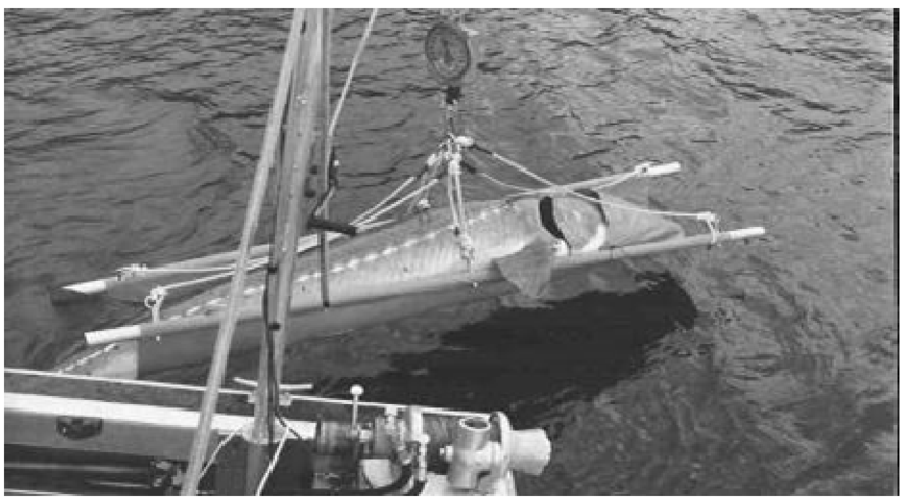
FISHERY RESEARCH

KOOTENAI RIVER WHITE STURGEON SPAWNING AND RECRUITMENT EVALUATION

ANNUAL PROGRESS REPORT
April 1, 2005 to March 31, 2006



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IDFG Report Number 07-23
March 2007

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Project Number 1988-065-00
Contract Number 00000148-00001

IDFG Report Number 07-23
March 2007

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ABSTRACT

The objective of this research was to determine the environmental requirements for successful spawning and recruitment of the Kootenai River white sturgeon *Acipenser transmontanus* population. Annual tasks include monitoring and evaluating the response of various life stages of Kootenai River white sturgeon to mitigation flows supplied by the United States Army Corps of Engineers. Sampling for adult Kootenai River white sturgeon in 2005 began in February and continued into June. One hundred fifty-five adult white sturgeon were captured with 3,973 hours of angling and set-lining effort in the Kootenai River in 2005. We used an array of 53 Vemco sonic telemetry receivers to monitor the movements of 29 adult sturgeon in Kootenay Lake, British Columbia and the Kootenai River throughout the year. Eighteen adult white sturgeon were tagged with sonic transmitters in 2005, and 11 adult white sturgeon were tagged in previous years and still had active transmitters. Sampling for white sturgeon eggs with artificial substrate mats began April 25 and ended June 22, 2005. We sampled 657 mat days during white sturgeon spawning and collected 10 white sturgeon eggs near Shortys Island. Sampling for larval white sturgeon began June 13 and continued until July 27, 2005. Sampling occurred primarily above Bonners Ferry below the egg release sites (near river kilometer [RKM] 262.1) in an attempt to document any recruitment that might have occurred from the egg release experiment. We collected 788 larval fish but did not collect any white sturgeon larvae or embryos. Juvenile white sturgeon sampling started August 7 and continued through September 22, 2005. A total of 198 hours of gillnetting effort captured 226 juvenile hatchery white sturgeon and two juvenile wild white sturgeon.

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INTRODUCTION

The Kootenai River white sturgeon *Acipenser transmontanus* population is comprised mainly of old aged adults, and significant recruitment has not occurred since the 1970s. The most recent population modeling suggests that the remaining adult white sturgeon population contains less than 500 adults with the numbers declining at a rate of about 9% each year (Paragamian et al. 2005). Based on these estimates, each year we sample about 30 percent of the adult population during spring setlining and angling efforts. Over a decade of artificial substrate mat sampling has indicated that from nine to 20 spawning events occur annually, and although many viable embryos are produced (Paragamian and Wakkinen 2002), few wild juvenile white sturgeon have been collected. Although the specific causes of recruitment failure remain unclear, years of study suggest that mortality occurs between embryo and larval stages. Most of the post-Libby Dam spawning events have been documented in areas where substrate conditions appear to be unsuitable for egg incubation and larval rearing (Paragamian et al. 2001), and no larvae and very few wild juveniles have been collected despite years of intensive sampling. Post-release hatchery reared juveniles (as young as 9 months of age at release) consistently exhibit successful growth, and second year survival rates exceed 90% (Ireland et al. 2002). Research to date suggests that egg and/or larval suffocation, predation, and/or other mortality factors associated with these early life stages contribute to persistent recruitment failure.

OBJECTIVE

Our primary study objective was to determine the environmental requirements for successful spawning and recruitment of Kootenai River white sturgeon *Acipenser transmontanus*. The main tasks of this program are to monitor the response of all life stages of Kootenai River white sturgeon to mitigative flows from Libby Dam provided by the United States Army Corps of Engineers (USACE).

The lack of clean substrates, which may result from decreased velocities, may be a major limiting factor in Kootenai River white sturgeon recruitment (Paragamian et al. 2001). The purpose of the experimental egg release was to determine the substrate and flow conditions in the field that enable successful egg hatching and larval recruitment. Potentially, secondary objectives of this experiment include supplementing hatchery production and imprinting young sturgeon on habitat conditions suitable for spawning and hatching.

STUDY SITE

The Kootenai River originates in Kootenay National Park, British Columbia (BC), Canada. The river flows south into Montana and turns northwest at Jennings, near the site of Libby Dam, at river kilometer (RKM) 352.4 (Figure 1). Kootenai Falls, 42 RKM downstream of Libby Dam, may be a barrier to Kootenai River white sturgeon. As the river flows through the northeast corner of Idaho, there is a gradient transition at Bonners Ferry. Upstream from Bonners Ferry, the channel has an average gradient of 0.6 m/km, and the velocities are often higher than 0.8 m/s. Downstream from Bonners Ferry, the river slows to velocities typically less than 0.4 m/s, the average gradient is 0.02 m/km, and the channel deepens as the river meanders north through the Kootenai River Valley. The river returns to BC at RKM 170.0 and enters the South Arm of Kootenay Lake at RKM 120.0. The river leaves the lake through the West Arm of Kootenay Lake and flows 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 (Bonde and Bush 1975). Regulation of the Kootenai River following the construction of Libby Dam in 1974 changed the natural hydrograph of the river. Spring flows were reduced by about a third, and flows during winter are now three to four times higher (Figure 2). Since 1991, Libby Dam has released spring flows intended to benefit Kootenai River white sturgeon (hereafter white sturgeon) spawning by increasing discharge and river stage (Figure 2).

METHODS

Water Levels and Temperature

Kootenai River discharge and water temperature data at Bonners Ferry were obtained from USACE. Based on the final April-August volume runoff forecast of 0.640 million hectare-meter for Kootenai River white sturgeon, the minimum recommended release volume for Kootenai River white sturgeon conservation under current circumstances is 98.64 thousand hectare-meters (USFWS 1999). Specific flow recommendations from Libby Dam for May and June 2005 are provided in Systems Operation Request (SOR) #2005-FWS-1 (USFW 2005).

Adult White Sturgeon Sampling

Adult white sturgeon were collected by angling or setlines from March 1 through June 8 and in September 2005, following the methods of Paragamian et al. (1996). In March and April, most of the sampling occurred in the staging areas at RKM 205 and 215. These areas are backwater habitats and have depths in excess of 20 meters and low current velocities (<0.05 m/s). Later in the spring, areas further upstream closer to the spawning locations were sampled more frequently (near RKM 229.0). Fall sampling occurred in the spring staging areas and near the Kootenai River delta at RKM 120. We biopsied adult sturgeon to determine sex and gonad stage. Male and female white sturgeon expected to spawn in 2006 or later were tagged with Vemco model V16 sonic transmitters and released. Adult female white sturgeon expected to spawn in 2006 were jetted to the Kootenai Tribe of Hatchery for hatchery production. Gametes from ripe male white sturgeon were collected in the field by extraction through the urogenital opening with a syringe. Gametes were placed in a Ziploc® bag, transported to the KTOI hatchery, and stored in a refrigerator. Normally, white sturgeon sperm is viable for only 48 hours after extraction, so we did not collect male gametes until a female was initially induced to ovulate.

To determine trends in the distribution of adult white sturgeon captures, we compared setline and angling data between 1995 to 2006 in Idaho and British Columbia portions of the Kootenai River/Kootenay Lake system.

Experimental Egg Release

Female white sturgeon expected to spawn in 2005 were transported to the KTOI hatchery, and a sample of their eggs was used for an experimental egg release study. The female's eggs were sampled periodically by KTOI hatchery personnel to check progression of the polarity index and germinal vesicle breakdown to determine when spawning would occur. When the eggs were ripe, the first of two hormone injections was administered at 24-hour intervals to induce ovulation. The number of eggs spawned per female was determined by enumerating a small volume of eggs in a beaker, then extrapolating this rate to the entire volume released from each female. Spawned eggs were then placed into 2 L plastic buckets and the lids were sealed. The buckets were placed into coolers and partly submerged in water from the hatchery to assure ambient temperatures were maintained. A control group from each release (totaling approximately 2200 de-adhesed fertilized eggs) was placed into Macdonald jars at the KTOI hatchery to estimate fertilization success and to provide a benchmark for hatching in the river.

Fertilization took place at the release sites. After the spawn was completed, the eggs and sperm were jetted by boat upriver to one of four predetermined release sites. Egg release sites were selected that closely resembled spawning and rearing conditions of other successfully recruiting white sturgeon populations (Parsley and Beckman 1994). Upon arrival to each site, water temperature was measured inside the coolers and from the river to ensure no shock would occur to the eggs and sperm. Sperm from at least two males (to create multiple families) was mixed with 2 liters of water in a large stainless steel bowl to initiate motility. The mixture was then added to the egg buckets and stirred with a feather for 2-3 minutes until the eggs began to adhere to the feather. The eggs were broadcast across the thalweg immediately upstream of the target area. In addition to the hatchery control, 6.5 ml (approximately 200) of fertilized eggs were placed into perforated egg canisters and anchored to the bottom to test hatching success inside the canisters. Current velocity, Secchi disk depth, depth, GPS coordinates, and temperature were recorded at each release site at the time of release. Thermographs were deployed near each site to provide information on dispersal timing of hatchlings, embryos, or larvae as described by Richmond and Kynard (1995).

Adult White Sturgeon Telemetry

Monitoring daily and seasonal movements of Kootenai River white sturgeon throughout the Kootenai River/Lake system continues to be a high priority of this investigation. Beginning in 2003 and continuing into 2005, we deployed an array of passive Vemco model VR2 sonic receivers from Kootenai Lake, British Columbia upstream to near the Montana border in Idaho (Figure 4). We selected sites based on river morphology and we deployed receivers in areas where fish pass through but do not usually hold for long periods to avoid redundant data collection. Most sites are below river bends or along straight stretches that allow for good signal reception, but are reasonably free of drifting debris and out of sight of potential vandals. Each receiver was tethered to a float to keep the hydrophone off the substrate, then anchored to a cement block and chained to the riverbank. This array allows continuous monitoring of sturgeon movements within the Kootenai river system and into Kootenai Lake.

Artificial Substrate Mat Sampling

We used artificial substrate mats to document white sturgeon spawning in the Kootenai River (McCabe and Beckman 1990). Post-Libby Dam sturgeon spawning locations in the Kootenai River have been well-documented (Paragamian et al. 2002). By sampling near these well-defined areas, we can effectively predict the beginning of the spawning period and use it as an index to document the initiation and extent of spawning. Up to 20 substrate mats were placed near the Shortys Island reach (near RKM 231.0) until eggs were collected, marking the beginning of the spawning season. After the beginning of the spawning period was documented, we focused our efforts on documenting spawning in other sections of the Kootenai River between Deep Creek (RKM 240.0) and Ambush Rock (RKM 246.6). Secchi disk depth was recorded during egg mat sampling in 2005 to provide a measure of light penetration and turbidity during the spawning season. We measured Secchi disk depth at Shortys Island (RKM 229.5), Deep Creek (RKM 240.0), and Ambush Rock (RKM 244.5).

For the experimental egg release, we were uncertain whether the released eggs would drift beyond the intended hatching sites. To determine the distribution of fertilized eggs after release, we placed between six and nine substrate mats downstream of the release sites.

Larval White Sturgeon Sampling

Larval sturgeon have never been collected in the Kootenai River in D-ring or conical ½ meter plankton nets. In 2005, larval sturgeon sampling focused on documenting any successful hatching resulting from the experimental egg release. We sampled from June 13 to July 27, between RKM 248.5 and 267.1. Sampling effort increased when hatchery control eggs began to hatch at 13°C (slightly warmer than ambient river water). Effort also intensified when hatchery control larvae had absorbed their yolk sacs, as any larvae hiding in the rock substrates within the release sites may become vulnerable to drift when they begin exogenous feeding. When conditions allowed, tows were conducted directly below (within one RKM) the release sites. The standard sampling method consisted of passively towing from a boat two benthic D- rings on the substrate and two conical ½ meter nets, one of which was placed near mid column and the other on the surface. Lead weights ranging from 2.7-9.1 kg were attached to nets to achieve desired depths. A divers watch was attached to the mid column nets to record specific depth within the water column. A General Oceanics model 2030R flow meter was attached to the mouth of each net to record rotor revolutions, which was used along with net diameter and sampling time to give the total volume of water sampled. Sampling occurred at all hours within a 24-hour period. In addition to the standard boat sampling, later in the season after river discharge decreased, conical 1-meter nets and D-ring nets were anchored with 100 kg cement blocks in shallow water and were fished overnight unattended.

Juvenile White Sturgeon Sampling

Beginning in 1990 and continuing to the present, the KTOI hatchery has released over 86,000 juvenile white sturgeon. Prior to release, each fish is passive integrated transponder (PIT) tagged and a pattern of scutes are removed which provides a unique mark for each brood year. We used weighted multifilament gill nets with 2.5, 5.1, 7.6, 10.2, and 15.2 cm stretch mesh to sample juvenile and young-of-the-year (YOY) sturgeon from July to September 2005 and followed the methodology of Paragamian et al. (1996). We sampled 10 different sites between RKM 190.0 and 244.0. Gill nets were set during the daytime and checked every hour to eliminate mortality of sampled fish and all fish were released alive. We recorded fork and total length, weight, PIT tag numbers, fish condition, and scute removal patterns for each sampled fish. Pectoral fin ray sections were removed from all wild juvenile white sturgeon for age determination.

RESULTS

Water Levels and Temperature

Kootenai River discharge and stage at Bonners Ferry remained stable January 1 through May 19 and peaked during late December 2005 (Figure 3). In accordance with SOR #2005-FWS-1 (Susan Martin, written communication), beginning May 19, discharge from Libby Dam increased from 113 m^3/s to 425 m^3/s to accommodate USGS suspended sediment sampling, acoustic Doppler current profiling, and bathymetry mapping within the braided reach above Bonners Ferry (above RKM 246.0). Discharge gradually increased at about 142 m^3/s increments every few days through May 25, when spring discharge peaked at 721 m^3/s. By May 28, discharge decreased to 550 m^3/s and continued to decrease to 393 m^3/s by June 11. Beginning June 12, discharge increased again to 669 m^3/s and remained between 513 m^3/s and 650 m^3/s through August before decreasing to below 400 m^3/s by late August (Figure 3).

River temperature remained below 5°C through early April 2005 (Figure 3). Beginning in mid April, temperature slowly began increasing through the spring and summer period, and reached a maximum of 16°C by early August 2005. River temperatures at Bonners Ferry decreased as discharge from Libby Dam increased (Figure 3).

Adult White Sturgeon Sampling

Between March 1 and September 9, 2005, we captured 67 adult white sturgeon by angling and 88 adult white sturgeon with setlines. Five additional adult white sturgeon were caught in gillnets while sampling for juvenile white sturgeon. Total effort for adult sampling was 3,972 hours. The catch per unit effort (CPUE) was 0.1122 fish per rod hour for angling and 0.0261 fish per setline hour for setlines (Table 1). We biopsied 39 adult white sturgeon in 2005, and 18 adult white sturgeon were tagged with Vemco sonic transmitters.

We evaluated the adult recaptures in Idaho and British Columbia between 1995 and 2006 to determine trends in the percentage of new fish in the population and the distribution of new fish in the Kootenai River/Lake system. One hundred eighteen (74%) of the 160 adult white sturgeon collected were recaptures from previous years (Table 1). The percentage of new fish captured during setlining and angling has declined slowly between 1995 and 2006 (Figure 5). Most of the adults collected between 1995 and 2006 came from Idaho portions of the Kootenai River. Although the total percentage of new fish has declined over the period, the percentage of new fish captured in British Columbia (the delta) has remained stable over the period (Figure 5).

Experimental Egg Release

During adult sampling, 13 late vitellogenic females were captured and taken to the KTOI hatchery facility. Sperm was extracted from 22 ripe males during the spawning season. Motility was estimated for each male prior to the spawn by KTOI hatchery personnel. Female polarity indices and germinal vesicle breakdown were calculated for each female during the spawning season, and only 11 of the 13 females met the specifications to induce ovulation. One of the 11 fish weighed only 30 kg, had an underdeveloped egg skein, and was not used in the egg release experiment due to low egg production. The other two fish had underdeveloped eggs.

Spawning took place from June 2 through June 29, 2005 (Table 2). A total of 1,056,700 eggs (about 29 liters) were collected from the 10 females and the egg volume averaged 32.1 eggs per ml. (Table 2). The controls in the hatchery all had hatching success above 80%. The eggs were released at one of four release sites between RKM 250.3 and 274.5 (Table 2). The average velocity reading for the release sites was 2.0 m/s with a mean temperature of 12.6°C (Table 2). The eggs were released in an average water depth of 3.2 m, and discharge measured at Bonners Ferry during the period ranged from 489 to 833 m^3/s (Table 2).

The egg canisters failed to produce any hatchlings for all 10 releases, but fertilization was observed in nearly every egg at the hatchery controls. In every case, the eggs were covered with silt or with a white fungus.

Adult White Sturgeon Telemetry

The Vemco stationary receiver array allowed for adult white sturgeon movement monitoring throughout the Kootenai River/Kootenay Lake system. Receivers were downloaded at 53 locations from RKM 18.0, near the mouth of the Lardeau River in Kootenay Lake, BC, upstream to RKM 275.5, just below the Montana border (Figure 4). Eighteen adult white sturgeon were tagged with Vemco sonic transmitters in 2005, and 11 adult white sturgeon had active Vemco sonic transmitters from previous years (Table 3).

Seven adult white sturgeon were tagged in the fall of 2005 and 15 of the remaining 22 adult white sturgeon (8 females and 7 males) made upstream spawning movements in spring of 2005. Sixty-seven percent (10) of the migrating adult white sturgeon went upstream as far as RKM 243.5 (Ambush Rock) and 47% (7) went above Ambush Rock to near the Hwy. 95 Bridge in Bonners Ferry. While any of these seven tagged adult white sturgeon may have moved above Bonners Ferry in 2005, none were recorded at the receiver located at RKM 248.6. No receivers were deployed between the Hwy. 95 Bridge (RKM 245.5) and RKM 248.6 in 2005.

Movements of stage F4 (Beer 1981) female white sturgeon in response to flow operations and resulting temperatures is a primary concern of this investigation. When discharge volume increases at Libby Dam during the spring, temperature in the Kootenai River often decreases (Figure 3). In 2005, four of the tagged F4 female white sturgeon moved downstream after May 16, as river water temperatures began declining rapidly (Appendix 1). Movement histories of six F4 female white sturgeon (fish 276 was stage F3 but was assumed to be stage F4 by May of June) are listed in Appendix 1.

Artificial Substrate Mat Sampling

We deployed substrate mats at four sites within the traditional post-Libby Dam spawning reach (RKM 229.0–246.6) and sampled 633 mat days between April 25 and June 22, 2005. Ten eggs were collected from three mats at Shortys Island on May 18. Seven eggs were collected from one mat at RKM 230.4, 1 egg was collected at a mat at RKM 230.3, and 2 eggs were collected at RKM 230.2 (Table 4). All eggs were dead at the time of collection so spawning date and timing could not be determined.

We also deployed substrate mats at two general locations below the egg release sites (RKM 253.0–275.0) to evaluate the distribution of the fertilized eggs after they were released (Table 4). No eggs were collected below the egg release sites, and the substrate mats were not deployed during the last releases due to the inability to anchor the mats at high discharges.

Larval White Sturgeon Sampling

We sampled for white sturgeon embryos and larvae between June 16 and July 27, 2005 (Table 5). We spent a total of 908 hours sampling at five sites. The majority of the sampling occurred below Hemlock Bar (RKM 262.6) in an attempt to capture embryos or larvae from the experimental egg release (Table 5). No early life stage sturgeon were captured in 2005, but 12 egg casings were found that may have been from recently hatched sturgeon eggs. Additionally, 788 larval fish were collected, primarily of the Catostomidae family.

Juvenile White Sturgeon Sampling

Relative abundance and age class distribution of hatchery reared and wild juvenile white sturgeon was determined by gillnet sampling. We sampled for juvenile white sturgeon with gillnets between August 7 and September 22, 2005 at 10 sites and captured 226 hatchery reared juvenile white sturgeon and two wild juvenile white sturgeon. A total of 198 hours of sampling effort was exerted gillnetting in 2005 (Table 1). The 10.2 cm gillnets had the highest catch with 81 individuals and the highest catch rates, followed by the 2.5 cm nets (Table 6). Rock Creek had the highest catch with 55 percent of the individuals and had the highest catch rates with 2.4 fish per hour (Table 7). The average fork and total lengths of the 228 juvenile white sturgeon sampled was 40.0 cm and 46.5 cm, and weight averaged 0.46 kg, respectively (Table 8).

Examination of the age frequency distribution of juvenile white sturgeon captures in 2005 showed few captures of juveniles from the 2001 and 2002 brood years and under-representation of several other recent year classes (2000, 2003, and 2004). Despite increasing numbers of fish released (Table 9), there was a general decline in the number of captures and the relative recapture frequency by brood year from 2000 through to 2004 (Figure 6). Within this general decline the 2001 and 2002 brood years were very under-represented compared to all other release years and the relative recapture frequencies were very low (0-0.5%) (Figure 6). In comparison, some of the early 1990's brood year annual relative recapture rates were as high as 14% (Figure 6).

Two wild juvenile white sturgeon were captured in 2005. One individual was captured at RKM 207.0 in 5.1 cm mesh and had a total length and fork length 28.7 cm and 24.8 cm, respectively. The other individual was captured at RKM 225 in 10.2 cm mesh and had a total length, fork length, and weight of 30.4 cm, 26.1 cm, and 0.108 kg, respectively. Each fish was aged by removing a pectoral fin ray section and both individuals were assigned to the 2003 year class.

Appendix 2 lists the details on sizes and numbers and recapture rates of hatchery juvenile white sturgeon released in the Kootenai River since 1990. Appendix 3 provides the specific growth parameters of the juvenile white sturgeon captured in 2005. Appendix 4 shows the number of wild juvenile white sturgeon collected annually from 1977 to 2005. Appendix 5 shows the year class assignments from a sample of the wild juvenile white sturgeon collected between 1957 and 2005 that could be aged.

DISCUSSION

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 2002). 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 the number of days during the spawning period ranging from 17 to 31 days. The most consistent year of Kootenai River white sturgeon spawning was 1996 when spawning was detected during 18 of 19 days, flow ranged from 891 to 1,259 m^3/s (31,465-44,461 cfs) and averaged about 1,131 m^3/s (~40,000 cfs) for the first 11 events before there was a day of undocumented spawning. 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 2002). However, despite our improved understanding of spawning events there has been little success at measuring recruitment of young white sturgeon from mitigated flow years and with the available data the present level of recovery is still unknown (Paragamian and Wakkinen 2002; Paragamian et al. 2002).

Flow was also an important variable affecting sturgeon spawning. 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 2002). Our analysis suggests flows for optimum white sturgeon spawning in the Kootenai River should be held above 630 m^3/s (22,248 cfs), an ideal temperature range of 9.5 to 12°C (49.1-53.6°F), and a duration of 42 d which is based on recommendations in the Kootenai River White Sturgeon Recovery Plan (USFWS 1999). As previously noted the most consistent spawning took place at an average of about 1,131 m^3/s (~40,000 cfs). However, of the two variables temperature is the most difficult to control.

The most recent population modeling suggests that the remaining adult white sturgeon population contains less than 500 adults with the numbers declining at a rate of about 9% each year (Paragamian et al. 2005). Based on these estimates, each year we sample about 30 percent of the adult population during spring setlining and angling efforts. In 2005, we did a brief analysis of the trends in the adult recapture rates in Idaho and British Columbia between 1995 and 2006. The number and percentage of new adult white sturgeon captured in Idaho has slowly decreased between 1995 and 2006, and although sampling effort has not been consistent between years, the percentage of new adult white sturgeon captured in British Columbia has remained stable. The population modeling is based largely on fish captured and recaptured in Idaho portions of the Kootenai River while fish are on a spawning migration. The relatively high percentage of new fish captured in British Columbia at the lake delta (RKM 120) and the fact that these percentages have remained stable since 1995 provides some evidence that we may be underestimating the adult population in the Kootenai River/Lake system. Including additional sampling location strata such as Kootenai Lake into the population model may more accurately estimate the current adult population size. Continued tagging of adult white sturgeon in Kootenay Lake and in Idaho portions of the Kootenai River and continued movement monitoring with the passive telemetry array may provide information into different spawning locations and different life history and movement strategies.

During the egg release experiment in 2005, no larval white sturgeon were collected below the release sites but over 700 nontarget larvae were collected. We may have chosen release sites that are unsuitable for sturgeon eggs to hatch or the release numbers may not be large enough to have a reasonable chance of documenting hatch in a river as large as the

Kootenai. The egg canisters failed to produce any hatchlings for all 10 releases and in every case, the eggs in the canisters were covered with either silt or a white fungus. However, fertilization was observed in nearly every egg at the hatchery controls. Several different approaches were used to combat this siltation problem including drilling holes and placing the canisters in very high velocities to increase oxygen and flow over the eggs. Although siltation was alleviated, white fungus persisted in nearly every treatment.

Because of Libby Dam operations, increases in discharge often causes decreases in water temperatures during the white sturgeon spawning season (Figure 3). Female Kootenai River white sturgeon have been shown to move downstream when this occurs (Paragamian and Wakkinen 2002). The short-term effects of this situation on spawning behavior and success and the long-term effects of this on subsequent recruitment are concerning. In 2005, at least four of the six sonic tagged female sturgeon moved downstream when water temperatures decreased (Appendix 1). Selectively placing gates at the forebay of Libby Dam and releasing warmer water may help ameliorate this situation.

The Vemco VR2 passive telemetry array has allowed for cost effective, continuous monitoring of white sturgeon movements throughout the Kootenai River system. While it will take several years of monitoring to understand important life history strategies such as spawning site fidelity, but it has provided new insights. First, some white sturgeon use the entire lake-river system and Kootenay Lake, and the Kootenay Lake delta may be more valuable adult habitat than previously thought. Second, some white sturgeon move between Kootenay Lake and the Kootenai River several times per year and each environment may provide important requirements for different individuals or at different times of the year. Finally, while tagged white sturgeon have been recorded near Bonners Ferry in past years, and in 2005, 67% (10) of the sonic tagged spawning population went upstream as far as Ambush Rock (RKM 243.5). While it is unknown if these individuals spawned here in 2005 (no eggs were collected and not all tagged fish were in spawning stage), habitat conditions for spawning appear to be more suitable in this reach. Hopefully, this technology can be used to refine movement extents and patterns and give us insight into what conditions to provide to keep spawning adults in (or upstream of) this area.

One drawback to our existing VR2 array is that it fails to provide real-time data or point location data. New equipment from Vemco (V-rap) is available that allows individual fish locations around a specific habitat reach to be determined remotely on a real-time basis. This (V-rap) technology is compatible with our existing Vemco sonic transmitter technology and can provide information on how fish move in response to physical habitat enhancement.

Artificial substrate mats have been used successfully for many years to document the spatial and temporal distribution of white sturgeon spawning events (Paragamian and Wakkinen 2002). Beginning in 2004, substrate mats have been used to provide an index to determine the beginning and spatial extent of spawning. Comparatively few mats are deployed and mats are checked less frequently with this new protocol. Egg mortality has also been higher which may result from increased siltation and suffocation with more time between mat checks.

The lack of substantial recruitment of the 2001 and 2002 year classes to our gillnetting gear in 2005 may represent a decline in survival from these release groups. Continued gillnet monitoring and analysis in future years may provide some answers, but more precise estimates of survival using mark-recapture methods and examination of all potential biases needs to be completed before this data supports a change to the current stocking strategy.

RECOMMENDATIONS

1. As soon as water temperature reaches 7°C after April 1, provide flows of 425 m^3/s at Bonners Ferry with stable or increasing temperature to initiate and maintain spawning migration of Kootenai River white sturgeon.

2. Provide minimum flows of 630 m^3/s for 42 d (as prescribed for spawning and rearing in the Kootenai River White Sturgeon Recovery Plan) at Bonners Ferry once water temperatures of 8-10°C are reached to stimulate spawning and optimize egg/larval survival of Kootenai River white sturgeon.

3. Release 1,000,000 fertilized eggs (embryos) in areas upstream of Bonners Ferry with flow and substrate conditions thought to be more suitable for successful egg hatching and larval recruitment. Monitor hatch success and larval recruitment with standard D-ring and ½ meter nets placed below release sites.

4. Use Vemco V-rap system to collect pretreatment habitat use data of sonic tagged white sturgeon near the proposed Shortys Island pilot study reach (near RKM 231).

ACKNOWLEDGMENTS

We would like to thank Seth Richards and Jon Stein of IDFG for their assistance with data collection during the 2005 field season. We also thank Chris Lewandowski, Jack Siple, and Sue Ireland of the KTOI and Matt Neufeld and Don Miller of the BC Ministry of Environment. Special thanks to Greg Schoby, Tim Copeland, and Vaughn Paragamian of IDFG for reviewing this document. The Bonneville Power Administration provided funding for this work.

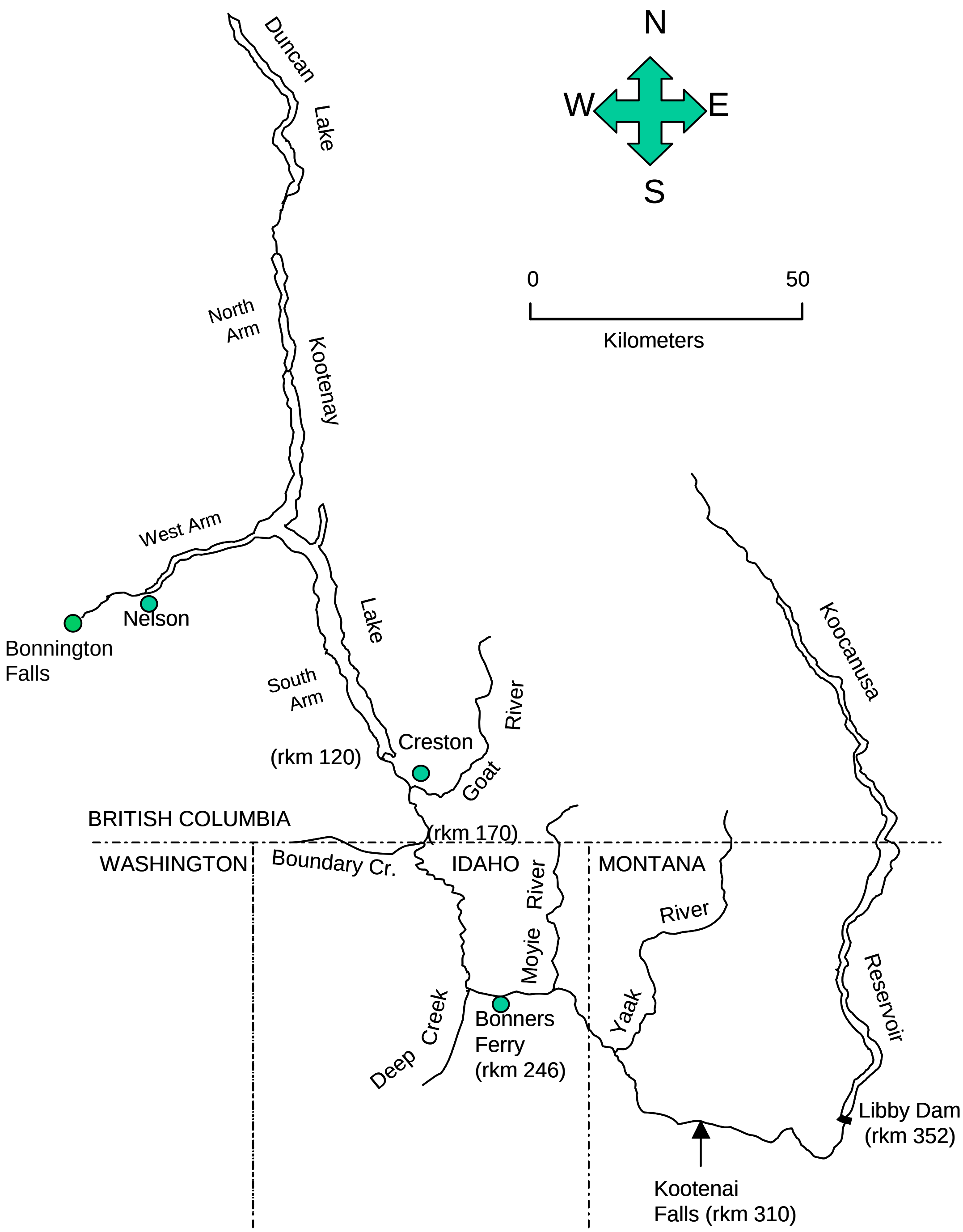

Figure 1. Location of the Kootenai River, Kootenay Lake, Lake Koocanusa, and major tributaries. The river distances from the northernmost reach of Kootenay Lake are in river kilometers (RKM) and are indicated at important access points.

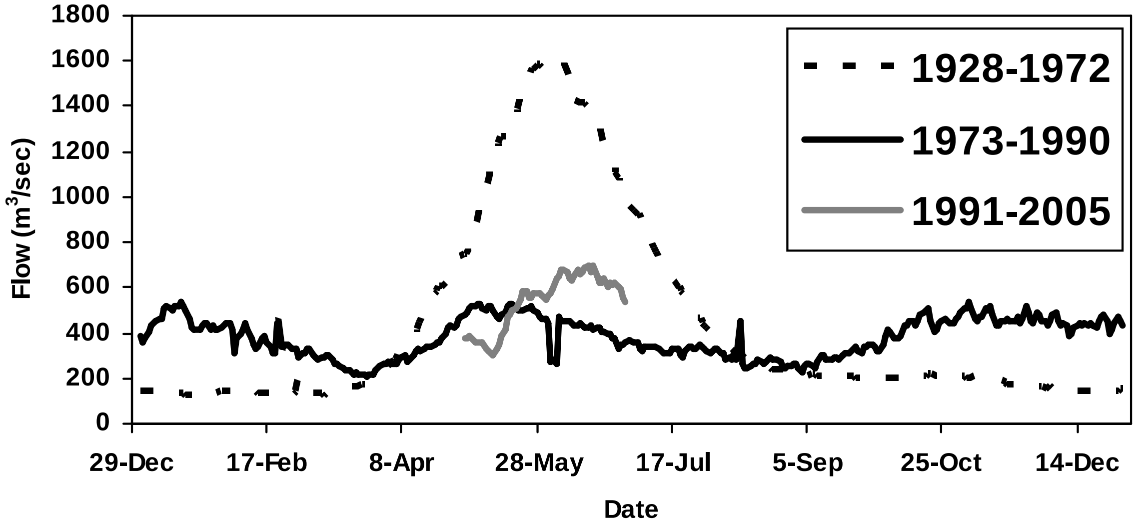

Figure 2. Mean daily flow patterns in the Kootenai River at Bonners Ferry, Idaho from 1928-1972 (pre-Libby Dam), 1973-1990 (post-Libby Dam), and 1991-2005 (post-Libby Dam with augmented flows May 1 through June 30).

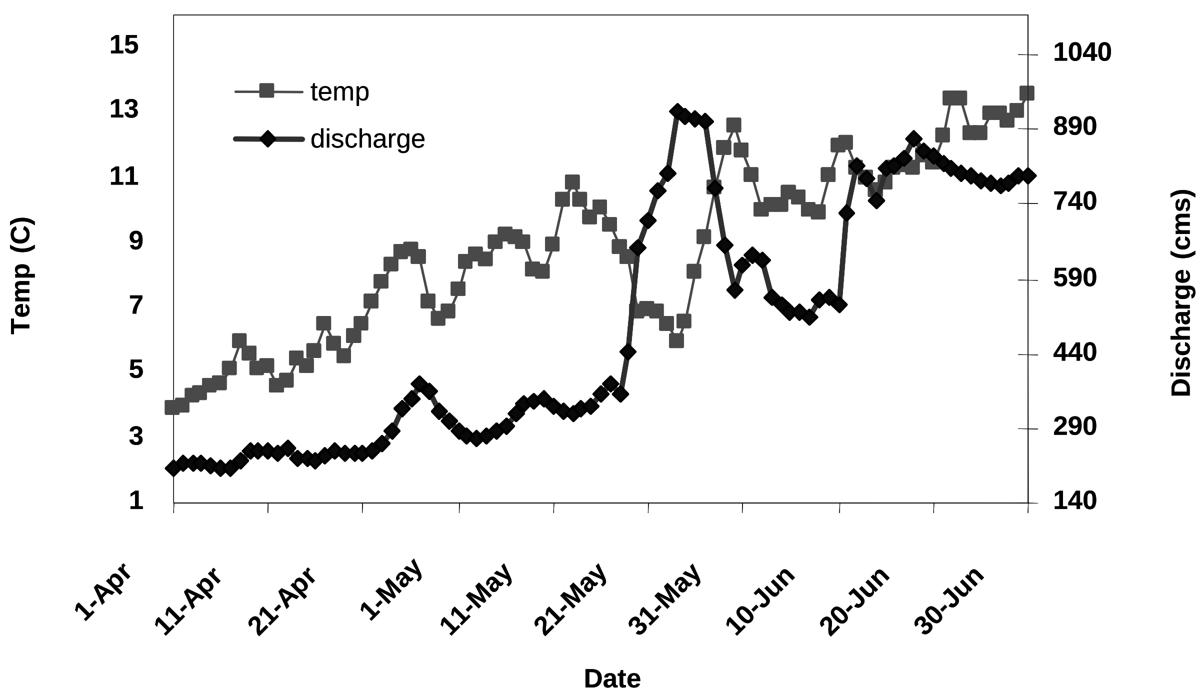

Figure 3. Discharge and temperature during white sturgeon spawning season near Bonners Ferry, Kootenai River, Idaho, 2005.

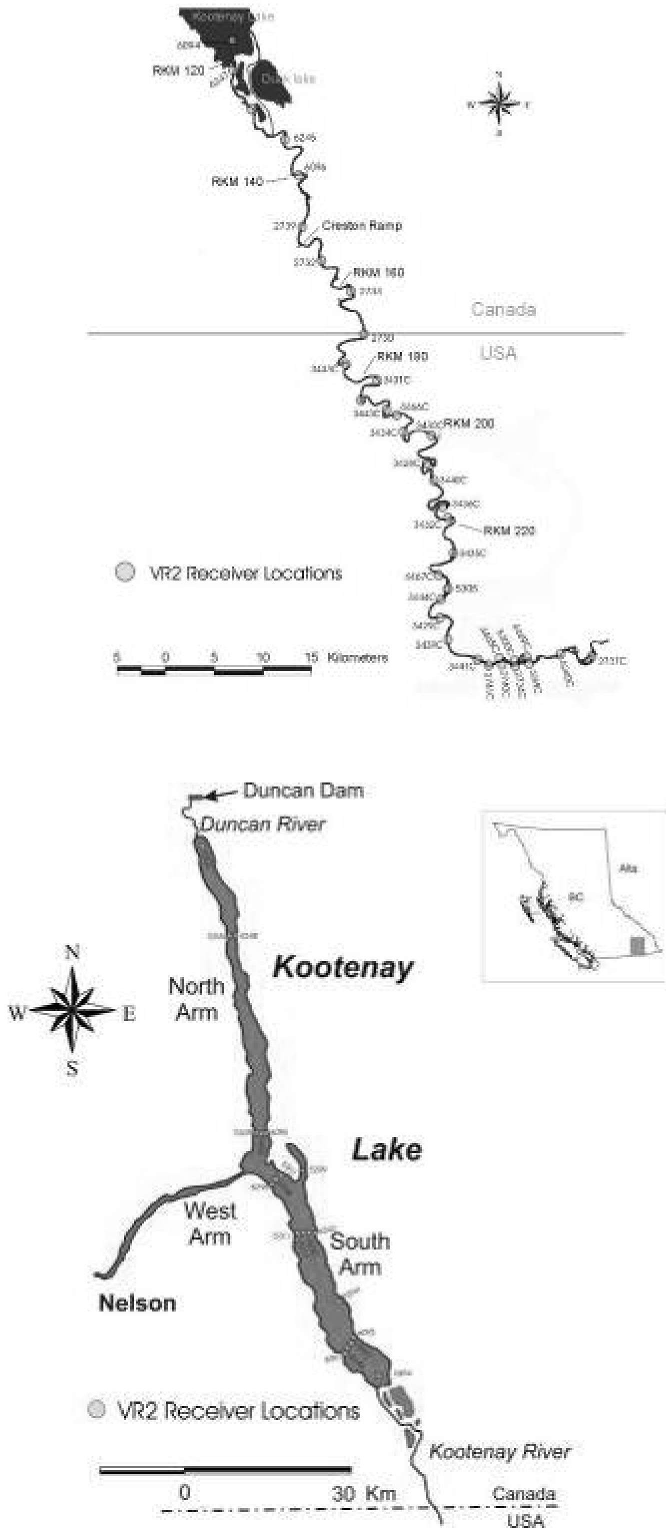

Figure 4. Location of Vemco VR2 receivers in Kootenai River/Lake system, Idaho and British Columbia, Canada, 2005.

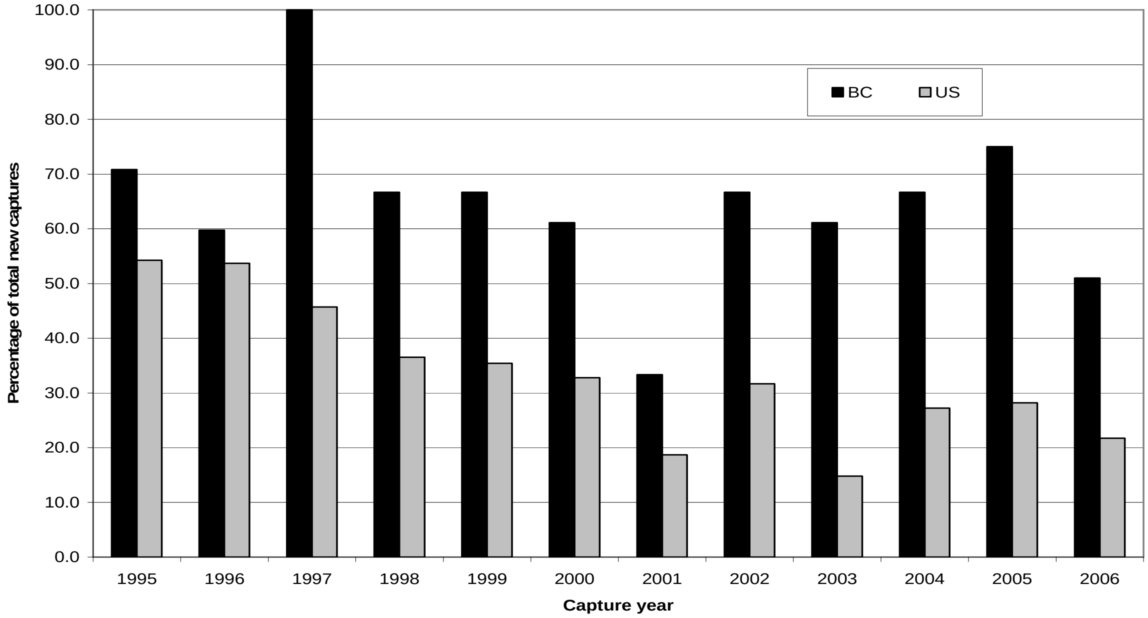

Figure 5. Percent total of new captures of adult white sturgeon in Idaho and British Columbia portions of the Kootenai River between 1995 and 2006.

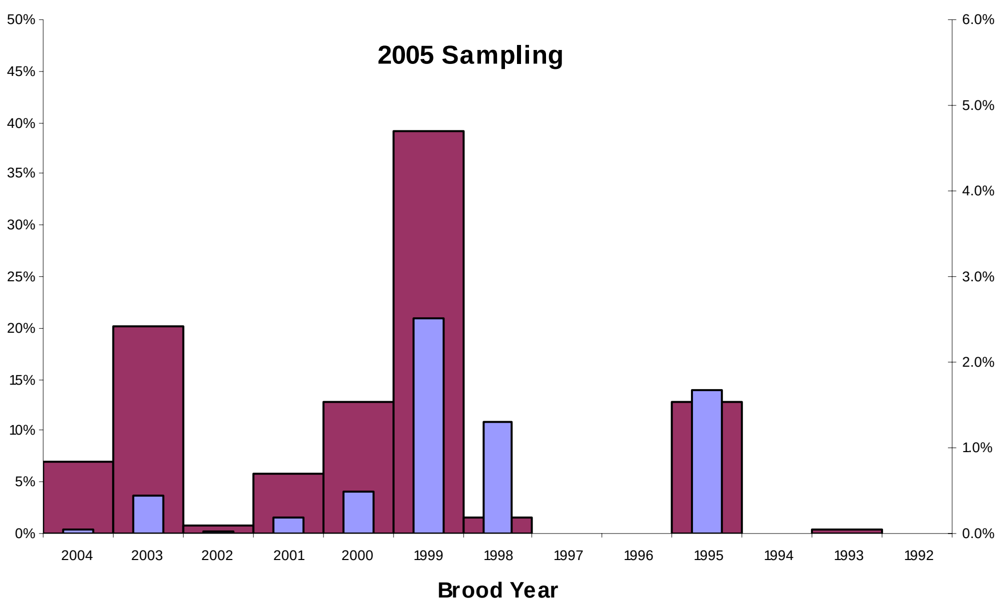

Figure 6. Annual relative age frequency (black bar) (brood year based on IDFG database) and relative recapture frequency (white bar) (number of brood year captured relative to original number released by sampling year) from 2005 sampling efforts, Kootenai River, Idaho.

Table 1. Sampling effort and number of adult and juvenile white sturgeon caught by the Idaho Department of Fish and Game alone or with Kootenai Tribe of Idaho personnel in the Kootenai River, Idaho, February 28, 2005 to October 5, 2005.

	Hours of effort	Number of juvenile sturgeon caught (No. of recaptures)	Number of adult sturgeon caught (No. of recaptures)	Juvenile CPUE (fish/h)	Adult CPUE (fish/h)
Gillnet	198.05	228 (194)	5 (4)	1.1512	0.0252
Angling	597	0	67 (50)[b]	0	0.1122
Setline	3,375.67[a]	1 (1)	88 (64)	0.0003	0.0261
Total	4,170.72	229 (195)	160 (118)		

[a] Based on 24-hour sets.
[b] There were an additional seven adults captured (2 recaptures) during angling efforts by BCE staff for IDFG from May 9–17, 2005 and 14 adults captured (10 recaptures) during angling efforts by IDFG staff from September 26–27, 2005. There was no effort data associated with these captures.

Table 2. Egg release site specifications and water quality parameters from egg release experiment, Kootenai River, Idaho, 2005.

Site Number	River kilometer	Date	Eggs released	Release time	Release number	Mean velocity (m/s)	Water temp °C	Leonia discharge (m^3/s)	Leonia stage (m)
1	274.5	21-Jun	81,375	7:40 PM	5	2.7[a]	13.5	784	5.6
		27-Jun	148,680	3:15 PM	8	2.7	13.5	756	5.6
		Total	**230,055**						
2	270.0	23-Jun	251,300	5:22 PM	7	1.5	14.4	776	5.6
		29-Jun	58,080	4:00 PM	10	n/a	12.8	767	5.6
		Total	**309,380**						
3	262.5	22-Jun	102,960	7:40 PM	6	1.8	15.0	773	5.6
		28-Jun	122,100	6:40 PM	9	1.9	13.0	758	5.5
		Total	**225,060**						
4	250.3	2-Jun	68,250	12:11 AM	1	1.8	11.0	537	5.2
		6-Jun	90,000	8:00 AM	2	1.6	10.0	489	4.8
		11-Jun	65,625	4:10 AM	3	2.0	12.0	520	5.6
		18- Jun	76,150	12:30 AM	4	1.8	11.0	833	5.7
		Total	**300,025**						
		Total	**1,064,520**						

[a] Surface measurement only.

Table 3. Vital statistics from Kootenai River adult white sturgeon marked with Vemco sonic tags as part of a telemetry study, Kootenai River, Idaho, 2003-2005.

Tag year	Sex-Development Stage	Release Date	Release RKM	Fish Number	Fork Length (cm)	Total Length (cm)	Weight (kg)	Vemco Code
2003	F-2	8/26/03	119.0	2117	173.0	195.5	37.8	52
2003	na	9/8/03	19.0	1471	181.0	205.0	45.0	51
2004	F-3	9/7/04	121.0	22212	204.0	229.0	78.8	259
2004	M-8	9/7/04	121.0	22214	179.5	203.0	48.6	261
2004	M	9/7/04	121.0	1791	141.0	163.0	22.5	264
2004	na	9/7/04	121.0	1792	138.0	164.0	26.0	265
2004	F-3	9/8/04	121.0	22211	186.0	213.0	56.3	260
2004	M-8	9/8/04	121.0	22210	169.0	191.0	38.3	262
2004	M-8	9/8/04	121.0	22222	182.0	204.0	45.9	263
2004	M-8	9/8/04	121.0	690	168.5	190.0	38.3	266
2004	M-8	10/4/04	119.0	22213	195.5	220.0	54.9	257
2005	F-4	3/10/05	204	53853	170.0	197.0	41.0	275
2005	F-2	3/16/05	215	53855	215.0	241.0	na	277
2005	F-4	3/29/05	215	53872	165.0	191.0	48.0	274
2005	F-3	3/29/05	215	53871	182.0	209.0	47.0	276
2005	F-3	4/12/05	215	53863	182.0	200.0	59.0	273
2005	F-4	4/26/05	215	947	142.0	162.0	26.0	272
2005	F-4[a]	4/28/05	226.5	958	189.0	220.0	58.0	280
2005	F-1	5/18/05	230.7	348	161.0	184.0	na	278
2005	M-8	6/08/05	229	906	166.0	191.0	35.0	281
2005	M-8	6/08/05	229	330	179.0	206.0	43.0	279
2005	M-8	6/08/05	229	53894	189.0	217.0	70.0	271
2005	F-4[b]	6/28/05	243.0	2117	170.0	196.0	40.0	52
2005	M-7	9/26/05	215	406	168.0	192.0	43.0	50
2005	F-4[a]	9/26/05	215	345	164.0	189.0	52.0	269
2005	F-4[a]	9/26/05	215	535	177.0	204.0	57.0	270
2005	F-4	9/27/05	215	1578	178.0	200.0	40.0	267
2005	U[c]	9/27/05	215	804	105.0	132.0	14.0	87
2005	F-4	9/27/05	215	1795	185.0	208.0	54.0	268
2005	M-7	9/27/05	215	1794	197.0	224.0	63.0	258

[a] F-1 eggs present.
[b] Fish recaptured; no mention of sonic tag.
[c] Unknown sex/ development; 3-year tag.

Table 4. Location (RKM), depth (m), effort, and white sturgeon egg catch by standard artificial substrate mats, Kootenai River, Idaho, 2005.

Geographical description	River location (RKM)	Depth range (m)	Total mat days[a]	Number white sturgeon eggs
Middle Shortys Island	229.6-231.5	3.0-9.5	327.1	10
Hatchery	240.6-243.9	4.3-4.3	2.9	0
Ambush Rock	244.0-244.6	5.8-6.7	23.1	0
US Hwy 95	244.7-246.6	1.5-6.7	280.5	0
Crossport/Moyie River	253.0-260.9	1.5-7.6	18.8	0
Curley Creek	270.0-275.0	3.0-5.2	4.1	0
All sections	229.6-275.0	1.5-9.5	656.5	0

[a] One mat day is one 24-hour set.

Table 5. Summary of 2005 white sturgeon larval sampling effort and volume sampled by gear type and location, Kootenai River, Idaho.

Gear type	Location (river kilometer)	Sampling Dates	Catch	No. Sites	Effort (hours) Mean (SD)	Effort (hours) Total	Volume (m^3) sampled Mean (SD)	Volume (m^3) sampled Total
Surface and mid-column	248.5	6/13-6/28	40	84	1.8 (0.6)	153.6	791 (618.7)	66468
½ meter net								
	262.1-262.2	7/1-7/26	210	56	3.8 (2.6)	213.2	2443 (1460.8)	136800
	248.5-248.7	6/13-6/28	24	80	1.9 (1.2)	153.2	957 (991.5)	76538
	249-249.5	6/20-6/23	22	8	9.9 (5.7)	79.0	2743 (2342.7)	21945
Benthic D-ring								
	249.9-250.0	6/13-6/27	0	5	6.5 (1.3)	33.4	2432 (1962.1)	12246
	262.1-262.5	7/1-7/27	252	60	7.1 (4.9)	226.9	3924 (2530.3)	136432
	267.1	7/6-7/8	240	3	16.2 (1.2)	48.7	7770 (1838.0)	23311
Combined	All	6/13-7/27	788	296		908		473740

Table 6. Idaho Department of Fish and Game juvenile white sturgeon gillnet sampling effort by mesh size for August through September 2005.

Gillnet Mesh size	Number of sets	Hours of effort	Number of adults captured	Number of juveniles captured	Sturgeon catch per unit of effort
1” stretch	29	47.9	2	64	1.3779
2” stretch	25	38.7	0	37	0.9561
3” stretch	22	34.7	0	22	0.634
4” stretch	37	54.8	2	81	1.5146
5” stretch	14	21.5	1	24	1.1628
Unknown	2	0.5	0	0	na

Table 7. Idaho Department of Fish and Game juvenile white sturgeon gill net sampling effort by sampling location for August through October 2005.

River Kilometer	Number of sets	Hours of Effort	Number of adults captured	Number of juveniles captured	Sturgeon catch per unit of effort
190.0	12	17.9	0	7	0.3911
192.0	9	13.6	0	4	0.2941
205.0	27	42.2	0	51	1.2085
207.0	12	18.5	0	20	1.0811
210.0	6	4.4	0	1	0.2273
215.0	33	53.6	5	124	2.4067
219.0	3	5.2	0	4	0.7692
225.0	12	18.6	0	6	0.3226
230.0	6	10.1	0	4	0.3922
244.0	9	14.0	0	7	0.5

Table 8. Vital statistics of recaptured juvenile hatchery white sturgeon (N = 226) from 2005 gillnet sampling by the Idaho Department of Fish and Game.

	Statistic	FL (cm)	TL (cm)	WT (kg)
	Average	40.0	46.5	0.46
Recaptures	Standard deviation	10.1	11.6	0.35
N = 226	Minimum	15.4	17.2	0.01
	Maximum	67.3	77.6	1.82

Table 9. Number of juvenile white sturgeon released by brood year from 1990 to 2004, Kootenai River, 2004 (Data provided by Kootenai Tribe of Idaho).

Brood Year	Total # Released
2004	36,114
2003	12,562
2002	14,785
2001	8,856
2000	7,311
1999	4,260
1998	309
1997	-
1996	-
1995	2,083
1994	-
1993	-
1992	123
1991	104
1990	14
All Years	**86,521**

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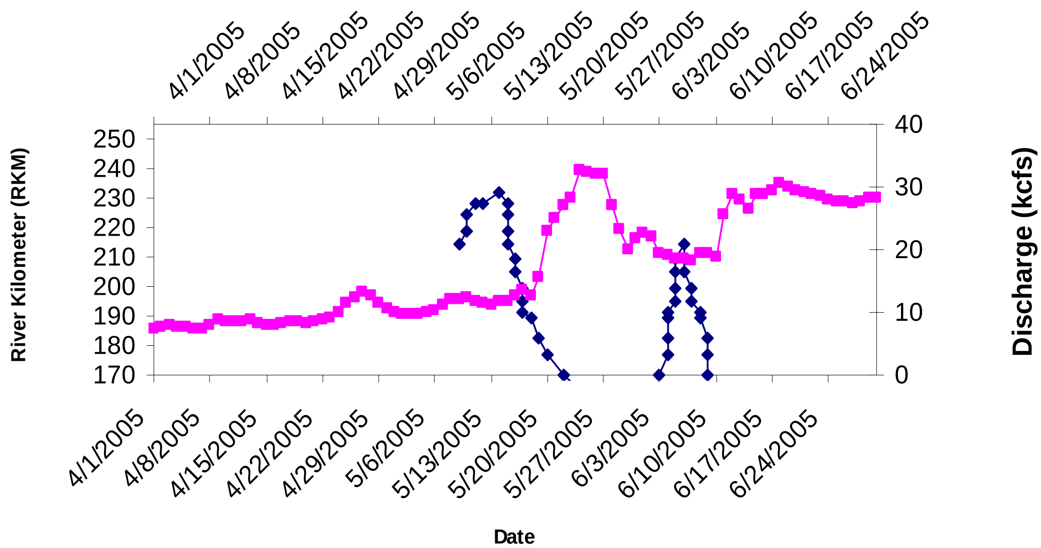
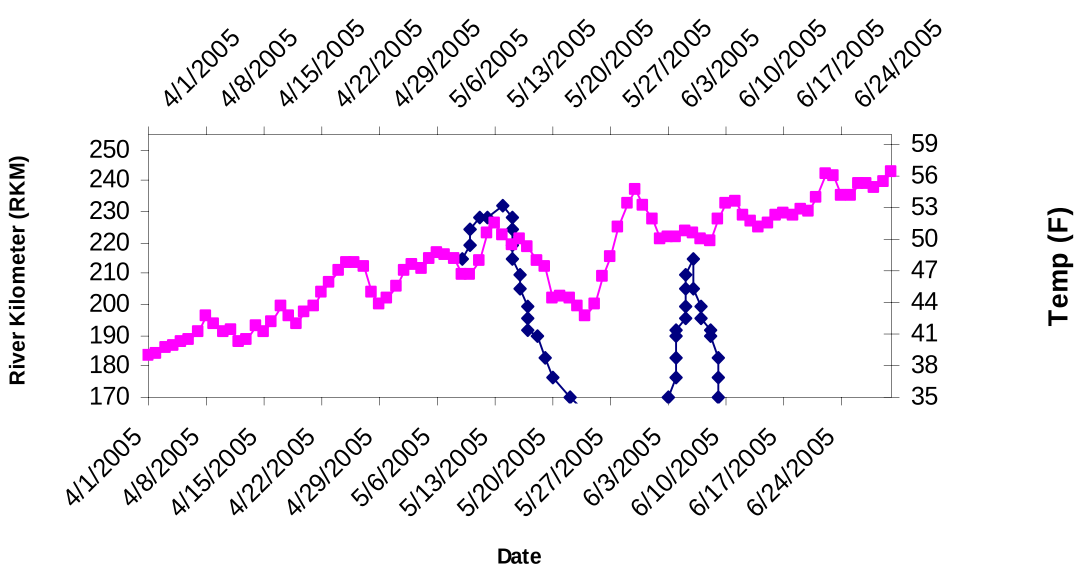
APPENDICES

Appendix 1. Migration for six female sturgeon, all of which are believed to have spawned in the Kootenai River, Idaho, 2005. Black lines indicate fish movements.

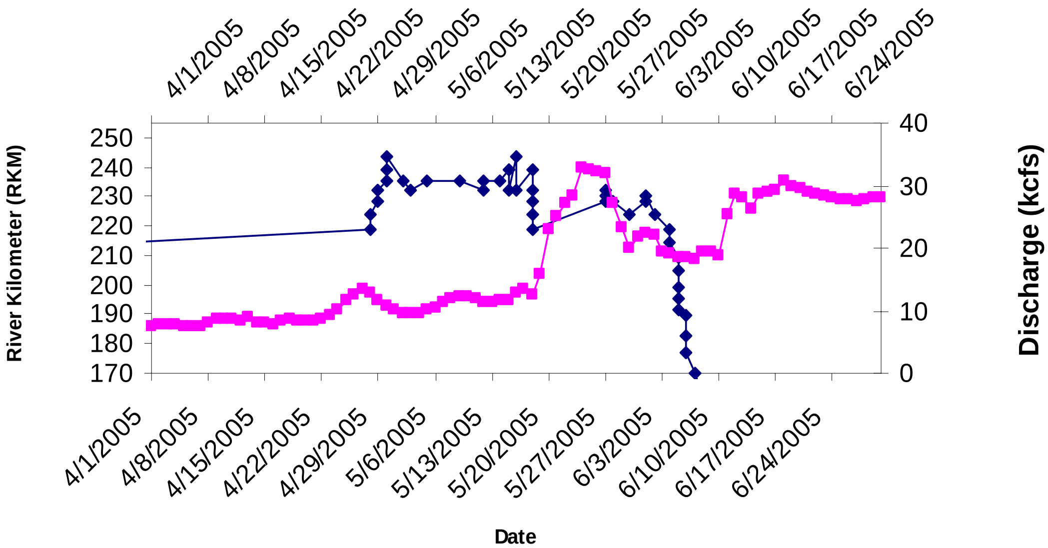
276 – F3, tagged 3/29/05 at RKM 215

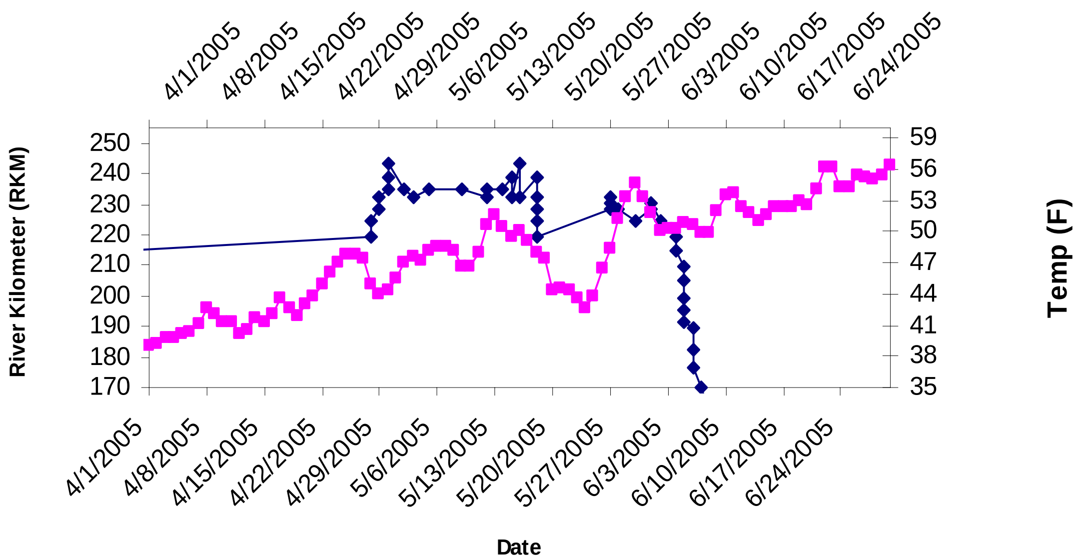




Appendix 1. Continued.

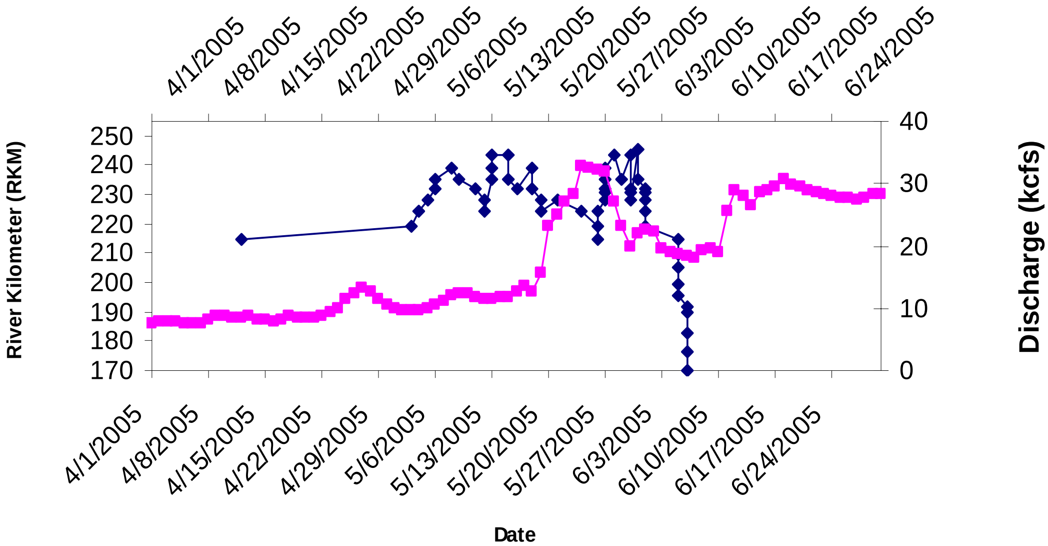
274 – F4, tagged 3/29/05 at RKM 215

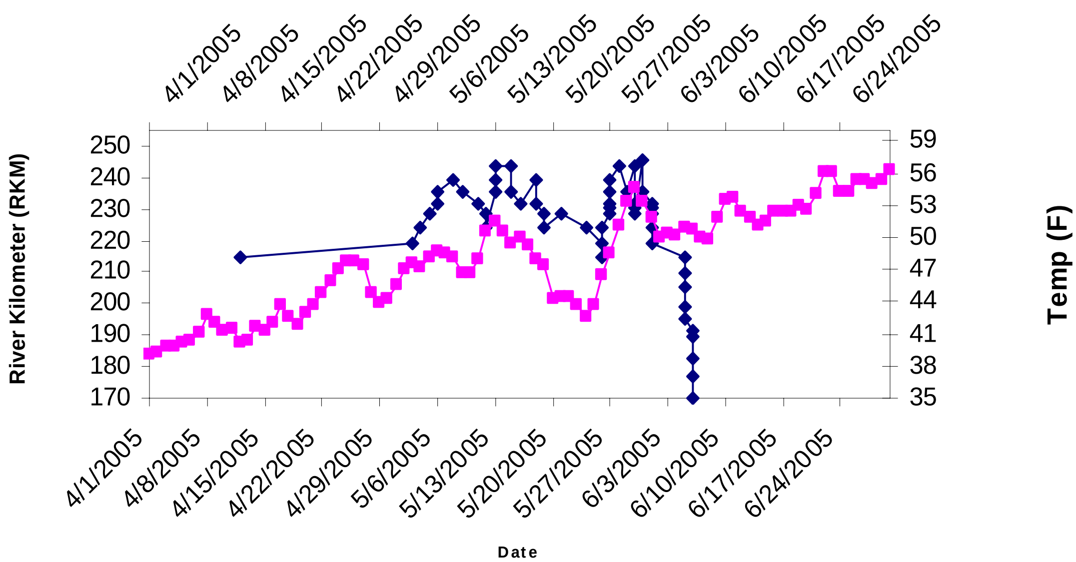




Appendix 1. Continued.

273 – F4, tagged 4/12/05 at RKM 215





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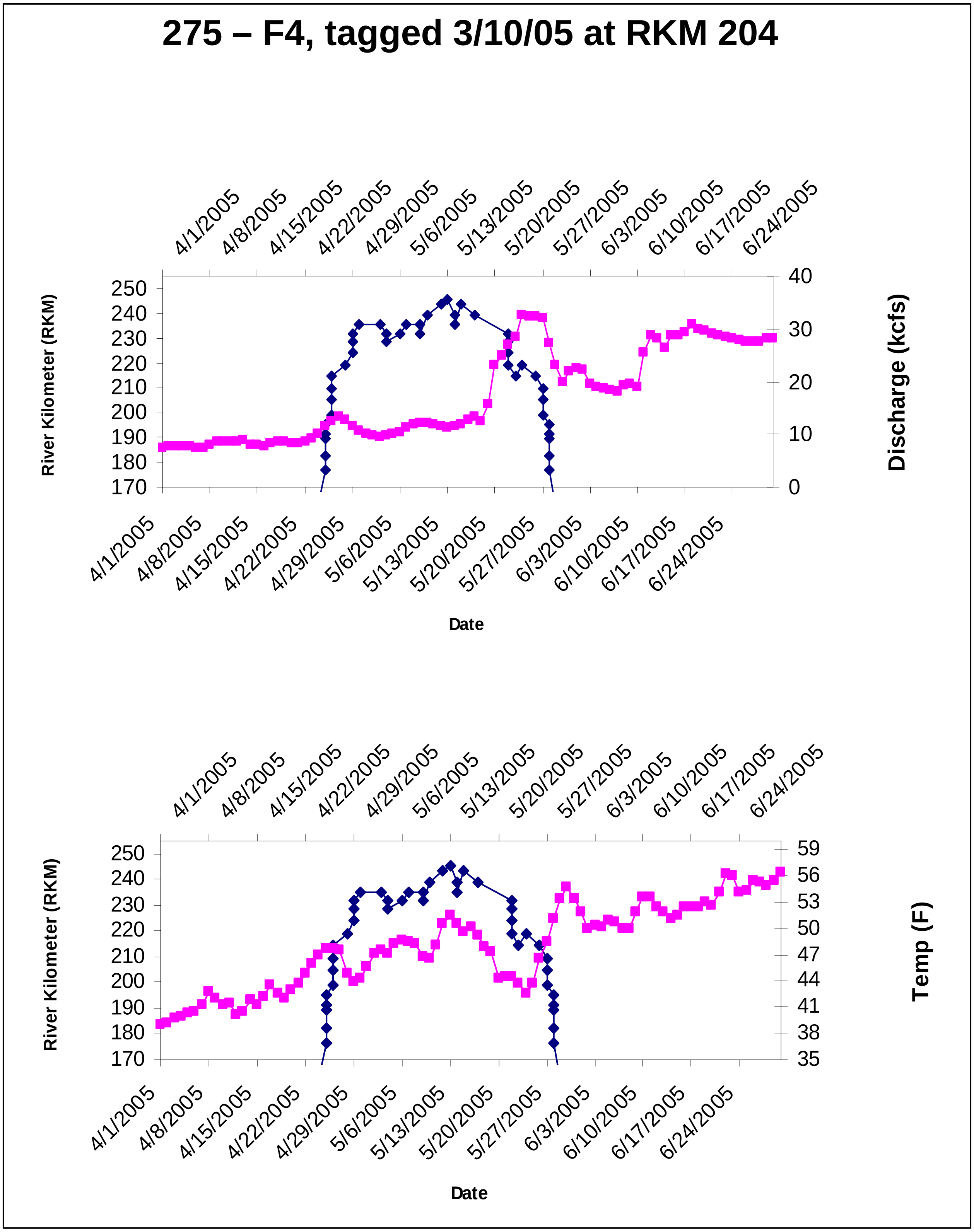

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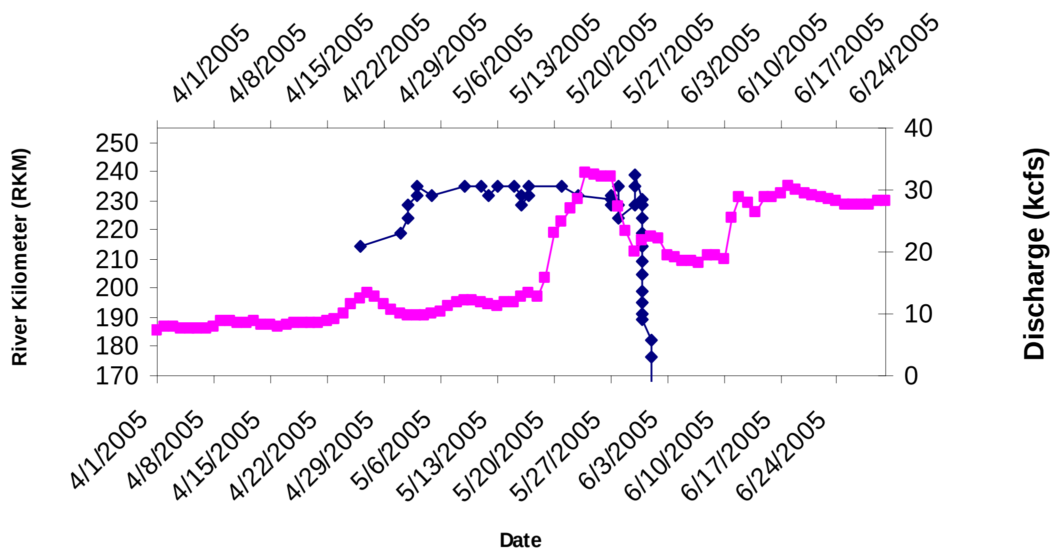
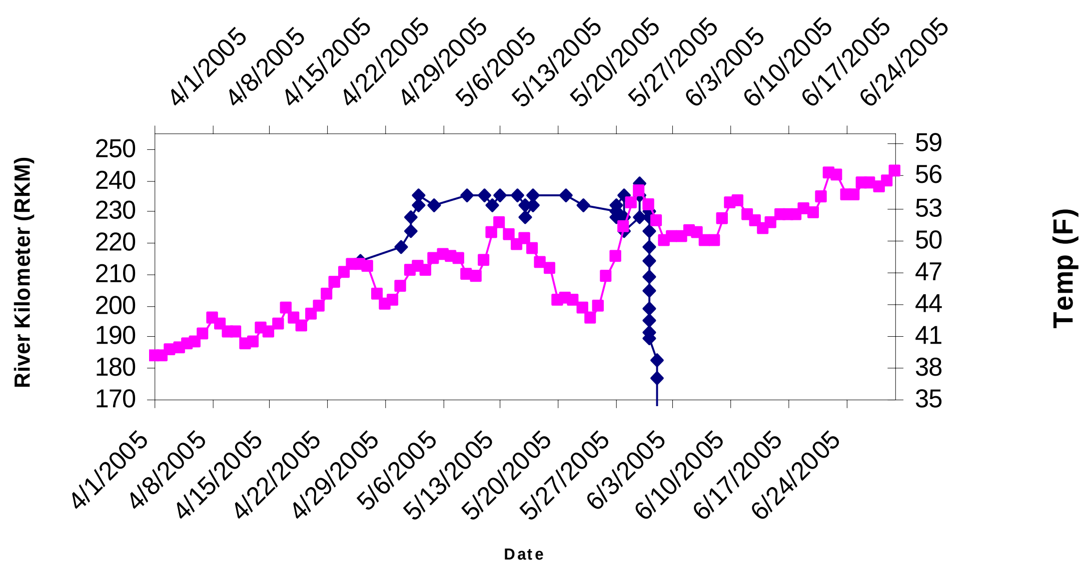
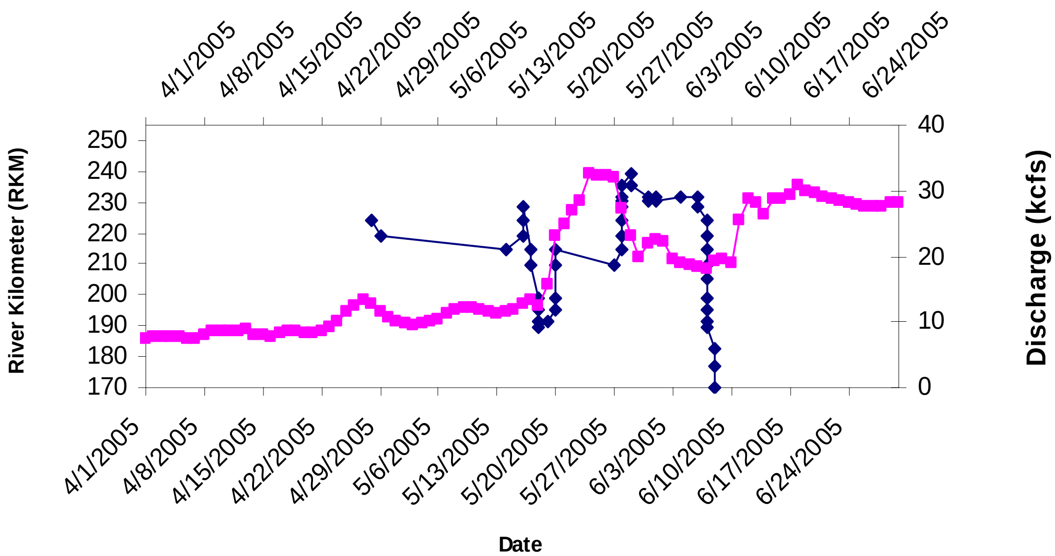
272 – F4, tagged 4/26/05 at RKM 215

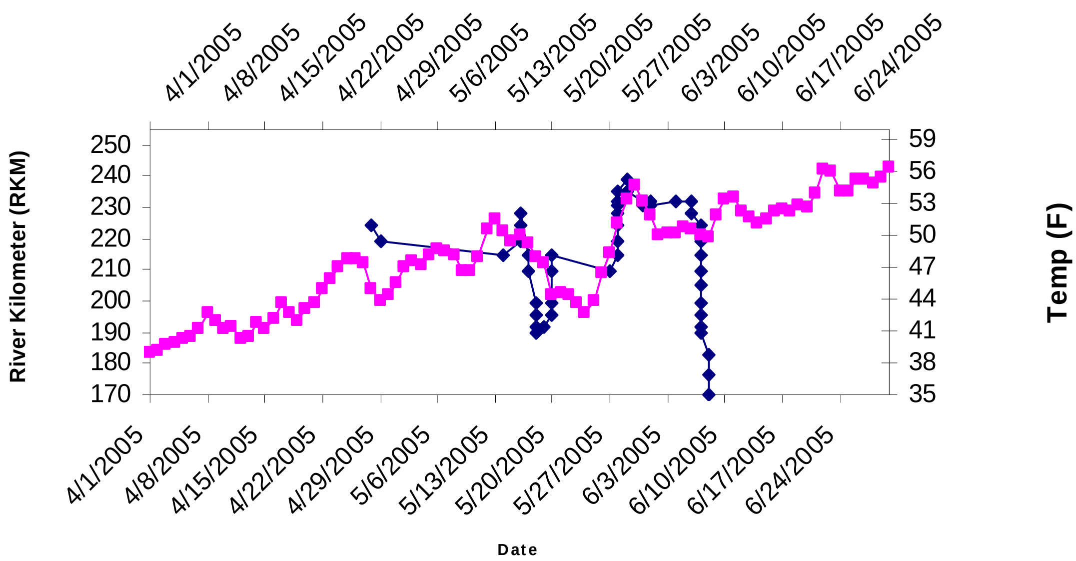




Appendix 1. Continued.

280 – F4, tagged 4/28/05 at RKM 226.5





Appendix 2. Numbers and recapture rates of hatchery produced white sturgeon juveniles (progeny of wild broodstock) released into the Kootenai River and Kootenay Lake in Idaho, Montana, and British Columbia between 1990 and 2005.

Year class	Hatchery facility[a]	Release number	Mean total length (mm) at release (SD)	Mean weight (g) at release (SD)	Release season and year	Percent (#) of all recaptures
1990	KTOI	14	456.9 (53.0)	320.8 (112.3)	Summer 1992	0.35%(10)
1991	KTOI	104	254.7 (17.3)	66.1 (13.1)	Summer 1992	3.92%(111)
1992	KTOI	123	482.6 (113.0)	549.3 (482.9)	Fall 1994	3.71%(105)
1995	KTOI	--	--	--	?[b]	1.27%(36)
1995	KTOI	1,075	228.5 (27.0)	47.3 (16.6)	Spring 1997	15.40%(436)
1995	KTOI	887	343.6 (43.8)	147.9 (64.0)	Fall 1997	14.58%(413)
1995	KTOI	96	410.7 (68.2)	288.5 (137.8)	Summer 1998	2.05%(58)
1995	KTOI	25	581.5 (40.5)	863.3 (197.9)	Summer 1999	0.46%(13)
1998	KTOI	309	260.1 (41.9)	79.0 (44.4)	Fall 1999	1.69%(48)
1999	KTOI	828	256.1 (22.2)	70.6 (18.2)		
1999	KH	1,358	248.1 (32.9)	67.2 (27.6)	Fall 2000	14.83%(420)
1999	—	—	—	—	Fall 2000	0.04%(1)
1999	KTOI	491	284.3 (54.4)	107.6 (60.1)		
1999	KH	1,583	306.5 (40.4)	55.9 (39.5)	Spring 2001	15.18%(430)
1999	—	—	—	—	?[b]	0.88%(25)
2000	KTOI	2,286	244.0 (38.9)	64.2 (31.0)		
2000	KH	1,654	240.0 (23.2)	57.7 (16.4)	Fall 2001	6.07%(172)
2000	KH	2,209	283.1 (28.7)	99.3 (30.2)	Spring 2002	0.07%(2)
2000	KH	30	365.4 (14.0)	195.3 (19.9)	Summer 2002	--(0)
2000	KTOI	214	409.4 (53.5)	294.1 (109.8)	Fall 2002	0.71%(20)
2000	KTOI	907[c]	334.2 (36.9)	192.9 (62.7)	Jan. 2003	2.15%(61)
2000	KTOI	11[d]	557.7 (28.4)	87.6 (18.4)	Feb. 2004	--(0)
2001	KTOI	2,672	200.1 (37.9)	33.0 (15.6)		
2001	KH	4,469	227.4 (24.2)	51.6 (16.6)	Fall 2002	1.80%(51)
2001	KH	1,715	257.1 (26.4)	71.8 (24.2)	April 2003	--(0)
2002	KH	5,864	217.3 (25.2)	41.3 (14.2)	May 2003	0.07%(2)
2002	KTOI	856	214.0 (43.8)	41.9 (22.6)	Oct. 2003	--(0)
2002	KTOI	~550[e]			Nov. 2003	NRD
2002	KTOI	3,852	215.4 (37.3)	43.4 (20.0)	Late wtr. 2003	0.07%(2)
2002	KTOI	3,663	214.2 (54.8)	43.1 (27.2)	Late wtr.'03-early wtr. '04	0.18%(5)
2003	KH	9,020	222.8 (25.7)	48.9 (24.4)	Spring 2004	8.79%(249)
2003	KH	23[f]	229.5 (26.7)	51.9 (18.5)	Sept. 2004	--(0)
2003	KTOI	3,519	226.9(46.3)	55.4(31.6)	Late wtr. 2004	0.04%(1)
2004	KTOI	3,000			Fall 2004	NRD
2004	KTOI	1,275			Late wtr.'04-early wtr. '05	NRD
2004	KTOI	17,723				
2004	KH	5,479	196.2(27.7) [g]	57.4(33.0)	Spring 2005	0.07%(2)
2004	KTOI	8,637			Summer 2005	NRD
?[h]	KTOI	—	—	—	—	0.07%(2)
?[h]	—	—	—	—	—	5.54%(157)
Total		**86,521**	—	—	—	**3.27%(2,832)**

[a] Hatchery facility refers to the rearing hatchery: Kootenai Tribal Hatchery in Idaho (KTOI) or Kootenay Hatchery in British Columbia (KH).
[b] Year class determined by scute removal; fish had shed PIT tag or PIT tag was not matched in database to determine stock year.
[c] Eleven fish held over for later upriver release with transmitters.
[d] These fish were released upriver (RKM 306.5) with sonic and radio tags.
[e] No measurements available; exact number not known; NRD (number recaptured cannot be determined).
[f] These fish were first taken to Kokanee Creek Provincial Park, then released in September 2004
[g] No total length was recorded for these fish. Value given is mean fork length (mm) on a subsample of 2,038 fish.
[h] These juvenile white sturgeon had no PIT tag; year class could not be determined by scute removals.

Appendix 3. Year class, number captured, capture locations, fork length (cm), total length (cm), and weight (kg) of hatchery released juvenile sturgeon captured with gill net from Kootenai River, Idaho, 2005.

Year class	Number captured	Capture RKM	Fork length (cm)	Total length (cm)	Weight (kg)
1990	1	120.0	76.5	88.0	3.00
	3	205.0	61.0-81.4	74.0-95.0	1.75-2.70
	2	215.4	55.4-66.2	66.2-78.1	1.86
	1	215.6	65.2	76.0	2.00
	1	215.7	69.0	82.0	2.25
	1	225.1	65.8	77.0	1.95
	1	Unknown	66.5	76.1	1.95
1991	3	119.0	73.0-85.0	85.5-98.0	1.10-4.50
	1	119.5	75.0	88.5	--
	4	120.0	63.0-102.5	73.5-118.5	1.60-6.65
	3	121.0	67.0-76.5	77.2-92.0	2.10-3.85
	1	190.0	70.0	83.0	2.20
	1	203.4	56.0	64.0	1.05
	4	203.5	52.0-72.0	61.0-83.0	0.95-2.70
	1	204.5	64.0	76.0	--
	1	204.7	60.0	68.8	1.36
	21	205.0	47.0-84.0	55.0-100.0	0.16-3.60
	1	205.4	51.0	60.0	1.10
	4	205.5	47.0-76.0	56.0-89.1	0.69-3.10
	5	215.0	40.0-53.0	47.0-62.0	0.14-0.70
	1	215.3	47.0	56.0	0.70
	1	215.4	64.2	75.4	2.15
	18	215.5	46.0-74.0	54.0-85.1	0.21-2.85
	8	215.6	41.0-57.0	48.0-66.2	0.43-1.80
	4	215.7	39.0-61.0	46.0-72.0	1.05-1.60
	3	216.0	44.0-53.0	51.0-61.0	0.50-0.88
	1	217.1	33.0	42.0	0.49
	1	224.6	48.0	58.0	0.65
	1	224.7	46.0	55.0	0.70
	2	224.9	42.0-73.5	50.0-84.8	0.45-2.80
	10	225.0	38.0-60.5	45.0-70.0	0.40-1.65
	3	225.1	39.0-49.6	46.0-58.0	0.40-0.78
	2	225.5	50.0-52.0	55.0-61.0	1.90-1.95
	1	227.0	36.0	43.0	0.52
1992	4	119.0	61.0-102.0	69.0-118.0	1.20-5.50
	1	120.0	70.5	80.5	2.20
	1	121.0	77.0	92.0	3.19
	1	134.0	77.1	90.5	2.95
	1	161.0	67.3	77.5	2.10
	1	174.3	56.0	62.0	1.06
	1	182.5	51.5	59.0	0.78
	1	190.3	61.2	71.0	1.53
	1	190.4	73.0	86.0	4.25
	1	203.4	74.0	85.0	5.20
	4	203.5	52.0-66.0	62.0-75.0	1.55-1.90
	1	204.0	59.0	69.5	1.50
	1	204.3	64.5	75.0	1.77
	1	204.7	65.8	75.6	1.60
	17	205.0	49.0-68.6	58.0-79.2	2.00
	1	205.3	50.0	90.0	1.80
	2	205.4	62.0-65.3	75.0-75.2	1.83
	6	205.5	49.0-69.0	57.0-79.1	0.20-3.50
	1	205.6	54.0	64.0	--

Appendix 3. Continued.

Year class	Number captured	Capture RKM	Fork length (cm)	Total length (cm)	Weight (kg)
	1	208.0	70.4	79.4	1.90
	1	210.5	66.3	75.6	1.80
	1	215.0	50.0	59.0	0.70
	2	215.1	59.0-67.90	67.5-81.0	1.11-2.10
	1	215.3	58.0	66.5	1.20
	11	215.5	50.2-72.5	57.9-83.5	0.11-2.13
	8	215.6	45.0-62.0	52.0-75.0	0.48-2.40
	6	215.7	42.0-66.0	49.0-77.0	1.05-2.30
	1	215.8	57.0	65.0	1.08
	1	215.9	63.0	75.0	1.35
1992	2	216.0	49.0-67.5	56.0-78.6	0.70-1.78
	2	217.1	30.0-36.0	35.0-44.0	0.35-0.51
	1	224.5	56.5	66.5	1.16
	2	224.9	50.0-69.5	61.0-80.5	1.30-1.68
	5	225.0	31.0-55.0	37.0-65.0	0.35-1.10
	4	225.1	47.0-62.0	56.0-73.0	0.60-1.30
	1	227.0	66.0	80.0	1.70
	1	227.4	59.1	62.0	1.00
	1	227.8	42.0	49.0	0.90
	1	229.0	46.0	55.0	0.55
	3	119.0	49.0-58.0	56.5-67.1	0.70-1.27
	11	120.0	56.5-86.9	65.5-99.0	0.83-3.90
	14	121.0	43.9-74.0	50.0-85.5	0.53-2.20
	2	123.0	65.2	70.1-76.0	1.30-1.90
	3	130.0	38.0-49.5	43.9-57.4	0.46-0.73
	2	134.0	49.0-61.3	57.0-70.5	0.73-1.28
	1	137.0	50.9	59.2	0.76
	1	141.0	53.8	60.4	0.83
	1	144.3	39.8	45.3	0.38
	2	144.5	29.0-45.5	33.5-52.0	0.14-0.56
	3	145.0	42.5-59.5	50.0-68.9	0.50-1.25
	1	157.0	54.1	62.6	0.99
	1	157.5	33.2	37.3	0.18
	2	161.0	45.6	51.8	0.44
	1	163.0	49.1	56.9	0.73
	2	174.5	26.3-52.4	30.2-60.7	0.09-0.77
	1	176.0	33.9	40.0	0.20
	4	176.3	24.7-49.3	40.0-58.1	0.15-0.68
	4	176.4	42.5-51.0	50.0-59.0	0.42-0.71
1995	2	176.5	39.3-44.1	46.2-53.0	0.33-0.48
	2	177.3	37.9-45.0	43.7-52.0	0.28-0.49
	1	184.9	44.2	51.0	0.31
	1	185.0	39.1	43.3	0.33
	1	189.9	51.5	59.5	0.74
	16	190.0	31.0-51.5	36.0-60.5	0.15-0.78
	4	190.1	36.8-54.0	43.9-63.5	0.28-0.87
	2	190.3	27.2-48.5	31.7-56.0	0.15-0.63
	1	190.4	43.0	50.5	0.47
	1	191.9	35.7	41.3	0.20
	1	192.0	34.7	38.2	0.18
	1	192.1	36.1	42.0	0.25
	3	195.7	35.5-50.0	42.0-57.0	0.24-0.65
	2	195.8	47.5-49.0	55.5-57.0	0.64-1.34
	1	195.9	43.0	50.5	0.42
	1	203.3	39.3	45.5	0.34
	2	203.4	33.2-37.0	38.5-42.9	0.25-0.36
	7	203.5	36.5-49.8	42.5-57.5	0.28-0.60
	3	204.0	37.9-47.5	43.5-54.0	0.27-0.72

Appendix 3. Continued.

Year class	Number captured	Capture RKM	Fork length (cm)	Total length (cm)	Weight (kg)
	1	204.1	39.0	45.0	0.35
	1	204.3	44.0	51.0	0.35
	3	204.7	43.0-54.3	49.8-63.6	0.43-1.00
	4	204.8	46.5-50.3	53.8-58.4	0.54-0.67
	6	204.9	41.9-48.0	48.3-55.2	0.40-0.62
	155	205.0	30.8-69.1	35.0-81.1	0.13-2.30
	3	205.3	38.0-50.0	44.0-51.0	0.30-0.76
	10	205.4	36.0-50.5	42.2-58.5	0.28-0.78
	33	205.5	26.0-62.1	31.0-71.8	0.08-1.50
	2	213.2	51.4-58.1	60.2-67.0	0.85-1.17
1995	1	213.5	58.6	67.6	1.13
	28	215.0	33.1-67.3	37.8-77.6	0.10-0.18
	9	215.1	36.1-49.5	41.1-58.2	0.25-0.69
	6	215.2	25.0-47.0	30.0-55.5	0.05-0.55
	23	215.4	31.2-49.0	36.5-56.4	0.20-0.75
	149	215.5	25.5-64.8	29.1-74.0	0.06-1.32
	41	215.6	30.0-48.9	34.2-56.8	0.13-0.60
	61	215.7	25.0-54.8	29.0-63.8	0.05-0.93
	9	215.8	25.0-50.2	30.0-58.4	0.08-0.68
	2	216.0	40.5-45.6	47.3-52.5	0.39-0.53
	4	219.0	22.0-58.4	25.3-67.4	0.10-1.18
	2	219.8	28.7-33.5	33.5-39.0	0.13-0.25
	1	220.0	32.5	38.0	0.24
	4	222.0	25.9-30.5	30.0-35.0	0.20-0.30
	1	222.7	33.0	38.2	0.20
	1	224.0	61.2	70.9	1.32
	1	224.5	39.0	45.4	0.34
	2	224.6	29.4-35.0	33.0-42.0	0.15-0.19
	12	224.7	31.4-50.9	36.0-58.7	0.18-0.95
	15	224.8	31.9-48.0	36.2-59.3	0.18-0.65
	24	224.9	30.4-64.0	34.2-74.0	0.15-1.70
	99	225.0	21.0-62.0	24.0-71.8	0.05-1.45
	33	225.1	28.0-55.4	32.0-64.2	0.09-1.20
	2	225.2	24.0-27.0	28.0-32.0	0.05
	1	225.4	37.1	43.0	0.20
	1	226.1	45.3	52.3	0.53
	5	227.0	29.5-51.0	33.5-61.0	0.10-1.00
	3	227.2	33.0-35.0	38.0-40.5	0.20
	6	227.3	30.0-34.5	34.5-39.0	0.10-0.20
	11	227.4	22.7-41.4	33.0-48.6	0.10-0.45
	2	227.8	48.3-51.5	54.8-60.2	0.65-0.78
	1	229.7	46.3	53.5	0.55
	2	229.8	39.9-42.3	46.6-50.1	0.35-0.38
	1	230.5	51.5	60.3	0.75
	2	230.8	29.0-36.3	35.0-41.3	0.13-0.25
	3	230.9	27.9-47.5	32.3-55.0	0.13-0.68
	1	234.3	33.2	37.0	--
	2	234.4	25.0-37.0	29.0-42.0	0.09-0.20
	5	234.5	224.0-52.0	27.0-60.2	0.06-0.83
	1	244.0	56.8	66.2	0.98
	1	244.4	33.8	43.4	--
	1	244.5	48.2	56.6	0.65
	1	244.6	31.5	36.6	0.13
	6	Unknown	45.5-55.5	52.2-65.3	0.56-1.13

Appendix 3. Continued.

Year class	Number captured	Capture RKM	Fork length (cm)	Total length (cm)	Weight (kg)
	1	204.0	38.4	44.4	0.28
	9	205.0	30.0-41.5	35.0-47.5	0.13-0.42
	1	213.2	35.5	41.5	0.24
	3	215.0	43.5-50.8	52.0-57.2	0.51-0.53
	6	215.5	22.6-46.6	26.7-52.5	0.08-0.34
	1	215.7	33.2	38.7	0.20
	1	224.0	32.5	38.7	0.20
	1	224.8	36.0	41.7	0.30
	6	224.9	30.0-51.0	35.1-60.2	0.12-0.83
1998	6	225.0	27.0-38.5	31.6-44.6	0.06-0.36
	2	225.1	27.7-27.8	32.0-32.4	0.10-0.14
	1	226.1	36.1	41.8	0.28
	1	227.4	25.7	30.5	0.07
	1	227.8	28.4	33.1	0.13
	2	229.8	22.5-25.6	26.4-30.2	0.06-0.10
	1	230.0	54.0	63.7	1.1
	2	230.9	23.5-25.0	28.0-29.5	0.07-0.08
	1	244.5	40.7	47.4	0.35
	1	Unknown	32.0	40.5	0.23
	2	119.0	—	39.0-45.2	0.24-0.38
	35	120.0	33.5-55.5	39.5-64.3	0.24-1.05
	31	121.0	29.5-65.0	34.0-75.5	0.17-1.95
	9	123.0	32.1-51.0	37.5-59.0	0.22-0.95
	9	130.0	27.6-41.1	31.8-48.4	0.12-0.40
	9	134.0	31.3-40.5	36.5-47.0	0.17-0.38
	3	137.0	28.3-45.0	33.4-57.0	0.14-.70
	8	145.0	26.5-46.0	31.1-53.1	0.11-0.55
	3	150.0	37.5-41.5	43.6-48.2	0.35-0.45
	5	157.0	31.2-35.0	36.9-40.0	0.19-0.27
	12	161.0	27.4-38.7	31.9-45.0	0.13-0.37
	2	163.0	29.0	33.7	0.15
	6	165.0	27.2-36.5	31.0-42.6	0.14-0.25
	2	167.0	32.1-32.7	37.1-38.1	0.16-0.20
	30	174.5	24.1-33.4	28.3-38.9	0.04-0.20
	1	176.1	35.7	42.4	0.25
	1	176.4	26.5	30.5	0.10
	2	176.5	24.5-29.0	28.5-33.6	0.07-0.14
	1	176.9	31.3	36.3	0.17
1999	5	182.0	30.1-38.5	35.6-44.5	0.15-0.29
	1	189.9	29.0	34.0	0.13
	33	190.0	23.0-42.3	26.5-49.0	0.06-0.46
	2	190.1	27.0-29.0	31.0-33.0	0.10-0.14
	2	190.2	23.5-31.0	28.0-36.0	0.07-0.15
	8	190.3	27.0-41.5	31.1-49.1	0.10-0.36
	5	190.4	27.0-36.0	31.0-41.5	0.10-0.20
	5	192.0	28.5-35.5	33.0-41.4	0.15-0.24
	4	195.7	22.3-32.0	25.9-37.0	0.08-0.20
	12	195.8	24.5-36.0	28.6-42.0	0.07-0.31
	14	195.9	22.5-33.5	26.5-39.2	0.04-0.68
	6	196.0	25.5-33.5	30.0-38.5	0.05-0.23
	1	203.5	27.5	32.1	0.12
	1	204.0	30.5	35.6	0.15
	3	204.7	26.3-31.7	29.8-38.0	0.11-0.21
	1	204.8	29.0	34.0	0.12
	4	204.9	27.6-32.4	32.0-37.9	0.11-0.19
	206	205.0	19.5-45.8	28.5-53.2	0.05-0.57
	1	205.3	28.0	32.0	0.10
	1	205.4	24.0	29.3	0.05

Appendix 3. Continued.

Year class	Number captured	Capture RKM	Fork length (cm)	Total length (cm)	Weight (kg)
1999	48	205.5	25.6-44.0	29.1-49.7	0.11-0.50
	12	207.0	34.4-45.5	40.1-53.0	--
	7	208.0	27.1-35.1	31.4-41.5	0.12-0.23
	4	213.2	29.6-40.6	33.6-47.3	0.15-0.35
	1	213.5	31.0	36.1	0.18
	48	215.0	34.5-51.1	39.6-59.6	0.23-0.77
	82	215.5	25.5-28.5	30.0-33.5	0.10-0.14
	1	216.0	28.9	33.6	0.11
	1	219.5	36.0	41.2	0.30
	6	224.7	22.6-30.0	24.9-34.9	0.05-0.15
	8	224.8	25.0-27.4	28.5-32.2	0.08-0.12
	14	224.9	26.9-43.5	30.9-50.7	0.10-0.67
	28	225.0	23.2-42.2	26.1-48.6	0.07-0.55
	1	225.1	26.5	30.7	0.12
	3	230.0	27.0-44.0	32.0-51.2	0.10-0.47
	4	230.9	25.0-27.5	29.0-32.0	0.10-0.14
	2	231.0	25.5-285	30.0-33.5	0.10-0.14
	1	244.0	42.3	49.3	0.47
	3	244.5	27.5-33.1	30.5-37.7	0.11-0.20
	92	Unknown	19.0-39.0	22.0-44.2	0.05-0.32
2000	1	76.0	25.6	31.0	0.11
	12	120.0	26.3-48.5	30.9-56.5	0.12-0.57
	11	121.0	26.4-51.1	30.4-56.8	0.12-0.75
	7	130.0	25.1-35.0	29.3-39.5	0.09-0.28
	1	134.0	42.5	49.2	0.48
	1	137.0	28.2	32.6	0.11
	2	141.0	30.8-31.4	34.8-36.1	0.14
	3	145.0	31.1-39.7	33.2-45.7	0.15-0.38
	2	150.0	29.3-33.5	34.0-39.0	0.19-0.21
	4	157.0	23.5-27.8	27.0-31.9	0.09-0.11
	7	161.0	21.8-33.4	24.5-39.0	0.07-0.24
	3	163.0	25.5-29.0	29.6-33.5	0.13-0.14
	9	165.0	26.0-31.0	29.7-35.6	0.09-0.17
	3	167.0	27.2-35.5	31.4-41.5	0.10-0.26
	2	182.0	29.2-29.4	33.5-34.7	0.13-0.15
	1	190.0	26.1	30.6	0.09
	2	190.3	25.5-29.0	30.9-33.6	0.09-0.14
	2	192.0	30.0	35.0	0.14-0.16
	5	195.8	26.5-34.2	32.3-40.2	0.11-0.27
	59	205.0	21.0-43.1	26.2-50.0	0.05-0.54
	25	205.5	24.1-42.7	28.0-49.2	0.08-0.42
	1	207.0	33.6	38.5	--
	2	208.0	25.6-32.0	30.0-37.5	0.10-0.19
	1	210.0	34.2	40.4	0.25
	10	213.2	26.0-35.3	30.2-41.1	0.10-0.29
	4	213.5	28.0-32.5	32.0-38.6	0.12-0.19
	12	215.0	30.2-42.8	33.8-50.4	0.14-0.44
	24	215.5	25.1-37.7	27.3-44.0	0.09-0.30
	1	219.0	38.7	45.4	0.37
	6	224.0	29.6-38.0	34.3-44.0	0.15-0.31
	9	224.9	32.2-39.0	37.7-45.5	0.23-0.44
	16	225.0	26.1-41.8	30.5-48.5	0.09-0.40
	1	227.8	24.3	27.8	0.09
	1	230.5	32.9	37.5	0.21

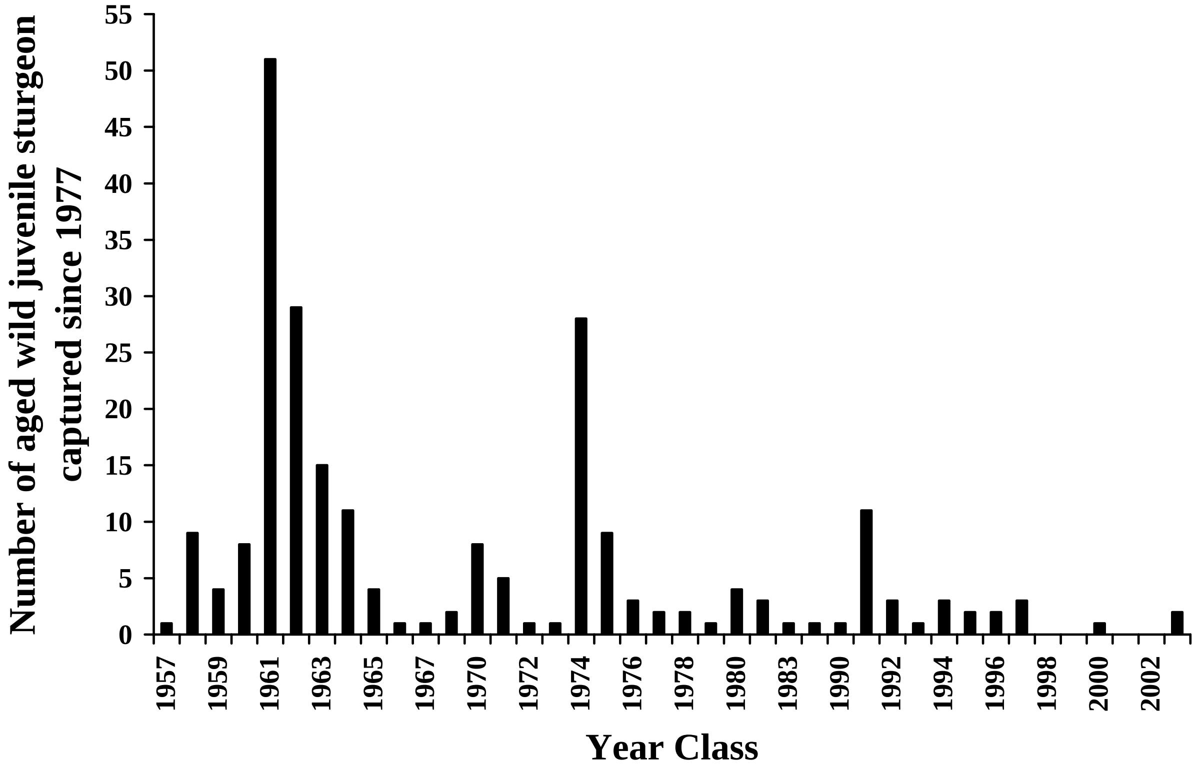
Appendix 3. Continued.

Year class	Number captured	Capture RKM	Fork length (cm)	Total length (cm)	Weight (kg)
2001	1	161.0	18.9	21.9	0.04
	2	195.8	21.9	25.2	0.06
	8	205.0	25.0-35.8	28.2-41.2	0.08-0.24
	3	205.5	23.6-29.1	27.2-33.7	0.08-0.13
	1	207.0	35.3	41.3	--
	1	213.2	23.0	26.5	0.07
	1	213.5	24.5	28.9	0.09
	12	215.0	28.9-35.1	30.9-41.7	0.14-0.26
	7	215.5	21.2-29.3	24.4-33.8	0.05-0.15
	2	224.0	22.9-26.1	26.6-30.4	0.07-0.09
	3	224.9	22.3-29.0	25.8-33.2	0.06-0.20
	8	225.0	18.2-29.6	20.6-34.5	0.04-0.17
	1	228.5	22.7	26.6	0.06
2002	2	120.0	26.0-35.5	30.1-40.9	0.10-0.26
	1	123.0	26.0	30.1	0.08
	1	161.0	24.2	27.8	0.07
	1	163.0	19.0	22.2	0.03
	1	167.0	21.0	24.0	0.05
	1	205.0	27.5	31.6	0.11
	2	205.5	27.7	31.4	0.10-0.13
2003	2	120.0	30.0-39.0	35.0-45.2	0.16-0.45
	5	121.0	21.0-30.5	24.8-33.0	0.08
	3	123.0	22.5-26.3	26.1-30.7	0.06-0.09
	7	130.0	20.2-29.4	23.4-34.2	0.04-0.13
	23	134.0	19.5-27.8	23.0-32.4	0.05-0.12
	12	137.0	21.3-25.0	24.6-29.5	0.04-0.09
	8	141.0	20.0-32.1	23.1-36.9	0.06-0.17
	52	145.0	19.0-28.5	22.1-33.4	0.04-0.11
	30	150.0	17.8-26.4	20.8-31.0	0.03-0.10
	3	157.0	20.6-23.0	24.1-26.5	0.07-0.08
	47	161.0	19.5-28.0	22.8-32.8	0.04-0.12
	12	163.0	20.9-27.8	23.8-32.1	0.04-0.11
	15	165.0	20.7-33.5	24.0-40.0	0.05-0.24
	4	167.0	22.5-27.8	22.5-30.0	0.07-0.11
	1	190.0	28.0	32.7	0.13
	2	192.0	25.8-27.2	30.0-31.7	0.09-0.11
	10	205.0	26.9-38.5	30.5-45.2	0.11-0.34
	12	215.0	22.5-34.0	26.5-39.8	0.07-0.20
	1	225.0	25.8	29.7	0.11
	1	230.0	31.2	36.8	0.18
2004	2	244.0	23.5-24.7	27.2-28.6	0.07-0.08
Unknown year class	5	120.0	29.1-45.5	33.9-52.5	0.16-0.58
	8	121.0	33.4-76.0	39.6-91.0	0.22-3.25
	2	123.0	26.2-36.4	31.3-42.4	0.09-0.28
	5	130.0	22.0-40.0	25.7-46.1	0.07-0.35
	2	134.0	24.0-70.5	27.9-81.3	0.09-2.40
	1	137.0	26.4	30.6	0.10
	1	141.0	21.5	25.0	0.05
	13	145.0	20.8-38.3	24.1-44.7	0.04-0.30
	2	150.0	17.8-30.1	21.0-34.9	0.04-0.19
	1	157.0	25.5	30.5	0.08
	12	161.0	22.1-31.8	25.9-36.5	0.07-0.18
	3	163.0	18.5-25.6	21.0-29.6	0.03-0.07
	3	165.0	22.2-23.6	26.1-27.3	0.05-0.07

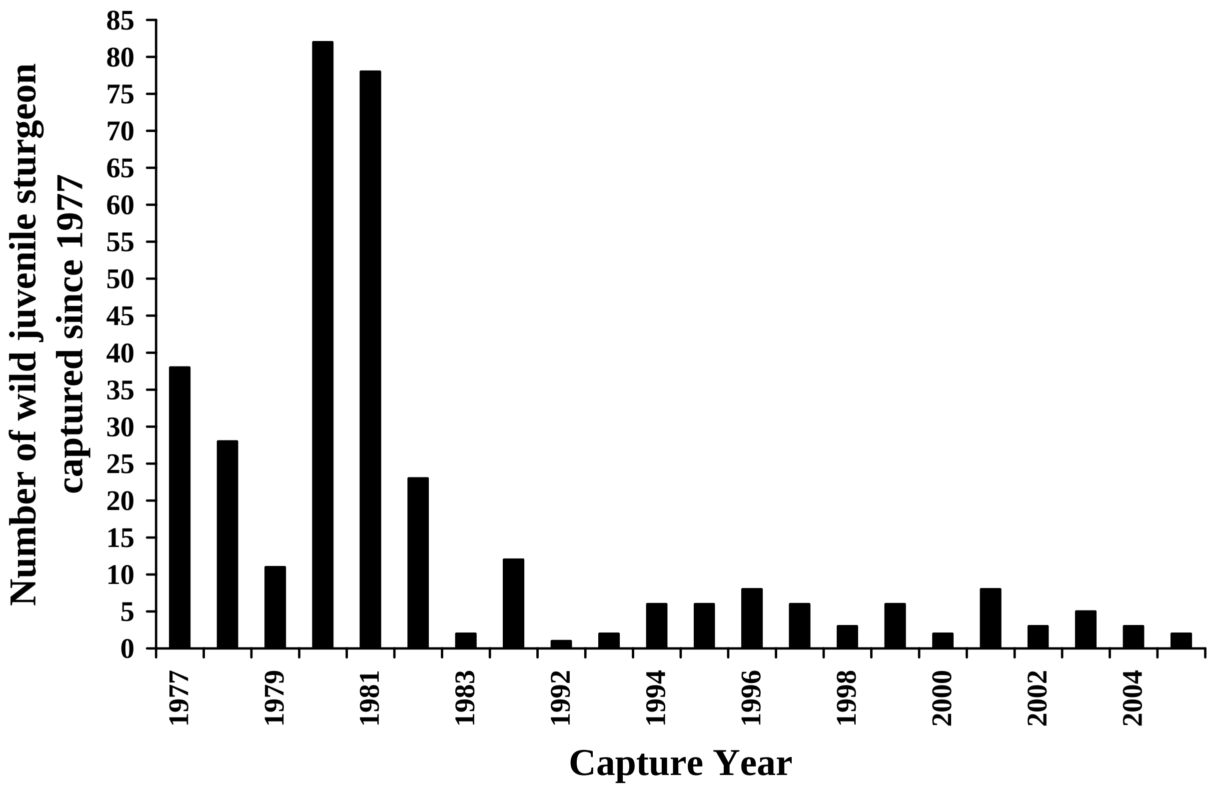
Appendix 3. Continued.

Year class	Number captured	Capture RKM	Fork length (cm)	Total length (cm)	Weight (kg)
Unknown year class	4	167.0	14.9-29.2	17.1-33.7	0.02-0.15
	2	190.0	29.6-32.5	34.1-37.2	0.20
	1	192.0	33.0	38.8	0.20
	1	195.8	34.2	38.0	0.20
	1	204.8	35.4	41.2	0.26
	1	204.9	35.2	41.2	0.20
	33	205.0	15.4-74.0	17.2-87.0	0.01-2.80
	8	205.5	27.7-51.5	31.7-60.0	0.13-0.88
	5	207.0	26.8-56.3	31.8-65.1	0.07
	1	213.5	37.7	43.2	0.28
	10	215.0	26.4-60.9	30.4-70.8	0.09-1.44
	1	215.4	61.0	72.0	1.10
	10	215.5	21.8-51.0	24.7-58.3	0.07-0.90
	2	219.5	30.9-33.0	35.5-36.7	0.20-0.23
	1	224.8	50.1	57.9	0.76
	3	224.9	30.0-36.1	34.6-40.7	0.13-0.26
	8	225.0	23.1-59.8	26.7-69.0	0.07-1.22
	1	225.1	53.5	61.5	1.05
	1	230.0	30.0	35.0	0.13
	3	244.0	21.5-24.6	25.3-28.7	0.06-0.09
	4	Unknown	24.0-32.2	27.2-38.0	0.08-0.18

Appendix 4. Number of aged wild juvenile white sturgeon captured by year class in the Kootenai River, Idaho, since 1977.



Appendix 5. Number of wild juvenile white sturgeon captured in the Kootenai River, Idaho, since1977.



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