FISHERY RESEARCH

KOOTENAI RIVER WHITE STURGEON SPAWNING AND RECRUITMENT EVALUATION

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January 1, 2000 – March 31, 2001

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Project Progress Report

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ABSTRACT

Sampling for adult Kootenai River white sturgeon *Acipenser transmontanus* began in March and continued through April 2000. Fifty-nine adult white sturgeon were captured with 3,307 hours of angling and set-lining effort, while two additional adult sturgeon were captured while gillnetting for juveniles. Flows for Kootenai River white sturgeon spawning were delayed until the release of hatchery white sturgeon larvae; the high flows were intended to simulate post-Libby Dam rearing conditions. However, flows were expected to be low because the snowpack in the basin was estimated at 85% of normal. Discharge from Libby Dam from mid-March through June 5 was maintained at 113 m^3/s (4,000 cfs). Flows in the Kootenai River at Bonners Ferry during April peaked at 641 m^3/s (22,600 cfs) on April 23. Flows subsided by mid-May to about 351 m^3/s (12,400 cfs) but rose to 606 m^3/s (21,400 cfs) by May 23 because of local runoff. Water temperature ranged from about 6 to 13°C (43 to 56°F) from May through early June. Mitigative spawning and incubation flows from Libby Dam began on June 5 with a gradual ramp through June 13 (three weeks after sturgeon began spawning) when flow at Bonners Ferry was brought to 948 m^3/s (33,500 cfs). An experimental release of 139,000 white sturgeon larvae from the Kootenai Indian Tribe of Idaho Hatchery began on June 12. During mitigated flows, water temperatures oscillated between 10 and 15°C (50 to 59°F). We monitored the movements of 26 adult sturgeon from September 1, 1999 to August 31, 2000. These included fish in Kootenay Lake, British Columbia, and the Kootenai River in Idaho and British Columbia. Eight adult white sturgeon with transmitters were eventually located in the spawning reach. Sampling for sturgeon eggs with mats began May 2 and ended July 6, 2000. We sampled 2,676 mat d (a mat d is one 24 h set) during white sturgeon spawning. A total of 186 white sturgeon eggs were collected from May 23 through June 23, 2000. A single mat on June 21 held 126 eggs comprising 68% of the total collection. Mats collected eggs within four of eight different geographic river sections that we sampled. The Refuge reach (river km 234.8 to 237.5) produced the most eggs (138) with 312 mat d of effort; Middle Shorty's section (river km 229.6 to 231.5) produced 24 eggs with 565 mat d of effort; Myrtle Creek section (river km 233.5 to 234.7) produced 19 eggs with 149 d of mat effort, and the Deep Creek section (river km 237.6 to 240.5) produced five white sturgeon eggs with 212 d of mat effort. All viable eggs were staged to determine spawning dates; each day spawning occurs is a single event. Thirteen spawning events were identified from May 23 through June 21, 2000. No wild sturgeon larvae were caught during our ½ m and D-ring sampling efforts. However, 33 of 139,000 hatchery larvae were caught soon after their release, indicating our gear is suitable for sampling sturgeon larvae in the Kootenai River providing larvae are available. We expended a total of 373 h of gill netting effort and captured a total of 189 hatchery juvenile white sturgeon from July 1 through September 1, 2000. No wild juveniles were captured with gill nets. Recommendations for the 2001 spawning season include coordinating the flow test with sturgeon spawning behavior and targeting river temperatures of 8 to 10°C (46 to 50°F) without jeopardizing sturgeon migration or spawning behavior.

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OBJECTIVE

1. Determine environmental requirements for adequate spawning and recruitment of white sturgeon *Acipenser transmontanus*.

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). The 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 though the West Arm of Kootenay Lake 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). Regulation of the Kootenai River with Libby Dam changed the natural hydrograph of the river. Post-Libby Dam flows during spring were reduced by about a third, and flows during winter are now three to four times higher (Figure 2). However, since 1991 mitigative spawning and rearing flows have further changed the Kootenai River spring hydrograph to accommodate white sturgeon spawning (Figure 2).

METHODS

Discharge, Water Temperature, and Secchi Measurements

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 U.S. Fish and Wildlife Service (USFWS) and USACE established operational guidelines for Libby Dam for the 2000 Kootenai River white sturgeon spawning season. The guidelines were altered from previous years of study in 2000 to restructure and coordinate the release of water with an experimental release of hatchery white sturgeon larvae (see Experimental Release of Hatchery White Sturgeon Larvae).

Secchi disc measurements were made daily from May 14 through July 5 during egg mat sampling to provide a measure of turbidity during spawning. Measurements were made at rkm 229.8, 240.0, and 244.5; daily measurements were averaged.

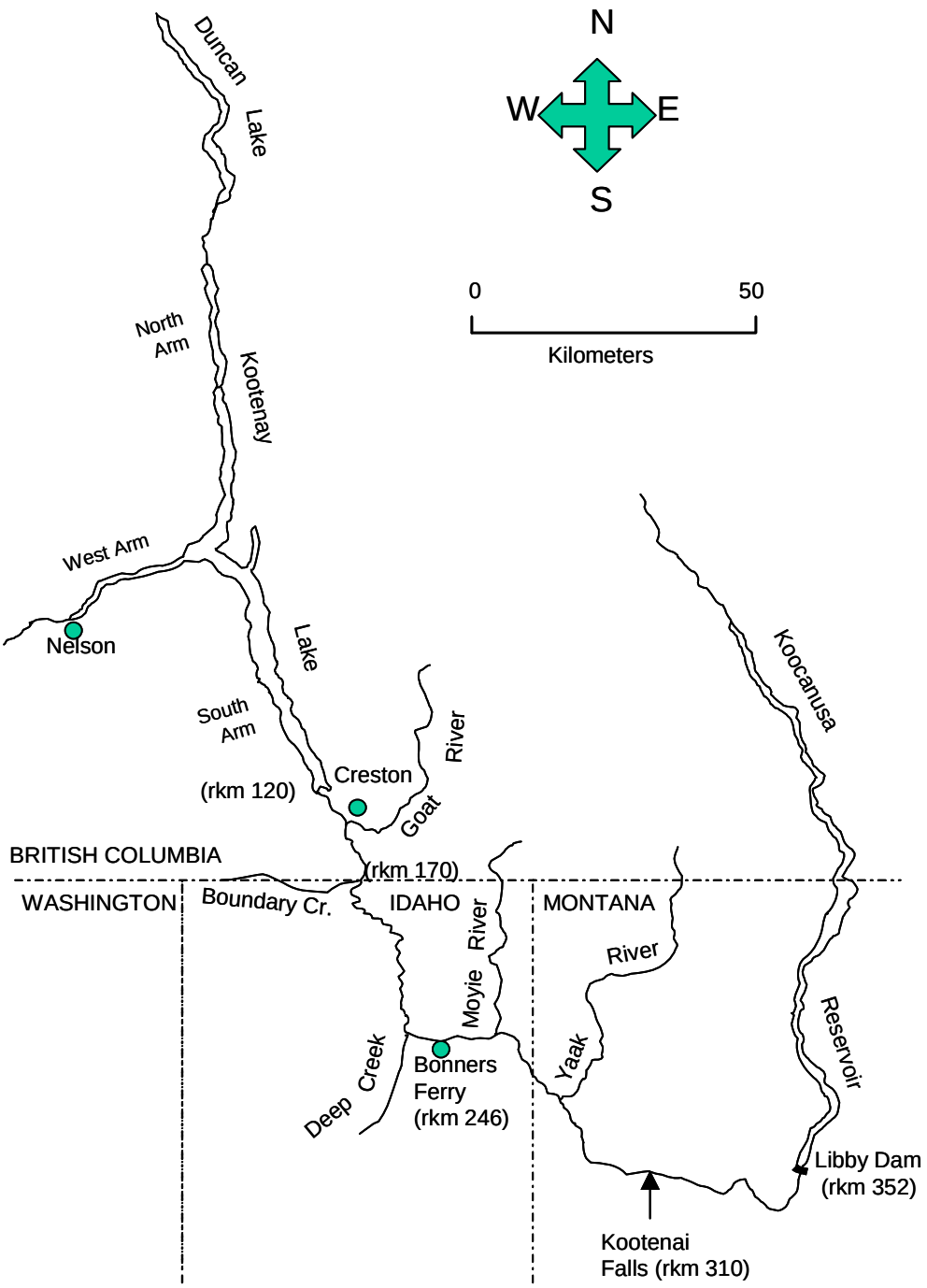

Figure 1. Location of the Kootenai River, Kootenay Lake, Lake Koocanusa, and major tributaries. The river distances from the northernmost reach of Kootenay Lake are in kilometers (rkm) and are indicated at important access points.

Adult White Sturgeon Sampling

Adult white sturgeon were captured with rod and reel or set lines from March 1, 2000 to March 25, 2000 as described in Paragamian et al. (1996). Adult white sturgeon expected to spawn in 2000 were tagged with radio and sonic tags and monitored to determine movements during the spawning season (Paragamian et al. 1996).

Adult White Sturgeon Telemetry Methods

Boat Telemetry

Movement and migration of adult white sturgeon fitted with sonic and radio transmitters were monitored monthly by boat 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 reproductive males migrating upstream to staging and spawning reaches. Each transmitter location was recorded to the nearest 0.1 rkm (0.061 mi). Effort to monitor sturgeon movement and activity varied with season. Less effort was provided during winter months when most fish moved less frequently than in spring and fall. Increased activity of tagged fish during the prespawning and spawning seasons required more frequent monitoring. Reaches above Copeland, Idaho (Figure 1) were monitored more intensively than downriver or Kootenay Lake, especially during the prespawning and spawning periods when mature sturgeon moved upstream.

Fixed Receiver Telemetry

Fixed location receivers provided us with the opportunity to detect movement into specific locations at documented times of the day, including the evening through morning hours. Three fixed receivers were stationed between rkm 230.5 and 244.5. Site 1 was situated furthest downriver at mid-Shorty's Island (rkm 230.5). This downriver position was selected to detect fish movements into the Shorty's Island spawning reach (rkm 229.9 to 231.0) from downriver staging reaches. Site 2 was located at the Kootenai National Wildlife Refuge (rkm 237.5). Site 3 was located just upriver from Ambush Rock (rkm 244.5) on the south side of the Kootenai River at the end of a straight reach of river. This upriver location was chosen in 1999 in an effort to detect fish movements above Ambush Rock (rkm 244.4), eliminate background noise problems experienced at previous sites on the north side of the river, and avoid vandalism that occurred at the previous south-side sites in 1997 and 1998. In addition, it is the lowermost reach of river with gravel and cobble substrate.

Each fixed-receiver station consisted of a scanning receiver (Advanced Telemetry Systems [ATS] model R2100), data logger (ATS model DCCII), 3-element Yagi antenna, and 12-volt deep-cycle battery to operate the system. Antennas were mounted on 1.8 m (6 ft) metal fence posts horizontal to the river and affording a clear 180-degree view of the river. Selected sites were all on straight reaches to facilitate reception of the radio frequencies of potential male and female spawners programmed into the receivers. Data loggers were set to record only those signals matching the specific pulse rates (pulse per minute) of the tagged white sturgeon. A pattern-matching option was also selected to verify signals. A test radio tag was used to verify detection range and strength at each site.

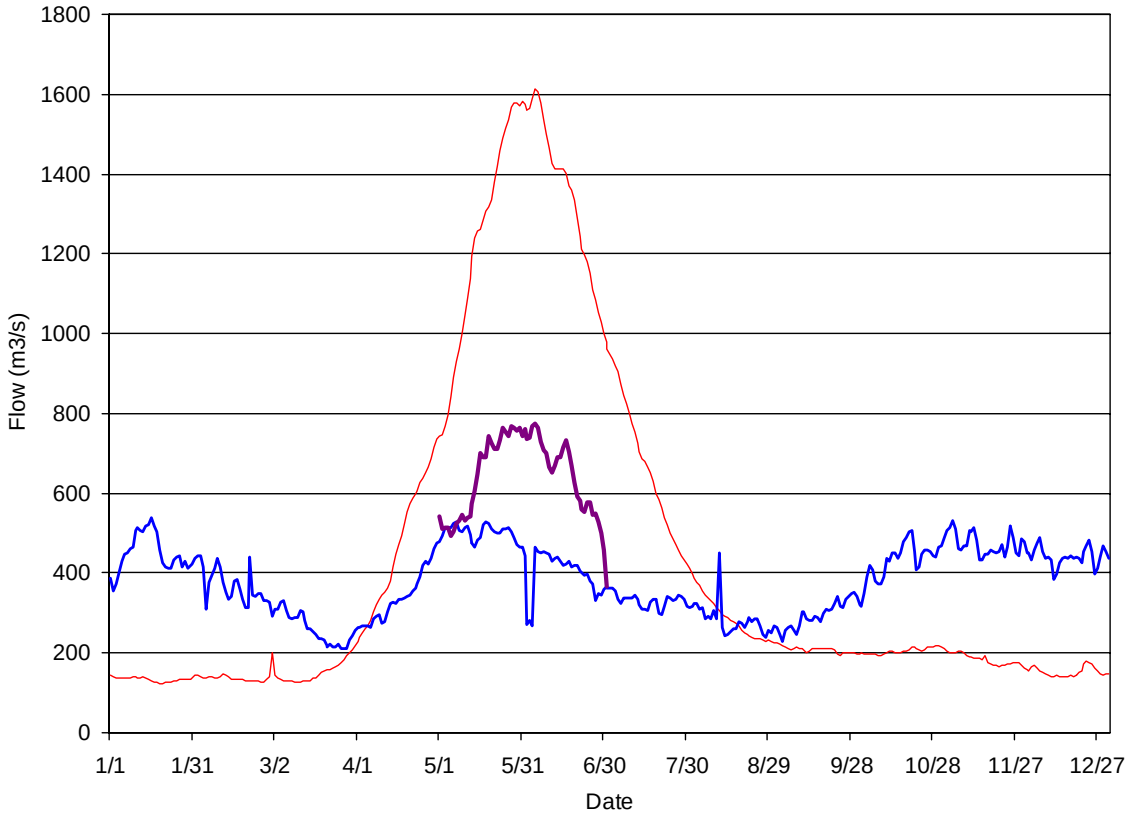

Figure 2. Mean daily flow patterns in the Kootenai River at Bonners Ferry, Idaho from 1928-1972 (pre-Libby Dam), 1973-1990 (post-Libby Dam), and 1991-2000 (post-Libby Dam with augmented flows).

Fixed Wing Telemetry

Two loop antennas were mounted on the wing struts of a Cessna 182 for fixed wing aerial telemetry. Flights followed a route downriver from Bonners Ferry to Kootenay Lake at an altitude of 152 to 305 m (500 to 1,000 ft) above the river and speeds of 60 to 80 knots. Up to 13 preset radio frequencies of potential spawners were cycled through an ATS model R2100 scanning receiver and deleted as fish were detected. The frequency cycling rate was two to four seconds to facilitate maximum numbers of fish cycled (13) without sacrificing detection range. Locations were recorded to the nearest 0.1 rkm.

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 sturgeon monitored by telemetry in previous years. Adult white sturgeon densities were classified as high, medium, and low based on numbers of observations of sonic- and

radio-tagged fish. Densities were classified as follows: high—sturgeon were frequently located, medium—sturgeon were occasionally located, and low—sturgeon were seldom located (Paragamian et al. 1997). The length of the spawning reach was marked along the shoreline with flag material at each 0.1 km increment. We set an average of 19 mats/1.0 km (30 mats/mi) in the high density sections (25 mats), an average of 1.05 mats/1.0 km (1.6 mats) in the medium density sections (21 mats), and an average of 0.16 mat/km (0.25 mat/mi) in the low density sections (24 mats). The reach from rkm 230-231 was not sampled because it was a broodstock collection reach for the Kootenai Tribe of Idaho (KTOI). Some of the high and medium sites were sampled with two mats. The sites that were sampled with two mats were chosen randomly from all high or medium density sites. About 70 mats were deployed; eggs were removed from mats, stored in labeled vials containing formalin or alcohol solution, and brought back to our laboratory. All viable eggs were staged by viewing at 120X under a dissecting microscope to estimate spawn date by the method of Beer (1981).

Experimental Release of Hatchery White Sturgeon Larvae

A total of 139,000 white sturgeon larvae from 3 to 23 d old (technically the older aged sturgeon cannot be referred to as larvae because of their advanced development) were released into the Kootenai River to help resolve a “larvae to juvenile survival bottleneck” hypothesis. White sturgeon larvae were released on five occasions from June 7 through July 14, 2000. Releases were from a boat at rkm 236. Substrate at the release site was comprised primarily of sand and fine gravel. Two boats were positioned, one at 0.5 km and the second at 1.0 km downstream of the release site. Each boat was equipped with a single D-ring (for benthic sampling) and two ½ m nets (surface and subsurface) deployed as passive gear. Sampling for the first and second releases with D-ring and ½ m nets began 1 h before the release (2000 h) and continued for 24 h after each release. Thereafter, sampling was for 6 h and releases occurred at 1000 h. White sturgeon larvae were reared at the KTOI hatchery,

Larval Sturgeon Sampling

We used surface and midwater paired ½ m nets, 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 and D-rings. Nets were towed upstream, against the current, during daylight and dusk hours or were passively deployed in a stationary position. Active and passive sampling were carried out at randomly selected locations between rkm 170 and rkm 240 in June and July.

Juvenile White Sturgeon Sampling

Benthic trawls and weighted multi-filament gill nets with 1.5 or 2 cm (3.8 or 5.1 in) bar mesh 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 was completed at randomly selected locations between rkm 170 and rkm 236. Gill nets were set during the day and checked every hour. Juvenile white sturgeon were processed by methods cited in Paragamian et al. (1996).

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 2000. The benthic trawl provided the opportunity to sample the bottom of the river with gear that would be selective for YOY and juvenile sturgeon.

RESULTS

Discharge, Water Temperature, and Secchi Measurements

Flows in 2000 were expected to be slightly below normal, because the snowpack in the basin was estimated at about 85% of normal and local inflows were expected to be very low <280 m^3/s (10,000 cfs) (conversions to cfs are rounded to hundreds). Flows for white sturgeon spawning were readjusted by the Kootenai River White Sturgeon Recovery Team (KRWSRT) in 2000 to facilitate an experimental release of hatchery white sturgeon larvae. Libby Dam discharge from mid-March through June 5 was maintained at 113 m^3/s (4,000 cfs). Flow at Bonners Ferry gradually increased from 246 m^3/s (8,700 cfs) on April 1 to a peak of 641 m^3/s (22,600 cfs) on April 23 (Figure 3). Flows subsided by mid-May to about 351 m^3/s (12,400 cfs) but rose to 606 m^3/s (21,400 cfs) by May 23 because of local runoff. Discharge subsided again to 335 m^3/s (11,800 cfs) June 3, 2000. Water temperature ranged from about 6 to 13°C (43 to 56°F) from May through early June (Figure 3). Mitigative flows from Libby Dam for the experimental release of hatchery white sturgeon larvae began on June 5 with a gradual ramp up to June 13 (three weeks after sturgeon began spawning) when flow at Bonners Ferry was brought to 948 m^3/s (33,500 cfs). Temperatures oscillated between 10 and 15°C (50 to 59°F). Flow gradually subsided at Bonners Ferry to 740 m^3/s (26,100 cfs) on June 29 before dropping further.

Secchi measurements from May 14 through July 5 averaged 2.54 m, N = 156, SD = 0.64 m (8.34 ft, SD = 2.1 ft) and ranged from 1.9 m (6.24 ft) to 3.18 m (10.44 ft) (Figure 4).

Adult White Sturgeon Sampling

Fifty-nine adult white sturgeon were captured with 3,307 hours of angling and set-lining effort between March 6 and April 27, 2000 (Table 1). Two adult sturgeon were captured during sampling for juvenile white sturgeon with gillnets during July and August 2000.

Thirty-nine (67%) of the 61 adult sturgeon captured were recaptures from previous years, and two were recaptures of fish originally caught in 2000 (Table 1). Catch per unit effort (CPUE) for adult white sturgeon caught by angling and setline gear was 0.138 and 0.011 fish/rod or setline h, respectively. Catch per unit effort in gillnets was 0.005 fish/gillnet h for adults captured during juvenile sampling (Table 1).

Forty-six biopsies were performed by the Idaho Department of Fish and Game (IDFG) on adult sturgeon during 2000 to determine sexual maturity stage of ovaries and testes (12 females, 32 males, 2 unknown) (Appendix 1). Sonic and radio tags were attached to three reproductively mature females and two mature male white sturgeon during this effort; all fish were released.

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, 2000 to September 1, 2000.

Gear Type	Hours of effort	Number of juvenile sturgeon caught (number of individuals–non-recaptures)	Number of adult sturgeon caught (Number of recaptures)	Juvenile CPUE (fish/h)	Adult CPUE (fish/h)
Hoopnet	3,205.6	1(1)	0	0.0003	0
Gill net	372.7	189(160)	2(1)	0.52	0.005
Angling	173.4	0	24(15)	0	0.138
Setline	3,133.8	0	35(25)	0	0.011
Total	**6,885.5**	**190(161)**	**61(41)**		

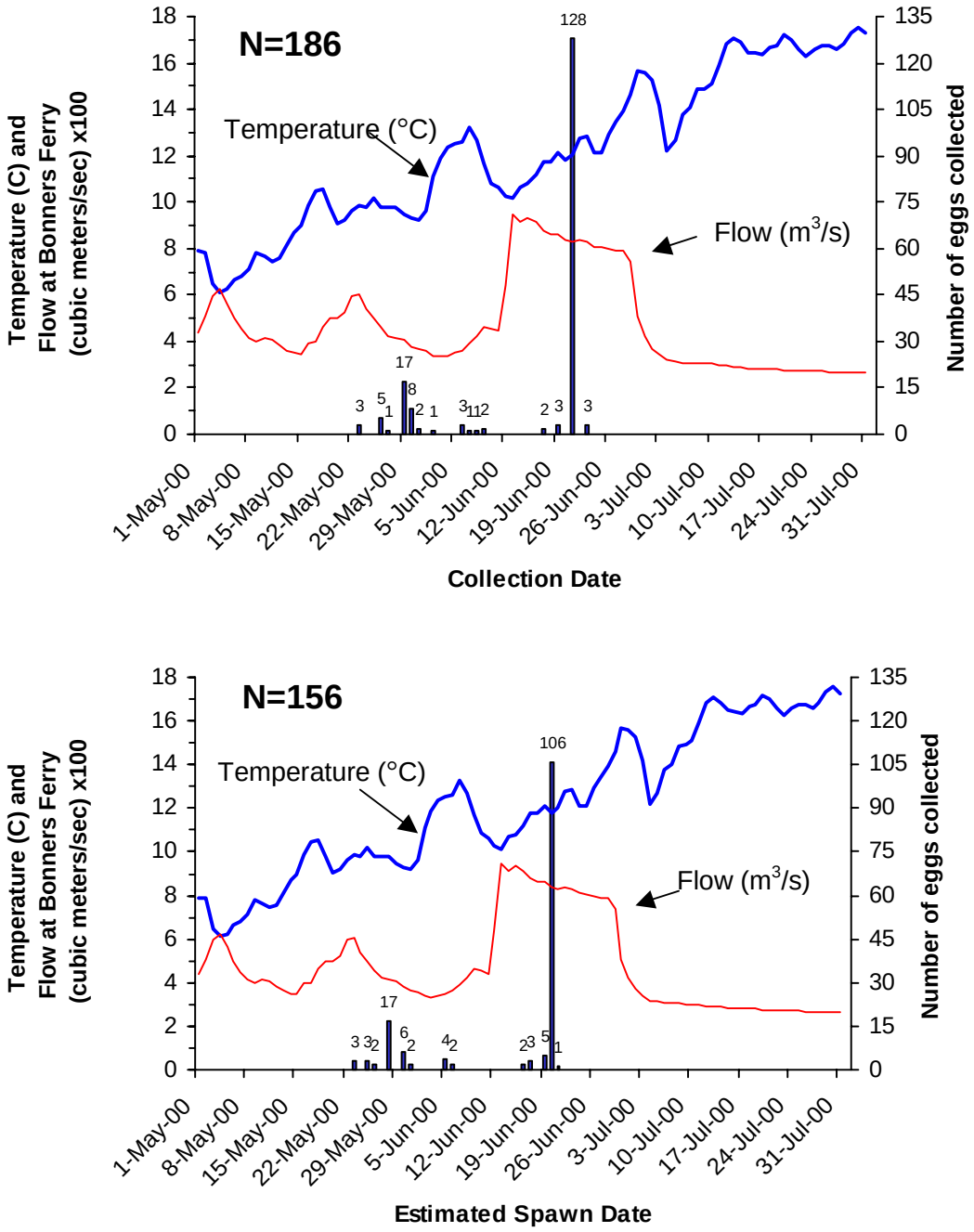

Figure 3. Top figure is collection date, number of eggs, temperature (°C), and flow (m^3/s), Kootenai River at Bonners Ferry, Idaho, 2000. Bottom figure is estimated spawn date, number of eggs, temperature (°C), and flow (m^3/s).

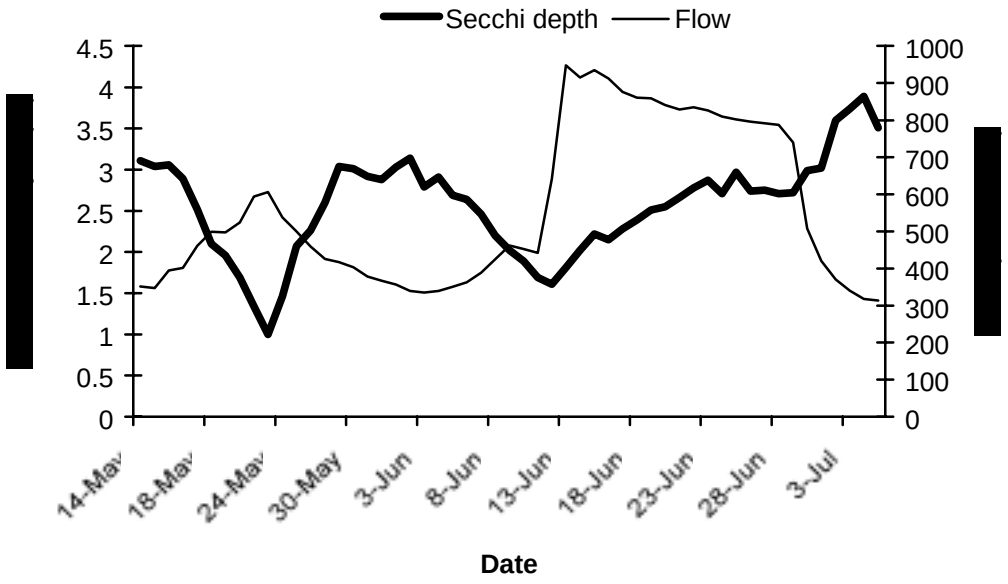

Figure 4. Average daily Secchi disk depth (m) and flow (m^3/s) in the Kootenai River near Bonners Ferry, Idaho from May 14 to July 5, 2000.

Adult White Sturgeon Telemetry

Migration of Monitored Sturgeon in 2000

We monitored the movements of 26 adult sturgeon from September 1, 1999 to August 31, 2000 that carried radio or sonic or both transmitters (Figure 5, Table 2, and Appendix 2, 3a, and 3b). These included fish in Kootenay Lake, BC and the Kootenai River in Idaho and BC. The total included 13 females and 13 males. Eighteen of the 26 adult sturgeon were monitored in the Kootenai River (Table 2). Two females (sonic codes 36 and 163) and four males (sonic codes 110, 174, 787, and 2202) most likely had previously shed their tags. Of the 12 remaining monitored in the river, nine (six females and three males) moved to the spawning reach from various staging or over-wintering areas (Table 2 and Appendix 2, 3a, and 3b). Seven fish (females sonic codes 886, 909, 912 925 and males coded 317, 460, and 2239) were located in the spawning reach (rkm 228 to 246) during times when eggs were estimated to have been spawned (Table 3), but eight fish (females sonic codes 882, 886, 909, 912, 925 and males coded 317, 460, 2239) are thought to have spawned, because the additional fish was also in the spawning reach (Table 2). During the third week of April, three mature fish, females coded 882, 886 and 909, were located in the spawning reach but left before any eggs were collected.

Table 2. Upriver locations of white sturgeon monitored in the Kootenai River from March 1, 2000 through August 31, 2000 (some fish moved out of Kootenay Lake, BC).

Fish No.		Tagging location	Date	Highest upstream location rkm (date)		Last previous date located
Male	Female	(rkm)	tagged	>120 <225	>225	above rkm 225
—	36[b]	214.9	3/11/98	—	237.5(4/1-8/10)[c]	Shed tag 6/99[d]
110[b]	—	215.5	3/17/99	—	230.3(4/27-8/10)[c]	Shed tag 5/99[d]
124[e,f]	—	78.0	8/1/96	—	—	—
174[b]	—	215.4	3/9/98	—	231.0(4/27-8/10)[c]	Shed ~ 9/98?[d]
—	221	205.0	3/1/99	204.0(7/26)[g,h]	—	—
317[a]		215.5	3/7/00	—[i]	244.5(6/14-21)	7/2
—	348[b]	203.0	4/1/94	—	—	—
460[a]	—	215.6	3/9/00	—	236.7(5/30)	6/27
—	628[b,f]	215.0	3/29/95	—	—	—
635	—	215.4	3/6/98	122.0(6/28)[h]	—	—
—	636	205.0	4/4/95	[f]	—	—
720[a]	—	215.6	3/6/96	120.2(8/23)[c,h]	—	—
773[b]	—	215.6	3/18/99	205.0(3/16)[h]	—	—
779[a]	—	215.7	3/4/97	122.0(7/5)[c,h]	—	—
781[a,f]	—	215.5	3/10/97	—	—	—
—	814	205.0	3/2/98	215.5(Mar-Aug)[c]	—	—
819[a]	—	215.1	3/17/98	122.0(6/28)[c,h]	—	—
—	882[a]	215.6	3/17/99	—	244.5(4/20-22)[c]	8/10
—	886[a]	205.2	3/16/99	[c]	244.5(4/20-24,26)	[d]
—	890	215.6	3/24/99	205.5(7/26)	—	—
—	909[a]	215.5	3/7/00	—	244.5(4/21,22,6/10)	6/27
—	912[a]	215.5	3/29/00	—	239.0(6/5)	6/5
—	925[a]	208.0	4/13/00	—	244.5(5/21-25)	6/27
—	2189[b]	215.7	3/17/99	[c]	230.5(6/22-27)	6/27
2202[b]	—	215.1	3/17/98	—	231.0(5/31)[c,h]	Shed ~ 5/98?[d]
2239[a]	—	215.5	3/2/98	—	234.3(6/6)	[d]
n = 13	n = 13	Combined (n = 26)				
n = 11	n = 9	Spawners (n = 20)				
n = 2	n = 4	Non-spawners (n = 6)				

[a] These fish were suspected spawners in 2000.
[b] These fish were uncertain spawners in 1999.
[c] These fish over-wintered in this section.
[d] These fish never dropped below river kilometer 225.
[e] These fish were not sexed prior to tagging.
[f] These fish had no locations in 2000.
[g] These fish had only one location below river kilometer 225.
[h] This fish had only one location from 3/1/00 through 8/31/00.
[i] These fish made no upriver movements out of Kootenay Lake in 2000.

Boat Telemetry

Boat telemetry for sturgeon locations was carried out from September 1, 1999 through August 31, 2000 (Figure 5). Sixty-nine trips were made for a total of 141 h, during which 310 white sturgeon locations were made. The most active months for white sturgeon telemetry took place in May and June with 20.6 and 36.1 h sampled each month (Figure 5).

Fixed Receiver Telemetry

Fixed site 1 logged data May 4 through July 5. Site 2 operated April 17 through May 8. Site 3 collected data April 18 through July 5. These dates corresponded to the period of upriver movements of spawning fish as noted by boat, aerial, and fixed-station telemetry. Fixed location receiver 3 provided the most valuable information, because it was located at Bonners Ferry, the lowest upstream reach of gravel and cobble substrate. Only locations verified by boat or aerial telemetry are discussed in our analysis.

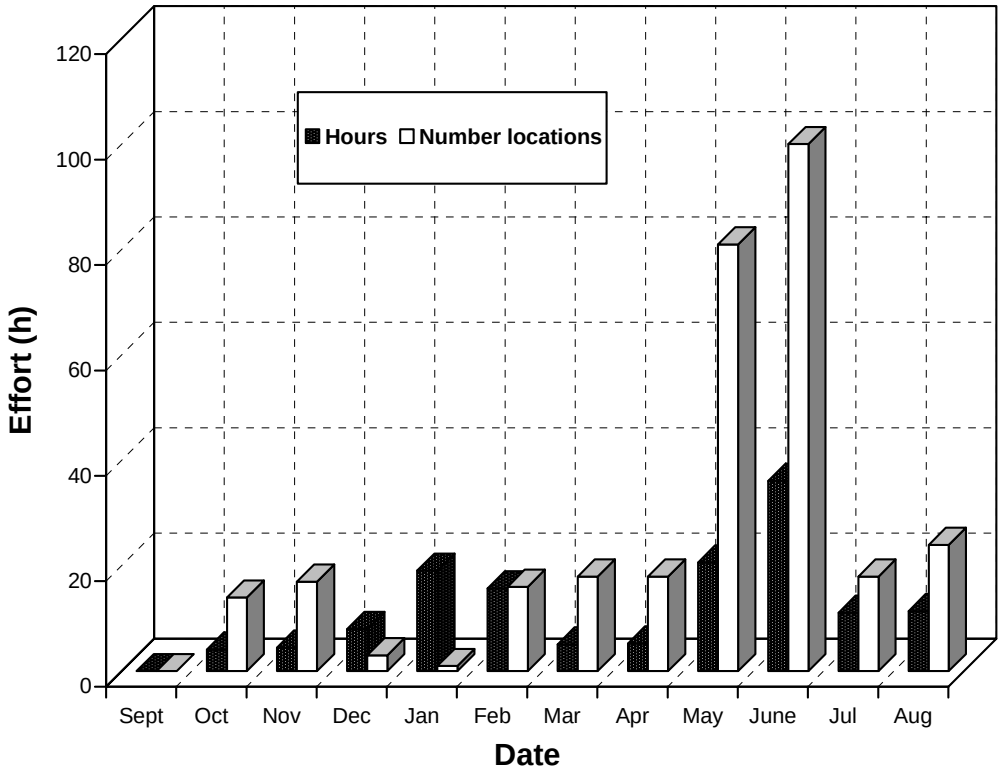

Figure 5. Telemetry effort (hours) and number of times white sturgeon were located monthly from September 1, 1999 to August 31, 2000, Kootenai River, Idaho. Telemetry effort and white sturgeon locations share the same axis.

Table 3. White sturgeon adults tracked to sections of the Kootenai River, Idaho where sturgeon eggs were spawned (back calculated to estimated spawning date) within 24 h preceding spawning, 2000.

Location	Estimated spawn date[a]	Fish number	
		Males	Females
Lower Shorty's Island (rkm 227-229.5	None	None	None
Middle Shorty's Island (rkm 229.6-231.5)	May 23, 25, 26, 30, 31 June 5, 6, and 20	317, 460, 2239	886, 909, 912, 925
Wildlife Refuge (rkm 234.0-240.0)	May 26, 28 June 5, 6,16,17, 19, 20, and 21	317, 460, 2239	909, 912

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

The 3-element Yagi antennas detected the movements of seven fish past one or more of the three fixed stations. This included five females (sonic codes 882, 886, 909, 925, and 2189) and two males (codes 317 and 460). These upriver movements were all supported by previous and later locations of the same frequencies by boat and aerial tracking or locations at more than one fixed-station site. Four fish, females 882, 886, 909 and 925, were detected as high as the upriver station (site 3 at Ambush Rock, rkm 244.5). Fish 882 was detected at site 3, its furthest known upriver location, several times April 20 and 22 and again at site 2 on April 25. After May 22, she was located downriver from the staging area. Fish 886 was also detected at site 3 from April 20 through 24 and again on April 26. She was located at site 2 April 25 and 26. All other locations were near Shorty's Island. Female 909 was detected at site 3 on April 21 and 22 and at site 2 on April 22. Throughout June, she moved from Shorty's Island, where she was detected several times at site 1, past the Refuge and back up to site 3 on June 10. After June 28, she was detected below the spawning reach (rkm 228 to 240).

Fixed Wing Telemetry

Fixed-wing flights took place from September 23, 1999 through July 5, 2000. All flights occurred in conjunction with tracking flights for tagged bull trout *Salvelinus confluentus* and rainbow trout *Oncorhynchus mykiss*. Five flights were made searching for white sturgeon from Bonners Ferry to Kootenay Lake. In approximately 6.2 hours of flying concentrating on sturgeon, 29 sturgeon locations were made. This accounted for 38.7% of the fish tags searched for. Sixteen different fish were located. These included seven potential spawners (five females, sonic codes 882, 886, 909, 912, and 925, and two males, 317 and 460). Locations were recorded to the nearest 0.1 rkm. The majority of the flying occurred from Bonners Ferry (rkm 245.0) to the Canadian border (170.0), but also down to the Kootenai River Delta (rkm 113.0 to 122.0).

Artificial Substrate Mat Sampling

We sampled 2,676 mat d (a mat day is one 24 h set) in the Kootenai River during white sturgeon spawning in 2000 (Table 4). Sampling with mats began May 2 and ended July 6, 2000. Debris in the river occasionally 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 64,224 h. A total of 186 sturgeon eggs were collected (Figure 3). A single mat on June 21 held 126 eggs, comprising 68% of the total collection (Appendix 4 and 5). Staging of eggs suggested an estimated 13 spawning events took place from May 23 through June 21, 2000 (Figure 3).

Sampling mats collected eggs within four of eight different geographic river sections sampled in 2000 (Table 4 and Appendix 4). The Refuge reach (rkm 234.8 to 237.5) produced the most eggs (138) with 312 mat d of effort. The Middle Shorty's section (rkm 229.6 to 231.5) produced 24 eggs with 565 mat d of effort. The Myrtle Creek section (rkm 233.5 to 234.7) produced 19 eggs with 149 d of mat effort, and the Deep Creek section (rkm 237.6 to 240.5) produced five white sturgeon eggs with 212 d of mat effort. No eggs were collected above the Deep Creek section (>rkm 240.5) with 1,002 mat d of effort. Depth of artificial substrate mat placement ranged from 1.2 to 28.0 m (4 to 92 ft) for all mats (Table 4). Mats that collected eggs ranged from 5.5 to 22.6 m (18 to 74 ft) in depth, averaging 11.2 m (37 ft) (Appendix 4 and 5). Near surface velocities (0.2 depth in m) at 23 egg collection sites ranged from 0.31 to 1.99 m/s (1.02 to 6.53 ft/s) and averaged 0.71 m/s (2.31 f/s) (Appendix 4 and 5). Velocities near the river substrate (0.8 depth in m) at the egg collection sites ranged from 0.25 to 1.13 m/s (0.82 to 3.71 ft/s) and averaged 0.63 m/s (2.07 ft/s). Mean column velocity by section and egg collection ranged from 0.56 to 0.88 m/s (1.84 to 2.89 ft/s) and averaged 0.72 m/s (2.37 ft/s) (Appendix 4).

Table 4. Location (rkm), depth (m), effort, and white sturgeon egg catch by standard artificial substrate mats, Kootenai River, Idaho, 2000.

Geographical description	River location (rkm)	Depth range (m)	Total sample hours (days)[a]	Number white sturgeon eggs
Lower Shorty's Island	228.0-229.5	4.3-19.8	3,678 (153)	0
Middle Shorty's Island	229.6-231.5	1.5-28.0	13,558 (565)	24
Upper Shorty's Island	231.6-233.4	4.9-16.8	6,776 (282)	0
Myrtle Creek	233.5-234.7	5.2-19.8	3,585 (149)	19
Refuge	234.8-237.5	4.3-24.1	7,495 (312)	138
Deep Creek	237.6-240.5	4.0-14.6	5,080 (212)	5
Hatchery	240.6-243.9	No sampling	No sampling	No sampling
Ambush Rock	244.0-244.6	No sampling	No sampling	No sampling
US Hwy 95	244.7-246.6	1.2-12.5	19,991 (833)	0
Upper Pump Station	246.7-247.7	1.8-9.8	4,061 (169)	0
All Sections	228.0-247.7	1.2-28.0	64,224 (2,676)	186

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

One hundred fifty-six (84%) of the 186 white sturgeon eggs collected in 2000 were determined viable. Development ranged from stage 12 to 23 (1 h to 2 d old) (Appendix 5). Based on ages of viable eggs and the dates of egg collection, we estimated that white sturgeon spawned during at least 13 days in 2000 (Figure 3 and Appendix 5). The first spawning events were estimated to have occurred on May 23 with spawning continuing on five of the next eight days until May 31. The next events were estimated to have occurred June 5 and 6 and then sporadically from June 16 through the last day of spawning, June 21.

Experimental Release of Hatchery White Sturgeon Larvae

The KTOI released 139,000 hatchery white sturgeon larvae during five releases from June 12 through July 14, 2000 (Table 5). White sturgeon larvae were released at the surface. Sampling with ½ m nets and D-rings resulted in a total catch of 33 larvae during the experimental releases; all were captured immediately after their release by the first boat 0.5 km downstream, at rkm 235.5. The last larvae to be recaptured were caught approximately 1 h after release. Thirty of the larvae were caught near the river bottom in the D-ring set. No white sturgeon larvae were collected by the downstream boat (1.0 km below the release site).

Larval Sturgeon Sampling

White sturgeon larvae sampling was carried out between June 5 and July 27, 2000. We made 1,144 tows and sets with ½ m and D-ring nets between rkm 144.5 and 238.1 in the Kootenai River. No wild white sturgeon larvae were caught during 2000.

Table 5. Estimated number of hatchery white sturgeon larvae released, release date, and catch by D-ring or ½ m net.

			1/2 m net catch	
Release date	**Estimated number released**	**D- ring catch bottom**	**Surface**	**Mid-water**
June 12, 2000[a]	78,000	0	0	0
June 22, 2000	12,000	2	0	1
June 30, 2000	10,000	4	0	0
July 7, 2000	26,000	0	0	0
July 14, 2000	13,000	24	0	2
Total	**139,000**	**30**	**0**	**3**

[a] Night release approximately 2200 h.

Sampling with ½ m nets and D-rings, excluding the effort during the hatchery release, was accomplished primarily at night. Half-meter nets at the surface sampled 143,849 m^3 of water in 97.5 h, captured 68 non-sturgeon fish larvae, one non-sturgeon egg, and no wild white sturgeon. Half-meter nets at mid-column depths sampled 178,415 m^3 in 180.3 h and captured 44 non-sturgeon larvae and five non-sturgeon eggs. D-ring nets set at the river bottom sampled 36,390 m^3 in 234.5 h and captured 92 non-sturgeon larvae and seven non-sturgeon eggs. Duration of sets ranged from 3 minutes to 1 h and 22 minutes and averaged 26 to 27 minutes.

Juvenile White Sturgeon Sampling

We expended a total of 373 h of gill netting effort and captured 189 hatchery white sturgeon from July 1 through September 1, 2000 (Tables 1, 6, and Appendix 6). All were considered recaptures, because they were previously marked by scute removal and with PIT tags before release from the KTOI hatchery. Catch per unit effort for juvenile white sturgeon was 0.5 sturgeon/h. Juvenile hatchery white sturgeon ranged in total length from 22.5 cm (8.86 in) to 81.0 cm (31.89 in) and weights of 60 g (0.13 lb) to 2.4 kg (5.29 lb) at capture (Table 7). No wild juvenile fish were captured by gill net during the 2000 season.

Table 6. The Idaho Department of Fish and Game juvenile gill net sampling effort, mesh size, July 1 though September 1, 2000.

Mesh size cm (in)	Total hours	Number sets	Average depth in m (ft)	Number adult sturgeon	Number juvenile sturgeon	Total number sturgeon
1.5 (3.8)	136.7	71	14.8 (48.5)	1	60	61
2.0 (5.1)	236.0	126	17.0 (55.8)	1	129	130
Total	**372.7**	**197**	**16.2 (53.1)**	**2**	**189**	**191**

Table 7. Vital statistics of juvenile hatchery white sturgeon recaptures from summer 2000 gill net sampling by the Idaho Department of Fish and Game.

	Statistic	FL (cm)	TL (cm)	WT (kg)
Recaptures n = 189	Average	42.83	49.65	0.516
	Standard deviation	7.95	9.15	0.385
	Minimum	22.50	26.40	0.060
	Maximum	71.00	83.50	2.500

Relative Weights of White Sturgeon

We calculated fork length (FL) relative weight (Beamesderfer 1993) for 56 adult white sturgeon captured during the 2000 sampling period (Table 1). Fork length relative weight for adult white sturgeon ranged from 69 to 139, and the mean was 111 (SD = 14). Calculated FL relative weight for 168 juvenile hatchery white sturgeon of the 1995 brood year captured during the 2000 sampling period ranged from 89 to 166, and the mean was 89 (SD = 15).

DISCUSSION

The primary objective of this investigation is to identify Kootenai River mitigation flows and temperatures that are essential to recruitment of white sturgeon cohorts and that will lead to recovery of the population. Although seven years of study have resulted in the collection of more than 1,000 white sturgeon eggs (Paragamian et al. 2001), only four wild white sturgeon are known to have recruited from five mitigated flow test years (Appendix 7). The wild recruitment is too low to meet recovery goals for Kootenai River white sturgeon. Spawning of Kootenai River white sturgeon over sand substrate may be impacting egg and larvae survival (Paragamian et al. 2001). Eggs spawned over this substrate are often coated in sand when collected on artificial substrate mats and likely are buried within large mobile sand dunes (Paragamian et al. 1998). White sturgeon eggs are relatively large (2 to 3 mm) and adhesive. In the Kootenai River, fertilized eggs are unable to attach to large clean substrates found in white sturgeon spawning areas of other West Coast river systems (Brannon 1984). However, survival of hatchery-reared white sturgeon released at age-2+ (Appendix 8) is about 60% for the first year and about 90% thereafter (Ireland et al., in progress). The survival rates for hatchery white sturgeon are higher than initially expected in the Kootenai River White Sturgeon Recovery Plan. The inability to collect wild juvenile white sturgeon suggests poor survival occurs between eggs and age-2+ when sturgeon become vulnerable to sampling gear. Thus, we do not know if it is an egg or a larval survival problem.

The capture of hatchery-reared larvae immediately after their release during 2000 indicated our sampling gear is adequate to capture wild larvae providing they are present. Studies on the Columbia River have shown D-rings and ½ m nets to be useful in measuring the abundance of white sturgeon larvae (McCabe and Beckman 1990; McCabe and Tracy 1994; Parsley et al. 1993; Parsley and Beckman 1994). Because we are now confident that our sampling gear is suitable for the capture of wild white sturgeon larvae, we believe the reason we have failed to capture wild larvae during the past ten years is due to their scarcity. This supports our belief that the present spawning locations and associated habitat are unsuitable for adequate egg and larvae survival.

The flow test for the 2000 white sturgeon spawning season was restructured to facilitate the experimental release of hatchery larvae. Spawning may have been compromised by this action as there were only 13 spawning events in 2000 compared to 20 in 1998, the year with the most recorded spawning events (Paragamian et al. 1998).

Water temperature is the most important environmental variable to predict migration of female white sturgeon to the spawning reach and spawning (Paragamian and Kruse 2001). Migration temperatures from 1991 through 1997 for 25 female white sturgeon ranged from 6.6 to 10.7°C (Paragamian and Kruse 2001), which is cooler than observed elsewhere throughout their range. Migrations can occur as early as mid-April but are often later in the month or during May. Males migrate from the staging reach at temperatures above 6°C (42.8°F) but for females, the water is warmer at about 8°C (46.4°F). Spawning of white sturgeon in the Kootenai River is usually documented soon after the arrival of female sturgeon to the spawning reach (Paragamian and Kruse 2001).

We examined white sturgeon spawning events during the years 1994 through 2000 and compared them to daily average flow and daily average temperature at Bonners Ferry for each event (Paragamian and Wakkinen, in progress). We found white sturgeon often spawned during decreasing flows and that the number of events each year ranged from as few as nine to as

many as 20, with spawning occurring over a 17 to 31 day period. The most consistent year for spawning of Kootenai River white sturgeon was 1996 when spawning was detected during 18 of 19 days. The most consistent spawning in 1996 took place when flows averaged about 1,130 m^3/s (40,000 cfs). Average daily temperature during spawning ranged from 7.5 to 14°C (45.5-57.2°F), with the highest probability of spawning (48%) at the 9.5-9.9°C (49.1-49.9°F) range (Paragamian and Wakkinen, in progress) (Appendix 9 and 10). Average daily flow for spawning events ranged from 141 to 1,265 m^3/s (4,979-44,673 cfs), but most (63%) spawning took place above 630 m^3/s (22,248 cfs) (Paragamian and Wakkinen, in progress) (Appendix 9 and 10). Our analysis suggests flows for optimum white sturgeon spawning in the Kootenai River should be held above 630 m^3/s (22,248 cfs) and ideally 1,130 m^3/s (40,000 cfs) with an ideal temperature range of 9.5 to 12°C (49.1-53.6°F). However, of the two variables temperature is the most difficult to control.

The ideal location for successful white sturgeon spawning in the Kootenai River remains unresolved. Kootenai River white sturgeon have demonstrated a pattern in changing spawning locations (Paragamian et al., in progress). Initial spawning takes place in the lower portion of the spawning reach, and as the season progresses spawning takes place further upstream. However, spawning seldom occurs from Bonners Ferry upstream (rkm 245+) over cobble substrate. Several of the spawning locations were shown to be rather consistent during the most recent seven years of study (Paragamian et al., in progress). Selection of spawning locations was most likely habitat related, but locations also appeared to be determined by early or late timing of initiation of spawning and the elevation of Kootenay Lake as measured at Queen's Bay (Duke et al. 1999). We found 53.4% ($p = 0.0153$) of the variation in spawning location of Kootenai River white sturgeon from 1994 to 1999 was due to the prevailing elevation of Kootenay Lake; spawning occurred further upstream with increasing lake elevation. A linear model suggested historic Kootenay Lake elevations (file records BC Hydro, Nelson, BC) of 533 to 537 m (1,749 to 1,762 ft) above sea level would have placed white sturgeon spawning near Bonners Ferry. Furthermore, recent core samples from the Kootenai River have shown cobble and gravel substrates at rkm 242.5 at a depth of about 60 cm (23.6 in) (Gary Barton, USGS, personal communication). The layer above the cobble and gravel was comprised of what is thought to be a post-Libby Dam layer of silt and sand. Our model suggests at a Queens Bay elevation of 537 m (1,762 ft), white sturgeon would likely spawn at about rkm 242.5. Testing this hypothesis may be a political issue that will be difficult for the KRWSRT to overcome. Encroachment of the shoreline of Kootenay Lake by private development almost certainly prohibits restoration of Kootenay Lake to historic May and June elevations.

RECOMMENDATIONS

1. From April 15, provide 425 m^3/s (15,000 cfs) when water temperature is 7°C to 8°C (43°F to 46°F) for flow and temperature sufficient to initiate and maintain spawning migration of Kootenai River white sturgeon.

2. Provide flows of 1,130 m^3/s (40,000 cfs) for 42 d at Bonners Ferry once water temperatures of 8°C to 10°C (46°F to 50°F) are reached to stimulate spawning and optimize egg/larval survival of Kootenai River white sturgeon.

3. Evaluate the role of substrate composition (sand vs. cobble substrate) may play in the failure to recruit white sturgeon juveniles from successful spawning events.

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APPENDICES

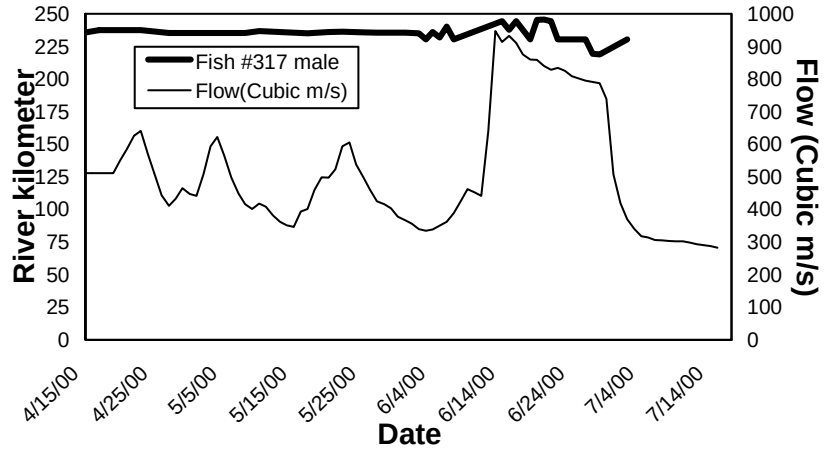
Appendix 1. Sexual development of white sturgeon sampled by Idaho Department of Fish and Game, Kootenai Tribes of Idaho, and British Columbia Ministry of Environment in the Kootenai River, Idaho, 1989 through 2000.

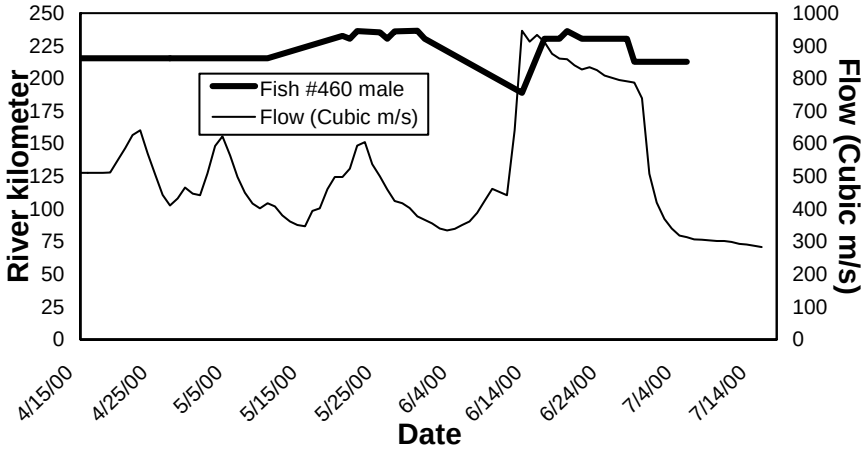
Categories of sexual development		Percent (number) of sample by year											
Category/Sex	**Description of development**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995[a]**	**1996[a]**	**1997**	**1998**	**1999**	**2000**
0/Unknown[b]	Gonad undifferentiated or not seen	32 (58)	14 (15)	6 (3)	2 (1)	0	24 (14)	0	45 (67)	19 (14)	15 (14)	13 (6)	42 (29)
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)	9 (4)	6 (4)
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)	2 (1)	6 (4)
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)	5 (2)	1 (1)
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)	22 (10)	13 (9)
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	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	0	0
R/Female	Reabsorbing eggs	0	0	0	2 (1)	0	0	0	1 (1)	0	0	0	0
7/Male	Non-reproductive: Testes with translucent smoky pigmentation	3 (6)	27 (30)	29 (15)	26 (11)	0	19 (11)	36 (10)	13 (20)	24 (17)	19 (18)	33 (15)	42 (29)
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)	16 (7)	35 (35)
9/Male	Ripe: Milt flowing; large white lobular testes	0	3 (3)	14 (7)	21 (9)	5 (1)	0	0	2 (3)	0	0	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	0	0

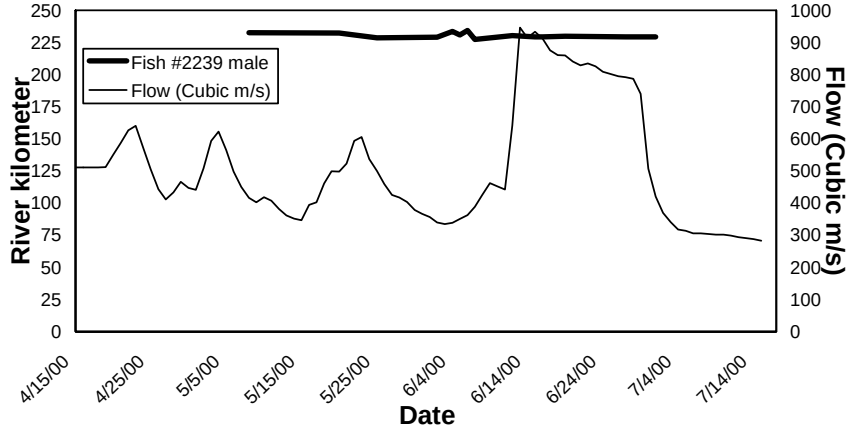
[a] Surgeries done by Idaho Department of Fish and Game and Kootenai Tribes of Idaho were carried out on fish that externally appeared to be candidates for spawning. Surgeries done by British Columbia Ministry of Environment and those done during previous years were more randomly distributed among fish >130 cm.

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

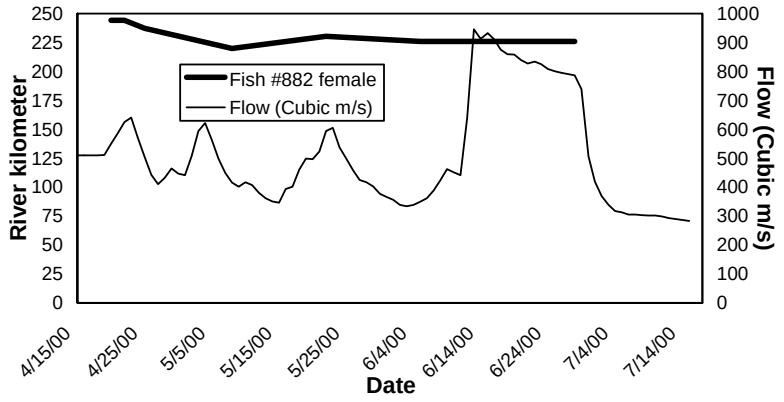
Appendix 2. Migration and flow (m^3/s) for three adult male white sturgeon believed to have spawned in the Kootenai River, Idaho, in 2000.

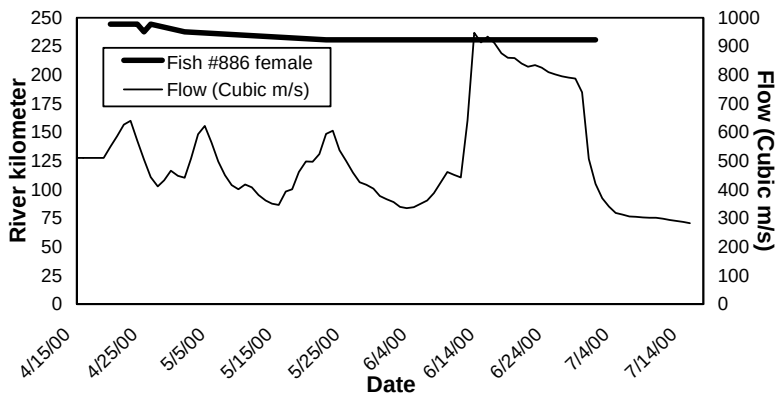


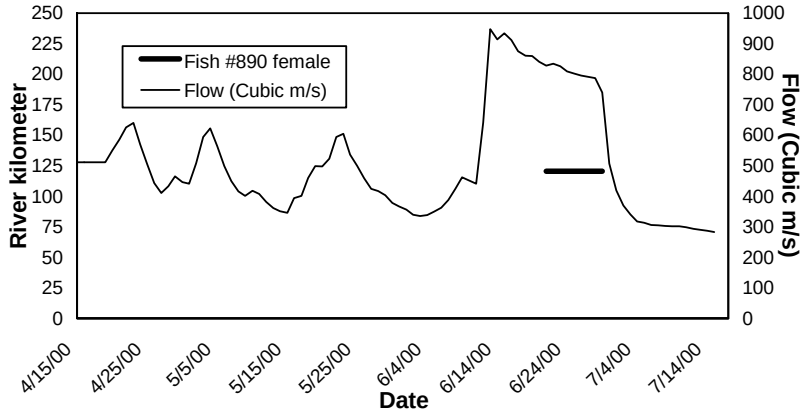


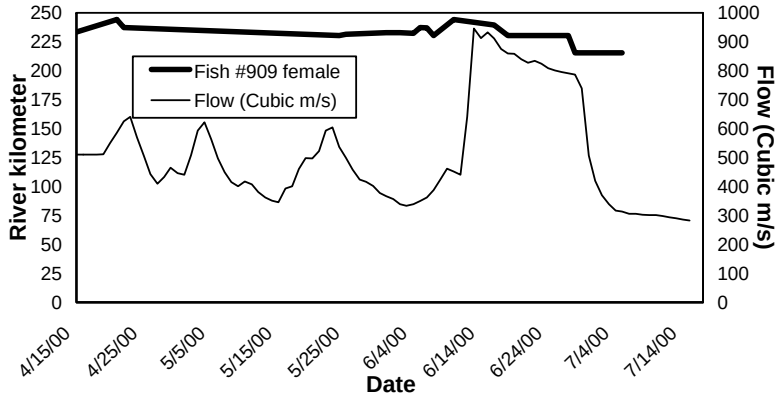


Appendix 3a. Migration and flow (m^3/s) for four of seven female adult white sturgeon. A total of six are believed to have spawned in the Kootenai River, Idaho, in 2000.

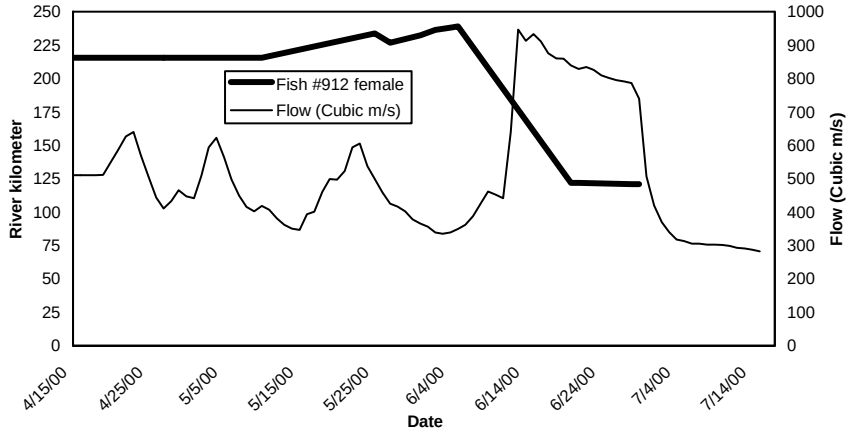


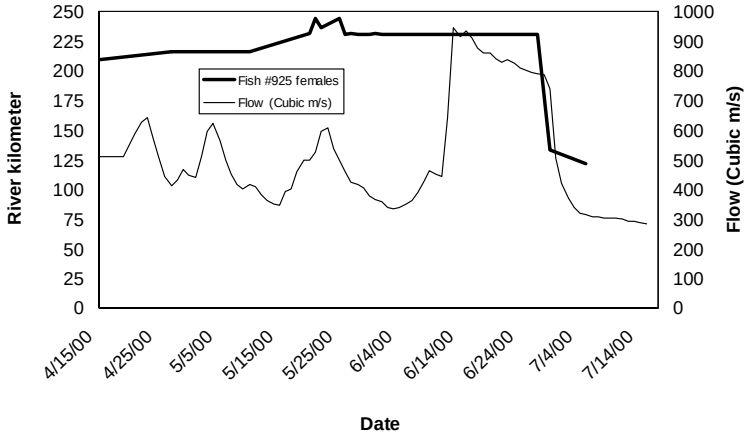


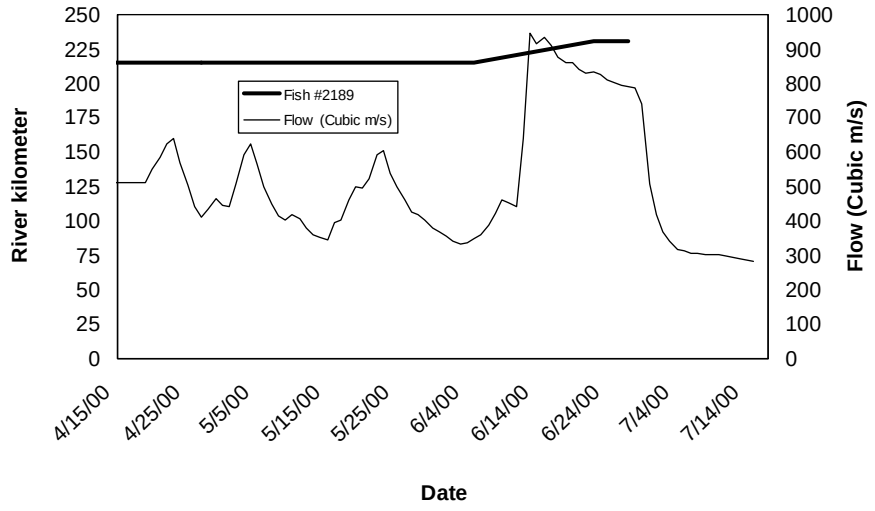




Appendix 3b. Migration and flow (m^3/s) for three of seven female adult white sturgeon. A total of six are believed to have spawned in the Kootenai River, Idaho, in 2000.







Appendix 4. River location (rkm), number of eggs, depth (m), and velocity (m/s) at sites where white sturgeon eggs were collected in the Kootenai River, Idaho, 2000.

River section (rkm)	Number of eggs collected	Number of 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)
229.6-231.5	24	10	6.7-17.7	10.2	0.65	0.61	0.62
233.5-234.7	19	3	11.6-13.7	12.0	0.88	0.77	0.83
234.8-237.5	138	8	5.6-22.6	10.0	0.60	0.51	0.56
237.6-240.5	5	2	10.7-11.9	11.4	1.02	.73	.88
All locations	**186**	**23**	**5.5-22.6**	**11.2**	**0.79**	**0.65**	**0.72**

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

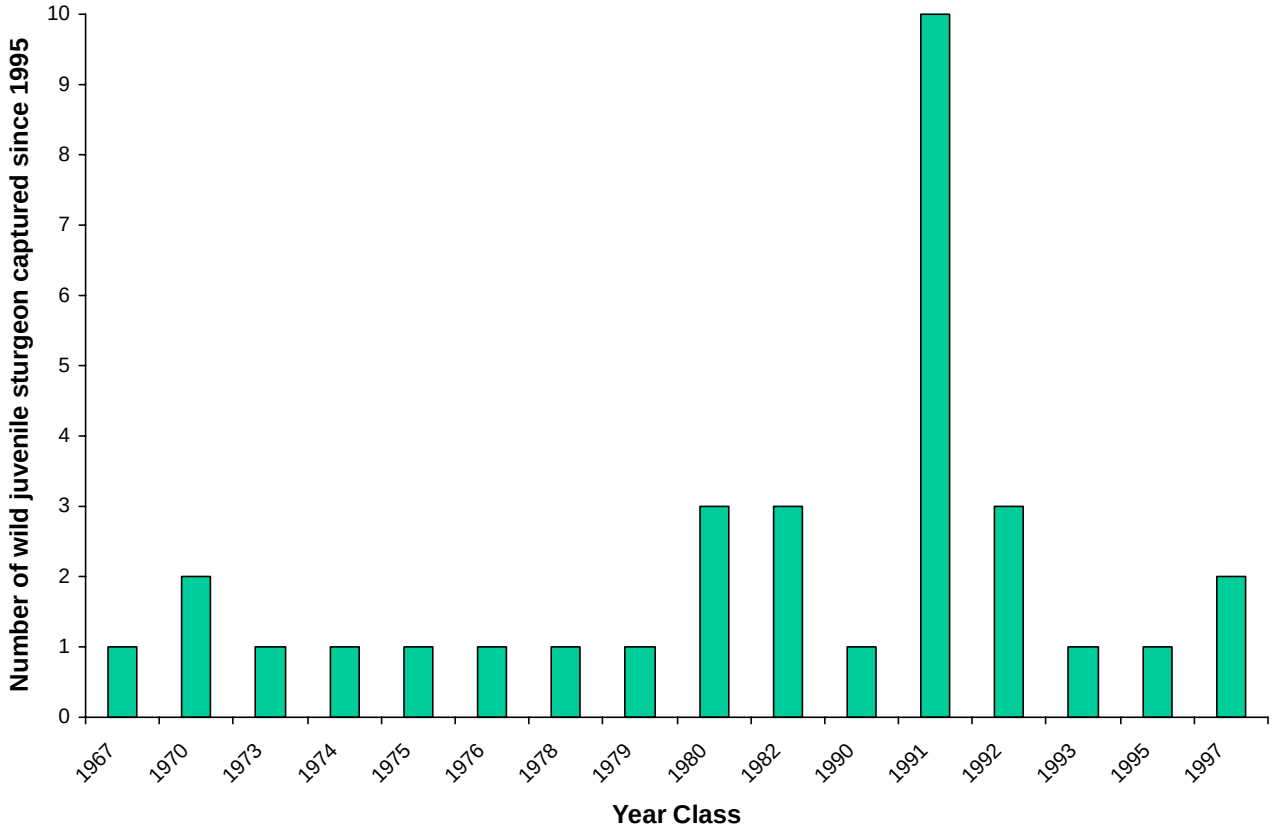
Appendix 5. White sturgeon egg collection locations, habitat attributes and staging data for eggs collected during the 2000 sampling season on the Kootenai River, Idaho.

Date	Rkm	Depth (m)	No. Eggs	Flow 0.2	Flow 0.8	Temp (C)	Discharge (m^3/s)	Stage (number)	Spawn Date
5/23/00	230.9	11.6	3	.54	.51	10	605.9	12(3)	May 23
5/26/00	230.9	10.7	2	.68	.67	10	544.7	Dead(1) 12(1)	— May 26
5/26/00	231.0	7.0	3	.75	.75	10	544.7	16(2) 17(1)	May 25 May 25
5/27/00	235.8	14.6	1	.57	.50	10	425.4	16(1)	May 26
5/29/00	234.1	11.5	17	.50	.60	10	403.3	Dead(1) 16(2) 17(14)	— May 28 May 28
5/30/00	231.1	7.6	7	.54	.31	10	378.3	Dead(1) 14(6)	— May 30
5/30/00	236.6	5.8	1	.55	.53	10	378.3	21(1)	May 28
5/31/00	231.0	6.7	2	.31	.27	10	366.9	14(2)	May 31
6/2/00	236.6	5.5	1	.58	.43	10	339.6	Dead(1)	—
6/6/00	231.0	7.9	3	.54	.56	12.5	362.3	17(3)	June 5
6/7/00	236.6	5.8	1	.63	.56	12.9	388.4	21(1)	June 5
6/8/00	234.0	13.7	1	1.99	1.13	13	424.7	Dead(1)	—
6/9/00	231.0	7.9	1	.70	.53	13	462.3	23(1)	June 6
6/9/00	234.1	9.4	1	.59	.46	13	462.3	21(1)	June 6
6/17/00	239.1	11.9	2	.85	.77	12	876.1	16(2)	June 16
6/19/00	239.1	11.3	3	.40	.25	12	859.6	21(3)	June 17
6/20/00	230.2	15.8	1	.94	.76	12.5	840.8	12(1)	June 20
6/20/00	235.6	22.6	5	.78	.61	12.5	840.8	Dead(3) 18(2)	— June 19
6/21/00	235.6	15.2	1	.90	.88	13	829.0	Dead(1)	—
6/21/00	230.8	13.4	1	.77	.81	13	829.0	Dead(1)	—
6/21/00	235.5	15.8	126	.81	.84	13	829.0	Dead(18) 19(1) 20(104) 21(3)	— June 20 June 20 June 19
6/23/00	230.8	44	1	.68	.92	13	826.2	Dead(1)	—
6/23/00	235.5	54	2	.62	.86	13	826.2	Dead(1) 22(1)	— June 21

Appendix 6. Year class, number captured, capture locations, fork length (cm), total length (cm), and weight (kg) of hatchery-released juvenile sturgeon captured with gillnets from the Kootenai River, Idaho, 2000.

Year class	No. Captured	Capture rkm	Fork Length (cm)	Total Length (cm)	Weight (g)
1991	3	215.5	55-66	64.4-75.5	1.1-2.4
1992	1	205.5	63.8	66.6	1.275
	2	215.1	59-67.9	67.5-81	1.11-2.1
	1	215.3	58	66.5	1.2
	3	215.5	56.7-64	66.4-76	1.15-1.76
	1	215.6	65.2	76	2
	1	215.7	63	72.1	1.65
	1	224.5	56.5	66.5	1.16
1995	1	176.0	33.9	40	0.2
	2	176.3	40-49	47.4-58.1	0.3-0.675
	2	176.4	43-44.8	50-52	0.45-0.525
	2	176.5	39.3-44.1	46.2-53	0.33-0.48
	2	177.3	53-59.7	37.9-52	0.28-0.49
	1	189.9	51.5	59.5	0.74
	3	190.0	37.4-46.5	44.5-52.5	0.3-0.61
	2	190.1	36.8-46.5	43.9-52.7	0.275-0.59
	1	203.3	39.3	45.5	0.34
	1	203.4	37	42.9	0.36
	8	205.0	37.3-51.5	43.8-60	0.2-0.8
	2	205.4	36-50.5	42.2-57	0.28-0.65
	11	205.5	34.2-63.8	40-65.4	0.2-1.8
	9	215.1	36.1-49.5	41.1-58.2	0.25-0.65
	4	215.2	42-447	48.5-55.5	0.42-0.55
	14	215.4	31.2-46.3	36.5-53.7	0.275-0.54
	32	215.5	32-56	37.9-64.8	0.2-0.935
	9	215.6	31.5-48.9	36.8-56.8	0.2-0.6
	38	215.7	30.5-54.8	35.5-63.8	0.19-0.925
	2	215.8	36.9-50.2	42-58.4	0.325-0.675
	1	224.5	39	45.4	0.34
	4	224.7	37.4-44.5	43.4-51.5	0.29-0.525
	2	224.8	44.5-46.5	51.7-54.2	0.49-0.59
	1	224.9	47.4	55	0.62
	5	225.0	38.9-49	44.7-57.5	0.39-0.625
	6	225.1	30.8-55	35.8-64.2	0.2-0.975
	1	229.7	46.3	53.5	0.55
	2	229.8	39.9-42.3	46.6-50.1	0.35-0.375
1998	1	215.5	22.6	26.7	0.075
	1	215.7	33.2	38.7	0.2
	1	225.0	27	31.6	0.06
	2	225.1	27.7-27.8	32-32.4	0.1-0.14
	2	229.8	22.5-25.6	26.4-30.2	0.1-0.6

Appendix 7. Capture of wild juvenile white sturgeon by year class (year of capture is not reflected) in the Kootenai River, Idaho, from 1995 through 2000; an additional fish thought to be of the 1995 year class was caught in 1998 but could not be aged. Captures were made primarily by gillnet.

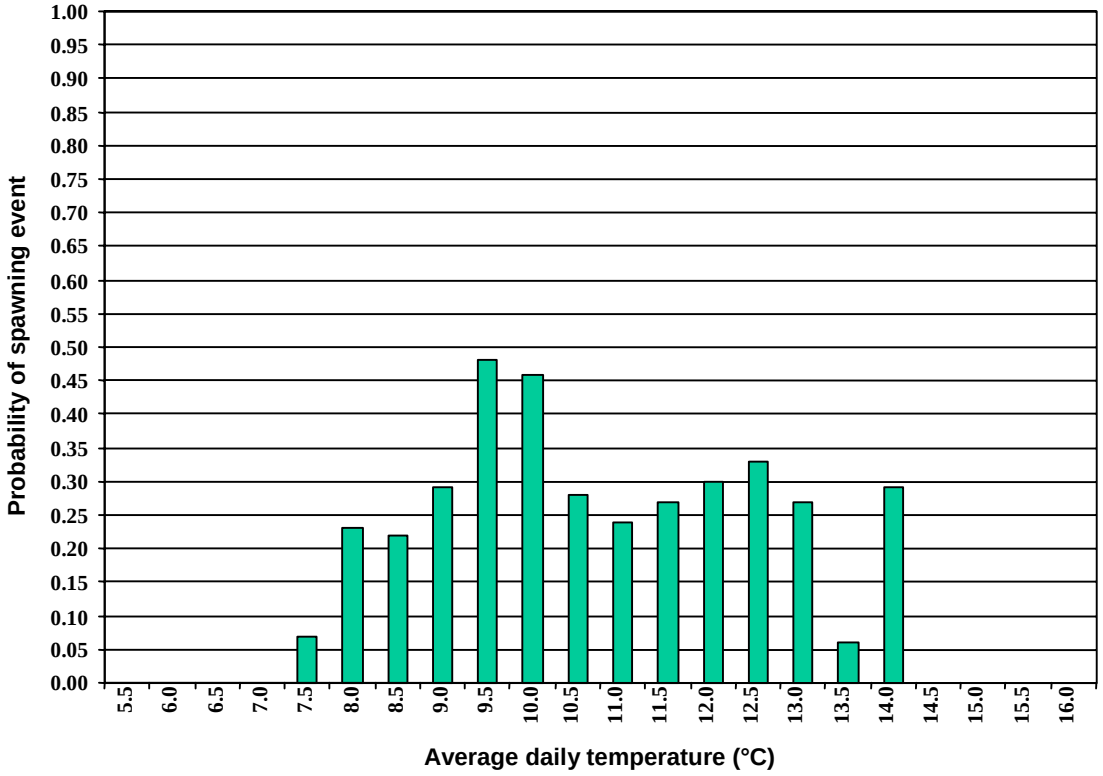


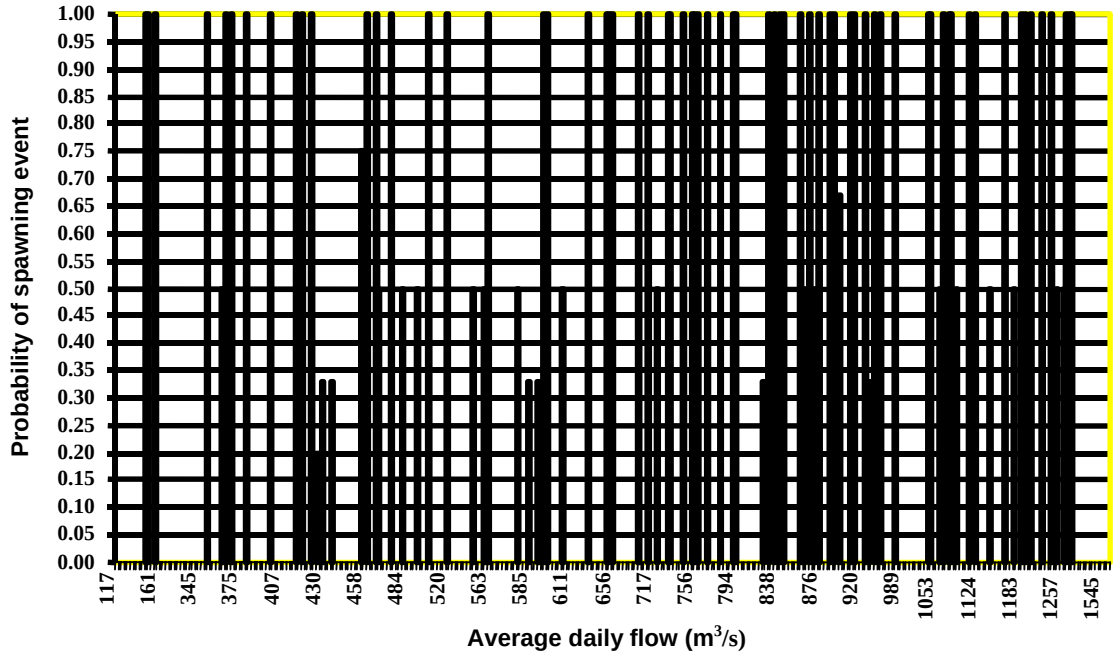
Appendix 8. Numbers and recapture rates of hatchery-produced white sturgeon juveniles (progeny of wild broodstock) released into the Kootenai River in Idaho and Montana between 1992 and 1999 (from Kootenai Tribe of Idaho and Idaho Department of Fish and Game Annual Reports 1992-1999).

Year Class	Number Released	Mean Total Length (mm) at Release (S.D.)	Mean Weight (g) at Release (S.D.)	Release Year	Percent (#) Recaptured[a]
1990	14	455	321	Summer 1992	25.2 (54)[b]
1991	200	255 (17)	66.2 (13.2)	Summer 1992	—
1992	91	483 (113)	550.2 (485)	Fall 1994	45 (41)
1995	1,076	229 (27)	47 (16)	Spring 1997	15 (295)[c]
1995	891	343 (43)	147 (61)	Fall 1997	—
1995	99	408 (70)	283.3 (136.8)	Summer 1998	6 (6)
1995	25	565 (71)	805.8 (276.4)	Summer 1999	<1 (2)
1998	306	261 (42)	79.5 (44.4)	Fall 1999	0
Total	2,702	—	—	NA	14.7% (398)

[a] Percent recaptured during 1993-1999 sampling period for each release year (excluding multiple recapture events).
[b] Includes 1990 and 1991 year class.
[c] Includes 1997 spring and fall release.

Appendix 9. Probability of Kootenai River white sturgeon spawning events by average daily temperature, 1994 through 2000 combined (upper panel). Probability of Kootenai River white sturgeon spawning events by average daily flow, 1994 through 2000 (lower panel).





Appendix 10. Average daily flow and average daily temperature at Bonners Ferry on days of spawning events in the Kootenai River from 1994 through 2000, combined.

Flow (m^3/s)	Number of events	Temperature (°C)	Number of events
101-200	3	7.6-8.0	4
201-300	0	8.1-8.5	6
301-400	6	8.6-9.0	7
401-500	15	9.1-9.5	8
501-600	10	9.6-10.0	19
601-700	6	10.1-10.5	9
701-800	14	10.6-11.0	13
801-900	16	11.1-11.5	10
901-1,000	7	11.6-12.0	4
1,001-1,100	8	12.1-12.5	9
1,101-1,200	7	12.6-13.0	5
1,201-1,300	7	13.1-13.5	2
1,301-1,400	0	13.6-14.0	1
1,401-1,500	0	14.1-14.5	2
1,501-1,600	0	14.6-15.0	0

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