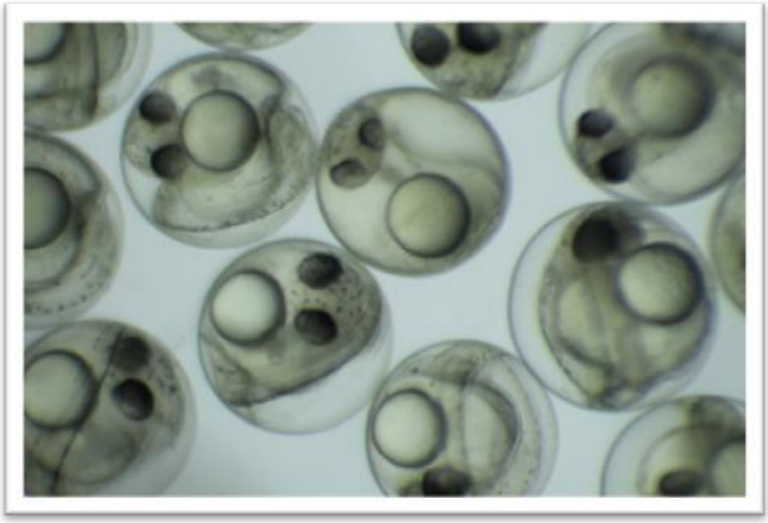
FISHERY RESEARCH

KOOTENAI RIVER RESIDENT FISH MITIGATION: WHITE STURGEON, BURBOT, NATIVE SALMONID MONITORING AND EVALUATION

Annual Progress Report
May 1, 2013 — April 31, 2014



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CHAPTER 1.1: WHITE STURGEON MONITORING AND EVALUATION
AUTHORS: PETE RUST AND VIRGINIA WAKKINEN

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 flow augmentation supplied by the U.S. Army Corps of Engineers. Between March 5 and November 4, Idaho Department of Fish and Game and British Columbia Ministry of Forests, Lands and Natural Resource Operations crews expended more than 7,539 h to capture 40 adult White Sturgeon by angling and 115 adult White Sturgeon by setlining. Catch rates were 0.34 fish per rod h for angling and 0.016 fish per setline h. One hundred twenty (78%) of the 157 adult White Sturgeon collected were recaptures from previous years. Thirteen adult White Sturgeon were newly tagged with Vemco sonic transmitters in spring and seven were tagged in fall. Thirty-nine sonic tagged adult White Sturgeon (33 females) were in spawning condition and exhibited a spawning migration in 2013. Thirty-seven (95%) of these tagged adults moved upstream as far as Deep Creek (rkm 235.0). Thirty-one (79%) of the migrating adults were recorded at rkm 240.7, just downstream of Deep Creek, and 18 (46%) of the migrating adults went upstream as far as rkm 244.5 (Ambush Rock). Additionally, at least 11 (28%, 8 females) of the tagged migrating adult sturgeon went upstream of the Hwy. 95 Bridge in Bonners Ferry into the braided reach in 2013. We deployed substrate mats to evaluate the temporal and spatial extent of White Sturgeon spawning events in the Kootenai River. We sampled 62,546 mat hrs between May 13 and July 15 and collected 503 eggs. The highest catch and the highest catch rate came from the Shorty's Island area (rkm 231.0), although most of the effort was in Myrtle Creek area (rkm 236.0). Based on 407 viable eggs, we estimate that White Sturgeon spawned at least 15 days in 2013 between June 11 and July 14. IDFG and BCMFLNRO sampled 25 sites between rkm 18.0 and 244.5 and collected 1419 juvenile sturgeon (1409 hatchery-reared, 99%) with 519 h of effort. The highest catch came from the Kootenay Lake delta (rkm 120.0) but catch was well distributed throughout the river. Ten wild juvenile White Sturgeon were captured while gill netting in Canada and Idaho in 2013. The TL of these five individuals ranged from 48.3 to 123.0 cm, and weights ranged from 0.45 to 6.0 kg. Four year classes (2002, 2003, 2006, and 2007) were represented in the 2013 sample.

INTRODUCTION

The Kootenai River White Sturgeon *Acipenser transmontanus* population is comprised mainly of old adults and significant recruitment has not occurred since the 1970s. Although the specific causes of recruitment failure remain unclear, years of study suggest that mortality occurs between egg and larval stages. Over a decade of artificial substrate mat sampling has indicated that from nine to 20 spawning events occur annually, and many viable embryos are produced (Paragamian et al. 2002). 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 only one larvae and relatively few wild juveniles have been collected despite years of intensive sampling. 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 (Kock et al. 2006). Hatchery-reared juveniles (as young as nine months of age at release) have average annual growth rates of 6.4 cm per year, and second year survival rates exceed 90% (Ireland et al. 2002). Growth and survival of hatchery juveniles released at a minimum of age-one further suggest that mortality occurs at the egg, embryonic, or larval stage. In an effort to improve spawning conditions for Kootenai River White Sturgeon (hereafter White Sturgeon) embryos and larvae, Libby Dam has been operated to provide increased spring discharge (>630 m^3/s or 22,248 ft^3/s for 42 d at Bonners Ferry) since 1991 when water supplies are suitable.

GOAL

To recover the Kootenai River White Sturgeon population to a level that is self-sustaining and can provide sportfishing opportunity to the public.

OBJECTIVE

To have suitable spawning, rearing, and incubation habitat for White Sturgeon for successful wild recruitment. The main task of this program is to monitor the response of all life stages of White Sturgeon to flow augmentation from Libby Dam provided by the U.S. Army Corps of Engineers (Corps).

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 1.1.1). Kootenai Falls, 42 rkm downstream of Libby Dam, may be an impassable barrier to 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 (average gradient 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 and temperatures of the river (Partridge 1983). Spring flows were reduced to about one third of pre-dam levels, and flows during winter are now three to four times higher than under the natural flow regime (Figure 1.1.2). Post-dam water temperatures are now cooler in summer and warmer in winter.

METHODS

Water Levels, Discharge, and River Temperature

Based on the United States Fish and Wildlife Service's (USFWS) February 2006 Biological Opinion (USFWS 2006) on operations of Libby Dam, and the volume runoff forecasts for 2013, the USFWS in cooperation with members of the Kootenai River White Sturgeon Recovery Team (KRWSRT) submitted System Operations Requests (SOR) FWS#2013-1 to the Corps' regional multiagency/entity Technical Management Team (TMT). The team determined the specific shape, timing, and volume of sturgeon augmentation flow from Libby Dam during the sturgeon spawning seasons. Specific details, justifications, and biological opinion success criteria are listed at FWS#2013-1 http://www.nwd-wc.usace.army.mil/tmt/sor/2013/2013_Libby_sturgeon_SOR.pdf.

The intent of these operation requests was to maintain higher, more stable summer discharges provided to the extent possible with the available water to meet White Sturgeon and Bull Trout ESA responsibilities (USFWS 2006) and to attempt to mimic a more natural river hydrograph (under VarQ regime). The intent was also to provide spawning and incubation flows to meet attributes for water depth, water velocity, and water temperature in the Kootenai River as defined in the 2006 Biological Opinion RPA for Kootenai River White Sturgeon (USFWS 2006) and improve conditions for spawning sturgeon to migrate upstream of Bonners Ferry into the braided reach (above rkm 246). We obtained Kootenai River stage, discharge, and water temperature data at Bonners Ferry from the Corps (Figure 1.1.3).

The 2013 April to July Kootenai River (MT) stream flow forecast, which includes the White Sturgeon spawning season, was 96% of average. Snow water equivalents in April 2013 were average. For the Kootenai Basin in Montana, discharges were expected to be near normal for 2013 http://www.nrcs.usda.gov/wps/portal/nrcs/detail/mt/newsroom/releases/?cid=NRCS144P2_057961.

White Sturgeon Sampling

Adult White Sturgeon were collected by angling and setlines from March through November 2013 following the methods of Paragamian et al. (1996). From March through April, most of the sampling occurred in the staging areas between rkm 200 and 215. These areas are backwater habitats and have depths in excess of 20 m and low current velocities (<0.05 m/s). Later in the spring, areas closer to the spawning locations (near rkm 229) were sampled more frequently. Fall sampling occurred near the Kootenai River delta at rkm 120 in 2013. We biopsied adult sturgeon to determine sex and level of maturity following the methods of Conte et al. (1988) and Van Eenennaam and Doroshov (1988). Male and female White Sturgeon expected to spawn each spring were tagged with Vemco model V16 sonic transmitters and released (see telemetry section). Working in cooperation with the Kootenai Tribe of Idaho (KTOI), some gravid female White Sturgeon expected to spawn during spring 2013 were

transported to the KTOI 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. White Sturgeon sperm is viable for only 48 hours after extraction, so male gametes were only collected when a female was in the hatchery and had been induced to ovulate.

Adult White Sturgeon Telemetry

Monitoring daily and seasonal spawning movements of White Sturgeon throughout the Kootenai River/Kootenay Lake system using passive telemetry continued to be a high priority of this investigation. Beginning in 2003 and continuing to the present, we maintain an array of Vemco model VR2 and VR2W sonic receivers located from rkm 18.0, near the mouth of the Lardeau River in Kootenay Lake, BC, upstream to rkm 285.5, near the Yaak River in Montana (Figure 1.1.4). Receivers were located in areas where fish pass through but do not usually hold for long periods to avoid redundant data collection. Most sites were below river bends or along straight reaches that allow for good signal reception but were reasonably free of drifting debris and at low risk of potential vandalism. Each receiver was tethered to a float to keep the hydrophone off the substrate, anchored to a cement block, and chained to the riverbank. Receivers were downloaded in late winter, during the spawning season, and in the fall. Data from receivers were stored in the .vrl files in VUE (Vemco) and imported into a Microsoft® Access™ database for analysis. This array allows continuous monitoring of sturgeon movements within the Kootenai river system and into Kootenay Lake.

Artificial Substrate Mat Sampling

Artificial substrate mats were used to document White Sturgeon spawning in the Kootenai River (McCabe and Beckman 1990). The main purpose of this monitoring was to evaluate temporal and spatial distribution of spawning events in the Kootenai River. Mats were deployed in four general areas based on previous years of known spawning locations and were checked two or three times per week. All eggs were removed from mats each day and when eggs were found, a new mat was deployed in the same location to remove any doubts if eggs captured the next day were new or missed from the previous day. Eggs were stored in formalin and brought back to the laboratory at the field station for analysis. All eggs were staged by viewing at 120X magnification under a dissecting microscope to estimate spawn date by the methods described by Beer (1981).

Juvenile White Sturgeon Sampling

We used weighted multifilament gill net with 2.5, 5.1, and 7.6 cm stretch mesh to sample juvenile and young-of-the-year (YOY) sturgeon. The purpose of this sampling was to evaluate natural recruitment, growth, and mortality rates of marked hatchery juveniles, as well as distribution and densities of both hatchery and wild juveniles. Sampling was conducted from July 17 through October 13, 2013 following the methodology of Paragamian et al. (1996). Gill nets were set during the daytime and checked every hour to reduce mortality and all sturgeon were released alive.

From 1992 to 2004, prior to release, each hatchery reared sturgeon received a passive integrated transponder (PIT) tag and a pattern of scutes were removed at the KTOI hatchery or at the Kootenay Trout and Sturgeon Hatchery located in Ft. Steele, BC, and operated by the Freshwater Fishery Society of BC as the backup facility for the KTOI. Most (92%) of the released juvenile White Sturgeon were not PIT tagged from 2005 through 2007, although scutes

were removed from each fish prior to release. Most hatchery reared juvenile sturgeon released in the Kootenai River after 2007 were PIT tagged and all had scutes removed. PIT tagging fish prior to release provides a unique identifier for each fish and allows tracking of the size at release, rearing facility, release location, and time of release. Scute removal patterns only identify brood year and rearing location, and there can be subjective errors with applying and recording scute patterns. Fork (FL) and total length (TL), weight, PIT tag numbers, fish condition, and scute removal patterns (to determine release date and location of hatchery fish) were recorded for each sampled sturgeon. Pectoral fin ray sections were removed from all wild juvenile White Sturgeon for age estimation. Each wild sturgeon received a PIT tag and the second left scute was removed for future identification. BC Ministry of Forests, Lands and Natural Resource Operations (BCMFLNRO) crews sampled 12 different sites from Kootenay Lake, BC upriver to rkm 165.0 and followed methods outlined above.

Mean length at time of capture (MLTOC) was analyzed for three-, four-, and five-year-old juvenile sturgeon from catch data from 1991 to 2013 using single factor ANOVA. Growth was compared among capture years for these three age classes from the Kootenai River/Lake system as a whole, in the Kootenai River above rkm 123, and the Kootenay Lake delta. Tukey's multiple comparisons test was used to determine which years differed and their level of significance. Students t-test was used to compare MLTOC during the same capture year for fish captured in the Kootenai River (above rkm 123) compared to delta captured fish.

RESULTS

Water Levels, Discharge, and River Temperature

On June 23, 2013, Koocanusa Reservoir inflow peaked at 2,523 m^3/s (89,100 ft^3/s) and the reservoir filled to elevation 749 m (2,457.7 feet) by July 6. Average daily Libby Dam outflow peaked July 7 at 1,019 m^3/s (36,000 ft^3/s). Flows remained above 425 m^3/s (15,000 ft^3/s) until July 23, and did not drop below 227 m^3/s (8,000 ft^3/s) until early September.

Water temperatures measured at Bonners Ferry in 2012 were cooler than normal due to the high volume of water released from Koocanusa Reservoir, and from the cool wet spring and early summer air temperatures. Water temperatures remained below 6°C until early May and remained cool through the spawning period. Mid-summer water temperatures also were cool, and temperatures did not exceed 12°C until late July (Figure 1.1.3). The maximum river water temperature in 2012 of 15.5°C did not occur until September 9, and water temperatures remained near 13°C through early fall before rapid cooling late in October.

Adult White Sturgeon Sampling

Between March 5 and November 4, 2013, IDFG and BCMFLRO crews expended more than 7,539 h to capture 40 adult White Sturgeon by angling and 115 adult White Sturgeon by setlining (Table 1.1.1). Additionally, two adult sturgeon were collected in gill nets while sampling for juvenile sturgeon and one was captured in a hoop net while sampling for burbot.

Catch rates were 0.34 fish per rod h for angling and 0.016 fish per setline h (Table 1.1.1). One hundred twenty (78%) of the 157 adult White Sturgeon collected were recaptures from previous years (Table 1.1.1). Twenty-six adult White Sturgeon were biopsied by IDFG and BCMFLNRO. Twenty-one (81%) of the biopsied adults were females, and sex could not be determined from five individuals. For some individuals, sex was determined based on previous

inspection recorded in a database. Thirteen of the 21 females biopsied (62%) were stage F4 (mature eggs), four were stage F3 (developing eggs), two were stage F2 (early developing eggs); and specific stage could not be determined from the remaining two females. Sex could not be determined at the time of sampling for five individuals. KTOI Hatchery personnel also captured and biopsied adult White Sturgeon for their propagation operations; Lewandowski (2013) provides adult capture information.

Adult White Sturgeon Telemetry

Migration, movement extent, and behavior during Libby Dam flow augmentation operations by adult sturgeon tagged with Vemco transmitters was determined after downloading 83 stationary Vemco VR2/W sonic receivers (Figure 1.1.4).

Thirteen adult White Sturgeon were tagged with Vemco sonic transmitters in spring/summer 2013 and seven were tagged in fall 2013. Including the 10 adult sturgeon tagged in spring 2013 with those tagged in previous years, 123 adult White Sturgeon had active Vemco sonic transmitters during the 2013 spawning season. Not all of these previously tagged sturgeon were expected to spawn in spring 2013 (Table 1.1.2).

Based on capture and telemetry data, 39 sonic tagged adult White Sturgeon (33 females) were in spawning condition and exhibited a spawning migration in 2013. A spawning migration was defined by fish observed in spawning condition in 2013 or expected to be in spawning condition based on previous biopsies, which moved upstream to at least the lower end of the spawning reach (rkm 228.0). Thirty-seven (95%) of these tagged adults moved upstream as far as rkm 235.0. Thirty-one (79%) of the migrating adults were recorded at rkm 240.7 just downstream of Deep Creek, and 18 (46%) of the migrating adults went upstream as far as rkm 244.5 (Ambush Rock). Additionally, at least 11 (28%, 8 females) of the tagged migrating adult sturgeon went upstream of the Hwy. 95 Bridge in Bonners Ferry into the braided reach in 2013.

Appendix 1.1.1 shows the movement histories of the eight female White Sturgeon that moved upstream of the Hwy. 95 Bridge in Bonners Ferry in 2013.

Artificial Substrate Mat Sampling

We deployed substrate mats in 2013 to evaluate the temporal and spatial extent of White Sturgeon spawning events in the Kootenai River. In 2013, we sampled 62,546 mat hrs between May 13 and July 15 and collected 507 eggs (Table 1.1.3). The highest catch and the highest catch rate came from the Shorty's Island area (rkm 231.0) although most of the effort was in the Myrtle Creek area (rkm 236.0, Table 1.1.3). The first eggs were collected on May 13, and the last eggs were collected on July 11.

Four hundred seventy of the 507 (93%) eggs could be staged and may have been viable. Egg stages ranged from 12 to 27, and 143 of the 470 eggs developed to stage 21 (Beer 1981). Based on the 470 viable eggs, we estimate that White Sturgeon spawned at least 15 days in 2013 between June 11 and July 14 (Table 1.1.4). Water temperature during the egg collection period ranged from 6.9° to 16.8°C (Table 1.1.4), surface water velocity ranged from 0.4 to 1.4 m/s (Table 1.1.4) and Secchi disk depth ranged from 0.6 to 3.2 m.

Juvenile White Sturgeon Sampling

Beginning in 1990 and continuing to the present, the KTOI and BC hatcheries have released over 228,000 juvenile White Sturgeon (Appendix 1.1.2). The purpose of this sampling was to evaluate natural recruitment, growth, and mortality rates of marked hatchery juveniles, as well as distribution and densities of both hatchery and wild juvenile White Sturgeon.

IDFG and BCMFLNRO sampled for juvenile White Sturgeon with gill nets between July 17 and September 24, 2013 in Idaho and Canadian sections of the Kootenai River and Kootenay Lake. Since this population is transboundary, data collected in Canada was included.

In 2013, IDFG and BCMFLNRO sampled 25 sites between rkm 18.0 and 244.5 and collected 1419 juvenile sturgeon (1409 hatchery-reared, 99%) with 519 h of effort (Table 1.1.5). The highest catch and highest catch rates came from the Kootenay Lake delta (rkm 120.0) but juvenile sturgeon were captured throughout the river and lake. Nick's Island (rkm 145.0) and Ferry Island (rkm 205.0) had the highest catch rates in the river, but several areas throughout the river had catch rates that exceeded one fish per hour. All sizes of gill nets used caught sturgeon, but the 4-inch mesh caught the most, accounting for over 45% of the catch (Table 1.1.6). The 2-inch mesh was fished the most, representing 48% of the sets. The highest CPUE was from the 4-inch mesh (4.5 sturgeon/net-hour).

The average fork and total length of the hatchery reared juvenile White Sturgeon was 47.5 cm and 55.2 cm, respectively, and weight of juvenile sturgeon captured in 2013 averaged 0.91 kg (Table 1.1.7).

Growth was compared among capture years for three age classes from the Kootenai River/Lake system as a whole, in the Kootenai River above rkm 123, and the Kootenay Lake delta. With river and delta data combined, MLTOC varied among years, with statistically significant (p = 0.05) differences in growth being common. Although growth rates were variable among the sample years, there was no observed decline in growth rates over time with all sites combined for three-, four-, or five-year-olds. MLTOC was most variable for three-year-olds and least variable for five-year-olds (Figure 1.1.5). Results were similar when MLTOC of three-, four-, and five-year-old juvenile sturgeon were compared at the delta reach alone, or from the Kootenai River above rkm 123 alone. Mean length at both river and delta sections varied among the ages and among years, but MLTOC was significantly ($P < 0.05$) greater for juveniles captured at the delta most years. Additionally, the greatest differences in growth between river sections occurred with the five-year-olds (Figure 1.1.5). We also compared MLTOC within the same capture year for fish captured in the Kootenai River (above rkm 123) to fish captured at the delta. Most years, MLTOC was significantly (p = 0.05) larger in the delta compared to the river sections (Figure 1.1.5). Although growth rates are comparatively higher in the Kootenay Lake delta compared to the river, there was no declining trend in growth in either the delta or river sections over time. Gillnet catch parameters pertaining to hatchery brood year assignments are in Appendix 1.1.3.

Ten wild juvenile (six recaptures) White Sturgeon were captured while gill netting in Canada and Idaho in 2013 (Table 1.1.8). The TL of these 10 individuals ranged from 48.3 to 123.0 cm, and weights ranged from 0.45 to 6.0 kg. Only four wild juveniles were aged, as several of the wild juveniles were recaptures and had been aged previously. Year classes from 2002, 2003, 2006, and 2007 were represented (Table 1.1.8). Figure 1.1.6 shows the year class assignments from a sample of the wild juvenile White Sturgeon collected between 1977 and

2013 that could be aged. Figure 1.1.7 shows the number of wild juvenile White Sturgeon collected annually from 1977 to 2013.

DISCUSSION

Described in SOR FWS#2013-1, the objective of the 2013 sturgeon augmentation operation was to provide two periods of peak river stages/flows during the spring run-off period. The first peak, timed to low-elevation run-off below Libby Dam, was intended to provide sturgeon cues to begin upstream migration and staging. The second peak, timed to high-elevation run-off above Libby Dam, was intended to provide sturgeon cues to migrate further upstream from their staging areas and spawn towards the end of the second peak and/or on its descending limb. Overall, the goal is to provide conditions that will enable sturgeon to migrate to, and spawn over, rocky substrates that exist upstream of Bonners Ferry. Results from this year's flow operations suggest that the double peak may have improved migration conditions, as more sturgeon migrated above Bonners Ferry in 2013 than in the previous three years. Although we are still constrained by Libby Dam operations and flood control issues at Bonners Ferry, small-scale adaptive flow management actions are important for understanding how sturgeon respond to different flow regimes and eventually may allow us to enhance upstream movements. The Vemco telemetry array has been in place for 10 years and has greatly improved our understanding of qualitative aspects of sturgeon movements and behaviors. The next step is to incorporate sturgeon movement data with physical habitat variables provided by Libby Dam and attempt to develop a predictive model to help determine how specifically to enhance sturgeon movement upstream of Bonners Ferry.

Flow management, described previously, is one approach being taken to improve sturgeon spawning migration above Bonners Ferry into areas with substrates and flow conditions that are thought to be more conducive to successful spawning and recruitment. The other approach is habitat enhancement in the current spawning reach at Shorty's Island and Myrtle Creek. Design and specific enhancement site locations for these habitat projects were developed by incorporating IDFG egg sampling data with USGS velocity, depth, and substrate modeling (detailed report in Chapter 3 of this report) to define areas of highest likelihood of spawning without sand or silt deposition. IDFG is tasked with monitoring and evaluating the biological responses to these substrate additions, which are scheduled for completion in summer 2014. Beginning in 2014, we plan to implement a detailed study design and collect pretreatment data on fish use (Vemco VPS system), spawning distribution (egg mat sampling), and larval production (modification of D-ring plankton nets) within the extent of the habitat projects. The intent is to provide a statistically rigid design to evaluate whether these structures improved sturgeon spawning extent and success.

Mean length at time of capture (MLTOC) was analyzed for three-, four-, and five-year-old juvenile sturgeon from catch data from 1991 to 2013 using single factor ANOVA. Although growth rates were variable among the sample years, there was no observed decline in growth rates over time with all sites combined or when each river section was analyzed alone. Comparing Kootenai River (above rkm 123) captured fish to delta captured fish, most years, MLTOC was significantly ($p = 0.05$) larger for delta captured fish compared to those captured in river sections. Although growth rates are consistently higher in the Kootenay Lake delta compared to the river, based on MLTOC there was no declining trend in growth in either the delta or river sections over time. This may suggest that growth rates have not declined over time or from increased juvenile sturgeon densities. MLTOC is useful for describing broad-scale growth changes over time and can be useful for general comparisons to other populations;

however, this is likely not an appropriate method for evaluating carrying capacity of density dependent growth change. To properly evaluate potential density dependent growth changes over time, incremental growth analysis using pectoral fin ray sections and modeling growth from groups of individual fish is likely a better option. This option would allow variables such as stocking numbers, nutrient addition days, or invertebrate densities, for example, to be used as covariates in the model and better explain the causes for the variability in growth.

RECOMMENDATIONS

1. As soon as water temperature at Bonners Ferry reaches 7°C after April 1, provide augmented flow from Libby Dam to achieve 425 m^3/s at Bonners Ferry. Provide stable or increasing temperature using the selective withdrawal gate system at Libby Dam as needed 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, USFWS 2006) 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. Incorporate new study designs and collect pretreatment data on proposed habitat enhancement pilot projects at Myrtle Creek and Shorty's Island. This will include evaluating spawning extent (egg mat sampling), larval recruitment (modified D-ring nets), and habitat use by spawning female sturgeon (Vemco VPS system).

4. Evaluate the effects of flow operations, including spill test years, on adult sturgeon movements and migration timing.

5. Collect juvenile sturgeon fin ray sections to evaluate changes in growth over time using incremental growth analysis.

TABLES

Table 1.1.1 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 or British Columbia Ministry of the Environment personnel, in the Kootenai River, Idaho, and Kootenay Lake, Canada, March 4 to November 5, 2013.

	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[a]	519.0	1,417(964)	2(1)	2.73	0.0038
Angling [b,c]	116.8	10(9)	40(28)	0.0856	0.3425
Setline[b,d]	7,422.6	29(25)	115(93)	0.0039	0.0155
Total	8,058.4	1,456(998)	157(122)		

[a] Includes 170.0 hours sampling by BCE for IDFG from July 17 – September 24, 2013. There were 834 juveniles (539 recaptures, 293 untraceable recaptures) and 1 adult (0 recaptures) caught during this period and included in the totals above.

[b] Does not include spring 2013 angling effort or captures by BCE at Kootenay Delta, which resulted in 2 adult captures (both recaptures). It does include 28.8 hours fall angling effort resulting in 14 (11 recaptures) adults and 7(6 recaptures) juveniles and 370.3 hours spring and fall setline effort with 23 (19 recaptures) adults and 9 (8 recaptures, 1 untraceable recapture) juvenile captures. It also includes 2 adults (both recaptures) captured by setline by IDFG May 1, 2013 for which effort is known but capture data was lost.

[c] There were an additional 108 adults (87 recaptures) and 15 juveniles (15 recaptures) during KTOI broodstock angling efforts from March 19 – June 13, 2013 for which no effort was recorded. During 13.24 hours fall adult sampling from September 17-19, 2013, 8 (7 recaptures) adults and 1(1 recapture) juvenile were captured. The fall effort and captures are included in the totals above.

[d] Based on 24 hour sets.

Table 1.1.2. Vital statistics from Kootenai River adult White Sturgeon marked with Vemco sonic tags as part of a telemetry study, Kootenai River, Idaho, 2003 through spring 2014.

Tag year	Sex/Development Stage	Release Date	Release RKM	Fish #	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[a]
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[b]
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[c]
2004	M-8	10/4/04	119.0	22213	195.5	220.0	54.9	257
2005	F-4	3/10/05	204.0	53853	170.0	197.0	41.0	275
2005	F-2	3/16/05	215.0	53855	215.0	241.0	[d]	277
2005	F-4	3/29/05	215.0	53872	165.0	191.0	48.0	274
2005	F-3	3/29/05	215.0	53871	182.0	209.0	47.0	276
2005	F-3	4/12/05	215.0	53863	182.0	200.0	59.0	273
2005	F-4	4/26/05	215.0	947	142.0	162.0	26.0	272
2005	F-4[e]	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	[d]	278[f]
2005	M-8	6/08/05	229.0	906	166.0	191.0	35.0	281
2005	M-8	6/08/05	229.0	330	179.0	206.0	43.0	279
2005	M-8	6/08/05	229.0	53894	189.0	217.0	70.0	271
2005	M-7	9/26/05	215.0	406	168.0	192.0	43.0	50
2005	F-4[e]	9/26/05	215.0	345	164.0	189.0	52.0	269
2005	F-4[e]	9/26/05	215.0	535	177.0	204.0	57.0	270
2005	F-4	9/27/05	215.0	1578	178.0	200.0	40.0	267
2005	U[g]	9/27/05	215.0	804	105.0	132.0	14.0	87
2005	F-4	9/27/05	215.0	1795	185.0	208.0	54.0	268
2005	M-7	9/27/05	215.0	1794	197.0	224.0	63.0	258
2006	F-4	3/23/06	207.0	1824	166.0	189.0	36.9	9dt[h]
2006	F-1	3/28/06	190.0	202	185.0	212.0	48.6	292[i]
2006	M	3/28/06	185.0	939	147.0	171.0	21.2	294
2006	M	3/28/06	185.0	65	167.0	193.0	27.9	290[j]
2006	F-4[e]	3/30/06	215.0	1305	158.0	182.0	36.9	3dt
2006	F-4[e]	4/4/06	205.0	22218	169.0	195.0	37.2	10dt
2006	M-8	4/4/06	187.5	86	161.0	195.0	33.3	7dt
2006	M-8	4/6/06	215.0	139	175.0	202.0	43.5	1dt
2006	F-4[e]	4/10/06	205.0	1828	185.0	215.0	56.0	6dt
2006	F-4[e]	4/13/06	215.0	1833	196.0	228.0	65.0	8dt
2006	F-4[e]	4/19/06	215.0	1837	194.0	223.0	65.9	4dt
2006	F-4[e]	4/25/06	215.0	1840	186.0	217.0	53.3	288
2006	M-8	4/26/06	204.0	987	151.0	174.0	25.5	291
2006	M-8	5/4/06	229.0	2230	214.0	243.0	54.2	2dt[k]
2006	F-4	5/4/06	229.0	22212	208.0	236.0	[d]	293[b]
2006	M-8	5/4/06	229.0	1842	155.0	179.0	30.5	295
2006	F-4	5/9/06	229.0	2227	170.0	190.0	37.2	287
2006	M-8	6/1/06	235.5	679	155.0	177.0	27.3	5dt
2006	M-9	6/6/06	229.0	1847	167.0	187.0	40.3	286

Tag year	Sex/Development Stage	Release Date	Release RKM	Fish #	Fork Length (cm)	Total Length (cm)	Weight (kg)	Vemco Code
2006	M-9	6/7/06	229.0	7917	145.0	165.0	23.3	289
2006	F-3	9/28/06	121.0	57859	118.0	121.6	57.0	299
2006	F-3	10/5/06	215.0	57035	172.0	194.0	42.8	296
2006	F-3	10/5/06	215.0	57033	179.0	210.0	48.2	298
2006	F-3	10/8/06	215.0	57034	182.0	205.0	54.0	301
2006	F-4	10/24/06	215.0	1854	185.0	213.0	60.0	297
2007	F-4[l]	3/12/07	120.0	57869	207.0	235.0	82	17dt
2007	F-4[l]	3/13/07	120.0	850	207.0	230.0	95	13dt
2007	F-4[l]	3/14/07	123.0	2216	194.0	220.0	67	303
2007	F-4[l]	3/14/07	120.0	152	178.0	197.0	65	305[m]
2007	F-4[l]	3/14/07	137.0	2198	170.0	192.0	51.3	20dt[n]
2007	U	3/19/07	215.0	57873	207.0	221.0	64.1	135
2007	F-4[l]	3/28/07	215.0	891	193.0	221.0	61.8	16dt
2007	M-8	3/28/07	205.0	252	172.0	208.0	49.7	15dt
2007	F-4[e]	3/29/07	215.0	57880	185.0	214.0	65.9	14dt
2007	F-4[e]	3/29/07	215.0	57881	162.0	186.0	47.0	18dt
2007	F-4[e]	3/29/07	215.0	57882	172.0	193.0	44.8	12dt
2007	M-8	3/29/07	215.0	57883	167.0	191.0	44.8	11dt
2007	M-8	4/3/07	215.0	2268	167.0	190.0	33.2	19dt
2007	M-8	4/10/07	215.0	162	188.0	218.0	58.2	302
2007	M-8	5/23/07	232.0	1141	154.0	178.0	[d]	300
2007	F-4	5/27/07	241.0	57891	186.0	211.0	57.0	304[o]
2007	F-4[e]	9/25/07	121.0	22232	144.0	169.0	30.9	306
2007	F-4/F-3[e]	10/17/07	215.0	136	152.0	172.0	41.7	313
2007	F-4/F-3[e]	10/17/07	215.0	22401	177.0	200.0	67.2	314
2008	F-4[e]	3/12/08	215.0	605	209.0	241.0	[d]	307
2008	F-4[e]	3/25/08	215.0	62259	186.0	200.0	71.7	311
2008	F-4[e]	3/25/08	205.0	62260	182.0	206.0	49.7	309
2008	F-4[e]	4/1/08	215.0	1605	180.0	211.0	56.9	319
2008	F-4[e]	4/3/08	205.0	62261	193.0	221.0	[d]	317
2008	M-8	4/10/08	205.0	337	204.0	235.0	[d]	321
2008	F-4[e]	4/9/08	205.0	524	189.0	216.0	[d]	323
2008	M-8	4/21/08	205.0	62262	169.0	198.0	40.3	320
2008	M-8	4/21/08	205.0	364	170.0	196.0	41.7	316
2008	M-8	4/22/08	205.0	62263	177.0	202.0	[d]	325
2008	M-8	4/23/08	205.0	62264	156.0	178.0	31.4	318
2008	F-4[e]	4/22/08	205.0	62265	181.0	206.0	[d]	315
2008	F-3	9/24/08	117.0	8	186.0	210.0	[c]	310
2008	M	11/4/08	205.0	970	149.0	168.0	54.0	312[p]
2008	U	11/12/08	205.0	67849	279.0	308.0	[d]	420[q]
2008	F-2	11/12/08	190.0	19	167.0	189.0	85.0	422
2009	F	2/24/09	215.0	812	185.0	213.0	[d]	417[r]
2009	M-7	3/3/09	199.5	595	178.0	207.0	38.7	418[s]
2009	M-7	3/3/09	215.0	642	154.0	178.0	26.6	416
2009	M-7	3/4/09	207.0	57878	154.0	177.0	25.7	419
2009	M-7	3/4/09	207.0	67853	156.0	171.0	27.0	421
2009	F-2	3/4/09	195.7	202	186.0	210.0	[d]	400[l]
2009	F-2	3/18/09	190.0	229	173.0	203.0	45.0	401[t]
2009	F-4	3/18/09	215.0	241	168.0	192.0	38.7	407[u]
2009	F-2	3/24/09	215.0	57872	123.0	141.0	11.3	404[v]
2009	F-4[l,w]	3/24/09	193.2	67855	157.0	183.0	36.5	403
2009	F-4[l,w]	4/7/09	190.0	373	190.0	214.0	[d]	406
2009	F-4[e]	4/21/09	222.3	213	172.0	202.0	41.0	402

Tag year	Sex/Development Stage	Release Date	Release RKM	Fish #	Fork Length (cm)	Total Length (cm)	Weight (kg)	Vemco Code
2009	F-4[e]	4/21/09	213.0	103	181.0	198.0	51.8	405
2009	F-3	5/21/09	120.0	2288	203.0	227.0	78.0	415
2009	F-4	9/21/09	215.0	22209	162.0	188.0	35.1	408
2009	F-4	9/21/09	215.0	712	168.0	192.0	39.2	410
2009	F-3	9/30/09	213.0	1480	178.0	205.0	53.0	409
2010	F-6	3/3/2010	187.0	199	121.0	163.0	27.0	414
2010	F-4[e]	3/3/2010	193.5	651	152.0	175.0	26.0	308
2010	M-8	3/23/10	213.0	106	190.0	220.0	[d]	547
2010	F-4[e]	3/24/10	205.0	936	190.0	221.0	67.0	549
2010	F-4[e]	3/24/10	207.5	81993	179.0	205.0	[d]	545
2010	M-8	3/25/10	205.0	1421	165.0	190.0	40.0	543
2010	F-4	3/25/10	207.5	81999	168.0	194.0	49.0	541
2010	F	3/30/10	205.0	163	189.0	215.0	37.0	551[y]
2010	F-4	3/30/10	207.5	22234	180.0	210.0	49.0	559
2010	F-4	3/31/10	207.5	692	187.0	213.0	[d]	411[z]
2010	F-2	3/31/10	207.5	348	167.0	192.0	33.0	558[f]
2010	M	3/31/10	207.5	57878	159.0	182.0	26.0	419
2010	F-4	3/31/10	207.5	81998	179.0	209.0	[d]	557
2010	F-4[e]	4/6/10	207.5	2344	179.0	210.0	65.0	560[aa]
2010	F-4[e]	4/8/10	213.0	56981	269.0	303.0	[d]	556
2010	F-4[e]	4/8/10	213.0	82003	175.0	201.0	49.0	554
2010	M	4/13/10	215.0	145	168.0	194.0	31.0	552
2010	M	4/19/10	207.5	971	169.0	192.0	32.0	550
2010	F-4[e]	4/19/10	207.5	62253	205.0	250.0	[d]	555
2010	M	4/20/10	213.0	349	188.0	220.0	47.0	542
2010	F-4[e]	4/20/10	207.0	82004	148.0	172.0	33.0	553
2010	F-4[e]	4/27/10	213.0	715	173.0	199.0	59.0	546
2010	F-4[e]	4/27/10	207.5	931	174.0	194.0	52.0	548
2010	F-3	11/4/10	207.5	909	151.0	172.0	33.0	719[ab]
2010	F-3	11/4/10	207.5	95246	186.0	216.0	63.0	544
2010	F-3	11/15/10	207.5	62245	210.0	243.0	88.0	717
2011	M	3/17/11	152.5	637	183.0	210.0	[d]	720[ac]
2011	M	3/22/11	143.0	1583	168.0	193.0	[d]	715
2011	F-4	3/29/11	213.0	1482	171.0	197.0	[d]	718
2011	F-4	3/30/11	215.0	95595	190.0	215.0	65.0	716
2011	F-4	4/5/11	213.0	95596	202.0	230.0	67.0	713
2011	F-4	4/19/11	207.5	890	216.0	248.0	99.0	711
2011	F-4	4/19/11	234.4	1499	193.0	220.0	60.0	714
2011	F-4	5/2/11	207.5	95603	193.0	222.0	69.0	712
2011	M-8	5/10/11	213.0	2230	122.0	152.0	76.0	709[k]
2011	F-4	5/11/11	207.5	57886	177.0	203.0	54.0	710
2011	F-2	9/29/11	122.0	22216	198.0	216.0	70.0	703
2012	F-4	3/13/12	207.7	101848	175.0	191.0	45.0	696
2012	F-4	4/5/12	207.7	101861	183.0	210.0	[d]	697
2012	M-8	4/5/12	207.0	1791	161.0	184.0	39.0	698
2012	F-4	4/5/12	207.0	1580	191.0	216.0	64.0	699
2012	M-8	4/16/12	207.0	860	169.0	193.0	44.0	700
2012	F-4	4/3/12	207.0	22210	172.0	201.0	[d]	701
2012	F-4	4/4/12	207.0	101860	189.0	214.0	[d]	704
2012	F-4	4/26/12	120.0	101885	197.0	220.0	71.0	705
2012	F	4/17/12	207.0	101866	185.0	211.0	70.0	707
2012	F-4	4/11/12	207.0	101864	190.0	212.0	65.0	708
2012	F-2	9/6/12	120.0	1836	204.0	233.0	89.0	702

Tag year	Sex/Development Stage	Release Date	Release RKM	Fish #	Fork Length (cm)	Total Length (cm)	Weight (kg)	Vemco Code
2012	F-3	9/27/12	122.0	131525	224.0	251.0	110.0	810
2013	F-4	3/6/13	207.5	131501	180.0	202.0	[d]	809
2013	F-4	3/7/13	207.0	131502	192.0	220.0	69.0	811
2013	F-4	3/14/13	207.0	131505	163.0	191.0	40.0	813
2013	F-3	4/8/13	121.0	2385	182.0	204.0	73.0	816
2013	F-4	4/9/13	121.0	53909	210.0	244.0	95.0	812
2013	F-3	4/11/13	121.0	228	186.0	216.0	73.0	818
2013	F-4	5/2/13	215.0	131512	179.0	209.0	[d]	815
2013	F-4	5/2/13	213.0	131511	174.0	202.0	[d]	819
2013	F-4	5/7/13	206.5	131513	169.0	194.0	50.0	817
2013	F-4	5/9/13	207.0	131518	199.0	228.0	68.0	820
2013	F-2	8/7/13	121.0	137652	195.0	222.0	75.0	814
2013	F-4	9/17/13	18.0	2248	199.0	224.0	76.7	51
2013	F-3	9/18/13	18.0	137626	186.0	207.0	51.0	39
2013	F-4	9/25/13	122.0	62258	172.0	196.0	40.0	43
2013	F-3	9/25/13	121.0	138079	169.0	188.6	44.0	917
2013	F-4	10/24/13	207.0	138091	164.0	187.0	38.0	53
2013	F-4	10/28/13	205.0	138089	176.0	196.0	49.0	49
2013	F-4	10/29/13	215.0	138092	148.0	171.0	32.0	35
2013	F-4	10/29/13	207.0	138084	183.0	207.0	73.0	45
2013	F-4	10/30/13	207.0	138087	165.0	181.0	43.0	31

[a] This fish (Vemco 52) recaptured 3/29/05, taken to KTOI hatchery, released 6/28/05.
[b] This fish was first tagged with Vemco 259 (2004), then re-tagged with 293 in May 2006.
[c] This fish (Vemco 266) captured 9/8/04 and recaptured 9/20/12 by BC.
[d] No weight taken.
[e] F-1 eggs present.
[f] Vemco 278 1st tagged 5/18/05; recaptured 2006, 2007 (twice), 2008, 2009 (twice), 2010. New Vemco 558 added 3/31/10.
[g] U = Unknown sex/ development.
[h] dt = depth sensitive tag.
[i] This fish (#202) 1st tagged with Vemco 292 (2006); new Vemco 400 added at 3/4/09 recapture.
[j] This fish (Vemco 290) recaptured 3/24/09.
[k] Vemco 2dt replaced with Vemco 709 5/10/11 (fish #2230).
[l] F-4 eggs present.
[m] This fish (Vemco 305) captured 3/14/07 and recaptured 6/1810.
[n] This is the second deployment of tag code 20dt (was on juvenile 21890 in 2003).
[o] Vemco 304 captured 5/20/07 @ 215.6; taken to KTOI hatchery, released 5/27/07; recap 5/31/07 @ 236.0. 1st captured by Montana in May 1976.
[p] This fish (Vemco 312) recaptured 4/12/11.
[q] This fish (Vemco 420) recaptured 9/22/09.
[r] This fish (Vemco 417) recaptured 2/24/09, Vemco 417 added to replace sonic 7226 (added 4/23/01); other recaptures: 3/25 & 6/2/10, 6/12/13.
[s] This fish (Vemco 418) recaptured 3/24/09.
[t] This fish (Vemco 401) captured 3/18/09 and recaptured 3/28/12.
[u] This fish (Vemco 407) captured 3/18/09 and recaptured 4/29/10.
[v] This fish (Vemco 404) captured 3/24/09, recaptured 3/9 (by KTOI) and 3/24/10 by ID.
[w] Eggs taken to hatchery.
[y] This fish (Vemco 551) captured 3/30/10, Vemco 551 added to replace sonic 654; recaptured 4/7/10 and 5/12/11.
[z] This fish (Vemco 411) captured 3/31/10 and recaptured 3/17/11.
[aa] This fish (Vemco 560) captured 4/6/2010 and recaptured 9/18/12 by BC.
[ab] This fish (Vemco 719) captured 11/4/10 and recaptured 5/4/11 by KTOI angling.
[ac] This fish (Vemco 720) captured 3/17/11; Vemco added to replace old sonic 3335 (added 4/4/95).

Table 1.1.3. Location (river kilometer), depth (m), White Sturgeon egg catch and catch per unit effort (CPUE) by standard artificial substrate mats, IDFG, Kootenai River, Idaho 2013.

Sample year	River location (rkm)	Depth range (ft)	Temperature range (°C)	Total mat hours	Number White Sturgeon eggs	CPUE
2013	231.0	11.2-56.9	7.3-16.8	7,783.0	212	0.0272[a]
	234.5	12.0-63.7	7.1-16.7	23,623.1	204	0.0086[a]
	246.0	11.8-29.0	6.9-15.9	15,273.9	91	0.0060[a]
	246.3	8.1-21.8	6.9-15.9	7,927.3	0	0
	246.7	6.4-17.0	7.0-15.9	7,939.1	0	0
2013	**231.0-246.7**	**6.4-63.7**	**6.9-16.8**	**62,546.4**	**507**	**0.0081**

[a] Water velocity measurements taken only when eggs were found.

Table 1.1.4. Stages of White Sturgeon eggs captured by artificial substrate mats, Kootenai River, Idaho, 2013.

Date Pull	Temp °C Pull	No. Egg	Egg Stage 12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	other	Notes	Hours from Fertilization (Spawn Date)
5/15	8.5	1																		1	broken	
5/20	7.3	3																		3	2 broken/1 dead	
6/3	10.1	2						2														15(6/2)
6/3	10.1	7	1				6															15(6/2);0(6/3)
6/3	11.2	2					2															14(6/2)
6/3	11/2	31	1				10	17												3	dead	14,20(6/2);0(6/3)
6/4	11.2	4					3	1														14,20(6/3)
6/4	11.2	3					3															14(6/3)
6/4	11.2	13							4			9										53(6/2);27(6/3)
6/4	11.2	1					1															17(6/3)
6/4	11.2	28					3	17		3		3								2	dead	53(6/2);14,20,33 (6/3)
6/6	12.0	6										3								3	2 dead/1 broken	48(6/4)
6/10	11.5	2																		2	1 dead/1 hatched, un-readable	
6/10	11.5	4								1	1		2									63(6/7);37(6/8);32 (6/9)
6/10	11.5	4												4								73(6/7)
6/10	11.5	7						4						1						2	broken	63(6/7);19.5(6/9)
6/10	12.0	167									2	11	4	142						8	Dead/broken	73(6/7);48,60(6/8); 35(6/9)
6/10	12.0	4						1												3	2 broken/1 unreadable	19(6/9)
6/10	12.0	2											2									60(6/8)
6/10	12.0	2					1					1										48(6/8);13(6/10)
6/10	12.0	2										1								1	broken	48(6/8)
6/10	12.0	2	2																			0(6/10)
6/10	12.0	7	7																			0(6/10)
6/13	12.0	3						1	2													19,24(6/12)
6/13	12.0	6					2	2	1											1	broken	13,19,24(6/12)
6/13	12.0	1						1														19(6/12)
6/13	12.0	1							1													24(6/12)
6/13	12.0	7										7										64(6/11)
6/13	12.0	6								1	4	1										48(6/11);30,35(6/12)
6/13	12.0	9								1	6									2	broken	30,35(6/12)

Date Pull	Temp °C Pull	No. Egg	Egg Stage 12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	other	Notes	Hours from Fertilization (Spawn Date)
6/17	13.0	20										16	3		1							74(6/14);43,54(6/15)
6/17	13.0	1													1							74(6/14)
6/17	13.0	2										1								1	Hatched/un-readable	43(6/15)
6/17	13.0	4										2								2	broken	43(6/15)
6/20	13.0	9					2	3	4													12,17,23(6/19)
6/24	13.0	1									1											33(6/23)
6/24	13.0	13							1		6	3	1	2								64(6/21);43,54 (6/22);23,33(6/23)
6/24	12.0	4							1				1	1						1	unknown	73(6/21);60(6/22);24(6/23)
6/24	12.0	6												6								73(6/21)
6/24	12.0	4												4								73(6/21)
6/27	13.0	34									1	31								2	broken	43(6/25);33(6/26)
6/27	13.0	8										8										43(6/25)
6/27	13.0	26										26										43(6/25)
6/27	13.0	14							1	2	2	7	2									43,54(6/25);23,28,33(6/26)
7/1	15.0	1										1										36(6/29)
7/1	14.0	1																1				162(6/24)
7/3	16.0	1										1										32(7/2)
7/3	16.0	6										6										32(7/2)
7/15	15.0	11										2		9								53(7/13);36(7/14)
7/15	15.0	4										3	1									45(7/13);36(7/14)
Total collected		507	11	0	0	0	33	49	15	8	23	143	16	169	2	0	0	1	0	37		
Total not staged		37																				

Table 1.1.5. Idaho Department of Fish and Game and British Columbia Ministry of the Environment Juvenile White Sturgeon gill net sampling effort by sampling location for July 30 through September 3, 2013 and July 17 through September 24, 2013, respectively.

Year	River Kilometer	Number of Sets	Hours of Effort	Number of Adults Captured	Number of Juveniles Captured	Sturgeon Catch Per Unit of Effort
2013	18.0	8	8.77		32	3.65
	70.0	1	0.82			0.00
	100.0	1	0.89			0.00
	120.0	20	16.36		308	18.83
	121.0	23	28.19	1	277	9.86
	123.0	9	9.24		18	1.95
	130.0	33	46.41		62	1.34
	141.0	36	51.78		54	1.04
	145.0	16	20.58		110	5.34
	150.0	8	11.74		12	1.02
	157.0	8	8.26		9	1.09
	161.0	17	18.34		8	0.44
	165.0	7	8.23		2	0.24
	170.0	12	20.46		6	0.29
	174.0	16	19.10		11	0.58
	176.0	23	39.39		14	0.36
	192.0	32	49.58		20	0.40
	205.0	23	37.86		195	5.15
	207.5	17	24.97		39	1.56
	213.0	12	20.72		24	1.16
	215.0	21	38.80		143	3.69
	225.0	15	22.89	1	67	2.97
	234.5	12	15.65		6	0.38
	Total	**370**	**519.03**	**2**	**1417**	**2.73**

Table 1.1.6. Idaho Department of Fish and Game and British Columbia Ministry of the Environment Juvenile White Sturgeon gill net sampling effort by mesh size for July 30 through September 3, 2013 and July 17 through September 24, 2013, respectively.

Year	Gill Net Mesh Size (cm)	Number of Sets	Hours of Effort	Number of Adults Captured	Number of Juveniles Captured	Sturgeon Catch Per Unit Effort
2013	2	178	252.83		595	2.35
	4	105	139.16		632	4.54
	6	87	127.04	2	190	1.51
	Total	**370**	**519.03**	**2**	**1417**	**2.73**

Table 1.1.7. Summary statistics of recaptured juvenile hatchery White Sturgeon from 2013 net sampling, Kootenai River, Idaho and Kootenay Lake, BC

Year	Statistic	Fork length (cm)	Total length (cm)	Mean weight (kg)
2013	N	1410	1410	1159
	Average	47.5	55.2	0.91
	Standard deviation	16.5	19.2	1.35
	Minimum	18.0	20.8	0.02
	Maximum	118.0	137.0[a]	16.00

[a] There were 8 hatchery juvenile recaptures with total lengths (cm) greater than 120 cm, which classifies them as adults now (based on length alone). These fish were from brood years 1991 (1), 1992 (3), 1995 (2), 1999 (1) and 2000 (1).

Table 1.1.8. Wild juvenile White Sturgeon captured in gillnets in 2013, Kootenai River, Idaho and Kootenay Lake, BC (does not include wild recaptures).

Year	Date	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)	Year class
2013	8/15	205.0	46.9	54.1	0.63	2007
	8/16	120.0	69.0	79.0	n/a	2003
	8/19	215.0	44.1	50.5	0.53	2006
	8/27	122.0	76.0	88.5	3.00	2002

FIGURES

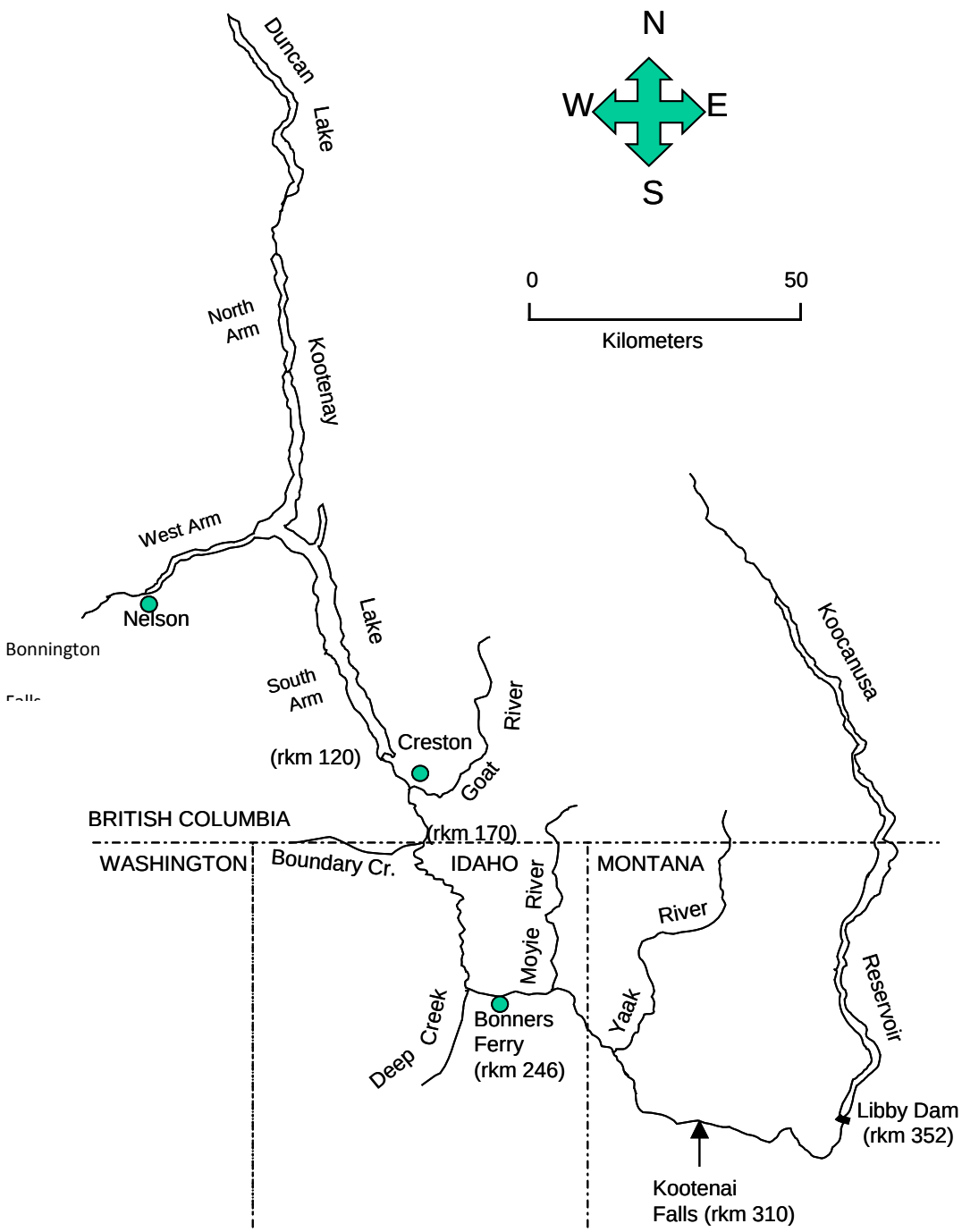


Figure 1.1.1. Location of the Kootenai River, Kootenay Lake, Lake Koocanusa, and major tributaries. The river distances from the northernmost reach of Kootenay Lake are in river kilometers (rkm) and are indicated at important access points.

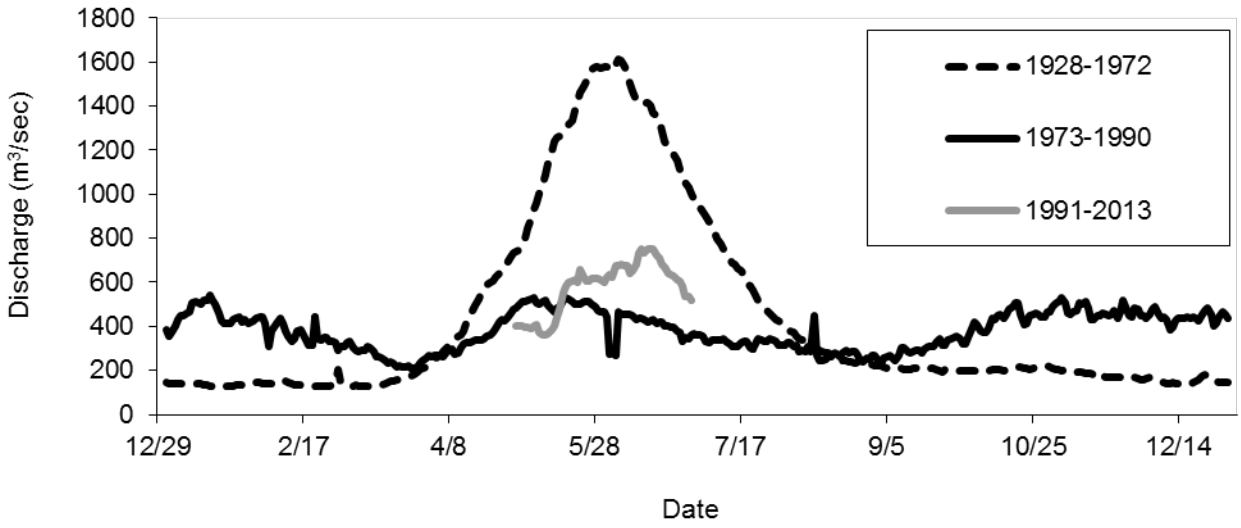


Figure 1.1.2 Mean daily flow patterns in the Kootenai River at Bonners Ferry, Idaho from 1928-1972 (pre-Libby Dam), 1973-1990 (post-Libby Dam), and 1991-2013 (post-Libby Dam with augmented flows, May 1 through June 30).

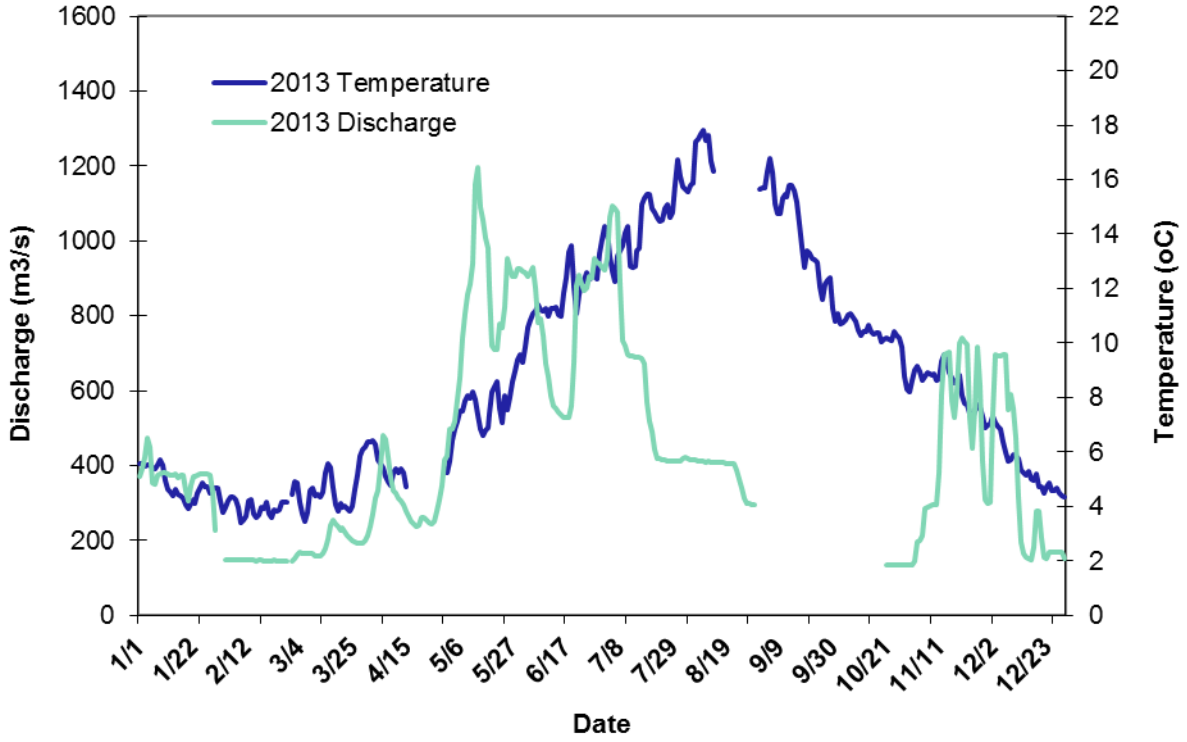


Figure 1.1.3. Mean daily discharge (m^3/sec) and temperature (°C) for Kootenai River at Bonners Ferry, Idaho, 2013.

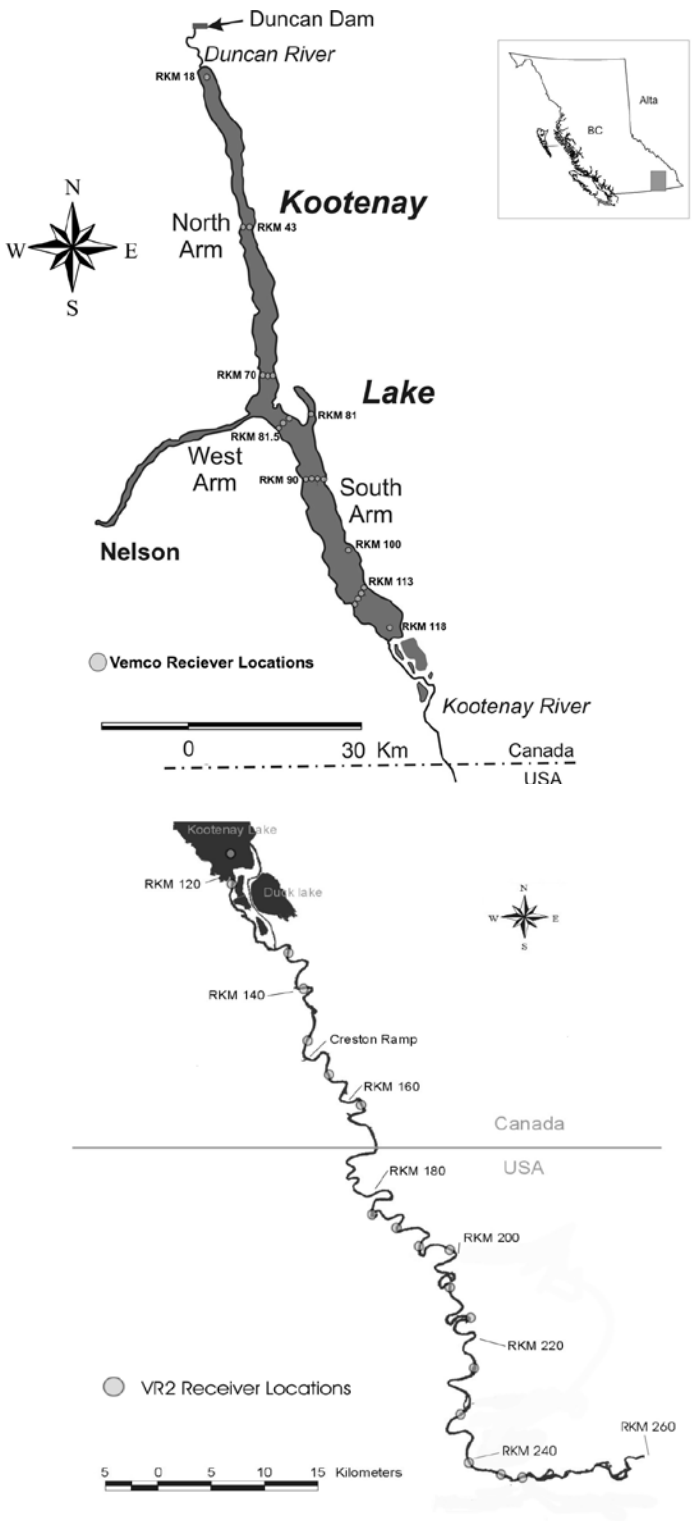


Figure 1.1.4. Location of Vemco VR2 receivers in Kootenai River/Lake system, Idaho and British Columbia, Canada, 2013 (receivers locations are depicted by circles).

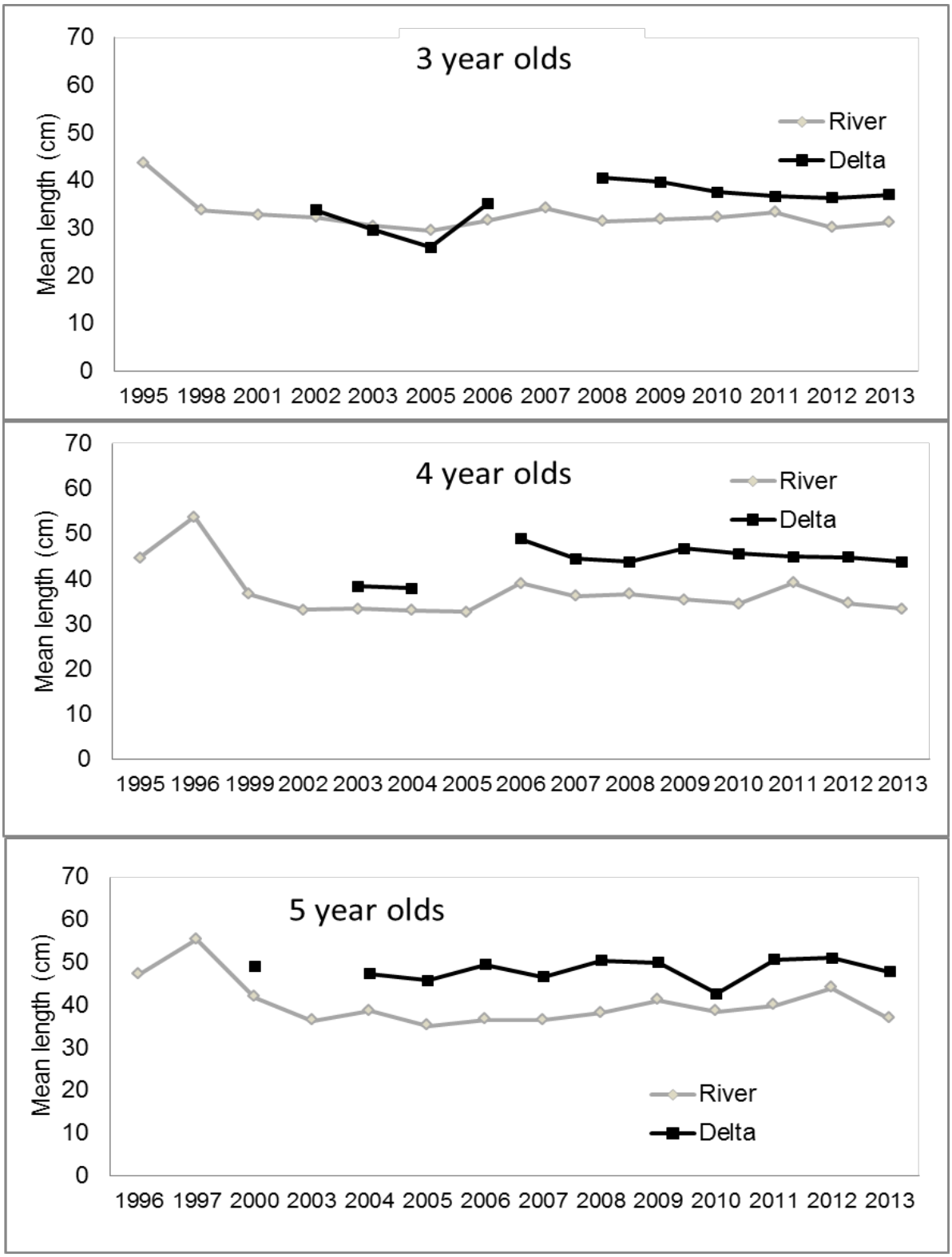


Figure 1.1.5. Differences in mean length at time of capture of 3, 4, and 5 year old juvenile sturgeon captured above river kilometer 123 (River) and below rkm 123 (Delta).

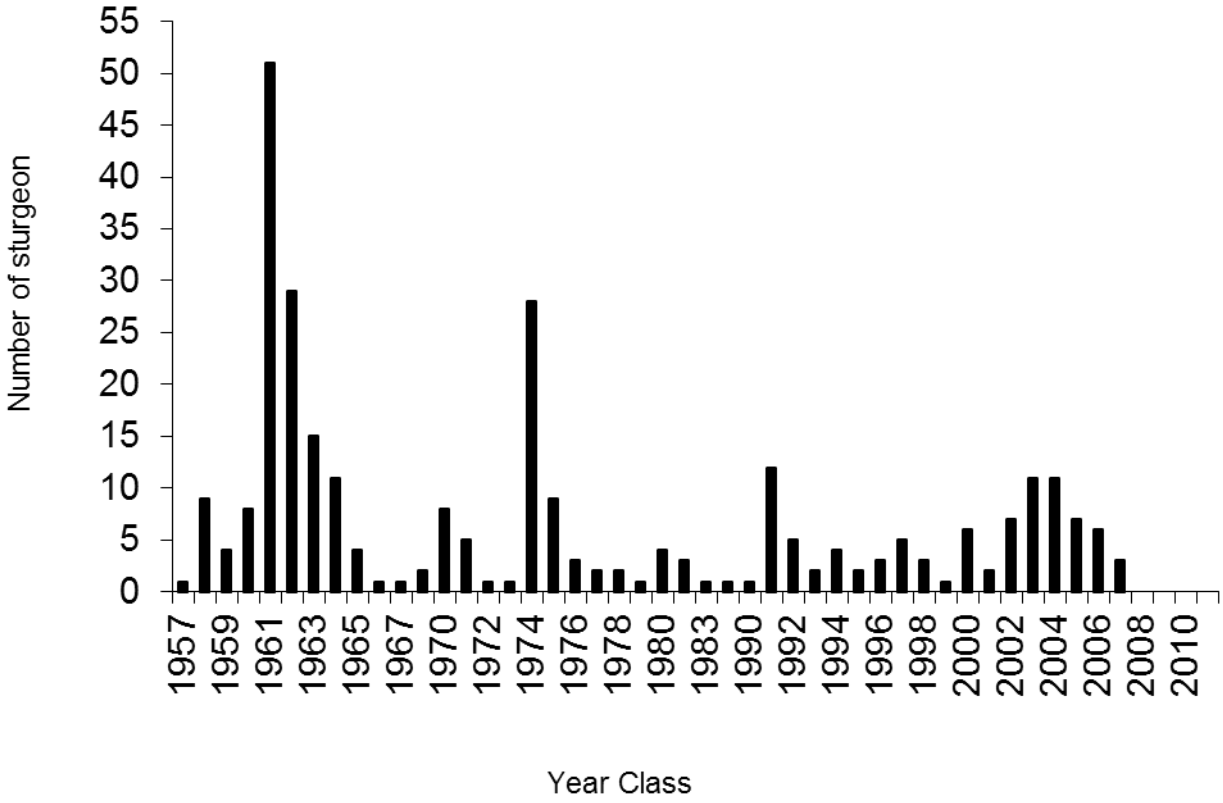


Figure 1.1.6. Number of wild juvenile White Sturgeon by age class captured in the Kootenai River, Idaho 1977-2013.

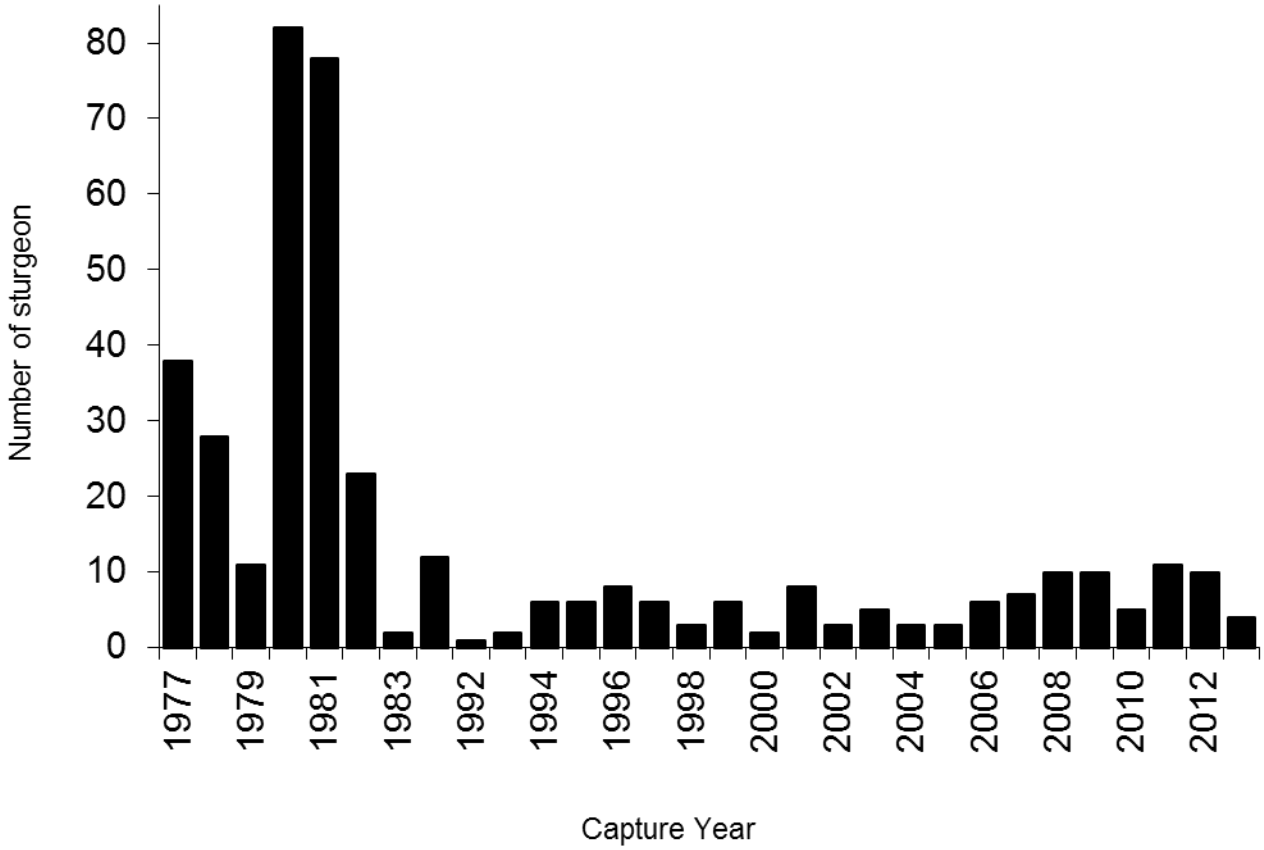
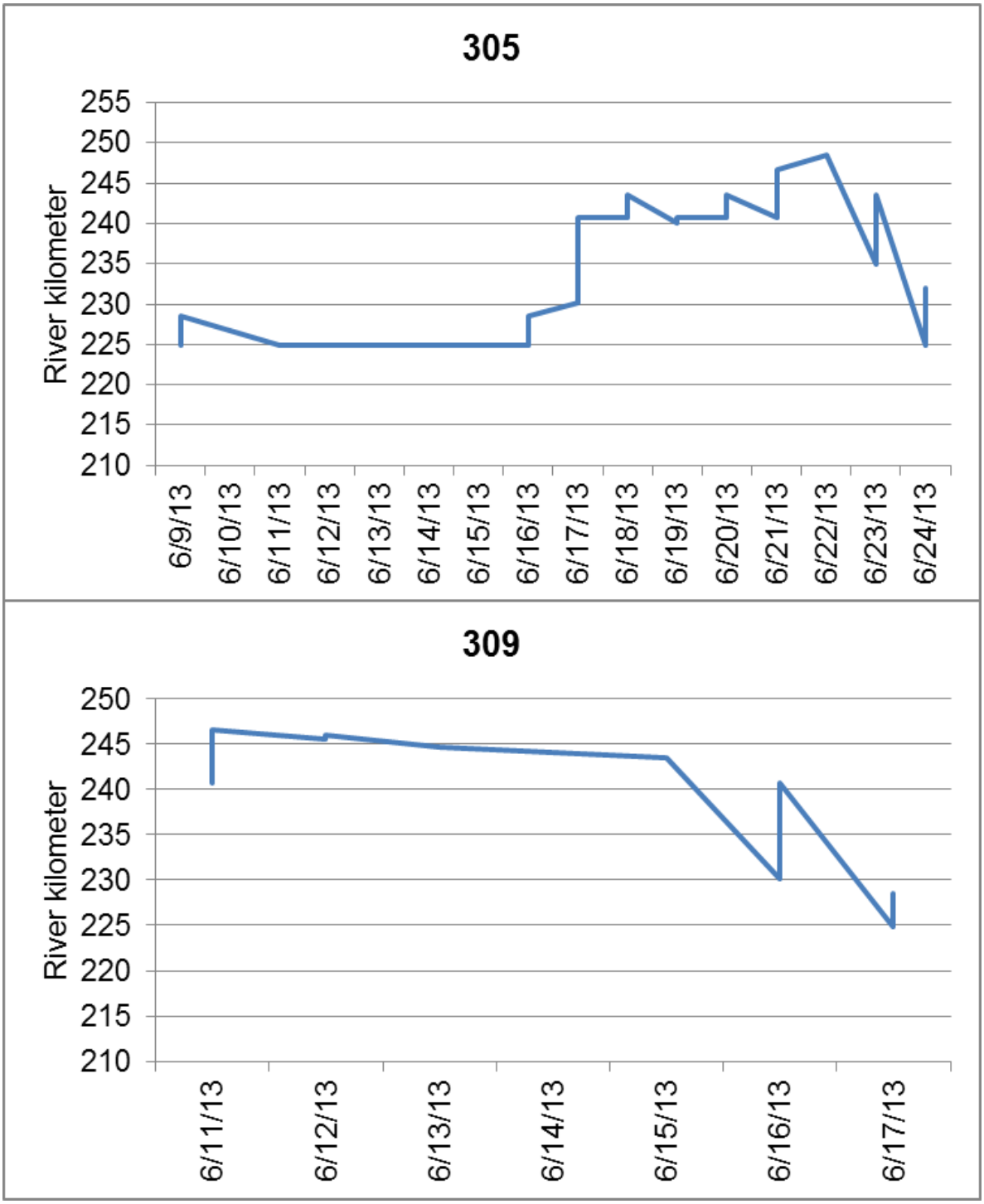


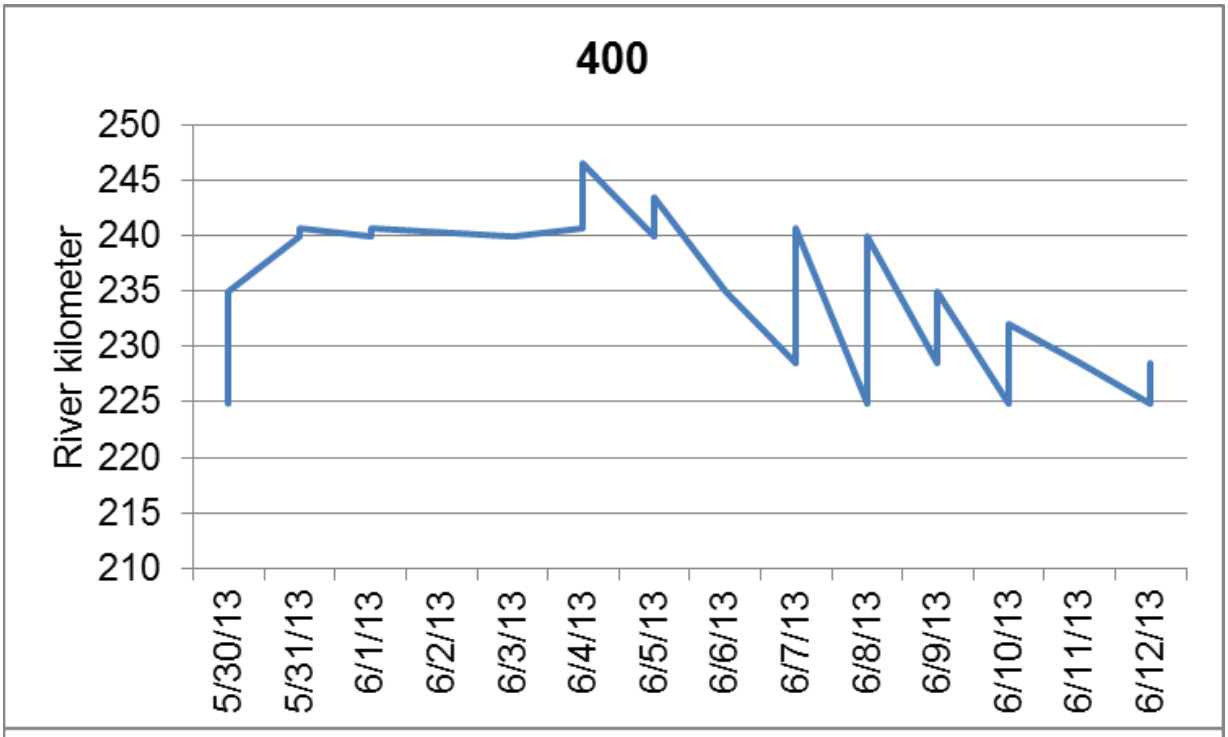
Figure 1.1.7. Number of wild juvenile White Sturgeon captured annually in the Kootenai River, Idaho, 1977-2013.

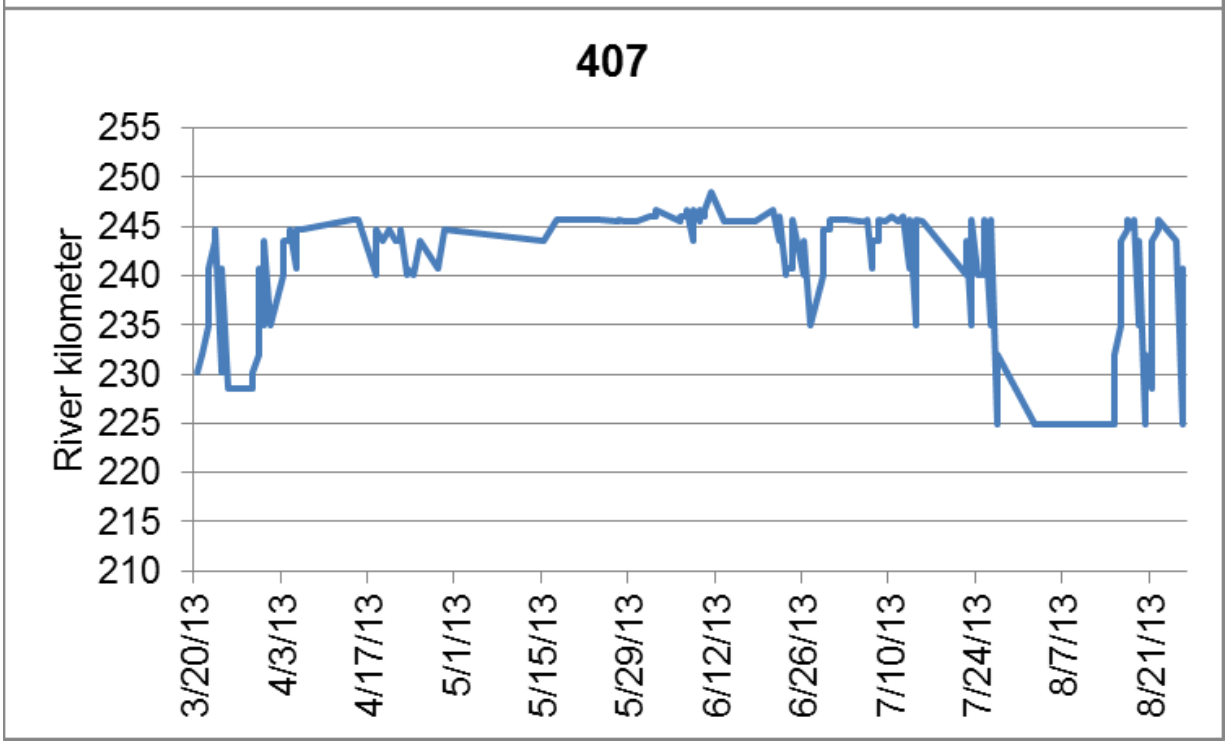
APPENDICES

Appendix 1.1.1. Movement histories of eight female White Sturgeon that migrated above Bonners Ferry during the spawning period in 2013.

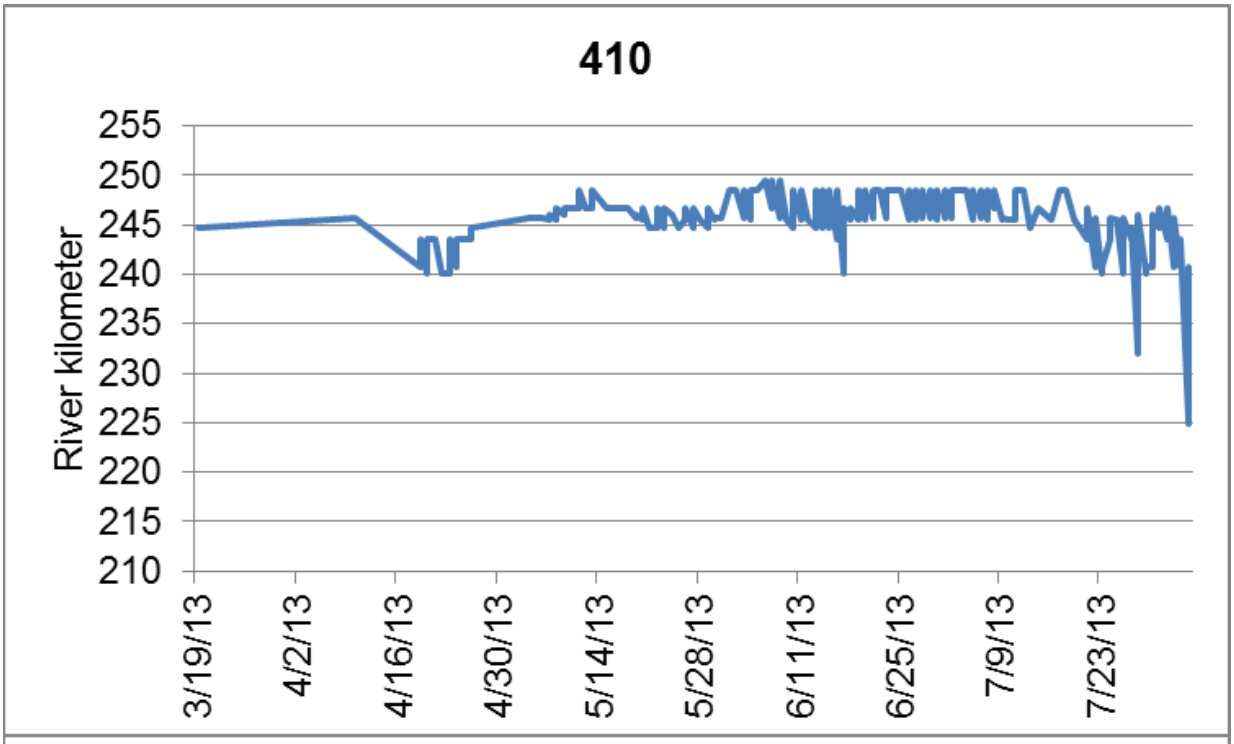


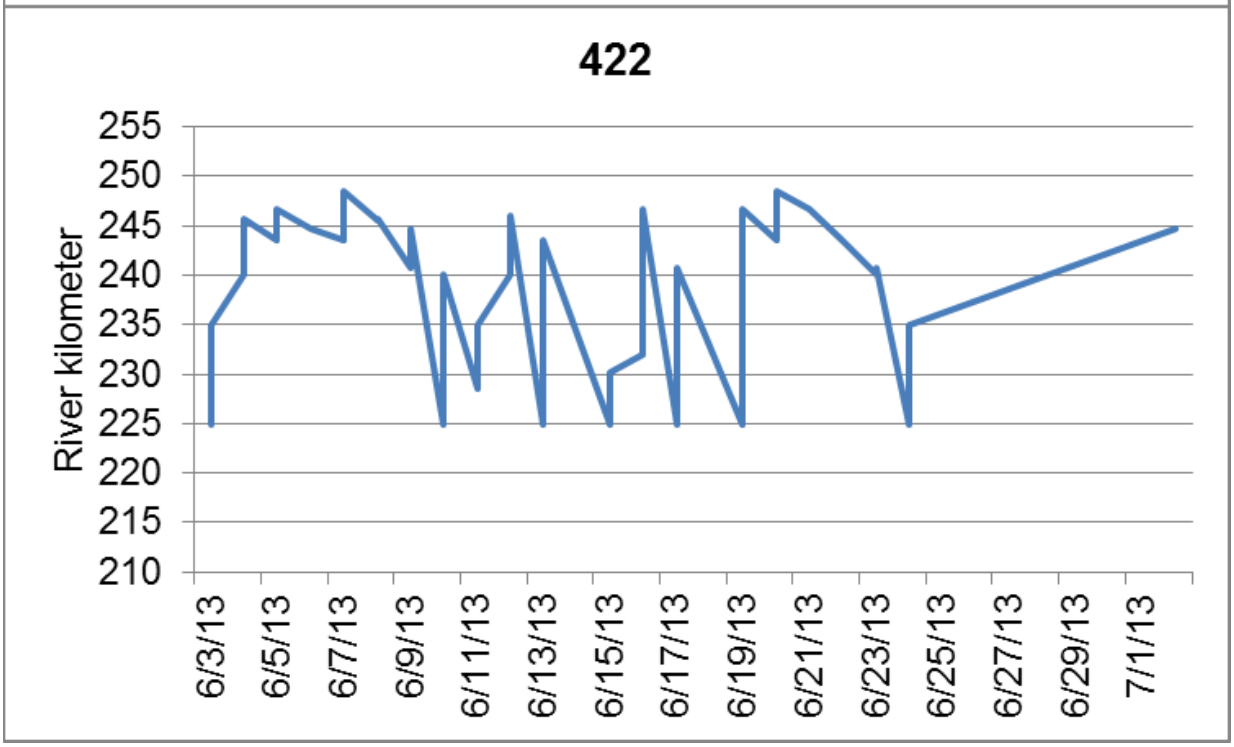
Appendix 1.1.1. Continued.



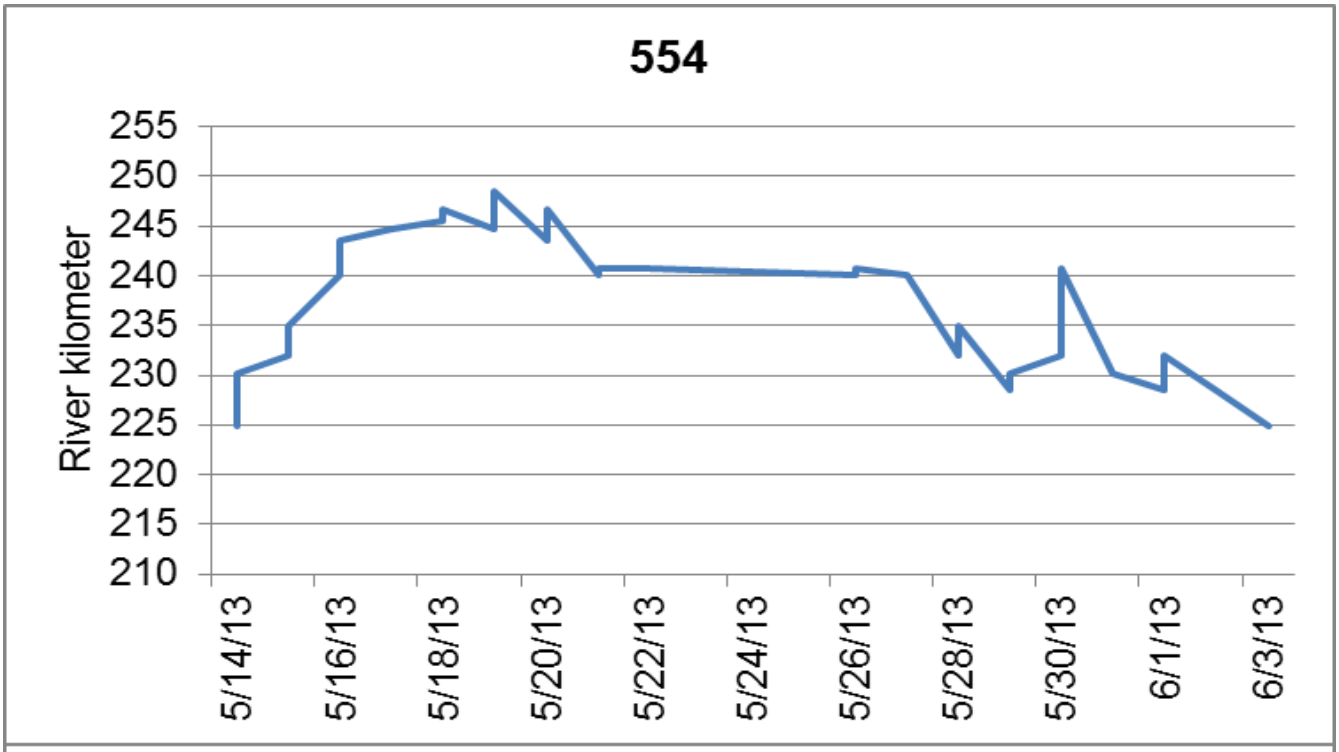


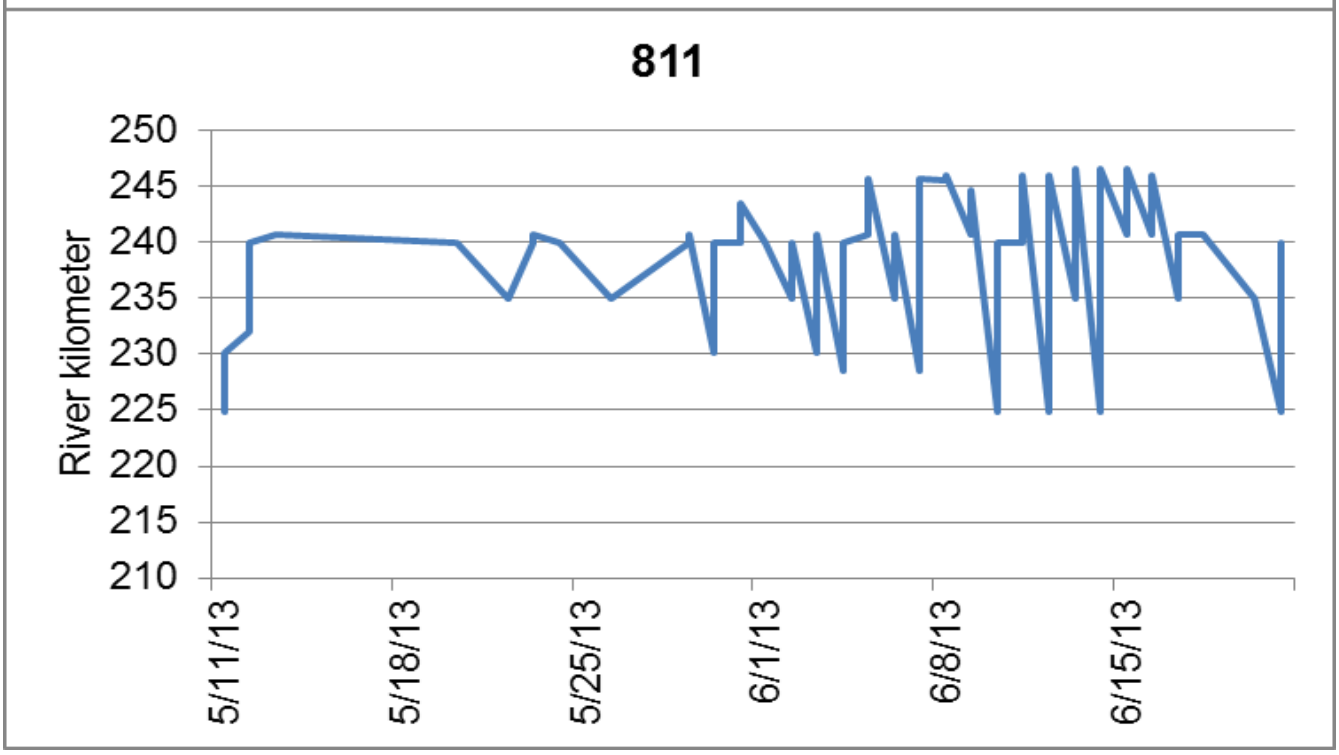
Appendix 1.1.1. Continued.





Appendix 1.1.1. Continued.





Appendix 1.1.2. Number of hatchery produced White Sturgeon juveniles released into the Kootenai River and Kootenay Lake in Idaho, Montana, and British Columbia, 1992 through fall 2013 hatchery releases.

Year class	Rearing facility [a]	Release number		Mean total length (mm) (SD[b])	Mean weight (g) (SD[b])	Release season & year
		Tagged	Untagged			
1990	KT	14	0	457 (53)	321 (112)	Summer 1992
1991	KT	104	0	255 (17)	66 (13)	Summer 1992
1992	KT	123	0	483 (113)	549 (483)	Fall 1994
1995	KT	1,075	0	228 (27)	47 (17)	Spring 1997
1995	KT	884	0	344 (44)	148 (64)	Fall 1997
1995	KT	96	0	411 (68)	288 (138)	Summer 1998
1995	KT	25	0	582 (40)	863 (198)	Summer 1999
1998	KT	309	0	260 (42)	79 (44)	Fall 1999
1999	KT	828	0	256 (22)	71 (18)	Fall 2000
1999	KH	1,358	0	248 (33)	67 (28)	Fall 2000
1999	KT	491	0	284 (54)	108 (60)	Spring 2001
1999	KH	1,583	0	306 (40)	56 (39)	Spring 2001
1999	KH	1	0	520[j]	980	Spring 2010
2000	KT	2,286	0	244 (39)	64 (31)	Fall 2001
2000	KH	1,654	0	240 (23)	58 (16)	Fall 2001
2000	KH	2,209	0	283 (29)	99 (30)	Spring 2002
2000	KH	30	0	365 (14)	195 (20)	Summer 2002
2000	KT	214	0	409 (54)	294 (110)	Fall 2002
2000	KT[c]	907	0	333 (36)	193 (63)	Jan. 2003
2000	KT[d]	10	0	558 (28)	88 (18)	Feb. 2004
2000	KT[e]	3	0	662 (61)	425 (66)	Summer 2006
2001	KT	2,672	0	200 (38)	33 (16)	Fall 2002
2001	KH	4,469	0	227 (24)	52 (17)	Fall 2002
2001	KH	1,715	0	257 (26)	72 (24)	April 2003
2001	KT[e]	1	0	570	750	Summer 2006
2001	KH[e]	1	0	560[j]	1152	Spring 2009
2002	KH	5,864	0	217 (25)	41 (14)	May 2003
2002	KT	856	0	214 (44)	42 (23)	Oct. 2003
2002	KT[f]	550	0			Nov. 2003
2002	KT	3,852	0	215 (37)	43 (20)	Winter 2003
2002	KT	3,663	0	214 (55)	43 (27)	Winter 2003-2004
2002	KT[e]	1	0	550	740	Summer 2006
2002	KH	3	0	523(25)[j]	1073(145)	Spring 2010
2002	KH	1	0	530	1020	Spring 2012
2003	KH	9,020	0	223 (26)	49 (24)	Spring 2004
2003	KH[g]	19	0	230 (27)	52 (19)	Sept. 2004
2003	KT	3,519	0	227(47)	55 (32)	Late winter 2004
2003	KT[e]	3	0	437 (27)	347 (49)	Summer 2006
2003	KT	1	0	690	[f]	Winter 2011
2004	KT[h]	0	3,000			Fall 2004
2004	KT[h]	0	1,275			Late wtr '04-early wtr '05
2004	KT[h]	0	17,723			Spring 2005
2004	KH[i]	1,238	800	196 (28)[j]	57 (33)	Spring 2005
2004	KH[h]	0	3,440			Spring 2005
2004	KT[h]	0	8,637			Summer 2005
2004	KT	1	0	510	490	Winter 2007
2004	KH[e]	5	0	452(23)[j]	563(116.5)	Spring 2009
2005	KT[h]	0	6,200			Fall 2005

Year class	Rearing facility [a]	Release number		Mean total length (mm) (SD[b])	Mean weight (g) (SD[b])	Release season & year
		Tagged	Untagged			
2005	KH[k]	14	0	299 (14)[j]	174 (28)	Spring 2006
2005	KH	1,762	0	198 (25)[j]	54 (22)	Spring 2006
2005	KH[h]	0	13,665			Spring 2006
2005	KT[h]	0	3,947			Spring 2006
2005	KT[l]	510	0	171(47)	27 (20)	Fall 2006
2005	KH[e]	1	0	330[j]	225	Spring 2009
2005	KH	2	0	400(34)[j]	414(132)	Spring 2010
2005	KH	2	0	500(42.4)	860(197)	Spring 2012
2006	KH[h]	0	6,900			Fall 2006
2006	KH[i]	0	600	149 (11)[j]	23 (5)	Fall 2006
2006	KT[h]	0	6,175			Fall 2006
2006	KH[h]	0	5,800			Spring 2007
2006	KH[i]	1,877	1,000	182 (15)[j]	44 (12)	Spring 2007
2006	KT[h]	0	12,973			Spring 2007
2006	KT	4,922	0	171 (30)	22 (11)	Winter 2007
2006	KH	1	0	390[j]	220	Spring 2010
2007	KH	2,167	0	241(24)[j]	92(27)	Spring 2008
2007	KT[i]	884	203	151(36)	20(10)	Fall 2008
2007	KT	7	0	455(46)	426(12)	Winter 2011
2008	KH	9,982	0	198(35)[j]	56(19)	Spring 2009
2008	KT[m]	3,875	882	194(52)	32(19)	Fall 2009
2008	KT	3	0	412(29)	276(74)	Winter 2011
2008	KH	1	0	430	555	Spring 2012
2009	KH	7,884	0	207(42)[j]	67(22)	Spring 2010
2009	KT[h]	5,343	808	218(39)	45(23)	Fall 2010
2010	KH	5,759	0	197(25)[j]	58(22)	Spring 2011
2010	KT	7,785	1,825	230(40)	56(29)	Winter 2011
2011	KH	11,243	0	202(20)[j]	56(22)	Spring 2012
2011	KT	10,280	907	244(34)	62(27)	Fall 2012
2012	KH	6,074	0	240(24)[j]	101((31)	Spring 2013
2012	KT[n]	132	0	265(30)	88(21)	Fall 2013
Subtotal		132,168	96,760			
Total		**228,928**				

[a] Kootenai Tribal Hatchery in Idaho (KT) or Kootenay Hatchery in British Columbia (KH).
[b] Standard deviation.
[c] Ten fish from this group held over for later upriver release with transmitters.
[d] These 10 fish were released upriver (rkm 306.5) with sonic and radio tags.
[e] These fish were held over for later release (2006-released with Vemco tags).
[f] No measurements available for these fish; exact number not known.
[g] These fish were first taken to Kokanee Creek Provincial Park, then released in September 2004.
[h] The untagged fish were not given a PIT tag or measured.
[i] The untagged fish did not have a PIT tag added and were all given fish #999.
[j] Value given is for mean fork length (mm).
[k] These fish were released upriver (299.0 and 258.7), 6 of them with Vemco sonic tags.
[l] There were 200 fish held over at KT hatchery for Biopar study.
[m] Includes KT "Children's' Release" 11/2009.
[n] Children's' Release.

Appendix 1.1.3. 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, through 2013.

Year class	Number captured	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)
1990	1	120.0	76.5	88.0	3.00
	4	205.0	55.0-81.4	63.0-95.0	1.10-2.70
	1	207.0	85.0	101.0	--
	2	208.0	85.0-87.0	101.0-104.0	4.0-7.0
	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
	3	306.5	84.6-85.6	100.7-101.0	3.78-4.06
	1	Unknown	66.5	76.1	1.95
Total 1990	**17**		**55.0-87.0**	**63.0-104.0**	**1.10-7.00**
1991	1	118.0	95.0	110.5	5.65
	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	83.5-107.0	96.0-126.0	3.80-8.0
	6	121.0	67.0-115.0	77.2-137.0	2.10-7.0
	1	134.0	82.0	94.5	4.10
	1	140.0	70.4	83.2	--
	1	141.0	118.0	137.0	16.0
	1	190.0	70.0	83.0	2.20
	1	192.0	35.1	40.8	0.16
	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
	22	205.0	26.5-84.0	30.5-100.0	0.11-3.60
	1	205.4	51.0	60.0	1.10
	4	205.5	47.0-76.0	56.0-89.1	0.69-3.10
	1	207.0	81.0	96.5	3.70
	1	208.0	85.0	99.0	4.20
	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
	2	227.5	63.0-73.0	74.0-88.0	2.0-3.0
	1	244.5	--	35.0	0.07
Total 1991	**120**		**26.5-118.0**	**30.5-137.0**	**0.07-16.00**
1992	2	18.0	107.5-120.0	126.0-137.0	7.95-28.0
	3	118.0	80.0-97.5	95.0-110.0	3.4-5.95

Year class	Number captured	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)
	4	119.0	61.0-102.0	69.0-118.0	1.20-5.5
	5	120.0	45.0-104.0	52.0-123.0	2.20-8.0
	6	121.0	77.0-111.0	92.0-129.0	3.19-7.7
	1	122.5	130.0	151.0	20.0
	5	123.0	78.0-105.3	90.5-124.7	3.3-6.95
	1	134.0	77.1	90.5	2.95
	2	161.0	67.3-87.5	77.5-110.0	2.10-4.2
	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	--
	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
	15	215.5	50.2-74.3	57.9-87.4	0.11-2.44
	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
	2	216.0	49.0-67.5	56.0-78.6	0.70-1.78
	1	216.9	64.0	75.0	2.3
	2	217.1	30.0-36.0	35.0-44.0	0.35-0.51
	1	224.5	56.5	66.5	1.16
	1	224.9	69.5	80.5	1.68
	10	225.0	31.0-78.0	37.0-94.0	0.35-2.95
	5	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
	2	229.0	46.0-68.0	55.0-80.0	0.55-4.0
	1	231.0	66.0	77.0	2.0
	1	231.1	71.0	85.0	2.3
	2	306.0	75.0-83.0	86.2-95.5	2.31-3.17
	1	306.5	74.8	86.5	2.38
Total 1992	**137**		**30.0-130.0**	**35.0-151.0**	**0.11-28.00**
1995	1	17.0	125.0	146.0	14.5
	5	18.0	99.5-122.5	121.0-141.5	7.5-13.0
	5	118.0	63.1-74.0	72.6-84.6	1.8-3.05
	3	119.0	49.0-58.0	56.5-67.1	0.70-1.27
	36	120.0	56.5-96.0	65.5-107.0	0.82-5.40
	37	121.0	43.9-111.0	50.0-131.5	0.53-9.20
	1	122.5	131.0	147.5	18.50
	8	123.0	65.2-88.5	70.1-100.2	1.30-5.35
	10	130.0	38.0-104.2	43.9-120.0	0.46-7.65
	3	134.0	49.0-70.5	57.0-81.3	0.73-2.40
	1	137.0	50.9	59.2	0.76

Year class	Number captured	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)
	2	141.0	53.8-85.1	60.4-100.5	0.83-4.55
	1	144.3	39.8	45.3	0.38
	2	144.5	29.0-45.5	33.5-52.0	0.14-0.56
	6	145.0	42.5-117.0	50.0-136.5	0.50-15.00
	1	150.0	88.5	100.0	4.25
	1	157.0	54.1	62.6	0.99
	1	157.5	33.2	37.3	0.18
	3	161.0	45.6-51.0	51.8-59.5	0.44-.70
	2	163.0	35.2-49.1	41.7-56.9	0.24-0.73
	1	165.0	92.0	103.0	5.0
	1	174.2	58.8	67.9	1.04
	1	174.5	52.4	60.7	0.77
	1	176.0	33.9	40.0	0.20
	4	176.3	24.7-49.0	40.0-58.1	0.15-0.68
	4	176.4	42.5-51.0	50.0-59.0	0.42-0.71
	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
	2	185.0	39.1-58.3	43.3-68.5	0.33-1.25
	1	189.9	51.5	59.5	0.74
	23	190.0	31.0-72.0	36.0-83.9	0.15-2.22
	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
	3	190.5	53.3-62.4	62.4-73.1	0.90-1.53
	1	191.9	35.7	41.3	0.20
	2	192.0	34.7-61.4	38.2-71.8	0.18-1.49
	1	192.1	36.1	42.0	0.25
	1	193.0	65.0	75.5	1.61
	3	193.2	57.8-69.9	67.7-79.5	1.14-2.31
	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
	6	204.0	37.9-61.0	43.5-70.0	0.27-1.39
	1	204.1	39.0	45.0	0.35
	1	204.3	44.0	51.0	0.55
	3	204.7	43.0-54.3	49.8-63.6	0.43-1.00
	5	204.8	35.4-50.3	41.2-58.4	0.26-0.67
	6	204.9	35.2-48.0	41.2-55.2	0.20-0.62
	177	205.0	30.8-99.0	35.0-114.0	0.15-8.0
	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
	29	207.0	45.8-96.0	52.5-111.0	0.54-7.0
	20	207.5	44.6-101.0	51.3-116.0	0.47-10.00
	2	207.8	28.4-39.5	33.0-45.9	0.15-0.3
	6	208.0	70.0-102.0	82.0-117.0	2.50-8.00
	1	213.0	81.0	94.0	4.00
	3	213.2	37.0-58.1	43.0-67.0	0.30-1.17
	1	213.5	58.6	67.6	1.13
	59	215.0	33.1-91.0	37.8-108.0	0.10-6.00
	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
	150	215.5	25.5-64.8	29.1-74.0	0.06-1.32
	40	215.6	30.0-48.9	34.2-56.8	0.13-0.60

Year class	Number captured	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)
	61	215.7	25.0-54.8	29.0-63.8	0.05-0.93
	8	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
	4	224.6	29.4-37.4	33.0-42.0	0.15-0.35
	13	224.7	29.8-50.9	34.4-58.7	0.16-0.95
	16	224.8	31.9-50.1	36.2-59.3	0.18-0.76
	24	224.9	30.4-64.0	34.2-74.0	0.15-1.70
	113	225.0	21.0-77.0	24.0-86.0	0.05-5.40
	33	225.1	28.0-55.0	32.0-64.2	0.09-0.98
	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
	6	227.0	29.5-106.0	33.5-127.0	0.10-7.00
	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	229.0	59.0	69.0	5.00
	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	230.0	64.0	75.0	--
	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	234.1	38.0	44.4	0.30
	1	234.2	66.0	77.0	1.00
	3	234.3	33.2-35.0	37.0-39.0	0.16-0.19
	2	234.4	25.0-37.0	29.0-42.0	0.09-0.20
	5	234.5	24.0-52.0	27.0-60.2	0.06-0.83
	1	235.5	34.2	39.0	0.21
	1	236.0	33.2	38.8	0.20
	1	237.0	48.9	55.7	0.60
	1	241.5	31.0	36.0	0.14
	5	244.0	56.8-66.0	66.2-76.3	0.98-1.67
	10	244.4	24.9-44.0	28.8-50.5	0.06-0.55
	20	244.5	24.8-75.0	33.3-86.0	0.10-2.16
	5	244.6	31.5-63.7	36.6-73.6	0.13-1.08
	1	244.7	--	61.4	0.85
	1	244.8	45.1	52.6	0.60
	1	257.4	67.3	77.1	1.93
	2	278.8	61.3-75.5	71.4-88.0	1.49-2.81
	2	300.3	80.1-87.9	91.0-100.5	3.63-4.46
	1	301.3	87.3	99.6	6.15
	4	305.0	83.3-95.8	96.3-109.0	4.19-6.98
	4	305.5	68.7-93.0	79.2-104.5	2.12-5.65
	1	306.0	68.0	78.0	1.87
	37	306.5	59.9-110.8	68.5-122.3	1.10-10.99
	9	Unknown	21.0-55.5	25.5-65.3	0.06-1.13
Total 1995	**1,250**		**21.0-131.0**	**24.0-147.5**	**0.05-18.50**
1998	3	120.0	71.0-78.0	83.0-92.0	2.50
	1	121.0	86.0	98.9	--

Year class	Number captured	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)
	1	145.0	28.5	31.1	0.13
	1	150.0	56.6	66.5	1.10
	1	193.5	50.0	57.6	0.71
	1	204.0	38.4	44.4	0.28
	10	205.0	30.0-59.1	35.0-69.4	0.13-1.28
	2	207.0	45.2-58.4	53.1-69.1	0.53-1.34
	1	207.5	69.0	81.0	1.58
	1	213.2	35.5	41.5	0.24
	1	213.5	37.7	43.2	0.28
	8	215.0	36.1-99.0	52.0-117.0	0.51-9.00
	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
	8	225.0	27.0-56.9	31.6-66.0	0.06-1.25
	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	1.10
	2	230.9	23.5-25.0	28.0-29.5	0.07-0.08
	6	244.5	40.7-76.0	47.4-90.0	0.35-4.12
	1	278.8	102.0	116.0	9.43
	1	300.3	70.3	81.5	2.37
	1	305.0	64.0	74.5	1.43
	1	305.5	73.4	85.8	2.83
	1	306.0	72.2	82.5	2.45
	2	306.5	84.7-84.8	99.8	4.56-4.63
Total 1998	**77**		**22.5-102.0**	**26.4-117.0**	**0.06-9.43**
1999	9	18.0	73.0-113.2	83.5-131.2	2.60-12.50
	54	118.0	42.3-74.0	49.5-86.6	0.47-3.25
	2	119.0	--	39.0-45.2	0.24-0.38
	136	120.0	29.1-95.5	33.9-110.0	0.16-6.60
	157	121.0	29.5-98.2	34.0-115.5	0.17-6.10
	1	122.0	78.7	90.2	3.05
	1	122.5	84.0	98.0	3.20
	32	123.0	32.1-107.8	37.5-125.3	0.19-8.40
	26	130.0	27.6-88.0	31.8-100.5	0.12-5.20
	9	134.0	31.3-40.5	36.5-47.0	0.17-0.38
	7	137.0	28.3-71.4	33.4-83.0	0.14-2.70
	5	141.0	48.8-83.5	57.1-97.2	0.60-3.85
	1	144.1	--	37.0	0.02
	1	144.8	53.9	62.4	0.90
	21	145.0	26.5-81.0	31.1-92.5	0.11-3.75
	1	147.0	22.4	25.9	0.10
	7	150.0	32.0-83.0	40.5-95.5	0.22-4.20
	1	152.7	33.8	39.5	0.24
	1	154.3	22.2	26.7	0.10
	2	154.5	26.4	31.2	0.10-0.12
	7	157.0	31.2-86.0	36.9-99.5	0.19-4.90
	23	161.0	27.4-86.0	31.9-101.0	0.12-3.90
	2	161.4	61.7-86.4	71.1-99.4	1.45-4.65
	2	163.0	29.0	33.1-34.3	0.18
	8	165.0	27.2-51.2	31.0-59.8	0.14-0.90
	2	167.0	32.1-32.7	37.1-38.1	0.16-0.20
	1	169.0	26.0	30.2	0.15

Year class	Number captured	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)
	3	169.6	21.0-22.7	24.5-26.5	0.05-0.10
	3	170.0	--	--	--
	1	170.2	37.2	44.4	0.20
	1	173.2	--	41.5	0.30
	2	174.0	46.0-57.4	53.7-67.0	0.55-1.06
	2	174.2	45.2-51.9	52.2-59.8	0.54-0.83
	28	174.5	24.1-33.4	28.3-38.9	0.04-0.20
	1	175.2	--	31.0	0.13
	1	176.0	59.5	69.2	1.37
	1	176.1	35.7	42.4	0.25
	1	176.4	26.5	30.5	0.10
	3	176.5	24.5-54.4	28.5-63.7	0.07-1.07
	1	176.9	31.3	36.3	0.17
	5	182.0	30.1-38.5	35.6-44.5	0.15-0.29
	5	185.0	44.1-53.9	50.7-62.9	0.5-0.95
	1	189.9	29.0	34.0	0.13
	59	190.0	23.0-58.7	26.5-69.7	0.06-1.14
	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
	3	190.5	47.1-49.5	54.6-57.4	0.57-0.69
	7	192.0	28.5-51.1	33.0-59.7	0.15-0.75
	3	193.0	46.5-49.2	54.3-57.3	0.61-0.76
	1	193.2	52.2	60.9	0.78
	2	193.5	48.3-48.7	55.4-56.5	0.48-0.62
	1	194.0	52.0	60.6	0.82
	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
	12	195.9	23.0-33.5	26.5-39.2	0.07-0.17
	6	196.0	25.5-33.5	30.0-38.5	0.05-0.23
	8	203.5	27.5-52.5	32.1-60.7	0.12-0.73
	12	204.0	30.5-51.5	35.6-59.7	0.15-86
	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
	296	205.0	19.5-85.0	28.5-99.0	0.05-4.22
	1	205.3	28.0	32.0	0.10
	1	205.4	24.0	29.3	0.05
	49	205.5	25.6-51.5	29.1-60.0	0.11-0.88
	53	207.0	34.4-62.9	40.1-74.0	0.45-1.39
	16	207.5	43.5-57.4	50.8-71.0	0.53-1.14
	10	208.0	27.1-87.0	31.4-104.0	0.12-7.00
	1	213.0	51.9	60.9	0.87
	4	213.2	29.6-40.6	33.6-47.3	0.15-0.35
	1	213.5	31.0	36.1	0.18
	141	215.0	34.5-62.7	39.6-72.1	0.23-1.39
	1	215.4	--	35.5	0.10
	89	215.5	20.9-83.6	31.5-98.0	0.14-4.06
	2	215.6	61.0-66.0	73.0-77.0	1.6-2.0
	1	216.0	28.9	33.6	0.11
	1	219.0	51.4	59.0	0.70
	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
	48	225.0	23.2-64.0	26.1-75.0	0.07-1.24
	1	225.1	26.5	30.7	0.12
	4	230.0	27.0-44.0	26.6-51.2	0.08-0.47

Year class	Number captured	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)
	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
	7	244.0	42.3-62.3	49.3-72.4	0.47-1.43
	15	244.5	27.5-57.5	27.3-66.8	0.10-1.17
	2	244.6	47.1-58.7	54.0-68.2	0.58-1.07
	2	300.3	58.5-67.3	67.0-77.0	1.09-2.06
	1	305.0	70.8	81.0	2.15
	12	306.5	51.5-94.2	59.7-108.5	0.73-6.95
	89	Unknown	19.0-39.0	22.0-44.2	0.05-0.90
Total 1999	**1,616**		**19.0-113.2**	**22.0-131.0**	**0.02-12.50**
2000	9	18.0	70.4-106.0	80.6-127.2	1.75-7.60
	1	76.0	25.6	31.0	0.11
	19	118.0	36.9-67.0	42.1-77.7	0.29-1.65
	88	120.0	26.3-87.1	30.9-100.2	0.12-3.80
	90	121.0	26.4-89.0	30.4-104.5	0.12-5.90
	1	122.0	70.0	79.0	--
	19	123.0	29.5-93.6	34.3-109.4	0.14-5.40
	25	130.0	25.1-70.6	29.3-84.5	0.09-2.55
	2	134.0	36.5-42.5	42.5-49.2	0.25-0.48
	2	137.0	28.2-42.0	32.6-48.3	0.11-0.51
	4	141.0	30.8-39.0	34.8-46.0	0.14-0.31
	7	145.0	31.1-84.3	33.2-98.0	0.15-3.75
	4	150.0	29.3-45.0	34.0-52.8	0.19-0.62
	6	157.0	23.5-94.5	27.0-113.0	0.09-7.20
	10	161.0	21.8-49.5	24.5-56.2	0.07-0.80
	3	163.0	25.5-29.0	29.6-33.5	0.13-0.14
	10	165.0	26.0-41.0	29.7-48.0	0.09-0.45
	4	167.0	27.2-35.5	31.4-41.5	0.10-0.26
	1	170.2	27.9	32.2	0.50
	4	174.0	38.9-53.0	44.8-61.0	0.34-0.86
	1	174.2	38.0	43.9	0.32
	1	176.0	50.8	58.3	0.90
	2	182.0	29.2-29.4	33.5-34.7	0.13-0.15
	3	185.0	40.0-42.7	46.3-50.1	0.36-0.47
	13	190.0	26.1-49.4	30.6-53.8	0.08-0.74
	2	190.3	25.5-29.0	30.9-33.6	0.09-0.14
	2	190.5	39.5-40.9	45.6-47.9	0.43-0.45
	4	192.0	30.0-41.9	35.0-48.4	0.14-0.47
	4	193.0	38.6-70.5	44.4-80.5	0.32-2.08
	3	193.2	36.1-49.8	41.7-57.9	0.30-0.78
	6	193.5	37.4-45.8	42.2-52.6	0.14-0.51
	5	195.8	26.5-34.2	32.3-40.2	0.11-0.27
	1	204.0	37.0	43.1	0.03
	110	205.0	21.0-57.6	26.2-66.9	0.05-1.24
	26	205.5	24.1-42.7	28.0-49.2	0.08-0.42
	24	207.0	33.6-53.2	38.5-62.2	0.29-0.89
	13	207.5	41.1-57.4	47.9-69.0	0.44-1.16
	2	208.0	25.6-32.0	30.0-37.5	0.10-0.19
	1	210.0	34.2	40.4	0.23
	1	213.0	51.5	60.0	0.83
	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
	46	215.0	30.2-54.5	33.8-64.2	0.13-0.78
	1	215.2	--	33.0	0.10
	25	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

Year class	Number captured	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)
	36	225.0	26.1-53.7	30.5-63.0	0.09-1.04
	1	227.8	24.3	27.8	0.09
	1	230.5	32.9	37.5	0.21
	5	244.0	38.7-47.9	45.6-55.8	0.38-0.82
	8	244.5	33.6-59.9	49.5-68.8	0.54-1.42
	3	244.6	45.3-48.5	52.3-56.2	0.56-0.80
	1	301.7	61.5	70.1	1.67
	2	305.5	60.4-65.5	68.6-75.8	1.57-1.61
	9	306.5	46.8-90.0	55.3-103.2	0.59-6.20
	3	Unknown	28.0-32.2	32.4-38.0	0.12-0.18
Total 2000	**704**		**21.0-106.0**	**24.5-127.2**	**0.03-7.60**
2001	4	18.0	51.0-100.0	59.5-120.0	0.90-8.00
	4	118.0	36.6-64.1	43.0-73.4	0.27-1.95
	24	120.0	42.8-83.0	49.6-95.7	0.51-3.80
	30	121.0	41.5-82.8	48.6-96.1	0.40-4.00
	6	123.0	33.6-65.5	38.8-76.0	0.20-2.08
	1	137.0	64.0	73.0	1.80
	1	144.8	56.0	65.0	1.05
	1	145.0	70.0	81.0	2.20
	1	161.0	18.9	21.9	0.04
	2	185.0	39.5-48.3	46.1-56.1	0.46-0.65
	3	190.0	31.5-40.8	36.6-47.9	0.19-0.36
	1	192.0	34.9	39.4	0.22
	1	193.0	54.4	64.0	0.98
	2	195.8	21.9	25.2	0.06
	2	203.5	40.9-42.0	47.6-49.1	0.18-0.34
	3	204.0	35.5-38.0	41.8-44.2	0.25-0.30
	21	205.0	25.0-49.4	28.2-57.0	0.08-0.64
	3	205.5	23.6-29.1	27.2-33.7	0.08-0.13
	8	207.0	35.3-47.4	41.3-54.5	0.33-0.57
	6	207.5	44.6-48.7	25.6-56.3	0.05-0.64
	2	213.0	43.9-59.0	51.2-69.2	0.50-1.17
	1	213.2	23.0	26.5	0.07
	1	213.5	24.5	28.9	0.09
	27	215.0	28.9-53.5	30.9-62.1	0.14-0.67
	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
	12	225.0	18.2-47.4	20.6-55.2	0.04-0.58
	1	228.5	22.7	26.6	0.06
	4	244.0	44.1-52.9	51.6-60.6	0.51-0.81
	1	244.5	40.0	47.1	0.34
	1	306.5	52.0	59.6	0.81
Total 2001	**186**		**18.2-100.0**	**20.6-120.0**	**0.04-8.00**
2002	4	18.0	47.5-118.0	54.7-135.0	0.60-1300
	2	118.0	51.5-53.0	61.0-62.8	0.89-1.10
	18	120.0	26.0-95.0	30.1-111.0	0.10-6.60
	40	121.0	24.5-81.1	27.5-94.0	0.08-3.80
	9	123.0	26.0-77.0	30.1-89.2	0.08-2.85
	5	130.0	22.0-67.0	25.7-78.2	0.07-2.30
	1	134.0	24.0	27.9	0.09
	2	137.0	26.4-54.2	30.6-63.2	0.10-1.20
	2	141.0	34.5-34.6	39.4-39.5	0.23
	4	145.0	20.8-23.4	24.1-27.1	0.05-0.08
	4	161.0	24.1-57.2	27.8-67.0	0.07-1.14
	2	163.0	19.0-21.9	22.2-25.2	0.030.06

Year class	Number captured	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)
	3	165.0	22.2-23.6	26.1-27.3	0.05-0.07
	1	167.0	21.0	24.0	0.05
	1	176.5	34.4	40.2	0.24
	1	177.5	36.6	41.9	0.31
	3	190.0	29.3-43.7	33.5-51.3	0.14-0.52
	3	205.0	27.5-117.0	31.6-138.0	0.11-16.00
	2	205.5	27.7	31.4	0.10-0.13
	1	207.0	35.0	40.2	0.24
	1	225.0	40.0	46.0	0.44
	4	306.5	70.9-72.3	83.5-85.2	2.64-2.93
Total 2002	**113**		**19.0-118.0**	**22.2-138.0**	**0.03-16.00**
2003	4	18.0	63.0-80.0	73.0-92.3	1.65-3.40
	4	118.0	33.8-36.0	39.0-42.0	0.21-0.27
	84	120.0	30.0-87.5	35.0-99.0	0.13-4.20
	127	121.0	21.0-84.0	24.8-98.1	0.08-4.50
	1	122.0	73.0	85.0	2.20
	1	122.5	67.0	80.0	1.80
	45	123.0	22.5-70.0	26.14-82.0	0.06-2.80
	74	130.0	20.2-79.5	23.4-92.5	0.04-3.10
	25	134.0	19.5-41.5	23.0-48.3	0.05-0.38
	14	137.0	21.3-40.5	24.6-47.3	0.04-0.44
	20	141.0	20.0-70.8	23.1-82.5	0.06-2.40
	1	141.5	61.5	83.4	1.75
	1	144.5	--	43.1	0.26
	3	144.8	42.4-70.7	48.5-83.4	0.50-2.40
	80	145.0	19.0-64.5	22.1-74.8	0.04-1.70
	38	150.0	17.8-41.5	20.8-48.2	0.03-0.47
	6	157.0	20.6-39.0	24.1-45.5	0.07-0.34
	1	157.3	44.5	51.1	0.55
	55	161.0	19.5-43.0	22.8-50.0	0.03-0.51
	1	161.4	51.1	59.4	0.65
	14	163.0	20.9-36.6	23.8-42.5	0.04-0.33
	21	165.0	20.7-42.5	24.0-49.3	0.05-0.46
	7	167.0	22.5-35.5	22.5-41.6	0.07-0.29
	2	170.0	35.4-36.9	40.7-43.4	0.15-0.19
	4	174.0	37.1-41.1	43.5-48.2	0.31-0.41
	2	174.2	41.7-42.2	48.8-49.3	0.33-0.48
	2	176.5	29.3-35.5	40.9-46.1	0.27-0.42
	14	185.0	23.9-41.8	29.6-49.1	0.13-0.43
	1	188.0	32.5	37.7	0.21
	55	190.0	28.0-48.3	32.7-55.6	0.13-0.69
	7	190.5	33.5-51.8	39.2-60.4	0.23-0.85
	6	192.0	20.4-50.4	29.6-59.4	0.08-0.78
	5	193.0	27.4-42.9	38.1-50.0	0.20-0.52
	3	193.2	38.4-42.5	44.7-49.6	0.35-0.50
	5	193.5	31.9-41.0	37.4-47.4	0.12-0.41
	3	203.5	33.5-44.1	39.3-50.9	0.24-0.43
	4	204.0	31.0-35.7	36.1-41.5	0.02-0.22
	88	205.0	26.9-56.8	30.5-65.4	0.11-1.08
	52	207.0	29.9-54.3	36.8-63.0	0.22-1.03
	33	207.5	33.2-55.1	39.0-64.0	0.22-1.00
	2	208.0	45.0-62.0	54.0-73.0	0.60-1.20
	124	215.0	22.5-57.0	26.5-66.6	0.07-1.12
	17	215.5	41.1-53.7	47.6-63.0	0.44-1.01
	33	225.0	25.8-53.1	29.7-62.7	0.11-0.97
	1	230.0	31.2	36.8	0.18
	9	244.0	38.0-54.4	43.4-62.9	0.31-0.96
	6	244.5	41.1-51.7	49.1-60.7	0.18-0.82

Year class	Number captured	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)
	5	244.6	32.4-56.2	37.9-65.1	0.17-0.89
	1	257.4	50.3	59.0	0.81
	1	301.7	52.9	61.4	0.94
	1	305.0	73.9	86.3	2.80
	1	305.5	57.5	66.0	1.08
	9	306.5	47.4-61.3	55.1-69.9	0.73-1.47
	1	Unknown	21.0	25.0	0.07
Total 2003	**1,124**		**17.8-87.5**	**20.8-99.0**	**0.02-4.50**
2004	1	118.0	27.9	32.1	0.11
	6	120.0	43.0-69.5	50.0-82.0	1.05-3.20
	8	121.0	42.0-78.4	49.3-91.9	0.55-3.15
	5	123.0	26.2-57.4	31.3-66.5	0.09-1.30
	10	130.0	23.6-55.2	27.5-65.0	0.08-0.65
	1	134.0	23.8	28.4	0.07
	4	141.0	20.5-21.5	23.5-25.3	0.04-0.06
	1	144.8	36.9	43.2	0.29
	12	145.0	19.0-47.6	22.0-56.6	0.02-0.57
	4	150.0	17.8-31.0	21.0-35.1	0.04-0.15
	2	157.0	25.5-28.0	29.6-30.5	0.08-0.12
	5	161.0	24.0-29.2	27.9-34.2	0.07-0.14
	1	161.4	39.2	45.8	0.38
	2	165.0	28.0-30.0	32.6-35.2	0.11-0.15
	2	167.0	29.0-29.4	33.4-34.3	0.12-0.16
	1	174.0	35.4	40.5	0.28
	1	174.2	38.0	43.9	0.29
	1	185.0	36.2	42.0	0.30
	1	190.0	32.1	37.3	0.13
	3	193.0	31.2-33.6	35.5-39.3	0.18-0.23
	5	193.5	26.8-34.5	30.6-40.2	0.01-.20
	2	204.0	25.9-30.0	30.0-33.5	0.09-0.12
	8	205.0	24.9-48.6	29.1-56.1	0.09-0.73
	4	207.0	28.0-41.2	32.7-48.0	0.13-0.42
	1	207.5	40.5	48.4	0.39
	1	213.0	53.1	62.4	0.96
	5	215.0	32.9-42.5	37.9-49.7	0.22-0.54
	2	215.5	35.5-41.2	41.9-47.5	0.25-0.40
	11	225.0	25.6-45.5	26.0-53.4	0.06-0.62
	8	244.0	23.5-55.2	27.2-64.7	0.07-1.05
	9	244.5	25.4-50.0	29.9-58.0	0.09-0.81
	6	244.6	34.2-44.0	40.3-51.6	0.21-0.48
	1	245.5	46.9	55.1	0.68
Total 2004	**134**		**17.8-78.4**	**21.0-91.9**	**0.01-3.20**
2005	44	120.0	23.1-69.0	27.3-81.5	0.06-1.80
	33	121.0	38.5-69.9	45.5-80.9	0.31-2.40
	7	123.0	42.4-55.0	50.1-65.0	0.50-1.30
	18	130.0	23.3-63.8	26.8-73.4	0.06-1.65
	1	134.0	22.6	26.5	0.06
	8	137.0	25.0-36.5	30.0-43.4	0.07-0.26
	12	141.0	20.5-31.2	24.0-36.8	0.04-0.18
	1	141.5	35.9	42.0	0.28
	1	144.8	37.3	44.3	0.35
	25	145.0	19.5-44.5	23.2-56.5	0.04-0.60
	2	150.0	27.7-30.0	32.7-35.2	0.12-0.16
	1	157.0	25.5	30.7	0.09
	13	161.0	21.3-37.5	22.9-43.5	0.05-0.31
	2	163.0	20.9-24.1	24.5-28.8	0.04-0.09
	6	165.0	23.0-31.3	27.0-36.3	0.06-0.17

Year class	Number captured	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)
	1	167.0	31.0	36.0	0.16
	1	177.5	31.4	37.1	0.17
	1	185.0	35.1	41.8	0.26
	8	190.0	20.8-36.4	23.2-42.8	0.05-0.27
	3	190.5	29.5-39.1	35.0-45.8	0.14-0.33
	3	192.0	22.6-24.3	26.9-27.6	0.06-0.08
	5	193.0	25.8-32.7	33.3-38.3	0.15-0.19
	5	193.5	25.3-29.4	29.5-34.6	0.06-0.10
	9	204.0	19.5-25.5	22.6-29.2	0.03-0.08
	15	205.0	20.5-42.6	23.7-50.0	0.05-0.40
	4	207.0	25.0-36.3	28.9-43.2	0.06-0.28
	3	207.5	31.8-38.4	37.4-44.9	0.19-0.31
	1	213.0	39.3	46.5	0.40
	15	215.0	28.6-46.6	33.2-55.4	0.12-0.67
	1	215.5	43.0	49.9	0.44
	15	225.0	20.0-45.4	24.3-52.8	0.06-0.51
	3	229.0	25.1-28.6	29.5-33.0	0.08-0.13
	1	235.0	29.9	35.0	0.13
	9	244.0	32.6-49.7	39.5-59.7	0.21-0.77
	27	244.5	18.5-49.3	21.1-58.1	0.03-0.82
	4	244.6	21.6-33.5	25.2-39.3	0.06-0.18
	5	306.5	43.5-48.5	50.5-56.4	0.50-0.60
Total 2005	**313**		**18.5-69.9**	**21.1-81.5**	**0.03-2.40**
2006	31	120.0	35.5-67.0	41.3-77.0	0.25-2.30
	18	121.0	33.0-66.5	38.3-77.2	0.20-1.95
	4	123.0	24.5-51.5	28.5-60.0	0.09-0.85
	10	130.0	32.9-46.5	38.5-54.2	0.17-0.70
	1	137.0	29.8	34.5	0.15
	2	141.0	22.5-24.0	26.0-28.2	0.07-0.08
	1	141.5	36.5	41.7	0.50
	1	144.8	40.5	47.5	0.45
	7	145.0	26.9-36.3	31.1-42.3	0.10-0.26
	2	150.0	22.4-23.0	26.4-26.6	0.07-0.08
	5	165.0	27.5-34.4	32.2-39.4	0.10-0.14
	5	190.0	30.7-36.4	35.4-42.2	0.15-0.23
	1	190.5	50.0	58.2	0.73
	2	192.0	25.5-33.7	39.8-41.5	.26-.42
	1	193.0	27.0	30.5	0.13
	12	193.5	20.6-31.0	23.7-36.3	0.03-0.11
	6	205.0	22.4-45.5	27.6-53.5	0.19-0.96
	1	213.0	42.5	49.4	0.48
	4	215.0	36.2-48.5	41.8-56.3	0.26-0.64
	4	225.0	37.0-46.0	43.3-52.7	0.38-0.55
	1	240.5	24.0	27.0	0.08
	10	244.0	29.1-48.5	33.1-57.0	0.14-0.70
	10	244.5	19.6-37.0	23.6-44.0	0.05-0.21
	7	244.6	23.8-27.6	27.9-39.6	0.04-0.11
	1	257.4	43.9	50.8	0.55
	1	306.0	50.0	58.0	0.74
	1	306.5	62.1	73.3	1.73
Total 2006	**149**		**19.6-67.0**	**23.6-77.2**	**0.03-2.30**
2007	17	120.0	33.6-64.0	38.5-74.0	0.19-1.25
	11	121.0	31.7-62.0	37.0-72.2	0.15-1.50
	8	123.0	34.0-63.9	40.3-74.0	0.24-1.60
	11	130.0	29.8-55.0	34.5-63.5	0.13-1.05
	4	137.0	27.5-32.0	32.6-38.0	0.12-0.21
	2	141.0	30.5-32.0	35.7-37.5	0.12-0.19

Year class	Number captured	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)
	15	145.0	26.0-44.1	30.5-48.5	0.07-0.50
	1	150.0	30.0	36.0	0.18
	2	157.0	27.7-32.8	31.0-38.4	0.11-0.21
	1	163.0	28.0	32.8	0.12
	3	165.0	29.0-33.5	33.8-38.7	0.12-0.18
	2	174.0	30.1-34.6	34.6-40.5	0.14-0.24
	3	174.2	20.9-32.2	24.0-37.2	0.07-0.17
	7	176.5	20.2-33.0	23.7-38.1	0.12-0.94
	2	185.0	29.4-34.6	34.3-40.4	0.13-0.25
	6	190.0	22.8-31.8	26.5-37.4	0.06-0.16
	1	190.5	33.1	38.6	0.21
	1	192.0	32.9	38.3	0.20
	3	193.0	27.4-31.7	31.9-36.9	0.12-0.16
	1	193.2	30.7	35.7	0.17
	1	199.5	30.1	35.6	0.15
	15	205.0	27.8-40.7	33.0-48.5	0.13-0.43
	6	207.0	21.6-33.2	26.4-38.2	0.07-0.23
	4	207.5	30.8-38.3	35.3-45.0	0.15-0.29
	9	215.0	31.1-43.7	36.3-51.5	0.17-.52
	1	215.5	35.2	40.7	0.25
	4	225.0	29.0-39.0	34.2-45.4	0.12-0.34
	44	244.0	23.9-50.7	28.3-59.4	0.08-0.70
	21	244.5	20.8-38.5	25.3-45.0	0.05-0.35
	3	244.6	45.8-46.5	53.1-55.1	0.56-0.58
	1	280.5	69.5	80.3	2.46
	1	306.5	56.3	65.2	1.11
Total 2007	**211**		**20.2-69.5**	**23.7-80.3**	**0.05-2.46**
2008	25	120.0	30.5-59.0	35.4-68.5	0.14-1.20
	14	121.0	34.9-56.6	39.5-66.6	0.35-1.25
	4	123.0	29.5-46.5	35.0-54.0	0.15-0.60
	20	130.0	18.0-39.6	22.0-47.4	0.04-0.34
	1	137.0	31.4	36.4	0.16
	9	141.0	24.9-39.1	29.1-45.6	0.05-0.33
	5	144.8	28.6-34.3	33.5-40.1	0.14-0.22
	70	145.0	18.0-42.0	21.1-48.5	0.03-0.42
	49	150.0	20.1-37.2	22.3-44.0	0.05-0.30
	9	157.0	21.5-.6	24.2-36.0	0.04-0.17
	1	157.3	34.5	40.5	0.24
	12	161.0	24.0-36.8	27.9-43.2	0.06-0.27
	2	161.4	33.0-35.2	38.7-41.1	0.20-0.25
	23	165.0	20.0-35.3	23.0-41.0	0.04-0.24
	8	174.2	22.2-31.1	26.0-36.5	0.06-0.14
	2	176.0	33.2-33.7	39.3-40.0	0.20-0.22
	5	176.5	23.1-29.7	27.0-35.0	0.06-0.15
	1	185.0	36.3	42.5	0.26
	17	190.0	23.5-31.6	28.2-36.4	0.07-0.16
	2	190.5	31.5-35.0	35.5-40.4	0.15-0.23
	10	192.0	24.2-30.6	28.3-35.8	0.07-0.16
	8	193.2	22.9-29.7	27.2-34.6	0.08-0.92
	2	193.5	27.1-28.2	31.6-33.3	0.10-0.11
	5	199.5	23.5-26.8	28.0-31.1	0.07-0.10
	78	205.0	23.2-39.8	27.3-46.5	0.07-0.94
	16	207.0	24.7-32.8	28.8-38.5	0.07-0.92
	14	207.5	27.4-32.2	32.6-37.8	0.09-0.18
	23	215.0	23.9-52.0	25.2-59.6	0.08-0.41
	2	215.5	34.0-37.0	40.0-43.5	0.21-0.28
	19	225.0	25.1-44.1	28.0-52.3	0.09-0.50
	27	244.0	33.8-42.1	39.5-49.1	0.21-0.41

Year class	Number captured	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)
	31	244.5	20.3-44.0	23.5-52.0	0.05-0.80
	3	244.6	37.0-41.9	43.6-49.0	0.29-0.43
Total 2008	**517**		**18.0-59.0**	**21.1-68.5**	**0.03-1.25**
2009	26	120.0	27.5-68.0	32.5-78.5	0.13-1.90
	12	121.0	24.7-48.9	27.9-56.6	0.11-0.70
	4	123.0	30.3-39.1	34.9-43.8	0.16-0.33
	20	130.0	25.0-36.7	29.4-42.4	0.10-0.27
	2	137.0	23.0-26.3	27.7-29.7	0.05-0.09
	11	141.0	25.1-37.3	29.2-43.5	0.07-0.29
	1	141.5	32.5	37.9	0.21
	7	144.8	26.9-31.7	30.4-36.0	0.12-0.17
	24	145.0	23.0-37.5	24.9-43.5	0.05-0.28
	31	150.0	21.0-34.0	24.8-38.9	0.03-0.21
	6	161.0	24.1-27.1	27.9-31.5	0.07-0.10
	1	161.4	30.0	34.1	0.15
	5	165.0	23.0-38.7	26.5-34.5	0.05-0.15
	1	169.0	26.0	30.9	--
	4	174.0	23.8-33.8	27.4-39.3	0.08-0.24
	2	174.2	25.1-26.2	29.7-30.3	0.08-0.09
	1	176.0	31.2	36.1	0.08
	1	176.5	25.2	28.9	0.08
	9	190.0	25.1-28.4	29.2-32.3	0.07-0.12
	2	190.5	27.1-30.1	32.2-36.1	0.11-0.17
	7	192.0	27.0-35.2	21.2-40.4	0.10-0.22
	2	193.2	27.0-28.2	30.1-33.0	0.10-0.13
	1	193.5	24.5	28.1	0.09
	14	205.0	27.1-35.8	31.0-41.4	0.12-0.28
	2	207.5	27.0-31.5	31.6-36.0	0.11-0.18
	2	213.0	28.7-32.0	33.0-36.6	0.13-0.17
	7	215.0	29.8-34.5	35.3-40.5	0.16-0.25
	1	215.5	29.3	34.4	0.16
	9	244.0	23.3-32.6	27.3-38.3	0.09-0.19
	1	244.5	23.8	27.5	0.07
	1	244.6	27.2	31.5	0.11
Total 2009	**217**		**21.0-68.0**	**21.2-78.5**	**0.03-1.90**
2010	1	120.0	37.0	42.5	--
	2	121.0	26.0-31.5	30.4-37.8	0.11-0.21
	1	123.0	30.6	35.0	0.16
	10	130.0	25.2-35.6	29.5-41.0	0.09-0.25
	5	141.0	20.5-31.7	24.2-53.2	0.06-0.19
	14	144.8	24.0-31.0	28.0-36.1	0.09-0.16
	21	145.0	21.5-35.0	23.0-40.1	0.06-0.23
	7	150.0	21.0-30.8	24.5-35.7	0.05-0.18
	1	157.0	29.8	35.0	0.15
	1	157.3	26.6	31.1	0.11
	4	161.0	24.0-28.0	28.0-32.5	0.08-0.13
	3	161.4	27.8-29.6	32.5-34.3	0.12-0.15
	4	165.0	26.0-28.1	30.1-32.3	0.09-0.13
	1	170.0	31.0	36.1	0.18
	3	174.0	29.0-30.8	34.3-35.8	0.14-0.17
	1	185.0	26.4	31.3	0.12
	3	190.0	22.4-26.2	26.5-29.9	0.08-0.10
	1	190.5	28.7	33.6	0.14
	1	193.0	27.9	32.2	0.11
	31	205.0	24.2-33.1	28.5-38.9	0.06-0.23
	3	207.5	27.6-29.0	30.1-34.1	0.10-0.14
	1	213.0	29.4	33.2	0.14

Year class	Number captured	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)
	10	215.0	27.6-34.1	31.6-39.9	0.13-0.22
	2	215.5	29.1-30.5	33.6-35.5	0.14-0.16
	4	225.0	23.5-31.8	27.8-38.0	0.07-0.18
	1	234.5	33.0	38.7	0.22
	80	244.0	17.5-33.3	22.6-37.7	0.06-0.90
	4	244.6	26.6-30.4	31.3-36.1	0.10-0.15
	1	Unknown	--	28.5	0.15
Total 2010	**221**		**17.5-37.0**	**22.6-53.2**	**0.05-0.90**
2011	1	120.0	33.0	37.5	--
	3	121.0	29.5-35.5	34.2-41.2	0.14-0.19
	3	130.0	21.5-28.0	25.1-31.9	0.06-0.12
	13	141.0	21.5-29.9	24.8-35.0	0.02-0.15
	2	141.5	22.5-23.6	26.6-28.5	0.07-0.08
	1	144.5	28.5	--	--
	13	144.8	16.2-28.7	13.2-32.9	0.06-0.12
	18	145.0	18.6-29.5	20.8-34.0	0.04-0.14
	9	150.0	23.0-29.3	26.1-33.5	0.06-0.12
	2	157.0	24.1-25.9	28.1-30.2	0.06-0.09
	10	157.3	22.5-27.0	26.1-31.5	0.06-0.11
	2	161.0	24.6-25.0	27.6-29.0	0.08
	17	161.4	21.8-27.2	25.6-31.6	0.05-0.10
	6	165.0	21.8-25.0	25.2-29.5	0.06-0.09
	4	170.0	22.0-30.4	31.1-34.9	0.05-0.16
	3	174.0	24.2-29.6	28.1-33.7	0.08-0.13
	7	176.0	24.5-28.7	27.8-33.5	0.07-0.16
	3	190.5	25.5-29.0	29.5-33.9	0.09-0.12
	6	192.0	26.4-29.0	29.9-33.4	0.09-0.13
	1	193.0	23.9	27.5	0.06
	1	199.5	22.3		0.60
	40	205.0	22.2-30.0	25.2-35.0	0.04-0.15
	2	207.0	27.7-28.4	32.6-33.0	0.10-0.11
	18	207.5	24.3-28.9	27.7-36.6	0.07-0.12
	2	213.0	28.5-29.9	33.4-34.2	0.12-0.16
	10	215.0	21.6-30.3	24.5-35.1	0.05-0.12
	3	215.5	22.1-27.0	27.6-31.1	0.06-0.10
	5	225.0	23.0-33.0	26.7-38.7	0.07-0.19
	1	244.0	26.0	30.0	0.09
Total 2011	**206**		**16.2-35.5**	**13.2-41.2**	**0.02-0.60**
2012	1	120.0	32.0	37.4	0.18
	1	123.0	30.0	34.6	0.14
	4	130.0	26.0-28.0	30.5-32.7	0.11-0.15
	17	141.0	21.1-30.6	23.3-34.2	0.05-0.16
	33	145.0	24.9-33.4	28.2-38.5	0.08-0.21
	5	150.0	25.1-28.6	28.6-33.0	0.09-0.13
	1	157.0	28.0	31.5	0.13
	3	161.0	29.1-31.8	33.6-37.4	0.12-0.17
	2	170.0	25.0-31.0	29.1-36.0	0.07-0.15
	3	176.0	23.6-28.5	27.6-33.4	0.07-0.13
	2	192.0	26.5-28.5	30.4-33.1	0.10-0.12
	5	205.0	27.5-31.5	31.6-35.9	0.11-0.16
	2	207.5	27.0-29.0	32.0-32.2	0.11
	1	215.0	28.6	33.0	0.16
	5	225.0	25.8-33.0	28.5-35.2	0.10-0.15
	2	234.5	22.8-28.8	32.6-34.7	0.13
Total 2012	**87**		**21.1-33.4**	**23.3-38.5**	**0.05-0.21**

Year class	Number captured	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)
Unknown year class	19	18.0	54.2-92.5	62.1-107.0	1.10-5.60
	4	118.0	44.5-60.0	51.5-69.2	0.52-1.80
	421	120.0	33.5-89.0	39.3-102.0	0.21-3.80
	346	121.0	24.5-98.5	28.5-115.0	0.08-7.20
	94	123.0	27.2-85.4	31.8-98.6	0.11-4.25
	138	130.0	18.0-96.5	21.8-108.5	0.03-6.00
	9	134.0	21.4-99.0	25.1-111.0	0.05-4.25
	24	137.0	22.5-94.2	26.0-114.5	0.06-6.90
	1	137.4	37.3	44.4	0.31
	51	141.0	18.0-77.5	21.5-90.0	0.03-3.20
	1	141.5	38.5	45.0	0.30
	2	144.5	42.0-47.0	39.7-48.6	0.37-0.45
	15	144.8	25.3-55.2	29.5-63.0	0.10-1.25
	122	145.0	19.5-84.0	22.8-96.5	0.04-4.10
	37	150.0	20.3-56.5	23.4-66.0	0.05-1.00
	17	157.0	21.6-39.4	24.1-45.0	0.06-0.45
	2	157.3	36.5-40.4	42.3-46.6	0.29-0.46
	36	161.0	22.1-65.0	25.9-75.0	0.07-1.80
	4	161.4	32.1-40.1	36.4-47.2	0.17-0.37
	7	163.0	18.5-34.7	21.0-40.7	0.03-0.22
	57	165.0	16.8-49.5	19.0-57.1	0.03-0.76
	6	167.0	15.4-40.0	17.8-46.0	0.02-0.35
	4	170.0	24.8-32.0	29.2-37.7	0.05-0.11
	12	174.0	27.0-40.0	31.4-46.8	0.12-0.40
	39	174.2	23.6-85.6	29.0-45.0	0.12-0.30
	4	176.0	37.6-42.0	44.2-50.2	0.31-0.50
	28	176.5	28.3-52.2	32.6-60.3	0.13-0.95
	3	177.5	31.2-36.8	35.8-43.4	0.16-0.28
	5	182.0	26.2-33.5	30.5-38.8	0.10-0.21
	42	185.0	25.9-67.3	30.1-78.0	0.04-2.01
	4	188.0	26.3-34.0	30.2-39.3	0.06-0.19
	163	190.0	20.5-72.2	24.7-83.0	0.06-2.34
	33	190.5	26.9-69.1	31.5-81.0	0.10-2.06
	19	192.0	21.4-37.8	24.6-44.6	0.03-0.35
	33	193.0	20.3-73.1	28.3-83.5	0.10-2.35
	23	193.2	25.5-37.2	30.1-44.2	0.10-0.30
	31	193.5	21.1-45.7	23.8-52.9	0.03-0.42
	1	194.0	35.8	41.7	0.27
	1	195.8	34.2	38.0	0.20
	8	203.5	25.0-65.9	30.0-75.7	0.07-1.42
	4	204.0	21.2-72.5	25.0-84.8	0.05-0.56
	173	205.0	23.7-90.0	28.1-105.0	0.01-4.00
	6	205.5	33.4-35.0	38.1-40.7	0.16-0.33
	125	207.0	22.9-91.0	26.2-106.0	0.05-2.63
	78	207.5	25.6-113.0	30.0-121.0	0.05-7.00
	5	208.0	53.0-93.0	65.0-110.0	3.00-5.00
	12	213.0	34.0-65.8	39.1-76.8	0.22-1.79
	210	215.0	24.0-76.3	28.5-92.0	0.06-2.79
	1	215.4	61.0	72.0	1.10
	24	215.5	21.8-51.0	24.7-60.1	0.07-0.90
	1	215.6	55.0	66.0	1.20
	2	219.5	30.9-33.0	35.5-36.7	0.20-0.23
	1	224.8	57.9	68.5	1.24
	4	224.9	30.0-56.8	34.6-67.5	0.13-1.86
	172	225.0	21.3-76.0	26.7-88.9	0.07-2.35
	1	227.0	106.0	126.0	--
	1	228.7	29.0	33.0	--
	1	230.0	68.0	78.0	1.70
	1	231.0	60.0	71.0	2.50

Year class	Number captured	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)
	4	234.5	38.0-69.0	45.4-82.0	0.36-2.00
	1	235.0	27.5	33.1	0.12
	1	241.0	24.7	29.0	0.05
	64	244.0	22.4-68.0	25.4-80.8	0.06-1.87
	52	244.5	19.1-106.0	22.0-126.0	0.04-19.00
	37	244.6	20.8-62.4	22.3-72.5	0.03-1.40
	2	305.0	65.9-66.0	75.2-75.5	1.58-1.60
	3	Unknown	24.0-55.8	27.2-66.5	0.08-1.20
Total Unknown	**2,853**		**15.4-113.0**	**17.8-126.0**	**0.1-19.00**
Total	**10,251**		**15.4-131.0**	**13.2-151.0**	**0.01-28.00**

CHAPTER 1.2: JUVENILE WHITE STURGEON ANALYSIS USING PROGRAM MARK
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INTRODUCTION

White Sturgeon (*Acipenser transmontanus*) have been reintroduced into the Kootenai River system of Idaho, Montana, and British Columbia (BC) since 1992 (Paragamian and Beamesderfer 2004). Due to geographic isolation, declining abundance, and ongoing recruitment failure, the population was listed as endangered in the U.S. under the Endangered Species Act (ESA) in 1994 (Duke at al. 1999), Paragamian et al. 2005, USFWS 2006), and in British Columbia under the Canadian Species at Risk Act in 2007. Although the specific causes of recruitment failure remain unclear, research to date suggests that egg and/or larval suffocation, predation, and/or other factors of early life mortality contribute to persistent recruitment failure (Kock et al. 2006). The Kootenai River White Sturgeon population is comprised mainly of old adults, and significant recruitment has not occurred since the 1970s. Until recruitment failure can be addressed through habitat enhancement or other mitigation efforts, this species will only survive with the aid of conservation aquaculture (Paragamian and Beamesderfer 2004). The reliance on hatchery-reared fish to maintain this population has prompted a need for detailed information on population size, annual survival, and the influence of specific release strategies.

Study Area

The Kootenai River originates in Kootenay National Park, 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 1.2.1). River kilometers were defined as the upstream distance (in kilometers) from the northern most reach of Kootenay Lake. Kootenai Falls, located 42 rkms downstream from Libby Dam, may be an impassable barrier to White Sturgeon, along with other fish species. 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 (average gradient of 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 and enters the South Arm of Kootenay Lake at rkm 120. The river leaves the lake through the West Arm of Kootenay Lake (rkm 76) 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 entire Kootenai River 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 and temperatures of the river, which has had lasting effects on White Sturgeon and other fish species in the river (Partridge 1983).

METHODS

The specific objectives of these data analyses were to:

1. Make sampling recommendations to meet population closure assumptions needed to estimate population size.

2. Provide updated estimates of annual survival as a function of age class.

3. Investigate the influence of individual covariates and hatchery source on annual survival.

4. Replicate a virtual population analysis to estimate juvenile abundance by year similar to Beamesderfer et al. (2013).

5. Investigate effects on growth over time in this population using length-frequency data.

Juvenile White Sturgeon Sampling

Weighted, multifilament gill nets with 1.3, 1.9, 2.5, 3.8, 5.1, 6.4, and 7.6 cm stretch mesh were used to sample juvenile sturgeon. Sampling was conducted annually from 1992 to 2012 during July through October following the methodology of Paragamian et al. (1996). Gill nets were set during the daytime and checked every hour to reduce mortality, and all sturgeon were released alive. Upon capture, fork (FL) and total length (TL), weight, Passive Integrated Transponder (PIT) tag numbers, fish condition, and scute removal patterns were recorded for each sturgeon collected during gill netting efforts. Idaho Department of Fish and Game personnel sampled upstream of rkm 170 and BC Ministry of Forests, Lands and Natural Resource Operations (BCMFLNRO) personnel sampled from Kootenay Lake, BC to rkm 165.

From the years 1992 to 2004, prior to release, each hatchery reared sturgeon received a PIT tag and a pattern of scutes was removed at the Kootenai Tribe of Idaho (KTOI) hatchery located in Bonners Ferry, Idaho or at the Kootenay Trout and Sturgeon Hatchery located in Ft. Steele, BC. The Kootenay Trout and Sturgeon Hatchery is operated by the Freshwater Fishery Society of BC as the backup facility for the KTOI. Most (92%) of the released juvenile White Sturgeon were not PIT tagged from 2005 through 2007; however, scutes were removed from each fish prior to release, functionally serving as batch marks. Over 90% of the hatchery reared juvenile sturgeon released in the Kootenai River after 2007 were PIT tagged and all had scutes removed. Total numbers of hatchery releases are provided in Table 1.2.1. PIT tagging fish prior to release provided a unique identifier for each fish and allowed tracking of the size-at-release, rearing facility, release location, and time of release.

Closure Assumption

One objective of the Kootenai River White Sturgeon recovery efforts was to estimate the number of sturgeon in the system. Previous studies used differing methods and sets of assumptions to estimate abundance (Justice et al. 2009, Beamesderfer et al. 2013). One challenge of estimating population size is that it must be done under the assumption of population closure. The demographic closure assumption means that there cannot be births, deaths, immigration, or emigration occurring during the sampling period. In practice, this is difficult to achieve because sampling efforts for sturgeon present many logistical challenges and because recapture probabilities are low overall (Beamesderfer et al. 2013).

In summer 2013, researchers attempted a more intensive sampling effort than usual at two sites in BC (rkm 130 and 141) with the goal of using a closed capture model to estimate the abundance of juvenile sturgeon. Researchers sampled for three days at both sites using standard gill net sampling (Stephenson et al. 2013), with the goal of improving capture and recapture probabilities. This, in turn, would potentially allow the later use of a robust design analysis (Kendall et al. 1995) that could provide estimates of fish abundance and annual survival. To evaluate the closure assumption, closed captures model in Program MARK (White

and Burnham 1999) were used to model capture and recapture probabilities and population abundance at each of the two sites.

Annual Survival

A dataset comprised of 21 years of capture and recapture data for the Kootenai River White Sturgeon was used for this analysis. The dataset required some initial "cleaning" with respect to assigning age-at-release to some fish, updating capture histories, and reconciling minor data entry errors. Thus, the final sample for use with these analyses was slightly different from the 125,948 used in Beamesderfer et al. (2013; Table 1.2.2).

After data cleaning, the capture and recapture information was summarized into an encounter history for each fish. The dataset consisted of 21 years (1992 to 2012), and fish were grouped into four age classes (age-1, age-2, age-3+, and Unknown age) with five individual covariates (Hatchery, Fork Length, Weight, Release Area, and Release Season) for analyses. In a small number of cases (<0.1% of the total) the individual covariate values were missing; for each such case the missing value was interpolated as the mean from the entire sample.

Annual age-specific survival was estimated using the live recaptures (Cormack-Jolly-Seber; CJS) model in Program MARK (White and Burnham 1999). The parameters in this model were annual apparent survival (ϕ) and conditional capture probability (p). With 21 years of data, this model yielded 20 estimates of annual survival and 20 estimates of capture probability. Dependency in the data was tested for using the median c-hat procedure in MARK. The standard 120 simulations were run with no model failures, and c-hat was estimated as 1.31 from the global model. This adjustment was done in MARK and changed model selection from AIC to quasi-likelihood theory (QAICc), because c-hat was no longer assumed to equal the default value of 1.0 (Akaike 1973).

The modeling approach to estimate age-specific annual survival occurred in several steps, each to answer a specific question. The first step was to update the survival estimates in Beamesderfer et al. (2013) by using true age and not time-since-release. The Beamesderfer et al. (2013) analysis used the latter approach, but called this an "age" effect. For the analysis reported herein, the entire dataset was reformatted to code for true age effects. Beamesderfer et al. (2013) would have modeled the annual survival of a fish of any age-at-release as a function of time-since-release (one year, two years, etc.). The current analysis instead used all fish of a particular age (e.g., age-1 at-release) and modeled annual survival independently for each age class. Beamesderfer et al. (2013) modeled annual survival by release group, where a release group may have been comprised of more than one age class. Because age-0 fish were not individually marked, this age class was missing from these analyses. "Age-1" in this analysis matched up with the first year post-release (also age-1), "age-2" corresponded with the second year post-release, etc. As an initial comparison of age effects and time-since-release, the seven models in Table 1 of Beamesderfer et al. (2013) were re-analyzed; this provided a direct comparison of the model selection results and resulting estimates of annual survival and capture probability.

After the initial analysis was completed it became apparent that some of the survival and recapture parameters were either inestimable or were estimated very poorly because they were close to zero or 1. This is a frequent problem in these types of analyses, and additional estimation procedures are sometimes required to obtain interpretable estimates. In this case, the Markov-Chain Monte Carlo (MCMC) tool in Program MARK (White and Burnham 1999) was used to resolve estimation problems in some age classes and years. The MCMC tool is

computer intensive, so this was only used on the best model from the CJS analysis described above. In MARK the default settings (4,000 tuning samples, 2,000 burn-in samples, 10,000 iterations saved) were used to get parameter estimates, standard errors, and 95% credible intervals. A credible interval is akin to a 95% confidence interval, except that the limits are the 2.5% and 97.5% values from the posterior distribution of the parameter of interest.

Covariate Effects on Survival

Following the initial comparison of survival estimates to Beamesderfer et al. (2013), a more thorough analysis of the capture-recapture data was completed that incorporated additional covariate effects. The five covariates considered in the analysis were Hatchery, Fork Length, Weight, Release Area, and Release Season. Hatchery was coded as 1 = KT, -1 = BC, and 0 for an unknown hatchery. Fork length was measured at initial capture in cm and weight was measured at initial capture in kilograms; both were modeled only on the first year post-release because the value of each covariate was expected to change in subsequent years. Release area was designed to parse out differences by region and was coded as unknown (0), Kootenay Lake (1), Kootenay River in British Columbia (2), Kootenai River in Idaho below rkm 245 (3), Moyie River in Idaho (4), Leonia, Idaho/Montana (5), Yaak, Montana (6), and Troy, Montana (7) (Figure 1.2.1). Release area was not incorporated into the current analyses, but this could be explored later, if necessary. Finally, sturgeon were released under different strategies by season, and this covariate was coded as “0” for unknown, “1” for spring (March 20 – June 20), “2” for summer (June 21 – September 21), “3” for fall (September 22 – December 20), or “4” for winter (December 21 – March 19).

After completing the covariate analysis, the effect(s) of fork length on predicted survival of age-1 fish were cursorily evaluated. The mean value for a typical release from all hatcheries was calculated (25 cm) and used; age-specific annual survival of age-1 fish was predicted for a spring and fall release. Varying fork length within the spring release was also evaluated and annual survival for the mean (25 cm) in addition to small (20 cm) and large (30 cm) fish was predicted. This portion of the analysis was intended to provide additional insight into the possible effect(s) of releasing juvenile sturgeon during different seasons, at different fork lengths, and the interaction between these two variables.

Lastly, comments from external reviewers on an earlier version of this report raised questions about possible differences in the annual survival of age-2 fish as a function of whether they were released as age-1 fish and grew into this age class, or whether they were newly released at age-2 (i.e., did not grow into the age-2 class, in river). To address this question, year effects were added for 2001, 2002, and 2004 (the three years when age-2 fish were available in both scenarios) to the best model for annual survival.

Virtual Population Analysis

In general, the virtual population analysis of Beamesderfer et al. (2013) was replicated but with different estimates of annual survival. Importantly, for age-0 fish, annual survival was inestimable because none of the previously released age-0 fish were uniquely marked. Therefore, an annual age-0 survival rate of 0.0004 (derived from Gulf Sturgeon data; Pine et al. 2001) was used as a surrogate for age-0 survival. A deterministic, stage-based projection model was constructed to estimate the number of fish each year that were attributed to each release year. Numbers were then summed across age classes to obtain annual estimates of the sturgeon population. This approach had a few key assumptions that raised concerns during the analysis. Because there was some evidence that fish were mobile, even during short time

periods (Neufeld and Rust 2009), the assumption of population closure under which population size was estimated was problematic. The model also used estimates of apparent survival (apparent survival was the product of true survival and fidelity), which may have been biased low if there was substantial permanent emigration from sampling sites. Lastly, these estimates were presented with an understanding that they were most informative of population processes when combined with other information on annual survival, recruitment, and dispersal.

RESULTS

Juvenile White Sturgeon Sampling

These analyses of annual survival of Kootenai River White Sturgeon incorporated capture and recapture information from 122,642 fish. These fish were released into the system at age-1 (107,995), age-2 (11,383), age-3+ (1,148), or an unknown age (2,116) (Table 1.2.1). Of this total, 69,807 were released from the BC hatchery, 50,521 were released from the KTOI hatchery, and 2,314 had an unknown hatchery source. The large dataset of capture and recapture data for the Kootenai River White Sturgeon was used for this analysis. The dataset required some initial "cleaning" with respect to assigning age-at-release to some fish, updating capture histories, and reconciling minor data entry errors. Thus, the final sample for use with these analyses was slightly different from the 125,948 in Beamesderfer et al. (2013; Table 1.2.2).

Closure Assumption

The three-day sampling efforts in summer 2013 yielded 66 juvenile sturgeon captures at rkm 130 and 54 juvenile captures at rkm 141. Of these initial captures, there was a recapture at rkm 141 and no recaptures at rkm 130 within the three-day sampling period. The estimates of capture and recapture probability were not estimable (too few recaptures), and sturgeon abundance could not be estimated at either site. It was concluded that either the closure assumption was violated within the three-day sampling period (e.g., there was substantial fish movement within even this short time period), or capture and recapture probabilities were inherently low and would require more intensive sampling to estimate "well." Based on these efforts, it is unlikely that a robust design sampling approach would be worthwhile for estimating White Sturgeon abundance in this system.

Annual Survival

The analyses of annual survival of White Sturgeon incorporated capture and recapture information from 122,642 fish. M-array summaries of the input and recapture data for each of the four groups used in the analysis can be found in Table 1.2.2.

The comparison to the seven models in Beamesderfer et al. (2013) revealed that both approaches selected the more parameterized models that included age effects (Table 1.2.3). In the current analysis, all weight was in a single model, and it was clear that there were age-specific patterns in annual survival. Patterns in annual survival were generally similar for each analysis, except that this analysis incorporated true age effects that were not confounded with time-since-release.

After this initial model set was considered, the analysis was expanded to include other sources of variation in annual survival, including linear and quadratic trends across years and

various combinations of individual covariate effects. In total, 45 models were considered in the analyses of patterns of annual survival (Table 1.2.4). The best model to explain variation in White Sturgeon survival was one that included annual variation in age-1 survival with the additive effects of fork length and release season, annual variation in age-2 survival, and constant survival in age-3+. Most closely ranked models also had annual variation in age-1 survival and constant age-3+ survival. Model selection favored a three-age-class structure over a two-age-class structure, and annual patterns in survival were best explained by year effects rather than trends across years.

Capture probability was also estimated as part of the survival analyses. Strong evidence of additive yearly variation and fork length in capture probability was found; no other models of capture probability were competitive. When year and fork length were modeled separately, it was clear that year was the stronger effect on capture probability of White Sturgeon. This additive year and fork length effect in capture probability was included in all top models. Models where capture probability was constant or a function of age class or a trend across years received no support. The strong yearly variation in capture probability closely mirrored that reported by Beamesderfer et al. (2013) with levels ranging from 0.11 to 0.23 between 1995 and 2001, but then dropping below 0.09 in all subsequent years (Figure 1.2.2).

The MCMC analysis improved estimates of survival and capture probability for some years and age classes. Because this approach reduced numerical convergence and estimation problems encountered with the CJS approach, these results were used to illustrate patterns in age-specific annual survival. For age-1 sturgeon, annual survival generally declined rapidly across the study period from 0.88 in 1992 to less than 0.13 after 2003 (Figure 1.2.3). The general pattern in yearly estimates was a close match to those reported in Beamesderfer et al. (2013). For age-2 fish, the pattern was less clear, although annual survival was generally much greater than for age-1 fish (Figure 1.2.4). The extremely low estimates in 2002 and 2004 (Figure 1.2.4) were due to a release effect on age-2 survival and are discussed at the end of the next section. Annual survival for age-3+ fish was best explained by a model without annual variation and the estimate was ϕ = 0.927 (SE = 0.006).

Covariate Effects on Survival

The final model set included models that incorporated most of the individual covariates that were included in the dataset, except for release location (Table 1.2.4). Three of these covariates had strong effects on age-1 survival. The hatchery effect was negative ($\beta_{Hatchery}$ = -0.17 [SE = 0.06]), which indicates that the survival of fish from the BC hatchery was greater than that of fish from the KTOI hatchery. This finding was similar to that of Beamesderfer et al. (2013). Both fork length (β_{FL} = 0.11 [SE = 0.01]) and weight (β_{Weight}= 32.65 [SE = 1.72]) had strong positive effects on age-1 survival, indicating that longer and heavier fish had greater survival to age-2 than did shorter or lighter fish. Additive and multiplicative models were also included in this analysis to account for other patterns in covariates, although multiplicative models were not well supported.

The influence of release season on annual survival was also explored in some detail. Using the best model (see Table 1.2.4) but fixing years constant because of computing time, the probability of a 25 cm age-1 sturgeon surviving to the next year was predicted as a function of its release season (spring, summer, fall, or winter). This prediction showed that spring release fish had the greatest estimated annual survival, and that annual survival steadily declined through summer, fall, and winter (Figure 1.2.5). The survival of winter-released fish to the

following spring, despite the short time interval, was approximately 25% that of a spring-released fish.

After the initial analyses were completed, feedback from other researchers raised concerns about a possible confounding between hatchery origin and release season, and between fork length and release season. To address these concerns four models were added, two each with additive and multiplicative interactions of these effects added to the best model from the initial analyses. The results showed that models incorporating fork length were a significant improvement with the additive and multiplicative models, respectively, ranking as the top two models (Table 1.2.4). The multiplicative effect was estimated at -0.26 with a large standard error and a 95% confidence interval that included zero (95% CI was -0.64 to 0.12). This suggests that there was at least some seasonal balance in numbers of releases from both hatcheries, a conclusion that is at least partially affirmed by looking at the raw releases by season and hatchery (Table 1.2.5).

The predicted survival of age-1 fish varied as a function of release season with spring releases having significantly greater survival than fall releases (Figure 1.2.6). In general, annual survival was much greater from 1999 to 2002 and dropped considerably after 2005. Annual survival for spring releases only was also evaluated, and it was found that larger fish had significantly greater survival than small fish in most years, although some of the estimates for 30 cm fish were estimated imprecisely (Figure 1.2.7). However, in no year did the 20 cm fish have a greater annual survival rate than any of the larger fish. The survival difference between a 20 cm fish and a 30 cm fish was striking in some years, but in other years there were no differences. For some years (1999-2002), the difference between a 25 cm fish and a 30 cm fish was less obvious, and mainly arose because many of the 95% confidence intervals on estimates for 30 cm fish were large. But for at least a couple of recent years (e.g., 2008 and 2010), this was not the case and 30 cm age-1 fish were predicted to survive at much greater rates than 25 cm age-1 fish in those years. The underlying pattern was probably more complex; however, it is likely that a 30 cm age-1 fish had a greater chance of surviving to age-2 than a 20 or 25 cm fish.

Finally, a model where age-2 survival differed between newly-released fish and those that survived from age-1 was developed by modifying the top model from the initial survival analyses. This new model outperformed the previous best model by almost 108 ΔAIC units and showed that the survival of newly-released age-2 sturgeon was significantly lower than those released at age-1. The predicted annual survival of newly- and previously-released age-2 sturgeon, respectively, was 0.067 and 0.935 (2001), 0.047 and 0.642 (2002), and 0.033 and 0.959 (2004). These differences are more than ten-fold across all three years and show that newly-released age-2 fish have much lower annual survival than fish that grew to age-2 in the river.

Virtual Population Analysis

This analysis provided estimates of the number of fish by release year that comprised the total population during each year of the study period (Figure 1.2.8). The estimated population size was small through 1997, never having more than 200 fish. From the late 1990s to the early 2000s the population was estimated to grow rapidly to nearly 8,000 fish by 2004. The population more than doubled in 2005, but in subsequent years it ranged from an estimated 12,000 to 15,000 fish. This differed slightly from the results of Beamesderfer et al. (2013), which showed similar growth through 2004, but then showed that the population peaked later (in 2007 instead of 2005) and had lower estimates of the population size since about 2001.

DISCUSSION

The findings from the analyses reported herein add to an expanding knowledge of the demography of the Kootenai River White Sturgeon. More importantly, they provide additional insight into survival patterns of this species, some of which may help shape future management of this population. The most important findings are as follows:

1. These analyses provide the first age-specific estimates of annual survival for the Kootenai River White Sturgeon; previous analyses of these data have addressed components of survival and time-since-release (Justice et al. 2009, Beamesderfer et al. 2013). As in many long-lived vertebrates, survival in early life stages is often low and difficult to estimate. Estimates of age-1 survival have declined dramatically since the early 1990s. Annual survival of age-2 and older fish has been much greater and is showing no evidence of a decline. Understanding why age-1 survival has declined so sharply should thus be a priority for future study.

2. Estimates of capture probability were similar to those from earlier analyses of these data, confirming the slow decline in this parameter through time. The similarity to results from Beamesderfer et al. (2013) is not surprising because both analyses included year effects on capture probability. This pattern of decline has likely resulted from increases in sturgeon density or possibly other factors.

3. Survival analyses confirmed the importance of fork length, weight, and hatchery source as correlates with annual age-specific survival. Fork length and weight were positively correlated with age-1 survival and predicted that longer and heavier fish at release had a significantly greater chance of surviving to age-2. The clear message was that size at release should be kept as large as possible. The source of fish for stocking was also an important predictor of age-1 survival, with fish reared in British Colombia having significantly greater survival than those reared in the KTOI hatchery.

4. The findings presented in this report represented true age effects rather than survival as a function of time-since-release. From an ecological perspective, an understanding of true age effects on survival represents the best approach to understanding patterns of annual survival. Differences between the survival estimates presented herein and those from a previous analysis (Beamesderfer et al. 2013) were most evident in age-2 fish. Although the datasets were similar for both analyses, and the population contained relatively few age-2 fish, the differences in modeling true age as opposed to time-since-release can still result in substantially different estimates of annual survival. This was ultimately a methods issue at the analysis stage, and in the future it is suggested that only true age effects be included in models of annual survival.

5. Analyses of the influence of release season showed that this was an important predictor of annual survival with spring > summer > fall > winter. Justice et al. (2009) discussed the influence of size and stocking density on release strategies, and the present study built on their approach. Annual survival of spring released sturgeon was 40% greater than survival of fish released in summer. Based on these results, limiting future releases to spring would likely result in significantly greater survival to age-1 and should be a priority if maximizing annual survival is a recovery goal.

6. The virtual population analysis repeated here was similar to that of Beamesderfer et al. (2013) except that it peaked earlier (in 2005 versus 2007) and indicated the overall population was slightly larger. These differences probably resulted from the influence of true age effects in survival, especially since 1999 when larger numbers of age-1 fish were released.

7. Two three-day sampling periods, during which the goal was to estimate capture and recapture probabilities under the assumption of population closure, were unsuccessful because sufficient recaptures could not be achieved. Thus, continuing this sampling scheme to use a robust design to estimate population size is not recommended.

TABLES

Table 1.2.1. Releases of White Sturgeon by year and age class in the Kootenai River system from 1992-2012. Not shown are 2,116 unknown-age fish that were included in the dataset, but not subsequently incorporated into any survival analyses. A total of 122,642 juveniles were included the analyses.

Year	age-1	age-2	age-3+
1992	105	13	
1993			
1994		123	
1995			
1996			
1997		1959	77
1998			42
1999	309		10
2000	2187	1	4
2001	3943	2081	4
2002	7140	4172	7
2003	11219		914
2004	12540	3001	21
2005	1242		8
2006	2368	33	31
2007	6801		2
2008	3053		
2009	14739		7
2010	14031		7
2011	15338		11
2012	12980		3
TOTAL	**107995**	**11383**	**1148**

Table 1.2.2. Summaries of input data in *m*-array format for White Sturgeon released into the Kootenai River system from 1992-2012. Shown are separate *m*-arrays for each of the four groups used in the analysis: a) group 1 (age-1 fish), b) group 2 (age-2 fish), c) group 3 (age-3+ fish), and d) group 4 (unknown-age fish). The number of fish that comprised each release [R(i)] is shown in rows by sampling occasion (Occ.), which corresponded to years (Occ. 1 is 1992, Occ. 2 is 1993, etc.). The j columns (2 through 21) show the number of fish first recaptured on that occasion; the total number of recaptures is shown in the rightmost column.

(a) Age-1 fish

Occ.	R(i)	j = 1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total
1992	105	1	0	14	21	4	3	8	2	0	2	2	3	0	0	0	0	0	0	0	0	**60**
1993	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1994	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1995	14				3	1	3	1	3	1	0	0	0	0	0	0	0	0	0	0	0	**12**
1996	24					4	1	3	3	0	0	1	0	0	0	0	0	0	0	0	0	**12**
1997	9						1	3	0	0	2	0	0	0	1	0	0	0	0	0	0	**7**
1998	8							1	0	1	1	0	1	0	0	0	0	0	0	0	0	**4**
1999	325								8	15	7	4	2	3	1	3	3	5	2	1	4	**58**
2000	2203									141	54	51	51	44	30	26	23	9	22	10	10	**471**
2001	4101										54	63	52	22	25	35	41	31	13	14	19	**369**
2002	7260											32	11	18	17	9	22	12	6	7	9	**143**
2003	11372												8	2	12	4	16	15	6	13	12	**88**
2004	12668													75	83	83	123	96	94	86	57	**697**
2005	1406														17	14	18	8	4	9	6	**76**
2006	2554															15	31	18	15	26	11	**116**
2007	6990																24	23	22	24	10	**103**
2008	3354																	59	45	54	36	**194**
2009	15015																		118	91	45	**254**
2010	14378																			76	43	**119**
2011	15749																				57	**57**

(b) Age-2 fish

Occ.	R(i)	j = 1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total
1992	13	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
1993	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1994	123			12	11	9	5	3	5	1	7	0	2	0	1	0	0	0	0	1	2	**59**
1995	12				5	2	2	0	0	1	0	0	0	0	0	0	0	0	1	0	0	**11**
1996	18					1	1	2	2	2	0	1	0	0	2	0	1	0	0	0	0	**12**
1997	1971						168	99	98	77	45	21	42	19	10	12	15	12	11	7	10	**646**
1998	176							11	23	9	9	1	4	1	2	2	1	3	0	2	3	**71**
1999	116								19	19	8	1	0	1	0	0	1	2	3	0	0	**54**
2000	148									33	13	4	8	3	2	3	1	1	3	0	1	**72**
2001	2223										116	56	69	40	58	41	65	47	20	23	20	**555**
2002	4370											11	23	8	22	3	14	14	6	4	11	**116**
2003	95												3	5	1	1	3	4	0	1	1	**19**
2004	3152													8	8	6	3	5	5	4	8	**47**
2005	85														2	5	1	4	0	1	1	**14**
2006	141															6	12	8	3	6	3	**38**
2007	79																9	6	0	6	3	**24**
2008	126																	10	2	10	4	**26**
2009	116																		9	10	4	**23**
2010	63																			5	5	**10**
2011	80																				5	**5**

(c) Age-3+ fish

Occ.	R(i)	j = 1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1993	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1994	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1995	0				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1996	0					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1997	77						58	19	0	0	0	0	0	0	0	0	0	0	0	0	0	**77**
1998	100							7	15	11	3	1	0	1	0	2	3	1	1	0	0	**45**
1999	36								5	1	2	1	1	0	0	0	0	0	1	1	0	**12**
2000	24									4	3	1	0	1	0	0	1	0	0	0	0	**10**
2001	20										2	2	1	0	0	0	0	0	0	0	0	**5**
2002	17											1	2	0	0	0	1	0	0	0	0	**4**
2003	920												29	10	14	16	23	12	7	13	10	**134**
2004	54													1	1	1	1	0	1	1	2	**8**
2005	21														0	0	1	0	0	0	1	**2**
2006	46															1	3	3	4	3	2	**16**
2007	22																1	2	0	0	0	**3**
2008	34																	1	2	0	0	**3**
2009	26																		0	1	1	**2**
2010	23																			0	1	**1**
2011	30																				2	**2**

(d) Age unknown fish

Occ.	R(i)	j = 1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1993	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1994	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1995	1				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1996	0					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1997	0						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1998	0							0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1999	2								0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
2000	0									0	0	0	0	0	0	0	0	0	0	0	0	**0**
2001	2										0	0	0	0	0	0	0	0	0	0	0	**0**
2002	10											1	0	0	0	0	0	0	0	0	1	**2**
2003	13												0	0	1	0	0	0	0	0	0	**1**
2004	26													0	0	0	0	1	0	0	0	**1**
2005	11														0	1	1	1	1	1	0	**5**
2006	39															0	1	0	0	1	0	**2**
2007	264																13	11	8	5	3	**40**
2008	409																	19	22	27	13	**81**
2009	415																		18	20	13	**51**
2010	344																			22	21	**43**
2011	493																				16	**16**

Table 1.2.3 Comparison of seven models between the current analysis and those of Beamesderfer et al. (2013; Table 1). Models are ranked from best supported at the top to lowest supported at the bottom. Also shown are the number of parameters (K) and the model weight. This analysis was done as a comparison with the findings of Beamesderfer et al. (2013), only; it did not include any covariates, and the results were not used to make any inferences about sturgeon survival.

Beamesderfer et al. (2013)			Current analysis		
Model	K	Weight	Model	K	Weight
7	69	0.710	6/7	47	1.000
3	37	0.107	4	44	0.000
6	52	0.106	5	33	0.000
5	38	0.056	3	33	0.000
4	54	0.021	2	21	0.000
2	21	0.000	1	34	0.000
1	38	0.000			

Table 1.2.4. Model selection results for analysis of the annual survival of Kootenai River White Sturgeon from 1992-2012. The two parameters are annual apparent survival (Phi) and conditional capture probability (p). Panel (a) shows the fitting of the best model of capture probability to a simple age class model for apparent survival. Panel (b) shows only models with a ΔQAICc value <100; the effect on capture probability was an additive combination of year and fork length. Model effects include age class (a1 = age-1, a2 = age-2, a3 = age-3+), year (Year), fork length at release (FL), weight at release (Weight), hatchery, release season (R_season), patterns across the 21-year study that were constant (.), and linear (T) or quadratic (TT). Models could include effects that were either additive (+) or multiplicative (*). Models were ranked by ΔQAICc, and the model weight (all sum to 1) and number of parameters (K) are also shown.

(a) Capture Probability

Model	ΔQAICc	Weight	K
Year+FL	0	1.0	22
Year	242.27	0	21
Quadratic time trend (TT)	739.73	0	5
Linear time trend (T)	977.82	0	4
a1*Year, all others constant	1393.27	0	23
FL	1468.83	0	6
R_Season	1489.91	0	6
age class	1690.99	0	8
age-1 different	1704.50	0	5
Weight	1716.62	0	6
No effects	1723.84	0	5
Hatchery	1791.05	0	4

(b) Annual Survival

Model	ΔQAICc	Weight	K
age class: a1*year+R_Season+FL, a2*year, all others constant	0.00	0.73	42
age class: a1*year+R_Season*FL, a2*year, all others constant	2.00	0.27	43
age class: a1*year+R_Season+Hatchery, a2*year, all others constant	48.22	0	41
age class: a1*year+R_Season*Hatchery, a2*year, all others constant		0	

Table 1.2.5. Summary of releases of age-1 White Sturgeon by release season and hatchery in the Kootenai River system from 1992-2012.

Release season	Kootenai Tribe	British Columbia
Spring	1	56,741
Summer	105	0
Fall	30,582	7,500
Winter	12,960	0

FIGURES

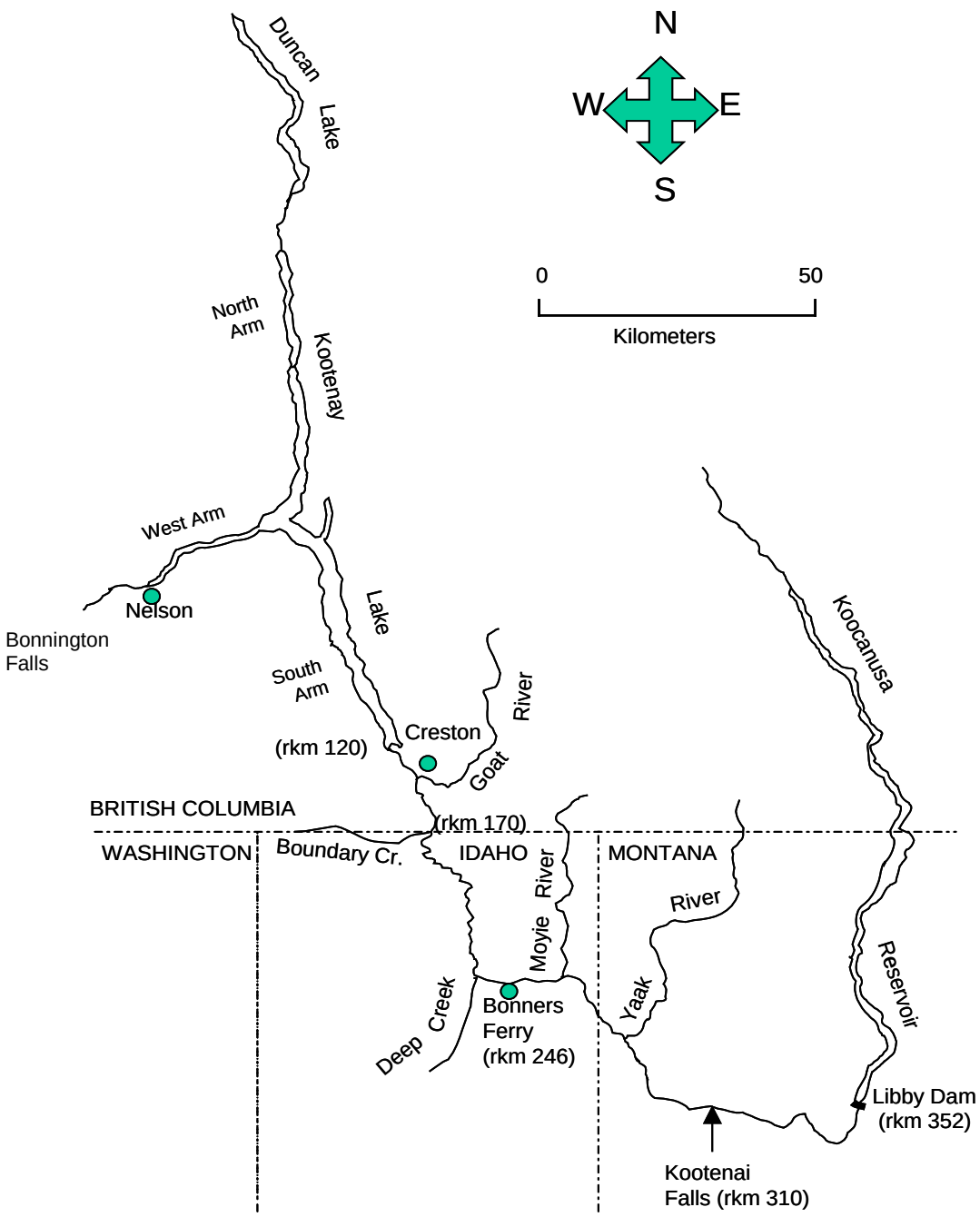

Figure 1.2.1. Location of the Kootenai River, Kootenay Lake, Lake Koocanusa, and major tributaries. The river distances from the northernmost reach of Kootenay Lake are in river kilometers (rkm) and are indicated at important access points.

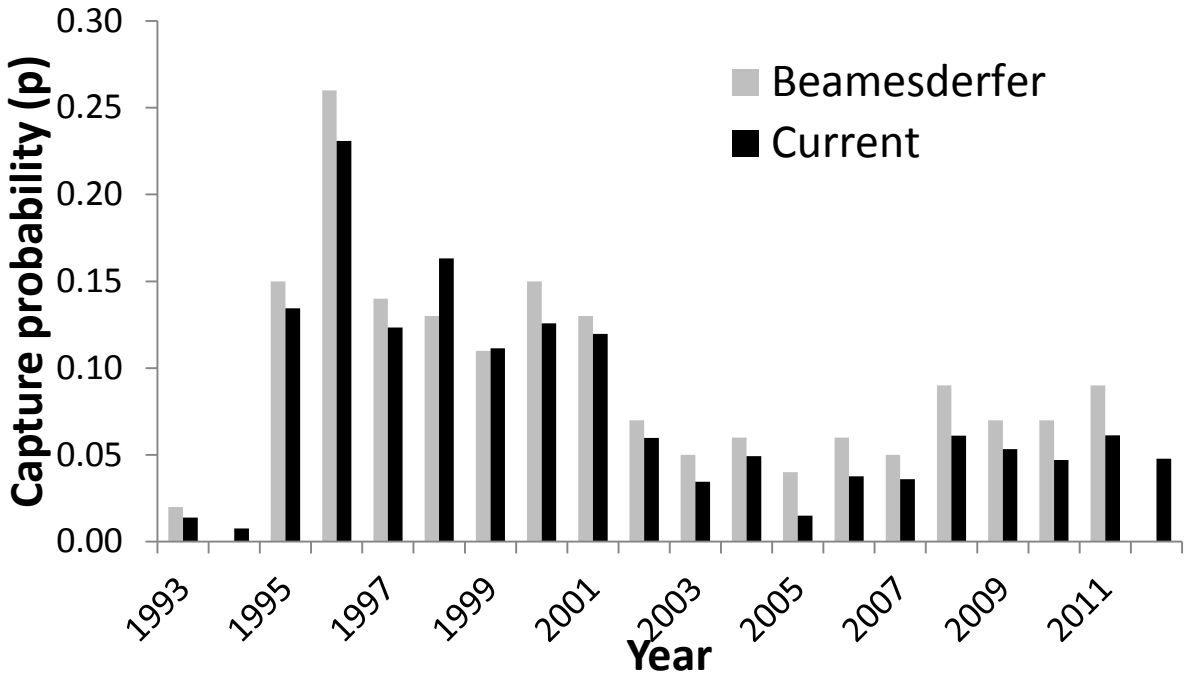

Figure 1.2.2. Estimated conditional capture probability of age-1 White Sturgeon in the Kootenai River system from 1992-2012. Capture probability estimates from the present study are shown along with those reported in Beamesderfer et al. (2013) for comparison. Estimates from both studies are missing from some years and indicate times when there were insufficient recaptures.

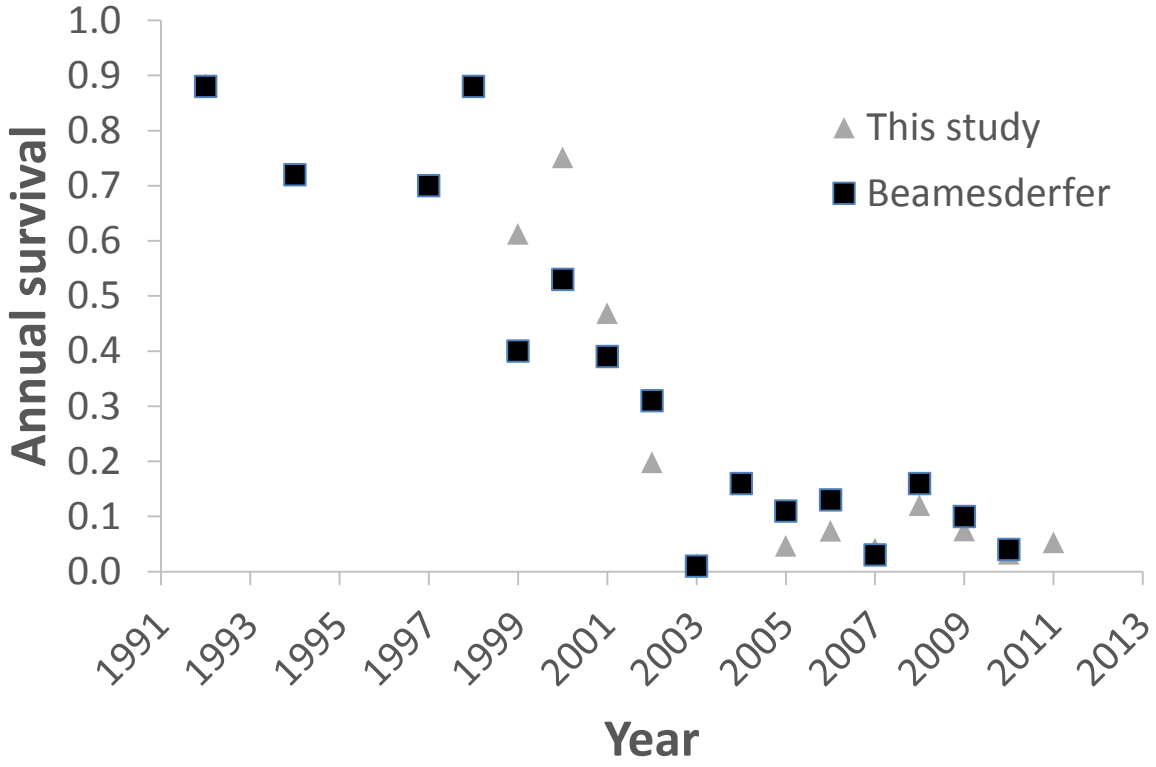

Figure 1.2.3. Estimated annual survival of age-1 White Sturgeon in the Kootenai River system from 1992-2012. Survival estimates from the present study are shown along with those reported in Beamesderfer et al. (2013) for comparison. Here, "Year" refers to the annual survival of a particular age class (this study) or release year (Beamesderfer et al. 2013). Estimates from both studies are missing from some years and indicate times when there were insufficient recaptures.

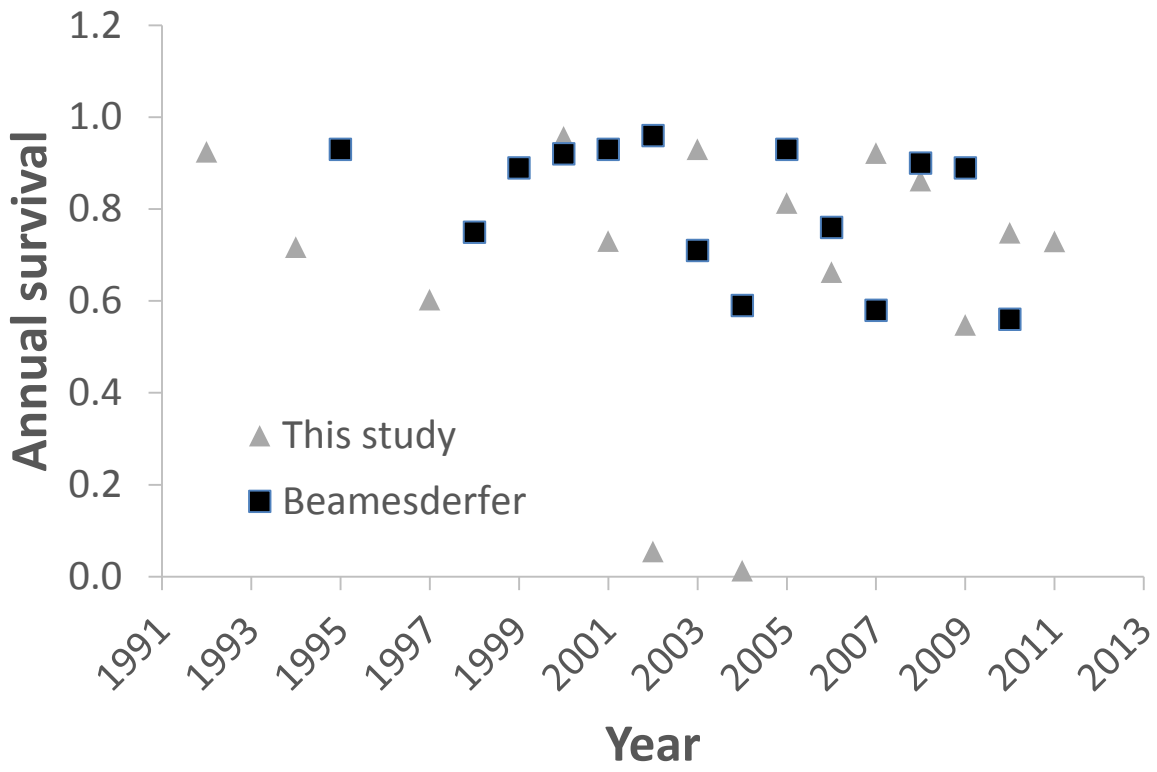

Figure 1.2.4. Estimated annual survival of age-2 White Sturgeon in the Kootenai River system from 1992-2012. Survival estimates from the present study are shown along with those reported in Beamesderfer et al. (2013) for comparison. Here, "Year" refers to the annual survival of a particular age class (this study) or release year (Beamesderfer et al. 2013). Estimates from both studies are missing from some years and indicate times when there were insufficient recaptures.

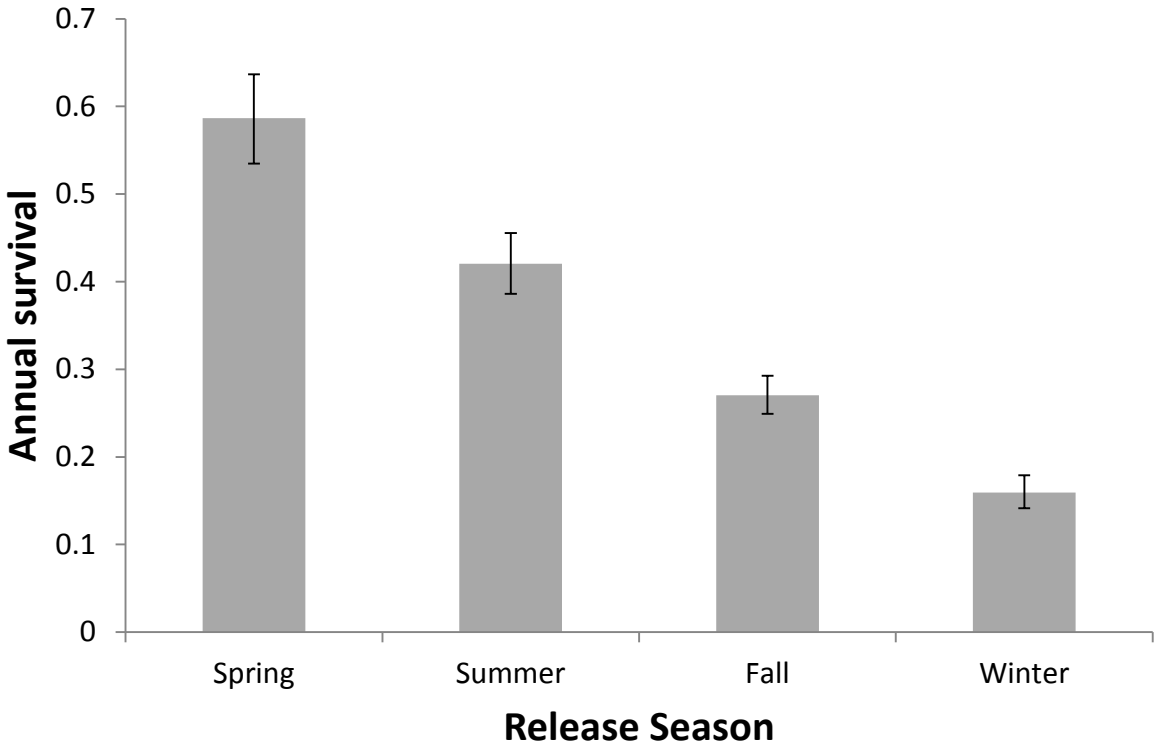

Figure 1.2.5. Predicted annual survival (and 95% confidence interval) of age-1 White Sturgeon in the Kootenai River system from 1992-2012. Using the best model from the survival analysis, annual survival was predicted with no annual variation for a juvenile sturgeon released in spring, summer, fall, and winter. Estimates do not account for potential confounding by hatchery source.

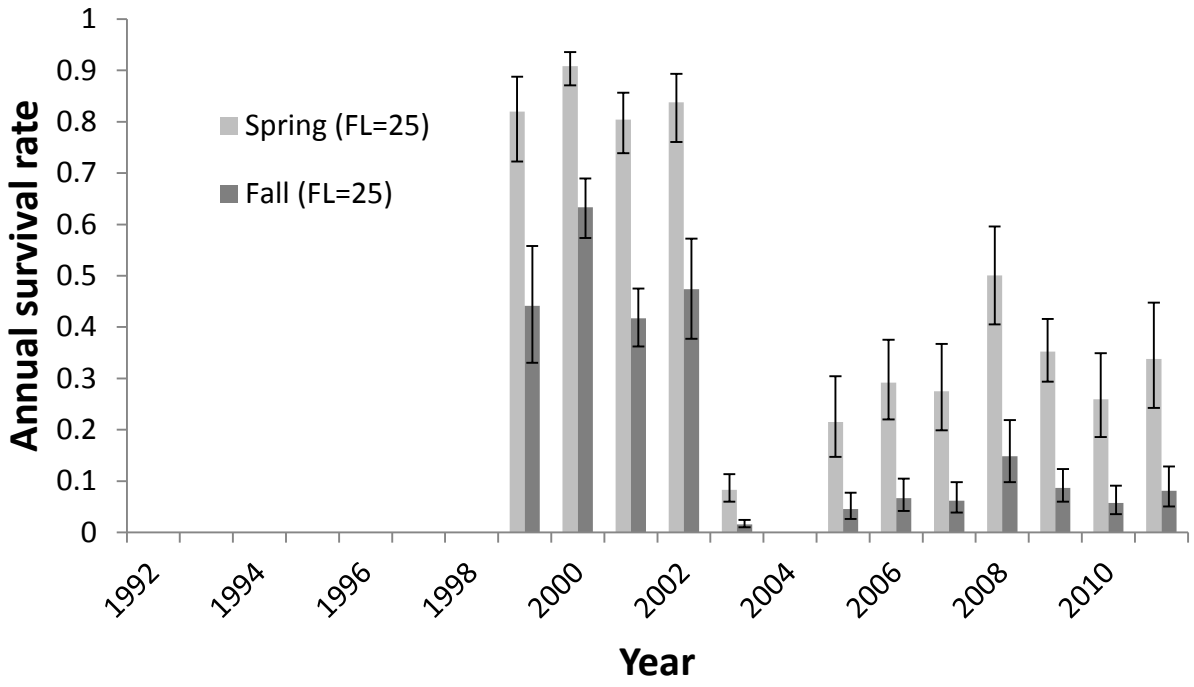

Figure 1.2.6. Predicted annual survival of age-1 White Sturgeon in the Kootenai River system from 1992-2012. Annual survival (and 95% confidence interval) is illustrated for fish that were released in the spring and fall. The years with no estimates are when age-1 fish were released. Estimates do not account for potential confounding by hatchery sources.

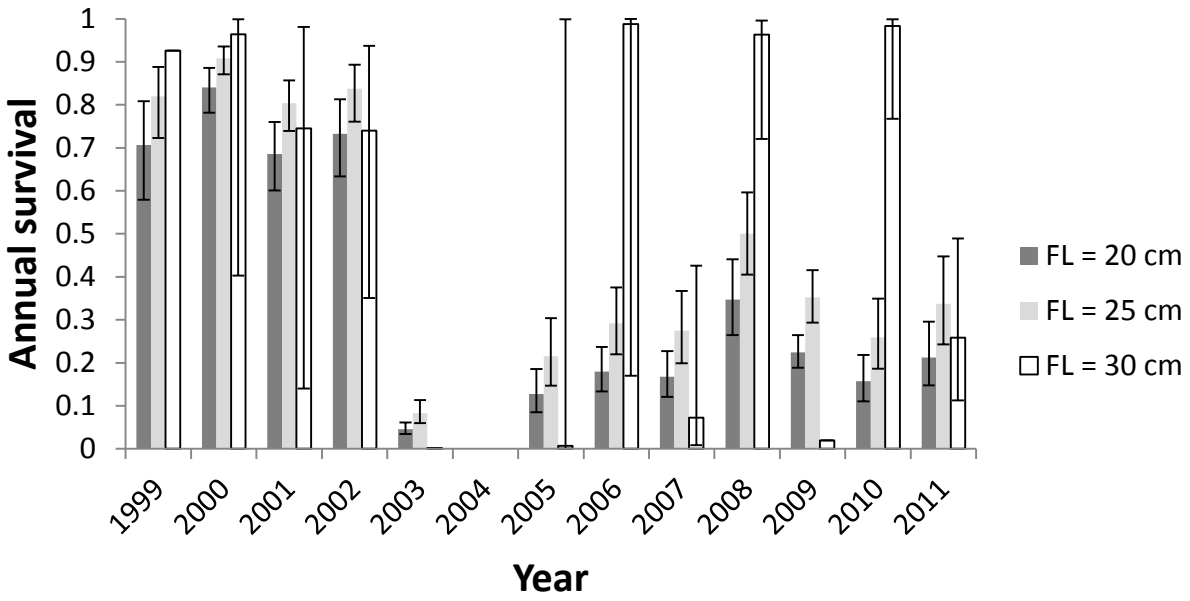

Figure 1.2.7. Predicted annual survival of age-1 White Sturgeon in the Kootenai River system from 1992-2012. Annual survival (and 95% CI) is illustrated for fish that were released at three different fork lengths (20 cm, 25 cm, and 30 cm) during spring only. The years with no estimates are when age-1 fish were released. Estimates do not account for potential confounding by hatchery source.

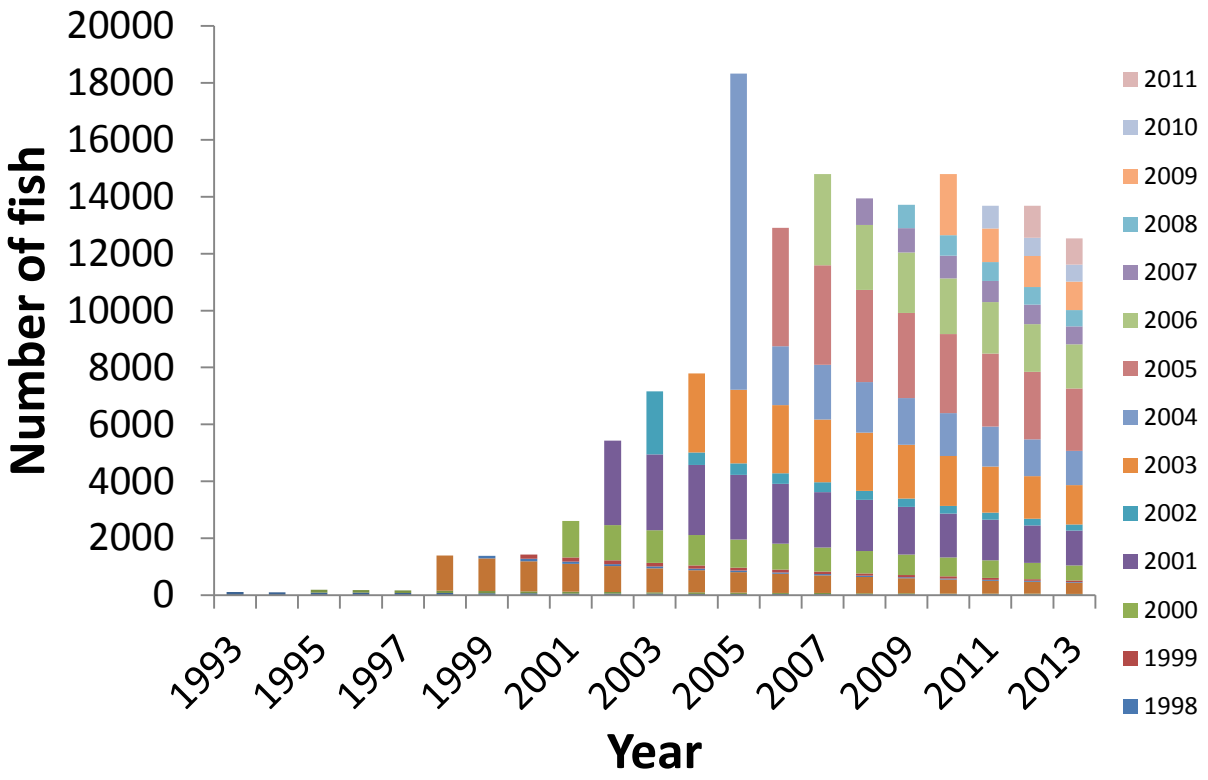

Figure 1.2.8. Estimated annual numbers of White Sturgeon of all age classes, by release year, for the Kootenai River system from 1992-2012.

CHAPTER 1.3: MAPS AND GEOSPATIAL DATA FOR THE SHORTY'S ISLAND AND MYRTLE CREEK SUBSTRATE ENHANCEMENT PILOT PROJECTS, KOOTENAI RIVER NEAR BONNERS FERRY, IDAHO.

AUTHOR: RYAN FOSNESS

ABSTRACT

The U.S. Geological Survey, in cooperation with the Idaho Department of Fish and Game, conducted a study to characterize the physical habitat occupied by Kootenai River White Sturgeon during spawning and early-life phases. The objective was to gain a better understanding of spawning behavior, site selection, and type of habitat used during egg incubation in two sub-reaches of the Kootenai River. Habitat characterizations generated by this study will assist in the design of a substrate enhancement pilot project.

This report presents the methods used to develop georeferenced portable document format maps and geospatial data that describe spawning locations and physical habitat characteristics (including egg mat locations, bathymetry, surficial sediment facies, and streamflow velocity) within the substrate enhancement pilot project study area. The results are presented as two maps illustrating the physical habitat characteristics along with proposed habitat enhancement areas, aerial imagery, and hydrography. The results of this study will assist researchers, policy makers, and management agencies in deciding the spatial location and extent of the substrate enhancement pilot project.

INTRODUCTION

In 1994, the U.S. Fish and Wildlife Service (USFWS) listed the Kootenai River population of White Sturgeon (*Acipenser transmontanus*) as an endangered species under the provisions of the Endangered Species Act (ESA) of 1973, as amended. The listing was the result of decreasing population numbers and a lack of juvenile recruitment that was first noted in the mid-1960s (Federal Register 1994; U.S. Fish and Wildlife Service 1999). Many researchers attributed the decreasing numbers and lack of recruitment to the degradation of White Sturgeon habitat, particularly the habitat used for spawning (Paragamian et al. 2001 and 2002; Kock et al. 2006). A 29 km reach extending from river kilometer (rkm) 257, downstream of the Moyie River confluence, to rkm 228 in the meander reach downstream of Shorty's Island, was designated as Kootenai River White Sturgeon critical habitat (Federal Register 2008; Figure 1). Most sturgeon spawn in the lower part of the critical habitat (rkm 228–240.5), with preference given to five primary spawning sub-reaches, including Lower Shorty's Island (rkm 228.7–229.6), Middle (also referred to as South) Shorty's Island (rkm 230.0–231), Myrtle Creek (rkm 233.5-234.7), Kootenai National Wildlife Refuge (rkm 235.2–235.9 and rkm 236.1–236.9), and Deep Creek (rkm 238.9–239.9) (Paragamian et al. 2002).

Because of the lack of suitable spawning and early-life substrate in the lower meander reach, one recommendation from the Kootenai River White Sturgeon (KRWS) Recovery Implementation Plan proposed "add rock to substrate in current spawning areas to evaluate its role in providing suitable spawning and incubation conditions" (Anders et al. 2007). In April 2010, under the authority provided by the Continuing Authorities Program, Section 1135, the U.S. Army Corps of Engineers, in cooperation with the Kootenai Tribe of Idaho, initiated a feasibility study to "identify and implement cost-effective, self-sustaining ecosystem restoration actions to improve ecosystem function and habitat attributes for the early life stage survival of the ESA-listed KRWS" (U.S. Army Corps of Engineers [USACE] 2012). The U.S. Army Corps of Engineers feasibility study recommended a substrate enhancement pilot project (SEPP) at two locations: Shorty's Island South and Myrtle Creek. In 2013, the Kootenai Tribe of Idaho continued the implementation of the SEPP at two sites in the meander reach. The objective of the SEPP is to test "the sustainability and effectiveness of placing rock substrate over existing clay surfaces in two subreaches of the river where wild KRWS currently spawn" (Kootenai Tribe of Idaho 2013).

The U.S. Geological Survey, in cooperation with the Idaho Department of Fish and Game (IDFG), conducted a 2-year study to characterize the physical habitat occupied by KRWS during spawning and early-life phases. The objective of the study was to gain a better understanding of spawning behavior, site selection, and type of habitat used during egg incubation at the two subreaches planned for the SEPP. The study areas included two primary spawning subreaches located within KRWS critical habitat Figure 1.3.1. The first study area is located between rkm 234–235 near the mouth of Myrtle Creek confluence, and is referred to as Myrtle Bend. The second study area is located between rkm 230–231.5 near a prominent island known commonly as Shorty's Island.

Purpose and Scope

This report presents two layered georeferenced portable document format (GeoPDF) maps and all geospatial data and metadata that describe spawning locations and physical habitat characteristics within the SEPP study area of the Kootenai River. Spawning locations are represented by the IDFG egg mat network and physical habitat characteristics including bathymetry, surficial sediment facies, and streamflow velocity mapping. Shaded relief imagery

and surficial sediment facies data provide a visualization of the habitat characteristics near current KRWS spawning grounds. The bathymetric contours are provided as a reference to the general elevations in the study areas. The streamflow velocity mapping data provide depth-averaged velocity magnitude and direction data intended to provide biological and morphological streamflow information that may be of use for describing habitat conditions.

A brief discussion of the data collection and data processing methods used to develop each dataset is presented. Physical habitat characterizations are presented as two maps illustrating the physical habitat characteristics along with other ancillary information (egg mat locations, substrate enhancement areas, aerial imagery, and other metrics in relation to the egg mats). The results of this study will assist science researchers, policy makers, and management agencies in deciding the spatial location and extent of the SEPP.

METHODS

Bathymetry

High-resolution bathymetry data were collected in June 2010 within each of the study areas using a multibeam echo sounder (MBES). A description of the methods used to complete the MBES survey is presented in Fosness (2013). Point data from the MBES survey were used to create a surface raster, or digital elevation model (DEM), for each of the study areas. One meter interval contours were created from the DEM to provide elevation reference for each of the study sites. A shaded relief (or hillshade) was created from the DEM and then applied to the contours as a background hillshade.

Sediment Facies

Surficial bed sediments, herein referred to as sediment facies, were classified into categories based on particle size and, in some instances, color. Sediment facies categories included the following ranges based on the standard Wentworth scale division: gravel (2–64 mm diameter), sand (0.063–2 mm), and silt/clay (<0.063 mm) (Wentworth 1922). An underwater video monitoring system (UVMS) was used to capture video images of the sediment facies and record the geographical position of the substrate. UVMS data were collected intermittently at each site from 2006 to 2012 using the same methods described in Weakland et al. (2011). Underwater video images were captured at discrete points along numerous transects throughout the study areas, allowing for sufficient detail to record distinct differences between each type of sediment facies. The DEM from the bathymetry was used in combination with the sediment facies map to identify sediment category boundaries, and to delineate the sediment features, such as sand dunes, major and minor clay steps, and clay benches. Major clay step features had a vertical face greater than 1.5 m; whereas, minor clay step features were less than or equal to 1.5 m. Clay step features were verified using the UVMS, and the extent and magnitude of the clay step features were mapped using the DEM. ESRI© ArcGIS™ was used to create a geographic information system (GIS) layer defining the dominant sediment facies classifications: gravel, sand, clay, silt, and major and minor clay steps.

Velocity Mapping

Acoustic Doppler current profiling (ADCP) data were collected at the Shorty's Island study area on June 1, 2012, and the Myrtle Bend study area on June 3, 2013. Twenty-nine transects were surveyed at each study area, and each transect was surveyed a minimum of four

times following procedures outlined in Mueller et al. (2013). ADCP data were post-processed using WinRiverII software, and the velocity data was produced using the Velocity Mapping Toolbox (VMT) software (Parsons et al. 2013). The velocity data were depth-averaged and horizontal spacing was set to 10 m. ADCP data including the coordinates, magnitude, and direction of the depth-averaged velocity vectors and were saved as a GIS layer.

Idaho Department of Fish and Game Egg Mat Network

Artificial substrate mats, herein referred to as egg mats, consist of a weighted frame covered with a material designed to retain and trap sturgeon eggs. The egg mat data from this study were located in the Shorty's Island and Myrtle Bend study areas. Data used for this study are a subset of a larger egg mat network operated by the Idaho Department of Fish and Game (Hardy et al. 2014). The egg mat data were provided by IDFG for 2007–13 and included date, number of eggs collected, and the spatial location.

Idaho Fish and Game personnel installed and retrieved the egg mats on a 24–48 hour rotation during the spawning season. The egg mat spatial locations were recorded using a mapping-grade GPS unit, and the date and time were recorded for both the installation and retrieval. If eggs were present upon retrieval, the number of eggs and the date and time of retrieval were recorded and entered into a database for each year. An ESRI© shapefile was created in ArcMap containing all of the egg mat data from 2007 to 2013. Attributes were created for the date, number of eggs collected, and spatial location.

Substrate Enhancement Pilot Project Extent

GIS layers for the Myrtle Bend and Shorty's Island SEPP study areas represent the areal extent for placement of artificial substrate. The SEPP extent was created by analyzing the egg mat network, bathymetric features, surficial sediment facies, and streamflow characteristics. The egg mat data describe where sturgeon eggs were captured in previous years, indicating a preference of spawning location. The bathymetry and surficial sediment facies data were used to delineate relatively flat areas located entirely within the lacustrine clay outcroppings. The streamflow data, consisting of acoustic Doppler current profiles, were used to determine areas where streamflow velocity is sufficient to maintain transport of sand and fine-grained sediment, and to prevent deposition of sediment. The completed SEPP extent GIS layers represent locations where sturgeon have historically spawned. These areas are on a low sloped and predominantly lacustrine clay surface with relatively high streamflow velocities.

SUBSTRATE ENHANCEMENT PILOT PROJECT MAPS

Using the geospatial data from each component of the study, two digitally formatted GeoPDF study area maps were created for the Kootenai River SEPP near Myrtle Bend and Shorty's Island study areas on the Kootenai River near Bonners Ferry, Idaho. Geospatial data included in the maps are ADCP data (Figures 1.3.2 and 1.3.3), IDFG egg mat network information (Figures 1.3.4 and 1.3.5), surficial sediment facies, proposed substrate patch, and digital elevation model data including high-resolution shaded relief and elevation contours. Additionally, orthoimagery, grids, geographic names, hydrography, and other selected geospatial data in this map are from selected National Map data holdings and other government sources (Dollison 2010).

The GeoPDF maps were created for general viewing purposes using Adobe® Reader® and intended for users who may not have access to or experience with geographical information systems. Each map was produced using TerraGo Publisher® for ArcGIS® software, which adds a geospatial reference along with an option to turn individual layers on and off. A metadata file is embedded within the GeoPDF document to provide detailed information for each of the layers in the map.

ESRI© shapefiles were created for each dataset and can be used in various types of geospatial software applications. A hyperlink to the metadata and GIS data is included for each dataset.

SUMMARY

The U.S. Geological Survey, in cooperation with Idaho Department of Fish and Game, conducted a 2-year study to characterize the physical habitat occupied by Kootenai River White Sturgeon (KRWS) during spawning and early-life phases. The objective of the study was to gain a better understanding of spawning behavior, site selection, and type of habitat used during egg incubation at the two subreaches of the KRWS critical habitat planned for the substrate enhancement pilot project (SEPP). The basic data and habitat characterizations generated by this study will assist in the design of the SEPP near Myrtle Bend and Shorty's Island.

This report presented the methods used to develop two layered GeoPDF maps that describe spawning locations and physical habitat characteristics within the SEPP study area. Spawning locations are represented by Idaho Department of Fish and Game egg mat network data. Physical habitat characteristics include bathymetry, surficial sediment facies, and streamflow velocity. Bathymetric contours, shaded relief imagery, and surficial sediment facies data provide a visualization of the habitat characteristics near current KRWS spawning grounds. The bathymetric contours provide a reference to the general elevations in the study area. The streamflow velocity mapping data provides depth-averaged velocity magnitude and direction data intended to provide biological and morphological streamflow information that may be of use for describing habitat conditions.

The results are presented as two maps that illustrate the physical habitat characteristics along with supporting geospatial data and metadata. The results of this study will assist researchers, policy makers, and management agencies in deciding the spatial location and extent of the SEPP.

FIGURES

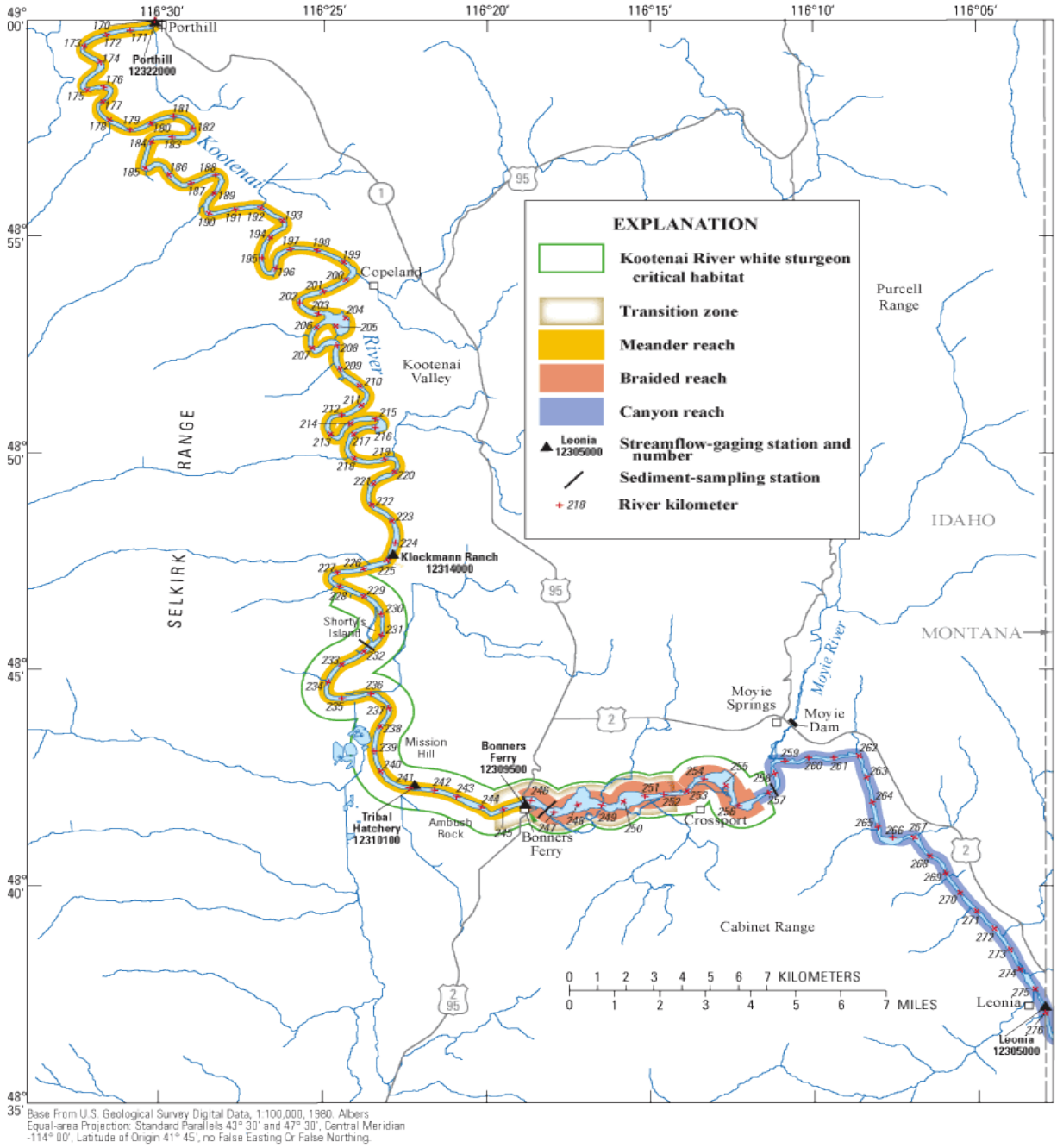

Figure 1.3.1. Location of the Kootenai River White Sturgeon critical habitat in the study reach, near Bonners Ferry, Idaho. (From Fosness and Williams 2009)

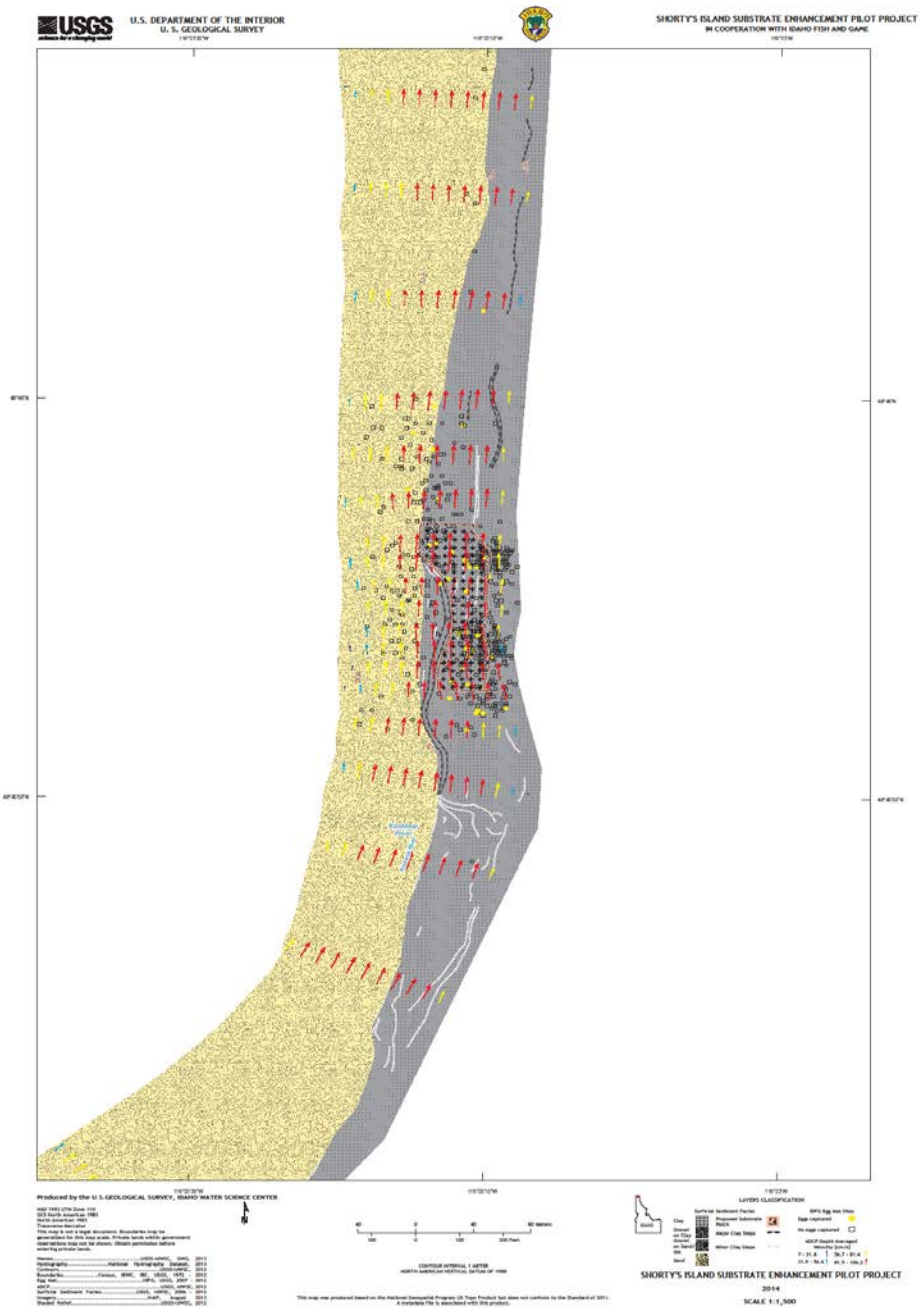

Figure 1.3.2. Surficial sediment facies and ADCP velocity map for Shorty's Island substrate enhancement pilot project site, Kootenai River near Bonners Ferry, Idaho. Grey area on right bank designates clay substrates while black/yellow mottled sections designate sand substrates. Red arrows indicate areas of higher velocity, yellow arrows indicate slower velocities.

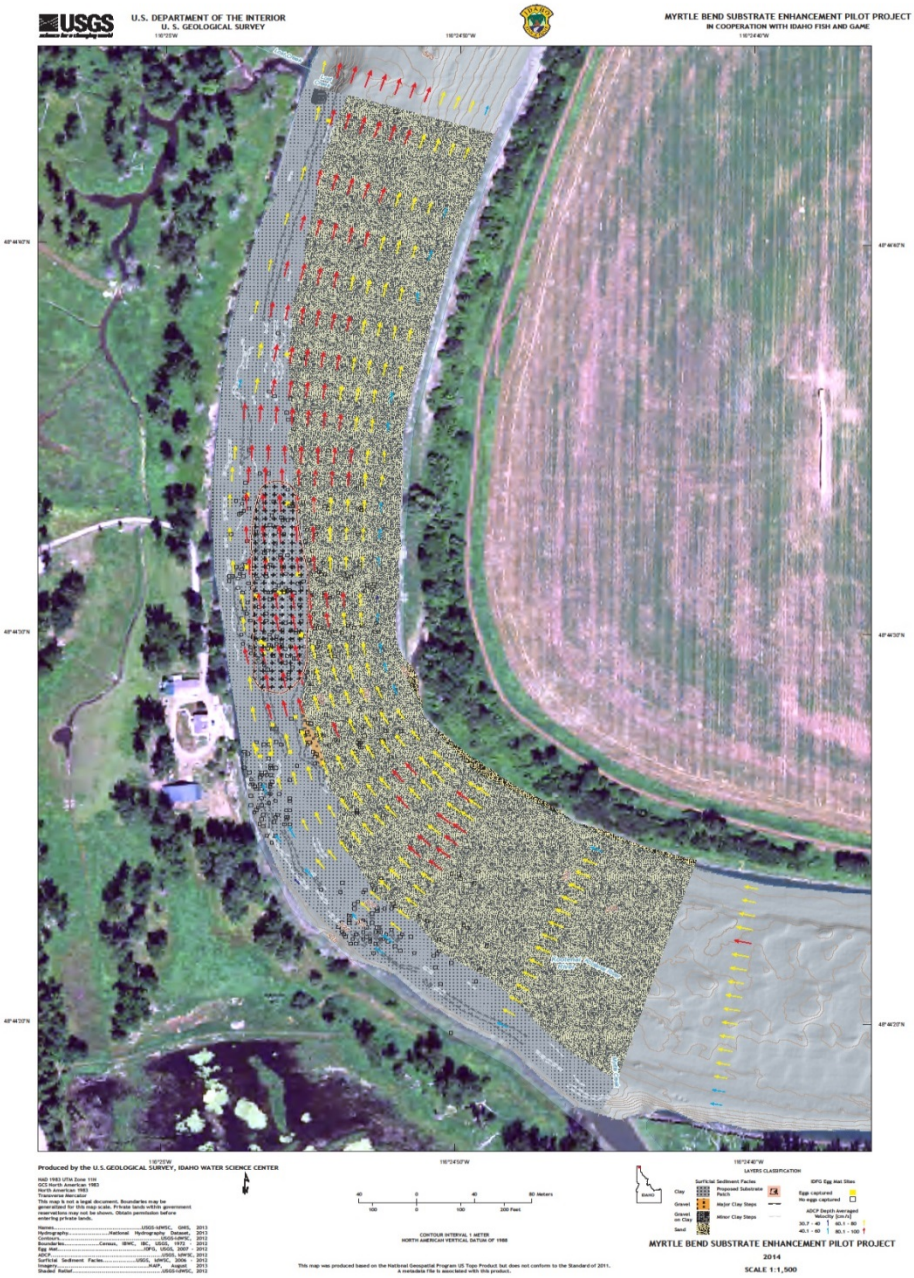

Figure 1.3.3. Surficial sediment facies and ADCP velocity map for Myrtle Bend substrate enhancement pilot project site, Kootenai River near Bonners Ferry, Idaho. Grey area on left bank designates clay substrates while black/yellow mottled sections designate sand substrates. Red arrows indicate areas of higher velocity, yellow arrows indicate slower velocities.

Figure 1.3.4. Location of substrate mats with (yellow dots) and without (green dots) eggs at Shorty's Island substrate enhancement pilot project site, Kootenai River near Bonners Ferry, Idaho. Oval outline denotes proposed enhancement pilot project site.

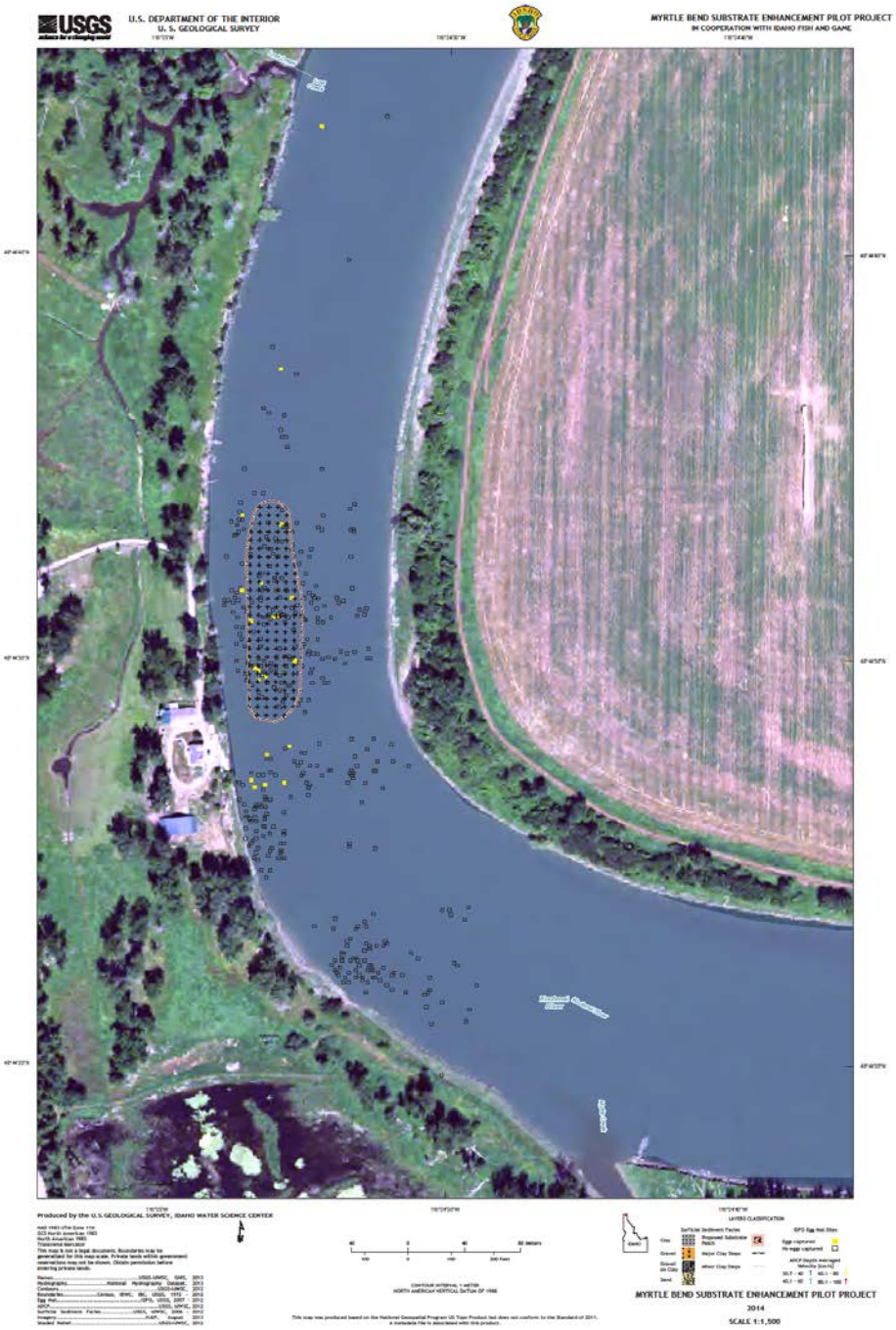

Figure 1.3.5. Location of substrate mats with (yellow dots) and without (green dots) eggs at Myrtle Bend substrate enhancement pilot project site, Kootenai River near Bonners Ferry, Idaho. Oval outline denotes proposed enhancement pilot project site.

CHAPTER 2: BURBOT MONITORING AND EVALUATION
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ABSTRACT

Burbot numbers in Kootenay Lake and Kootenai River of British Columbia, Idaho, and Montana have diminished primarily due to physical habitat changes. Recent implementation of a conservation strategy included aquaculture to supplement the population using a donor stock from a self-sustaining lake population within the Kootenai watershed. Our evaluation of release strategies suggests that lake origin Burbot have not only adapted well to the Kootenai system, but selected riverine over lacustrine habitat. Previous telemetry work identified good survival and dispersal of released Burbot, and in some cases, vast dispersal distance and lacustrine use. However, our analysis of a broader telemetry dataset indicated that only 24% of age 1-4 Burbot were detected in the lake. Recapture hoop-net data indicated that Burbot currently residing in the river have growth and survival rates comparable to the historical population. Spawning of hatchery origin fish was detected at a historical riverine spawn location. Other than a later spawn timing, our evaluations suggest these lake origin fish are mimicking movement and habitat use of the historical riverine population. This study, in combination with other recent investigations, provides evidence that Burbot progeny from lacustrine broodstock can successfully survive, grow, disperse, and spawn in a riverine environment.

INTRODUCTION

Although Burbot *Lota lota maculosa* are widespread and abundant throughout much of their natural range (Evenson and Hansen 1991), many populations are in serious decline (Arndt and Hutchinson 2000; Paragamian et al. 2000). As a result, restoration efforts have been initiated to mitigate factors that threaten these populations from further decline or localized extirpation (Dillen et al. 2008; Worthington et al. 2009; Stapanian et al. 2010). Primary sources of declines have been attributed to significant changes in habitat often stemming from the construction of dams used in flood control or electric generation. This is the case on the Kootenai (spelled Kootenay in Canada) River in Idaho, where Libby Dam, constructed in the early 1970s, has significantly increased winter discharge and temperature during the spawning period (Partridge 1983), which is thought to have negatively impacted recruitment (Hardy and Paragamian 2013). Additional impacts from the construction of the dam and diking within the Kootenai floodplain include decreases in nutrient availability and loss of habitat from floodplain isolation (Hardy 2003). Following the dam's construction, impacts to the Idaho population resulted in the fishery rapidly declining in the mid-1980s and ultimately, closure in 1992. Concomitant to the collapse in Idaho was the rapid decline of the Burbot fishery in Kootenay Lake and Kootenay River, British Columbia (BC), which resulted in those fisheries also being closed in 1997 (Paragamian et al. 2000).

Because of the widespread cultural and recreational importance of Burbot in the Kootenai River prior to the collapse, an International Burbot Conservation Strategy (Strategy) was developed by a community-wide working group to help restore the population (Paragamian et al. 2002; KVRI 2005; Ireland and Perry 2008). The Strategy outlined rehabilitation measures, including changes to the operation of Libby Dam and development of conservation aquaculture to supplement the wild stock during population rehabilitation. Following these criteria, managers deemed it necessary to locate and introduce a donor stock to aid in restoration efforts. Of the water bodies sampled, Burbot from Moyie Lake, BC were found to be of a similar phylogenetic group as the Kootenai River population (Powell et al. 2008) and suitable as a donor stock. Shortly after locating the broodstock source, intensive rearing techniques were successfully developed at the University of Idaho Aquaculture Research Institute (UIARI; Jensen et al. 2008a). As a result of this success, the Kootenai Tribe of Idaho (KTOI), Idaho Department of Fish and Game (IDFG), and British Columbia Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) have stocked larval, juvenile, and adult Burbot into the Kootenai River and its tributaries since 2009 in an effort to aid natural production and test specific population limiting factors.

As identified by Neufeld et al. (2011), one important facet to the success of the conservation aquaculture efforts on the Kootenai River was to determine if hatchery progeny from lake-origin Burbot would adapt well to use riverine environments. Previous telemetry evaluations of lake-origin juvenile Burbot released into the Kootenay River (Neufeld et al. 2011; Stephenson et al. 2013), revealed that adult Burbot (age-2+) dispersed quickly from release tributaries and dispersed great distances, covering up to 235 km, including both lacustrine and riverine habitat. In comparison, the dispersal of the age-1 (juvenile) Burbot was slow, or non-existent, from release tributaries and was significantly lower than that of the older Burbot (Stephenson et al. 2013). These studies began to provide insight on Burbot early life history and adaptation; however, the long-term adaptation of lake-origin Burbot progeny released into a riverine environment is still poorly understood. Using passive sonic telemetry, a Passive Integrated Transponder (PIT) array, and mark recapture evaluations through hoop net sampling, our research investigated survival, growth, spawn timing, and movements of lake-origin Burbot released into the Kootenai River basin and compared these to the historical native population.

This information is particularly important for guiding current and future restoration programs in the Kootenai drainage and across the Northwest.

GOAL

The management goal of this study is to restore the Burbot population in the Idaho reach of the Kootenai River in order to provide a sustainable harvest of Burbot.

OBJECTIVES

1. Conduct monitoring and evaluation studies of sufficient rigor to enable development of a viable Burbot fishery.

2. Evaluate timing of downstream outmigration of Burbot in Deep Creek.

3. Evaluate survival of larval Burbot reared in different substrate types in Boundary Creek ponds.

STUDY AREA

The Kootenai River is the second largest tributary to the Columbia River and its drainage is the third largest (approx. 49,987 km^2; Bonde and Bush 1975). The river originates in Kootenay National Park, BC, and discharges south into Montana, where Libby Dam impounds water into Canada and forms Lake Koocanusa. The river flows west from Libby Dam, northwest into Idaho, then north into BC and Kootenay Lake. The river then drains out of the West Arm of Kootenay Lake, and it eventually joins the Columbia River near Castlegar, BC. The habitat in BC includes river kilometer (rkm) 165 to 121 of riverine habitat and rkm 120 to 18 of lacustrine habitat in Kootenay Lake. Kootenay Lake has a surface area of 390 km^2 and is a fjord-like lake, running north-south in the trench formed between the Selkirk and Purcell mountains. Approximately 105 rkm flow through the Idaho section of the Kootenai basin.

During the study period, index hoop net sampling for adult Burbot occurred at 18 sites between rkm 144.5 (Nick's Island near Creston, BC) and 244.5 (Ambush Rock near Bonners Ferry, Idaho) (Figure 2.1). The coverage of the passive telemetry array began in Montana at rkm 305 downstream throughout Idaho and BC portions of the river and throughout Kootenay Lake, for a total coverage of over 325 linear kilometers (further described in Stephenson et al. 2013; Figure 2.1).

Extensive rearing of Burbot was conducted at two similar sized ponds at Boundary Creek Wildlife Management Area (BCWMA; Figure 2.1). Excavated in 2010, each BCWMA pond is approximately 13 x 27 x 3 m, and fills naturally through runoff and seepage. A PIT tag array was installed in Deep Creek, approximately seven km upstream from its confluence with the Kootenai River (Figure 2.1).

METHODS

Burbot Hoop Net Sampling

Burbot Stocking

Following the success of intensive culture at the UIARI, approximately 329,000 Burbot were released into the Kootenai River and its tributaries from 2009-2013, of which 32,000 juveniles (age-0 to -2; mean total length [TL] 193.7 mm ± 6.9 SE) were tagged with PIT tags (FDX; BioMark Inc.; 9 mm) and released into tributaries and the mainstem of the Kootenai River by KTOI, MFLNRO and IDFG personnel (Table 2.1).

Burbot Hoop Net Sampling

Adult Burbot were sampled at 18 locations using 32 baited hoop nets during winter 2013/14 (seven Canadian and 11 U.S. sites; Figure 2.1) to measure relative changes in the population through catch-per-unit-of-effort (CPUE). Six historical index sites (since 1994) along with an additional 12 sites were sampled annually from December 1 to March 31 to collect information on CPUE, growth, year class survival, and spawning activity within the Kootenai River. Each river site was sampled using hoop nets (2.00 m x 0.61 m) with 25.4 and 19.1 mm bar-mesh sizes. Beginning in 2010, two hoop nets of 19.1 and 6.4 mm bar-mesh sizes were paired at each site to account for possible gear selectivity. Nets were baited with frozen kokanee *Oncorhynchus nerka* and checked three times per week. Burbot captured in nets deeper than nine meters were re-set to one-half the original depth for approximately 24 hours to allow for fish decompression and reduce barotrauma-related mortality (Neufeld and Spence 2007). All Burbot were counted, measured for TL (mm), weighed (g), sex determined (i.e., if flowing milt or eggs), and examined for previous tags. All untagged Burbot were injected with a unique PIT-tag into their right anterior dorsal muscle for future population estimates, growth, and survival by brood year. Tissue samples for genetic analysis were collected from the anterior portion of the dorsal fin of all untagged Burbot to determine origin (hatchery or wild) and year-class using Parental Based Tagging (PBT) analysis (methods described by Anderson and Garza 2005; Steele and Campbell 2011) in the future. Evidence of spawning was determined by methods described by Kozfkay and Paragamian (2002), where the number of flowing males, gravid females, and spent adults were recorded. Fish that were recaptured within a 14-day period and exhibited weight loss were also used to identify approximate spawn timing.

Tributary Outmigration

On October 11, 2012, three FDX Biolite BioMark Passover PIT antennas were placed in Deep Creek (9.14 m channel width) approximately 7 rkm from the confluence with the Kootenai River. The array was powered by a thermo-electric generator fueled with four 100-pound propane tanks. To evaluate timing of downstream outmigration, 3,000 juvenile Burbot (age-0; 180 days-post-hatch; mean TL = 108.7 mm ± 0.2 SE) were stocked upstream of the antenna on November 6, 2012. Prior to release, Burbot were PIT tagged abdominally (RFID solutions; PT300; 9 mm) on October 1, 2012 and held for one month to account for tagging-induced mortality. Two sites upstream from the mouth of Deep Creek (Naples at 21 rkm upstream and McArthur Lake at 34 rkm upstream) were each stocked with 1,500 age-0 Burbot on November 6, 2012. An additional 1,200 were stocked at each of these locations again in November 2013. All detections of PIT-tagged fish from this stocking, as well as those that entered the stream from prior capture events, were recorded on the array data recorder. The PIT tag array could not determine direction of fish movements; therefore, time of outmigration was defined as the

first time of detection by the array. To gather information on growth and survival of age-0 Burbot from these two stocking events, one 6.4 mm mesh hoop net was set at each of the two stocking locations from January-April 2014.

Sonic Tagging

A total of 196 lake-origin hatchery reared Burbot were tagged with sonic tags (VEMCO Division, AMIRIX Systems Inc., Halifax, Nova Scotia). From 2009-2012, 181 Burbot were tagged prior to release into Kootenay River. These fish ranged in age from 1 to 3 years and were all tagged with V9-2L tags (methods and tag specifications further described in Stephenson et al. 2013). Mean total length (TL) of age 1-3 Burbot was 246 mm (± 5.8 SE), 326 mm (± 6.3 SE), and 413 mm (± 15.9 SE), respectively. Fifteen adult hatchery Burbot (mean TL = 544 mm ± 14.3 SE) recaptured in hoop nets set in the mainstem of the Kootenai River were tagged with V13-2L tags. Although exact ages of the Burbot tagged in the river were unknown, all were assumed adults based on length and age relationships of the historical wild population of the Kootenai River (Partridge 1983) and other systems (Katzman and Zale 2000).

Telemetry Array

In the Kootenay River and Kootenay Lake there was an established array of 73 Vemco (VR2s and VR2Ws) 81 kHz receivers that extended from the border of Idaho with Montana, downstream throughout the Kootenay River and Kootenay Lake (Figure 2.1). The receivers were set at specific stations as “gates” to detect movement of any tag that passed a specific rkm. In the river, single receivers were sufficient to form a gate, while in the lake, as many as four receivers were required to form a gate. The number of receivers required at each station was based on a minimum detection range of 500 m. The mean distance between stations was 4.4 km, and ranged from 100 m to 13.0 km apart (further described in Neufeld and Rust 2009). All tracking locations of telemetered fish resulted from detections by this passive monitoring system.

Telemetry Evaluations and Analysis

Telemetry evaluations were initiated with the first release of hatchery-reared Burbot into the Goat River, a Kootenay River tributary, on October 21, 2009. The tagging and release locations ranged from rkm 153 upstream to rkm 259, stretching across the study area and included both tributary and mainstem releases (Figure 2.1). Detection data was available until tag battery life expired, fish died, or until final download of receivers in March 2014. Detections were first evaluated to eliminate erroneous detections (further described in Neufeld and Rust 2009). Initial survival was defined as sonic tagged fish that survived a minimum of one month post release, as indicated by detections on receivers. Long-term survival was evaluated by identifying tags that were detected by sonic receivers for a minimum of one year post release. The range of movement for each fish was calculated as a linear distance (rkm) by subtracting the furthermost downstream detection and subtracting it from the furthermost upstream detection location. The extent of movement was evaluated from all records of Burbot that survived a minimum of one month post-release. Minimum and maximum detection locations were compared to release locations to evaluate directionality of movements. The proportion of Burbot that survived and entered Kootenay Lake (<rkm 122) was also evaluated to determine extent of lake habitat use. A one-way analysis of variance (ANOVA) was used to compare mean total movement (rkm) within the study area, between ages, and between the hatchery adults tagged in-river or tagged prior to release. The level of significance for main effects was set at

alpha of 0.05. A Chi square analysis was used to compare the proportion of Burbot that entered the lake and to evaluate differences in survival.

Extensive Burbot Rearing

We evaluated Burbot growth, survival, food preference, and the effect of different substrates on cannibalism of larval Burbot reared in two manmade ponds at BCWMA. Each pond measured approximately 25.0 x 15.0 x 3.5 m. For 2013 sampling, collection methods for Burbot and zooplankton were similar to 2012. Hatch date for Burbot stocked into the ponds ranged from March 27 to April 5, 2013. For analysis, April 1 was used as the hatch date for all Burbot stocked into the BCWMA ponds. On May 22, 2012, we stocked 50,000 feeding larval Burbot into each BCWMA pond (0.04 fish/L). We drained each pond on July 25-27, 2013 using gas powered water pumps and conducted multiple passes with a 1,000 µm mesh beach seine to capture all Burbot remaining from the original stocking event. All fish were anesthetized with MS-222, weighed (g), measured (TL; mm), and PIT tagged in the abdominal cavity if they were >65 mm. After tagging, all Burbot were transported and stocked into Boundary Creek, 2 rkm above the confluence.

RESULTS

Burbot Hoop Net Sampling

We sampled 18 sites from December 1, 2013 to March 30, 2014, totaling 3,395 net d and captured 447 Burbot. CPUE for the 2013/14 season by river site ranged from 0.005-0.50 Burbot/net d, with an overall CPUE of 0.13 Burbot/net d. This most recent sample season was a 1.9-fold increase in catch rates from the 2012/13 season and a 33-fold increase from the 2006-2011 mean (Figure 2.2). The overall CPUE for index sites also increased from 0.09 Burbot/net d in 2012/13 to 0.18 Burbot/net d in 2013/14 (Figure 2.2). Catch rates across all sites remained relatively constant temporally throughout the sampling period, with a substantial increase at U.S. sites from mid-February to mid-March. During this peak (2012-2014), 34 flowing males (289-760 mm) and four gravid females (353-751 mm) were captured, primarily at the Ambush Rock (rkm 244.5). Sixteen of these 38 spawners were conclusively identified as hatchery-reared fish based on PIT tags. The 2012/13 peak in CPUE coincided with a significant amount of weight loss from Burbot recaptured within 14 days of initial handling. Comparison of the 2013 and 2014 catch rate peaks (March 11, 2013 and March 4, 2014) with the historically greatest sampling season catch rate for wild Burbot (February 11, 2001) suggests that spawn timing peaked approximately 30 days later for the lake-origin progeny. Mean water temperatures during the spawn at Ambush Rock were 2.7°C (± 0.12 SE) in 2001, 4.5°C (± 0.15 SE) in 2013, and 2.0°C (± 0.21 SE) in 2014 (Figure 2.3 and 2.4). Duration of spawning activity observed during the three spawning seasons was nearly identical at approximately 22 days.

Of the 447 total captures, 371 (83%) were unique individuals consisting of 173 Burbot without PIT tags and 198 with PIT tags at first capture during 2013/14. Of the PIT tags that returned to the hoop nets this season, year class assignments showed that the majority came from 2009 and 2011 brood years (Table 2.2; Figure 2.5). However, 2007 and 2008 had the highest proportion of returns, based on the total number stocked with PIT tags by brood year (Table 2.2). The 198 Burbot recaptured with PIT tags were identifiable to a release location and age-at-release (Figure 2.6). Evaluation of 245 Burbot recaptures from the combined 2012/13 and 2013/14 winter hoop net seasons showed that hatchery reared Burbot distributed throughout the sample locations, with the majority being recaptured upstream of their original

stocking location (Figure 2.6). The highest return of PIT tags came from the Boundary Creek and Porthill release locations with a cumulative return of 1.7 and 0.9% respectively. Burbot originally released from all six primary release locations were recaptured at rkm 244.5. Those fish initially released the farthest downstream (75 rkm) represented the highest percent return at this location at 0.6%.

Evaluation of mesh types using total CPUE and mean TL showed that 6.4 mm mesh was lower in CPUE (0.11 fish/d) and caught smaller (TL 420 mm) fish than the 19.1 mm mesh (0.27 fish/d and 437 mm respectively; Table 2.3). However, with respect to depth of net sets, there was no difference in catch rates for those nets set greater or less than 25 m (Table 2.4).

Length-at-age (at the time of capture) indicated that Burbot were increasing in growth annually, ranging from 60-114 mm / yr. Growth rates appear to be similar to those from wild Kootenai River Burbot captured and aged using otoliths in the early 1980s, and higher than those obtained in the late 1950s (Figure 2.7; Partridge 1983).

Tributary Release Monitoring

Between October 1, 2012 and January 15, 2014, 129 Burbot were detected by the Deep Creek PIT tag array (Table 2.5). One hundred of the detections were from the 3,000 Burbot released in Deep Creek on November 6, 2012, 16 from other stocking events, and 13 adult Burbot of unknown origin that were tagged in the mainstem of the Kootenai River during hoop net sampling in previous years. Of the 16 Burbot from other stocking locations, seven came from stocking events 35-70 rkms downstream of the array location (Table 2.5). The 13 adult Burbot of unknown origin were detected during the period identified as peak spawning in the mainstem Kootenai River. In 2013, one male was captured in January at Ambush Rock in the Kootenai River. Subsequently the same male was detected by the PIT tag array in Deep Creek on February 22, remained above the array for 18 hrs, and then returned to the mainstem where he was then recaptured at Ambush Rock on March 4, weighing approximately 450 g less. This weight loss suggests spawning took place during that period. None of the age-0 Burbot from the 2,500 stocked in 2013, two months prior, were detected out-migrating.

Despite the lack of recapture for this release group, hoop net sampling in the two release locations in Deep Creek confirmed survival of fish from both stocking events. Fourteen juvenile Burbot were recaptured in 77 net days of sampling. Of these, 12 were from the 2012 age-0 stocking and two were from the 2013 age-0 stocking event (Table 2.6). Three juveniles stocked at the Naples location in 2012 were subsequently recaptured 13 rkm upstream at the McArthur Lake outlet release location. Mean increase in total length and weight for 2012 was 90 mm (± 7 SE) and 90 g (± 10 SE) respectively.

Telemetry Monitoring

Overall survival after one year at large was 48% for all sonic tagged Burbot (Table 2.7). The annual survival differed between the juvenile (age-1) and adult (age-2+) Burbot tagged at the hatchery prior to release (χ^2 = 4.02; df = 1; P = 0.045); however, first year survival of hatchery adults tagged prior to release and adults tagged in-river were virtually identical (Table 2.7). The mean total range of movements for the entire study period differed between the three groups ($F_{2,126}$ = 11.1; P <0.001). The total detection ranges for the hatchery adults tagged prior to release was statistically higher than both the adults tagged in-river and the juveniles tagged prior to release. Mean total range of movement for age-1 was 41.3 km (± 6.6 SE), 86.4 km (± 8.4 SE) for age-2+, and 35.5 km (± 10.9 SE) for adults tagged in-river. Comparisons between

upstream and downstream ranges showed variability of downstream movement ($F_{2,126} = 8.45$; $P < 0.001$), similar to total range comparisons; however, there were no detectable differences between groups for the upstream range of movement ($F_{2,126} = 1.49$; $P = 0.2$; Figure 2.8).

Of the 129 radio-tagged Burbot that survived release, 31 (24%) were detected in the lake. Of these, the majority (74%) were hatchery fish tagged and released at age-2+ ($\chi^2 = 15.88$; df = 2; P = 0.0004). Two distinct movements were evident for Burbot that entered Kootenay Lake following release. Thirteen (42%) of the 31 Burbot that entered the Lake following release were detected less than 20 km from the mouth of the River during the study period. Of these, 46% subsequently returned upstream to the main-stem Kootenai River. The other dominant lake movement was made by 12 Burbot (39%) moving to the north end of the Lake, where they remained for the duration of the study.

Extensive Burbot Rearing

Following main-stem sampling, larval Burbot were cultured at the UIARI and released into our two extensive rearing ponds on the Boundary Creek WMA. After two months, we drained the ponds on July 27 and recovered 1,273 juvenile Burbot for a total survival of 1.4% from the original stocking event. Of these, 184 were large enough to PIT tag and release into Boundary Creek. As with previous years, growth rates of fish in the East Pond were higher than the West Pond (Figure 2.9).

DISCUSSION

Burbot Hoop Net Sampling

Main-stem Hoop Net Sampling

Initial estimation based on PIT tag returns showed that lake-origin hatchery fish survived, grew, and matured following release events into the Kootenai River and tributaries. Trend CPUE of Burbot captured in hoop nets increased 33-fold in the 2013/14 sampling season (0.132 fish/d) relative to mean catch rates from 2006 to 2011 (0.004 fish/d). In addition, these tag returns also revealed that many Burbot remained near or upstream of their stocking locations. At the beginning of this evaluation, managers were concerned that stocking Burbot progeny from lacustrine broodstock would result in fish migrating downstream to reside strictly in Kootenay Lake. Many lacustrine Burbot populations are adfluvial in nature, residing in a lake environment and migrating to rivers only to spawn (Sorokin 1971). The present study suggests that this species possesses an adaptive plasticity to survive various habitats despite parental origin.

As density of this species increases in the Kootenai River, factors limiting the recruitment of this population will also be better understood. It is important to note that although there have been substantial increases in Burbot CPUE since initial stocking, the Kootenai River population remains low relative to other Burbot populations, and successful recruitment in the wild has yet to be confirmed. As a comparison, CPUE in Moyie Lake was 0.5 to 2.2 fish/d (Prince 2007), the Chena and Tanana rivers of Alaska were 0.9 and 1.2 fish/d, respectively (Evenson 1993), and Burbot in four Alaskan Lakes ranged from 0.5-3 fish/d (Parker et al. 1988). Since the abundance of Burbot in the Kootenai River was unknown prior to Libby Dam, Paragamian and Hansen (2009) used the population and CPUE data in the aforementioned water bodies as surrogate restoration targets to guide the Kootenai River recovery program. With catch rates of Burbot in

the Kootenai River continuing to increase annually, these population objectives may be achieved in a relatively short period.

Along with increasing densities, the present study also shows that Burbot stocked into the Kootenai River have located adequate food resources. Growth rates of this lake-origin hatchery stock were similar to those of wild fish historically captured in the Kootenai River in the early 1980s, higher than those captured in the late 1950s (Partridge 1983), and comparable to other northern waterbodies that support healthy Burbot populations (Katzman and Zale 2000). Burbot grow rapidly in their first year and, depending on food resources and length of growing season, can reach 110-120 mm in TL by late fall (Chen 1969; Sandlund et al. 1985). Although few age-1 fish were recaptured in the present study, mean growth across all age groups averaged 96 mm/yr. As density increases, trends in growth rates will likely decrease toward the levels recorded in the 1950s. As such, close monitoring of this rate function will be crucial for balancing release numbers with food and habitat availability.

Multiple lines of evidence suggested that lake-origin hatchery reared Burbot adapted to spawn in the Kootenai River near Ambush Rock in late February to mid-March of 2013 and 2014. Additionally, adults of an untraceable origin made distinct movements into and from Deep Creek during this same period, suggesting that Deep Creek may also be a possible spawning location. In addition, although these are known historical spawning locations for Burbot in the river (Paragamian et al. 2000), these recent spawning events peaked later and at warmer temperatures than reported for wild Kootenai River Burbot (Kozfkay and Paragamian 2002). The observed peak in spawn timing in 2013 and 2014 was also later than the mid- to late February spawn-timing in Moyie Lake, where the original broodstock were collected (Matt Neufeld, MFLNRO, personal communication). This outcome was not expected and the shift in spawn timing may directly affect hatching success of Burbot in the Kootenai River. Taylor and McPhail (2000) suggested that maximum egg survival occurred at 3°C, with 0% survival above 6°C. In addition, these authors reported the mean time to hatching increased from 41 to 46-d if the incubation temperature was reduced from 5 to 3°C. Temperatures in the Kootenai River following the 2013 spawning event exceeded the lethal temperature (6°C) during the critical 40-45 day incubation period. The spawn timing of this newly stocked population may be later than the historical and donor population, therefore subjecting eggs to greater peaks above lethal temperatures. Identification of hatchery reared Burbot first surviving and then spawning in known historical riverine locations was a significant step in the success of this conservation aquaculture program. Going forward, the final step is to identify recruitment in the wild, and will likely include determining temperature influence on spawn timing and how temperature affects egg-hatching success. Not only will this information help drive identification of tributaries to focus on for release efforts, it may also provide useful recommendations to the United States Army Corps of Engineers (USACOE) on how to manage the selective temperature withdrawal system at Libby Dam in a way that will promote successful Burbot recruitment through increased egg survival.

PIT Antenna Monitoring

Relatively few juvenile Burbot passed over the PIT tag array in Deep Creek during the 15-month monitoring period, and the majority were detected within 30 days after stocking. Further evaluation with hoop nets set at the stocking locations upstream of the array showed that at least a portion of those that were not detected leaving, survived and increased in length and weight during this time. Previous telemetry study results also suggested similar results with wide-ranging dispersal rates by age-2 and -3 Burbot, while age-1 Burbot remained relatively close to stocking locations (Stephenson et al. 2013). These findings suggest that stocking

Burbot at younger ages may increase residence time in targeted tributaries that have suitable habitat. On the contrary, detections of 16 additional hatchery-reared Burbot revealed interesting and unexpected movement patterns, as they were originally stocked in the main stem of the Kootenai River as far as 70 rkm downstream of Deep Creek. This also suggests the ability of younger hatchery Burbot to pioneer new habitats and choose suitable habitat if it exists. In the near future, estimates of relative survival and movement of fish stocked into Deep Creek and other tributaries should aid in determining optimal release strategies that will promote survival and ultimately wild Burbot recruitment in the Kootenai River system.

Telemetry Monitoring

Through the broad telemetry array in Kootenay Lake and River, Burbot were noted covering extensive distances, yet the majority of Burbot monitored in this study remained within the main stem of the river throughout their detection period. The maximum distance traveled from a sonic-tagged hatchery Burbot was 241 km from its release location in the Moyie River (rkm 259) to its final detection point at the north end of Kootenay Lake (rkm 18). Although such wide-ranging dispersal to the north end the Lake was not the dominant movement trend, it demonstrates their ability to migrate long distances within the system.

Only one of the adult Burbot tagged in-river was detected in Kootenay Lake. Burbot from these in-river tagging events were at large at least two years post-hatchery release, and given this extended period, suggests they would have established a home range (Ebner and Thiem 2009). The mean total range for these adult Burbot provides a maximum estimate for a linear home range calculation (Crook 2004) at approximately 35.5 km^2, which was similar to the highest estimate for home ranges of Burbot within the nearby Koocanusa Reservoir (Dunnigan and Sinclair 2008). Minns (1995) found that home ranges of freshwater fish are approximately 20-fold greater in lentic than lotic environments and speculated that in systems with low productivity some fish travel farther as an instinct to locate preferred habitats with adequate prey items. Despite the evident wide-ranging ability of Burbot in the present study, lake use was relatively low and suggests that these fish selected for available habitat within Kootenai River.

Annual survival estimates from telemetry data for all adult sonic tagged Burbot were comparable to what has been observed in other systems. Survivorship was expectably higher for the adult Burbot versus younger hatchery reared Burbot, as most fish species suffer higher mortality at younger life stages (Jones 1991). In our evaluations, the mean annual survival rate was 54% for age-2+ Burbot. This was comparable to an estimate of adult Burbot in Moyie Lake completed in 2007 (53%; Prince 2007) and another southern adult population in western Lake Superior (57%; Schram 2000), yet lower than another survival estimate from adult Burbot within Moyie Lake completed in 2008 (70-80%; Neufeld 2008). Although the annual survival calculation includes the first month post release for the hatchery-tagged Burbot when hatchery released fish likely experience higher mortality (Ebner and Thiem 2009), the comparable annual survival rates for both in-river tagged Burbot and hatchery released adults suggests that 54% is a realistic survival estimate.

It is apparent that a limitation of the current telemetry evaluation is that the analysis of in-river captured adults was restricted to those captured within the current standardized hoop net sampling program, which takes place exclusively in the main stem of the Kootenai River (ending 24.5 rkm upstream of the Lake). Considering this, those Burbot utilizing more of the Lake habitat may have been excluded from the analysis in the present study. However, additional hoop and cod trap sampling efforts by the MFLNRO within Kootenay Lake have not captured hatchery-reared Burbot to date, despite confirmed residence there through telemetry data. Further work

will be needed to determine if more Burbot from Kootenai River releases are present within the Lake; whether direct releases into Kootenay Lake will be necessary to recover the once abundant Kootenay Lake Burbot population; or whether these hatchery reared Burbot will continue to select the available riverine habitat over lacustrine habitat.

Extensive Pond Rearing

The rearing ponds on the Boundary Creek WMA have shown that extensive rearing is possible and result in good growth of larvae fed on natural diets. Extensive rearing of larvae has been effective at increasing growth and survival of Burbot for the purposes of restoration when released as fingerlings (Dillen et al. 2008; Vught et al. 2008) and was considered important to an initial restoration strategy for Kootenai River Burbot (Jensen et al. 2008a; Jensen et al. 2008b; Vught et al. 2008). This will continue to be a facet of our program in order to serve as a backup should high mortality be experienced in the hatchery.

SUMMARY

This study, in combination with other recent investigations (Neufeld et al. 2011; Stephenson et al. 2013) provides evidence that Burbot progeny from a lacustrine broodstock can successfully survive, grow, disperse, and spawn in a riverine environment. Similar to many fish species, Burbot express fluvial, adfluvial, and lacustrine forms of migration and homing during their life history (Sorokin 1971, Evenson 1993, McPhail and Paragamian 2000). With potential broodstock sources readily available in many lacustrine environments, the release strategies in this study may be important to current and future restoration programs across the Northwest.

RECOMMENDATIONS

1. Provide comprehensive analyses and recommendations to management by 2015 that provide clear criteria for opening up a Burbot fishery on the Kootenai River.

2. Fully evaluate natural production and hatchery contribution through using PIT tags and PBT genetic marking.

3. Use available data to refine our understanding of what is limiting natural production in order to optimize a Systems Operation Request to the ACOE for Libby Dam.

4. Continue sampling index locations to measure changes in abundance, survival, size structure, and hatchery vs. natural production.

TABLES

Table 2.1. Total number of Burbot released from 2009-2013 into the Kootenai River and its tributaries. Fish were tagged with FDX PIT tags. Those without tags were primarily larval releases. Untagged fish from 2011 – present will be able to have brood year assigned by genetic analysis.

Stock year	Brood Year	Fish released with tags	Fish released without tags	Total fish released
2009	2006	7	-	7
	2007	23	-	23
	2008	1	178	179
2010	2007	5	-	5
	2008	18	-	18
	2009	555	-	555
	2010	-	1,576	1,576
2011	2009	-	26	26
	2010	36	90	126
	2011	16,297	53,966	70,263
2012	2010	82	-	82
	2011	656	-	656
	2012	3,392	204,805	208,197
2013	2011	71	0	71
	2012	601	0	601
	2013	10,017	36,866	46,883
Total		**31,761**	**297,507**	**329,268**

Table 2.2. Total number of Burbot stocked from 2006-2013, PIT tagged, and recaptured in hoop nets during the 2013/14 winter season.

Year Class	Total number released	Total number PIT tagged	Total not tagged	Number recaptured	% recapture
2006	7	7	-	0	0.000
2007	28	28	-	1	3.571
2008	197	19	178	1	5.263
2009	581	555	26	37	6.667
2010	1,784	118	1,666	1	0.847
2011	70,990	17,024	53,966	150	0.881
2012	208,798	3,993	204,805	8	0.200
2013	46,883	10,017	36,866	0	0.000
Totals	329,268	31,761	297,507	198	

Table 2.3. Burbot catch, effort, CPUE (Burbot/net-d), mean length (mm), and mean weight (g) with standard error in parentheses (SE), separated by mesh size for 2013/14 season. Recaptures were included in the calculations.

Mesh size (mm)	Count	CPUE	Mean length (SE)	Mean weight (SE)
6.4	172	0.11	419.5 (6.8)	572.4 (36.2)
19.1	266	0.27	437.1 (5.6)	646.5 (30.5)

Table 2.4. Burbot catch, CPUE (Burbot/net-d), mean length (mm), and mean weight (g) with standard error in parentheses (SE), separated by depth of the hoop net set during the 2013/14 season. Recaptures were included in the calculations.

Depth (m)	Count	CPUE	Mean length (SE)	Mean weight (SE)
≤ 7.6	185	0.18	425.7 (8.7)	603.4 (33.2)
≥ 7.6	214	0.17	431.9 (9.3)	646.5 (35.6)

Table 2.5. Number, release location, release year, and brood year of Burbot detected at the Deep Creek PIT tag array from 10/1/2012– 1/15/2014.

Stocking Location	Distance (rkm) and Direction of Stocking From Array	Year Stocked	Year Class	Number Detected
Boundary Creek	77.4 (downstream)	2011	2011	4
Ferry Island in Kootenai River	42.3 (downstream)	2011	2011	3
Deep Creek at McArthur outlet	34 (upstream)	2012	2012	13
Deep Creek at Naples	21 (upstream)	2012	2012	87
Unknown (Adults)	10 to 20 (downstream in main-stem)	-	-	13
Deep Creek at Confluence	7 (downstream)	2012	2011	5
Deep Creek at Confluence	7 (downstream)	2011	2011	4
Total				129

Table 2.6. Length and weight of Burbot released and subsequently recaptured in Deep Creek at two primary release locations with hoop nets from January 15 – April 30, 2014.

Sample Site	Date Caught	Release Date	Release TL (mm)	Recapture TL (mm)	Release Weight (g)	Recapture Weight (g)	Release Location
Deep Creek at Naples	1/23/2014	10/30/2013	118	165	11	28	Deep Creek at Naples
Deep Creek at McArthur Lake Outlet	1/23/2014	11/6/2012	156	265	28	125	Deep Creek at McArthur Lake Outlet
Deep Creek at McArthur Lake Outlet	1/24/2014	11/6/2012	156	233	28	113	Deep Creek at McArthur Lake Outlet
Deep Creek at Naples	2/5/2014	11/6/2012	162	270	31	174	Deep Creek at Naples
Deep Creek at Naples	2/5/2014	11/6/2012	162	250	31	131	Deep Creek at Naples
Deep Creek at Naples	2/5/2014	10/30/2013	118	295	11	170	Deep Creek at Naples
Deep Creek at Naples	2/5/2014	11/6/2012	162	288	31	179	Deep Creek at Naples
Deep Creek at Naples	2/5/2014	11/6/2012	162	270	31	136	Deep Creek at Naples
Deep Creek at McArthur Lake Outlet	2/5/2014	11/6/2012	162	213	31	69	Deep Creek at Naples
Deep Creek at McArthur Lake Outlet	3/4/2014	11/6/2012	162	223	31	80	Deep Creek at Naples
Deep Creek at McArthur Lake Outlet	3/4/2014	11/6/2012	156	245	28	93	Deep Creek at McArthur Lake Outlet
Deep Creek at McArthur Lake Outlet	3/4/2014	11/6/2012	156	271	28	142	Deep Creek at McArthur Lake Outlet
Deep Creek at McArthur Lake Outlet	3/18/2014	11/6/2012	162	224	31	75	Deep Creek at Naples
Deep Creek at McArthur Lake Outlet	4/3/2014	11/6/2012	156	NA	28	NA	Deep Creek at McArthur Lake Outlet

Table 2.7. Survival of sonic tagged Burbot in Kootenai/ Kootenay River, tagged between 2009 and 2013.

	Tagging Origin	N	Release survival (%)	Survive first year (%)
Age-1	Hatchery	91	65%	42%
Age-2+	Hatchery	90	62%	54%
	In-river	15	93%	53%
	Total	**196**	**66%**	**48%**

FIGURES

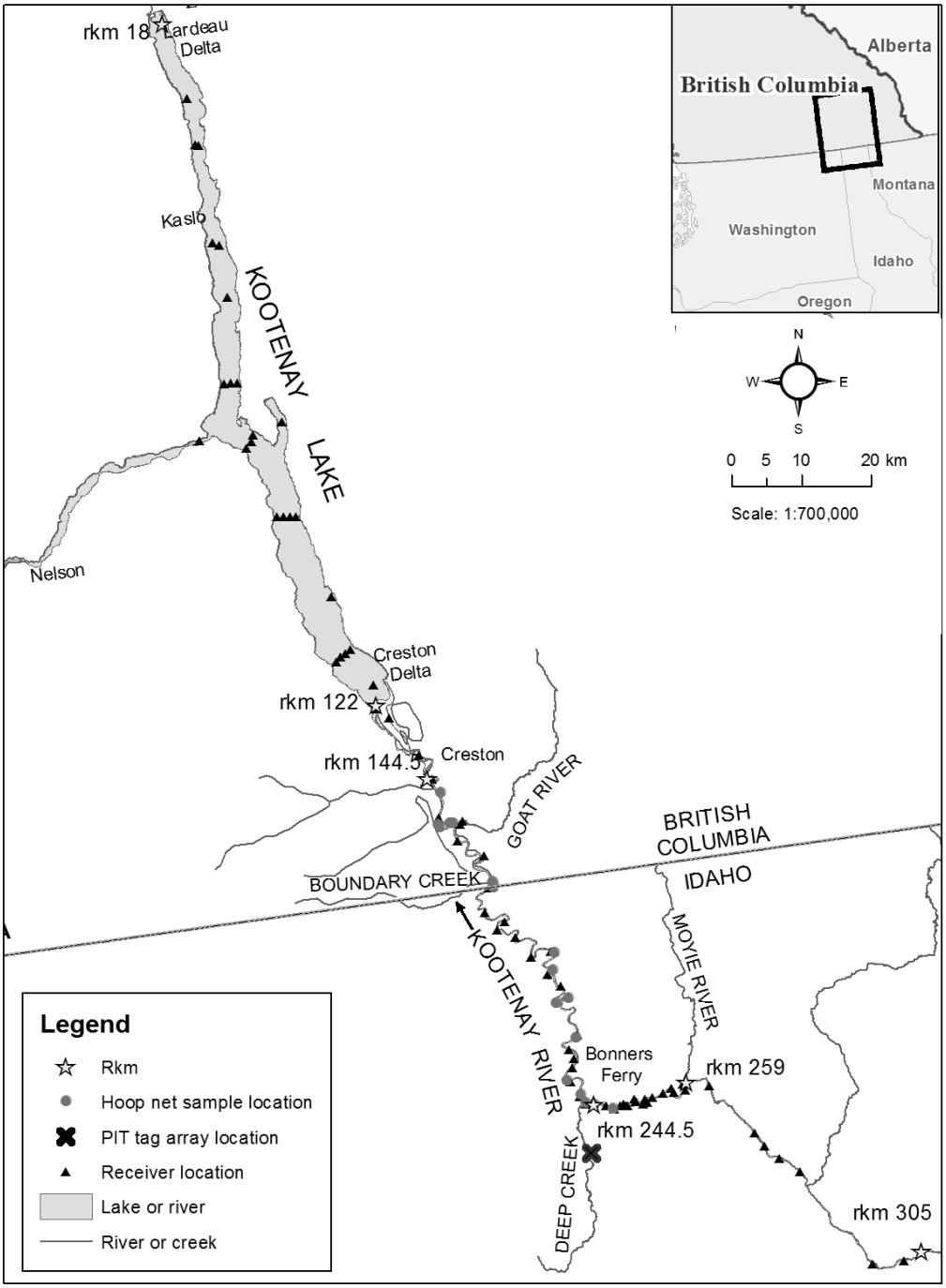

Figure 2.1. Study area overview; locations of hoop net sample sites during 2012-2014 sample seasons indicated by solid grey circles, Deep Creek PIT tag array location indicated with an X; Vemco receiver locations indicated by triangles, and key river kilometers (rkm) markers noted by stars.

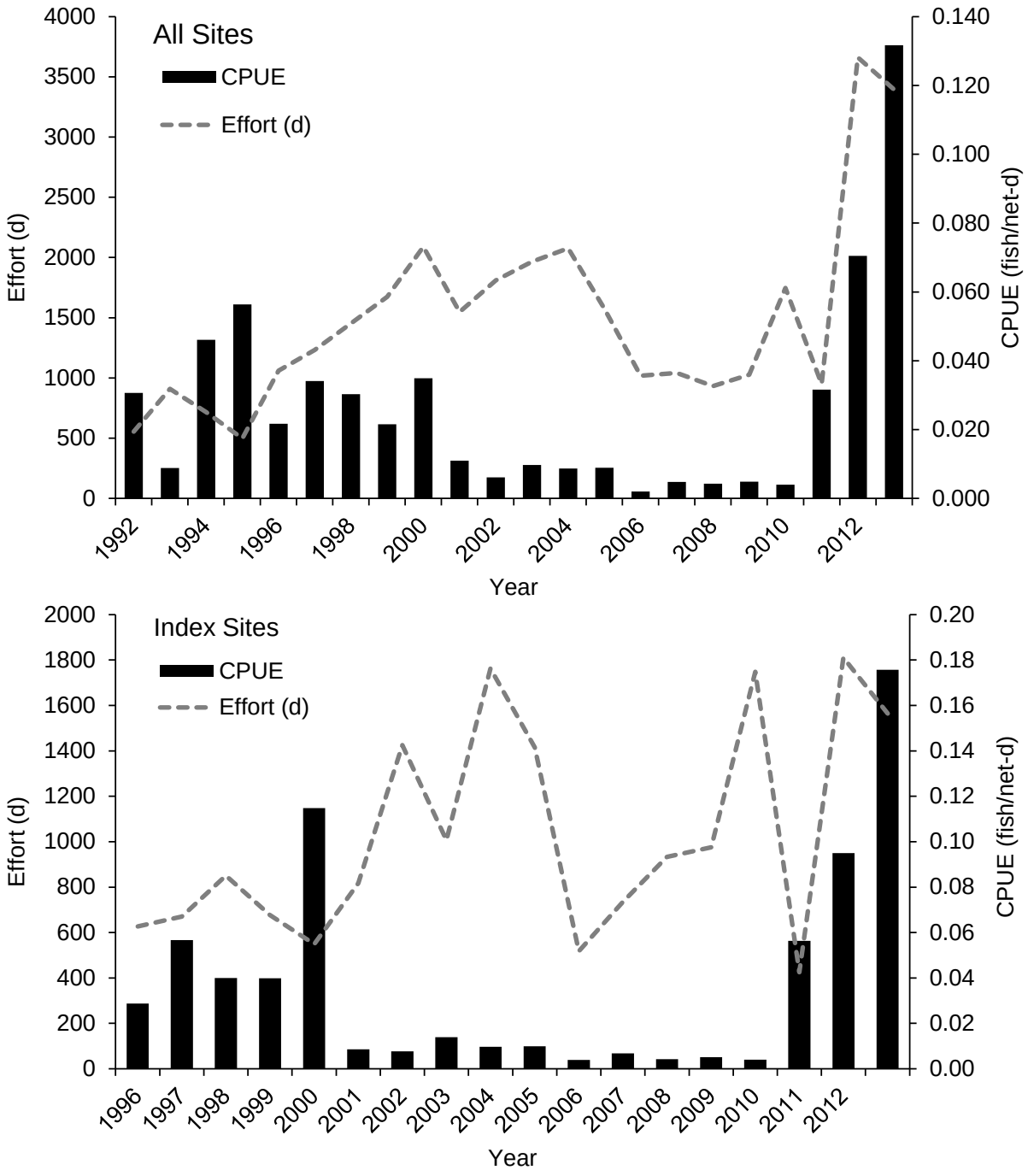

Figure 2.2. Catch-per-unit-of-effort (Burbot/net-d) and effort (d) of hoop net sampling for all sites (top panel) and index sites (bottom panel) from 1992-2013. Annual sampling started December 1 and ended March 31. Sample year indicates the year sampling started (e.g. 2013/14 season is 2013 on the x-axis).

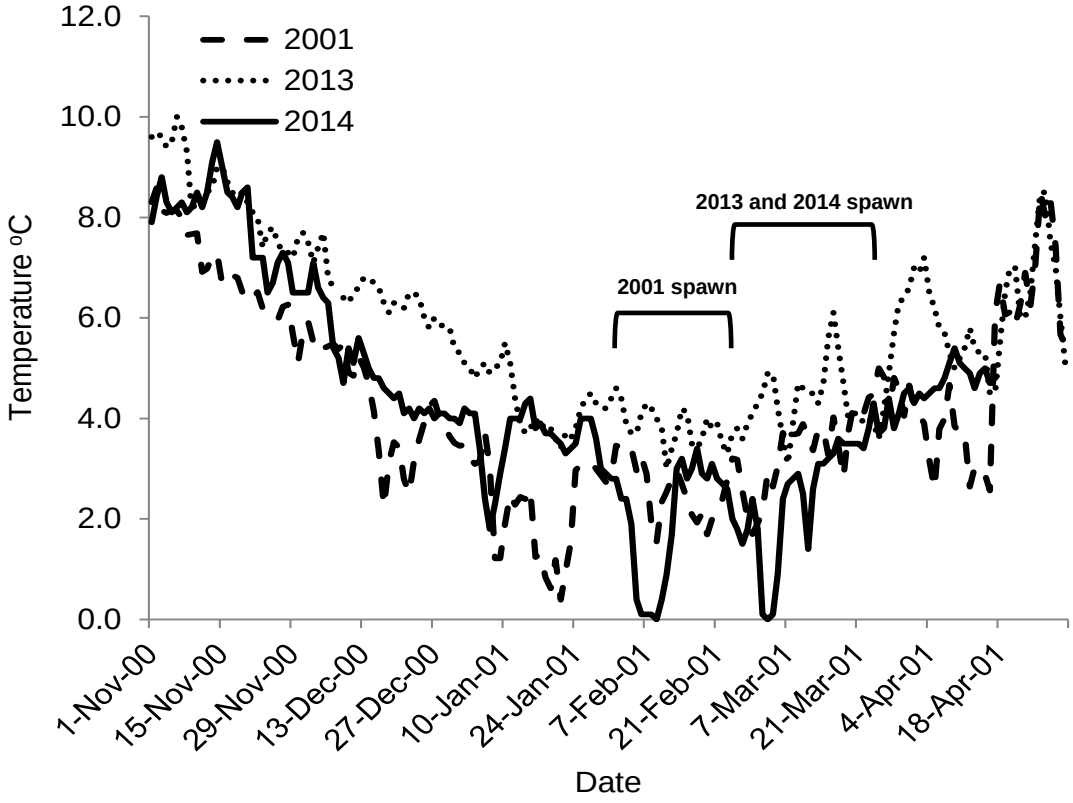

Figure 2.3. Temperatures in the Kootenai River at Ambush Rock during identified Burbot spawning events in 2001, 2013, and 2014.

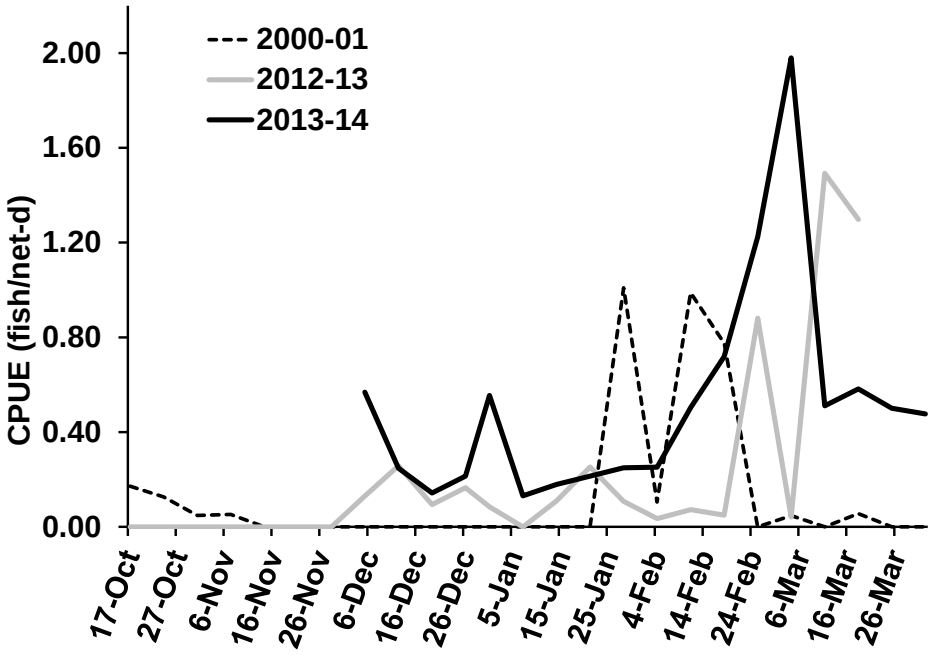

Figure 2.4. Catch-per-unit-of-effort (Burbot/net-d) of Burbot captured in hoop nets at Ambush Rock (historical index location) in the Kootenai River in the 2000/01, 2012/13, and 2013/14 winter sample seasons.

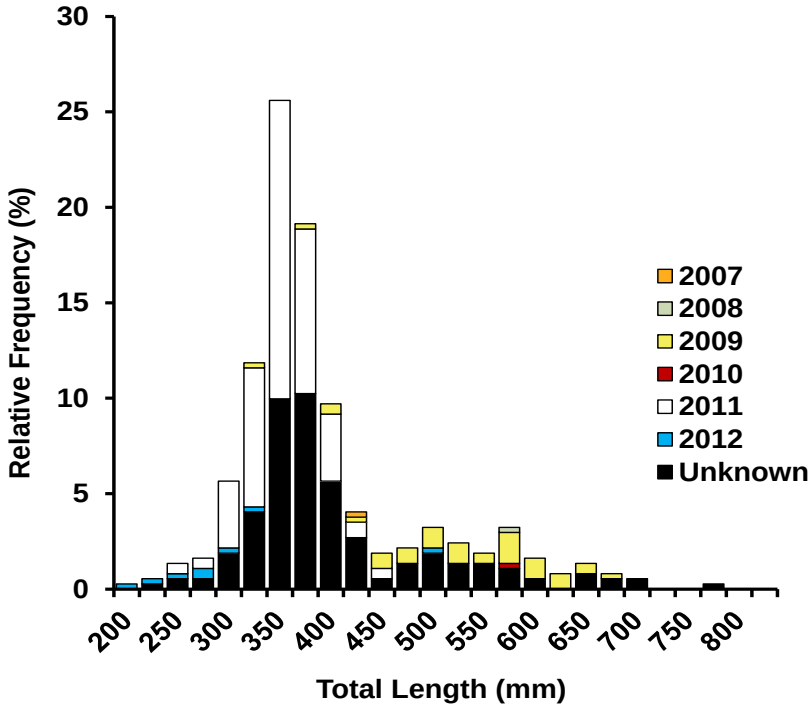

Figure 2.5. Length frequency and year class assignments from PIT-tags of Burbot captured in hoop nets in the Kootenai River from December 1, 2013 through March 31, 2014.

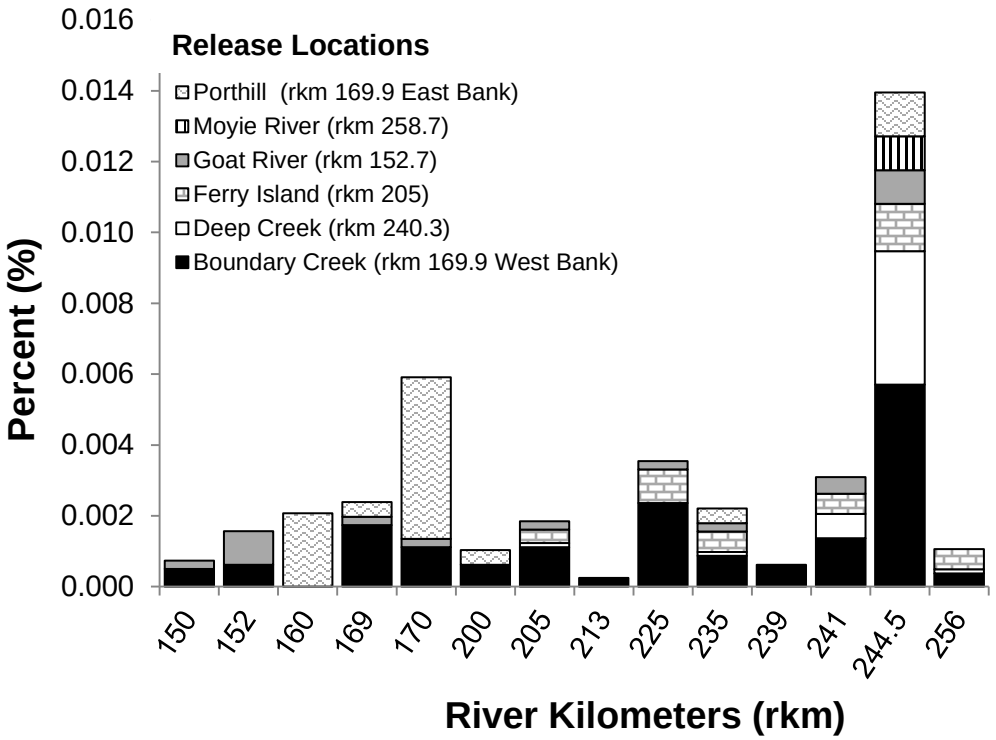

Figure 2.6. Percent of Burbot recaptured in the 2012/13 and 2013/14 winter hoop net sampling seasons in relation to their original release location. N = 245).

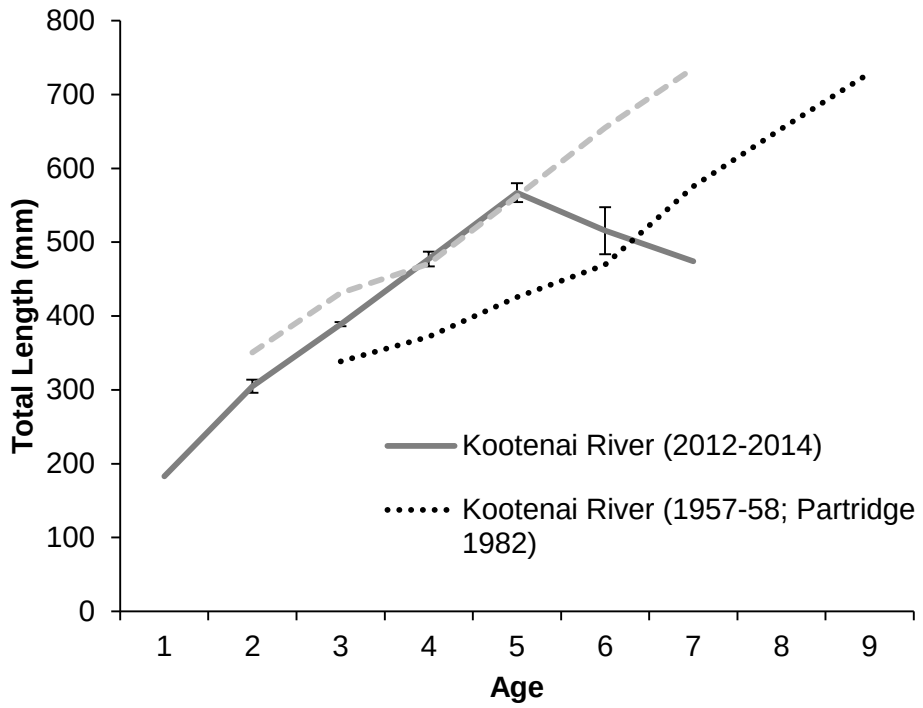

Figure 2.7. Mean length-at-age-at-time-of-capture for Burbot captured in hoop nets in 2012/13 compared to that of fish captured in 1979-81 and 1957/58). Error bars (± 1 standard error) could not be calculated for data prior to 2012.

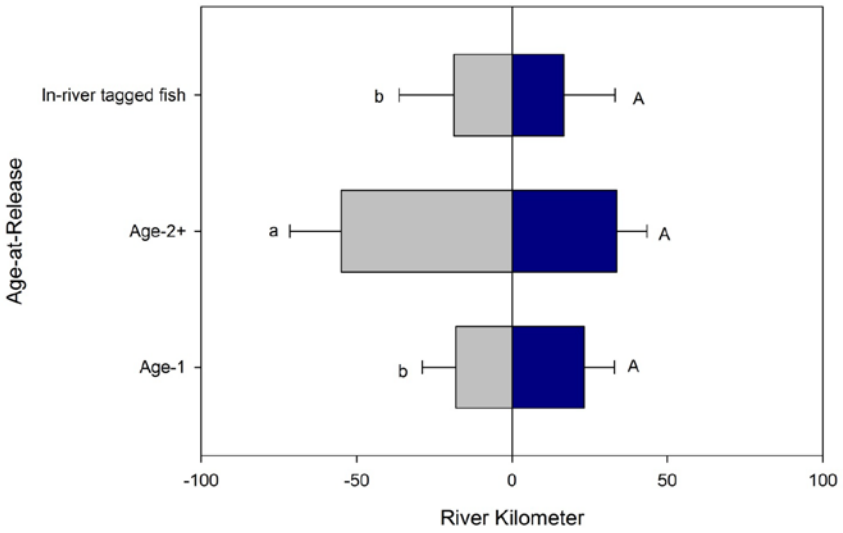

Figure 2.8. Mean upstream and downstream range of movements, based on age for the Burbot tagged prior to release from the hatchery and for the adult Burbot tagged in-river. Upper case letters were used to denote differences in upstream movement and lower case letters denote differences in downstream movement. Error bars represent 95% CI.

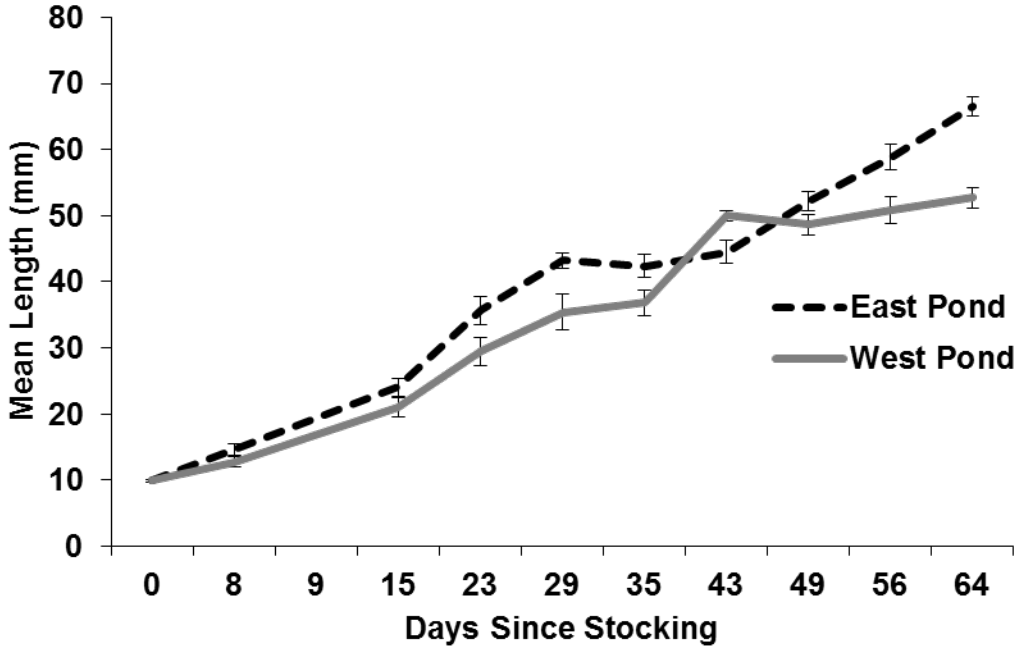

Figure 2.9. Mean daily growth of Burbot stocked into Boundary Creek WMA ponds. Stocking occurred on May 22, 2014 and the ponds were drained on July 27, 2014. Error bars represent ± 1 SE.

CHAPTER 3: NATIVE SALMONID MONITORING AND EVALUATION
AUTHOR: T.J. ROSS

ABSTRACT

A large-scale nutrient restoration program (utilizing phosphate fertilizer) was implemented in the Idaho portion of the Kootenai River in 2005 to restore fisheries by increasing primary production. Lake Koocanusa, the reservoir created by Libby Dam in Montana, acts as a nutrient sink, retaining approximately 63% of total phosphorus and 25% of total nitrogen entering the system. Declines in fish stocks have long been attributed to this loss of nutrients (along with other factors) via bottom-up trophic cascades. Annual electrofishing surveys were conducted at multiple biomonitoring sites before and after nutrient addition in order to evaluate fish catch-per-unit-of-effort (CPUE), biomass-per-unit-of-effort (BPUE), and various population metrics. In addition, an otolith microchemistry pilot study was conducted to determine natal origins of catchable, adult Rainbow Trout in the Kootenai River. All analyses indicated that river Zone was the largest driver influencing the fish assemblage. Total (i.e., all species, combined) CPUE and CPUE of Mountain Whitefish *Prosopium williamsoni* were significantly higher post-treatment compared with pretreatment, within the Nutrient Addition Zone. A similar trend was observed for CPUE of Rainbow Trout *Oncorhynchus mykiss* and total BPUE; however, increases were not statistically significant. Results from the otolith microchemistry study were in opposition to many of the historical speculations and findings with regard to early life history of Rainbow Trout in the Kootenai River; therefore, justification exists for more in-depth investigation(s) to address newly unveiled questions. Collectively, results indicate that this program has largely been successful; however, additional research and analyses are needed to better understand different effect levels.

INTRODUCTION

The Kootenai River basin has been impacted by many anthropogenic activities (e.g., agriculture, mining, land use practices, and the construction and operation of Libby Dam), all of which have affected the ecosystem and led to declines in resident fish populations. Libby Dam has significantly altered the flow regimes and channel morphology of the Kootenai River since it was constructed in the early 1970s, and it has depleted nutrients and caused a decline in primary productivity in the Idaho portion of the river (Woods 1982; Snyder and Minshall 1996). By the 1990s, this reduction in productivity translated to a two- to four-fold decrease in the number of Mountain Whitefish *Prosopium williamsoni*, compared to numbers present in 1980-81 (Partridge 1983; Paragamian 1990); this was one noticeable effect among many.

Lake Koocanusa, the reservoir created by Libby Dam, acts as a nutrient sink (Snyder and Minshall 1996), retaining approximately 63% of total phosphorus (P) and 25% of total nitrogen (N) entering the reservoir (Woods 1982). Due to low current velocities in the reservoir, these nutrients bind to sediments and precipitate out of solution (Snyder and Minshall 1996), making them unavailable to organisms in the river below the dam. Consequently, the Idaho portion of the Kootenai River has been considered “nutrient poor” (ultraoligotrophic) and P-limited (Snyder and Minshall 1996) since the completion of Libby Dam. The loss of nutrients in the Idaho portion of the Kootenai River has reduced primary production, and this has likely contributed to poor sport and non-sport fish production over the past two decades.

Primary production is thought to be the foundation of bioenergetic development in higher trophic levels (Vannote et al. 1980). Evidence of community shifts in the Kootenai River has been seen at multiple trophic levels before and after the completion of Libby Dam. For example, macroinvertebrate abundance and species diversity prior to the construction of Libby Dam were significantly higher in the upper canyon sections (near the current Nutrient Addition Zone) of the river and are now considered low in relation to other rivers in northern Idaho (Bonde and Bush 1975; Snyder and Minshall 1996). Specialized species such as caddisflies, stoneflies, and mayflies decreased in abundance (Hauer and Stanford 1997), and generalist species, such as aquatic worms, increased (C. Holderman, Kootenai Tribe of Idaho, personal communication,). This could be problematic for those fish species that rely on insect diversity for survival. Paragamian (2002) reported shifts in fish species assemblages in the Kootenai River from feeding “specialists,” such as Rainbow Trout *Oncorhynchus mykiss* and Mountain Whitefish, to more habitat and feeding “generalists,” such as Peamouth Chub *Mylocheilus caurinus* and Largescale Suckers *Catostomus macrocheilus.*

Increases in primary production have been successfully facilitated through the addition of inorganic P and N in other aquatic ecosystems (Ashley et al. 1999), which in turn has been successful in recovering wild fish populations. For example, a large-scale nutrient restoration program was implemented in the north arm of Kootenay Lake, British Columbia (BC) in 1992 in an attempt to recover declining Kokanee Salmon *Oncorhynchus nerka* populations. The results of this effort significantly increased abundance at all levels of the food web (Ashley et al. 1999). Significant increases in zooplankton, resulting from increased algal growth, produced a higher abundance of kokanee in the lake. Within seven years, Kokanee spawners in two main tributaries to the North Arm increased from 300,000 (1992) to 2.1 million (1998). Similarly, a study on the Kuparuk River, Alaska found that a dramatic increase in algal biomass and productivity lead to increased growth rates of some insect species, age-0 fish, and adult fish after four years of phosphorus addition (Peterson et al. 1993). Based on results such as these, it was proposed that increases in primary production through nutrient restoration could be used to

stimulate fish production in the Kootenai River from bottom up trophic cascades (Snyder and Minshall 1996).

Liquid phosphate fertilizer (10-34-0 [N-P-K; nitrogen-phosphorus-potassium]) was first added to the Kootenai River on July 13, 2005. During the first year, phosphorous was added to achieve a phosphate concentration of 1.5 µg/L. In subsequent years, the dosing rate was increased in order to achieve a phosphate concentration of 3.0 µg/L. Target concentrations of soluble reactive phosphorus (3-5 µg/L) in streams is generally one-third to one-half of nuisance concentrations (10 µg/L), but concentrations need to be high enough to be effective over several river kilometers (Ashley and Stockner 2003). Nitrogen was identified to be potentially co-limiting in the Kootenai River as the growing season progressed. Due to the potential stripping of nitrate from solution by increased primary production, a threshold of 60 µg/L (of nitrate) was established, at which point nitrate fertilizer (32-0-0) would be added to the river.

The Kootenai River Ecosystem Project was designed to support recovery of fish populations utilizing an ecosystem-based strategy, as opposed to simply treating the symptoms of degrading stocks and individually declining species. The addition of nutrients to this ultraoligotrophic system was hypothesized to stimulate production in the nutrient-depleted food web and reverse the downward trends in populations of Trout, Kokanee Salmon, Mountain Whitefish, Burbot *Lota lota*, White Sturgeon *Acipenser transmontanus*, as well as other species. This report summarizes results specific to fish populations. Results relative to changes in primary productivity and macroinvertebrate communities will be reported by the Kootenai Tribe of Idaho.

RESEARCH GOAL

Restore fish populations in the Idaho reach of the Kootenai River to densities present prior to Libby Dam.

OBJECTIVES

1. Use multivariate analyses to determine whether the fish assemblage in the Kootenai River has changed from pre- to post-nutrient addition periods.

2. Use before-after-control-impact analyses (i.e., repeated measures analysis of variance) to determine whether the total and species-specific catch and biomass rates have changed from pre- to post-nutrient addition periods.

3. Initiate a cooperative pilot study using strontium ratios (derived from Rainbow Trout otolith microchemistry) to (1) establish tributary-specific strontium signatures and (2) assign adult Rainbow Trout to natal tributaries.

STUDY AREA

The headwaters of the Kootenai River originate in Kootenay National Park in southeastern BC, Canada (Figure 3.1). The river then flows south into northwestern Montana and enters Lake Koocanusa, the reservoir formed by Libby Dam. The river then flows west into the Idaho Panhandle, then north back into BC to form Kootenay Lake, and finally to the

confluence with the Columbia River at Castlegar, BC. The Kootenai River is the second largest of the Columbia River tributaries and the third largest in drainage size (approximately 50,000 km^2; Bonde and Bush 1975). The study area was comprised of approximately 106 km of the river that flowed through the Idaho Panhandle, along with two control sites (one in Montana and one in BC).

The Montana and Idaho portions of the Kootenai River below Libby Dam can be separated into three distinct river habitat types. Directly below the dam, the river flows through a narrow canyon segment characterized by steep canyon walls, high gradients, and boulder/cobble substrates. In this segment of the river, the channel has an average gradient of 0.6 m/km, and the velocities are often higher than 0.8 m/s. Downstream from the canyon segment there is a braided transition segment that extends from the Moyie River to the town of Bonners Ferry (Figure 3.1). Downstream from the braided transition segment, velocities slow to less than 0.4 m/s, average gradient is 0.02 m/km, the channel deepens, and the river meanders through the Kootenai Valley (termed the meander segment).

Biomonitoring sites for this study were established to gather fisheries and lower trophic level data, before and after nutrient addition (Figure 3.2). Fish populations were surveyed at six biomonitoring sites, two of which were control sites. The first control site (KR14) was located above Lake Koocanusa near Wardner, BC; this site served as an unimpounded control site. Site KR14 markedly differed (in habitat and fish community) from all sites below Libby Dam; therefore, it was not used in any analyses. The second control site (KR10) was located in the Montana portion of the Kootenai River, termed the Control Zone of the river. Three sites were located within the Nutrient Addition Zone of the river (sites KR9.1, KR9, and KR6). Site KR9.1, located one km downstream from the nutrient addition site, was added in 2009. This site did not have any pre-nutrient addition data, so it was not included in any analyses. Site KR9 was located approximately ten km downstream from the nutrient addition site. Site KR6 was located approximately 20 km downstream from the nutrient addition site. The next two sites were downstream from the town of Bonners Ferry, and they were considered to be in the Downstream Zone of the river. Site KR4 was approximately 68 km downstream from the nutrient addition site, and site KR2 was approximately 157 km downstream from the nutrient addition site.

METHODS

Fish Community Assessment

Abundance and Biomass

Boat electrofishing was conducted during August and September from 2002-2013 at five biomonitoring sites. Site KR14 was added as a biomonitoring site from 2004-2013, and in 2009 site KR9.1 was added one km below the nutrient addition site. Collectively, sites that were surveyed in 2013 included KR14, KR10, KR9.1, KR9, KR6, KR4, and KR2. Data from these sites were used to assess relative species abundance and biomass and to compare various population metrics. Specific population indices that were indexed included relative species abundance as catch-per-unit-of-effort (CPUE), species abundance by weight as biomass-per-unit-of-effort (BPUE), relative weight (W_r), and length-at-age-at-time-of-capture. These data were used to document temporal trends in the fish community and to evaluate the effectiveness of the addition of nutrients to the Idaho section of the Kootenai River. Sites were sampled using a jet boat (five meters long) equipped with a Coffelt VVP-15 electroshocker powered by a 5000

watt Honda generator. Electrofishing settings were typically set to generate 6-8 amps at 175-200 volts. The sampling crew consisted of two netters and one driver. All fish, regardless of species and size, were netted in order to get a representative sample of the fish community at each site. In order to increase replication, each biomonitoring site was divided into six equal subsections of 333 m with 150 m separating each to ensure that each subsection was independent of the next. This sampling design resulted in one kilometer of electrofishing occurring on both the left and right banks for a total of two kilometers of sampling, per site. A single pass was made through each subsection, starting with lower sections first to ensure that no fish drifted into areas that had not yet been sampled. After each subsection was sampled, the elapsed sampling time was recorded and fish that had been collected were taken to a workup station where they were identified to species, measured (total length [TL], mm), and weighed (g). Scales were removed from a subsample (five fish in each ten mm length interval) of Mountain Whitefish and Rainbow Trout at each site for ageing.

Population Status

Since the implementation of a new regulation change (for Rainbow Trout) in 2002 (two fish, none under 16 inches) proportional stock density (PSD) and quality stock density (QSD) have been calculated annually (Anderson 1976; Gabelhouse 1984) to evaluate changes in the size structure of the population as well as changes in estimated densities. Proportional stock density and QSD standards are species-specific, defined in the aforementioned references, and calculated as:

$$PSD = \frac{Number\ of\ fish\ \geq minimum\ quality\ length}{Number\ of\ fish\ \geq minimum\ stock\ length}\ X\ 100$$

$$QSD = \frac{Number\ of\ fish\ \geq specified\ length}{Number\ of\ fish\ \geq minimum\ stock\ length}\ X\ 100$$

Proportional stock density was calculated for Rainbow Trout using 200 mm TL as stock length and 305 mm TL as quality length (Schill 1991). Quality stock density was calculated using 406 mm as the specified length, which is the minimum legal length for harvest in the Kootenai River.

Strontium Isotope Analysis: Otolith Microchemistry

This study had two objectives, both of which are detailed below in *Phases 1* and *2*. This study was a collaborative effort between the New Mexico Cooperative Fish and Wildlife Research Unit, Idaho Cooperative Fish and Wildlife Research Unit, IDFG, and Montana Fish, Wildlife and Parks (MFWP). Funding for this study was provided by the U.S. Geological Study through the Idaho Cooperative Fish and Wildlife Research Unit.

Phase 1—The objective of this phase was to establish baseline strontium signatures for a subsample of tributaries to the Kootenai River. During the first week of November 2012, age-0 Rainbow Trout were sampled from Trail, 20-Mile, Deep, Boulder, and Caboose creeks and the Moyie River in Idaho. The Yaak River and Star, O'Brien, and Lake creeks were sampled in Montana. Fish were collected using a Smith-Root backpack electrofishing unit. When possible, all fish were collected a minimum of 0.5 km upstream from where the tributary was confluent with the main-stem Kootenai River. This was done to ensure that the strontium isotope signatures of each particular tributary would not be confounded by movement of fish between the tributary and Kootenai River. Attempts were made to collect ten age-0 Rainbow Trout from

each tributary. Collected fish were euthanized, placed into labeled bags, transported on ice, and then frozen. Whole fish were then transported to a lab at the University of Idaho where sagittal otoliths were removed from each fish and placed (dry) into a labeled vial. Otoliths were then transported to the University of California-Davis where they were analyzed for strontium ratios. Each otolith underwent laser ablation from edge-to-edge, with the laser passing directly through the core of the otolith.

Phase 2 —The objective of this phase was to determine the natal (tributary) origins of a subsample of adult Rainbow Trout collected from the main-stem Kootenai River. This phase relied on tributary-specific strontium signatures identified during Phase 1. From the summer of 2012 through the summer of 2013, 29 adult Rainbow Trout were collected from the main-stem Kootenai River, near biomonitoring site KR6. Collections were completed by a graduate student at the University of Idaho. All of the Rainbow Trout were sacrificed, and their sagittal otoliths were collected, stored, and processed following the same protocols detailed in Phase 1.

Statistical Analysis

The years from 2002-2005 were considered the pretreatment period, and 2006-2013 were considered the post-treatment period for all analyses involving data from the biomonitoring sites. Site KR10 comprised the “Control Zone” of the river, sites KR9 and KR6 comprised the “Nutrient Addition Zone,” and sites KR4 and KR2 comprised the “Downstream Zone.” This delineation remained consistent across all analyses. R statistical software (R Core Team 2012) and SAS 9.3 (SAS Institute, Cary NC) were used for all statistical tests.

Fish Assemblage

Fish assemblage relationships were evaluated following methods similar to those described by Kwak and Peterson (2007) utilizing hierarchical clustering analysis and nonmetric multidimensional scaling (NMDS). Clustering analysis and NMDS are both robust multivariate techniques that are widely used to evaluate relationships and structure among fish assemblages (Helms et al. 2005; Rowe et al. 2009; Ruetz et al. 2007). Bray-Curtis dissimilarity values were calculated using presence-absence (i.e., species occurrence) data that included all sites, years, and fish species. In addition, Bray-Curtis dissimilarity values were calculated using CPUE data and BPUE data; these data also included all sites, years, and fish species. Data were pooled across sites within respective river zones and across years within respective pre- and post-treatment periods. The resulting dissimilarity matrices were used in (1) hierarchical clustering analysis (average-linkage) and (2) NMDS. Clustering analysis was executed using only the species occurrence dissimilarity matrix; whereas, three separate NMDS analyses were run, each utilizing a different dissimilarity matrix. One NMDS analysis was run utilizing the species occurrence dissimilarity matrix, one utilizing the CPUE dissimilarity matrix, and one utilizing the BPUE dissimilarity matrix. Differences in fish assemblage structure (i.e., by Zone, Period and the interaction of Zone*Period) were evaluated using a permutational multivariate analysis of variance (PERMANOVA). Similar to the NMDS analyses, separate PERMANOVAs were conducted for each of the species occurrence, CPUE and BPUE dissimilarity matrices. Bray-Curtis dissimilarity matrices were calculated using the Vegdist function, hierarchical clustering analyses were executed using the Hclust function, and NMDS and PERMANOVA analyses were executed using the MetaMDS and Adonis functions, respectively, in the Vegan package, Program R.

Abundance and Biomass

Catch-per-unit-of-effort and BPUE data from pre- and post-treatment periods were compared using a repeated measures analysis of variance (ANOVA) model. The form of the model was:

$$Y_{ijk} = \mu + \alpha_i + T_k(i) + \beta_j + \alpha\beta_{jj} + \varepsilon_{ijk},$$

where:

Y_{ijk} = the catch metric (i.e., CPUE or BPUE),
μ = the intercept (i.e., overall mean),
α_i = the main effect "Period" (i.e., pre- or post-treatment),
$T_k(i)$ = the effect of year within Period,
β_j = the main effect "Zone" (i.e., Control, Nutrient Addition or Downstream),
$\alpha\beta_{jj}$ = the interaction effect "Period*Zone", and
ε_{ijk} = the model error.

If model effects were found to be significant, post-hoc comparisons were made using differences of least square means.

RESULTS

Fish Community Assessment

Fish Assemblage

Clustering analysis indicated that the species occurrence data clustered by Zone (Figure 3.3). Sites within the Control and Nutrient Addition Zones (i.e., KR10, KR9, and KR6) clustered, and sites within the Downstream Zone (i.e., KR4 and KR2) clustered. There was little evidence of clustering based on Period (i.e., before and after nutrient addition) within or across sites. Stable NMDS ordinations were present for the species occurrence, CPUE (Figure 3.4) and BPUE data (Figure 3.5); however, only the NMDS ordinations for CPUE and BPUE had final iterations of stress indicative of good model fits to the data (0.06 and 0.09, respectively). The final iteration of stress for the species occurrence NMDS was 0.19, which is higher than the 0.15 final iteration of stress threshold proposed by Kruskal and Wish (1984). PERMANOVA analyses for each response variable indicated that species occurrence differed by Zone *($F = 12.89$; $P = 0.001$)*; CPUE differed by Zone (*$F = 95.74$; $P = 0.001$*), Period (*$F = 7.24$; $P = 0.003$*), and the interaction between Zone and Period (*$F = 4.49$; $P = 0.003$*); and BPUE differed by Zone (*$F = 49.91$; $P = 0.001$*) and Period (*$F = 4.84$; $P = 0.013$*). Ordination plots of each NMDS analysis corroborated the PERMANOVA results (Figures 4 and 5).

Abundance and Biomass

Eighteen species of fish were identified in the catch from 2002-2013, and 20,716 individual fish were captured during the same time. The proportion of species within the catch and the number of species identified in the catch remained relatively consistent across all years. Six species dominated the catch in the Control and Nutrient Addition Zones, including Mountain Whitefish, Largescale Sucker, Northern Pikeminnow *Ptychocheilus oregonensis*, Rainbow Trout, Peamouth Chub, and Redside Shiner *Richardsonius balteatus*. Biomass was dominated by the same species as catch, with the exception of Redside Shiner, which contributed little to

the biomass because of small body size. Proportion of species dominating catch and biomass in the Downstream Zone was similar to that observed in the Control and Nutrient Addition Zones, with the exception of lower proportions of Mountain Whitefish and Rainbow Trout.

Abundance (CPUE**)—**The repeated measures ANOVA model for total CPUE (i.e., all species, combined) indicated significant effects for Zone (*F = 31.06, DF = 2, P = 0.004*), Period (*F = 20.69, DF = 1, P = 0.01*), and the interaction of Zone*Period (*F = 19.31, DF = 2, P = 0.009)* (Figure 3.6). Repeated measures ANOVA models for CPUE were run for the following species: Brown Bullhead *Ameiurus nebulosus* (BBH), Bluegill *Lepomis macrochirus* (BLG), Brook Trout *Salvelinus fontinalis* (BKT), Brown Trout *Salmo trutta* (BRT), Burbot (BUR), Black Crappie *Pomoxis nigromaculatus* (BC), Longnose Dace *Rhinichthys cataractae* (LND), Long-nose Sucker *Catastomus catostomus* (LNS), Largescale Sucker (LSS), Mountain Whitefish (MWF), Northern Pikeminnow (NPM), Peamouth Chub (PMC), Pumpkinseed *Lepomis gibbosus* (PMK), Rainbow Trout (RBT), Redside Shiner (RSS), Sculpin *Cottus cognatus* (SCU), Westslope Cutthroat Trout *Oncorhynchus clarkii lewisi* (WCT), and Yellow Perch *Perca flavescens* (YEP). Models for the following species indicated that there was no main effect of Zone or Period and no interaction effect of Zone*Period: BBH, BLG, BRK, BRT, BUR, CRAP, LND, LNS, LSS, NPM, PMK, SCU, WCT, and YEP (Table 1). Models for NPM (*F = 66.94, DF = 2, P <0.001*), PMC (*F = 59.01, DF = 2, P = 0.001*), and RSS (*F = 79.60, DF = 2, P <0.001*) indicated that there was a significant effect of Zone (Figure 3.7). The model for RBT indicated significant Zone (*F = 35.98, DF = 2, P = 0.002*) and Period (*F = 11.68, DF = 1, P = 0.027*) effects, and the model for MWF indicated significant effects for Zone (*F = 214.06, DF = 2, P <0.0001*), Period (*F = 14.61, DF = 1, P = 0.02*), and the interaction of Zone*Period (*F = 6.91, DF = 2, P = 0.05*) (Figure 3.8).

Biomass (BPUE**)** - The repeated measures ANOVA model for total BPUE (i.e., all species, combined) indicated significant effects for Zone (*F = 17.04, DF = 2, P = 0.01;* Figure 3.9), but not for the Period or interaction of Zone*Period effects. Repeated measures ANOVA models for BPUE were run for the following species: BBH, BLG, BKT, BRT, BUR, CRAP, LND, LNS, LSS, MWF, NPM, PMC, PMK, RBT, RSS, SCU, WCT, and YEP. The model for BRK failed to converge and is not reported below. Models for the following species revealed that there was no effect of Zone, Period or the interaction of Zone*Period: BBH, BLG, BRT, BUR, CRAP, LND, PMK, SCU, WCT, and YEP (Table 2). Models for LSS (*F = 8.10, DF = 2, P = 0.04*), MWF (*F = 119.16, DF = 2, P<0.001*), NPM (*F = 14.39, DF = 2, P = 0.01*), PMC (*F = 32.80, DF = 2, P = 0.003*), RBT (*F = 11.61, DF = 2, P = 0.02*), and RSS (*F = 69.32, DF = 2, P <0.001*) revealed a significant Zone effect (Figure 3.10). The effects of Period and Zone*Period were not significant for any of the 17 species.

Population Status

Values for PSD and QSD for Rainbow Trout in the Nutrient Addition Zone of the Kootenai River during 2013 were 44 and 3, respectively. These values were similar to long-term averages for PSD (43) and QSD (3).

Strontium Isotope Analysis: Otolith Microchemistry

Results from Phase 1 of the study indicated that the mean strontium isotope value differed for all of the sampled tributaries with the exception of O'Brien and Star creeks (Figure 11). The success of this technique for age-0 Rainbow Trout in the Kootenai River drainage suggests that this technique would likely be successful in determining natal origins of adult Rainbow Trout in the main-stem Kootenai River.

Results from Phase 2 of the study indicated that 23 of the 29 adult Rainbow Trout that were collected were spawned in a tributary and out-migrated to the Kootenai River. The remaining six fish spent their entire lives in the main-stem Kootenai River, suggesting that they were spawned in the main stem and likely never resided in a tributary. The majority of adults had natal origins in Callahan Creek (25%), the Moyie River (29%), or the main-stem Kootenai River (21%). The remainder of the contribution came from Boulder Creek (7%), Caboose Creek (4%), Star or O'Brien Creek (11%), and the Yaak River (4%). Collectively, 39% of the adult Rainbow Trout had natal origins in Montana, 39% in Idaho, and 21% unknown (from the main-stem Kootenai River).

DISCUSSION

Fish Community Assessment

Results from the clustering analysis and the various NMDS analyses indicated that, although there were subtle differences in fish assemblage by the Zone*Period interaction, the largest driver of differences in fish assemblage was river Zone. This response has been observed in other studies on the Kootenai River (Smith 2013). Each of the three river Zones provided habitats that varied in their suitability for various fish species. For example, habitat conditions in the downstream reach were comprised of low flow velocities, fine substrates, and aquatic vegetation. The fish assemblage in the Downstream Zone was dominated by Northern Pikeminnow, Peamouth Chub, and Redside Shiner, all of which were species that were better suited for these types of habitat conditions. Flow velocities were higher and the substrate was largely comprised of cobble in the Control and Nutrient Addition Zones. Mountain Whitefish and Rainbow Trout, species preferring cobble substrate and higher flow velocities, were more predominant in both of these river Zones. Nonmetric multidimensional scaling analyses utilizing CPUE and BPUE data revealed some clustering by the Zone*Period interaction term. This response was not driven by habitat differences; rather, it could likely be attributed to increases in relative abundances of a few select species (i.e., Mountain Whitefish and Rainbow Trout) in response to the addition of nutrients. These results were corroborated by subsequent ANOVA analyses for catch and biomass rates.

Abundance and Biomass

Species-specific CPUE and BPUE changed little from pre- to post-nutrient addition within each river zone (based on the Zone*Period interaction term); however, total CPUE was significantly higher and BPUE was notably higher post-nutrient addition (relative to pre-nutrient addition) within the Nutrient Addition Zone. Total CPUE and BPUE are generally considered metrics with limited inferential capabilities; however, the nutrient addition project reported herein was implemented under the assumption that any potential effects would be observed at the ecosystem-level. Therefore, these metrics offer important insight when evaluating effects of the project. The majority of species-specific catch and biomass rates revealed small, statistically insignificant increases from pre- to post-nutrient addition within the Nutrient Addition Zone. Although this result, in itself, is not particularly meaningful, the cumulative effect of these incremental increases (by species) resulted in increases in both the total abundance and biomass of fish within the Kootenai River. This has important implications for the food web of the Kootenai River, ranging from potentially altering predator-prey interactions and ratios, to potentially altering demand on lower trophic-level forage (i.e., periphyton and macroinvertebrates), to potentially altering the composition of species within the river (Larkin

1978; Carpenter et al. 1985). It is currently unknown whether these potential effects are occurring (in the Kootenai River); however, additional research is needed to better understand larger, more holistic effects of nutrient additions on the food web in the Kootenai River.

It is often difficult to predict the outcome(s) of large-scale, manipulation-type experiments at all trophic levels, and it is not uncommon for unexpected or unforeseen outcomes to arise (Cross et al. 2011). A primary target for the nutrient project that was identified by the Idaho Department of Fish and Game was to increase the abundance of Rainbow Trout. Marked increases in CPUE were achieved for mountain whitefish, an often undervalued sport fish; however, CPUE of Rainbow Trout did not show the same magnitude of increase (as Mountain Whitefish), and recent population estimates for Rainbow Trout suggest the same. Davis et al. (2010) suggested that unexpected predator-prey responses and effects on food web efficiencies could occur with long-term nutrient enrichment projects, such as the one on the Kootenai River. It is unknown whether the aforementioned types of responses are occurring in the Kootenai River; however, it is possible that the addition of nutrients to the Kootenai River has affected the food web in unforeseen ways that have allowed Mountain Whitefish to capitalize on specific prey items more readily than Rainbow Trout. This, in turn, could potentially explain the higher increase in catch of Mountain Whitefish relative to Rainbow Trout. Alternatively, the response of Rainbow Trout compared to Mountain Whitefish (as gauged by CPUE), may not be related to forage and growth, but rather, it may be an artifact of spawning and recruitment. Mountain Whitefish are known to be spawning generalists that utilize both tributary and main-stem systems for spawning (Wallace and Zaroban 2013); whereas, Rainbow Trout are known to have more specific requirements for spawning habitat (Wallace and Zaroban 2013). Lack of spawning habitat for Rainbow Trout in the Kootenai River (in Idaho) has long been proposed to be a factor limiting recruitment (in addition to food limitation; Partridge 1983). In contrast, forage limitation has been identified to be a primary limiting factor for Mountain Whitefish and other fish species in the Kootenai River (Snyder and Minshall 1996). Therefore, it perhaps is not surprising that Mountain Whitefish have shown more drastic increases in catch than Rainbow Trout. This information may provide evidence to eliminate forage availability from the list of potential factors limiting the recruitment of Rainbow Trout to the Kootenai River. Additional research is needed (and currently underway) to determine the extent to which spawning habitat may be limiting recruitment of Rainbow Trout.

Catch rates of Rainbow Trout increased from pre- to post-nutrient addition in both the Control and Nutrient Addition Zones of the river. The mechanism(s) driving this response is not entirely understood; however, it is speculated that (specific to Rainbow Trout) the Control and Nutrient Addition Zones may not be independent of one another. Several studies have revealed that adult Rainbow Trout residing in Idaho migrate to tributaries (to the Kootenai River) in Montana to spawn, and the adults return to the Idaho portion of the river, post-spawn (Walters et al. 2005). These spawning migrations typically occur in the spring, which does not coincide with the time frame during which sampling for the nutrient project is conducted. Therefore, it is unlikely that movement of adult Rainbow Trout is directly influencing catch rates in the Control Zone. The more probable mechanism may be indirect and related to increased recruitment (as a result of nutrient additions) and variable out-migrant dispersal. A long-term nutrient enhancement project on the Kuparuk River, Alaska found that adult Arctic Grayling had greater reproductive potential within a “treatment reach” relative to a control reach (Deegan and Peterson 1992). Therefore, although it has not been directly quantified, it is possible that Rainbow Trout within the Nutrient Addition Zone of the Kootenai River have greater reproductive potential (post-nutrient addition), resulting in a greater potential for increased production from both Idaho and Montana tributaries. Bradford and Taylor (1997) suggested that stream-type Chinook Salmon *Oncorhynchus tshawytscha* exhibited variable post-emergence dispersal

patterns, ranging from no dispersal to 100 km downstream. Furthermore, they suggested that newly emerged fry would inhabit all available rearing habitats, independent from dispersal distance. Therefore, it is possible that newly emerged and freshly out-migrated Rainbow Trout that were spawned in Montana tributaries are exhibiting variable dispersal patterns, ranging from remaining within close proximity to natal tributaries to migrating downstream into Idaho. This could ultimately result in increased relative abundances of Rainbow Trout in both Idaho and Montana, under the assumption (based on findings from Bradford and Taylor [1997]) that out-migrants from Montana tributaries are seeding both the Montana and Idaho portions of the Kootenai River. Long-term population monitoring (for Rainbow Trout) conducted by the MFWP support this possibility (Jim Dunnigan, MWFP, personal communication). Biologists with the MFWP have documented increases in the Rainbow Trout population within the Control Zone of the river from pre- to post-nutrient addition. In contrast, populations are stable or in decline in river reaches located upstream from the Control Zone during the same time frame, potentially eliminating the notion that increases in the Control Zone are due to some background, environmental effect (i.e., climate conditions or dam operations).

Strontium Isotope Analysis: Otolith Microchemistry

Results from the strontium isotope analysis were in opposition to several long-standing findings and speculations relative to Rainbow Trout in the Kootenai River. Historical information (from IDFG) on early life history of Rainbow Trout in the Kootenai River, Idaho suggests that very little main-stem spawning occurs, few Rainbow Trout out-migrate from the Moyie River, and large numbers of Rainbow Trout annually out-migrate from Boulder Creek. Interpreting the results of the pilot study are tenuous given limitations associated with the opportunistic nature of the sampling; however, the results can be used to inform the direction and design of future projects (on the Kootenai River) using this technique. The unexpectedly high proportion of adult Rainbow Trout that had purported natal origins in the Kootenai River (i.e., spawned in the main-stem river) leads to a host of additional questions, most of which cannot be adequately addressed with otolith microchemistry. However, this result does provide justification for further investigating the magnitude of main-stem spawning, as well as subsequent survival and recruitment to the catchable adult population. Some research has been conducted on spawning of Rainbow Trout in the Kootenai River (Walters et al. 2005), but additional research is needed. All of the adult Rainbow Trout that were used in this pilot study were collected within close proximity to the Moyie River (downstream from its confluence with the Kootenai River). The high proportion of adults that had natal origins in the Moyie River may indicate an important spatial structure related to site fidelity of Rainbow Trout (i.e., adults remain within close proximity to their natal tributary). Furthermore, this could provide justification for expanding the spatial extent of any future collections of adult RBT that would be used to determine natal origins. Altering the spatial extent of future study designs could also potentially address the discrepancy with regard to the unexpectedly low contribution of Boulder Creek to the catchable adult population of Rainbow Trout. More specifically, a spatially extensive study design in which adult Rainbow Trout are collected from the entire length of the Kootenai River would likely provide a more accurate and clear understanding of percent contribution (of catchable, adult Rainbow Trout) originating from all tributaries to the Kootenai River. This information, in turn, could aide with tributary prioritization efforts (e.g., for restoration projects) as well as guide the decision of whether or not to stock a mainstem spawning strain of Rainbow Trout in the river.

MANAGEMENT RECOMMENDATIONS

1. Collaboratively continue (with the KTOI) annual addition of ammonium polyphosphate (10-34-0) and ammonium nitrate (32-0-0) to the Kootenai River, following established protocols, through 2017.

2. Continue fall electrofishing at all fish monitoring sites for trend monitoring of sportfish.

3. Initiate a spatially extensive study to evaluate natal origins of catchable, adult Rainbow Trout in the Kootenai River.

4. Begin developing plans to quantify (1) the magnitude of main-stem spawning (of Rainbow Trout) and (2) subsequent survival and recruitment to the catchable, adult population.

TABLES

Table 3.1. Mean CPUE (fish·minute^{-1}) for 18 species captured during electrofishing sampling from 2002-2013. Values shown are separated by species, Zone and Period and denote mean ± standard error. Species in which the repeated measures ANOVA model indicated significant differences are shaded in grey and denoted by *. Taxa present in the table include: brown Bullhead (BBH), Bluegill (BLG), Brook Trout (BKT), Brown Trout (BRT), Burbot (BUR), Black Crappie (BC), Longnose Dace (LND), Longnose Sucker (LNS), Largescale Sucker (LSS), Mountain Whitefish (MWF), Northern Pikeminnow (NPM), Peamouth Chub (PMC), Pumpkinseed (PMK), Rainbow Trout (RBT), Redside Shiner (RSS), Sculpin (SCU), Westslope Cutthroat Trout (WCT), and Yellow Perch (YEP).

	Control Zone		Nutrient Addition Zone		Downstream Zone	
	Pre	Post	Pre	Post	Pre	Post
BBH	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
BLG	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
BRK	0.00 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
BRT	0.00 ± 0.00	0.02 ± 0.01	0.00 ± 0.00	0.01 ± 0.01	0.00 ± 0.00	0.00 ± 0.00
BUR	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
BC	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
LND	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.03 ± 0.02	0.00 ± 0.00	0.00 ± 0.00
LNS	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.00	0.01 ± 0.01	0.05 ± 0.02	0.03 ± 0.01
LSS	0.46 ± 0.11	0.43 ± 0.07	0.53 ± 0.06	0.85 ± 0.14	0.47 ± 0.08	0.49 ± 0.09
MWF*	2.25 ± 0.50	3.42 ± 0.30	3.68 ± 0.36	7.55 ± 0.64	0.18 ± 0.06	0.16 ± 0.06
NPM*	0.13 ± 0.01	0.18 ± 0.03	0.14 ± 0.02	0.21 ± 0.04	1.53 ± 0.19	1.57 ± 0.19
PMC*	0.05 ± 0.02	0.10 ± 0.03	0.03 ± 0.01	0.03 ± 0.01	1.18 ± 0.27	0.66 ± 0.15
PMK	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.01 ± 0.01
RBT*	0.37 ± 0.05	0.80 ± 0.08	0.29 ± 0.06	0.51 ± 0.07	0.05 ± 0.02	0.05 ± 0.01
RSS*	0.16 ± 0.08	0.24 ± 0.06	0.10 ± 0.04	0.16 ± 0.04	0.87 ± 0.10	0.85 ± 0.17
SCU	0.00 ± 0.00	0.01 ± 0.01	0.00 ± 0.00	0.01 ± 0.00	0.02 ± 0.01	0.02 ± 0.00
WCT	0.02 ± 0.00	0.03 ± 0.01	0.01 ± 0.00	0.02 ± 0.00	0.01 ± 0.01	0.00 ± 0.00
YEP	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.03 ± 0.02

Table 3.2. Mean BPUE (kg of fish·minute^{-1}) for 17 species captured during electrofishing sampling from 2002-2013. Values shown are separated by species, Zone and Period and denote mean ± standard error. Species in which the repeated measures ANOVA model indicated significant differences are shaded in grey and denoted by *. Taxa present in the table include: Brown Bullhead (BBH), Bluegill (BLG), Brown Trout (BRT), Burbot (BUR), Black Crappie (BC), Longnose Dace (LND), Longnose Sucker (LNS), Largescale Sucker (LSS), Mountain Whitefish (MWF), Northern Pikeminnow (NPM), Peamouth Chub (PMC), Pumpkinseed (PMK), Rainbow Trout (RBT), Redside Shiner (RSS), Sculpin (SCU), Westslope Cutthroat Trout (WCT), and Yellow Perch (YEP).

	Control Zone		Nutrient Addition Zone		Downstream Zone	
	Pre	Post	Pre	Post	Pre	Post
BBH	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.23 ± 0.23	0.18 ± 0.14
BLG	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.04 ± 0.00
BRT	0.71 ± 0.71	4.64 ± 1.30	0.16 ± 0.16	2.41 ± 1.14	0.00 ± 0.00	0.70 ± 0.70
BUR	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
BC	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
LND	0.00 ± 0.00	0.05 ± 0.05	0.00 ± 0.00	0.11 ± 0.05	0.00 ± 0.00	0.00 ± 0.00
LNS	1.25 ± 1.25	2.04 ± 1.34	1.73 ± 1.14	4.99 ± 3.75	11.79 ± 4.48	6.70 ± 2.75
LSS*	283.32 ± 74.60	216.13 ± 35.88	365.03 ± 48.64	673.65 ± 89.92	205.65 ± 28.13	255.12 ± 40.01
MWF*	415.33 ± 88.94	497.34 ± 64.26	490.44 ± 72.53	843.02 ± 98.89	4.78 ± 1.82	2.31 ± 0.77
NPM*	20.42 ± 5.62	21.16 ± 2.47	39.87 ± 12.08	35.83 ± 6.26	57.04 ± 7.81	54.29 ± 6.38
PMC*	6.58 ± 3.43	11.25 ± 4.30	4.22 ± 2.35	3.08 ± 1.36	75.69 ± 15.25	36.25 ± 5.66
PMK	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.13 ± 0.13	0.05 ± 0.03	0.17 ± 0.11
RBT*	77.14 ± 11.23	131.55 ± 17.63	57.12 ± 15.56	86.39 ± 12.07	6.39 ± 2.23	6.33 ± 2.11
RSS*	2.29 ± 1.05	3.41 ± 0.94	0.97 ± 0.37	1.67 ± 0.42	6.65 ± 0.91	5.89 ± 1.38
SCU	0.00 ± 0.00	0.09 ± 0.04	0.01 ± 0.01	0.05 ± 0.03	0.09 ± 0.03	0.11 ± 0.03
WCT	6.23± 2.43	7.19 ± 2.07	3.90 ± 1.80	3.95 ± 2.00	4.47 ± 2.35	0.41 ± 0.31
YEP	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.27 ± 0.34	0.39 ± 0.23

FIGURES

Figure 3.1. Location of the Kootenai River, Kootenay Lake, Lake Koocanusa, Libby Dam, and Bonners Ferry.

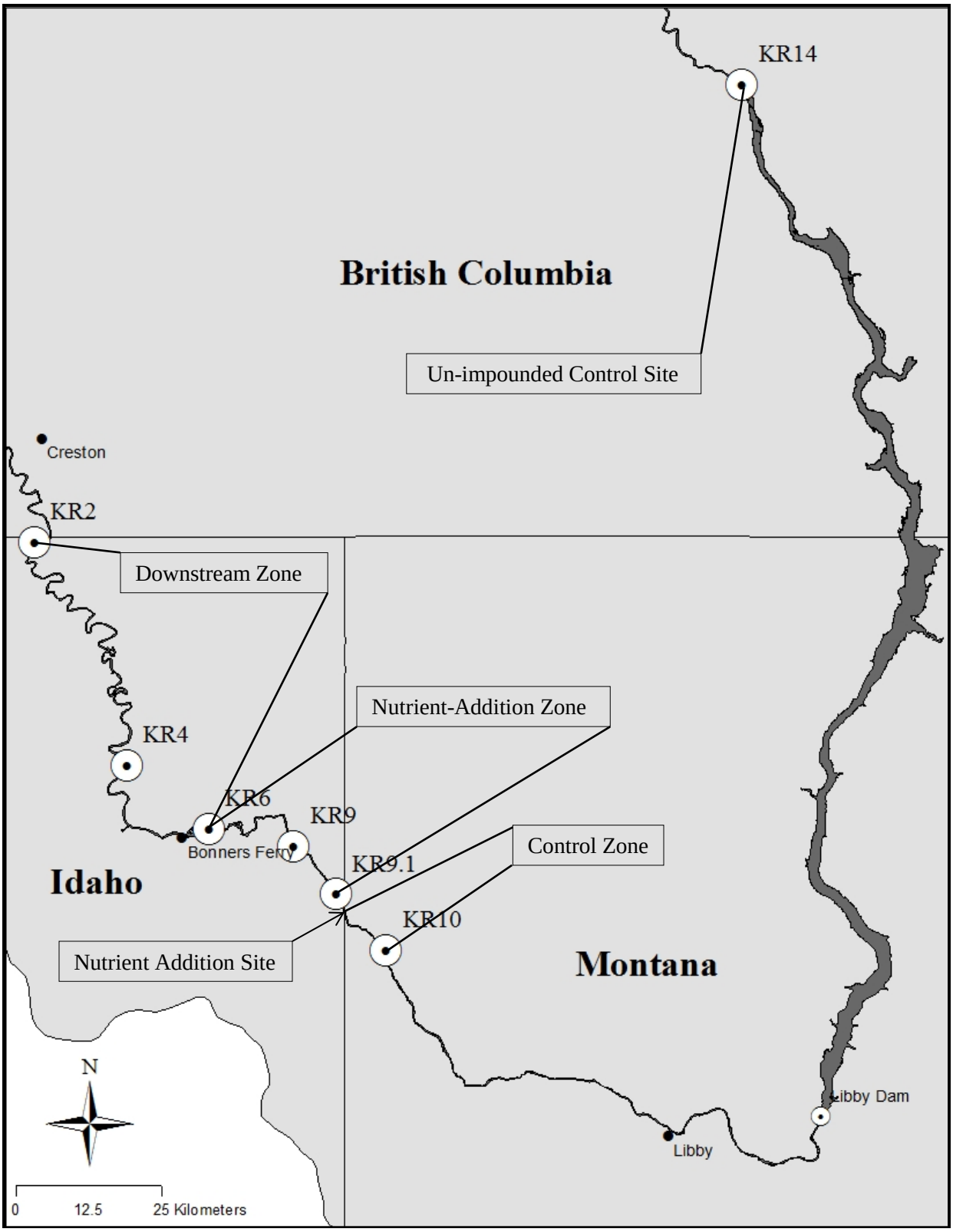

Figure 3.2. Kootenai River ecosystem study area and approximate locations of biomonitoring sites and locations of the three river Zones.

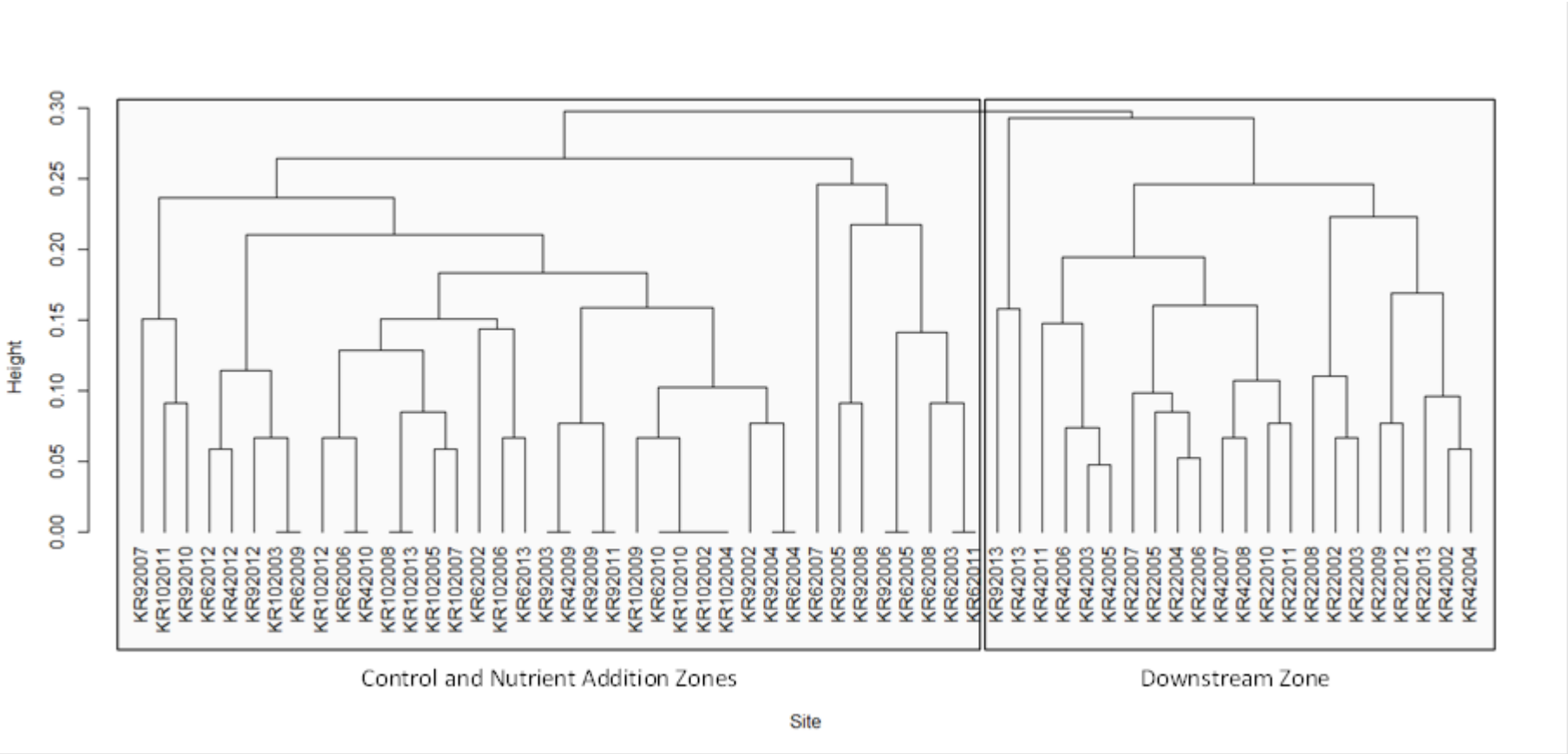

Figure 3.3. Hierarchical clustering analysis of the species occurrence data. Values on the x-axis represent all site-year combinations for the duration of the study. The cluster on the left is comprised of sites within the Control and Nutrient Addition Zones during both pre- and post-treatment periods. The cluster on the right is comprised of sites within the Downstream Zone during both pre- and post-treatment periods.

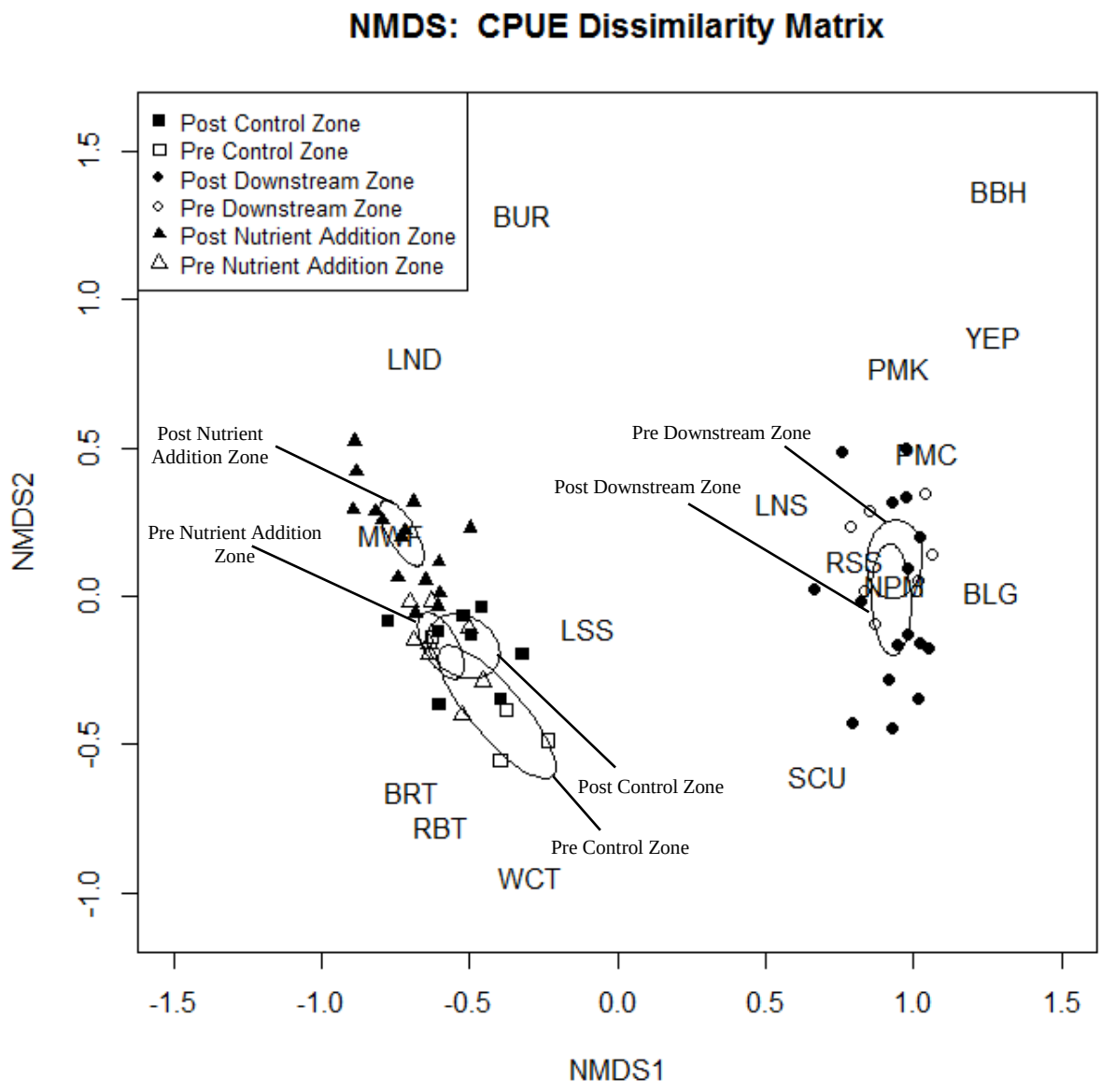

Figure 3.4. Nonmetric multidimensional scaling plot of the Kootenai River fish assemblage utilizing the CPUE data (final iteration of stress: 0.06). Points are organized by Period*Zone combination, and ellipses are representative of standard errors in the ordination space. The grouping to the right is the Downstream Zone, and the grouping to the left is the Control and Nutrient Addition Zones. Within the grouping on the left, there is separation between the pre- and post-treatment periods within the Nutrient Addition Zone. Taxa present in the plot include: Brown Bullhead (BBH), Bluegill (BLG), Brook Trout (BKT), Brown Trout (BRT), Burbot (BUR), Black Crappie (BC), Longnose Dace (LND), Longnose Sucker (LNS), Largescale Sucker (LSS), Mountain Whitefish (MWF), Northern Pikeminnow (NPM), Peamouth Chub (PMC), Pumpkinseed (PMK), Rainbow Trout (RBT), Redside Shiner (RSS), Sculpin (SCU), Westslope Cutthroat Trout (WCT), and Yellow Perch (YEP).

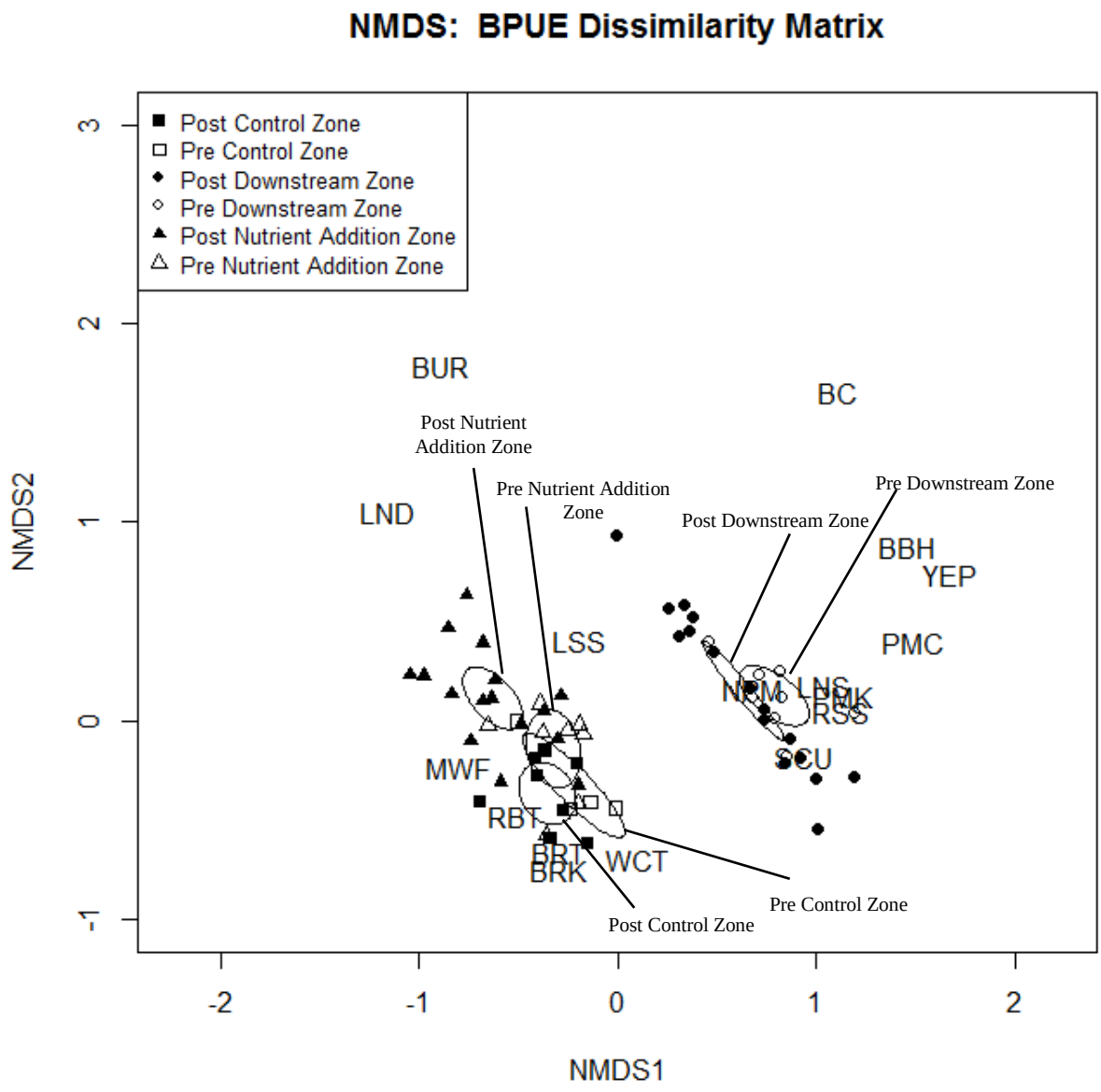

Figure 3.5. Nonmetric multidimensional scaling plot of the Kootenai River fish assemblage utilizing the BPUE dissimilarity matrix (final iteration of stress: 0.09). Points are organized by Period*Zone combination, and ellipses are representative of standard errors in the ordination space. The grouping to the right is the Downstream Zone, and the grouping to the left is the Control and Nutrient Addition Zones. Taxa present in the plot include: Brown Bullhead (BBH), Bluegill (BLG), Brook Trout (BKT), Brown Trout (BRT), Burbot (BUR), Black Crappie (BC), Longnose Dace (LND), Longnose Sucker (LNS), Largescale Sucker (LSS), Mountain Whitefish (MWF), Northern Pikeminnow (NPM), Peamouth Chub (PMC), Pumpkinseed (PMK), Rainbow Trout (RBT), Redside Shiner (RSS), Sculpin(SCU), Westslope Cutthroat Trout (WCT), and Yellow Perch (YEP).

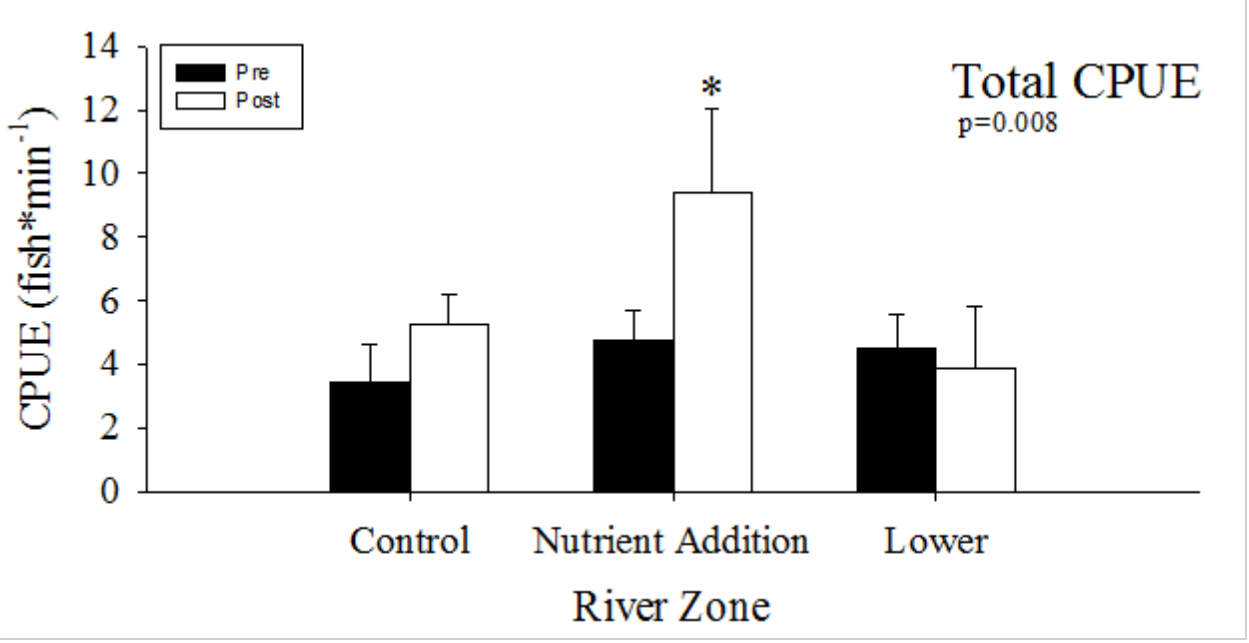

Figure 3.6. Mean total CPUE (i.e., all species, combined) from all three river Zones, segregated by Period. Figure depicts the interaction term (Zone*Period) in the repeated measures ANOVA model. Errors bars represent ±1 standard error. Significant differences within each Zone*Period are indicated by *.

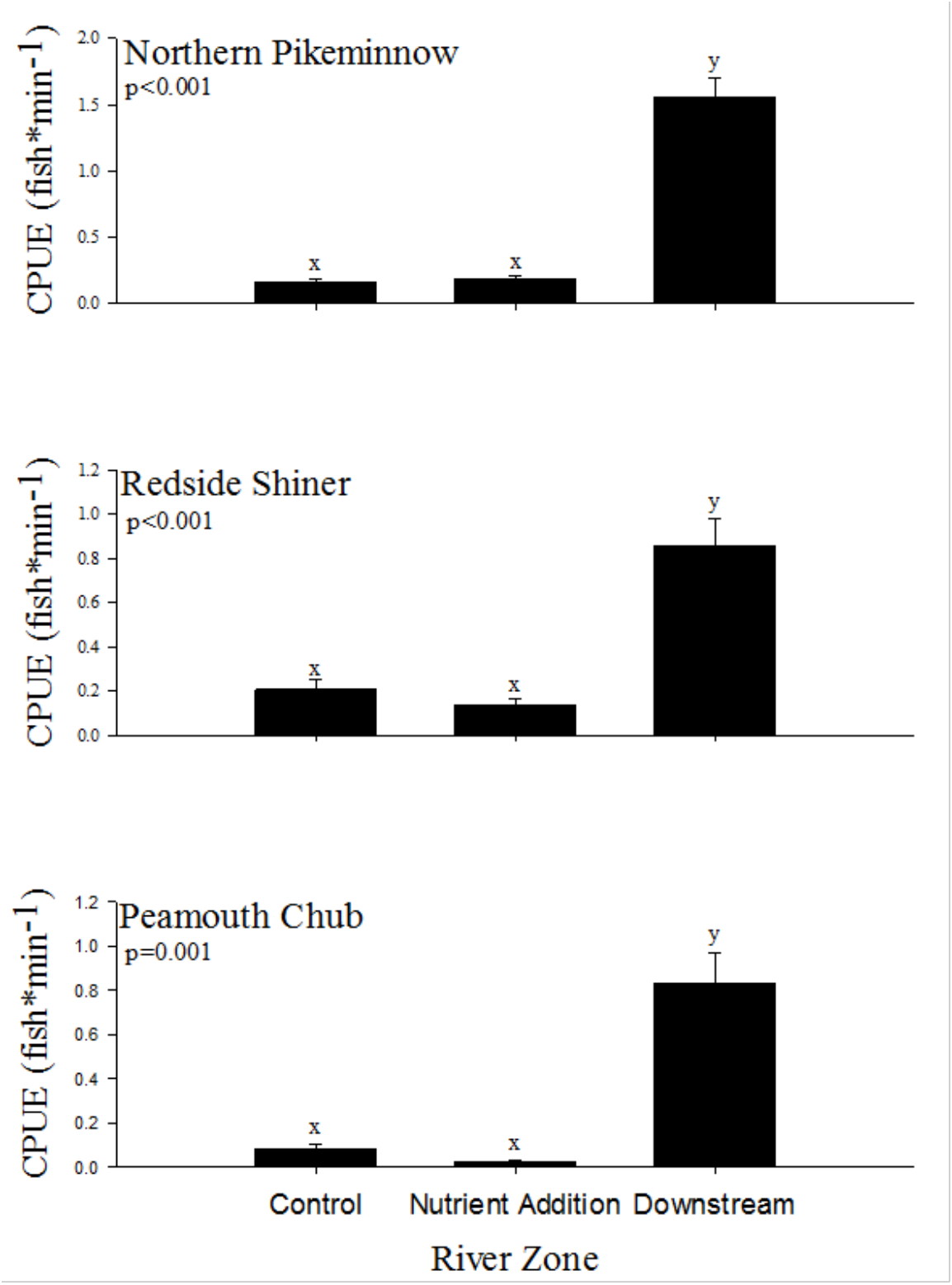

Figure 3.7. Mean CPUE for Northern Pikeminnow, Redside Shiner, and Peamouth chub from all three river Zones. Figure depicts the main effect of Zone in the repeated measures ANOVA model. Errors bars represent ±1 standard error. Bars with different letters are significantly different from one another (by species) based on least squares means.

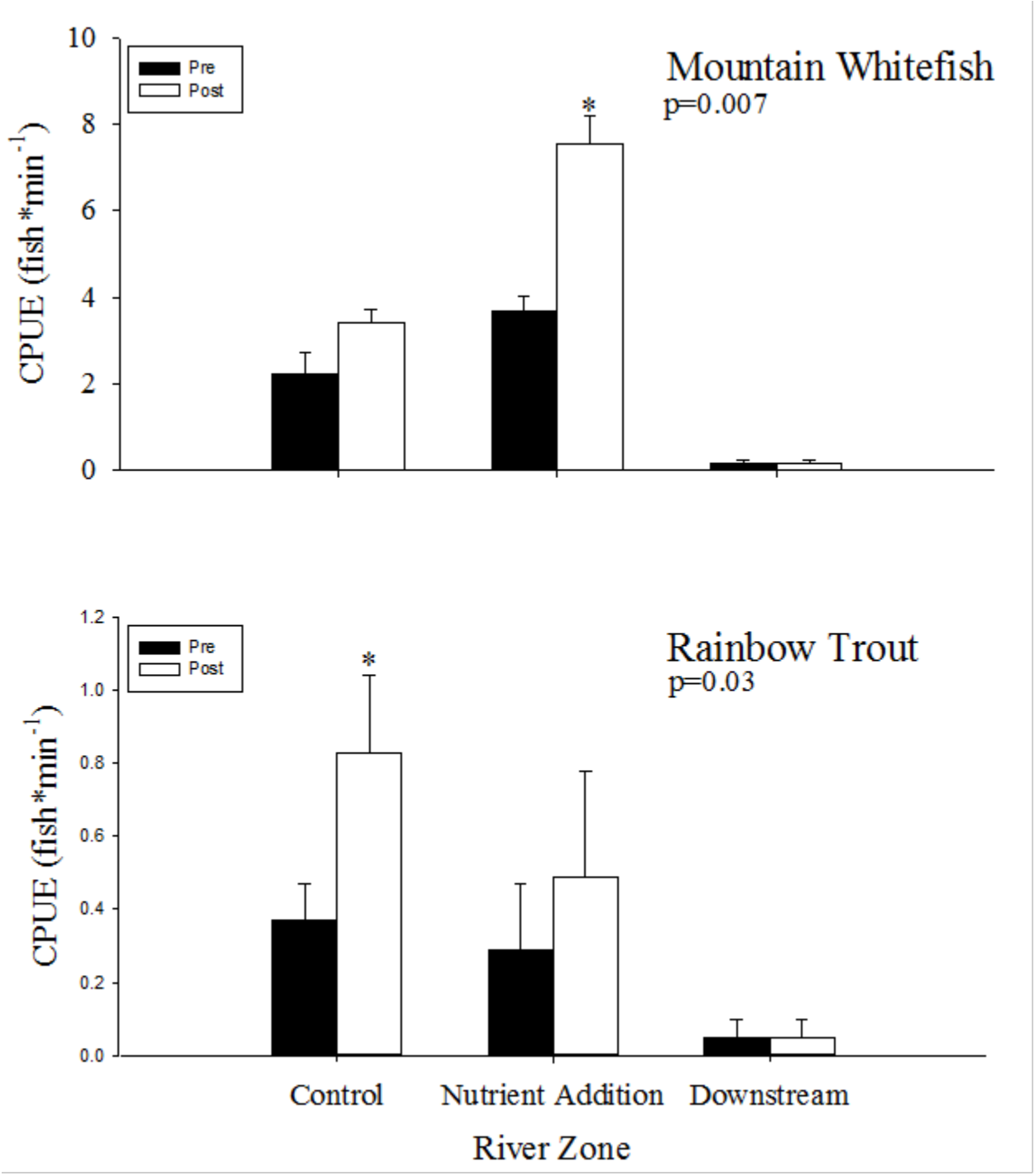

Figure 3.8. Mean CPUE for Mountain Whitefish and Rainbow Trout from all three river Zones, segregated by Period. Figure depicts the interaction term (Zone*Period) in the repeated measures ANOVA model. Errors bars represent ±1 standard error. Significant differences within each Zone*Period are indicated by *.

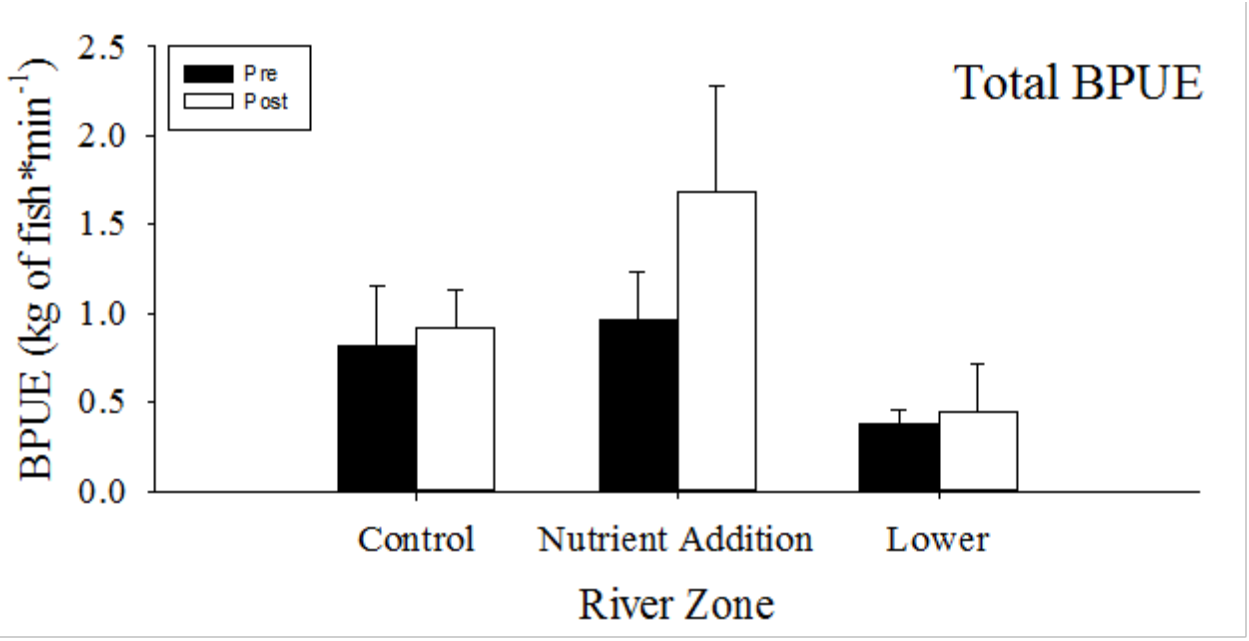

Figure 3.9. Mean total BPUE (i.e., all species, combined) from all three river Zones, segregated by Period. Figure depicts the interaction term (Zone*Period) in the repeated measures ANOVA model. Errors bars represent ±1 standard error.

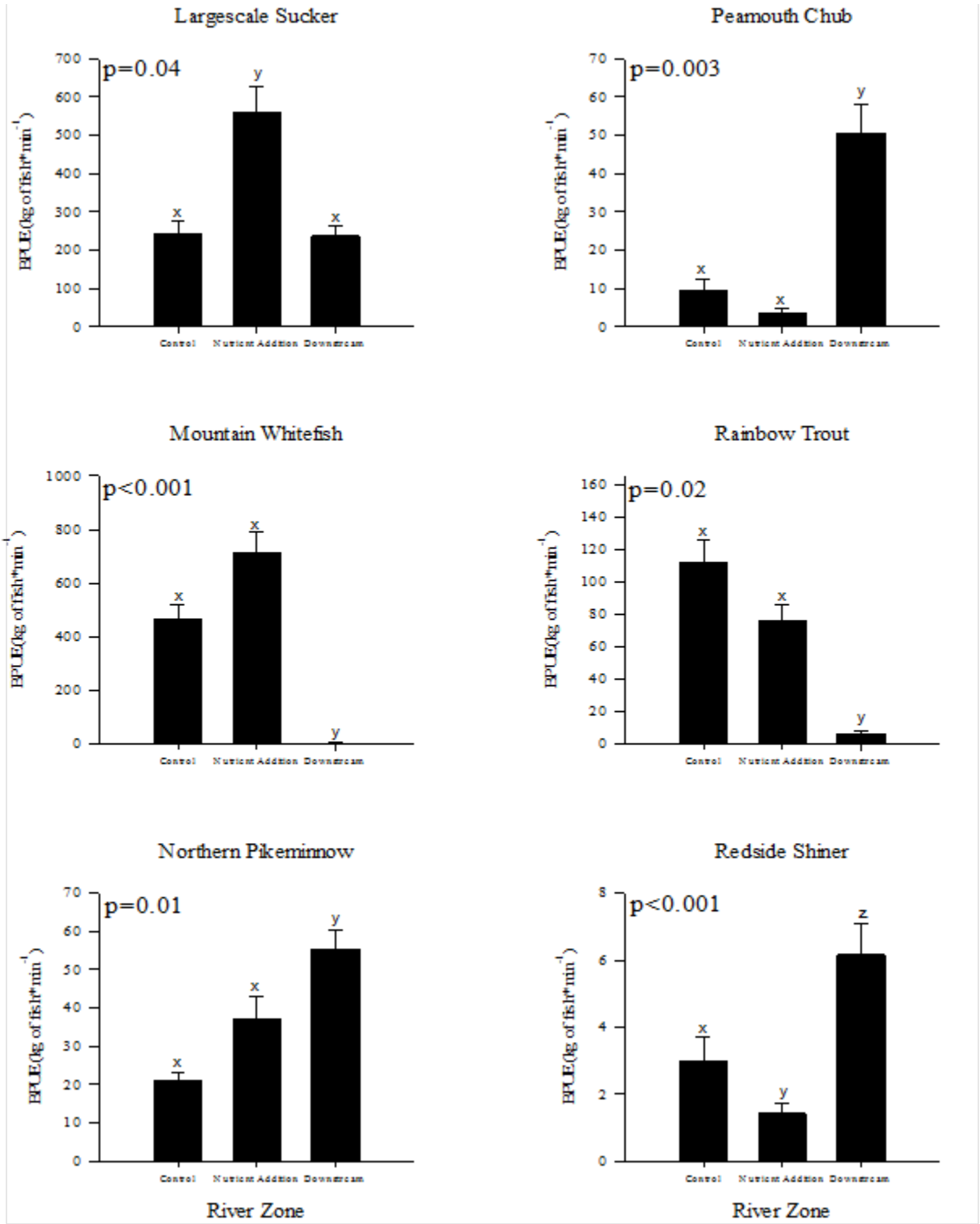

Figure 3.10. Mean BPUE for Largescale Sucker, Mountain Whitefish, Northern Pikeminnow, Peamouth Chub, Rainbow Trout, and Redside Shiner from all three river Zones. Figure depicts the main effect of Zone in the repeated measures ANOVA model. Errors bars represent ±1 standard error. Bars with different letters are significantly different from one another (by species) based on least squares means.

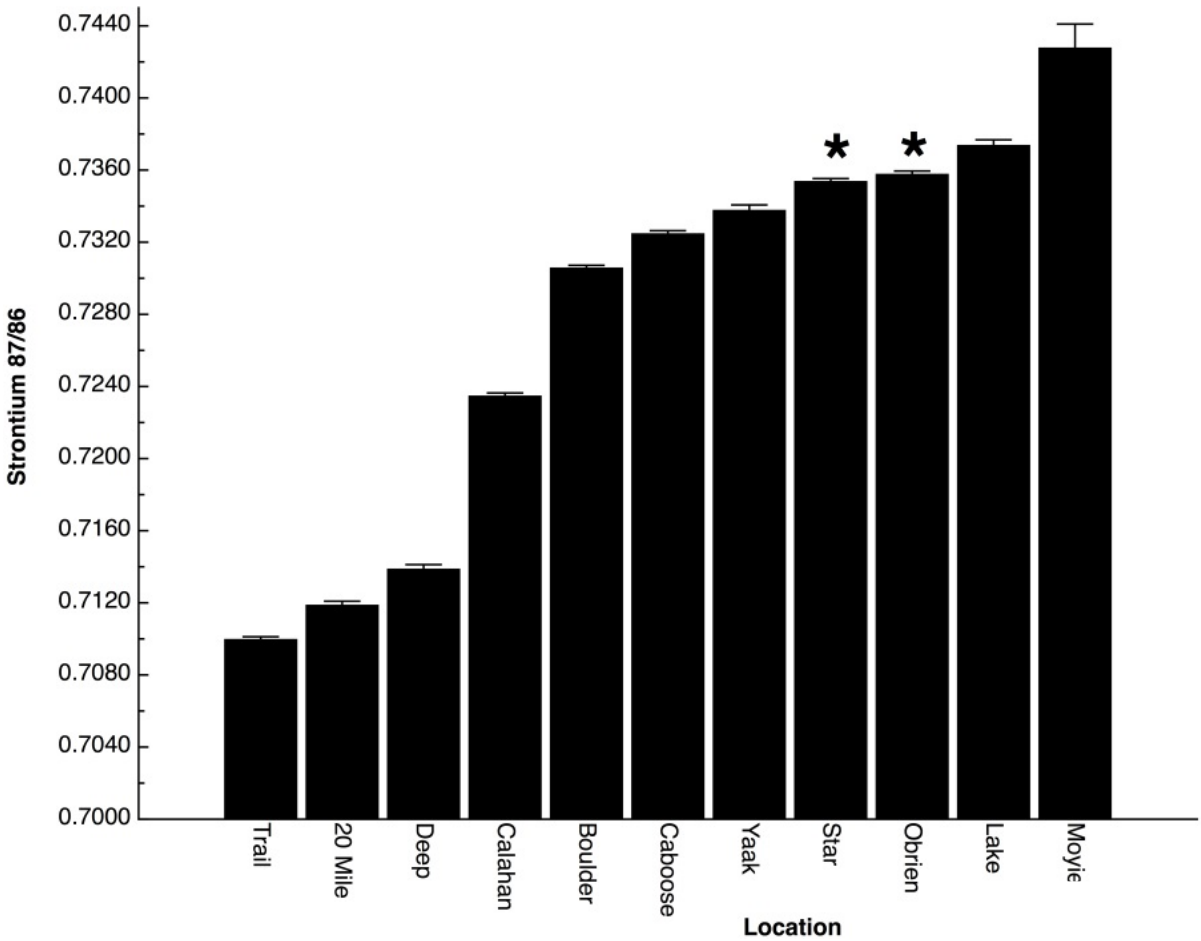

Figure 3.11. Mean strontium signature of all tributaries sampled in 2012. Values indicate mean ± one standard error. Stars above O'Brien and Star Creeks indicate that signatures from these two tributaries were not significantly different.

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