Columbia River Project Water Use Plan

Kinbasket Reservoir Fish And Wildlife Information Plan

Kinbasket Reservoir Rainbow Trout Life History and Habitat Use Assessment

Final Summary Report

Year 04

Reference: CLBMON-07

Kinbasket Reservoir Rainbow Trout Life History and Habitat Use Assessment (Final Summary Report)

Study Period: September 2014 – August 2018

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WLR Monitoring Study No. CLBMON-07
Kinbasket Reservoir Rainbow Trout Life History and Habitat Use Assessment (Final Summary Report)

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Succour Creek flowing into the Kinbasket Reservoir (April 2018). Photos in this document © Katrina Caley and Misun Kang, KNC.

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EXECUTIVE SUMMARY

Rainbow Trout (*Oncorhynchus mykiss*) were historically distributed throughout the Columbia and Canoe Rivers, and historic Kinbasket Lake, which were impounded by the construction of the Mica Dam in 1973. The Mica Dam created the Kinbasket Reservoir, a 216 km long, 43,200 ha ultraoligotrophic water body. This technical report summarizes the findings of a multi-year monitoring study of the life history, habitat use, and potential operational impacts of the Mica Dam on the spawning ecology of Rainbow Trout in Kinbasket Reservoir.

Kinbasket Reservoir has a normal annual operating range of approximately 25 m, and during periods below full pool, a large shoreline drawdown zone is exposed. Typical reservoir drawdown occurs during the winter months, reaching low pool level by approximately the end of April. The timing of low pool level coincides with the general regional timing of Rainbow Trout migration to tributaries to spawn. Rainbow Trout have specific spawning habitat requirements in tributaries, preferring a range of stream gradients, depths, and velocities, in addition to gravel substrate and a thermal regime suitable for spawning and embryo development. Locations of adfluvial Rainbow Trout spawning are currently unknown in tributaries to Kinbasket Reservoir. If suitable spawning habitat is present in the portion of tributaries that traverse the drawdown zone or migration barriers are exposed in these portions during the spawning migration, dam operations may potentially impact the success of Rainbow Trout spawning or subsequent embryo incubation.

This study used a combination of biotelemetry and habitat surveys to determine biological characteristics and movement of Rainbow Trout during the suspected pre-spawn and spawning time periods, as well as the habitat characteristics and thermal regimes of potential spawning streams through the portions that traverse the drawdown zone. Snorkel surveys designed to detect Rainbow Trout spawning were conducted through the spring in the drawdown zone of Succour Creek, a stream with high potential to support spawning of Rainbow Trout.

Three fish capture sessions occurred, in the fall of 2014, 2015 and 2017, and an additional summer capture session in 2015. 73 Rainbow Trout were captured by angling throughout the reservoir, across 1,310.75 rod hours of effort during fall sessions (catch per unit effort of 0.056 fish/rod hour). Size distributions, stomach contents and size-at-age data suggest that there is a small-bodied insectivorous morph, and large-bodied, piscivorous morph in the reservoir, although the latter had much lower capture rates.

Twenty-seven fish were tagged throughout the course of this study with biotelemetry tags. Fixed acoustic receivers placed throughout the reservoir revealed large scale movement patterns of 19 of these 27 tagged Rainbow Trout from September 2014 to May 2018. Fish detected by acoustic receivers had a variety of home range size and location preferences. Pre-spawn and/or post-spawn movements to and from home ranges appeared to occur in five tagged fish in late March-late April, and late May-mid June, respectively. Several fish migrated to the upstream end of the Columbia Reach of the reservoir during these forays.

Small tributaries with the potential to support Rainbow Trout spawning were identified from a literature review, and the drawdown zone of 12 of these streams was surveyed during low pool in late April and early May in 2015, 2016, 2017 and 2018. Surveys extended from the top of the drawdown zone at the high pool mark (~754 m) to the reservoir at the lowest elevation possible during the sampling session (at ~730 m in most tributaries). Seven tributaries had fish migration impediments that were exposed within the drawdown zone; however, in only one stream was a barrier considered completely impassable.

In most surveyed streams, habitat suitability for Rainbow Trout spawning within the drawdown zone appears marginal and limited in the surveyed length of all tributaries except in Succour Creek. In addition, the spring thermal regimes of surveyed streams except for Succour Creek would likely restrict spawning to late spring and early summer, during the period of rapid reservoir refilling. This is likely to preclude the establishment of any spawning populations in the drawdown zones of these streams, as typical operations inundate significant drawdown zone reaches prior to the thermally suitable spawning period, and would also subsequently inundate all remaining exposed drawdown zone to the yearly full pool level prior to model-predicted fry emergence times.

Unlike all other surveyed tributaries, Succour Creek contains extensive habitat which appears physically suitable to support Rainbow Trout spawning, and thermally aligned with an earlier, low pool period. Despite the apparent suitability of habitat, no Rainbow Trout spawning activity or redds were observed during extensive redd and snorkel surveys in any of the four years of study.

It is unlikely that operational modifications would significantly benefit Rainbow Trout populations in small tributaries to Kinbasket Reservoir. There is no evidence that Rainbow Trout currently spawn in the drawdown zone of any small tributary. The habitat of the upper drawdown zone (~730-754 m) of most tributaries appears marginal and limited to support Rainbow Trout spawning, and minor operational modifications may not improve these conditions in most streams. Large tributaries to the reservoir and the lower drawdown zone reaches of small tributaries could not be surveyed mostly due to logistical and safety reasons, and remain a large uncertainty with respect to the Management Hypotheses tested in this study.

Management Question	Associated Hypotheses	Status
What are some basic biological characteristics of Rainbow Trout populations in Kinbasket Reservoir (e.g., distribution, abundance, growth and age structure)?		Rainbow Trout are distributed throughout the reservoir. Capture rates appear generally low to moderate relative to creel data from comparable large lakes in the Kootenay region. A more comprehensive monitoring program would be necessary to estimate population size. Size-at-age, size distributions and stomach contents suggest two Rainbow Trout morphs may be present in Kinbasket Reservoir – a smaller insectivorous morph and a larger piscivorous morph. However, no conclusions can be made regarding the presence of these two morphs as samples sizes were too small to test statistically. Limited biotelemetry sample sizes suggest that Rainbow Trout home range size is variable, and spawning movements of a subset of the population occur during the spring period to the upstream (Columbia Reach) section of the reservoir.
Does operation of Kinbasket Reservoir result in blockage or reduced success of upstream migration of Rainbow Trout spawners in tributary streams?	H1: The productivity of Rainbow Trout populations is limited by habitat impacts directly related to operation of Kinbasket Reservoir.	The hypothesis could not be directly tested because the ability of these tributaries to support adfluvial Rainbow Trout spawning above the drawdown zone is currently unknown.

		Although we did not find evidence that RB were migrating into tributaries, we cannot reject the possibility that reservoir operations may have impeded Rainbow Trout migration through the drawdown zone of some small tributaries.
	H1A: Operation of the reservoir restricts upstream passage of Rainbow Trout spawners to reservoir tributaries due to low water elevations.	Migration impediments were found in the drawdown zones of seven of 13 surveyed tributaries and a complete barrier in one tributary between reservoir elevations of ~730 and 754 m; however, the hypothesis could not be directly tested because the ability of these tributaries to support adfluvial Rainbow Trout spawning above the drawdown zone is currently unknown. The presence of barriers at reservoir elevations <730 m in most streams also remains unknown due to sampling limitations. It is possible that freshet and reservoir filling during spawning may mitigate some migration impediments, but this could not be confirmed.
Does operation of Kinbasket Reservoir cause the flooding of Rainbow Trout spawning habitat within the drawdown zone and lower sections of tributaries, causing adverse effects on egg and fry survival?	H1: The productivity of Rainbow Trout populations is limited by habitat impacts directly related to operation of Kinbasket Reservoir.	The hypothesis could not be directly tested because Rainbow Trout were not observed migrating into tributaries. The causes for the absence of localized spawning populations could not be assessed.
	H1B: Operation of the reservoir reduces Rainbow Trout egg and	The hypothesis could not be directly tested because there

	fry survival due to inundation of spawning habitats within the drawdown zone.	was no evidence that Rainbow Trout populations currently use the drawdown zone reaches of small tributaries between reservoir elevations of ~730 and 754 m. The hypothesis could not be tested in large tributaries (e.g., Canoe, Columbia Rivers), since methods used in this study could not directly test the hypothesis in streams of this size.
Can modifications be made to the operation of Kinbasket Reservoir to protect or enhance spawning success of these Rainbow Trout populations?		It is unlikely that operational modifications would significantly benefit Rainbow Trout populations in small tributaries to Kinbasket Reservoir. The drawdown zone appears largely marginal and limited to support Rainbow Trout spawning, and minor operational modifications may not improve these conditions in most streams. Fish passage conditions may be improved in some small tributaries to the Reservoir, but this can likely be achieved through physical works after further assessment rather than operational modifications.

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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 13 km long and had a surface area of 2,250 ha (Prince 2001a). 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. Three 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 the 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 754.68 m on application to the Comptroller of Water Rights if there is a high probability of spill (BC Hydro 2007). 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 late April. During the spring, discharge from Mica dam decreases, which coincides with the normal spring freshet, which rapidly refills the reservoir through the spring and early summer.

Interior populations of Rainbow Trout (*Oncorhynchus mykiss*) spawn in the spring in streams, during periods of rising water temperatures consistently exceeding 6-8°C and the ascending limb of the hydrograph (McPhail 2007; Figure 1). Spawn timing for inland populations may occur in April-July, and mostly depends on hydrographic characteristics of the spawning stream, the latitude and elevation. Spawning is followed by egg incubation in gravels before emerging as fry. This process typically lasts 1-2 months depending on incubation temperature (McPhail 2007). Rainbow Trout spawning and incubation timing thus coincides with the period that Kinbasket Reservoir is refilling from low pool elevation.

This can result in two potential alternatives in which reservoir operations can limit Rainbow Trout recruitment, and thus productivity. Firstly, the pre-spawning migration period into critical spawning habitat may be obstructed by migration barriers exposed in the drawdown zone during the coinciding low pool elevations of the reservoir. Secondly, Rainbow Trout may spawn in the drawdown zone of streams immediately upstream from their confluence with the reservoir in low pool periods. These habitats may be inundated in some years of reservoir operation when reservoir elevations do not reach typical low pool, or fill rapidly or early, or else they may be inundated subsequent to spawning. Inundation of gravels where embryos are incubating changes the nature of the incubation environment; Rainbow Trout require flowing water to constantly provide developing embryos with oxygen and to remove metabolic waste products. In addition, emergence of fry directly into an open water lentic habitat may increase predation and reduce foraging opportunities. This study was designed to detect whether Rainbow Trout are susceptible to these potential limitations on recruitment, as these uncertainties were identified by the Water Use Plan Consultative Committee (BC Hydro 2007).

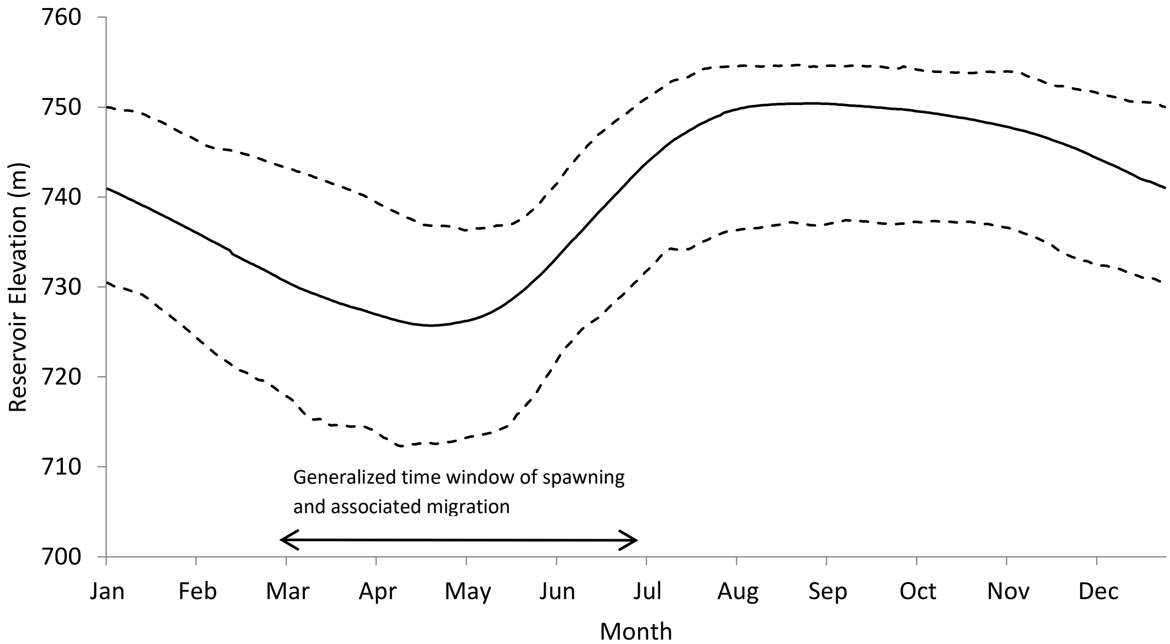


Figure 1. Generalized life history timing of Rainbow Trout compared with the mean (solid line) and minimum and maximum (dashed lines) reservoir elevations in the Kinbasket Reservoir, 1976-2015.

Rainbow Trout: Life history and biological characteristics in Kinbasket Reservoir

Kinbasket Reservoir holds a modestly popular, but productive fishery for Rainbow Trout (Pole 1995, Bray 2002). The original stock of Rainbow Trout in Kinbasket Reservoir is from Redband Columbia River trout that were locally adapted to the upper Columbia River complex from Arrow Lakes, upstream to Columbia Lake. The indigenous strain included a large piscivorous form, colloquially referred to as yellowfin trout, which was largely adfluvial from the Arrow Lakes, and spawned in the Canoe River and its tributaries (Peterson and Withler 1965, Prince 2001b). Post-reservoir phenotypic and genetic surveys indicate that current strains appear to be a cross between indigenous forms and introduced hatchery origin, which source from the Lardeau River, a tributary to Kootenay Lake (“Gerrard” strain) (Fidler 1994, Taylor 2000).

A large amount of Rainbow Trout habitat was inundated upstream of Mica Dam resulting in a shift of valley bottom habitat from primarily riverine to lacustrine. The life history form that now inhabits the reservoir is adfluvial. Spawning and rearing habitat may be limited in tributaries to the reservoir, as most of these provide poor habitat for Rainbow Trout spawning and rearing, or have suitable sections that are seasonally inundated (Fielden et al. 1992, Oliver 2001). Based on the similar but slightly higher elevation and latitude of Kinbasket Reservoir, spawn timing for adfluvial Rainbow Trout may mirror that or be slightly later than Arrow Lakes Reservoir. Spawning and associated migration occurs in Arrow Lake populations between April and June (inclusive), with peak migration and spawn timing of the final week in May (Toth and Tsumura 1996, Drieschner et al. 2008). Emergence periods follow from mid-June to early September, although most fry out-migrate shortly after emergence in late June to early August (Drieschner et al. 2008, Hawes and Drieschner 2013). Although many fish emigrate as fry, juveniles may rear within the stream for an additional time period, as they do in tributaries to Arrow Lakes Reservoir (Decker and Hagen 2007).

Few tributaries in Kinbasket Reservoir are likely to support resident Rainbow Trout populations or a large spawning population of adfluvial forms above the full pool mark, due to physical habitat characteristics that are limiting for this species. Limiting habitat characteristics include: low productivity and cold water temperatures due to glacial origin, high stream gradients or barriers above the drawdown zone and large freshet discharges that interfere with optimal flow stability that are conducive to Rainbow Trout spawning ecology (Fielden et al. 1992, Fausch et al. 2001, Oliver 2001, Golder 2003). Of direct tributaries to the reservoir that are possibly impacted by drawdown, Succour Creek has consistently been identified by prior research as having the highest abundance and densities of Rainbow Trout (Fielden et al. 1992, Oliver 2001). This stream was theorized to have greater Rainbow Trout abundance due to its lower gradient, stable flows, non-glacial origin (low turbidity and warmer temperatures) and suitable rearing habitat. Rainbow Trout have also been observed occupying the drawdown zone in the spring, during the generalized regional spawn timing window for the species.

In addition, Camp Creek near Valemount may have historically been, and may continue to be an important Rainbow Trout spawning stream, particularly for indigenous Columbia River Yellowfin Rainbow Trout (Peterson and Withler 1965, Fidler 1994, Prince 2001b). This tributary does not flow directly into Kinbasket Reservoir, but flows into the Canoe River shortly above its confluence with the reservoir. Other tributaries support low densities of Rainbow Trout and thus may support adfluvial spawning and juvenile rearing. The drawdown zone has been theorized to support Rainbow Trout spawning for the tributary portions that traverses this shoreline, but this has not been confirmed by any study (Fielden et al. 1992; Oliver 2001). Arndt (2009) speculates that adfluvial Rainbow Trout from Kinbasket Reservoir may migrate into tributaries to the Columbia River upstream from the reservoir, rather than tributaries directly feeding into the reservoir, due to more favourable spawning habitat.

Management Questions

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

1) What are some of the basic biological characteristics of Rainbow Trout in Kinbasket Reservoir?
2) Does operation of Kinbasket Reservoir result in blockage or reduced success of upstream migration of Rainbow Trout spawners in tributary streams?

3) Does operation of Kinbasket Reservoir cause the flooding of Rainbow Trout spawning habitat within the drawdown zone and lower sections of tributaries, causing adverse effects on egg and fry survival?
4) Can modifications be made to the operation of Kinbasket Reservoir to protect or enhance these Rainbow Trout populations?

The purpose of the monitoring program was to provide a quantitative baseline dataset to establish basic biological characteristics of the Rainbow Trout in Kinbasket Reservoir. During the program, information on habitat use, life history and rough estimates of abundance, and possible factors affecting Rainbow Trout productivity was gathered.

Management Hypotheses

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

H_1: The productivity of Rainbow Trout populations is limited by habitat impacts directly related to operation of Kinbasket Reservoir.

$H_{1A:}$ Operation of the reservoir restricts upstream passage of Rainbow Trout spawners to reservoir tributaries due to low water elevations.

$H_{1B:}$ Operation of the reservoir reduces Rainbow Trout egg and fry survival due to inundation of spawning habitats within the drawdown zone.

Key Water Use Decision Affected

Implementation of the 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 Rainbow Trout populations.

METHODS

Overview and study objectives

The general approach of this study partially drew upon the design of a previous Water Use Planning tributary fish migration access assessment, CLBMON-32A (Drieschner et al. 2008, Hawes et al. 2010, 2011, 2012, 2013, 2014) and refined it to apply to the Kinbasket Reservoir with additional biotelemetry data collected on the population of Rainbow Trout.

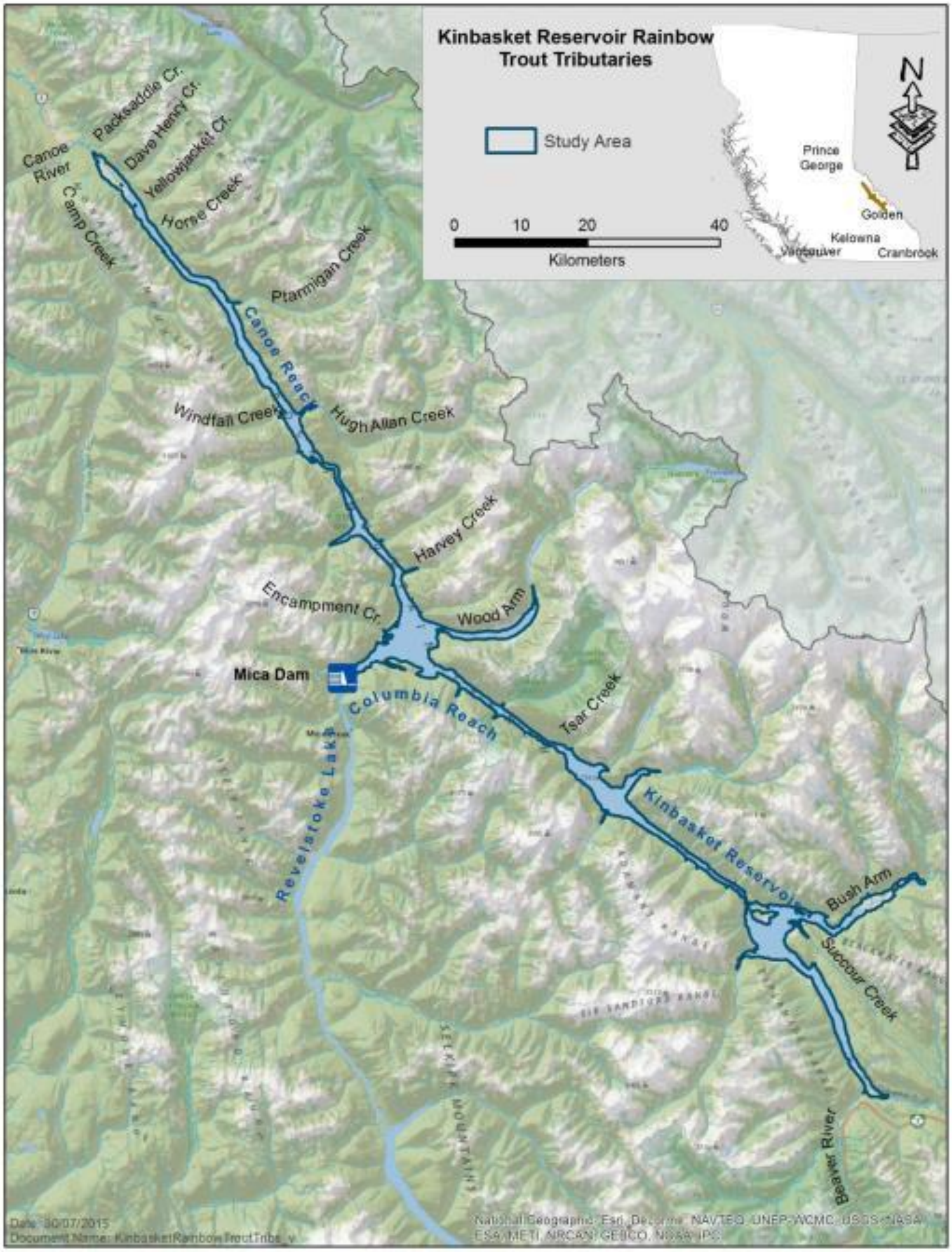


Figure 2. Overview of Kinbasket Reservoir showing tributaries surveyed in this study.

The study was designed to answer the management questions (MQs) as outlined in the previous section. Tributary surveys were conducted in the drawdown zone during the low pool period in the spring, to determine if: a) there are any migratory barriers exposed during low pool, and b) if there is suitable habitat available for Rainbow Trout spawning, or presence of Rainbow Trout spawning. Selected tributaries (Table 1) were chosen based on prior research which indicated possible Rainbow Trout spawning habitat (Oliver 2001) and observations of the presence of the species (FIDQ 2014).

Rainbow Trout capture and tagging

Capture and tagging of Rainbow Trout were conducted in 2014, 2015 and 2017. Tagging did not occur in 2016; however, since tags transmit for more than a year, fish that were tagged in 2014, 2015 and 2017 were tracked by fixed receivers in 2016.

17 Rainbow Trout were implanted with combined acoustic-radio tags (CART) in the first two years of the study. In Year 4, ten Rainbow Trout were implanted with acoustic-only tags. Acoustic-only tags were used as radio tracking had previously been removed from the program due to a limited number of fish being tagged (Caley and Warnock 2015). The fish surgeries and tag implantation followed the same methodology as was used in Caley and Warnock (2015); however, acoustic tags do not have an antenna and therefore, the steps to insert the antenna were excluded. See Caley and Warnock (2017) for full details on capture and tagging methodology.

Angling effort focused on discrete reservoir areas (Figure 3). A professional guide with extensive local knowledge and prior experience in capture of fish for biotelemetry in Kinbasket Reservoir (Martins et al. 2013) was employed for all capture efforts.

Basic capture-per-unit-effort (CPUE) metrics are provided as rough, relative estimates of abundance for MQ1 from a targeting angling sampling approach across all discrete reservoir areas. Mean CPUE was expressed as number of fish per rod hour, and data were both summarized for the current year and combined across all study years. All mortalities were examined for gut contents and biological samples of otoliths were removed from mortalities for aging.

Rainbow Trout biological attributes were assessed by recording the mean weight and length within each of the four reservoir areas and across all sampling areas. In addition, temperature was measured at the time of each capture. Descriptive statistics were run in the program R 3.2.1, and all data on aging and biological attributes were combined across all study years.

Fixed receiver tracking

This study was designed to detect year-round habitat use of Rainbow Trout and aspects of their migratory life history (e.g., adfluvial movements; MQ1), as well as tributary use during the pre-spawn and spawning season (MQs 2 and 3). Originally mobile radio tracking CART tags from fixed-wing aircraft were to be used to detect movements during the spawning season (Caley and Warnock 2016); however, due to low numbers of tagged Rainbow Trout, mobile radio tracking from fixed-wing aircraft was removed from the study. Opportunistic ground tracking was not conducted in Years 3 or 4, due to the small likelihood of detection. The CART transmitters use a coded radio (codes 111-160) frequency of 150.210 MHz for individual tag identification and an acoustic transmission of 76 KHz. The radio burst rate is 4.5 or 5.0 seconds continuous and acoustic pulses are transmitted every 60.5 s (CART16) or 100.5s (CART11). The acoustic-only tags used in Year 4 also used an acoustic transmission of 76 KHz, but transmitted pulses every 1.5 s.

As part of the CLBMON-05 Kinbasket Reservoir Burbot Life History and Habitat Use Assessment (Warnock et al. 2014, Kang et al. 2015), multiple fixed acoustic receivers were deployed in the study area in June 2014, July 2015 and May 2016 (Figure 3). Four of the receivers deployed in 2016 were replacements for the 2015 receivers that could not be retrieved due to loss or malfunction. A total of 26 receivers were actively tracking during Year 3 of the CLBMON-07 study. See reports of CLBMON-05[1] for more information on receiver set timings and active tracking periods. Acoustic tracking for CLBMON-05 ended in summer 2017 and the receivers were retrieved from the reservoir. Subsequently, an additional year of tagging and acoustic tracking was added to CLBMON-07. Receivers were re-deployed in fall 2017 for one final year of tracking and then removed in late June 2018. A reduced acoustic receiver network was deployed in 2017 due to limited remaining budget and window of opportunity for deployments. A total of 12 receivers were deployed for tracking in 2017-18 (Figure 3).

Receiver locations were selected such that constrictions in the valley were “gated” to track movement amongst reservoir areas (Gutowsky et al. 2013). Fish were considered to use a “home range” by reviewing the quantity and duration of detections in a specific reservoir area (Figure 3). Where the majority of detections occurred over a sustained period of several months, within one or more large reservoir areas, this was considered the home range for the tagged fish. Fish were assessed as making potential pre or post-spawn movements if they appeared to make a directed movement from or back to a preferred home range during the months of March, April, May or June, which coincides with the generalized timing window for pre and post-spawn movements in Rainbow Trout. To be interpreted as a possible pre-spawning migration, a fish must have migrated past two successive receivers, away from its home range, and remained undetected returning to its home range throughout the spawning season or until it was detected making a post-spawn migration. Post-spawning migrations were inferred if the fish returned past the same successive receivers in a directed movement after a period of being absent for at least 7 days.

[1]https://www.bchydro.com/about/sustainability/conservation/water_use_planning/southern_interior/columbia_river/kinbasket-fish-wildlife.html

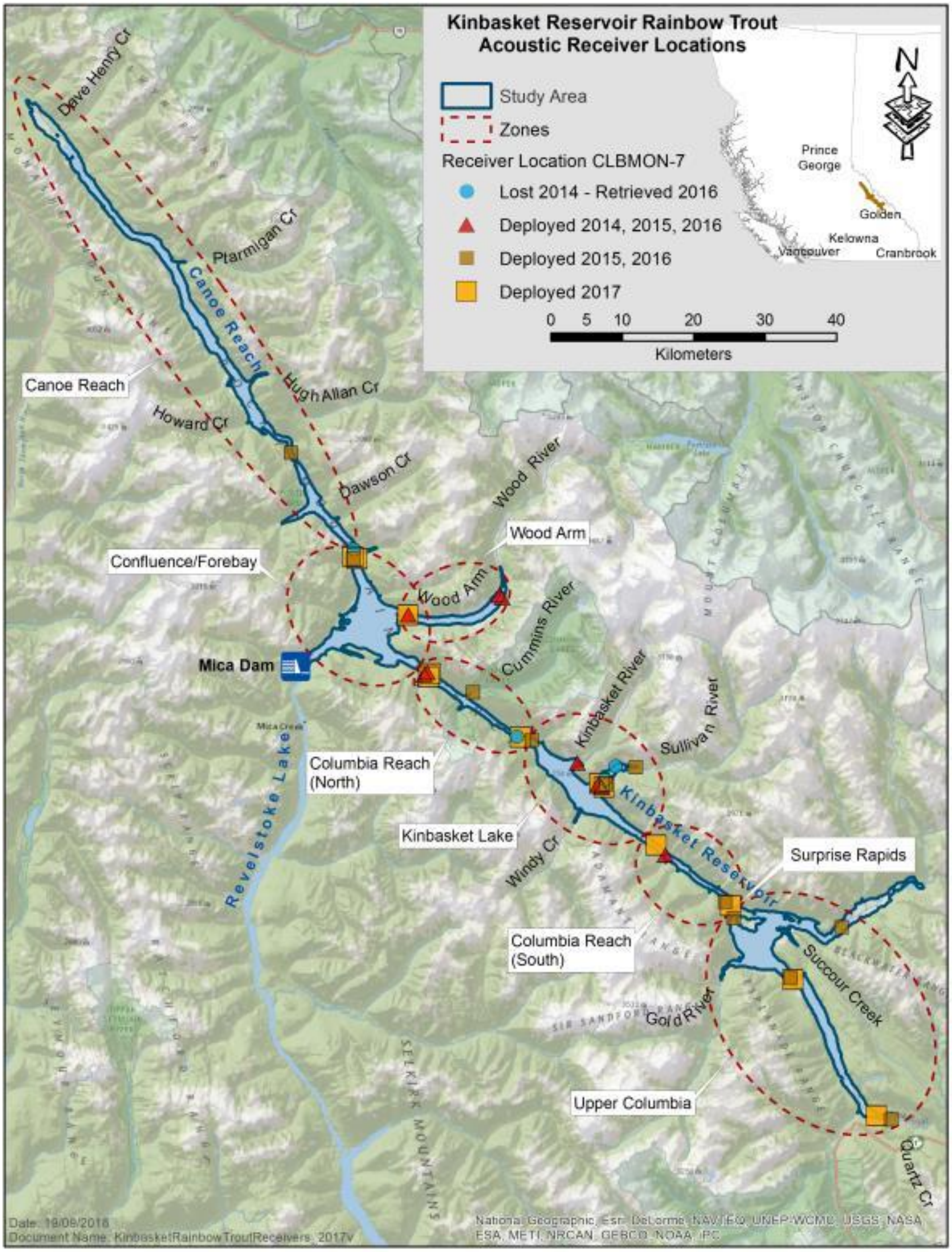


Figure 3. Locations of acoustic receivers deployed within Kinbasket Reservoir and general areas of reservoir sampling for Rainbow Trout describing home ranges or movement.

Tributary access
Detailed surveys of selected tributaries were completed annually from 2015 until 2018. Surveys were conducted during the low pool period for the Kinbasket Reservoir which typically occurs between mid-April and early May. The purpose of the surveys was to: i) identify potential barriers to upstream movement of adult Rainbow Trout; and ii) record stream habitat characteristics to identify potential Rainbow Trout spawning habitat.

The majority of the surveys were completed in years 1 and 2. Tributaries were revisited in subsequent years if the low pool reservoir elevation dropped lower than the previous survey(s). Surveys were then extended to include previously flooded sections of the drawdown zone. Where tributaries flowed directly into the Canoe or Columbia Rivers (e.g., Packsaddle Creek) it was not necessary to revisit them as the full extent of the drawdown zone was captured by the survey. A summary of all tributary surveys completed is provided in Table 1. A map showing tributary locations is provided in (Figure 2).

Stream elevation was measured using a Sokkia GRX2 RTK-accurate GPS at the boundaries of consistently measured reaches along the full length of the stream beginning at the top of the drawdown zone (~754 m). Typical elevation accuracy using this equipment is +/- 30 cm. The length of each reach depended on the total horizontal length of stream through the drawdown zone; we estimated reach length in order to provide a total number of over 15-20 measured transects so that stream habitat would be adequately characterized. Horizontal reach length was determined on-site using an angle compensating digital rangefinder. Any barriers encountered were also surveyed. Elevation was recorded at the top and bottom of the barrier so that length and height could be calculated. The type of barrier (i.e., woody debris, boulders) was also noted. Elevations obtained from the Sokkia were verified by taking daily reference measurements at the reservoir level (or other fixed points) and comparing them to known reservoir levels provided by BC Hydro. Any differences between the recorded and known reservoir elevations were used to correct stream elevation measurements.

Stream habitat
Stream habitat characteristics were recorded at a transect perpendicular to the stream taken at each reach boundary using methods similar to Oliver (2001). Parameters measured included: gradient, water depth, wetted and bankfull widths, water velocity, dominant and sub-dominant bed material, cover type, and habitat unit type. Gradient was calculated as a % slope based on the total measured horizontal length of the drawdown zone and total elevation lost from the top to bottom of the drawdown zone, Stream width was measured with a survey tape, and depth was measured by averaging three meter stick measurements across the transect. The Velocity-Head Rod method was also used to roughly determine velocity at each of the depth measurement locations by observing the degree of deflection of water on the meter stick (Carufel 1980). Substrate, cover type and habitat unit type were determined by visual inspection along each reach. Substrate was classified according to Wentworth scale particle classifications, and potential spawning gravels were considered if they were in the 4-64 mm size range. The linear distance of suitable spawning gravel outcroppings was noted wherever they were encountered, unless they occurred in a small patch that could not support a single Rainbow Trout redd (<0.2 m^2; Bjornn and Reiser 1991). Biological observations were made in tributaries during habitat surveys, and the presence of any fish or redds were noted as they were encountered.

Table 1. Summary of tributary surveys conducted in 2015-2018.

Tributary	Lowest Elevation Surveyed (m)	Tributary Survey Completed	Temperature Logger Installed
Packsaddle Creek	749.07[a]	X	X X
Dave Henry Creek	731.19[a]	X	X
Yellowjacket Creek	731.41	X	X
Horse Creek	731.14	X	X[c]
Ptarmigan Creek	731.8	X	X[c]
Hugh Allan Creek	728.93	X X	
Windfall Creek	728.98	X X	X[c]
Harvey Creek	728.94	X X	X
Encampment Creek	n/c[b]	n/c[b]	X X X[c]
Tsar Creek	728.96	X	X[c]
Unnamed tributary north of Gold River	738.26	X	X[c]
Beaver River	734.47[a]	X	
Succour Creek	720.87	X X X X	X X X X

[a] Survey captured the full extent of the drawdown zone as these tributaries flow into the Canoe or Columbia Rivers at the lowest elevation surveyed.
[b] Not completed due to unsafe conditions.
[c] Temperature logger could not be retrieved.
X = 2015 field activities, X = 2016 field activities, X = 2017 field activities, X = 2018 field activities

Thermal suitability

A temperature logger (Hobo Pendant® Data Logger) was installed at the top of the drawdown zone of five surveyed tributaries (Table 1). Each logger was placed in a housing unit constructed of PVC pipe which was secured to a 1 m length of t-post. The t-post was used to anchor the housed logger which was buried at the approximate depth that Rainbow Trout redds are excavated (15-30 cm; see Irvine et al. 2013). Loggers were programmed to record temperature hourly throughout the reservoir refilling period and generalized regional Rainbow Trout spawn timing window (April 1 – July 31).

Literature values suggest Rainbow Trout initiate spawning when mean daily water temperatures exceed 6°C, optimal incubation temperatures occur between 7 and 10°C, and acute mortality for developing embryos is encountered at 16°C (McCullough et al. 2001, Muhlfeld 2002, Carter 2008). We thus used lower and upper thresholds of 6 and 16°C to determine if and when the thermally suitable time period occurred for spawning and incubation in each stream. Where water temperature was available, we modeled fry emergence from the date when spawning would be initiated above the 6°C threshold assuming a regionally developed threshold of 480 accumulated thermal units for incubation (Irvine et al. 2013). Spawn initiation dates and model-predicted fry emergence dates were then compared to reservoir elevations to determine the severity of reservoir inundation over suitable habitat for Rainbow Trout spawning within the stream. Where data were available, the severity of impact was determined by plotting the cumulative inundation of potentially suitable spawning substrate (see above section describing habitat surveys) exposed during the thermally suitable incubation time period, from the first thermally suitable spawn date, to the first date of model-predicted fry emergence, and to the last day of the thermally suitable incubation period (i.e., when the upper 16°C incubation threshold was exceeded), or when the typical high pool period occurs after July 31, whichever came first.

Snorkel surveys

Snorkel surveys were conducted annually from 2016 until 2018 in Succour Creek to assess the presence and abundance of Rainbow Trout during the spawning period and presence of redds. Succour Creek was selected for snorkel surveys as it has the highest potential to support Rainbow Trout spawning (Caley and Warnock 2016, Oliver 2001). The stream originates from a lake, and unlike most snowmelt dominated or glacial fed stream in the region, stream clarity remains high throughout the spring freshet period. Habitat surveys in Year 1 of the study indicated potential for the drawdown zone portion of Succour Creek to provide extensive spawning habitat for Rainbow Trout (Caley and Warnock 2016). Snorkel surveys were selected as the most appropriate method to monitor Succour Creek for Rainbow Trout spawning activity as they cause minimal disturbance to the habitat and fish, are low cost, and have modest equipment requirements, which is ideal for remote locations (O'Neal 2007).

Surveys generally occurred monthly from April until June (see Table 6); however, due to access issues and safety concerns (i.e., poor road conditions, snow and ice shelves) some surveys were not completed. Snorkel surveys started at the top of the drawdown zone and progressed downstream until the reservoir was reached. Fish species and numbers observed during the survey, as well as the presence of redds were recorded. A crew of two people was used to complete the surveys. One person snorkeled while the other person supervised the survey from the stream bank. The supervising crew member recorded data and ensured that any potential hazards were mitigated for (e.g., woody debris, wildlife).

Study limitations

The main limiting factor of study on the Kinbasket Reservoir was the size of the system. Due to the large area of the reservoir, our capture methodology was impractical for estimating total abundance in Kinbasket Reservoir. As described in the Rainbow Trout capture and tagging section, this limitation has been addressed by calculating basic CPUE for each discrete reservoir area which serves as a rough estimate of relative abundance. In addition, the remoteness of the reservoir required extensive travel with limited safe access and contact points. Given these safety and logistical constraints, sampling effort to capture fish for biotelemetry was biased to focus on central and southern portions of the reservoir.

Another limitation of the study is that it was designed exclusively for sampling small tributaries. The operational effects on larger tributaries (e.g., Canoe River, Columbia River, Bush River) cannot be assessed by this study design.

RESULTS

Rainbow Trout capture and tagging

Rainbow Trout capture summary statistics by reservoir area are shown in Table 2 and Table 3. All data collected during the capture program can be found in Appendix A.1. 73 Rainbow Trout were caught throughout the course of the study, with sampling sessions occurring in 2014, 2015 and 2017. CPUE for all Rainbow Trout throughout the reservoir was 0.056 fish per rod hour, over a total of 1,310.75 rod hours expended during fall sampling throughout the program. By size, CPUE for fish <50 cm was 0.049 fish per rod hour, and CPUE for fish >50 cm was 0.0069 fish per rod hour. An additional short effort during the summer was attempted in 2015, with 0 Rainbow Trout caught in 163.75 rod hours.

Rainbow Trout caught throughout the entire program were 418 mm +/- 73.9 mm and 0.96 kg +/- 0.66 kg (Table 3, Figure 4; n=73). Larger fish (>500 mm) made up only 12.3% of the total catch. Bycatch made up 33% (n=36) of the fishes caught and included only Bull Trout. Tag sizes limited the sample size of fish that could be tagged in the first two years of study, as the majority of fish caught were too small for minimum tag size.

The capture and tagging program was more successful in 2017 than in other years (Table 2). More fish were tagged due to the use of smaller acoustic-only tags which allowed for smaller Rainbow Trout to be tagged. A total of 27 fish were implanted with biotelemetry tags throughout the course of the program, ranging from 0.56 kg (354 mm) to 3.3 kg (736 mm).

Mortalities (n=15) were used to determine size at maturity, size at age and diet characteristics. Mortalities examined ranged in size from 0.44 kg (340mm) to 2.33 kg (564 mm). All fish examined within this size range were mature. Stomach contents of smaller fish (340-442 mm) were comprised of insects, whereas the stomach contents of larger fish (539-564 mm) were comprised of fish (kokanee). Thirteen (13) of the 15 Rainbow Trout mortalities had otoliths in appropriate condition for aging (Figure 5). These fish ranged from three to six years of age. Sample size was too limited to statistically determine if size-at-age or growth rates differed between fish that were piscivorous and insectivorous.

Table 2. Summary statistics of Rainbow Trout (RB) captured across four general areas of Kinbasket Reservoir during fall sampling sessions, September-October, 2014-2017.

Reservoir area	Year	Mean Water Temp (°C)	S.D. Water Temp (°C)	N RB caught	Mean CPUE (fish/hr)	S.D. CPUE (fish/hr)	95% CI CPUE (fish/hr)
Confluence/Forebay/ Wood Arm	2014	14.3	0.6	17	0.08	0.06	0.04
	2015	12.9	0.3	15	0.08	0.03	0.03
	2017	13.2	0.3	9	0.02	0.05	0.03
	All Years	**13.6**	**0.8**	**41**	**0.06**	**0.05**	**0.02**
Old Kinbasket Lake	2014	14.5	0.1	4	0.04	0.04	0.05
	2015	12.6	0.1	3	0.07[a]	n/a	n/a
	2017	13.7[a]	n/a	1	0.03[a]	n/a	n/a
	All Years	**13.7**	**1.0**	**8**	**0.04**	**0.03**	**0.03**
Canoe Reach	2014	14.6	0.7	15	0.11	0.08	0.07
	2015	12.5	0.1	2	0.07	0.12	0.13
	2017	-	-	-	-	-	-
	All Years	**14.3**	**1.0**	**17**	**0.10**	**0.09**	**0.06**
Columbia Reach (North)	2014	-	-	-	-	-	-
	2015	-	-	-	-	-	-
	2017	13.2	0.1	5	0.07	0.06	0.08
	All Years	**13.2**	**0.1**	**5**	**0.07**	**0.06**	**0.08**
Upper Columbia	2014	-	-	-	-	-	-
	2015	11.5	0.2	2	0.04	0.05	0.04
	2017	-	-	-	-	-	-
	All Years	**11.5**	**0.2**	**2**	**0.04**	**0.05**	**0.04**
All sites	2014	14.5	0.6	36	0.08	0.07	0.03
	2015	12.7	0.5	22	0.06	0.06	0.03
	2017	13.2	0.2	15	0.03	0.05	0.03
	All Years	**13.7**	**0.9**	**73**	**0.06**	**0.06**	**0.02**

[a] The value is not a mean. It either represents a single visit or a single fish captured.

Table 3. Summary statistics of Rainbow Trout catches and individual fish data across five general areas of Kinbasket Reservoir, September-October, 2014-2017.

Reservoir area	Year	N	N RB tagged	Mean length (mm)[a]	S.D. length (mm)	Mean weight (kg)[a]	S.D. weight (kg)
Confluence/Forebay/ Wood Arm	2014	17	4	414	116	0.960	0.947
	2015	15	5	415	47.4	0.871	0.540
	2017	9	8	396	36.0	0.766	0.186
	Total	**41**	**17**	**410**	**80.4**	**0.885**	**0.688**
Old Kinbasket Lake	2014	4	2	472	40.4	1.33	0.522
	2015	3	2	535	47.2	2.01	0.777
	2017	1	0	364	n/a	0.540	n/a
	Total	**8**	**4**	**482**	**67.7**	**1.49**	**0.740**
Canoe Reach	2014	15	4	413	51.8	0.838	0.556
	2015	2	0	385	10.6	0.615	0.064
	2017	-	-	-	-	-	-
	Total	**17**	**4**	**410**	**49.4**	**0.812**	**0.525**
Columbia Reach (North)	2014	-	-	-	-	-	-
	2015	-	-	-	-	-	-
	2017	5	0	394	17.2	0.654	0.064
	Total	**5**	**0**	**394**	**17.2**	**0.654**	**0.064**
Upper Columbia	2014	-	-	-	-	-	-
	2015	2	0	311	36.8	0.348	0.153
	2017	-	-	-	-	-	-
	Total	**2**	**0**	**311**	**36.8**	**0.348**	**0.153**
All sites	2014	36	10	420	87.6	0.950	0.761
	2015	22	7	419	70.3	0.955	0.680
	2017	15	10	393	29.8	0.713	0.162
	Total	**73**	**27**	**418**	**73.9**	**0.958**	**0.656**

[a] Mean lengths and weights presented in this table have been calculated for all fish caught.

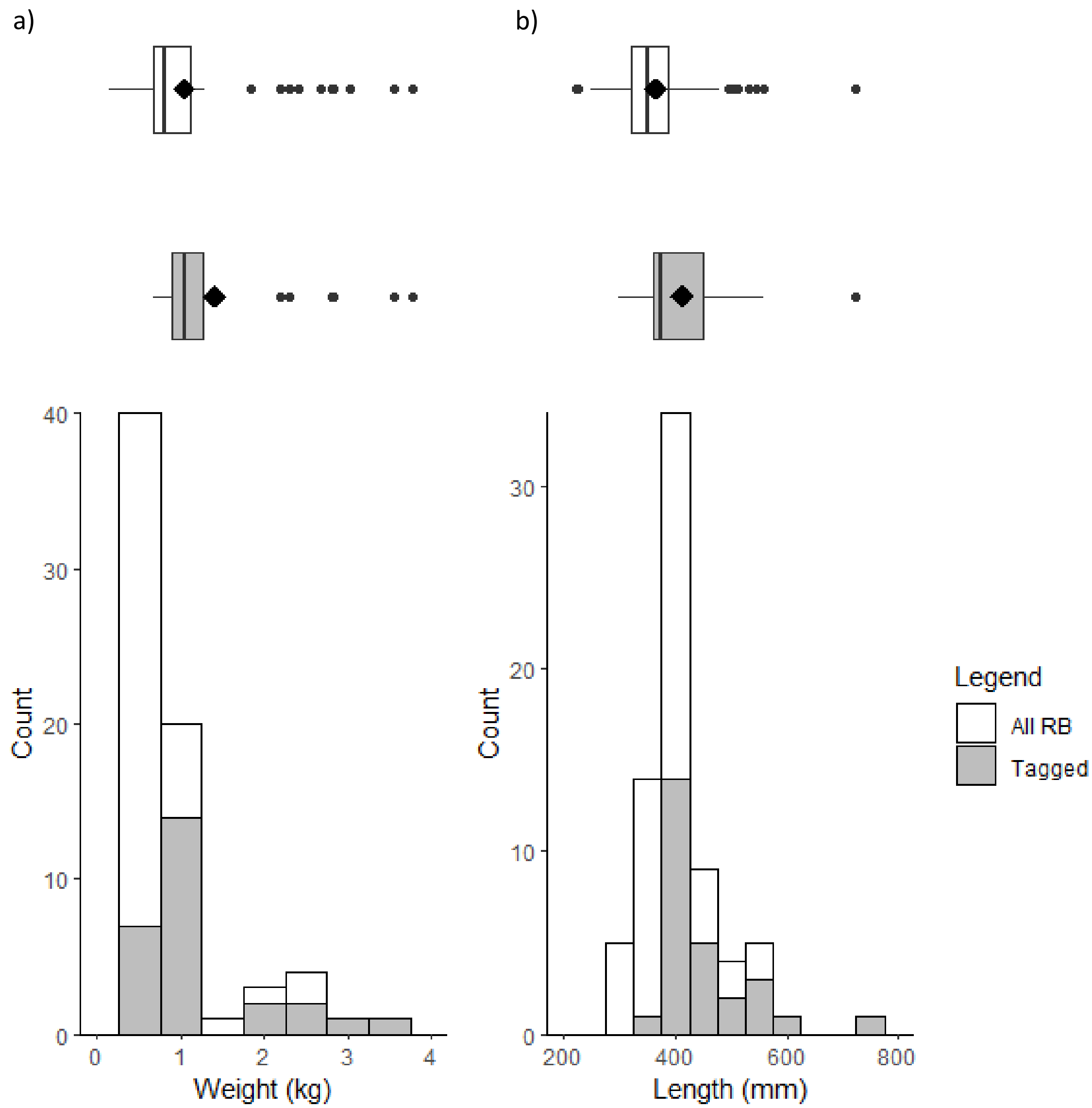


Figure 4. Size (length and weight) distributions and box plots of Rainbow Trout (n=22) caught and measured in Kinbasket Reservoir during all capture programs in 2014, 2015 and 2017. Plot a) includes the box plots and histogram showing the weight distributions for all RB caught (n= 73) tagged RB (a subset of fish caught, n= 27). Plot b) shows the same plots for RB length. Boxes represent interquartile range, diamonds represent the sample mean, while the middle line in the box is the median sample value. Whiskers represent observations outside of the interquartile range with outlier data points.

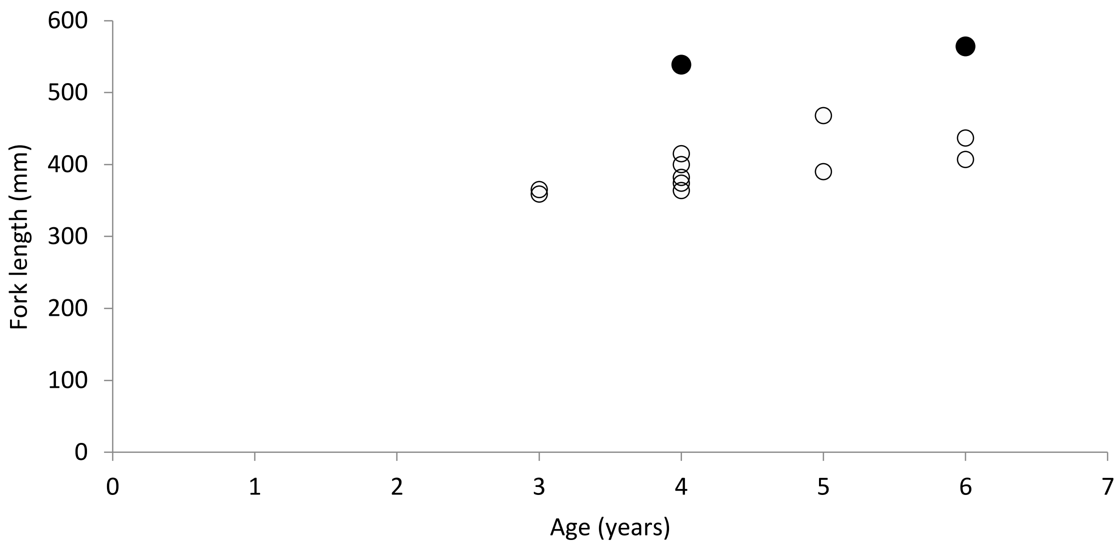


Figure 5. Length at age of Rainbow Trout, as examined from otoliths of piscivorous (closed circles; n = 2) and non-piscivorous (open circles; n = 11) individuals, taken from incidental mortalities throughout the course of the study.

Fixed receiver tracking

Nineteen of 27 implanted tags were detected by acoustic receivers during all years of this program. Eight of these fish were detected in the final year of study, and all were tagged in 2017. Movement patterns of each individually tracked Rainbow Trout are described in Appendix A.2 for the entire period of tracking data available. Greater detail is given about movements during periods of presumed pre-spawning or spawning and post-spawning periods (March to June); however, in 2017 and 2018, the tracking period could not detect post-spawn movements, as battery life of receivers did not last into June. Reservoir areas and detection locations can be visually cross referenced with descriptions by consulting Figure 3.

Fifteen of the 19 fish tracked by fixed receivers provided data during the presumed pre-spawning and spawning period, and five of these appeared to make directed movements that were interpreted as possible pre or post-spawn migrations. Of the fish that made possible spawning forays, all five appeared to make directed movements upstream from the Columbia Reach and into the Upper Columbia area, and two of these appeared to head towards the confluence of the Columbia River with the reservoir, at the upstream end of the Upper Columbia area (Figure 3). One fish appeared to repeat the same spawning movement in two subsequent years. The timing of these possible pre-spawn movements was between late March and late April during which time average monthly water temperatures[2] were approximately 2.3°C and 3.6°C, respectively[3]. Where post-spawn tracking was available, all of these fish returned to their home ranges by late May to mid-June. See Appendix A.3 for maps showing the

[2] Average monthly water temperatures are provided for Succour Creek in 2018.
[3] Rainbow Trout typically begin spawning when water temperatures rise above 6°C (McPhail 2007).

locations of acoustic receivers that detected each tagged fish. All physical characteristics recorded at the time of capture are summarized in this report and in Caley and Warnock (2016, 2017).

Tributary access

Two tributaries were surveyed during the spring 2018 program, coinciding with the minimum reservoir level elevation. No migration barriers were encountered during these surveys. A summary of key tributary measurements and observations is provided in Table 4. Photographs of surveyed tributaries are shown in Appendix B.1. Longitudinal elevation profiles for each surveyed stream can be found in Appendix B.2.

No migration barriers were encountered during the 2018 surveys. In previous surveys completed by this study, potential fish migration barriers were encountered in seven surveyed streams, and only one stream had a complete fish migration barrier identified. Photographs of potential barriers on each stream are shown in Appendix B.1.

Windfall Creek had the most barriers identified, with five found throughout the drawdown zone surveyed; however, it is unclear whether any of these is a complete migration barrier. These barriers were primarily formed from boulders or jammed large woody debris.

The Unnamed Creek surveyed in 2015 had one barrier identified, composed of boulders and large woody debris.

The Beaver River has a swift flowing cascade that may be a velocity barrier to fish migration; however, the degree to which this impedes fish migration is unclear.

Horse, Dave Henry and Yellowjacket Creeks have poorly defined channel morphology in their lower drawdown zone reaches. The alluvial fans in the lower reaches of these streams create multiple, shallow migration corridors, which may impede migration during low stream flows.

Tsar Creek is the only stream with a complete fish migration barrier identified. This stream had two barriers identified, one 2.5 m in height, occurring within the drawdown zone at 738 m elevation, and another 1.7 m in height occurring at 735 m elevation (see Appendix B.2, Figure B-10). The first barrier (2.5 m height) appears to be a complete migration barrier due to its height and the second is a potential barrier, as there is an alternate bank which fish may be able to ascend.

Stream habitat

12 streams were surveyed successfully throughout the course of the study. Encampment Creek was never surveyed due to inaccessible conditions at low pool elevations on the survey year. Coverage of habitat surveys in the drawdown zone of streams varied, depending on the minimum reservoir elevation encountered.

The entire drawdown zones of the Beaver River and Dave Henry and Packsaddle Creeks were surveyed. Succour Creek was surveyed to the lowest elevation of ~720 m.

All other tributaries were surveyed to a lowest elevation of ~730 m, which is similar to the average low pool elevation in Kinbasket Reservoir. It is important to note that the drawdown zone of these streams extends below these surveyed elevations, thus data presented is incomplete for most streams. Summary statistics and information for all surveyed tributaries is presented in Table 4.

Water clarity was generally high for most tributaries, so visual surveys to collect data were possible throughout the course of this study in all streams except the Beaver River. Fish presence in the drawdown zone was not observed in any streams throughout the course of study.

Channel morphology in most streams varied, from very steep (>8%), creating cascade-type stream habitats, to moderately steep (2-5%), displaying step-pool or plane-bed type morphology, to low gradient (0-0.5%). Low gradient streams displayed pool-riffle morphology.

Gravel substrate in the size range suitable for Rainbow Trout spawning was found nine surveyed streams, but not in great quantities in any stream except Succour Creek. Gravels of the size class possibly suitable for Rainbow Trout spawning tended to be distributed at the lower end of the surveyed area of the drawdown zone in some streams, as the gradient of some tributaries became shallow as they approached the reservoir elevation (~729 m) (See Appendix B.1. (Photographs 2, 4, 6, and 8) and Appendix B.2.). Unlike other streams, Succour Creek contained extensive low-gradient habitat, and reaches with substrate that may be suitable for Rainbow Trout spawning.

Table 4. Summary of key tributary measurements and observations during the 2015-2018 surveys.

Parameter	Packsaddle Creek	Dave Henry Creek	Yellowjacket Creek	Horse Creek	Ptarmigan Creek	Hugh Allan Creek[a]	Windfall Creek[a]	Harvey Creek[a]	Encampment Creek	Tsar Creek	Unnamed Creek	Beaver River	Succour Creek[a]
Survey Date(s)	May 1, 2018	April 22, 2016	April 22, 2016	April 20, 2016	April 21, 2016	April 26, 2015 & May 2, 2017	April 27, 2015 & May 2, 2017	April 25, 2015 & May 3, 2017	n/a	03-May-17	May 1, 2015	May 4, 2016	April 28-30, 2015, April 18, 2016 & April 19, 2018
Reservoir Elevation (m)	720.27	731.19	731.19	730.96	730.92	728.93	728.93	728.78		728.78	737.99	734.09	719.77[e]
Length of DDZ Surveyed (m)	160	900	690	520	600	1020	600	780		280	180	2,076[f]	7,041
No. of Reaches	9	19	24	27	25	52	32	37		14	13	22	37
Reach Length (m)	20	50	30	20	25	20	20	20		20	15	100	150-300
Channel Type	Plane Bed	Plane Bed	Plane Bed	Plane Bed / Step Pool	Step Pool	Plane Bed	Step pool	Plane Bed		Cascade	Cascade	Upper: Cascade / Lower: Pool-Riffle	Pool-Riffle
Mean Depth (cm)	24.8	n/a[c]	n/a[c]	21.0	n/a[c]	n/a[b]	31	32		29	16.0	n/a[b]	50.0
Mean Bankfull Width (m)	13.0	58.0	58.0	98.7	27.0	111.5	77.1	94.7		168.2	12.2	65.2	9.86
Mean Wetted Width (m)	8.9	17.1	23.8	17.4	21.2	19.2	8.8	9.8		6.4	4.9	79.6	8.66
Gradient (%)	2.15	2.21	3.31	4.49	3.31	2.5	4.3	3.2		8.0	8.8	0.30	0.39
Mean Velocity (m/s)	0.85	n/a[b]	n/a[b]	0.82	n/a[b]	n/a[b]	0.80	1.0		1.8	0.68	n/a[b]	0.67
Dominant Substrate	Cobble	Cobble	Cobble	Cobble	Cobble	Boulder	Cobble	Gravel		Cobble	Cobble	[d]	Gravel
Spawning Gravels (m)	0	355	210	0	10	100	120	155		10	2	[d]	2,327
Fish Present	0	0	0	0	0	0	0	0		0	0	[d]	Yes - See snorkel survey results
Redds Observed	0	0	0	0	0	0	0	0		0	0	0	No
Fish detected during opportunistic radio tracking?	No[c]	No	No	No	No	No[c]	No[c]	No[c]		No[c]	No	No	No
Barriers / Type	None	Possible (alluvial fan)	Possible (alluvial fan)	Possible (alluvial fan)	None	None	5 (coarse woody debris, boulders)	None		2 (coarse woody debris)	1 (coarse woody debris, boulders)	Possible (cascade)	None

[a] Values presented reflect information collected from multiple surveys.

[b] Stream was too deep and swift to wade.

[c] Opportunistic radio tracking not completed in 2017 due to expiry of active tags and low likelihood of detection.

[d] High turbidity. Information not available.

[e] Survey ended at 720.87 m due to unconsolidated sediment and unsafe conditions.

[f] Measurements are only available for part of the drawdown zone.

Thermal suitability

Temperature data were available from five of the tributaries surveyed: In Encampment Creek (2015 and 2016) Yellowjacket Creek (2016 and 2017), Dave Henry Creek (2016 and 2017), Packsaddle Creek (2016, 2017 and 2018) and Succour Creek (2015, 2016, 2017 and 2018). Temperature data for all available years in which data were available for these tributaries was compared to spring reservoir elevations to determine the potential impact of reservoir operations on thermally mediated biological life cycle requirements of Rainbow Trout within potentially suitable spawning habitat in the drawdown zone. Prior reports describe analysis in detail (see analysis in Caley and Warnock 2017).

In Encampment, Yellowjacket, Packsaddle and Dave Henry Creeks, water temperatures were cold during the spring, and resulted in temperatures not becoming suitable for spawning until May-June; according to the ATU model of embryonic development, emergence could only occur in these streams in late July or August (Table 5). Temperatures exceeding spawning and incubation thresholds were never exceeded in these streams. Succour Creek was much warmer than the other four streams where temperature data were available, characterized by rapid warming during the reservoir refilling period (Table 5).

Reservoir operations during the refilling period of April 1 – July 31 were compared to the thermal regime in each stream, in each year where data were available (Figure 6). In all years, the thermal regime of Succour Creek became suitable for spawning from mid-April to mid-May (depending on the year), and emergence was predicted to commence starting in the first half of June. Emergence typically was predicted to occur shortly prior to when temperatures became too high for embryonic development, due to the rapid warming pattern in this stream. Thus, Succour Creek was thermally suitable for spawning commencing during the typical period of low reservoir levels, and remained suitable for spawning and embryonic development throughout the reservoir refilling period. In contrast, the four other streams surveyed were cooler, resulting in onset of the thermally suitable spawning period later into the refilling period. Those streams remained cool throughout the refilling period, resulting in modeled emergence times that occurred close to the summer maximum reservoir elevation.

Table 5. Streams with temperature data available throughout the study period, and dates that daily average temperature thresholds were exceeded through the spring reservoir refilling period (April 1 – July 31).

Stream	Year	First thermally suitable spawn date (>6°C)	First possible date of emergence (>480°C ATU)	Date of Thermal exceedance for spawning or embryo development (>16°C)
Encampment Creek	2015	05-Jun	29-Jul	N/E*
	2016	04-Jun	> Aug 1	N/E*
Dave Henry Creek	2016	17-May	17-Jul	N/E*
	2017	12-Jun	> Aug 1	N/E*
Yellowjacket Creek	2016	15-May	14-Jul	N/E*
	2017	12-Jun	> Aug 1	N/E*
Packsaddle Creek	2016	15-May	16-Jul	N/E*
	2017	07-Jun	> Aug 1	N/E*
	2018	22-May	21-Jul	N/E*
Succour Creek	2015	22-Apr	07-Jun	26-Jun
	2016	16-Apr	31-May	07-Jun
	2017	02-May	13-Jun	01-Jul
	2018	10-May	19-Jun	20-Jun

* N/E = temperature not exceeded.

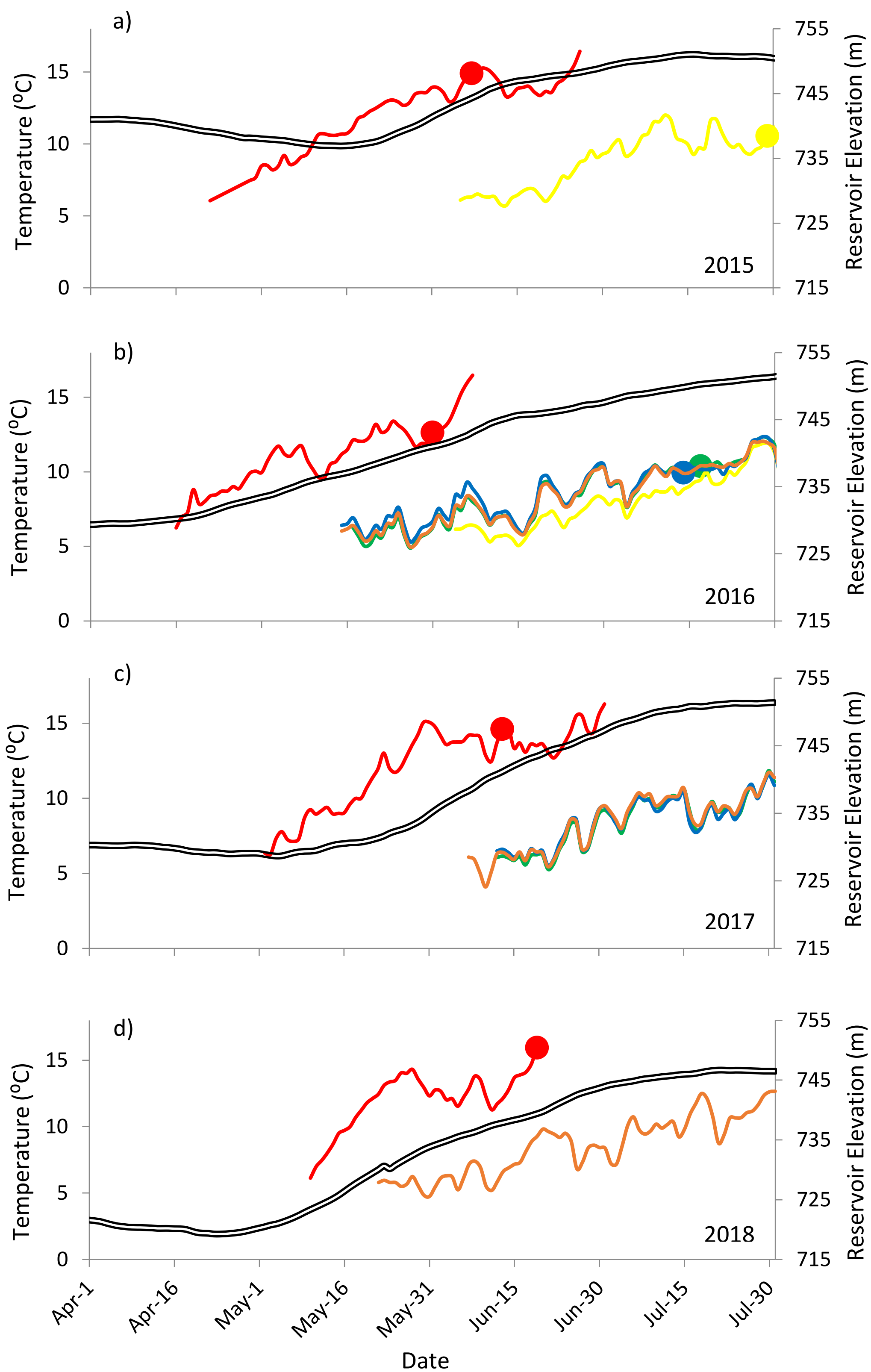


Figure 6. Stream daily average temperatures for Succour Creek (red), Dave Henry Creek (green), Yellowjacket Creek (blue), Packsaddle Creek (orange) and Encampment Creek (yellow), relative to daily

average reservoir elevations (double black line) during the refilling period in a) 2015, b) 2016, c) 2017 and d) 2018. The stream temperature record shown represents the thermal regime through the thermally defined spawning and embryo incubation period, corresponding to the day in which daily average temperatures exceeded 6, until temperatures in the stream exceeded 16 (or July 31; the end of the typical refilling period). Coloured dots represent the first possible date of modeled emergence timing. If a dot is absent on the thermal profile, the modeled emergence date for that stream occurred after July 31. Note that stream temperatures in Succour Creek for the month of April are modeled (see Warnock and Caley 2018).

Reservoir operations during the refilling period of April 1 – July 31, in relation to inundation of spawning substrate and biological temperature thresholds were summarized for each year, for each of the streams where temperature and substrate data were available (Figure 7). Potential impacts varied substantially by year in Succour Creek. In 2015 (Figure 7a), and 2017 (Figure 7c), a substantial proportion of exposed substrates was inundated by reservoir operations by the modeled first date of spawning, and inundation continued through the modeled emergence period, resulting in most suitable substrate being inundated by the end of the thermally suitable period. Potential Impacts were modeled to be less severe in 2016 (Figure 7b) and 2018 (Figure 7d) in Succour Creek. In Dave Henry and Yellowjacket Creeks, reservoir operations were estimated to inundate all exposed suitable substrate in 2016 (Figure 7b), and inundating all suitable substrate prior to the thermally suitable spawning window in 2017 (Figure 7c). Substrate data were not available for Encampment Creek. Packsaddle Creek did not have any substrate considered suitable for spawning, and thus was not included in the analysis.

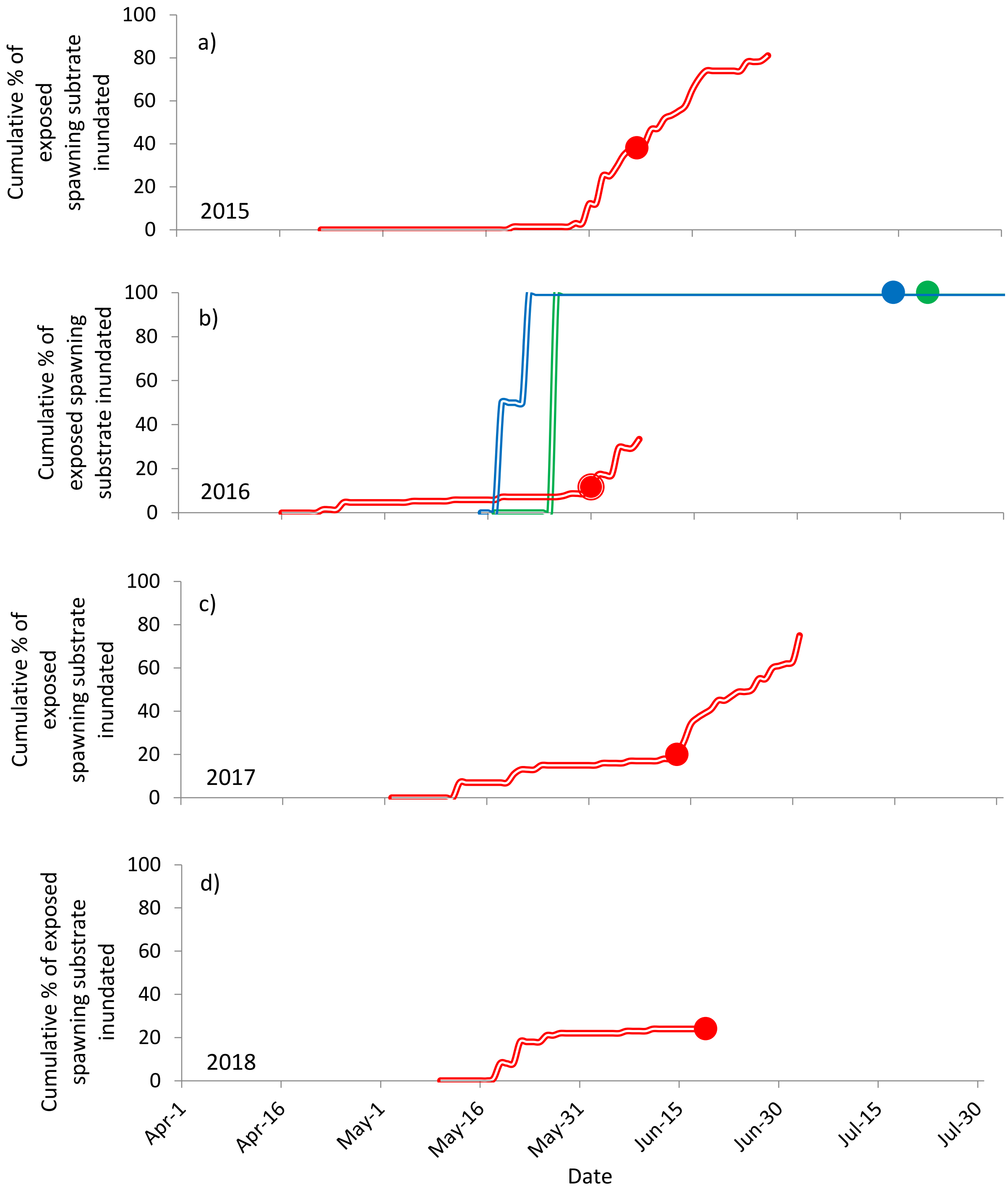


Figure 7. Cumulative percent of drawdown zone potential spawning substrate inundated through the thermally suitable spawning and embryo incubation window during the reservoir refilling period for Succour Creek (red), Dave Henry Creek (green) and Yellowjacket Creek (blue) in a) 2015, b) 2016, c) 2017 and d) 2018. Coloured dots represent the first possible date of modeled emergence timing. Packsaddle and Encampment Creek are not shown due to absence of spawning substrate and data deficiencies, respectively. Note that data were available in 2017 for Dave Henry and Yellowjacket Creeks, but reservoir operations inundated all potentially suitable substrate by the first thermally suitable spawning date.

Snorkel surveys

Two snorkel surveys on Succour Creek were conducted in 2018, in May and June. An April survey was not completed in 2018 due to extensive shelf ice limiting safe working conditions for a snorkel crew. A summary of fish counts for surveys in all years is provided in Table 6.

Counts and size classes of rainbow trout observed in the 2018 survey were similar to the 2016 and 2017 surveys, and the majority of the observed fish were <20 cm in length and thus likely immature (Figure 8). Large numbers of large-bodied Largescale Suckers (Figure 9) were observed in all years. These fish appeared to be aggregated, and had colouration indicative of spawning. Nine species were encountered in all years of surveys, and earlier surveys (April and May) tended to have lower diversity than June surveys. No redds were observed during any survey.

Figure 8. Juvenile Rainbow Trout observed in Succour Creek (May 18, 2016).

Figure 9. Largescale suckers observed in Succour Creek (May 18, 2016).

Table 6. Summary of snorkel survey observations in Succour Creek, 2016-2018.

Species	Date	Counts (size bins in cm)						Total Count
		0-10	10-20	20-30	30-40	40-50	50-60	
Rainbow Trout	April 19, 2016		5	1	1			7
	May 17, 2016	30	17					47
	June 17, 2016		5					5
	June 15, 2017	38	4	3				45
	May 17, 2018	2	1					3
	June 14, 2018	30	45	7	2			84
Mountain Whitefish	April 19, 2016			1				1
	May 17, 2016	62	60	8	1			131
	June 17, 2016		4					4
	June 15, 2017	89	22					111
	May 17, 2018		2					2
	June 14, 2018	17	8	9	1			35
Brook Trout	April 19, 2016	1						1
	May 17, 2016	4	2					6
	June 17, 2016		4	3	1			8
	June 15, 2017	2	3	1				6
	June 14, 2018	1	4	4	2			11
Largescale Sucker	May 17, 2016			756	464			1,220
	June 15, 2017			273	318	2		593
	May 17, 2018			654	277			931
	June 14, 2018			90	250			340
Redside Shiner	June 17, 2016		1					1
	June 15, 2017	1						1
	June 14, 2018	3						3
Sculpin	June 17, 2016	4						4
	June 15, 2017	1						1
Northern Pikeminnow	June 15, 2017				3	3	1	7
Bull Trout	May 17, 2016			1				1
Kokanee	June 17, 2016		1					1

DISCUSSION

Rainbow Trout capture, biological characteristics and tagging

Despite a very high capture effort of 1,310.75 total rod hours by angling, a small mean CPUE of 0.056 fish/rod hour resulted across all three fall capture sessions. A short exploratory capture session in summer of 2015 resulted in a CPUE of 0.0 fish/rod hour, through 163.75 rod hours of effort (Caley and Warnock 2015). Capture of larger fish (>500 mm) was very low, with a CPUE of 0.0069 fish/rod hour across fall sampling sessions. CPUEs of 0.117 fish/rod hour (Gazey 1994) and 0.07 fish/rod hour (Bray and Campbell 2001) have been documented for Rainbow Trout in the Revelstoke Reservoir. Arrow Lakes Reservoir has had CPUE between 0.03 and 0.104 fish/rod hour (Arndt 2004, 2014), while Kootenay Lake was found to have a CPUE of 0.08 fish/rod hour (Andrusak and Andrusak 2012). All these reported values are generated from multiple methods of angler surveys, encompassing multiple seasons and a range of angler abilities and multiple angling techniques which may have inherent biases for comparison to CPUEs generated in this study; however, given that professional guiding services employed in this study should upwardly bias capture, the CPUEs generated in this study appear low relative to other large lakes in the Kootenay region. Catch of Rainbow Trout by other metrics in Kinbasket Reservoir has similarly been low in recent years from other studies. Rainbow Trout were absent in bycatch from gillnet sets (Sebastien and Weir 2014) or angling targeting other large predators in the reservoir (Gutowsky et al. 2013), and their low abundance in the Mica Dam tailrace (Bisset et al. 2015) may imply that few Rainbow Trout are entrained through Mica Dam. These results suggest that Rainbow Trout abundance in Kinbasket Reservoir may have been low in recent years. None of these studies were designed to generate an estimate of abundance, and this should be a focus of future study in the reservoir.

Kinbasket Reservoir is generally data poor relative to other large lakes, but Rainbow Trout catches may have declined from levels seen in previous decades (CPUE of 0.15-0.19 fish/rod hour depending on method of creel data collected; Pole 1995, 1996, Bray 2002). If Rainbow Trout have been declining in abundance in Kinbasket Reservoir, this could be due to a variety of reasons that are beyond the scope of this study. Reasons for decline may include: naturally low productivity, increased access and angler effort (resulting in increased harvest over the last two decades), poor reproductive success due to reservoir operations or naturally limiting conditions in spawning areas, cessation of stocking programs (Rainbow Trout were stocked in Kinbasket Reservoir with Lardeau River “Gerrard” strain from 1984-1992; FFSBC 2015), poor capture success during capture session and/or insufficient capture effort expended across seasons to provide an accurate CPUE estimate. Prey availability is unlikely to explain decreased abundance of Rainbow Trout due to high and sustained abundance of Kokanee and zooplankton densities in recent years (Bray 2014; Sebastien and Weir 2014) and high catch of Bull Trout, an alternate predator in the reservoir (Gutowsky et al. 2013). Low water transparency is also not likely a limiting factor for visually acute Rainbow Trout predators in Kinbasket Reservoir (see Beauchamp et al. 1999), as Secchi depth in Kinbasket Reservoir is similar to that found in Kootenay Lake (Bray 2014, Schindler et al. 2014). Rainbow trout were captured throughout the reservoir, thus they are distributed throughout it.

In Year 1 we observed a subtle bimodal size distribution of captured fish and stomach samples examined led us to hypothesize that there could be two forms of Rainbow Trout in Kinbasket Reservoir (Caley and Warnock 2015); despite small sample size, biological data in Years 2 and 4 of the study are consistent with those in Year 1 and provide further support for this hypothesis. Data on length-at-age also suggest that piscivorous fish were larger for equivalent age than non-piscivorous forms (Figure 5), which is consistent with this hypothesis, but the sample size was not sufficient to test statistically. Large lakes in the Kootenay region and elsewhere in interior BC may have sympatric insectivorous and piscivorous morphs of Rainbow Trout (Arndt 2009). These forms are often easily distinguished by their size, and can represent reproductively segregated populations (Andrusak and Andrusak 2012). In these lakes, Rainbow Trout >500 mm or >2 kg tend to be primarily piscivorous (Andrusak and Andrusak 2006, 2012). The presence of large bodied fish in Kinbasket Reservoir is almost certainly as a result of foraging specialization in those individuals for piscivory; however, it is not apparent whether those individuals represent some form of unique ecotype, rather than just some exceptional individuals in the population. The existence of separate, reproductively isolated populations of these two forms is possible in Kinbasket Reservoir, but beyond the scope of this study.

The angling method employed in this study was biased to preferentially target the larger bodied fish. Large bodied piscivorous fish were targeted due to their ability to receive large tag burdens, as large tags with long battery life were required for this study. Despite capture method bias to piscivorous Rainbow Trout, the much lower capture success for large-bodied fish (CPUE of 0.0069 fish/rod hour for fish >500 mm vs CPUE of 0.049 fish/rod hour for fish <500 mm) implies that larger bodied piscivorous Rainbow Trout may be less abundant relative to the smaller insectivorous ones. A more comprehensive, unbiased sampling program would still be needed to accurately determine the relative abundance of the two size groups.

Small, insectivorous Rainbow Trout production may be limited because littoral productivity in Kinbasket Reservoir is limited by dam operations which cause fluctuating water levels. Some limited foraging areas may be seasonally inundated or contiguous with the continuously inundated pool of the reservoir in areas where wetlands and ponds occur within the drawdown zone near the full pool (753-754 m) elevation, and these indeed contain macroinvertebrates and macrophytes (Adama et al. 2014); however, the extent of these areas is not a significant proportion of the perimeter of the reservoir and they are only connected with the greater reservoir area at limited times of year and only in years when reservoir elevations near the full pool mark. Pelagic and benthic macroinvertebrates, terrestrial insects and benthic invertebrates at stream mouths may provide other forage sources for the insectivorous fish, with terrestrial insects typically being the most important food source for large lakes in the Kootenay region (Arndt 2009).

Fixed receiver tracking

Throughout the course of this study, 27 fish were implanted with biotelemetry tags. Radio telemetry had limited use: small sample size made tracking via aerial methods uneconomical and opportunistic ground tracking did not detect fish. Acoustic telemetry provided some useful information; however, readers should note that the following discussion is based on a small sample size.

Generally, the majority of detections outside of the spawning season (i.e., July to March) were between the outlet of Canoe Reach and the Sullivan Bay entrance. Rainbow Trout 157 had the greatest coverage of the reservoir, traveling between the outlet of Canoe Reach to Esplanade Bay at the southeast end of Kinbasket Lake. Large-scale movements of Rainbow Trout have been documented in other large systems where seasonal movements are made to access suitable habitat for feeding, overwintering or spawning (Ford et al. 1995, Andrusak and Thorley 2013). Rainbow Trout 116 traveled the least of the tagged fish, with detections only at the entrance of Sullivan Bay. Thus, Rainbow Trout home range size varied in Kinbasket Reservoir, with individuals ranging from relatively close to their capture location to highly mobile (Grant and Noakes 1987, Harrison et al. 2014).

Some limited information was available from this program for acoustically tagged Rainbow Trout movements during the spawning and spawning migration season. Throughout the course of this study, five fish were inferred to make spawning movements away from their home ranges. Four of these fish made both pre-spawn movements and post-spawn movements. Rainbow Trout 117 repeated the same pre-spawn movement timing and direction in 2017 that it had undertaken in 2016. Pre-spawn movements generally occurred between late March and late April, and post-spawn return movement generally occurred between late May and mid-June (Figure 10).

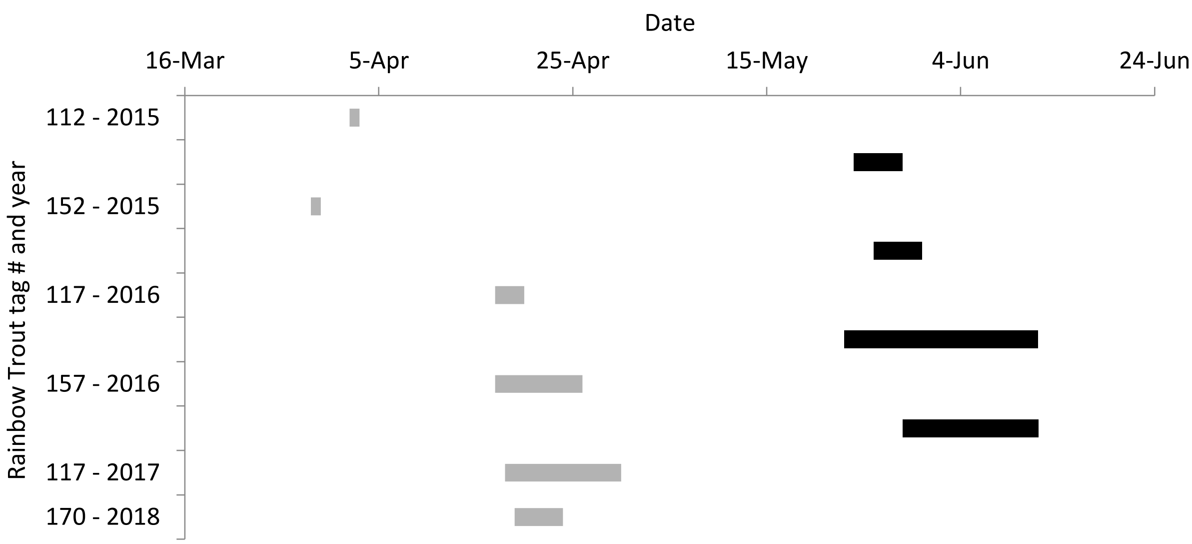


Figure 10. Pre (grey bars) and post (black bars) spawning migration timing interpreted from acoustic receiver detections of tagged fish during the generalized spawning period for Rainbow Trout. Pre-spawn bar width is the time period between the detection date of the fish leaving its home range and the last detection at subsequent upstream receivers within the reservoir. Post-spawn bar width is the time period that elapsed for the fish to make the return journey during the pre-spawn period. Post-spawn timing tracking was not available in 2017 and 2018, hence only pre-spawn movement were inferred for fish #117 and #170.

Timing of pre and post-spawn movements were similar to the timing of migration and spawning observed in tributaries to Arrow Lakes Reservoir (Toth and Tsumura 1996, Drieschner et al. 2008). Location of spawning was not possible to determine, but it appears that all five fish made directed movements to the upstream portions of the Columbia Reach and Upper Columbia areas of the Reservoir in the pre-spawn period. Detections of all five fish were made up to the inlet of Old Kinbasket Lake. Three fish continued upstream and were recorded at Surprise Rapids. Arndt (2009) speculated that Rainbow Trout may migrate upstream entirely from the Reservoir, up the Columbia River to spawn in tributaries; however, the receiver installed on Kinbasket Reservoir at Quartz Creek (close to the confluence of the Columbia River; Figure 3) did not detect any of the tagged Rainbow Trout.

The receiver coverage could only detect broad scale movements of fish away from their home ranges. Our methods thus do not have the ability to detect spawning migrations into tributaries within home ranges. Thus, it is possible that the majority of fish tracked in this study spawned in a tributary within their home range and we were unable to make inferences of spawning location or timing.

Tributary access, stream habitat and thermal suitability

Thirteen small tributaries were pre-selected as having possible Rainbow Trout spawning populations at the beginning of this study. Twelve were successfully surveyed during the course of this study, and surveys consisted of barrier assessment as well as physical habitat characterization. Stream habitat data was recorded through the spring period in all streams, but temperature data was only retrieved in five tributaries. Surveys took place during the general low pool period in late April and early May during the four years of this study, from 2015 to 2018. Reservoir elevation during this low pool survey period varied from year to year. As of May 1, the reservoir elevation was 738.1 m in 2015, 733.4 m in 2016, 729.1 m in 2017 and 720.3 m in 2018. Historically (1977 to 2014), the reservoir has experienced a mean reservoir elevation of 726.0 m, with a minimum elevation of 712.9 m and a maximum elevation of 736.6 m for this same date. Since low pool elevations were higher during most survey years than the lower minimum and mean low pool elevation the reservoir experiences, surveys only partially captured the full extent of the drawdown zone in most surveyed tributaries, to elevations of ~730 m in most streams. The full extent of the drawdown zone was captured in Packsaddle and Dave Henry Creeks and the Beaver River, as these streams flow into the Canoe and Columbia Rivers, respectively, during low pool reservoir elevation. In addition, a large portion of the drawdown zone of Succour Creek was surveyed, capitalizing on a low pool period in 2018 (to ~720 m).

Of all 12 tributaries surveyed, seven contained possible fish migration barriers through their drawdown zone reaches; however, only one contained a migration barrier considered impassable. A fish migration barrier considered impassable occurred on Tsar Creek, at an elevation of 735 m (Appendix B.2, Figure B-9) and would be exposed during periods of low pool in most years of operation, depending on the freshet volume. Windfall Creek in particular had five potential fish migration barriers, scattered throughout the drawdown zone, and thus tributary access may be an issue if adfluvial fish use this stream for spawning during periods of low reservoir elevations. However, it is unknown if either of these streams contain runs of adfluvial Rainbow Trout and would thus be impacted. A cascade is present at the top of the drawdown zone on the Beaver River, which may restrict fish migration (Appendix B.1., Photograph 21). This barrier has been exposed during the potential pre-spawn migration period (early spring) during all years of the operation of Mica Dam.

Bull Trout have been observed actively ascending the upper portion of the cascade, and large bodied, presumably adfluvial, Bull Trout spawn in tributaries to the Beaver River (Thorley 2013), thus the barrier may not restrict passage of all fish (Thorley 2013). It is possible that the barrier may restrict movement of Rainbow Trout, particularly smaller size classes, as smaller salmonids cannot ascend equivalent vertical barriers as successfully as larger conspecifics (Kondratieff and Myrick 2006).

Horse, Dave Henry and Yellowjacket Creeks flow into northeast shore of the Canoe Reach and all have similar, undefined channel morphologies. These streams flow through alluvial fans, braiding into multiple, shallow channels through extensive sections of the drawdown zone. Reservoir operations likely contribute to the instability of these channels, and impacts to Kokanee access have been observed in tributaries to the southern Arrow Lakes Reservoir during periods of low stream discharge (Hawes and Drieschner 2013, 2014). It is possible that the channels in some streams surveyed in this study may be too shallow to navigate under low flow regimes. We did not observe depths that would be considered too shallow to pass migratory fish in these streams in 2016, but flows were much higher than average for that time of year (Figure 11). These streams could contain fish passage barriers depending on flow, especially since Rainbow Trout spawning migration may occur during the period of pre-freshet base flow conditions, which coincides with the period of lowest elevations in Kinbasket Reservoir. It is, however, unknown if any of these streams contain runs of adfluvial Rainbow Trout and would thus be impacted. A large, impassable and natural fish migration barrier occurs on Dave Henry Creek 250 m upstream from the high pool elevation of Kinbasket Reservoir (Fielden et al. 1992), and thus may be unlikely to support a migratory population in any case.

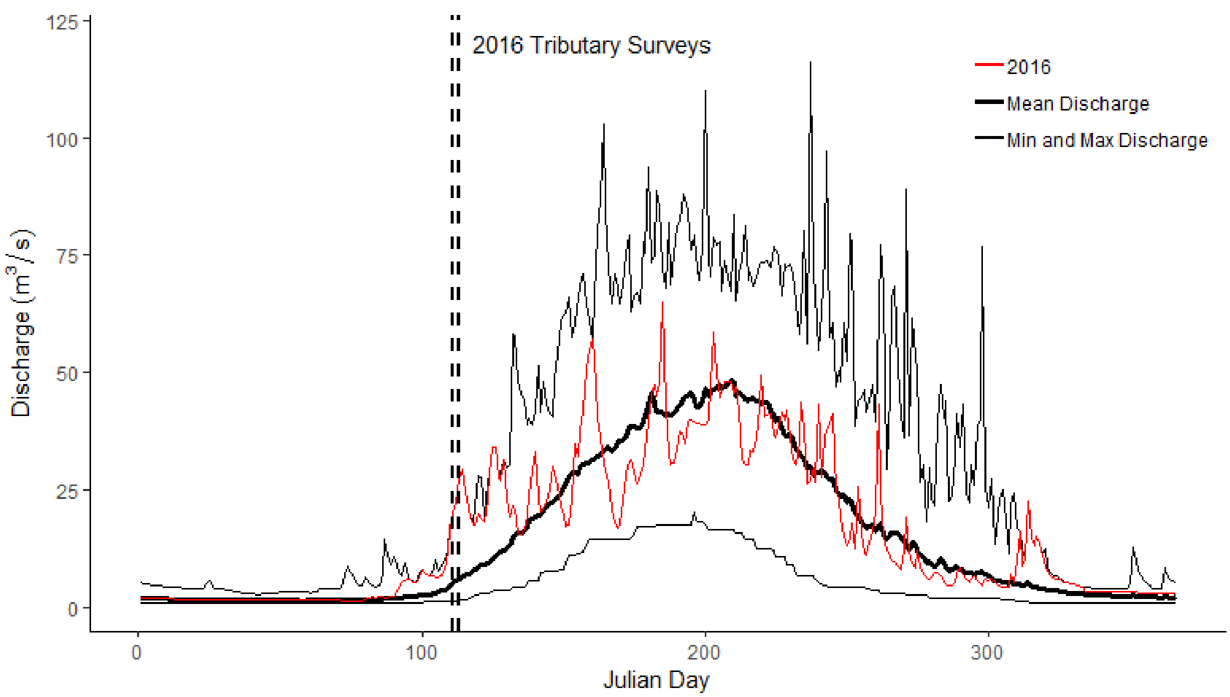


Figure 11. Stream discharge for Water Survey of Canada hydrometric station 08NC004 on the Canoe River (1971-2016). Minimum, maximum and mean discharge are presented along with 2016 discharge data. Vertical lines indicate when tributary surveys were conducted in 2016 (April 20th and April 22nd, 2016).

During the tributary surveys, the presence of suitable spawning substrates and their linear length were recorded. Gravel substrate approximately no larger than 10% of female spawner body length (Kondolf 2000) is considered suitable for spawning Rainbow Trout to construct their redds. Except for Succour Creek (cf. below), scattered spawning gravels were only observed in some reaches of many streams surveyed, particularly in the lower reaches (Appendix B.1, Photographs 14, 16, 18, and 23). Although these patches were not extensive, those in the lower reaches would be strongly affected by reservoir operations if they supported Rainbow Trout spawning, as their location within the drawdown zone occurs at elevations that would become inundated during the spring. Unlike all other streams surveyed, Succour Creek contained extensive reaches of gravel that may be suitable for Rainbow Trout spawning. The linear stream distance of reaches with potential spawning gravels was 3,290 m, totalled across all twelve surveyed streams; however, Succour Creek accounted for 2,328 m or 70.8% of this total linear distance.

Rainbow Trout spawn in the spring, and the redds of non-anadromous forms are generally shallow, and thus extremely sensitive to scour in snowmelt dominated watersheds with steep channel (>3%) morphology and spring flood disturbance (Montgomery 1999, Fausch et al. 2001). The hydrology of tributaries in Kinbasket Reservoir is, without exception, snowmelt dominated. Most tributaries of Kinbasket Reservoir contain step-pool channel morphology with steep (>3%) gradients (Fielden et al. 1992) that likely limit the suitability of spawning habitat due to spring scour. Most tributaries surveyed were on the border of or exceeded the 3% steepness threshold on average (Table 4), with plane-bed, step-pool and cascade channel morphology. Based on gradient and channel morphology, these tributaries are likely to have marginal suitability for spawning except through limited reaches where gradient becomes shallower (e.g., lower reaches; Appendix B.2.). In comparison to most tributaries sampled throughout the study program, only Succour Creek and the Beaver River contain significant reaches of low gradient habitat (Figure 12 and Figure 13).

Stream temperature profiles are likely to greatly influence the timing of spawning, subsequent embryo development and fry emergence timing. Temperature data were available in five streams sampled during the course of this study. This allowed the modelling of biological life cycle timing for spawning, embryo incubation, and emergence for Rainbow Trout in these streams during the reservoir refilling period. Potential impacts were predicted by determining whether reservoir operations resulted in the inundation of stream reaches with potentially suitable spawning substrate within each stream, prior to modeled spawn or emergence timing dates.

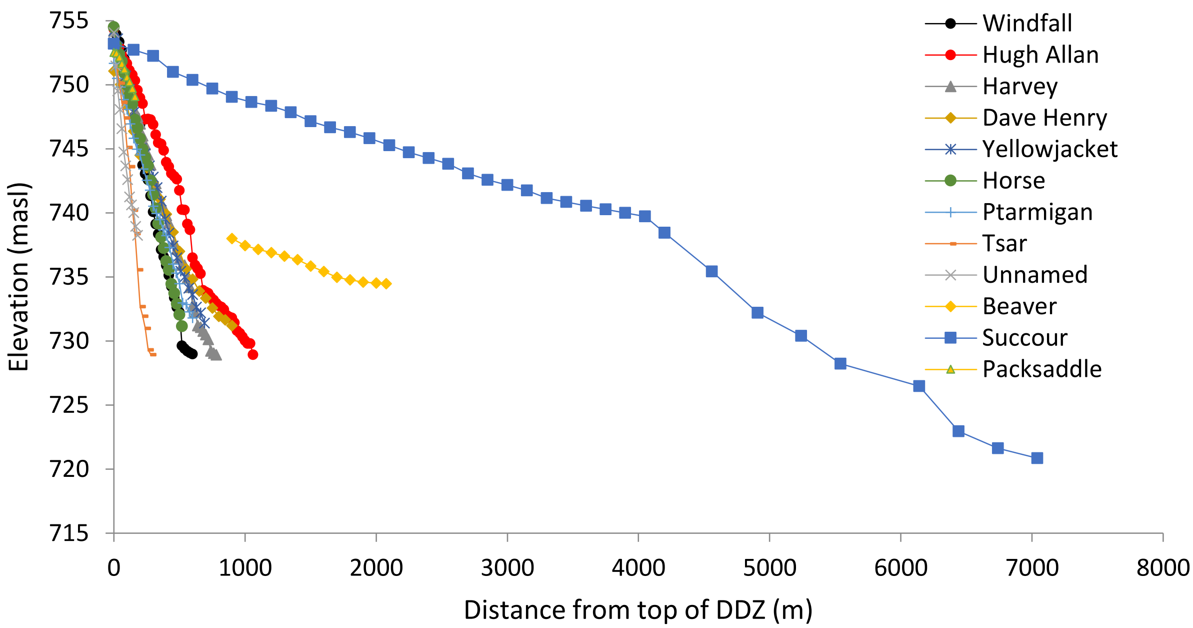


Figure 12. Longitudinal profile of tributaries sampled throughout the CLBMON-07 study program.

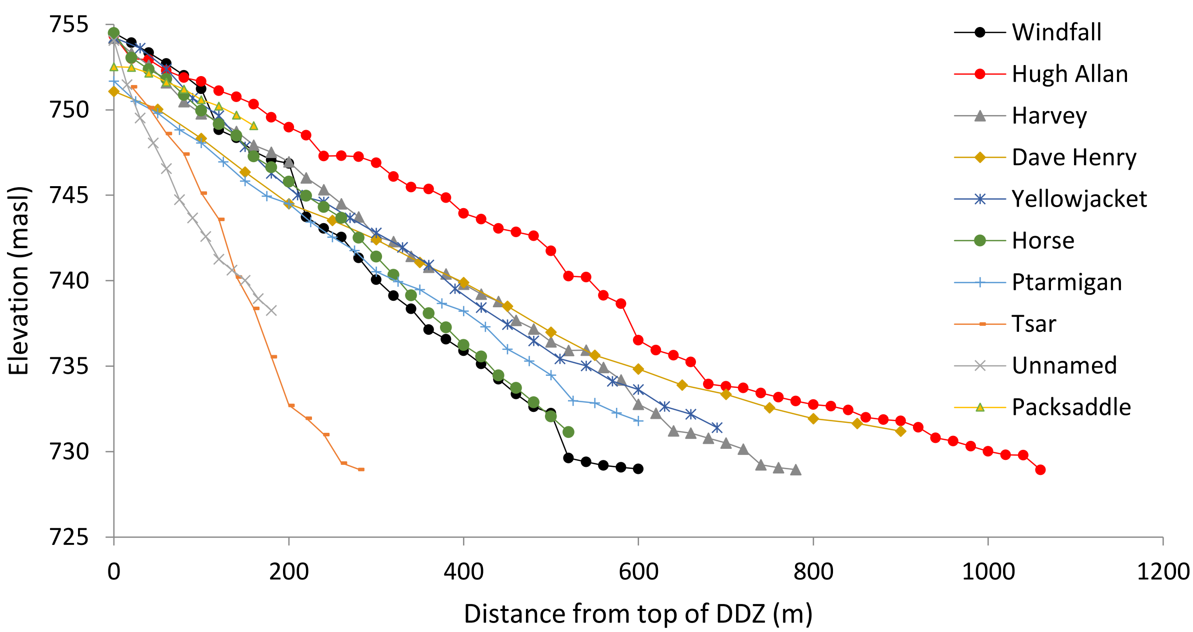


Figure 13. Longitudinal profile of tributaries sampled throughout the CLBMON-07 study program, excluding the Beaver River and Succour Creek.

In Succour Creek, thermal regimes were much warmer than the other four thermally measured streams, and the predicted commencement of spawn timing occurred during typical low pool, indicating a strong potential for impacts in the drawdown zone. The predicted severity of impact in this stream varied annually depending on the spring reservoir operation and stream temperature regime. In two out of four years for which data were available, the operations resulted in the inundation of most (75-81%) potentially suitable drawdown zone spawning habitat by the last modeled spawning and incubation date; however, in all years, the earliest modeled date of emergence occurred prior to most substrate being inundated (12-38% of suitable habitat inundated). Thus, while the impact from operations of reservoir inundation over suitable spawning habitat may be present in Succour Creek, our models suggest that the impact is not so severe as to completely exclude spawning and embryo incubation success during any year of study.

Spring temperatures were much colder in Yellowjacket, Dave Henry, Packsaddle and Encampment Creeks than in Succour Creek. This resulted in predicted spawn timing that would commence during the steep ascending limb of the refilling period. Thus, exposed habitat was limited to the upper reaches of these streams during the years of study. In Yellowjacket and Dave Henry Creeks, all stream reaches potentially suitable for spawning were either inundated prior to the first modeled date of spawning, or were subsequently inundated prior to the first possible date of modeled emergence timing. Habitat data were not available for Encampment Creek; however, modeled dates of first emergence were predicted during or after full pool operations in the summer. Thus, in these three streams, reservoir operations had the potential to completely exclude spawning or embryo incubation success within the drawdown zone to the full pool level during the years of observation. Packsaddle Creek did not contain suitable spawning substrates within the drawdown zone, and therefore would be unaffected by reservoir operations.

Stream temperature data were not available for most streams surveyed; however, given the similar attributes of Encampment, Yellowjacket, Packsaddle and Dave Henry Creeks to most other surveyed streams throughout the reservoir (latitude, gradient, mean elevation of drainage area, glacial influence, non-lake-headed, etc.), thermal regimes are more likely to be similar to these streams than to Succour Creek. Thus, other tributaries to Kinbasket Reservoir are likely to have spawn timing restricted to later in the spring. It is likely that most streams surveyed would experience severe impacts to any population component of Rainbow Trout that attempted to spawn within the drawdown zone given these later spawn timings dates. Upper reaches of drawdown zones (~upper 5 m of drawdown zone from maximum full pool elevation) may be buffered from impacts, since full pool elevations vary annually; however, few streams had a significant amount of substrate suitable for spawning observed in the upper reaches of the drawdown zone.

Habitat surveys and stream temperature modeling were conducted in small tributaries to Kinbasket Reservoir. The reservoir has many larger tributaries (e.g., Canoe River, Columbia River, Bush River, etc.) which could not be assessed according to methodology in this study. Therefore, is it unknown whether suitable habitat exists for Rainbow Trout spawning in these larger river environments, or how the life-cycle timing is mediated by their temperature in conjunction with spring reservoir operations.

Snorkel surveys

Succour Creek was selected for snorkel surveys in order to determine spring occupation of the drawdown zone and spawning by Rainbow Trout. Although the extensive drawdown zone of Succour

Creek contains habitat that appears to have the potential to support spawning during the periods of the survey, no mature Rainbow Trout were observed, and there was no evidence of redd construction in any year of study. Snorkel surveys in all three years of study occurred during times that coincided with, or occurred subsequent to, the thermally suitable time period for spawning.

Salmonid spawn timing is selected to optimize survival to emergence and ensure that emergence timing occurs during a favourable period for growth (Brannon 1987, Quinn 2005). Given the expected timing of first emergence, it is possible that Rainbow Trout are limited by rapidly escalating temperatures or inundation prior to emergence for most spawning dates, for most locations in the drawdown zone of Succour Creek. It is also possible that the drawdown zone suffers from extremely poor productivity of benthic invertebrates and does not provide feeding opportunities for emergent fry (Brännäs 1995). Rainbow Trout, like all salmonids, return to natal areas to spawn. It is possible that the habitat is severely limited (for any of the above reasons or other reasons) to the extent that the local spawning population has been extirpated and cannot re-establish itself in the drawdown zone.

Fish abundance and diversity in the drawdown zone of Succour Creek in May and June was high, and very large numbers of Largescale Sucker were observed in all three years of study. These fish were large bodied and exhibited colouration indicative of secondary sex characteristics displayed during spawning. Habitat characteristics in the stream were consistent with those reported as preferred by Largescale Sucker (McPhail 2007). Succour Creek appears to support a large spawning population of adfluvial Largescale Sucker, a life history form that has not previously been reported to our knowledge. An interesting observation is the relatively high abundance of other species, particularly juvenile Rainbow Trout and Mountain Whitefish, coinciding with the presence of the Largescale Sucker. The higher abundance of these species at this time could be explained by preference for the habitat at this time of year, migration through the drawdown zone, or feeding opportunities for eggs released during Largescale Sucker spawning events.

CONCLUSIONS

Throughout the course of this study, several observations were made to further our understanding of Rainbow Trout life history and habitat use in Kinbasket Reservoir and its tributaries. The following sections address each management question, and discuss the conclusions with respect to each question and associated management hypotheses.

Management Question 1
What are some of the basic biological characteristics of Rainbow Trout in Kinbasket Reservoir?

Based on fish capture metrics, and weight-of-evidence from concurrent Water Use Planning studies, abundance of Rainbow Trout in Kinbasket Reservoir appears to be low to moderate in recent years, and compared to other large Lakes in the Kootenay Region. Capture rates were especially low for large-bodied (>500 mm) fish.

It is possible that piscivorous and non-piscivorous forms of Rainbow Trout may be present in Kinbasket Reservoir, although these observations were not supported by sample sizes that permit statistical testing. Other studies in have shown that morphological differences within a species were associated with different feeding strategies and prey use (Wainwright and Barton 1995, Keeley et al. 2005). If two different Rainbow Trout forms indeed exist, the large-bodied piscivorous form is likely less abundant, as capture rates were extremely low for larger size classes, despite capture bias in angling method for large fish.

Capture success of large fish was low, and few Rainbow Trout were of sufficient size to be surgically implanted with biotelemetry tags, limiting sample size for tracking movements throughout the course of this study. Tagged fish were observed to have individual differences in home range size and location, with the most frequent home ranges between the confluence and the inlet into Kinbasket Lake (Figure 3). Some spawning migrations appeared to occur to and from home ranges, with several fish migrating upstream from Surprise Rapids in the Columbia Reach of the Reservoir in late March to early April, and returning between late May and mid-June. This may indicate movements of fish to spawning locations at the southern end of the reservoir, and provides some data on the possible timing of pre and post spawn movements.

Management Question 2 and associated Management Hypotheses
Does operation of Kinbasket Reservoir result in blockage or reduced success of upstream migration of Rainbow Trout spawners in tributary streams?

H1: The productivity of Rainbow Trout populations is limited by habitat impacts directly related to operation of Kinbasket Reservoir.

H1A: Operation of the reservoir restricts upstream passage of Rainbow Trout spawners to reservoir tributaries due to low water elevations.

It is possible that barriers exposed in the drawdown zone of seven of 12 surveyed tributaries impede fish migration, and thus could reduce the success of upstream migration of Rainbow Trout spawners in tributary streams.

With respect to Management Hypothesis H1, barriers that were exposed in small streams could have been created or exacerbated by habitat impacts directly related to operation of Kinbasket Reservoir. Shallow braiding in the alluvial fans of the lower drawdown zone reaches of some tributaries may restrict migration during years of especially low flows. The braiding and undefined channel morphology in these streams may have been exacerbated by reservoir operations disturbing channel maintenance through the removal of rooted vegetation and inundation during high flow events. Barriers formed in other small streams due to jammed large woody debris or boulders may not benefit from channel-redefining flows, as operations inundate streams through freshet periods.

Further barrier assessment and remediation may be a relatively low-cost and a multi-year option to improve fish passage conditions. Barrier remediation would not however apply to the top of the drawdown zone of the Beaver River. This barrier is formed from a bedrock channel confinement, and is not exacerbated by the operations of Kinbasket Reservoir. It is unknown whether this is a complete or partial fish migration barrier, but its presence predates the reservoir and thus should not be considered an interruption to the natural processes that regulate fisheries production potential in Kinbasket Reservoir.

It is important to note that our surveys did not capture the full extent of the drawdown zone in many tributaries and may underestimate the presence of barriers at lower reservoir elevations; however, since these would not be exposed in all years, their presence would have limited consequences.

Biotelemetry methods employed in this study could not detect migrations into tributaries to test Management Hypothesis H1A directly. Given the poor capture success of Rainbow Trout in the reservoir and technology constraints, as well as difficult study conditions during the Rainbow Trout migration time period, it is unlikely that biotelemetry could confidently determine system-wide adfluvial migration patterns of Rainbow Trout into small tributaries of Kinbasket Reservoir.

Although the drawdown zones of larger tributaries (e.g., Columbia River, Canoe River) were not surveyed, there is no previous record in the literature to suggest that fish migration barriers occur in these streams.

Management Question 3 and associated Management Hypotheses
Does operation of Kinbasket Reservoir cause the flooding of Rainbow Trout spawning habitat within the drawdown zone and lower sections of tributaries, causing adverse effects on egg and fry survival?

H1A: The productivity of Rainbow Trout populations is limited by habitat impacts directly related to operation of Kinbasket Reservoir.

H1B: Operation of the reservoir reduces Rainbow Trout egg and fry survival due to inundation of spawning habitats within the drawdown zone.

Typical spring operations of Kinbasket Reservoir could impact or exclude spawning of Rainbow Trout in typical small, high-gradient and cold tributaries of Kinbasket Reservoir, through inundation of suitable spawning habitats in the drawdown zone; however, the total amount of spawning habitat available appears limited and marginal in these streams at reservoir elevations between ~730 m and the full pool elevation of ~754 m. The exception to this pattern is found in Succour Creek, which may permit earlier spawning and has extensive habitat that appears suitable for Rainbow Trout spawning throughout its drawdown zone between ~720 m and ~754 m. Despite the apparent suitability of this habitat, no Rainbow Trout spawning was observed in this stream through three years of observation.

In ten surveyed streams, habitat suitability for Rainbow Trout spawning within the drawdown zone appeared marginal and limited in the surveyed length. Channel morphology, stream gradient, and substrate in these streams were generally not aligned with conditions considered suitable for Rainbow Trout from those described in the literature. In addition, the spring thermal regimes of surveyed streams, except for Succour Creek, would likely restrict spawning to late spring and early summer, during the period of rapid reservoir refilling. This is likely to preclude the establishment of any spawning populations in the drawdown zones of these streams, as operations inundate significant drawdown zone reaches prior to the thermally suitable spawning period, and would also subsequently inundate all remaining exposed drawdown zone to the yearly full pool level prior to predicted fry emergence times. Habitat data collected in the Beaver River did not allow us to assess potential impacts in this river.

Unlike all other surveyed tributaries, Succour Creek contains extensive habitat which appears physically and thermally suitable to support Rainbow Trout spawning. Despite the apparent suitability of habitat, no Rainbow Trout spawning activity or redds were observed during extensive redd and snorkel surveys in any of the four years of study. It is possible that operations contribute to the persistent lack of establishment of a localized Rainbow Trout spawning population through interrupting spawning or embryo incubation.

Hypothesis H1A (the productivity of Rainbow Trout is limited affected by impacts directly related to operations) could not be directly tested because the ability of these tributaries to support adfluvial Rainbow Trout spawning above the drawdown zone is currently unknown. Although we did not find evidence that Rainbow Trout were migrating into tributaries, it is currently not possible to reject the possibility that reservoir operations may impede Rainbow Trout migration through the drawdown zone of some small tributaries.

With respect to hypothesis H1B (operations reduce Rainbow Trout egg and fry survival through inundation of drawdown zone spawning habitat), the hypothesis could not be directly tested because there is no evidence that Rainbow Trout populations currently use the drawdown zone of small tributaries between reservoir elevations of ~730 and 754 m.

The hypotheses could not be tested in large tributaries (e.g., Canoe, Columbia Rivers), since methods used in this study could not be used in streams of this size. Methods to determine operational impacts in streams this size may include large-river physical habitat modeling (Golder 2013) or direct assessment of spawning via aerial methods (Irvine et al. 2018).

Management Question 4
Can modifications be made to the operation of Kinbasket Reservoir to protect or enhance spawning success of these Rainbow Trout populations?

It is unlikely that operational modifications would significantly benefit Rainbow Trout populations in small tributaries to Kinbasket Reservoir, if a winter and spring operation resembling the current proceeds. The drawdown zone appears largely marginal and limited to support Rainbow Trout spawning in most tributaries, and minor operational modifications may not improve these conditions in most streams.

Fish passage conditions may be improved in some small tributaries to the Reservoir, but this can likely be achieved through physical works after further assessment rather than operational modifications.

RECOMMENDATIONS

1) Implement a more comprehensive program directed to understanding basic biology of Rainbow Trout in Kinbasket Reservoir, including robust methodology for population size estimation
2) Undertake a genetic study to examine the potential for Rainbow Trout sub-populations.
3) Potential for fish passage:
    a. Assess the location and timing of barriers to Rainbow Trout passage in tributaries.
    b. Scope the feasibility of minor fish passage improvements in the drawdown zones of streams where fish passage impediments have been confirmed.
4) Determine whether large tributaries to Kinbasket Reservoir (e.g., Columbia River, Canoe River etc.) have the potential to, or currently, support Rainbow Trout spawning through the drawdown zone.
5) Determine whether there are proximate causes preventing Rainbow Trout from spawning in the drawdown zone of Succour Creek.

REFERENCES

Andrusak, H. and G. Andrusak, 2006. Analysis of Gerrard Rainbow Trout size, age, fecundity and growth data. Prepared for the Habitat Conservation Trust Foundation, Nelson, B.C.

Andrusak, G.F., and J.L. Thorley, 2013. Kootenay Lake Exploitation Study: Fishing and Natural Mortality of Large Rainbow Trout and Bull Trout: 2013 Annual Report. Prepared for the Habitat Conservation Trust Foundation, Victoria, B.C.

Arndt, S., 2009. Footprint impacts of BC Hydro dams on rainbow trout in the Columbia River Basin, British Columbia. Prepared for the Columbia Basin Fish and Wildlife Compensation Program. Nelson, B.C.

BC Hydro, 2007. Columbia River Projects Water Use Plan. Revised for Acceptance by the Comptroller of Water Rights.

Bjornn, T. C., and D. W. Reiser, 1991. Habitat requirements of salmonids in streams. Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. American Fisheries Society Special Publication **19**:83-138.

Brännäs, E. 1995. First access to territorial space and exposure to strong predation pressure: a conflict in early emerging Atlantic salmon (*Salmo salar* L.) fry. Evolutionary Ecology **9**:411-420.

Brannon, E. L. 1987. Mechanisms stabilizing fry emergence timing. Canadian Special Publication of Fisheries and Aquatic Sciences **96**:120-124.

Bray, K., 2002. Fish derby summary: Shelter Bay, Nakusp, and Mica 1997-2001. Prepared for Columbia Basin Fish & Wildlife Compensation Program. Revelstoke, B.C.

Caley, K.A., and W.G. Warnock. 2016. WLR Monitoring Study No. CLBMON-07 (Year 1) Kinbasket Reservoir Rainbow Trout Life History and Habitat Use Assessment. Prepared for BC Hydro by the Canadian Columbia River Inter-tribal Fisheries Commission. Cranbrook, B.C.

Caley, K.A., and W.G. Warnock. 2017. WLR Monitoring Study No. CLBMON-07 (Year 2) Kinbasket Reservoir Rainbow Trout Life History and Habitat Use Assessment. Prepared for BC Hydro by the Canadian Columbia River Inter-tribal Fisheries Commission. Cranbrook, B.C.

Carter, K. 2008. Effects of Temperature, Dissolved Oxygen/Total Dissolved Gas, Ammonia, and pH on Salmonids: Implications for California's North Coast TMDLs. California Regional Water Quality Control Board, North Coast Region.

Carufel, L.H., 1980. Construction and use of a velocity head rod for measuring mountain stream velocity and flow. BLM/Alaska Technical Report 5, pp. 10.

Decker, S., and J. Hagen, 2007. Distribution of adfluvial bull trout production in tributaries of the Arrow Lakes Reservoir and the feasibility of monitoring juvenile and adult abundance. prepared for Columbia Basin Fish & Wildlife Compensation Program. Nelson, B.C.

Drieschner, D., K. Hawes, M. A. Olson-Russello, and J. Schleppe, 2008. WLR Monitoring Study No. CLBMON-32A Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program. Prepared for BC Hydro. Castlegar, B.C.

Fausch, K. D., Y. Taniguchi, S. Nakano, G. D. Grossman, and C. R. Townsend, 2001. Flood disturbance regimes influence rainbow trout invasion success among five holarctic regions. Ecological Applications **11**:1438-1455.

Fidler, L. E., 1994. Camp Creek fishery study - 1993. prepared for B.C. Ministry of Environment, Lands and Parks. Aspen Applied Sciences Ltd. Valemount, B.C., pp. 42

Fielden, R. J., T. L. Slaney, and A. W. Wood, 1992. Survey of tributaries to Kinbasket Reservoir. Prepared for B.C. Hydro & B.C. Ministry of Environment, Lands and Parks. A. R. Ltd. Vancouver, B.C.

FIDQ. 2014. Fisheries information data queries. Ministry of Environment, Province of British Columbia. Accessed starting July 2014. Available from: http://a100.gov.bc.ca/pub/fidq/welcome.do

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 thirteen sport fish species in the Peace, Liard and Columbia River drainages of British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2321: pp. xxiv+342.

Golder Associates Ltd, 2003. Kinbasket Reservoir tributary fish passage improvement 2002-2003 Phase I. prepared for Columbia Basin Fish and Wildlife Compensation Program. Revelstoke, B.C.

Golder Associates Ltd, 2013. Lower Columbia River whitefish spawning ground topography survey: Year 3 data report. Report prepared for BC Hydro, Castlegar, B.C. Golder Report No. 10-1492-0142F: 68 p. + 3 app

Grant, J.W.A. and D.L.G. Noakes, 1987. Movers and stayers: foraging tactics of young-of-the-year Brook Charr, *Salvelinus fontinalis*. Journal of Animal Ecology **56**: 1001-1013.

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. G. Gutowsky, E. G. Martins, D. A. Patterson, S. J. Cooke, and M. Power. 2014. Personality-dependent spatial ecology occurs independently from dispersal in wild burbot (*Lota lota*). Behavioral Ecology **26**

Hawes, K., and D. Drieschner, 2012. WLR Monitoring Study No. CLBMON-32A (Year 4) Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program. Prepared for BC Hydro. Ecoscape Environmental Consultants Ltd. Kelowna, B.C.

Hawes, K., and D. Drieschner, 2013. WLR Monitoring Study No. CLBMON-32A (Year 5) Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program. Prepared for BC Hydro. Ecoscape Environmental Consultants Ltd. Kelowna, B.C.

Hawes, K., D. Drieschner, and R. Wagner, 2011. WLR Monitoring Study No. CLBMON-32A (Year 3) Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program. Prepared for BC Hydro. Ecoscape Environmental Consultants Ltd. Kelowna, B.C.

Hawes, K., D. Drieschner, and R. Wagner, 2014. WLR Monitoring Study No. CLBMON-32A (Year 6) Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program. Prepared for BC Hydro. Ecoscape Environmental Consultants Ltd. Kelowna, B.C.

Hawes, K., and R. Wagner, 2010. WLR Monitoring Study No. CLBMON-32A (Year 2) Arrow Lakes Tributary Fish Migration Access Assessment and Monitoring Program. Prepared for BC Hydro. Ecoscape Environmental Consultants Ltd. Kelowna, B.C.

Irvine, R. L., J. Baxter, and J. L. Thorley, 2013. WLR Monitoring Study No. CLBMON-46 (Year 5) Lower Columbia River Rainbow Trout Spawning Assessment. Prepared for BC Hydro. Castlegar, B.C.

R.L. Irvine, J.T.A., Baxter, and J.L. Thorley (2018). WLR Monitoring Study No. CLBMON-46 (Year 10) Lower Columbia River Rainbow Trout Spawning Assessment. Columbia River Water Use Plan. BC Hydro, Castlegar, B.C. A Mountain Water Research and Poisson Consulting Ltd. Final Report.

Kang, M., Warnock, W.G, Cope, R.S. and A. Prince. 2015. WLR Monitoring Study CLBMON-05 (Year 2) Kinbasket Reservoir Burbot Life History and Habitat Use Assessment. Prepared for BC Hydro by the Canadian Columbia River Inter-tribal Fisheries Commission and Westslope Fisheries Ltd., Cranbrook, BC.

Kondolf, G. M., 2000. Assessing salmonid spawning gravel quality. Transactions of the American Fisheries Society **129**:262-281.

McCullough, D., S. Spalding, D. Sturdevant, and M. Hicks, 2001. Issue Paper 5. Summary of technical literature examining the physiological effects of temperature on salmonids. Prepared as part of U.S. EPA Region 10 Temperature Water Quality Criteria Guidance Development Project. EPA-910-D-01-005.

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

Montgomery, D. R., E. M. Beamer, G. R. Pess, and T. P. Quinn, 1999. Channel type and salmonid spawning distribution and abundance. Canadian Journal of Fisheries and Aquatic Sciences **56**:377-387.

Muhlfeld, C. C., 2002. Spawning characteristics of redband trout in a headwater stream in Montana. North American Journal of Fisheries Management **22**:1314-1320.

Oliver, G. G., 2001. 2001 fish access assessment of selected tributaries to Kinbasket Reservoir. Prepared for BC Hydro. Castlegar, B.C.

O'Neal, J. S., 2007. Snorkel surveys. *Salmonid Field Protocols Handbook: Techniques for Assessing Status and Trends in Salmon and Trout Populations.* American Fisheries Society, Bethesda, Maryland.

Keeley, E.R., Parkinson, E.A., and E.B. Taylor, 2005. Ecotypic differentiation of native rainbow trout (*Oncorhynchus mykiss*) populations from British Columbia. Can. J. Fish. Aquat. Sci. **62**: 1523-1539.

Peterson, G. R., and I. C. Withler, 1965. Effects on fish and game species of development of Mica Dam for hydroelectric purposes. Prepared for BC Fish and Wildlife Branch. Victoria, B.C.

Pole, M., 1995. 1994 Kinbasket Reservoir creel survey. Prepared for Columbia Basin Fish & Wildlife Compensation Program. Nelson, B.C.

Prince, A., 2001a. 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

Prince, A., 2001b. Local Knowledge of Columbia River fisheries in British Columbia, Canada. Prepared for the Columbia-Kootenay Fisheries Renewal Partnership, Cranbrook, B.C.

Quinn, T. P. 2005. The behavior and ecology of Pacific salmon and trout. American Fisheries Society in association with the University of Washington Press, Bethesda, MD.

Taylor, E. B., 2000. Microsatellite DNA polymorphism in rainbow trout (*Oncorhynchus mykiss*) from the Upper Arrow and Kinbasket Watersheds in British Columbia, Part II: analysis at additional loci. Prepared for Columbia Basin Fish & Wildlife Compensation Program. Vancouver, B.C.

Toth, B. M., and K. Tsumura, 1996. Arrow Lakes rainbow trout broodstock collection. Prepared for Columbia Basin Fish & Wildlife Compensation Program. Nelson, B.C.

Wainwright, P.C. and B.A. Richard, 1995. Predicting patterns of prey use from morphology of fishes. Environmental Biology of Fishes **44**: 97-113.

Warnock, W.G, Cope, R.S. and A. Prince, 2014. WLR Monitoring Study No. CLBMON-05 (Year 1) Kinbasket Reservoir Burbot Life History and Habitat Use Assessment. Prepared for BC Hydro by the Canadian Columbia River Inter-Tribal Fisheries Commission and Westslope Fisheries Ltd. Cranbrook, B.C.

APPENDIX A.1 – Rainbow Trout capture data

ID	Capture Date/Time		Capture Location			Species Code	Recap (Y/N)	Acoustic Code	Radio Code	Radio Freq	Length (mm)	Weight (kg)	MORT (Y/N)	Sex (M/F)	Tissue (Y/N)	Otolith (Y/N)	Fish Comments	H_2O ^0C	Weather & Water Conditions
	Date	Time	Easting	Northing	General Description														
1	16-Sep-14	14:00	404175	5773655	Confluence	BT	N				370		N	U	Y	N			clear, calm
2	16-Sep-14	17:49	406814	5771111	Confluence	RB	N				437	0.840	Y	U	Y	Y	mature yellowfin	14.9	clear, calm
3	17-Sep-14	11:50	402758	5780024	Canoe Reach	RT	N				320	0.370	N	U	Y	N	too small for tag	14.7	overcast, calm
4	17-Sep-14	13:03	402429	5780599	Canoe Reach	RB	N				380	0.590	N	U	Y	N	too small for tag	14.9	overcast, calm
5	17-Sep-14	16:30	402488	5780624	Canoe Reach	RB	N				405	0.740	N	U	Y	N	poor condition, hooked in eye	14.5	overcast, calm
6	17-Sep-14	16:59	402487	5780571	Canoe Reach	RB	N				385	0.550	N	U	Y	N	too small for tag; hooked in back	14.5	overcast, calm
7	17-Sep-14	17:30	402420	5780664	Canoe Reach	RB	N				415	0.660	Y	F	Y	Y	mature, hook broke off in head	14.5	overcast, calm
8	17-Sep-14	17:35	402564	5780495	Canoe Reach	BT	N				520	1.380	N	U	Y	N	hooked in belly, shallow wound	14.7	overcast, calm
9	18-Sep-14	10:15	410968	57777050	Wood Arm	RB	N				366	0.450	N	U	Y	N		14.5	light rain, calm
10	18-Sep-14	10:17	411064	5777079	Wood Arm	RB	N				370	0.570	N	U	Y	N	hooked in head	14.5	light rain, calm
11	18-Sep-14	11:30	416467	5776879	Wood Arm	RB	N				289	0.160	N	U	Y	N	hooked in eye	14.3	rain, calm
12	18-Sep-14	11:45	417386	5777323	Wood Arm	RB	N				285	0.110	N	U	Y	N	too small for tag	14.3	overcast, calm
13	18-Sep-14	14:32	402667	5780273	Canoe Reach	RB	N				388	0.500	N	U	Y	N	too small for tag	14.7	overcast, calm
14	18-Sep-14	15:20	402279	5778357	Canoe Reach	RB	N				413	0.500	N	U	Y	N	poor condition, head wound	14.7	overcast, calm
15	19-Sep-14	10:14	429804	5756212	Old Kinbasket Lake	RB	N	151	151	150.210	420	0.750	N	U	Y	N	good condition	14.5	partly cloudy, calm
16	19-Sep-14	12:10	435054	5755266	Old Kinbasket Lake	BT	N				460	0.848	N	U	Y	N		14.8	partly cloudy, calm
17	19-Sep-14	16:16	418779	5762967	Old Kinbasket Lake	BT	N				390	0.623	N	U	Y	N	hooked lower jaw, air in belly	14.5	partly cloudy, calm
18	20-Sep-14	9:18	393195	5772457	Mica Dam Forebay	BT	N				488	1.110	Y	F	Y	Y	hooked below gills, air in belly	13.3	partly cloudy, calm, light wind
19	20-Sep-14	9:37	394045	5773108	Mica Dam Forebay	RB	N				369	0.563	N	U	Y	N	hooked in eye, too small for tag	13.4	partly cloudy, calm, light wind
20	20-Sep-14	9:40	394422	5773217	Mica Dam Forebay	RB	N	152	152	150.210	409	0.811	N	U	Y	N		13.6	clear, calm
21	20-Sep-14	10:30	394920	5773793	Mica Dam Forebay	BT	N				350	0.400	N	U	Y	N		13.6	clear, calm
22	20-Sep-14	11:23	393330	5771490	Mica Dam Forebay	RB	N				365	0.603	Y	F	Y	Y	poor condition, mature	13.3	clear, calm
23	20-Sep-14	13:14	399994	5780253	Confluence	RB	N				372	0.616	N	U	Y	N	too small for tag	14.3	clear, calm
24	20-Sep-14	16:42	401714	5772787	Confluence	RB	N				376	0.609	N	U	Y	N	too small for tag	15.4	clear, calm
25	21-Sep-14	11:34	404559	5775543	Canoe Reach	RB	N	153	153	150.210	412	0.788	N	U	Y	N	good condition	14.8	clear, calm
26	21-Sep-14	12:38	404139	5774888	Canoe Reach	RB	N				400	0.766	Y	F	Y	Y	hooked through eye and into gills, mature	14.9	clear, calm
27	21-Sep-14	13:11	405241	5775292	Canoe Reach	RB	N				406	0.663	N	U	Y	N	hooked through eye, too small for tag	15.6	clear, calm
28	21-Sep-14	17:03	401517	5773882	Canoe Reach	RB	N	111	111	150.210	510	2.000	N	U	Y	N		15.3	clear, calm
29	21-Sep-14	17:20	401843	5773577	Canoe Reach	BT	N				455	1.100	N	U	Y	N	good condition	15.3	clear, calm
30	21-Sep-14	17:39	402168	5773271	Canoe Reach	RB	N				539	2.330	Y	F	Y	Y	injury on side where hooked	15.2	clear, calm
31	22-Sep-14	15:55	401476	5776504	Confluence	RB	N	112	112	150.210	588	3.100	N	U	Y	N	good condition	14.6	rain, small waves
32	22-Sep-14	16:02	401438	5776296	Confluence	RB	N				564	2.100	Y	F	Y	Y	stomach full of kokanee, mature	14.6	rain, small waves
33	23-Sep-14	9:05	397966	5775800	Confluence	BT	N				550	1.560	N	U	Y	N	good condition	14.0	overcast, small waves

ID	Capture Date/Time		Capture Location			Species Code	Recap (Y/N)	Acoustic Code	Radio Code	Radio Freq	Length (mm)	Weight (kg)	MORT (Y/N)	Sex (M/F)	Tissue (Y/N)	Otolith (Y/N)	Fish Comments	H_2O ^0C	Weather & Water Conditions
	Date	Time	Easting	Northing	General Description														
34	23-Sep-14	10:05	398934	5775358	Confluence	RB	N				394	0.680	N	U	Y	N	too weak for surgery, borderline weight and length	14.0	overcast, small waves
35	24-Sep-14	12:10	429792	5753887	Old Kinbasket Lake	RB	N				468	1.060	Y	F	Y	Y		14.6	rain, small waves
36	24-Sep-14	13:24	433053	5753091	Old Kinbasket Lake	RB	N				484	1.600	N	U	Y	N	too weak for surgery	14.5	rain, small waves
37	24-Sep-14	14:25	432911	5753517	Old Kinbasket Lake	BT	N				438	0.810	N	U	Y	N		14.4	rain, small waves
38	24-Sep-14	14:34	433225	5753303	Old Kinbasket Lake	RB	N	113	113	150.210	517	1.910	N	U	Y	N		14.4	rain, small waves
39	24-Sep-14	15:05	433507	5752905	Old Kinbasket Lake	BT	N				438	0.830	N	U	Y	N		14.2	rain, small waves
40	24-Sep-14	15:27	433686	5752383	Old Kinbasket Lake	BT	N				512	1.410	N	U	Y	N		14.1	rain, small waves
41	25-Sep-14	11:18	384628	5807490	Canoe Reach	RB	N				387	0.588	N	U	Y	N	too small for tag, hooked through eye	13.3	rain, calm
42	25-Sep-14	15:26	356980	5845934	Canoe Reach	RB	N	154	154	150.210	422	0.780	N	U	Y	N	good condition	13.1	light rain, calm
43	26-Sep-14	10:00	394502	5794260	Canoe Reach	RB	N	155	155	150.210	419	0.745	N	U	Y	N	good condition, hooked through operculum	13.7	overcast, calm
44	26-Sep-14	14:45	401482	5779104	Confluence	BT	N				498	1.110	N	U	Y	N		13.7	rain, choppy
45	26-Sep-14	15:57	401435	5774852	Confluence	BT	N				424	0.750	N	U	Y	N		13.8	light rain, choppy
46	26-Sep-14	16:46	401919	5773220	Confluence	RB	N	114	114	150.210	736	3.300	N	F	Y	N	good condition	14.0	overcast, slightly choppy
47	26-Sep-14	18:06	401265	5773366	Confluence	RB	N	115	115	150.210	432	0.956	N	U	Y	N		13.9	overcast, slightly choppy
48	27-Sep-14	14:41	402424	5773533	Confluence	BT	N				488	1.275	N	U	Y	N	parasite (lice) on fins	15.4	clear, calm
49	27-Sep-14	15:06	401268	5773685	Confluence	RB	N				375	0.519	N	U	Y	N	too small for tag	15.4	clear, calm
50	27-Sep-14	17:46	402440	5772789	Confluence	RB	N				310	0.337	N	U	Y	N	too small for tag	14.8	clear, calm
51	27-Sep-14	18:12	401252	5773253	Confluence	BT	N				543	2.182	N	U	Y	N		14.5	clear, calm
1	25-Sep-15	13:26	455165	5730819	Upper Columbia (Succour Cr)	BT	N				530	1.250	N	U	Y	N	good condition	12.4	rain, wind
2	26-Sep-15	13:32	454997	5728697	Upper Columbia (Gold Cr)	BT	N				415	0.670	N	U	Y	N	slight bleeding from gills	12.2	overcast, calm
3	27-Sep-15	10:11	451234	5728549	Upper Columbia (Gold Cr)	BT	N				306	0.246	N	U	Y	N	good condition	11.3	overcast, calm
4	27-Sep-15	10:33	451187	5728407	Upper Columbia (Gold Cr)	RB	N				285	0.240	N	U	Y	N	good condition	11.3	overcast, calm
5	27-Sep-15	12:22	453744	5729708	Upper Columbia (Gold Cr)	RB	N				337	0.456	N	U	Y	N	good condition	11.6	overcast, calm
6	28-Sep-15	11:48	401525	5772931	Confluence	RB	N				400	0.650	N	U	Y	N	good condition	12.9	mixed, calm
7	28-Sep-15	12:32	400775	5773247	Confluence	RB	N	157	157	150.210	441	0.950	N	U	Y	N	damage to one eye	13.1	mixed, calm
8	28-Sep-15	14:11	400644	5773341	Confluence	RB	N	158	158	150.210	423	0.900	N	U	Y	N	good condition	13.2	mixed, calm
9	28-Sep-15	14:44	400983	5773171	Confluence	RB	N	159	159	150.210	472	1.100	N	U	Y	N	good condition	13.3	mixed, calm
10	28-Sep-15	16:06	400710	5773280	Confluence	RB	N				429	0.850	N	U	Y	N	hooked in top of mouth and eye	13.3	mixed, calm
11	28-Sep-15	18:25	401356	5773522	Confluence	RB	N	160	160	150.210	442	0.950	Y	U	Y	N	hooked in eye	13.2	mixed, calm
12	29-Sep-15	16:02	402838	5773012	Confluence	RB	N				371	0.400	N	U	Y	N	good condition	13.0	overcast, calm
13	29-Sep-15	16:35	401667	5772814	Confluence	RB	N				434	0.790	N	U	Y	N	good condition	13.0	overcast, calm
14	29-Sep-15	16:46	400926	5773160	Confluence	BT	N				464	0.980	N	U	Y	N	good condition; lice	12.9	overcast, calm

ID	Capture Date/Time		Capture Location			Species Code	Recap (Y/N)	Acoustic Code	Radio Code	Radio Freq	Length (mm)	Weight (kg)	MORT (Y/N)	Sex (M/F)	Tissue (Y/N)	Otolith (Y/N)	Fish Comments	H_2O ^0C	Weather & Water Conditions
	Date	Time	Easting	Northing	General Description														
15	29-Sep-15	17:48	400721	5773414	Confluence	RB	N				409	0.710	N	U	Y	N	good condition	12.7	overcast, calm
16	30-Sep-15	8:59	398863	5776668	Confluence	RB	N				359	0.450	Y	U	Y	Y	hooked under tongue	12.3	overcast, wind
17	30-Sep-15	10:26	399736	5779114	Confluence	BT	N				715	3.450	N	M	Y	N	good condition	12.3	clear, wind
18	30-Sep-15	12:19	400052	5778365	Confluence	RB	N	156	156	150.210	530	1.080	N	U	Y	N	good condition	12.8	overcast, calm
19	30-Sep-15	14:37	404893	5777899	Confluence	RB	N				395	0.630	N	U	Y	N	good condition	13.1	overcast, calm
20	30-Sep-15	15:13	404922	5777849	Confluence	RB	N				382	0.530	Y	F	Y	N	hooked in gill	13.3	overcast, calm
21	30-Sep-15	16:00	404968	5778135	Confluence	BT	N				685	3.850	N	M	Y	N	good condition	13.0	overcast, calm
22	30-Sep-15	16:49	404533	5777428	Confluence	BT	N				582	2.670	N	F	Y	N	good condition	13.4	overcast, calm
23	01-Oct-15	10:28	384193	5809754	Hugh Allan Cr	BT	N				508	1.240	N	U	Y	N	good condition	12.0	mixed, wind
24	01-Oct-15	17:40	394061	5793962	Foster Cr	RB	N				392	0.660	N	U	Y	N	lost one eye	12.5	clear, calm
25	01-Oct-15	17:49	394165	5793970	Foster Cr	RB	N				377	0.570	N	U	Y	N	signs of previous injuries	12.4	clear, calm
26	02-Oct-15	10:18	433140	5753139	Old Kinbasket Lake	BT	N				508	1.400	N	U	Y	N	good condition	12.5	overcast, calm
27	02-Oct-15	11:33	431711	5753954	Old Kinbasket Lake	BT	N				548	1.450	N	F	Y	N	good condition	12.6	overcast, calm
28	02-Oct-15	11:46	432485	5753529	Old Kinbasket Lake	RB	N	116	116	150.210	547	2.460	N	M	Y	N	good condition	12.6	overcast, calm
29	02-Oct-15	12:52	433323	5753375	Old Kinbasket Lake	RB	N				483	1.110	N	U	Y	N	good condition	12.6	overcast, calm
30	02-Oct-15	16:23	433171	5753284	Old Kinbasket Lake	RB	N	117	117	150.210	575	2.450	N	U	Y	N	good condition	12.5	rain, wind
31	03-Oct-15	12:42	404972	5778208	Confluence	RB	N				340	0.440	Y	F	Y	Y	hooked in head; insects in stomach	12.6	clear, calm
32	03-Oct-15	14:00	403937	5773929	Confluence	BT	N				492	1.180	N	U	Y	N	good condition; lice	12.5	clear, calm
33	03-Oct-15	16:34	397325	5773855	Confluence	RB	N				393	2.640	N	U	Y	N	hooked in head	12.4	clear, wind
1	30-Sep-17	14:59	404842	5778557	Mouth of Wood Arm	BT	N				525	1.16	N	U	Y	N	healthy	14.1	overcast, wavy
2	01-Oct-17	9:58	402329	5780735	Mouth of Wood Arm	RB	N	161	n/a	n/a	419	0.73	N	U	Y	N	foul hooked in eye and belly	13.2	overcast, wavy
3	01-Oct-17	10:43	404051	5778949	Mouth of Wood Arm	RB	N	162	n/a	n/a	410	0.84	N	U	Y	N	healthy	13.2	overcast, wavy
4	01-Oct-17	11:48	402633	5779944	Mouth of Wood Arm	RB	N	163	n/a	n/a	378	0.65	N	U	Y	N	healthy	13.3	overcast, wavy
5	01-Oct-17	13:33	404338	5778788	Mouth of Wood Arm	RB	N				345	0.48	N	U	Y	N	hooked in upper lip, healthy	13.3	overcast, wavy
6	02-Oct-17	13:55	410013	5769359	Columbia Reach (Narrows)	RB	N				407	0.57	Y	U	Y	Y	hooked in eye	13.3	partially overcast, wavy
7	02-Oct-17	14:19	414750	5766382	Columbia Reach (Narrows)	RB	N	164	n/a	n/a	416	0.67	N	U	Y	N	hooked in side of mouth	13.2	clear, calm
8	02-Oct-17	14:52	414959	5766136	Columbia Reach (Narrows)	RB	N	165	n/a	n/a	383	0.69	N	U	Y	N	hooked in top of mouth, healthy	13.2	clear, calm
9	02-Oct-17	15:32	415275	5766113	Columbia Reach (Narrows)	RB	N				390	0.73	Y	U	Y	Y	hooked in top of mouth, Healthy	13.2	clear, calm
10	03-Oct-17	11:00	415366	5765999	Cummins Cr	BT	N				507	1.13	N	U	Y	N	healthy	13.1	clear, calm
11	03-Oct-17	11:36	415262	5766161	Cummins Cr	BT	N				432	0.81	N	U	Y	N	healthy	13.1	clear, calm
12	03-Oct-17	12:31	415296	5765925	Cummins Cr	RB	N				374	0.61	Y	U	Y	Y	hooked on operculum	13.1	clear, calm
13	04-Oct-17	12:40	432850	5753818	Old Kinbasket Lake	BT	N				516	1.37	N	U	Y	N	hooked in mouth, healthy	13.3	clear, calm
14	04-Oct-17	15:22	433770	5754269	Old Kinbasket Lake	RB	N				364	0.54	Y	U	Y	Y	hooked in lower jaw, healthy	13.7	clear, calm
15	05-Oct-17	11:05	402455	5780665	Mouth of Molson Cr	RB	N	166	n/a	n/a	389	0.78	N	U	Y	N	healthy	13.0	clear, calm

ID	Capture Date/Time		Capture Location			Species Code	Recap (Y/N)	Acoustic Code	Radio Code	Radio Freq	Length (mm)	Weight (kg)	MORT (Y/N)	Sex (M/F)	Tissue (Y/N)	Otolith (Y/N)	Fish Comments	H_2O ^0C	Weather & Water Conditions
	Date	Time	Easting	Northing	General Description														
16	05-Oct-17	13:25	402504	5780622	Molson Cr	BT	N				608	1.96	N	U	Y	N	healthy	13.0	clear, calm
17	05-Oct-17	14:04	402536	5780438	Molson Cr	RB	N	171	n/a	n/a	354	0.56	N	U	Y	N	scar on head	13.2	clear, calm
18	05-Oct-17	14:47	404363	5778508	Molson Cr	RB	N	167	n/a	n/a	425	1.02	N	U	Y	N	healthy	13.6	clear, calm
19	05-Oct-17	16:34	397649	5773679	Molson Cr	RB	N	175	n/a	n/a	458	1.02	N	U	Y	N	pulled out eye while removing hook	13.4	clear, calm
20	06-Oct-17	12:47	400532	5775872	Encampment Cr	BT	N				525	1.6	N	U	Y	N	healthy	12.7	rain, windy
21	06-Oct-17	14:00	401797	5772913	Red Rock Canyon	BT	N				316	0.365	Y	U	Y	Y	terrestrial insects in stomach	12.6	rain, windy
22	06-Oct-17	14:48	402466	5772662	Red Rock Canyon	RB	N	170	n/a	n/a	382	0.816	N	U	Y	N	healthy	12.6	rain, windy
23	06-Oct-17	17:20	401081	5773204	Red Rock Canyon	BT	N				634	0.227	N	U	Y	N	healthy	12.6	calm
24	07-Oct-17	12:44	400282	3781962	Mouth of Canoe River	BT	N				426	0.68	N	U	Y	N	healthy	12.4	light wind
25	07-Oct-17	17:26	403853	5772253	Red Rock Canyon	BT	N				589	0.227	N	U	Y	N	healthy	12.6	light wind

APPENDIX A.2 – Rainbow Trout tracking descriptions

Acoustic tag 112 (possible spawning migration detected):

Captured on September 22nd, 2014 in the Confluence area (Figure 3), its last detection in the first year of tracking was on April 2nd, 2015 at the Kinbasket Lake outlet. Throughout the pre-spawning period in 2015 it was detected by the Sullivan Bay entrance receiver (March 1-3) and then only by the Kinbasket Lake inlet receiver (March 4th to April 2nd). It was next detected on May 24th, 2015 by the Kinbasket Lake south inlet receiver. Throughout most of May 2015 it remained near the Kinbasket River outlet and then moved to the Sullivan Bay entrance and the outlet of the Kinbasket River at the end of May. It was last detected on June 13th, 2015 at the entrance to Sullivan Bay. Since the fish left its preferred home range of the Kinbasket Lake area, in an upstream direction between April 2nd and May 24th, it is possible that the fish travelled upstream to an unknown location to spawn and returned. This fish was not redetected in the third year of tracking.

Acoustic tag 113:

Captured on September 24th, 2014 in Kinbasket Lake, its last detection in the first year of tracking was on March 27th, 2015 at the Sullivan Bay entrance receiver. The fish's preferred home range appeared to be in the Kinbasket Lake area. This tag was not re-detected after this date or in the second year of tracking. Although this fish was detected in the pre-spawn period in both 2014 and 2015, no inferences can be made about directed movements since it did not appear to make any directed movements. This fish was not redetected in the third year of tracking.

Acoustic tag 115:

Captured on September 26th, 2014 in the Confluence area, its last detection in the first year of tracking was on October 4th, 2014 at the south outlet of the Canoe Reach. It was not detected again until July 17th, 2015 at the north outlet of the Columbia Reach. Therefore, movement information is not available for the pre-spawn and spawning periods. This fish remained near the north outlet of the Columbia Reach until July 21st, 2015 where it was detected by the one of the Canoe Reach receivers. From the beginning of August until the end of October it moved between the Wood Arm outlet, Canoe Reach and north outlet of Columbia Reach. It was not re-detected until April 30th, 2016 at the most upstream receiver in the Canoe Reach. The fish was the redetected in its home range on May 8, 2016, and remained in the confluence/forebay area until the date of its last detection on June 27, 2016. No directed movements occurred in and out of this fish's home range of the Canoe reach and confluence/forebay.

Acoustic tag 116:

Captured on October 2nd, 2015 in Kinbasket Lake and was first detected on October 2nd, 2015 by one of the receivers in the Sullivan Bay entrance. Detections were made by the Sullivan Bay entrance receivers until December 3rd. It was not re-detected until April 2nd, 2016 where it was again in the Sullivan Bay entrance. The final detection in Year 2 was on April 27th, 2016 in the Sullivan Bay entrance. In Year 3, the fish remained in this area from May 12, 2016 until its final detection on November 24, 2016. The home range of this fish for tracking information available was restricted to the Kinbasket Lake area, and the fish used this area throughout the generalized spawn period.

Acoustic tag 117 (possible spawning migration detected):
Captured on October 2nd, 2015 in Kinbasket Lake and was first detected on October 10th, 2015 by one of the receivers in the Sullivan Bay entrance. It remained in the area of the Sullivan Bay entrance until October 6th, and then moved to the Kinbasket Lake outlet. Regular movements were then made between the outlet of Kinbasket Lake, the Kinbasket River outlet and the Sullivan Bay entrance between October 6th and February 11th, 2016. On February 19th it was detected at the south inlet of Kinbasket Lake where it stayed for the remainder of February. On April 17th and 18th it was detected at the south inlet of Kinbasket Lake and Surprise Rapids, respectively. The final detection in Year 2 was made on April 19th, 2016 in Esplanade Bay. In Year 3, it was next redetected in Esplanade Bay on May 23rd, 2016, subsequently detected at Surprise Rapids on June 11th, and then subsequently detected in Kinbasket Lake on June 18th. In 2016, this fish thus moved out of its preferred home range of the Kinbasket Lake area by Mid-April and was making a directed, rapid movement upstream towards the inlet of the Reservoir, which could indicate a pre-spawn movement to an upstream spawning area, then returned to its home range in a directed movement between late May and mid- June. The fish then remained in its home range of the Kinbasket Lake until its last detection on February 2, 2017. The fish then initiated what appears to be another directed upstream pre-spawn movement in mid-April 2017, as it was detected at Surprise Rapids on April 18th, 2017, and then subsequently at Esplanade Bay on April 28th, 2017.

Acoustic tag 152 (possible spawning migration detected):
Captured on September 20th, 2014 in the Mica Dam forebay, its last detection in the first year of tracking was on March 29th, 2015 at the outlet of the Sullivan River after having spent the previous winter in the Wood Arm, ~50 km away. It was re-detected on May 26th and 27th, 2015 at the south inlet of Kinbasket Lake. Its final detection was recorded by both receivers gating the north outlet of the Columbia Reach on May 30th. This fish thus made a directed movement in the pre-spawn period of late March upstream, either to or passing beyond Kinbasket Lake to the Upper Columbia area of the reservoir, then returned towards its preferred home range of the Confluence and Wood Arm areas in late May of the same year. This fish was not redetected in the third year of tracking.

Acoustic tag 153:
Captured on September 21st, 2014 in the Confluence, its last detection in the first year of tracking was on October 5th, 2014 in Kinbasket Lake. This tag was not re-detected in the second or third years of tracking. No inferences can be made about spawning movements or home range.

Acoustic tag 155:
Captured on September 26th, 2014 in the Canoe Reach and was first detected on July 28th, 2015 at the most upstream receiver in the Canoe Reach. Regular detections were made by receivers throughout the Canoe Reach September 16th and then again on January 29th, 2016. From February 2nd until the 19th it was detected at the outlet of the Wood Arm, and was detected at the outlet of the Canoe Reach on

April 6, 2016. In the second year of tracking, it was only detected at the outlet of the Columbia Reach. The preferred home range of this fish appeared to be concentrated in the Confluence and southern portions of the Canoe Reach. No inferences can be made on directed spawning movements.

Acoustic tag 157 (possible spawning migration detected):
Captured on September 28th, 2015 in the confluence and was first detected on October 10th, 2015 in the outlet of the Canoe Reach. From October 13th until November 14th regular detections were recorded at the outlet of the Wood Arm. It was then found at the north outlet of Columbia Reach on November 15th and 16th, and then in Cummins River from November 17th until the 19th. Throughout December it traveled between the outlet of Kinbasket Lake, Sullivan Bay entrance and the inlet of Kinbasket Lake. It was next detected on March 7th, 2016 at the entrance of Sullivan Bay. From the beginning of March until mid-April it continued to be detected between the same three receiver locations. On April 18th it was recorded at the inlet of the southern Columbia Reach and then finally at Esplanade Bay (the penultimate receiver location in the upstream portion of the Upper Columbia) on April 25th. This fish thus moved out of its preferred, extensive home range of the Kinbasket Lake/Columbia Reach/Confluence area, making a directed movement upstream towards the inlet of the Reservoir by late April, which could indicate a pre-spawn movement to an upstream spawning area. In the second year of tracking, it was redetected at Esplanade Bay on May 29, 2016, then at Surprise Rapids on June 11, 2016. This could indicate the timing of post-spawn movement back to the reservoir. Its last detection was on July 20, 2017.

Acoustic tag 158:
Captured on September 28th, 2015 in the confluence and was first detected on October 29th, 2015 in the Canoe Reach. It was regularly detected in the Canoe Reach until mid-November. In mid-December it was detected at the north outlet of the Columbia Reach and then in the Cummins River until the end of December. It was then recorded at the Sullivan Bay entrance at the end of January 2016, and again at the beginning of April. In the second year of tracking, it was detected at the outlet of Kinbasket Lake and the Sullivan Bay entrance on May 4 and May 19, 2016, respectively. The fish was not detected making a directed spawning movement out of its home range of the Kinbasket Lake/Confluence areas.

Acoustic tag 159:
Captured on September 28th, 2015 in the confluence and was first detected on October 17th, 2015 in the Canoe Reach. It was regularly detected in the Canoe Reach until the end of October, and then again from December 20th until the 23rd. Between December 29th, 2015 and January 2nd, 2016 it was recorded at the north outlet of the Columbia Reach. It then traveled to the outlet of Kinbasket Lake, then Cummins River and Surprise Rapids throughout January. Its final detection in the first year of tracking was on January 20th, 2016 at the inlet of Surprise Rapids. It was only subsequently detected in the second year of tracking in this same are, both in May, 2016, and again in August, 2016. Limited detections are available to make inferences of home range. No inferences can be made on spawning movements.

Acoustic tag 161:
Captured on October 1st, 2017 in the mouth of the Wood Arm and was first detected on April 16th, 2018 at the entrance of the Canoe Arm. Regular detections were made by the two receivers gating the entrance to the Canoe Arm between April 16th and April 21st and then again on April 30th. Given the limited frequency and total number of tracking detections, no inferences can be made regarding home range or spawning movements.

Acoustic tag 163:
Captured on October 1st, 2017 in the mouth of the Wood Arm and was first detected on October 6th, 2017 at the entrance of the Wood Arm. It was regularly detected in the Wood Arm until October 29th, and then no other detections were recorded until January 5th, 2018, again in the Wood Arm. From January 5th until April 30th, only detections at the Wood Arm entrance were recorded. On May 2nd, the fish was detected at the entrance to the Canoe Arm. It remained around the entrance to the Canoe Arm until the final detection on June 2nd. This fish appeared to have a restricted home range in proximity to its capture location in the Confluence; however, no inferences can be made of spawning movements.

Acoustic tag 164:
Captured on October 2nd, 2017 in the narrows of the Columbia Reach (northwest of Old Kinbasket Lake) and was first detected on October 5th, 2017 at the outlet of the Columbia Reach. On October 26th it was detected at the entrance to the Wood Arm where it was regularly detected until November 9th. It was then recorded by the two receivers at the entrance to the Canoe Arm on November 12th until the 14th. It returned to the Wood Arm on November 18th until the 20th. No other detections were recorded until January 17th, 2018 at the Canoe Arm entrance which was the final detection. No inferences can be made about spawning movements. The fish appeared to have a home range within the confluence and/or north Columbia Reach, but spawning movements could not be inferred.

Acoustic tag 165:
Captured on October 2nd, 2017 in the narrows of the Columbia Reach (northwest of Old Kinbasket Lake) and was first detected on October 5th, 2017 at the outlet of the Columbia Reach. Regular detections were made at the outlet of the Columbia Reach until October 17th, and then it was found at the entrance to the Canoe Arm on October 26th. No detections were recorded after October 29th. It was recorded at the outlet of the Columbia Reach on April 28th, 2018 until May 16th. Final detections were made on May 21st at the entrance to the Canoe Arm. The fish appeared to have a home range within the confluence and/or north Columbia Reach, but spawning movements could not be inferred.

Acoustic tag 166:
Captured on October 5th, 2017 near the mouth of Molson Creek and was first detected on October 28th, 2017 at the Wood Arm entrance. Detections were made at the Wood Arm entrance and the entrance to the Canoe Arm until November 1st and then it remained around the entrance to the Canoe Arm until November 12th. Regular detections were then made at the Wood Arm entrance until January 30th, 2018. Final detections were on April 27th at the Wood Arm entrance. This fish appeared to have a restricted

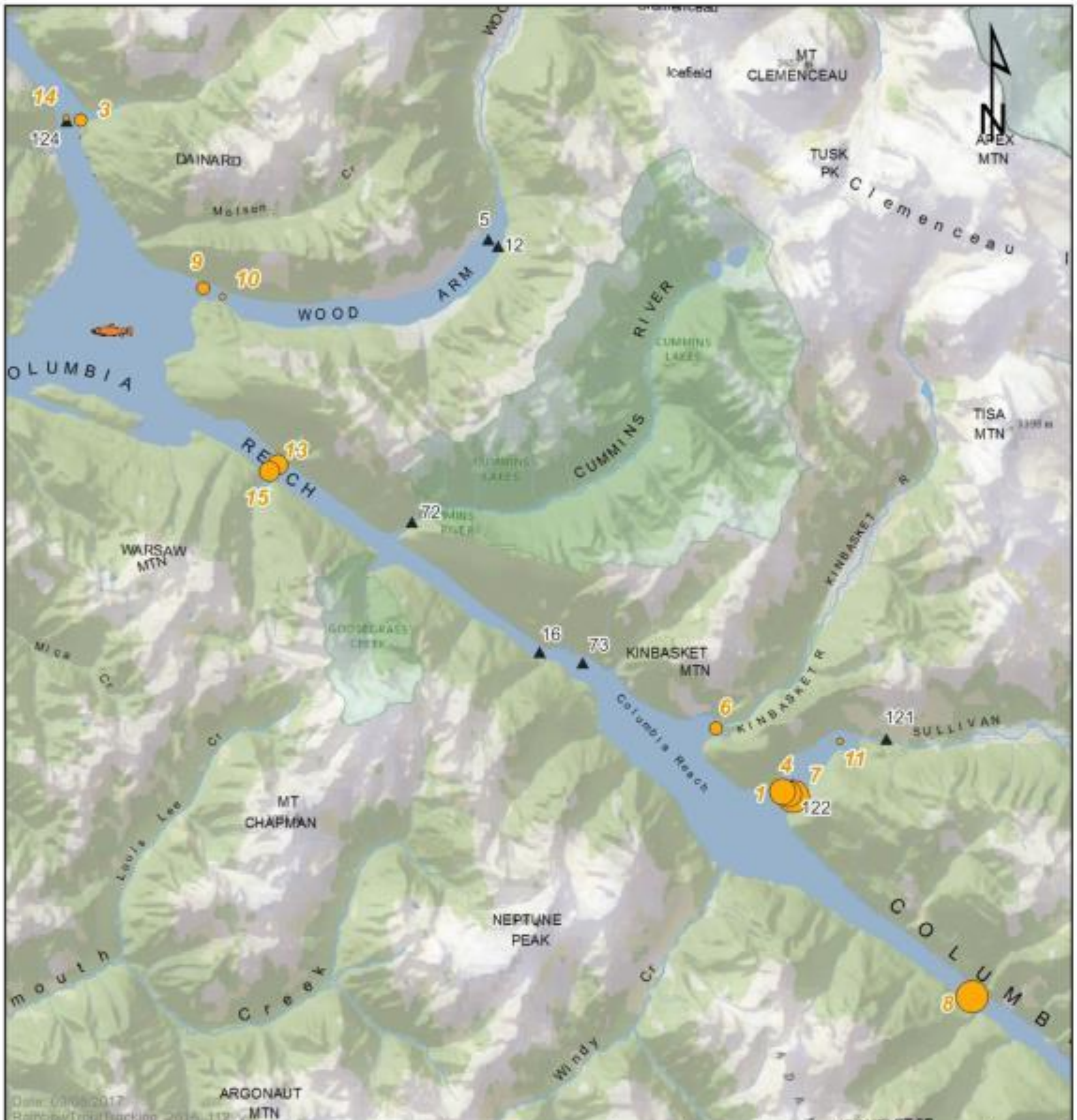
home range in proximity to its capture location in the Confluence; however, no inferences can be made of spawning movements.

Acoustic tag 167:
Captured on October 5th, 2017 near the mouth of Molson Creek and was first detected on October 26th, 2017 at the entrance to the Wood Arm. It was regularly detected at the Wood Arm entrance until November 1st. It was found again in the Wood Arm on December 20th until December 24th. It then moved to the Canoe Arm entrance on December 27th until January 2nd, 2018. It was detected again at the entrance to the Canoe Arm on April 5th until April 27th. Final detections were on May 25th at the Canoe Arm entrance. The fish appeared to have a home range within the confluence and/or north Columbia Reach, and although the fish moved extensively within the month of April, spawning movements could not be inferred.

Acoustic tag 170 (possible spawning migration detected):
Captured on October 6th, 2017 in the Confluence (Red Rock Canyon) and was first detected on October 14th, 2017 at the Columbia Reach outlet. It was regularly detected at the outlet of the Columbia Reach until October 19th and then it moved to the outlet of Old Kinbasket Lake on October 22nd. It moved between Old Kinbasket Lake (inlet and outlet) and the Sullivan Arm entrance and was regularly detected until January 21st, 2018. A few detections at the Sullivan Arm entrance were recorded in February 2018 and then regular detections were made again starting April 16th. Movements between Old Kinbasket Lake and the Sullivan Arm were recorded until April 19th. Final detections were on April 23rd at Surprise Rapids. This fish appeared to make a pre-spawn movement out of its home range, as it was detected moving upstream out of its home range of the Columbia Reach and Old Kinbasket Lake, and was undetected for the remainder of the tracking program.

Acoustic tag 171:
Captured on October 5th, 2017 near the mouth of Molson Creek and was first detected on October 26th, 2017 at the entrance to the Canoe Arm. It was detected regularly at the Canoe Arm entrance until October 28th. It then moved to the entrance of the Wood Arm on October 29th where it was detected until October 30th. Final detections were on November 4th, 2017 at the Wood Arm entrance. No inferences of spawning location or home range can be inferred with the limited tracking information.

APPENDIX A.3 – Rainbow Trout tracking maps



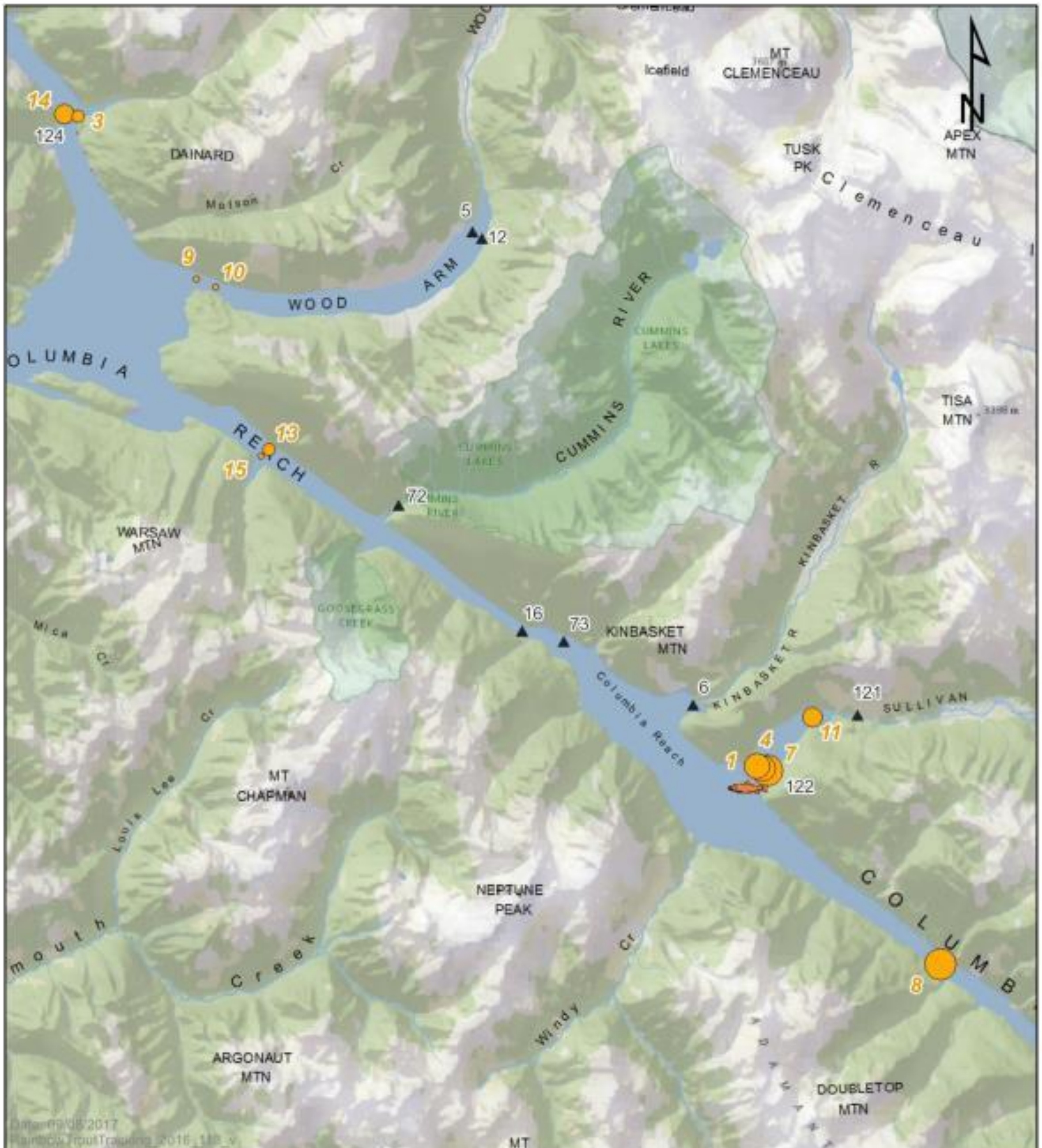
Receiver ID		1	3	4	6	7	8	9	10	11	13	14	15
2015 Download	Tracking Count	2001	305	2875	233	4328	5978	314	202	125	508	255	475
	Tracking Date Range	20/10/2014 - 30/01/2015	30/09/2014 - 04/10/2014	20/10/2014 - 16/02/2015	19/10/2014 - 02/11/2014	20/10/2014 - 03/03/2015	04/11/2014 - 02/04/2014	23/09/2014 - 05/10/2014	24/09/2014 - 26/09/2014	20/10/2014 - 06/01/2015	06/10/2014 - 09/10/2014	30/09/2014 - 04/10/2014	06/10/2014 - 09/10/2014
2016 Download	Tracking Count	36		32	132		1						
	Tracking Date Range	28/05/2015 - 13/06/2015		28/05/2015 - 13/06/2015	26/05/2015 - 04/06/2015		24/05/2015						

Kinbasket Reservoir Rainbow Trout Tracking: Acoustic Code 112

Capture Location | Undetected Receiver Location | Detected Receiver Location

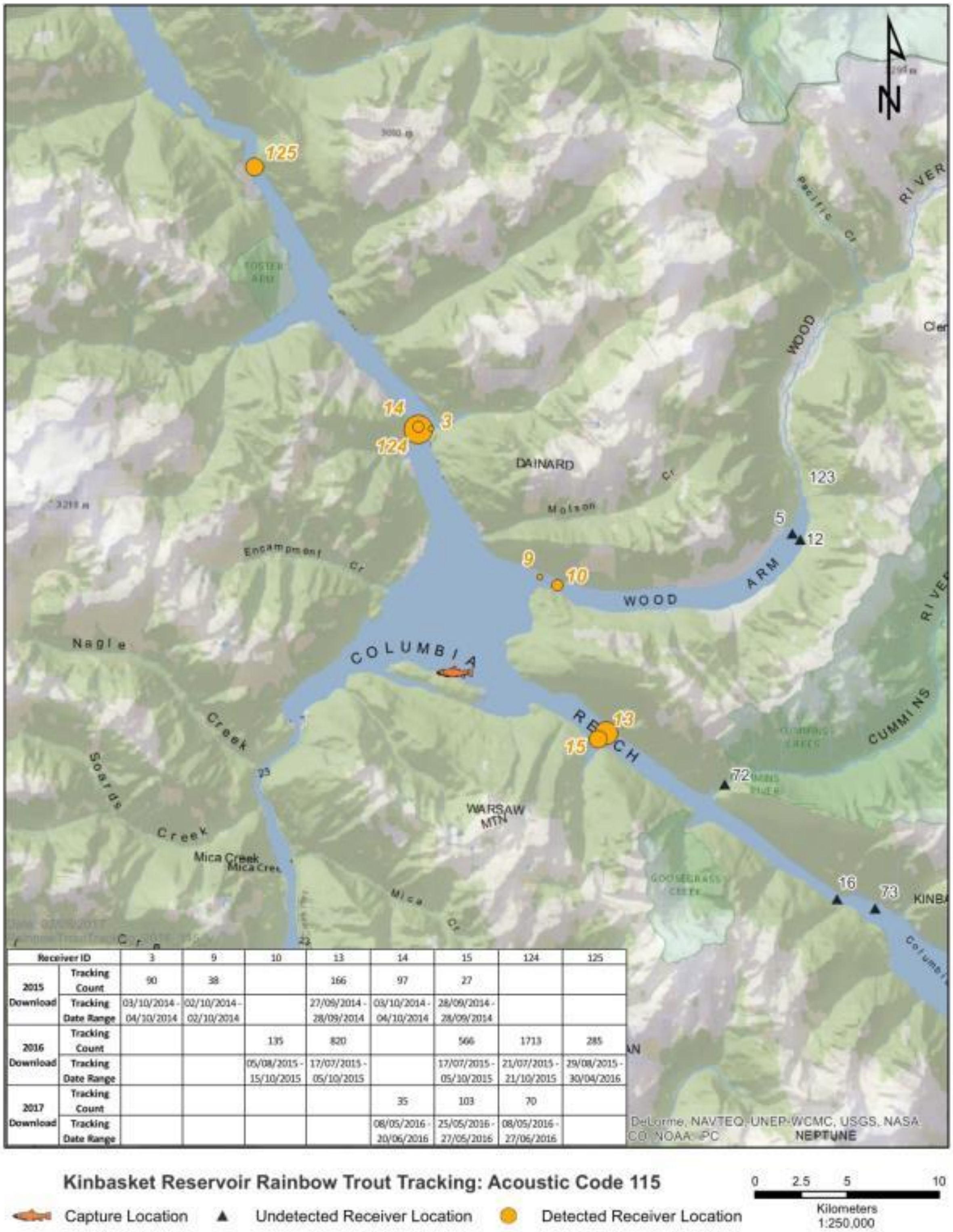
0 2.5 5 10 Kilometers 1:250,000

Figure A-1. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 112 and their tracking date ranges. Detected receiver location points are sized according to their relative number of detections. Capture and tag implantation occurred on September 22, 2014.



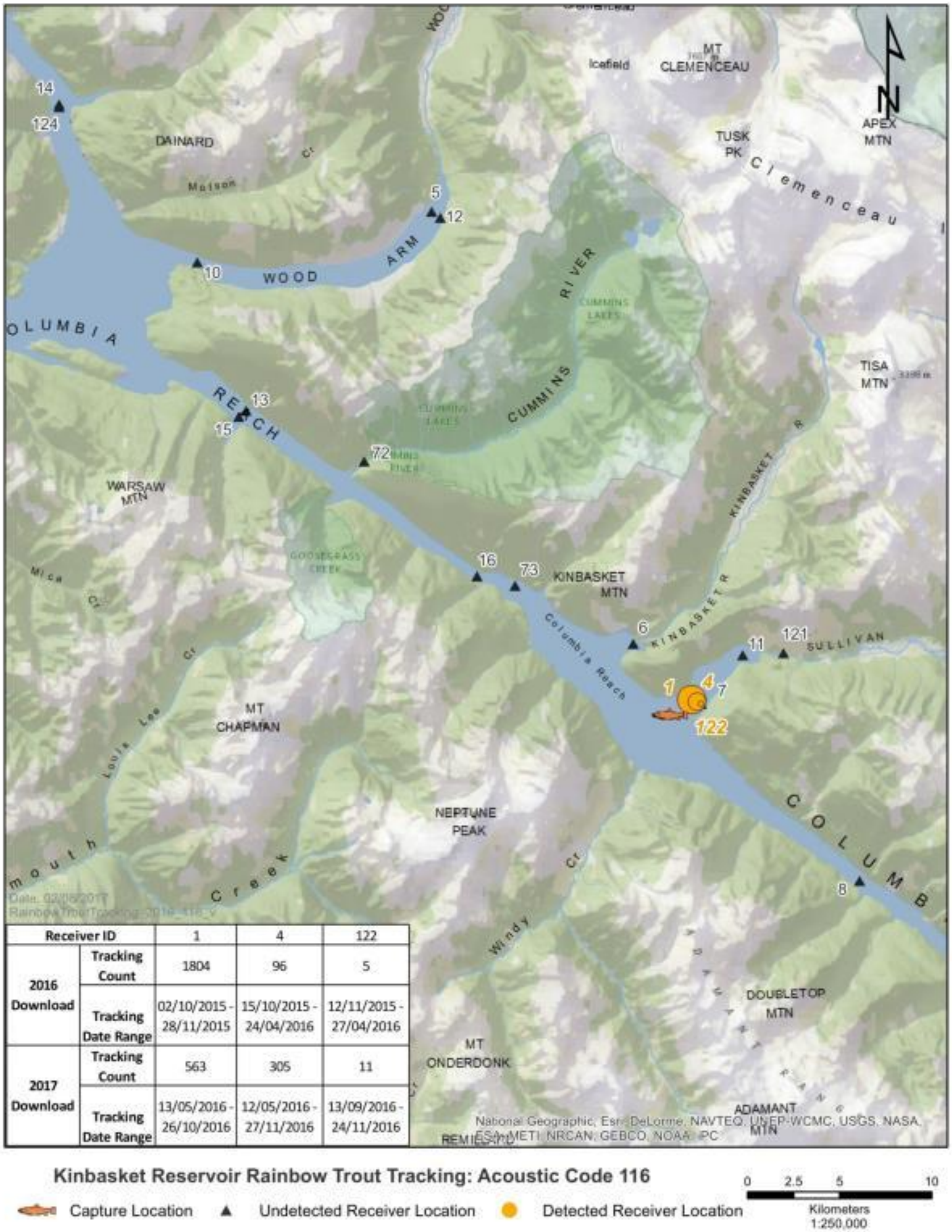
Receiver ID		1	3	4	7	8	9	10	11	13	14	15
2015 Download	Tracking Count	4288	519	4676	5383	5876	92	28	1204	148	656	77
	Tracking Date Range	24/09/2014 - 28/01/2015	14/02/2015 - 16/02/2015	24/09/2014 - 28/01/2015	24/09/2014 - 17/03/2015	30/09/2014 - 27/03/2014	05/02/2015 - 16/02/2015	05/02/2015 - 17/02/2015	26/09/2014 - 12/01/2015	02/02/2015 - 03/02/2015	13/02/2015 - 16/02/2015	31/01/2015 - 02/02/2015

Figure A-2. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 113 and their tracking date ranges. Detected receiver location points are sized according to their relative number of detections. Capture and tag implantation occurred on September 24, 2014.



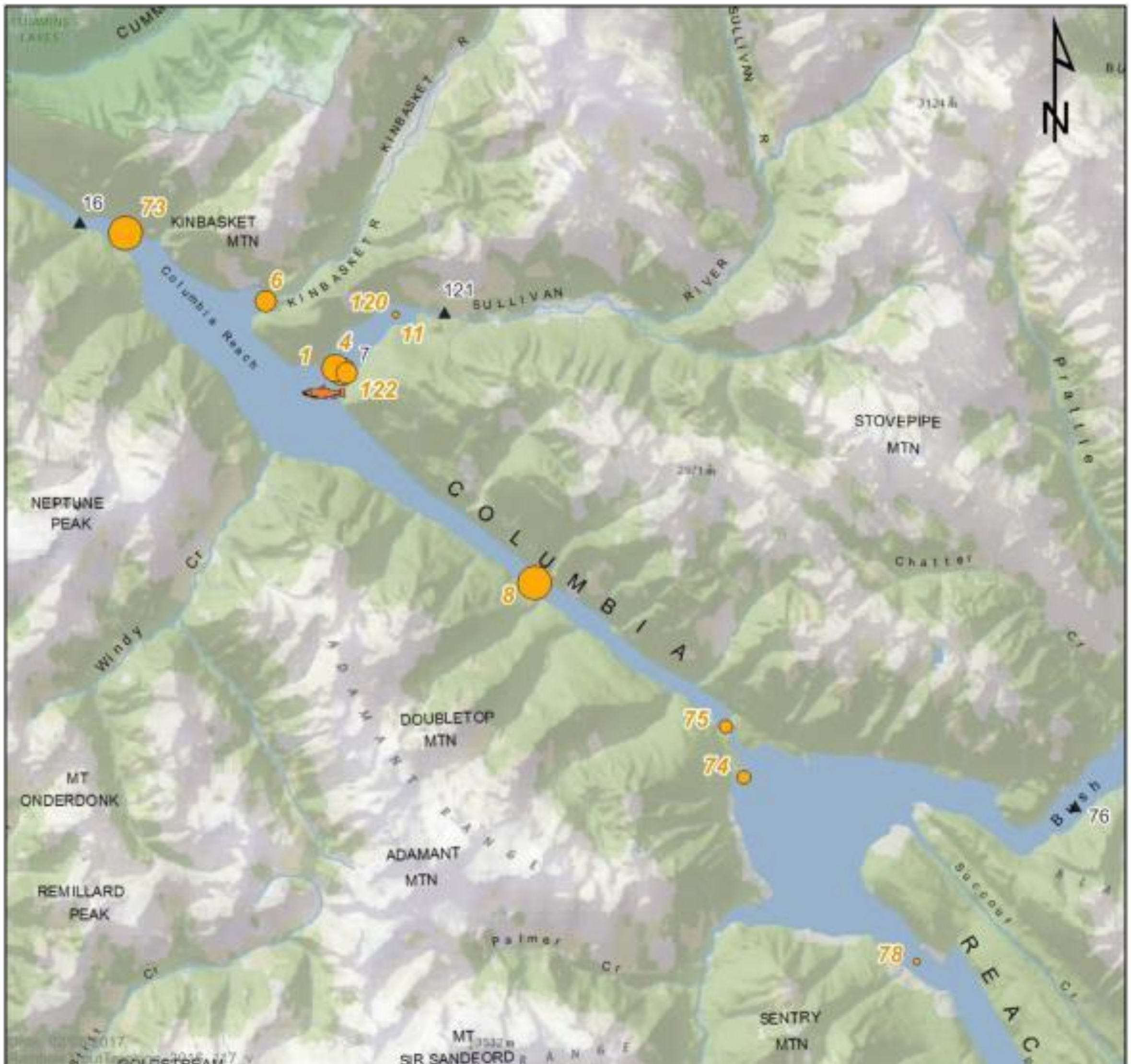
Receiver ID		3	9	10	13	14	15	124	125
2015 Download	Tracking Count	90	38		166	97	27		
	Tracking Date Range	03/10/2014 - 04/10/2014	02/10/2014 - 02/10/2014		27/09/2014 - 28/09/2014	03/10/2014 - 04/10/2014	28/09/2014 - 28/09/2014		
2016 Download	Tracking Count			135	820		566	1713	285
	Tracking Date Range			05/08/2015 - 15/10/2015	17/07/2015 - 05/10/2015		17/07/2015 - 05/10/2015	21/07/2015 - 21/10/2015	29/08/2015 - 30/04/2016
2017 Download	Tracking Count					35	103	70	
	Tracking Date Range					08/05/2016 - 20/06/2016	25/05/2016 - 27/05/2016	08/05/2016 - 27/06/2016	

Figure A-3. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 115 and their tracking date ranges. Detected receiver location points are sized according to their relative number of detections. Capture and tag implantation occurred on September 26, 2014.



Receiver ID		1	4	122
2016 Download	Tracking Count	1804	96	5
	Tracking Date Range	02/10/2015 - 28/11/2015	15/10/2015 - 24/04/2016	12/11/2015 - 27/04/2016
2017 Download	Tracking Count	563	305	11
	Tracking Date Range	13/05/2016 - 26/10/2016	12/05/2016 - 27/11/2016	13/09/2016 - 24/11/2016

Figure A-4. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 116 and their tracking date ranges. Detected receiver location points are sized according to their relative number of detections. Capture and tag implantation occurred on October 2, 2015.



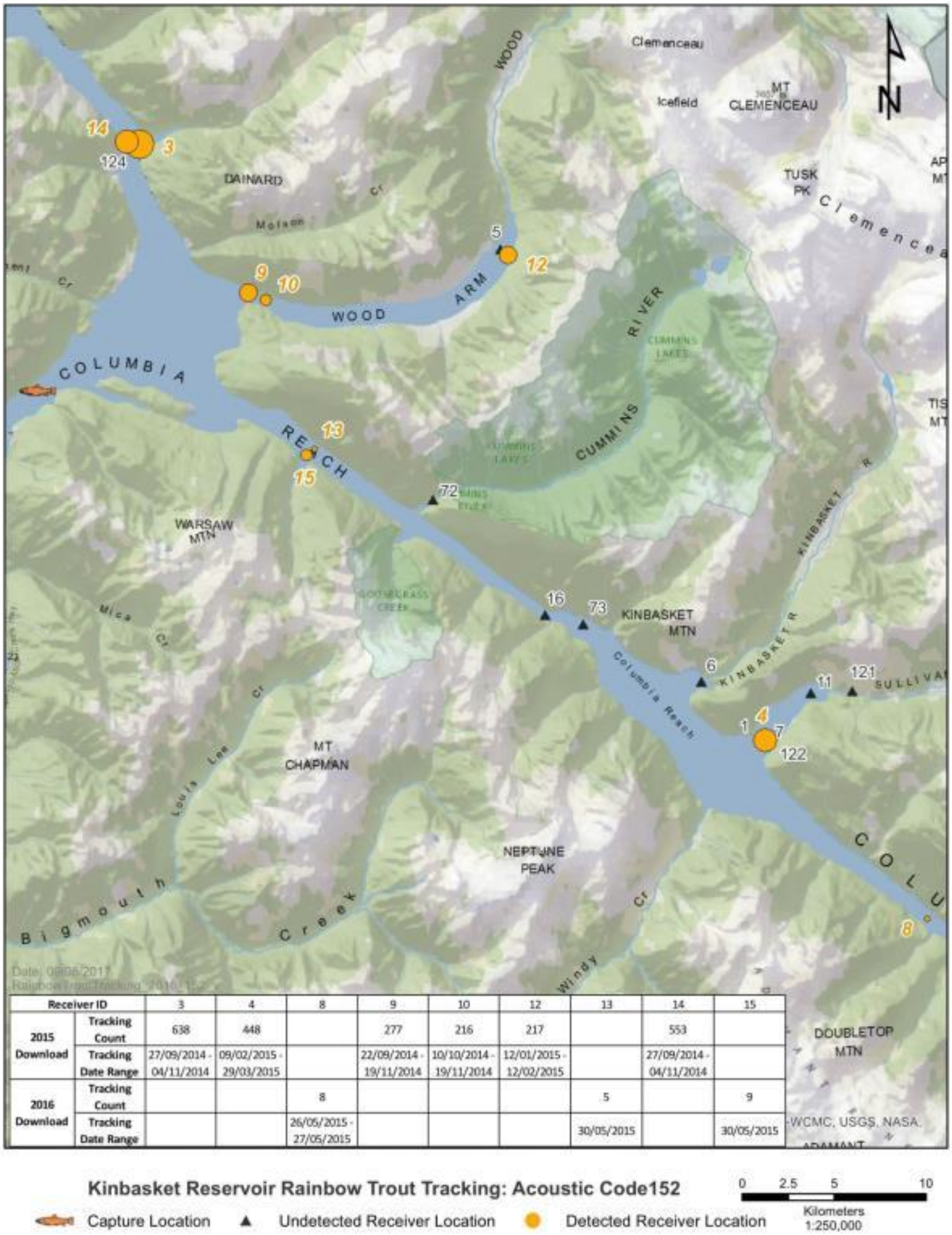
Receiver ID		1	4	6	8	11	73	74	75	78	122
2016 Download	Tracking Count	1061	1256	816	2035		783	92	404	2	664
	Tracking Date Range	02/10/2015 - 11/02/2016	02/10/2015 - 10/06/2016	09/10/2015 - 09/01/2016	21/10/2015 - 17/04/2016		06/10/2015 - 10/01/2016	15/03/2016 - 19/04/2016	15/03/2016 - 18/04/2016	19/04/2016	02/10/2015 - 09/02/2016
2017 Download	Tracking Count	746	1366	743	4075	56	2422	170	141	19	528
	Tracking Date Range	05/08/2016 - 02/02/2017	17/07/2016 - 02/02/2017	29/07/2016 - 25/01/2017	18/06/2016 - 08/02/2017	12/08/2016 - 05/12/2016	18/07/2016 - 16/01/2017	11/06/2016 - 14/06/2016	13/06/2016 - 14/06/2016, 13/12/2016 - 14/12/2016, 18/04/2017 - 21/04/2017	23/05/2016 - 31/05/2016, 28/04/2017 - 29/04/2017	17/07/2016 - 02/02/2017

Kinbasket Reservoir Rainbow Trout Tracking: Acoustic Code117

Capture Location ▲ Undetected Receiver Location ● Detected Receiver Location

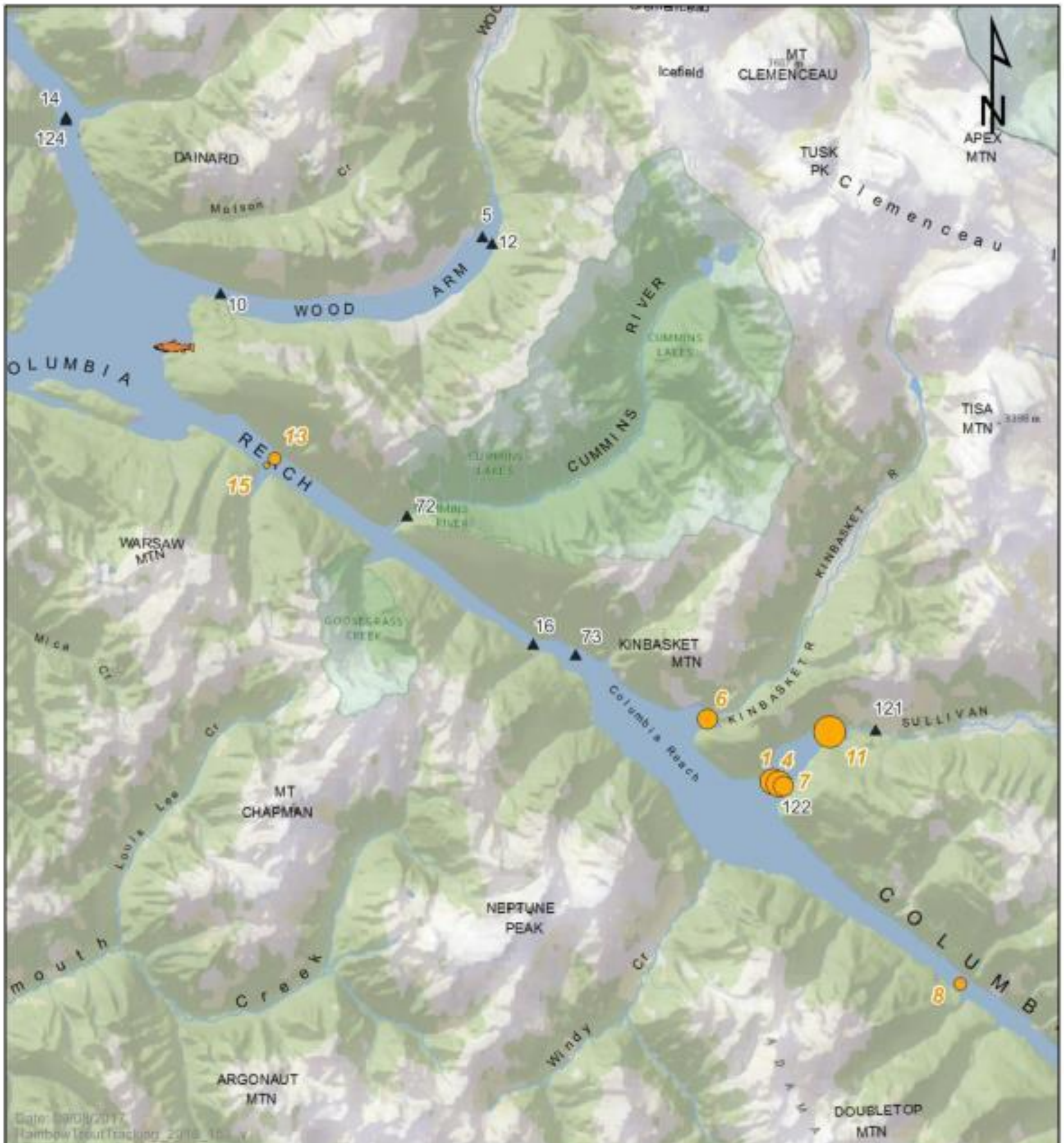
0 2.5 5 10 Kilometers 1:250,000

Figure A-5. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 117 and their tracking date ranges. Detected receiver location points are sized according to their relative number of detections. Capture and tag implantation occurred on October 2, 2015.



Receiver ID		3	4	8	9	10	12	13	14	15
2015 Download	Tracking Count	638	448		277	216	217		553	
	Tracking Date Range	27/09/2014 - 04/11/2014	09/02/2015 - 29/03/2015		22/09/2014 - 19/11/2014	10/10/2014 - 19/11/2014	12/01/2015 - 12/02/2015		27/09/2014 - 04/11/2014	
2016 Download	Tracking Count			8				5		9
	Tracking Date Range			26/05/2015 - 27/05/2015				30/05/2015		30/05/2015

Figure A-6. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 152 and their tracking date ranges. Detected receiver location points are sized according to their relative number of detections. Capture and tag implantation occurred on September 20, 2014.



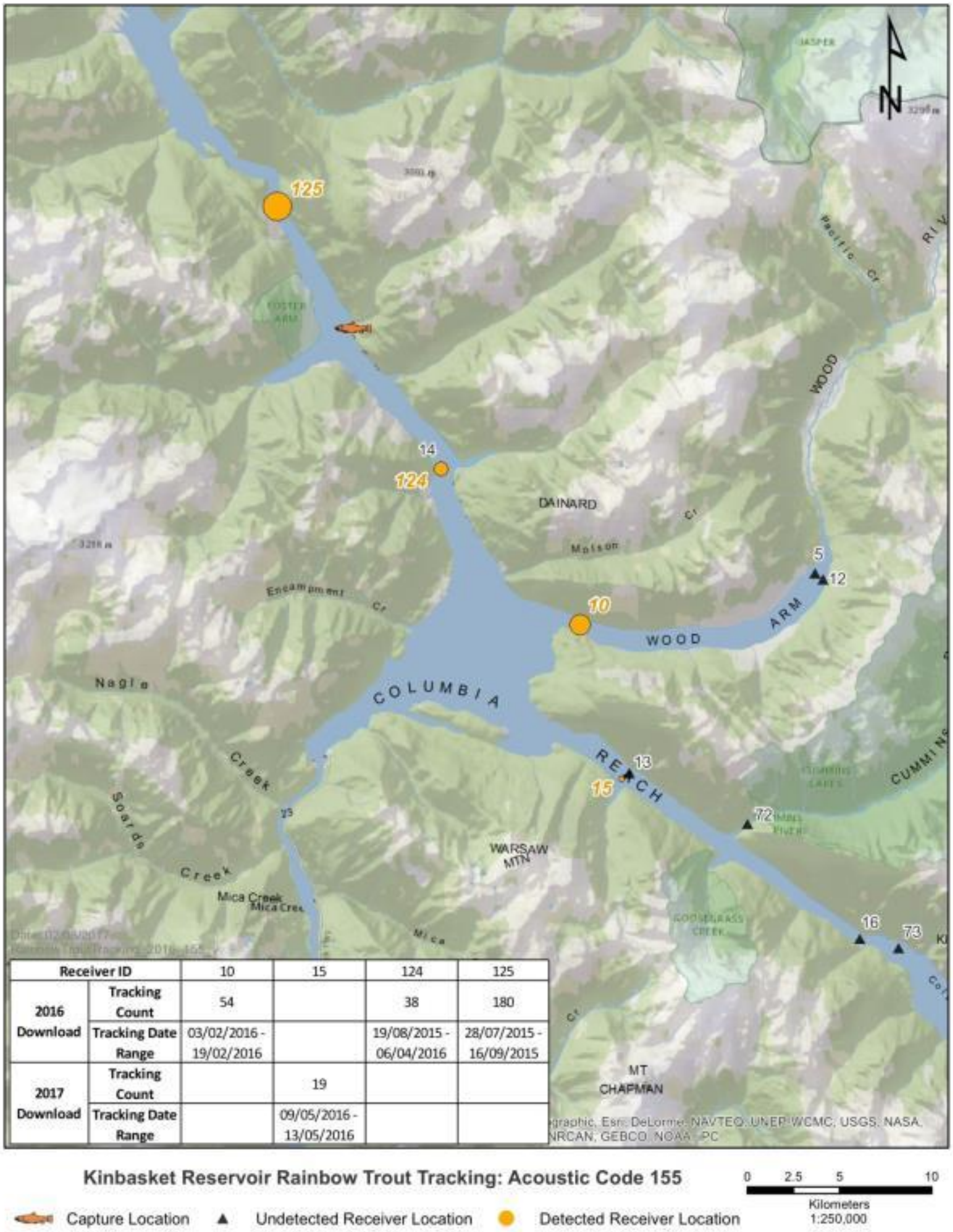
Receiver ID		1	4	6	7	8	11	13	15
2015 Download	Tracking Count	34	34	10	27	6	54	6	2
	Tracking Date Range	02/10/2014 - 05/10/2014	02/10/2014 - 05/10/2014	02/10/2014 - 02/10/2014	02/10/2014 - 05/10/2014	05/10/2014 - 05/10/2014	03/10/2014 - 04/10/2014	29/09/2014 - 29/09/2014	29/09/2014 - 29/09/2014

Kinbasket Reservoir Rainbow Trout Tracking: Acoustic Code 153

0 2.5 5 10 Kilometers 1:250,000

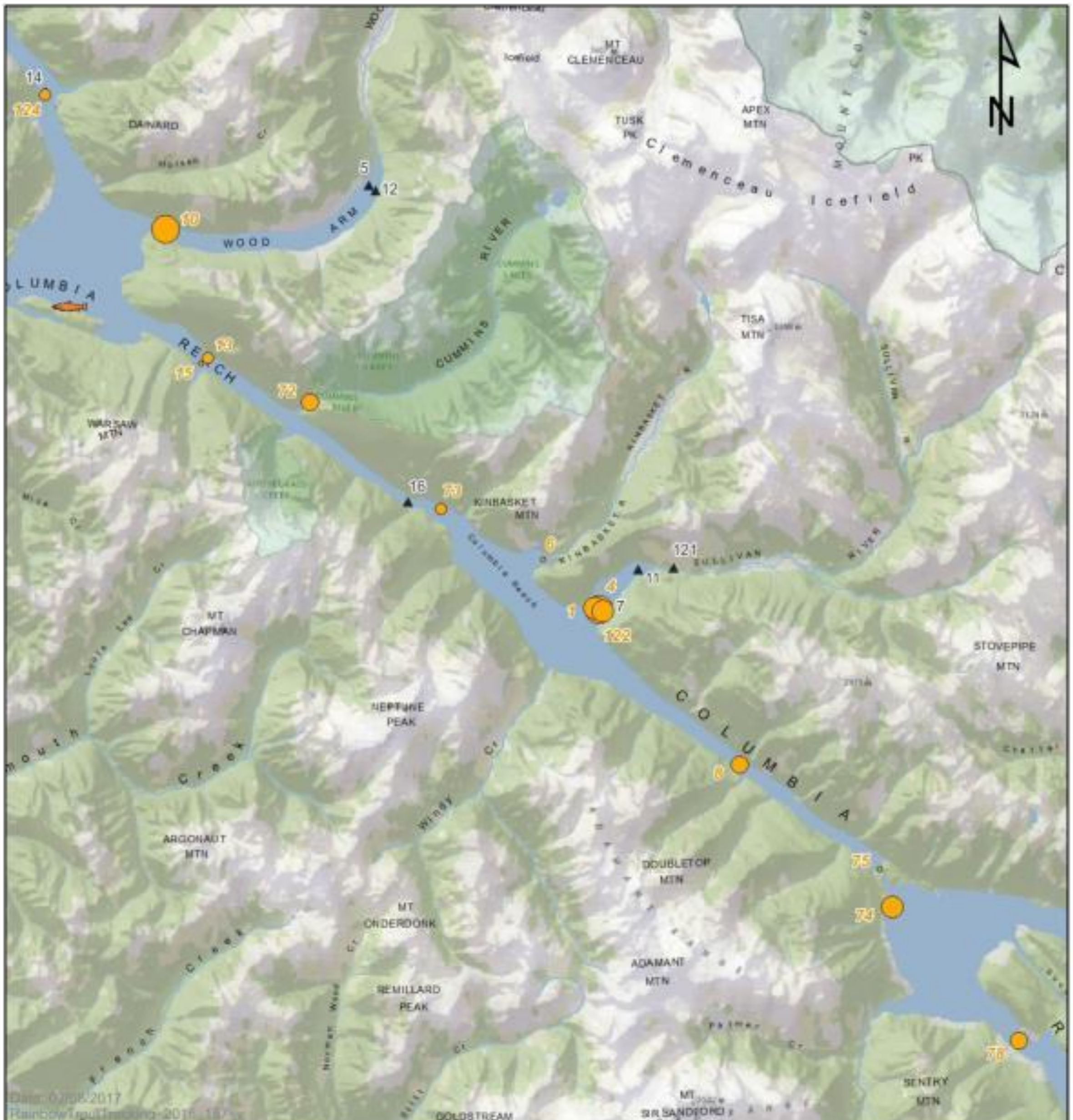
Capture Location ▲ Undetected Receiver Location ● Detected Receiver Location

Figure A-7. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 153 and their tracking date ranges. Detected receiver location points are sized according to their relative number of detections. Capture and tag implantation occurred on September 21, 2014.



Receiver ID		10	15	124	125
2016 Download	Tracking Count	54		38	180
	Tracking Date Range	03/02/2016 - 19/02/2016		19/08/2015 - 06/04/2016	28/07/2015 - 16/09/2015
2017 Download	Tracking Count		19		
	Tracking Date Range		09/05/2016 - 13/05/2016		

Figure A-8. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 155 and their tracking date ranges. Detected receiver location points are sized according to their relative number of detections. Capture and tag implantation occurred on September 26, 2014.



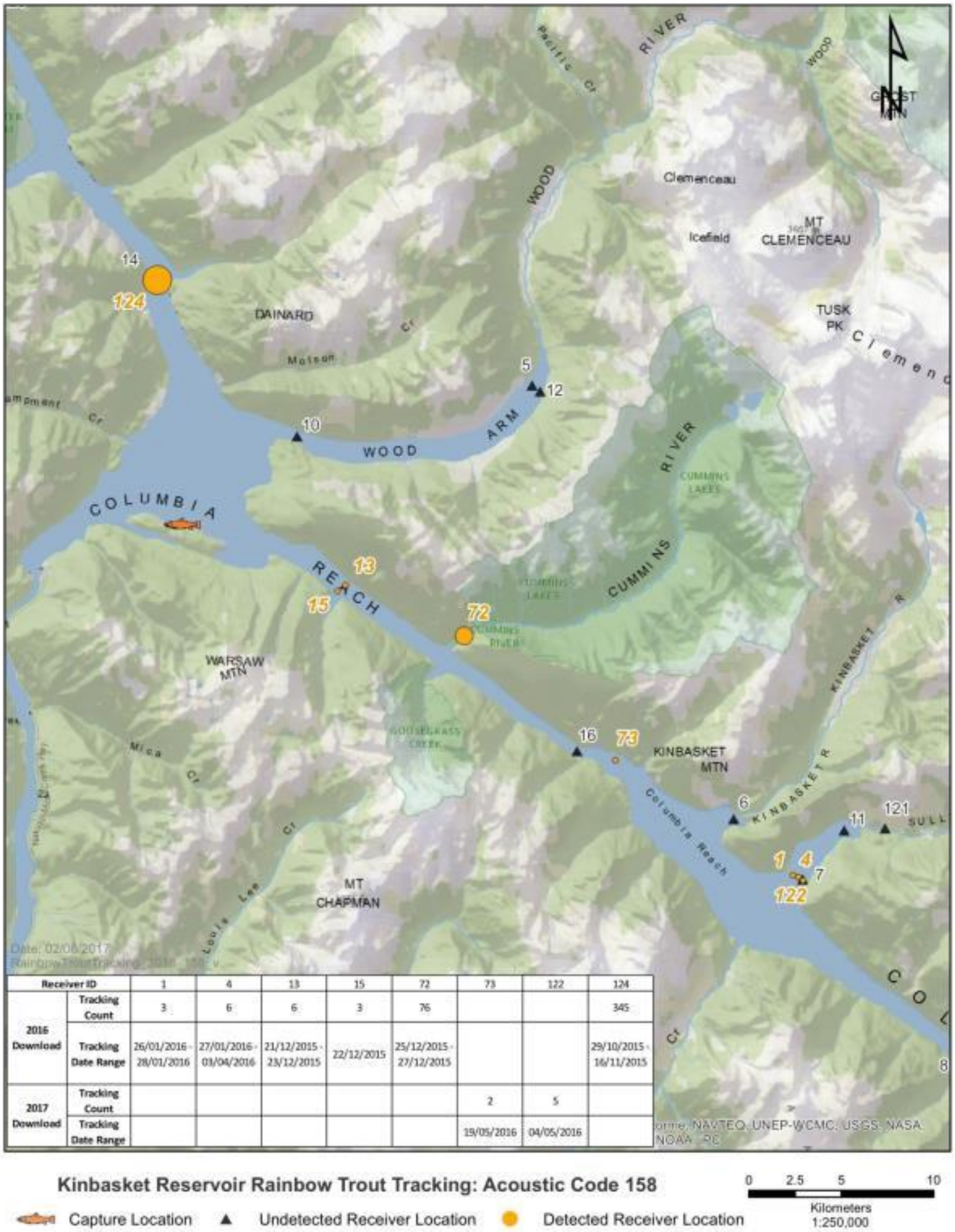
Receiver ID		1	4	6	8	10	11	15	72	73	74	75	76	122	124
2016 Download	Tracking Count	193	319	6	158	665	36	2	79	42	1	6	15	188	30
	Tracking Date Range	08/12/2015 - 11/03/2016	08/12/2015 - 12/04/2016	08/12/2015	18/12/2015 - 17/04/2016	13/10/2015 - 14/11/2015	15/11/2015 - 16/11/2015	16/11/2015 - 21/11/2015	17/11/2015 - 05/12/2015	07/12/2015 - 28/03/2016	23/04/2016	18/04/2016	25/04/2016	08/12/2015 - 12/04/2016	10/10/2015 - 11/10/2015
2017 Download	Tracking Count										170		38		
	Tracking Date Range										11/06/2016 - 14/06/2016		29/05/2016, 28/06/2016, 18/07/2016-20/07/2016		

Kinbasket Reservoir Rainbow Trout Tracking: Acoustic Code 157

Capture Location ▲ Undetected Receiver Location ● Detected Receiver Location

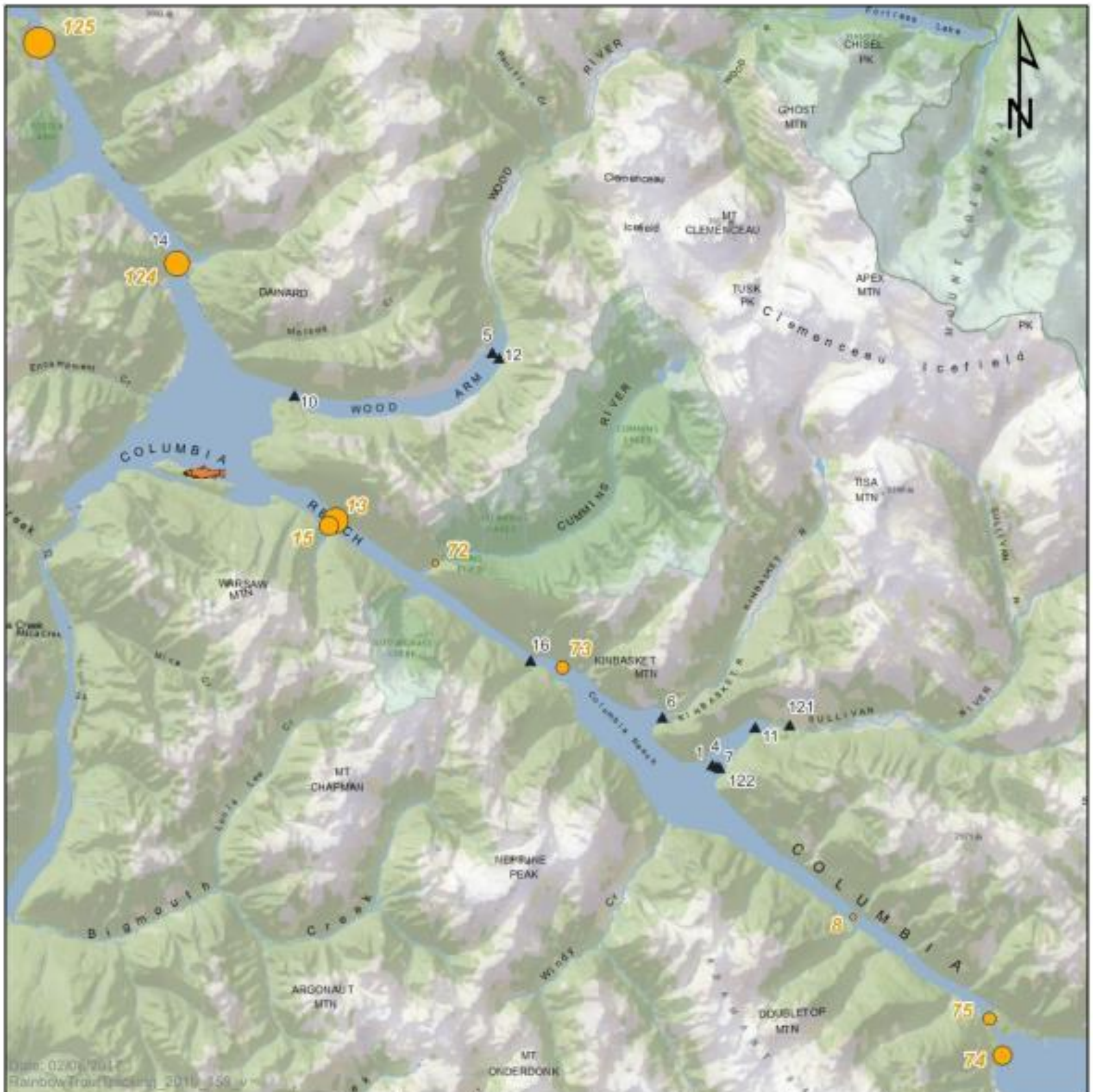
0 2.5 5 10 15 Kilometers 1:325,000

Figure A-9. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 157 and their tracking date ranges. Detected receiver location points are sized according to their relative number of detections. Capture and tag implantation occurred on September 28, 2015.



Receiver ID		1	4	13	15	72	73	122	124
2016 Download	Tracking Count	3	6	6	3	76			345
	Tracking Date Range	26/01/2016 - 28/01/2016	27/01/2016 - 03/04/2016	21/12/2015 - 23/12/2015	22/12/2015	25/12/2015 - 27/12/2015			29/10/2015 - 16/11/2015
2017 Download	Tracking Count						2	5	
	Tracking Date Range						19/05/2016	04/05/2016	

Figure A-10. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 158 and their tracking date ranges. Detected receiver location points are sized according to their relative number of detections. Capture and tag implantation occurred on September 28, 2015.



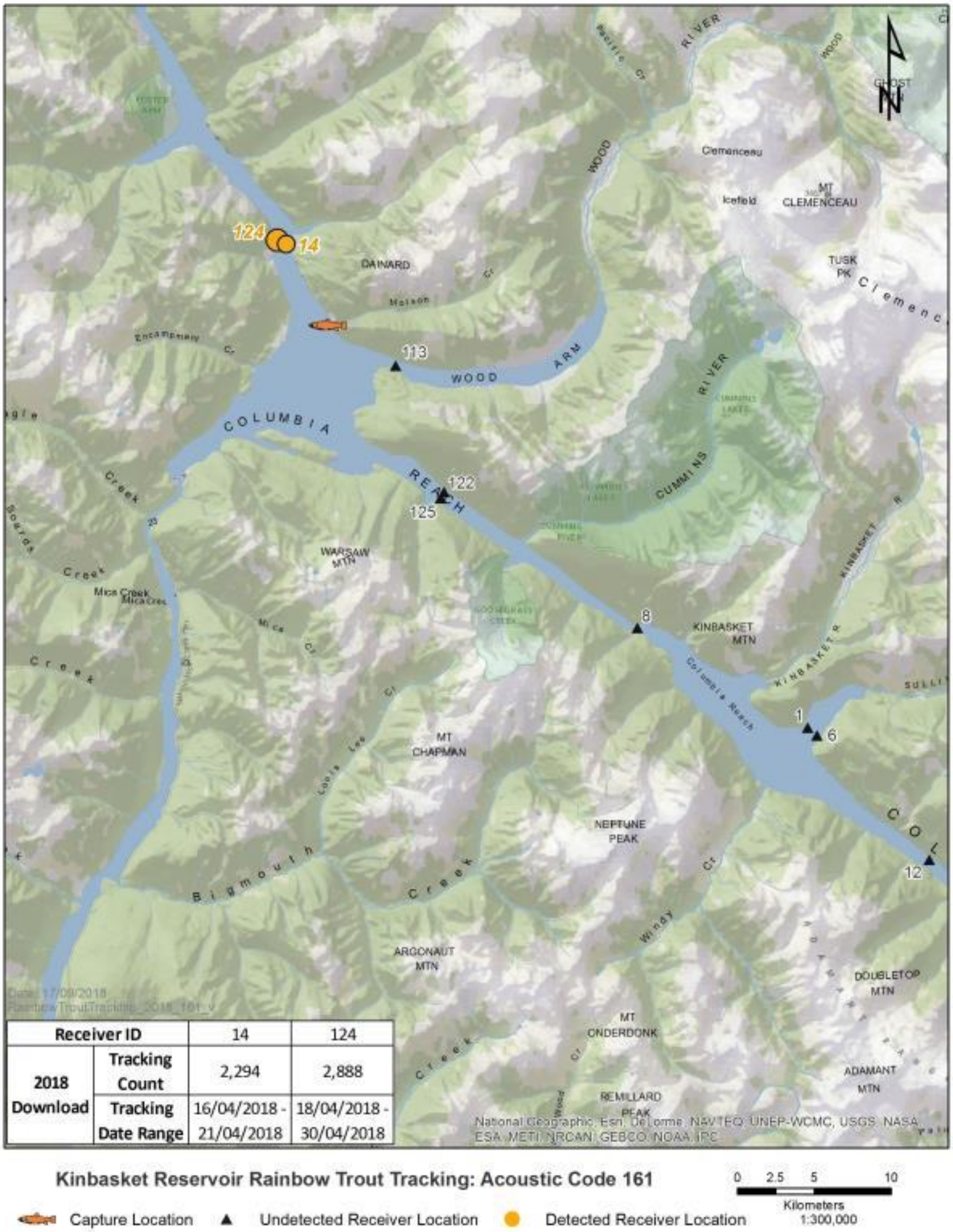
Receiver ID		8	13	15	72	73	74	75	124	125
2016 Download	Tracking Count	1	28	27	1	2	14	7	52	384
	Tracking Date Range	12/01/2016	29/12/2015 - 02/01/2016	29/12/2015 - 30/12/2015	08/01/2016	06/01/2016	14/01/2016 - 20/01/2016	14/01/2016	17/10/2015 - 23/12/2015	21/10/2015 - 20/12/2015
2017 Download	Tracking Count							2		
	Tracking Date Range							11/05/2016, 01/08/2016		

Kinbasket Reservoir Rainbow Trout Tracking: Acoustic Code 159

Capture Location ▲ Undetected Receiver Location ● Detected Receiver Location

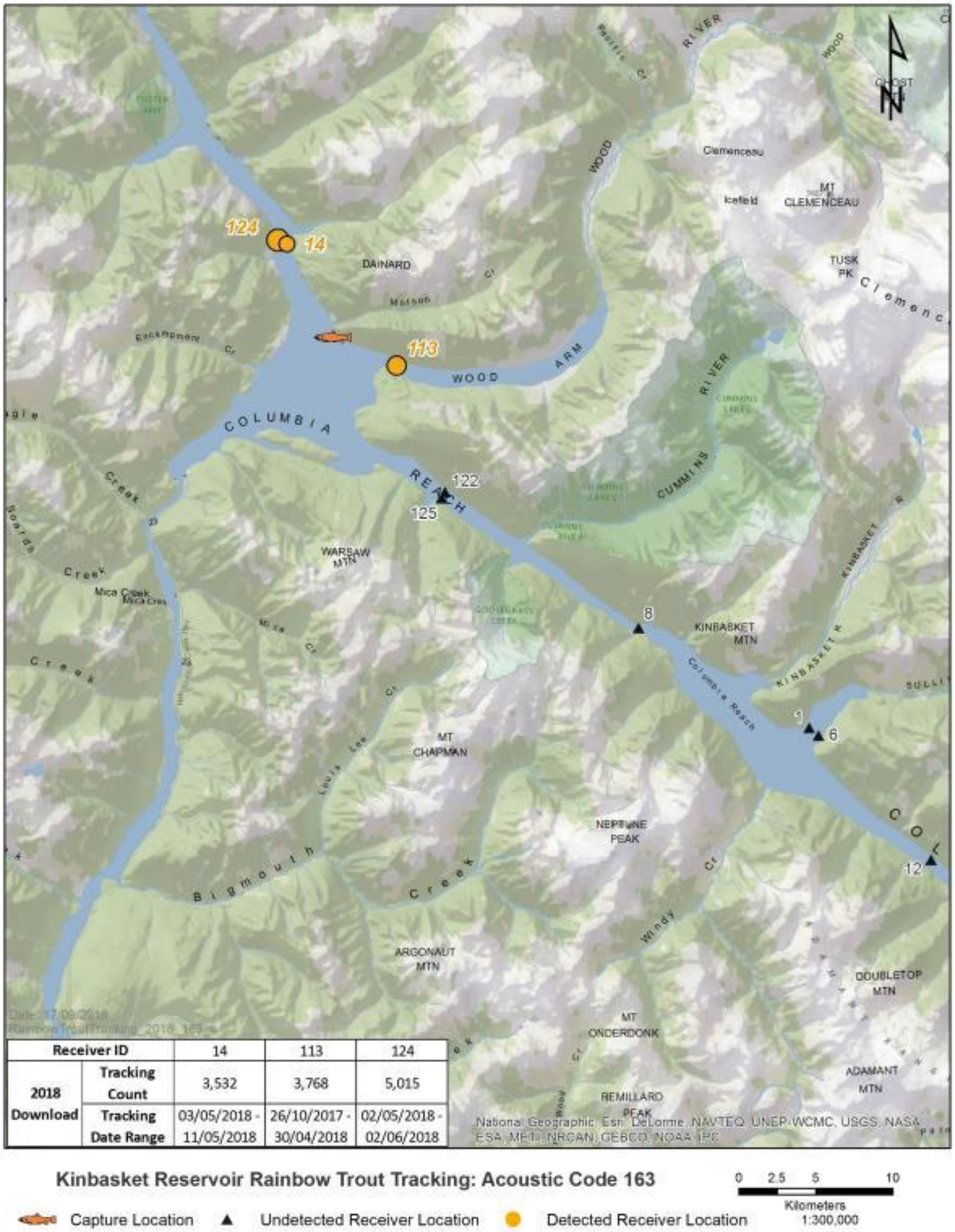
0 2.5 5 10 15 Kilometers 1:340,000

Figure A-11. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 159 and their tracking date ranges. Detected receiver location points are sized according to their relative number of detections. Capture and tag implantation occurred on September 28, 2015.



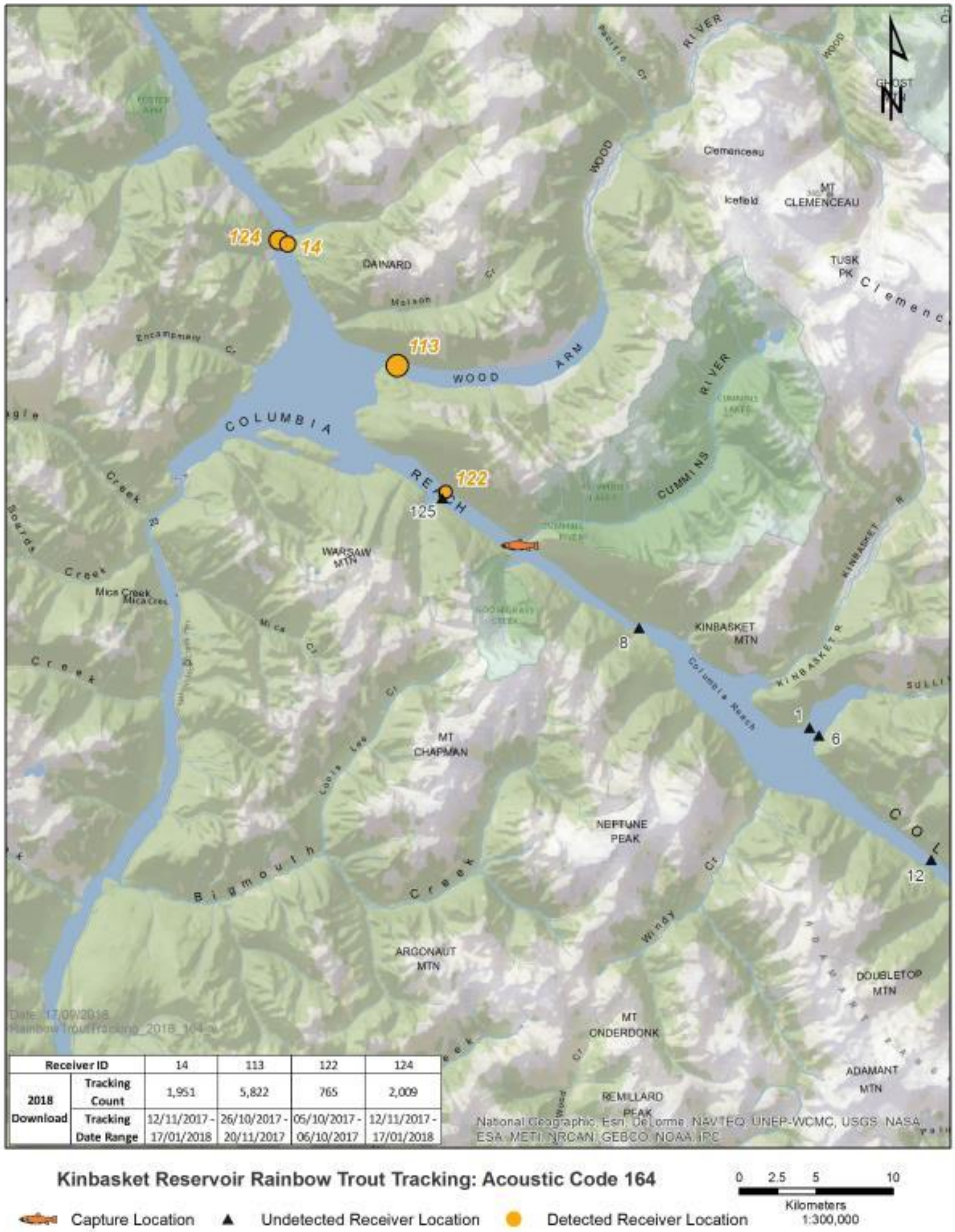
Receiver ID		14	124
2018 Download	Tracking Count	2,294	2,888
	Tracking Date Range	16/04/2018 - 21/04/2018	18/04/2018 - 30/04/2018

Figure A-12. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 161 and their tracking date ranges. Detected receiver location points are sized according to their relative number of detections. Capture and tag implantation occurred on October 1, 2017.



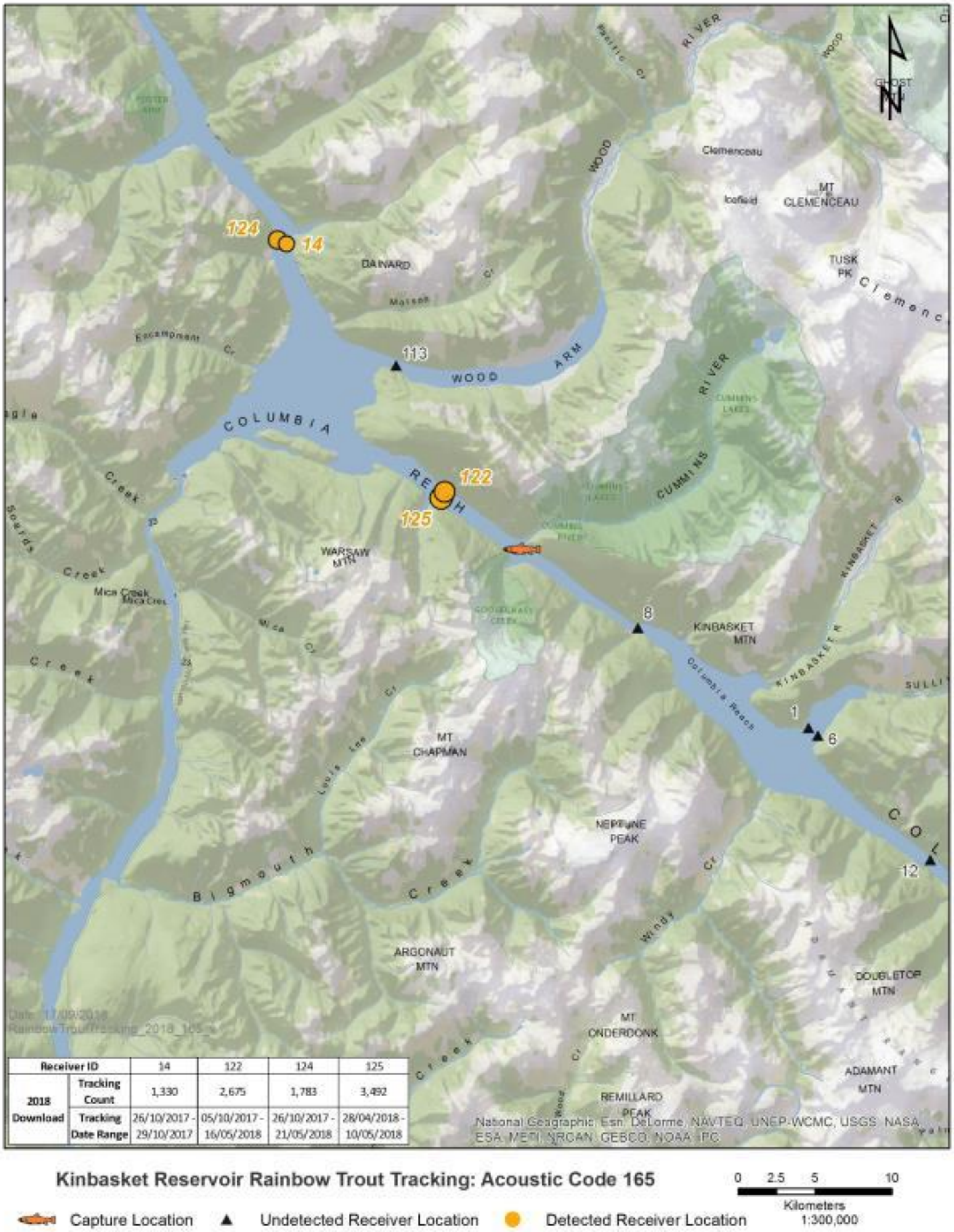
Receiver ID		14	113	124
2018 Download	Tracking Count	3,532	3,768	5,015
	Tracking Date Range	03/05/2018 - 11/05/2018	26/10/2017 - 30/04/2018	02/05/2018 - 02/06/2018

Figure A-13. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 163 and their tracking date ranges. Detected receiver location points are sized according to their relative number of detections. Capture and tag implantation occurred on October 1, 2017.



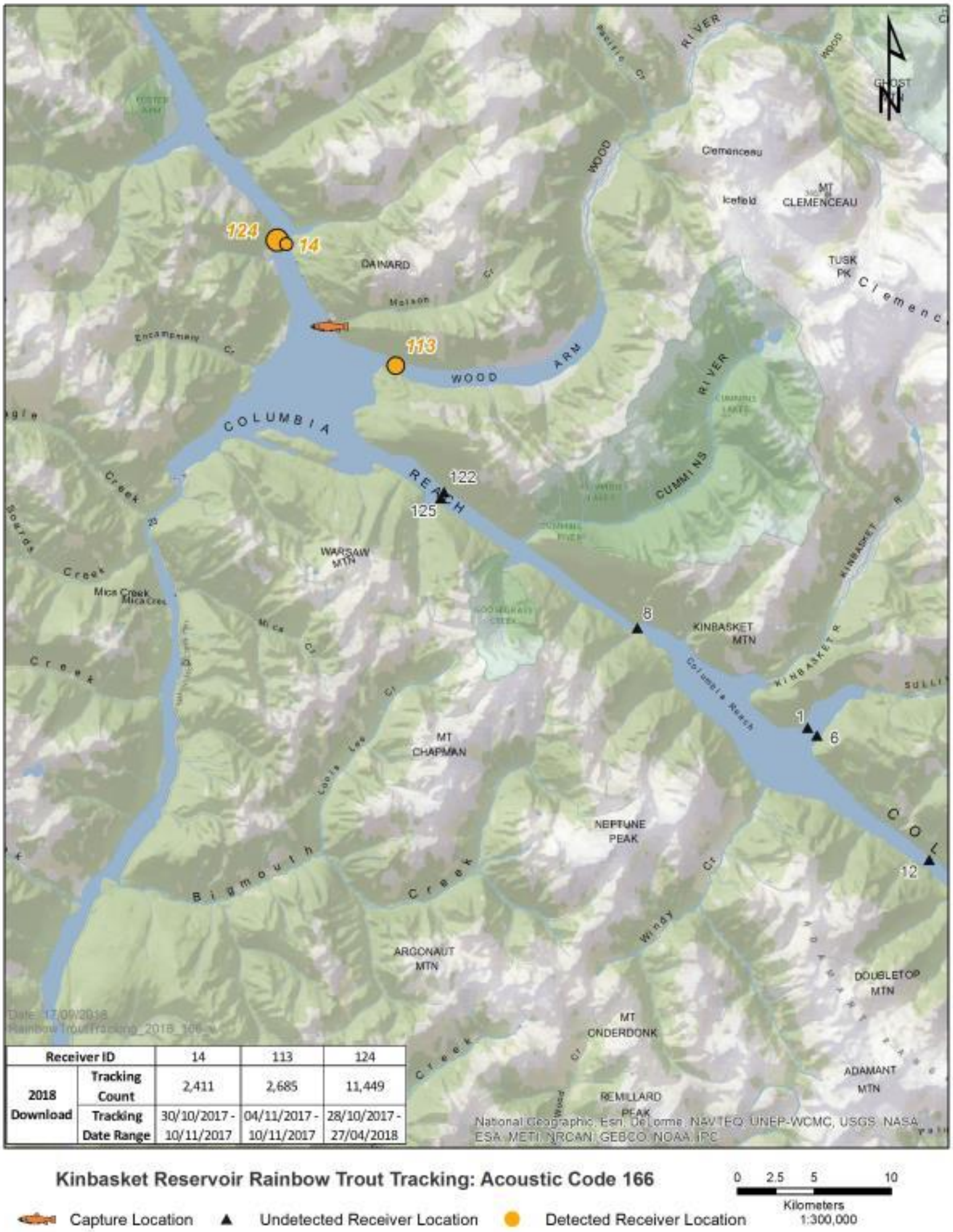
Receiver ID		14	113	122	124
2018 Download	Tracking Count	1,951	5,822	765	2,009
	Tracking Date Range	12/11/2017 - 17/01/2018	26/10/2017 - 20/11/2017	05/10/2017 - 06/10/2017	12/11/2017 - 17/01/2018

Figure A-14. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 164 and their tracking date ranges. Detected receiver location points are sized according to their relative number of detections. Capture and tag implantation occurred on October 2, 2017.



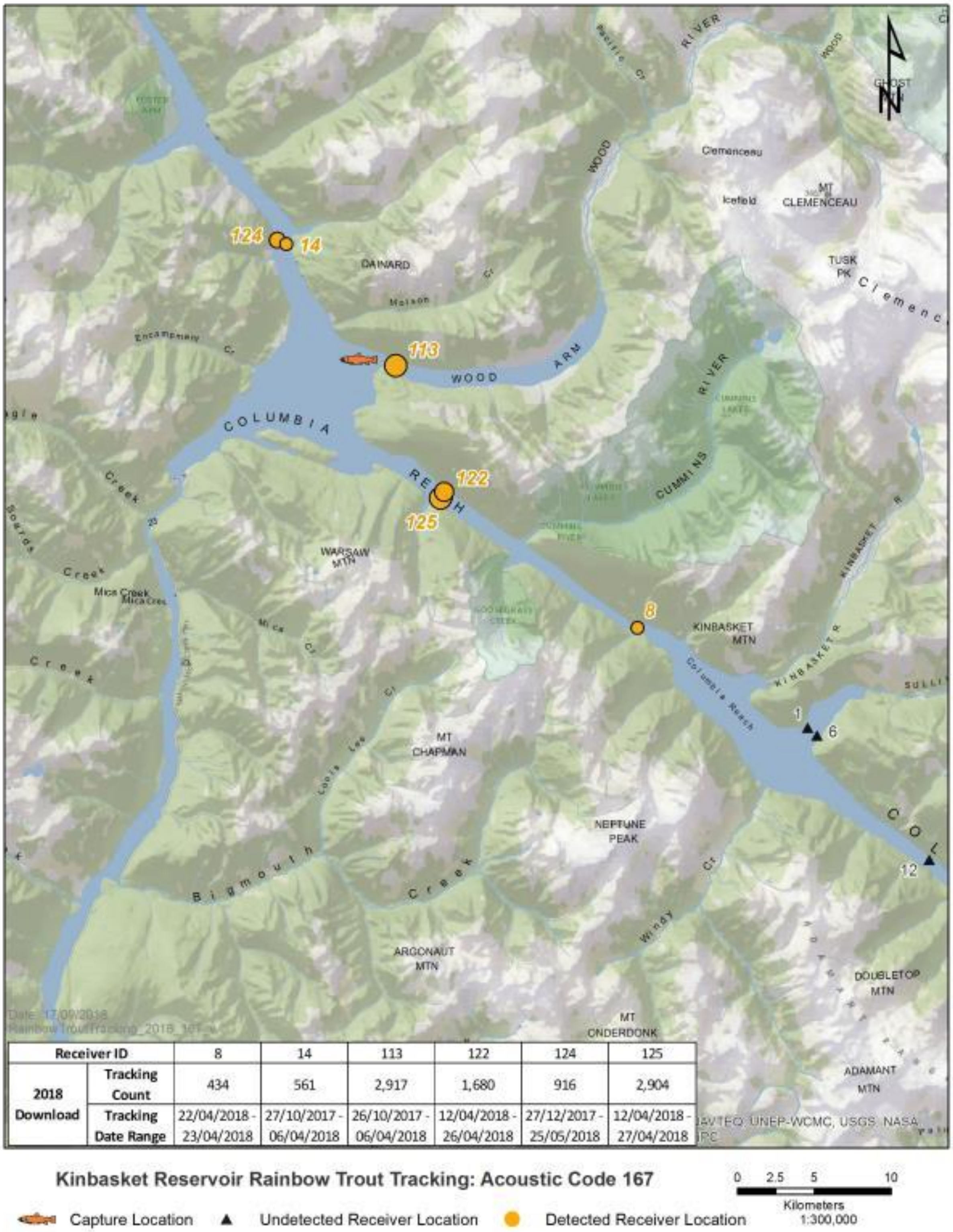
Receiver ID		14	122	124	125
2018 Download	Tracking Count	1,330	2,675	1,783	3,492
	Tracking Date Range	26/10/2017 - 29/10/2017	05/10/2017 - 16/05/2018	26/10/2017 - 21/05/2018	28/04/2018 - 10/05/2018

Figure A-15. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 165 and their tracking date ranges. Detected receiver location points are sized according to their relative number of detections. Capture and tag implantation occurred on October 2, 2017.



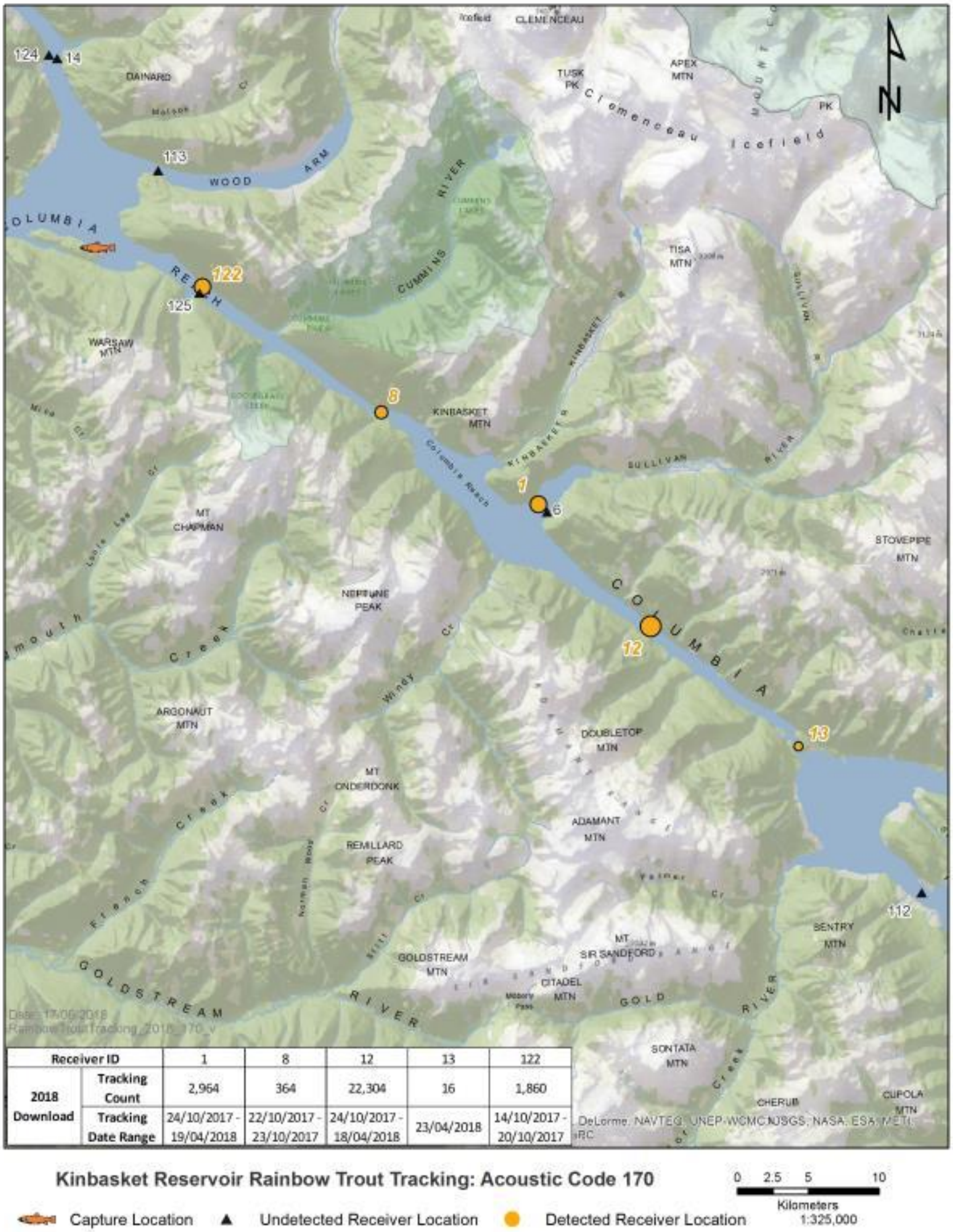
Receiver ID		14	113	124
2018 Download	Tracking Count	2,411	2,685	11,449
	Tracking Date Range	30/10/2017 - 10/11/2017	04/11/2017 - 10/11/2017	28/10/2017 - 27/04/2018

Figure A-16. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 166 and their tracking date ranges. Detected receiver location points are sized according to their relative number of detections. Capture and tag implantation occurred on October 5, 2017.



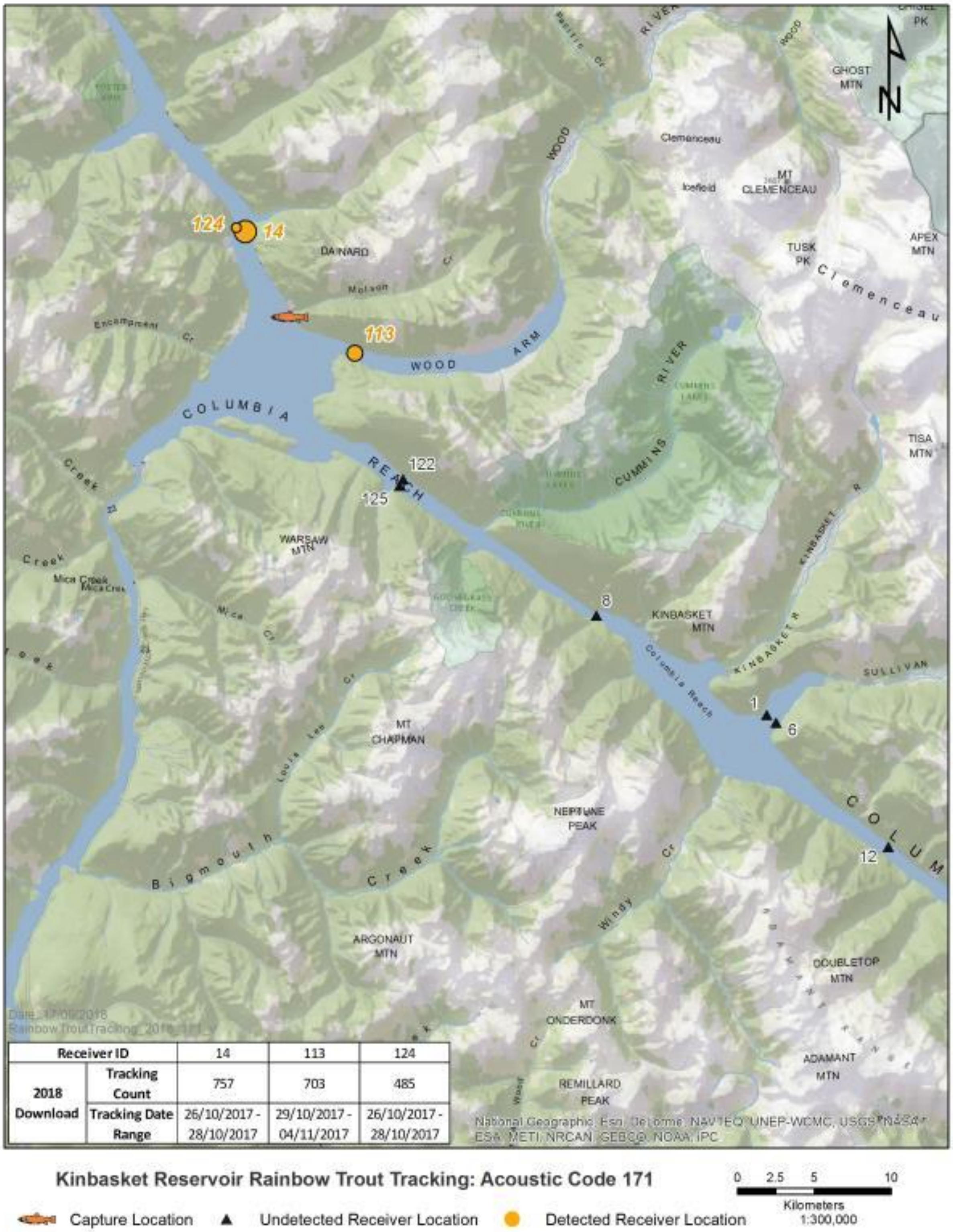
Receiver ID		8	14	113	122	124	125
2018 Download	Tracking Count	434	561	2,917	1,680	916	2,904
	Tracking Date Range	22/04/2018 - 23/04/2018	27/10/2017 - 06/04/2018	26/10/2017 - 06/04/2018	12/04/2018 - 26/04/2018	27/12/2017 - 25/05/2018	12/04/2018 - 27/04/2018

Figure A-17. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 167 and their tracking date ranges. Detected receiver location points are sized according to their relative number of detections. Capture and tag implantation occurred on October 5, 2017.



Receiver ID		1	8	12	13	122
2018 Download	Tracking Count	2,964	364	22,304	16	1,860
	Tracking Date Range	24/10/2017 - 19/04/2018	22/10/2017 - 23/10/2017	24/10/2017 - 18/04/2018	23/04/2018	14/10/2017 - 20/10/2017

Figure A-18. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 170 and their tracking date ranges. Detected receiver location points are sized according to their relative number of detections. Capture and tag implantation occurred on October 6, 2017.



Receiver ID		14	113	124
2018 Download	Tracking Count	757	703	485
	Tracking Date Range	26/10/2017 - 28/10/2017	29/10/2017 - 04/11/2017	26/10/2017 - 28/10/2017

Figure A-19. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 171 and their tracking date ranges. Detected receiver location points are sized according to their relative number of detections. Capture and tag implantation occurred on October 5, 2017.

APPENDIX B.1 – Tributary photographs

Photograph 1. Packsaddle Creek, approximately 20 m from the top of the drawdown zone (May 1st, 2018).

Photograph 2. Looking downstream Packsaddle Creek, approximately 80 m from the top of the drawdown zone (May 1st, 2018). Photograph shows braiding moving farther downstream.

Photograph 3. Dave Henry Creek at the top of the drawdown zone (April 22nd, 2016).

Photograph 4. Looking downstream Dave Henry Creek, approximately 500 m below the top of the drawdown zone (April 22nd, 2016). Photograph shows braiding moving farther downstream.

Photograph 5. Looking upstream from the top of the drawdown zone on Yellowjacket Creek (April 22nd, 2016).

Photograph 6. Yellowjacket Creek, approximately 390 m below the top of the drawdown zone (April 22nd, 2016). Photograph shows braiding moving farther downstream.

Photograph 7. Horse Creek at the top of the drawdown zone (April 20th, 2016).

Photograph 8. Horse Creek, approximately 340 m below the top of the drawdown zone (April 20th, 2016). Photograph shows braiding moving farther downstream.

Photograph 9. Ptarmigan Creek at the top of the drawdown zone (April 21st, 2016).

Photograph 10. Looking downstream Ptarmigan Creek, approximately 525 m below the top of the drawdown zone (April 21st, 2016).

Photograph 11. Hugh Allan Creek, approximately 680 m from the top of the drawdown zone (May 2nd, 2017).

Photograph 12. Hugh Allan Creek, approximately 1,000 m from the top of the drawdown zone (~730 m elevation), near the reservoir (May 2nd, 2017).

Photograph 13. Windfall Creek, approximately 360 m from the top of the drawdown zone (~737 m elevation; May 2nd, 2017).

Photograph 14. Windfall Creek, approximately 580 m from the top of the drawdown zone (~729 m elevation), near the reservoir (May 2nd, 2017). Photograph shows suitable spawning gravels for Rainbow Trout.

Photograph 15. Harvey Creek, approximately 560 m (~735 m elevation) from the top of the drawdown zone (May 3rd, 2017).

Photograph 16. Harvey Creek approximately 720 m (~730 m elevation) from the top of the drawdown zone, near the reservoir (May 3rd, 2017). Photograph shows suitable spawning gravels for Rainbow Trout.

Photograph 17. Tsar Creek, near the top of the drawdown zone (~751 m elevation; May 3rd, 2017).

Photograph 18. Tsar Creek, approximately 280 m from the top of the drawdown zone (~729 m elevation), near the reservoir (May 2nd, 2017). Photograph shows suitable spawning gravels for Rainbow Trout.

Photograph 19. The unnamed west tributary north of Gold Creek at the top of the drawdown zone (May 1st, 2015).

Photograph 20. The unnamed west tributary north of Gold Creek, approximately 175 m below the top of the drawdown zone (May 1st, 2015).

Photograph 21. Cascade at the top of the drawdown zone on the Beaver River (May 4th, 2016). This is a potential barrier to upstream movement by Rainbow Trout.

Photograph 22. Beaver River, approximately 1,500 m below the top of the drawdown zone (May 4th, 2016).

Photograph 23. Succour Creek at the top of the drawdown zone (April 28th, 2015). Photograph shows suitable spawning gravels for Rainbow Trout.

Photograph 24. Looking downstream Succour Creek, approximately 4,910 m below the top of the drawdown zone (April 18th, 2016).

Photograph 25. Looking downstream Succour Creek, approximately 7,041 m below the top of the drawdown zone (April 19th, 2018).

APPENDIX B.2 – Stream elevation profiles

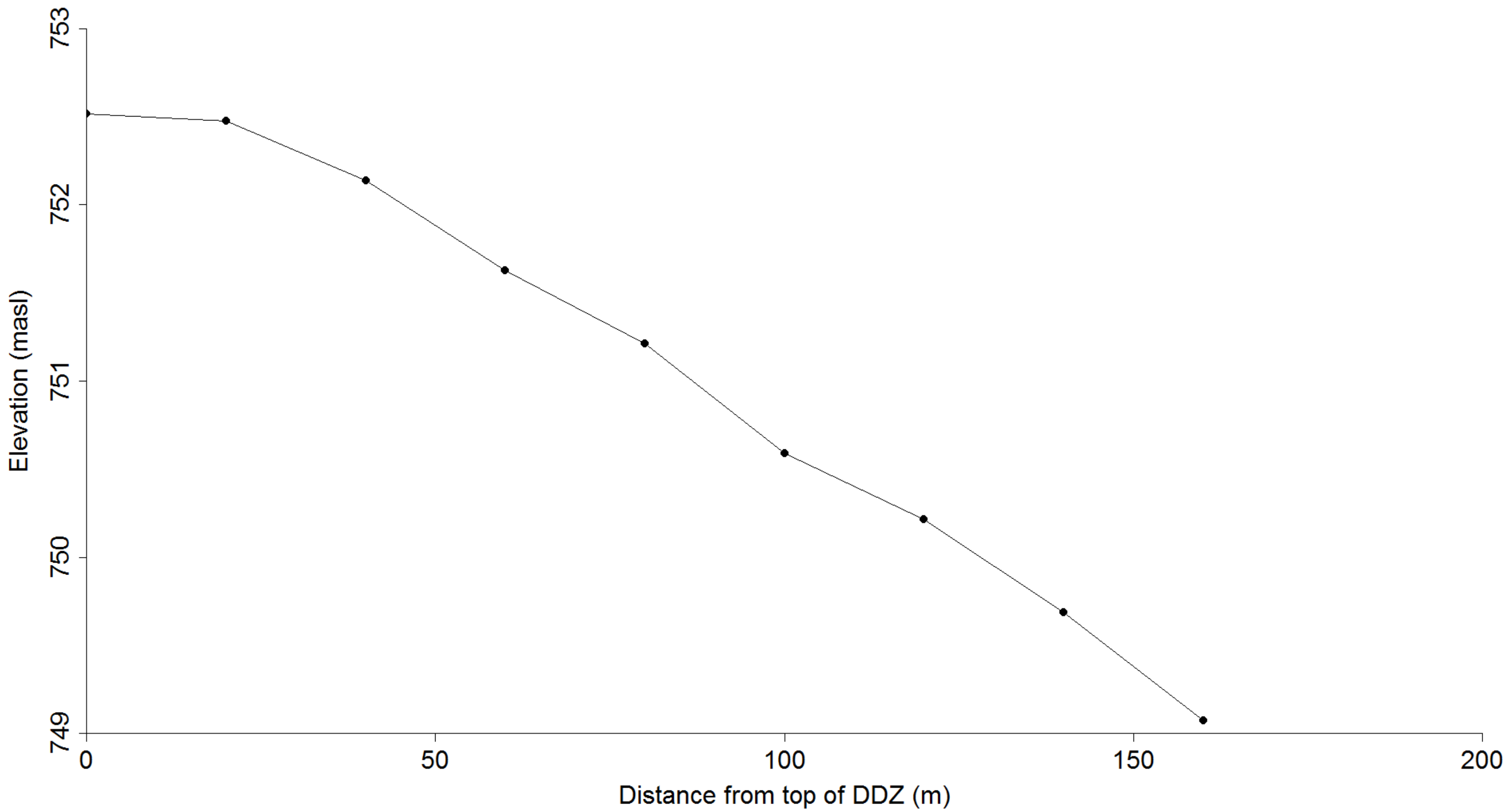


Figure B-1. Longitudinal profile of stream elevation for Packsaddle Creek (2018).

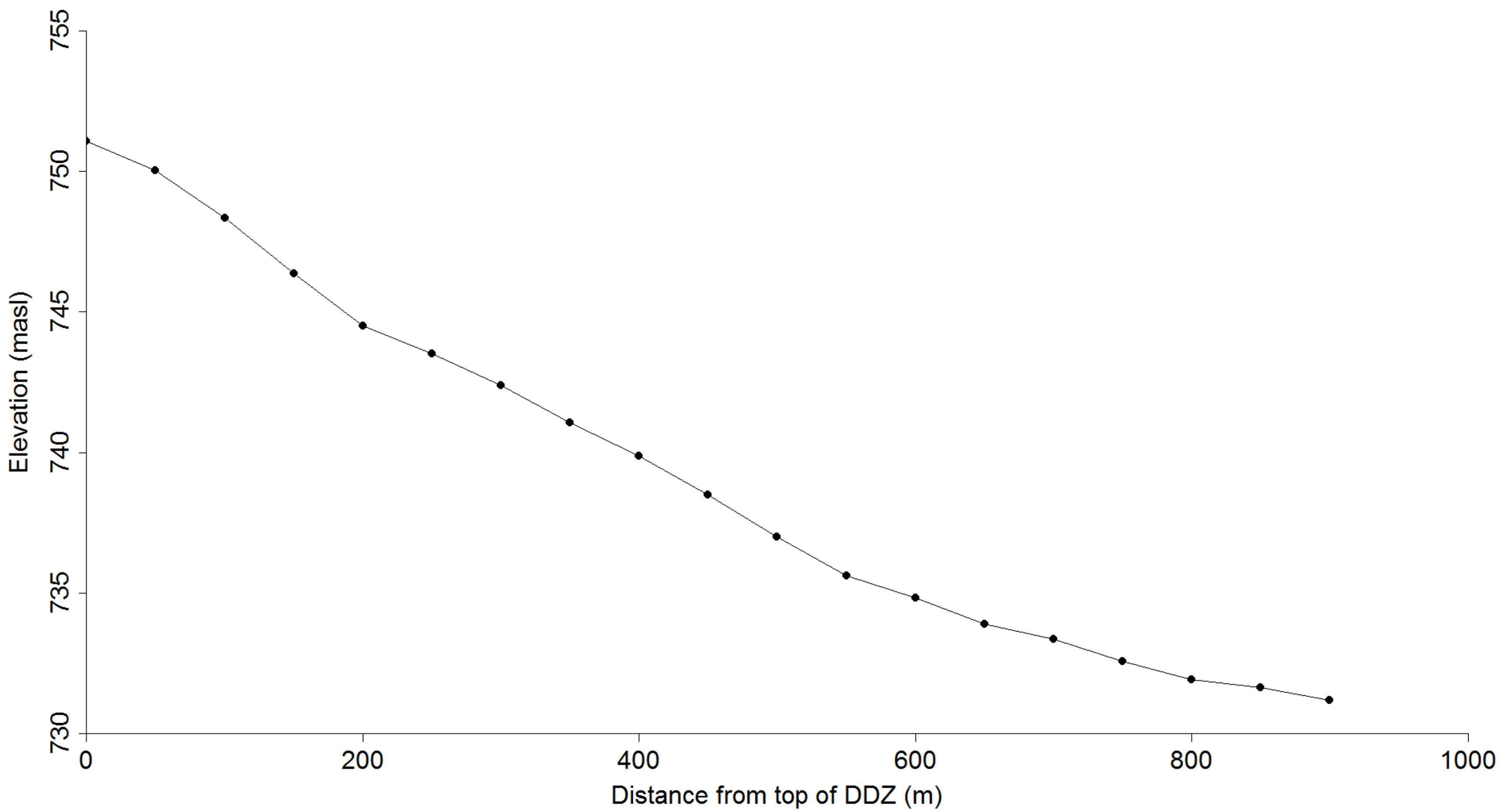


Figure B-2. Longitudinal profile of stream elevation for Dave Henry Creek (2016).

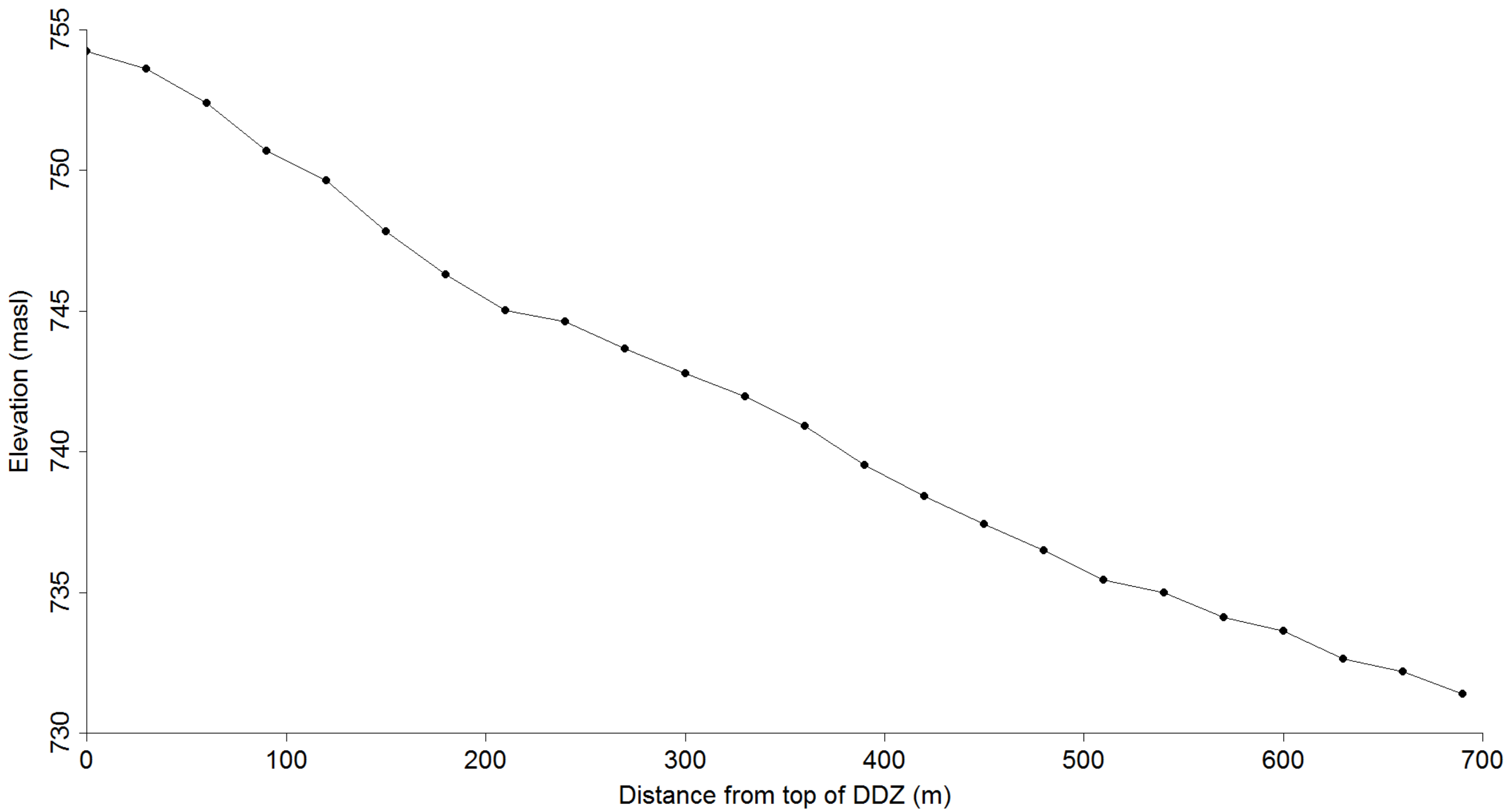


Figure B-3. Longitudinal profile of stream elevation for Yellowjacket Creek (2016).

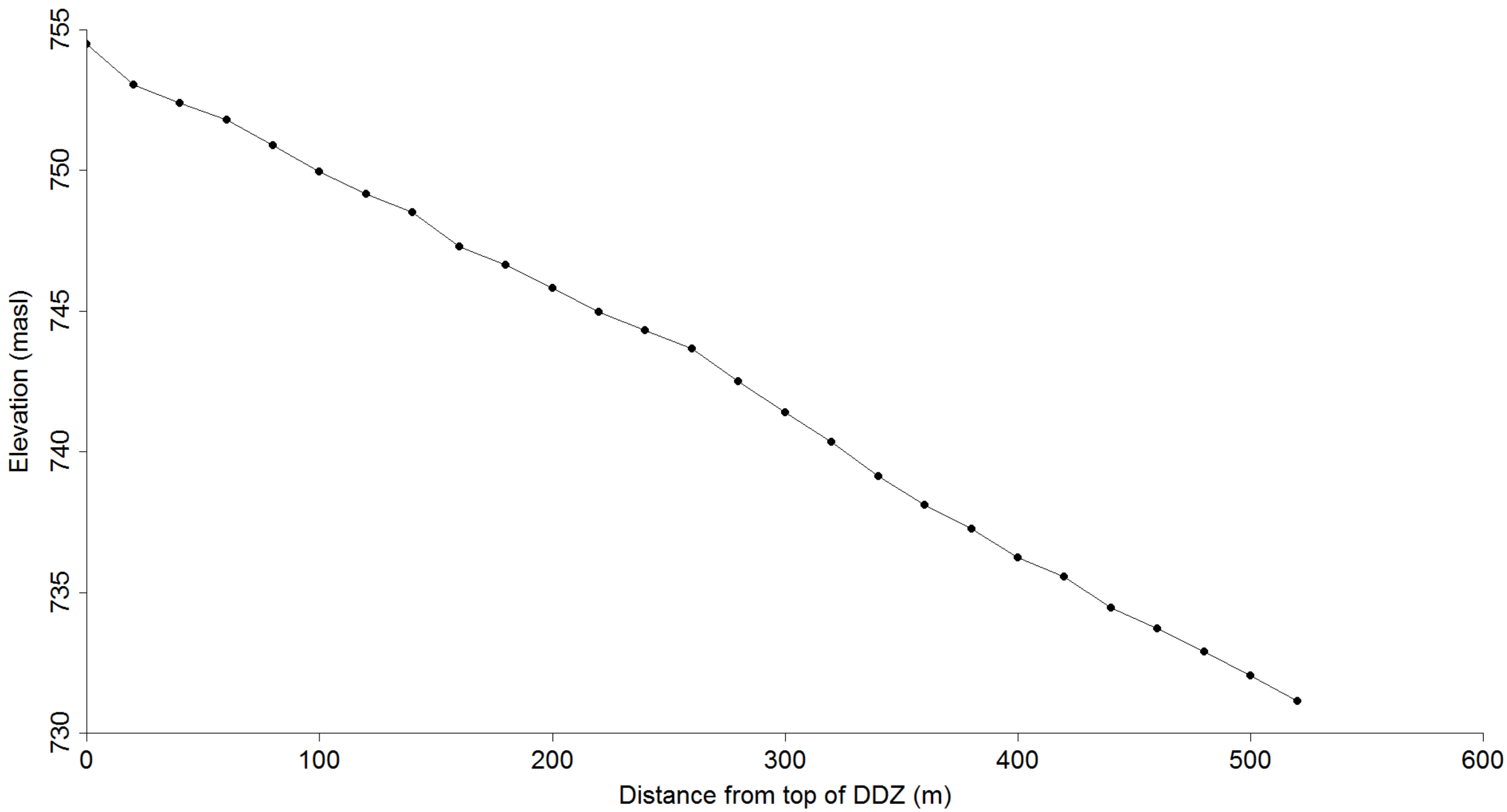


Figure B-4. Longitudinal profile of stream elevation for Horse Creek (2016).

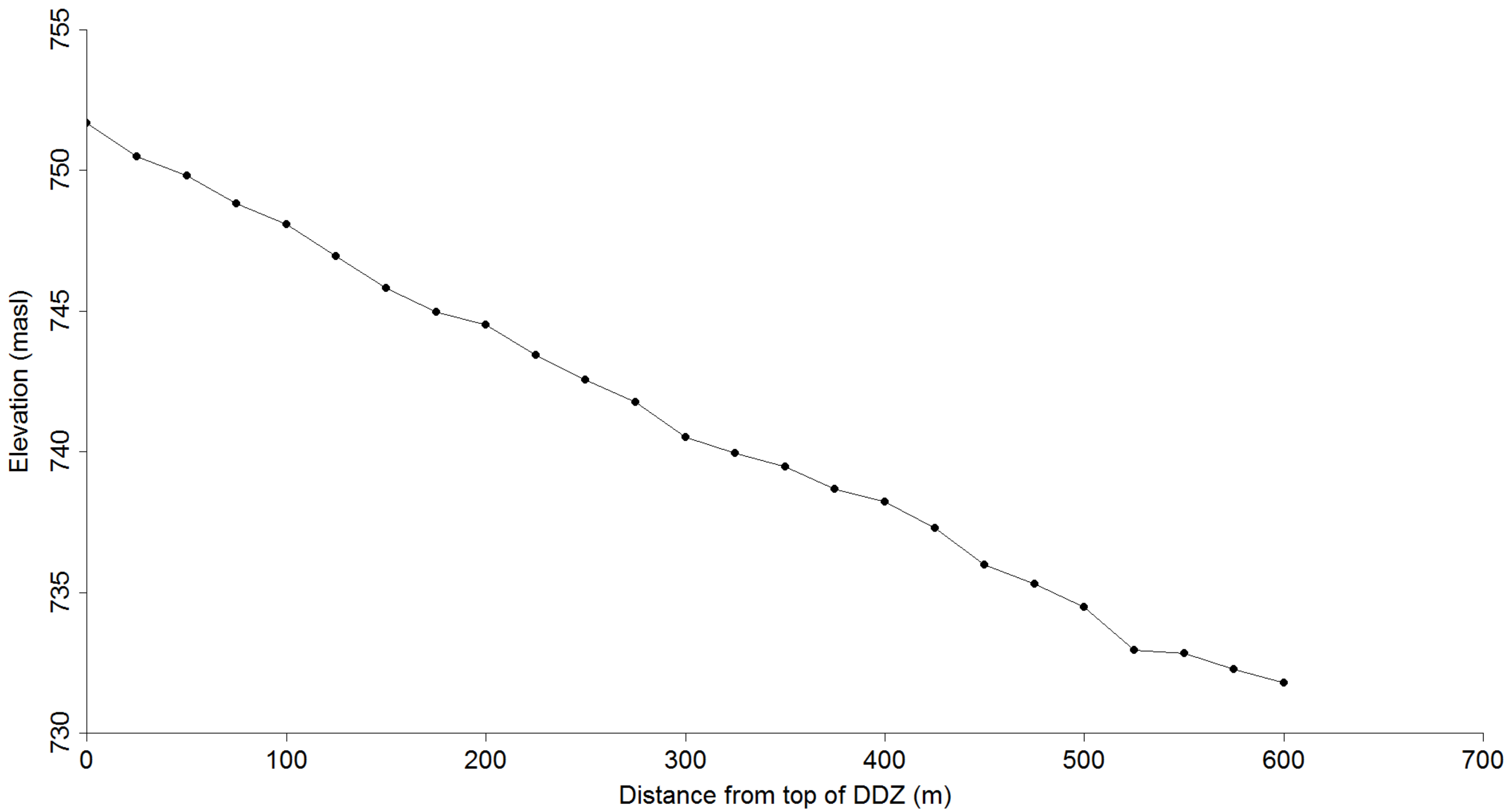


Figure B-5. Longitudinal profile of stream elevation for Ptarmigan Creek (2016).

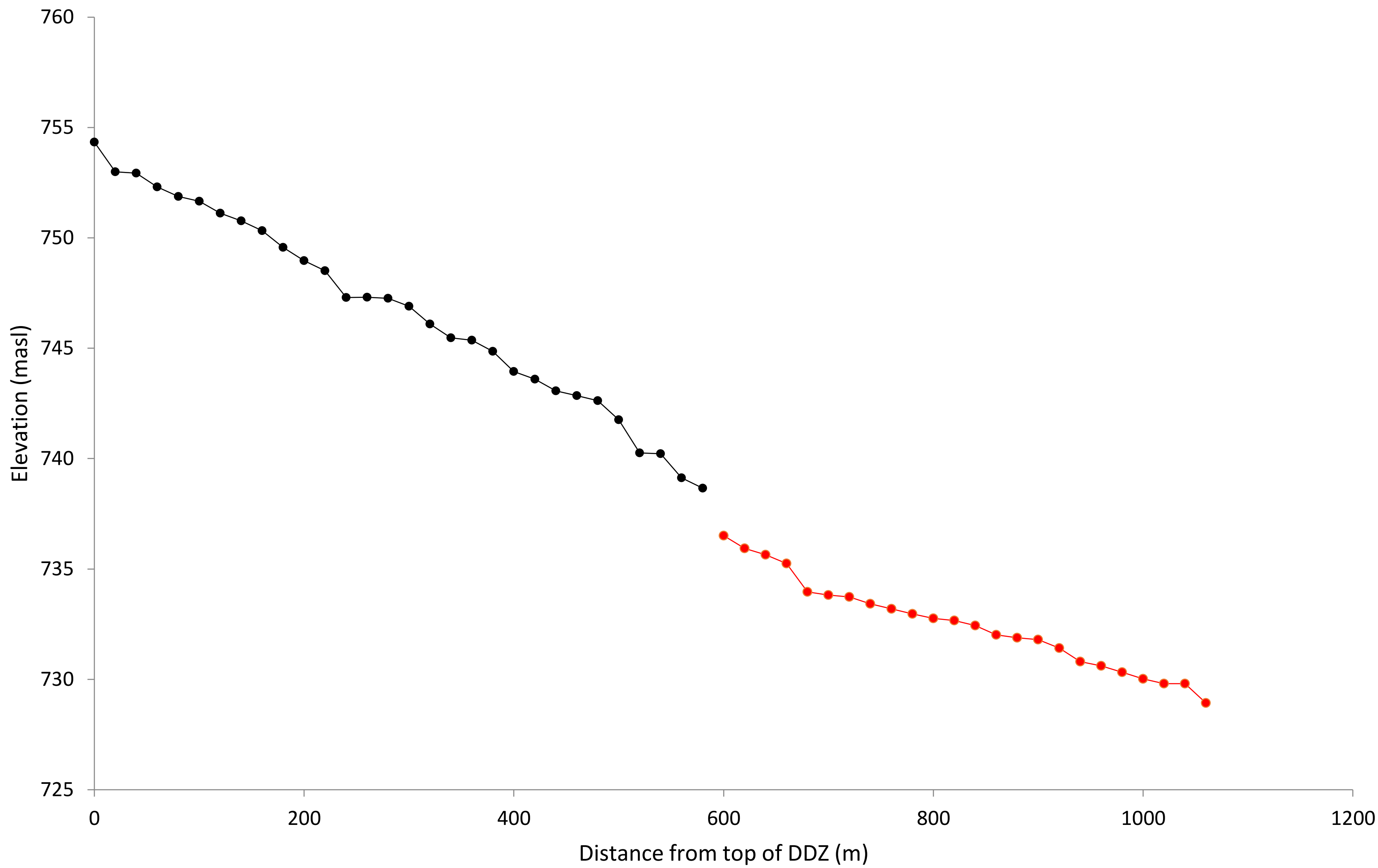


Figure B-6. Longitudinal profile of stream elevation for Hugh Allan Creek. Black markers are transect points taken in the 2015 survey, and red markers are points taken in the 2017 survey.

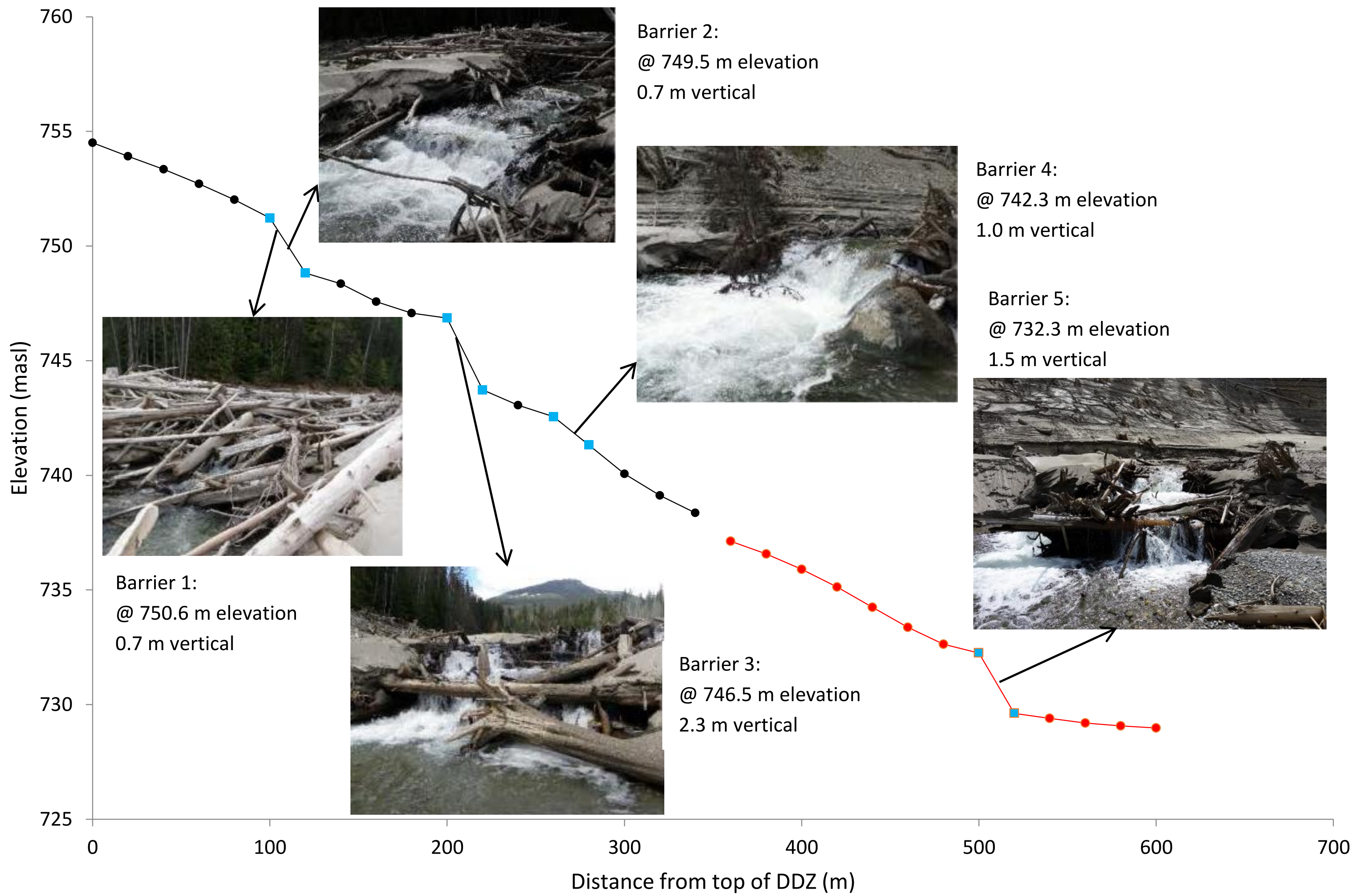


Figure B-7. Longitudinal profile of stream elevation for Windfall Creek. Black markers are transects taken in the 2015 survey, and red markers from the 2017 survey. Barriers are found in transects bounded by blue markers. Barrier photos and information are embedded in the figure.

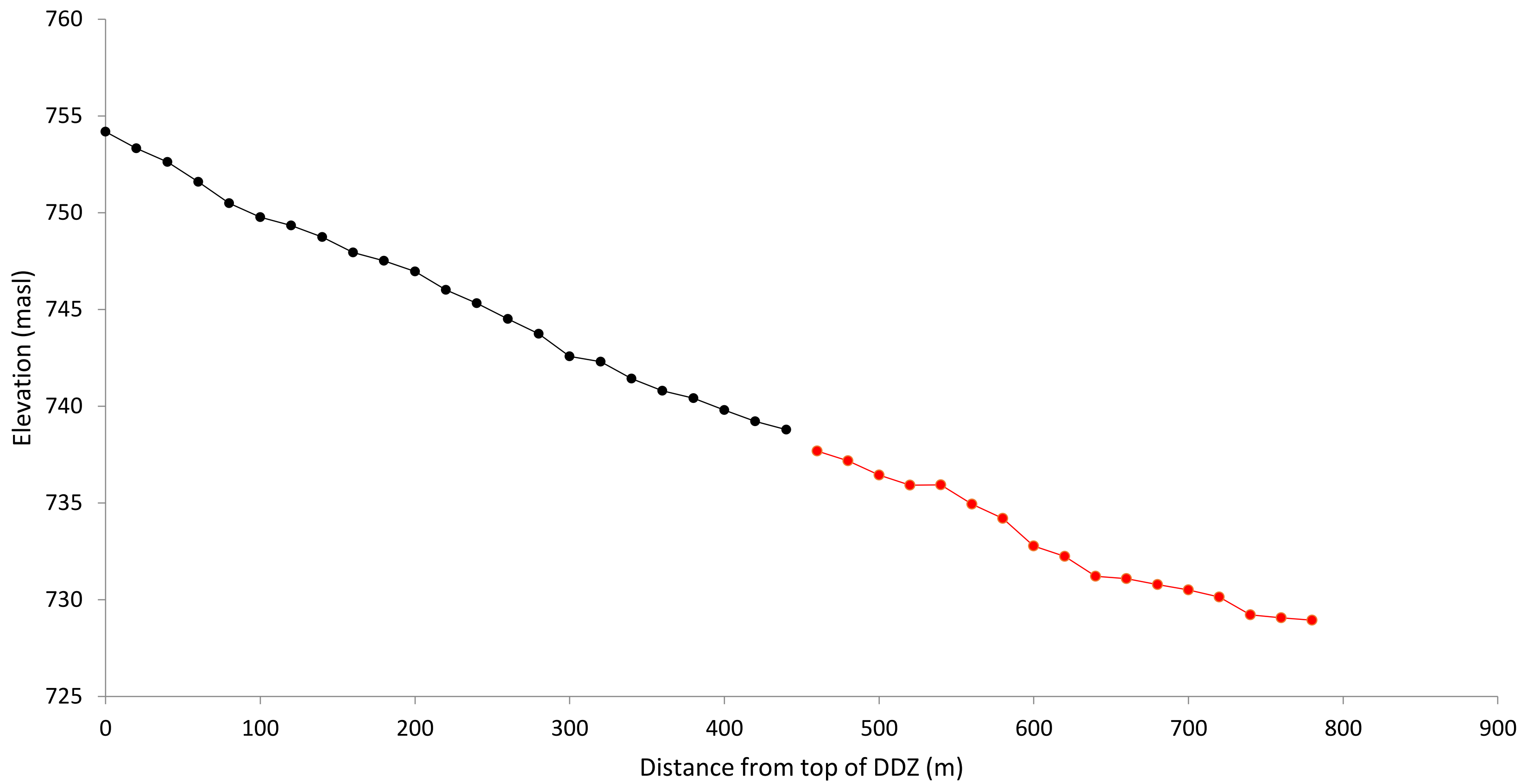


Figure B-8. Longitudinal profile of stream elevation for Harvey Creek. Black markers are transect points taken in the 2015 survey, and red markers are points taken in the 2017 survey.

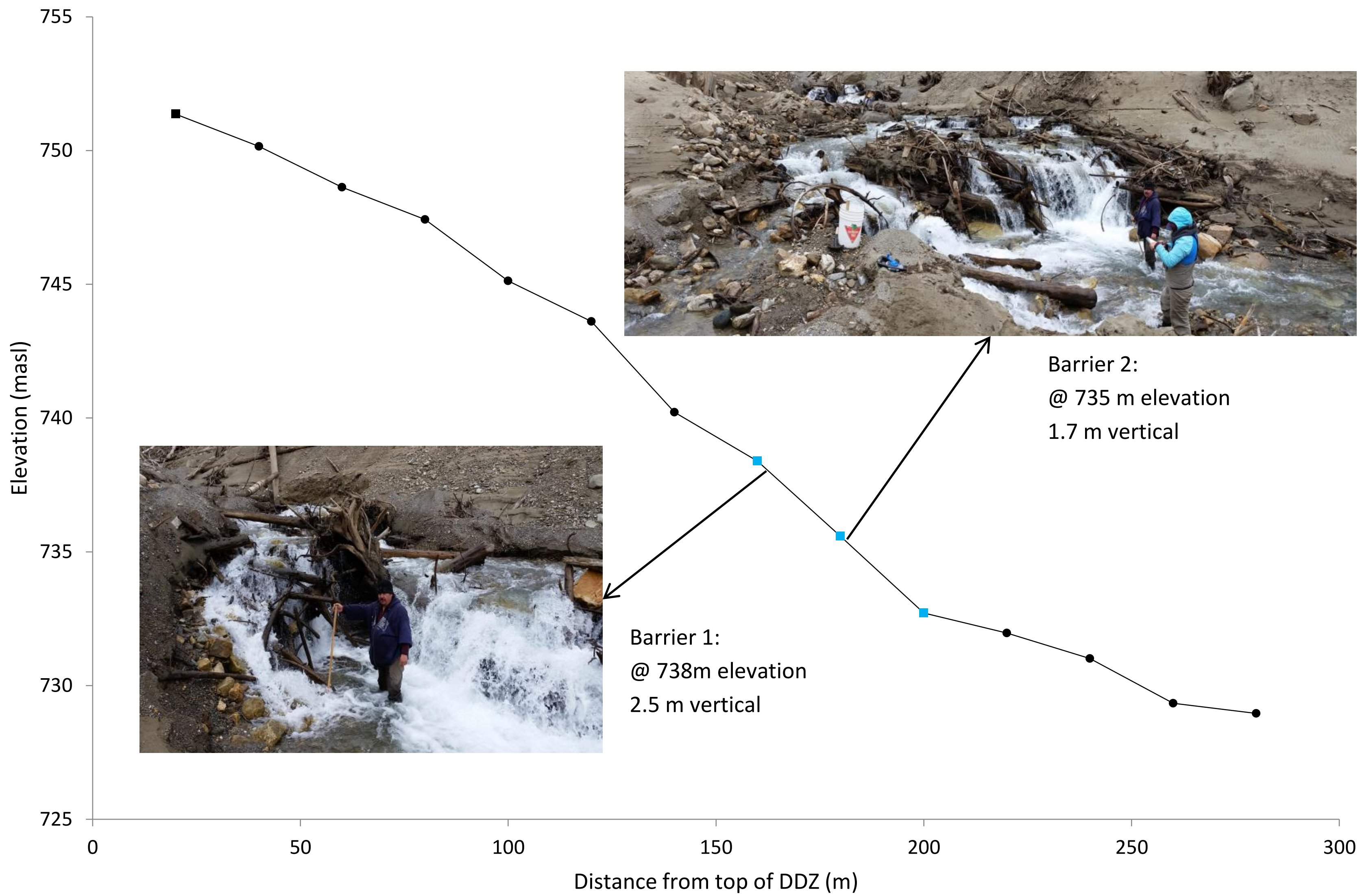


Figure B-9. Longitudinal profile of stream elevation for Tsar Creek from the 2017 survey. Barriers are found in transects bounded by blue markers. Barrier photos and information are embedded in the figure.

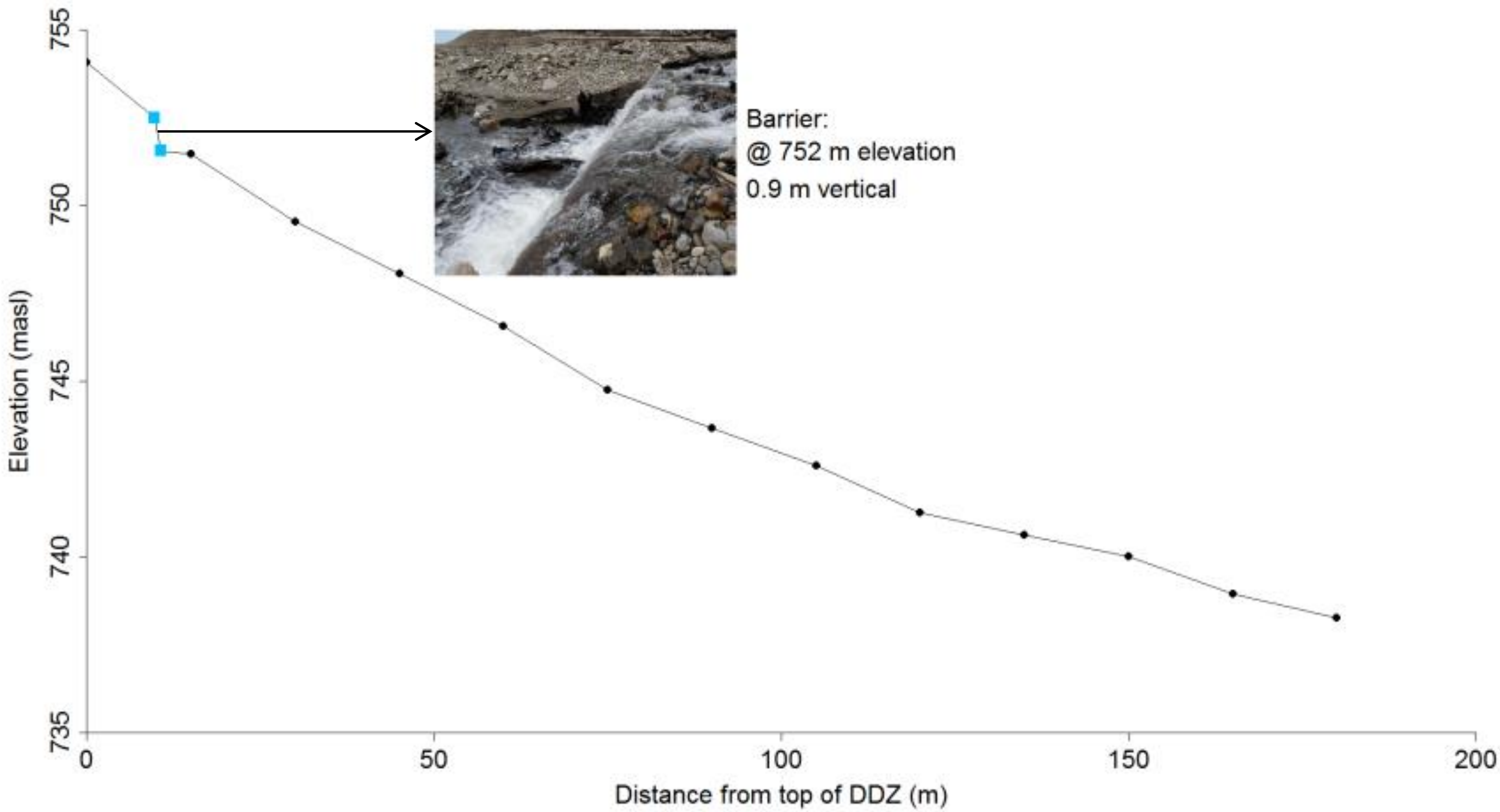


Figure B-10. Longitudinal profile of stream elevation for the unnamed tributary north of Gold River (2015). A single barrier was observed and the location is shown in transects bounded by blue markers. Barrier photo and information are embedded in the figure.

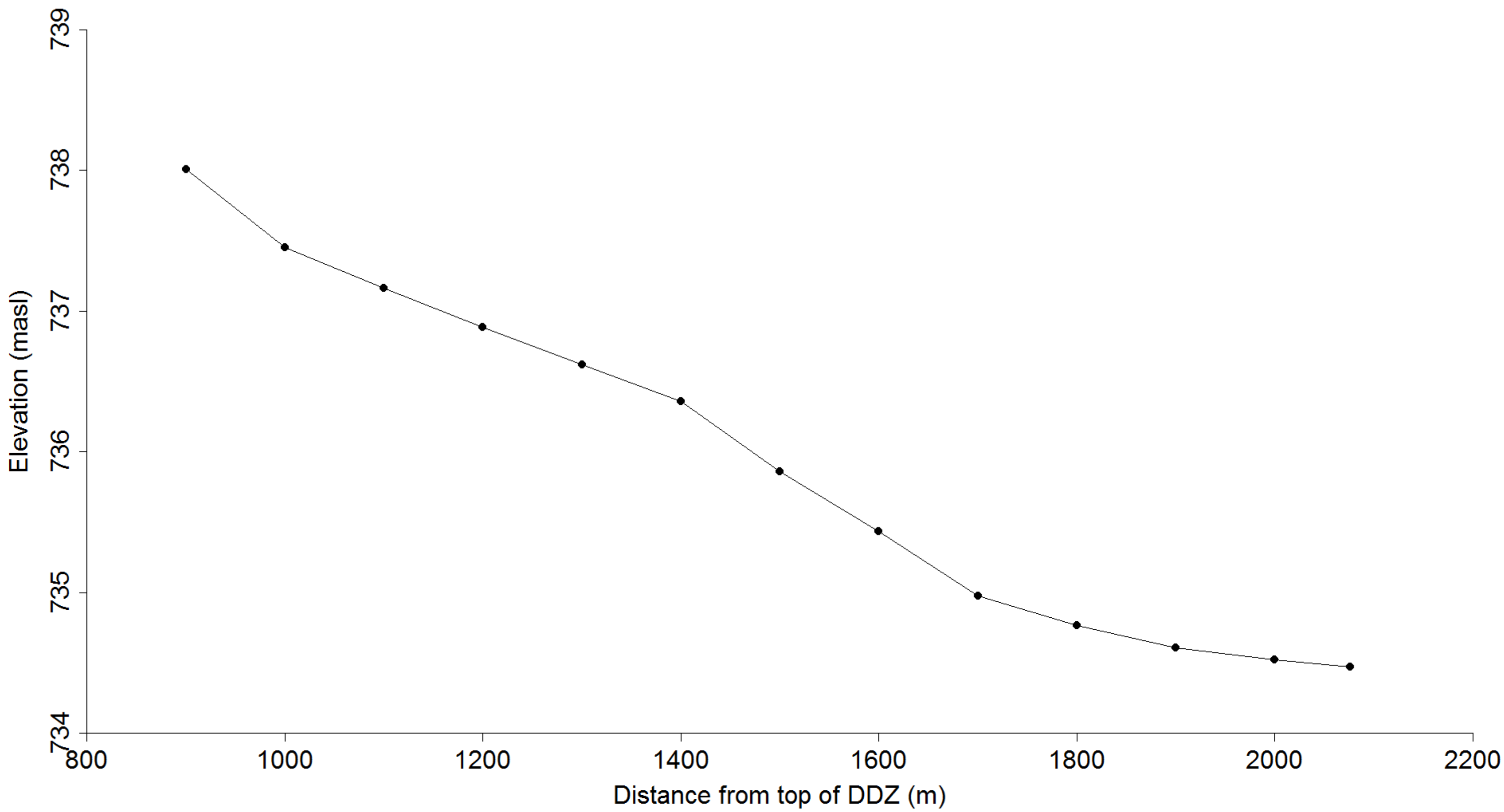


Figure B-11. Longitudinal profile of stream elevation for the Beaver River (2016).

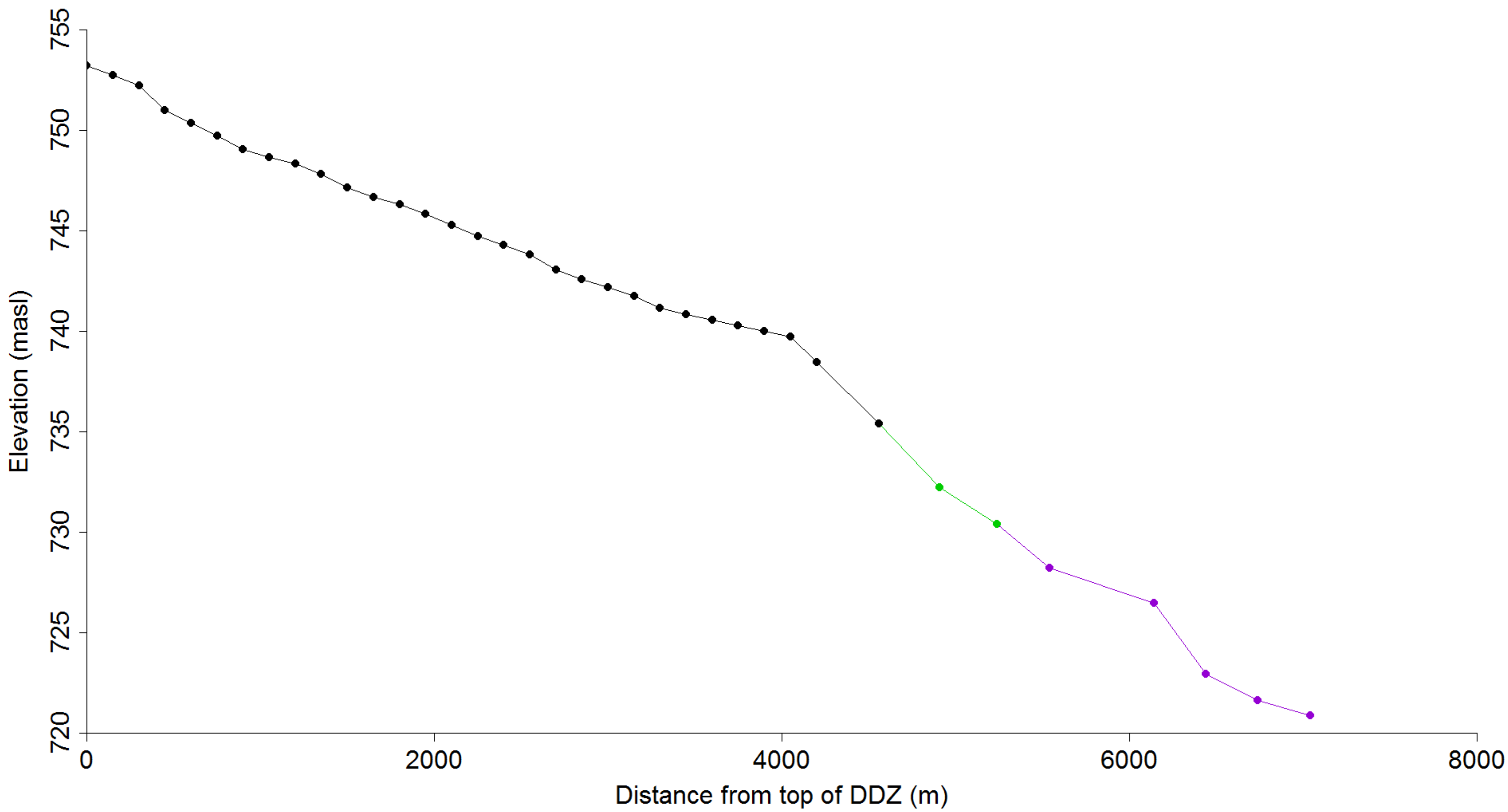


Figure B-12. Longitudinal profile of stream elevation for Succour Creek. Surveys were completed in 2015 (black), 2016 (green), and 2018 (purple) to extend the survey to the lowest possible reservoir elevation.