Columbia River Project Water Use Plan

Kinbasket Reservoir Fish and Wildlife Information Plan

Implementation Year 1

Reference: CLBMON-05

Kinbasket Reservoir Burbot Life History and Habitat Use Assessment

Study Period: April – June 2014

Canadian Columbia River Inter-Tribal Fisheries Commission.

7468 Mission Rd, Cranbrook, BC, V1C 7E5

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WLR Monitoring Study No. CLBMON-05 (Year 1)

Kinbasket Reservoir Burbot Life History and Habitat Use Assessment

Prepared for: BC Hydro

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Cover Photo:

Looking out over Kinbasket Reservoir and cod traps at low pool during spring capture session of burbot.

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EXECUTIVE SUMMARY

Burbot (*Lota lota*) were historically distributed throughout the Columbia and Canoe Rivers, and historic Kinbasket Lake, which were impounded by the construction of Mica Dam in 1973. Mica Dam created Kinbasket Reservoir, a 216 km long, 43,200 ha ultraoligotrophic water body. Burbot are present throughout Kinbasket Reservoir; this is a technical report that summarizes the findings of the first (2014) of a three year monitoring study of their life history and habitat use.

Kinbasket reservoir has a normal operating range of approximately 35 m. The reservoir experiences rapid drawdown during the winter months from January to April, when reservoir elevations decline by an average of 4.3 m/month. Burbot spawn during this time period, and the success of their spawning may be affected by declining water levels. Burbot often spawn in shallow water, and developing eggs require several weeks to months to develop before hatching, at which time larvae spend several days resting before becoming planktonic. It is during this time period that optimal spawning habitat, developing eggs or newly hatched larvae may become stranded by declining water levels in Kinbasket Reservoir. The fact that burbot still exist in Kinbasket Reservoir implies that populations persist despite impacts from declining water levels; however, spawning for a large population component may be affected by operations in all or some years.

This study uses biotelemetry to determine biological characteristics, movement and depth preferences of burbot during the suspected spawning time period. Previous data on capture rates and and logistical constraints limited the study area of Kinbasket Reservoir to the section between the Canoe Arm and Surprise Rapids. Burbot were captured by baited cod traps during the immediate post spawn period of late April and early May, 2014, shortly after ice-off and during the period of minimum reservoir elevation. Five major areas at reservoir narrows and stream confluences were targeted, as they had been identified as areas of high burbot occupancy in previous studies. Capture was conducted in shallow areas (< 20 m) to minimize mortality to captured fish.

A total of 124 burbot (mean size 663 +/- 106 mm; 1.6 +/- 0.71 kg) were caught in 12 days of trapping, yielding an overall CPUE of 0.83 fish/48 hr trapset (95% CI of 0.66-1.00 fish/trapset). Capture success varied between the five capture areas targeted in the reservoir, indicating that burbot abundance is not spatially uniform throughout the study area in the post spawn period. A weak positive relationship between burbot size and capture depth was found. Most burbot were in post spawn condition.

48 fish of a broad size range (0.9 kg – 4.6 kg) were surgically implanted with combined acoustic-radio transmitters (CART) that transmit depth and temperature sensor data. These fish will be tracked year-round by fixed acoustic receivers and during the spawning season by mobile radio tracking. Sixteen fixed acoustic receivers were deployed in specific areas to detect broad scale movements and in the vicinity of stream confluence areas that are suspected spawning areas. These receivers will record data of burbot biology and life history year-round and be used to determine movements towards spawning areas and depths used during the spawning season. Receivers will be downloaded in year 2 (2015). Mobile radio tracking will be conducted in year 2 (winter 2015) by helicopter, which may detect shallow reservoir and tributary habitat use during the spawning season.

Management Question	Hypotheses	Status
What are some basic biological characteristics of burbot populations in Kinbasket Reservoir (e.g., distribution, abundance, growth and age structure)?		To be addressed in years 2 and 3.
Does winter drawdown of Kinbasket Reservoir cause the dewatering of burbot spawning habitat and affect spawning success?	H1: Winter drawdown of Kinbasket Reservoir causes dewatering of burbot spawning habitat, which reduces egg survival and burbot spawning success. H2: Winter drawdown of Kinbasket Reservoir causes dewatering of access to burbot spawning habitat in some years.	To be addressed in years 2 and 3.
Can modifications be made to the operation of Kinbasket Reservoir to protect or enhance spawning success of these burbot populations?		To be addressed in years 2 and 3.

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INTRODUCTION

Background

Kinbasket Reservoir was created by the construction of Mica Dam in 1973, under the terms of the Columbia River Treaty. The purposes of the creation of this earthfill, high head dam and reservoir were for optimized, coordinated power generation between Columbia River mainstem dams in the US and Canada and for downstream flood control. The reservoir inundated 216 km of the length of the Columbia River between Mica and Donald, and is among the largest reservoirs in British Columbia, with a maximum surface area of 43,200 ha. Prior to dam construction, the majority of this habitat was free flowing, with the exception of a lacustrine portion known as Kinbasket Lake that was 13km long and had a surface area of 2,250 ha (Prince 2011). The reservoir can be coarsely segregated into two main reaches, with the Columbia and Canoe reaches meeting at the historic confluence of the Canoe and Columbia rivers, where the Columbia River turns southward approximately where Mica Dam is currently situated. The reaches of the reservoir are typically bounded by steep valleys and are narrow, with stretches becoming riverine at low pool. Thee large lacustrine portions of the reservoir occur at the confluence of the Canoe and Columbia Reaches, at the historic location of Kinbasket Lake near the confluence with the Sullivan River, and at the confluence with the Bush River. Stream inputs are largely glacial, draining the high elevation northern tips of the Selkirk and Monashee mountains from the West, and the extensively glaciated West slopes of the Canadian Rockies from the East.

Operations of Mica dam result in extreme annual fluctuations of the reservoir levels. Kinbasket reservoir elevations may vary between a maximum of 754.38 m and a minimum 707.41 m, and may occasionally be brought up to a maximum elevation of 754.68m on application to the Comptroller of Water Rights if there is a high probability of spill. Normal operating level for the 2008-2012 period was from a mean maximum of 753.26 m and a minimum of 718.12 m, with a normal operating range of 35.14 m. Drawdown from full pool normally begins slowly in September, and draft rate increases through the winter, with a levelling off of drafting and normal low pool occurring in mid-late April. During the spring period, discharge from Mica dam decreases, which coincides with the normal spring freshet, which rapidly refills the reservoir through the spring and early summer.

Burbot (*Lota lota*) were identified by the Columbia River Water Use Plan Consultative Committee (WUP CC) as a key fish species of concern in Kinbasket Reservoir because of their importance to the sport fishery, because of the potential for links between reservoir operations and burbot population productivity, and due to the dearth of information regarding burbot biology in the reservoir (but see Harrison et al. 2013). The WUP CC hypothesized that the greatest potential impact of reservoir operations on burbot populations may be the dewatering effect of winter drawdown on spawning success and egg survival in sites along the shoreline and in lower sections of tributaries. The WUP CC also had concerns that winter drawdown could affect burbot spawning habitat in tributary streams of Kinbasket Reservoir. To address these concerns, the WUP CC recommended that a life history and habitat use assessment be undertaken in Kinbasket Reservoir to gain a better understanding of how the current operating regime might be affecting burbot populations.

Burbot typically spawn between late January and April, with timing on major Columbia River system reservoirs (Duncan and Arrow) occurring in mid-February to early April (Arndt and Hutchinson 2000, Bisset and Cope 2002, Prince and Cope 2008, Cope 2011, Robichaud et al. 2013), either in lake habitats or low velocity stream habitats, and have an egg incubation period of 30-60 days (Taylor and McPhail 2000, McPhail 2007). After hatching, larvae spend several days resting on the bottom before becoming free-swimming and planktonic in the water column. It can be expected that the period of spawning and egg and early larval development occurs between February and May-June in Kinbasket Reservoir, which coincides with the period when reservoir water levels can decline by an average of 4.3 m/month before reaching low pool elevation (Figure 1).

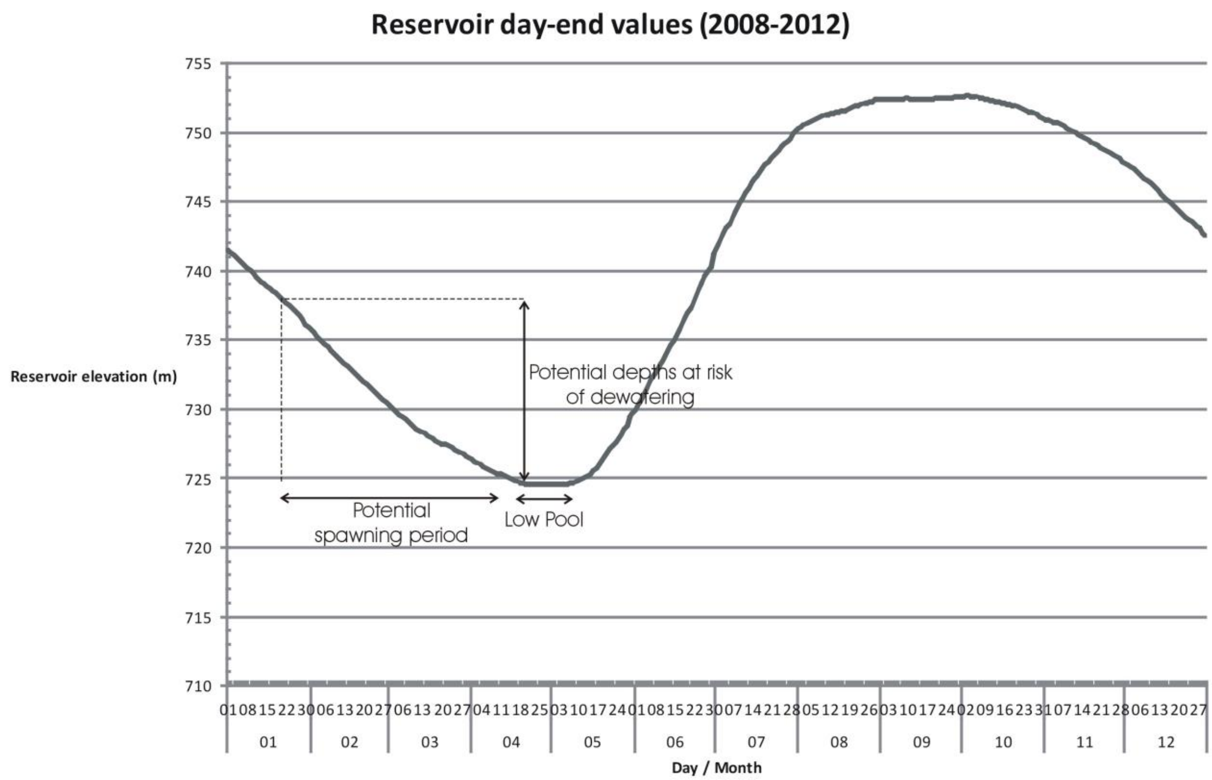

Figure 1: Potential depths used by burbot during the spawning period that are at risk of dewatering in an average year of reservoir operation. Greater depths are at less risk for dewatering as the spawning season progresses.

The greatest potential impact of reservoir operations on burbot populations may be the dewatering effect of winter drawdown on spawning success and egg survival in sites along the shoreline and in lower sections of tributaries. Burbot spawn in aggregations, often at night (McPhail 2007), and vocalization appears to be a key behaviour that may aid burbot in locating each other for spawning (Cott et al. 2014). In lakes and reservoirs, spawning may occur over near-shore shallows or over shallow offshore reefs and shoals (Ford et al. 1995, McPhail 2007, Spence 1999, Prince and Cope 2008), however, deeper spawning (>20m) may also take place (Robichaud et al 2013). In rivers and tributaries, burbot spawn in low velocity areas in main channels and in side channels behind depositional bars (McPhail 2007). In many cases, spawning in lakes is often associated with tributary confluences or upwelling; however microhabitat preferences for spawning appears to be general, as burbot may select a range of substrate, habitat characteristics and depths to spawn (Ford et al. 1995, McPhail 2007, Andrusak 1998, Baxter et al. 2002, Spence and Neufeld 2002, Prince and Cope 2008, Cope 2011). The depth at which spawning takes place, coupled with the timing of spawning until the period of maximum drawdown in April, dictates whether there is a risk of spawning failure due to reservoir operations (Figure 1).

Declining water levels may also interfere with burbot spawning migration and spawning activity. In a radio telemetry study of adult burbot in Duncan Reservoir, the extent of spawning migration into the upper Duncan River appeared to be influenced by reservoir water levels and related impacts on back-flooding and stream velocity (Spence and Neufeld 2002, Cope 2011). As back flooding from Duncan Reservoir declined, burbot tended to move downstream into areas with lower water velocities than the locations they had abandoned. Since stream spawning burbot tend to spawn in low velocity stream habitats (McPhail 2007), the burbot may have been moving downstream to more suitable lower velocity spawning sites. Burbot are known to have low swimming endurance and biotelemetry results in the Kootenay River below Libby Dam suggest that spawning migrations of burbot in the Kootenay River may be disrupted by high flows produced during hydropower production and flood control (Paragamian 2000).

The footprint impacts of Mica Dam depend on the life history strategy of resident burbot populations. As there is no pre-dam life history information available for burbot populations in this area, all that can be done is to provide an opinion based on habitat features, other species and other burbot populations. What is known is that before the dam there was habitat connectivity between historic Kinbasket Lake and upper Columbia watershed. It is also known that the upper Columbia supported strong runs of Chinook Salmon around big bend to their spawning habitats in the Upper Columbia.. The literature suggests that all three life history forms of burbot (lacustrine, adfluvial, fluvial) often co-exist within the same system (McPhail 2007) and this may have been the case for burbot occupying the historic Kinbasket Lake and upper Columbia system that is now inundated by Kinbasket Reservoir. Adfluvial and lacustrine remnant life history forms may still be present, or the population may be supported by fluvial immigrants from upstream sources. The relative contributions or existence of any of these three life history forms to the current Kinbasket burbot population is unknown.

While the life history and population status of Kinbasket Lake and the Columbia River burbot before dam construction is largely unknown, recent studies have provided some insight into important habitats and distribution of remnant stocks (Prince 2001; Harrison et al 2013). Burbot capture is relatively consistent and successful in the Confluence, Bush pool and historic Kinbasket Lake areas of the reservoir, and near tributary confluences in the Sullivan, Bush and Wood arms and Hugh Allan Creek (Prince 2001; Prince 2011; Harrison et al. 2013). Most burbot (~2/3 of fish captured in the confluence area between the Columbia and Canoe Reaches) appear to make limited seasonal movements, and diel vertical migration and seasonal shift to shallower habitats in winter is common (Harrison et al. 2013). This suggests that there may be many, non-central spawning areas, and/or fish may not spawn annually, a common observation for burbot (Paragamian and Wakkinen 2008), especially those in reservoirs (Dunnigan and Sinclair 2008). For fish that did move out of the confluence area, there does not appear to be a central spawning area that fish move towards (Harrison, pers. comm.). Growth rate is highly variable, as with other populations (Cope 2011). Entrainment rate through Mica Dam is low for fish in the confluence area, even those inhabiting the forebay, suggesting that the populations' productivity is not significantly affected by loss through dam entrainment at the adult life stage (Martins et al. 2013). This information provides some initial insight, but cannot be used to evaluate whether winter drawdown of Kinbasket Reservoir affects spawning success of burbot.

Management Questions

The management questions (MQs) associated with this monitoring program are (BC Hydro 2007):

1) What are some basic biological characteristics of Burbot populations in Kinbasket Reservoir (e.g., distribution, abundance, growth and age structure)?

2) Does winter drawdown of Kinbasket Reservoir cause the dewatering of Burbot spawning habitat and affect spawning success?

3) Can modifications be made to the operation of Kinbasket Reservoir to protect or enhance spawning success of these Burbot populations?

The monitoring program will provide a quantitative baseline dataset to establish basic biological characteristics of the burbot populations in Kinbasket Reservoir. It will provide information on habitat use, life history and rough estimates of abundance, and possible factors affecting burbot productivity. Specifically, the assessment will address uncertainty regarding the extent to which burbot are present in the drawdown zone during the spawning season, and if these areas are at risk for dewatering during the operational years of the study.

Management Hypothesis

The primary aim of this monitoring program is to provide baseline information on the burbot population in Kinbasket Reservoir to better inform on the relationship between reservoir operations and recruitment. It is designed to specifically test the following hypotheses using assumptions of winter (January-April) habitat use being linked to spawning activity:

H1: Winter drawdown of Kinbasket Reservoir causes dewatering of burbot spawning habitat, which reduces egg survival and burbot spawning success.

H2: Winter drawdown of Kinbasket Reservoir causes dewatering of access to Burbot spawning habitat in some years.

Key Water Use Decision Affected

Implementation of the proposed monitoring program will provide information to support more informed decision making with respect to the need to balance storage in Kinbasket Reservoir with impacts on fish populations in the reservoir. Specifically, it will provide the information that is required to support future decisions around maintaining the current operating regime or modifying operations to protect reservoir Burbot populations.

METHODS

Overview, study objectives and limitations

The methodology outlined in this section will detail the study and analytical design. The general approach of this study will be to draw upon the designs of previous Water Use Planning burbot life history and habitat use studies, particularly CLBMON-31 (Glova et al. 2009, 2010, Robichaud et al. 2011, 2012, 2013) and DDMON-11 (Cope 2009, 2010, 2011), and refine them to apply to a study in Kinbasket Reservoir.

The study is designed to answer the management questions (MQs), as outlined in the previous section. Unfortunately, the main drawbacks of work on Kinbasket reservoir are the size of the system, and inability to conduct work on-reservoir during the spawning season in February-March, which differs from the conditions of the previous two Water Use Planning studies on Arrow and Duncan Reservoirs. The study will therefore be concentrated in a reduced area of the reservoir, between the Wood arm and Surprise Rapids (Figure 2). This reduced area was chosen based on previous information of burbot occurrence and logistical considerations for working from the only accessible boat launch near Mica Dam during the low pool period. The study area covers 43% of the total area of the reservoir, and represents a variety of habitats that are representative of elsewhere in the basin, as well as the portion of the reservoir that encompasses the historic Kinbasket Lake. It is likely that inferences made from the study area extend to the entire reservoir burbot population. During the burbot spawning season, Kinbasket reservoir has unpredictable, dynamic ice conditions that make on-reservoir winter work unsafe. In addition, the remoteness of the reservoir requires extensive travel with limited safe access and contact points. Given these safety and logistical constraints, the following study design attempts to answer MQs 2 and 3 without working on-reservoir during the spawning season, and using a combination of fixed receiver and mobile helicopter tracking. These methods attempt to infer whether fish are present and congregating in shallow drawdown habitats during the spawning season. This approach cannot confirm spawning activity, thus presence of burbot will be assumed to be related to spawning activity when testing the management hypotheses outlined in the previous section.

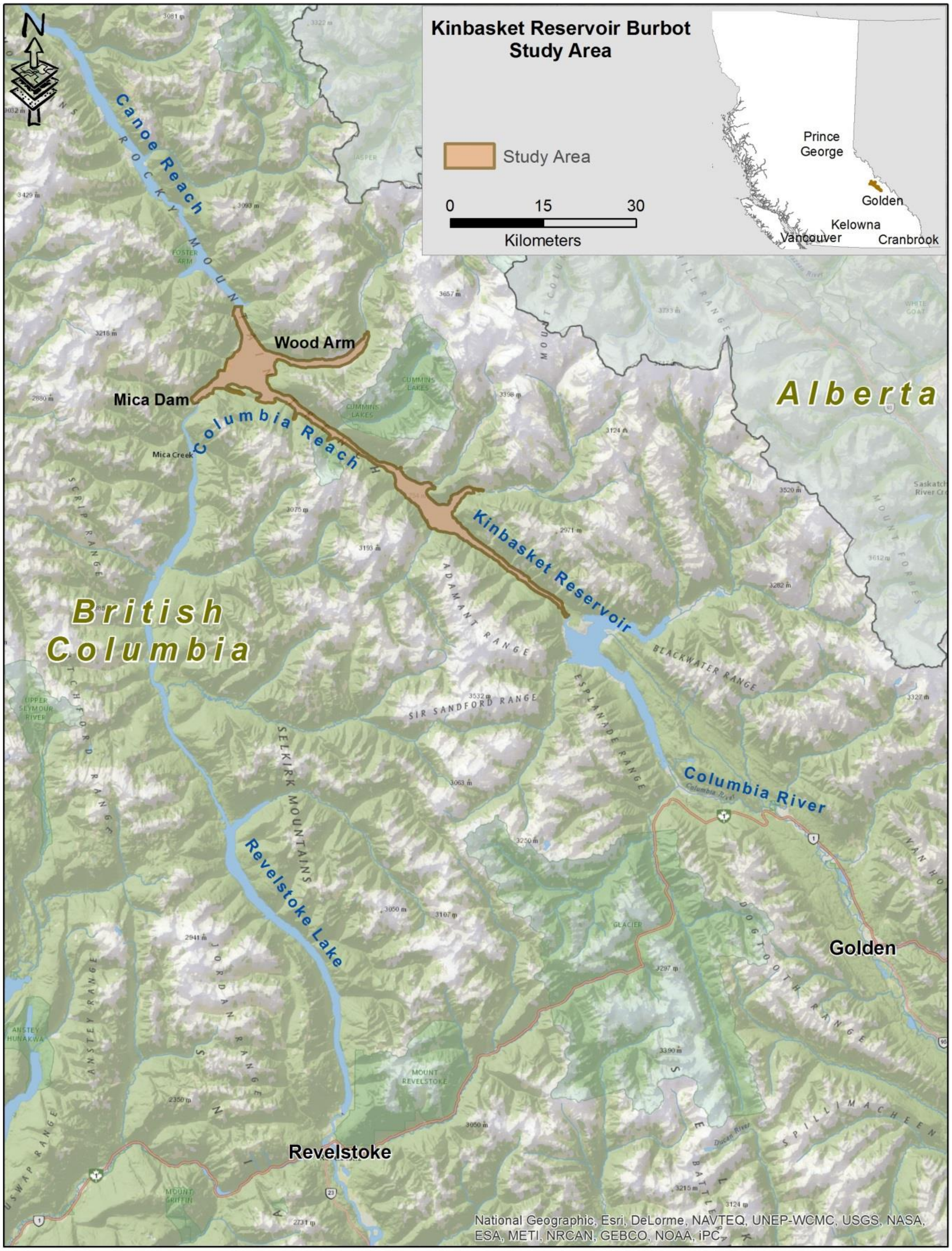

Figure 2: Study area within Kinbasket Reservoir

Burbot capture and tagging

Standardized capture techniques (i.e., time of year, depth, decompression methods and proper equipment) using baited cod traps have been developed and refined through many studies in the Kootenay region of British Columbia, and we applied these to minimize mortality and tag loss in captured fish. A spring capture time of year was chosen, as distribution shifts to shallower habitats, where the risk of barotrauma and mortality is lowest, while capture rates still remain high relative to other times of year (Bernard et al. 1993, Neufeld 2006, Cope 2009, Harrison et al. 2013). Capture during this time of year is further justified by minimizing stress that may interfere with spawning behaviour and maturation of adult fish (Cope 2009), and providing nearly a full year of recovery before the critical tracking season during the spawning period in 2015.

Further advantages of spring capture include isothermal, cool water column, thus minimizing temperature and decompression stress on fish brought up from depth (Harrison et al. 2013); and the low pool of the reservoir, thus improving the predictability and efficiency of capture by concentrating the burbot population from areas that are dewatered (Cope 2009).

Capture was conducted from April 29 to May 7, 2014 with 148, 48 hour trapsets. Ice-off occurred in the Mica Headpond in mid-April, about 2 weeks prior to the capture period. Ice was sparsely distributed throughout the reservoir during the capture season, thus trapping occurred immediately after ice-off. Trapping was conducted by targeted cod trapping with bait (chum salmon) in five reservoir areas where burbot bycatch efficiency was high from setline techniques in a previous study that attempted to capture white sturgeon (Prince 2007). The five areas are in the Wood Arm, Columbia Reach in vicinity of the Cummins River, in the vicinity of the confluence with the Kinbasket River, In the vicinity of the confluence with the Sullivan River and in the upstream portion of the Columbia Reach to Surprise Rapids (Figure 3). A variety of depths, between 3 and 20 m were sampled and specific areas and depths were randomly selected for trapsets within the five major sampling vicinities. Depths of over 20 m were avoided to minimize risk of barotrauma.

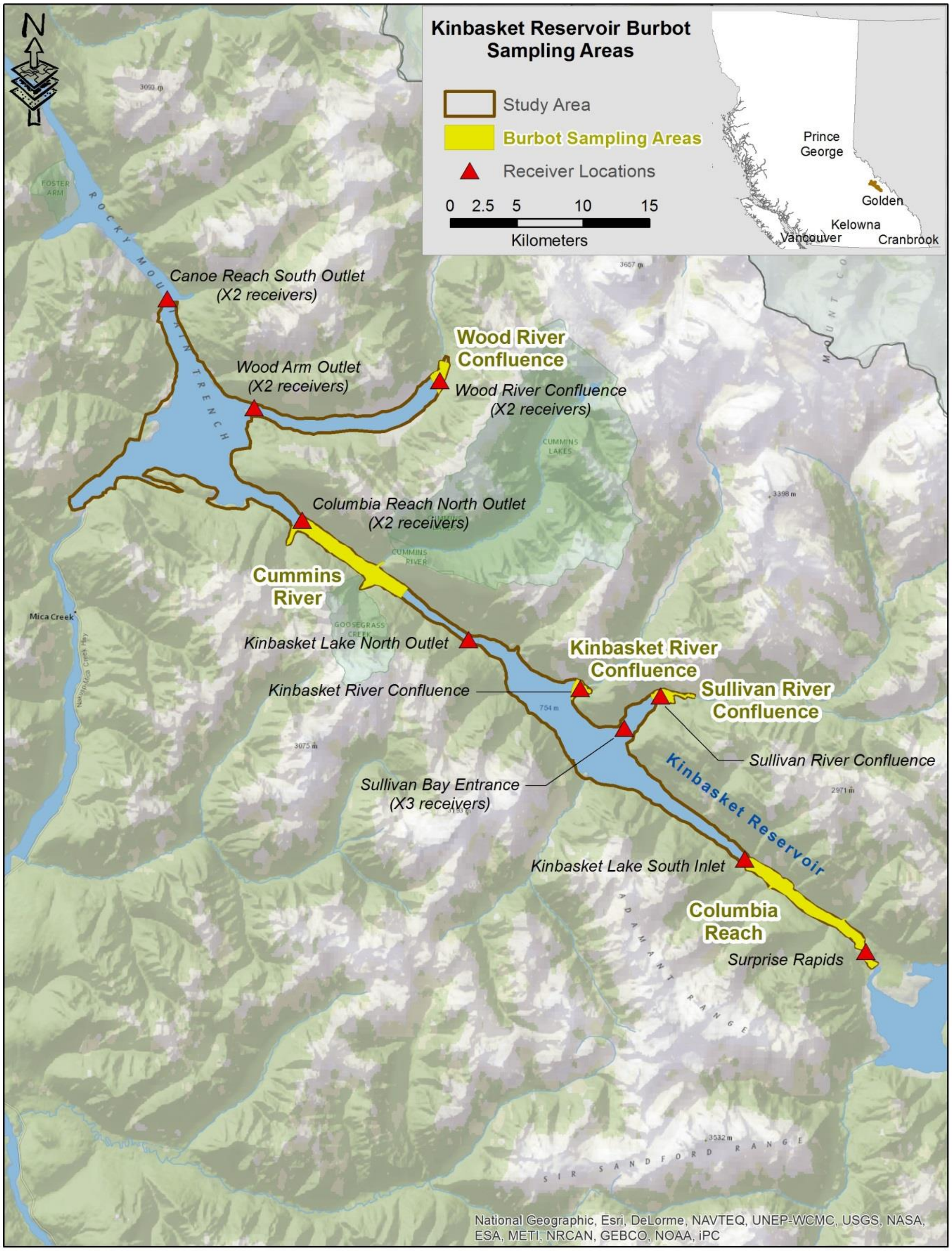

Figure 3: Five burbot trapping areas and locations of 16 acoustic receivers within Kinbasket Reservoir.

Abundance for burbot is unlikely to be estimated in a robust manner from traditional capture-mark-recapture techniques, based on the repeated limited success in other studies (Neufeld 2006, Prince 2007, Cope 2011), and poor recapture rates, which bias population estimates high. The amount of trapping effort required for a robust assessment in this study given the large spatial coverage of Kinbasket Reservoir and limited effort that can be expended upon a randomized capture effort make a population estimate especially impractical in this system; therefore, we provide basic capture-per-unit-effort (CPUE) metrics as rough, relative estimates of abundance for MQ1 from a targeted sampling approach in much the same way as it has been assessed in previous studies (Arndt and Baxter 2006; Neufeld 2006, Cope 2010, 2011). Mean CPUE was calculated by taking the simple arithmetic mean of the number of burbot caught, expressed in values of fish per 48 hr trapset. Because few fish enter traps during daylight and traps stop fishing after 48 hours, catches were not adjusted for the few hours' deviation in soak time (Cope 2009).

Transmitters (Lotek CART11, 12 g in air, n = 14, Lotek CART16, 31 g in air, n = 34) were surgically implanted at the location of capture, according to the 2% tag-to-body weight ratio in water rule (Brown et al. 1999, Harrison et al. 2013). Transmitters had additional temperature and pressure sensors on them. Lotek CART11 tags were implanted in smaller fish and have an estimated battery life of 372 days; whereas CART16 tags can be implanted in larger fish and have an estimated life of 831 days. Transmitter data will be useful to determine whether burbot are using depths that are at risk for detwatering during the spawning period, to the time of minimum reservoir elevation in the spring. Depth sensors are attached to the acoustic end of the tag, and read by acoustic receivers.

Sufficiently sized fish in good condition were selected and anaesthetized in a 60L bath of lake water, with a 100mg/L concentration of clove oil. Clove oil was first dissolved in ethanol before being added to water to ensure proper mixture of anaesthetic. Fish were transferred to surgery once they reached level four anaesthesia; total loss of movement and weak opercular motion (Cope 2009). Times to anaesthesia, surgery and recovery of fish were recorded for quality assurance.

Fish were weighed and measured prior to surgery, and were transferred to a surgical table with a V-shaped cradle of soft netting (Figure 4). A nurse provided a continuous supply of oxygenated water to the fish by hydrating the gills throughout the procedure. A small incision was made 3 cm from the mid-ventral line and the anus, and a catheter was inserted through the incision to a point 3-4 cm posterior and dorsal to the incision. The antenna wire was fed through the catheter, which was pulled through the body wall, and the transmitter was simultaneously placed within the body cavity (Figure 5). The incision was then closed using independent and permanent monofilament sutures (4/0 Ethicon) and tissue adhesive applied. Fish were transferred to a 120 l live well supplied with medical grade oxygen (0.2 to 0.7 l/min.) and gentle flow delivered via a submersible pump (Figure 6). Burbot were typically allowed 60 minutes to fully recover (i.e., attainment of fear response) before being returned to depth in a decompression cage and released at the original point of capture.

Figure 4: Surgical setup for transmitter implantation.

Figure 5: Incision and antenna placement for burbot transmitter surgery.

Figure 6: Burbot in oxygenated recovery tank

Mobile and fixed receiver tracking

This study is designed to detect year-round habitat use of burbot and aspects of migratory life history (e.g., adfluvial movements; MQ1), as well as shallow habitat use during the spawning season (MQs 2 and 3). This will be assessed using a combined approach of data collection from mobile tracking radio frequencies of CART tags from a helicopter, and acoustic frequencies of the same CART tags from a series of fixed receivers placed throughout the study area. The study period for tagging and tracking will occur over two years. CART transmitters use a coded radio (Codes 1-26) frequency of 150.25 and 150.30 MHz for individual tag identification and an acoustic transmission of 76KHz. The radio burst rate is 5-6 seconds continuous; pressure and temperature sensors continuously transmit data on the acoustic transmission, which transmit every 60.5 s (CART16) or 100.5s (CART11) .

Multiple fixed acoustic receivers (*n* = 16) were deployed through 10 areas in the study area from June 2-5, 2014 (Figure 3). In order to increase coverage, some of these locations consisted of an array of multiple receivers. An advantage of the basin shape of a river valley reservoir is that constrictions in the valley may be "gated" with receiver arrays to track movement amongst areas (Gutowsky et al. 2013). Areas were gated at the study area limits at Surprise Rapids and the Canoe Reach. Additional receiver gates were placed within the study area at the Wood Arm outlet, Columbia Reach North outlet, Kinbasket Lake North Outlet, Sullivan Bay entrance and Kinbasket Lake South inlet. These gates will record valuable information on large scale movements within the reservoir to detect movement towards spawning locations during the spawning and pre-season period. Additional receivers were placed near the confluences with the Wood, Kinbasket and Sullivan Rivers, as these are known areas where burbot concentrate during the post-spawn period in the spring. These receivers may be used to detect movements of burbot and depths used during the spawning season.

Acoustic receivers used were Lotek WH3250E 76 KHz underwater hydrophone dataloggers (Figure 7), with an estimated receiving range of 750 m. Receivers were generally placed within 400 m from shore, or, where an array of receivers was deployed, within 400 m from each other. These receivers will continuously record data throughout the study, receiving acoustic transmissions from CART tags. Receivers were anchored with sandbags, which were dropped to the bottom of the water column. Receivers were suspended approx. 1/3 of the way up from the bottom in the water column, attached to polypropylene floating line, which was floated to the surface with 2 high density foam buoys (6”x12”). Receiver deployment date is important: if receivers are deployed at low pool, operations in subsequent years may not reach as low a reservoir elevation and thus receivers would not be able to be retrieved. If receivers are deployed at high pool, there will be too much slack line in the mooring system, potentially causing hazards for boat traffic and leading to troubles with tangling with ice and debris, particularly as water levels drop through the winter period. The early June deployment date corresponds to the time period when Kinbasket Reservoir elevations were~730 m in 2014. The reservoir elevation target of 730m was chosen, as operations have not resulted in a low pool elevation of greater than this in the last 10 years.

Acoustic receiver and transmitter range testing was conducted with the use of a digital rangefinder and a test transmitter. Range testing results will be reviewed when downloaded in 2015. Radio receiver and transmitter range testing was completed the Columbia Reach (clear water, cobble bottom) and the Wood River confluence (turbid water, silt bottom). Both tests revealed a vertical detection depth range of 12 m at breast height from the water surface.

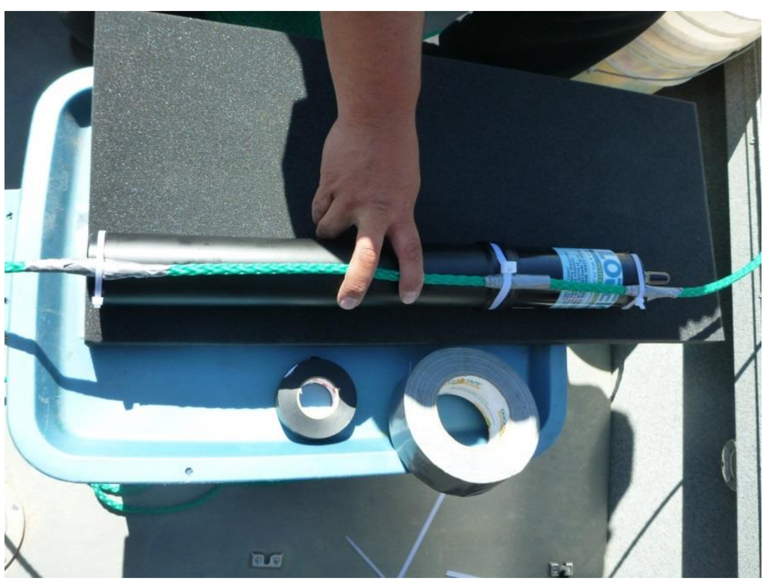

Figure 7: Receivers used in study, attached to floating line.

Mobile helicopter tracking will start in 2015. Opportunistic radio tracking of tagged fish was conducted during the receiver deployment in June 3 and 5, 2014.

Statistical analysis

Burbot distribution and biological attributes were assessed by statistically examining the association between burbot capture and several predictor variables. Statistics were run in the program JMP® 8.0.

Burbot CPUE was highly skewed (Figure 8), as a large amount of trapsets returned no fish and multiple captures in a single trap were relatively rare (Figure 9), therefore, CPUE was not treated as the primary response variable in parametric statistical tests due to strong violations of normality and behaviour of the variable as nominal rather than continuous (*sensu* Robichaud et al. 2011). Instead, a binary response variable of whether fish were successfully captured in a trap was used for analysis. A Pearson chi-square test was used to determine whether burbot capture success was different among the five major capture locations in the reservoir. Logistic regression was used to determine whether burbot capture success varied due to depth of trapset. Burbot trapset locations were spatially diffuse in the Wood Arm and Cummins River confluence locations; logistic regressions were run independently for each of these locations to determine whether successful capture was dependent on the linear distance to the confluence with the river. Linear distance was calculated by GIS analysis.

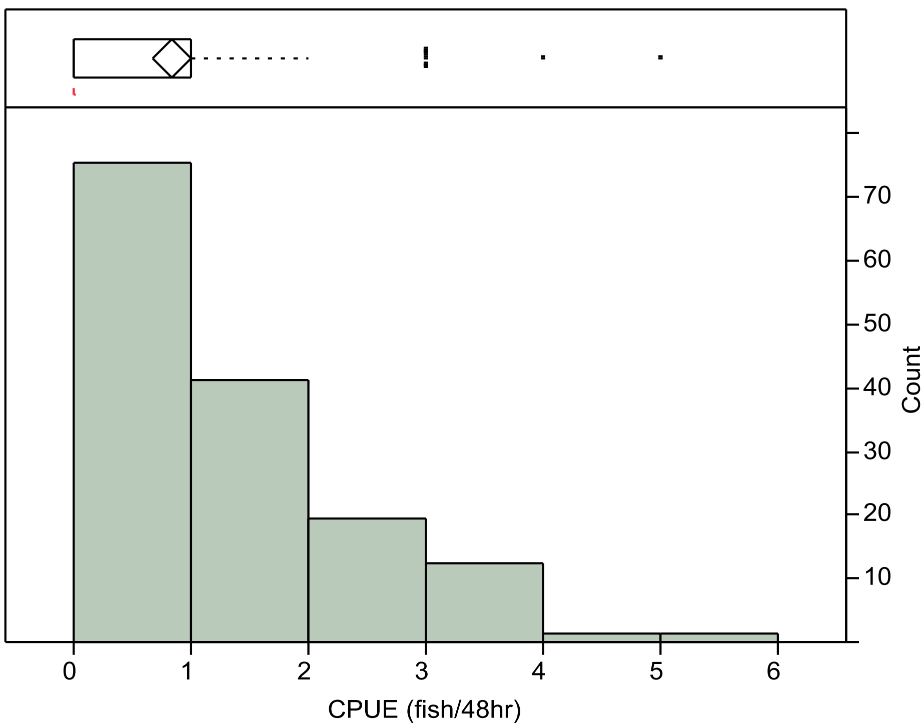

Figure 8: Distribution (histogram and box plot) of CPUE for 149, 48hr trapping events in Kinbasket Reservoir. Boxes represent interquartile range, diamonds represent the sample mean and 95% confidence interval, while the middle line in the box is the median sample value. Whiskers represent observations outside of the interquartile range, with outlier data points. The red line indicates the shortest half, which is the densest 50% of the observations.

Figure 9: Multiple fish capture events in a trapset such as above were relatively rare

To determine whether burbot size was dependent on capture location in the reservoir or by depth, a general linear model was constructed with size as the dependent variable and depth and capture location as continuous and categorical covariates, respectively.

RESULTS

Burbot capture and tagging

Burbot capture summary statistics by reservoir area are available in Table 1 and Table 2. Detailed capture data can be found in the Appendix. 149, 48 hr trapsets were expended across the five areas of the reservoir from April 30 to May 9, 2014. 124 burbot were caught, ranging from 465 to 950 mm (Figure 10). 48 of these burbot were surgically implanted with CART tags (see methods). Tagged fish size ranged from 0.9 kg (592 mm) to 4.6 kg (950 mm). No mortalities occurred during the sampling program, and fish surgery was minimally invasive, with quick surgery and recovery times (Appendix). Bycatch was minimal, consisting of 7 northern pikeminnow, 1 peamouth chub and several mottled and slimy sculpin.

Table 1: Summary statistics of burbot capture data across 5 sampling areas of Kinbasket Reservoir

Reservoir area	N trapsets	N trapsets with BB	N BB caught	N BB tagged	Mean CPUE (fish/48 hr)	S.D. CPUE (fish/48 hr)	95% CI CPUE (fish/48 hr)
Columbia Reach	29	13	19	8	0.66	0.86	0.33-0.98
Cummins River	20	6	11	5	0.55	0.94	0.11-0.99
Kinbasket River	30	7	11	8	0.37	0.76	0.08-0.65
Sullivan River	23	16	36	14	1.56	1.44	0.94-2.19
Wood Arm	47	32	47	13	0.93	0.93	0.14-0.93
All sites	149	74	124	48	0.83	1.05	0.66-1.00

Table 2: Summary statistics of burbot capture and individual fish data across 5 sampling areas of Kinbasket Reservoir

Reservoir area	Depth range (m)	Mean depth (m)	S.D. depth (m)	N BB caught	Mean length (mm)	S.D. length (mm)	Mean weight (kg)	S.D. weight (kg)
Columbia Reach	5.6-14.4	10	2.6	19	720	134	2	0.85
Cummins River	9.2-16.5	12.6	1.7	11	642	126	1.5	0.9
Kinbasket River	3.5-14.6	10.2	2.8	11	674	108	1.6	1
Sullivan River	2.2-14.1	7.6	3.6	36	675	72	1.7	0.44
Wood Arm	2.6-15.4	8	3.3	47	625	103	1.4	0.47
All sites	2.2-16.5	9.4	3.4	124	663	106	1.6	0.71

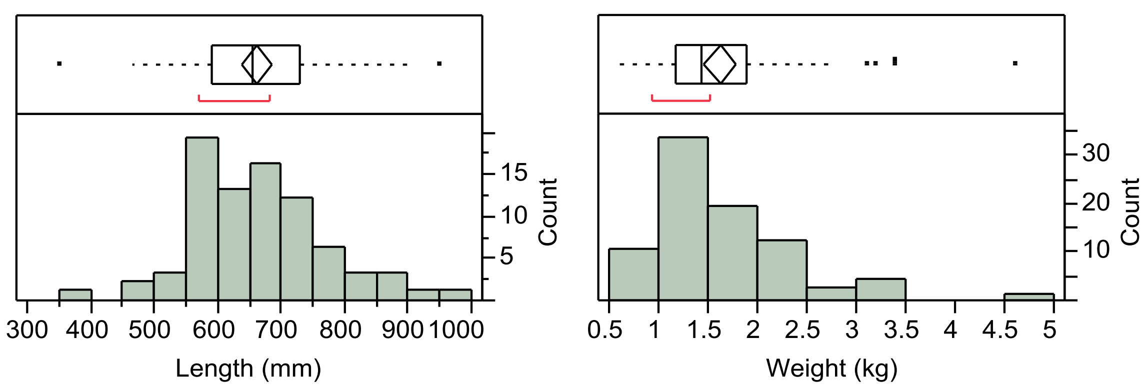

Figure 10: Size (length and weight) distributions and box plots of burbot (n=81) caught and measured in Kinbasket Reservoir. Boxes represent interquartile range, diamonds represent the sample mean and 95% confidence interval, while the middle line in the box is the median sample value. Whiskers represent observations outside of the interquartile range, with outlier data points. The red line indicates the shortest half, which is the densest 50% of the observations.

A single ripe (flowing) male was captured in the vicinity of the Cummins River and a ripe male and female were caught at the mouth of the Sullivan River. Many burbot had slack bodies, indicating post spawn period.

Burbot capture success varied between different areas of the reservoir (Figure 11), with the highest capture success in the Wood River and Sullivan River areas.

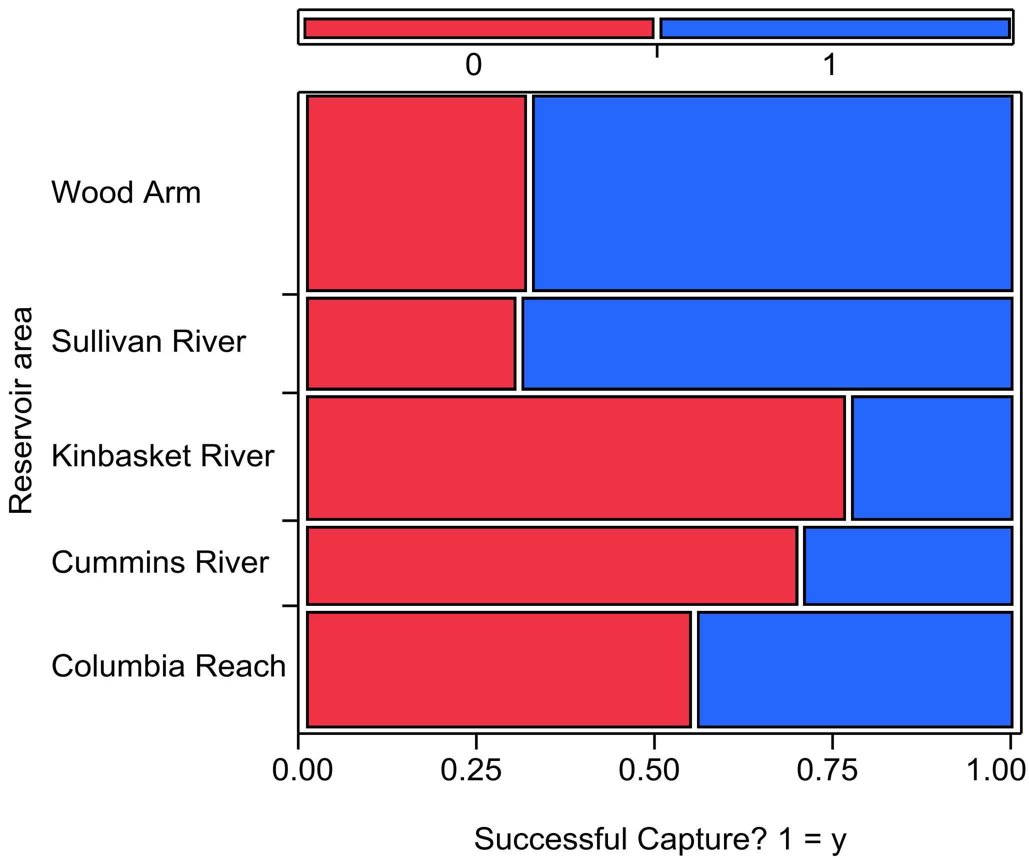

Figure 11: Mosaic plot of burbot capture success in different areas of the Reservoir. Burbot capture differed between areas of the reservoir χ^2 = 21.7 *P* = 0.0002, *n* = 149, *df* = 4

Logistic regression fit the data well (χ^2 = 1.69, *P* = 0.1939) for burbot capture success dependence on depth; depth was neither a strong correlate or significant, as indicated by a small (i.e., shallow slope) parameter estimate (0.064) and relatively large standard error (0.049), yielding an odds ratio of 1.07 with a 95% CI of 0.97-1.17. Odds ratios (OR) with values of 1 falling in between their 95% CIs are considered non-significant, as this indicates an interval that encompasses both a positive and negative relationship between the dependent and independent variable(s).

Logistic regression also fit the data well for burbot capture success dependence on distance to the confluence for both the Cummins River (χ^2 = 2.42, *P* = 0.1197) and Wood River (χ^2 = 1.59 *P* = 0.2073);

however, distance to confluence was not a significant factor in explaining capture success in either the Cummins River (OR = 2.0; 95% CI = 0.68-5.9) or Wood River (OR = 0.32; 95% CI = 0.05-2.0) areas.

Burbot size (weight) was weakly correlated with reservoir area and depth (R^2 = 0.21; F = 2.15; P = 0.036; df = 80). An interaction term between depth and reservoir area was not significant and removed from further analysis. Further effect tests revealed a positive relationship between depth and fish size (P = 0.024) but not between reservoir area and fish size (P = 0.079).

Mobile tracking

Two fish were recaptured by an individual angler in the Kinbasket River area in July, 2014. One fish was harvested and its tag returned, the other was recognized as tagged by the external antenna and released. The harvested fish (Acoustic tag number 30800) was initially caught in the Sullivan River area, indicating it had moved into the Kinbasket River area for the summer period. During receiver deployment (June 3-5), 9 fish were detected in the vicinity of where they were caught with radio tracking, including two smaller fish that were redetected up in the current in the Sullivan River at its confluence with Kinbasket Reservoir (Figure 12).

Figure 12: Using mobile radio receiver to track burbot up the flow of the Sullivan River at its confluence with Kinbasket Reservoir on June 3, 2014.

DISCUSSION and RECOMMENDATIONS

Burbot capture, biological characteristics and tagging

Burbot capture data for 2014 indicate that Kinbasket reservoir has moderate trap CPUEs. Cope (2009, 2010, 2011) and Neufeld (2006) found that burbot CPUEs in Duncan Reservoir generally fell between 0.14 and 0.41 fish/trapset for targeted sampling designs with cod traps. Arrow Lakes are the other well studied reservoir system in the Kootenay region and have generally found mean CPUEs ranging around 0.5-8.5 fish/trapset when using a targeted sampling design with cod traps (Arndt and Baxter 2006, Glova et al. 2009, 2010, Robichaud et al. 2011, 2012, 2013). Kinbasket Reservoir in the year of study thus is intermediate to Arrow and Duncan Reservoirs when comparing abundance by similar methodology; however, caution must be stressed in interpreting these results. Targeted sampling catchability will vary based on time of year, length of trapset, the familiarity of the field crew with the locations of burbot concentrations and efficiency of gear used. Randomized grid design, stratified by depth and area and standardized trapset length is the most preferable for evaluating catch per unit effort, as trapping effort is unbiased (Cope 2009); however, this sampling design is subject to high error and low capture rates since burbot are generally of low abundance and unevenly distributed within lakes, thus a large amount of effort must be expended to return a reliable CPUE estimate (Cope et al. 2009). Effort should also scale to the size of the system, thus large lakes will be subject to a higher degree of error with limited sampling effort. Since the primary goal of this program is telemetric tracking of fish, capture rates must remain high in order to capture a sufficient sample size of fish to tag; therefore, a targeted sampling program should continue in Year 2 (*sensu* Cope 2010).

Burbot CPUE varied between areas within the reservoir. This resulted in a higher amount of fish tagged in the Wood Arm and Sullivan River areas. These two locations, particularly, the Sullivan River confluence, had high trapping returns, of similar levels to some of the higher CPUEs observed in the Kootenay Region (Arndt and Baxter 2006). High spatial variability of catch within lakes and reservoirs for burbot is normal, and possibly driven by food availability, bioenergetics, temperature preference or proximity to habitat features preferable for completion of some life history requirement (e.g., spawning). It may be reasonable to speculate that some areas targeted with high CPUE may be in the vicinity of spawning aggregations. It is also possible that legacy effects of conserved habitat preference for the lacustrine population of burbot that existed, and supported a fishery in Kinbasket Lake (Prince 2001) explain the high abundance of fish in the Sullivan River confluence area, which may act as a similar habitat to the historic Kinbasket Lake Flats. These flats were an extensive shallow area where the Sullivan and Columbia Rivers entered the historic lake. Year 2 sampling effort should target some new areas of the reservoir in order to more evenly distribute tag coverage of the reservoir, particularly with more coverage of historic Kinbasket Lake.

Burbot captured in this study were relatively large, and size distribution of adult fish was broad. This is similar to the capture results of burbot caught in Harrison et al. (2013) and Prince (2007) in Kinbasket Reservoir, and similar to the size distributions of burbot captured in Arrow Lakes Reservoir (Arndt and Baxter 2006). Burbot size-at-age has been examined in a previous study by Cope (2011), and has generally found that burbot in Kinbasket Reservoir are slow growing, averaging 13.6 years of age at 673.9 mm. This size is similar to the mean size of fish captured in this study (663 mm). Cope (2011) found that Kinbasket Reservoir populations have smaller size-at-age than Moyie and Arrow Lakes, two other well studied systems in the Kootenay region. Thus burbot populations in Kinbasket Reservoir are likely less resilient to population effects of recruitment failure and harvest than other lakes if their slower growth trajectory results in greater age at maturity, even if the standing size structure of the adult population is similar. Differences in growth trajectory between Kinbasket and other systems may be related to growing season, temperature regime differences, food abundance and total productivity of the reservoir food web. Given that Kinbasket Reservoir is an ultraoligotrophic, cold water body slow growth of a top piscivore such as burbot is not surprising. While growth may be loosely predicted based on a curve of size-at-age, the variability is extremely high, based on previous studies on within-population relationships for burbot (Ahrens and Korman 2002, Cope 2011). It is therefore unrealistic to predictively model the age structure of the population in Kinbasket Reservoir based on the size structure from our capture data and existing size-at-age relationships developed for the reservoir (Cope 2011).

Burbot catch success relationship to increasing depth is generally found to be strong during the summer and fall (Glova et al. 2009); we found that burbot size but not capture success increased with increasing depth, and the relationship we found was relatively weak. This is likely due to the time of year sampled. Burbot may be largely absent from shallow water during the summer and fall during daylight hours, but more omnipresent in shallow areas during the ice off time (Bernard et al 1993, Giroux 2005, Prince 2007, Cope 2009, Harrison et al. 2013). Burbot depth preference size dependency has been shown in burbot in Kinbasket Reservoir, with smaller individuals occupying significantly deeper water than larger individuals at night but not during the day in prespawning, spawning and summer periods (Harrison et al. 2013). Our data indicated a relationship in the opposite direction during the day, as large individuals over 2.5 kg were never caught in depths of less than 10 m; however, it should be noted that the slope of the relationship was shallow and the correlation was weak. Significance was only detected because many fish were captured, allowing many degrees of freedom (i.e., high power) for the test to resolve significance.

Qualitative observations of habitat at capture locations indicate that burbot were generally captured in areas of silt, gravel or cobble, and in the latter two cases, generally with silt deposition over larger substrate. This supports the observation that burbot are benthic, but specific habitat preferences for substrate are not necessarily specialized at the adult life stage (McPhail 2007).

Arrow Reservoir spawning occurs over a protracted period, beginning in late February or early March and continuing to end March or early April (Robichaud et al. 2013). Qualitative observations thus far (3/124 fish ripe; many spawned out fish; concentrations of fish) suggest that sampling was conducted at the tail end of spawning or post spawn period in Kinbasket Reservoir. The presence of these observations in early May indicates that peak spawning may have taken place in late winter in Kinbasket

Reservoir, at similar or later periods to Arrow Reservoir. Thus, our assumption of spawning period from February to April is likely valid, with peak spawning probably occurring in late March to mid-April in 2014. It should be noted that 2014 winter temperatures in the Kootenay region were ~1.2˚C lower than average (1981-2010 period) from January to end April and ice coverage on Kinbasket Reservoir was more extensive than in average years. Burbot peak spawning times can vary between years (Robichaud et al. 2013), but the effect of climate variables and ice cover in determining inter-annual variation in spawn timing are largely unknown.

Mobile tracking

The first tracking period will occur in Year 2 of the study, in the late winter of 2015 (February - early April), to coincide with the suspected spawning period. Mobile radio tracking will be exclusively conducted by helicopter, and thus be limited to detecting fish that are using shallow depths and/or tributary streams during the day. Acoustic mobile tracking is not feasible due to aforementioned reasons of boat access during the winter. This is a major methodological constraint, relative to other studies conducted on lake systems with winter boat access (Robichaud et al. 2013). The inability to detect fish at greater depths (threshold of ~10m for detecting 95% of fish with radio-telemetry) limits detection and tracking of deeper spawning aggregations. In addition, burbot have been observed to make diel vertical migrations to shallow spawning areas at night (McPhail 2007), which would be undetected by mobile radio tracking during the daytime period. Indeed, shallow habitat use during the night has been observed in the spawning season for Kinbasket burbot (Harrison et al. 2013). By depending solely on radio tracking, this limits our ability to answer management questions 2 and 3, to only apply to the proportion of the population that are shoal spawners at shallow depths (<10 m) and spawn during the daytime period, or population components that are adfluvial. To overcome this sole dependency on radio tracking, a complementary program of fixed receiver tracking with acoustic receivers has been developed, and may be strengthened by engaging an alternate study design (see subsequent sections).

Helicopter tracking is advantageous because of the large spatial coverage and ability to track fish into tributaries, as well as relatively strong detection efficiency when fish are present in shallow water. In order to further maximize probability of detection, flights will be concentrated in areas where fish are suspected to be spawning, based on an initial reconnaissance of areas at risk of dewatering during the drafting period that may be suitable spawning habitat, as well as a literature survey of areas that appear to have had high burbot use during the past (Prince 2001, Martins et al. 2013). Tributaries will also be flown to assess whether burbot are making adfluvial movements to spawn, enriching the dataset for MQ1 and affording useful information for MQs 2 and 3. Flights will occur bi-weekly within the spawning period in 2015.

Fixed receiver tracking

Fixed receivers will be downloaded during the spring 2015 trapping session. In subsequent years, receivers will be moved and deployed into areas where burbot have been found to be congregating towards from the previous years' mobile and fixed receiver data.

Fixed receiver tracking will enrich the dataset for MQ1, and can be used to detect movement towards and within spawning areas for informing MQs 2 and 3. Depth sensor data will also augment a robust dataset collected on year-round habitat use from fixed receiver tracking (Harrison et al. 2013). If fixed receivers can gather a sufficient amount of depth data during the suspected spawning period, this may be used to calculate the minimum depths burbot use during the study years, and inform whether those depths are at risk for dewatering from the drawdown period to the time of low pool. Since this data is collected throughout the day, it is possible to detect shallow habitat use at night if burbot are making significant diel vertical migrations to shallow habitat during the spawning season (Harrison et al. 2013).

Alternate design, years 2 and 3

Mobile tracking with a helicopter is a relatively sensitive method to detecting shallow and adfluvial habitat use; however, since burbot may make diel vertical migrations at night (Harrison et al. 2013) when helicopter flight is impractical, the use of this method may not detect this critical behaviour. If a significant number of burbot are tracked by mobile tracking with a helicopter in the first year (15 of 48 tagged fish), there is clear evidence that burbot are using shallow habitat. This is due to the detection efficiency of radio tags dropping precipitously past 10m depth in water. If fewer than 15 burbot are tracked in the first year, an alternate design concentrating more effort on fixed acoustic receiver tracking will be engaged in years 2 and 3. The budget that would be allocated to helicopter tracking in 2016 will be redistributed to the purchase of additional acoustic receivers and deployment, and they will be deployed after reviewing the first year of fixed receiver tracking data. This data will be used to determine whether there are areas burbot are concentrating towards in the pre-spawn and spawning seasons. Additional receivers will be placed in these suspected spawning areas in 2015 for the final year of fixed receiver tracking. These additional receivers will increase the sensitivity of the study to detecting shallow habitat use during the spawning season, and will return actual depth data from fish from pressure sensors in the transmitter.

REFERENCES

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

Andrusak, H., 1998. Investigation of burbot in Kootenay Lake. prepared for B. C. M. o. Environment. Victoria, B.C., pp. 22

Arndt, S., and J. Baxter, 2006. Status of burbot (Lota lota) in Arrow Lakes Reservoir. prepared for Columbia Basin Fish & Wildlife Compensation Program. Nelson, B.C.

Arndt, S., and J. Hutchinson. 2000. Characteristics of burbot spawning in a tributary of Columbia Lake, British Columbia, over a four-year period. Pages 48-59 in V. L. Paragamian and D. W. Willis, editors. Burbot: biology, ecology, and management. American Fisheries Society.

Baxter, J., C. Spence, and M. D. Neufeld, 2002. Kootenay Lake burbot studies – Progress 2001 - 2002. prepared for L. a. P. Ministry of Environment. Nelson, B.C., pp. 32

Bernard, D. R., J. F. Parker, and R. Lafferty. 1993. Stock assessment of burbot populations in small and moderate-size lakes. North American Journal of Fisheries Management 13:657-675.

Bisset, J. E., and R. S. Cope, 2002. Goat River burbot spawner enumeration program, Creston, B.C. prepared for Columbia-Kootenay Fisheries Renewal Partnership. Westslope Fisheries Ltd. Cranbrook, B.C., pp. 23

Brown, R. S., S. J. Cooke, W. G. Anderson, and R. S. McKinley. 1999. Evidence to challenge to "2% rule" for biotelemetry. North American Journal of Fisheries Management 19:867-871.

Cope, R. S., 2008. Footprint impacts of BC Hydro dams on burbot populations in the Columbia River Basin, British Columbia. prepared for Fish and Wildlife Compensation Program. W. F. Ltd. Nelson, B.C., pp. 75

Cope, R. S., 2009. Duncan Reservoir burbot monitoring annual report: 2008-2009. prepared for BC Hydro. Westslope Fisheries Ltd. Cranbrook, B.C., pp. 35

Cope, R. S., 2010. Duncan Reservoir burbot monitoring annual report: 2009-2010. prepared for BC Hydro. Westslope Fisheries Ltd. Cranbrook, B.C., pp. 56

Cope, R. S., 2011. Duncan Reservoir burbot monitoring annual report: 2010-2011. prepared for BC Hydro. Westslope Fisheries Ltd. Cranbrook, B.C., pp. 57

Cott, P. A., A. D. Hawkins, D. Zeddies, B. Martin, T. A. Johnston, J. D. Reist, J. M. Gunn, and D. M. Higgs. 2014. Song of the burbot: Under-ice acoustic signaling by a freshwater gadoid fish. Journal of Great Lakes Research 40:435-440.

Dunnigan, J. L., and C. L. Sinclair. 2008. Home range and movement patterns of burbot in Koocanusa Reservoir, Montana, USA. Pages 43-54 in V. L. Paragamian and D. H. Bennett, editors. Burbot: ecology, management, and culture. American Fisheries Society, Bethesda, M.D.

Ford, B. S., P. S. Higgins, A. F. Lewis, K. L. Cooper, T. A. Watson, C. M. Gee, G. L. Ennis, and R. L. Sweeting, 1995. Literature reviews of the life history, habitat requirements and mitigation/compensation strategies for selected fish species in the Peace, Liard and Columbia River drainages of British Columbia. prepared for F. a. O. Canada. Vancouver, BV

Glova, G., D. Robichaud, and R. Bussanich, 2009. Arrow Lakes Reservoir burbot life history and habitat use (Year 1). prepared for BC Hydro. LGL Limited. Sidney, B.C., pp. 35

Glova, G., D. Robichaud, E. Plate, and M. Matthew, 2010. Arrow Lakes Reservoir burbot life history and habitat use (Year 2). prepared for BC Hydro. LGL Limited. Sidney, B.C., pp. 37

Gutowsky, L., P. Harrison, E. Martins, A. Leake, D. Patterson, M. Power, and S. Cooke. 2013. Diel vertical migration hypotheses explain size-dependent behaviour in a freshwater piscivore. Animal Behaviour 86:365-373.

Harrison, P. M., L. F. Gutowsky, E. G. Martins, D. A. Patterson, A. Leake, S. J. Cooke, and M. Power. 2013. Diel vertical migration of adult burbot: A dynamic trade-off between feeding opportunity, predation avoidance, and bioenergetic gain. Canadian Journal of Fisheries and Aquatic Sciences 70: 1765-1774.

Martins, E. G., L. F. Gutowsky, P. M. Harrison, D. A. Patterson, M. Power, D. Z. Zhu, A. Leake, and S. J. Cooke. 2013. Forebay use and entrainment rates of resident adult fish in a large hydropower reservoir. Aquatic Biology 19:253-263.

McPhail, J. D. 2007. The freshwater fishes of British Columbia. The University of Alberta Press, Edmonton, AB.

Neufeld, M. D., 2006. Kootenay burbot recovery projects in British Columbia, 2005-2006. prepared for BC Ministry of Environment. Nelson, B.C., pp. 24

Neufeld, M. D., 2008. Moyie Lake burbot: population assessment 2007. prepared for BC Ministry of Environment. Nelson, B.C., pp. 24

Neufeld, M. D., and C. Spence, 2009. Moyie Lake burbot program 2008-2009: Sport Fishery, Juvenile Sampling and Conservation Aquaculture/Spawning Surveys. prepared for BC Ministry of Environment. Nelson, B.C., pp. 48

Paragamian, V. L. 2000. The effects of variable flows on burbot spawning migrations in the Kootenai River, Idaho, USA, and Kootenay Lake, British Columbia, Canada, after construction of the Libby Dam. Pages 30-37 in V. L. Paragamian and D. W. Willis, editors. Burbot: biology, ecology, and management. American Fisheries Society, Bethesda, M.D.

Paragamian, V. L., and V. D. Wakkinen. 2008. Seasonal movement of burbot in relation to temperature and discharge in the Kootenai River, Idaho, USA and British Columbia, Canada. Pages 55-77 in V. L. Paragamian and D. H. Bennett, editors. Burbot: ecology, management, and culture. American Fisheries Society, Bethesda, M.D.

Prince, A., 2001. Local knowledge of Columbia River fisheries in British Columbia, Canada. prepared for Columbia-Kootenay Fisheries Renewal Partnership. Westslope Fisheries Ltd. Cranbrook, B.C., pp. 50

Prince, A., 2007. East Kootenay burbot population assessment. prepared for BC Ministry of Environment. Westslope Fisheries Ltd. Cranbrook, B.C., pp. 25

Prince, A., 2011. Kinbasket Reservoir white sturgeon inventory and habitat use assessment (final report). prepared for BC Hydro. Canadian Columbia River Inter-tribal Fisheries Commission. Cranbrook, B.C., pp. 20

Robichaud, D., G. Glova, and S. Kingshott, 2013. Arrow Lakes Reservoir burbot life history and habitat use (Year 5). prepared for BC Hydro. LGL Limited. Sidney, B.C., pp. 23

Robichaud, D., G. Glova, M. Matthews, and S. Kingshott, 2012. Arrow Lakes Reservoir burbot life history and habitat use (Year 4). prepared for BC Hydro. LGL Limited. Sidney, B.C., pp. 40

Robichaud, D., G. Glova, E. Plate, and M. Matthew, 2011. Arrow Lakes Reservoir burbot life history and habitat use (Year 3). prepared for BC Hydro. LGL Limited. Sidney, B.C., pp. 41

Schwarz, C. J., 2011. Review of mark-recapture sampling program to estimate abundance of burbot in Moyie Lake, British Columbia. prepared for, pp. 14

Spence, C., 1999. Kootenay Lake burbot studies progress 1998-99. prepared for M. o. Environment. Nelson, B.C., pp. 42

Spence, C., and M. D. Neufeld, 2002. Radio telemetry studies of Duncan Reservoir burbot. prepared for BC Ministry of Environment. Nelson, B.C., pp. 21

Taylor, J. L., and J. D. McPhail. 2000. Temperature, development and behaviour in the early life history of burbot from Columbia Lake, British Columbia. Pages 30-37 in V. L. Paragamian and D. W. Willis, editors. Burbot: biology, ecology, and management. American Fisheries Society, Bethesda, M.D.

APPENDIX

Individual fish and trapping data

	Trap Set			Trap Set Location			Trap Pull			Species	RECAP	Acoustic	Radio	Radio	Length	Weight	MORT	Sex
ID #	Date	Time	Depth (m)	Easting	Northing	General Description	Date	Time	Catch	Code	(Y/N)	Code	Code	Freq	(mm)	(kg)	(Y/N)	(M/F)
1	29-Apr-14	9:20	3.3	420073	5781240	Wood Arm	30-Apr-14	9:25	3	BB	N	29600	2	150.25	715	2.000	N	M
1	29-Apr-14	9:20	3.3	420073	5781240	Wood Arm	30-Apr-14	9:25		BB	N	34200	22	150.3	683	1.420	N	U
1	29-Apr-14	9:20	3.3	420073	5781240	Wood Arm	30-Apr-14	9:25		BB	N	34300	23	150.3	642	1.360	N	U
2	29-Apr-14	9:30	4.8	420014	5781130	Wood Arm	30-Apr-14	12:43	0									
3	29-Apr-14	9:35	5.1	419935	5781024	Wood Arm	30-Apr-14	12:47	0									
4	29-Apr-14	9:40	6.0	419864	5780908	Wood Arm	30-Apr-14	12:51	1	BB	N	33500	15	150.3	656	1.210	N	U
5	29-Apr-14	9:45	8.0	419781	5780801	Wood Arm	02-May-14	15:12	1	BB	N							
6	29-Apr-14	9:50	11.7	419739	5780712	Wood Arm	02-May-14	15:15	2	BB	N							
7	29-Apr-14	9:55	14.0	419643	5780563	Wood Arm	30-Apr-14	16:40	4	BB	N	29500	1	150.25	742	1.600	N	U
7	29-Apr-14	9:55	14.0	419643	5780563	Wood Arm	30-Apr-14	16:40		BB	N				618	1.500	N	U
7	29-Apr-14	9:55	14.0	419643	5780563	Wood Arm	30-Apr-14	16:40		BB	N				626	1.340	N	U
7	29-Apr-14	9:55	14.0	419643	5780563	Wood Arm	30-Apr-14	16:40		BB	N				581	1.360	N	U
8	29-Apr-14	10:00	14.7	419295	5780646	Wood Arm	02-May-14	14:31	1	BB	N							
9	29-Apr-14	10:05	12.0	419356	5780852	Wood Arm	02-May-14	14:37	1	BB	N							
10	29-Apr-14	10:10	10.0	419503	5780956	Wood Arm	02-May-14	14:41	1	BB	N							
11	29-Apr-14	10:25	7.2	419650	5781000	Wood Arm	02-May-14	14:46	1	BB	N							
12	29-Apr-14	10:30	5.2	419781	5781137	Wood Arm	02-May-14	14:48	1	BB	N							
13	29-Apr-14	10:35	6.8	420089	5781095	Wood Arm	30-Apr-14	13:38	1	BB	N	29700	3	150.25	705	1.680	N	F
14	29-Apr-14	10:40	3.8	420159	5781206	Wood Arm	30-Apr-14	13:15	1	BB	N				562	1.000	N	U
15	29-Apr-14	10:45	8.0	420140	5780968	Wood Arm	30-Apr-14	14:15	2	BB	N	33400	14	150.3	570	1.000	N	U

	Trap Set			Trap Set Location			Trap Pull			Species	RECAP	Acoustic	Radio	Radio	Length	Weight	MORT	Sex
ID #	Date	Time	Depth (m)	Easting	Northing	General Description	Date	Time	Catch	Code	(Y/N)	Code	Code	Freq	(mm)	(kg)	(Y/N)	(M/F)
15	29-Apr-14	10:45	8.0	420140	5780968	Wood Arm	30-Apr-14	14:15		BB	N				510	0.580	N	U
16	29-Apr-14	10:50	8.8	420037	5780779	Wood Arm	30-Apr-14	14:45	0									
17	29-Apr-14	10:55	9.9	420007	5780553	Wood Arm	30-Apr-14	15:00	1	BB	N	30100	7	150.25	795	2.450	N	U
18	29-Apr-14	11:00	12.0	419934	5780370	Wood Arm	30-Apr-14	15:40	1	BB	N				665	1.360	N	U
19	29-Apr-14	11:05	15.4	419956	5780194	Wood Arm	30-Apr-14	15:50	0									
20	29-Apr-14	11:15	10.8	419654	5779852	Wood Arm	30-Apr-14	16:00	1	BB	N	29800	4	150.25	770	2.400	N	U
21	29-Apr-14	14:00	10.8	417156	5764989	Cummins River	01-May-14	13:25	0									
22	29-Apr-14	14:05	13.9	416859	5765191	Cummins River	01-May-14	13:30	0									
23	29-Apr-14	14:15	11.0	415487	5765196	Cummins River	01-May-14	13:20	1	BB	N				600		N	U
24	29-Apr-14	14:20	12.5	415249	5765292	Cummins River	01-May-14	12:15	1	BB	N	29900	5	150.25	904	3.400	N	U
25	29-Apr-14	14:25	12.8	414762	5765263	Cummins River	01-May-14	13:00	2	BB	N				703	1.950	N	U
25	29-Apr-14	14:25	12.8	414762	5765263	Cummins River	01-May-14	13:00		BB	N				535	0.895	N	U
26	29-Apr-14	14:30	11.8	414171	5765101	Cummins River	01-May-14	12:00	0									
27	29-Apr-14	14:40	13.0	414428	5765557	Cummins River	01-May-14	11:20	2	BB	N	33000	10	150.3	810	2.700	N	U
27	29-Apr-14	14:40	13.0	414428	5765557	Cummins River	01-May-14	11:20		BB	N				480	0.700	N	U
28	29-Apr-14	14:45	13.2	414475	5765660	Cummins River	01-May-14	10:30	2	BB	N	30200	8	150.25	642	1.500	N	U
28	29-Apr-14	14:45	13.2	414475	5765660	Cummins River	01-May-14	10:30		BB	N				530	0.880	N	U
29	29-Apr-14	14:50	14.7	415063	5766335	Cummins River	01-May-14	10:20	0									
30	29-Apr-14	14:55	9.2	415028	5766441	Cummins River	01-May-14	10:20	0									
31	29-Apr-14	15:00	10.3	415630	5766981	Cummins River	01-May-14	8:55	3	BB	N	34100	21	150.3	685	1.3	N	U
31	29-Apr-14	15:00	10.3	415630	5766981	Cummins River	01-May-14	8:55		BB	N	34500	25	150.3	592	0.9	N	U
31	29-Apr-14	15:00	10.3	415630	5766981	Cummins River	01-May-14	8:55		BB	N				590	0.96	N	U
32	29-Apr-14	15:05	11.6	414834	5766522	Cummins River	01-May-14	8:52	0									

	Trap Set			Trap Set Location			Trap Pull			Species	RECAP	Acoustic	Radio	Radio	Length	Weight	MORT	Sex
ID #	Date	Time	Depth (m)	Easting	Northing	General Description	Date	Time	Catch	Code	(Y/N)	Code	Code	Freq	(mm)	(kg)	(Y/N)	(M/F)
33	29-Apr-14	15:10	14.0	414499	5766615	Cummins River	01-May-14	8:50	0									
34	29-Apr-14	15:15	14.1	414048	5766747	Cummins River	01-May-14	8:47	0									
35	29-Apr-14	15:20	12.4	413741	5767101	Cummins River	01-May-14	8:45	0									
36	29-Apr-14	15:25	16.5	413392	5767405	Cummins River	01-May-14	8:42	0									
37	29-Apr-14	15:30	12.9	412591	5768070	Cummins River	01-May-14	8:40	0									
38	29-Apr-14	15:35	12.0	412306	5768152	Cummins River	01-May-14	8:35	0									
39	29-Apr-14	15:40	13.5	412156	5768599	Cummins River	01-May-14	8:30	0									
40	29-Apr-14	15:55	11.8	408654	5768708	Cummins River	01-May-14	8:20	0									
41	30-Apr-14	17:46	14.3	419657	5780555	Wood Arm	02-May-14	15:19	2	BB	N						N	U
42	30-Apr-14	17:50	11.6	419876	5780559	Wood Arm	02-May-14	15:23	2	BB	N						N	U
43	30-Apr-14	17:53	9.4	419961	5780640	Wood Arm	02-May-14	15:32	1	BB	N						N	U
44	30-Apr-14	17:56	8.4	420007	5780797	Wood Arm	02-May-14	15:36	1	BB	N						N	U
45	30-Apr-14	18:00	6.4	419944	5780935	Wood Arm	02-May-14	15:10	1	BB	N						N	U
46	30-Apr-14	18:02	6.6	420080	5781097	Wood Arm	02-May-14	15:04	1	BB	N						N	U
47	30-Apr-14	18:05	4.0	419992	5781199	Wood Arm	02-May-14	15:50	0									
48	30-Apr-14	18:10	2.6	420033	5781329	Wood Arm	02-May-14	15:53	2	BB	N						N	U
49	30-Apr-14	18:13	3.7	420182	5781171	Wood Arm	02-May-14	15:00	2	BB	N						N	U
50	30-Apr-14	18:16	6.2	420161	5781056	Wood Arm	02-May-14	15:03	1	BB	N						N	U
51	30-Apr-14	18:20	8.2	420099	5780931	Wood Arm	02-May-14	15:08	1	BB	N						N	U
52	30-Apr-14	18:25	10.0	420009	5780528	Wood Arm	02-May-14	15:26	0									
53	30-Apr-14	18:30	11.8	419665	5779895	Wood Arm	02-May-14	15:33	3	BB	N						N	U
54	01-May-14	14:20	11.4	430344	5757725	Kinbasket River	03-May-14	12:20	0									
55	01-May-14	14:25	11.5	430450	5757605	Kinbasket River	03-May-14	12:15	1	BB	N	30300	9	150.25	720	1.800	N	U
56	01-May-14	14:30	12.3	430584	5757542	Kinbasket River	03-May-14	12:10	0									

	Trap Set			Trap Set Location			Trap Pull			Species	RECAP	Acoustic	Radio	Radio	Length	Weight	MORT	Sex
ID #	Date	Time	Depth (m)	Easting	Northing	General Description	Date	Time	Catch	Code	(Y/N)	Code	Code	Freq	(mm)	(kg)	(Y/N)	(M/F)
57	01-May-14	14:35	4	430748	5757522	Kinbasket River	03-May-14	10:30	3	BB	N	30400	10	150.25	668	1.600	N	U
57	01-May-14	14:35	4	430748	5757522	Kinbasket River	03-May-14	10:30		BB	N				580	0.800	N	U
57	01-May-14	14:35	4	430748	5757522	Kinbasket River	03-May-14	10:30		BB	N	34400	24	150.3	592	1.020	N	U
58	01-May-14	14:40	3.5	430853	5757610	Kinbasket River	03-May-14	10:29	0									
59	01-May-14	14:45	8.7	430659	430659	Kinbasket River	03-May-14	12:03	1	BB	N				597	1.060	N	U
60	01-May-14	14:50	12.8	430707	5757429	Kinbasket River	03-May-14	13:05	1	BB	N	30600	12	150.25	655	1.500	N	U
61	01-May-14	14:55	13.2	430796	5757360	Kinbasket River	03-May-14	13:36	0									
62	01-May-14	15:00	11	430841	5757287	Kinbasket River	03-May-14	13:40	0									
63	01-May-14	15:05	10.7	430855	5757179	Kinbasket River	03-May-14	13:42	0									
64	01-May-14	15:10	14.6	430692	5757138	Kinbasket River	03-May-14	13:45	0									
65	01-May-14	15:15	12.3	430399	5757131	Kinbasket River	03-May-14	13:48	0									
66	01-May-14	15:20	10.5	430179	5756998	Kinbasket River	03-May-14	13:52	0									
67	01-May-14	15:25	12.8	429901	5756856	Kinbasket River	03-May-14	13:55	0									
68	01-May-14	15:30	9.1	429807	5756695	Kinbasket River	03-May-14	14:00	0									
69	03-May-14	9:27	2.2	436850	5756860	Sullivan River	04-May-14	9:40	1	BB	N	30500	11	150.25	735	2.000	N	M
70	03-May-14	9:30	4.9	436809	5756813	Sullivan River	04-May-14	9:16	1	BB	N	33300	13	150.3	653	1.300	N	U
71	03-May-14	9:32	6.7	436738	5756759	Sullivan River	04-May-14	9:14	0									
72	03-May-14	9:34	8.2	436660	5756734	Sullivan River	04-May-14	9:12	0									
73	03-May-14	9:37	14.1	436588	5756688	Sullivan River	06-May-14	12:35	3	BB								
74	03-May-14	9:40	13.5	436704	5756539	Sullivan River	06-May-14	12:20	3	BB								
75	03-May-14	9:42	4.8	436811	5756614	Sullivan River	04-May-14	11:40	1	BB	N	30900	15	150.25	768	2.400	N	U
76	03-May-14	9:45	3	436934	5756668	Sullivan River	04-May-14	10:20	3	BB	N	30700	13	150.25	742	1.820	N	U
76	03-May-14	9:45	3	436934	5756668	Sullivan River	04-May-14	10:20		BB	N	30800	14	150.25	695	1.810	N	U
76	03-May-14	9:45	3	436934	5756668	Sullivan River	04-May-14	10:20		BB	N	34000	20	150.3	665	1.400	N	U

	Trap Set			Trap Set Location			Trap Pull			Species	RECAP	Acoustic	Radio	Radio	Length	Weight	MORT	Sex
ID #	Date	Time	Depth (m)	Easting	Northing	General Description	Date	Time	Catch	Code	(Y/N)	Code	Code	Freq	(mm)	(kg)	(Y/N)	(M/F)
77	03-May-14	9:50	4.8	436815	5756976	Sullivan River	04-May-14	12:05	0									
78	03-May-14	9:52	8	436731	5757027	Sullivan River	04-May-14	12:20	3	BB	N	31000	16	150.25	794	2.250	N	U
78	03-May-14	9:52	8	436731	5757027	Sullivan River	04-May-14	12:20		BB	N	33200	12	150.3	647	1.400	N	U
78	03-May-14	9:52	8	436731	5757027	Sullivan River	04-May-14	12:20		BB	N				577	0.940	N	U
79	03-May-14	9:54	11.9	436577	5757068	Sullivan River	06-May-14	12:40	1	BB								
80	03-May-14	10:00	12.4	436276	5757145	Sullivan River	06-May-14	12:45	1	BB								
81	03-May-14	10:03	12	436083	5757042	Sullivan River	06-May-14	12:50	3	BB								
82	03-May-14	10:03	9.3	436000	5756819	Sullivan River	06-May-14	12:55	0									
83	03-May-14	10:06	13.1	435858	5756723	Sullivan River	06-May-14	13:00	0									
84	03-May-14	14:25	9.4	430678	5757450	Kinbasket River	05-May-14	9:55	1	BB	N				632	1.140	N	U
85	03-May-14	14:27	8.5	430732	5757452	Kinbasket River	05-May-14	10:05	0									
86	03-May-14	14:29	9	430691	5757499	Kinbasket River	05-May-14	10:15	0									
87	03-May-14	14:31	13	430612	5757464	Kinbasket River	05-May-14	9:30	2	BB	N	31100	17	150.25	950	4.600	N	U
87	03-May-14	14:31	13	430612	5757464	Kinbasket River	05-May-14	9:30		BB	N	31200	18	150.25	710	1.850	N	U
88	03-May-14	14:33	12.1	430612	5757507	Kinbasket River	05-May-14	9:15	2	BB	N	33700	7	150.3	645	1.240	N	U
88	03-May-14	14:33	12.1	430612	5757507	Kinbasket River	05-May-14	9:15		BB	N	33100	11	150.3		1.050	N	U
89	03-May-14	14:35	10.6	430611	5757556	Kinbasket River	05-May-14	10:20	0									
90	03-May-14	14:40	4.8	430731	5757520	Kinbasket River	05-May-14	10:10	0									
91	03-May-14	14:45	5.3	430729	5757468	Kinbasket River	05-May-14	10:02	0									
92	03-May-14	14:50	10	430588	5757552	Kinbasket River	05-May-14	9:12	0									
93	03-May-14	14:55	8.8	430537	5757589	Kinbasket River	05-May-14	9:08	0									
94	03-May-14	14:57	12.6	430442	5757597	Kinbasket River	05-May-14	9:05	1	NPM	N				410	0.790	N	U
95	03-May-14	15:00	11	430408	5757642	Kinbasket River	05-May-14	9:00	0									
96	03-May-14	15:02	11.2	430379	5757718	Kinbasket River	05-May-14	8:57	0									

	Trap Set			Trap Set Location			Trap Pull			Species	RECAP	Acoustic	Radio	Radio	Length	Weight	MORT	Sex
ID #	Date	Time	Depth (m)	Easting	Northing	General Description	Date	Time	Catch	Code	(Y/N)	Code	Code	Freq	(mm)	(kg)	(Y/N)	(M/F)
97	03-May-14	15:04	8.5	430328	5757744	Kinbasket River	05-May-14	8:54	0									
98	03-May-14	15:05	13.3	430331	5757869	Kinbasket River	05-May-14	8:50	0									
99	04-May-14	13:20	5.2	436838	5757036	Sullivan River	06-May-14	9:20	0									
100	04-May-14	13:30	5	436816	5756950	Sullivan River	06-May-14	9:25	0									
101	04-May-14	13:34	7.5	436741	5756906	Sullivan River	06-May-14	9:30	2	BB	N	31400	20	150.25	744	2.050	N	U
101	04-May-14	13:34	7.5	436741	5756906	Sullivan River	06-May-14	9:30		BB	N	31300	19	150.25	731	2.050	N	U
102	04-May-14	13:37	7	436737	5756762	Sullivan River	06-May-14	10:20	3	BB	N	31500	21	150.25	678	1.800	N	U
102	04-May-14	13:37	7	436737	5756762	Sullivan River	06-May-14	10:20		BB	N				590	1.200	N	U
102	04-May-14	13:37	7	436737	5756762	Sullivan River	06-May-14	10:20		BB	N				610	1.500	N	U
103	04-May-14	13:40	3.8	436858	5756749	Sullivan River	06-May-14	10:55	5	BB	N	31600	22	150.25	784	2.400	N	M
103	04-May-14	13:40	3.8	436858	5756749	Sullivan River	06-May-14	10:55		BB	N	31700	23	150.25	674	1.600	N	U
103	04-May-14	13:40	3.8	436858	5756749	Sullivan River	06-May-14	10:55		BB	N				605	1.480	N	U
103	04-May-14	13:40	3.8	436858	5756749	Sullivan River	06-May-14	10:55		BB	N				580	1.240	N	U
103	04-May-14	13:40	3.8	436858	5756749	Sullivan River	06-May-14	10:55		BB	N				653	1.340	N	U
103	04-May-14	13:40	3.8	436858	5756749	Sullivan River	06-May-14	10:55	1	NPM	N				405	0.900	N	U
104	04-May-14	13:43	4.3	436867	5756623	Sullivan River	06-May-14	12:10	3	BB	N				583	1.250	N	U
104	04-May-14	13:43	4.3	436867	5756623	Sullivan River	06-May-14	12:10		BB	N				615	1.440	N	U
104	04-May-14	13:43	4.3	436867	5756623	Sullivan River	06-May-14	12:10		BB	N				776	2.400	N	U
105	04-May-14	13:45	5.3	436748	5756608	Sullivan River	06-May-14	12:22	2	BB	N				590	1.520	N	U
105	04-May-14	13:45	5.3	436748	5756608	Sullivan River	06-May-14	12:22		BB	N				710	2.250	N	F
106	04-May-14	13:50	8	436719	5756652	Sullivan River	06-May-14	12:30	1	BB	N							
107	05-May-14	12:00	14	443109	5744401	Columbia Reach	07-May-14	10:45	0									
108	05-May-14	12:05	10.3	443242	5744437	Columbia Reach	07-May-14	10:42	0									
109	05-May-14	12:10	6.6	443282	5744441	Columbia Reach	07-May-14	10:40	1	BB	N	33600	16	150.3	574	1.140	N	M

ID #	Trap Set Date	Trap Set Time	Trap Set Depth (m)	Trap Set Location Easting	Trap Set Location Northing	Trap Set Location General Description	Trap Pull Date	Trap Pull Time	Catch	Species Code	RECAP (Y/N)	Acoustic Code	Radio Code	Radio Freq	Length (mm)	Weight (kg)	MORT (Y/N)	Sex (M/F)
110	05-May-14	12:15	10.1	443290	5744314	Columbia Reach	07-May-14	10:35	1	NPM	N				505	1.400	N	U
111	05-May-14	12:20	13	443027	5743816	Columbia Reach	07-May-14	9:40	0									
112	05-May-14	12:22	5.6	443032	5743747	Columbia Reach	07-May-14	9:35	1	NPM	N				335	0.270	N	U
114	05-May-14	12:30	13	443248	5743798	Columbia Reach	07-May-14	10:00	1	BB	N	31800	24	150.25	692	1.500	N	U
115	05-May-14	12:35	12.5	444739	5742808	Columbia Reach	07-May-14	11:40	1	BB	N	31900	25	150.25	678	1.700	N	U
116	05-May-14	12:40	9.4	444789	5742687	Columbia Reach	07-May-14	11:45	0									
117	05-May-14	12:42	6	444787	5742602	Columbia Reach	07-May-14	11:42	0									
118	05-May-14	12:45	7.8	444907	5742595	Columbia Reach	07-May-14	12:15	0									
119	05-May-14	12:50	7.3	446038	5742152	Columbia Reach	07-May-14	12:50	1	NPM	N							
120	05-May-14	12:55	7.7	446035	5742253	Columbia Reach	07-May-14	12:50	1	NPM	N				125			
121	05-May-14	13:00	7.3	445940	5742356	Columbia Reach	07-May-14	12:45	0									
122	06-May-14	13:50	7.4	449208	5739712	Columbia Reach	08-May-14	15:25	0									
123	06-May-14	14:00	9.7	449242	5739749	Columbia Reach	08-May-14	15:27	0									
124	06-May-14	14:05	11.5	449466	5739590	Columbia Reach	08-May-14	15:20	0									
125	06-May-14	14:10	6	450059	5739543	Columbia Reach	08-May-14	14:45	2	BB	N							
126	06-May-14	14:20	14.4	450139	5739587	Columbia Reach	08-May-14	14:10	2	BB	N	32400	4	150.3	842	3.1	N	U
126	06-May-14	14:20	14.4	450139	5739587	Columbia Reach	08-May-14	14:10		BB	N							
127	06-May-14	14:25	7.8	450227	5739666	Columbia Reach	08-May-14	14:00	1	BB	N							
128	06-May-14	14:30	12.4	451050	5738582	Columbia Reach	08-May-14	12:55	2	BB	N	32200	2	150.3	895	3.400	N	U
128	06-May-14	14:30	12.4	451050	5738582	Columbia Reach	08-May-14	12:55		BB	N	32300	3	150.3	884	2.800	N	U
129	06-May-14	14:35	10.8	451101	5738453	Columbia Reach	08-May-14	12:05	1	BB	N	32100	1	150.3	880	3.200	N	U
130	06-May-14	14:40	10.2	451249	5737948	Columbia Reach	08-May-14	12:00	0									
131	06-May-14	14:45	14	451616	5737839	Columbia Reach	08-May-14	11:30	1	BB	N	30000	6	150.25	810	2.375	N	U
132	06-May-14	14:50	12	452243	5736537	Columbia Reach	08-May-14	10:45	1	BB	N	32700	7	150.3	658	1.750	N	U

	Trap Set			Trap Set Location			Trap Pull			Species	RECAP	Acoustic	Radio	Radio	Length	Weight	MORT	Sex
ID #	Date	Time	Depth (m)	Easting	Northing	General Description	Date	Time	Catch	Code	(Y/N)	Code	Code	Freq	(mm)	(kg)	(Y/N)	(M/F)
133	06-May-14	14:55	11	452566	5736493	Columbia Reach	08-May-14	10:07	3	BB	N	32000	26	150.25		1.400	N	U
133	06-May-14	14:55	11	452566	5736493	Columbia Reach	08-May-14	10:07		BB	N				560	1.200	N	U
133	06-May-14	14:55	11	452566	5736493	Columbia Reach	08-May-14	10:07		BB	N				550	1.150	N	U
134	06-May-14	15:00	10	452783	5736394	Columbia Reach	08-May-14	10:05	0									
135	06-May-14	15:05	10.8	452950	5736354	Columbia Reach	08-May-14	9:35	1	BB	N	33900	19	150.3	620	1.310	N	U
136	06-May-14	15:10	10.5	449206	5739828	Columbia Reach	08-May-14	15:30	2	BB	N							
136	07-May-14	15:20	3.2	420077	5781273	Wood Arm	09-May-14	8:55	1	BB	N				465	0.83	N	U
137	07-May-14	15:15	3.1	419471	5781551	Wood Arm	09-May-14	9:00	1	BB	N				605	1.06	N	U
137	07-May-14	15:15	3.1	419471	5781551	Wood Arm	09-May-14	9:00		NPM	N				540	2.05	N	U
138	07-May-14	15:25	5.2	419581	5781426	Wood Arm	09-May-14	9:05	0						350	0.71	N	U
139	07-May-14	15:28	4.6	419449	5781140	Wood Arm	09-May-14	9:10	1	BB	N	32500	5	150.3	747	1.82	N	U
140	07-May-14	15:33	4.9	419416	5781530	Wood Arm	09-May-14	9:35	0									
141	07-May-14	15:35	5.7	419954	5781086	Wood Arm	09-May-14	9:40	0									
142	07-May-14	15:38	7.3	420027	5781051	Wood Arm	09-May-14	9:42	2	BB	N	32600	6	150.3	660	1.45	N	U
142	07-May-14	15:38	7.3	420027	5781051	Wood Arm	09-May-14	9:42		BB	N				580	1.24	N	U
143	07-May-14	15:45	8.1	420086	5781010	Wood Arm	09-May-14	10:16	0									
144	07-May-14	15:49	9.1	420118	5780915	Wood Arm	09-May-14	10:20	0									
145	07-May-14	15:52	9.7	420025	5780939	Wood Arm	09-May-14	10:25	0									
146	07-May-14	15:55	6	419911	5780991	Wood Arm	09-May-14	10:30	0									
147	07-May-14	15:59	7.9	419997	5780846	Wood Arm	09-May-14	10:32	2	BB	N				570	1.24	N	U
147	07-May-14	15:59	7.9	419997	5780846	Wood Arm	09-May-14	10:32		BB	N				560	1.09	N	U
148	07-May-14	16:02	9.2	420021	5780761	Wood Arm	09-May-14	10:35	0									
149	07-May-14	16:05	10.2	420079	5780635	Wood Arm	09-May-14	10:40	0									

Individual fish surgery data and habitat conditions trapping

ID #	Acoustic Code	Radio Code	Radio Freq	Anaesthesia (min:sec)	Surgery (min:sec)	Recovery (min:sec)	Release (min:sec)	Camera drop Habitat Comments	Set H_2O^0C:	Pull H_2O^0C:	Weather & Water Conditions
1	29600	2	150.25	6:30	12:18	16:00	34:00	River outlet, Silt Flats, High Turbidity, some submerged LWD, lots organics	3.0	4.0	clear calm sunny
1	34200	22	150.3	6:45	12:11	17:10	26:00	River outlet, Silt Flats, High Turbidity, some submerged LWD, lots organics	3.0	4.0	clear calm sunny
1	34300	23	150.3	7:05	12:27	16:00	24:00	River outlet, Silt Flats, High Turbidity, some submerged LWD, lots organics	3.0	4.0	clear calm sunny
2								River outlet, Silt Flats, High Turbidity, some submerged LWD, lots organics			
3								River outlet, Silt Flats, High Turbidity, some submerged LWD, lots organics			
4	33500	15	150.3	7:14	12:48	16:30	22:00	River outlet, Silt Flats, High Turbidity, Ice	3.0	4.0	clear calm sunny
5								River outlet, Silt Flats, High Turbidity, some submerged LWD, lots organics			
6								River outlet, Silt Flats, High Turbidity, some submerged LWD, lots organics			
7	29500	1	150.25	7:25	13:44	21:00	30:00	River outlet, Silt Flats, High Turbidity, some submerged LWD, lots organics	3.0	4.0	clear calm sunny
7								River outlet, Silt Flats, High Turbidity, some submerged LWD, lots organics	3.0	4.0	clear calm sunny
7								River outlet, Silt Flats, High Turbidity, some submerged LWD, lots organics	3.0	4.0	clear calm sunny
7								River outlet, Silt Flats, High Turbidity, some submerged LWD, lots organics	3.0	4.0	clear calm sunny
8								River outlet, Silt Flats, High Turbidity, some submerged LWD, lots organics			
9								River outlet, Silt Flats, High Turbidity, some submerged LWD, lots organics			
10								River outlet, Silt Flats, High Turbidity, some submerged LWD, lots organics			
11								River outlet, Silt Flats, High Turbidity, some submerged LWD, lots organics			
12								River outlet, Silt Flats, High Turbidity, some submerged LWD, lots organics			
13	29700	3	150.25	6:56	13:00	16:00	30:00	River outlet, Silt Flats, High Turbidity	3.0	4.0	clear calm sunny
14								River outlet, Silt Flats, High Turbidity	3.0	4.0	clear calm sunny
15	33400	14	150.3	5:55	10:53	20:00	28:00	River outlet, Silt Flats, High Turbidity	3.0	4.0	clear calm sunny
15								River outlet, Silt Flats, High Turbidity	3.0	4.0	clear calm sunny
16											

ID #	Acoustic Code	Radio Code	Radio Freq	Anaesthesia (min:sec)	Surgery (min:sec)	Recovery (min:sec)	Release (min:sec)	Camera drop Habitat Comments	Set H_2O^0C:	Pull H_2O^0C:	Weather & Water Conditions
17	30100	7	150.25	6:55	11:41	20:00	30:00	River outlet, Silt Flats, High Turbidity	3.0	4.0	clear calm sunny
18								River outlet, Silt Flats, High Turbidity	3.0	4.0	clear calm sunny
19											
20	29800	4	150.25	7:00	15:00	22:00	32:00	River outlet, Silt Flats, High Turbidity	3.0	4.0	clear calm sunny
21								Ice flows moved in jammed narrows. Low turbidity	3.0	4.0	clear calm sunny
22								Ice flows moved in jammed narrows. Low turbidity	3.0	4.0	clear calm sunny
23								Ice flows moved in jammed narrows. Low turbidity, clay, mud, lwd	3.0	4.0	clear calm sunny
24	29900	5	150.25	6:30	14:00	21:00	28:00	Ice flows moved in jammed narrows. Low turbidity	3.0	4.0	clear calm sunny
25								silt overlain bedrock in historic flooded canyon, lots submerged LWD	3.0	4.0	clear calm sunny
25								silt overlain bedrock in historic flooded canyon, lots submerged LWD	3.0	4.0	clear calm sunny
26								silt and sand, lots sand, stumps			
27	33000	10	150.3	7:15	15:30	18:30	30:00	silt and sand, lots sand, stumps	3.0	4.0	clear calm sunny
27								silt and sand, lots sand, stumps	3.0	4.0	clear calm sunny
28	30200	8	150.25	4:50	10:35	12:00	22:00	point across from cummings river, creek in bay	3.0	4.0	clear calm sunny
28								point across from cummings river, creek in bay	3.0	4.0	clear calm sunny
29											
30											
31	34100	21	150.3	3:25	8:28	23:00	28:00		3.0	4.0	clear calm sunny
31	34500	25	150.3	3:00	7:28	20:00	30:00		3.0	4.0	clear calm sunny
31									3.0	4.0	clear calm sunny
32											
33											
34											

ID #	Acoustic Code	Radio Code	Radio Freq	Anaesthesia (min:sec)	Surgery (min:sec)	Recovery (min:sec)	Release (min:sec)	Camera drop Habitat Comments	Set H_2O^0C:	Pull H_2O^0C:	Weather & Water Conditions
35											
36											
37											
38											
39											
40											
41								silt bottom outflow plume	3.3		
42								silt bottom outflow plume	3.3		
43								silt bottom outflow plume	3.3		
44								silt bottom outflow plume	3.3		
45								silt bottom outflow plume	3.3		
46								silt bottom outflow plume	3.3		
47								silt bottom outflow plume	3.3		
48								silt bottom outflow plume	3.3		
49								silt bottom outflow plume	3.3		
50								silt bottom outflow plume	3.3		
51								silt bottom outflow plume	3.3		
52								silt bottom outflow plume	3.3		
53								silt bottom outflow plume	3.3		
54											
55	30300	9	150.25	5:05	10:35	13:00	28:00	silt bottom outflow plume	4.0		cloudy overcast mostly calm
56											
57	30400	10	150.25	6:55	11:30	22:00	31:00	silt bottom outflow plume	4.0		cloudy overcast mostly calm
57								silt bottom outflow plume	4.0		cloudy overcast mostly calm

ID #	Acoustic Code	Radio Code	Radio Freq	Anaesthesia (min:sec)	Surgery (min:sec)	Recovery (min:sec)	Release (min:sec)	Camera drop Habitat Comments	Set H_2O^0C:	Pull H_2O^0C:	Weather & Water Conditions
57	34400	24	150.3	7:00	12:00	23:00	30:00	silt bottom outflow plume	4.0		cloudy overcast mostly calm
58											
59									4.0		cloudy overcast mostly calm
60	30600	12	150.25	5:30	10:20	16:50	26:00	silt bottom outflow plume	4.0		cloudy overcast mostly calm
61											
62											
63											
64											
65											
66											
67											
68											
69	30500	11	150.25	6:45	10:00	22:00	30:00	silt bottom, turbid	3.0	3.3	rain, snow, windy
70	33300	13	150.3	6:00	12:07	1:00	37:00	silt bottom, turbid	3.0	3.3	rain, snow, windy
71								silt bottom, turbid	3.0	3.3	rain, snow, windy
72								silt bottom, turbid	3.0	3.3	rain, snow, windy
73								silt bottom, turbid	3.0	3.3	rain, snow, windy
74								silt bottom, turbid	3.0	3.3	rain, snow, windy
75	30900	15	150.25	5:45	14:04	24:00	34:00	silt bottom, turbid	3.0	3.3	rain, snow, windy
76	30700	13	150.25	7:00	9:55	16:00	23:00	silt bottom, turbid	3.0	3.3	rain, snow, windy
76	30800	14	150.25	5:30	10:23	28:00	50:00	silt bottom, turbid	3.0	3.3	rain, snow, windy
76	34000	20	150.3	6:10	10:50	20:00	24:00	silt bottom, turbid	3.0	3.3	rain, snow, windy
77								silt bottom, turbid	3.0	3.3	rain, snow, windy

ID #	Acoustic Code	Radio Code	Radio Freq	Anaesthesia (min:sec)	Surgery (min:sec)	Recovery (min:sec)	Release (min:sec)	Camera drop Habitat Comments	Set H_2O^0C:	Pull H_2O^0C:	Weather & Water Conditions
78	31000	16	150.25	5:39	11:00	32:00	75:00	cobble bottom, silt sub-dom, clear	3.0	3.3	rain, snow, windy
78	33200	12	150.3	4:00	9:16	40:00	70:00	cobble bottom, silt sub-dom, clear	3.0	3.3	rain, snow, windy
78								cobble bottom, silt sub-dom, clear	3.0	3.3	rain, snow, windy
79								cobble bottom, silt sub-dom, clear	3.0	3.3	rain, snow, windy
80								cobble bottom, silt sub-dom, clear	3.0	3.3	rain, snow, windy
81								cobble bottom, silt sub-dom, clear	3.0	3.3	rain, snow, windy
82								cobble bottom, silt sub-dom, clear	3.0	3.3	rain, snow, windy
83								cobble bottom, silt sub-dom, clear	3.0	3.3	rain, snow, windy
84								silt plume, turbid, silt bottom	3.0		cold wet windy
85								silt plume, turbid, silt bottom	3.0		cold wet windy
86								silt plume, turbid, silt bottom	3.0		cold wet windy
87	31100	17	150.25	5:30	11:00	18:00	27:00	silt plume, turbid, silt bottom	3.0		cold wet windy
87	31200	18	150.25	6:00	10:40	12:00	24:00	silt plume, turbid, silt bottom	3.0		cold wet windy
88	33700	7	150.3	6:00	10:50	17:50	27:00	silt plume, turbid, silt bottom	3.0		cold wet windy
88	33100	11	150.3	6:00	10:05	14:00	26:00	silt plume, turbid, silt bottom	3.0		cold wet windy
89								silt plume, turbid, silt bottom	3.0		cold wet windy
90								silt plume, turbid, silt bottom	3.0		cold wet windy
91								silt plume, turbid, silt bottom	3.0		cold wet windy
92								cobble bottom, silt sub-dom, clear	3.0		cold wet windy
93								cobble bottom, silt sub-dom, clear	3.0		cold wet windy
94								cobble bottom, silt sub-dom, clear	3.0		cold wet windy
95								cobble bottom, silt sub-dom, clear	3.0		cold wet windy
96								cobble bottom, silt sub-dom, clear	3.0		cold wet windy
97								cobble bottom, silt sub-dom, clear	3.0		cold wet windy

ID #	Acoustic Code	Radio Code	Radio Freq	Anaesthesia (min:sec)	Surgery (min:sec)	Recovery (min:sec)	Release (min:sec)	Camera drop Habitat Comments	Set H_2O^0C:	Pull H_2O^0C:	Weather & Water Conditions
98								cobble bottom, silt sub-dom, clear	3.0		cold wet windy
99											
100											
101	31400	20	150.25	6:00	13:00	23:00	43:00	silt plume, turbid, silt bottom	3.0	3.3	cold wet windy
101	31300	19	150.25	6:40	13:25	25:00	39:00	silt plume, turbid, silt bottom	3.0	3.3	cold wet windy
102	31500	21	150.25	6:00	13:00	28:00	40:00	silt plume, turbid, silt bottom	3.0	3.3	cold wet windy
102								silt plume, turbid, silt bottom	3.0	3.3	cold wet windy
102								silt plume, turbid, silt bottom	3.0	3.3	cold wet windy
103	31600	22	150.25	9:00	15:20	21:00	27:00	silt plume, turbid, silt bottom	3.0	3.3	cold wet windy
103	31700	23	150.25	7:00	12:30	20:00	33:00	silt plume, turbid, silt bottom	3.0	3.3	cold wet windy
103								silt plume, turbid, silt bottom	3.0	3.3	cold wet windy
103								silt plume, turbid, silt bottom	3.0	3.3	cold wet windy
103								silt plume, turbid, silt bottom	3.0	3.3	cold wet windy
103								silt plume, turbid, silt bottom	3.0	3.3	cold wet windy
104								silt plume, turbid, silt bottom	3.0	3.3	cold wet windy
104								silt plume, turbid, silt bottom	3.0	3.3	cold wet windy
104								silt plume, turbid, silt bottom	3.0	3.3	cold wet windy
105								silt plume, turbid, silt bottom	3.0	3.3	cold wet windy
105								silt plume, turbid, silt bottom	3.0	3.3	cold wet windy
106											
107								Creek mouths have spawning gravel at flow interface to silt mud	3.0	2.7	clear calm sunny
108								Creek mouths have spawning gravel at flow interface to silt mud	3.0	2.7	clear calm sunny
109	33600	16	150.3	5:50	11:45	15:00	22:00	Creek mouths have spawning gravel at flow interface to silt mud	3.0	2.7	clear calm sunny

ID #	Acoustic Code	Radio Code	Radio Freq	Anaesthesia (min:sec)	Surgery (min:sec)	Recovery (min:sec)	Release (min:sec)	Camera drop Habitat Comments	Set H_2O^0C:	Pull H_2O^0C:	Weather & Water Conditions
110								Creek mouths have spawning gravel at flow interface to silt mud	3.0	2.7	clear calm sunny
111								Creek mouths have spawning gravel at flow interface to silt mud	3.0	2.7	clear calm sunny
112								Creek mouths have spawning gravel at flow interface to silt mud	3.0	2.7	clear calm sunny
114	31800	24	150.25	5:20	10:50	15:00	25:00	Creek mouths have spawning gravel at flow interface to silt mud	3.0	2.7	clear calm sunny
115	31900	25	150.25	9:00	18:20	25:00	40:00	Creek mouths have spawning gravel at flow interface to silt mud	3.0	2.7	clear calm sunny
116								Creek mouths have spawning gravel at flow interface to silt mud	3.0	2.7	clear calm sunny
117								Creek mouths have spawning gravel at flow interface to silt mud	3.0	2.7	clear calm sunny
118								Creek mouths have spawning gravel at flow interface to silt mud	3.0	2.7	clear calm sunny
119								Creek mouths have spawning gravel at flow interface to silt mud	3.0	2.7	clear calm sunny
120								Creek mouths have spawning gravel at flow interface to silt mud	3.0	2.7	clear calm sunny
121								Creek mouths have spawning gravel at flow interface to silt mud	3.0	2.7	clear calm sunny
122								silt	9.0	9.0	windy cloudy showers cold
123								silt	9.0	9.0	windy cloudy showers cold
124								silt	9.0	9.0	windy cloudy showers cold
125								silt	9.0	9.0	windy cloudy showers cold
126	32400	4	150.3	7:14	11:41	30:00	40:00	silt	9.0	9.0	windy cloudy showers cold
126								silt	9.0	9.0	windy cloudy showers cold
127								silt	9.0	9.0	windy cloudy showers cold
128	32200	2	150.3	8:00	14:00	28:00	40:00	silt	9.0	9.0	windy cloudy showers cold
128	32300	3	150.3	7:05	13:35	31:00	76:00	silt	9.0	9.0	windy cloudy showers cold
129	32100	1	150.3	8:30	16:00	34:00	49:00	silt overlain historic coarse substrate	9.0	9.0	windy cloudy showers cold
130								silt overlain historic coarse substrate	9.0	9.0	windy cloudy showers cold
131	30000	6	150.25	8:30	21:00	36:00	70:00	silt overlain historic coarse substrate	9.0	9.0	windy cloudy showers cold
132	32700	7	150.3	5:30	11:40	26:00	32:00	silt overlain historic coarse substrate	9.0	9.0	windy cloudy showers cold

ID #	Acoustic Code	Radio Code	Radio Freq	Anaesthesia (min:sec)	Surgery (min:sec)	Recovery (min:sec)	Release (min:sec)	Camera drop Habitat Comments	Set H_2O^0C:	Pull H_2O^0C:	Weather & Water Conditions
133	32000	26	150.25	6:20	13:20	18:30	20:00	silt overlain historic coarse substrate	9.0	9.0	windy cloudy showers cold
133								silt overlain historic coarse substrate	9.0	9.0	windy cloudy showers cold
133								silt overlain historic coarse substrate	9.0	9.0	windy cloudy showers cold
134								silt overlain historic coarse substrate	9.0	9.0	windy cloudy showers cold
135	33900	19	150.3	4:45	10:30	26:00	43:00	silt overlain historic coarse substrate	9.0	9.0	windy cloudy showers cold
135.5								silt overlain historic coarse substrate	9.0	9.0	windy cloudy showers cold
136								Silt, turbid	6.9	5.6	calm, overcast, cold
137								Silt, turbid	6.9	5.6	calm, overcast, cold
137								Silt, turbid	6.9	5.6	calm, overcast, cold
138								Silt, turbid	6.9	5.6	calm, overcast, cold
139	32500	5	150.3	8:00	15:00	25:00:00	30:00:00	Silt, turbid	6.9	5.6	calm, overcast, cold
140								Silt, turbid	6.9	5.6	calm, overcast, cold
141								Silt, turbid	6.9	5.6	calm, overcast, cold
142	32600	6	150.3	8:00	13:50	30:00:00	60:00:00	Silt, turbid	6.9	5.6	calm, overcast, cold
142								Silt, turbid	6.9	5.6	calm, overcast, cold
143								Silt, turbid	6.9	5.6	calm, overcast, cold
144								Silt, turbid	6.9	5.6	calm, overcast, cold
145								Silt, turbid	6.9	5.6	calm, overcast, cold
146								Silt, turbid	6.9	5.6	calm, overcast, cold
147								Silt, turbid	6.9	5.6	calm, overcast, cold
147								Silt, turbid	6.9	5.6	calm, overcast, cold
148								Silt, turbid	6.9	5.6	calm, overcast, cold
149								Silt, turbid	6.9	5.6	calm, overcast, cold