2016-17 lower Kootenay burbot summary: Moyie Lake and Kootenay Lake/River

Sarah Stephenson
&
Valerie Evans

BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development
401 – 333 Victoria Street
Nelson, BC V1L 4K3

April 3, 2018

The Bonneville Power Administration (Northwest Power and Conservation Council Fish and Wildlife Program through the Idaho Department of Fish and Game and the Kootenai Tribe of Idaho) provided funding for much of this project.

Table of Contents

List of Tables

List of Figures

List of Appendices

Acknowledgements

Many thanks to all that were involved in this work. Thanks to colleagues at FLNR for support with field assistance, data compilation and reporting: Matt Neufeld, Jeff Burrows, Marley Bassett, Kathrine McGlynn and Stephanie Whyte. Many thanks to the following co-partners at Kootenai Tribe of Idaho who provide administrative support, field and technical direction as well as data collection: Sue Ireland , Shawn Young, Chris Lewandowski, Nathan Jensen, Guadalupe Ponce, Desire Aitken, Daniel Craig, Brian Michaels, Cara Holem-Ball, Dan Aitken, Brycen Lunger, Chris Miner, Riley Jones, Micheal Barzewski, Mark Elliston and Sarah Clark. Thank you to the following Idaho Fish and Game co-partners who also provide administrative support, field and technical direction as well as data collection assistance: Ryan Hardy, TJ Ross, Dylan Gollen, Dustin Horn, Simon Boycott, Riley Gallagher, Dan Eardley, Jesse McCane and Laura Redfield. Thank you to the following staff from the Aquatic Research Institute with the University of Idaho for supporting restorative efforts with research support: Kenneth Cain, Neil Ashton, Joseph Evavold, Luke Oliver, Tracy Kennedy and Patrick Blaufuss. Furthermore, thank you to Greg Hoffman from the U.S. Army Corps of Engineers and Don Miller with Kootenay Wildlife Services Ltd. for support with field work and data collection. Funding for this program is thanks to the Bonneville Power Administration (Northwest Power and Conservation Council's Fish and Wildlife Program) through the Idaho Department of Fish and Game and the Kootenai Tribe of Idaho.

Introduction

The lower Kootenay burbot (*Lota lota*) population is of special concern, with a range throughout the Kootenay River (spelled Kootenai in the US) in Montana, downstream into Idaho and British Columbia (BC) and into Kootenay Lake in BC. This population supported a popular fishery through the 1960s and 1970s, after which a severe decline of burbot in both the US and Canada resulted in the closure of the Idaho fishery in 1992 and the BC fishery in 1997 (Partridge 1980; Paragamian *et al.* 2000; Paragamian *et al.* 2008; Ahrens and Korman 2002). Likely factors that led this population near extirpation include decreased food availability, overfishing, habitat changes (particularly due to significantly increased winter discharge and temperature changes during the spawning period, and others (Partridge 1983). Presently, Kootenay burbot are Red listed (S1) in BC (BC CDC 2013) and the entire population has been recognized at near extirpation. Subsequently, a multilateral agreement was signed in 2005 to guide work towards Kootenay burbot restoration across their range in Montana, Idaho and BC (KVRI Burbot Committee 2005; Ireland and Perry 2008).

By the early 2000s, the Kootenay burbot population size was deemed by co-managers to be too small to recover on its own, which prompted investigations to develop conservation aquaculture techniques (Baxter *et al.* 2002 a,b; Neufeld and Spence 2004; Neufeld 2005; Jensen *et al.* 2008). Several lakes with healthy burbot populations were evaluated for potential use as broodstock sources and eventually Moyie Lake was identified as a suitable broodstock choice due to genetic similarities and location within the Kootenay River drainage (Powell *et al.* 2008; Neufeld *et al.* 2011b). With the cooperative efforts of Idaho Fish and Game (IDFG), the Kootenai Tribe of Idaho (KTOI), the University of Idaho Aquaculture Research Institute (ARI) and the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNR), annual gamete collection and on site fertilization have been successfully completed on Moyie Lake since 2009.

Releases of hatchery reared burbot into the Kootenay River (including tributaries) and Lake have been completed annually since 2009, including larval, juvenile and adult burbot. Monitoring of hatchery released burbot has been a cooperative effort between IDFG and FLNR and includes hoop net sampling within the Kootenay River (in US and Canada), passive sonic telemetry evaluations, and cod trapping within Kootenay Lake. Since 1994, IDFG has led annual hoop net sampling; until the hatchery program, hoop net catch rates were declining, but in 2011 catch rates started to increase and by 2012 exceeded levels observed prior to 2000 (Rust *et al.* 2017). Catch rates and growth rates suggested hatchery released burbot are adapting and surviving well in the river (Rust *et al.* 2017). Passive acoustic telemetry studies were initiated with the first hatchery releases in 2009 and have identified extensive movements and good survival rates (Neufeld *et al.* 2011a; Stephenson *et al.* 2013; Hardy *et al.* 2015). Data from the telemetered fish suggest that 25% of sub-adults and adults released into the river have used the available habitat within Kootenay Lake (Hardy *et al.* 2015), triggering re-initialization of cod trapping within Kootenay Lake in 2013 to recapture hatchery released burbot and any remnant wild burbot (Stephenson and Evans 2014).

This report includes all of FLNR's burbot sampling efforts in 2016-2017 (April 2016 through March 2017) completed as part of lower Kootenay burbot recovery efforts. The Moyie Lake portion of this report includes a summary of the gamete collections and an update from the passive acoustic telemetry study initiated in 2013. The monitoring and evaluation efforts within the Kootenay River and Lake in BC included in this report are cod trapping and passive sonic telemetry, as well as an update on hatchery releases from 2016. Other monitoring programs include the large hoop netting program completed by IDFG (for 2015-16 results see Rust *et al.* 2017). All monitoring programs are carried out with cooperative efforts from all international co-managers in order to assist in the evaluation of hatchery success as well as to inform the trajectory of the remaining wild population.

Section 1: Moyie Lake gamete collections

1.1 Executive summary

The 2017 Moyie Lake burbot gamete collection efforts were a success due to the cooperative efforts of IDFG, KTOI, ARI and FLNR. This year was the ninth consecutive year of gamete collection from Moyie Lake burbot for the restoration efforts of the Kootenay burbot population. This year sampling occurred between February 13-17 and February 20-24, at a location in the south east corner of the North basin. In total there were 390 burbot captures and gametes were collected from 29 females and 58 males. We collected and fertilized over 7.1 million eggs from 58 different families, meeting the pre-established egg collection target agreed upon at the 2016 Annual Program Review. In total 6.85 million eggs from 56 families were sent to the Twin Rivers hatchery while 243,360 eggs were sent to ARI. The egg viability 48hrs post fertilization at Twin Rivers was on average 89.7%, with only one family that had no survival; the egg estimate at 48hrs was 6.07 million eggs. The egg viability of the five families sent to ARI was 74.4% at hatch (approximately 40 days post fertilization) which equates to approximately 180,000 eggs.

1.2 Introduction

Moyie Lake burbot gamete collection and on site fertilization has been successfully completed annually since 2009. In the last nine years of burbot gamete collection on Moyie Lake there has been continued annual improvement of collection and fertilization methods. These projects have contributed to key data relating to our understanding of basic life history traits of burbot (Neufeld and Spence 2009; Neufeld 2010; Neufeld *et al.* 2011b; Stephenson and Neufeld 2013; Stephenson and Evans 2014, 2015 and 2016). In 2017 we continued to improve our abilities to meet targets established by co-managers at the international lower Kootenay burbot Annual Program Review.

Specifically, this year our objectives were to:

- Collect 7 million eggs from up to 60 families with an aim to use 30 or more females and create family sizes between 90,100 to 180,200 eggs (50-100 mL unfertilized eggs).
    - All eggs will be used for hatchery production at Twin Rivers except for an approximate subsample of five families representing 200,000 eggs which will be sent to ARI for research,
    - Collect genetic samples from all hatchery broodstock for tracking the hatchery burbot with parental based tagging (PBT) once released into the Kootenay system, and;
- Record key data from all captured burbot (tags present, length and weight) and ensure a tag is present on all fish before release to help improve population estimates.

1.3 Methods

1.3.1 Sampling location

Moyie Lake is located in south eastern BC, approximately 20 km south of Cranbrook. Due to poor ice conditions, sampling occurred in the same location as 2013 through 2016 which is approximately 2.5 km further south of the initial sampling location at the Cotton Creek (Figure 1). All gamete collections were completed in a two week sampling period between February 13-17 and Feb 20-24, 2017.

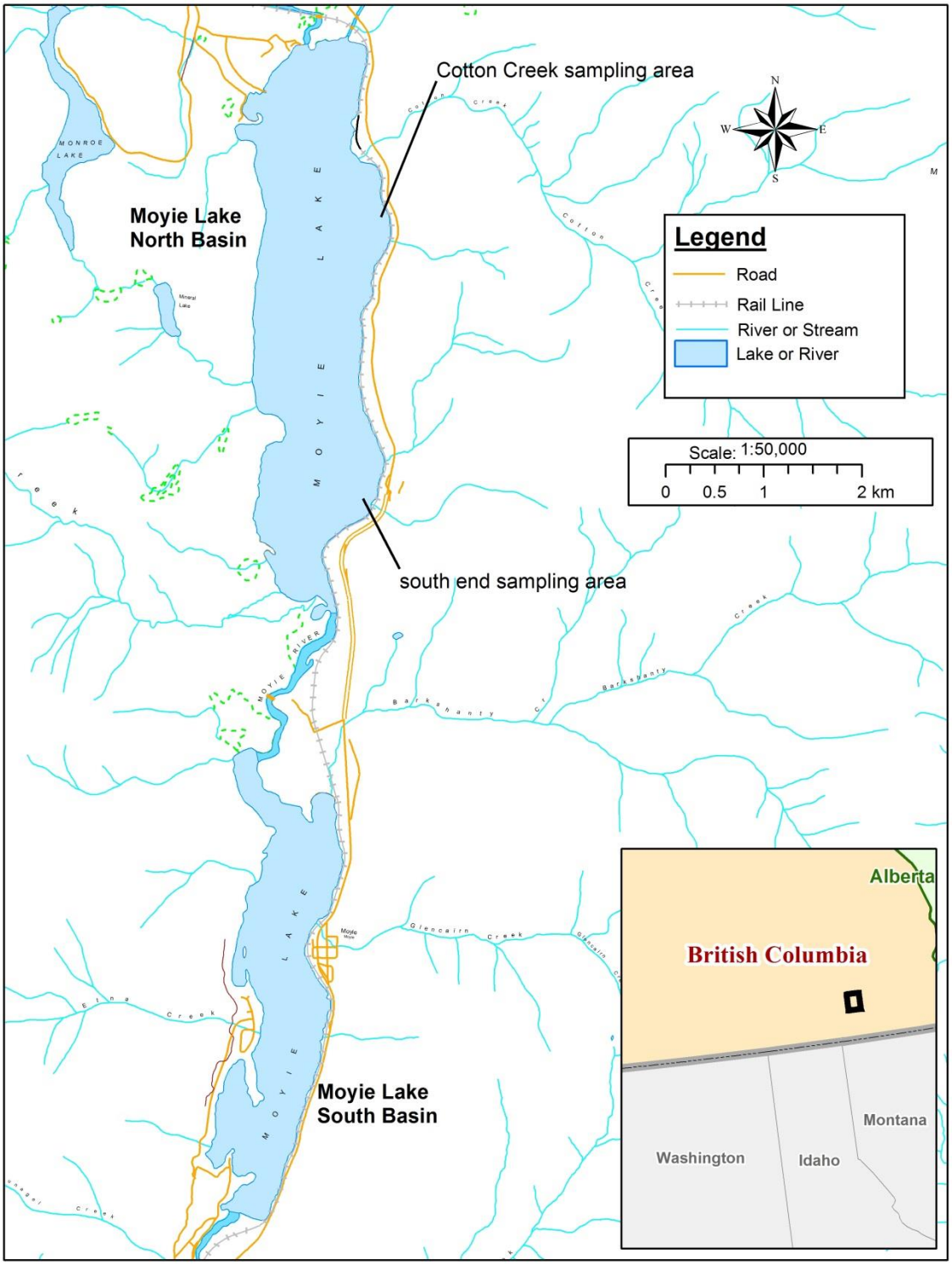

Figure 1. Study area overview, 2017. Sampling took place at the south end of the North basin.

1.3.2 Collection methods

Burbot were primarily collected by angling through augured holes in the ice primarily with IHN free Kokanee (*Oncorhynchus nerka*) as well as baitfish caught on Moyie Lake such as suckers (catastomus sp.). Congregations of spawning burbot were targeted by directly looking through holes in the ice or by using underwater video cameras (e.g., Aqua-Vu's Micro 5 Pro). Trammel nets were deployed in addition to angling to ensure sampling success. Trammel nets were constructed of two sizes of net with 2" and 19" stretch measure openings, and measuring 1.6 m deep and 11.6 m long. These nets were deployed under the ice using 1 hour sets, were generally placed within close proximity of the spawning tent.

On capture, all burbot were inspected for an existing passive integrated transponder (PIT) tag or a Floy tag. Floy tags were the primary unique identifier for Moyie burbot and a PIT tag was part of the assessment on Floy tag loss. If no Floy tag was present on capture, a Floy tag was inserted through the dorsal fin rays. All captured burbot were weighed to the nearest 50 g, total length was measured to the nearest millimetre, and assessed for spawn condition. Recapture history of burbot in ripe spawn condition was obtained from the capture database to avoid using burbot that were spawned in past years.

1.3.3 Spawning

Burbot spawning condition was classified on capture. With slight pressure, ripe males easily expressed milt while ripe females easily expressed eggs. Green males and females had firm abdomens and did not easily express milt and eggs respectively. Spent males and females had flaccid abdomens and only expressed a small amount of milt and a few eggs. Any burbot for which gametes were not observed were classified as unknown. Ripe individuals needed for spawning were transported to the onsite spawning tent to collect gametes needed for the fertilization process as outlined in Neufeld *et al.* (2011b). A tissue sample from the dorsal fin of each spawned burbot was collected for genetic analysis purposes in order to utilize PBT on hatchery released burbot captured in the Kootenay River (Ross *et al*. 2015).

Milt samples were stored at temperatures between 0-2ºC and their motility was tested regularly and immediately prior to use. The time of each motility evaluation was recorded to assess changes in sperm motility over time therefore ensuring several viable batches of milt were on hand when needed. Similarly, egg quality observations were recorded for each family to evaluate their effects on family survival. To improve upon our ability to identify egg viability in the field, all egg batches collected in 2017 had the following criteria recorded: eggs bloody from start or only at the end, eggs contained fungus. Any additional observations, including egg consistency or floating eggs were also recorded in the comments.

To generate an unfertilized volumetric egg estimate we collected egg batches directly into graduated cylinders. The volumetric unfertilized eggs per mL estimate was 1802 unfertilized eggs/ mL (Stephenson and Neufeld 2013). This estimate was applied in the field in order to create family sizes between 54,100 and 108,200 eggs or between 50 and 100 mL of eggs per female. Egg viability was assessed at KTOI's Twin Rivers hatchery at 48 hours post fertilization and at ~40 days post hatch at ARI.

Ripe females are the lowest proportion of the catch (Stephenson and Evans 2014, 2015, 2016), and therefore optimizing ripe females available for egg take is a priority. To assist with this, green females were placed in PVC holding tubes under the ice for up to allow time for egg maturation. Fish placed in these holding tubes were usually released within 48 hours if they did not become ripe. The use of these PVC tubes was initiated in 2011 and has greatly improved efficiency on the ice (methods further described in Neufeld *et al.* 2011b). We continued to use a maximum of six tubes, with each tube able to hold four to six burbot. Similar to efforts in 2013 -2016, we used one or two of the tubes to hold ripe males overnight to have the ability to collect milt and test sperm motility first thing the next morning.

1.3.4 Data comparisons across all years (2009-2017)

Catch data was compared between 2017 and the previous eight years of gamete collection efforts on Moyie Lake. Sampling has always taken place in February and has occured over 5-10 days each year. The number of captures, recapture rate, size of burbot captured and gamete collection results were compared across all years. JMP vers 10.0.0 was used for statistical analyses. We used a one way analysis of variance (ANOVA) to compare the mean length and weight of burbot across all years and Tukey HSD test to identify the years that had signicant differences. An α of 0.05 was used to define significant difference.

1.4 Results

1.4.1 Effort and catch data

Sampling by approximately 10-15 anglers, occurred over the course of ten days between February 13 and 24, 2017. Ice cover was approximately 30-38 cm thick for the duration of the study and mean water temperatures of 2.4°C (ranging between 1.7°C –3.1°C) in water ~4.5 m deep. The total catch in 2017 was 390 burbot. Of the 390 capture events 19 were intra-year recapture events (17 fish were captured twice and 1 fish was captured thrice) resulting in the capture of 372 individual burbot captured in 2017. Of the 372 individuals caught; 61 were female, 299 were male and 12 were unknown. There were also 82 inter-year recaptures (82/372; 22.0%). Inter-year recaptures were either tagged during previous gamete collection efforts which occurred between 2009 and 2016 or were tagged as part of population estimates on Moyie Lake which occurred prior to 2009 and during the short cod trapping efforts for the telemetry project in 2013 and 2014 (Stephenson and Evans 2014 and 2015). No mortalities were noted in 2017.

Our analysis included 369 individual burbot with lengths and weights. The mean length of burbot captured was 540 mm (SE=4); the range was 340 mm to 790 mm (Figure 2). Mean length of individual males and females were significantly different ($p<0.0001$) at 533 (SE=4) and 578 mm (SE=8) respectively. The mean weight of all individuals was 1,195 g (SE=23) with a range of 325 g to 3200g (Figure 3). Females were significantly heavier in weight ($p<0.0001$); the mean weight of all females was 1,455 g (SE=63) and mean weight of males was 1,137 g (SE=23). It should be noted that six of the 61 weighed females were weighed after they were spawned; therefore the mean weight of females presented here is an underestimate of the true mean weight.

Of the 390 captures, 363 captures were angled and 27 captures were from the trammel nets. Weights and lengths did not differ between sampling methods ($p>0.4$ for both weight and length).

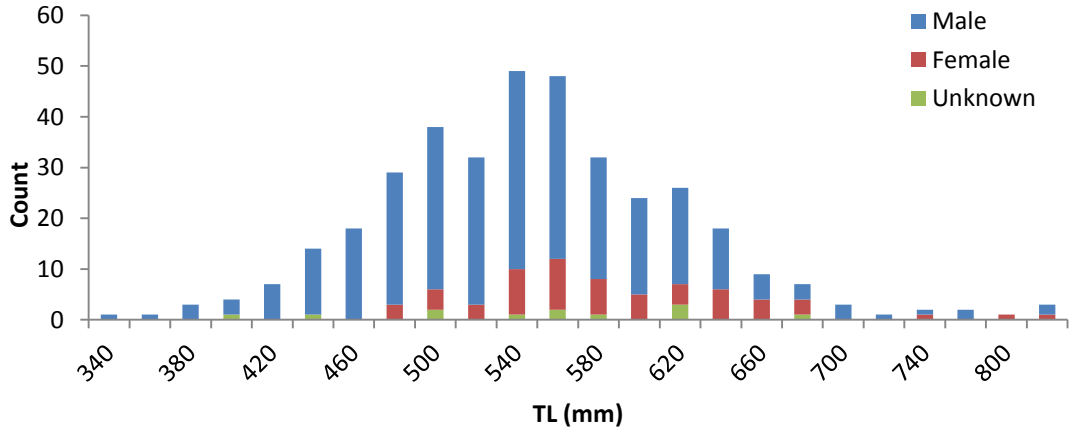

Figure 2. Length frequency histogram (20 mm bins) of 369 individual burbot captured by angling and trammel nets during gamete collection on Moyie Lake, February 2017.

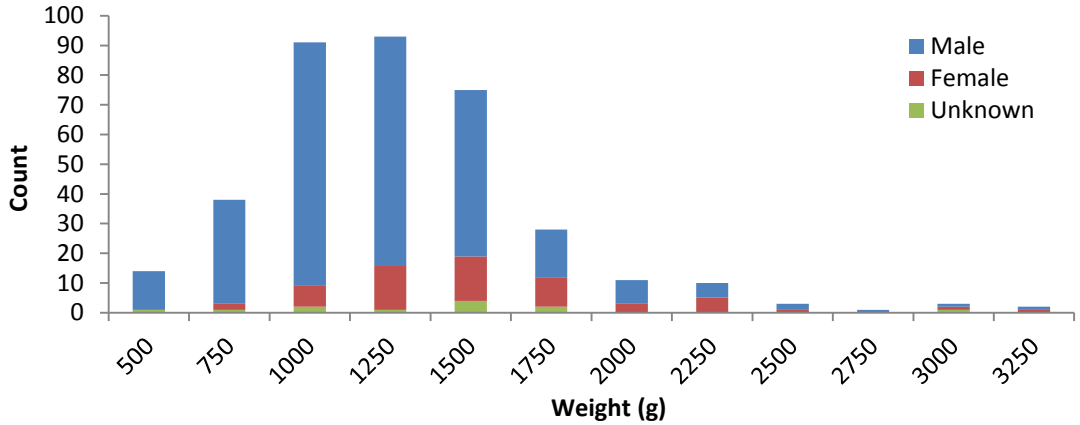

Figure 3. Weight frequency histogram (250g bins) of 369 individual burbot captured by angling and trammel nets, during burbot gamete collection on Moyie Lake, February 2017.

1.4.2 Spawning data

Of the 372 individual captures: 299 were male: five males were green, 292 were ripe and two were spent. Of the 292 ripe males captured, gametes were collected from 97; 60% (58/97) of milt samples collected were used to fertilize eggs. Of the 61 individual females collected, two were spent, 27 were ripe and 32 were green upon capture; 78% (25/32) of the green females were placed in holding tubes. We spawned 20 females that were ripe upon capture and 9 females that were held in the tubes. The seven un-spawned females that were ripe upon capture were either deemed unsuitable for spawning due to egg condition or they ended up spawning overnight in the tubes on the first night of sampling. Females spawned after being held in tubes accounted for 31% (9/29) of all females spawned this season. Furthermore, we also used the tubes to hold a total of 69 ripe males overnight to have males on hand first thing the next morning; 59% (34/58) of spawned males came from the tubes. Overall 98 burbot were held in the tubes this season.

A total of 58, single cross families were created in the field using 29 females and 58 males (Table 1). A tissue sample for DNA analysis was collected from all 87 burbot that were spawned. Milt was collected from 97 different males to ensure a sample with good motility was available when a spawning female was available. This year the average time a milt sample was held prior to use was 46 minutes (min = 0.13 hrs, max= 2.57 hrs). Of the 97 milt samples collected: 81% (79/97) had greater than 80% motility and were deemed viable to use for fertilization while the remaining 18 milt samples were not motile or were not tested.

The volume of unfertilized eggs was measured in the field for each family. The egg volume ranged between 25 mL to 125 mL (mean=68 mL; SE=2.8) and an estimated range of 45,000 to 225,000 eggs (mean 122,369 eggs; SE=5,043) per family. The total number of eggs collected in 2017 was estimated in the field at 7,096,860 (Table 1). A sample of 243,360 eggs from five different families was sent to ARI for temperature studies (Appendix A).

Of the 58 families sent to Twin Rivers one did not survive while the remaining 57 had 48 hour viability ranging between 20% and 100%. The mean 48 hour survival, of all 58 Twin Rivers families, was 89.7% (SE=0.02; Appendix A). The egg batches with potential low quality indicators in the field did not correspond to low viability in the hatchery (Table 2). Total egg count from Twin Rivers at 48 hours post fertilization was 6,073,922 eggs. Egg survival estimates from ARI indicated 74% survival of all families ~40 days post hatch.

Table 1. Summary of burbot families created and egg count in the field in 2017

Date	Number of families	Total egg estimate in field	# of individual females	# of individual males
14-Feb-17	6	954,000	3	6
15-Feb-17	8	1,062,000	4	8
16-Feb-17	8	1,084,860	5	8
17-Feb-17	11	1,602,000	5	11
21-Feb-17	4	315,000	4	4
23-Feb-17	11	1,080,000	6	11
24-Feb-17	10	999,000	2	10
Total	***58***	***7,096,860***	***29***	***58***

Table 2. Egg quality descriptors observed in the field and their corresponding egg viability observations at the families sent to the Twin Rivers hatchery.

Egg batch descriptors	N	Range in egg viability 48h post fertilization
Fungus	6	87.05% – 98.70%
Bloody from start of egg take	0	NA
Bloody only at end of egg take	12	67.76%-99.50%

1.4.3 Data comparisons across all years (2009-2017)

Catch data was compared between 2017 and the previous eight years of gamete collection efforts on Moyie Lake. The number of burbot captures has ranged from 181 (2009) to 554 (2010), for a total of 3,155 burbot captures in the past nine years (Table 3). Every new capture receives a tag and over the course of the nine years of this study a total of 2,645 individual burbot have been tagged with a Floy tag. The burbot recapture rate was approximately 7% during the first five years of this study, and although still low, increased substantially in the last few years (Table 3).

Table 3. Summary of burbot captures during gamete collection efforts between 2009-2017.

Year	Number of Captures	Number of individuals captured	Number of Intra-year recaptures	Number of Inter-year recaptures	
				N	% recaptures
2009	181	180	1	11	6.1%
2010	554	539	15	46	8.5%
2011	378	366	11	23	6.3%
2012	238	236	2	19	8.1%
2013	302	298	4	19	6.4%
2014	314	308	6	44	14.3%
2015	354	343	11	37	10.8%
2016	444	412	32	90	21.8%
2017	390	372	19	82	22.0%
Total	***3,155***	***3,055***	***101***	***371***	***12.1***

The mean length of burbot captures has differed significantly between years of sampling ($p<0.0001$; Figure 4); the largest was in 2009 (586 mm; SE= 7) and the smallest mean length was in 2016 (538 mm; SE= 4). The mean length of all burbot caught in 2017 differed from 2009 ($p<0.0001$), 2010 ($p=0.0026$), 2013 ($p<0.0001$) and 2014 (<.0001; Figure 4). The mean length of males caught in 2017 (533 mm) only differed from the mean lengths in 2009 ($p<0.0001$) and 2013 ($p<0.001$). The mean length of females caught in 2017 only differed from females caught in 2014 ($p=0.0111$).

The mean weight of all burbot captures collected in 2017 differed between the mean weight of the following years: 2009 ($p<0.0189$), 2011 ($p<0.0001$), 2012 ($p<0.0315$), 2013 ($p<0.0001$) and 2014 ($p<0.0001$; Figure 5). Mean weight of the 2017 male burbot captures differed from male mean weights in: 2009 ($p=0.0169$), 2011 ($p=<0.0001$), 2012 ($p=0.0272$), 2013 ($p<0.0001$) and 2014 ($p<0.0001$). Mean weights of females caught in 2017 did not differ from previous years.

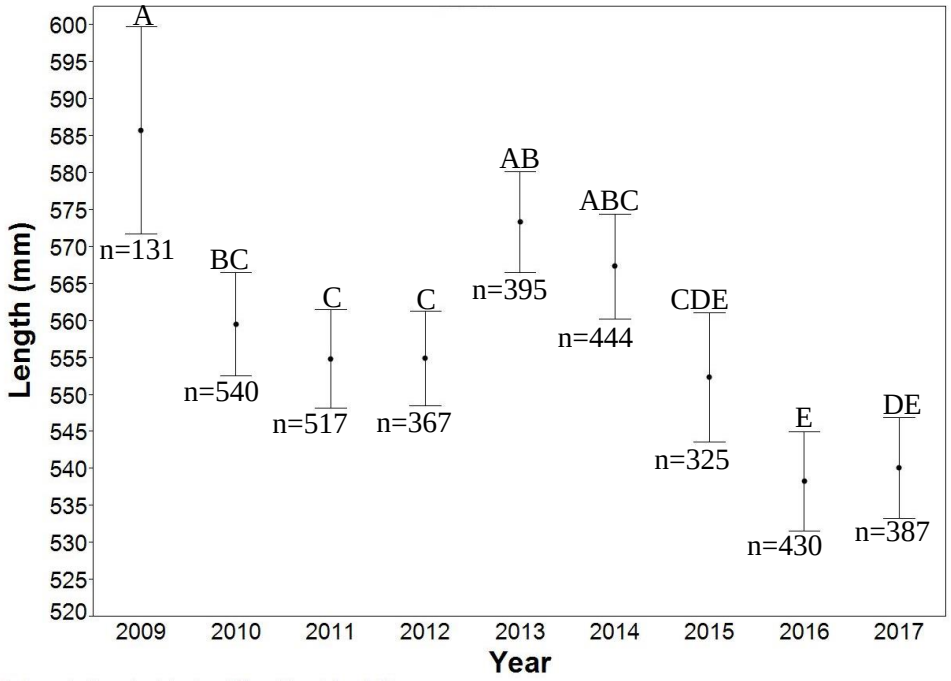

Figure 4. Mean length (mm) of all burbot captures (95% CI) during 2009-17 gamete collection efforts. Letters denote which years have comparable sizes and if letters differ, the years differed ($p<0.05$).

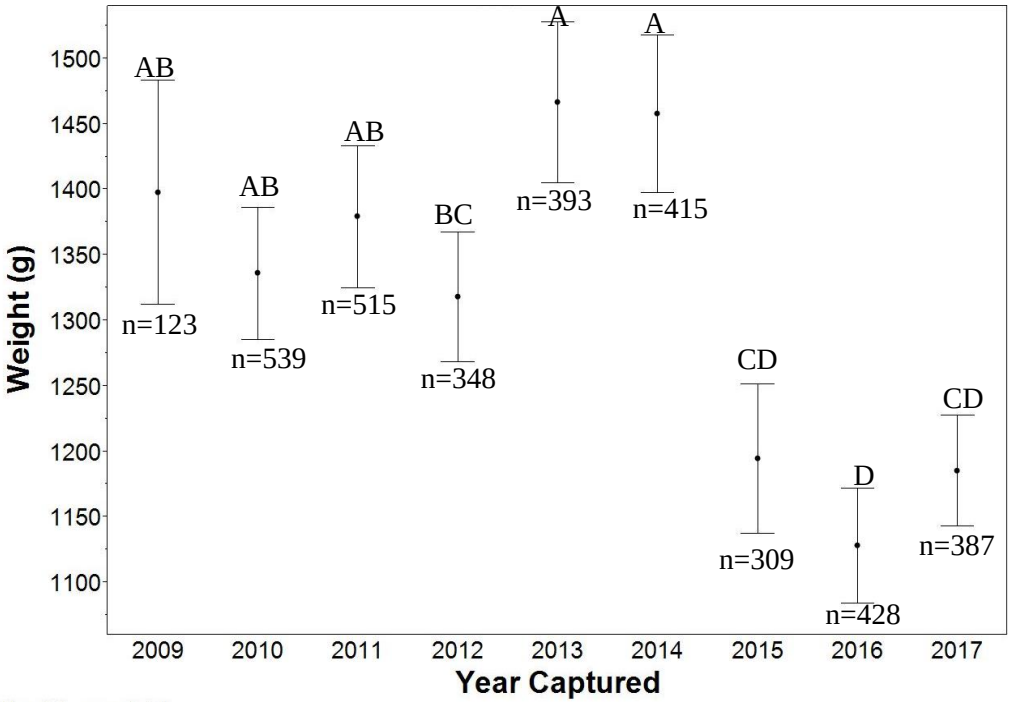

Figure 5. Mean weight (g) of all burbot captures (95% CI) during 2009-2017 gamete collection efforts. Letters denote which years have comparable sizes and if letters differ, the years differed ($p<0.05$).

Every year since 2009, gamete collection efforts have met the egg collection targets. Egg survival rates have steadily risen since the start of egg take (Appendix B). From 2009-2014 all eggs were delivered to the ARI hatchery facility; starting in 2015 the majority of eggs were delivered to Twin Rivers for hatchery production, with up to one million unfertilized eggs were sent to ARI for temperature research. Mortalities from rearing and other egg mortality causes, after 48 hours, are not recorded in this report, however in particular there was low viability from the smaller family sizes in 2017 (Nate Jensen, Twin Rivers Burbot Manager, pers comm, August 2017). Production from the egg take has varied in the first three years of Twin Rivers production (Table 4).

Table 4. Egg and production approximate results, at the main 6 month old life stage target, for the years since KTOI's Twin Rivers Hatchery has been in production. Details of production can be found in Appendix B.

Year	Fertilized egg estimate	Approximate juvenile burbot released (6 month olds in fall)	Approximate egg-juvenile survival (%)
2015	7.3 million	260,000	3.5%
2016	7.1 million	140,000	2.0%
2017	6 million	40,000	0.67%

1.5 Discussion

Overall 2017 was another successful year for our burbot gamete collections. Angling continues to be an effective method of targeting spawning burbot in Moyie Lake and our egg collection efforts produced met the fertilized egg targets for hatchery production. In order to do so the following methodologies have continued to be developed and become more refined over the years: fertilization procedures, volumetric egg estimates, sperm motility testing, egg transport protocol and genetic tagging (e.g, Stephenson and Evans 2016; Neufeld *et al.* 2011b)

Learnings and take homes from 2017:

- Mid-February timing continues to be effective for gamete collections, 2017 the peak egg take was February 17th.
    - In 2018, fish sampling should only occur during days when spawning is a possibility to reduce the possibility of ripe females spawning out in tubes.
    - In 2018, consider continuing gamete collection efforts through the weekend to prevent the possibility of losing the chance to spawn green females caught on the last day of the first week.
- The south end sampling site was effective for accessing high-density spawning burbot.
- Angling was the primary capture method and trammel nets, set at random, provided a secondary source of sampling
    - In 2018 a focused effort should be made to deploy trammels nets in proximity to angling locations to determine if the efficiency increases and to see if the proportion of recaptured burbot differs from angling.
- Low recapture rates in this program across years, will be a challenge for mark-recapture modelling
    - In 2018, complete an updated abundance estimate.
- Tubes continue to provide a valuable tool for holding burbot, both males and females, to minimize the number of burbot handled in a season.
- 50 ml of unfertilized eggs per family was too small for Twin River incubation cones, leading to decreased survival of eggs;
    - In 2018 family size should be increased to a minimum of 75 ml.
- Single family crosses, and taking genetic samples from all crosses, continue to be a valuable tool for tracking hatchery burbot with parental based tagging (PBT) once released in the Kootenay system,
- As in past years, egg quality observations in the field did not correlate to egg viability in the hatchery.

Section 2: Moyie Lake telemetry and temperature evaluations

2.1 Introduction

An accurate population estimate is very important for the continued protection of the Moyie Lake burbot population in relation to its ability to sustain the gamete collection efforts and also to support a popular First Nation and recreational fishery (Neufeld and Spence 2009). The most recent population abundance estimate of Moyie burbot was 10,000 and reflected data collected from 2007-2012 (Schwarz 2012). This estimate was five times the previous estimate of 2,000 (Neufeld and Spence 2009; Neufeld 2008). Further investigations were needed to clarify assumptions which would allow for improved statistical modelling of the Moyie Lake burbot population and associated population estimates.

There were a number of assumptions in previous estimates that could have led to positive biases in population estimates. In 2011 we started double tagging a subsample of the burbot caught within the gamete collection efforts to address the assumption that Floy tag loss was not an issue in our sampling (suggested in Schwarz 2011). In addition to tag loss there were four key unanswered assumptions that needed to be addressed to confirm that the current sampling efforts during the spawning season in one area of Moyie Lake allows for an accurate population estimate of the entire Moyie Lake adult burbot population. The assumptions were as follows: (1) tagged burbot have equal chance of capture relative to untagged fish (i.e., no learned avoidance of sampling gear), (2) burbot spawn every year and therefore tagged burbot have equal opportunity of capture each sampling session, (3) burbot tagged at our current sample locations at Cotton Creek and the south end of the North basin mix equally within the entire population (i.e., low levels of spawning site fidelity), and (4) burbot move freely throughout both basins in Moyie Lake. To clarify our treatment of these assumptions, a passive sonic telemetry project was initiated in 2013. This study entailed sonic tagging 30 burbot from North and South Moyie Lake with V13 depth sensor sonic tags between 2013 and 2014 (see Stephenson and Evans 2013 & 2014 for details). Monitoring will continue into 2017 after which point an analysis will be completed on the entire telemetry dataset; this report summarizes the annual update after the fourth year of the study.

To increase our understanding of the importance of temperature for burbot, particularly during spawn and incubation period, temperature loggers were deployed with the telemetry receivers. These data will expand on the data collected in 2009-10 (Neufeld 2010) demonstrating cool and stable temperatures (<6°C) during the incubation period.

2.2 Methods

2.2.1 Telemetry array

An array of eight Vemco VR2W receivers were installed throughout both basins in October 2013, a ninth receiver was added in April 2015 (Figure 6). Receivers were downloaded bi-annually (once post spawn in April and once in the fall) and batteries were changed once a year. All data from the receivers were stored as raw vrl files and within a VUE (Vemco User Environment) database.

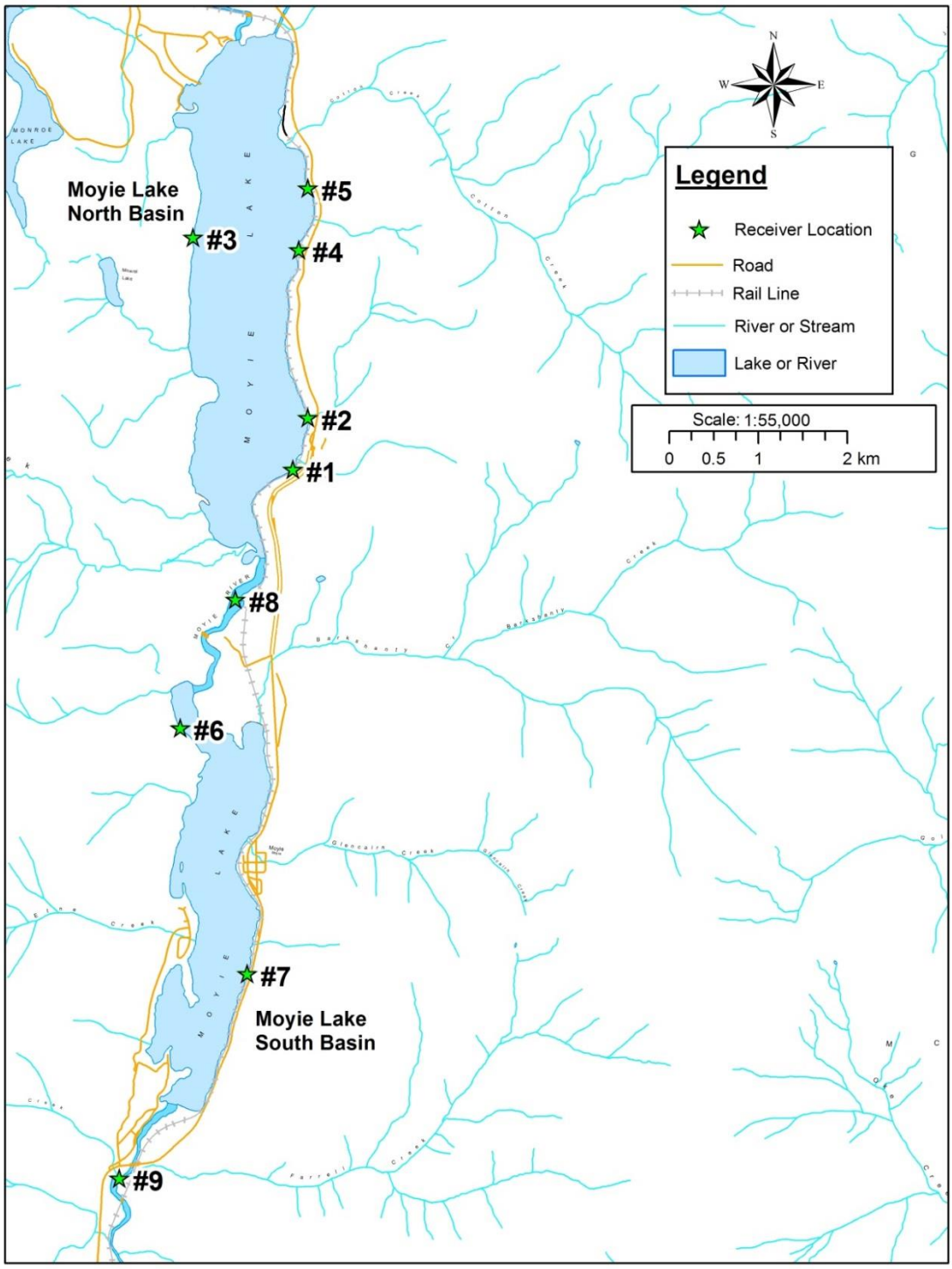

Figure 6. Receiver locations in Moyie Lake.

2.2.2 Temperature monitoring

Four Onset Hobo Tidbit water temperature data loggers were deployed in Moyie Lake; three in the North basin and one in the South basin (receivers #1,#5 and #7; Figure 6). The Tidbits were fastened to the ropes that were used to tie off to shore for the deployment of the VR2W receivers. Spawn activity occurs in shallow waters in Moyie Lake; to monitor temperatures in areas where eggs would be deposited three of the four temperature loggers were placed at depths < 5m. The thermocline in Moyie Lake was estimated to be at 15 m, so one Tidbit was placed below the thermocline in the North basin (Andrusak 1970). With observed peak spawn in Moyie Lake in mid-February, similar to what was observed in the Kootenay River, spawn and incubation was defined as February 7 to April 16 (Hardy *et al*. 2016)

2.2.3 Data summary

Detection data of all sonic tagged burbot within Moyie Lake were managed within a Vemco Vue database. Survival estimates were made using detections and angler induced mortalities were evaluated with a $100 reward Floy tag associated with every sonic tagged burbot. Movement between basins was determined by detections from any of the receivers in either of the basins. Spawn site fidelity between the two known spawning sites in the North basin (Stephenson and Evans 2014, 2015; Neufeld 2010) was evaluated by looking at detections shallower than 8m, within the period of February 1 to March 15, to account for fish presence on the spawning grounds. The two known spawn locations both had two receivers that were used to denote detections within either location. Receivers #1 and 2 were within the south end of the North basin and receivers #4 and 5 were within the Cotton Creek spawning area (Figure 6).

2.3 Results

2.3.1 Telemetry array

In the 2016-17 season all nine receivers were downloaded and serviced at least once. All receivers were in good working order and in the proper locations. The data was offloaded and stored in the Vemco Vue database.

2.3.2 Temperature monitoring

Four temperature loggers were deployed in the North and South basin of Moyie Lake April 24, 2014 and were downloaded bi-annually. Although temperature loggers have been deployed continuously since 2014 there are some data gaps due to logger malfunction; data during the spawn period was available for 2015 and 2017.

In addition to temperature data collected during the span of the Moyie Lake telemetry study we included temperature data for the North basin between October 20th 2009 and April 25, 2010 (Neufeld 2010). Every year, for 2010, 2015 and 2017, mean daily temperatures in the spawn period stay below 6°C (Figure 7). The year with the most variable spawn temperatures; warm, with limited ice cover was in 2015.

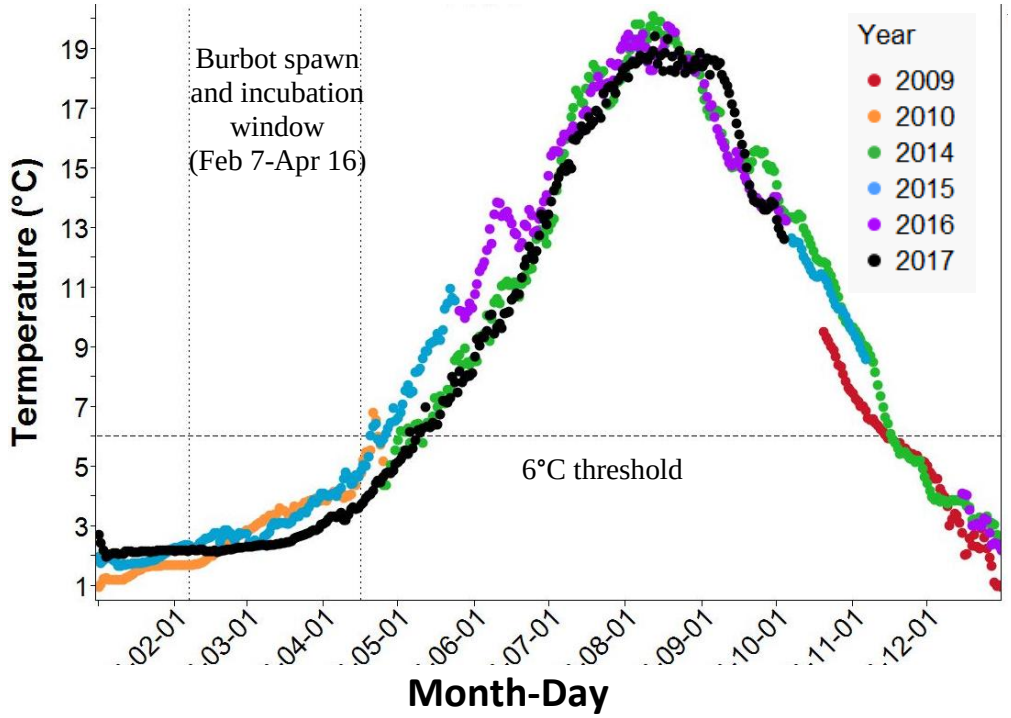

Figure 7. Annual Moyie Lake (North basin),mean daily water temperatures by year (2009 -2017) at a depth of 3m-6m using the logger from the South end of the North basin (Receiver #1) as well as the shallow Cotton Creek logger (Receiver #5).

2.3.3 Reward tag reports

Between November 2013 and April 2017, five sonic tagged burbot have been caught by public anglers or through this program's gamete collection efforts. Of the three reward tags caught by the public, only one burbot was released alive. Additionally, two sonic tagged burbot were caught during the February gamete collection efforts (Stephenson and Evans 2016).

2.3.4 Telemetry data summary

Of the 30 sonic tagged burbot, only 15 tags were active for the 2017 spawn season; 8 survived to this fourth and final spawn year of our study. Of the 8 burbot alive during the 2017 spawn period, only 6 were detected during the spawn period (February 1 to March 15; Table 5 & 6). During the spawn period burbot were detected in both basins and within both spawning areas in the North basin. During the 2017 spawn season three were detected exclusively in the North basin and three were detected in both basins, none were exclusive to the South basin. Over all four years of this study and of the fish believed to be alive during at least one spawn period (n=28), 61% used both basins, 39% used the North basin exclusively and none were exclusive to the South basin.

Table 5. Detection summary for Moyie Lake sonic tagged burbot during the spawn season (last download was April 2017).

Year	Number of burbot			basin detected during spawning season			
	# of active tags	# believed to be alive	not detected during spawn but not classified as dead	Both	North	South	Total
2014	15	14	0	5	6	2	15
2015	30	25	1	12	11	0	23
2016	30	21	4	7	9	1	17
2017	15	8	2	3	3	0	6

Table 6. Detailed detection summary for Moyie Lake sonic tagged burbot (last download was April 2017). Spawn period was defined as Feb 1 – Mar 15.

Tag #	year tagged[1]	basin of tagging	Did the fish use the other basin	If other basin was used, it was detected again in its basin of origin	2014 spawn season			2015 spawn season			2016 spawn season			2017 Spawn season		
					South basin	North basin		South basin	North basin		South basin	North basin		South basin	North basin	
						Cotton Creek	South End		Cotton Creek	South End		Cotton Creek	South End		Cotton Creek	South End
65	2013	N	YES	YES	X	X	X	X	X	X	X	X	X	N/A	N/A	N/A
66	2013	N	YES	YES	X	X	X		X		X	X	X	N/A	N/A	N/A
70	2013	N	NO	N/A	-	-	-	-	-	-	-	-	-	N/A	N/A	N/A
56	2013	N	YES	YES		X	X	X	X	X	-	-	-	N/A	N/A	N/A
69	2013	N	NO	N/A		X	X	-	-	-	-	-	-	N/A	N/A	N/A
64	2013	N	YES	NO	X	X	X				-	-	-	N/A	N/A	N/A
67	2013	N	NO	N/A		X	X		X	X		X	X	N/A	N/A	N/A
68	2013	N	NO	N/A		X	X		X	X		X	X	N/A	N/A	N/A
62	2013	S	YES	YES	X	X	X	X	X	X		X	X	N/A	N/A	N/A
59	2013	S	YES	YES	X		X	-	-	-	-	-	-	N/A	N/A	N/A
60	2013	S	YES	YES	X	X	X	-	-	-	-	-	-	N/A	N/A	N/A
58	2013	S	YES	NO	X	X	X		X			X		N/A	N/A	N/A
57	2013	S	YES	YES	X			X	X	X	X	X	X	N/A	N/A	N/A
61	2013	S	YES	YES	X			X	X	X	X	X	X	N/A	N/A	N/A
63	2013	S	YES	YES	X			X	X	X	X	X	X	N/A	N/A	N/A
114	2014	N	YES	YES	N/A	N/A	N/A	X		X	-	-	-	-	-	-
102	2014	N	NO	N/A	N/A	N/A	N/A		X	X		X	X		X	X
103	2014	N	NO	N/A	N/A	N/A	N/A		X	X		X	X			X
104	2014	N	NO	N/A	N/A	N/A	N/A		X	X	-	-	-	-	-	-
105	2014	N	NO	N/A	N/A	N/A	N/A		X	X	-	-	-	-	-	-
106	2014	N	NO	N/A	N/A	N/A	N/A		X	X	-	-	-	-	-	-
107	2014	N	NO	N/A	N/A	N/A	N/A		X	X	-	-	-	-	-	-
113	2014	N	NO	N/A	N/A	N/A	N/A		X			X				
116	2014	N	NO	N/A	N/A	N/A	N/A		X	X		X	X		X	X
108	2014	S	YES	YES	N/A	N/A	N/A	X	X	X	X	X	X	X	X	X
110	2014	S	YES	YES	N/A	N/A	N/A	X	X	X	X	X	X	X	X	X
111	2014	S	YES	YES	N/A	N/A	N/A	X	X	X	X			-	-	-
112	2014	S	YES	YES	N/A	N/A	N/A	X	X	X	-	-	-	-	-	-
115	2014	S	YES	YES	N/A	N/A	N/A	X	X	X	X	X	X	X	X	X
109	2014	S	NO	N/A	N/A	N/A	N/A	-	-	-	-	-	-	-	-	-

'-' denotes when a burbot was not detected and assumed dead while blank indicates the fish is alive but not detected during specified time period

[1] Tags put out in 2013 expired mid March 2016 and tags from 2014 expire October 2017.

2.4 Discussion and conclusions

Temperatures during spawn period in Moyie Lake were consistently below 6°C. Even during a warm winter, with limited ice cover, like 2015, the spawn temperatures were well below the critical temperature limit. The importance of ice cover may be important for spawner behaviour, but evidence that the temperature would be a recruitment limitation for egg survival (Cain and Ashton 2018). Although the telemetry array will be removed fall 2017, temperature loggers will continue to be maintained and downloaded biannually.

Preliminary telemetry results suggest high survival rates of sonic tagged burbot and extensive mixing between basins as well as mixed use of the two known spawning sites within the North basin. Preliminary data suggests more use of the North basin during the spawn period. Interestingly, there were no detections on the receiver at the outlet of Moyie Lake on the Moyie River, suggesting limited emigration from Moyie Lake. Depth data analysis and the full complement of data from the telemetry work will be available for analysis in the spring of 2018.

Section 3: Kootenay Lake and River: monitoring and evaluations of hatchery releases and remnant population

3.1 Introduction

Lower Kootenay burbot efforts focused on identifying remnant wild stock and monitoring and evaluating the hatchery burbot introductions. Releases of hatchery reared burbot into the Kootenay River (including tributaries) and Lake were completed annually since 2009; releases include larval, juvenile and adult burbot. Monitoring and evaluation field techniques include hoop netting, PIT tag arrays, passive sonic telemetry, cod trapping and spot light surveys (e.g., Hardy *et al.* 2016; Stephenson and Evans 2016). Through these efforts data suggest that burbot currently residing in the river have good growth and survival rates comparable to the historical population and other successful burbot populations (Hardy *et al*. 2016). Additionally, hatchery origin fish are spawning at historical riverine spawn location and hoop net data suggest these lake origin fish were mimicking movement and habitat use of the historical riverine population (Hardy *et al*. 2016).

Although data suggest early success of hatchery origin burbot within the river, several data gaps remain; specifically, data are needed for spawn timing within the river and tributaries, temperature limitations for egg incubation and larval development, success of hatchery burbot within Kootenay Lake and mixing rates between the lake and river. Peak spawning of occurred on February 18 in 2015 (Hardy *et al*. 2016) with a spawning window of approximately 22 days in total (February 7 through to March 1) which differs from the peak spawn of the historic Kootenay River burbot population (February 11th in 2001; Hardy *et al*. 2016). Spawn timing is important to understand temperature regime for incubation and early larval development. Temperatures >6°C can be lethal for egg development (Taylor and McPhail 2000; Vught *et al*. 2008; Zarski *et al.* 2010) and new studies suggest that larval development was improved with temperatures >5°C (Cain and Ashton, 2018). More data are needed around the implications of the temperature fluctuations within the regulated Kootenay River during spawn, incubation and larval development. IDFG and KTOI are leading the in river research to identify spawn timing and temperature limitations relative to early life stage development in partnership with the University of Idaho (e.g., Hardy *et al*. 2016). This report will summarize temperature data from main tributaries to the Kootenay River in BC.

An increase of hatchery releases into Kootenay Lake starting in 2015, coupled with mixing from burbot released into Kootenay River, hatchery burbot are monitored within the lake with cod traps and telemetry work (Hardy *et al*. 2016; Stephenson and Evans 2016). Telemetry work has included tagging fish prior to release from the hatchery and tagging fish caught in the river during the hoop net sampling. The telemetry data supports high survival rate of juveniles and adults within the river, but limited mixing rates from the river to the lake (Hardy *et al*. 2015; Stephenson *et al*. 2013). To investigate the behaviour of hatchery burbot released into the lake a study was initiated in 2015. Juveniles and adults were sonic tagged prior to release in the West Arm (Stephenson and Evans 2016). This year's report will summarize cod trapping efforts in the lake from 2017 and telemetry data summary from summer 2015 until spring 2017.

3.2 Methods

3.2.1 Hatchery juvenile burbot releases

The 2016 Canadian burbot releases were carried out by FLNR and KTOI staff. The release locations (Goat River and mouth of the West Arm of Kootenay Lake) were chosen based on known historical spawning or high use areas. In river water temperatures were monitored in order to ensure hatchery water temperatures were within a suitable range for the final release. Releases took place between July and October; the main release target was 6 month old juveniles in October.

3.2.2 Temperature monitoring

Goat River, Corn and Summit Creek are potential burbot spawning and rearing tributaries. Temperatures from these three Kootenay River tributaries were monitored between August 6th, 2014 and August 23rd, 2017. Data were also available from a site, managed through another project at FLNR, at Balfour in the West Arm, from 2013 through 2016. All temperature loggers were Tidbits from Onset (accurate to ±0.21°C from 0° to 50°C). Corn Creek and Goat River both received two temperature loggers as backups in case the creek ran dry or there were difficulties accessing the logger (Figure 8). The temperature loggers were anchored to the bottom of the creek and were downloaded biannually. Although data is available between August 2014 and August 2017 some data gaps were present due to technical difficulties. Logging intervals ranged between one minute and one hour; mean daily temperatures were calculated. Spawn and incubation windows were delineated on each graph (February 7 to April 16; Hardy *et al*. 2016). For this summary, the mean spawn and incubation temperatures were compared between years and by stream using JMP's Tukey Honest Significant Difference (HSD) test.

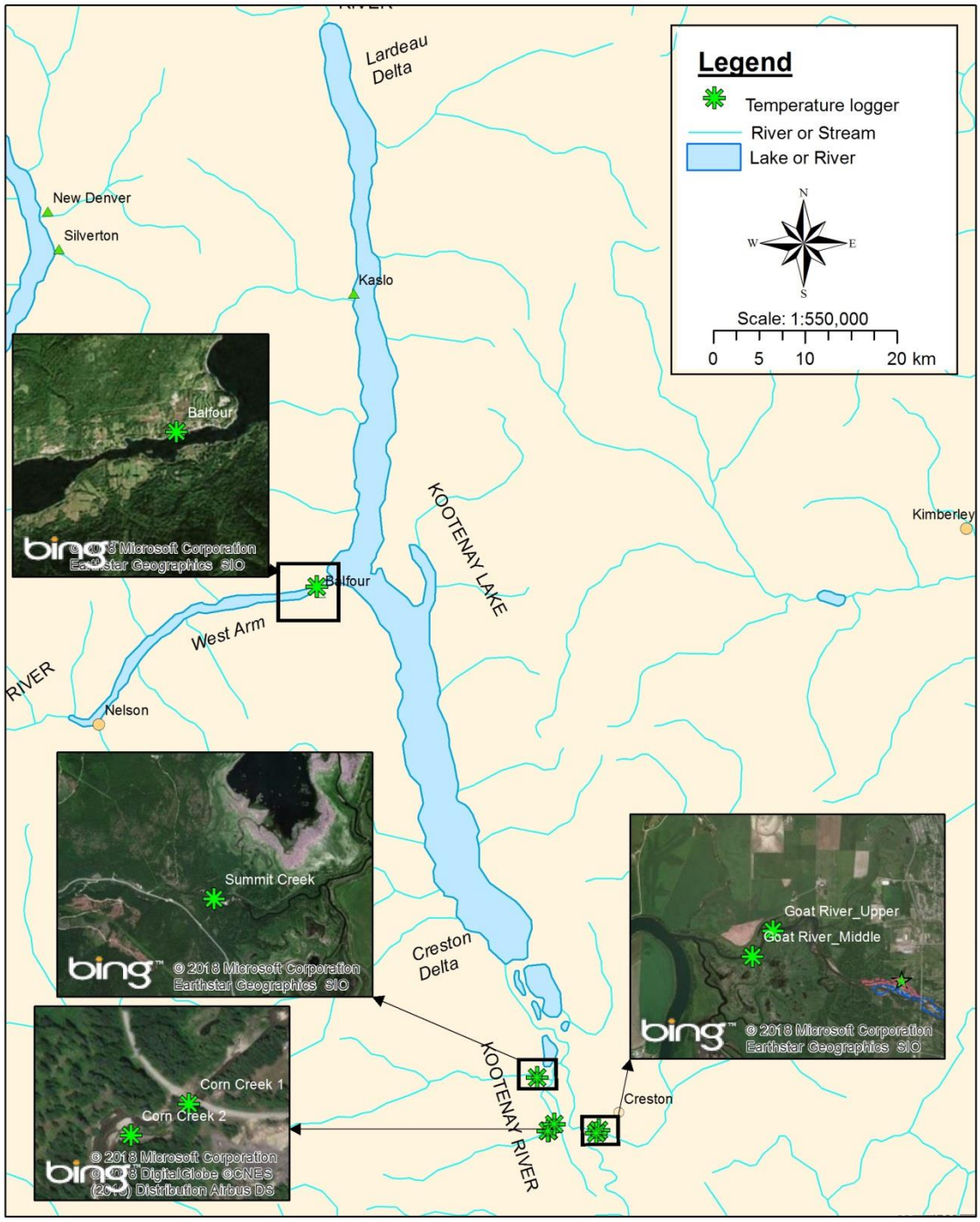

Figure 8. Map of temperature logger locations in Goat River, Summit and Corn Creeks and the West Arm (Balfour) of Kootenay Lake.

3.2.3 Passive acoustic telemetry

In 2015, 30 age-1year and 30 age 3-5 year burbot were sonic tagged at the University of Idaho Aquaculture Institute prior to release at Balfour in the West Arm of Kootenay Lake (methods further described in Stephenson and Evans 2016). The smaller tags in the juveniles were estimated to expire by the end of April 2017 and the adults have tags active until 2019. Tracking of tagged fish was completed using the established telemetry array within the Kootenay Lake and River (Figure 9; array further described in Stephenson *et al*. 2013; Stephenson and Evans 2016). All data was saved in the Vemco Vue database format and then cleaned and stored for analysis in an Access database. This report will summarize data from 2015 until April 2017.

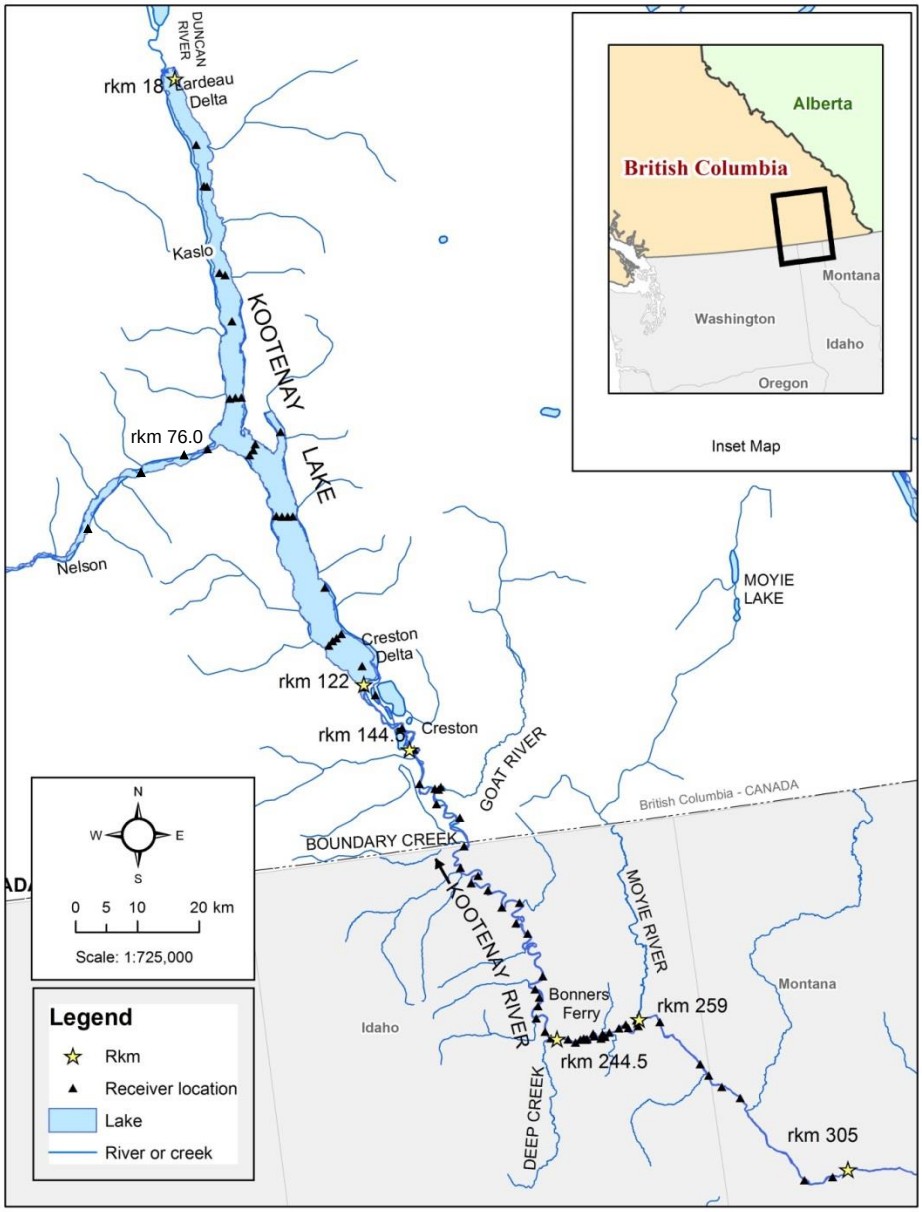

Figure 9. Map of Vemco VR2W receivers. A few key river kilometres (rkms) are denoted for context.

3.2.4 Kootenay Lake cod trapping

(a) Sampling locations

Sampling took place on Kootenay Lake between March 17 and April 12, 2017, with sites near the mouth and first narrows of the West Arm (RKM 75-76), in the vicinity of the Lardeau Delta (RKM 17-20), and on the Creston Delta and nearby shoreline (RKM 114-120; Figure 10). Sampling locations were selected on the Lardeau Delta and mouth of the West Arm based on historical capture locations (Spence 1999a, b), while other locations were exploratory and selected based on potential suitable habitat for burbot.

(b) Collection methods

All Kootenay lake sampling was completed with cod traps, an alternative to hoop netting, following methods detailed in Spence (2000). All traps were baited with kokanee (*Oncorhynchus nerka*) spawner carcasses, set in less than 30 m, and fished for between one and five days. Information recorded for each trap included: depth (m), location (UTM), water temperature, time of set and pull, bycatch, and burbot catches.

(c) Fish workup

All captured burbot were weighed to the nearest 50 g, measured to the nearest mm and notes were taken regarding sex and maturity (refer to section 1.3.3 for sex and maturity definitions). Prior to release all burbot received a passive integrated transponder (PIT) tag (12 mm HDX; BioMark Inc) and a genetic sample was taken. The workup on burbot was completed in less than two minutes per individual for a quick release of burbot to depth of capture. On release, a weighted mesh box was used to return burbot to depth of capture and reduce the occurrence of symptoms associated with decompression trauma (Neufeld and Spence 2001). After release, crews remained in the area to ensure burbot did not return to the surface.

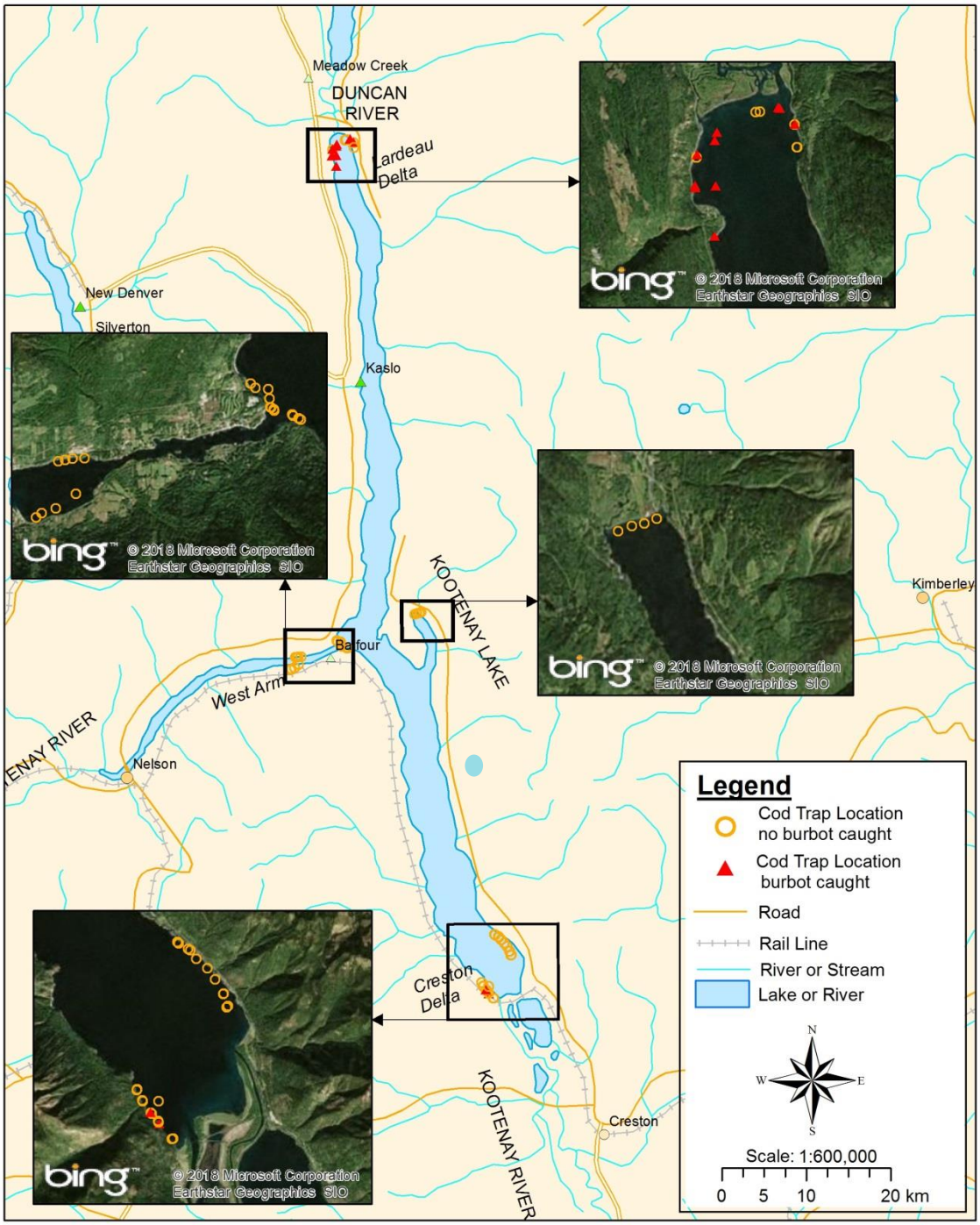

Figure 10. Overview of study area with 2017 cod trap locations.

3.3 Results

3.3.1 Hatchery juvenile burbot releases

The 2016, 43,837 juvenile burbot (6 months old) were released into the Canadian portion of Kootenay Lake and River (Table 7). This was the second year of large release efforts of hatchery reared juveniles into Kootenay Lake.

Table 7. 2016 Burbot releases into the Canadian portion of Kootenay Lake and River

Release date	Release location	Final release #	# BB PIT tagged	# telemetry tagged BB	Year class	~Mean TL (mm)	Agency
02-Oct-16	Balfour/Queens Bay	21,739	0	0	2016	NA	KTOI
02-Oct-16	Goat River	17,691	0	0	2016	NA	KTOI
11-Oct-16	Balfour/Queens Bay	1,970	1,970	0	2016	108.2	KTOI
11-Oct-16	Goat River	2,437	2,437	0	2016	112.7	KTOI
Total	-	43,837	4,407	-	-	-	-

3.3.2 Temperature monitoring

In 2017, mean daily temperatures during spawn and incubation for all three tributaries (Goat, Corn and Summit) remained below 6°C (Table 8; Figure 11). No data were available for 2017 at the Balfour site. In recent years, temperatures during spawn have varied; 2017 was the stable, cooler of the three. Mean daily temperatures in the three tributaries varied significantly across all years ($p<0.0001$), except in the Goat River there were no difference between 2015 and 2017. Over the course of this study, Goat River and Balfour temperatures have exceeded 6°C near the end of the incubation window (no temperature data from 2017 for Balfour).

Table 8. Summary of mean daily temperatures during the Kootenay River burbot spawning and incubation window (Feb 7 to Apr 16) for Corn Creek, Goat River and Summit Creek and Kootenay Lake's West Arm by Balfour.

Location	Year	Mean temp. (°C)	Mean SE	Min. temp. (°C)	Max. temp. (°C)	Date of first record	Date of last record
Corn Creek (loggers 1 and 2)	2015	3.0	0.12	0.1	5.0	7-Feb-15	11-Apr-15
	2016	3.3	0.08	1.1	4.9	7-Feb-16	16-Apr-16
	2017	2.2	0.11	0.0	4.2	7-Feb-17	16-Apr-17
Goat River (Mid Goat logger)	2015	3.6	0.17	0.6	6.2	7-Feb-15	11-Apr-15
	2016	4.6	0.16	1.8	6.8	7-Feb-16	11-Apr-16
	2017	3.9	0.21	1.1	6.3	7-Mar-17	16-Apr-17
Summit Creek	2015	4.0	0.11	3.0	4.8	21-Mar-15	16-Apr-17
	2016	3.1	0.14	0.9	4.9	7-Feb-16	16-Apr-16
	2017	2.0	0.16	0	4.1	7-Feb-17	16-Apr-17
Balfour/West Arm	2014	4.3	0.05	3.8	5.5	7-Feb-14	16-Apr-14
	2015	4.8	0.05	4.4	5.7	7-Feb-15	16-Apr-15
	2016	5.2	0.07	4.9	7.55	7-Feb-16	11-Apr-16
	*2017	NA	NA	NA	NA	NA	NA

*There are no 2017 Balfour/West Arm temperatures due to the loss of the temperature logger

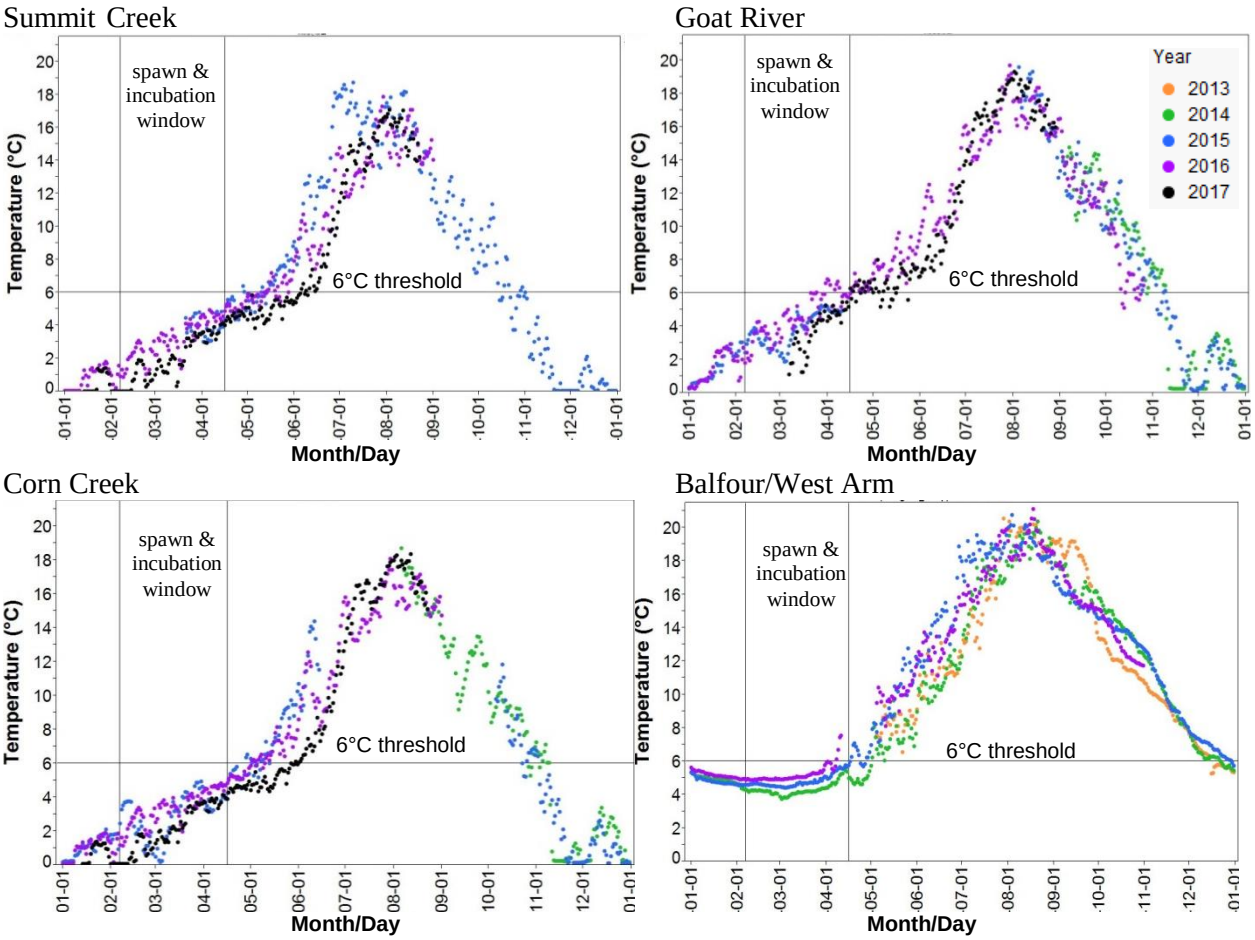

Figure 11. Mean daily water temperatures from 2013-2017 in Summit Creek, Goat River (Mid-Goat Logger), Corn Creek (Loggers #1 and #2) and Balfour/West Arm boathouse. Burbot spawn and incubation windows were identified between February 7 and April 16.

3.3.3 Passive acoustic telemetry

Of the 60 burbot released into the West Arm, 70% survived release (i.e., survived one month minimum; n=42) and 43% survived one year post release (n=26). Higher first year survival rates were observed for the older release group (age 3-5 years) compared to the age 1 release group (50% and 37% respectively).

The older release group showed more extensive dispersal and habitat use than the age 1 release group (Figure 12). Of all the burbot that survived at minimum one month post release; 40% (17/42) did not leave the West Arm. Those burbot that dispersed out of the West Arm (n=25), 9.5% (n=4) were detected at least once in Kootenay River (upstream of river kilometer 120; Figure 12). Interestingly, two of the four fish detected in the river were from the younger release group. Although dispersal and habitat use varied wildly between individuals, outside of the West Arm, a few locations stood out as having higher use, both for count of burbot and number of detections at a location, specifically the top two were Pilot Point (RKM 81.5), Coffee Creek (RKM 70; Figure 13).

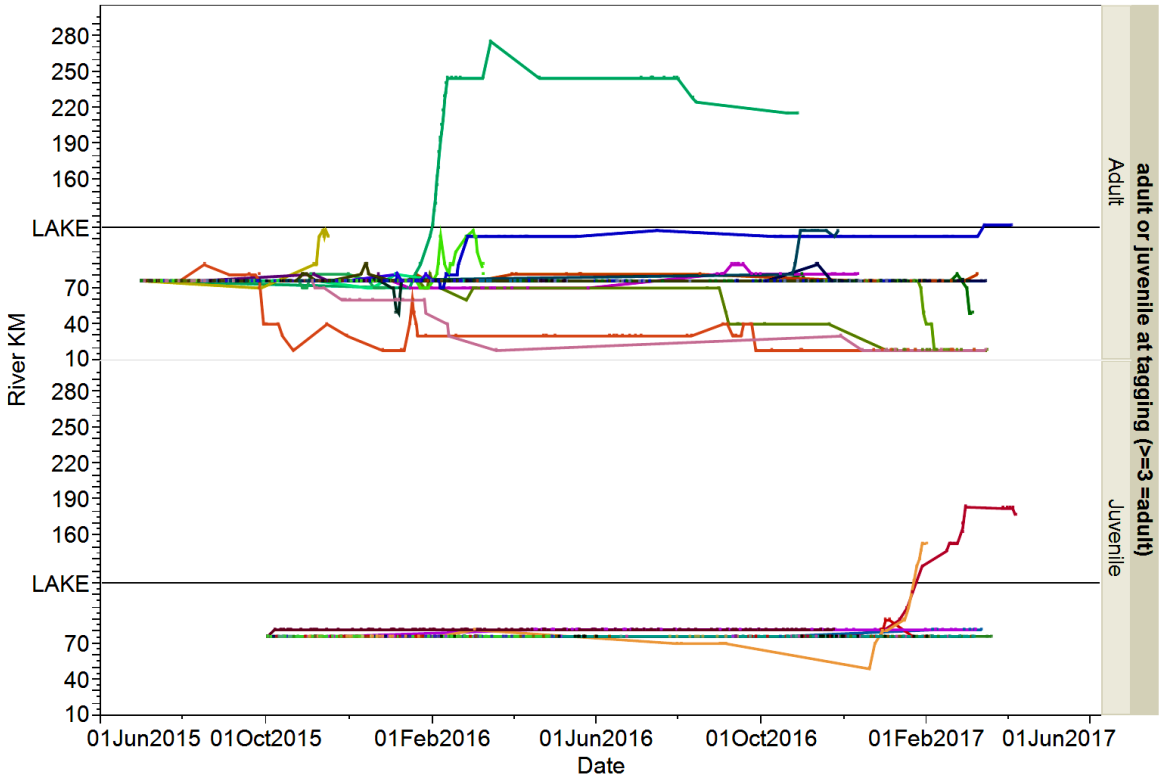

Figure 12. Detections of all individual sonic tagged hatchery burbot released into Kootenay Lake at Balfour (West Arm). The transition from lake to river is denoted as "LAKE" on the Y axis.

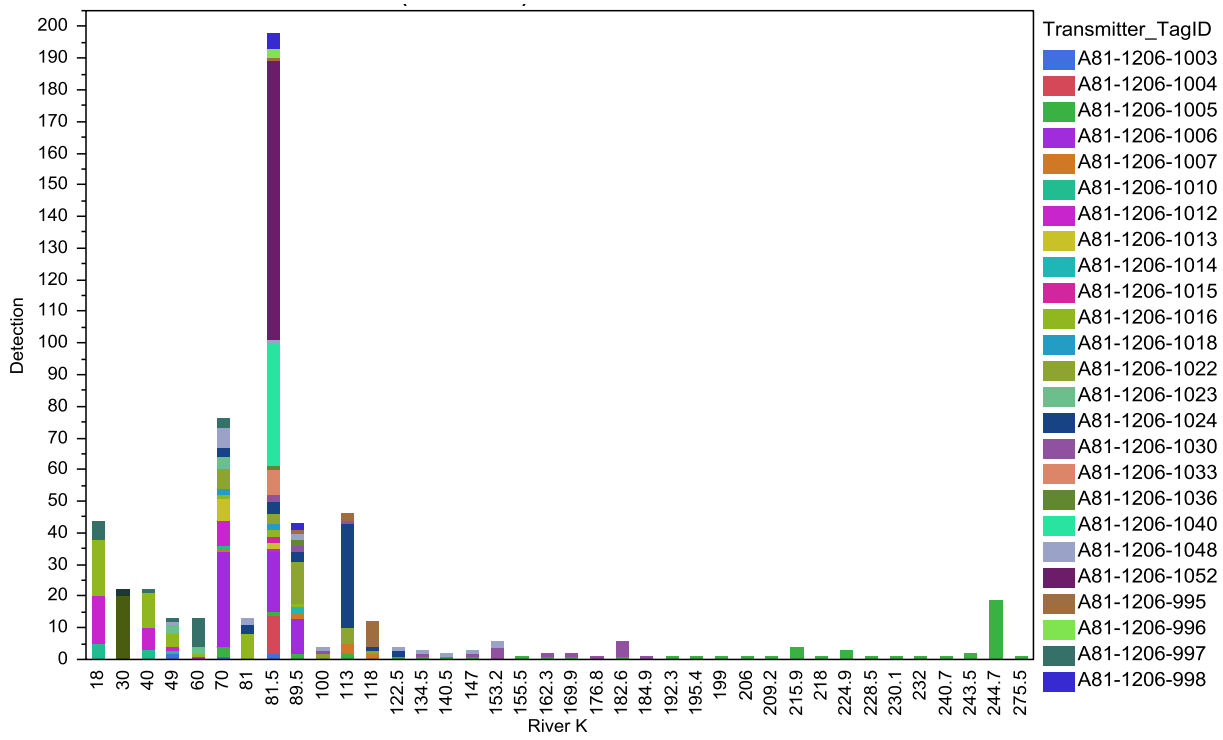

Figure 13. Summary of detections by tags and receiver location; receiver locations denoted by river kilometer. Note that river km 70, 81.5, 89.5, 113 have receiver arrays of three to four receivers so detection probability is higher at those locations.

3.3.4 Kootenay Lake cod trapping

A total of 69 cod trap sets were completed between March 17 and April 12, 2017. Effort and catch was similar to last year at 6,354 trapping hours and 12 burbot caught; total catch per unit effort (CPUE) was 0.05 burbot per 24 hours (Table 9; Appendix C for trap set information). The mean fishing time was 3.8 days, the mean depth was 17.0 m (ranging between 10.0-32.0 m) and the mean temperature was 3.0°C (ranging between 2.0 and 4.0°C). Bycatch collected during this study included: 12 peamouth chub (*Mylocheilus caurinus*), 14 northern pikeminnow (*Ptychocheilus oregonensis)*, two sculpin (*Cottus sp*.), one longnose sucker (*Rhinichthys cataractae*) and one bull trout (*Salvelinus confluentus*).

Table 9. Summary of Kootenay Lake Cod trapping effort and catch between 2013-2017.

Year	Trapping date ranges	# Traps	# Trapping hrs	# Burbot caught	CPUE (# BB/ 24hrs)	Mean length (mm)	SE of mean length
2013	Mar 14 - Apr 3	25	1,889	7	0.09	872.9	24.85
2014	Mar 5 - Mar 25	46	3,816	3	0.02	755.0	43.30
2015	Mar 6 - Apr 1	38	2,809	7	0.06	862.9	32.9
2016	Mar 7 – Apr 8	84	6,517	10	0.04	810.0	27.09
2017	Mar 17-Apr 12	69	6,354	12	0.05	763.8	34.95
Total	**-**	**262**	**21,385**	**39**	**0.04**	**812.4**	**16.41**

Ten of the burbot were collected near the Lardeau Delta and two were from the Creston Delta. No burbot were caught in the West Arm. Seven of the ten burbot captured had no signs of previous capture; the other three were confirmed hatchery origin (Appendix D for burbot capture information). One burbot had a PIT tag on capture when caught at the Lardeau Delta and was from the 2009 brood year, released in 2010 at either RKM 258.6 or 170. Furthermore, this fish was previously recaptured during hoop net sampling and given an acoustic tag (A81-1206-948) at RKM 244, in 2013; data suggests this fish has been living in the lake since fall 2015 (Figure 14). The remaining two hatchery fish did not have PIT tags on capture, but were identified as hatchery based on genetics; they did not however assign to a PBT baseline which means that we cannot identify their year class.

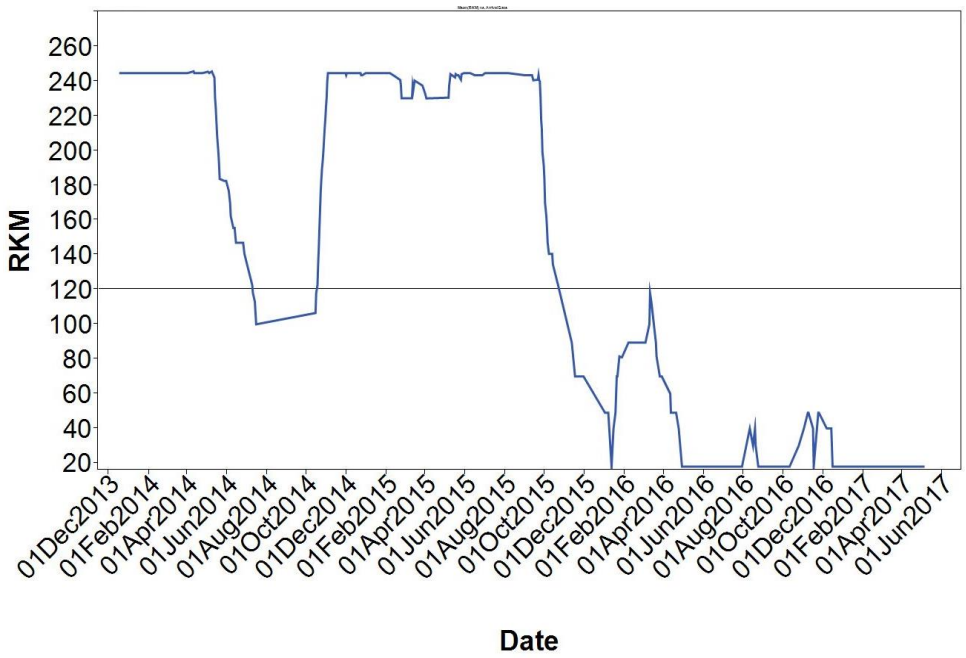

Figure 14. Detections of burbot sonic tag number A81-1206-948; tag expired January 6, 2017. Line at RKM 120 denotes the transition from lake to river.

3.4 Discussion

Our cod trap efforts have yet to indicate large numbers of hatchery burbot within Kootenay Lake, however telemetry data suggests extensive habitat use within the lake from those sonic tagged burbot within the lake. Additionally, with increased hatchery release efforts in the last two years, we would expect to see recruitment to our cod traps by these hatchery fish starting in 2018 when these fish reach age 3. Once burbot numbers increase and spawning occurs, temperature data suggests that there would be suitable thermal refuge available for egg incubation in the BC Kootenay River tributaries and at the mouth of the West Arm in Kootenay Lake.

The sonic tagged burbot released into Kootenay Lake in 2015, had similar good survival to the river release evaluations (Stephenson *et al*. 2013). In all Kootenay hatchery telemetry studies, evidence points to low mixing rates between the lake and the river. In studies evaluating the mixing rates from the river to the lake it was less 25% of the fish (Stephenson *et al*. 2013; Hardy *et al*. 2015), further demonstrating the current low mixing rates, the newest data from burbot released into the lake, only 10% went up into the river from the lake. Detections at the receivers in the West Arm, Pilot Pt and Lardeau suggest these are areas the burbot would be found and this confirms the areas we are targeting with cod traps and we could expand further north from the Creston Delta to the receiver array at RKM 113.

As an increasing number of hatchery burbot are released into Kootenay Lake, and the number of hatchery burbot increase in Kootenay River, more burbot will be expected in Kootenay Lake. Additionally, if sonic telemetry, or cod trap catch rates, does not show an increase in lake use, from river tagged fish, hatchery release locations will be adapted to include more lake releases. Annual cod trapping and ongoing telemetry monitoring in the lake will enable tracking of burbot from the hatchery program as well as track the remnant wild population.

Literature cited

Ahrens, R., and J. Korman. 2002. What happened to the West Arm burbot stock in Kootenay Lake? Use of an age-structured population model to determine the possible causes of recruitment failure. Report prepared for the B.C. Ministry of Water, Land, and Air Protection, the Habitat Conservation Trust Fund, and the Bonneville Power Administration.

Andrusak, H. 1970. Report: Moyie Lake, Lake Survey 1969 00671KOTL. Report prepared for the BC Kootenay Region Fish and Wildlife Department.

Baxter, J., C. Spence and M. Neufeld. 2002a. Kootenay Lake Burbot Studies Progress 2000-2001. A report prepared for the Ministry of Water Land and Air Protection

Baxter, J., C. Spence and M. Neufeld. 2002b. Kootenay Lake Burbot Studies Progress 2001-2002. A report prepared for the Ministry of Water Land and Air Protection

Cain, K.D and N.K. Ashton. 2018. Thermal Bottlenecks Affecting Early Life History and Recruitment of Burbot: 2017 Progress Report. Report prepared for the Idaho Department of Fish and Game.

Hardy, R.S., S.M. Stephenson, M.N. Neufeld, and S.P. Young. 2015. Adaptation of Lake-Origin Burbot Stocked into a Large River Environment. Hydrobiologia, 757(1):35-47

Hardy, R., P. Rust, TJ Ross, S. Stephenson, and V. Wakkinen. 2016. Kootenai River resident fish mitigation: white sturgeon, burbot, native salmonid monitoring and evaluation. Prepared for Bonneville Power Administration. IDFG Annual Progress Report, Report for 5/1/2014-04/31/201.

Ireland, S. C., and P. N. Perry. 2008. Burbot restoration in the Kootenai River basin: using agency, tribal, and community collaboration to develop and implement a conservation strategy. Pages 251-256 in V.L. Paragamian, and D.H. Bennett, editors. Burbot: ecology, management, and culture. American Fisheries Society, Symposium 59, Bethesda, Maryland.

Jensen, N. R., Williams, S. R., Ireland, S. C., Siple, J. T., Neufeld, M.D., and K.D. Cain. 2008. Preliminary captive burbot spawning observations. In: Burbot: ecology, management, and culture. V.L. Paragamian and D. H. Bennett (Eds). Am. Fish. Soc. Symp. 59: 155–165.

KVRI (Kootenai Valley Resource Initiative) Burbot Committee. 2005. Kootenai River/Kootenay Lake burbot conservation strategy. Kootenai Tribe of Idaho, Bonner's Ferry, Idaho.

Neufeld, M.D. 2005. White Sturgeon and Burbot Recovery Progress in British Columbia 2004-05. Report prepared for Ministry of Environment, Lands and Parks, Nelson B.C.

Neufeld, M.D. 2008. Moyie Lake burbot: population assessment 2007. Report prepared for Ministry of Environment, Lands and Parks, Nelson B.C.

Neufeld, M.D. 2010. Moyie Lake burbot program 2009-1010: conservation aquaculture gamete collection and spawning surveys. Report prepared for Ministry of Environment, Lands and Parks, Nelson B.C.

Neufeld, M.D., and C. Spence. 2001. A simple decompression procedure to reduce gas bubble trauma in burbot, 2002. Report prepared for Ministry of Environment, Lands and Parks, Nelson B.C.

Neufeld, M.D., and C. Spence. 2004. Kootenay Fisheries Investigations, Sturgeon and Burbot Progress, 2002. Report prepared for Ministry of Environment, Lands and Parks, Nelson B.C.

Neufeld, M.D., and C. Spence. 2009. Moyie Lake burbot program 2008-2009: sport fishery, juvenile sampling and conservation aquaculture/spawning surveys. Report prepared for the British Columbia Ministry of Environment, Nelson, BC, 49 p.

Neufeld, M. D., K. D. Cain, N. R. Jensen, S. C. Ireland, and V. L. Paragamian. 2011a. Movement of lake-origin Burbot reared in a hatchery environment and released into a large river drainage. North American Journal of Fisheries Management 31:56–62.

Neufeld, M. D., C.A Davis, K. Cain, N. Jensen, S. Ireland and C. Lewandowski. 2011b. Evaluation of methods for the collection and fertilization of burbot eggs from a wild stock for conservation aquaculture operations. Journal of Applied Ichthyology. 27:9-15.

Paragamian, V. L., V. Whitman, J. Hammond and H. Andrusak. 2000. Collapse of the burbot fisheries in Kootenay Lake, British Columbia Canada, and the Kootenai River, Idaho, USA, post-Libby Dam. Pages 155-164 in V.L. Paragamian and D. W. Willis, editors. Burbot: biology, ecology, and management. American Fisheries Society, Fisheries Management Section, Publication 1, Bethesda, Maryland.

Paragamian, V.L., J.L. Mccormick, and C. Laude. 2008. Changes in population indices of a diminishing burbot population in the Kootenai River, Idaho, USA and British Columbia, Canada. Journal of Freshwater Ecology, 23(4):553-563.

Partridge, F. 1980. River and stream investigations − Study VI: Kootenai River fisheries investigations period covered: 1 March 1979 to 29 February 1980. Idaho Fish and Game, Project F-73-R-2, Bonner's Ferry, Idaho.

Partridge, F. 1983. Kootenai River fisheries investigations in Idaho. Completion Report. Prepared for the US Army Corps of Engineers by the Idaho Department of Fish and Game.

Powell, M., V.L. Paragamian, and J. Dunnigan. 2008. Mitochondrial variation in western North American burbot with special reference to the Kootenai River in Idaho and Montana. In: Burbot: ecology, management, and culture. V. L. Paragamian and D. Bennett (Eds). Am. Fish. Soc. Symp. 59, Bethesda, MD, USA, pp. 3–27.

Ross, T.J., Rust, P., Hardy, R., Stephenson, S., S. Dinsmore and R. Fosness. 2015. Kootenai River resident fish mitigation: white sturgeon, burbot, native salmonid monitoring and evaluation. IDFG report number 15-01, Prepared for Bonneville Power Administration. Annual Progress Report for 5/1/2013 – 04/30/2014.

Rust, P., T.J. Ross, R. Hardy, S. Dinsmore, and V. Wakkinen. 2017. Kootenai River resident fish mitigation: white sturgeon, burbot, native salmonid monitoring and evaluation. IDFG report number 17-03, Report for 5/1.2015-04/31/2016.

Schwarz, C. J. 2011. Review of mark-recapture sampling program to estimate abundance of Burbot in Moyie Lake, British Columbia. Prepared for B.C. MOE. Dated 2011-01-28. 14 pp.

Schwarz, C. J. 2012. Estimating the number of burbot in Moyie Lake, British Columba based on a mark recapture experiment. Prepared for B.C. MFLNR. Dated 2012-07-25. 11 pp.

Spence, C.R. 1999a. A Comparison of Catch Success Between Two Styles of Burbot Traps in Lakes, pages 165-170. *In*: V.L. Paragamian and D.W. Willis (editors). Burbot Biology, Ecology, and Management. Publication Number 1, Fisheries Management Section of the American Fisheries Society. Spokane, WA.

Spence, C.R. 1999b. Kootenay Lake Burbot Studies: Progress 1998-1999. Report to Habitat Conservation Trust Fund and Bonneville Power Administration from the Ministry of Environment, Lands and Parks, Nelson, B.C. ii+53 pp.

Spence, C.R. 2000. A comparison of catch success between two styles of burbot traps in lakes. Pages 165-170 *In*: Paragamian, V.L. and D.W. Willis. (Eds.) Burbot Biology, Ecology, and Management. American Fisheries Society, Fisheries Management Section, Publication Number 1.

Stephenson, S., and M. Neufeld. 2013. Moyie Lake burbot gamete collection. 2013. Ministry of Forest, Lands and Natural Resource Operations, Nelson B.C.

Stephenson, S., M. Neufeld, S. Young, S. Ireland, R. Hardy, and P. Rust, 2013. Survival and dispersal of sonic tagged hatchery-reared burbot released into the Kootenai River. Transactions of the American Fisheries Society 142:1671-1679.

Stephenson, S., and V. Evans. 2014. 2013-2014 Kootenay burbot summary: Moyie Lake and Kootenay Lake. Ministry of Forests Lands and Natural Resource Operations, Nelson B.C.

Stephenson, S., and V. Evans. 2015. 2014-2015 Kootenay burbot summary: Moyie Lake and Kootenay Lake. Ministry of Forests Lands and Natural Resource Operations, Nelson B.C.

Stephenson, S., and V. Evans. 2016. 2015-2016 Kootenay burbot summary: Moyie Lake and Kootenay Lake. Ministry of Forests Lands and Natural Resource Operations, Nelson B.C.

Taylor, J.L., and J.D. McPhail, 2000. Temperature, development, and behavior in the early life history of Burbot from Columbia Lake, British Columbia. Pages 30-37. In V.L. Paragamian and D.W. Willis (editors), Burbot: biology, management, and ecology. American Fisheries Society, Fisheries Management Section, Publication Number 1, Bethesda, Maryland.

Vught, I., A.S. Harzevilli, J. Auwerx, D. De Charleroy, V.L. Paragamian, & D.H. Bennet. 2008. Aspects of reproduction and larviculture of burbot under hatchery conditions. In Burbot: Ecology, Management and Culture (Paragamian, V. L. & Bennet, D. H., eds), pp. 167–178. American Fisheries Society Symposium 59.

Zarski, D., D. Kucharczyk, W. Sasinowski, K. Targoska, & A. Mamcarz. 2010. The influence of temperature on successful reproductions of Burbot, Lota lota (L.) under hatchery conditions. Polish Journal of Natural Sciences 25, 93–105.

Appendices

Appendix A: Summary of all families created from Moyie Lake burbot gamete collection, 2017. Includes the volume of eggs taken in the field and the Hatchery results of egg viability post fertilization and egg count calculations.

Field									Hatchery				
spawn date	female floy tag #	male floy tag #	mL of eggs taken[1]	egg # estimate from field[2]	eggs bloody from start? Yes/ No	eggs bloody at end? Yes/No	eggs have fungus? Yes/No	fertilization comments	Hatch-ery[3]	48 hour viability (%)	48 hour post fertilization survival (# eggs)	Survival at hatch ~40 days (%)	Egg estimate at hatch
14-Feb-17	14325	14974	100	180,000	No	No	No	Look Good	KTOI	0.01	1,800		
14-Feb-17	14325	14841	100	180,000	No	No	No	Look Good	KTOI	0.953	171,540		
14-Feb-17	14049	14849	90	162,000	No	No	No	Look Good	KTOI	0.831	134,622		
14-Feb-17	14049	14973	75	135,000	No	No	No	Look Good	KTOI	0.736	99,360		
14-Feb-17	14330	14971	80	144,000	No	No	No	floating/white eggs present	KTOI	0.788	113,472		
14-Feb-17	14330	14838	85	153,000	No	No	No	floating/white eggs present	KTOI	0.198	30,294		
15-Feb-17	14846	14994	80	144,000	No	No	No	Good eggs	KTOI	0.99	142,560		
15-Feb-17	14846	14840	90	162,000	No	Yes	No	Good eggs	KTOI	0.966	156,492		
15-Feb-17	14048	14843	80	144,000	No	No	No	Good eggs	KTOI	0.9805	141,192		
15-Feb-17	14048	14823	90	162,000	No	No	No	Good eggs	KTOI	0.9608	155,649.6		
15-Feb-17	14950	14842	75	135,000	No	No	No	Good eggs	KTOI	0.975	131,625		
15-Feb-17	14950	14047	70	126,000	No	Yes	No	Good eggs	KTOI	0.9387	118,276.2		
15-Feb-17	14977	14676	60	108,000	No	No	No	Has some floating eggs	KTOI	0.994	107,352		
15-Feb-17	14977	14982	45	81,000	No	No	No	No comment	KTOI	0.9797	79,355.7		
16-Feb-17	14045	14976	62.5	112,500	No	No	No	ARI has sample of this family	KTOI	0.9399	105,738.75		
16-Feb-17	14045	14976	12.5	22,500	No	No	No	ARI took 25ml ~1hr post fertilization equating to ~12.5ml unfertilized eggs	UofI			0.79	17775
16-Feb-17	14045	14421	60	108,000	No	No	No	No Comment	KTOI	0.9739	105,181.2		
16-Feb-17	14331	14423	87.5	157,500	No	No	No	ARI has sample of this family	KTOI	0.9078	142,978.5		
16-Feb-17	14331	14423	12.2	21,960	No	No	No	ARI took 25ml ~1hr post fertilization equating to ~12.5ml unfertilized eggs	UofI			0.52	11419
16-Feb-17	14331	12721	100	180,000	No	No	No	No Comment	KTOI	0.9295	167,310		
16-Feb-17	14331	14835	75	135,000	No	Yes	No	No Comment	KTOI	0.6897	93,109.5		
16-Feb-17	14960	14890	82.5	148,500	No	No	No	ARI has sample of this family	KTOI	0.9537	141,624.45		

Appendix A: Summary of all families created from Moyie Lake burbot gamete collection, 2017. Includes the volume of eggs taken in the field and the Hatchery results of egg viability post fertilization and egg count calculations.

Field									Hatchery				
spawn date	female floy tag #	male floy tag #	mL of eggs taken[1]	egg # estimate from field[2]	eggs bloody from start? Yes/ No	eggs bloody at end? Yes/No	eggs have fungus? Yes/No	fertilization comments	Hatch-ery[3]	48 hour viability (%)	48 hour post fertilization survival (# eggs)	Survival at hatch ~40 days (%)	Egg estimate at hatch
16-Feb-17	14960	14890	12.5	22,500	No	No	No	ARI took 25ml ~1hr post fertilization equating to ~12.5ml unfertilized eggs	UofI			0.91	20475
16-Feb-17	14895	14820	38	68,400	No	No	No	All 38mL of unfertilized eggs to ARI; eggs lighter in color	UofI			0.71	48564
16-Feb-17	13084	14819	60	108,000	No	Yes	No	All 60mL of unfertilized eggs to go to U of I	UofI			0.79	85320
17-Feb-17	14415	14043	100	180,000	No	No	No	No Comment	KTOI	0.959	172,620		
17-Feb-17	14418	14042	60	108,000	No	Yes	No	No Comment	KTOI	0.995	107,460		
17-Feb-17	14418	14333	50	90,000	No	Yes	No	No Comment	KTOI	0.932	83,880		
17-Feb-17	14972	14150	120	216,000	No	No	No	No Comment	KTOI	0.942	203,472		
17-Feb-17	14972	14898	125	225,000	No	No	No	No Comment	KTOI	0.586	131,850		
17-Feb-17	14311	14814	75	135,000	No	Yes	No	No Comment	KTOI	0.881	118,935		
17-Feb-17	14311	14894	75	135,000	No	Yes	No	No Comment	KTOI	0.838	113,130		
17-Feb-17	14311	12551	80	144,000	No	Yes	No	No Comment	KTOI	0.961	138,384		
17-Feb-17	14975	14414	75	135,000	No	No	Yes	No Comment	KTOI	0.97	130,950		
17-Feb-17	14975	14897	60	108,000	No	No	Yes	No Comment	KTOI	0.981	105,948		
17-Feb-17	14975	14829	70	126,000	No	No	Yes	No Comment	KTOI	0.987	124,362		
21-Feb-17	14800	14409	85	153,000	No	Yes	Yes	No Comment	KTOI	0.8705	133,186.5		
21-Feb-17	14553	14449	25	45,000	No	No	No	No Comment	KTOI	1	45,000		
21-Feb-17	14559	14557	25	45,000	No	Yes	No	No Comment	KTOI	0.6776	30,492		
21-Feb-17	14360	14373	40	72,000	No	Yes	No	No Comment	KTOI	0.9716	69,955.2		
23-Feb-17	13734	14878	60	108,000	No	Yes	No		KTOI	0.987	106,596		
23-Feb-17	14972	12249	65	117,000	No	No	Yes	No Comment	KTOI	0.977	114,309		
23-Feb-17	14972	14752	55	99,000	No	No	No	No Comment	KTOI	0.985	97,515		

Appendix A: Summary of all families created from Moyie Lake burbot gamete collection, 2017. Includes the volume of eggs taken in the field and the Hatchery results of egg viability post fertilization and egg count calculations.

Field									Hatchery				
spawn date	female floy tag #	male floy tag #	mL of eggs taken[1]	egg # estimate from field[2]	eggs bloody from start? Yes/ No	eggs bloody at end? Yes/No	eggs have fungus? Yes/No	fertilization comments	Hatch-ery[3]	48 hour viability (%)	48 hour post fertilization survival (# eggs)	Survival at hatch ~40 days (%)	Egg estimate at hatch
23-Feb-17	14351	14751	55	99,000	No	No	No	Some egg clumping upon strip; accidentally left in Ovadine for 50 min extra	KTOI	0.976	96,624		
23-Feb-17	14351	14408	60	108,000	No	No	No	Some egg clumping upon strip; accidentally left in Ovadine for 50 min extra	KTOI	0.982	106,056		
23-Feb-17	14909	14903	60	108,000	No	No	No	No Comment	KTOI	0.984	106,272		
23-Feb-17	14909	14754	60	108,000	No	No	No	No Comment	KTOI	0.972	104,976		
23-Feb-17	14909	14168	50	90,000	No	No	No	No Comment	KTOI	0.986	88,740		
23-Feb-17	13547	14464	45	81,000	No	No	Yes	No Comment	KTOI	0.936	75,816		
23-Feb-17	14912	14910	45	81,000	No	No	No	male lost red tag in tube and was re-tagged with 14910; feces present in eggs	KTOI	0.9882	80,044.2		
23-Feb-17	14912	14038	45	81,000	No	No	No	No Comment	KTOI	0.973	78,813		
24-Feb-17	14354 & 14035	14382	60	108,000	No	No	No	Eggs are lighter in colour but look great (*Shawn's fish!)	KTOI	0.992	107,136		
24-Feb-17	14354 & 14035	14603	60	108,000	No	No	No	Eggs are lighter in colour but look great (*Shawn's fish!)	KTOI	0.961	103,788		
24-Feb-17	14354 & 14035	14614	75	135,000	No	No	No	Eggs are lighter in colour but look great (*Shawn's fish!)	KTOI	0.973	131,355		
24-Feb-17	14354 & 14035	14915	50	90,000	No	No	No	Eggs are lighter in colour but look great (*Shawn's fish!)	KTOI	0.986	88,740		
24-Feb-17	14354 & 14035	14378	50	90,000	No	No	No	Eggs are lighter in colour but look great (*Shawn's fish!)	KTOI	0.922	82,980		

Appendix A: Summary of all families created from Moyie Lake burbot gamete collection, 2017. Includes the volume of eggs taken in the field and the Hatchery results of egg viability post fertilization and egg count calculations.

Field									Hatchery				
spawn date	female floy tag #	male floy tag #	mL of eggs taken[1]	egg # estimate from field[2]	eggs bloody from start? Yes/ No	eggs bloody at end? Yes/No	eggs have fungus? Yes/No	fertilization comments	Hatch-ery[3]	48 hour viability (%)	48 hour post fertilization survival (# eggs)	Survival at hatch ~40 days (%)	Egg estimate at hatch
24-Feb-17	14354 & 14035	14617	50	90,000	No	No	No	Eggs are lighter in colour but look great (*Shawn's fish!)	KTOI	0.971	87,390		
24-Feb-17	12058	14916	60	108,000	No	No	No	Female was spawned in 2013, Shawn said to use	KTOI	0.988	106,704		
24-Feb-17	12058	14600	50	90,000	No	No	No	Female was spawned in 2013, Shawn said to use	KTOI	0.97	87,300		
24-Feb-17	12058	14376	50	90,000	No	No	No	Female was spawned in 2013, Shawn said to use	KTOI	0.975	87,750		
24-Feb-17	12058	14604	50	90,000	No	No	No	Female was spawned in 2013, Shawn said to use	KTOI	0.954	85,860		
Subtotal		KTOI	3,807.5	6,853,500	-	-	-		KTOI		6,073,922		
		UofI	135.2	243,360				**Survival**	UofI		183,553		
Total			**3,943**	**7,096,860**					**Total**		**6,257,475**		

[1] Egg volume of eggs sent to ARI were measured post-fertilization and rinse.
[2]Egg numbers were estimated in the field using the 1802 unfertilized eggs/mL ratio established in 2013
[3] Hatcheries: Aquaculture Research Institute (ARI) and Twin Rivers (TW)

Appendix B: Summary of annual egg count, percent egg survival and number of adults, juveniles and larval burbot released into the Kootenay system between 2009 and 2017 from the University of Idaho's Aquaculture Research Institute (ARI) and KTOI's Twin River's hatchery (TR)

Measure[1]	*Year*								
	2009	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
Hatchery involved	ARI	ARI	ARI	ARI	ARI	ARI	ARI and TR	ARI and TR	ARI and TR
# of live eggs 48hours post fertilization	353,429	3,032,143	3,970,283	4,532,500	5,939,208	5,667,871		6,574,230	6,073,922
48 hr mean egg survival (%)	12	48	73	65	70	87		90[2]	91[3]
# of live eggs 10 days post fertilization	-	-	-	-	-	-	6,378,225	-	-
10 day mean egg survival (%)	-	-	-	-	-	-	91	-	-
# of live eggs at hatch (~40 days post fertilization)									183,553[3]
mean egg survival (%)at hatch (~40 days post fertilization)									75
# Adult burbot released (>2 years)	7	23	32	55	71	32	30	0	0
# of Juvenile burbot released (<2 years & > 60 days post hatch)	202	2,131	70,384	29,130	11,484	3,691	272,870	138,237	36,482
# of Larval burbot released (<60 days post hatch)	0	0	0	243,250	450,000	0	632,590	0	

[1] All years, except 2015, egg viability was measured at 48 hours. In 2015 the 10 day mean egg survival was consistently measured between both hatcheries.
[2] Survival applies only to eggs sent to Twin Rivers. No survival rate provided for the estimated 200,000 eggs sent to ARI.
[3] 48 hour from TR only and 10 day from ARI

Appendix C: Cod trapping set information and capture summary from Kootenay Lake, 2017.

Cod Trap #	PullDate	Rkm	Zone	Easting	Northing	Water Depth (m)	Water Temp (C)	Total time deployed (in hours)	Number of burbot captured	BB caught/24h (CPUE)	Bycatch species captured
1	20-Mar-17	76	11	503521	5497948	16	3	84.87	0	0.00	
2	20-Mar-17	76	11	503647	5497845	17	2	72.91	0	0.00	PCC
3	20-Mar-17	76	11	503977	5497812	18	3	73.01	0	0.00	
4	20-Mar-17	76	11	504003	5497569	13	3	73.18	0	0.00	NPC,PCC
5	20-Mar-17	76	11	504050	5497342	17	3	73.24	0	0.00	
6	20-Mar-17	76	11	504133	5497265	14	3	73.36	0	0.00	
7	20-Mar-17	76	11	504610	5497134	17	3	73.45	0	0.00	
8	20-Mar-17	76	11	504808	5497029	15	3	73.58	0	0.00	PCC
1	23-Mar-17	76	11	503521	5497948	17	3	69.39	1	0.35	PCC
2	23-Mar-17	76	11	530647	5497845	20	3	69.29	1	0.35	PCC
3	23-Mar-17	76	11	530977	5497812	20	3	69.21	0	0.00	NPC,PCC
4	23-Mar-17	76	11	504003	5497569	15	3	69.16	1	0.35	NPC
5	23-Mar-17	76	11	504030	5497351	13	3	69.26	0	0.00	NPC, PCC
6	23-Mar-17	76	11	504116	5497293	22	3	69.24	1	0.35	NPC
7	23-Mar-17	76	11	504590	5497159	18	3	69.20	0	0.00	NPC
8	23-Mar-17	76	11	504759	5497067	27	3	69.13	0	0.00	PCC
1	24-Mar-17	18	11	503493	5554149	19	2	71.21	0	0.00	
2	24-Mar-17	18	11	502993	5555380	16	2	71.44	0	0.00	
3	24-Mar-17	18	11	503032	5556135	16	2	71.48	0	0.00	LSU
4	24-Mar-17	18	11	503481	5556568	16	2	71.44	0	0.00	NPC
5	24-Mar-17	18	11	504524	5557280	14	2	71.59	0	0.00	NPC
6	24-Mar-17	18	11	505092	5557403	15	2	71.65	0	0.00	
7	24-Mar-17	18	11	505518	5556975	14	2	71.72	0	0.00	
8	24-Mar-17	18	11	505575	5556395	13	2	71.74	0	0.00	
1	28-Mar-17	76	11	498017	5494530	23	3	117.91	0	0.00	PCC
2	28-Mar-17	76	11	498165	5494636	32	3	117.96	0	0.00	
3	28-Mar-17	76	11	498519	5494756	25	3	117.95	0	0.00	
4	28-Mar-17	76	11	499036	5495135	23	3	117.98	0	0.00	
5	28-Mar-17	76	11	499260	5496049	15	3	117.97	0	0.00	PCC
6	28-Mar-17	76	11	498953	5496037	16	3	117.98	0	0.00	CC

Appendix C: Cod trapping set information and capture summary from Kootenay Lake, 2017.

Cod Trap #	PullDate	Rkm	Zone	Easting	Northing	Water Depth (m)	Water Temp (C)	Total time deployed (in hours)	Number of burbot captured	BB caught/24h (CPUE)	Bycatch species captured
7	28-Mar-17	76	11	498766	5496003	15	3	118.13	0	0.00	
8	28-Mar-17	76	11	498590	5495966	17	3	117.98	0	0.00	
1	29-Mar-17	18	11	503504	5555415	20	2	120.24	1	0.20	
2	29-Mar-17	18	11	502986	5555429	14	2	120.16	1	0.20	
3	29-Mar-17	18	11	503046	5556211	15	2	120.19	1	0.20	
4	29-Mar-17	18	11	503536	5556774	17	2	120.17	1	0.20	
5	29-Mar-17	18	11	504640	5557298	20	2	120.14	0	0.00	
6	29-Mar-17	18	11	505133	5557380	19	3	120.04	1	0.20	
7	29-Mar-17	18	11	505515	5556984	14	3	120.12	1	0.20	
8	29-Mar-17	18	11	505583	5556394	12	3	120.22	0	0.00	
1	30-Mar-17	77	11	512779	5501078	19	4	47.61	0	0.00	
2	30-Mar-17	77	11	513043	5501179	17	4	47.62	0	0.00	
3	30-Mar-17	77	11	513280	5501225	20	4	47.64	0	0.00	
4	30-Mar-17	77	11	513515	5501316	20	4	47.73	0	0.00	
11	04-Apr-17	119	11	524170	5460668	21	3	121.21	0	0.00	
2	04-Apr-17	120	11	524044	5461189	18	3	121.19	0	0.00	
3	04-Apr-17	120	11	523707	5461733	18	3	121.20	0	0.00	
4	04-Apr-17	120	11	523406	5462171	16	3	121.21	0	0.00	
5	04-Apr-17	120	11	522975	5462535	20	3	121.17	0	0.00	
6	04-Apr-17	120	11	522121	5455596	18	3	121.92	0	0.00	
7	04-Apr-17	120	11	521565	5456169	15	3	121.54	1	0.20	
8	04-Apr-17	120	11	521274	5456557	16	3	121.31	0	0.00	
9	04-Apr-17	120	11	520915	5457060	15	3	121.08	0	0.00	NPC
10	04-Apr-17	120	11	520713	5457488	15	3	120.88	0	0.00	NPC
4	07-Apr-17	117	11	522745	5462855	16	4	70.86	0	0.00	
5	07-Apr-17	117	11	522297	5463125	11	4	70.94	0	0.00	
6	07-Apr-17	117	11	520690	5457460	15	4	71.01	0	0.00	CC
3	07-Apr-17	118	11	523717	5461737	19	4	71.03	0	0.00	
7	07-Apr-17	118	11	520923	5457035	10	3	71.02	0	0.00	BT
1	07-Apr-17	119	11	524211	5460722	17	4	71.04	0	0.00	

Appendix C: Cod trapping set information and capture summary from Kootenay Lake, 2017.

Cod Trap #	PullDate	Rkm	Zone	Easting	Northing	Water Depth (m)	Water Temp (C)	Total time deployed (in hours)	Number of burbot captured	BB caught/24h (CPUE)	Bycatch species captured
2	07-Apr-17	119	11	524035	5461187	18	4	71.02	0	0.00	
8	07-Apr-17	119	11	521253	5456582	17	4	71.02	0	0.00	
9	07-Apr-17	119	11	521547	5456226	20	3	71.04	0	0.00	
10	07-Apr-17	122	11	522056	5455580	15	3	70.94	0	0.00	
1	12-Apr-17	116	11	522669	5462917	12	3	123.17	0	0.00	
1	12-Apr-17	117	11	521524	5456268	17	3	121.87	0	0.00	PCC
2	12-Apr-17	117	11	522253	5463165	10	3	123.01	0	0.00	
1	12-Apr-17	118	11	521237	5456603	19	3	122.21	1	0.20	
1	12-Apr-17	119	11	521547	5457035	11	3	121.60	0	0.00	

[2]BT=Bull Trout, LSU=Longnose sucker, NSC=northern pikeminnow, PCC=peamouth chub, CC=Sculpin spp.

Appendix D: Burbot captures from 2016, Kootenay Lake cod trapping efforts

RKM	Capture Date	Total Length (mm)	Weight (g)	PIT	Prior Tags	Genetic Sample #	Hatchery Fish (based on genetics)	Development Stage	Comments
18	21-Mar-17	800	2,700	226000718973	No	LloKOOL17S-001	No	Unknown	eyes were bulged out
18	21-Mar-17	550	1,050	226000803748	No	LloKOOL17S-002	No	Unknown	No Comments
18	21-Mar-17	830	3,350	226000719030	No	LloKOOL17S-003	No	Unknown	Missing one eye
18	21-Mar-17	660	1,800	3D9.1C2D4D19A6	Yes	LloKOOL17S-004	Yes	Unknown	Surgery scar on abdomen. Confirmed has sonic tag
18	24-Mar-17	780	2,300	900 226000803732	No	LloKOOL17S-005	No	RM	No Comments
18	24-Mar-17	750	2,200	900 226000803555	No	LloKOOL17S-006	No	Unknown	No Comments
18	24-Mar-17	840	3,400	900 226000718949	No	LloKOOL17S-007	No	SF	No Comments
18	24-Mar-17	890	3,900	900 226000803717	No	LloKOOL17S-008	No	Unknown	One bulging eye
18	24-Mar-17	910	4,500	900 226000719008	No	LloKOOL17S-009	No	Unknown	No Comments
18	24-Mar-17	880	3,600	900 226000803531	No	LloKOOL17S-010	No	Unknown	No Comments
120	30-Mar-17	710	2,600	226000803672	No	LloKOOL17S-011	Yes	SF	Female. Whitish Opaque eggs.
121	07-Apr-17	566	1,600	226000818470	No	LloKOOL17S-012	Yes	GF	she was expressing "green" eggs probably due to pressure