



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

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CHAPTER 1: KOOTENAI STURGEON MONITORING AND EVALUATION

ABSTRACT

Kootenai River White Sturgeon were listed as endangered in 1994 primarily due to recruitment failure and overharvest. This population had been declining for the last 40 years, and natural reproduction has been inconsistent since 1974. Libby Dam, completed in 1972, drastically changed the Kootenai River ecosystem by disrupting the natural flow regime and altering seasonal and daily water temperatures. Idaho Department of Fish and Game is funded through Bonneville Power Administration to monitor and evaluate the effects of mitigated flows from Libby Dam on all life stages on Kootenai Sturgeon and to provide recommendations for recovery to action agencies. The objective of these studies is to determine how current Dam operations influence recruitment, survival, and behavior. The Kootenai Sturgeon flow augmentation in 2016 included a single peak, to maximize the use of a very limited water supply to improve Kootenai Sturgeon spawning and migration conditions. Adult Kootenai Sturgeon were implanted with acoustic transmitters to assess how flow augmentation influences migration extent. Additionally we use acoustic telemetry to collect initial adult spawning data on habitat enhancement projects near Shorty's Island and Myrtle Creek. Based solely on movement extent, only 16 percent of the spawning group of Kootenai Sturgeon moved above Bonners Ferry in 2016. To improve spawning and incubation habitat, two substrate enhancement pilot projects were constructed in winter 2014 near Shorty's Island and Myrtle Creek. In 2016, we continued the new sampling techniques to begin evaluating adult Kootenai Sturgeon habitat use, spawning distribution, and larval hatching successes resulting from these habitat enhancement projects. Results indicate Kootenai Sturgeon are using and spawning on the new habitat, but successful, large-scale larval recruitment was not documented in 2016. Hatchery produced juvenile Kootenai Sturgeon densities continued to remain high, similar to the numbers seen in 2015. The hatchery population is well distributed throughout the Kootenai River and Kootenay Lake and many age classes are represented.

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INTRODUCTION

Since the 1970s the population of Kootenai River White Sturgeon *Acipenser transmontanus* (hereafter Kootenai Sturgeon) has been in decline. The primary drivers of the population decline has been a combination of over harvest and anthropogenic caused habitat degradation. Although harvest has been eliminated since 1994, the lack of adequate spawning and rearing habitats has limited recruitment to almost nonexistent levels since the installation of Libby Dam. Libby Dam was constructed in 1972 and has been the largest contributing factor to the decline of suitable Sturgeon spawning and rearing habitats in particular. Historic Dam operations disrupted natural flow and temperature regimes. Specifically, current spring flows, which coincides with Kootenai Sturgeon spawning, are significantly lower compared to historic flows. These lowered flows no longer allow the Kootenai River to inundate its historic floodplains. Taken together these changes in the Kootenai River have created an environment unable to support reliable Sturgeon recruitment.

Spawning for Kootenai Sturgeon begins each spring when the Kootenai River experiences its highest flows. It is believed that these high flows act as a cue for adult Sturgeon residing in Kootenay Lake and in the lower parts of Kootenai River to begin their upstream migration to the spawning grounds (Paragamian et al. 2002). Spawning and egg deposition tends to occur on the descending limb of the hydrograph when instream temperatures begin to increase to approximately 9 C (Hardy et al. 2016). Kootenai Sturgeon will spawn roughly once every 4 to 6 years, which means on any given year only ~20% of the adult population will make the spawning migration. Fertilized eggs are commonly observed in the river; however, juvenile and larval Sturgeon have rarely been observed since the construction of Libby Dam.

Although the exact mechanisms responsible for lowered levels of recruitment remain unclear, years of study suggest that mortality occurs between egg and larval stages (Paragamian et al. 2002). Over a decade of artificial substrate mat sampling has indicated that from nine to 20 spawning events occur annually and these events can be capable of producing viable embryos (Paragamian et al. 2002). Most post-Libby Dam spawning events have been documented in reaches where substrate conditions appear to be unsuitable for egg incubation and larval rearing (Paragamian et al. 2001). Only a handful of larvae (<10) and relatively few wild juveniles have been collected despite years of intensive sampling. Our investigations suggest that egg and/or larval suffocation, predation, or other mortality factors associated with these early life stages contribute to persistent recruitment failure (Kock et al. 2006).

In response to the decline in Kootenai Sturgeon recruitment the Kootenai Tribe of Idaho (KTOI) began a conservation aquaculture program in 1989. Each spring, broodstock (approximately 6 females and 12 males) is collected and spawned in the hatchery. The resulting offspring are reared and are stocked back into the river after six to nine months. In addition to subsidizing the wild population of Sturgeon, the conservation aquaculture program has provided many insights into the window where we believe recruitment failure to be taking place. 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 recent years our efforts have been focused on monitoring and then evaluating Kootenai Sturgeon spawning and juvenile rearing. We hope that through extended monitoring we may begin to understand the exact mechanism causing the lack of recruitment of Kootenai

River White Sturgeon. In this report we present the finding from our efforts during the 2016 spawning and rearing season.

OBJECTIVE

The fundamental objective of this project is to recover the Kootenai Sturgeon population to a self-sustaining level that can support sportfishing opportunity for the public. In support of this effort, we are tasked to monitor the response of all life stages of Kootenai Sturgeon to flow augmentation from Libby Dam provided by the U.S. Army Corps of Engineers (USACOE) and provide suitable spawning, rearing, and incubation habitat for Kootenai Sturgeon for successful wild recruitment.

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). Kootenai Falls, 42 rkm downstream of Libby Dam, is thought to be a historically impassable barrier to Kootenai 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 exits through the West Arm of Kootenay Lake and joins the Columbia River at Castlegar, BC. A natural barrier at Bonnington Falls (now a series of four dams) has isolated the Kootenai Sturgeon from other populations in the Columbia River basin for approximately 10,000 years (Northcote 1973). The basin drains an area of 49,987 km² (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 three to four times higher than under the natural flow regime (Figure 1.2). However, starting in 1991 Libby Dam has been operated to provide increased spring discharge (>630 m³/s or 22,248 ft³/s for 42 d at Bonners Ferry) when water supplies are suitable to improve spawning conditions for Kootenai Sturgeon embryos and larvae. Post-dam water temperatures are on average cooler in summer and warmer in winter.

METHODS

Water levels, discharge, and river temperature manipulation

The exact shape, timing, and volume of flows during the year are detailed through System Operations Request (SOR) FWS#2016-1 that was submitted to the USACOE' regional multiagency/entity Technical Management Team (TMT). The intent of these SORs was to maintain higher, more stable summer discharges to the extent possible with the available water to meet Kootenai Sturgeon and Bull Trout *Salvelinus confluentus* ESA responsibilities (US Fish and Wildlife Service 2006) and to attempt to mimic a more natural river hydrograph (under VarQ regime). Another objective of the SORs is 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 Sturgeon (US Fish and Wildlife Service 2006). An additional objective of this SOR is to improve conditions for spawning Sturgeon to migrate upstream of Bonners Ferry into the braided reach (above rkm 246).

The 2016 SOR was designed to meet these objectives by providing peak river stages/flows during the spring run-off period. This peak, timed to high elevation run-off below Libby Dam, is intended to first provide Sturgeon cues to begin upstream migration and staging, then as river temperatures warm to 8-10°C, provide Sturgeon cues to migrate further upstream from their staging areas and spawn on the peak and 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. Although a two-peak approach was successfully implemented in 2013 and 2014, lower water supply conditions in the Kootenai River basin preclude a repeat in 2016, as was the case in 2015. Telemetry data for spawning Kootenai Sturgeon females from 2013-2015 indicate that a higher proportion migrated just upstream of Bonners Ferry than in previous years. A second year of single-peak Sturgeon operations will allow us to collect more information on how different water management strategies can influence the spawning behavior of Kootenai River White Sturgeon.

Adult Kootenai Sturgeon Sampling

Adult Kootenai Sturgeon were collected by angling and setlining from March through October 2016 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 documented spawning locations (near and above rkm 229) were sampled more frequently. Fall sampling in 2016 occurred throughout the lower river (rkm 207.5 – 308) and into the Kootenay Lake delta (rkm 18) in BC as well. During sampling we attempted to sex and determine the level of maturity of adult Sturgeon following the gonadal biopsy protocol of Conte et al. (1988) and Van Eenennaam and Doroshov (1998). Male and female Kootenai Sturgeon expected to spawn each spring were tagged with Vemco model V16 sonic transmitters and released. Working in cooperation with the Kootenai Tribe of Idaho (KTOI), a total of nine female Kootenai Sturgeon expected to spawn (based on gonadal examination) during spring 2016 were transported to the KTOI Hatchery for hatchery production. Gametes from ripe male Kootenai Sturgeon (n = 28) were collected in the field by extraction through the urogenital opening with a syringe. Gametes were placed in a sealed plastic bag transported to the KTOI Hatchery, and stored in a refrigerator. Kootenai 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 Kootenai Sturgeon Telemetry

We continued to monitor daily and seasonal spawning movements of Kootenai Sturgeon throughout the Kootenai River/Kootenay Lake system using a passive telemetry array. Beginning in 2003 and continuing to the present, we maintained an array of 89 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 306, below Kootenai Falls (Figure 1.3 and 1.4). From this array we are able to analyze occupancy (present/absence) as well as individual movements in different reaches throughout Kootenay Lake and Kootenai River. A total of 124 implanted transmitters (n females = 104, n males = 20) were active in adults during the sampling period of 5/1/2016 – 4/30/2017. 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/theft. We tethered each receiver to an anchored float, chained to the riverbank, to keep the hydrophone off the substrate (Neufeld and Rust 2009). We downloaded the movement information from the receivers twice a year, once in late winter, prior to the spawning season, and again in the fall.

Substrate Enhancement Pilot Projects

Previous observations have shown that Kootenai Sturgeon spawn primarily between rkms 228 and 240.5 (Paragamian et al. 2002). The substrates of this reach are primarily made up of sand, silt, and clay (Fosness 2013). These types of substrates are considered unsuitable for successful survival in the early life stages of White Sturgeon. Other White Sturgeon populations in the Columbia basin spawn specifically over some combination of rock and gravel which provides adequate egg and larval aeration as well as suitable hiding spaces (Parsley et al. 1993). Because of the lack of substrates that are able to support spawning and early life-stages in this meander reach, the Kootenai River Recovery Implementation Plan proposed “adding rock substrate in the current spawning areas and evaluating its role in providing suitable spawning and incubation conditions.”

In April 2010, under the authority provided by the Continuing Authorities Program, Section 1135, the USACOE, in cooperation with the KTOI, 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 Kootenai Sturgeon” (US Army Corps of Engineers 2012). The US Army Corps of Engineers’ feasibility study recommended a substrate enhancement pilot project (SEPP) at two locations: Shorty’s Island South and Myrtle Creek (Figure 1.5). In 2013, KTOI continued the implementation of the SEPP at two sites in the meander reach. The objective of the SEPP was to test “the sustainability and effectiveness of placing rock substrate over existing clay surfaces in two sub-reaches of the river where wild Kootenai Sturgeon currently spawn” (Kootenai Tribe of Idaho 2013). Construction of the SEPPs was completed in winter 2014.

2016 was the third year of monitoring on the SEPPs, and we expect 2017 to be the fourth and final year of monitoring. We monitored the biological responses of Kootenai Sturgeon during three life stages to evaluate if the SEPPs quantitatively changed: 1) habitat selection by spawning females, 2) occurrence of spawning on the projects, and 3) hatching success of eggs deposited on the site. Statistical analysis of habitat selection by spawning females is currently being conducted by Golder and Associates and we expect those results to be incorporated after completion of the monitoring in 2017. However, the field methods for the habitat selection component are described below. Methods and this year’s results of spawning occurrence and hatching success are provided below.

Habitat Selection

To determine habitat usage by adult spawning Sturgeon on the Shorty’s Island and Myrtle Creek SEPPs in 2016, we incorporated a Vemco VR2W Positioning System (VPS) system. VPS is a low-cost, non-real-time underwater acoustic fine-scale positioning system, using the same equipment used in our passive telemetry array. Initial set up of the VPS system involved placing six VR2W receivers in a grid of equidistant triangles and squares (Figure 1.6), to ensure that every tag transmission was detected by at least three receivers. Ideally, the area of interest is covered with enough receivers to ensure that tagged Sturgeon are always inside of a triangle of receivers to ensure spatial triangulation is possible. In this study receivers were

placed close enough together to maximize the overlap in detections among receivers. Synchronization transmitter tags were moored along with each receiver (co-located) to correct for clock drift between submerged receivers. We placed additional reference tags within the receiver grid in known locations to measure system performance. We used a Trimble Juno 3D and differentially correct positions which allowed accuracies in receiver deployments of up to 15 cm which improved post-processed Sturgeon position accuracies to less than 5 meters.

The first phase of the monitoring plan included tagging 12 adult female Sturgeon (gonadal stage = F4) with specialized Vemco V16 transmitters (V16TP-6X) that included a depth sensor for increased position accuracy and a temperature sensor to account for speed of sound in water variability. Tagging Sturgeon with these V16TP tags began in the fall of 2014, continued through 2015, and into 2016. Prior to the study, we had at least 90 Sturgeon with active telemetry transmitters (V16 transmitters without the depth component), which were also compatible with the VPS system, although less accurate.

On a periodic basis, we sent receiver data to VEMCO to determine if the system was functioning properly and for position resolution. After VR2W receiver data was collected at the end of the study, VEMCO provided a final report of calculated positions. For most studies, expected position accuracy is similar to that provided by the GPS standard positioning service: 95% of positions within a 15-meter error circle.

Spawning Occurrence

We used artificial substrate mats (McCabe and Beckman 1990) to evaluate whether Kootenai Sturgeon were spawning either on or off the SEPPs and specifically to determine if spawning females used the substrate additions at higher rates. We sampled Shorty's Island and Myrtle Creek in a systematic design (Figure 1.6) using 21 mats at each site. Seven mats were deployed in three independent treatment locations including one on each habitat enhancement site (Strata 1) and two control locations. At each location the first control site (Strata 2) was approximately 500 m downstream of the substrate enhancement site in an area that has traditionally yielded eggs and had similar physical conditions to the treatment site prior to the installation of the SEPP. An additional control site (Strata 3) was on river left, 150 m downstream of the treatment site in an area where few eggs have been collected in the past. Total area sampled within the treatment reach and at the two control sites was identical. Designs are identical for both the Shorty's Island and Myrtle Creek SEPP sites (Figure 1.6). We retrieved and reset mats at least twice per week and all eggs were stored in formalin and brought back to the laboratory 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). More details of the substrate sampling methods are available in Rust and Wakkinen (2010).

Hatching Success

Hatching success was determined through extensive larval sampling around the Shorty's Island and Myrtle Creek SEPP sites and occurred concurrently with egg mat sampling. We continued the larval sampling design of Crossman and Hildebrand (2014) for the duration of this study. Two nets were paired on a metal frame with each net being 80 cm wide X 60 cm high with 1.6 mm net mesh. The cod end of each net was made of a 3-gallon polyurethane bucket with 1.6 mm mesh windows. While deployed, each frame was independently anchored to the substrate which allowed us to retrieve each set of nets without resetting the anchor. When the nets were retrieved the cod ends were replaced and the debris was examined for larval

Sturgeon. In 2016, we sampled two pairs of frames (four nets per site) above and below each SEPP and one pair of nets in the lower end of the straight reach near Bonners Ferry (near rkm 245.0). We attempted to begin sampling about 10 days after the first eggs were observed on the egg mats. Sampling efficiency and duration was a function of river conditions (debris and flow) and sampling effort and duration increased as the hydrograph receded and debris load reduced. Full 24 h sets began once drifting debris was at a low enough level to allow nets to fish the entire night period without debris fully saturating the net holding capacity.

Juvenile Kootenai Sturgeon Sampling

Beginning in 1990 and continuing to the present, the KTOI and BC hatcheries have released over 286,000 juvenile Kootenai Sturgeon. There were three primary reasons for sampling these juvenile Kootenai Sturgeon: 1) the distribution, stock status, and densities of marked hatchery juveniles, 2) survival and growth rates of marked hatchery juveniles, and 3) any natural recruitment as determined by capture of unmarked juveniles. Since this population is transboundary, data collected in Canada were included.

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, as well as distribution, densities, growth, and mortality rates of both hatchery and wild juveniles. We followed the sampling methodologies provided in Ross et al. (2015). Gill nets were set during the daytime and checked every hour to reduce mortality, and all Sturgeon were released alive. All fish that were sampled in gill nets were checked for PIT tags as well as scute removals. These markings allow us to keep track of recaptures and differentiate between wild and hatchery origin individuals.

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 either at the KTOI hatchery or at the Kootenay Trout and Sturgeon Hatchery located in Ft. Steele, BC, (operated by the Freshwater Fishery Society of BC as the backup facility for the KTOI). Most of the released juvenile Kootenai Sturgeon (92%) 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 again PIT tagged and all had scutes removed. PIT tagging fish prior to release provides a unique individual identifier for each fish and allows tracking of the size at release, rearing facility, release location, and time of release as well as subsequent individual performance (annual growth, etc.). Scute removal patterns only identify brood year and rearing location; however, due to the nature of such marks there can be subjective errors with applying and recording scute patterns (e.g. miscounts or incomplete scute removals). Fork (FL) and total length (TL), weight, PIT tag numbers, fish condition, and scute removal patterns were recorded for each sampled Sturgeon. Additionally, pectoral fin ray sections were removed from all wild juvenile Kootenai Sturgeon for age estimation. Each newly encountered wild Sturgeon received a PIT tag and the second left scute was removed for future identification.

RESULTS

Water Levels, Discharge, and River Temperature

The 2016 Sturgeon operation involved a single peak in Libby Dam outflows. The first peak began on May 15, when Libby outflows of 16 kcfs were increased to 20 kcfs when local

Kootenai River tributaries were forecasted to have peak outflows downstream of Libby Dam. Outflows were increased again between the dates of May 16 and May 21 when Libby maintained powerhouse capacity outflows of 24 kcfs (Figure 1.7). The end of the first pulse occurred on May 22 when Libby Dam outflows were reduced down to 18 kcfs. Libby Dam maintained these lower outflows (18 kcfs) until the second pulse started on June 2 when Libby outflows were increased to 22 kcfs. Then Libby Dam maintained powerhouse capacity outflows of 25 kcfs June 3 through 11. The ramp down for the second pulse began on June 12 when Libby outflows were decreased to 22 kcfs. Subsequently outflows were reduced to 20 kcfs June 13 through 15, and again down to 17 kcfs between the dates of June 16 and 18. The second pulse ended on June 14 when outflows were decreased to 14 kcfs.

Temperature in the Bonners Ferry reach during Sturgeon flow augmentation ranged from 9.5 to 16°C; temperatures of 10°C at Bonners Ferry were observed at the beginning of May (Figure 1.7). Release temperature from Libby Dam ranged from 8 to 15°C and temperatures below Libby Dam decreased slightly as flow increased for the peak of the operation, and then increased from 9 to 12°C as selective withdrawal gates were placed and flow was decreased. The decrease in volume released from Libby Dam (during the receding limb of the hydrograph) allowed river temperature to increase as water reached the spawning area near Bonners Ferry.

Adult Kootenai Sturgeon Sampling

Between May 2 and October 13, 2016, IDFG, British Columbia Ministry of Forests, Lands, Natural Resources and Rural Development, and KTOI crews expended more than 721.51 rod hours to capture 113 adult Kootenai Sturgeon by angling (Table 1.1). This resulted in a net catch rate of 0.63 fish per rod hour. The vast majority of this effort took place in the Idaho section of the Kootenai River (rkms >170). This effort was primarily focused during the spring season, which coincides with adult broodstock collection. Of the adults collected, the vast majority (~80%) were recaptures.

Additionally, IDFG and British Columbia Ministry of Forests, Lands and Natural Resource Operations (BCFLNRO) sampled for adult Sturgeon using setlines between April 4 and October 13. A total of 270 sets were deployed, each with 6 to 8 hooks, which resulted in a final effort of 29,345.18 hook hours. 129 Sturgeon were sampled through these setlines, which resulted in 0.041 fish per setline hour. Approximately 88% of the Kootenai Sturgeon sampled via setlining were recaptures (Table 1.2). Lastly, only five adults were sampled during the gill netting, all of which were recaptures.

After capture, we biopsied 45 adult Kootenai Sturgeon to determine sex and reproductive stage. Twenty-five (55%) of the biopsied adults were females, and sex could not be determined for 15 individuals. Of these 25 females Sturgeon biopsied, 12 were stage F4 (mature eggs), while the specific stage could not be determined for the remaining female. KTOI Hatchery personnel also captured and biopsied adult Kootenai Sturgeon for their propagation operations; Lewandowski (2016) provides adult capture information.

Adult Kootenai Sturgeon Telemetry

We monitored adult white Sturgeon spawning migration, movement extent, and behavior during the Libby Dam flow augmentation operations using Vemco acoustic transmitters. Six adult Kootenai Sturgeon were tagged with Vemco sonic transmitters in fall 2016 and five were tagged in spring 2017. All were tagged with Vemco V-16TP-6X transmitters to coincide with the

2015 SEPP evaluations using VPS. In addition to providing detailed information within the VPS arrays, these VPS tags were also compatible with the existing VR2W array and individuals containing these transmitters were included in large-scale movement analysis. Based on transmitter downloads, in 2016, 40 (82%) tagged adult Sturgeon moved upstream as far as rkm 240.0 (Below Deep Creek), and 28 (57%) of the migrating adults went upstream as far as rkm 244.5 (Ambush Rock). Additionally, at least 12 (24%) of the tagged migrating adult Sturgeon went upstream of the Hwy 95 Bridge in Bonners Ferry into the braided reach in 2015 (Figure 1.8 and 1.9).

Substrate Enhancement Pilot Projects

Sampling in 2016 provided the second year of post-treatment data from which to compare changes resulting from the SEPP construction in 2015. Next year, 2017, will provide the final year of VPS analysis at these sites, and at that time we will provide a full write up to determine the effectiveness of the SEPPs on adult spawning.

Spawning Occurrence

We deployed substrate mats in 2016 to evaluate the temporal extent of Kootenai Sturgeon spawning events in the Kootenai River. Our sampling efforts were targeted on or near both the SEPP sites to evaluate their efficacy to spawning adults. We also sampled an area near Bonners Ferry (rkm 246) to evaluate egg deposition near town. We sampled a total of 73,572.59 mat hours between May 16 and July 11 and collected 342 eggs (Table 1.3). The highest catch and the highest catch rate came from the Myrtle Creek area (rkm 234.5, Table 1.4). Egg collection on the SEPPs in 2016 were consistent with previous years where all the eggs were found in Strata 1 and 2 and no eggs were collected on the control sites (Stratum 1).

All 342 eggs that were collected could be staged and may have been viable. Egg stages ranged from 12 to 23; however, the majority of eggs collected appeared to be in stages 16 or 17 (Beer 1981). Based on the viable eggs, we estimate that Kootenai Sturgeon spawned across 28 days from May 21 and June 18 (Figure 1.10 and 1.11). Water temperature during the egg collection period ranged from 8.7° to 15.5°C, surface water velocity ranged from 0.3 to 1.33 m/s and Secchi disk depth ranged from 0.9 to 4 m.

Hatching Success

We sampled for larval Sturgeon between June 8 and July 30, 2016 for a total of 8,768.41 hours of effort (Table 1.5). Sampling effort was similar between the Shorty's Island and the Myrtle Creek sites. Effort was much lower at the sites near Bonners Ferry due to high debris loads in the water column. In this portion of the river there is enough debris to fill and clog a larval net in as little as two hours, which makes effective sampling near impossible. For that reason the Bonners Ferry site was sampled after flows, and subsequently the debris load, came down considerably. Only a single larval Sturgeon was collected at Shorty's Island. Non-target larvae were collected at all three sites but were not quantified. Most of the non-target larval fish were mountain whitefish (*Prosopium williamsoni*) or belonged to the *Catostomidae* family.

Juvenile Kootenai Sturgeon Sampling

In 2016, IDFG and BCMFLNRO sampled for juvenile Kootenai Sturgeon with gill nets between July 15 and October 25, 2016 in Idaho and Canadian sections of the Kootenai River and Kootenay Lake. We sampled 25 sites between rkm 18.0 and 244.5 and collected 1,841

juvenile Sturgeon (1,836 hatchery-reared, >99%) with 500 hours of effort (Figure 1.1, Table 1.6). The majority of the catch was from the Idaho portion of the river (>170.0 rkm), and this coincided with where catch rates were the highest as well (Table 1.7). Juvenile Sturgeon were well distributed throughout the river and lake. Ferry Island (rkm 205.0), Rock Creek (rkm 215.0), and Ambush Rock (rkm 244.5) had the highest catch rates in the river, but most areas throughout the river had catch rates that exceeded one fish per hour. All sizes of gill nets used caught Sturgeon at roughly comparable rates; however, the 2-inch mesh had the highest catch rates (Figure 1.12). The 2-inch mesh was fished the most, representing 49% of the sets. The average fork and total length of the hatchery reared juvenile Kootenai Sturgeon was 42.67 cm and 49.7 cm, respectively, and weight of juvenile Sturgeon captured in 2016 averaged 0.67 kg.

Fifteen wild juvenile Kootenai Sturgeon were captured while gill netting in Canada and Idaho in 2016 (Table 1.6). The TL of these seven individuals ranged from 32.0 to 118.0 cm, and weights ranged from 0.18 to 7.2 kg. All seven wild juveniles were aged by sectioning the pectoral fin ray and counting annuli. Figure 1.13 shows the number of wild juvenile Kootenai Sturgeon collected annually from 1977 to 2016. The number of new wild fish we encountered in 2016 was roughly the same as the numbers we have seen in the previous 10 years. We attempted to assign year class Figure 1.14 shows the year class assignments from a sample of the wild juvenile Kootenai Sturgeon collected between 1977 and 2015 that could be aged.

DISCUSSION

Libby Dam Kootenai Sturgeon flow augmentation operations for 2016 consisted a single period of high flow, beginning at the start of March and continuing through April. These periods of high flow were then followed by flows that quickly descended to base flows starting in mid-June (Figure 1.7). This operation efficiently used the limited water supply to benefit Kootenai Sturgeon spawning by extending the highest available discharges throughout the spawning period. 2016 saw a similar flow strategy that was also implemented during the spring of 2015. In 2016, 34% of the tagged spawning group migrated above Bonners Ferry (rkm 246), which was a slight increase over the running average of the previous five years. Although it appears that upstream Kootenai Sturgeon migration extent improved under the single peak operations, it is difficult to separate all the environmental factors that control upstream movements on an annual basis. This is further confounded by the fact that each year provides a different cohort of spawners, which potentially introduces yet another source of noise in the form of individual behaviors. We will continue our adult tagging efforts, and additionally will plan to concentrate on a portion of those fish that have expired tags in order to provide more information on movement and spawn periodicity in relation to age. Future work may be focused on leveraging our long-term telemetry database to evaluate large-scale patterns in Kootenai Sturgeon spawning movements.

Sonic tagging efforts to monitor Kootenai Sturgeon movements have generally been focused on adult fish in the past; however, we believe it would be beneficial to incorporate more juvenile fish into those efforts. Relatively little is known about the movement of juvenile Kootenai Sturgeon, especially regarding how often they transition between the lake and river environments. We have observed that juvenile Kootenai Sturgeon that are encountered in Kootenay Lake tend to be larger on average; however, it remains unclear to what extent they use the lake habitat exclusively. Additionally, it would be beneficial to tag some of the larger (>140cm) hatchery origin juveniles that will potentially join the spawning population in the next 5 or 10 years. These fish will represent the first cohort of hatchery origin spawners and as such it

would be beneficial to understand the circumstances (size, age, or environmental factors) that are required for them to become spawning adults.

During 2017 KTOI is set to complete a large-scale habitat restoration project in the braided reach of the Kootenai River (> rkm 146). This project was designed, among other things, to provide adult Sturgeon spawning habitats. We plan on developing methods for monitoring spawning movements and habitat usage in these new habitats. We are currently investigating a method to reduce the area a passive acoustic receiver can detect (e.g., a detection radius of 15m rather than 400m), which will allow us to have a finer resolution of specific habitat usage. Additionally, we hope to do more early life history monitoring near and above Bonners Ferry to evaluate if the newly constructed habitat is being actively used.

Larval captures in 2016 continued to be low with only three individuals being captured. Currently, we are unable to determine if our capture efficiency is low and those individuals are actually representative of the density of larval Sturgeon or if our larval nets are not fishing optimally. We have started working with U.S. Geological Survey to develop a particle drift model to aid in determining the efficacy of our larval nets. This model incorporates a 2-D hydraulic model of the Kootenai River and then simulates particles deterministically drifting downstream. A model such as this can allow us to determine which locations on the river we would expect to see a high concentration of particles and better understand how larval Kootenai Sturgeon may drift downstream. In the future we plan to incorporate this model to better inform our larval sampling design in order to maximize our sampling efficiency.

The combined 2016 IDFG and BCMFLNRO gillnet catch of 1,841 juvenile Kootenai Sturgeon was the second highest on record, second only to the gillnet catch of 2015. Densities and catch rates continue to increase throughout the river and lake and juvenile Kootenai Sturgeon are well distributed throughout the system. Even though this continues to indicate the success of KTOI conservation aquaculture program, our concern is when and if densities increase to the point where mortalities increase or growth slows to the point where we are delaying potential sportfishing opportunities. In 2014 we completed a survival analysis of juvenile Kootenai Sturgeon using mark/recapture methods. We plan on repeating this analysis in 2017 to determine if juvenile survival declined since the last analysis. Updating these survival rates would provide some evidence as to whether juvenile Kootenai Sturgeon experience density dependent survival.

RECOMMENDATIONS

As soon as water temperature at Bonners Ferry reaches 7°C after April 1, provide augmented flow from Libby Dam to achieve 425 m³/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 Sturgeon.

Provide minimum flows of 630 m³/s for 42 d (as prescribed for spawning and rearing in the Kootenai 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 Sturgeon.

Continue the SEPP evaluation at Shorty's Island and Myrtle Creek in 2017 for a third year of post-treatment evaluation. This will include evaluating habitat use by spawning female

Sturgeon (Vemco VPS system), spawning occurrence (egg mat sampling), and hatching success (larval Sturgeon sampling).

Continue the multistate movement modeling research adding additional covariates, comparing years and conditions with high percentages of upstream movements, and comparing years and conditions with relatively high recruitment rates.

Continue collecting fin rays from hatchery reared juvenile Sturgeon to evaluate changes in growth over time using incremental growth analysis.

TABLES

Table 1.1 - Angling Sampling effort of adult and juvenile Kootenai Sturgeon during 2016. All sampling was done by Idaho Department of Fish and Game (ID), Kootenai Tribe of Idaho (KTOI) and British Columbia Ministry of the Environment (BC). Untraceable recaptures refers to fish that were captured but their origin (wild vs hatchery) is unknown due to incomplete marking or tagging. Sampling done in the Montana portion of the Kootenai River is not included in these figures.

Season	Location	RKM Range	Crew	Start Date	End Date	Total Effort (Rod hrs)	Total Catch		Total CPUE		Recaptures		Untraceable Recaptures	
							Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
Fall	Lake	≤122	BC	9/13/2016	9/29/2016	20.60	1	0	0.049	0.000	0	0	1	0
			ID	10/12/2016	10/12/2016	4.05	1	2	0.247	0.494	1	2	0	0
			KTOI	9/12/2016	10/13/2016	177.70	20	0	0.113	0.000	13	0	0	0
	BC River	123-170	ID	10/13/2016	10/13/2016	4.57	0	0	0.000	0.000	0	0	0	0
	ID River	≥170	ID	9/15/2016	10/11/2016	32.25	19	0	0.589	0.000	17	0	1	0
KTOI			8/2/2016	8/24/2016	30.90	2	0	0.065	0.000	2	0	0	0	
Spring	ID River	≥170	ID	5/5/2016	3/30/2017	25.76	3	0	0.116	0.000	1	0	1	0
			KTOI	5/2/2016	6/8/2016	425.68	65	0	0.153	0.000	52	0	5	0

Table 1.2 - Setline sampling effort of adult and juvenile Kootenai Sturgeon during 2016. All sampling was done by Idaho Department of Fish and Game (ID) and British Columbia Ministry of the Environment (BC). Untraceable recaptures refers to fish that were captured but their origin (wild vs hatchery) is unknown due to incomplete marking or tagging. Sampling done in the Montana portion of the Kootenai River is not included in these figures.

Season	Location	RKM Range	Crew	Start Date	End Date	Total Effort (Hook hrs)	Total Catch		Total CPUE		Recaptures		Untraceable	
							Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
Fall	Lake	≤122	BC	9/27/2016	10/13/2016	719.21	18	9	0.0250	0.0125	14	7	4	2
	BC River	123-170	BC	9/27/2016	10/13/2016	1286.82	10	0	0.0078	0.0000	10	0	0	0
			ID	10/12/2016	10/13/2016	267.36	1	0	0.0037	0.0000	0	0	0	0
	ID River	≥170	ID	9/15/2016	10/11/2016	162.73	8	0	0.0492	0.0000	7	0	0	0
Spring	Lake	≤122	BC	4/4/2017	4/28/2017	640.67	11	1	0.0172	0.0016	10	1	0	0
	BC River	123-170	BC	4/4/2017	4/28/2017	819.45	1	0	0.0012	0.0000	1	0	0	0
	ID River	≥170	ID	3/7/2017	4/27/2017	25448.95	57	13	0.0022	0.0005	54	10	0	3

Table 1.3 - Total effort and catch of Kootenai Sturgeon eggs via artificial substrate mat sampling during the spring (May 16 to July 11) of 2016. Three sites were sampled continuously throughout the period.

Site Description	River km	Depth Range (ft)	Temperature Range (°C)	Total Mat Effort (Hours)	Total Eggs	CPUE
Shorty's Island	230.5	8 - 43	8.9 - 16.5	29785.95	104	0.0035
Myrtle Creek	234.5	3 - 46	9 - 16.5	29556.22	224	0.0076
Bonnars Ferry	245	6 - 30	9.1 - 17	14230.42	14	0.0010

Table 1.4 - Distribution of eggs near KTOI SEPPs from 2014 to 2016 by artificial substrate mats. Strata 1 refers to mats that were on the SEPP, Strata 2 refers to mats that were just downstream of the SEPP and Strata 3 refers to mats that were on a dissimilar substrate.

Site Description	River Km	Strata	Number of Eggs		
			2014	2015	2016
Shorty's Island	230.5	1	48	14	60
	230.5	2	25	44	44
	230.5	3	0	0	0
		Total	73	58	104
Myrtle Creek	234.5	1	111	15	144
	234.5	2	127	107	80
	234.5	3	0	0	0
		Total	238	122	224

Table 1.5 - Total effort and catch of Idaho department of Fish and Game larval Kootenai Sturgeon sampling for 2016 summarized by sampling location. Sampling occurred June 8 to July 30.

Sampling Location	River Kilometer	Total Time (hours)	Volume Sampled (m ³)	Larva Captured
Shorty's Island	230.5	4028.72	1052164.89	1
Myrtle Creek	235	4101.27	803273.56	0
Bonnars Ferry	245.5	638.42	183311.47	0

Table 1.6 - Angling Sampling effort of adult and juvenile Kootenai Sturgeon during 2016. All sampling was done by Idaho Department of Fish and Game (ID), Kootenai Tribe of Idaho (KTOI) and British Columbia Ministry of the Environment (BC). Untraceable recaptures refers to fish that were captured but their origin (wild vs hatchery) is unknown due to incomplete marking or tagging. Sampling done in the Montana portion of the Kootenai River is not included in these figures.

Crew	Location	RKM Range	Start Date	End Date	Total Number of Sets	Total Effort (hr)	Catch		CPUE		Recaptures		Untraceable Recaptures	
							Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
BC	Lake	≤122	7/28/2016	9/14/2016	65	68.69	3	205	0.044	2.984	3	148	0	57
BC	BC River	123-170	7/15/2016	8/23/2016	97	125.16	2	208	0.016	1.662	0	171	2	37
ID	ID River	≥170	8/1/2016	10/25/2016	231	306.07	0	1428	0.000	4.666	0	1164	0	253

Table 1.7 - Total effort and catch of Kootenai Sturgeon via gill net sampling by Idaho department of Fish and Game and British Columbia Ministry of the Environment summarized by river kilometer. Sampling occurred between July 15th and October 25 2016. For reference, the US/Canada border is at rkm 170 and the and rkm < 120 is in Kootenay Lake.

River Kilometer	Number of Sets	Hours of Effort	Adults Captured	Juveniles Captured	CPUE (fish/hour)
18	11	12.484	0	19	1.5219
120	27	27.549	1	64	2.3594
121	25	26.519	2	122	4.6759
121.5	2	2.141	0	0	0.0000
123	8	7.974	0	6	0.7524
130	16	18.670	1	42	2.3032
141	8	9.365	0	17	1.8153
145	16	17.945	0	55	3.0649
150	8	8.653	0	14	1.6179
157	8	11.150	0	23	2.0628
161	17	33.274	1	36	1.1120
165	16	18.133	0	15	0.8272
174	14	17.155	0	26	1.5156
176	29	35.200	0	55	1.5625
190	32	37.884	0	157	4.1442
192	16	21.791	0	9	0.4130
193	20	28.087	0	65	2.3142
205	20	30.356	0	352	11.5957
207.5	15	21.761	0	128	5.8821
213	16	17.376	0	56	3.2228
225	39	55.809	0	268	4.8021
244.5	20	29.343	0	311	10.5988
262	6	6.722	0	1	0.1488
266.5	2	2.169	0	0	0.0000
269	2	2.420	0	0	0.0000

FIGURES

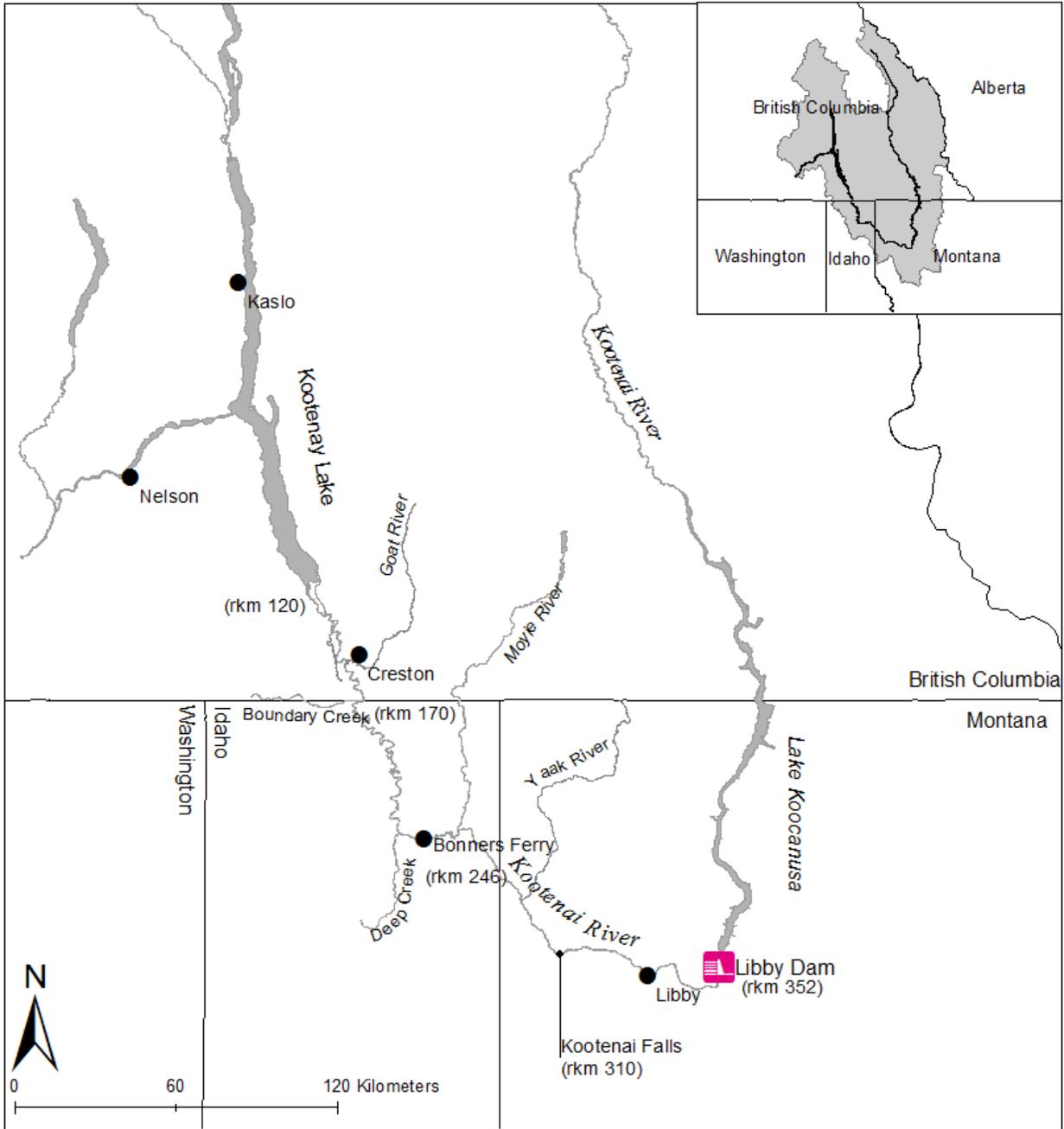


Figure 1.1. Location of the Kootenai River, Kootenay Lake, Lake Kooconusa, and major tributaries. River distances are from the northernmost reach of Kootenay Lake and are in river kilometer (rkm).

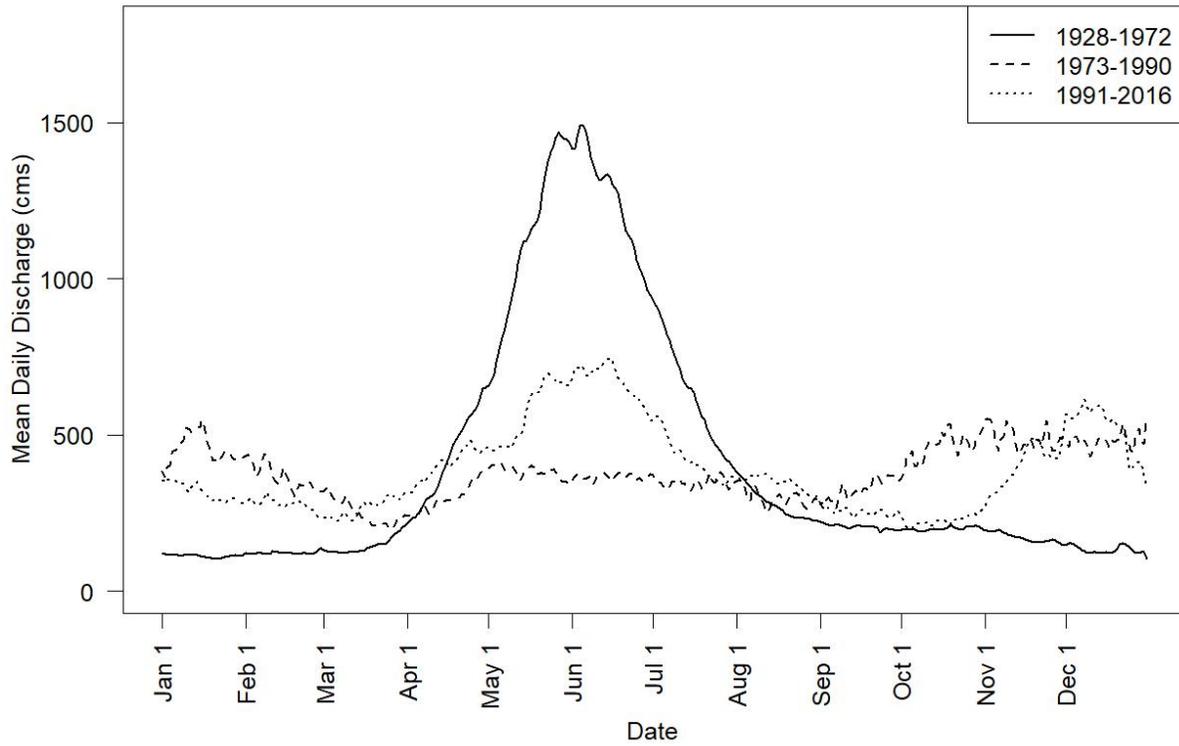


Figure 1.2. Mean daily flow patterns in the Kootenai River at Bonners Ferry, Idaho from 1928-1972 (pre-Libby Dam), 1973-1990 (post-Libby Dam) and 1991 – 2015 (post-Libby Dam with augmented springtime flows). Data was obtained via a USGS gauge located in Bonners Ferry, Idaho.

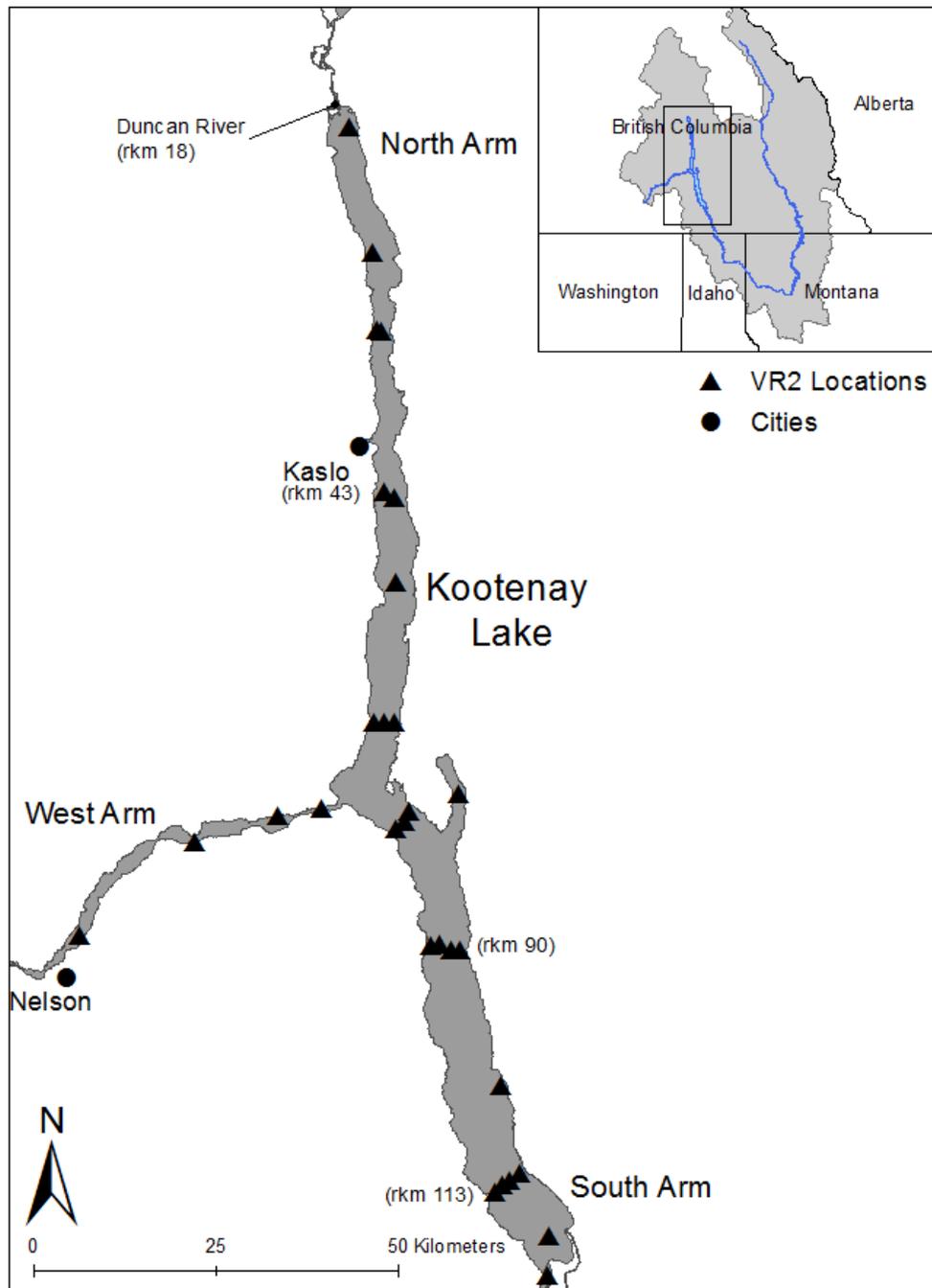


Figure 1.3. Location of Vemco VR2 receivers in Kootenay Lake, BC. These passive acoustic receivers detect movements and behaviors from Kootenai Sturgeon that have transmitters implanted in them (n = 129). A total of 89 receivers make up the entire Lake/River array.

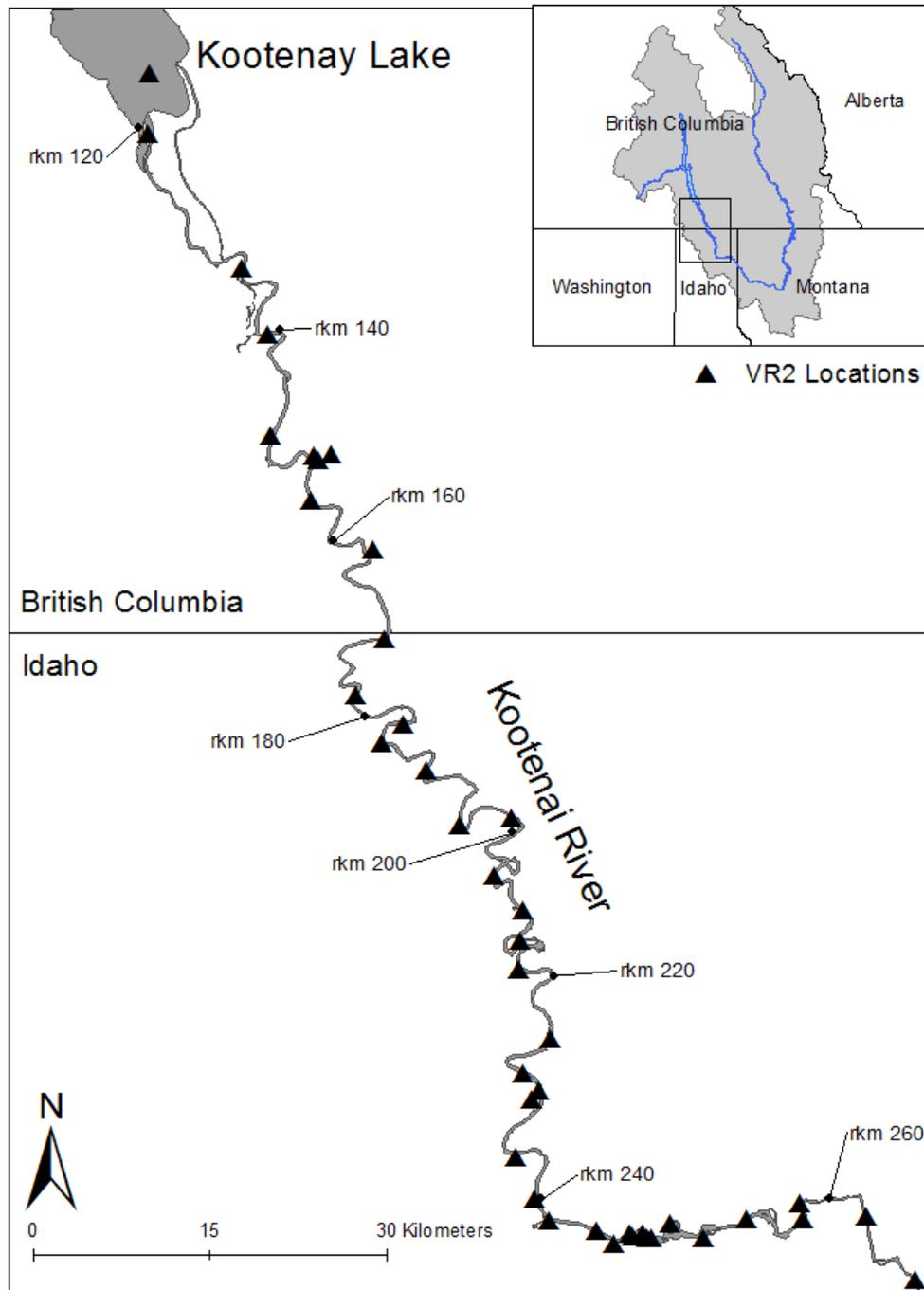


Figure 1.4. Location of Vemco VR2 receivers in Kootenai River. These passive acoustic receivers detect movements and behaviors from Kootenai Sturgeon that have transmitters implanted in them ($n = 129$). A total of 89 receivers make up the entire Lake/River array.



Figure 1.5. Location of Spawning Enhancement Pilot Projects (SEPP), Kootenai River, Idaho, 2014. Top figure is Myrtle Bend project near rkm 234.0. Bottom figure is Shorty's Island project near rkm 231.0.

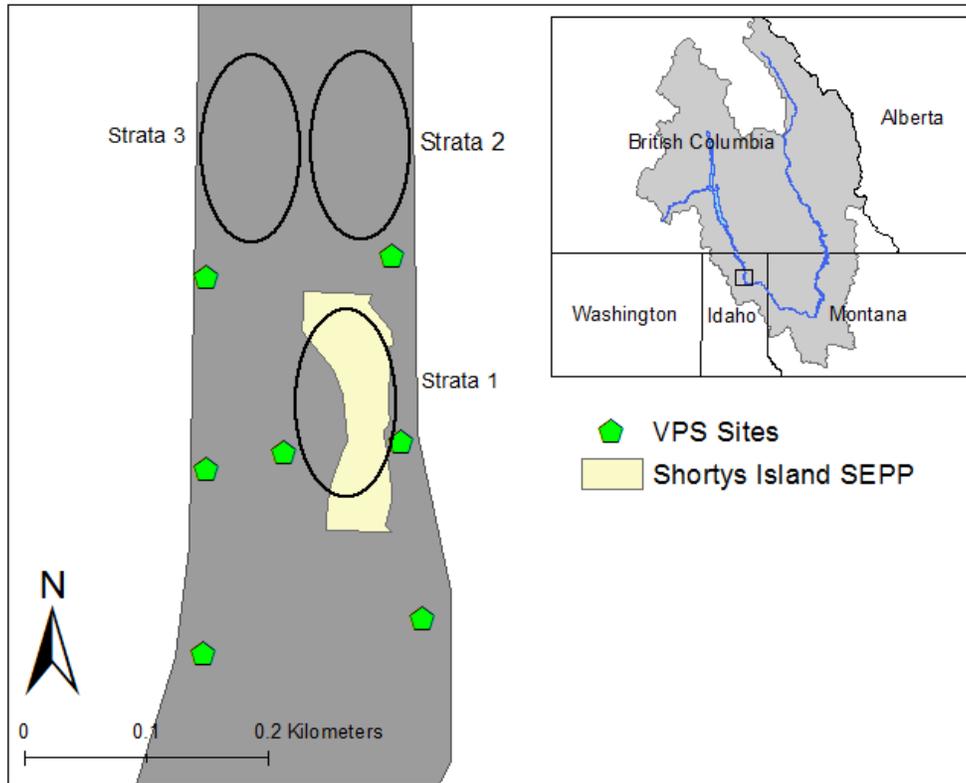


Figure 1.6. Substrate mat sampling design with reference to Spawning Enhancement Pilot Project (SEPP) area at Shorty's Island (rkm 231), Kootenai River, Idaho. The ovals (strata) depict the different areas artificial substrate (egg mat) sampling took place. Strata 1 and 2 were both areas with similar substrates and documented spawning prior to SEPP construction. The substrate in Strata 3 was dissimilar to that of 1 and 2. Green dots on periphery denote location and arrangement of Vemco VR2W for VPS study.

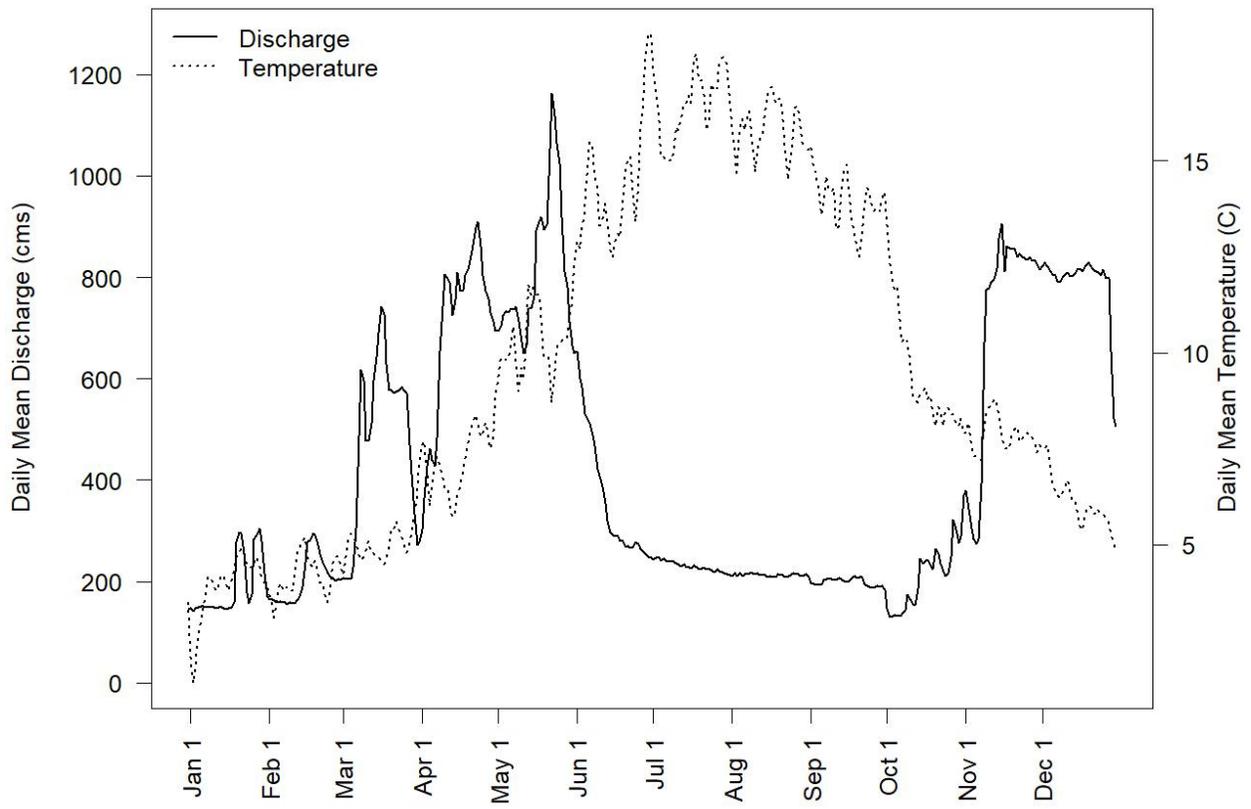


Figure 1.7. Mean daily discharge and temperature of the Kootenai River, Idaho for Jan. 1 – Dec. 31 2016. Data was retrieved from gage 12310100 which is operated by USGS.

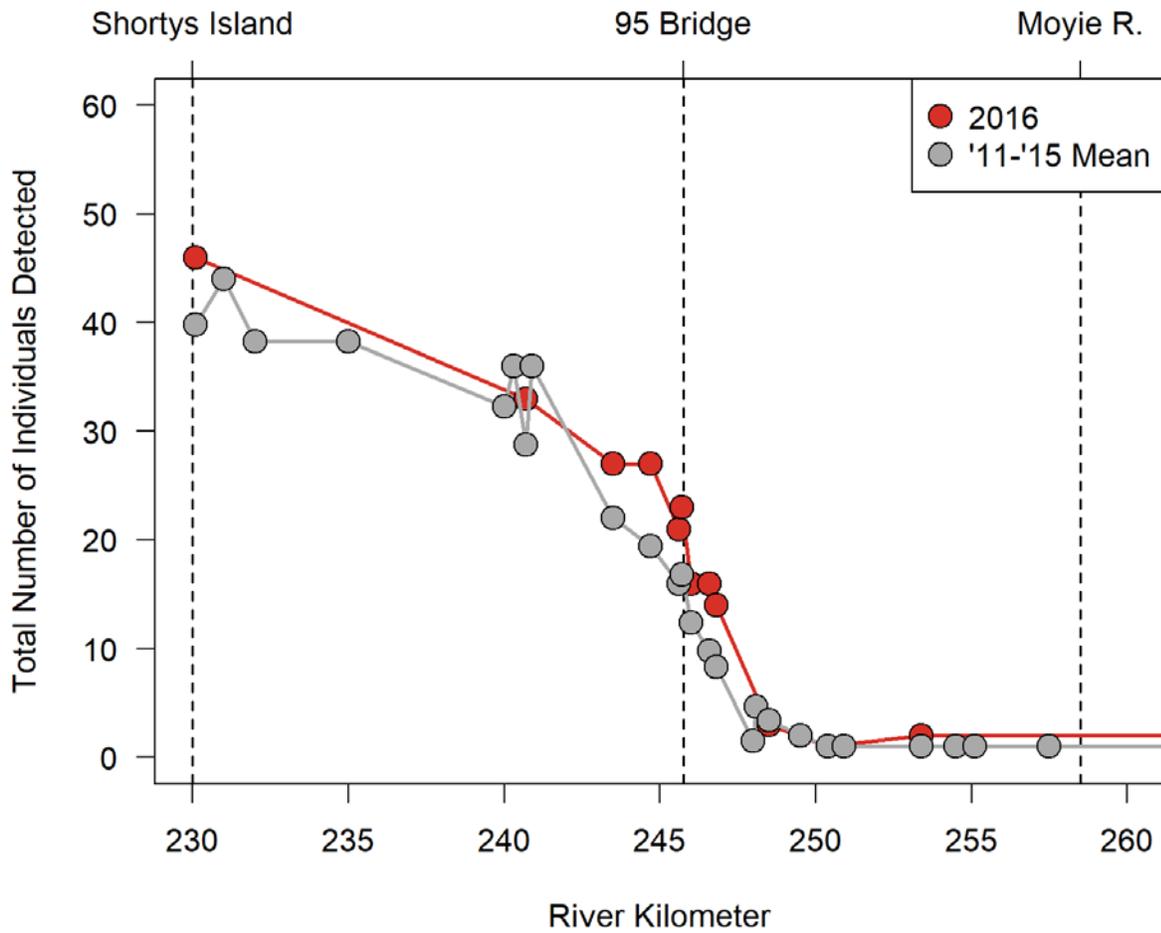


Figure 1.8. Total number of individually unique detections of adult Kootenai Sturgeon tagged with acoustic transmitters by river kilometer. Shorty's Island is the most downstream known spawning site, thus fish that make it to rkm 230 are considered part of the spawning population. This demonstrates how spawners (in terms of total numbers) utilize upstream habitats. The red line indicates the totals from 2016 and the grey line shows the mean number from the

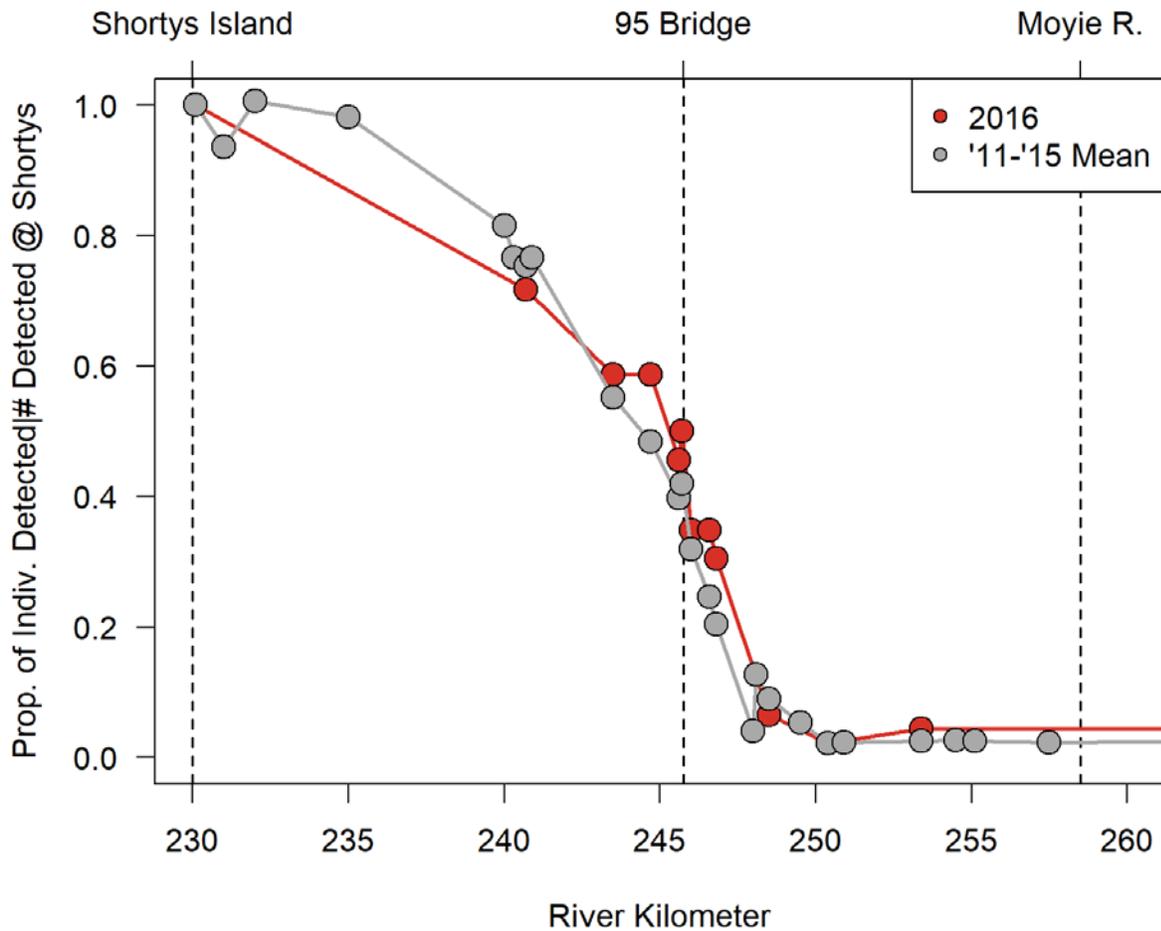


Figure 1.9. This plot shows the proportion of individuals that made it to a specific rkm given they had made it to Shorty's Island prior. Data was collected from adult Kootenai Sturgeon tagged with acoustic transmitters. Shorty's Island is the most downstream known spawning site, thus fish that make it to rkm 230 are considered part of the spawning population. For instance, about 50% of all the fish that made it to Shorty's Island in 2016 made it to rkm 246. This demonstrates how spawners (in terms of yearly proportions) utilize upstream habitats. The red line indicates the proportions from 2016 and the grey line shows the mean proportions from the previous five years.

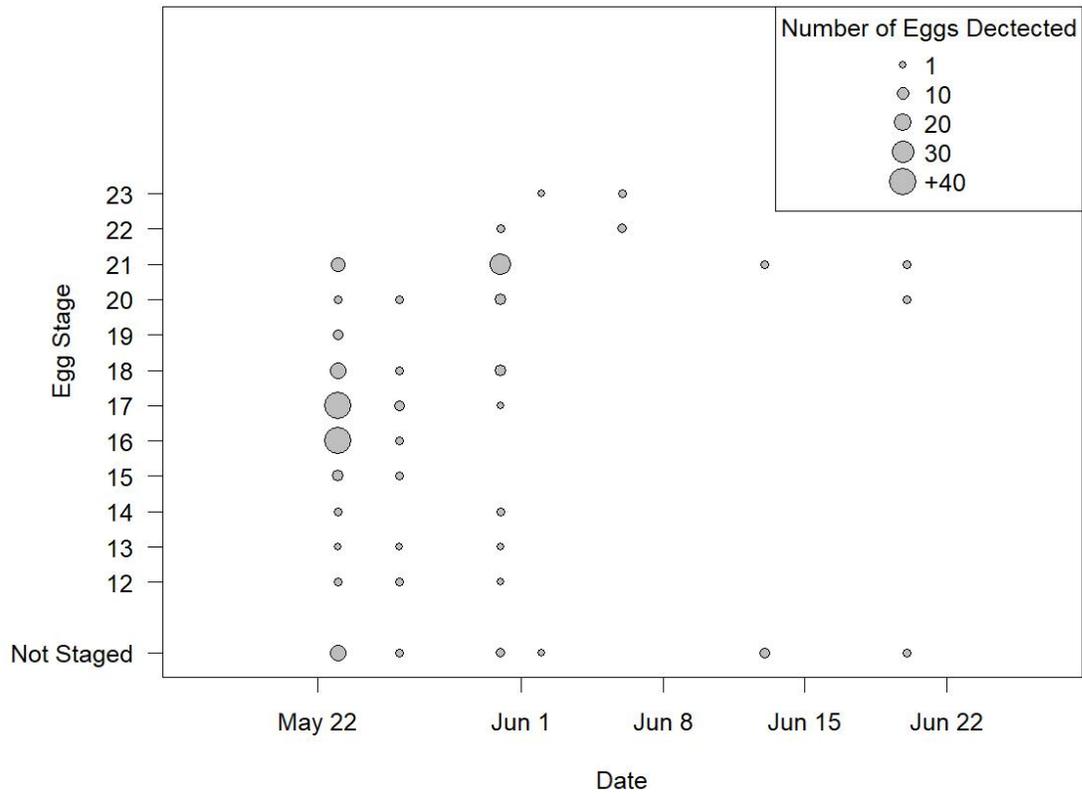


Figure 1.10. Egg collections from artificial substrate sampling in the spring of 2016 (May 16 to June 11). May 23 was the first date that eggs were detected. The y-axis shows the egg stage (Beer 1981) and the size of each dot indicates the number of total eggs that were detected on that day.

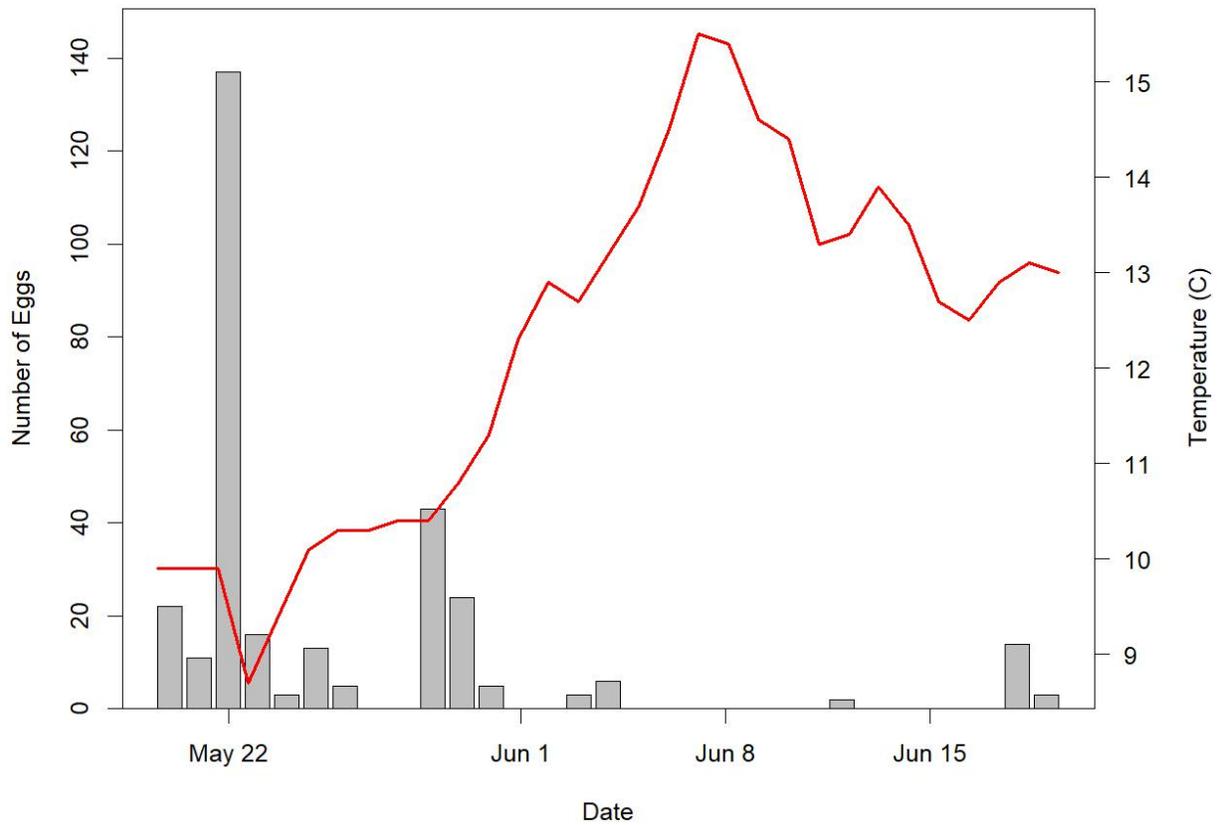


Figure 1.11. From the X eggs that were collected during the egg mat sampling in 2016 on the Kootenai River, Idaho, Y were staged (Beer 1981) to determine the approximate date of fertilization. This histogram shows the estimated fertilization date from the collected eggs we were able to sample and stage. The red line shows the daily mean temperature in Bonners Ferry, Idaho for reference.

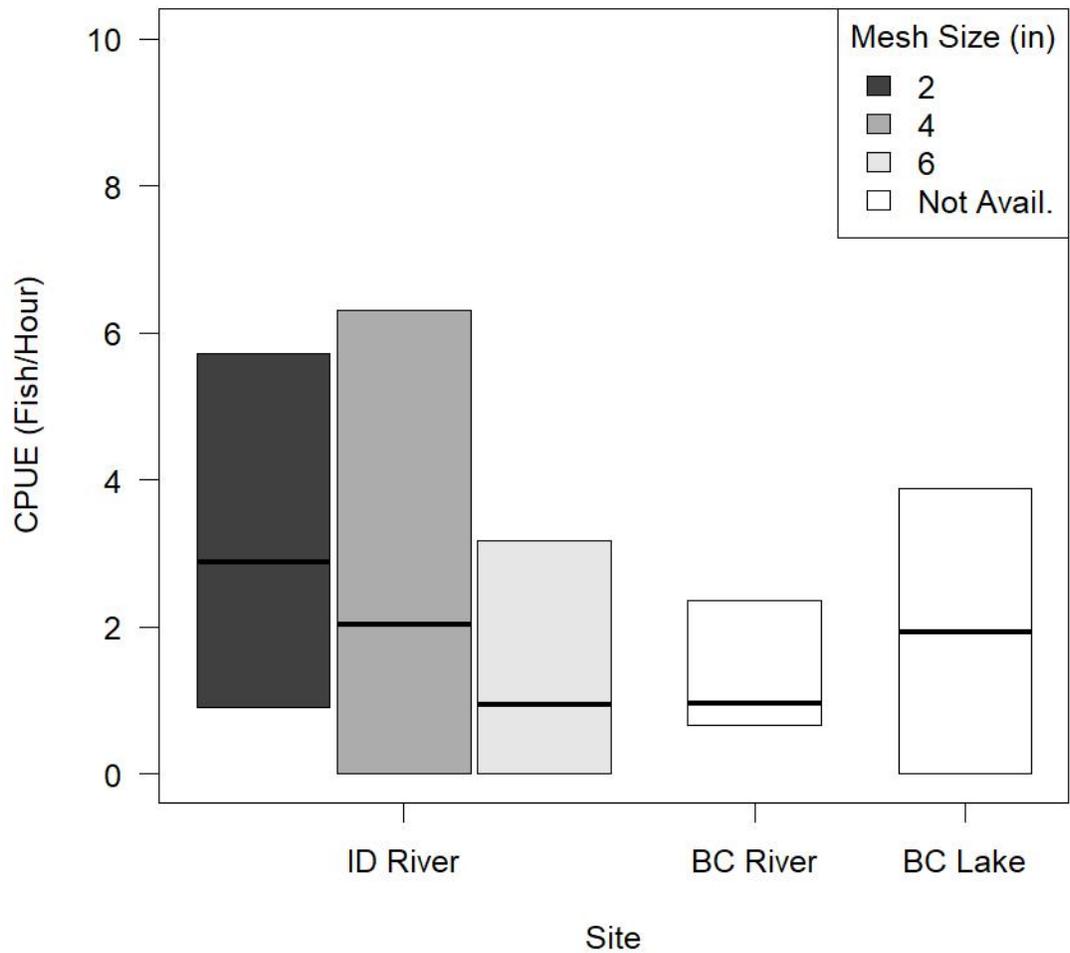


Figure 1.12. Box plots that show the relationship between CPUE (fish/hour) and gill net mesh size in different parts of Kootenay Lake and Kootenai River for the 2016 juvenile sampling season.

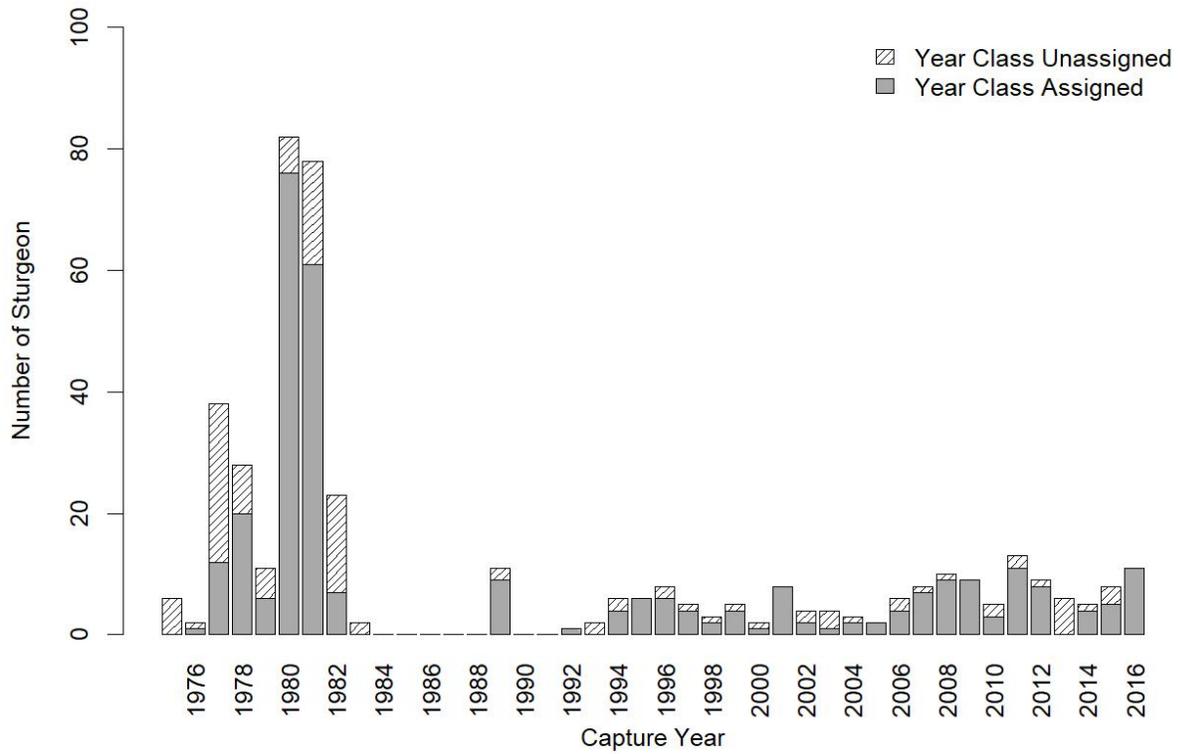


Figure 1.13. Number of first encounters (no recaptures) of wild juvenile Kootenai Sturgeon captured annually in the Kootenai River, Idaho 1977-2016. Age class was determined by sectioned pectoral fins; however, not all fish were assigned a year class in every year.

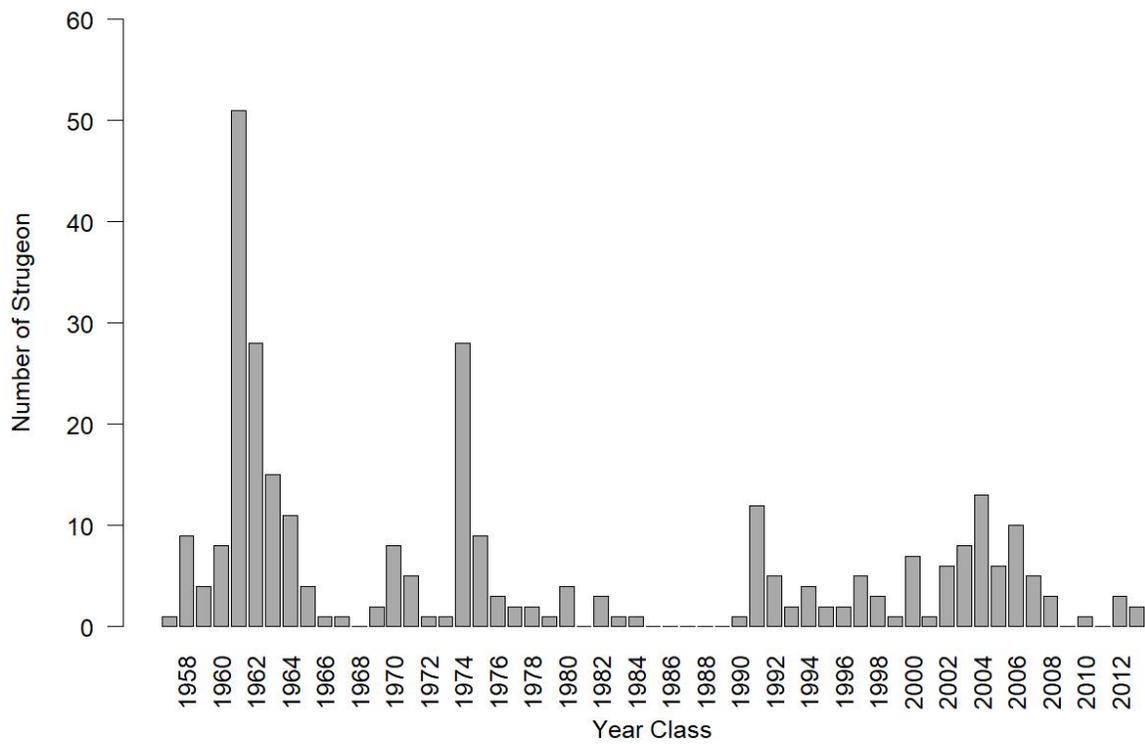


Figure 1.14. Number of wild juvenile Kootenai Sturgeon by age class captured in the Kootenai River, Idaho 1977-2016. Age class was determined by sectioned pectoral fins.

CHAPTER 2: BURBOT MONITORING AND EVALUATION

ABSTRACT

Burbot (*Lota lota maculosa*) were once abundant in the Kootenai/ay River basin in Idaho, Montana, and British Columbia where they provided important commercial, recreational, and cultural fisheries throughout the basin. However, cumulative effects of purported over-exploitation and the completion of Libby Dam in Montana in 1972 resulted in the entire fishery collapsing and being closed to harvest by 1992. Until recent years, the population was considered functionally extinct. Conservation aquaculture efforts by the University of Idaho Aquaculture Research Institute and the Kootenai Tribe of Idaho, in conjunction with largescale mitigation efforts and long-term monitoring and evaluation, have revealed key insights into the current status of the species in the Kootenai River basin. Results through the spring of 2017 indicate that Burbot numbers are consistently increasing, and the fishery is currently comprised of multiple year classes produced from hatchery efforts, indicative of a healthy and growing population. Apparent survival estimates derived from Cormack-Jolly-Seber models in Program MARK indicate that Burbot are surviving in the river after being released from the hatchery, and there is differential survival based on age-at-release as well as location of release. Burbot are pioneering into tributary habitats during the spawning season, which could potentially provide a mechanism for natural recruitment if the temperature regime in the mainstem river is responsible for the recruitment bottleneck, as purported. Lastly, virtual population analyses indicate that by 2019 the adult population could reach recovery targets identified in the conservation strategy. Although recruitment failure persists at this time, all other indicators suggest that the population is increasing due to the release of hatchery-reared Burbot and restoration targets could be met in the near future. As such, managers have begun discussing and empirically modeling options for a harvest fishery.

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INTRODUCTION

Although Burbot *Lota lota maculosa* are widespread and abundant throughout much of their natural range (Evenson and Hansen 1991), many populations are in severe decline (Arndt and Hutchinson 2000; Paragamian et al. 2000). As a result, restoration efforts have been initiated to mitigate factors that threaten populations with further decline or localized extirpation (Dillen et al. 2008; Worthington et al. 2009; Stapanian et al. 2010). A primary source of decline has been attributed to significant changes in habitat often stemming from the construction of dams used in flood control or power generation; this is the case in the Kootenai River basin in Idaho, Montana, and British Columbia. Libby Dam, constructed in the early 1970s, has significantly increased discharge and water temperature during the winter spawning period for Burbot (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 construction of the dam and subsequent impacts to the Burbot population, the fishery rapidly declined in the mid-1980s and ultimately culminated in a complete closure of the fishery in 1992. Concomitant to the collapse in the Idaho portion of the Kootenai River, a rapid decline of the Burbot fishery in Kootenay Lake and Kootenay River, British Columbia (BC) was observed, resulting in those fisheries being closed in 1997 (Paragamian et al. 2000).

Due to the widespread cultural and recreational importance of Burbot in the Kootenai River Basin prior to the collapse of the population, an International Burbot Conservation Strategy (Strategy) was developed by a community-wide working group to help restore the population (Paragamian et al. 2002; KVRl 2005; Ireland and Perry 2008). The Strategy outlined rehabilitation measures, including changes to operations of Libby Dam and development of conservation aquaculture to supplement the wild stock during population rehabilitation. Because the Burbot population was speculated to be too small to recover on its own or provide gametes for a conservation aquaculture program, managers deemed it necessary to locate and use a donor stock to aid in restoration efforts. Of the many water bodies sampled, Burbot from Moyie Lake, BC (Figure 2.1) were selected as a suitable donor stock because they were found to be of a similar phylogenetic group as the Kootenai River population (Powell et al. 2008), abundant enough to provide sufficient gametes, and had spawning sites that provided easy access to spawners. Concurrent with studies to locate a broodstock source, intensive rearing techniques were successfully developed at the University of Idaho Aquaculture Research Institute (UIARI; Jensen et al. 2008). 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, Natural Resource Operations, and Rural Development (FLNRORD) have stocked larval, juvenile, and adult Burbot into the Kootenai River Basin 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 a riverine environment. 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 age-1 (juvenile) Burbot from release tributaries was slow (or non-existent) and was substantially less than that of older Burbot (Stephenson et al. 2013). These studies provided crucial insight on Burbot early life history and adaptation. In addition, recent studies have provided valuable insights on the long-term adaptation of lake-

origin Burbot progeny released into a riverine environment. Using a Passive Integrated Transponder (PIT) array and mark recapture evaluations through hoopnet sampling, research reported herein investigated survival, growth, spawn timing, and broad-scale dispersal of lake-origin Burbot released into the Kootenai River basin and compared these metrics to those of the historical, native population. Such information is particularly important for guiding current and future restoration programs in the Kootenai River Basin and across the northwestern United States.

GOAL

The long-term management goal of this study was to restore a naturally reproducing and harvestable Burbot population in the Kootenai Basin.

OBJECTIVES

1. Characterize the status of the Burbot population in the Kootenai River, Idaho.
2. Characterize spatiotemporal occurrence(s) of spawning in the Kootenai River, Idaho.
3. Provide broodstock from the Kootenai River for the Kootenai Tribe of Idaho hatchery at Twin Rivers, Idaho.
4. Evaluate use of the braided and meander reaches of the Kootenai River by Burbot during winter 2016/17.
5. Evaluate the success of various aquaculture stocking strategies, from 2009-2017.
6. Identify and experimentally evaluate potential factors limiting recruitment of Burbot in the Kootenai River, Idaho.
7. Evaluate broad-scale use of Deep Creek by Burbot in the winter months.
8. Estimate efficiency of larval light traps.
9. Estimate age-specific survival of Burbot, and conduct a virtual population estimate as of winter 2016/17.

STUDY AREA

The Kootenai River is the second largest tributary to the Columbia River, and its drainage is the third largest (approximately 49,987 km²; 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 Montana and forms Lake Kooconusa (Figure 2.1). 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. Kootenay Lake has a surface area of 390 km² and is a fjord-like lake, running north-south in the trench formed between the Selkirk and Purcell

mountains. Approximately 105 river kilometers (rkms) flow through the Idaho section of the Kootenai River Basin.

During the study period reported herein, hoopnet sampling for Burbot occurred at 28 sites between rkm 144.5 (Nick's Island, near Creston, BC) and rkm 276 (Leonia, at the Idaho and Montana border) (Figure 2.2). Larval sampling occurred from rkm 170 (Porthill, near the Idaho and BC border) to Ambush Rock. A PIT tag array was installed in Deep Creek in October 2012, approximately seven km upstream from its confluence with the Kootenai River (Figure 2.2), and it has been operated continuously since installation.

METHODS

Burbot Hoopnet Sampling

Burbot Stocking

Following the success of intensive culture at the UIARI and the new KTOI Burbot and Sturgeon hatchery, approximately 9,200,000 Burbot (ranging in age from larvae to age-2) were released into the Kootenai River and its tributaries from 2009-2017 (Tables 2.1 and 2.2). During this same time, approximately 60,000 juveniles (age-0 to -2) were tagged with PIT tags (FDX [2009-2013] and HDX [2014-2017]; BioMark Inc. 9 mm and Oregon RFID 12 mm, respectively) and released into tributaries to and the mainstem of the Kootenai River by KTOI, MFLNRORD and IDFG personnel (Table 2.1). In addition, approximately 315,000 planktivorous-feeding larvae (40-days post-hatch [DPH]) were released at each of Ambush Rock and Porthill in spring 2015 to (1) evaluate whether or not larval-released Burbot would survive and recruit to the adult population and (2) estimate survival of larval-released Burbot. Lastly, winter 2016/17 was the first attempt at providing broodstock from the Kootenai River to the Kootenai Tribe of Idaho hatchery at Twin Rivers.

Mainstem Hoopnet Sampling

Adult Burbot were sampled at 28 locations using 56 baited hoopnets during winter 2016/17 (eight Canadian and 20 U.S. sites; Figure 2.2) in order to measure relative changes in the population through catch-per-unit-of-effort (CPUE; number of Burbot/net-day) and other population metrics. Six historical index sites (since 1994) along with an additional 22 sites were sampled from December 1, 2016 to March 31, 2017 to collect information on CPUE, growth, year class survival, and spawning activity within the Kootenai River. From 1996-2009, each river site was sampled using hoopnets (2.00 m x 0.61 m) with 25.4 and 19.1 mm bar-mesh sizes. Beginning in 2010, two hoopnets of 19.1 and 6.4 mm bar-mesh sizes were paired at each site to evaluate gear selectivity; this has been the standard protocol since 2010. All nets were baited with frozen kokanee *Oncorhynchus nerka* and checked 2-3 times per week. All captured Burbot were counted, measured for TL (mm), weighed (g), and examined for previous tags. All untagged Burbot were injected with a unique HDX PIT-tag into the right anterior dorsal muscle for future analyses, including population estimates, growth, survival by year class, and others. Tissue samples for genetic analysis were collected from the anterior portion of the dorsal fin of all tagged and untagged Burbot to determine origin (i.e., hatchery or wild), year-class, release location, age-at-release, and sex using Parental Based Tagging (PBT) analysis (methods described by Anderson and Garza 2005; Steele and Campbell 2011). In addition, all Burbot captured from January 2 - January 31 were transported to the Kootenai Tribe of Idaho hatchery at Twin Rivers where they were used as broodstock for different lab studies.

Burbot Survival, Movement, and Habitat Use in Deep Creek, Idaho

On October 11, 2012, a dual-reader (i.e., FDX and HDX) Biolite BioMark Passover PIT antenna was installed in Deep Creek, Idaho, approximately seven rkms from the confluence with the Kootenai River (Figure 2.2). Details regarding operations of the array, Burbot PIT tagging protocol, and Burbot release numbers and locations (from 2012-2015) can be found in Ross et al. (2015). To date, very few of the Burbot stocked into Deep Creek have been (1) captured in mainstem or Deep Creek hoopnetting or (2) detected crossing the Biomark dual reader PIT array in Deep Creek; the fate of these fish remains unknown. Therefore, the Idaho Department of Fish and Game began funding a graduate project with the Idaho Cooperative Fish and Wildlife Research at the University of Idaho in summer 2014. The primary objective of the project was to evaluate survival, movement, distribution, and habitat use of Burbot that were stocked into Deep Creek, Idaho. The study was completed in 2016 and details of the study can be found in Beard et al. (2017a) and Beard et al. (2017b).

Briefly, methodology for the project included: measuring habitat across transects in Deep Creek, measuring habitat at known Burbot locations, systematic electrofishing surveys, systematic mobile PIT tag reader surveys, installation and maintenance of five stationary, pass-over HDX PIT tag arrays distributed throughout Deep Creek, and Program MARK survival analyses.

Potential Effects of Water Temperature on the Egg Hatching Success, Larval Development, and Larval Survival of Burbot

The Idaho Department of Fish and Game began funding a PhD dissertation with the UIARI in fall 2015. The project is ongoing and scheduled to be completed in 2018. The primary research objectives were threefold: (1) to assess historic and contemporary regimes of the lower Kootenai River in relation to Libby Dam operations and climate; (2) to conduct experiments that tested the effects of different temperatures on Burbot spawning, embryo development and larvae energetics; and (3) to identify models of river flow management and climate that supported early life stages of Burbot. The overarching goal was to provide resource managers with information that determines if post-dam river regimes enable or prohibit natural recruitment. Results from the study will be available on or before 2018 in the form of multiple peer-reviewed manuscripts and a dissertation.

Briefly, methodology for the project included: (1) identifying “typical” thermal regimes and temperature spikes for the lower Kootenai River from 1994-2016 and historic pre-dam temperature regimes from 1967-1972, (2) exposing adult Burbot to different temperature regimes before spawning and evaluating potential effects on spawn timing and early embryo development, and (3) evaluating the effect of exposing Burbot eggs to varying temperature regimes as gauged by egg hatching success, embryo deformity, and larval survival.

Efficiency Estimate of Larval Light Traps

Following an unsuccessful year of larval light trapping in spring 2016 (Rust et al. 2017) a collaborative effort was made to estimate the efficacy and efficiency of light traps for capturing larval Burbot in Spring 2017. Four sites in the mainstem Kootenai River were sampled for a known number (7,329,180) of non-feeding, larval Burbot released at Ambush Rock (rkm 244.5) on April 11, 2017. Site selection was informed by results of larval drift models generated by project collaborators with the USGS (Rich McDonald, USGS, unpublished data). Chosen sites were in areas of the river where the model predicted the highest densities of larval drift particles

based largely on river hydraulics. The light traps used were constructed by Aquatic Research Instruments. The light traps were clear, quatrefoil traps measuring 30 cm diameter x 25 cm height arranged with a cloverleaf shaped array of vertical cylinders containing 1.5 mm wide vertical slits for larval entry into the traps. The traps were constructed of clear polycarbonate material and contained a fixed width collection basin with a 400 micron sieve to drain water. The top of the trap was fit with a flotation block of foam, and the central light tube was 28 mm diameter x 25 cm height with a rubber cap. Illumination of the traps was achieved via 48-hour military-grade chemical light sticks. Two light traps were set at each of the following locations: Ambush Rock (rkm 244.5), Ball Creek (rkm 227.5), Rock Creek (rkm 215), and Ferry Island (rkm 204). Light traps were set for the first time on April 11, 2017 and pulled out of the river on May 12, 2017. The traps were set every Monday, checked every 24 hours through Friday, and then removed from the river over all weekends. Contents in each trap were placed into vials while in the field and processed later in a lab. Processing of samples included visual identification and enumeration of all larval Burbot (if observed) and enumeration (only) of all bycatch.

Burbot Survival Analysis

The goal of the survival analysis was to provide baseline, age-specific annual survival estimates and explore the effects of release location and other individual physical attributes for hatchery-released Burbot in the Kootenai River. Data for all Burbot that were released and captured between 2009 and 2016 were used for the analysis. All data were collected as part of the IDFG annual hoopnetting surveys that run from December 1-March 31 each year. Hoopnetting data indicated that Burbot did not fully recruit to the gear until age-3; therefore, all releases and recoveries of age-0 fish after 2012 were excluded from the analysis because they had not yet fully recruited to the gear at the time of analysis. This was done by fixing annual apparent survival (ϕ) and annual apparent capture probability (p) to zero for these sampling occasions. Ultimately, single estimates of annual survival (2011-12) and annual capture probability (2012) were generated for age-0 fish because there were no age-0 releases in 2009 or 2010. Estimates for older fish applied to earlier years beginning in 2009 (age-2 and age-3 fish), 2010 (age-1 fish), 2010 (age-4 fish), and 2011 (age-5+ fish). In summary, release and recapture data for 809,612 Burbot in the Kootenai River system between 2009 and 2016 were used for analysis. Most of these releases (>774,000) did not contribute to the parameter estimates because of gear recruitment considerations; they are only included in case any are recovered in future years.

The Cormack-Jolly-Seber (CJS) model with live recaptures (Cormack 1964, Jolly 1965, Seber 1965) in Program MARK was used to estimate ϕ and p . Annual apparent survival was modeled as a constant across years, but separate for each release site (age-0 fish only) and age-class. The model set included a 4-age-class (age-4+) model and a 5-age-class (age-5+) model. Capture probability was modeled as a function of age-class only, and allowed the model to choose between a full age-array (i.e., five age classes) as well as reduced models with three or four age classes. Year effects were not included in either apparent survival or apparent capture probability estimates because of limited sample sizes and the extremely low recapture probabilities for younger fish. The individual covariates included two measures of fish size (length and weight) plus three categorical measures of release sites: age-0 good and bad sites [A0GB], river/lake [Main_Lk], and one where Deep Creek was separate from all other sites [Main_DP]).

Model fit was examined by looking at the pooled results of Tests 2 and 3 in Program Release in MARK. This goodness-of-fit test was run on the global time-varying model without

any covariates, and as such, did not closely mimic how data for this analysis were used. This test was also used to check the data for over-dispersion and estimate a variance inflation factor using the median \hat{c} procedure in MARK.

A hierarchical modeling approach was taken for this analysis. Apparent survival always included an age-effect, but this was allowed to vary for older fish by considering models with (1) three age classes where age-3+ survival was constant, (2) four age classes where age-4+ survival was constant, and (3) five age classes where age-5+ survival was constant. For all fish, a model was also considered where there was an age-specific release effect on apparent survival (PrevMark). This effect was estimated separately for each age class under the hypothesis that newly-released fish of a particular age-class would have lower survival than a fish that grew into that age class from being released at an earlier age. Next, two models were considered for capture probability: (1) a model with three age classes where age-3+ survival was constant, and (2) a model with four age classes where age-4+ survival was constant. After finding a best model for baseline apparent survival and capture probability the five individual covariates were singly added to arrive at a best model for inference.

The Markov Chain Monte Carlo (MCMC) estimator in Program MARK was used to get parameter estimates and associated 95% credible intervals for inference and to check performance of the MARK model runs. Akaike's Information Criterion adjusted for small samples (AIC_c) was used to select among competing models (Akaike 1973, Burnham and Anderson 2002). Models were ranked by ΔAIC_c values, and competitive models were defined as those with $\Delta AIC_c \leq 2$. Normalized Akaike weights (w_i) and ratios of Akaike weights ($w_i w_j^{-1}$) were used to determine the relative support for a given model. Estimates of apparent survival and capture probability ($\pm SE$) were reported from the best model because there was so little model-selection uncertainty.

Virtual Population Analysis

The virtual population analysis (VPA) is a widely used method for assessing the status and population trends of long-lived stocks of fish, and it assumes the population is as it would be if it did not experience natural mortality (Fry 1949). Since Burbot in the Kootenai River are currently not susceptible to fishing mortality, the VPA was quite simple. Parameters in the analysis included release numbers for each year since 2009 and annual apparent survival rates for each age-class. From these data, a back-calculation procedure was used to estimate the virtual population as of 2016. The procedure involved tracing a release cohort through time, ensuring to multiply its initial starting population size at each age-cohort by that cohort's annual apparent survival rate. The terminal virtual population was the sum of all age-cohort population estimates (i.e., age-0 through age-5+) by 2016. More than 8,000,000 larval Burbot have been released into the Kootenai River since 2009 (Table 2.1); however, larval annual apparent survival has not yet been estimated. Therefore, six different values were considered for larval survival in the VPA; these values were: 0.02, 0.01, 0.005, 0.002, 0.001, and 0.0001.

RESULTS

Burbot Hoopnet Sampling

Eighteen river sites downstream from Bonners Ferry were sampled from December 1, 2016 to March 31, 2017, totaling 2,295 net-days and 439 captured Burbot. However, sampling was interrupted from January 31, 2017 to February 12, 2017 due to ice conditions on the river,

resulting in large amounts of lost or unusable data. Catch-per-unit-of-effort across all sites (i.e., index and non-index) in the 2016/17 season (0.19 Burbot/net-d; Figure 2.3a) dropped approximately 42% from the record high observed in the 2014/15 season (0.33 Burbot/net-d). Similarly, CPUE at only the index sites during the 2016/17 season (0.131 Burbot/net-d; Figure 2.3b) dropped approximately 55% from that observed in the record high 2014/15 season (0.292 Burbot/net-d). Catch-per-unit-of-effort at the index sites has been consistently monitored from 1996-2016, and, therefore, is the most reliable metric for long-term trend interpretation. Given the extreme weather conditions and other abnormal factors, CPUE data from the 2016/17 season should be interpreted with caution. An additional ten sites upstream from Bonners Ferry were sampled from January 2, 2017-March 31, 2017, totaling 763 net-days, 33 captured Burbot, and a catch rate of 0.04 Burbot/net-d.

Since 2012, notable increases in catch rates from mid-February to mid-March have been observed primarily at Ambush Rock (rkm 244.5; Figure 2.4), Deep Creek Confluence (rkm 240), Myrtle Creek (rkm 234), and Porthill (rkm 170). Catch rates across all river sites in 2016 remained relatively constant (temporally) throughout the sampling period, with the exception of a substantial increase at only one U.S. site (i.e., Deep Creek; Figure 2.5) in late February. Catch rates at Ambush Rock and Porthill did not climb like they have in previous years (Figures 2.4 and 2.5). Peaks in CPUE (during spawning) since 2012 have coincided with a substantial amount of weight loss in Burbot recaptured within 14 days of initial handling, which was indirect evidence of spawning (attempts) in the river; the same trend was observed in 2016. Comparison of the 2013 and 2014 catch rate peaks at Ambush Rock (March 11, 2013 and March 4, 2014) with the historically greatest sampling season catch rate for wild Burbot (February 11, 2001) indicated that spawn timing peaked approximately 30 days later for the lake-origin progeny. However, for three consecutive years peak CPUE at known spawning locations has occurred between February 18 and February 25, which was only one to two weeks later than when it was recorded for wild Burbot in 2001.

The age-structure of the Burbot population has been shifting (i.e., increasing in age and size) since the aquaculture program began in 2011 (Figure 2.6). The shift has been documented via fish that were PIT tagged at release and fish that were assigned to a year class via PBT. Catch composition during the 2016 season represented the most diverse age-structure observed to date (Figure 2.6d) with a representation of eight year classes from 2009-2016. It appears that the once strong 2011 year class of Burbot has begun to taper off and be replaced by younger age-classes; the shift has been observed since the 2013/14 season (Figure 2.6). Specifically, there is a significant amount of demographic momentum via the 2015 year class of Burbot (Figure 2.6d). A total of 151 Burbot from 2015 year class were captured during the 2016/17 season, which is approximately 30% of the total catch for the season. Of these, approximately 35% assigned (via PBT) to releases at Ambush Rock and Boundary Creek confluence as planktivorous feeding larvae. Prior to capture of these fish, it was unknown whether or not planktivorous feeding larvae could survive in the Kootenai River. Interestingly, larval-released Burbot from the 2015 year class were, on average, 30% larger by length (i.e., $376.1 \pm 38.1\text{mm}$; Figure 2.7) and 62% larger by weight (i.e., $418.4 \pm 140.8\text{g}$; Figure 2.8) than Burbot from the 2015 year class that were released as juvenile fingerlings (i.e., $285.3 \pm 33.4\text{mm}$ and $157.4 \pm 53.0\text{g}$). These data suggest there may be some fitness advantage to being released as planktivorous feeding larvae compared to juvenile fingerlings.

Length-at-age at time of capture indicated that annual growth of Burbot ranged from 60-114 mm/ year (Figure 2.9). Growth rates appeared to be similar to those from wild Kootenai River Burbot captured and aged using otoliths in the early 1980s, and higher than rates

estimated in the late 1950s (Figure 2.9; Partridge 1983). It is expected that growth rates may change depending on how the larval-released Burbot grown and perform in the coming years.

Since the Burbot aquaculture program began, it has been clear that the primary direction of movement from stocking location has been upstream (Hardy et al. 2016). The trend has been evaluated using release information from PIT tags and PBT assignments. A similar trend was also observed during the 2016/17 season; however, there was also a notable amount of movement downstream (Figure 2.10). Most of the downstream movement was attributable to larval Burbot that were released at Ambush Rock and Boundary Creek confluence. It is likely that larval-released fish were carried downstream by the river current until they found refuge, which appears to have been somewhere around rkm 150.2 (Figure 2.10).

Burbot Survival, Movement, and Habitat Use in Deep Creek, Idaho

Between October 1, 2016 and March 31, 2017, 87 unique Burbot were detected crossing the Deep Creek PIT tag array (Tables 2.3 and 2.4; Figure 2.11). Thirty of the detections (35%) were Burbot that were originally released into Deep Creek as juveniles, and the remaining 55 detections (65%) were from individuals that were released at locations in the mainstem Kootenai River from as far downstream as Porthill (Table 2.3). Interestingly, Burbot from all release locations except the Moyie River confluence were detected crossing the PIT tag array in Deep Creek, with the two most dominant release locations being individuals from Porthill and Deep Creek proper (Table 2.3). Individuals from nearly all year classes (i.e., 2011-2016) were detected at the array, with the majority of detections from the 2011 and 2015 year classes (Table 2.4). Substantial use of Deep Creek by Burbot during the spawning season has been consistently documented since the winter of 2014/15. Since that time, the vast majority of detections occurred from late January through early March, which is roughly the spawning window for Burbot in the Kootenai basin.

The IDFG-funded Master's project was completed in 2016. Methodology, results, and management implications of the study can be found in Beard et al. (2017a), Beard et al. (2017b), and Beard et al. (*In Review*).

Potential Effects of Water Temperature on the Egg Hatching Success, Larval Development, and Larval Survival of Burbot

This study is currently underway and scheduled to be completed by 2018. When the study is completed, a PhD dissertation and multiple peer-reviewed manuscripts will be cited to reference the findings.

Efficiency Estimate of Larval Light Traps

No larval Burbot were captured during the sampling period; however, several other species of larval fish were captured, indicating that the light traps were effective at attracting and capturing larval fish.

Burbot Survival Analysis

The overall test result for model fit (sum of Tests 2 and 3 in Release) was $\chi^2 = 300.52$ (df = 38, $P < 0.001$). Most models' lack of fit (90% of chi-square test statistic) was due to age-0 releases at Porthill and age-2 releases; all other groups fit the model well. Estimates of median \hat{c} were < 1.0 using bootstrap simulations in Program MARK and in the end adjust \hat{c} was

not adjusted (retained at 1.0). Models run using the MCMC estimator generally converged nicely and all model diagnostics were favorable (e.g., chain jumps were mostly in the range of 35% to 55%).

We ran a series of models that included varying combinations of the age class and individual covariates on Burbot survival and capture probability (Table 2.5). At the end of the modeling process, we had a best model with 49% of the model weight and an AICc value of 225,756.89. This model contained 27 parameters, 21 for ϕ and six for p . The next two closest competing models (all remaining model weight; 51%) were very similar with one lacking a weight effect and the other replacing weight with a length effect (Table 2.5).

Modeling results indicated that p differed among age-classes (Figure 2.12). The top three models with all model weight included a 5-age-class effect on p . Capture probabilities for age-0 fish were very low (~ 0.01), but increased steadily through age-5+ to 0.55. The p estimates for age-3 and age-4 fish were less precise than those for other age classes. Models with a 3-age-class or a 4-age-class effect on capture probability had low support.

Modeling results showed strong support for age differences in apparent annual survival of Burbot (Figures 2.13, 2.14, and 2.15). All support was for a 5-age-class survival model; a 4-age-class survival model had no support. Estimates of baseline annual apparent survival (from a model with no covariates on annual survival; $\Delta AICc = 2.04$) indicated that survival was lowest for age-0 fish (8.7%), and then comparatively high and variable for ages 1-5+ (95%-83%, respectively; Figure 2.13). There was also strong support for an age-specific effect of previous marking on annual survival where fish that grew into an age-class in the wild had significantly greater survival than newly-released fish (Figures 2.13 and 2.14). For age classes 1 to 4, the increase in survival for previously released fish ranged from 0.40 to 0.72. Note that this effect could not be estimated for age-5+ fish because there were no releases in this age class (i.e., all were age-4+).

The effect of release locations was strong for age-0 Burbot with measurable differences in survival (Figure 2.15). The survival rate was highest at Porthill (13.3%) and Deep Creek (12.5%) and lowest at the Moyie River (1.8%); mean apparent survival across all release locations was 8.7%. At all release sites, age-0 survival never exceeded 14% in the absence of any covariate effects. The only individual covariates with any support were the effect of weight and total length on the annual survival of age-0 fish (Figures 2.16 and 2.17). The effects were not estimated well, so the predicted increase in survival as release total length and weight increased was small and imprecise. Models with covariate effects where age-0 fish were subdivided into good and bad sites [A0GB], river/lake sites [Main_Lk], and one where Deep Creek was separate from all other sites [Main_DP] had no support (all model weights were zero; Table 2).

Virtual Population Analysis

Results from the VPA indicated that, given known release numbers from 2009-2017 and current estimates of annual apparent survival, the Burbot population in the Kootenai River was somewhere in the range of 33,187 to 51,285 individuals ranging from age-0 to age-5+ (Figure 2.18). The majority of the population was comprised of age-0 and age-1 fish, and there were very few age-2 and age-3 fish. The observed differences in year class strength were exclusively the result of variable production from the hatcheries at KTOI and the University of Idaho. Paragamian and Hansen (2009) suggested that the Kootenai River Burbot population could be considered recovered when it reached an adult population of 17,500 individuals age-4+.

Although age-4+ numbers of Burbot were well below the identified target as of winter 2016/17, there was significant demographic momentum in age-0 and age-1 individuals. It is likely the target of 17,500 age-4+ adult Burbot will be reached in the coming years.

DISCUSSION

Although the Burbot population in the Kootenai River was considered functionally extinct by the early 2000s, the population trend has largely reversed, and current understanding of factors potentially limiting natural recruitment has substantially grown. Even though catch rates in winter 2016/17 were the lowest recorded since 2013/14, average catch rates over the last six years (i.e., 2011-2016; 0.17 fish/net-d) represent a 1600% increase over the average from 2005-2009 (0.01 fish/net-d). It is important to note that, although catch rates of Burbot have substantially increased since initial stocking, the Kootenai River population remains low in abundance relative to other Burbot populations. For comparison, catch rates of Burbot in Moyie Lake, B.C. were 0.5 to 2.2 fish/net-d (Prince 2007), in the Chena and Tanana rivers of Alaska were 0.9 and 1.2 fish/net-d, respectively (Evenson 1993), and in four Alaskan Lakes ranged from 0.5-3.0 fish/net-d (Parker et al. 1988). Although natural recruitment has not yet been detected, multiple lines of evidence suggested that adult Burbot attempted to spawn in the Kootenai River and its tributaries. For example, increases in catch rates have been documented at Ambush Rock, Deep Creek, Myrtle Creek, and Porthill during mid-February, and adult Burbot continued to migrate into Deep Creek and other tributaries during mid-February. Recaptures of Burbot released as planktivorous feeding larvae (in 2015) significantly narrowed current understanding of the life stage at which recruitment failure may be occurring. Continued recaptures from this release group in later years will continue to answer important questions about recruitment limitation and larval survival. Lastly, Burbot are being stocked at levels and surviving at rates that will soon reach restoration targets for adults (i.e., 17,500 age-4+ adults). Reaching this target has initiated conversation, analysis, and planning around the potential for a harvest fishery for Burbot by January 2019.

The winter of 2016/17 marked the first since winter 2009/10 that hoopnet catch rates of Burbot dropped. The drop in catch was initially unexpected coming off of record high catch rates in winter 2015/16. There are several explanations for why this may have occurred. Winter 2016/17 marked the first sampling season during which broodstock were collected from the Kootenai River and transported to the KTOI hatchery at Twin Rivers. Approximately 120 Burbot ranging from age-1 to age-8 were captured, transported to, and spawned at the hatchery during January 2017. Burbot are communal spawners, forming spawning balls consisting of many males and females writhing in the water and releasing pheromones and gametes (Cahn 1936). Furthermore, Burbot in the Kootenai River (Paragamian and Wakkinen 2008) and other rivers (Sorokin 1971) have been documented making migrations to historical spawning locations (e.g., Ambush Rock) in recent years, and the majority of Burbot transported to the KTOI hatchery were captured at or near known spawning locations the month prior to peak spawn (i.e., January). Assuming captured Burbot were staging at known spawning locations, their removal from the river may have affected the formation or size of spawning aggregations at known spawning locations, which could have contributed to the decrease in catch. Winter 2016/17 was also colder than average, to the extent that the Kootenai River developed significant ice coverage from January 31-February 12, 2017. This time frame coincided with peak or near peak spawn in previous winters, and IDFG field crews were unable to access nets for the duration of ice coverage. When the ice came off, many nets were fouled (e.g., stuck or destroyed) or completely lost; therefore, it is likely that catch rates were affected by the ice event. Lastly, Burbot recruit to hoopnet sampling gear at age-3, which would have coincided with the 2014

year class recruiting to IDFG hoopnets in winter 2016/17. Unfortunately, production at the hatchery was low in 2014, with approximately 3,000 juvenile Burbot being released. Over 95% of those were released into Deep Creek (proper), which functionally equated to a missing year class that should have recruited to IDFG hoopnets in winter 2016/17. In summary, the decrease in catch rates was, perhaps, not surprising or alarming given the aforementioned explanations. All other indicators were positive with regard to the status of the population.

Along with increasing densities, the present study also indicated that Burbot stocked into the Kootenai River have located adequate food resources. Growth rates of Burbot from 2009-present 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 increments across all age groups averaged 96 mm/yr. As density increases, trends in growth rates could change and potentially affect other vital rate functions. Therefore, monitoring (of this rate function) is crucial for balancing release numbers with food and habitat availability.

Age-structure of Burbot captured in winter 2016/17 was the most diverse it has been since PBT went live in 2011, which is indicative of a healthy and robust population. This finding has important implications for both population recovery and fishery implementation. First, it is well established that diverse age structure is desirable and beneficial from a reproductive perspective. More specifically, studies have suggested that across many fish species, different age cohorts may spawn at different times and locations in a given system (Berkeley et al. 2004; Hixon et al. 2013), which may ensure that there is at least some reproductive success within a given year. Several studies are currently underway to evaluate whether or not this purported population resiliency process occurs in Burbot in the Kootenai River. From the perspective of a fishery potential, harvest of Burbot in the Kootenai River, Idaho has been closed since 1992. As such, it is unknown whether fishing mortality will be skewed toward younger (smaller) fish, older (larger) fish, or not skewed at all. The presence of diverse age and size structures in Burbot in the Kootenai River allows for better population resiliency to harvest, regardless of the age or size bias in angler catch.

Recaptures of larval-released Burbot revealed important insights that have a variety of implications for hatchery production and operations and future research, monitoring, and evaluation. Much of the research, monitoring, and evaluation focus in the Kootenai River has centered on identifying the cause of and life stage at which recruitment failure has been occurring. Prior to recapturing larval-released Burbot in winter 2016/17, it was well established that juvenile (i.e., six-month-old fingerling) Burbot released at different locations in the Kootenai River survived to sexual maturity. With the recapture of larval-released Burbot in winter 2016/17, the recruitment failure window was significantly narrowed to occurring sometime prior to feeding on zooplankton (i.e., egg incubation or early feeding). This finding has instigated collaborative research to further investigate specific early life stages in both lab and field settings. Additionally, the apparent fitness advantage (i.e., based on weight and total length) of larval-released compared to juvenile-released Burbot is striking and raises important considerations for hatchery operations and production. Significant resources (e.g., time, money, and effort) are expended to raise Burbot from eggs to six-month-old juveniles in the hatchery. It may be worthwhile for the KTOI hatchery to consider stocking planktivorous feeding larval Burbot in the future; the decision may not only save resources, but it appears it may also result in a more robust end product in the river. Lastly, 63% of the larval-released Burbot that were recaptured in

winter 2016/17 came from Deep Creek confluence (rkm 240.5; 28%) and just downstream from the Goat River confluence (rkm 150.2; 35%). Interestingly, individuals released at both Ambush Rock and Boundary Creek confluence were recaptured at both Deep Creek and Goat River confluences in relatively equal proportions, indicating extreme movement in both an upstream and downstream direction. It is unknown what drove the observed trend, but it is possible that Deep Creek and the Goat River provide viable prey sources for larval Burbot residing in the river. Additional effort should be placed on PBT-based larval evaluations in the Goat River and Deep Creek drainages, as these tributaries (and others) may provide spawning opportunities not affected by conditions in the mainstem Kootenai River.

Adult Burbot have passed over the IDFG PIT tag array in Deep Creek during the spawning season for three consecutive winters, which has important implications for recruitment bottleneck(s) and future research, monitoring, and evaluation. The majority of fish passing over the PIT tag array were adult fish stocked at mainstem Kootenai River locations, and a smaller proportion were Burbot stocked into Deep Creek (proper) from 2012-2015. Interestingly, fish passing over the PIT tag array were stocked as far downstream as the Goat River (rkm 152) and as far upstream as the Moyie River (rkm 259), and they represented nearly all year classes to date. Detections of adult Burbot in Deep Creek indicate that hatchery Burbot have the ability to pioneer into novel habitats and tributaries, presumably in search of suitable spawning habitats. Some Burbot populations use tributary habitats for spawning (Arndt and Hutchinson 2000), and it appears the Kootenai River population may do the same. Since the thermal, nutrient, and hydrologic regimes of the Kootenai River are heavily altered, spawning attempts (by Burbot) in tributaries may afford spawning conditions that are more conducive to successful recruitment relative to the mainstem Kootenai River. Furthermore, ice cover is a common denominator among thriving, naturally reproducing Burbot populations (McPhail and Paragamian 2000). Such ice cover was once common in the Kootenai River (i.e., prior to Libby Dam); however, ice rarely forms for extended periods of time since the completion of Libby Dam. Conversely, extensive ice cover forms every winter in most tributaries to the Kootenai River, including Deep Creek, Boundary Creek, Goat River, and others, which could potentially bolster the chances of natural recruitment. Additional research should be conducted to evaluate the extent of tributary use in the Kootenai River basin.

In general, Burbot are an under-studied fish species (McPhail and Paragamian 2000), so it stands to reason that very little information exists on survival in the wild. Estimates of annual apparent survival in the present study provide useful, baseline information for Burbot in the Kootenai River and other systems. The present study found that apparent survival of Burbot released as six-month old juveniles was lowest for age-0 fish (~9%) and then between 80-90% for age-1 through age-5+ individuals. There are currently no studies that report survival of Burbot from age-0 through age-5+ using mark-recapture analyses, which further underlines the importance of the estimates generated in the study reported herein. Interestingly, survival rates of Burbot released at older ages (i.e., larger size) were much lower than those of fish released as six-month old juveniles. Burbot released at age-1 experienced 25% survival their first year in the river, at age-2 survival was 44%, at age-3 it was 27%, and at age-4 it was 17%. These values differ from many reported in the literature; however, a similar trend between survival of fish released at an older age and fish released as juveniles was observed in Kootenai River White Sturgeon (Ross et al. 2015). Using telemetry-generated estimates, Hardy et al. (2015) reported 42% annual apparent survival of age-1 released Burbot in the Kootenai River and 53% for age-2 released fish, both of which are higher than rates found in the study reported herein. Again using telemetry-derived estimates, Stephenson et al. (2013) reported 78% survival of hatchery-reared Burbot released at different locations in the Kootenai Basin and ranging from age-1 to age-3. The trends observed in survival will likely inform future hatchery operations and

production targets. Perhaps most importantly, survival estimates generated in the present study will be essential parameters for evaluating whether or not the Burbot population in the Kootenai River could withstand harvest in the future. Future efforts should focus on annually updating survival estimates to better understand whether or not the Burbot population will begin to experience density dependence that could be manifested in survival.

The VPA indicated that the Burbot population in the Kootenai River would likely hit restoration targets for adults (i.e., 17,500; Paragamian and Hansen 2009) by 2019, possibly earlier. Although natural recruitment has not been detected, hitting the restoration target for adults would be a significant success for the Burbot program, and it underlines the need for analytically evaluating whether or not the population could support a harvest fishery. Year class production shifted from the UI-ARI hatchery to the KTOI hatchery beginning in 2015, and as a result of increased capacity at the new hatchery, annual year class size has grown substantially. The average release number of juveniles between 2015 and 2016 was approximately 197,000/year, relative to an average of approximately 32,000/year from 2011-2014. As a result, there is significant demographic momentum from the 2015 and 2016 year classes that will soon be entering into the spawning adult population. When Burbot from these year classes enter the adult population, not only could the population meet the adult restoration targets, but there could be adults in excess of the restoration targets available for harvest. Future research should use existing survival data and stocking numbers and simulated fishing mortalities, catch composition, and density dependent functions to better understand whether or not harvest could occur such that long-term restoration targets for adults were not compromised.

RECOMMENDATIONS

1. Provide comprehensive analyses and recommendations to management by 2018-19 that provide clear criteria for opening up a Burbot fishery on the Kootenai River.
2. Develop and implement a study to characterize growth of Burbot in the Kootenai River.
3. Fully evaluate natural production and hatchery contribution using PIT tags and PBT genetic marking. Consider specifically targeting different Kootenai River Habitat Restoration Program projects and their effect(s) on larval survival.
4. Continue working with UI PhD student to identify recruitment bottlenecks for Burbot, and then provide recommendation to USACOE, when ready.
5. Continue sampling index locations to measure changes in abundance, survival, and size structure.
6. Deploy HDX arrays in tributaries to the Kootenai River that were once known to be used by Burbot.
7. Develop and implement a study using eDNA to broadly characterize current use of tributaries by Burbot.

TABLES

Table 2.1. Total number of Burbot released from 2009-2017 into the Kootenai River and its tributaries. Fish were tagged with FDX PIT tags from 2009-2013; fish have been tagged with HDX PIT tags since 2014. Those without tags were primarily larval releases. Untagged fish from 2011-2016 will be able to have year class and gender assigned by genetic analysis, and untagged fish from 2015 and beyond will also be able to have release location and age-at-release assigned by genetic analysis. It is important to note that the number released in 2017 indicate only those fish released as planktivorous feeding larvae. Fish released as juvenile fingerlings in 2017 were not included in the total because they were released after the scope of this report.

Stock Year	Year Class	Tagged Releases	Untagged Releases	Total Release Number
2009	2006	7	-	7
	2007	23	-	23
	2008	1	-	1
	2009	-	178	178
2010	2007	5	-	5
	2008	18	-	18
	2009	551	4	555
	2010	-	1,576	1,576
2011	2009	6	26	32
	2010	30	90	120
	2011	16,289	53,975	70,264
2012	2010	82	-	82
	2011	656	-	656
	2012	3,392	268,305	271,697
2013	2011	71	-	71
	2012	600	1	601
	2013	10,011	450,872	460,883
2014	2010	16	-	16
	2012	16	-	16
	2013	218	-	218
	2014	3,473	-	3,473
2015	2014	30	-	30
	2015	9,946	895,205	905,181
2016	2016	14,618	123,618	138,236
2017	2017	-	7,329,180	7,329,180
Total		60,059	1,793,850	9,183,119

Table 2.2. Total number of Burbot stocked from 2009-2017 and recaptured in hoopnets since the conservation aquaculture program began. Year classes from 2006-2008 were stocked in 2009. Percent return indicates the total number of recaptures since stocking began in 2009. Note that the larval release from 2017 was not included in the total.

Year Class	Total Released	Recaptured	% Return
2006	7	0	0.00
2007	28	4	14.29
2008	19	4	21.10
2009	765	112	14.64
2010	1,794	8	0.45
2011	70,991	768	1.08
2012	272,314	224	0.08
2013	461,101	221	0.05
2014	3,503	17	0.50
2015	905,181	158	0.02
2016	138,236	1	0.00
Totals	1,853,939	1948	0.11

Table 2.3. Number, release location, and direction and distance of movement of Burbot detected at the Deep Creek PIT tag array from 10/01/2016– 3/23/2017.

Release Location	Direction from Array	Distance from Array (rkms)	<i>n</i>
Boundary Creek	Downstream	77	2
Deep Creek Confluence	Downstream	7	6
Deep Creek Proper	Upstream	2-14	30
Ferry Island	Downstream	42	8
Goat River	Downstream	94	0
Moyie River	Upstream	26	0
Porthill	Downstream	77	15
Unknown	-	-	26
Total	-	-	87

Table 2.4. Number of Burbot from each year class detected at the Deep Creek PIT tag array from 10/01/2016-3/23/2017.

Year Class	<i>n</i>
2011	22
2012	11
2013	12
2014	13
2015	21
2016	1
Unknown	7
Total	87

Table 2.5. Model selection results for Burbot annual survival (ϕ) and conditional capture probability (p) in the Kootenai River system, 2009-2016.

Model	¹ Δ AICc	Wi	K	Deviance
Phi(Age5+, Age0+Site+Weight, All+PrevMark) p(Age5+)	0.00	0.49	27	225,702.89
Phi(Age5+, Age0+Site+Length, All+PrevMark) p(Age5+)	0.79	0.33	27	225,703.68
Phi(Age5+, Age0+Site, All+PrevMark) p(Age5+)	2.04	0.18	26	225,706.93
Phi(Age5+, Age0+Site+Weight, All+PrevMark) p(Age4+)	9.40	0.00	26	225,714.29
Phi(Age5+, Age0+Site+Length, All+PrevMark) p(Age4+)	10.22	0.00	26	225,715.11
Phi(Age5+, Age0+Site, All+PrevMark) p(Age4+)	11.31	0.00	25	225,718.20
Phi(Age4+, Age0+Site, All+PrevMark) p(Age4+)	48.11	0.00	24	225,757.00
Phi(Age4+, Age0+Site, All+PrevMark) p(Age3+)	52.27	0.00	23	225,763.16
Phi(Age4+, Age0+Site, All+PrevMark) p(Age5+)	56.06	0.00	25	225,762.95
Phi(Age5+, Age0+A0GB, All+PrevMark) p(Age5+)	58.65	0.00	18	225,779.54
Phi(Age5+, Age0+Main_DP, All+PrevMark) p(Age5+)	83.07	0.00	18	225,803.96
Phi(Age5+, Age0+Main_Lk, All+PrevMark) p(Age5+)	140.77	0.00	18	225,861.66

¹The AICc value of the top model was 225,756.89.

FIGURES

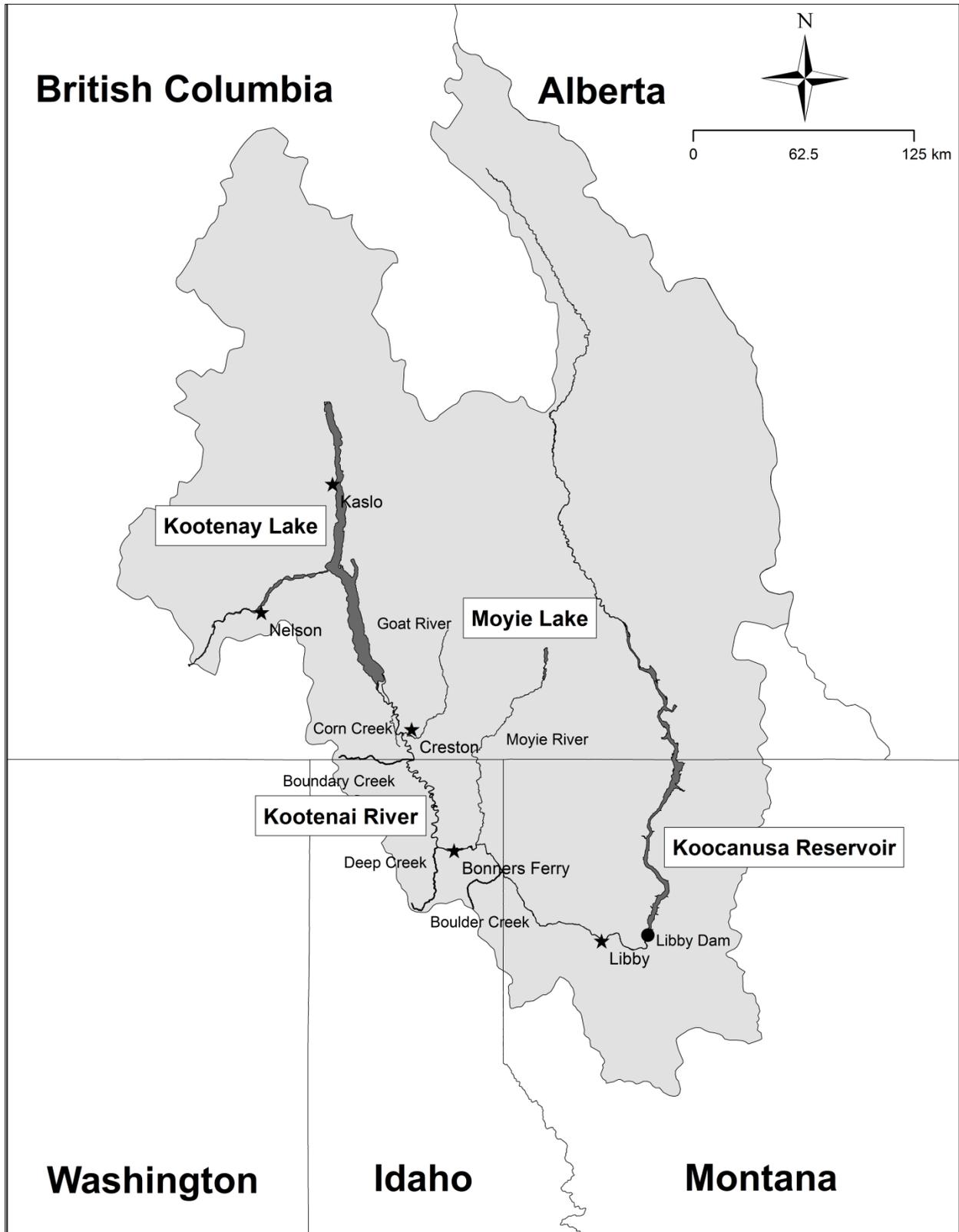


Figure 2.1. Map of the Kootenai Basin, including Kootenay Lake, the Kootenai River, Kooconusa Reservoir, Moyie Lake, and major tributaries to the Kootenai River in Idaho and British Columbia.



Figure 2.2. Map of all hoopnet locations sampled in the Kootenai River in Idaho and British Columbia during winter 2016/17.

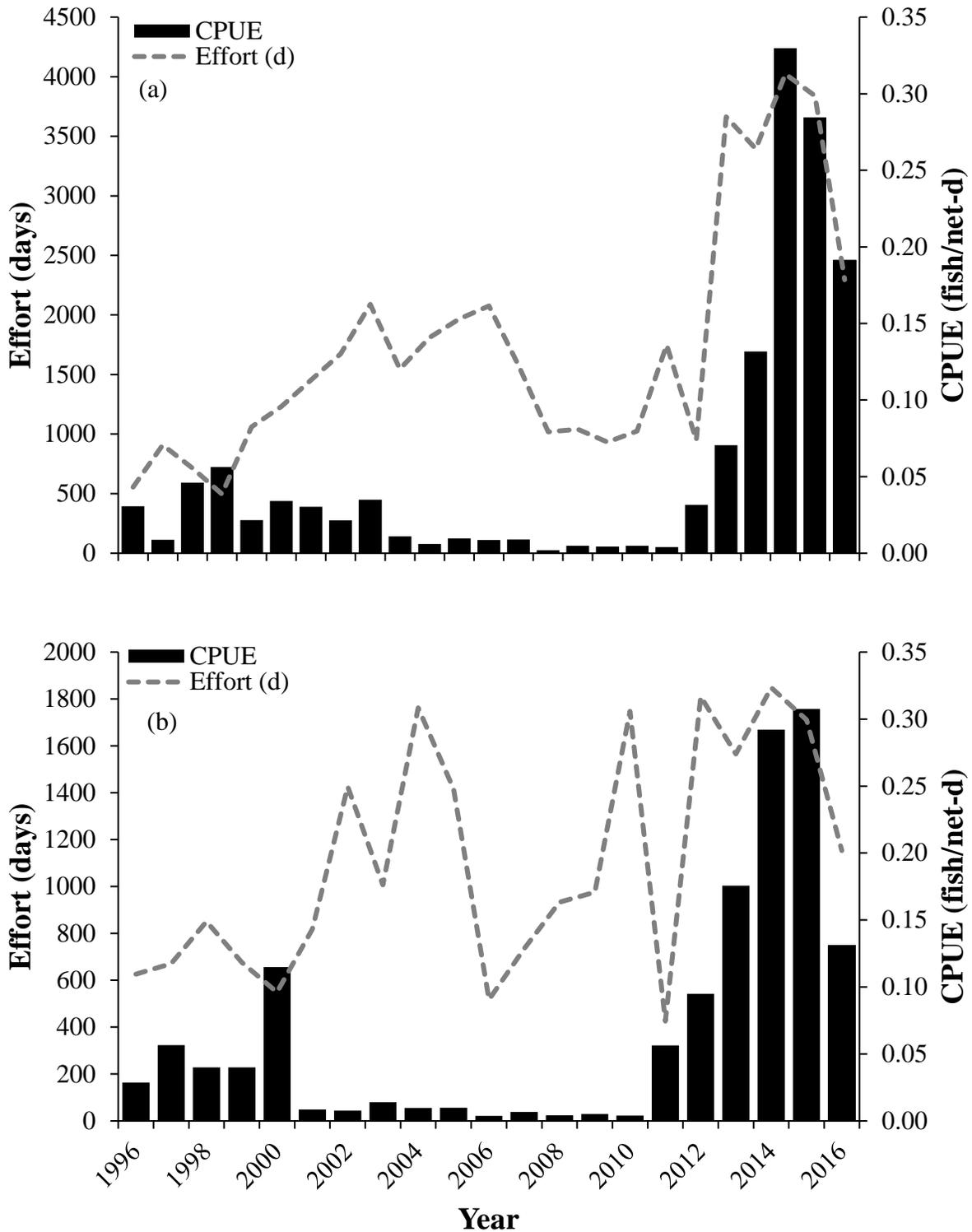


Figure 2.3. Catch-per-unit-of-effort (Burbot/net-day) and effort (days) of hoopnet sampling for (a) all sites and (b) index sites from 1992-2016. Data from sites upstream from Bonners Ferry are not included. Annual sampling started December 1 and ended March 31. Sample year indicates the year sampling started (e.g. 2016/17 season is 2016 on the x-axis).

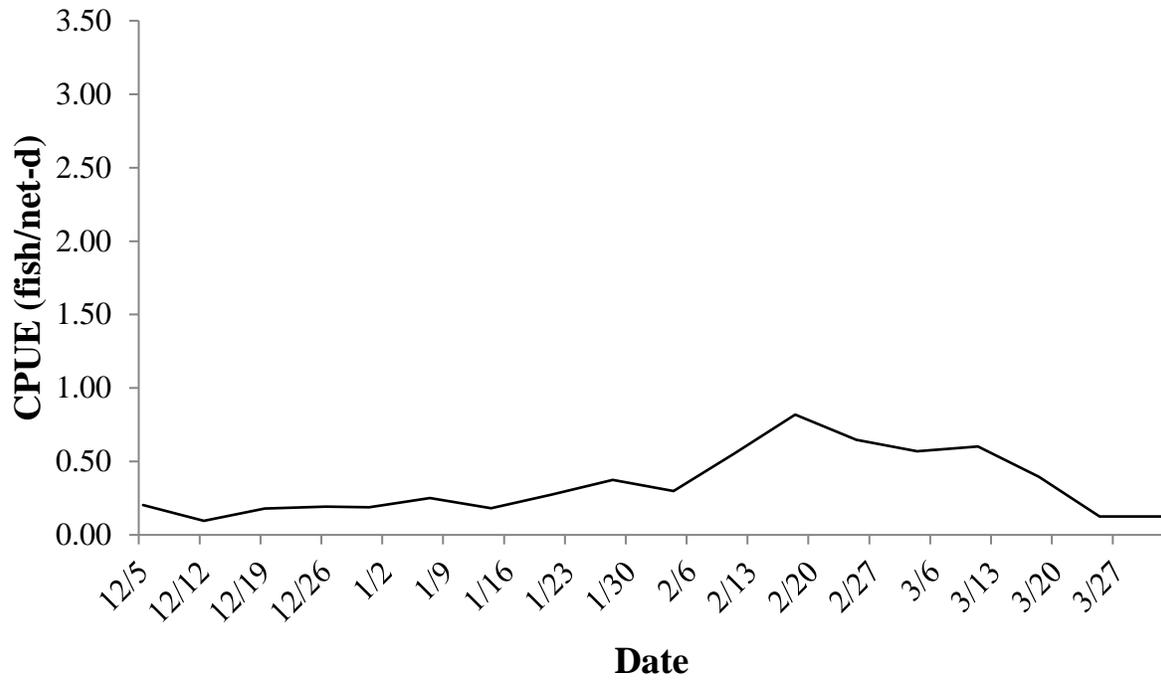


Figure 2.4. Mean spawn timing of Burbot captured at Ambush Rock (rkm 244.5; historical index location) as gauged by catch-per-unit-of-effort (Burbot/net-day). Data shown represent all years from 2012-2016/17.

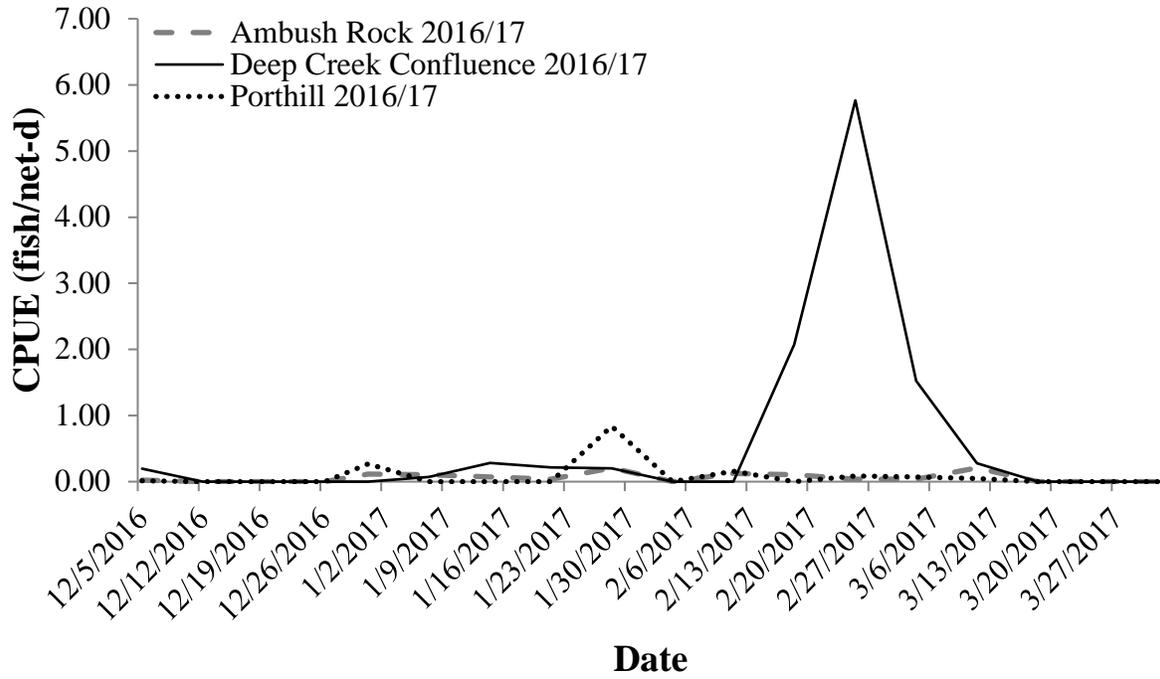


Figure 2.5. Spawn timing at Ambush Rock (rkm 244.5), Deep Creek confluence (rkm 240.5), and Porthill (rkm 170) during winter 2016/17.

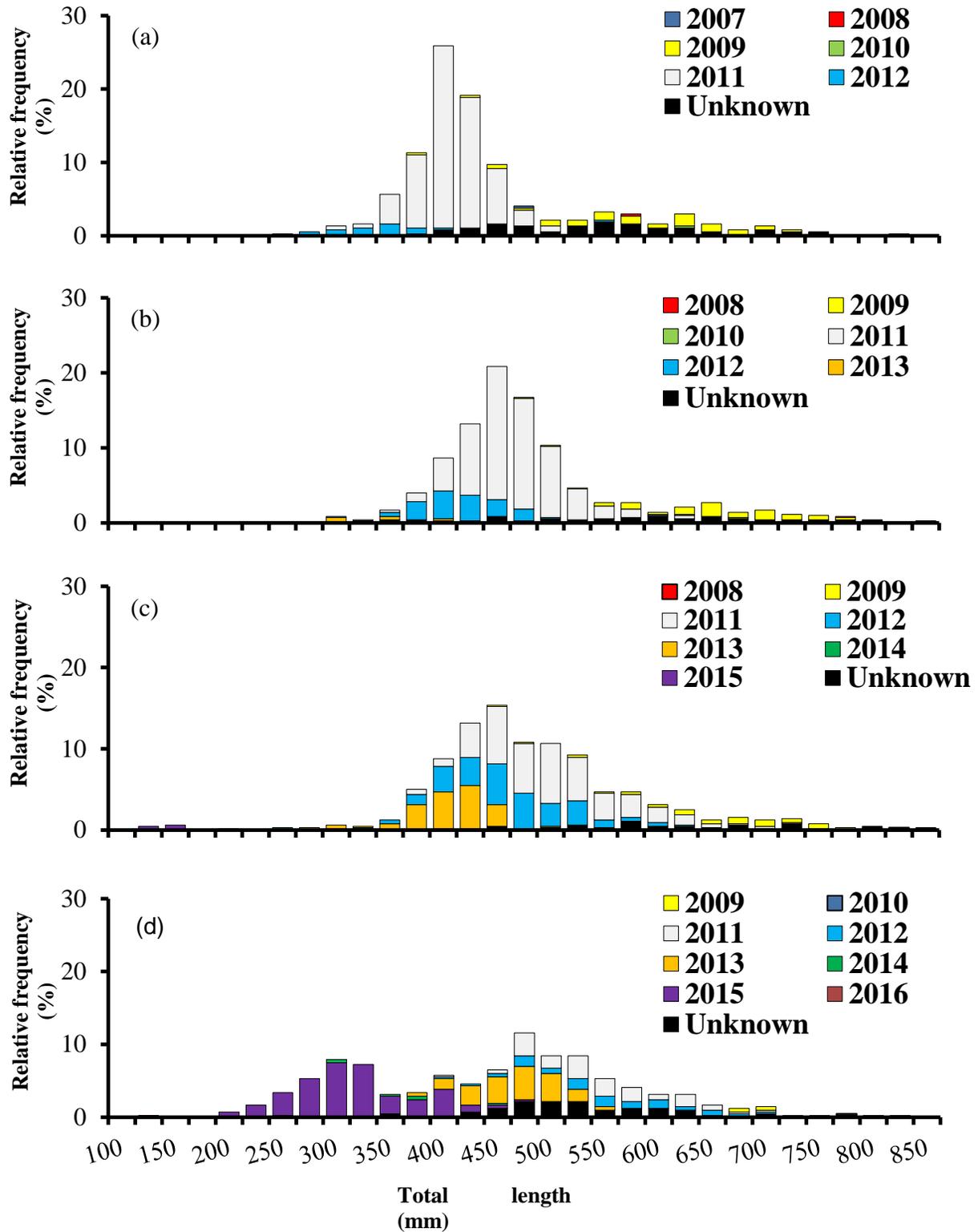


Figure 2.6. Length frequency and year class assignments from PIT-tagged and PBT-assigned Burbot captured in hoopnets in the Kootenai River from December 1 through March 31 during 2013/14 (a), 2014/15 (b), 2015/16 (c), and 2016/17 (d) winters.

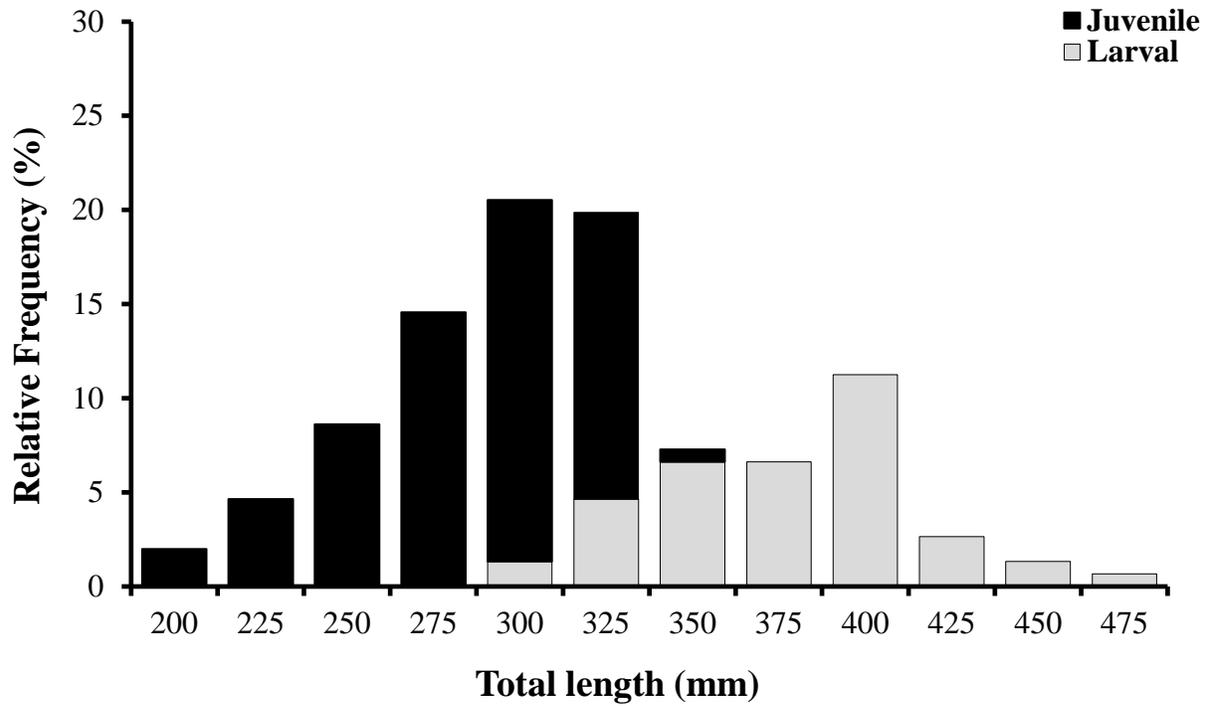


Figure 2.7. Length frequency of Burbot from the 2015 year class that were captured during winter 2016/17. Black bars denote fish that were released into the river as six-month old juveniles ($n = 98$ captures). Gray bars denote fish that were released into the river as planktivorous feeding larvae ($n = 52$ captures).

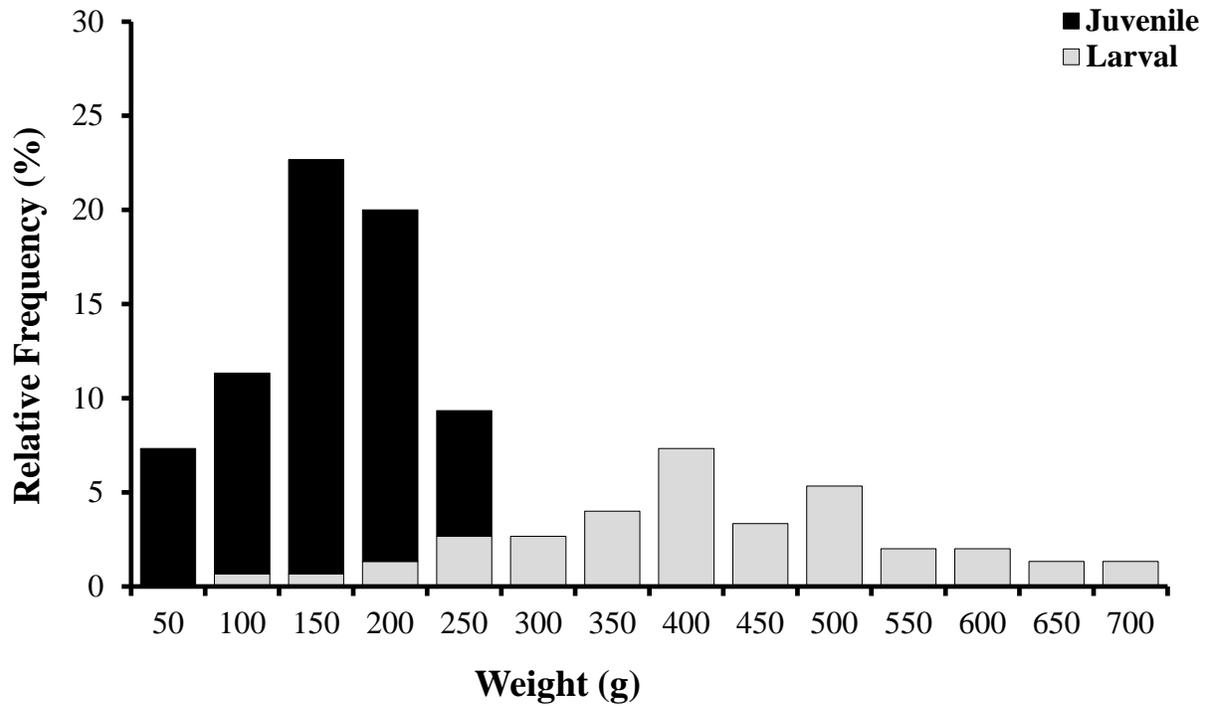


Figure 2.8. Weight frequency of Burbot from the 2015 year class that were captured during winter 2016/17. Black bars denote fish that were released into the river as six-month old juveniles ($n=98$ captures). Gray bars denote fish that were released into the river as planktivorous feeding larvae ($n = 52$ captures).

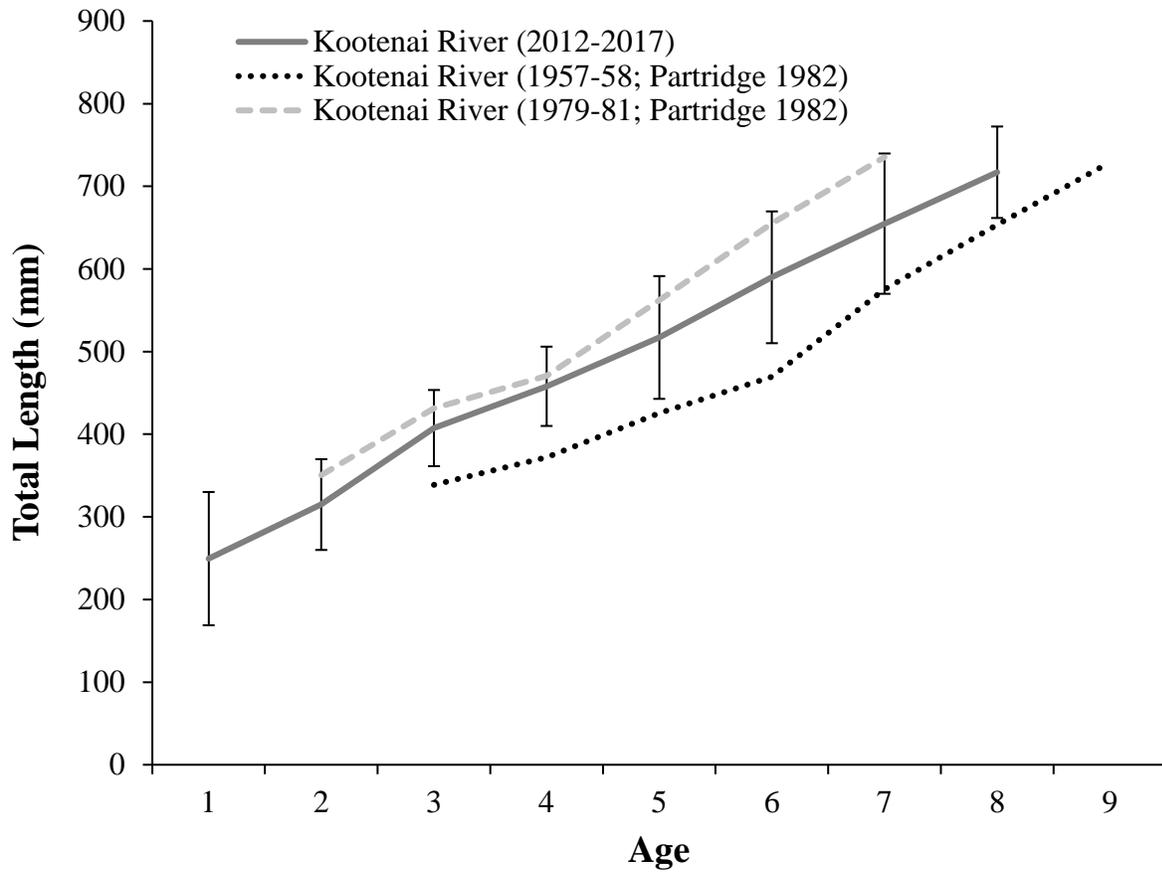


Figure 2.9. Mean length-at-age-at-time-of-capture for Burbot captured in hoopnets from winters 2011/12 through 2016/17 compared to that of fish captured in winters 1979/81 and 1957/58.

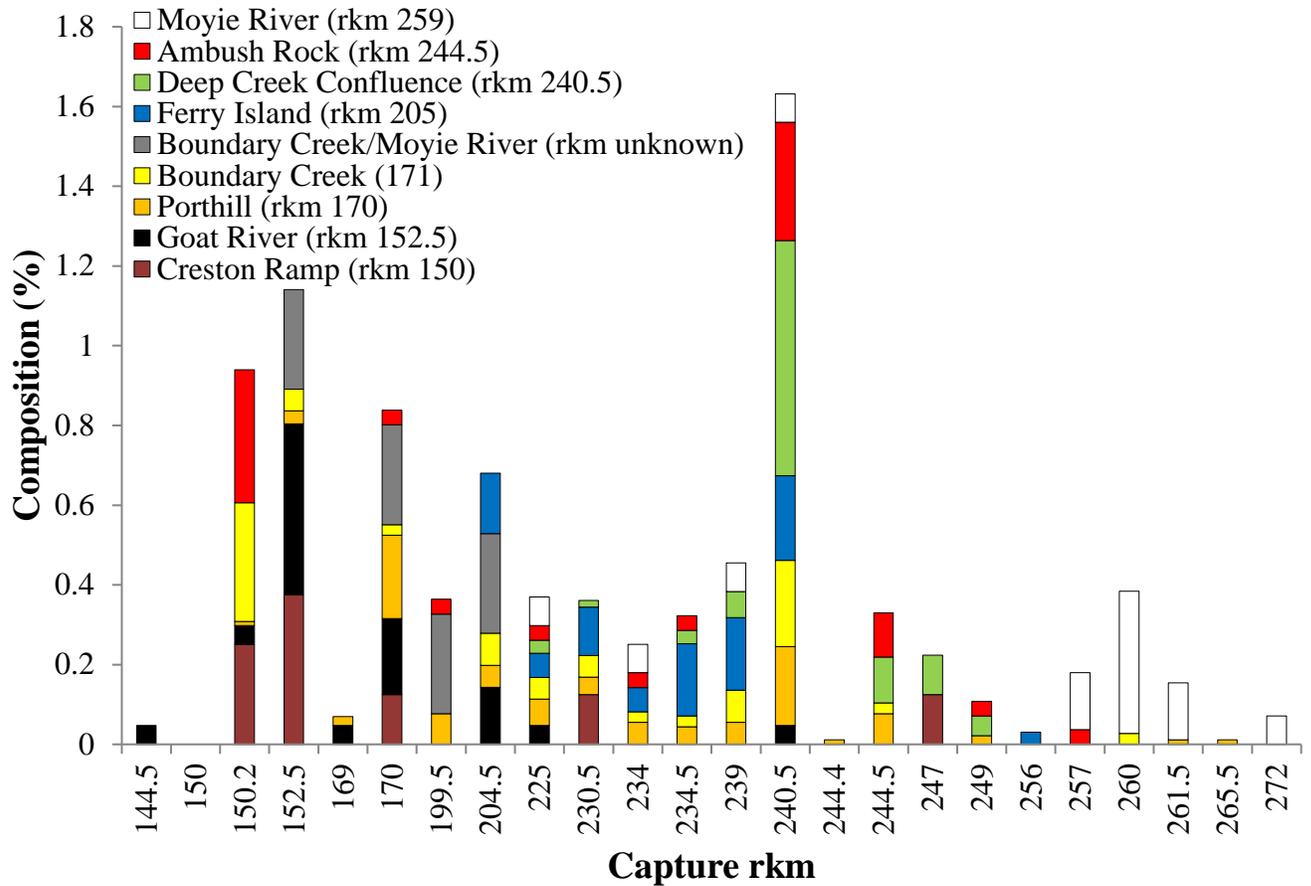


Figure 2.10. Proportion of Burbot recaptured in the 2016/17 winter hoopnet sampling season in relation to their original release location.

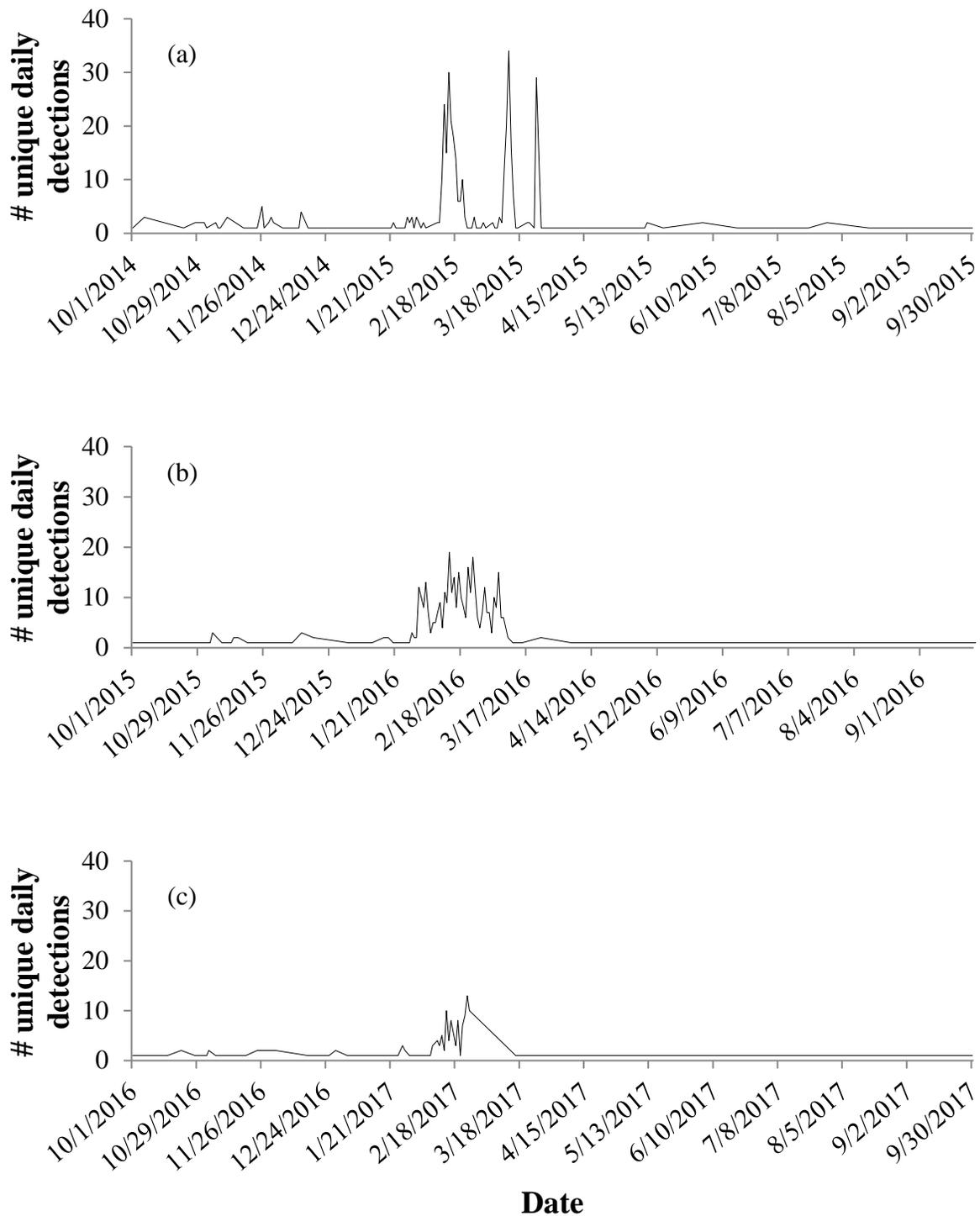


Figure 2.11. Number of unique daily detections at the Deep Creek PIT-tag array during the 2014/15 (a), 2015/16 (b), and 2016/17 (c) winter seasons.

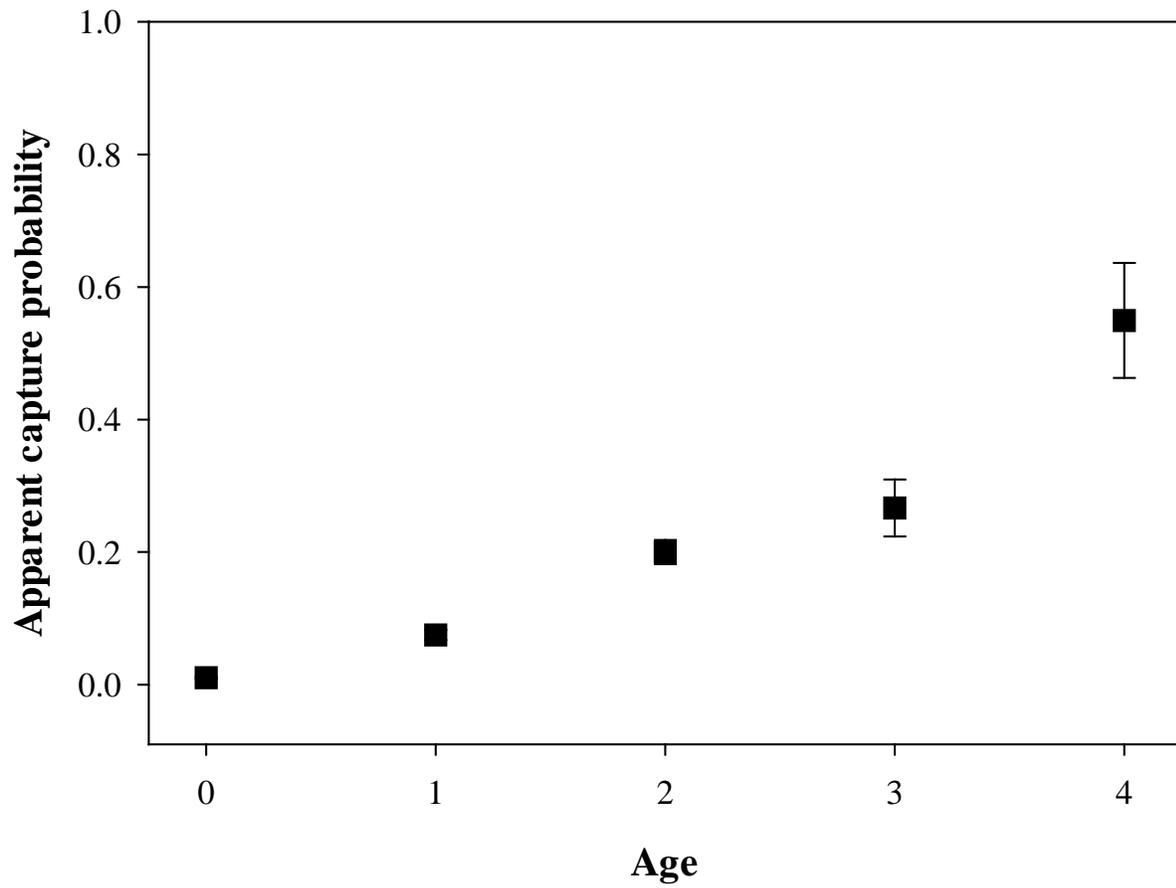


Figure 2.12. Age-specific annual apparent capture probability (95% credible interval) of Burbot in the Kootenai River system, 2009-2016. There were no recapture data available for larval releases at the time of this report.

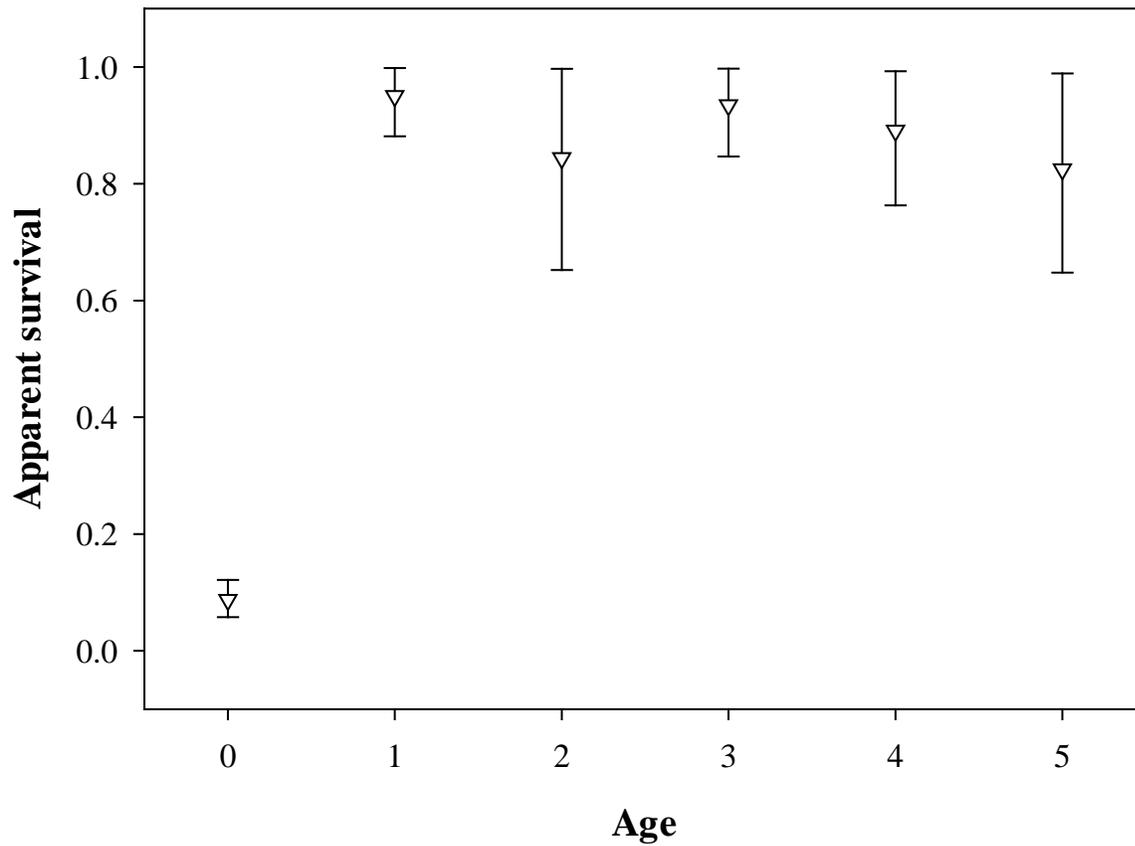


Figure 2.13. Age-specific annual apparent survival (95% credible interval) of Burbot in the Kootenai River system, 2009-2016. Estimates depicted are apparent survival and do not include any covariate effects.

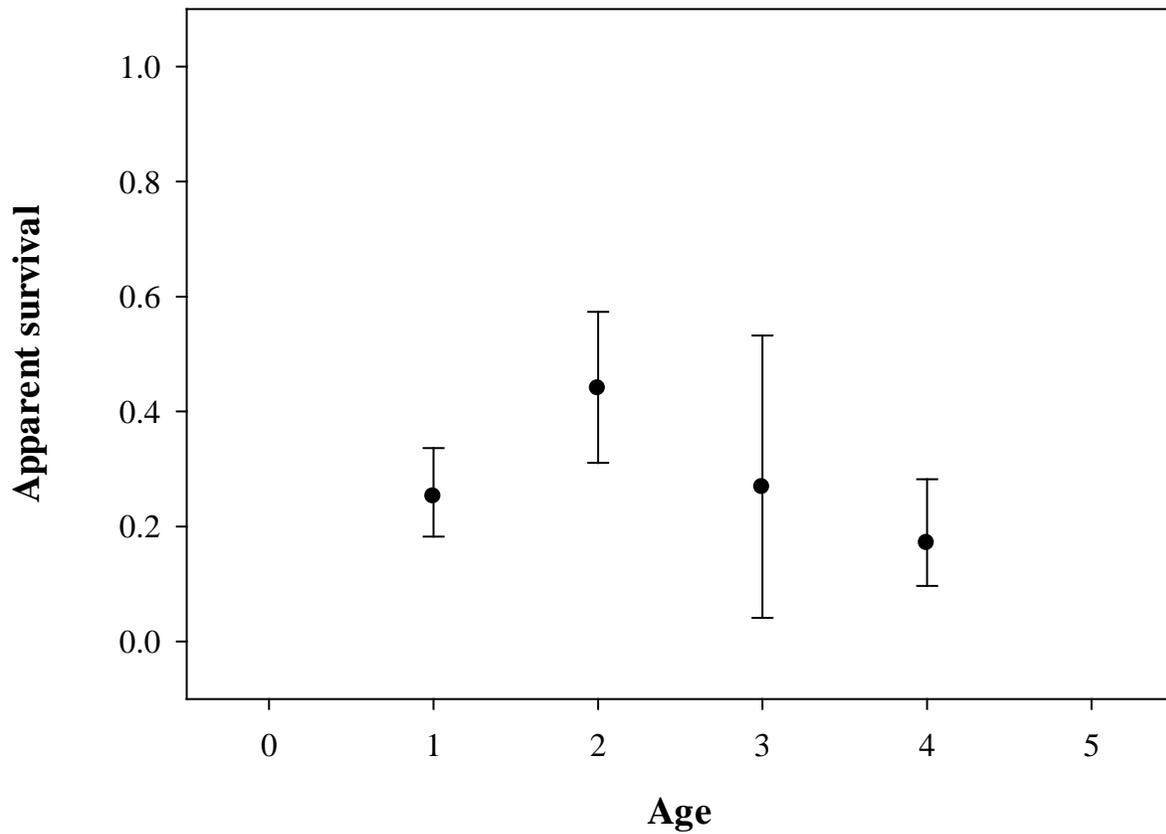


Figure 2.14. Age-specific annual apparent survival (95% credible interval) of Burbot in the Kootenai River system, 2009-2016. Estimates depicted are one year post-release at the specified age.

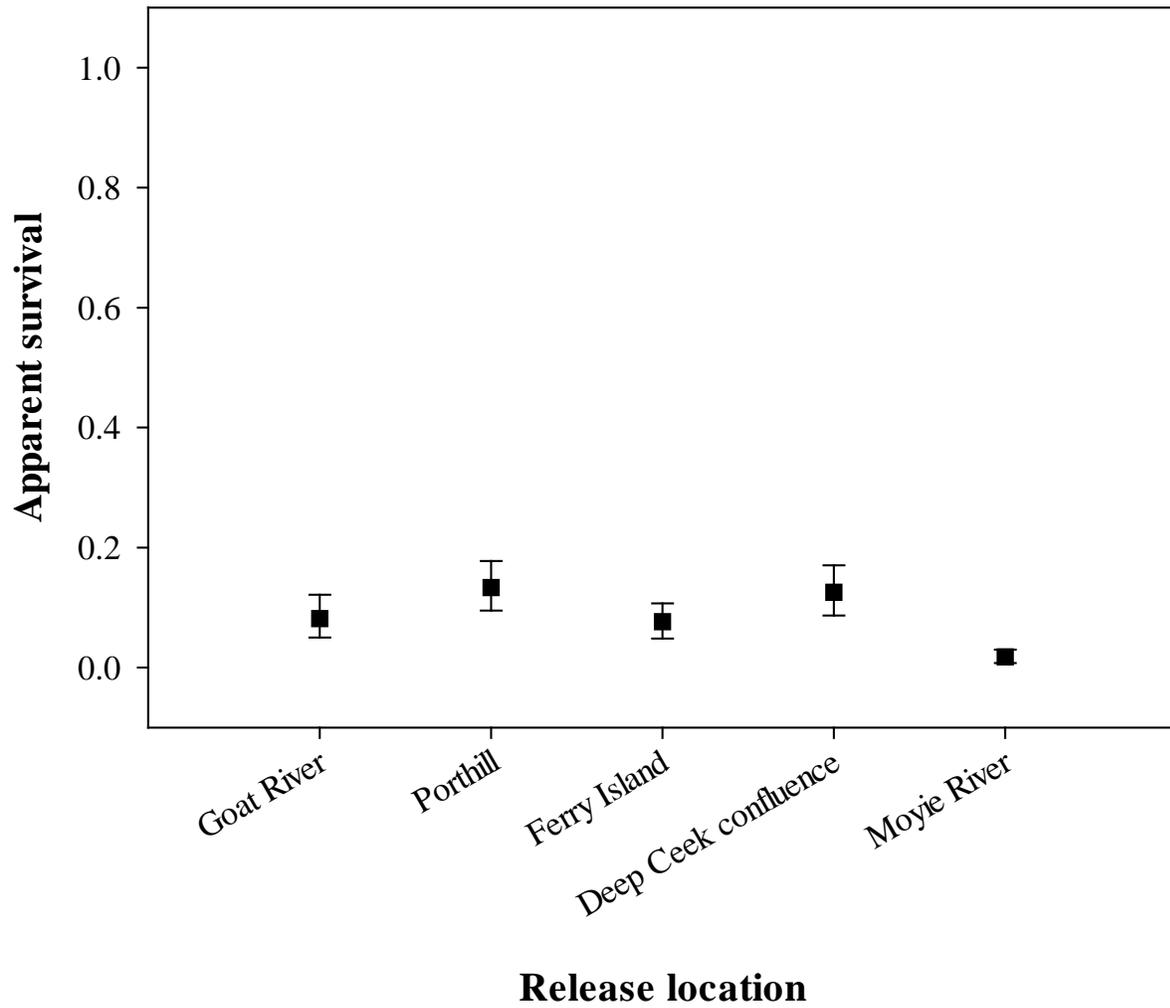


Figure 2.15. Annual apparent survival (95% credible interval) of Burbot released into the Kootenai River system as an age-0 (i.e., six-month-old juvenile). Estimates depict survival to age-1.

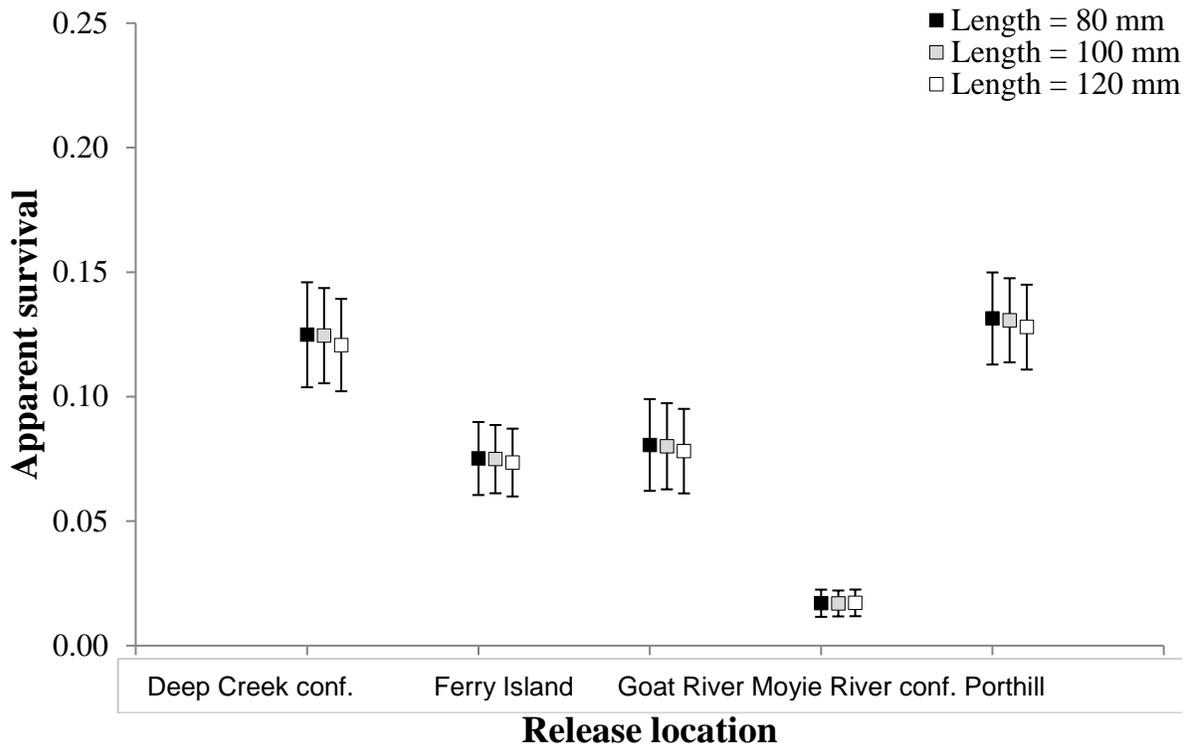


Figure 2.16. Annual apparent survival (95% credible interval) of Burbot released into the Kootenai River system as an age-0 (i.e., six-month old juvenile). Estimates depict survival to age-1 segregated by length bins at release. Black square represent 80 mm at release, gray represent 100 mm, and white represent 120 mm.

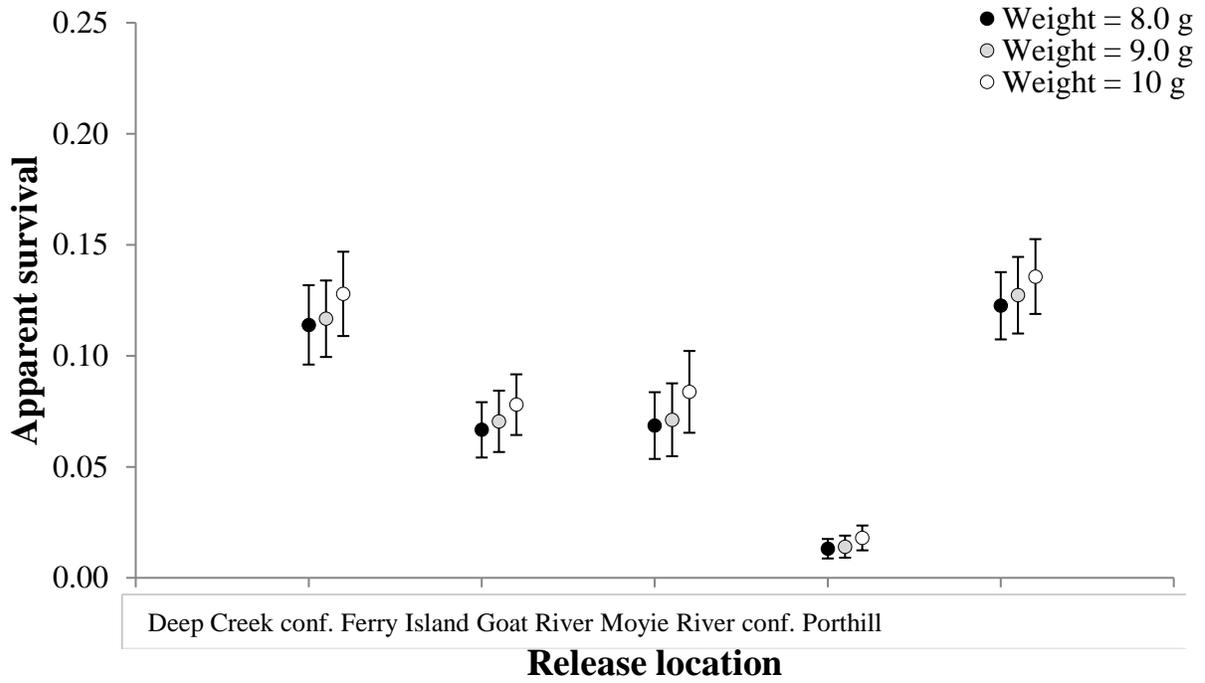


Figure 2.17. Annual apparent survival (95% credible interval) of Burbot released into the Kootenai River system as an age-0 (i.e., six-month-old juvenile). Estimates depict survival to age-1 segregated by weight bins at release. Black square represent 8.0 g at release, gray represent 9.0 g mm, and white represent 10.0 g.

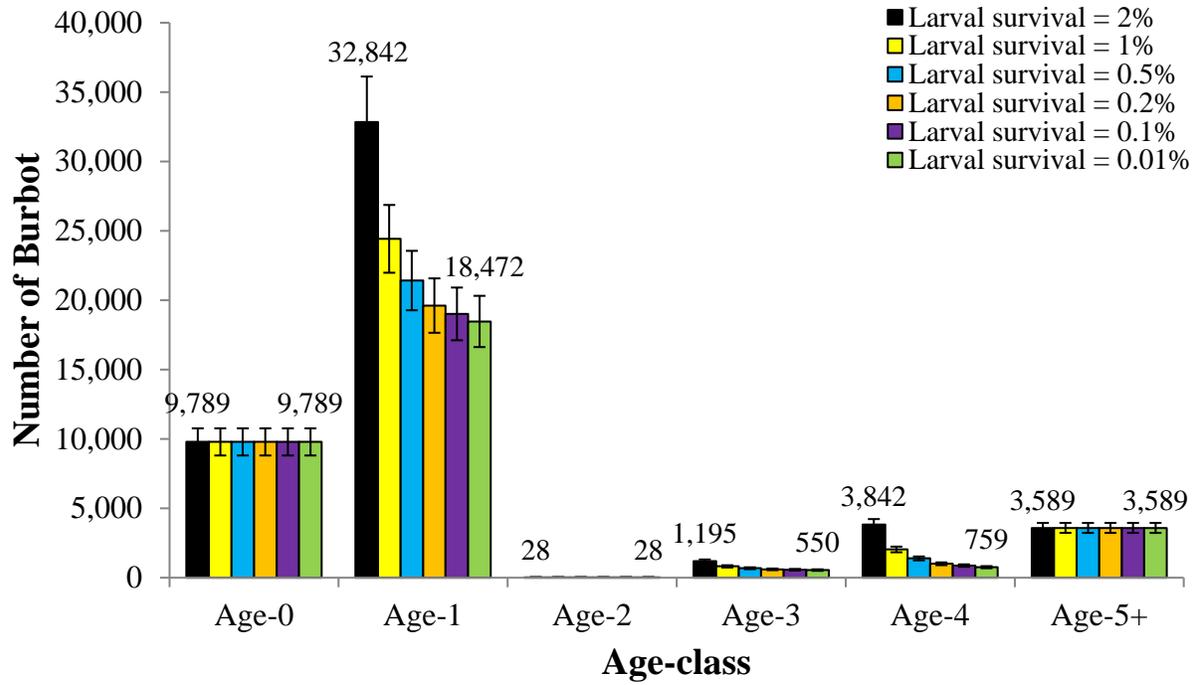


Figure 2.18. Age-specific virtual population estimate for Burbot in the Kootenai River system as of 2016. Survival of larval Burbot was not estimable at the time of this report; therefore, various survival values were considered. Black bars denote a larval survival estimate of 2%, yellow bars of 1%, blue bars of 0.5%, orange bars of 0.2%, purple bars of 0.1%, and green bars of 0.01%.

CHAPTER 3: NATIVE SALMONID MONITORING AND EVALUATION

ABSTRACT

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 Kootenai River system. Declines in fish stocks in the Kootenai River have long been attributed to this loss of nutrients (along with other factors) via bottom-up trophic cascades. A large-scale nutrient restoration program (using phosphate fertilizer) was implemented in the Idaho portion of the Kootenai River in 2005 to restore resident fisheries by increasing primary production. Annual electrofishing surveys were conducted at multiple biomonitoring sites in Idaho and Montana before and after nutrient addition in order to evaluate fish catch-per-unit-of-effort, biomass-per-unit-of-effort, and various population metrics (e.g., survival, recruitment, and others). An additional biomonitoring site was added and sampled in 2015, upstream from the nutrient addition site. In addition, abundances of Mountain Whitefish *Prosopium williamsoni*, Rainbow Trout *Oncorhynchus mykiss*, and Largescale Suckers *Catostomus macrocheilus* have been estimated in a three-kilometer reach of the Kootenai River (Hemlock Bar) since the early 1980s. Collectively, results of this project indicate that the program has largely been successful; however, additional research and analyses are needed to better understand different effect levels.

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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. It has depleted nutrients downstream and caused a decline in primary productivity in the Idaho portion of the river (Woods 1982; Snyder and Minshall 1996). By the 1990s, reduction in productivity translated to a two- to four-fold decrease in the number of Mountain Whitefish *Prosopium williamsoni* compared to 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, nutrients bind to sediments and precipitate out of solution (Snyder and Minshall 1996), making them unavailable to organisms 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 has likely contributed to poor fish production over the past two decades.

Primary production is 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 [KTOI], 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 via 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 KTOI.

Information presented in this report summarized results using (1) 95% confidence intervals and (2) effect sizes (Cohen's *d*; Cohen 1988) for statistically different comparisons (as gauged by 95% confidence intervals), rather than formal analyses. Effect sizes were interpreted as large ($d \geq 0.8$), medium ($0.8 > d > 0.2$), and small ($d \leq 0.2$) (Cohen 1988). Comprehensive and diverse statistical analyses were conducted on data from the nutrient restoration project and summarized in Ross et al. (2015). Similar analyses will be conducted and reported every three years; 95% confidence intervals and effect sizes will be calculated and reported in the off years.

RESEARCH GOAL

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

OBJECTIVES

1. Evaluate whether or not total and species-specific catch and biomass rates have changed from pre- to post-treatment periods.
2. Evaluate whether or not relative weight (W_r) of has changed from pre- to post-treatment periods.
3. Evaluate trend population size of Rainbow Trout, Mountain Whitefish, and Largescale Suckers of in a three-kilometer section (Hemlock Bar) of the nutrient addition zone.

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 km²; Bonde and Bush 1975). The study area was comprised of approximately 106 km of the river that flowed through the Idaho Panhandle, along with three control sites (two 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, Idaho to the town of Bonners Ferry, Idaho (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 the study were established to gather fisheries and lower trophic level data, before and after nutrient addition (Figure 3.2). Fish populations were surveyed at eight biomonitoring sites in 2015, two of which were control sites. The first control site (KR10) was located in the Montana portion of the Kootenai River, termed the Control Zone of the river, and it was sampled from 2002-2015. The second control site (KR10.5) was also located in the Control Zone of the river near the town of Troy, Montana, and it was first sampled in 2015. Four sites were located within the Nutrient Addition Zone of the river (sites KR9.1, KR9, KR7, and KR6). Site KR9.1, located one km downstream from the nutrient addition site, was sampled from 2009-2015. Site KR9 was located approximately ten km downstream from the nutrient addition site, and it was sampled from 2002-2015. Site KR7, located approximately 15 km downstream from the nutrient addition site, was sampled from 2014-2015. Site KR6 was located approximately 20 km downstream from the nutrient addition site, and it was sampled from 2002-2015. The next two sites were downstream from the town of Bonners Ferry, Idaho, 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. Both KR4 and KR2 were sampled from 2002-2015. Sites KR10.5, KR9.1, and KR7 did not have any pretreatment data, so they were not included in any formal analyses.

METHODS

Fish Community Assessment

Abundance, Biomass, and Relative Weight

Boat electrofishing was conducted during September from 2002-2015 at five biomonitoring sites (sites KR10, KR9, KR6, KR4, and KR2). Site KR9.1 was sampled from 2009-2015, KR7 was sampled from 2014-2015, and KR10.5 was sampled beginning in 2015.

Collectively, sites that were surveyed in 2015 included KR10, KR10.5, KR9.1, KR9, KR7, KR6, KR4, and KR2 (Figure 3.2). 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 subsection to ensure one was spatially 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 subsequent ageing in the lab.

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; number of fish/minute), species abundance by weight as biomass-per-unit-of-effort (BPUE; kg of fish/minute) and W_r . 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. Relative weight was calculated using the following equation:

$$W_r = \frac{W}{W_s} * 100$$

where:

W was the actual fish weight (g), and

W_s was a standard weight (g) for fish of the same length.

Relative weight was calculated for Rainbow Trout, Mountain Whitefish, and Largescale Sucker using the W_s available in literature (Anderson and Neumann 1996; Richter 2007). Minimum total lengths used to calculate W_s were 120 mm for Rainbow Trout (Simpkins and Hubert 1996), 140 mm for Mountain Whitefish (Rogers et al. 1996), and a range of 170-640 mm for Largescale Suckers (Richter 2007). Only fish that met these length criteria were included in the W_r analysis.

Population Status

Since the implementation of new regulations 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 and calculated as:

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

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

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.

Mark-recite population estimates were periodically conducted within a three-kilometer (km) section within the Nutrient Addition Zone from 1980 until 2016 using boat electrofishing as described by Downs (2000). Although these estimates were not originally designed to determine the effect of nutrients on fish populations, these data were a useful reference in monitoring the abundance trend in combination with additional statistical modeling specifically designed for this study. In order to estimate abundance, mountain whitefish, largescale sucker, and rainbow trout were uniquely marked the second week in August and recaptured the following week to allow adequate mixing within the sample location. Population estimates were calculated using Chapman's modification of the Petersen Method (Ricker 1975; Krebs 1999):

$$N = \left[(M + 1) * \frac{C + 1}{R + 1} \right] - 1$$

where:

N = population estimate,

M = number of marked fish,

C = number of fish captured during the recapture sample, and

R = number of recapture marks in the recapture sample.

The 95% confidence limits for the population estimates were calculated based on the Poisson distribution (Ricker 1975; Seber 1982).

Analysis Considerations

The years from 2002-2005 were considered the Pretreatment Period, and 2006-2016 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. Sites KR10.5, KR9.1, and KR7 lacked data from the Pretreatment Period and, therefore, were not used in any analyses.

RESULTS

Fish Community Assessment

Abundance, Biomass, and Relative Weight

Twenty-three species of fish were identified in the catch from 2002-2016, and 43,311 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)—Catch-per-unit-of-effort was calculated for the following species, segregated by Period and river zone (Table 3.1): Brown Bullhead *Ameiurus nebulosus*, Bluegill *Lepomis macrochirus*, Brook Trout *Salvelinus fontinalis*, Brown Trout *Salmo trutta*, Burbot, Black Crappie *Pomoxis nigromaculatus*, Largemouth Bass *Micropterus salmoides*, Longnose Dace *Rhinichthys cataractae*, Longnose Sucker *Catostomus catostomus*, Largescale Sucker, Mountain Whitefish, Northern Pikeminnow, Peamouth Chub, Pumpkinseed *Lepomis gibbosus*, Rainbow Trout, Redside Shiner, Smallmouth Bass *Micropterus dolomieu*, Sculpin *Cottus cognatus*, Westslope Cutthroat Trout *Oncorhynchus clarkii lewisi*, and Yellow Perch *Perca flavescens*. Total CPUE (i.e., all species, combined) was greater from Pre- to Post-treatment periods within the Nutrient Addition Zone (Figure 3.4), but not in the Downstream or Control zones. The primary factor affecting catch rates for multiple species was river zone (Table 3.1). Catch rates of all species were similar between periods within each river zone, with the exception of Mountain Whitefish, Rainbow Trout, and Largescale Suckers (Table 3.1). Catch rates of Mountain Whitefish and Largescale Suckers were greater from Pre- to Post-treatment periods within the Nutrient Addition Zone (Figures 3.5 and 3.6 respectively), but not in the Downstream or Control zones. Catch rates of Rainbow Trout were greater from Pre- to Post-treatment periods within the Control and Nutrient Addition zones (Figure 3.7), but not in the Downstream Zone. It is also important to note that the greater catch rates of Rainbow Trout from Pre- to Post-treatment periods in the Control Zone was largely driven by increased numbers of sexually immature individuals (i.e., ≤ 250 mm; Figure 3.8), which may represent an indirect and recruitment-related effect of nutrient addition in the Control Zone.

Biomass (BPUE)—Biomass-per-unit-of-effort was calculated for the following species, segregated by Period and river Zone (Table 3.2): Brown Bullhead, Bluegill, Brook Trout, Brown Trout, Burbot, Black Crappie, Largemouth Bass, Longnose Dace, Longnose Sucker, Largescale Sucker, Mountain Whitefish, Northern Pikeminnow, Peamouth Chub, Pumpkinseed, Rainbow Trout, Redside Shiner, Sculpin, Westslope Cutthroat Trout, and Yellow Perch. Similar to total CPUE, total BPUE was also greater from Pre- to Post-treatment periods within the Nutrient Addition Zone (Figure 3.4, but not in the Downstream or Control zones. The primary factor affecting biomass rates for multiple species was also river zone, similar to CPUE (Table 3.2). Biomass rates of all species were similar between periods within each river zone, with the exception of Largescale Suckers and Rainbow Trout (Table 3.2). Biomass rates of Largescale Suckers were greater from Pre- to Post-treatment periods within the Nutrient Addition Zone (Figure 3.6), but not in the Downstream or Control zones. Biomass rates of Rainbow Trout were greater from Pre- to Post-treatment periods within the Control Zone (Figure 3.7), but not in the Downstream or Nutrient Addition zones. Biomass rates of Mountain Whitefish in the Nutrient Addition Zone were greater from Pre- to Post-treatment periods, but 95% confidence intervals did not indicate statistical differences between the means.

Relative Weight (W_r)—Relative weight was calculated for Mountain Whitefish, Rainbow Trout, and Largescale Suckers (Table 3.3.; Figure 3.9). Mean W_r for Mountain Whitefish and Rainbow Trout was not different from Pre- to Post-treatment periods within any of the river zones (Table 3.3); however, mean W_r of Largescale Suckers was greater from Pre- to Post-treatment periods in the Nutrient Addition and Control zones (Figure 3.9).

Population Status

Values for PSD and QSD for Rainbow Trout in the Nutrient Addition Zone of the Kootenai River during 2016 were 28 and 2, respectively. These values were near the long-term averages for PSD (38) and QSD (3) in the Kootenai River, and they were in the range of other stable, healthy fish populations (Anderson 1976; Gabelhouse 1984).

Population Estimate

A total of 1,334 fish were marked during the population estimate efforts at Hemlock Bar in August 2016. Numbers of Mountain Whitefish, Rainbow Trout, and Largescale Suckers were sufficient to estimate the population size and corresponding confidence limits for each species. Mountain Whitefish was the most abundant species at $n = 9,763$ (7914, 12,047; 95% confidence limits), Largescale Suckers were the next most abundant species at $n = 9,017$ (6,011, 14,170), and Rainbow Trout were the least abundant species at $n = 653$ (492, 888) (Table 3.4; Figure 3.10). In general, estimates for all three species were similar to those generated in previous years.

DISCUSSION

Fish Community Assessment

The proportion of species in the catch during both periods and all river zones indicated that the largest driver shaping the fish community in the Kootenai River 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 Zone 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 well suited for these types of habitat conditions. In contrast, the Control and Nutrient Addition zones had higher flow velocities and the substrate was largely comprised of cobble. Mountain Whitefish and Rainbow Trout, species preferring cobble substrate and higher flow velocities, were more abundant in both of these river zones relative to the Downstream Zone. These results were corroborated by subsequent summaries on and analyses of species-specific catch and biomass rates.

Abundance, Biomass, and Relative Weight

Species-specific CPUE and BPUE changed little from Pre- to Post-treatment periods within each river zone; however, total CPUE and BPUE were greater and statistically different post-treatment (relative to pretreatment) 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-treatment periods 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 in the river. This has important implications for the food web of the Kootenai River, ranging from potentially altering predator-

prey interactions and ratios, to altering demand on lower trophic-level forage (i.e., periphyton and macroinvertebrates), to 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 IDFG 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). Davis et al. (2010) suggested that unexpected predator-prey responses and effects on food web efficiencies could occur with long-term nutrient enrichment projects. Although it is unknown whether the aforementioned types of responses are occurring in the Kootenai River, 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 mainstem 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 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-treatment periods 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. Two lines of inference support this potential mechanism. First, the documented (and statistically different) increase in catch rates of immature Rainbow Trout from Pre- to Post-treatment periods in the Control Zone of the river suggests that recruitment of Rainbow Trout has increased, post-treatment. Second, long-term population monitoring (for Rainbow Trout) conducted by the MFWP has documented increases in the Rainbow Trout population within the Control Zone of the river from pre- to post-treatment (Jim Dunnigan, Montana Fish Wildlife and Parks, personal communication).

Largescale Suckers responded most positively (of all species) to nutrient additions, as gauged by greater CPUE and BPUE and improved W_r from Pre- to Post-treatment periods. The increase in CPUE and BPUE was not observed until recent years and appeared to be a delayed effect of nutrient additions. Largescale Suckers in the Kootenai River do not fully recruit to electrofishing gear until age-7 (Watkins et al. 2017); therefore, it is logical that increases in CPUE and BPUE of Largescale Suckers were only being documented in recent years. It is expected that this response will continue to be manifested in future years. Relative weight is a metric that gauges ecological and physical optimums (Anderson and Neumann 1996; Blackwell et al. 2000), and when interpreted in the context of relative abundance and growth metrics, can be particularly useful. Growth of Largescale Suckers has been found to be positively and strongly correlated with the addition of nutrients to the Kootenai River (Watkins et al. 2017), providing an additional line of inference to support the notion that nutrient additions have improved the status of the Largescale Sucker population in the Kootenai River. Largescale Suckers are benthic feeders consuming periphyton, zooplankton, invertebrates, detritus, and plant material. Since nutrient additions began in 2005, the amount of periphyton on substrate in the river has increased, as have macroinvertebrates and levels of chlorophyll a (C. Holderman, KTOI, personal communication). It is likely that suckers have been able to utilize the increased primary production more rapidly and directly than Mountain Whitefish and Rainbow Trout, which may explain the observed increases in CPUE, BPUE, growth, and W_r .

Population Estimate

In general, population estimates for all three species corroborated trends observed in species-specific catch rates during pre- and post-treatment periods in the Nutrient Addition Zone; however, the estimates were difficult to interpret without the context of similar estimates from the Control Zone. Although the 2016 population estimates for Mountain Whitefish and Largescale Suckers were less than estimates from previous years (e.g., 2011 and 2014), they were still greater than those documented prior the addition of nutrients to the Kootenai River. The Mountain Whitefish population nearly doubled in size from the pretreatment period, and the Largescale Sucker population increased nearly five-fold. Furthermore, the 2016 estimate for Rainbow Trout was the second highest recorded since 1980, equating to a doubling in size from the pretreatment period. One target of the nutrient addition program was to restore the Mountain Whitefish population to levels documented in the 1980-81 estimates (i.e., 14,000-16,000 fish; Partridge 1983). Estimates for Mountain Whitefish during the post-treatment period initially exceeded (2008 and 2011) and then dropped below (2014 and 2016) this target. Estimates from

1999-2011 documented consistent increases in the population sizes of all three species; however, 2016 marked the second year of declines in estimates for Mountain Whitefish and Largescale Suckers. Although the 2014 and 2016 population estimates for each species likely represented typical variability in population cycles, it is possible that these populations have fully capitalized on the newly-established levels of primary production (due to nutrient additions) and are beginning to stabilize at (respective) population maxima. Therefore, it is important to continue the population survey at Hemlock Bar in future years.

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 sport fish.
3. Complete a spatially extensive study to evaluate natal origins of catchable, adult Rainbow Trout in the Kootenai River.
4. Conduct the population survey at Hemlock Bar every two years.

TABLES

Table 3.1. Mean CPUE (fish·minute⁻¹) for 20 species captured during electrofishing sampling from 2002-2016. Values shown are separated by species, Zone and Period and denote mean ± standard deviation. Taxa present in the table include: Brown Bullhead (BBH), Bluegill (BLG), Brook Trout (BKT), Brown Trout (BRT), Burbot (BUR), Black Crappie (BC), Largemouth Bass (LMB) 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), Smallmouth Bass (SMB), Westslope Cutthroat Trout (WCT), and Yellow Perch (YEP). Shaded portions of the table highlight LSS, MWF, and RBT, which are the three primary indicator species for the nutrient addition project.

	<u>Control Zone</u>		<u>Nutrient Addition Zone</u>		<u>Downstream Zone</u>	
	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 ± 0.01	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	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
BRT	0.00 ± 0.01	0.02 ± 0.02	0.00 ± 0.01	0.01 ± 0.02	0.00 ± 0.00	0.00 ± 0.00
BUR	0.00 ± 0.00	0.00 ± 0.01	0.00 ± 0.00	0.00 ± 0.01	0.00 ± 0.00	0.00 ± 0.01
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
LMB	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 ± 0.07	0.00 ± 0.01	0.04 ± 0.07	0.00 ± 0.00	0.00 ± 0.00
LNS	0.01 ± 0.03	0.01 ± 0.04	0.01 ± 0.01	0.02 ± 0.04	0.05 ± 0.05	0.02 ± 0.24
LSS	0.46 ± 0.22	0.42 ± 0.66	0.53 ± 0.16	1.02 ± 0.65	0.47 ± 0.23	0.60 ± 0.47
MWF	2.25 ± 0.99	3.20 ± 2.35	3.68 ± 1.01	7.23 ± 2.38	0.18 ± 0.18	0.21 ± 0.25
NPM	0.13 ± 0.03	0.19 ± 0.18	0.14 ± 0.04	0.22 ± 0.17	1.53 ± 0.53	1.55 ± 2.38
PMC	0.05 ± 0.06	0.10 ± 0.06	0.03 ± 0.04	0.03 ± 0.05	1.18 ± 0.75	0.96 ± 2.08
PMK	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01	0.01 ± 0.03
RBT	0.37 ± 0.10	0.80 ± 0.36	0.29 ± 0.18	0.59 ± 0.35	0.05 ± 0.05	0.06 ± 0.07
RSS	0.16 ± 0.15	0.20 ± 0.28	0.10 ± 0.10	0.24 ± 0.23	0.87 ± 0.28	0.91 ± 1.08
SCU	0.00 ± 0.00	0.01 ± 0.03	0.00 ± 0.01	0.01 ± 0.03	0.02 ± 0.02	0.02 ± 0.03
SMB	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
WCT	7.77 ± 15.49	0.02 ± 0.00	0.01 ± 0.01	0.01 ± 0.02	0.01 ± 0.02	0.00 ± 0.07
YEP	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01	0.03 ± 0.08

Table 3.2. Mean BPUE (kg of fish-minute⁻¹) for 20 species captured during electrofishing sampling from 2002-2016. Values shown are separated by species, Zone and Period and denote mean ± standard deviation. Taxa present in the table include: Brown Bullhead (BBH), Bluegill (BLG), Brook Trout (BKT), Brown Trout (BRT), Burbot (BUR), Black Crappie (BC), Largemouth Bass (LMB) 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), Smallmouth Bass (SMB), Westslope Cutthroat Trout (WCT), and Yellow Perch (YEP). Shaded portions of the table highlight LSS, MWF, and RBT, which are the three primary indicator species for the nutrient addition project.

	<u>Control Zone</u>		<u>Nutrient Addition Zone</u>		<u>Downstream Zone</u>	
	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	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
BRT	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
BUR	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.01	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
LMB	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	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
LNS	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.03	0.01 ± 0.01	0.01 ± 0.01
LSS	0.28 ± 0.15	0.28 ± 0.15	0.37 ± 0.14	0.91 ± 0.56	0.21 ± 0.08	0.32 ± 0.26
MWF	0.42 ± 0.18	0.51 ± 0.17	0.49 ± 0.21	0.71 ± 0.35	0.00 ± 0.01	0.00 ± 0.00
NPM	0.02 ± 0.01	0.03 ± 0.01	0.04 ± 0.03	0.04 ± 0.03	0.06 ± 0.02	0.06 ± 0.02
PMC	0.01 ± 0.01	0.01 ± 0.01	0.00 ± 0.01	0.00 ± 0.01	0.08 ± 0.04	0.06 ± 0.06
PMK	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
RBT	0.08 ± 0.02	0.14 ± 0.05	0.06 ± 0.04	0.11 ± 0.07	0.01 ± 0.01	0.01 ± 0.01
RSS	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.01 ± 0.01
SCU	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
SMB	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
WCT	0.01 ± 0.00	0.01 ± 0.01	0.00 ± 0.01	0.01 ± 0.01	0.00 ± 0.01	0.00 ± 0.00
YEP	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Table 3.3. Mean W_r for Mountain Whitefish (MWF) and Rainbow Trout (RBT) from 2002-2016. Values shown are separated by species, zone, and period and denote mean ± standard deviation.

	<u>Control Zone</u>		<u>Nutrient Addition Zone</u>		<u>Downstream Zone</u>	
	Pre	Post	Pre	Post	Pre	Post
MWF	92.8 ± 1.5	88.4 ± 5.5	85.9 ± 6.2	87.0 ± 5.2	78.5 ± 11.6	73.1 ± 12.3
RBT	90.5 ± 3.7	91.5 ± 3.1	87.8 ± 4.2	89.1 ± 6.0	81.4 ± 7.2	82.0 ± 6.0

Table 3.4. Historical population estimates and upper (Upper) and lower (Lower) 95% confidence limits for Mountain Whitefish, Rainbow Trout, and Largemouth Sucker.

Year	<u>Mountain Whitefish</u>			<u>Rainbow Trout</u>			<u>Largemouth Sucker</u>		
	N	Lower	Upper	N	Lower	Upper	N	Lower	Upper
1980	16,084	-	-	-	-	-	-	-	-
1981	13,965	-	-	-	-	-	-	-	-
1993	3,440	-	-	98	-	-	-	-	-
1994	6,953	-	-	135	-	-	-	-	-
1998	4,043	3,068	5,459	203	146	295	-	-	-
1999	6,357	4,373	9,611	203	132	331	1,735	708	4,339
2004	8,077	5,994	11,160	332	193	623	2,186	994	5,467
2008	17,569	14,684	21,028	598	409	913	7,540	3,078	18,852
2011	26,385	18,267	39,579	682	323	1,577	14,903	4,516	27,098
2014	11,148	8,148	15,692	512	353	776	9,899	6,140	16,851
2016	9,763	7,914	12,047	653	492	888	9,017	6,011	14,170

FIGURES



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

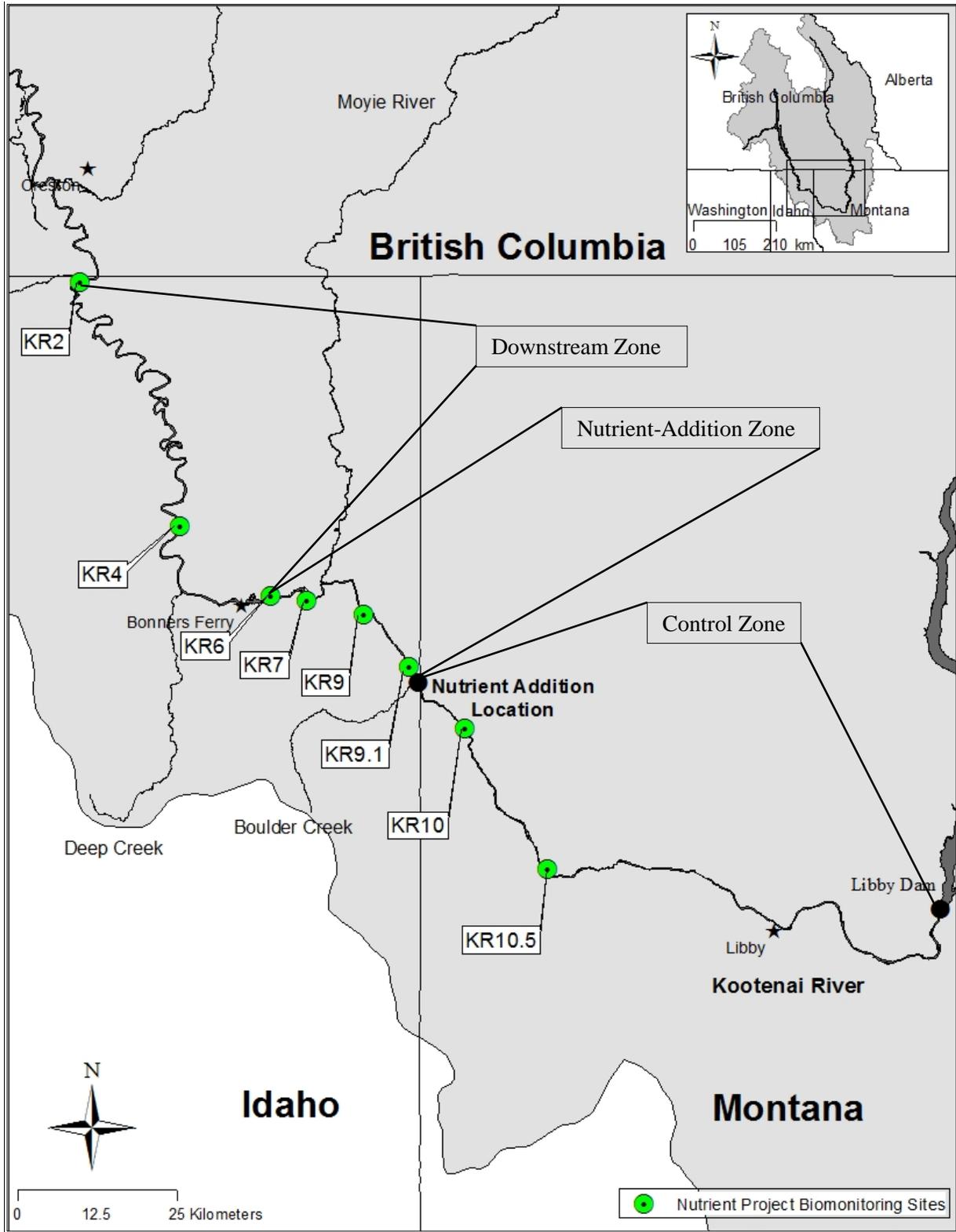


Figure 3.2. Kootenai River ecosystem study area and approximate locations of biomonitoring sites and the three river zones.

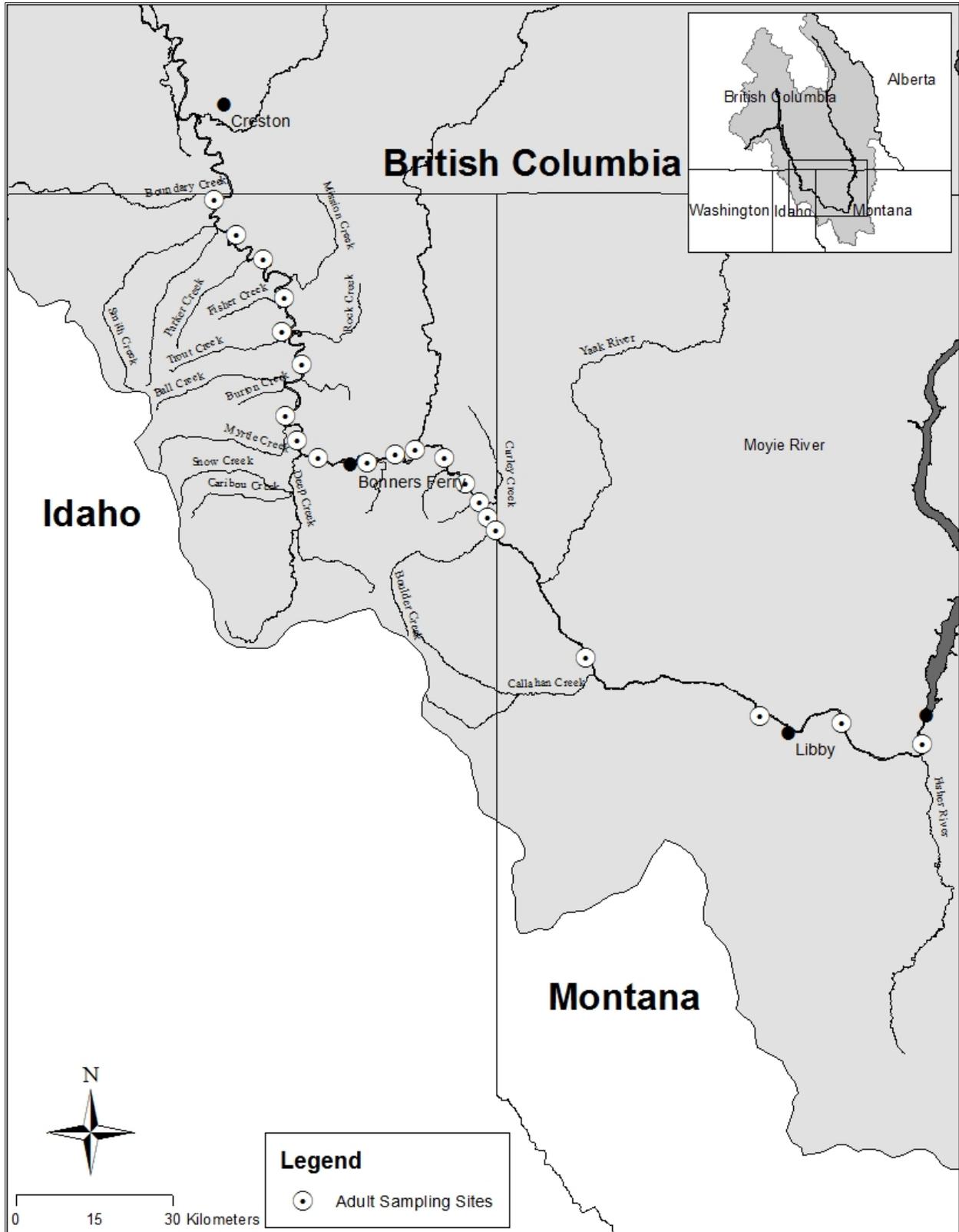


Figure 3.3. Locations of tributaries to and sites in the mainstem Kootenai River, Idaho and Montana that were sampled during Phases 1 and 2 of the otolith microchemistry study.

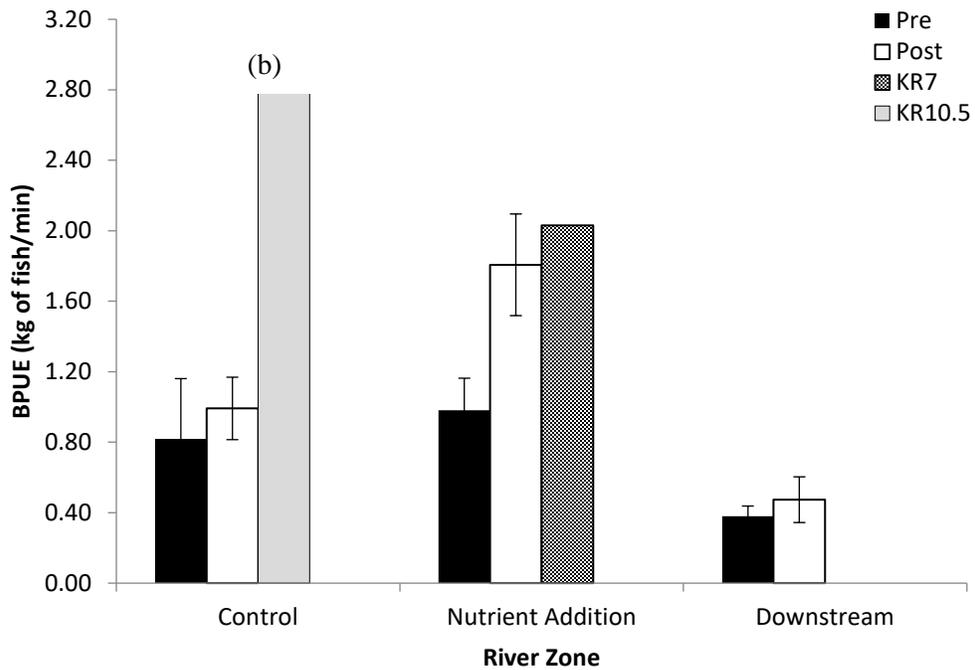
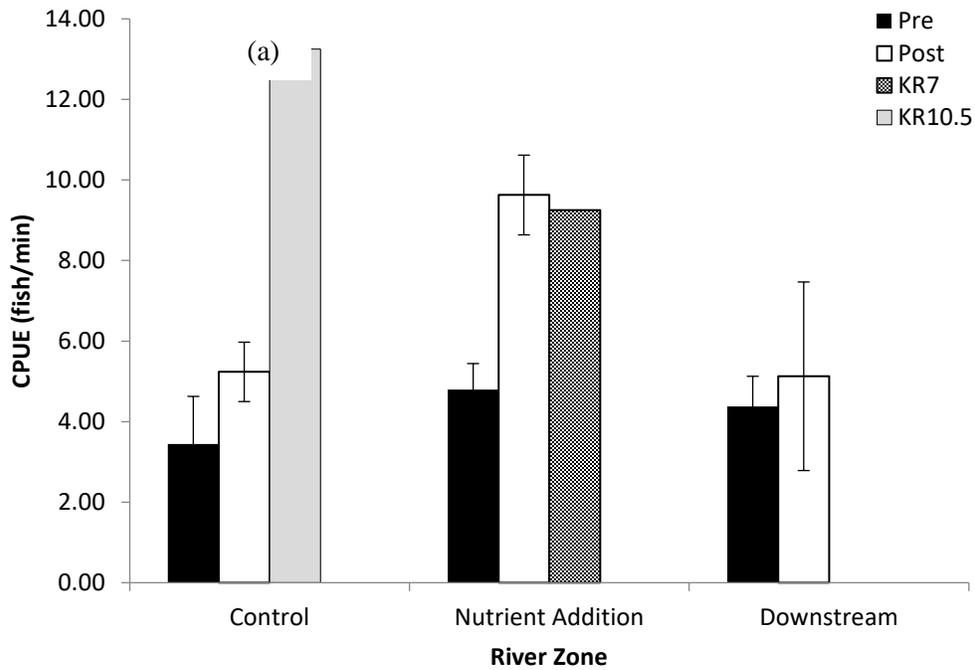


Figure 3.4. Mean total (i.e., all species, combined) CPUE (a) and BPUE (b) from 2002-2016. Data include all three river zones, segregated by period. The hatch-marked bar represents mean total CPUE and BPUE from site KR7 (2014-16), and the light gray bar represents values from site KR10.5 (2015-16). Error bars represent 95% confidence intervals.

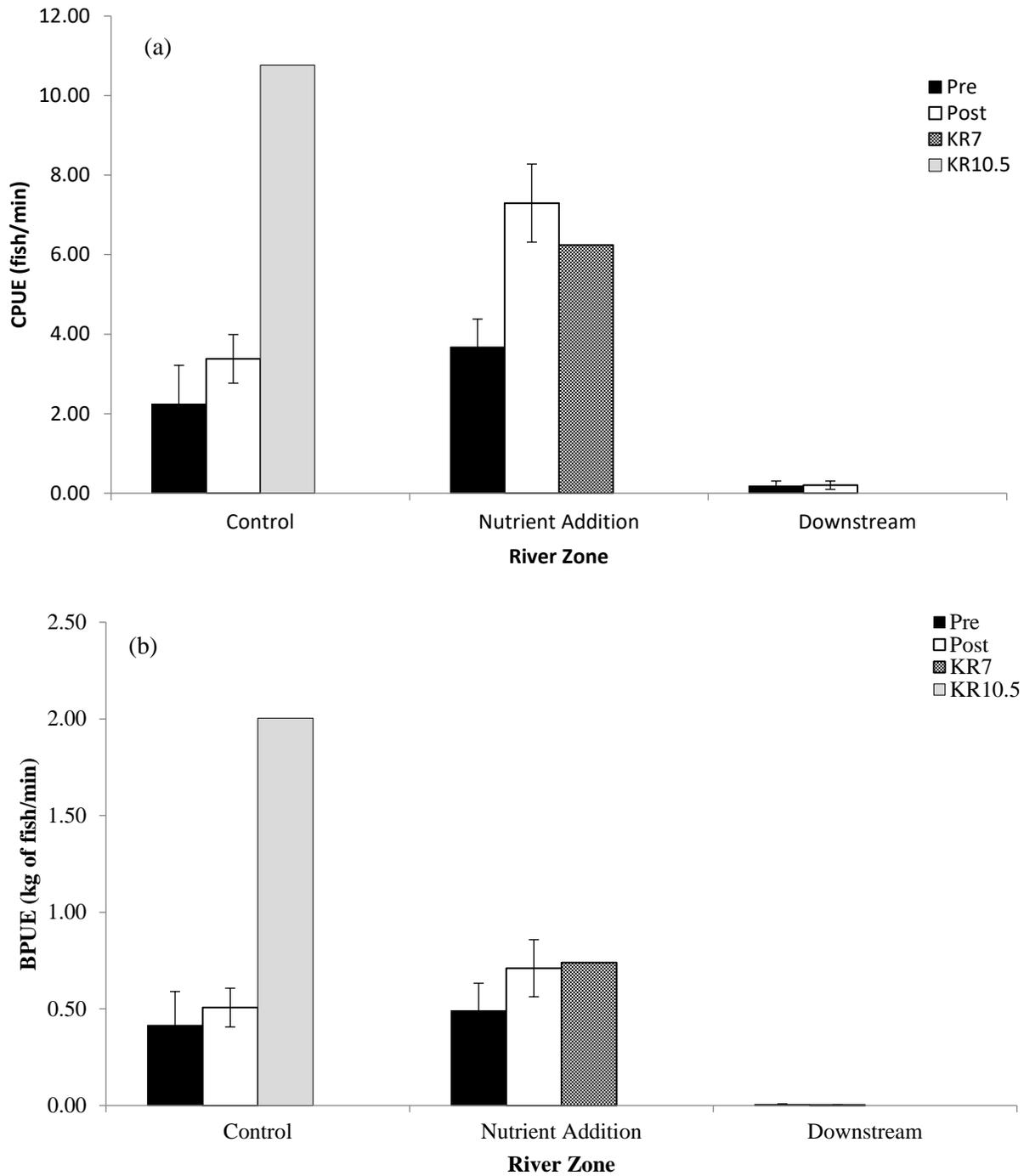


Figure 3.5. Mean CPUE (a) and BPUE (b) of Mountain Whitefish from 2002-2016. Data include all three river zones, segregated by period. The hatch-marked bar represents mean CPUE and BPUE from site KR7 (2014-16), and the light gray bar represents values from site KR10.5 (2015-16). Error bars represent 95% confidence intervals.

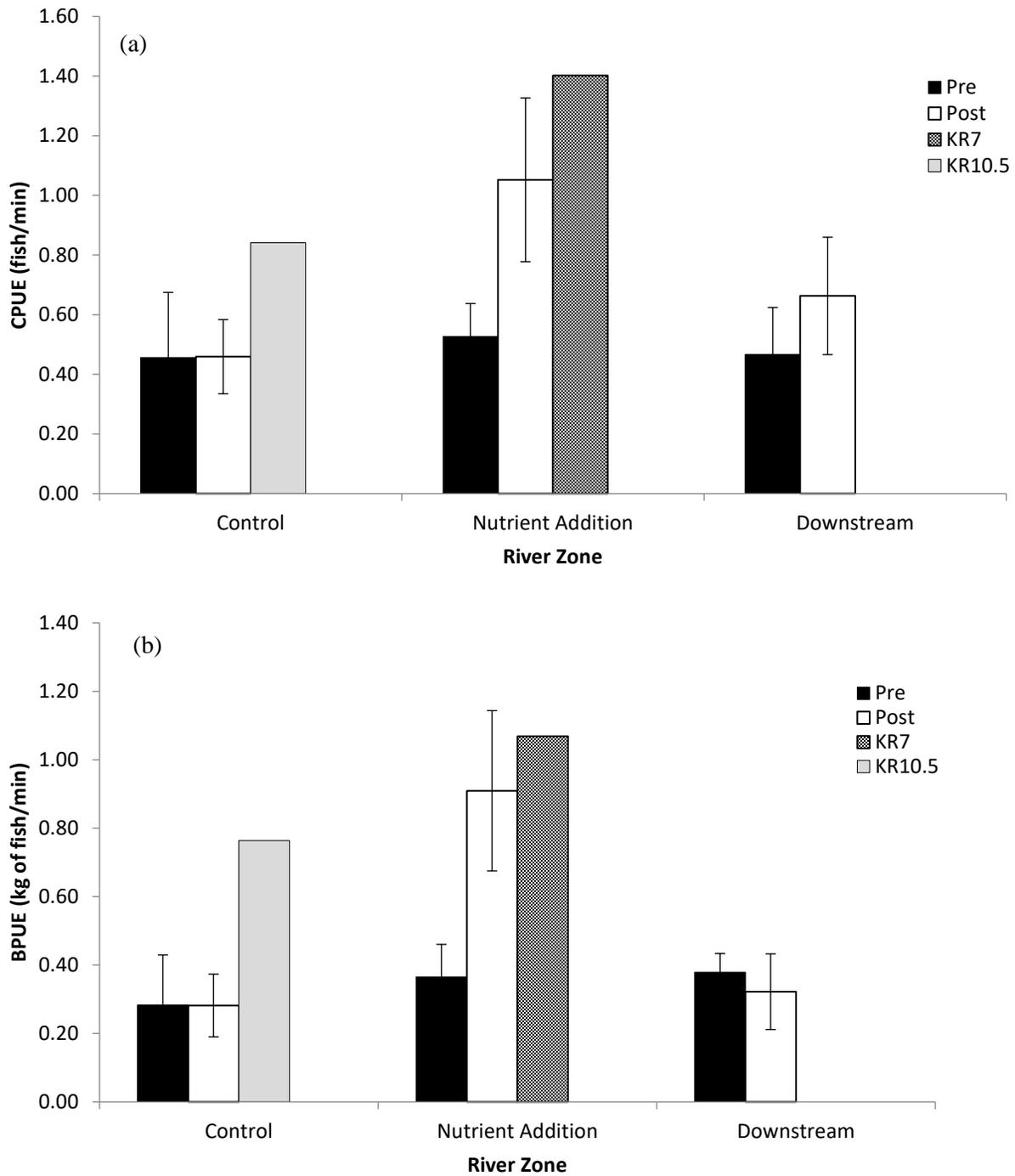


Figure 3.6. Mean CPUE (a) and BPUE (b) of Largescale Suckers from 2002-2016. Data include all three river zones, segregated by period. The hatch-marked bar represents mean CPUE and BPUE from site KR7 (2014-16), and the light gray bar represents values from site KR10.5 (2015-16). Error bars represent 95% confidence intervals.

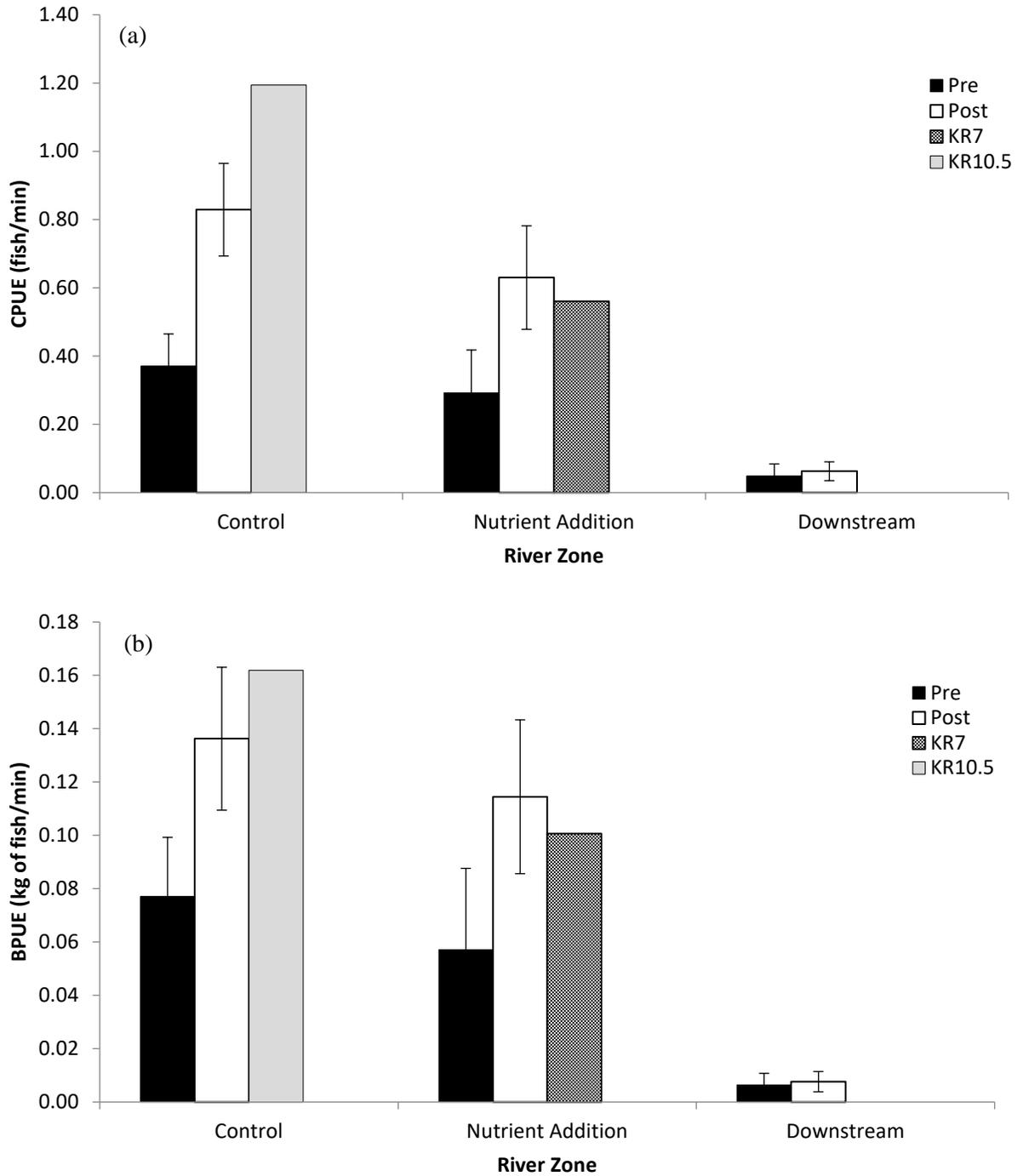


Figure 3.7. Mean CPUE (a) and BPUE (b) of Rainbow Trout from 2002-2016. Data include all three river zones, segregated by period. The hatch-marked bar represents mean CPUE and BPUE from site KR7 (2014-16), and the light gray bar represents values from site KR10.5 (2015-16). Error bars represent 95% confidence intervals.

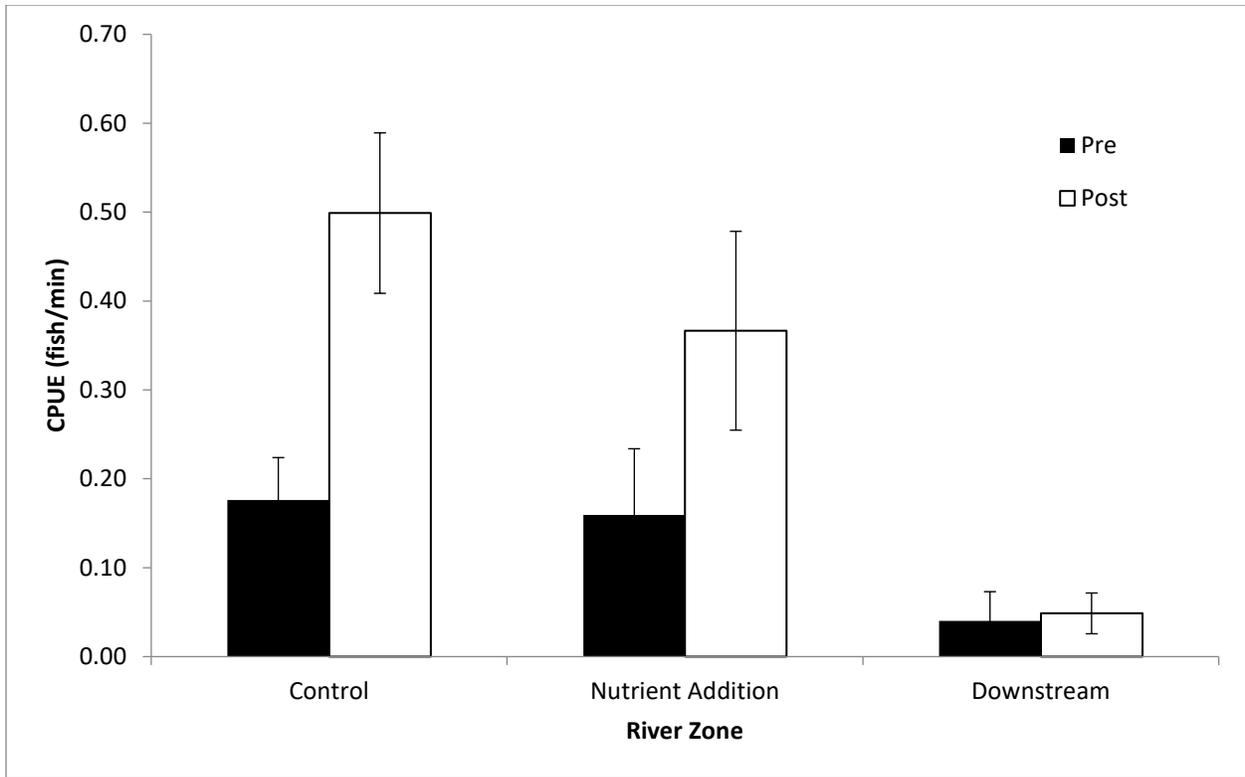


Figure 3.8. Mean CPUE of sexually immature Rainbow Trout (i.e., ≤ 250 mm) from all three river zones, segregated by period. Years represented are 2002-2016. Error bars represent 95% confidence intervals.

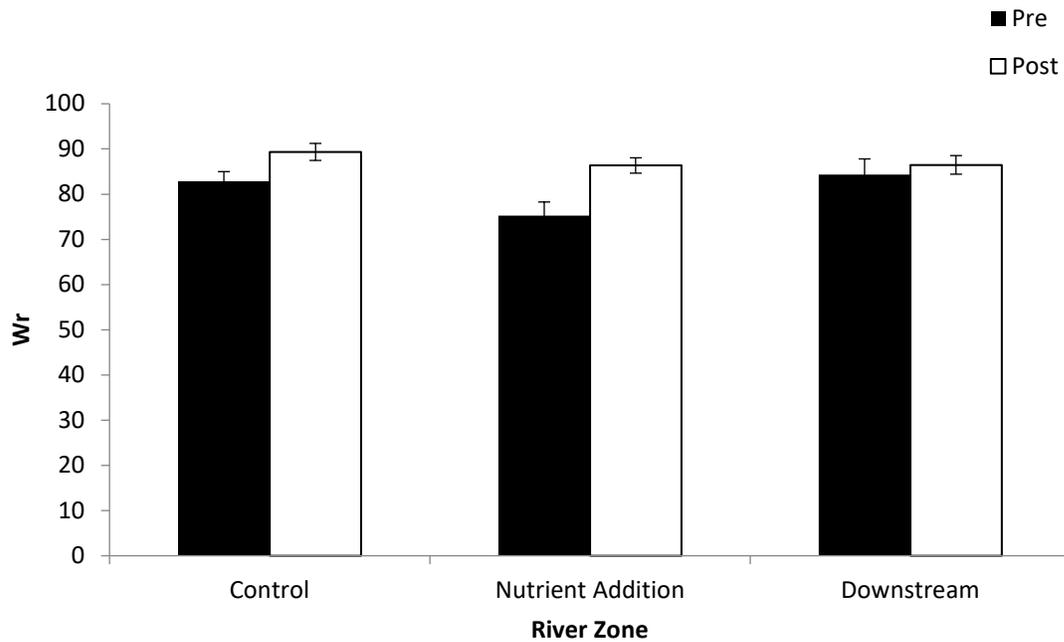


Figure 3.9. Mean W_r for Largescale Sucker from all three river zones, segregated by period. Years represented are 2002-2016. Error bars represent 95% confidence intervals.

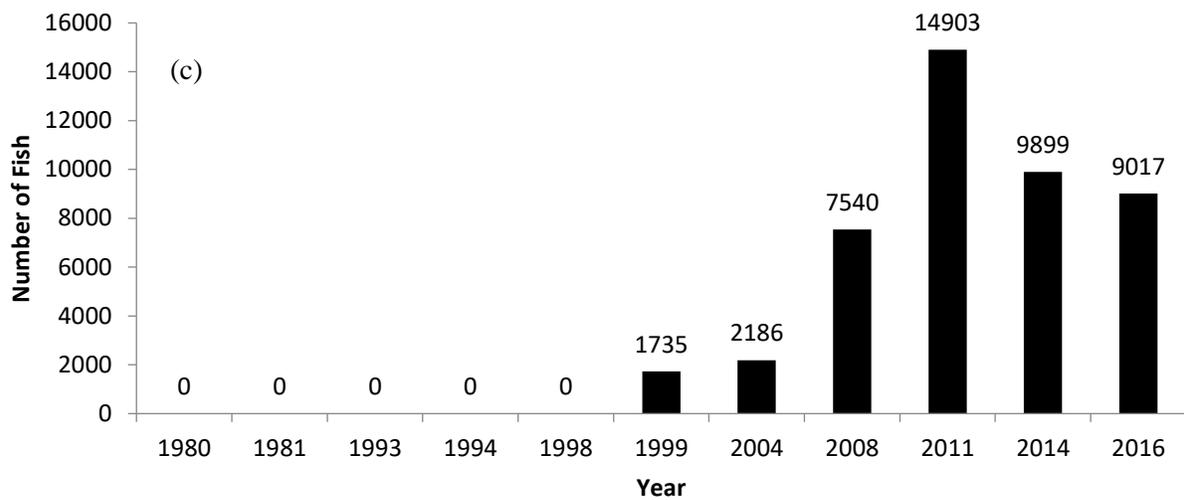
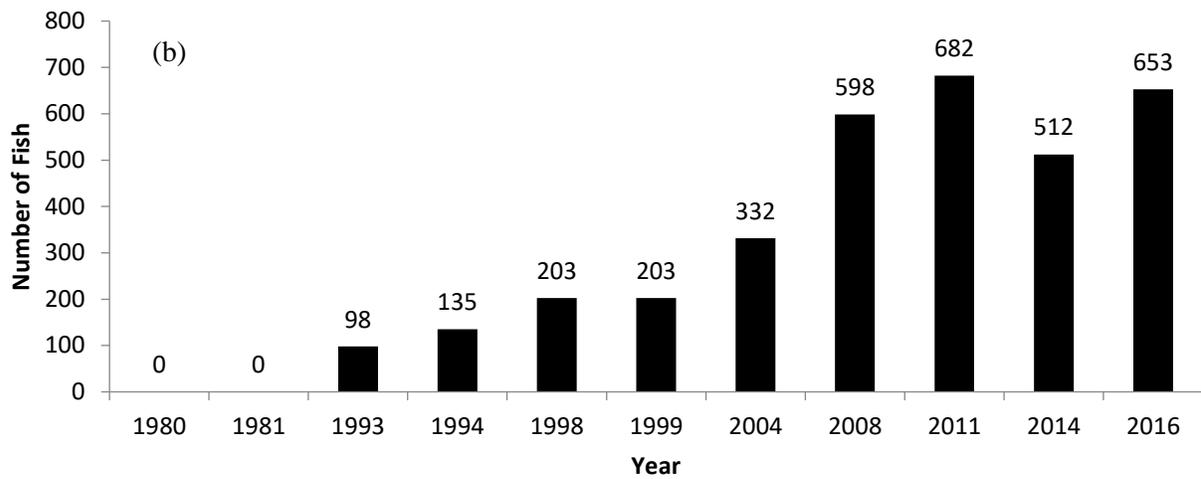
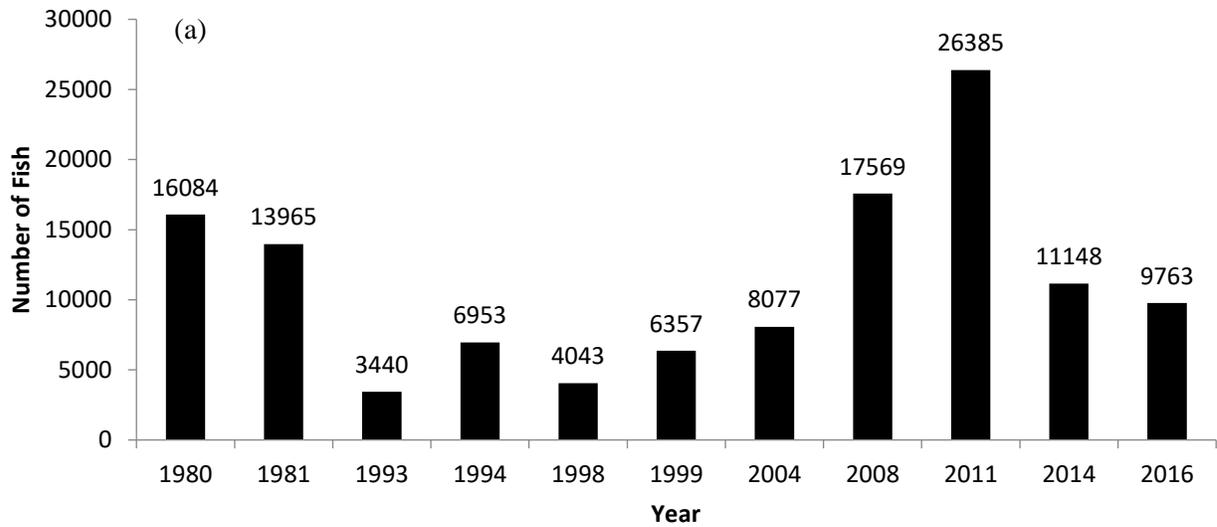


Figure 3.10. Historical population estimates for Mountain Whitefish (a), Rainbow Trout (b), and Largescale Sucker (c) at Hemlock Bar.

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2017 BIOP REPORT

As per BPA instructions, this Biological Opinion (BIOP) report is attached to the end of this document to fulfill in-season reporting requirements for the previous calendar year. This report serves as a link to the Libby BIOP, which can be found on BPA's Columbia Basin Fish and Wildlife website (www.cbfish.org).

SECTION 1: IMPLEMENTATION

Operation of Libby Dam for hydropower and flood control has significantly changed seasonal flows in the Kootenai River relative to historical flow regimes. Generally, both springtime peak flows and base flows are lower than what they were prior to the installation of Libby Dam. Additionally, during the last 100 years almost all of the lower portion of the river below Bonners Ferry, Idaho has been diked. These two factors, dam operations and dike construction, prevent the Kootenai River from inundating most of its historic floodplains which has caused the river to become incised and deeply channelized. The channelization of the Kootenai River has caused the degradation of spawning and rearing habitats that Kootenai River White Sturgeon (*Acipenser transmontanus*) rely on. Habitat degradation and flow alteration have created unfavorable ecological conditions for consistent, successful Kootenai River White Sturgeon recruitment. Since the installation of Libby Dam there has only been two years with high recruitment rates of juvenile White Sturgeon (1974 and 1991). Both these years experienced exceptional precipitation and river discharge.

The Kootenai River White Sturgeon was listed as an Endangered Species in September of 1994. The listing was consistent with the population abundance and genetic status. Genetic analysis of the Kootenai River White Sturgeon in 1991 indicated this population was genetically distinct from other populations of Sturgeon in the Columbia Basin. At the request of the Kootenai River White Sturgeon Steering Committee (comprised of representatives from the agencies and tribes), the U.S. Army Corps of Engineers has provided mitigative, experimental flows for White Sturgeon spawning and rearing since 1991. The objective of this investigation is to determine flow and habitat conditions that will affect recovery of this population. This study is supported by, and adheres to conditions set by the Recovery Plan for the Kootenai River White Sturgeon.

This information is presented in accordance with the lettered or numbered items identified in the "Special Terms and Conditions" for the Subpermit (dated October 14, 1997). The USFWS has issued three opinions on Libby Dam (1995, 2000, and 2006). In accordance with these Biological Opinions, this project is listed as necessary and appropriate. The 2006 Libby BiOp specifically lists Reasonable and Prudent Alternatives (RPA) that our IDFG sponsored program is directly responsible for either for implementation or monitoring and evaluation of mitigation actions. A list and description of the RPA components and their associated actions is listed in <http://www.cbfish.org/Project.mvc/Display/1988-065-00>. Results from our 2017 investigations are listed below.

SECTION 2: RESULTS

Adult Movements

In 2017, as in other years, Idaho Department of Fish and Game (IDFG) personnel monitored spawning migrations of sonic-tagged Sturgeon in the Kootenai River downstream and upstream of Bonners Ferry (Figure 1). IDFG deployed 89 acoustic receivers throughout Kootenay Lake and Kootenai River to detect the movements of tagged individuals. Fifty-three sonic-tagged adult Sturgeon were detected above Shorty's Island: 48 females and 5 males (river kilometer [RKM]) 230; Table 1). Of these 53 Sturgeon, 34 were documented as far upstream as Ambush Rock (RKM 244.5), and 25 adult Sturgeon (22 females and 3 males) were detected in the braided reach above the Highway 95 Bridge (RKM 246), mainly during the 2017 spawning season. The furthest upstream migration was by a single adult female just beyond the Moyie River (RKM 258.5). In addition, six hatchery reared juvenile Sturgeon were documented above the Highway 95 Bridge in Bonners Ferry during the spawning period and throughout the summer. Compared to previous years, 2017 saw a larger proportion of the tagged spawning population (defined as adults that are detected at Shorty's Island during the spawning season) compared to previous years. In fact, 2017 saw nearly 20% increase in the number of tagged adult spawners that migrated above Bonners Ferry compared to the average of the previous seven years (Figure 2). It is unclear as to whether the increase in upstream movement extents of adult Kootenai Sturgeon is due to the increased flows in 2017 or due to newly constructed habitat projects. During the last five years the Kootenai Tribe of Idaho (KTOI) has implemented several habitat restoration projects above Bonners Ferry. One of the goals of these projects was to provide attractive holding habitat for spawning Kootenai Sturgeon. Although there was a large number of tagged adults that moved above Bonners Ferry, it remains unknown if these fish actively spawned in these locations. In the next few years we expect some of the hatchery origin juveniles to begin to join the spawning population. Further work in 2018 is aimed at understanding the size at maturity for these hatchery origin individuals.

Spawning and Early Life History Monitoring

Sturgeon spawning habitat quality is critical to successful egg deposition and hatching. Poor Sturgeon spawning habitat quality in the Kootenai River has been identified as a potential limiting factor responsible for lack of recruitment into the population for over 30 years. IDFG systematically monitors egg deposition location with artificial substrate egg mats in the Kootenai River and in 2017 reported that a total of 262 eggs were collected between June 1 and June 26 (Table 2). Of the eggs captured in 2017, 22 were collected in the straight reach near RKM 245.8; 145 were collected at the Myrtle Creek area (RKM 234.0); and 95 were collected at Shorty's Island. Sampling effort was similar between the Myrtle Creek and Shorty's Island sites. We did not sample for eggs upstream of Bonners Ferry due to high flows and a lack of adequate sampling locations.

In addition to monitoring egg deposition, IDFG also tracks hatching success through larval sampling. Larval sampling is done through the use of passive drift nets that are anchored to the substrate. Sampling was focused below Shorty's Island and Myrtle Creek spawning locations as well as in the straight reach. In 2017, despite 4560 hours of total fishing effort between June 26 and July 19, only a single larval Sturgeon was captured at the Myrtle Creek site (Table 2). Larval sampling in 2017 was especially difficult due to the high debris load in the water column created by higher than average flows.

Gillnetting by IDFG and British Columbia Ministry of Forest Land and Resource Operations (BCMFLNRO) personnel was conducted from Ambush Rock downstream to Kootenay Lake, including both the Kootenay River delta and the Lardeau River delta at the north end of the lake to determine density, distribution, and length-frequency and age distribution of hatchery reared and wild juvenile white Sturgeon in the system. Sampling in 2017 occurred between July 24 and September 17. We used gill nets with panels including 2.5, 5.1, and 7.6 cm bar mesh. Soak time for our gill net sampling ranged from 60 to 90 minutes to minimize risk of accidental mortality. All Sturgeon were measured, weighed, scanned for PIT tags, and released. If no PIT tag was found, a new tag was implanted in the individual. Combining IDFG and BCMFLNRO efforts, a total of 1645 (538 in BC) juvenile Sturgeon were captured in gillnets in 2017 (Table 2). Eight of the sampled juveniles were of wild origin and all of these fish were captured in Canadian waters. All wild origin fish were aged by removing a portion of the pectoral fin ray. There were no mortalities.

Sampling in Idaho and Canada by IDFG or BCMFLNRO for adult Sturgeon commenced on March 17 and continued through October 26, 2017. Two gear types were used: rod and reel angling, and setlines with 12/0, 14/0, and 16/0 circle hooks set with six to eight hooks per line. A total of 131 wild adult Sturgeon were captured with setlines and angling in 2017 (Table 2). Additionally, 9 adult hatchery reared Sturgeon (fish released as juveniles that grew into the adult 120 cm total length size range) and 45 hatchery reared juvenile Sturgeon were captured in 2017. Of the 131 wild adult Sturgeon captured in Idaho and BC in 2017, 119 (91%) were recaptures from previous years. Twelve adult Sturgeon (10 females and 2 males) were tagged with special Vemco V16 VPS sonic transmitters in 2016 as part of a telemetry system deployed to evaluate habitat use of the Shorty's Island and Myrtle Creek Substrate Enhancement Pilot Projects (SEPPs). There were no mortalities from telemetry tagging.

SECTION 3: FUTURE MANAGEMENT

Based on the U.S. Fish and Wildlife Service's (Service) February 2006 Biological Opinion (2006 BO) on operations of Libby Dam and the May final April-August volume runoff forecast of 8.19 million acre-feet, we are within a Tier 5 operations year for Kootenai River White Sturgeon. The minimum recommended release volume for Sturgeon conservation in a Tier 5 year is 1.2 million acre-feet, and we recommend the following procedures for discharge of at least this minimum volume from Libby Dam: the precise means that will be utilized to meet these objectives are largely dependent on real-time conditions and in-season management. It is not possible to develop a single definitive recommendation for a Sturgeon operation at this time due to the uncertainties in the forecast, and shape and volume of inflow. Given these uncertainties, the Service has developed the following guidelines for Sturgeon operations in 2017: The 2017 Sturgeon operations at Libby Dam will consist of one period of pre-peak flow (20,000 cubic feet per second [cfs]), one period of peak flow (powerhouse capacity), one period of interim flow maintenance (~18-21 kcfs at Bonners Ferry), a second period of peak flow (powerhouse capacity), and one period of post-peak flow (ramp-down). The ramp-down from peak operation will occur within 2006 BO ramping rates, and will exhaust remaining Sturgeon volume following the second period of peak flow augmentation. Specific details on 2017 Libby dam Sturgeon operations is available at: http://www.nwd-wc.usace.army.mil/tmt/sor/2016/0511_2016_USFWS_Libby_Sturgeon_SOR.pdf.

One of the primary objectives of this project is to provide conditions that will enable Sturgeon to migrate to, and spawn over, rocky substrates that exist upstream of Bonners Ferry. Since the results from the 2013-2016 operations showed a higher proportion of tagged Sturgeon

migrated above Bonners Ferry than in previous years, the two peak approach warranted at least another year of testing. Due to the high water supply in 2017 resulting from favorable snowpack conditions, the double peak augmentation operations in 2017 was thought to be the best available option. The 2017 operations allowed 47% of tagged adult Sturgeon (25 adults) to move above Bonners Ferry. Comparatively, 36% of tagged adult Sturgeon group moved above Bonners Ferry in 2016, and 28% migrated above Bonners Ferry in 2015. Although we are still constrained by Libby Dam operations and flood control issues at Bonners Ferry, small-scale flow management actions are important for understanding how Sturgeon respond to different flow regimes and eventually may allow us to increase the proportion of the spawning population that migrate above Bonners Ferry.

The Vemco telemetry array (which currently consists of 89 receivers throughout Kootenay Lake and Kootenai River) has been deployed in the Kootenai River for 14 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 some physical habitat variables (e.g. amount of spawning habitat, number of deep pools, etc.) and attempt to develop a predictive model to help determine how to enhance White Sturgeon movement above Bonners Ferry. There is also a need to evaluate how the recently completed habitat projects in the braided reach have affected Sturgeon migration movements and behavior. For instance, there are now several large, deep pools that were dug in the braided reach with the intention to provide adult Sturgeon holding habitat. It remains unknown how these pools are used by spawning Sturgeon. Our telemetry array should be equipped to answer that question beginning in the spring of 2018.

In addition to spawning habitat use, we have moved forward on analysis of specific metrics from hatchery produced juveniles to aid in determining population demographics as it relates to stocking strategies. With the anticipated continued stocking of hatchery-reared Sturgeon, it is evident that these fish can fulfill a continued useful role for research. One of our key objectives is to make adequate recommendations to stocking numbers so that it achieves the needs of maintaining the population while not negatively affecting wild production. There is a need for evaluating changes in growth rates over time to determine what, if any, effects stocking density or other habitat improvements are having on growth. This is done by removing fin ray sections from a subsample of juvenile Sturgeon and using those in incremental growth modeling. Although this is minimally invasive to juvenile Sturgeon, it has been proven to not adversely affect survival or swimming performance. In 2015, we began collecting ten fin rays from each brood year, with five from juvenile Sturgeon collected upstream of rkm 123 in river sections, and five from juveniles residing in the Kootenay Lake delta. Analysis will be done through the University of Idaho assisting us on the incremental age and growth as it relates to changes in density and habitat improvements.

Table 1 -The extent of movement of tagged adult Kootenai River white Sturgeon since 2005. RKM 229 is at Shorty's Island. RKM 264 is upstream of the Moyie River. The blue shaded area represents the Straight Reach (RKM 240-246); the green shaded area represents the Braided Reach (RKM 246-257). Fish movement is depicted as numbers of fish observed at receivers located at a particular RKM; e.g., 25 of 47 fish detected at RKM 230.1 (Straight Reach) in 2017 were also observed at RKM 246.7 (Braided

RKM	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
230.1			28	29	24		35	34	43	44	49	49	47
230.5	13	31											
231											46		
232	16	29	27	28	22		34	34	43	45		48	53
235			28	25	21	36	35	32	42		48		
235.2	15	27											
239	12	23											
240			22	25	16	32	25	27		35	47		
240.3											38		
240.7			21	23		31	25	25	34	34		36	40
240.9											38		
243.5		15	13	19		24	19	19	22	23	29	29	36
244.5		12	0										
244.7			14	18	7	20	16	16	20	21	26	29	34
245		3	0										
245.5	7	0											
245.6			13	15	7	13	11	13	16	19	23	23	28
245.7						15	13	14	15	20	23	25	29
245.8		9	0										
245.9		9	0										
246						9	13	13	11	13	14	17	24
246.6		5	7	13	3	7	6	10	12	11	11	18	25
246.7		5	0										
246.8								7	0	10	9	16	25
247.3		1	0										
247.99													13
248	0	0			0	0	1	2	1	2	0	0	0
248.1						2	3	5	6				
248.2					0	0							
248.5						2	4	4	6	3	1	3	
248.6		2	0										
248.8		0											
249.5						0	0	2	2	0	0	0	3
249.55													2
249.6		0	1										
250				1	0	0	0	0	0	0	0	0	0
250.4									0	0	1	1	2
250.7			0	4	1	0							
250.9				0	1	1	0	0	1	0	0		
253.4			0	2	1	1	1	0	1	0	1	2	2
254.5					0	0	1	0	1	0	0	0	0
255.1				0	0	1	1	0	1	0	1	0	2
256	0	0	0										
256.1			0										
257.5				0	1	1	0	0	1	0	1	0	1
258.7								0	0	0	0	0	0
264			0	1	1	0	1	0	1	0	1	0	1

Table 2 - Summary of IDFG and BCMFLNRO Kootenay Lake and Kootenai River White Sturgeon sampling efforts in 2017 under US Fish and Wildlife Service Permit 702631.

Target	Sampling Dates	Numbers Caught					Mortality	Gear Type
		Adults	Juveniles	Larvae	Eggs			
Adult	3/17 - 10/26	145	45	-	-	0	Rod and Reel, Set lines (12/0, 14/0, 16/0 sized hooks)	
Juvenile	7/24 - 9/17	5	1645	-	-	0	Gill Net (2", 4", 6" stretch mesh)	
Egg	6/1 - 6/26	-	-	-	262	262	Artificial substrate egg mats	
Larvae	6/26 - 7/19	-	-	1	-	0	Paired larval plankton nets	
Totals		150	1690	1	262	262		

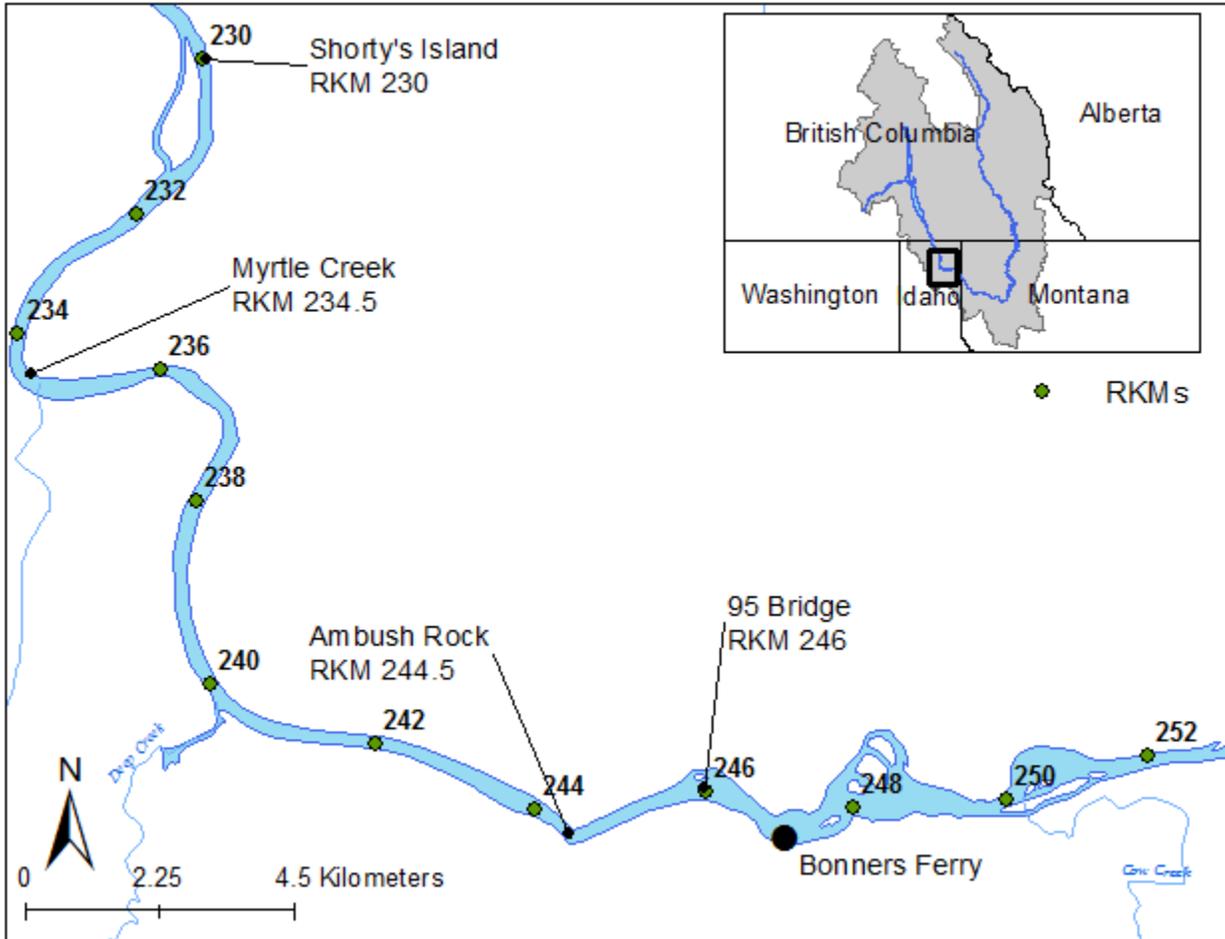


Figure 1 - Kootenai River white Sturgeon spawning reach near Bonners Ferry, Idaho. Pictured above are the river kilometers (RKM) where the majority White Sturgeon spawning occurs. RKM delineations begin at the north end of Kootenay Lake and increase as one moves up stream. USFWS Critical Habitat designation for Kootenai River white Sturgeon is RKM 230 (Shorty's Island) to RKM 158.5 (Moyie River confluence).

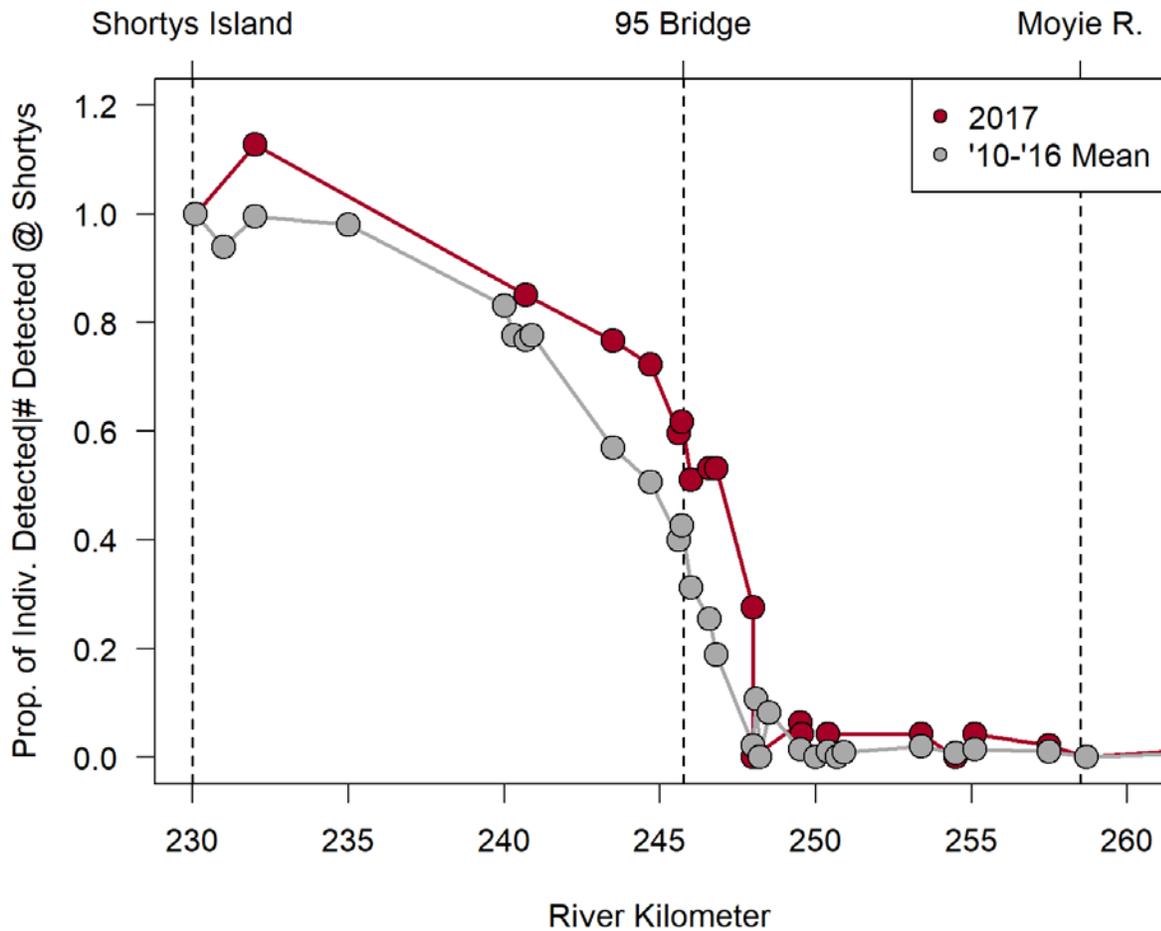


Figure 2 - This plot shows the proportion of individuals that made it to a specific rkm given they had made it to Shorty's Island prior in 2017. Data was collected from adult Kootenai Sturgeon tagged with acoustic transmitters. Shorty's island is the most downstream known spawning site, thus fish that make it to rkm 230 are considered part of the spawning population. For instance, about 50% of all the fish that made it to Shorty's Island in 2017 made it to rkm 246. This demonstrates how spawners (in terms of yearly proportions) utilize upstream habitats. The red line indicates the proportions from 2017 and the grey line shows the mean proportions from the previous seven years.

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