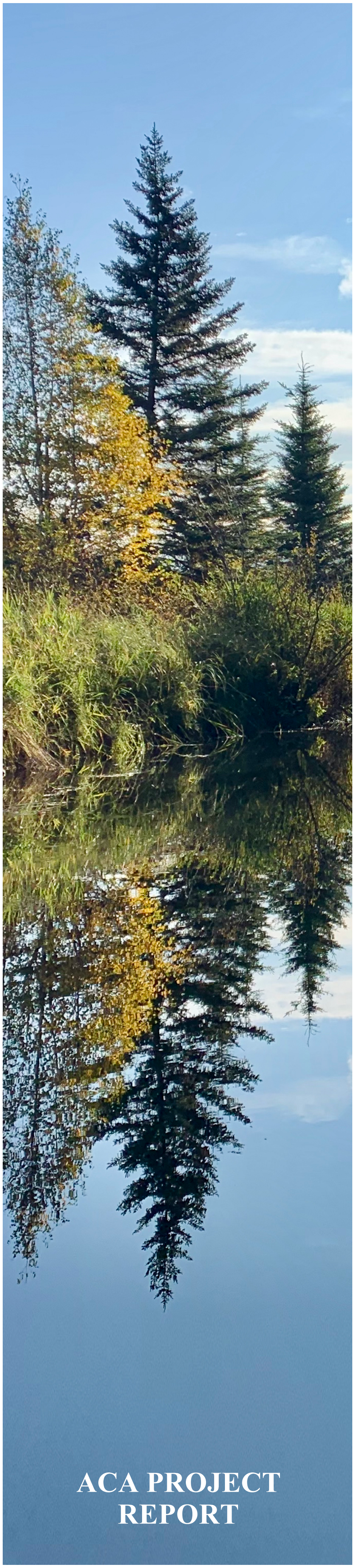

Ram River Bull Trout Assessment, 2017–2022

Alberta Conservation Association

wildlife | fish | habitat

Ram River Bull Trout Assessment, 2017–2022

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EXECUTIVE SUMMARY

Bull trout (*Salvelinus confluentus*) in Alberta have decreased in population size and distribution compared to historical levels, and Saskatchewan–Nelson River populations are listed as *Threatened* under the *Species at Risk Act*. The federal recovery strategy identifies anthropogenic threats including habitat alteration and fragmentation, sediment introductions, non-native fish stocking, hybridization, and angling mortality as the leading causes of the decline in bull trout populations. The Native Trout Recovery Program is a collaboration between government and non-government organizations with the goal of assessing, recovering, and monitoring native trout populations throughout Alberta's eastern slopes. Recovery of the populations can be achieved by mitigating the identified threats in the watersheds through actions such as restoring degraded habitat, reducing sediment inputs, suppression of non-native fish, and possibly changes in angling regulations. Our objective was to monitor the distribution and abundance of bull trout and other salmonids in the Ram River watershed in Alberta, which has been identified through the Native Trout Recovery Program as a priority watershed for mitigation measures and monitoring of the bull trout population.

We used backpack electrofishing gear to monitor bull trout and other fish species abundance and distribution from 2017 to 2021 in Ram River tributaries. We sampled between 8 and 12 sites per year throughout the study area; because of changes in study methods not all sites were sampled each year. During our study, we captured a total of 273 salmonids, including 182 bull trout. Bull trout ranged in size from 45 to 478 mm fork length. There were six sample sites that had zero fish captures the entire study period, while only one site had bull trout each of the five years of the study. Non-native brook trout (*Salvelinus fontinalis*) were found primarily in Makwa Creek and made up a small percentage of our overall catch. We did, however, capture suspected brook trout x bull trout hybrids at two sites during our sampling.

Water conditions early in our study made monitoring bull trout abundance in the Ram River impractical, so we used redd surveys (2018–2022) and fish counts (2019–2022) in Fall Creek to monitor adult bull trout abundance in the watershed. Fall Creek is a tributary to the Ram River used by migratory bull trout from the river for spawning. Redd counts ranged between 42 and 76 during the study period and together with our fish fence counts we estimated 1.2–1.3 spawners per redd. Independent redd surveys were between 79% and 124% of our best counts. Based on sixteen years of survey data collected by ACA, the bull trout population spawning in Fall Creek appears to fluctuate in a cyclic manner with no significant linear trend. Surveying Fall Creek for redds is a cost-effective technique for monitoring the Ram River's migratory bull trout population.

Key words: Alberta, Ram River watershed, Fall Creek, bull trout, distribution, abundance, redd surveys.

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1.0 INTRODUCTION

Native trout along the Eastern Slopes of the Rocky Mountains in Alberta have intrinsic economic and ecologic value yet have decreased in population size and distribution compared to historical levels (Sinnatamby et al. 2020). Bull trout (*Salvelinus confluentus*), Saskatchewan–Nelson River populations, are listed as *Threatened* under the *Species at Risk Act* (Government of Canada 2023) with a federal recovery strategy developed to protect, maintain, and recover bull trout to self-sustaining populations where recovery is likely (Fisheries and Oceans Canada 2020). Provincially, bull trout is listed as *Threatened* under Alberta's *Wildlife Act* (Alberta King's Printer 2023). Anthropogenic threats are the leading cause of bull trout population declines (Fisheries and Oceans 2020). These threats include habitat degradation and fragmentation, sedimentation, introduction of non-native fish, hybridization, and angling mortality (COSEWIC 2012, Sawatzky 2016).

The Native Trout Recovery Program is a collaboration between government and non-government organizations with the goal of assessing, recovering, and monitoring native trout populations throughout Alberta's eastern slopes. Population recovery can be achieved by mitigating species threats in impacted watersheds through implementation of conservation actions such as restoring degraded habitat, reducing sediment inputs, suppressing non-native fish, and changing angling regulations. The Alberta Fish Sustainability Index (FSI) is a standardized assessment process that provides a landscape-level overview of fish sustainability by species within the province and enables broad-scale evaluation of management actions and land-use planning (MacPherson et al. 2014). The FSI evaluates fish species on four groups of metrics: population integrity, productivity, threats, and data reliability (MacPherson et al. 2014). Fish inventory data are particularly suited to evaluation of the population integrity (adult and immature density) and productive potential (geographic extent). When conducting fishery inventories in Alberta, watersheds are scaled using a hydrological unit code (HUC), appropriate for the focal fish species, with HUC 2 being the coarsest level and HUC 10 being the finest level. Bull trout populations are being assessed at a HUC 10 scale.

The Ram River watershed was identified through the Native Trout Recovery Program as a priority watershed for monitoring the bull trout population. Fall Creek, a tributary to the Ram River, provides spawning habitat for fluvial bull trout from the Ram, North Saskatchewan, and Clearwater rivers (Rodtka et al. 2010). Because of this importance, Fall Creek is classified as a Class A waterbody under Alberta's *Water Act*, limiting industrial development, and has an angling closure on the lower section of the creek. In 2018, extensive decommissioning and reclamation of the Fall Creek off-highway vehicle trail was completed including removal of over 50 stream crossings, further reducing anthropogenic threats within the creek (Government of Alberta 2018).

We had two original objectives for this study:

- Monitor bull trout and other salmonid species distribution and abundance in the Lower Ram River and Fall Creek HUC 10 sub-watersheds for five years.
- Monitor adult bull trout abundance in the Ram River HUC 8 watershed for five years.

Based on project developments, in 2018 we removed the Fall Creek HUC10 sub-watershed from our monitoring objective and added a new objective:

- Assess the validity of using Fall Creek redd counts to monitor adult bull trout abundance in the Ram River.

2.0 STUDY AREA

The Ram River originates in the Upper Clearwater/Ram Public Land Use Zone west of Rocky Mountain House, Alberta and flows approximately 122 km eastward to its confluence with the North Saskatchewan River. The watershed is approximately 1,800 km^2 and major tributaries within the watershed include the North Ram River, Fall Creek, and Makwa Creek (Figure 1). Waterfalls on Fall Creek and the Ram River are barriers to upstream fish passage and both systems were historically fishless upstream of these barriers. Cutthroat trout (*Onchorhynchus clarkii*) have been stocked in the watershed (Government of Alberta 2022) and are now self-sustaining in Fall Creek and the Ram River. Land-use activities within the study area include forestry, livestock grazing, oil and gas exploration, and recreation (North Saskatchewan Watershed Alliance 2005). Our study area includes the Ram River and tributaries below the waterfall barriers within the Lower Ram River and Fall Creek HUC 10 sub-watersheds.

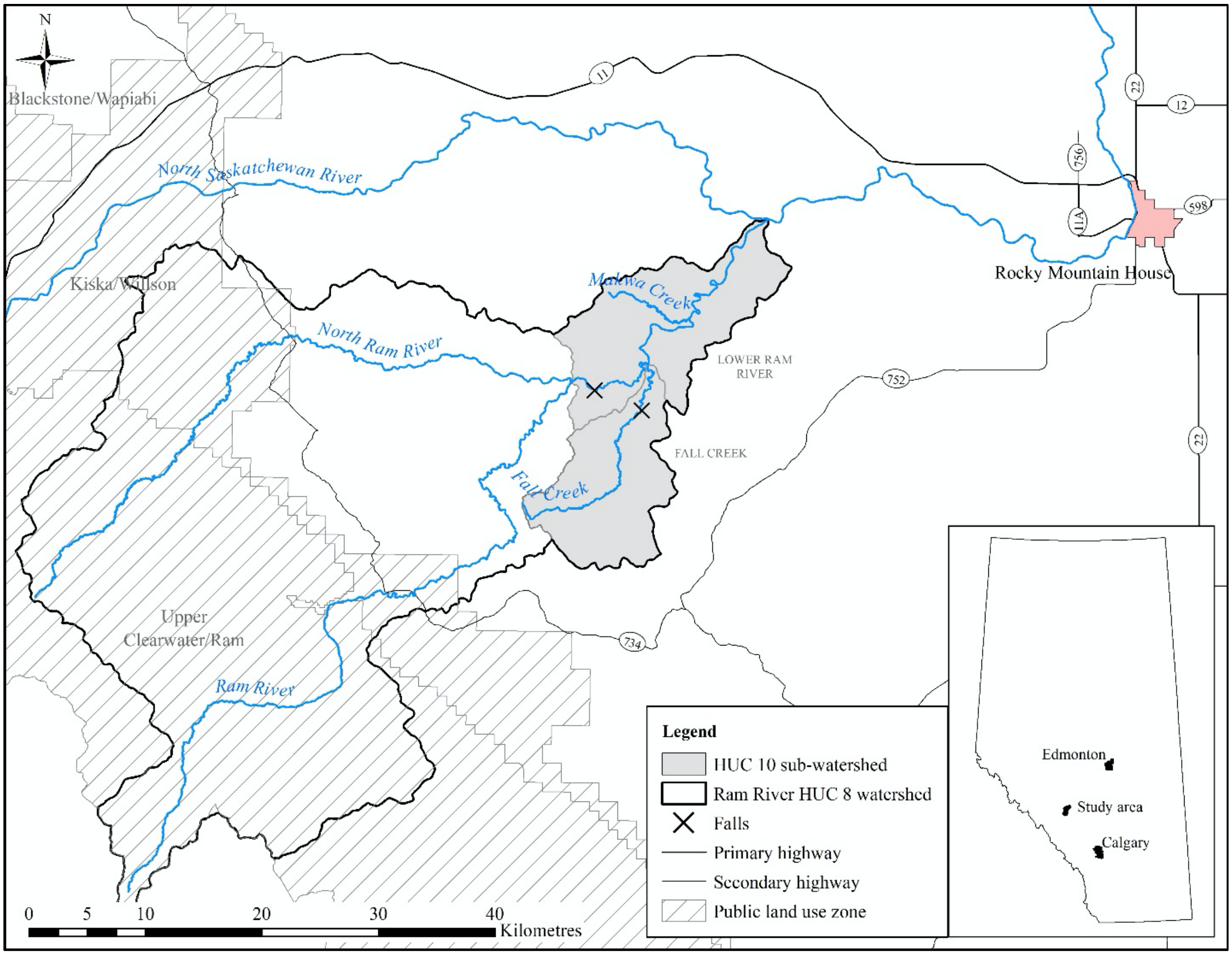

Figure 1. Map of the Ram River HUC 8 watershed and HUC 10 sub-watersheds. Inset map shows the location of the study area within the province of Alberta.

3.0 MATERIALS AND METHODS

3.1 Ram River tributaries

During the months of July and August from 2017 to 2021, we used backpack electrofishing gear to sample between 8 and 12 sites in tributaries to the Ram River to describe bull trout and other salmonid species distribution, population structure, and relative abundance (fish/300m) (Figure 2). We distributed prospective sample sites at 800 m intervals in an upstream progression along the length of third- to fifth-order streams (>400 meters; 1:20,000 scale) (Strahler 1952) within the study area using a geographical information system (GIS) (ArcGIS version 10.6). Sample sites were randomly selected without replacement using a generalized random-tessellation stratified design (Stevens and Olsen 2004). This design allowed us to adjust our sample size to accommodate non-response sites while maintaining a spatially balanced sample (Stevens and

Olsen 2004). We used a conservative target of ten sample sites based on past evaluations of our power to detect immature bull trout (Rodtka and Judd 2015, Rodtka et al. 2015). We selected 15 sites to accommodate non-response sites: sites that were inaccessible (greater than 1,000 m from access) or dry. In 2017, sites R8 and R11 were confirmed as non-response sites. After 2017, the Government of Alberta (GOA) assumed responsibility for sampling sites that occurred on Fall Creek (sites R1 and R5). Sites R13 and R14 were added to our sampling frame to replace these sites, resulting in a total of 12 sample sites in subsequent years. In 2020, our field season was reduced due to COVID work restrictions and we were only able to sample eight sites. These sites were chosen because they were relatively easy to access and had a high probability of containing fish. With the removal of the Fall Creek sites and reduced sampling effort in 2020, only sites R4, R6, R7, R9, R10, and R12 were sampled every year of the study. Site-specific location information is provided in Appendix 1.

We used a handheld Global Positioning System (GPS) to locate our sample sites and, for consistency, all sampling commenced at the head of riffle habitat. Following the provincial standard for sampling small streams, our sample sites were 300 m long (measured with a hip chain) (GOA 2013). In 2020, Site R8 was only 200 m due to low water conditions. Sites were sampled using a Smith-Root LR-20B backpack electrofisher with pulsed DC (voltage 100–350 V, frequency 30–60 Hz, and pulse width 4.2–12.9 ms).

Sample sites were divided into 50 m transects, and fish and habitat measurements were collected after electrofishing each transect. We identified fish species and recorded size (fork length; FL) of all fish. Bull trout were inspected for morphological features of hybridization with brook trout (*Salvelinus fontinalis*) as documented by Popowich et al. (2011). We collected standard fish habitat data (i.e., stream wetted and rooted widths, stream type, substrate composition, water temperature, conductivity, and maximum depth) at the time of sampling at each site, in accordance with provincial standards (GOA 2013). Site-specific habitat data are summarized in Appendix 2.

We calculated relative abundance (fish/300 m) of salmonid species as the bootstrapped mean abundance (10,000 replicates) of fish captured by sample year. For comparative purposes, only sample sites that were visited all five years of the study were included in our bootstrap analysis. We report bull trout abundance by maturity classification to align with FSI convention. Immature bull trout are defined as having a FL less than 150 mm (L. MacPherson, pers. comm.). Fish under 70 mm FL were not included in our analysis because they are difficult to capture with electrofishing gear and can bias abundance estimates (Peterson et al. 2004).

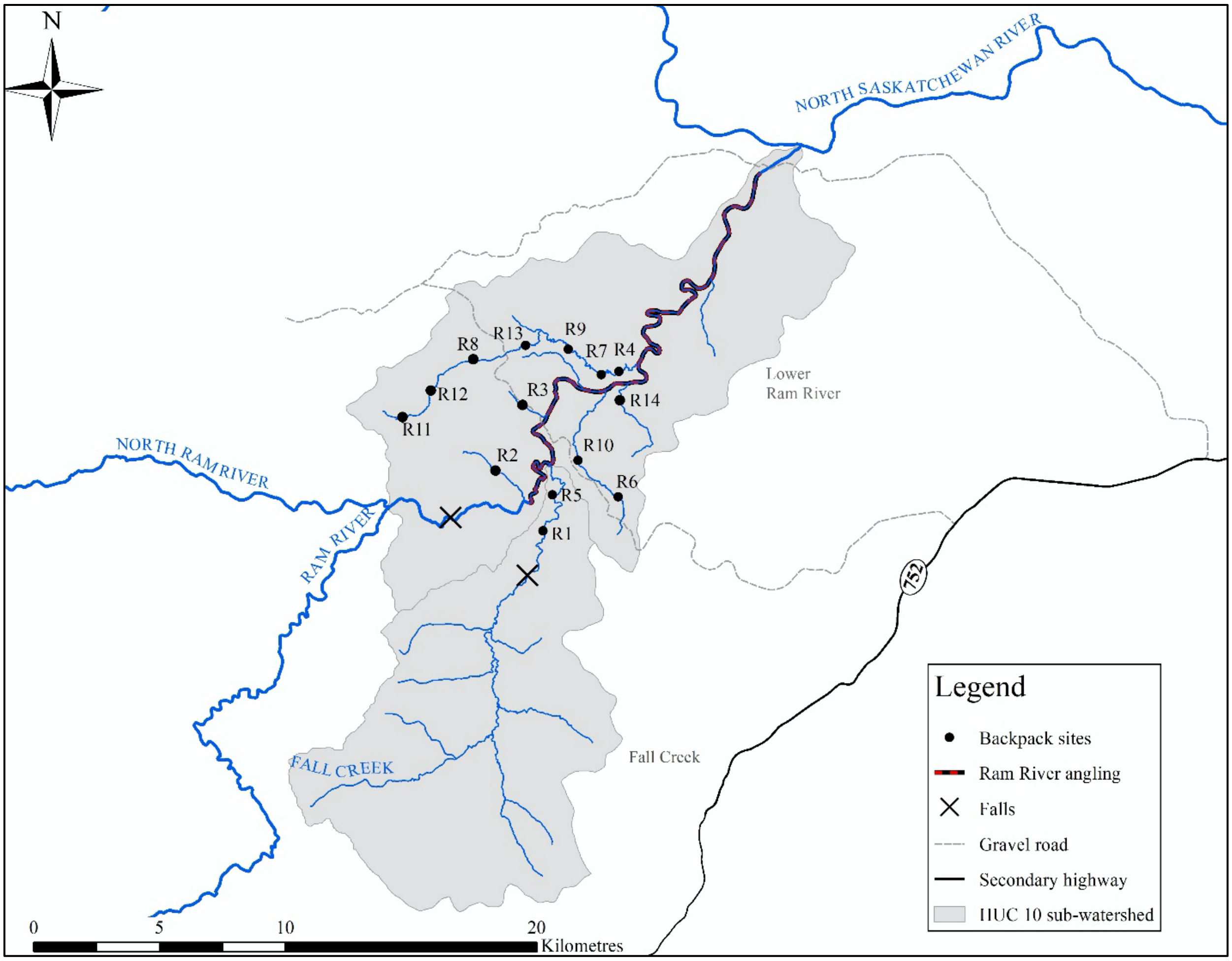

Figure 2. Electrofishing sites and angling reach within the HUC 10 sub-watersheds of the Ram River watershed in Alberta, 2017 to 2021.

3.2 Ram River mainstem

To assess adult bull trout abundance in the mainstem Ram River, we attempted mark-recapture estimates on a 26 km reach of the river using angling (marking run) and electrofishing (recapture run) gear (Figure 2). During marking runs, crews of two to four angled pool and deep riffle or run sections of the river using jigs and spinners with baited hooks. Captured bull trout greater or equal to 250 mm FL were implanted with a passive integrated transponder tag in the dorsal musculature and had either an adipose or upper caudal fin clipped to permit assessment of tag loss. Although water conditions in 2017 allowed us to successfully angle the reach in July, persistent low flow conditions thereafter prevented us from completing a recapture run. A landslide upstream of the study reach in 2018 made effective sampling of the river impossible due to low water clarity, although we did angle a 10 km section in August while assessing river conditions. Based on our experience in the first two years of the study, we concluded multi-year monitoring of bull trout abundance in the river would be impractical. Consequently, we shifted our focus to assessing the abundance of migratory, fluvial bull trout spawning in Fall Creek.

3.3 Fall Creek redd surveys

The relationship between redd and adult fish abundance of the Fall Creek spawning stock had not been rigorously assessed. Additionally, the precision of our redd counts was unknown. Both quantities are essential for critical evaluation of redd counts for monitoring bull trout abundance (Dunham et al. 2001, Muhlfeld et al. 2006, Howell and Sankovich 2012). Additionally, there is some evidence to suggest a minority of bull trout in the Ram River may have been spawned elsewhere, possibly the river (Rodtka et al. 2010). Finally, it had been nearly a decade since we critically assessed the location and timing of bull trout spawning activity in Fall Creek, although we have conducted a redd survey on the upper reach annually since 2007. These uncertainties needed to be addressed before we could consider redd abundance in the upper reach of Fall Creek a reliable index of fluvial bull trout abundance in the Ram River.

To reassess the timing and location of redds in the upper reach of Fall Creek, we conducted biweekly redd surveys during the autumns of 2018 to 2022. Redd surveys started the first week of September and ended the first week of October. During surveys, crews of two would walk upstream identifying redds as either definite (clean, defined pit and tailspill) or probable (missing one of these attributes) (Bonar et al. 1997). Redds were marked with a GPS and flagged on a nearby bank. In subsequent surveys, new redds were marked and the visibility of previously flagged redds was recorded. All flagging was removed during the final survey and the accumulated count of flagged, definite redds represented our best estimate of redd abundance for the year. During our last survey of each year (except 2020) we walked all 7.5 km of stream available to migrating bull trout to identify and mark the location of any spawning activity in lower Fall Creek.

To assess the precision of our counts, two-person crews independently completed redd surveys on the upper reach after our primary survey was complete in 2018 and 2020 (single crew), and 2021 and 2022 (two crews). Crew members had extensive experience conducting redd surveys in other watersheds (median 10 years), but limited experience conducting redd surveys in Fall Creek specifically (median 2 years). Each year, crews were given a brief overview of study methods, but in 2022 the orientation was expanded to include training on redd identification tailored to field conditions typical of Fall Creek. All surveys were conducted on the same day and redds (definite or probable) were marked by GPS. To assess variability in counts each year, we compare the total count of definite redds obtained by the independent crews to our best estimate. We also surveyed the Ram River below the falls October 11, 2019, and October 9, 2020, to identify any bull trout spawning in the mainstem. River surveys were conducted on foot, by raft, and rotary-winged aircraft.

To estimate the number of adult bull trout spawning in upper Fall Creek for comparison to redd counts we operated a flow-through, conduit fish fence from 2019 to 2022. The fence consisted of upstream and downstream wings attached to an open-ended box placed in the thalweg. The wings funneled fish through the box past video cameras mounted inside. Box openings were 70 cm wide; cameras included an underwater, side-mounted camera, and an overhead camera mounted on the box lid. Both cameras were connected to an onshore DVR set to continuously record. The interior of the box was dimly illuminated with an underwater LED light at night and marked at 20 cm intervals to allow a rough estimate of fish length. Although we were targeting the downstream run, fence design allowed free movement of fish in either direction. We used two, 300-watt solar panels connected to four, 100 ah deep-cycle batteries to power the cameras, light, and DVR. We checked the fence twice a week and changed the DVR weekly. The fish fence was installed in late August and was operational until after our final redd survey in early October each year. A typical year resulted in over 900 hours of video being recorded.

We used the motion-detection software program MotionMeerkat (Weinstein 2015) to detect bull trout in the video recordings. MotionMeerkat detects movement in video files and outputs the relevant footage as image frames for user review, drastically reducing the time required to process video files (Weinstein 2015). To test the accuracy of MotionMeerkat for our purposes, we counted individual bull trout in 15 randomly selected, 30-minute video clips annually, and compared that count to the same count independently derived using the MotionMeerkat output. In all cases, counts were ±2% of each other.

Two reviewers independently analyzed the MotionMeerkat output annually, identifying individual bull trout, where possible, based on unique markings and estimated length, and noting the time and direction of travel. We then compared counts and resolved any discrepancies based on review of the original video to arrive at a final count of adult (i.e., >400 mm FL) bull trout for the year. In periods when gear malfunction (2019 and 2021) or low water clarity (2021) precluded counts (133 and 148 hrs in 2019 and 2021, respectively; Appendix 3), we used the missForest package (Stekhoven. 2022) to impute bull trout counts. The imputation method used by missForest is an iterative, machine learning method based on a random forest algorithm. Advantages of the approach for our use were that it is non-parametric, accommodates mixed data types, and estimates imputation error without the need of a test set or cross validation (Stekhoven and Bühlmann 2012). Since 95% (250 of 264) of downstream counts occurred at night, imputations were broken into 12-hour blocks, corresponding roughly to hours of daylight (7:30 a.m. to 7 p.m.) and dark (7:30 p.m. to 7 a.m.). We used the default settings in missForest with year, month, day, and photoperiod as input variables when imputing missing bull trout counts. Although imputations were in half-day increments, we report the sum of all imputed and observed counts for a year as recommended by Arriagada et al. (2021). The out-of-bag, normalized root mean squared error estimate of 0.1035 for the imputation indicated good performance of the algorithm for our application (Stekhoven and Bühlmann 2012).

To assess trend in the bull trout population spawning in Fall Creek, we used loglinear regression of definite redd annual abundance in the upper reach. While this method is still widely used in conservation biology (d'Eon-Eggertson et al. 2015), and bull trout conservation specifically (Kovach et al. 2018), it assumes variability in the data arises purely because of sampling (i.e., observation) error, which is unlikely in many populations. Although the resulting trend estimate is unbiased, confidence intervals around the estimate will be overly narrow if the population's growth rate is impacted by environmental variability (i.e., process error) (Humbert et al. 2009). Although less conservative than methods that account for both observation and process error, loglinear regression can be useful for early detection of population trend (Kovach et al. 2018). All analyses were implemented in R 3.5.1 (R Core team 2018).

3.4 Stream temperature measurement

We measured summer (July 1–August 31) stream temperature (1°C) hourly using temperature loggers at stations located throughout the study area to describe the thermal habitats available (Figure 3). We stopped monitoring water temperature at Unnamed1 after 2017 because water temperature at this location was very similar to temperature at Unnamed2. Loggers were installed using weights and cable or rebar and placed as close to the thalweg as possible (USEPA 2014). All fish, habitat, and temperature information acquired in the field was submitted for inclusion into the GOA's Fisheries and Wildlife Management Information System (FWMIS) database.

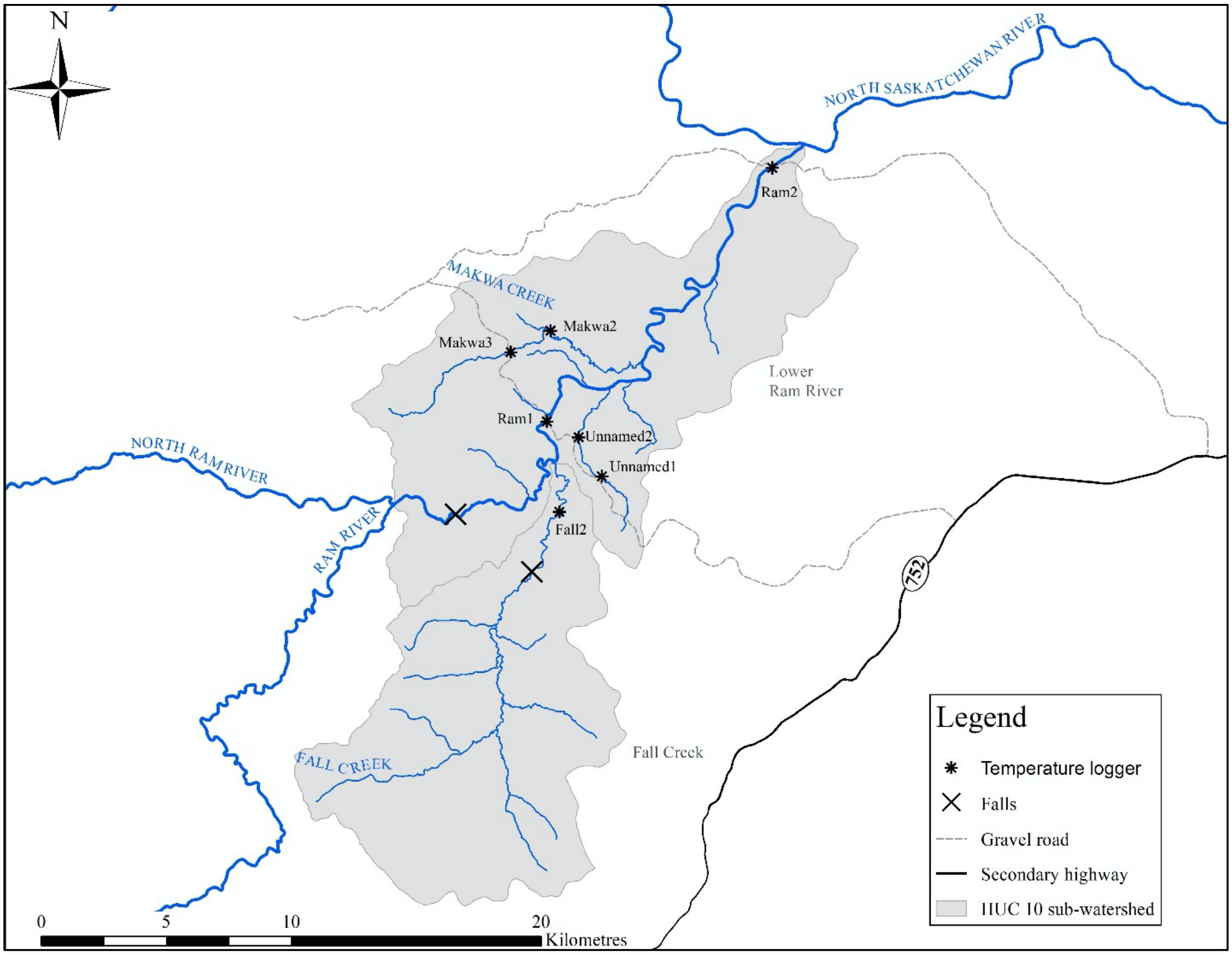

Figure 3. Locations of stream temperature stations in the Ram River watershed in Alberta, 2017 to 2021.

4.0 RESULTS

4.1 Ram River tributaries

Between 2017 and 2021, our salmonid capture in the Fall Creek and Lower Ram River HUC 10 sub-watersheds totaled 273 fish and included brook trout, brown trout (*Salmo trutta*), bull trout, cutthroat trout, and mountain whitefish (*Prosopium williamsoni*) (Table 1). In 2018, we also caught three suspected brook trout x bull trout hybrids. Bull trout were caught at least once at every site where fish were detected in the study area, but R10 was the only site where they were captured every year (Figure 4). Six sample sites had zero fish captures throughout the study period. Site-specific catch information is provided in Appendix 4. Other fish species in our catch but not summarized in this report included longnose dace (*Rhinichthys cataractae*), longnose sucker (*Catostomus catostomus*), mountain sucker (*Catostomus platyrhynchus*), and white sucker (*Catostomus commersonii*).

Table 1. Annual and total catch of salmonid species in Fall Creek and Lower Ram River HUC 10 sub-watersheds using backpack electrofishing gear, 2017 to 2021.

Species[1]	2017	2018	2019	2020	2021	Total Catch (%)
BKTR	8	4	6	17	15	50 (18)
BLTR	76	45	25	22	14	182 (67)
BLBK	0	3	0	0	0	3 (1)
BNTR	0	0	1	0	0	1 (<1)
CTTR	16	0	2	9	0	27 (10)
MNWH	3	1	5	1	0	10 (4)

[1]BKTR = brook trout, BLTR = bull trout, BLBK = brook trout x bull trout hybrid, BNTR = brown trout, CTTR = cutthroat trout, MNWH = mountain whitefish.

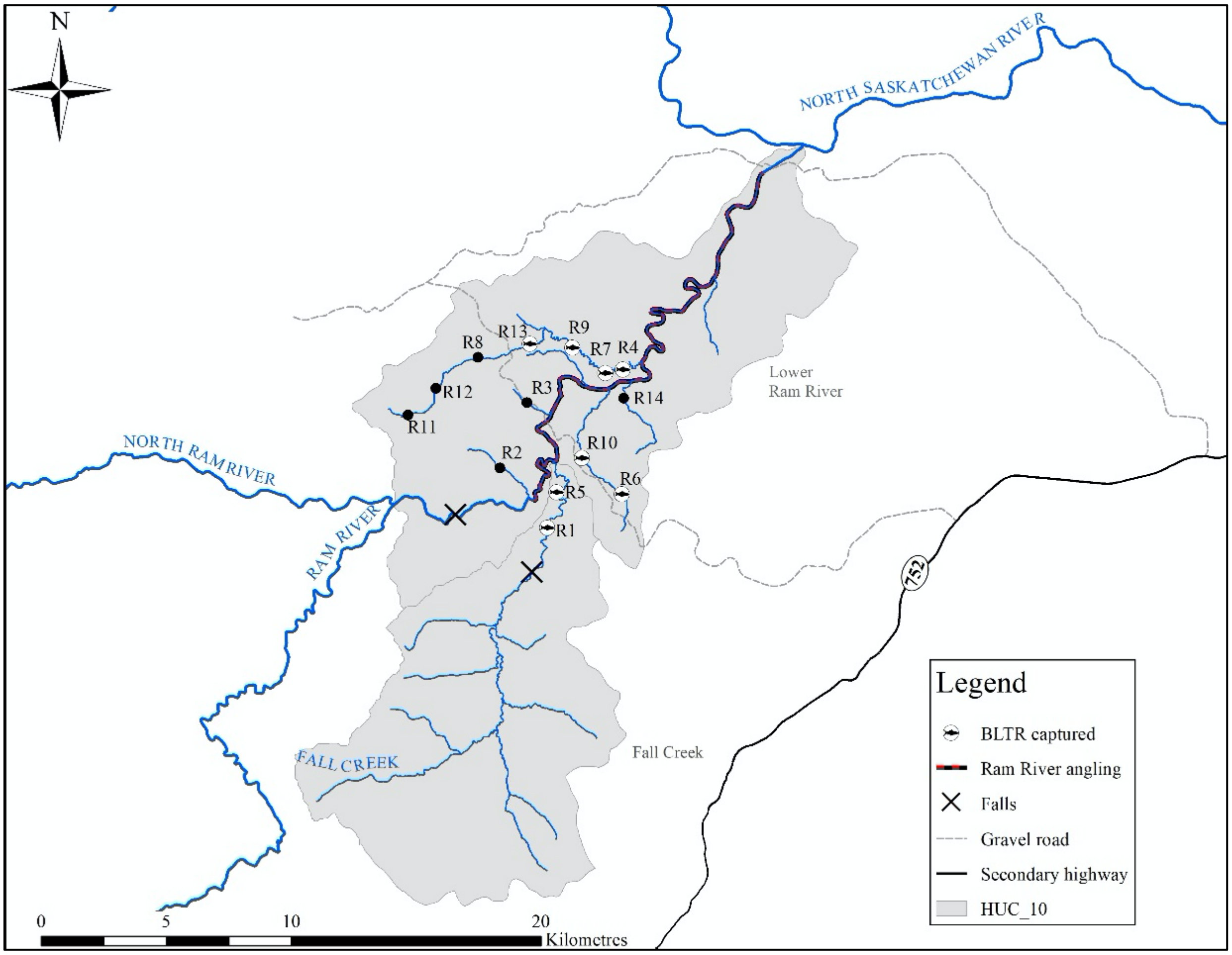

Figure 4. Locations of electrofishing sites with bull trout detections within the HUC 10 sub-watersheds of the Ram River, 2017 to 2021.

Our bull trout catch ranged in size from 45 to 478 mm (FL) and included young-of-year fish as well as suspected fluvial, migratory fish in Fall Creek (Table 2a). Most of the bull trout in our catch were immature (i.e., <150 mm FL). Size distributions of our salmonid catch are in Tables 2a and 2b. Length frequency histograms of our bull trout catch are contained in Appendix 5. Considering only sites sampled every year, bull trout tended to be the most abundant salmonid in our catch, with catch peaking in 2018 (Table 3). Most of our bull trout catch in 2018 was of juvenile fish from Site R10 in an unnamed tributary to the Ram River. Site R10 accounted for a high proportion of our bull trout catch every year of the study (Appendix 4).

Table 2a. Size distribution of brook trout, bull trout, and brook trout x bull trout hybrids captured in the Ram River watershed using backpack electrofishing gear, 2017 to 2021.

Year	Fork length (mm)								
	BKTR[1]			BLBK[1]			BLTR[1]		
	Mean ± SD	Range	n	Mean ± SD	Range	n	Mean ± SD	Range	n
2017	133 ± 48	89–216	8	–	–	–	126 ± 72	45–478	76
2018	131 ± 16	109–145	4	137 ± 57	101–203	3	96 ± 33	70–251	45
2019	172 ± 34	134–218	6	–	–	–	131 ± 16	109–173	25
2020	97 ± 75	50–254	17	–	–	–	156 ± 30	111–200	22
2021	108 ± 28	46–139	15	–	–	–	132 ± 18	102–158	14

[1]BKTR = brook trout, BLTR = bull trout, BLBK = brook trout x bull trout hybrid.

Table 2b. Size distribution of brown trout, cutthroat trout, and mountain whitefish captured in the Ram River watershed using backpack electrofishing gear, 2017 to 2021.

Year	Fork length (mm)								
	BNTR[1]			CTTR[1]			MNWH[1]		
	Mean ± SD	Range	n	Mean ± SD	Range	n	Mean ± SD	Range	n
2017	–	–	–	203 ± 76	143–435	16	176 ± 81	106–265	3
2018	–	–	–	–	–	–	115 ± 0	–	1
2019	341 ± 0	–	1	185 ± 71	135–235	2	162 ± 39	123–220	5
2020	–	–	–	183 ± 28	145–226	9	134 ± 0	–	1
2021	–	–	–	–	–	–	–	–	–

[1] BNTR = brown trout, CTTR = cutthroat trout, MNWH = mountain whitefish.

Table 3. Bootstrapped mean relative abundance (fish/300 m) of salmonids caught in the Ram River watershed per year using backpack electrofishing gear, 2017 to 2021.

Species[1]	Mean catch/300 m (95% CI) by year				
	2017	2018	2019	2020	2021
BKTR	1.4 (0–3.4)	0.7 (0–1.7)	1.0 (0–3.0)	1.0 (0.2–2.0	2.2 (0.2–5.8)
BLBK	–	0.5 (0 – 1.2)	–	–	–
BLTR – all	1.8 (0.2–4.4)	7.5 (0.5– 0.7)	4.2 (0.7–10.7)	3.7 (1.3–6.0)	2.4 (0–7.0)
BLTR – immature[2]	0.2 (0–0.6)	6.9 (0.2–20.3)	3.6 (0.2–10.3)	1.5 (0.3–3.3)	2.0 (0–6.0)
BLTR– non-immature[3]	1.6 (0.2–3.8)	0.5 (0–1.2)	0.5 (0–1.2)	2.2 (0.5–4.3)	0.3 (0–1.0)
BNTR	–	–	0.2 (0 – 0.5)	–	–
CTTR	1.0 (0.2–2.0)	–	0.3 (0–1.0)	1.5 (0.3–2.8)	–
MNWH	0.4 (0–0.8)	0.2 (0–0.5)	0.8 (0.2–1.5)	0.2 (0–0.5)	–

[1]BKTR = brook trout, BLTR = bull trout, BLBK = brook trout x bull trout hybrid, BNTR = brown trout, CTTR = cutthroat trout, MNWH = mountain whitefish.
[2]Immature <150 mm FL
[3]Non-immature ≥150 mm FL

4.2 Ram River mainstem

We captured a total of 79 bull trout in the Ram River mainstem, including six suspected bull trout x brook trout hybrids, in 44.3 hours of angling in 2017 (Appendix 6). Bull trout mean catch per hour was 2.3 ± 1.9 [SD] fish/h, and our mean catch size was 438 ± 116 [SD] mm FL with a range of 173 to 772 mm FL (Appendix 7). While assessing water conditions in 2018, we captured 8 bull trout in 11 hours of angling (0.7 fish/h); we suspect low water clarity negatively impacted our catch.

4.3 Fall Creek redd surveys and fish fence

Bull trout redd counts in the upper reach of Fall Creek during 2018–2022 were within long-term extremes documented for the population, ranging from 42 to 76 redds (Figure 5). Across all years of the study, bull trout spawning activity peaked in mid-September and was complete by early October and redds remained visible throughout this period. We counted only six redds in the lower section of Fall Creek (five in 2018, one in 2019), and no spawning was observed in the Ram River. None of these aspects of the Fall Creek bull trout spawning run have changed appreciably since first documented by Rodtka et al. (2010). Redd locations within the upper reach remained consistent throughout the study until 2022. That year, a newly constructed beaver dam disrupted fish movement and displaced bull trout spawning activity resulting in an unusually high concentration of redds below the dam (Figure 6). This is the first time we have observed a beaver dam in the reach since we began surveys in 2007.

Variation in the independently conducted redd surveys ranged between 79% and 124% of our best estimate, with a mean of 101% ± 20% (SD) (Table 4). Comparing our best estimate of redd abundance to the count of adult bull trout moving downstream of the fence resulted in a remarkably consistent spawner-to-redd ratio of between 1.2 and 1.3 spawners to each redd (Table 4). This result compares favourably to the original estimate of 1.4:1 in 2008 (Rodtka et al. 2010).

Even though uncertainty was likely under-represented in the model, the fitted loglinear regression line of redd count versus time was not significant ($r^2 = 0.11$, $F_{1,13} = 1.61$, $p = 0.23$) with no indication of trend ($b = 0.02 \pm 0.02$ [SE]) (Figure 5). Rather, the process underlying redd counts in Fall Creek appears to be cyclic, peaking approximately every five or six years, but this is difficult to evaluate quantitatively with a time series spanning only 16 years.

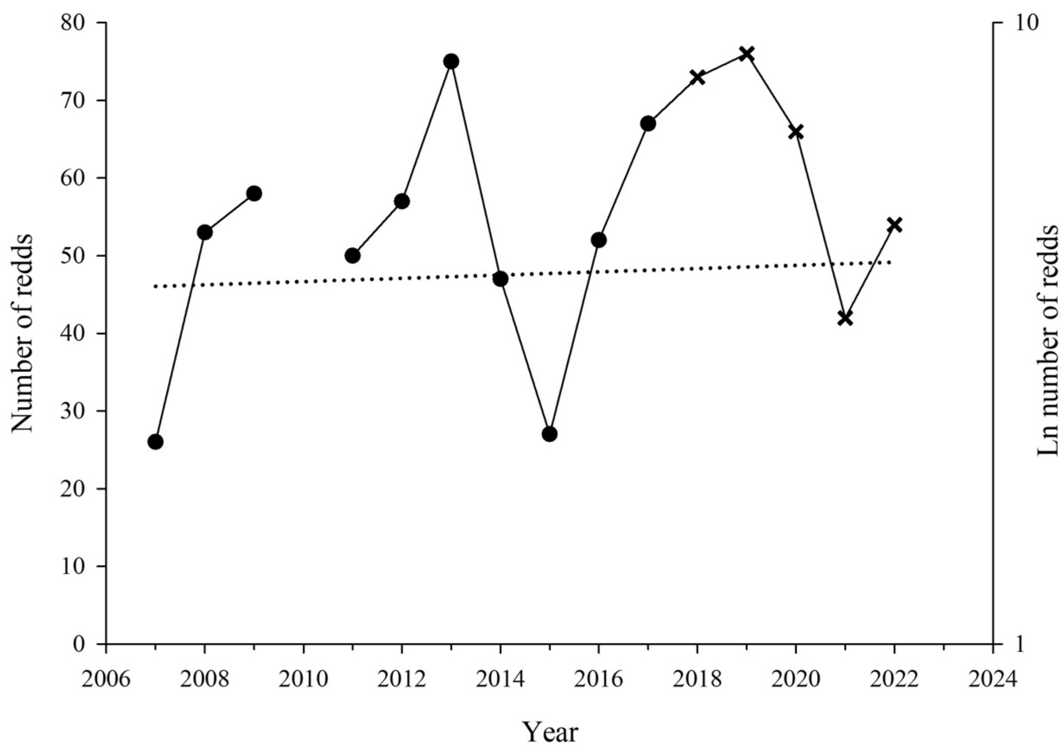

Figure 5. Fall Creek bull trout redd counts from 2007 to 2022 (current study represented by X symbol). Dotted line is the linear regression line of $\log_e$ (redd count): $r^2 = 0.11$, $F_{1,13} = 1.61$, $p = 0.23$. Note that no survey was completed in 2010.

Table 4. Summary of redd and adult bull trout counts in Fall Creek, 2018–2022.

Year	Redd count	Independent redd count	Adult bull trout	Spawner-to-redd-ratio
2018	73	62	–	–
2019	76	–	94[1]	1.2
2020	66	74	76	1.2
2021	42	33–52	56[2]	1.3
2022	54	48–65	63[3]	1.2

[1]Total includes imputation of 16 fish.
[2]Total includes imputation of two fish.
[3]Includes seven bull trout observed staging in the impoundment upstream of a newly constructed beaver dam on our last survey.

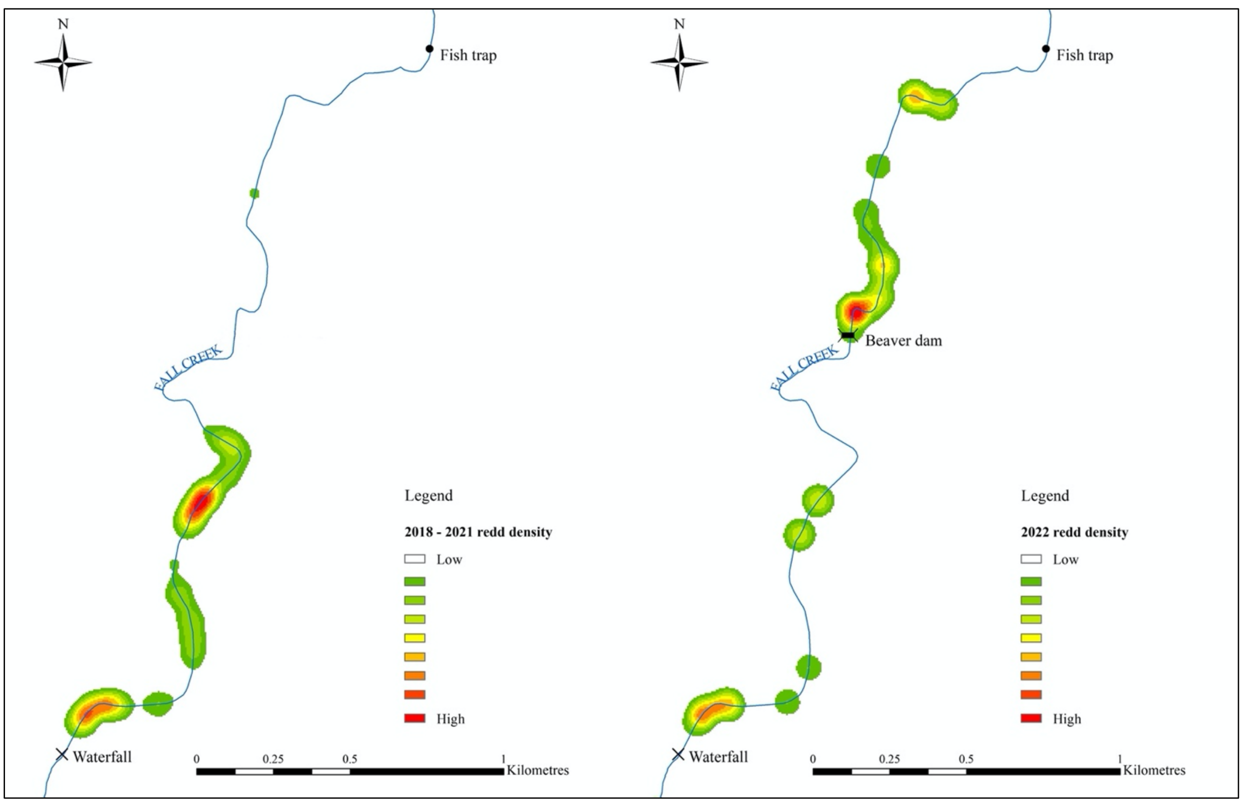

Figure 6. Bull trout redd density, calculated using the kernel density function in ArcGIS 10.6, above the fish fence in Fall Creek from 2018 – 2021 (left), and in 2022 (right).

4.4 Stream thermal habitat

Summer water temperatures indicate that thermal habitat was available to bull trout in the Ram River watershed throughout the study period. The temperature logger at the Unnamed2 station (Figure 3) was consistently at or below 12°C throughout the study and within the preferred temperature range of bull trout (Table 5). A two-day moving average of stream temperatures recorded at each station is presented in Appendix 8.

Table 5. Summary of summer (July 1 to August 31) stream temperature measurements in the Ram River watershed 2017 to 2021.

Year	Station	UTM Location NAD 83 Zone 11		Mean ± SD temperature (°C)	Temperature range (°C)
		Easting	Northing		
2017	Fall2	599047	5789333	13 ± 2	8–18
	Makwa2	598611	5796653	14 ± 2	9–21
	Makwa3	597075	5795780	13 ± 2	8–20
	Ram2	607405	5803184	15 ± 2	10–20
	Unnamed1	600624	5790764	7 ± 1	5–10
	Unnamed2	599809	5792224	9 ± 1	6–12
2018	Fall2	599047	5789333	11 ± 2	6–17
	Makwa2	598611	5796653	14 ± 3	8–21
	Makwa3	597075	5795780	13 ± 2	7–19
	Ram2	607405	5803184	12 ± 2	6–18
	Unnamed2	599793	5792206	9 ± 1	5–13
2019	Fall2	599049	5789327	10 ± 2	4–16
	Makwa2	598608	5796646	11 ± 2	6–18
	Makwa3	597075	5795783	9 ± 2	5–15
	Ram2	607356	5803165	12 ± 2	6–18
	Unnamed2	599817	5792363	7 ± 1	4–10
2020	Makwa2	510873	5922528	12 ± 3	6–19
	Makwa3	477683	5907377	10 ± 3	5–16
	Unnamed2	489528	5909896	8 ± 1	5–11
2021	Fall2	599049	5789327	13 ± 3	6–21
	Makwa2	598608	5796646	16 ± 2	10–21
	Makwa3	597075	5795783	15 ± 3	7–24
	Ram1	598283	5792904	13 ± 2	7–19
	Ram2	607333	5803164	15 ± 3	8–21
	Unnamed2	599817	5792363	10 ± 2	6–15

5.0 SUMMARY

Alberta Conservation Association staff used backpack electrofishing gear to sample 12 tributary sites within the Ram River watershed between 2017 and 2021. During our five years of electrofishing surveys, we captured 273 salmonids, including 182 bull trout. Despite containing suitable habitat, six sites consistently had zero fish captures, and we suspect downstream barriers limited access to the sites. Bull trout catch from one site (R10) in the Lower Ram River HUC 10 sub-watershed accounted for nearly 50% of our total catch over the study period, and bull trout were consistently captured at the site. Stream temperature plays an important role in aquatic community processes and has been correlated to fish species distribution and abundance (Rieman et al. 2007, Isaak et al. 2012). Bull trout tend to be found in streams with temperatures below 16° C, with different preferences depending on life stage (COSEWIC 2012). Although summer water temperatures suitable for bull trout were observed throughout the study area, temperature in the unnamed creek where site R10 was located was consistently colder. Non-native brook trout were found in Makwa Creek and at site M13 but only made up a small percentage of our catch. We did, however, find suspected brook trout x bull trout hybrids at two sites during sampling.

As the only known bull trout spawning habitat in the Ram River watershed, Fall Creek has considerable potential for monitoring the abundance of migratory bull trout from the Ram River. Surveying Fall Creek for redds is a cost-effective technique for monitoring the Ram River's migratory bull trout population. The low, clear flows typical of Fall Creek in autumn enhances redd detection while the timing and extent of bull trout spawning activity in the stream is discrete. Variation in independent redd counts performed in Fall Creek using experienced crews was 79%–124% of our best count, which compares favourably to error documented by Dunham et al. (2001) (28%–254%) and was comparable to ranges reported by Muhlfeld et al. (2006) (78%–130%) and Howel and Sankovich (2012) (67%–122%). This study provides evidence that redds can be a reliable indicator of spawner abundance. Since first documented in 2008, the spawner-to-redd ratio in Fall Creek has only ranged between 1.2 and 1.4 fish per redd in the five years we assessed it. This consistency is remarkable, considering that bull trout redd numbers varied by almost a factor of two those years and included the 2022 count when a beaver dam resulted in a major displacement of spawning activity. Although we found no evidence of an overall trend in the Fall Creek redd count over the past 16 years, counts do appear to fluctuate in a cyclic fashion, which is consistent with bull trout ecology (Paul et al. 2000).

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7.0 APPENDICES

Appendix 1. Summary of backpack electrofishing site locations (UTM NAD 83, Zone 11) in the Ram River watershed, 2017 to 2021.

Year	Site	Date (dd/mm/yyyy)	UTM Easting	UTM Northing	Distance (m)	Effort (s)
2017	R1	26/07/2017	598586	5788768	300	1,149
	R2	28/06/2017	596308	5791569	300	711
	R3	28/06/2017	597731	5793753	300	433
	R4	28/06/2017	601606	5795103	300	1,009
	R5	26/07/2017	598943	5790200	300	1,044
	R6	27/06/2017	601576	5790111	300	610
	R7	28/06/2017	600896	5794990	300	1,139
	R9	28/06/2017	599579	5795981	300	867
	R10	27/06/2017	599958	5791562	300	1,105
	R12	29/06/2017	594102	5794329	300	989
2018	R2	12/07/2018	596668	5791149	300	915
	R3	13/07/2018	597737	5793741	300	758
	R4	10/07/2018	601604	5795107	300	1,748
	R6	12/07/2018	601567	5790105	300	1,058
	R7	10/07/2018	600896	5794993	300	1,853
	R8	11/07/2018	595803	5795582	300	653
	R9	10/07/2018	599579	5795980	300	2,199
	R10	12/07/2018	599953	5791549	300	1,431
	R11	11/07/2018	592986	5793278	300	805
	R12	11/07/2018	594102	5794339	300	948
	R13	11/07/2018	597893	5796118	300	1,256
	R14	13/07/2018	601620	5793937	300	675
2019	R2	30/07/2019	596319	5791561	300	1,031
	R3	30/07/2019	597753	5793749	300	699
	R4	31/07/2019	601605	5795107	300	1,552
	R6	31/07/2019	601569	5790103	300	781
	R7	31/07/2019	600894	5794986	300	1,612
	R8	31/07/2019	595808	5795574	300	542
	R9	31/07/2019	599581	5795978	300	1,596
	R10	31/07/2019	599956	5791560	300	926
	R11	30/07/2019	592534	5793304	300	1,001
	R12	30/07/2019	594112	5794333	300	814
	R13	01/08/2019	597884	5796112	300	1,164
	R14	30/07/2019	602513	5792937	300	414

Appendix 1 continued.

Year	Site	Date (dd/mm/yyyy)	UTM Easting	UTM Northing	Distance (m)	Effort (s)
2020	R4	12/08/2020	601610	5795102	300	1,880
	R6	19/08/2020	601563	5790119	300	1,155
	R7	12/08/2020	600927	5794979	300	2,191
	R8	17/08/2020	595798	5795574	200	375
	R9	13/08/2020	599594	5795978	300	1,529
	R10	19/08/2020	599958	5791552	300	1,468
	R12	17/08/2020	594039	5794211	300	999
	R13	13/08/2020	597883	5796109	300	1,242
2021	R2	07/07/2021	596682	5791151	300	474
	R3	06/07/2021	597745	5793752	300	667
	R4	08/07/2021	601605	5795107	300	720
	R6	06/07/2021	601517	5790137	300	1,240
	R7	08/07/2021	600885	5794994	300	1,150
	R8	06/07/2021	595801	5795571	300	754
	R9	08/07/2021	599557	5796110	300	857
	R10	06/07/2021	599977	5791602	300	1,826
	R11	07/07/2021	592984	5793260	300	680
	R12	05/07/2021	594113	5794333	300	771
	R13	06/07/2021	597886	5796109	300	929
	R14	09/07/2021	601623	5793963	300	594

Appendix 2. Summary of habitat measurements at electrofishing sites in the Ram River watershed, 2017 to 2021.

Year	Site ID	Temp (°C)	Ambient cond. (µS/cm)	Mean wetted width ± SD (m)	Mean rooted width ± SD (m)	Mean depth ± SD (m)	Dominant/secondary substrate[1]	Percentage pool (mean(min-max))	Percentage riffle (mean(min-max))	Percentage run (mean(min-max))
2017	R1	15.0	715	7.7 ± 1.5	17.7 ± 5.3	0.27 ± 0.07	C/LG	0(0–0)	57(5–100)	43(0–95)
	R2	7.6	113	2.1 ± 0.6	4.0 ± 1.0	0.16 ± 0.07	LG/C	4(0–10)	86(70–100)	10(0–30)
	R3	6.9	290	1.3 ± 0.4	1.9 ± 0.4	0.20 ± 0.05	LG/SG	3(0–10)	52(40–70)	45(30–60)
	R4	11.5	443	3.9 ± 1.5	12.0 ± 2.4	0.32 ± 0.15	LG/F,SG,LG	6(0–15)	23(10–40)	72(60–90)
	R5	13.0	660	7.9 ± 3.1	16.5 ± 1.6	0.45 ± 0.20	C/LG	7(0–20)	28(10–50)	65(50–90)
	R6	6.5	239	1.0 ± 0.2	1.6 ± 0.3	0.23 ± 0.14	C/LG	2(0–5)	77(60–90)	22(10–40)
	R7	12.8	438	2.9 ± 0.7	12.3 ± 3.8	0.35 ± 0.08	C/LG	6(0–10)	27(20–40)	68(55–75)
	R9	14.9	430	4.2 ± 0.6	10.2 ± 4.2	0.20 ± 0.04	SG/F,LG	9(0–15)	22(10–30)	69(60–85)
	R10	6.8	274	2.5 ± 0.4	4.8 ± 0.4	0.24 ± 0.08	LG/C	13(5–20)	27(20–50)	61(40–75)
	R12	6.9	242	3.1 ± 0.4	4.8 ± 1.4	0.22 ± 0.05	C/LG	7(0–10)	76(65–90)	18(10–25)
2018	R2	7.4	107	1.8 ± 0.4	3.2 ± 0.5	0.14 ± 0.03	C/LG	2(0–5)	61(50–70)	38(30–45)
	R3	7.3	316	1.3 ± 0.3	1.6 ± 0.5	0.19 ± 0.15	LG/SG	2(0–5)	64(50–75)	34(20–50)
	R4	12.4	263	3.8 ± 1.6	12.5 ± 2.1	0.32 ± 0.15	C/SG	8(0–15)	58(50–70)	33(20–40)
	R6	6.7	210	1.4 ± 0.4	1.8 ± 0.6	0.19 ± 0.04	C/F, LG	3(0–5)	77(70–80)	21(15–25)
	R7	14.0	268	4 ± 1.6	9.7 ± 1.9	0.32 ± 0.19	C, LG/LG	4(0–10)	21(10–35)	75(60–90)
	R8	11.4	165	2.1 ± 0.4	5.1 ± 2.5	0.21 ± 0.14	LG/SG	4(0–10)	44(30–70)	52(30–65)
	R9	16.1	287	5.5 ± 0.7	8.3 ± 2.1	0.21 ± 0.08	LG/SG	3(0–5)	28(20–40)	69(60–80)
	R10	9.3	256	2.3 ± 0.7	3.8 ± 0.7	0.28 ± 0.08	C, LG/C, LG	3(0–5)	43(30–60)	53(35–70)
	R11	7.4	61	1.7 ± 0.5	3.3 ± 1.4	0.13 ± 0.02	LG/C	5(0–10)	86(70–100)	9(0–30)
	R12	6.5	90	3.1 ± 0.9	4.5 ± 0.7	0.22 ± 0.05	C/LG	18(10–25)	39(30–50)	43(30–60)
	R13	18.6	298	2.8 ± 0.7	6.2 ± 1.3	0.29 ± 0.15	LG/SG	5(0–10)	34(10–45)	61(50–85)
	R14	6.8	324	1.3 ± 0.2	1.4 ± 0.4	0.19 ± 0.04	C/SG	2(0–5)	71(65–75)	28(25–30)

[1]Substrate codes: B = boulder, C = cobble, F = fines, LG = large gravel, SG = small gravel.

Appendix 2 continued.

Year	Site ID	Temp (°C)	Ambient cond. (µS/cm)	Mean wetted width ± SD (m)	Mean rooted width ± SD (m)	Mean depth ± SD (m)	Dominant/secondary substrate[1]	Percentage pool (mean(min-max))	Percentage riffle (mean(min-max))	Percentage run (mean(min-max))
2019	R2	7.8	159	2.0 ± 0.9	3.6 ± 0.6	0.19 ± 0.07	C/LG	3(0–10)	88(80–100)	8(0–10)
	R3	7.6	368	1.3 ± 0.4	1.3 ± 0.5	0.18 ± 0.06	LG/SG	2(0–5)	78(65–90)	21(10–30)
	R4	10.8	323	4.9 ± 1.7	11.4 ± 2.5	0.39 ± 0.16	C, LG/C, LG	2(0–5)	46(30–70)	53(30–70)
	R6	6.4	287	1.5 ± 0.4	1.8 ± 0.8	0.24 ± 0.08	C/F, LG	1(0–5)	75(60–90)	24(10–40)
	R7	12.8	338	3.7 ± 0.7	11.0 ± 2.5	0.31 ± 0.10	C, LG/C, LG	0(0–0)	80(50–100)	20(0–50)
	R8	12.1	220	1.8 ± 0.5	5.5 ± 1.6	0.16 ± 0.07	C/LG	1(0–5)	66(60–75)	33(20–40)
	R9	14.2	354	4.1 ± 1.3	7.5 ± 1.4	0.39 ± 0.07	LG/C	2(0–5)	37(30–45)	62(50–70)
	R10	6.9	317	2.5 ± 0.4	3.7 ± 0.7	0.25 ± 0.11	C/LG	2(0–5)	58(40–70)	40(25–60)
	R11	7.6	80	1.6 ± 0.2	3.3 ± 2.1	0.14 ± 0.04	C/LG	0(0–0)	100(100–100)	0(0–0)
	R12	6.9	142	3.2 ± 0.7	4.6 ± 1.0	0.24 ± 0.08	C, LG/C, LG	9(5–15)	80(75–85)	11(10–15)
	R13	10.3	302	3.6 ± 1.1	6.7 ± 1.4	0.19 ± 0.03	LG/SG	0(0–0)	90(80–100)	10(0–20)
	R14	6.0	327	1.3 ± 0.6	2.3 ± 0.9	0.19 ± 0.09	F, SG/LG	3(0–5)	92(85–100)	6(0–10)
2020	R4	11.8	180	4.8 ± 1.4	10.9 ± 3.1	0.34 ± 0.14	C, LG/C, LG	3(0–5)	38(30–50)	58(50–65)
	R6	6.9	284	1.2 ± 0.3	1.5 ± 0.5	0.24 ± 0.08	C/LG	8(5–15)	54(30–70)	38(25–60)
	R7	14.7	192	11.7 ± 1.1	11.7 ± 3.2	0.28 ± 0.09	C/LG	3(0–5)	33(20–50)	64(45–80)
	R8	10	257	1.8 ± 1	4.7 ± 0.8	0.2 ± 0.04	C/LG	55(0–100)	8(0–20)	38(0–90)
	R9	10.3	177	3.7 ± 1.1	7.4 ± 1.1	0.43 ± 0.19	C, LG/C, LG	13(0–40)	23(10–60)	65(30–80)
	R10	7.3	314	2.8 ± 0.3	2.8 ± 0.5	0.32 ± 0.18	LG/C	12(5–20)	35(25–55)	53(40–70)
	R12	8.8	187	2.4 ± 0.5	4.6 ± 0.8	0.25 ± 0.1	C/LG	8(5–15)	63(55–70)	29(20–40)
	R13	12.7	171	2.5 ± 0.7	4.7 ± 0.9	0.25 ± 0.1	LG/C, SG	3(0–5)	45(35–55)	52(40–60)

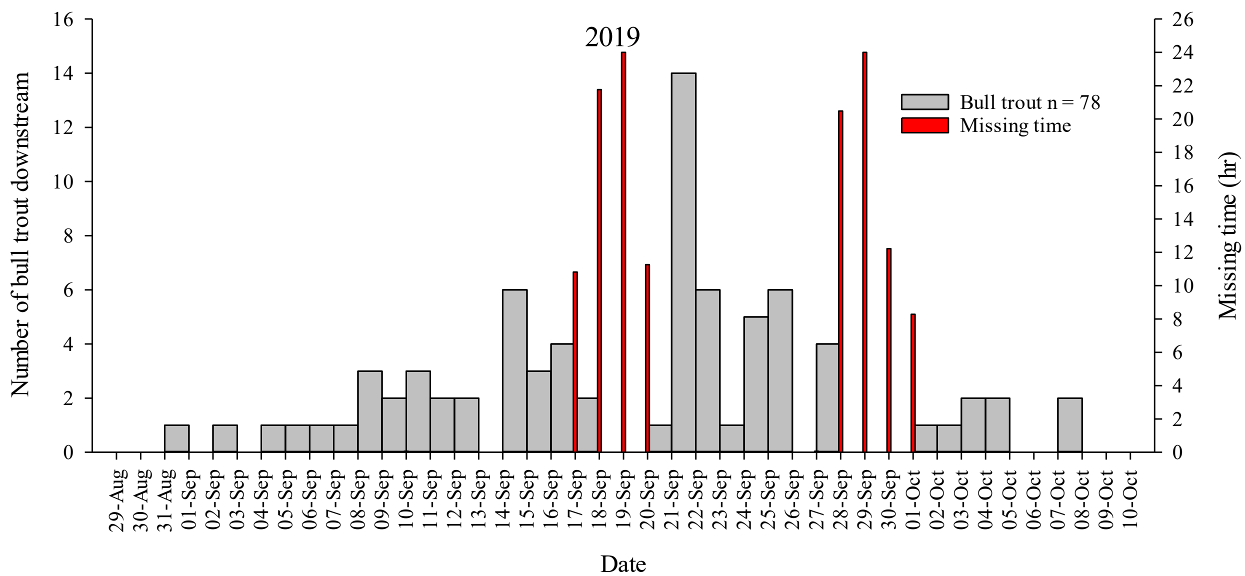
[1]Substrate codes: B = boulder, C = cobble, F = fines, LG = large gravel, SG = small gravel.

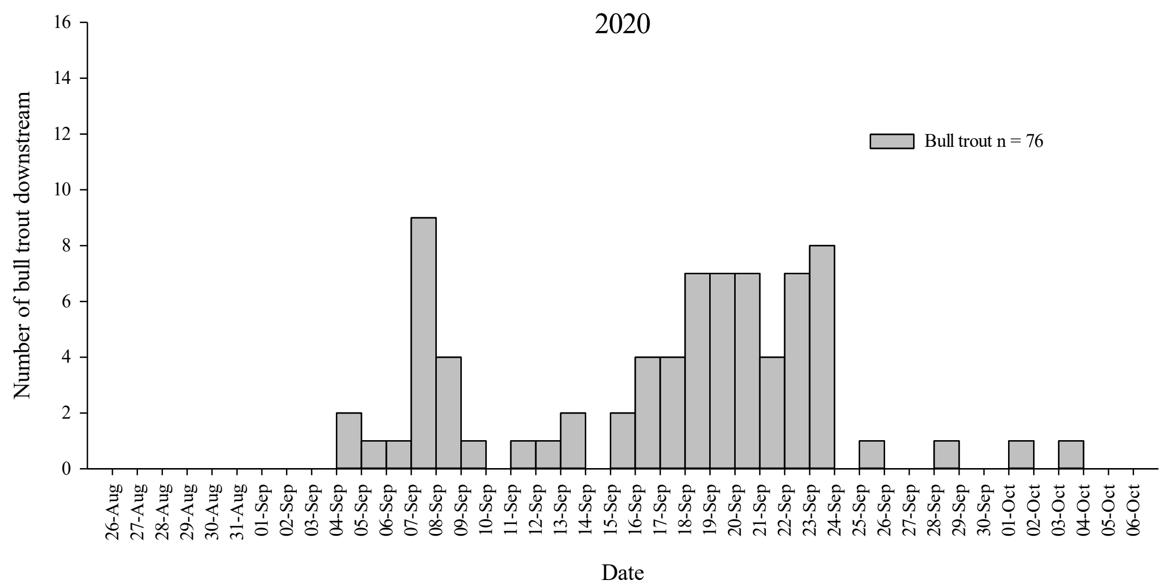
Appendix 2 continued.

Year	Site ID	Temp (°C)	Ambient cond. (µS/cm)	Mean wetted width ± SD (m)	Mean rooted width ± SD (m)	Mean depth ± SD (m)	Dominant/secondary substrate[1]	Percentage pool (mean(min-max))	Percentage riffle (mean(min-max))	Percentage run (mean(min-max))
2021	R2	10.7	150	1.6 ± 0.3	3.6 ± 0.7	0.16 ± 0.03	C, LG/C, LG	4(0–10)	87(80–90)	9(5–10)
	R3	9.5	338	1.1 ± 0.3	1.1 ± 0.3	0.2 ± 0.09	LG/C	9(5–15)	45(30–60)	46(35–65)
	R4	16.5	361	4.1 ± 2.3	9.6 ± 1.7	0.32 ± 0.11	C, LG/C, LG	3(0–5)	31(20–40)	66(55–75)
	R6	8.5	282	1.4 ± 0.4	1.7 ± 0.7	0.31 ± 0.08	C, F, LG/C, LG, SG	5(0–10)	55(40–70)	40(30–60)
	R7	19	374	4.6 ± 1.4	9.4 ± 3.3	0.29 ± 0.13	LG/C, SG	8(0–20)	43(25–65)	50(25–65)
	R8	11.1	120	2.6 ± 0.8	4.2 ± 0.9	0.21 ± 0.11	LG/SG	8(5–15)	49(40–70)	44(20–55)
	R9	21.6	400	3.5 ± 1	6.1 ± 1.8	0.34 ± 0.21	C, LG/C, LG	5(0–10)	36(25–50)	59(45–70)
	R10	9.2	353	2.3 ± 0.4	4 ± 0.8	0.22 ± 0.04	C, LG/F, LG, SG	10(0–20)	45(30–50)	45(30–60)
	R11	10.2	94	1.6 ± 0.5	3.2 ± 0.8	0.09 ± 0.03	C/LG	3(0–5)	74(70–80)	23(20–30)
	R12	8.9	152	3.1 ± 0.3	4.2 ± 0.9	0.24 ± 0.12	LG/C, SG	10(0–20)	22(15–30)	68(60–80)
	R13	18.4	378	2.2 ± 0.8	4 ± 0.9	0.25 ± 0.13	LG/SG	7(5–10)	40(30–60)	53(35–65)
	R14	7.5	334	0.9 ± 0.3	1 ± 0.3	0.13 ± 0.05	LG, SG/LG, SG	3(0–10)	70(15–90)	27(10–75)

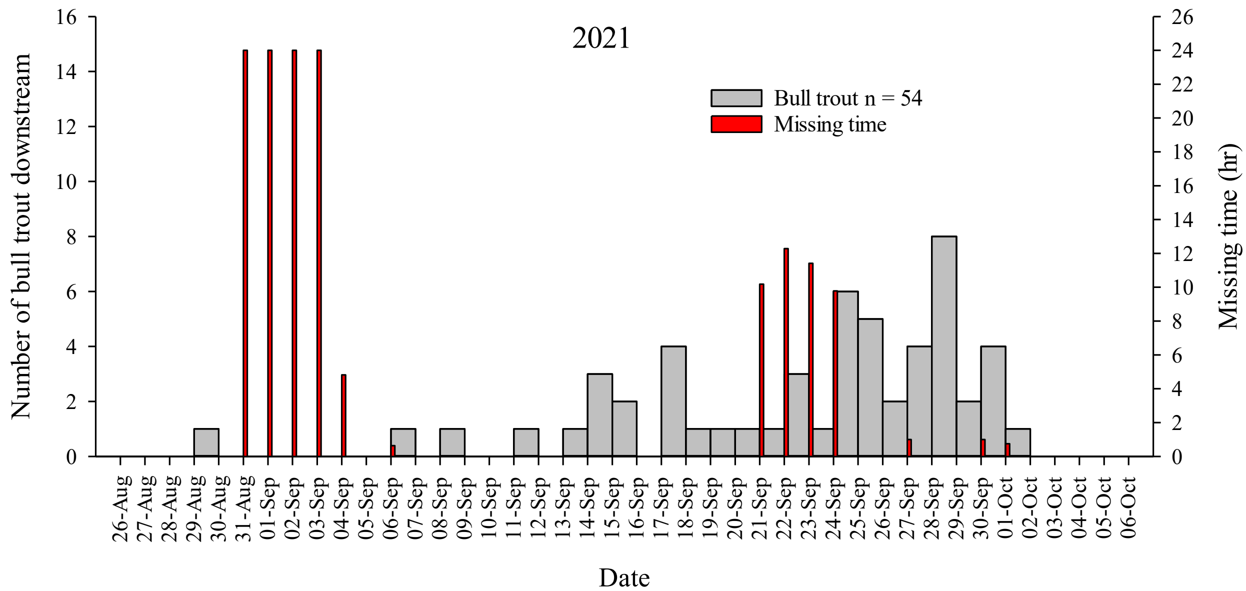
[1]Substrate codes: B = boulder, C = cobble, F = fines, LG = large gravel, SG = small gravel.

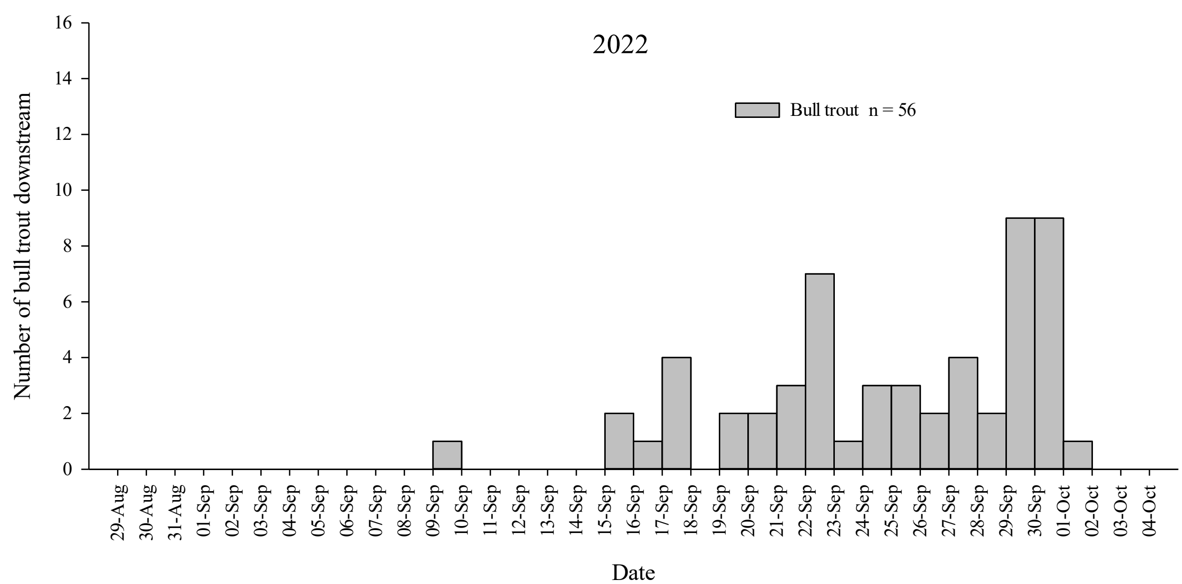
Appendix 3. Daily bull trout (> 400 mm FL) movement downstream through the fish fence installed in upper Fall Creek, including missing time in 2019 and 2021.





Appendix 3 continued.





Appendix 4. Summary of backpack electrofishing salmonid catch in the Ram River watershed, 2017 to 2021.

Year	Site	Species[1]					
		BKTR	BLBK	BLTR	BNTR	CTTR	MNWH
2017	R1	0	0	49	0	4	0
	R2	0	0	0	0	0	0
	R3	0	0	0	0	0	0
	R4	2	0	0	0	0	1
	R5	1	0	18	0	7	1
	R6	0	0	1	0	0	0
	R7	5	0	0	0	1	1
	R9	0	0	1	0	1	0
	R10	0	0	7	0	3	0
	R12	0	0	0	0	0	0
2018	R2	0	0	0	0	0	0
	R3	0	0	0	0	0	0
	R4	0	0	1	0	0	1
	R6	0	1	0	0	0	0
	R7	1	0	2	0	0	0
	R8	0	0	0	0	0	0
	R9	0	0	2	0	0	0
	R10	0	2	40	0	0	0
	R11	0	0	0	0	0	0
	R12	0	0	0	0	0	0
	R13	3	0	0	0	0	0
	R14	0	0	0	0	0	0
2019	R2	0	0	0	0	0	0
	R3	0	0	0	0	0	0
	R4	0	0	1	1	2	2
	R6	0	0	0	0	0	0
	R7	0	0	1	0	0	1
	R8	0	0	0	0	0	0
	R9	0	0	1	0	0	2
	R10	0	0	20	0	0	0
	R11	0	0	0	0	0	0
	R12	0	0	0	0	0	0
	R13	6	0	2	0	0	0
	R14	0	0	0	0	0	0

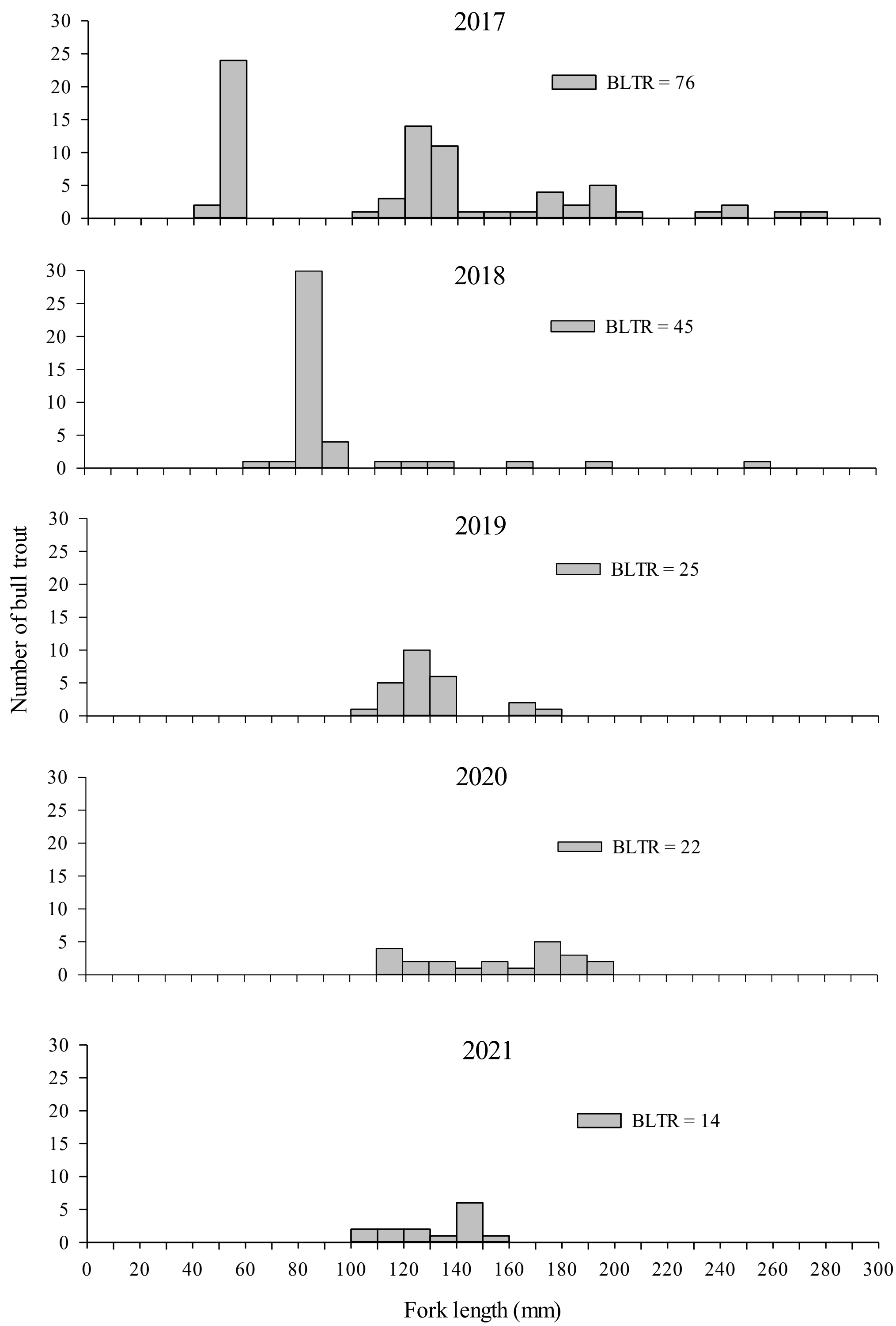
[1]BKTR = brook trout, BLTR = bull trout, BLBK = brook trout x bull trout hybrid, BNTR = brown trout, CTTR = cutthroat trout, MNWH = mountain whitefish.

Appendix 4 continued.

Year	Site	Species[1]					
		BKTR	BLBK	BLTR	BNTR	CTTR	MNWH
2020	R4	0	0	1	0	3	0
	R6	0	0	1	0	0	0
	R7	1	0	1	0	1	0
	R8	0	0	0	0	0	0
	R9	2	0	8	0	4	1
	R10	0	0	8	0	1	0
	R12	0	0	0	0	0	0
	R13	14	0	3	0	0	0
2021	R2	0	0	0	0	0	0
	R3	0	0	0	0	0	0
	R4	0	0	0	0	0	0
	R6	0	0	0	0	0	0
	R7	1	0	0	0	0	0
	R8	0	0	0	0	0	0
	R9	2	0	0	0	0	0
	R10	0	0	14	0	0	0
	R11	0	0	0	0	0	0
	R12	0	0	0	0	0	0
	R13	12	0	0	0	0	0
	R14	0	0	0	0	0	0

[1]BKTR = brook trout, BLTR = bull trout, BLBK = brook trout x bull trout hybrid, BNTR = brown trout, CTTR = cutthroat trout, MNWH = mountain whitefish.

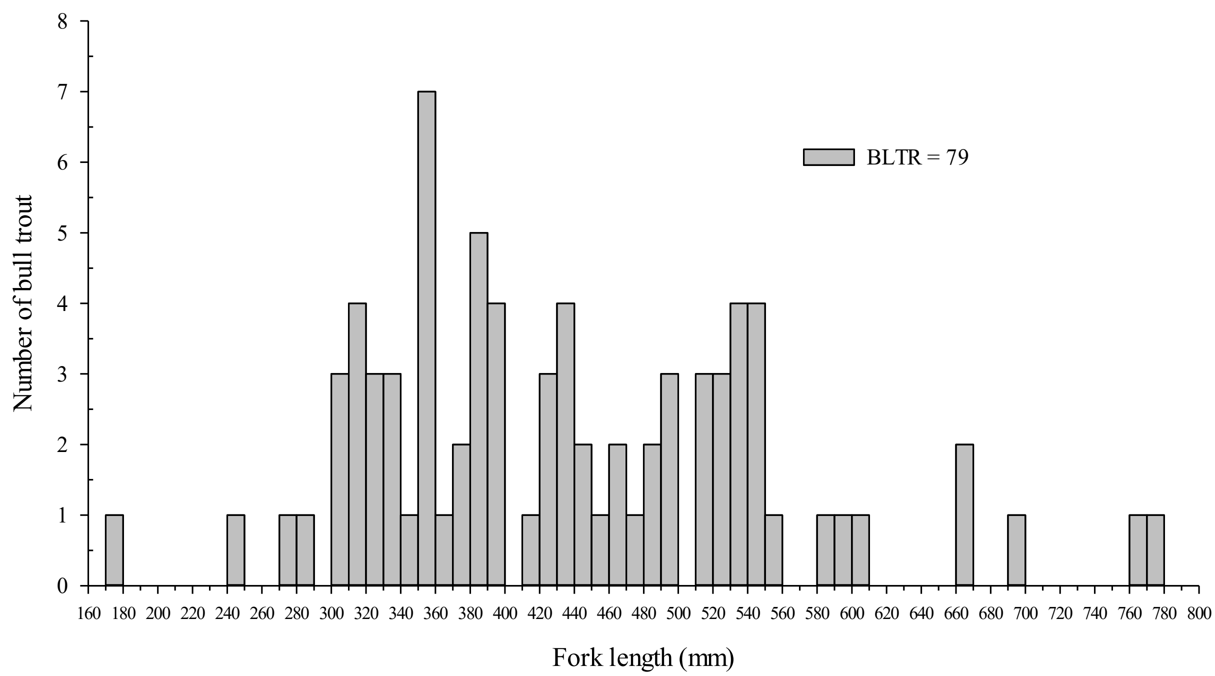
Appendix 5. Length frequency histograms of bull trout captured using backpack electrofishing gear in the Ram River watershed, 2017 to 2021. Note: in 2017, one 478 mm bull trout captured was omitted.



Appendix 6. Summary of angling locations (UTM NAD 83, Zone 11) and effort in the Ram River mainstem, 2017.

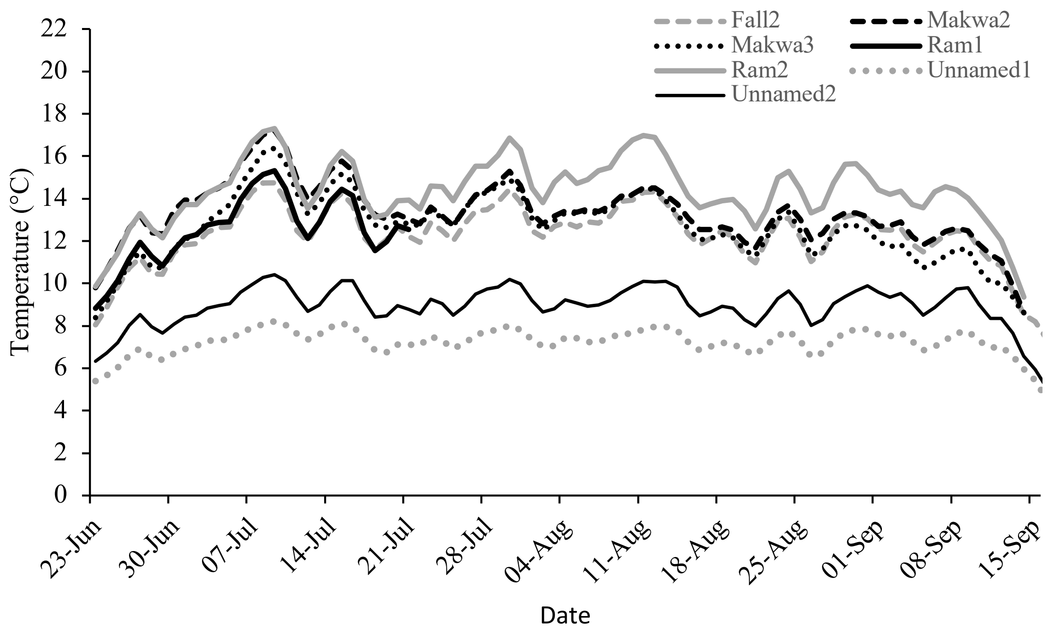
Date	UTM Start		UTM End		Distance	Effort	BLTR	
	Easting	Northing	Easting	Northing	(km)	(h)	Catch	Fish/h
July 12	598554	5793003	598488	5791238	2.7	6.4	5	0.8
July 24	598257	5792828	598754	5791444	2.0	3.0	2	0.7
July 25	598818	5791406	598013	5789862	3.2	7.6	8	1.0
July 25	602691	5794819	602916	5797511	4.9	3.7	6	1.6
July 26	598477	5792960	607399	5803157	13.1	3.5	21	6.0
July 27	601548	5794705	607399	5803157	16.2	4.3	14	3.3
July 27	598198	5792738	601548	5794706	5.1	15.8	23	1.5

Appendix 7. Length frequency histogram of bull trout captured angling the Ram River, 2017.

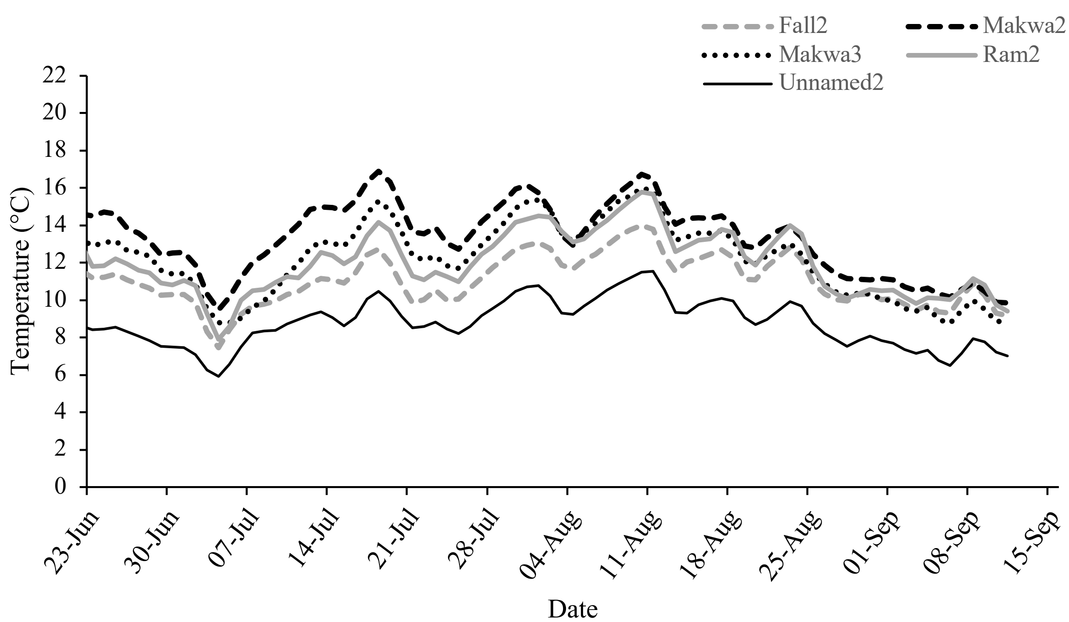


Appendix 8. Two-day moving average stream temperature at stations in the Ram River watershed, 2017 to 2021.

2017

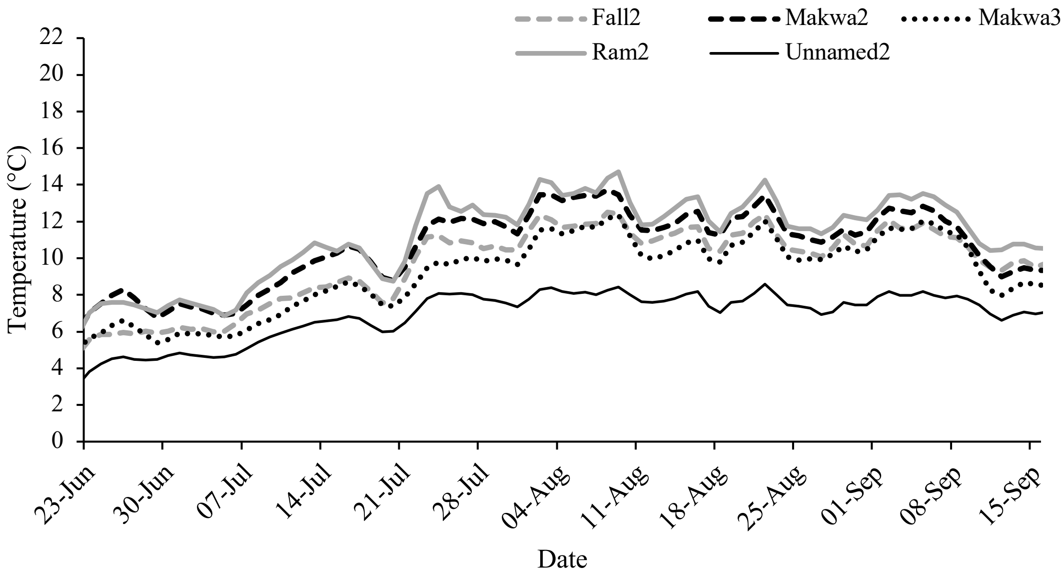


2018

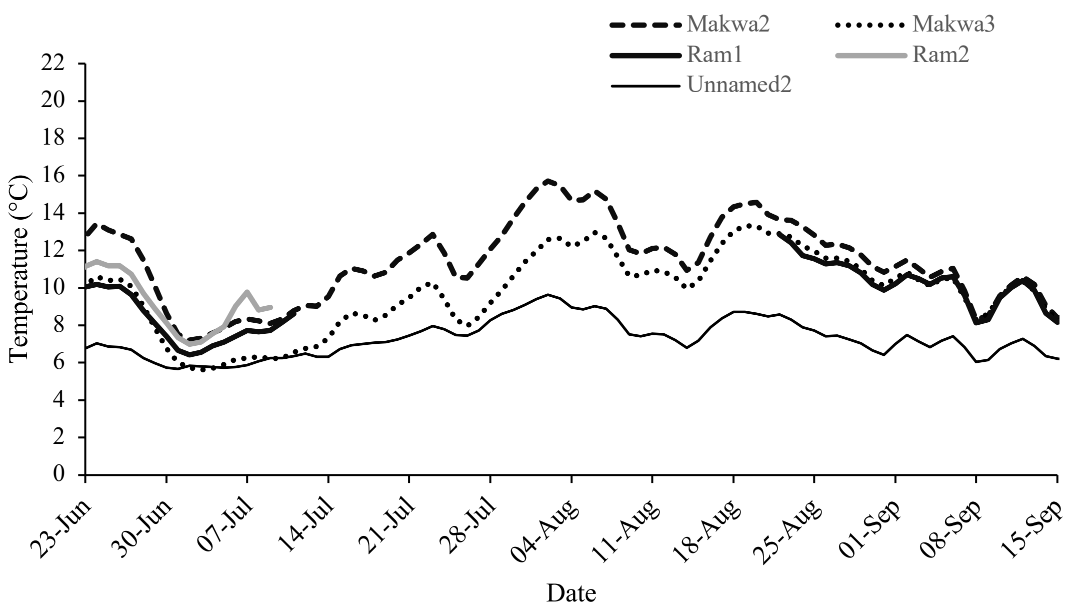


Appendix 8 continued.

2019

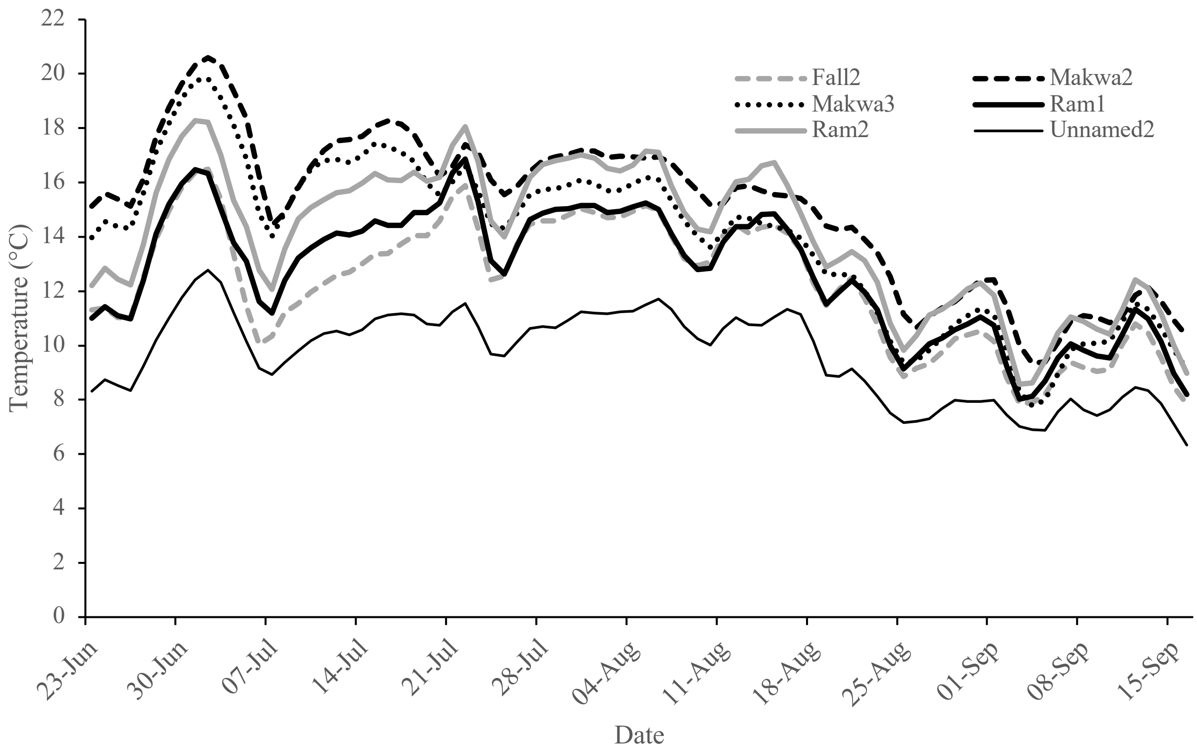


2020



Appendix 8 continued.

2021



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