2	38.9-44.3	.25-0.3
	1	205.3	38	44	0.3
	2	215	33.1-34.3	37.8-39.7	0.1-0.175
	1	215.2	35.1	41	0.175
	6	215.4	32.3-36.5	37.4-42.5	0.2-0.25
	31	215.5	25.5-39.2	29.1-45.3	.06-.275
	30	215.6	30-41.5	34.2-49	.125-.42
	4	215.7	30.4-37.4	34.1-44.5	0.15-0.36
	5	215.8	28.7-38.4	33.5-44.5	.13-0.36
	1	220	32.5	38	0.24

Appendix 6. continued.

Year class	No. captured	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)
	4	222	25.9-30.5	30-35	0.2-0.3
	1	222.7	33.3	38.2	0.2
1995	2	224.6	29.4-35	33-42	015.019
	2	224.7	31.4-32.9	36-38	0.18-0.19
	4	224.8	31.9-40.5	36.2-46	0.175-0.4
	3	224.9	30.4-34.5	34.2-39.5	0.15-0.2
	27	225	30-41	33.1-45	.1-.375
	10	225.1	28-53.5	32.2-61.5	0.1-1.05
	2	227.3	31.8	36.9-37	0.175-0.2
	1	227.4	22.7	34.6	0.15
	1	230.8	36.3	41.3	0.25
	2	230.9	27.9-35	32.3-40.1	0.125-0.25
	1	244.6	31.5	36.6	0.134

Appendix 7. Capture location, fork length (cm), total length (cm), weight and year class of wild juvenile sturgeon captured in the Kootenai River, Idaho, 1998.

Fish number	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)	Year class
3275	203.4	47.6	55.1	0.75	1991
3255	204	65.7	76.0	2.26	1991
5250	215.5	58.6	68.7	1.35	1992

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