2017-18 lower Kootenay burbot summary: Moyie Lake and Kootenay Lake/River

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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, Ross *et al.* 2018). 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). In 2018 the first case of successful in-river spawning was confirmed, and the virtual population analysis indicated the Kootenay River population would reach recovery targets of 17,500 adult (4+) burbot by January 2019 therefore Idaho Fish and Game has moved forward with re-opening the burbot fishery in the river (Ross *et al*. and Squier 2019). Details of the fishery will be found in IDFG's annual report. BC biologists are closely monitoring and evaluating the establishment and growth of the population and will consider a fishery in the future assuming the population remains stable.

This report includes all of FLNRORD's burbot sampling efforts in 2017-2018 (June 2017 through May 2018) completed as part of lower Kootenay burbot recovery efforts as well as recommendations for changes to future sampling. The Moyie Lake portion of this report includes a summary of the gamete collections, a summary of the passive acoustic telemetry study initiated in 2013 and a summary of the

Moyie Lake spawning population estimate based on re-capture records. 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 2017. Other monitoring programs include the large hoop netting program completed annually by IDFG (for all annual reports see IDFG's library on their main website). 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 2018 Moyie Lake burbot gamete collection efforts were a success due to the cooperative efforts of IDFG, KTOI, ARI and FLNRORD (Appendix G:Photograph 1 of the 2018 Moyie Lake Burbot gamete collection field crew). This year was the tenth consecutive year of gamete collection from Moyie Lake burbot for the restoration efforts of the Kootenay burbot population. This year sampling occurred between February 12-16 at a location in the south east corner of the North basin. In total there were 415 burbot captures and gametes were collected from 32 females and 49 males. We collected and fertilized 7.85 million eggs on ice from 49 different families, meeting the pre-established egg collection target agreed upon at the 2017 Annual Program Review. In total 7.6 million eggs from 49 families were sent to the Twin Rivers hatchery while 234,260 eggs were sent to ARI. The egg viability 48hrs post fertilization at Twin Rivers was on average 91.7% which equates to an egg survival estimate of 6.96 million eggs. The mean egg viability of four of the five families sent to ARI was 80.2% at hatch (approximately 16 days post fertilization), the survival of the remaining family was not measured as it was sacrificed during a temperature study.

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, 2016 and 2018). In 2018 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 as many families as possible and create family sizes greater than 75mL of eggs (135,150 unfertilized eggs)
    - All eggs will be used for hatchery production at Twin Rivers except for an approximate subsample of five families representing ~250,000 eggs which will be sent to ARI for research,
- Collect genetic samples from all hatchery broodstock for tracking 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 12-16.

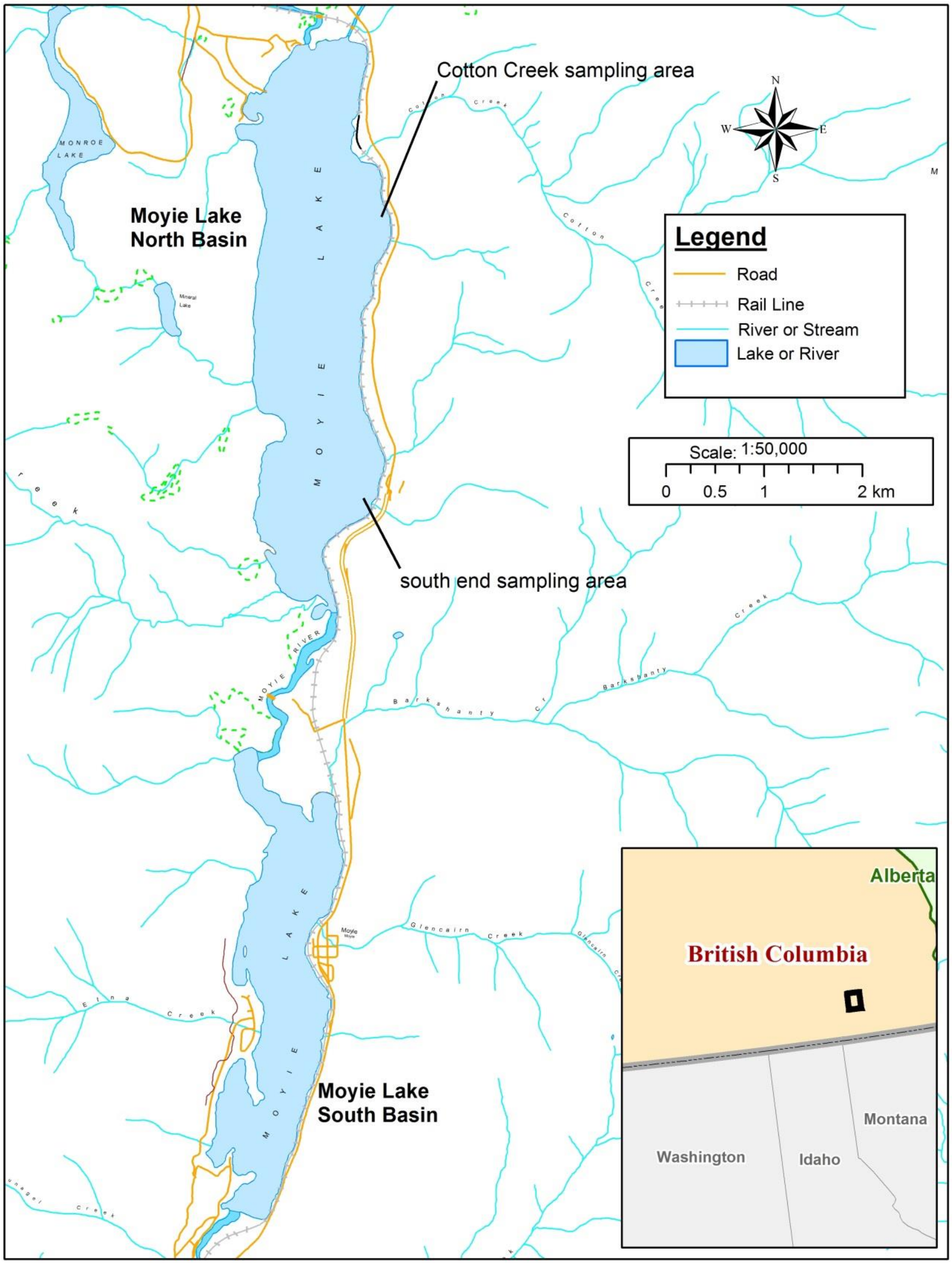

Figure 1. Study area overview, 2017. Sampling took place at the south end of the North basin.

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. 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 approximately 1-hour sets. As advised in 2018 (Stephenson and Evans 2018) a focused effort was made to deploy trammel nets in proximity to angling locations to evaluate capture biases in the long-term angling collection method. Angling could produce skewed results in a number of ways; examples include capturing a different proportion of sexes due to their spawning behaviours or due to their learned behaviours over time. Trammel effort and catch data are presented in this section while Section 2 will utilize this data to address the capture biases which could influence how recapture data is used to estimate survival and abundance of the total population.

On capture, all burbot were inspected for an existing Floy tag. Floy tags were the primary unique identifier for Moyie burbot. If no Floy tag was present on capture, a Floy tag was inserted through the dorsal fin rays, angled to the rear. All captured burbot were weighed to the nearest 50 g, total length was measured to the nearest millimetre and each fish was 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 2018 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. Egg viability was assessed at KTOI's Twin Rivers hatchery at 48 hours post fertilization and at ~16 days post hatch at ARI.

Ripe females are the lowest proportion of the catch (Stephenson and Evans 2014, 2015, 2016, 2018), 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 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 -2017, we used a few of the tubes to hold ripe males overnight to have the ability to collect milt and test sperm motility first thing the next morning. See Appendix G: Photographs 2-18 for a depiction of all steps taken to collect data from all burbot as well as the process taken to create families.

1.3.4 Data comparisons across all years (2009-2017)

Catch data was compared between 2018 and the previous nine 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 pairs of 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 five days totaling approximately 32 hours, between February 12 and 16, 2018. Individual rod hours were not tracked. Ice cover was approximately 10 cm thick for the duration of the study and mean water temperatures of 1.9°C SE 0.01 (ranging between 1.2°C –2.0°C) in water ~4.5 m deep. The total catch in 2018 was 415 burbot. Of the 415 capture events 11 were intra-year recapture events (10 fish were captured twice, and 1 fish was captured thrice) resulting in the capture of 404 individual burbot in 2018. Of the 404 individuals caught; 67 were female, 334 were male and 14 were unknown. There were also 80 inter-year recaptures (80/404; 19.8%). Inter-year recaptures were either tagged during previous gamete collection efforts which occurred between 2009 and 2017 or were tagged 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 2018.

Our analysis included 404 individual burbot with lengths and weights. The mean length of burbot captured was 536.3 mm (SE=3); the range was 340 mm to 755 mm (Figure 2). Mean length of individual males and females were significantly different ($p<0.0001$) at 527 (SE=4) and 574 mm (SE=8) respectively. The mean weight of all individuals was 1,195 g (SE=24) 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 1,364 g (SE=59) and mean weight of males was 1,144 g (SE=26). It should be noted that 12 of the 66 individual 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 415 captures, 388 captures were angled yielding an approximate CPUE 12 burbot/ sampling hour (388 burbot/32 hrs) and 27 captures were from the trammel nets yielding a CPUE of 5.9 burbot per sampling hour (27 burbot / 4.6 hours).

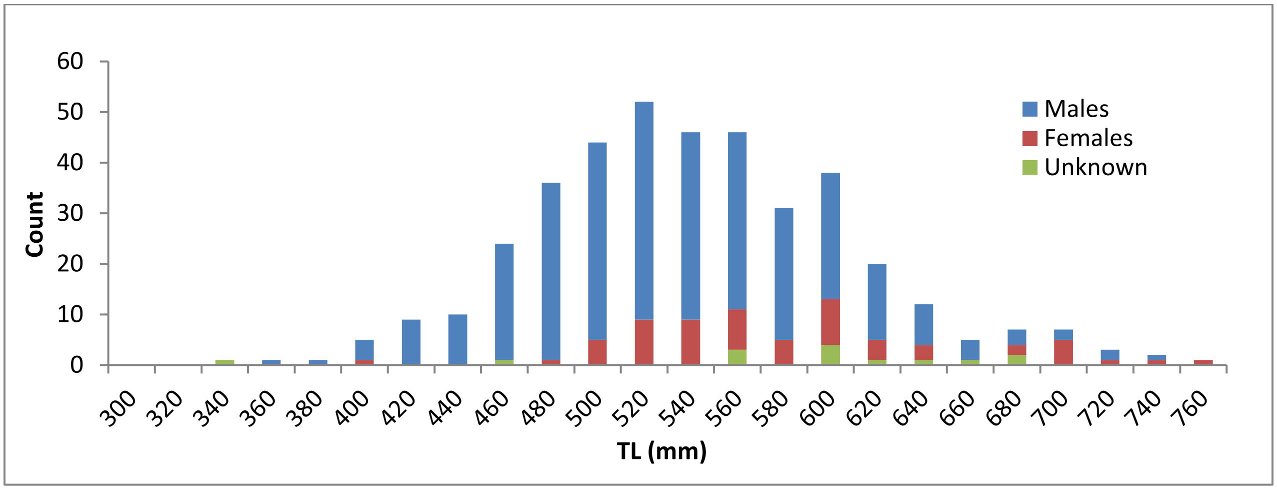

Figure 2. Length frequency histogram (20 mm bins) of 404 individual burbot captured by angling and trammel nets during gamete collection on Moyie Lake, February 2018.

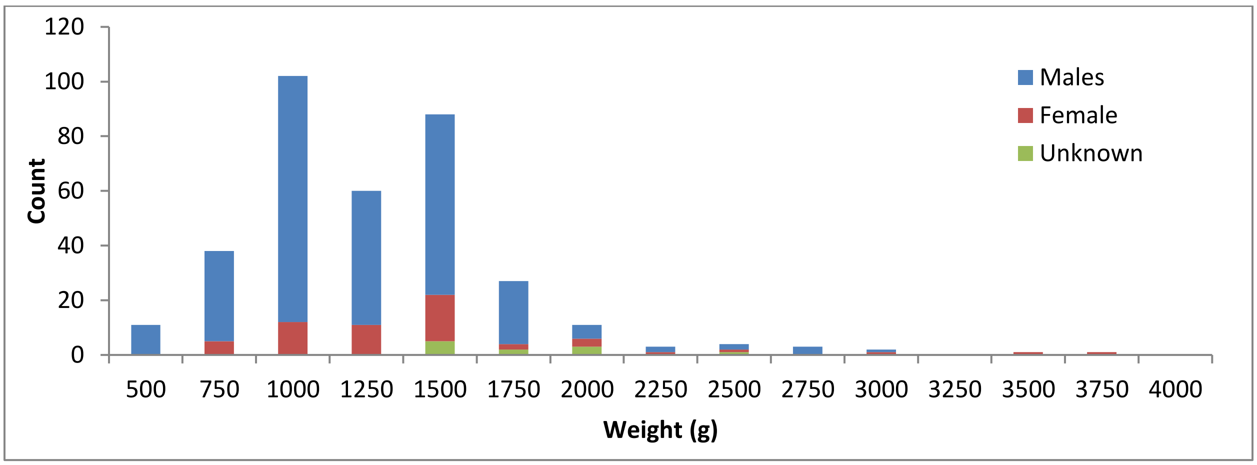

Figure 3. Weight frequency histogram (250g bins) of 351 individual burbot captured by angling and trammel nets, during burbot gamete collection on Moyie Lake, February 2018.

1.4.2 Spawning data

Of the 404 individual captures: 324 were male: one male was green, 319 were ripe and four were spent. Of the 319 ripe males captured, gametes were collected from 79; 25% (79/319) of milt samples collected were used to fertilize eggs. Of the 66 individual females collected, four were spent, 20 were ripe and 42 were green upon capture; 69% (29/42) of the green females were placed in holding tubes. We spawned 19 females that were ripe upon capture and 12 females that were held in the tubes. The two un-spawned females that were ripe upon capture were deemed unsuitable for spawning due to egg or body condition. Females spawned after being held in tubes accounted for 38% (12/32) of all females spawned this season. Furthermore, we also used the tubes to hold a total of 39 ripe males overnight to have males on hand first thing the next morning; 43% (21/49) of spawned males came from the tubes. Overall 68 burbot were held in the tubes this season.

A total of 49, single cross families were created in the field using 32 females and 49 males (Table 1). A tissue sample for DNA analysis was collected from all 80 burbot that were spawned. Milt was collected from 79 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 1.16 hours (min = 0.2 hrs, max= 4.73 hrs). Of the 79 milt samples collected: 89% (70/79) had greater than 80% motility and were deemed viable to use for fertilization while four samples were not motile, and five samples were not tested.

The volume of unfertilized eggs was measured in the field for each family. The egg volume ranged between 20-30 mL (22 mL; SE=1.7) for ARI and 50 mL to 135 mL (mean=86 mL; SE=2.4) for KTOI. The estimated number of eggs per family sent to ARI ranged from 36,040 to 54,060 eggs (mean 39,043: SE 3,003) and the estimated number of eggs per family sent to KTOI ranged from 90,100 to 243,270 eggs (mean 155,450 eggs; SE=4,401) per family. The total number of eggs collected in 2018 was estimated in the field at 7,851,314 (Table 1). A sample of 234,260 eggs from five different families was sent to ARI for temperature studies (Appendix A).

All of the 49 families sent to Twin Rivers had good survival. Survival within the first 48 hours ranged between 38.2 % to 100% (mean survival 91.0 %; SE = 1.8) and the survival after the first 10 days ranged from 12.8% to 99.6% (mean survival 92.2 %; SE=2.2; Appendix A). Survival of four of the five egg batches sent to ARI was measured and ranged between 40 % to 97% (mean 80.2%; SE = 0.1). The survival of the remaining ARI egg batch was not measured as these eggs were used for temperature studies. The egg batches with potential low-quality indicators in the field did not consistently correspond to low viability in the hatchery (Table 2). Total egg count from Twin Rivers at 48 hours and 10-day post fertilization was 6,961,094 eggs and 6,583,323 eggs respectively.

Table 1. Summary of Moyie Lake burbot families created and egg count in the field in 2018.

Date	Number of families	Total egg estimate in field	# of individual females	# of individual males
12-Feb-18	2	297,330	1	2
13-Feb-18	7	1,275,816	6	7
14-Feb-18	12	1,960,576	7	12
15-Feb-18	24	2,816,526	12	24
16-Feb-18	10	1,501,066	6	10
Total	**55**	**7,851,314**	***32***	**55**

Table 2. 2018 Moyie Lake 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	14	61.1% - 100%
Bloody only at beginning of egg take	0	NA
Bloody only at end of egg take	2	61.1% - 92.6%

1.4.3Data comparisons across all years (2009-2018)

Catch data was compared between 2018 and the previous nine 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 3,570 burbot captures in the past ten years (Table 3). Every new capture receives a tag and over the course of the ten years of this study a total of 2,969 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 it has increased substantially in the last few years (Table 3).

Table 3. Summary of Moyie Lake burbot captures during gamete collection efforts between 2009-2018.

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%
2018	415	404	11	80	19.8%
Total	***3,570***	***3,459***	***110***	***451***	***13.0%***

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 2018 (536 mm; SE= 4). The mean length of all burbot caught in 2018 differed from all years prior to 2015; 2009 ($p<0.0001$), 2010 ($p=0.0026$), 2011 ($p= 0.0058$), 2012 ($p=0.0224$), 2013 ($p<0.0001$) and 2014 ($p<.0001$; Figure 4). The mean length of males caught in 2018 (527 mm, SE = 4) only differed from the mean lengths in 2009 ($p<0.0001$), 2013 ($p<0.001$) and 2014 ($p=0.0019$). The mean length of females (574 mm; SE = 10) caught in 2018 only differed from females caught in 2014 ($p=0.0115$).

The mean weight of all burbot captures collected in 2018 (1195 g; SE = 29) differed between the mean weight of the following years: 2009 ($p<0.0092$), 2010 ($p<0.0001$), 2011 ($p<0.0001$), 2013 ($p<0.0001$) and 2014 ($p<0.0001$; Figure 5). Mean weight of the 2018 male burbot captures differed from male mean weights in: 2009 ($p=0.0464$), 2011 ($p=<0.0003$), 2013 ($p<0.0001$) and 2014 ($p<0.0001$). Mean weights of females caught in 2018 (1364 g; SE = 102) differed only from females in 2014 ($p=0.0086$).

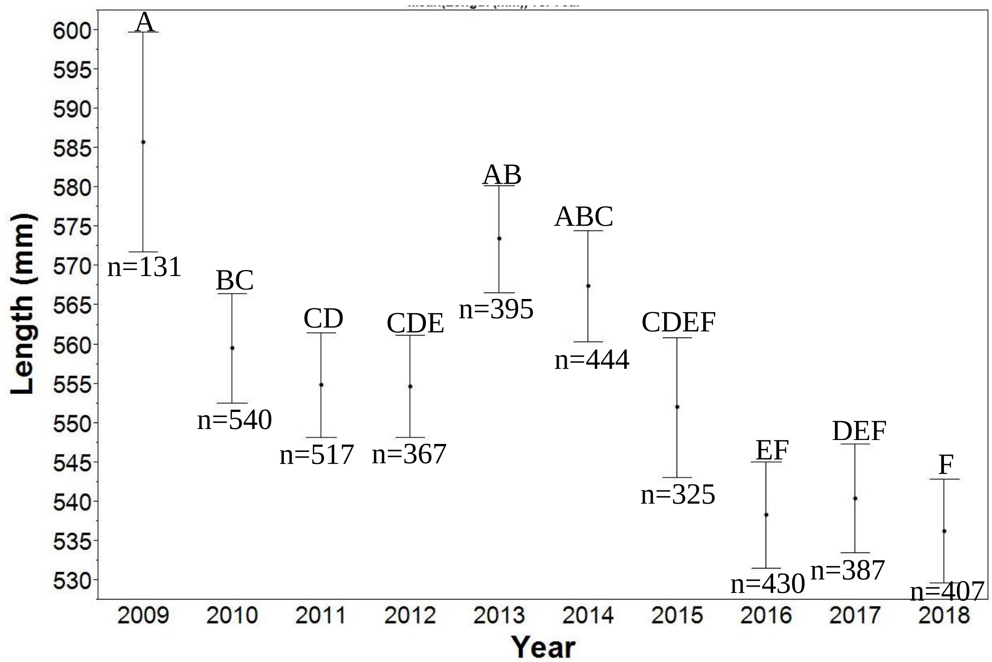

Figure 4. Mean length (mm) of all burbot captures (95% CI) during 2009-18 Moyie Lake gamete collection efforts. Letters denote which years have comparable sizes and if letters differ, the years differed (p<0.05).

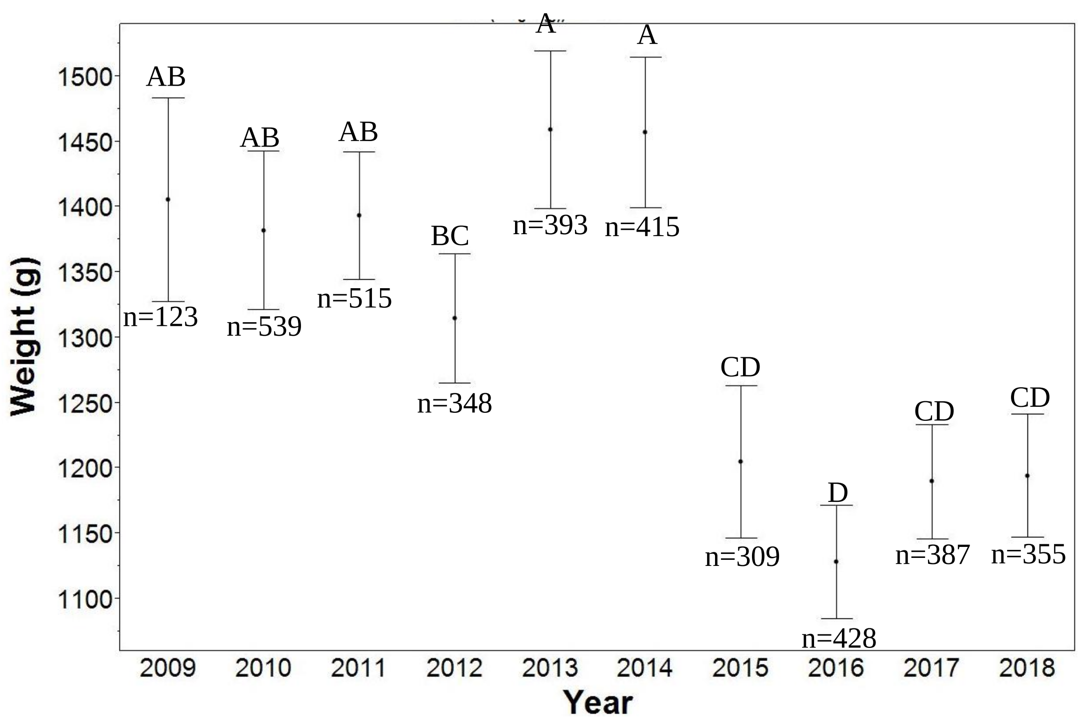

Figure 5. Mean weight (g) of all burbot captures (95% CI) during 2009-2018 Moyie Lake gamete collection efforts. Letters denote which years have comparable sizes and if letters differ, the years differed (p<0.05).

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 most eggs were delivered to Twin Rivers for hatchery production, with up to one million unfertilized eggs being sent to ARI for temperature research. Survival and production from the egg take has varied over the year of Twin Rivers production (Table 4).

Table 4. Approximate egg and production results from Moyie Lake gamete collections between 2015-2018 (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%
2018	7.8 million	96,711	1.23%

1.5 Discussion

Overall 2018 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 our met our unfertilized egg targets for hatchery production. In order to meet these targets, 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 2018:

- Mid-February timing continues to be effective for gamete collections; in 2018 the peak egg take was February 15th.
    - o In 2019, fish sampling should only occur during days when spawning is occurring to reduce the possibility of ripe females spawning out in tubes.
    - o In 2019, 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 was made to deploy trammels nets in proximity to angling locations to determine if our primary sampling method (angling) produces a biased catch; this data will be further analysed and summarized in section 2 of this report.

- Tubes continue to provide a valuable tool for holding burbot, both males and females, to minimize the number of burbot handled in a season.
    - o The minimum volume of unfertilized eggs to be collected per family moving forward is 75 ml. This minimum volume will decrease the chances of physical damage to eggs being aerated within the Twin River incubation cones.
- 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 temperature and telemetry evaluations and population estimates

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 Moyie Lake Burbot brood collection program has enabled the estimation of population abundance through a capture-mark-recapture program. Large sample sizes of fish (up to 500) are caught annually by angling during a short timing window annually (mid-February), when fish are hyper-aggregated for spawning. 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. This report summarizes the analysis of our mark-recapture dataset collected between 2009-2018 in the hopes to identify trends in the spawning population size as well as trends in body size (length and weight).

There were a number of assumptions in previous estimates that could have led to biases in population estimates. The assumptions were as follows: (1) tagged burbot have equal chance of capture relative to untagged fish (e.g., learned avoidance of sampling gear, selectivity bias of angling, etc.), (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.

Between 2011-2014 we double tagged a subsample of 519 burbot caught within the gamete collection efforts to partially address assumption 1, that Floy tag loss was not an issue; 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. Unfortunately, no results regarding the rate of Floy tag loss were able to be concluded from this study possibly due to an error in a failure to follow protocol or equipment malfunction. Evidence leading to this conclusion include a high number of recaptured double-tagged fish that had a Floy tag recorded without having a PIT recorded. Furthermore, PITs were detected in a few fish after being re-scanned at the spawn shack prior to spawning leading us to believe PIT tags were not accurately being detected therefore this dataset is not summarized in this report.

In an attempt to further address our assumptions, two studies were performed utilizing telemetry and trammel nets. The first study involved using a passive sonic telemetry array, which 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), with monitoring continuing into 2017. Telemetry data was used to observe whether burbot: spawn every year, display spawning philopatry and move freely throughout both basins. This information could be used to at least partially address assumptions 2-4 listed above. The second study entailed setting trammel nets to compare the difference in catch with our main sampling method; angling. While angling has proven to be a relatively easy way to catch large numbers of fish during this season, it is possible that angling could impart biases due to selectivity of the gear. Three possible sources of bias include: 1) Sex-bias, 2) Size bias, and 3) Capture history bias (e.g., after being captured once, individual fish may be less likely to be captured again due to learned gear avoidance behaviours). Thus, trammel net data could be used to at least partially test assumptions 1 described above.

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 Analysis of capture-mark-recapture data

A total of 4,404 capture records collected between 2005-2007, and 2009-2018 were analysed by Schwarz (2018a), which aims to estimate the abundance of Moyie Lake's adult (aged 4+ years) burbot population. An RMark package was used to fit several Jolly-Seber capture-recapture models to estimate the spawning population size by sex, catchability as well as survival and recruitment by sex. These models were then ranked using Akaikie's Information Criteria (AIC) which measure trade-offs between fit and complexity to find the best one.

2.2.2 Analysis of Telemetry Array data

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.

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).

Telemetry data was analyzed in detail by Schwarz (2018b), with the goal of examining whether trends in depth and site occupancy within and between years and spawning seasons affected assumptions of the Mark-recapture analysis. Spawning behaviour was deemed to be occurring if detections occurred < 4.5 m between February 4 and 25. If the proportions of detections from an individual occurred during spawning at < 4.5 m was more than 80% in a day, that individual was deemed to have spawned that day. Along with summarizing detections according to these study parameters, Schwarz (2018b) used paired t tests to assess differences of means of occupancy to the two spawning sites within a spawning season. Fish were not sexed during tagging, so sex-based differences in telemetry could not be analyzed.

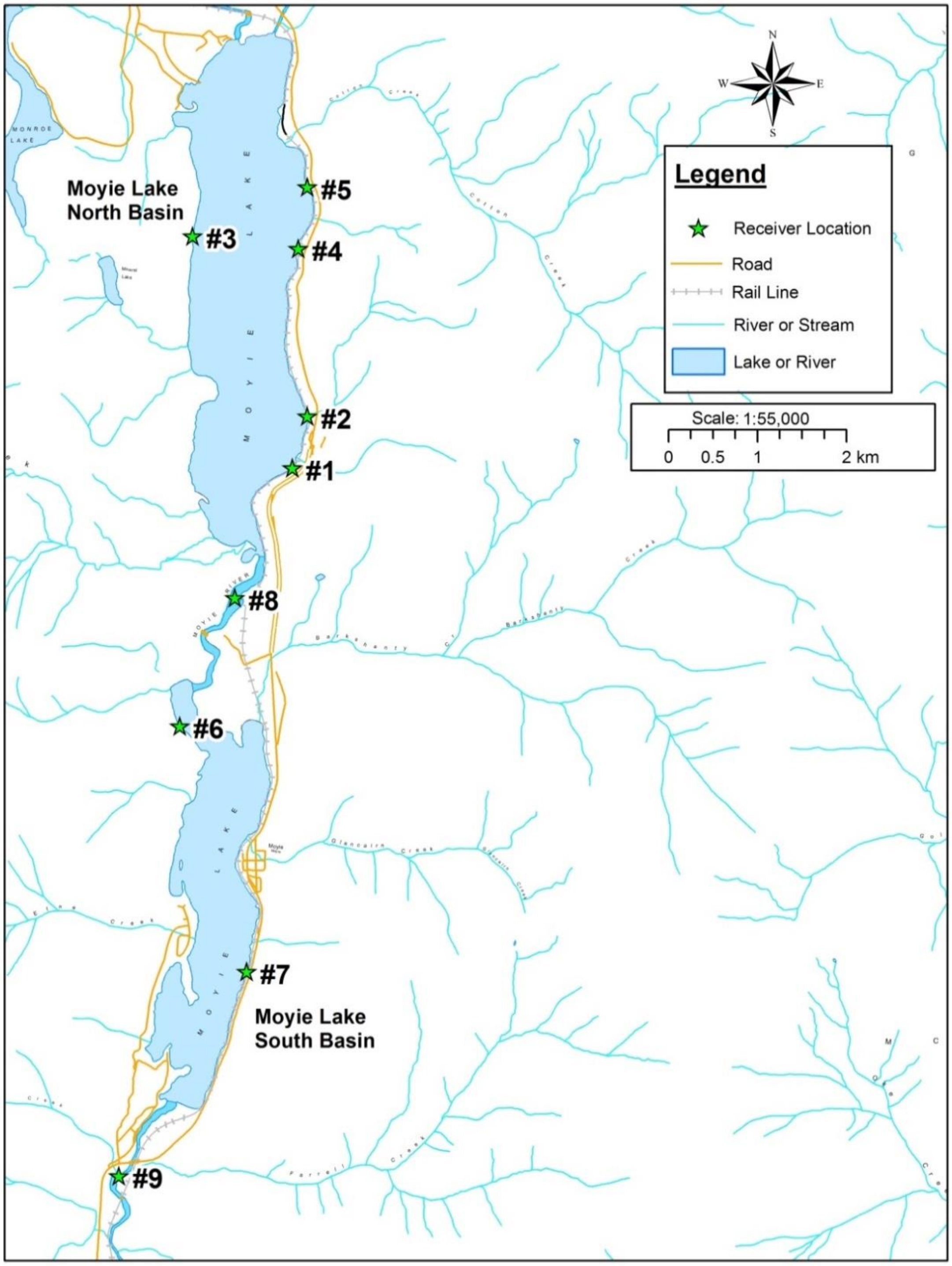

Figure 6. Receiver locations in Moyie Lake.

2.2.3 Testing for bias in capture-mark-recapture data using Trammel nets

During the capture seasons from 2015-2017, trammel nets were set in the general vicinity of angling locations, concurrent with the angling brood capture program. Trammel nets were set to determine their utility as an alternative capture method and independently assess any selectivity bias of the angling method used. Trammel nets are ideal to use for the latter purpose, as they may be more indiscriminate for selectivity due to the passive nature of sampling. The aggregated catch of all four years between trammel nets (*n* = 95) and angling (*n* = 1473) was compared statistically for sex-bias (chi square), size bias in males only (t-test; females caught in trammel nets had insufficient sample size for statistical analysis) and inter-year recapture bias (chi square). Intra-year captures (*n* = 71) were eliminated from the dataset because of the non-independent nature of the data, since trammel nets set in proximity to release locations may have been more likely to intercept fish caught previously in the same sampling session by angling. For statistical analysis of sex bias and size bias, fish of unknown sex (*n* = 47) were eliminated from the dataset.

2.2.4 Temperature evaluation

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)

2.3 Results

2.3.1 Analysis of mark-recapture data

The following is a summary of Schwarz' (2018a) analysis of Moyie Lake recapture data collected between 2009-2018. Ten percent of fish were recaptured more than once. As there are only a few recaptures, estimates of survival, recapture, recruitment and abundance will have poor precision (large standard errors). Furthermore, estimates of abundance are sensitive to heterogeneity in catchability therefore the small number of recaptures collected make it difficult to detect if heterogeneity exists and difficult to know if estimates of abundance have serious bias. Heterogeneity would also be compromised due to the study design as sampling only occurred for two weeks each year meaning fish may not have fully mixed throughout the lake within the sampling period.

The AIC showed strong support for one of the 32 Jolly-Seber capture-recapture models that were run; these models estimate the spawning (mature) population size considering catchability and recruitment for each sex. All records of individuals of unknown sex were removed to remove bias as behaviour due to sex may influence catchability. This top ranked model shows yearly survival (0.83) as the same for males and females across all years (Figure 7); catchability varies by sex and year (Figure 8); and the pattern of recruitment is the same for males and females. The model-averaged estimates of abundances for both sexes (2400 for females and 8400 for males) are seen in Figure 9.

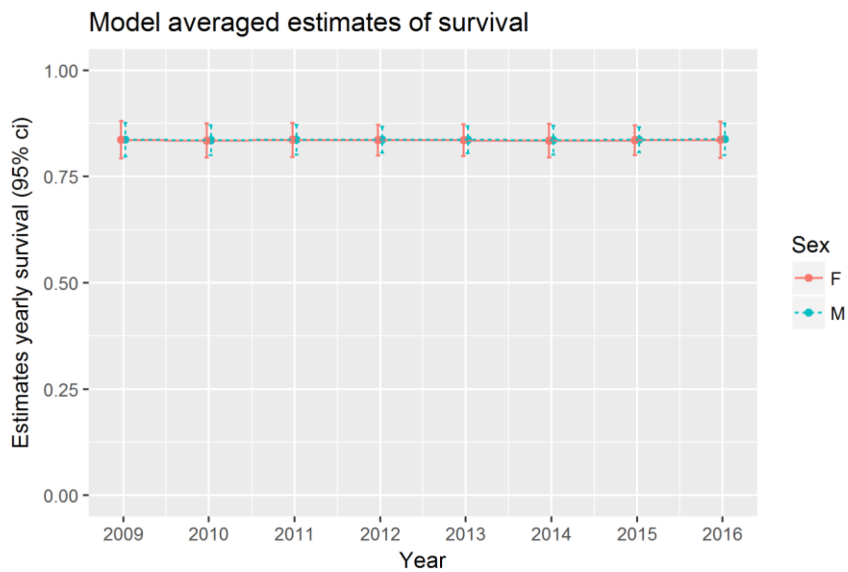

Figure 7. Moyie Lake burbot model averaged estimates of survival. Estimates of survival are not available for the last year of the study (Schwarz 2018a).

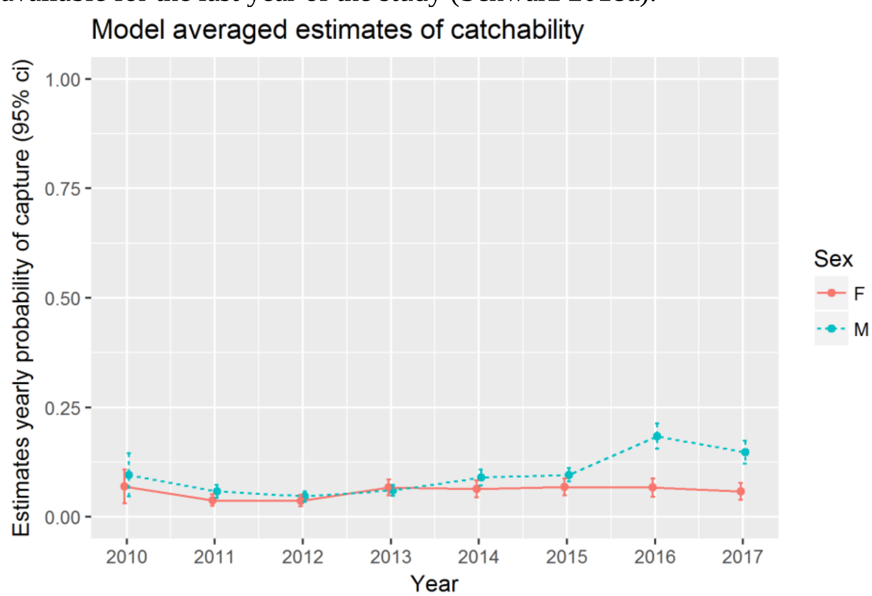

Figure 8. Moyie Lake burbot model averaged estimates of catchability. Note that estimates of catchability are not available for the first year (2009) or last year (2018) of the years used in the capture-recapture analysis (Schwarz 2018a).

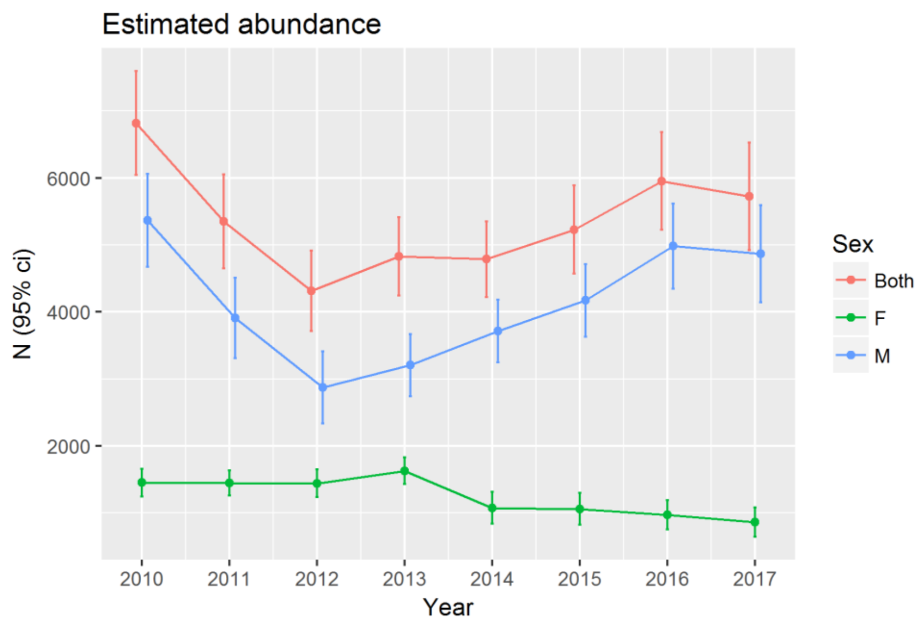

Figure 9. Moyie Lake burbot model averaged estimates of abundance. Note that estimates of abundance are not available for the first year (2009) or last year (2018) of the years used in the capture-recapture analysis (Schwarz 2018a).

Carl Schwarz 2018a also analysed the mean length, weight and standardized weight (W) of the sexes which were compared over time in Figure 10. There was evidence ($p < .0001$ for all variables) that the mean weight/length/W differed among years but this was a secondary effect and was not unexpected. There was however a decline in mean body length, mean body mass, and mean Ws since 2014. The estimated difference between females and males in the means is 46 (SE 3) mm for length; 340 (SE 22) g for weight; and 323 (SE 23) for Ws (Female mean – male mean).

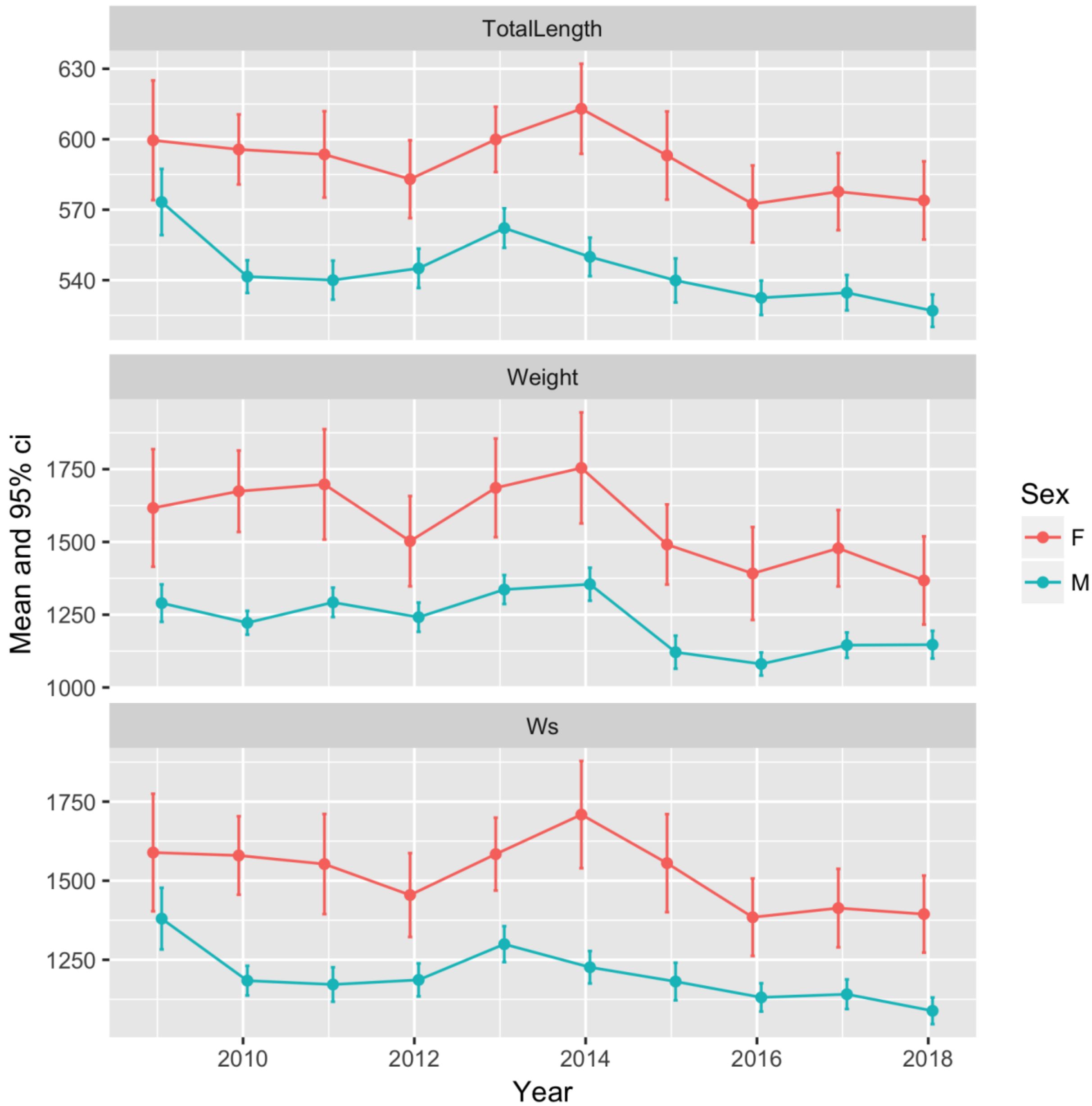

Figure 10. Moyie Lake burbot estimated mean weight, length, and standardized weight (Ws) by sex and by year assuming that sampled fish are a random sample from the population (Schwarz 2018a).

2.3.2 Analysis of Telemetry array data

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 and all receivers were removed in the fall of 2017 corresponding with the expiration of the tags. To view the detection summary as well as detailed detection results see Stephenson and Evans 2018.

According to Schwarz (2018b), most fish appear to move throughout both basins over the entire study period (late 2013 to late 2017) however approximately 30% of the fish tagged in the North basin did not move into the South basin over the course of three years. Furthermore, while there appears to be some mixing occurring between both known spawning grounds in the North basin within the spawning season (February 4 to 25.), the predominant trend was for fish to remain at one particular spawning ground. In paired t-tests, fish were found to not mix equally between spawning locations in only one out of four spawning seasons; sample size was low, thus limiting the power of these tests in years where the test was insignificant. Data were too sparse to examine whether philopatry exists between spawning seasons. Regarding observations interpreted as annual repeat spawning, 10 of 18 fish were undetected in at least one active tracking year on spawning grounds (Table 4 in Schwarz 2018b). These observations lend at least partial support to some assumptions (Seber analysis in Schwarz 2018a) of the mark-recapture analysis.

There was no difference in the mean number of days that fish engaged in spawning behaviour each year. Although data was sparse, over all three years it appears there is no difference in the amount of time fish spent at each spawning area (Schwarz 2018b).

2.3.3 Testing for bias in capture-mark-recapture data using Trammel nets

During the 2015-2018 sampling years, angling (n=1361) captured a smaller proportion of males (82%) than trammel nets (n=79; 91%), and the differences were marginally significant $\chi^2(1, n=1440) = 4.21$, $p = 0.040$. This implies that there may be a sex bias of the angling method, but it is likely not strong. Males caught by angling (531 +/- 70 mm; n=1118) were significantly smaller than males caught by trammel nets (550 +/- 60 mm; n=73) $p = 0.011$. This implies that angling may be biased to capture smaller males during the years when both capture methods were employed. The proportion of inter-year recaptures was not different between angling (19%) and trammel nets (22%) $\chi^2(1, n=1487) = 0.46$, $p = 0.50$. This implies that angling does not bias the catch due to learned behaviour arising from capture history.

2.3.4 Temperature array

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, 2017 and 2018.

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, 2017 and 2018, mean daily temperatures in the spawn period stay below 6°C (Figure 11). The year with the most variable spawn temperatures; warm, with limited ice cover was in 2015.

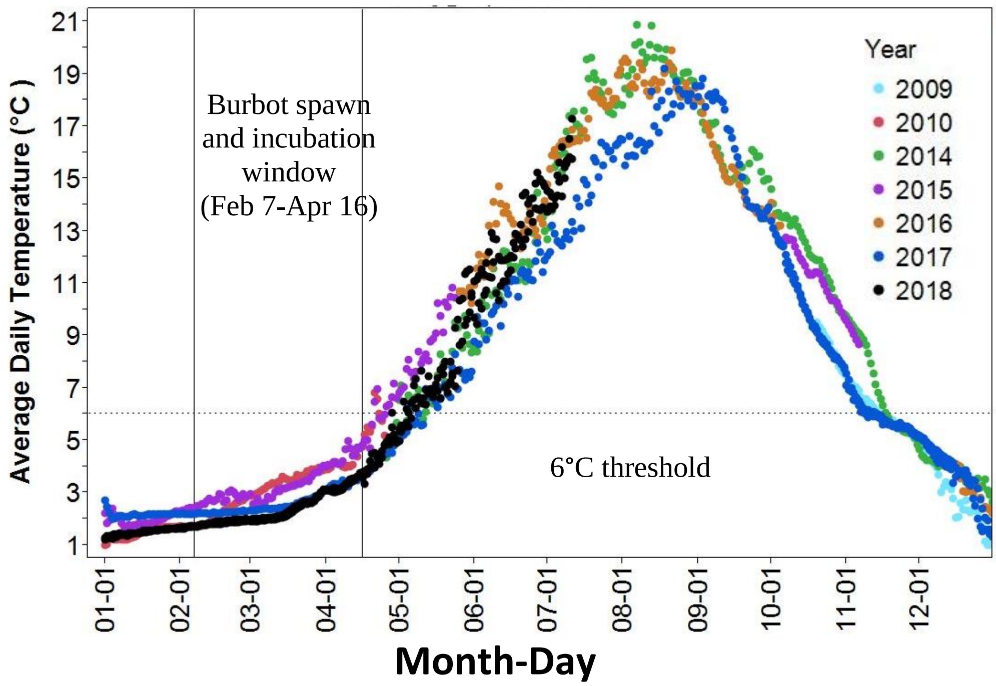

Figure 11. Annual Moyie Lake (North basin), mean daily water temperatures by year (2009 -2018) at a depth of 3m-6m using the logger from the South end of the North basin (Receiver #1) as well as the shallow Cotton Creek logger (Receiver #5).

2.4 Discussion and conclusions

The Schwarz (2018b) analysis of this three-year telemetry study indicated there was good mixing between North and South basins throughout the study period. This provides support to the assumption of mixing between basins (assumption # 4 in the introduction), so that the population estimate represents both lake basins. Although data were too sparse to comprehensively examine whether philopatry (i.e., faithfulness to one spawning location) to the two known spawning sites exists between years or sexes, limited evidence from one year (2015) with many observations suggests that fish are philopatric within a spawning season. If burbot are truly philopatric, the population estimate may be biased low if there are fish using spawning sites outside of the current two capture locations and therefore not being detected. The telemetry data did not provide enough evidence to test the assumption that fish spawn annually (assumption # 2 in the introduction), though data from limited sample size suggests that fish may not spawn annually. Other sources of bias under assumption 1 in the introduction may be caused by heterogeneity of catchability with the sampling technique, for example by catchability varying by size within sexes, or by individual differences in vulnerability to angling between fish. We attempted to address this by setting trammel nets close to angling locations.

Statistical analysis of the catch data between angling and trammel nets indicated some significant differences, which may influence bias for estimating population size; however, it is important to note that there may be an influence of data dependence between the catch (i.e., the catch of one method influencing the catch of the other). Trammel nets were set ~130 m from angling locations and set during the same hours that fishing was occurring. Some of the influence of this was minimized by eliminating intra-year recaptures from the dataset, however, data dependency could not be eliminated entirely.
Trammel nets caught a higher proportion of males in the catch than females, and this proportion was even higher than the angling catch. Although statistically significant, the magnitude of the difference was not large (< 10%), and the similar, highly male skewed trammel catch solidifies the observation that males

were much more common on the spawning grounds than females in 2015-2018. Males caught by trammel nets were larger than those caught by angling. It is unclear why this bias appears, but it may imply that smaller fish are more susceptible to recruit to angling gear. It may also be a by-product of the mating system, if smaller males are more hyper-aggregated around spawning locations that anglers are able to locate.

A common uncertainty with capture-mark-recapture methods employing angling is whether fish can learn to avoid gear, having been caught previously. This may bias population estimates high, as subsequent recapture probability may decrease. On the other hand, if some fish have or develop a propensity towards being caught by angling gear (i.e., positive selectivity bias) our recapture data could be underestimating the total population. The lack of differences in recapture proportions between trammel nets and angling provides evidence against these sources of bias.

It is important to note that while some potential sources of bias have been identified and assessed, all sources of bias cannot be tested by these methods. Since trammel nets were set in the general vicinity of angling locations, during the same sampling session as angling, sources of bias introduced from the sampling season and location have not been tested; in particular, for sex ratio, while the trammel net data provide support to a heavily skewed sex ratio on the spawning grounds, this may be a by-product of the sampling location, timing, and mating system of burbot rather than the true ratio of the entire population of the lake. If there are sex biases to spawning ground occupancy patterns (spatially or temporally), philopatry, alternate year spawning and/or habitat saturation effects, these may all influence population estimates, and those biases remain unassessed at this point.

Temperatures during the spawn period in Moyie Lake continue to be below 6°C even during a warm winter, with limited ice cover, such as 2015, the spawn temperatures were well below the critical 6°C temperature limit which would affect egg survival and therefore be a recruitment limitation (Cain and Ashton 2018). Temperature loggers continue to be maintained and downloaded annually despite the completion of the telemetry study prompting the removal of all receivers in the fall of 2017.

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

3.1 Introduction

Lower Kootenay burbot restoration efforts have focused on identifying remnant wild stock and monitoring and evaluating the survival and distribution of hatchery-reared burbot introductions. Releases of hatchery-reared burbot into the Kootenay River (including tributaries) and Lake have been completed annually since 2009; releases have included larval, juvenile and adult burbot. Although hatchery releases have occurred in the river from 2009 onward and the lake as of 2012, the majority of releases have occurred in the river, as agreed upon by the KVRI Burbot Conservation Committee which decided to focus on river recovery first (KVRI Burbot Committee 2005; Neufeld *et al* 2011c). A benefit of focusing on the river is the ability to more easily sample and therefore monitor population abundance, dynamics and distribution whereas sampling the lake can only occur in select locations due to the sheer size and depth of Kootenay Lake, therefore making it challenging to translate sample numbers into population size.

Field techniques for monitoring and evaluating Kootenay burbot 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 locations and hoop net data suggests these fish were mimicking movement and habitat use of the historical riverine population (Hardy *et al*. 2016). Modeling of river hoop net capture data predict the adult (age 4+ years) population in the river will surpass the target river population of 17,500 (density of 143 burbot /km ^{2}) by January 2019. In anticipation of this milestone, IDFG re-opened the burbot fishery while closely monitoring angler effort and harvest numbers (Paragamian and Hansen 2009, Squier 2019). MFLNRORD biologists are closely monitoring and evaluating the establishment and growth of the river population and will consider opening a fishery on the Canadian portion of the river assuming the river population remains stable and pending revision of provincial listing status.

Reaching the population target in the river has triggered the working group to shift stocking strategies to focus on placing the majority of, if not all of the Moyie Lake origin brood stock into Kootenay Lake while utilizing in-river Kootenay burbot as brood stock to continue stocking in the river. In order to advise an appropriate minimum release number, in 2018, MFLNRORD staff, in conjunction with statistician Carl Schwarz, developed a preliminary Kootenay Lake density driven target. of 20,000 aged 4+ adults based on several parameters. Remnant wild and hatchery reared burbot are monitored within the lake via cod traps and telemetry work (Hardy *et al*. 2016; Stephenson and Evans 2016). Cod trapping will play a crucial role in monitoring population numbers to know if recovery is occurring at the predicted rate.

Temperature data will continue to be important to collect within river and tributaries as temperatures >6°C can be lethal for egg incubation and larval development (Taylor and McPhail 2000; Vught *et al*. 2008; Zarski *et al.* 2010, Ashton *et al.* 2019). Ashton *et al*.'s 2019 manuscript identified that current Kootenay river and tributary water temperatures will most likely cause recruitment failure in some years but will produce some years with temperatures which will align with spawning, incubation and larval development stages and therefore be a success. Kootenay River peak spawning 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). Continuing to monitor river and tributary temperatures alongside spawn timing will better enable us to identify which years we should see successful recruitment, especially amidst climate change. This report will summarize temperature data from main tributaries to the Kootenay River in BC as well as temperatures in the Lake by Balfour.

Telemetry work has included tagging fish prior to release from the hatchery and caught in the river during the hoop net sampling. Telemetry data suggests a 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, sonic tagging hatchery juveniles and adults prior to release in the West Arm (Stephenson and Evans 2016). In addition, from 2017 onward adult hatchery-origin or wild fish captured during lake cod trapping and river hoop netting have been tagged to continue to observe behaviour, mixing between the lake and river as well as monitor movements in case shifts in density can be detected.

This year's report will summarize:

- 2017 hatchery releases
- Lake cod trapping efforts (2013-2018)
- Preliminary Kootenay Lake population, stocking and sampling targets
- Annual spawning and incubation temperatures (2013-2018)
- Active telemetry tags

3.2 Methods

3.2.1 Hatchery juvenile burbot releases

The 2017 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 on Kootenay Lake and in the Canadian portion of the Kootenay River on October 6th, 2017; the main release target was 6-month-old juveniles.

3.2.2 Kootenay Lake cod trapping

(a) Sampling locations

Sampling took place on Kootenay Lake between January 31 and May 22, 2018, with sites near the mouth and first narrows of the West Arm (RKM 75-76), in the vicinity of the Lardeau Delta (RKM 17-21), and on the Creston Delta and nearby shoreline (RKM 114-122; Figure 12). 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, most traps were set in shallow water (<10 m) to prevent decompression trauma (Neufeld and Spence 2001) while those set >20 m were pulled shallower and worked up at a later date to all fish time to decompress naturally (max set depth = 28 m). Cod traps were set between 22 to 168 hours. Information recorded for each trap included: depth (m), location (UTM), water temperature, time of set, time of pull, bycatch, and burbot catches. Sampling effort was increased temporally in an attempt to see if trapping efficiency is relatively equal in the spring versus March/April which would allow us to shift to spring sampling when lacustrine burbot populations have been documented to prefer warm littoral habitats (Harrison *et al* 2013, Cott *et al* 2015 and Scannell 2016).

(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.

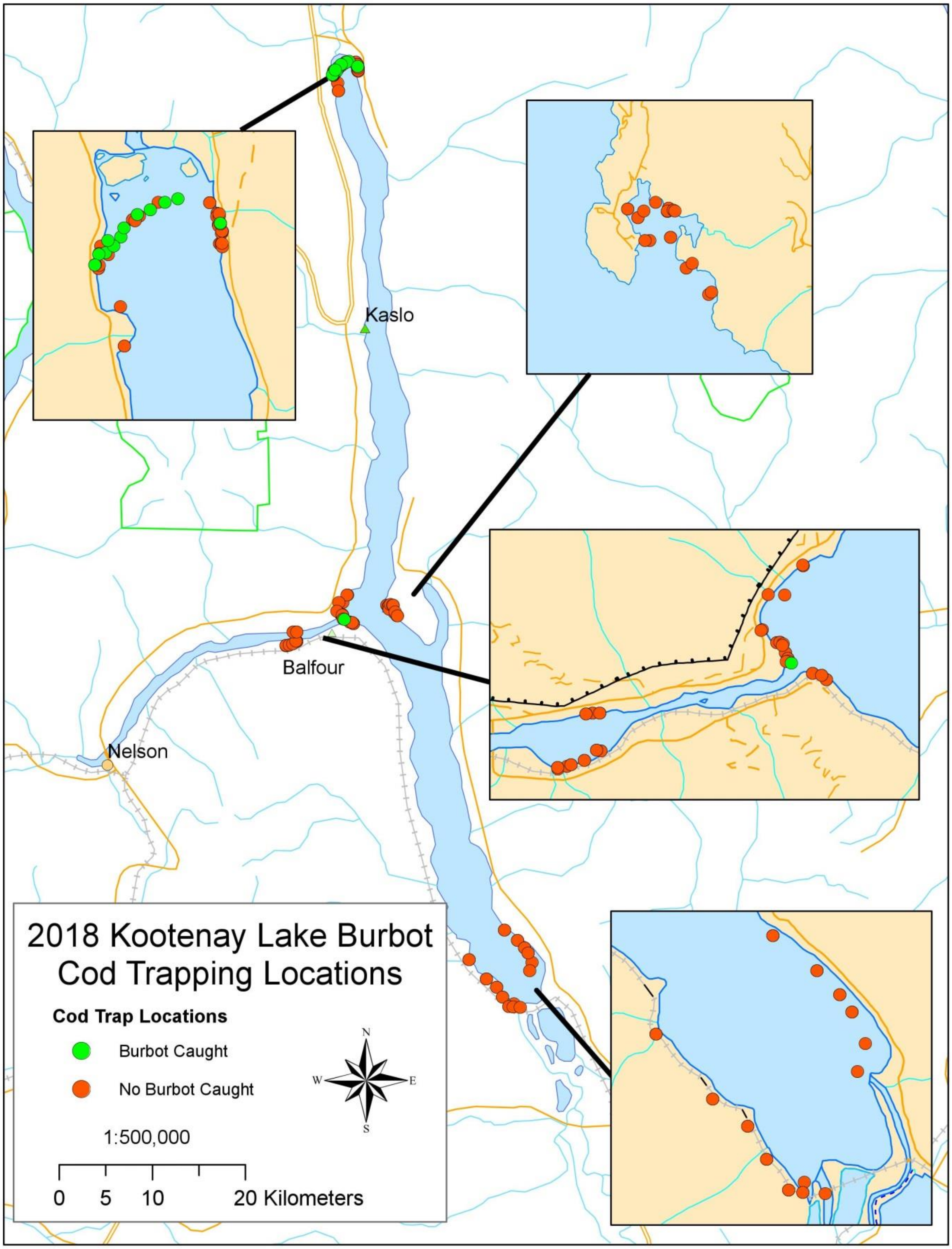

Figure 12. Overview of study area with 2018 cod trap locations.

3.2.3 Preliminary Kootenay Lake population, stocking and sampling target

The preliminary population target was generated based on Paragamian and Hansen's 2009, Kootenay River model taking into consideration historical population estimates and changes to the system. In order to confidently assess the survival and abundance of the Kootenay Lake burbot population via cod trap on an annual basis, MFLNRORD staff worked with statistician Carl Schwarz to re-run Paragamian and Hansen's 2009 catchability model for Kootenay Lake based on our current population estimate assuming age-specific survival is the same as river released burbot.

3.2.4Temperature monitoring

Goat River, Corn, Summit and Boulder Creek are potential burbot spawning and rearing tributaries. Temperatures from the first three Kootenay River tributaries have been monitored between August 6th, 2014 and October 30th, 2018. Boulder Creek temperatures have been monitored between October 26, 2017 and April 19, 2018. Data were also available from a site, managed through another project at FLNR, at Balfour in the West Arm, from 2013 through 2018 excluding 2017. 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 13). The temperature loggers were anchored to the bottom of the creek and were downloaded biannually. Although data is available between August 2014 and October 2018 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.

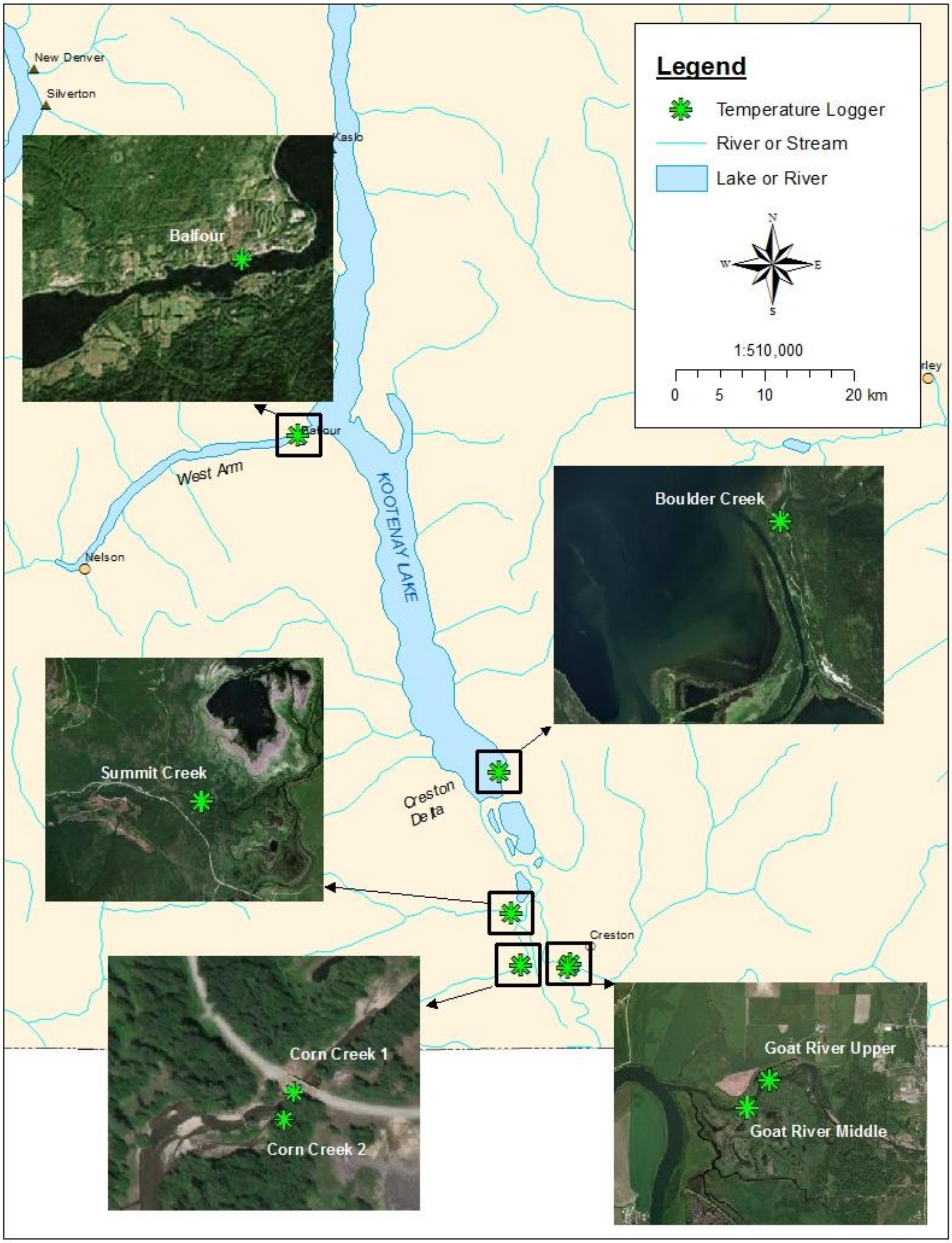

Figure 13. Map of temperature logger locations in Goat River, Summit and Corn Creeks and the West Arm (Balfour) of Kootenay Lake.

3.2.5 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 the spring of 2019. It should be noted that one of the 2015, age-1 hatchery tagged fish was taken to the Twin Rivers Hatchery January 28, for the purposes of spawning and incidentally died.

In 2017 two fish were tagged in-river in Canadian waters and two fish were tagged in-river in US waters during hoop netting. In 2018 four fish were tagged in-lake while two were tagged in-river in Canadian waters while nine were tagged in-river in US waters. Sonic tagging methods followed are described in Stephenson *et al.* 2013 and Neufeld *et al.* 2011a and photographs of this process can be seen in Appendix G: Photographs 19-22. Tracking of tagged fish was completed using the established telemetry array within the Kootenay Lake and River (Figure 14; array further described in Stephenson *et al*. 2013; Stephenson and Evans 2016). In order to close geographical data gaps, to help us better understand burbot movement, four additional receivers were installed this year; one in Queen's Bay, one in Pilot Point Peninsula Bay, one in Boulder Creek and the last at the southern end of the Kootenay River's East channel. All data was saved in the Vemco Vue database format and then cleaned and stored for analysis in an Access database. A summary of active Kootenay burbot tags will be provided in this report while analysis of fish movements tagged in 2015 will follow in the 2018-19 report when all tags have expired.

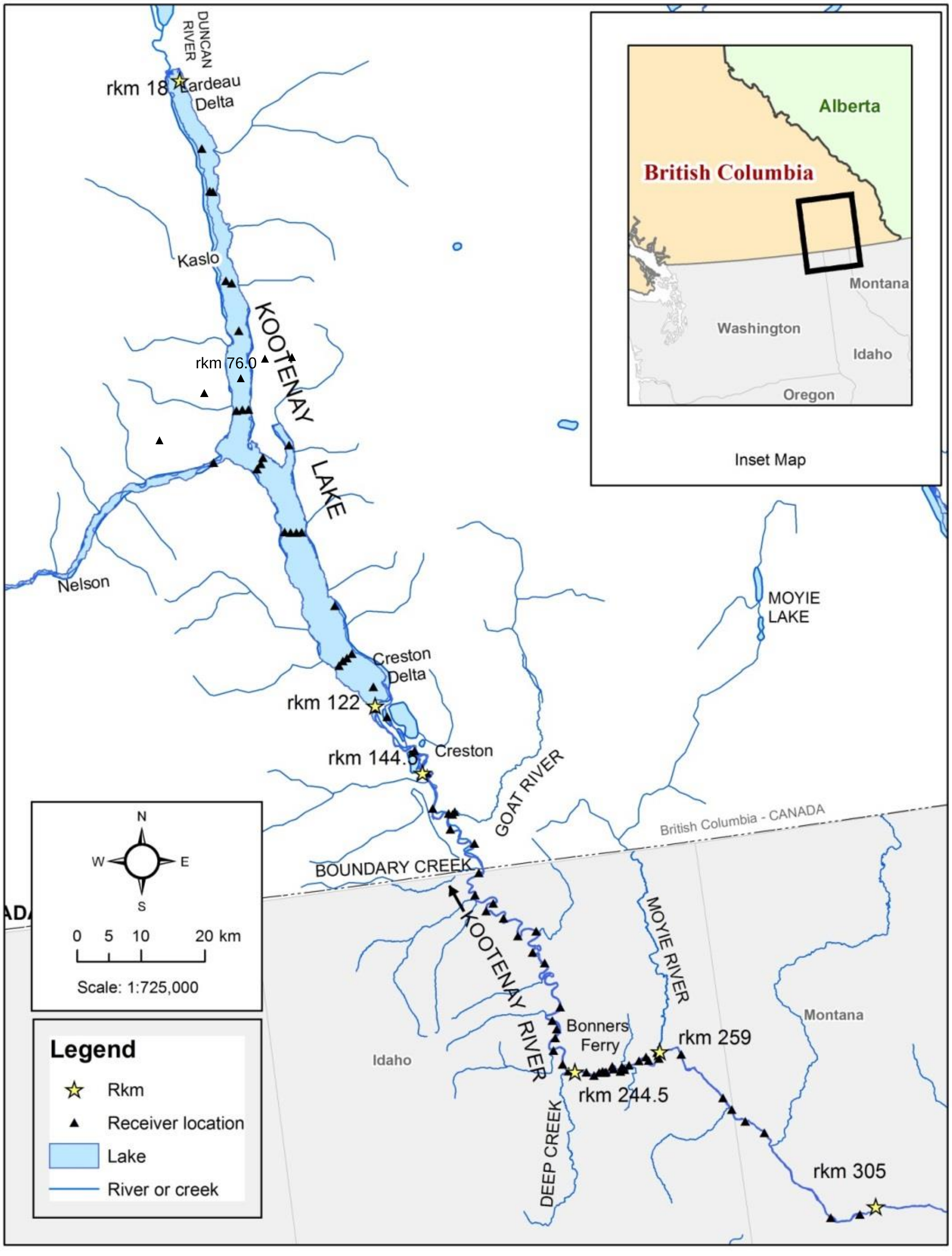

Figure 14. Map of Vemco VR2W receivers. A few key river kilometres (rkms) are denoted for context.

3.3 Results

3.3.1 Hatchery juvenile burbot releases

In 2017, 13,981 juvenile burbot (6 months old) were released into the Canadian portion of Kootenay Lake and River (Table 5). This was the third year of large release efforts of hatchery reared juveniles into Kootenay Lake. See Appendix C for a detailed summary of all Canadian releases between 2009 and 2017. A total of 127,921 juveniles/adults and a total of 464,000 larva have been released into Kootenay Lake beginning in 2012 while a total of 531,393 juveniles/adults and a total of 17,191,020 larva have been released into Kootenay River as of 2009. See Appendix D for a summary of all Kootenay Lake and River releases since 2009.

Table 5. 2017 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
06-Oct-17	Balfour/Queens Bay	7,114	121	0	2017	79.1	KTOI
06-Oct-17	Goat River	6,867	243	0	2017	65.9	KTOI
Total	-	13,981	364	-	-	-	-

3.3.2 Kootenay Lake cod trapping

A total of 134 cod trap sets were set between January 31 and May 24, 2018; however, one trap became fouled after it was found to have a hole and was therefore removed from the dataset. Effort increased to 10,036 trapping hours catching 15 burbot for a catch per unit effort (CPUE) of 0.04 burbot per 24 hours which is similar to previous years (Table 6; Appendix E for trap set information). The mean fishing time was 75.7 hours (SE = 3.0), the mean depth was 13.8 m (SE= 0.4 with a range between 6.0 m – 28.0 m) and the mean temperature was 5.2°C (SE= 0.3 with a range between 2.2 and 12.0°C). Bycatch collected during this study included: 40 peamouth chub (*Mylocheilus caurinus*), 17 northern pikeminnow (*Ptychocheilus oregonensis)*, one sculpin (*Cottus sp*.), one largescale sucker (*Catostomus macrocheilus*), one bull trout (*Salvelinus confluentus*), one mountain whitefish (*Prosopium williamsoni*), one rainbow trout (*Oncorhynchus mykiss*), three redside shiners (*Richardsonius balteatus*), three white sturgeon (*Acipenser transmontanus*) and four yellow perch (*Perca flavescens*).

Table 6. Summary of Kootenay Lake Cod trapping effort and catch between 2013-2018.

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
2018	Jan 31 – May 22	134	10,183	15	0.04	701.3	38.9
Total	**-**	**396**	**31,568**	**54**	**0.04**	**794.3**	**33.7**

Fourteen of the 15 burbot were collected near the Lardeau Delta and one was from the mouth of the West Arm in an area known locally as "the old ling beds" (Figure 15).

Thirteen of the 15 burbot captured had no signs of previous capture; the two remaining were confirmed hatchery origin (brood year 2012 and 2013) based on genetics as none had a PIT tag on capture (Appendix F for burbot capture information). The two hatchery origin fish were both males and were caught in the Lardeau Delta as well as the mouth of the west arm. The mean length of all burbot in 2018 was 701.3 mm (SE=33.7) while the mean weight was 1335.7 g (SE=333.7).

A total of 31,568 hours of cod trapping has occurred over the past t six years (2013-2018) and has resulted in the collection of 54 burbot; 5 of hatchery origin and 49 wild (Table 6 and Figure 16). Of the 54 fish caught 30 were identified as female, 9 were identified as male and 15 were identified as unknown sex using PBT (Figure 17). Figures 15 and 16 display captures separated by season (Mar-Apr and May) to demonstrate trapping efficiency between seasons. In 2018 six burbot were collected during March and April (0.02 burbot per 24hrs) while nine burbot were collected in May (0.08 burbot per 24 hrs). The mean length of hatchery and wild origin fish between years is presented in Figure 17. The mean length of fish caught in 2018 is statistically different from the mean in 2013, 2015, 2016 ($p<0.05$). The mean weight of wild fish caught in 2018 only differed from fish in 2013 and 2015 ($p<0.01$).

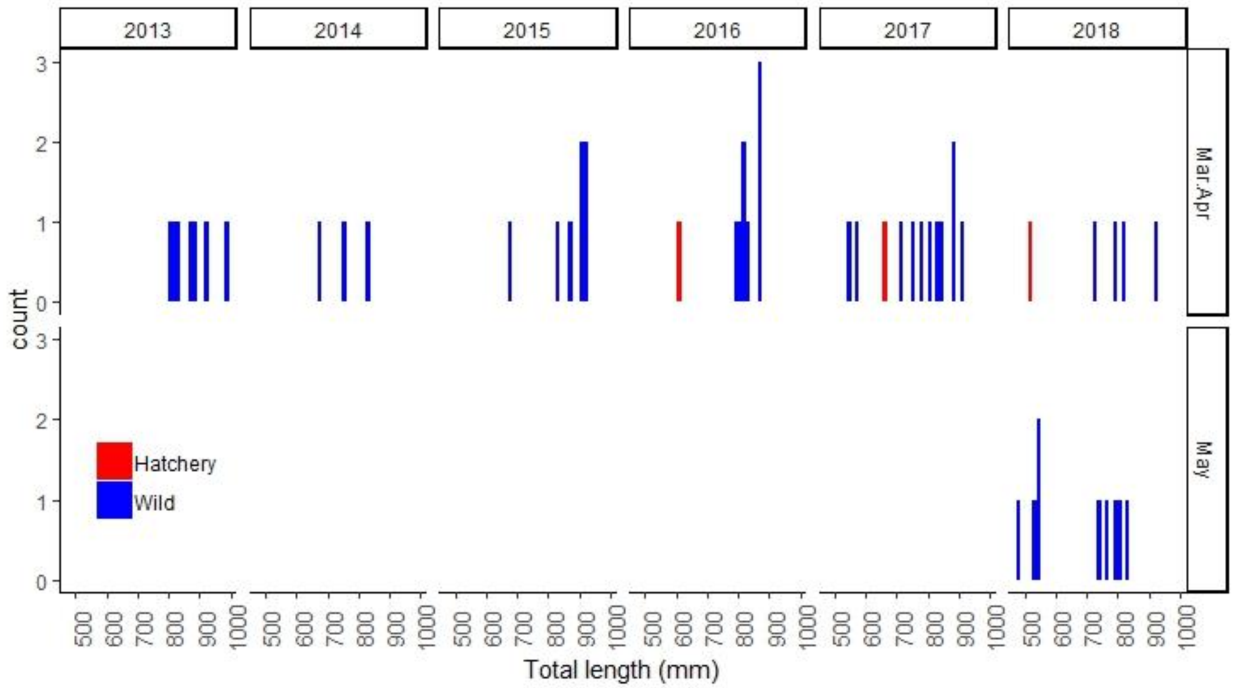

Figure 15. 2013-2018 Kootenay Lake cod trapping summary for burbot separated by year, season and origin (hatchery versus wild).

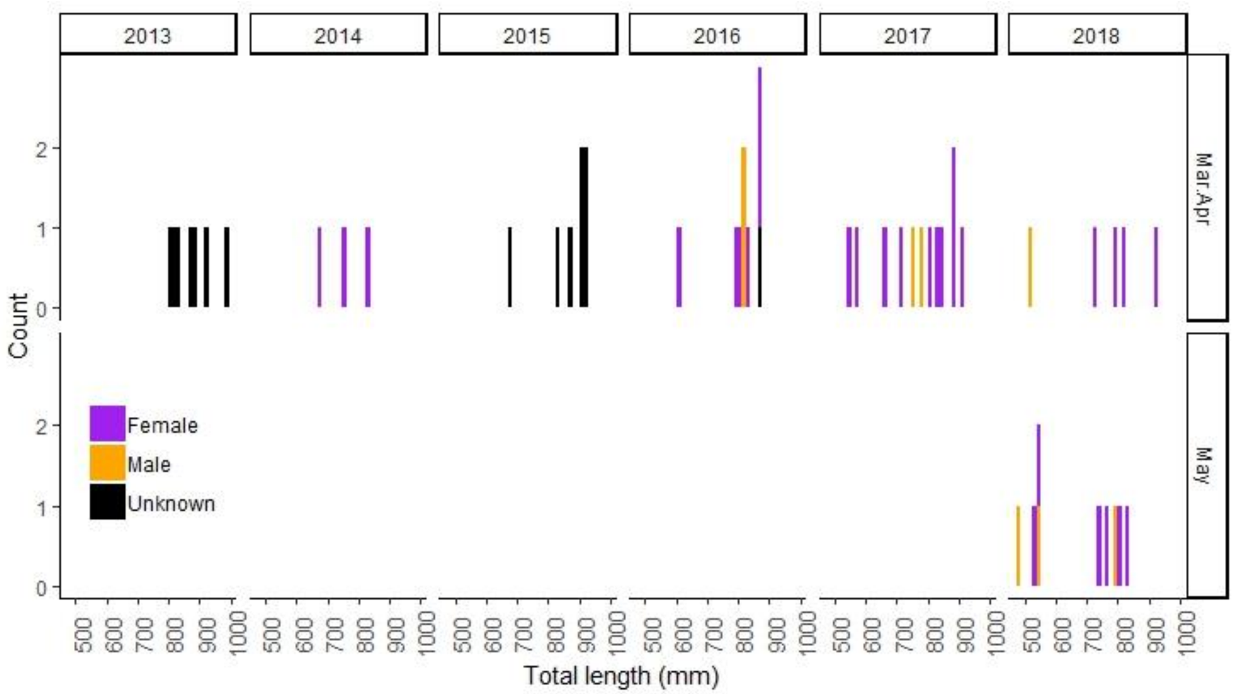

Figure 16. 2013-2018 Kootenay Lake cod trapping summary for burbot separated by year, season and sex.

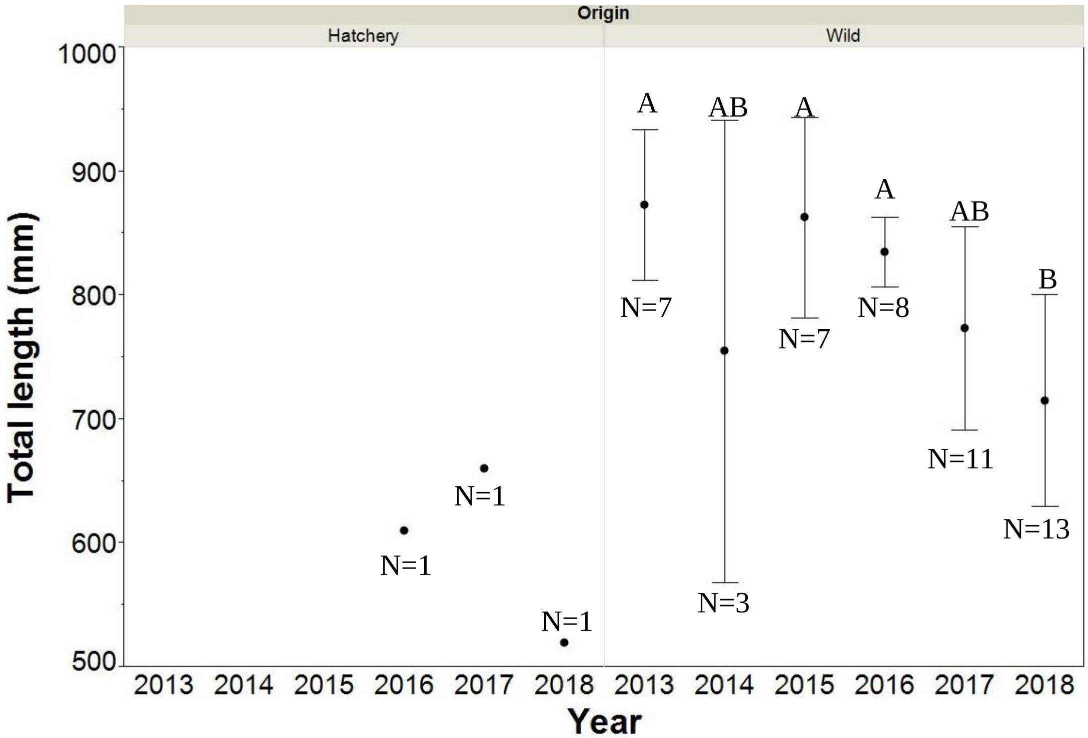

Figure 17. Mean length (mm) by year and origin of all burbot captures (95% CI) during 2003-18 Kootenay Lake cod trapping efforts. Letters denote which years have comparable sizes and if letters differ, the years differed ($p<0.05$). Lengths were not available for two wild fish (caught in year 2016 and 2018) and two hatchery fish (caught in 2016 and 2018).

3.3.3 Preliminary Kootenay Lake population, stocking and sampling target

Estimated 2018 Kootenay Lake population
Lake cod trapping efforts have yet to indicate large numbers of hatchery-reared burbot within Kootenay Lake. With increased hatchery release efforts in the last three years, we would have expected to see these hatchery-reared fish starting to recruit to our cod traps in 2018 when they reached the age of 3. Regardless of our catch, if the latest age specific river-survival estimates (Ross 2018) are applied to the current number of juveniles/adults and larva stocked in the lake, as of 2018 Kootenay Lake should contain approximately 35-600 age 4+ hatchery fish, and therefore, low capture rates of adult fish encountered in sampling efforts thus far was not unexpected.

Preliminary Kootenay Lake population target
The estimated historical Kootenay Lake burbot population was ~200,000 burbot at Queen's Bay or ~51 burbot/km^2. Dues to changes in the amount of available nutrients and therefore food availability, changes to flows and temperatures, low mixing rates between river and lake populations as well as burbot density data from other systems with similar characteristics (Paragamian and Hansen 2009; Stephenson 2018) our preliminary Kootenay Lake adult burbot target will be 10% of the historical estimate which equates to a population of 20,000 burbot.

Stocking targets based on preliminary population targets
Assuming burbot released into Kootenay Lake have age-specific survival rates similar to, the burbot stocked in Kootenay River, Kootenay Lake targets will come to fruition by 2028 assuming 60,000 6-month old hatchery-reared juveniles are released annually starting in 2020 (not including natural recruitment) as agreed upon by the Lower Kootenay Burbot comanagers (Stephenson 2018).).

Sampling targets based on preliminary population targets
In order to confidently assess the survival and abundance of the Kootenay Lake burbot population via cod trap on an annual basis, MFLNRORD staff worked with statistician Carl Schwarz to re-run Paragamian and Hansen's 2009 catchability model for the Lake. This model requires 10% of the annual population (age 4+ population) to be sampled. Applying Kootenay river survival to the lake hatchery releases to date, the predicted total population of burbot in 2019 should be ~9370 while the adult population alone (age 4+) would be ~3520. Ten percent of the adult population equates to capturing ~352 individuals. Paragamian and Hansen's 2009 catchability model was then used to translate this total number of fish handled per year into a CPUE of 0.35 burbot per 24hours based on catch rates and densities found in other systems. We would therefore need to sample ~24,137 hours ((352 burbot/0.35 burbot per 24 hours).

3.3.4 Temperature monitoring

In 2018, mean daily temperatures during spawn and incubation (February 7 to April 16) remained below 6°C for Goat, Corn and Boulder tributaries (Table 7; Figure 18). No temperature data were available for the Balfour site in 2017 or the Summit site in 2018. In recent years, tributary temperatures during spawn and incubation have varied; 2018 was cooler than previous. Mean daily temperatures during the spawning and incubation window, in the tributaries and at the Boathouse varied significantly across all years ($p<0.0001$), except in the Goat River (between 2015 and 2017; $p=0.76$) and in Corn Creek (between 2017 and 2018; $p=0.06$). Over the course of this study, Goat River and Balfour temperatures have exceeded or surpassed 6°C near the end of the incubation window (no temperature data from 2017 for Balfour).

Table 7. 2015-2018 summary of mean daily temperatures during the Kootenay River burbot spawning and incubation window (Feb 7 to Apr 16) for Corn Creek, Goat River, Summit Creek, Boulder Creek (logger installed fall 2017) and Kootenay Lake's West Arm by Balfour.

Location	Year	Average mean Daily temp. (°C)	Mean SE	Min. Mean Daily temp. (°C)	Max. Mean Daily 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
	2018	1.7	0.08	0.0	5.2	7-Feb-18	16-Apr-18
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
	2018	2.5	0.24	0.0	7.6	7-Feb-18	16-Apr-18
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
	*2018	NA	NA	NA	NA	NA	NA
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
	2018	4.0	0.03	3.4	4.6	7-Feb-18	16-Apr-18
Boulder Creek	2018	1.5	0.12	0.05	5.2	7-Feb-18	16-Apr-18

*There are no 2017 Balfour/West Arm or 2018 Summit Creek temperatures due to the loss of the temperature logger.

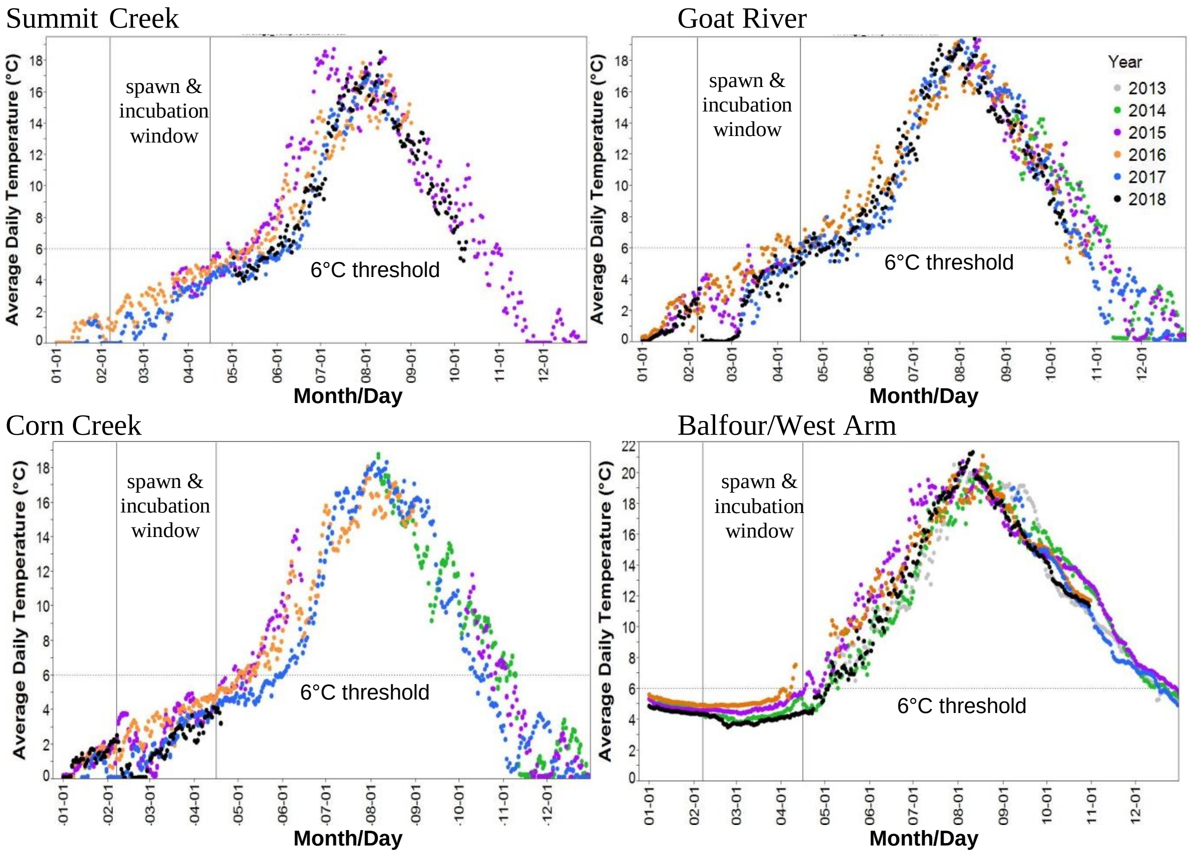

Figure 18. Mean daily water temperatures from 2013-2018 in Summit Creek, Goat River (Mid-Goat Logger), Corn Creek (Loggers #1 and #2) and Balfour/West Arm boathouse. Burbot spawn and incubation windows were identified between February 7 and April 16.

3.3.5 Passive acoustic telemetry

The most up to date summary of survival and movement of 2015 sonic tagged fish can be found in Stephenson and Evans 2018. A final summary of this tagging study will be presented in the 2018-19 annual burbot report when all tags have expired along with a summary of all in river and in lake tagged fish. In 2018 six sonic tags were successfully deployed into wild lake fish captured in the Lardeau Delta area in March and May. The mean length and weight of these fish are 678 mm (SE=77) and 2,291 g (SE=656) respectively. The genetic technique known as Parental based tagging (PBT) allowed us to identify the sex and origin of all six fish; one hatchery origin, male fish (broody year 2013) and five wild origin fish of which four were females and one was male. Table 8 provides a summary of the number of active burbot sonic tags present in the Kootenay system broken down by country, ecosystem and year while Appendix F provides details of the fish that were tagged. Unfortunately, one additional sonic tagging effort resulted in the death of one fish. This fish measured 730 mm and weighed 3400 g. After conducting a surgery, we concluded the fish was female and was most likely no longer contributing to the population as both ovaries were completely engulfed in fungus and rock hard. After sending her otolith to North/South Consultants Inc. the age was identified as 26 years old (Appendix G: Photograph 23). A total of 15 burbot were sonic tagged in the river between December 2017 and March 2018 (four in Canadian waters and eleven in American waters). The mean length and weight of 14 of these 15 fish are 503 mm (SE = 21) and 970 g (SE = 138) respectively (length and weight data of one of this fish is not available). Sex was assigned by PBT; ten of these individuals were females and five were males. Twelve of the 15 fish were of hatchery origin (6 females and 6 males), two were of wild origin (both females) and the data from one fish was removed due to error.

Table 8. Summary of active sonic tags deployed in Kootenay River and Lake Burbot in 2015 and later.

Country	Lake vs River	Tagged in Hatchery vs in the field	# of active sonic tags in the system* (tagging date of 2015 or later)			
			2015	2016	2017	2018
Canada	Lake	Hatchery	60	60	60	30
		In the field				6
	River	Hatchery				
		In the field			2	2
USA	River	Hatchery				
		In the field			2	9
Total			60	60	64	47

*sonic tags presented here are deemed active based on battery life and not based on detections.

3.4 Discussion and Recommendations

The 2017 hatchery releases comprised of 13,981 releases into Canadian waters (7,114 to Queen's Bay/Balfour and 6,867 to Goat River). Assuming Moyie Lake and in-river gamete collections produce sufficient hatchery-reared juveniles for release, the KVRI Burbot Conservation Committee is interested in placing the majority of Moyie Lake origin juveniles, collected between 2019 and 2021, into Kootenay Lake with the hopes of releasing a minimum of 60,000 juveniles per year. It is anticipated, these will be the last three years gametes will be collected from Moyie Lake for the purposes of raising brood stock for the Kootenay system. From 2022 and onward it is anticipated that gametes will be harvested solely from the Kootenay River stock. In addition to the release of 6-month old juveniles, larval releases have mainly occurred in the US portion of the river. The largest larval release occurred in 2015 and recruited to hoop nets en masse during the 2017-18 hoop net sampling season making it the largest brood year represented in the 2017-18 catch, therefore demonstrating good survival (Ross 2018, Squier 2019). In addition to this release, in the spring of 2018 a test release of pre-feeding and post feeding larvae occurred in April and May respectively. These larvae were released in the US at an area known as Nimz Ranch (an isolated pond that was reconnected to the river after larval plantings) and Ferry Island (off-channel of the Kootenay River) and fish from Nimz Ranch from both life-stages successfully recruited to minnow traps in July and August of the same year (Ross 2018). Further details of the larval study and survival will be available in IDFG's 2017-18 annual Kootenay River resident fish report. Given the successful survival of releasing these larval life stages in the river it would be ideal to also have the ability to release these life stages into Kootenay Lake. Changes made to the Canadian Food and Inspection Agency's (CFIA) border crossing permitting process in 2012 (taking effect 2014) does not permit larvae to be moved across the border due to their inability to be disease tested due to insufficient organ development. The MFLNRORD staff has and will continue to work closely with the CFIA and international disease testing parties to eliminate this barrier to allow larval burbot releases to take place in the Canadian portion of the Kootenay system as soon as possible.

Annual spawning and incubation temperatures continue to demonstrate there are suitable spawning and incubation temperatures in some Kootenay tributaries and the West Arm to support burbot life stages which are sensitive to temperatures >6°C. Recommendations include continuing temperature monitoring in Kootenay tributaries and on the West Arm of Kootenay Lake at Balfour.

Sonic tagged burbot released into Kootenay Lake in 2015, had similar survival to the river release evaluations (Stephenson *et al*. 2013, Stephenson and Evans 2018). In all Kootenay hatchery telemetry studies, evidence points to low mixing rates (less than 25%) between the lake and the river (Stephenson *et al*. 2013; Hardy *et al*. 2015). Results of fish tagged in 2015 will be presented in the 2018-19 annual report. An ongoing in-river and in-lake sonic tagging study commenced in 2018; during the 2017-18 field seasonal total of 15 burbot were tagged (6 in the lake and 9 in the river). MFLNRORD and IDFG staff will continue to implant wild and hatchery-reared fish collected during cod and hoop netting to better understand their behaviour, movements as we may be able to detect potential changes in distribution within the system as the population continues to grow. It will be interesting to see if mixing rates between lake and river change over time.

Cod trapping efforts have occurred on Kootenay Lake between 2013 and 2018 mainly during March and April. During this time a total of 396 traps were set totaling 31,568 trapping hours and resulting in the collection of 54 burbot with an average CPUE of 0.04 burbot per 24 hours. During the 2018 cod trapping season traps were set between January and May to explore the possibility of modifying the sampling design to sample in the spring which proved effective in some other systems (Harrison *et al* 2013, Cott *et al* 2015 and Scannell 2016). Sampling during the winter has proven to be quite challenging due to wind and snow, therefore increasing risk to crew and risk to fish if stranded in traps which are inaccessible due to weather. This issue started to become apparent in previous years and was further emphasized during the 2018 winter cod trapping season when traps on the Lardeau Delta were inaccessible for approximately two weeks due to poor weather. Data collected during the 2018 cod trapping season shows trapping during May (CPUE = 0.08 burbot per 24 hours) as being just as or more effective than March and April (CPUE = 0.02 burbot per 24 hours). As a result, future cod sampling on Kootenay Lake is recommended to take place in May.

Assuming Lake and River survival are equal, the 2018 Kootenay Lake population should contain approximately 35-600 age 4+ hatchery fish while the predicted 2019 total population should be ~9370 while the adult population alone (age 4+) would be ~3520. Our preliminary Kootenay Lake adult burbot target will be 10% of the historical estimate which equates to a population of 20,000 burbot. As agreed upon by the Lower Kootenay Burbot comanagers, we will attempt to release the equivalent of 60,000 juvenile burbot each year starting in 2020 to reach our target goal by 2028. Although this population target is utilizing survival estimates of 6-month old juveniles we have been and will continue to explore survival rates of larval released burbot which are showing good preliminary survival rates.

Using Paragamian and Hansen's 2009 catchability model we identified the need to sample ~24,137 hours to catch ~352 individuals. Due to the fact that this model assumes survival of lake-burbot to be the same as river burbot and does not take into consideration the potential for lake fish to emigrate to the river it is possible we could see a lower CPUE after sampling the suggested number of hours; in this case sampling would need to increase. It is recommended that the 2019 cod trapping season increase sampling to ~24,100 hours to test the initial model after which point we will re-evaluate whether the results are aligning with the model's predictions.

It is important to note that Kootenay Lake cod trapping occurs in targeted locations around the perimeter. Sampling is not randomized spatially or by depth due to bathymetric constraints. This sampling strategy will affect our ability to directly compare CPUE to other systems therefore it is important to be aware of these limitations while utilizing CPUE to estimate lake population sizes.

Kootenay Lake and River populations are expected to increase as more hatchery burbot are released into the system and be detected by sampling efforts. Annual sonic tagging will be key in monitoring movements of adult hatchery-origin fish in order to understand mixing rates and their shifts over time as dynamics may change alongside density. Annual cod trapping in the lake will enable tracking of burbot from the hatchery program as well as track the remnant wild population.

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Appendices

Appendix A: Summary of all families created from Moyie Lake burbot gamete collection, 2018.
Includes the volume of eggs taken in the field and the Hatchery results of egg viability post fertilization and egg count calculations.

Field										Hatchery						
Family #	Spawn date	Female floy tag #	Male floy tag #	Volume of eggs taken (mL)	Egg count using volume (1802eggs/ mL)	Eggs bloody from Start?	Eggs bloody at end Only?	Eggs had fungs?	Field comments	Hatchery	48- hour viability (%)	48 hour post fertilization survival (# eggs)	10 day viability (%)	10 day post fertilization survival (# eggs)	16 day viability	16 hour post fertilization survival (# eggs)
1	12-Feb-18	15520	15508	80	144160	No	No	Yes		KTOI	100	144,160	99	142,718		
2	12-Feb-18	15520	15509	85	153170	No	No	Yes		KTOI	100	153,170	99.3	152,098		
3	13-Feb-18	15046	15505	118	212636	No	No	Yes		KTOI	97.5	207,320	98.3	203,796		
4	13-Feb-18	15875	15503	75	135150	No	No	Yes		KTOI	92.6	125,149	92.3	115,512		
5	13-Feb-18	14401	15556	110	198220	No	No	No		KTOI	98.5	195,247	98.2	191,732		
6	13-Feb-18	14401	15501	95	171190	No	No	Yes		KTOI	97.4	166,739	99.6	166,072		
7	13-Feb-18	15048	15523	80	144160	No	No	No		KTOI	82.6	119,076	98.8	117,647		
8	13-Feb-18	15587	15623	115	207230	No	Yes	Yes	Pale eggs	KTOI	61.1	126,618	89.6	113,449		
9	13-Feb-18	15879	15625	115	207230	No	No	No		KTOI	92.2	191,066	98.9	188,964		
10	14-Feb-18	15518	15530	75	135150	No	No	No		KTOI	97.6	131,906	90.3	119,111		
11	14-Feb-18	15047	15036	120	216240	No	No	No		KTOI	98.5	212,996	94.1	200,430		
12	14-Feb-18	15047	15037	100	180200	No	No	No		KTOI	82	147,764	96.1	142,001		
13	14-Feb-18	15047	15034	75	135150	No	No	No		KTOI	94.4	127,582	94.3	120,309		
14	14-Feb-18	15047	15649	90	162180	No	No	No		KTOI	94.2	152,774	92.8	141,774		
15	14-Feb-18	15615	15606	135	243270	No	Yes	Yes		KTOI	91.7	223,079	95.7	213,486		
16	14-Feb-18	15880	15038	75	135150	No	No	No		KTOI	97.3	131,501	97.9	128,739		
17	14-Feb-18	15880	15528	80	144160	No	No	No		KTOI	96.9	139,691	98.5	137,596		
18	14-Feb-18	15749	14041	110	198220	No	No	No		KTOI	88.1	174,632	94.8	165,551		
19	14-Feb-18	15881	14680	75	135150	No	No	No		KTOI	90.2	121,905	93.8	114,347		
20	14-Feb-18	15885	15643	75	135150	No	No	No		KTOI	98.2	132,717	95.3	126,480		
21	14-Feb-18	15885	15742	78	140556	No	No	No		KTOI	95.4	134,090	95.4	127,922		
22	15-Feb-18	15989	15633	110	198220	No	No	No		KTOI	56.7	112,391	50	56,195		
22b	15-Feb-18	15989	15633	20	36040	No	No	No		UofI					97	34,959

Appendix A: Summary of all families created from Moyie Lake burbot gamete collection, 2018.
Includes the volume of eggs taken in the field and the Hatchery results of egg viability post fertilization and egg count calculations.

Field										Hatchery						
Family #	Spawn date	Female floy tag #	Male floy tag #	Volume of eggs taken (mL)	Egg count using volume (1802eggs/ mL)	Eggs bloody from Start?	Eggs bloody at end Only?	Eggs had fungs?	Field comments	Hatchery	48- hour viability (%)	48 hour post fertilization survival (# eggs)	10 day viability (%)	10 day post fertilization survival (# eggs)	16 day viability	16 hour post fertilization survival (# eggs)
23	15-Feb-18	15741	15634	75	135150	No	No	No	Watery eggs	KTOI	38.2	51,627	12.8	6,608		
23b	15-Feb-18	15741	15634	20	36040	No	No	No	Watery eggs	UofI					40	14,416
24	15-Feb-18	15529	15640	78	140556	No	No	Yes	Pale eggs	KTOI	93.5	131,420	87.9	115,518		
24b	15-Feb-18	15529	15640	20	36040	No	No	Yes	Pale eggs	UofI					75	27,030
25	15-Feb-18	15529	15632	78	140556	No	No	Yes		KTOI	84.1	118,208	93.8	110,879		
26	15-Feb-18	15510	15628	75	135150	No	No	No		KTOI	97.9	132,312	98	129,666		
26b	15-Feb-18	15510	15628	20	36040	No	No	No		UofI					93	33,517
27	15-Feb-18	15876	15893	120	216240	No	No	No		KTOI	96.3	208,239	96.2	200,326		
27b	15-Feb-18	15876	15893	20	36040	No	No	No		UofI					96	34,598
28	15-Feb-18	15992	15892	80	144160	No	No	No		KTOI	93.4	134,645	96.1	129,394		
28b	15-Feb-18	15992	15892	30	54060	No	No	No	eggs for larval study	UofI						
29	15-Feb-18	15992	15690	78	140556	No	No	No		KTOI	95.9	134,793	94.8	127,784		
30	15-Feb-18	15985	15573	85	153170	No	No	No		KTOI	88	134,790	93.5	126,028		
31	15-Feb-18	15985	15735	80	144160	No	No	No		KTOI	94.4	136,087	95.8	130,371		
32	15-Feb-18	13086	15733	50	90100	No	No	No		KTOI	87.8	79,108	94.4	74,678		
33	15-Feb-18	15995	15128	78	140556	No	No	No		KTOI	98.1	137,885	99.1	136,644		
34	15-Feb-18	15995	15130	75	135150	No	No	No		KTOI	96.9	130,960	98.8	129,389		
35	15-Feb-18	15998	15129	60	108120	No	No	No		KTOI	96.9	104,768	96.2	100,787		
36	15-Feb-18	15998	15127	75	135150	No	No	No		KTOI	97.4	131,636	98.6	129,793		
37	15-Feb-18	15178	15126	80	144160	No	No	Yes		KTOI	99	142,718	98.1	140,007		

Appendix A: Summary of all families created from Moyie Lake burbot gamete collection, 2018.
Includes the volume of eggs taken in the field and the Hatchery results of egg viability post fertilization and egg count calculations.

Field										Hatchery						
Family #	**Spawn date**	**Female floy tag #**	**Male floy tag #**	**Volume of eggs taken (mL)**	**Egg count using volume (1802eggs/ mL)**	**Eggs bloody from Start?**	**Eggs bloody at end Only?**	**Eggs had fungs?**	**Field comments**	**Hatchery**	48- hour viability (%)	48 hour post fertilization survival (# eggs)	10 day viability (%)	10 day post fertilization survival (# eggs)	16 day viability	16 hour post fertilization survival (# eggs)
38	15-Feb-18	15178	15134	78	140556	No	No	Yes		KTOI	96.4	135,496	97.6	132,244		
39	15-Feb-18	15903	15138	78	140556	No	No	No		KTOI	79.3	111,461	75.7	84,376		
40	16-Feb-18	15140	15133	100	180200	No	No	No		KTOI	92.4	166,505	98.9	164,673		
41	16-Feb-18	15188	15905	95	171190	No	No	No		KTOI	94.6	161,946	97.2	157,411		
42	16-Feb-18	15736	15904	75	135150	No	No	Yes		KTOI	92	124,338	96.7	120,235		
43	16-Feb-18	15736	15132	75	135150	No	No	Yes		KTOI	98.5	133,123	98.8	131,525		
44	16-Feb-18	15736	15743	75	135150	No	No	Yes		KTOI	92.4	124,879	96.5	120,508		
45	16-Feb-18	15990	15575	85	153170	No	No	No		KTOI	94	143,980	96.1	138,365		
46	16-Feb-18	15990	15570	85	153170	No	No	No		KTOI	98.3	150,566	99	149,060		
47	16-Feb-18	15190	13891	80	144160	No	No	No		KTOI	97	139,835	97.4	136,199		
48	16-Feb-18	15761	15183	85	153170	No	No	No		KTOI	98.5	150,872	97.3	146,799		
49	16-Feb-18	15761	15574	78	140556	No	No	No		KTOI	97.7	137,323	93.3	128,123		
Subtotal			**KTOI**	**4,227**	**7,617,054**					**KTOI**		**6,961,094**		**6,583,323**		NA
			UofI	**130**	**234,260**					**UofI**		NA		NA		**144,520**
Total				**4,357**	**7,851,314**											

[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: Summary of Moyie Lake origin, KTOI-reared hatchery burbot releases into Canadian waters between 2009-2017

year of release	Release Date	Release Location - Broad	Release Location - Specifics	Mean Release TL (mm)	Mean Release WT (g)	Number of hatchery burbot released	Marking	Life Stage
2009	21-Oct-09	Goat River	U/S from confluence with Kootenay	400.0	467.6	7	PIT tag and PBT genetic marker	Adult
2009	21-Oct-09	Goat River	U/S from confluence with Kootenay	414.1	529.5	23	PIT tag and PBT genetic marker	Juvenile
2010	03-Nov-10	Goat River	U/S from confluence with Kootenay	NA	NA	400	PBT genetic marker	Juvenile
2011	27-Oct-11	Goat River	U/S from confluence with Kootenay	NA	NA	26	PBT genetic marker	Juvenile
2011	27-Oct-11	Goat River	U/S from confluence with Kootenay	293.0	150.7	6	PIT tag and PBT genetic marker	Juvenile
2011	27-Oct-11	Goat River	U/S from confluence with Kootenay	111.3	9.9	1500	PIT tag and PBT genetic marker	Juvenile
2011	03-Nov-11	Goat River	U/S from confluence with Kootenay	238.7	77.6	15	PIT tag and PBT genetic marker	Juvenile
2011	06-Nov-11	Goat River	U/S from confluence with Kootenay	230.5	95.1	35	PIT tag and PBT genetic marker	Juvenile
2012	01-May-12	Goat River	Hwy Bridge	NA	NA	33250	PBT genetic marker	Larvae
2012	01-May-12	Goat River	Hwy Bridge	212.9	82.0	75	PIT tag and PBT genetic marker	Juvenile
2012	17-May-12	Kootenay Lake	Balfour/Queens Bay	NA	NA	7500	PBT genetic marker	Larvae
2012	17-May-12	Kootenay Lake	Boswell	NA	NA	12500	PBT genetic marker	Larvae
2012	17-May-12	Kootenay Lake	Kaslo	NA	NA	6000	PBT genetic marker	Larvae
2012	17-May-12	Kootenay Lake	Kuskanook	NA	NA	24000	PBT genetic marker	Larvae
2012	08-Jun-12	Kootenay Lake	Kuskanook	NA	NA	13500	PBT genetic marker	Juvenile
2012	13-Jul-12	Goat River	Hwy Bridge	256.2	127.1	77	PIT tag and PBT genetic marker	Juvenile
2012	13-Jul-12	Goat River	U/S from confluence with Kootenay	259.2	129.7	28	PIT tag and PBT genetic marker	Juvenile
2012	06-Nov-12	Goat River	Hwy Bridge	NA	NA	2000	PBT genetic marker	Juvenile

Appendix C: Summary of Moyie Lake origin, KTOI-reared hatchery burbot releases into Canadian waters between 2009-2017

year of release	Release Date	Release Location - Broad	Release Location - Specifics	Mean Release TL (mm)	Mean Release WT (g)	Number of hatchery burbot released	Marking	Life Stage
2013	02-May-13	Kootenay Lake	Boswell	NA	NA	90000	PBT genetic marker	Larvae
2013	02-May-13	Kootenay Lake	Kuskanook	NA	NA	99000	PBT genetic marker	Larvae
2013	08-May-13	Kootenay Lake	Balfour/Queens Bay	NA	NA	63000	PBT genetic marker	Larvae
2013	08-May-13	Kootenay Lake	Balfour/Queens Bay	NA	NA	63000	PBT genetic marker	Larvae
2013	08-May-13	Kootenay Lake	Kaslo	NA	NA	99000	PBT genetic marker	Larvae
2013	24-Oct-13	Goat River	Hwy Bridge	112.7	10.2	2465	PIT tag and PBT genetic marker	Juvenile
2015	01-Jul-15	Kootenay Lake	Balfour/Queens Bay	475.5	812.5	4	PIT tag and PBT genetic marker	Adult
2015	01-Jul-15	Kootenay Lake	Balfour/Queens Bay	461.1	900.0	7	PIT tag and PBT genetic marker	Adult
2015	01-Jul-15	Kootenay Lake	Balfour/Queens Bay	389.3	494.7	19	PIT tag and PBT genetic marker	Adult
2015	07-Jul-15	Kootenay Lake	Balfour/Queens Bay	NA	NA	7500	PBT genetic marker	Juvenile
2015	02-Oct-15	Kootenay Lake	Balfour/Queens Bay	NA	NA	35718	PBT genetic marker	Juvenile
2015	02-Oct-15	Kootenay Lake	Balfour/Queens Bay	NA	NA	2698	PBT genetic marker	Juvenile
2015	02-Oct-15	Kootenay River	Creston Boat Launch	NA	NA	44097	PBT genetic marker	Juvenile
2015	21-Oct-15	Kootenay River	Creston Boat Launch	109.1	NA	385	PIT tag and PBT genetic marker	Juvenile
2015	21-Oct-15	Goat River	U/S from confluence with Kootenay	102.0	NA	294	PIT tag and PBT genetic marker	Juvenile
2015	26-Oct-15	Kootenay Lake	Balfour/Queens Bay	101.6	NA	671	PIT tag and PBT genetic marker	Juvenile
2016	02-Oct-16	Kootenay Lake	Balfour/Queens Bay	NA	NA	21739	PBT genetic marker	Juvenile
2016	02-Oct-16	Goat River	U/S from confluence with Kootenay	NA	NA	17691	PBT genetic marker	Juvenile
2016	11-Oct-16	Kootenay Lake	Balfour/Queens Bay	108.2	NA	1970	PIT tag and PBT genetic marker	Juvenile
2016	11-Oct-16	Goat River	U/S from confluence with Kootenay	112.7	NA	2437	PIT tag and PBT genetic marker	Juvenile
2017	06-Oct-17	Goat River	U/S from confluence with Kootenay	65.9	2.1	243	PIT tag and PBT genetic marker	Juvenile

Appendix C: Summary of Moyie Lake origin, KTOI-reared hatchery burbot releases into Canadian waters between 2009-2017

year of release	Release Date	Release Location - Broad	Release Location - Specifics	Mean Release TL (mm)	Mean Release WT (g)	Number of hatchery burbot released	Marking	Life Stage
2017	06-Oct-17	Goat River	U/S from confluence with Kootenay	65.9	2.1	6624	PBT genetic marker	Juvenile
2017	06-Oct-17	Kootenay Lake	Balfour/Queens Bay	79.1	3.2	6993	PBT genetic marker	Juvenile
2017	06-Oct-17	Kootenay Lake	Balfour/Queens Bay	79.1	3.2	121	PIT tag and PBT genetic marker	Juvenile

Appendix D: Summary of all juvenile/adult and larval releases into the Kootenay Lake and river since the beginning of the stocking program (2009-2017).

Year	Juvenile/Adult Releases		Larval Releases	
	Lake	River	Lake	River
2009		209		
2010		2,154		
2011		70,416		
2012	13,500	15,685	50,000	193,250
2013		11,555	414,000	36,000
2014		3,623		
2015	46,647	225,977		632,590
2016	23,709	112,646		
2017	7,114	29,368		7,329,180
Total	**90,970**	**471,633**	**464,000**	**8,191,020**

Appendix E: Cod trapping set information and capture summary from Kootenay Lake, 2018.

Cod Trap #	Pull Date	Rkm	Zone	Easting	Northing	Water Depth (m)	Water Temp (C)	Total time deployed (in hours)	Number of burbot captured	BB caught/24h (CPUE)
1	02-Feb-18	76.1	11	499019	5494979	13	3.6	47.720	0	0.00
2	02-Feb-18	76.1	11	497870	5494495	16	3.3	47.588	0	0.00
3	02-Feb-18	76.1	11	498792	5495993	14	3.3	47.531	0	0.00
4	02-Feb-18	76	11	503979	5497612	14	3.4	47.677	0	0.00
5	02-Feb-18	76	11	503746	5497894	13	3.5	47.709	0	0.00
6	02-Feb-18	76	11	504709	5497064	14	3.4	47.675	0	0.00
7	02-Feb-18	76	11	505085	5496900	10	3.38	47.647	0	0.00
8	02-Feb-18	75	11	509276	5498891	11	3.14	47.433	0	0.00
9	02-Feb-18	75	11	508718	5498877	10	2.9	47.463	0	0.00
10	02-Feb-18	75	11	509300	5498492	12	3.34	47.408	0	0.00
11	05-Feb-18	76.1	11	499019	5494979	14.3	3.8	71.544	0	0.00
12	05-Feb-18	76.1	11	498107	5494572	13.4	3.28	71.479	0	0.00
13	05-Feb-18	76.1	11	498792	5495993	11	3.58	71.477	0	0.00
14	05-Feb-18	76	11	503979	5497612	15	3.3	71.172	0	0.00
15	05-Feb-18	76	11	503746	5497894	13	3.3	71.435	0	0.00
16	05-Feb-18	76	11	504709	5497064	11	3.4	71.470	0	0.00
17	05-Feb-18	76	11	505085	5496900	12	3.4	71.385	0	0.00
18	05-Feb-18	76	11	509276	5498891	11	3.1	71.556	0	0.00
19	05-Feb-18	76	11	508718	5498877	11.6	3.1	71.502	0	0.00
20	05-Feb-18	75	11	509300	5498492	11	3	71.485	0	0.00
21	09-Mar-18	115	11	521338	5463958	10	2.6	71.926	0	0.00
22	09-Mar-18	116	11	522760	5462830	13	2.6	71.964	0	0.00
23	09-Mar-18	117	11	523499	5462053	10	2.6	71.936	0	0.00
24	09-Mar-18	118	11	523900	5461499	8	2.6	71.993	0	0.00
25	09-Mar-18	119	11	524323	5460484	8.5	2.6	71.984	0	0.00
26	09-Mar-18	115	11	517565	5460778	12	2.6	71.421	0	0.00
27	09-Mar-18	118	11	519396	5458693	12	2.7	71.805	0	0.00
28	09-Mar-18	119	11	520529	5457807	13	2.9	72.156	0	0.00
29	09-Mar-18	121	11	521139	5456745	12	2.8	72.439	0	0.00
30	09-Mar-18	121.5	11	521845	5455752	10	3	72.745	0	0.00
31	09-Mar-18	121.5	11	522304	5455681	13	3	72.971	0	0.00

Appendix E: Cod trapping set information and capture summary from Kootenay Lake, 2018.

Cod Trap #	Pull Date	Rkm	Zone	Easting	Northing	Water Depth (m)	Water Temp (C)	Total time deployed (in hours)	Number of burbot captured	BB caught/24h (CPUE)
32	09-Mar-18	121.5	11	522362	5456012	8	2.6	73.153	0	0.00
33	12-Mar-18	115	11	521338	5463958	6	2.7	71.711	0	0.00
34	12-Mar-18	116	11	522760	5462830	9.5	2.73	71.696	0	0.00
35	12-Mar-18	117	11	523499	5462053	8	2.7	71.685	0	0.00
36	12-Mar-18	118	11	523900	5461499	9.5	2.64	71.631	0	0.00
37	12-Mar-18	119	11	524071	5459575	12	2.74	71.534	0	0.00
38	12-Mar-18	115	11	517565	5460778	15	2.65	71.446	0	0.00
39	12-Mar-18	118	11	519396	5458693	15.7	2.8	71.362	0	0.00
40	12-Mar-18	119	11	520529	5457807	8.2	2.9	71.282	0	0.00
41	12-Mar-18	121	11	521139	5456745	14	2.8	71.221	0	0.00
42	12-Mar-18	121.5	11	521845	5455752	10	2.9	71.150	0	0.00
43	12-Mar-18	121.5	11	522304	5455681	12	2.9	71.119	0	0.00
44	12-Mar-18	122	11	523036	5455633	11	2.9	71.025	0	0.00
45	19-Mar-18	77	11	509260	5498845	17	3.6	70.713	0	0.00
46	19-Mar-18	77	11	508854	5498762	19	3.6	70.998	0	0.00
47	19-Mar-18	77	11	504961	5497008	26	2.8	73.811	0	0.00
48	19-Mar-18	77	11	504048	5497467	17	2.8	74.018	0	0.00
49	19-Mar-18	76	11	504146	5497336	15	2.8	74.304	1	0.32
50	19-Mar-18	76	11	503832	5497897	22	2.8	74.143	0	0.00
51	19-Mar-18	76	11	498992	5495994	20	2.8	75.075	0	0.00
52	19-Mar-18	76.1	11	498621	5495977	15	2.8	75.396	0	0.00
53	19-Mar-18	76.1	11	497850	5494534	20	2.9	76.125	0	0.00
54	19-Mar-18	76.1	11	498216	5494614	17	2.8	76.021	0	0.00
55	19-Mar-18	76.1	11	498579	5494722	17	2.8	76.050	0	0.00
56	19-Mar-18	76.1	11	498905	5495007	20	2.8	76.038	0	0.00
57	22-Mar-18	76.1	11	497850	5494534	8.5	3.1	66.878	0	0.00
58	22-Mar-18	76.1	11	498216	5494614	14.4	3.1	66.922	0	0.00
59	22-Mar-18	76.1	11	498579	5494722	11.5	3.1	66.882	0	0.00
60	22-Mar-18	76.1	11	498905	5495007	10	3	66.836	0	0.00
61	22-Mar-18	76.1	11	498621	5495977	11	3	67.372	0	0.00
62	22-Mar-18	76.1	11	498992	5495994	12	3	67.735	0	0.00

Appendix E: Cod trapping set information and capture summary from Kootenay Lake, 2018.

Cod Trap #	Pull Date	Rkm	Zone	Easting	Northing	Water Depth (m)	Water Temp (C)	Total time deployed (in hours)	Number of burbot captured	BB caught/24h (CPUE)
63	22-Mar-18	76	11	504048	5497467	14	3.1	68.535	0	0.00
64	22-Mar-18	76	11	504961	5497008	12	3.2	68.999	0	0.00
65	22-Mar-18	76	11	503832	5497897	10	3.2	68.551	0	0.00
66	22-Mar-18	77	11	508854	5498762	11.5	3.5	71.509	0	0.00
67	22-Mar-18	77	11	509260	5498845	10	3.6	71.804	0	0.00
68	27-Mar-18	21	11	503504	5554149	17	2.5	119.308	0	0.00
69	29-Mar-18	20	11	503423	5554994	20	2.6	167.580	0	0.00
70	29-Mar-18	18	11	502942	5555816	18	2.2	167.689	0	0.00
71	29-Mar-18	17.5	11	503095	5556155	17	2.6	167.730	1	0.14
72	29-Mar-18	17	11	503428	5556496	19.8	2.83	167.742	1	0.14
73	29-Mar-18	17	11	503686	5556868	20	2.96	167.829	0	0.00
74	29-Mar-18	17	11	504067	5557079	21.6	2.7	167.848	2	0.29
75	29-Mar-18	17	11	504655	5557314	16	2.8	167.908	1	0.14
76	29-Mar-18	17	11	505344	5557234	15	2.9	167.915	0	0.00
77	29-Mar-18	17	11	505505	5557005	16	2.8	167.999	0	0.00
78	29-Mar-18	17	11	505528	5556757	18	2.8	168.051	0	0.00
79	29-Mar-18	18	11	505555	5556347	15	2.7	168.070	0	0.00
80	03-Apr-18	21	11	503504	5554149	10	4	119.132	0	0.00
81	03-Apr-18	18	11	505555	5556347	9	4	117.787	0	0.00
82	03-Apr-18	18	11	505528	5556757	10	4	118.008	0	0.00
83	03-Apr-18	17	11	505344	5557234	9	4	118.357	0	0.00
84	03-Apr-18	18	11	502942	5555816	10	4	132.056	0	0.00
85	03-Apr-18	17	11	503686	5556868	10	4	131.857	0	0.00
86	04-Apr-18	17	11	505505	5557005	10	4	144.642	0	0.00
87	14-May-18	77	11	509018	5498446	26	8.6	70.256	0	0.00
88	14-May-18	77	11	508936	5498850	22	8.3	70.325	0	0.00
89	14-May-18	77	11	509258	5498853	19.6	7.8	70.430	0	0.00
90	14-May-18	77	11	509518	5498071	22.8	7.2	70.449	0	0.00
91	14-May-18	77	11	509821	5497710	26	7.2	70.507	0	0.00
92	14-May-18	75	11	504455	5499952	28	8.7	70.490	0	0.00
93	14-May-18	75	11	503958	5499175	22	9.5	70.551	0	0.00

Appendix E: Cod trapping set information and capture summary from Kootenay Lake, 2018.

Cod Trap #	Pull Date	Rkm	Zone	Easting	Northing	Water Depth (m)	Water Temp (C)	Total time deployed (in hours)	Number of burbot captured	BB caught/24h (CPUE)
94	14-May-18	75	11	503353	5498240	25	9.4	70.385	0	0.00
95	14-May-18	75	11	503923	5497863	24	9.3	70.378	0	0.00
96	14-May-18	75	11	504056	5497389	24	9	70.359	0	0.00
97	16-May-18	77	11	508953	5498447	12.5	9.7	48.171	0	0.00
98	16-May-18	77	11	509099	5498968	11.3	9.8	48.100	0	0.00
99	16-May-18	77	11	509338	5498864	8	10.3	21.963	0	0.00
100	16-May-18	77	11	509361	5498850	9.5	9.8	23.932	0	0.00
101	16-May-18	77	11	509597	5498135	8.8	9.9	47.863	0	0.00
102	16-May-18	77	11	509862	5497744	10	10.7	47.826	0	0.00
103	16-May-18	75	11	504444	5499978	11.4	8.2	47.714	0	0.00
104	16-May-18	75	11	503522	5499181	10	8.6	47.610	0	0.00
105	16-May-18	75	11	503325	5498219	11.4	9	47.496	0	0.00
106	16-May-18	75	11	503898	5497819	8.8	9.9	47.441	0	0.00
107	16-May-18	75	11	504009	5497380	8.6	8.8	47.389	0	0.00
108	18-May-18	17	11	505586	5556352	15	7.6	45.406	0	0.00
109	18-May-18	17	11	505593	5556570	17.8	7.7	45.781	0	0.00
110	18-May-18	17	11	505540	5556728	20.6	8.1	45.772	0	0.00
111	18-May-18	17	11	505495	5556934	23	8.2	45.803	0	0.00
112	18-May-18	17	11	504379	5557242	22	9.1	45.564	2	1.05
113	18-May-18	17	11	503823	5556938	22.2	8.6	45.946	0	0.00
114	18-May-18	17	11	503499	5556687	18	9.8	45.945	1	0.52
115	18-May-18	17	11	503275	5556295	16.5	10	46.009	1	0.52
116	18-May-18	17	11	503159	5556116	23	9.7	46.071	0	0.00
117	18-May-18	17	11	502959	5555881	22	10.5	46.143	0	0.00
						Total		**9044.009**	**10**	**0.03**

Appendix F: Burbot captures from 2018, Kootenay Lake cod trapping efforts

RKM	Capture Date	BBID	PIT Number	Total Length (mm)	Weight (g)	PBT Sex	Year Class	Hatchery fish?	Comments
76	19-Mar-2018	43031	384.349eb14c26	NA	NA	M	2012	Yes	Recaptured. Sonic tagged 2015 at Balfour.
17	3-Apr-2018	66873	384.349EB14C49	520	800	M	2013	Yes	sonic tagged
17	3-Apr-2018	66869	384.349EB14C47	820	3400	F		No	sonic tagged
17	3-Apr-2018	66870	384.349EB14C35	730	3400	F	1992	No	Mortality. Aged via otolith.
17	3-Apr-2018	66871	384.349EB14C70	790	3600	F		No	sonic tagged
18	3-Apr-2018	66872	384.349EB14C34	925	4200	F		No	sonic tagged
17	22-May-2018	66874	384.349eb14c12	530	1100	F		No	sonic tagged
17	22-May-2018	66875	384.349eb29779	483	650	M		No	sonic tagged
17	22-May-2018	66876	384.349eb14cac	790	2250	M		No	
17	22-May-2018	66877	384.349eb29775	810	3250	F		No	
17	22-May-2018	66878	384.349eb2972f	765	2600	F		No	
17	22-May-2018	66879	384.349eb14c95	740	2500	F		No	Fungus noted with eggs when stripped.
17	22-May-2018	66880	384.349eb14cdf	830	3250	F		No	
17	22-May-2018	66881	384.349eb14cc3	545	800	F		No	
17	24-May-2018	66882	384.349eb14c57	540	900	M		No	

Appendix G: Photographs

Photograph 1: 2018 Moyie Lake, burbot gamete collection field crew with staff from the Ministry of Forests Lands and Natural Resource Operations and Rural Development, Kootenay Tribe of Idaho and Idaho fish and Game.

Photographs 2-18 demonstrate all steps taken to collect burbot gametes from Moyie Lake and create families which are transported to Kootenay Tribe of Idaho's Twin Rivers Burbot and Sturgeon Hatchery in Idaho to be reared and released into Kootenay Lake and River for recovery. Photographs were taken between 2015-2019.

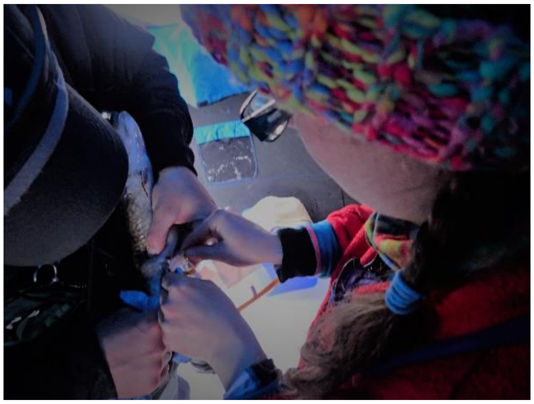
Photograph 2: Measuring burbot length.

Photograph 3: Measuring burbot weight.

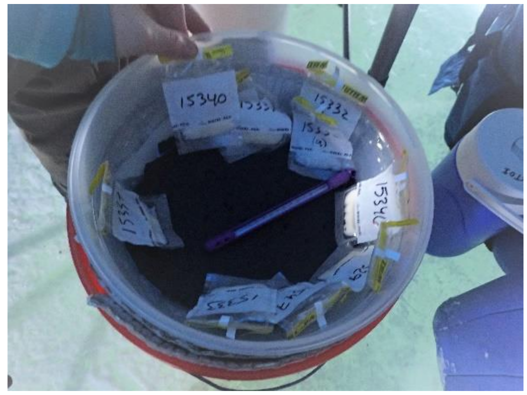
Photograph 4: Floy tag insertion.

Photograph 5: Placed in holding tank prior to proceeding with spawning process.

Appendix G: Photographs continued



Photograph 6: Burbot milt collection.

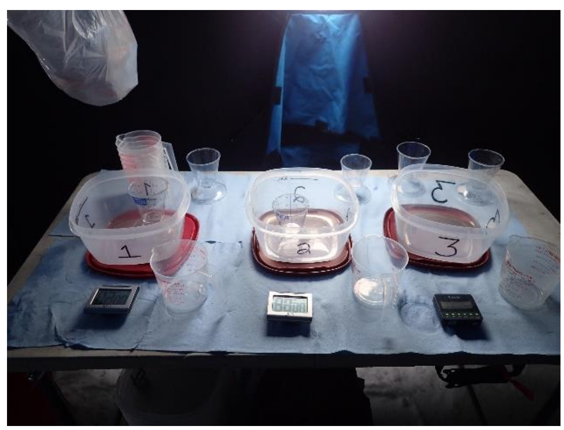


Photograph 7: Burbot milt samples being kept cool prior to being utilized to fertilize eggs.

Photograph 8: Microscope station used to verify motility of milt to ensure proper egg fertilization.

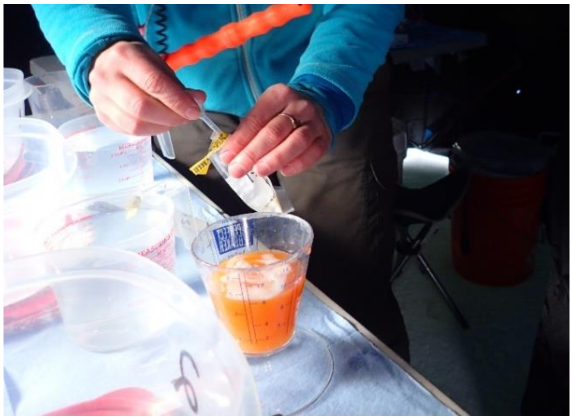
Photograph 9: Verifying milt motility to ensure proper egg fertilization.

Photograph 10: Collecting ripe eggs from a mature female burbot.



Photograph 11: Egg and milt mixing station.

Appendix G: Photographs continued



Photograph 12: Mixing milt and eggs.

Photograph 13: Activating milt with water to initiate fertilization process.

Photograph 14: Fertilization process takes place within 2 minutes.

Photograph 15: Rinsing of eggs occurs after fertilization has occurred and again after 30 minutes of water hardening.

Photograph 16: Eggs are placed into transport containers and super-oxygenated for a safe journey.

Photograph 17: All fish are released back into Moyie Lake immediately after gametes have been collected.

Appendix G: Photographs continued

Photograph 18: Parental based tagging fin clips taken from every spawned fish.

Photographs 19-22 demonstrate the burbot sonic tagging process utilized by both Canadian and American copartners in the Kootenay Lake and River recovery program. Photographs taken in 2019.

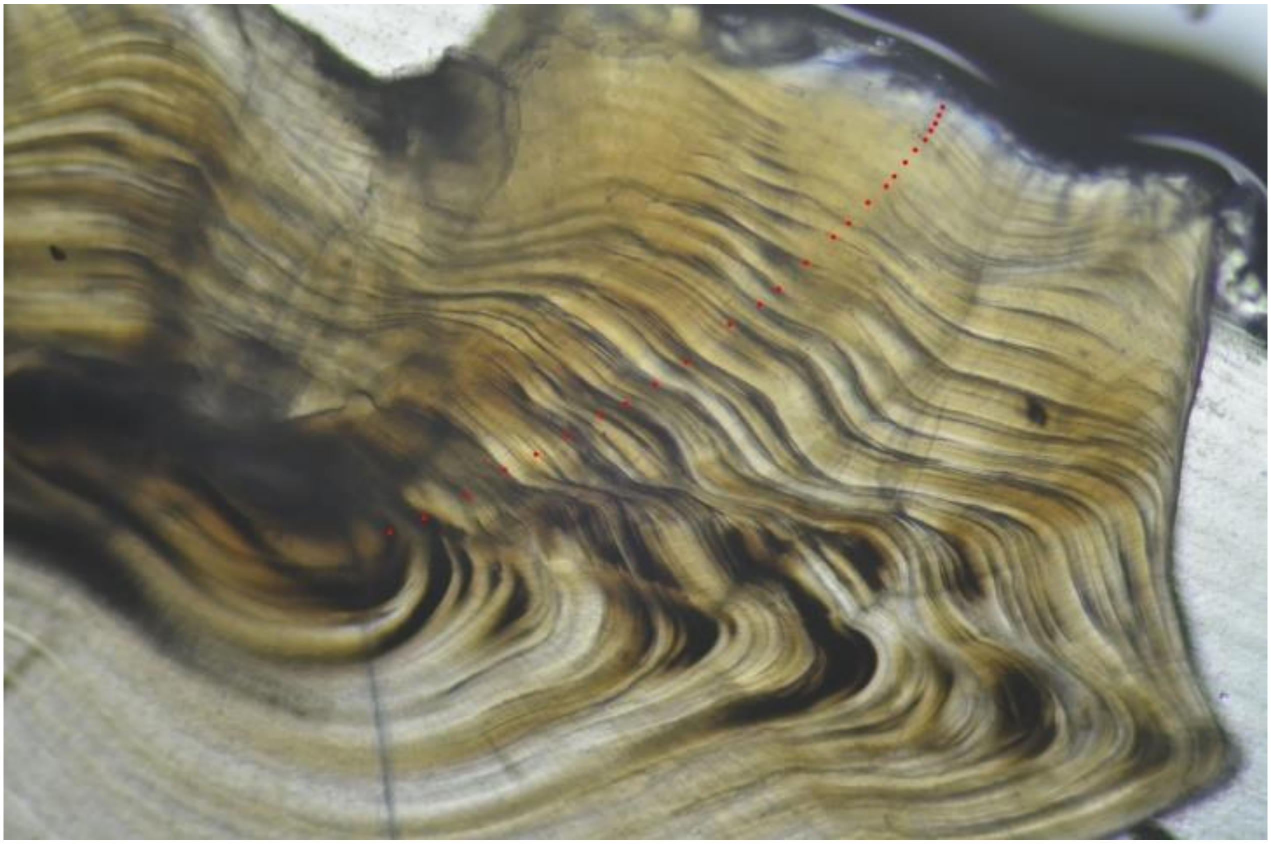
Photograph 19: Burbot sonic tagging station.

Photograph 20: Anesthetizing burbot prior to surgery.

Photograph 21: Anesthetized burbot ready for surgery.

Photograph 22: Recovery holding tank prior to release.

Appendix G: Photographs continued



Photograph 23: Otolith of 26-year-old Female burbot from Kootenay Lake. Each red dot represents one year of growth.