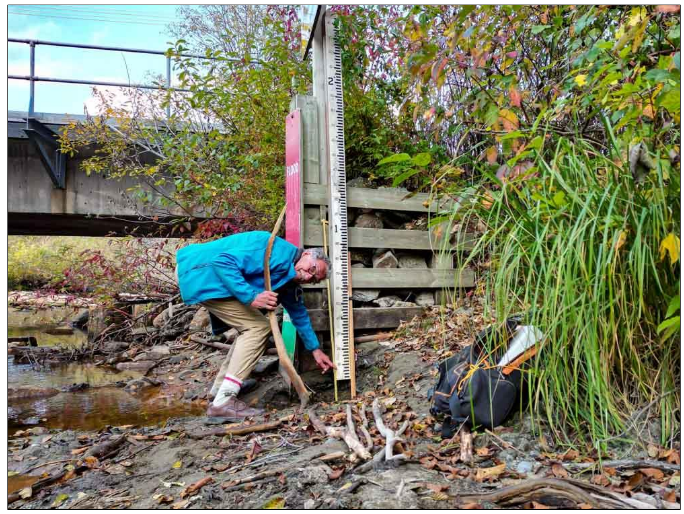

Whistler Ecosystems & Species Monitoring Program – 2022

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Resort Municipality of Whistler

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December 31, 2022

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Suggested Citation

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Executive Summary

The Resort Municipality of Whistler (RMOW) is located in the southern Coast Mountains of British Columbia, approximately 100 km north of Vancouver. The RMOW began the Ecosystems and Species Monitoring Program in 2013. The continuing objective of the program has been to identify and monitor indicators of ecosystem health.

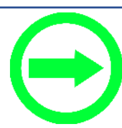
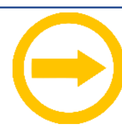
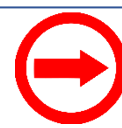
The indicators chosen for the 2022 program are mostly consistent with past years of the program and include: beavers, Northern Goshawks, Coastal Tailed Frogs, pond amphibians, benthic invertebrates, stream temperature and water quality, and basic climate indicators. The two main additions were: (i) eDNA sampling for Coastal Tailed Frogs in two creeks in which tadpoles had not been detected; and (ii) entry and preliminary analysis of water depths on Twenty-One Mile Creek (as an additional climate indicator).

Overall results show that the status of species and ecosystems monitored in this program is mostly stable as of 2022. The three exceptions detailed in this report include:

1) A possible downward trend in the tailed frog population in Archibald Creek,
2) Possible habitat degradation for benthic invertebrates in some creeks; and,
3) High stream temperatures in Jordan Creek that are near temperature thresholds for some fish.

The summaries on the following pages describe results by section. The icons below are used to help convey any trends detected. See Section 1.4 for a list of indicators and preferred trends for them.

Icons used to summarize trends in each section.

Trend	Desired Trend	Inconclusive Result and/or Data Deficient	Worsening Trend
Increasing			
Stable			
Decreasing			

Beavers:

Active Colonies: Stable | **Beaver-affected Wetlands: Stable**

1. As "ecosystem engineers," beavers create and maintain wetland habitat for countless other species. They also play an important in regulating water flows that mitigate droughts and floods. It is therefore a positive sign that the beaver population has been stable between 2021 and 2022, with 48 active colonies documented each year. The current estimated beaver population is 273 (+/-).
2. The unusual drought between July and October 2022 resulted in dramatically low water levels throughout the valley bottom. Water levels in beaver-affected areas, however, were either the same or even higher than in previous years. The ability of beavers to impound water, and potentially even more water in drought conditions, highlights their importance in protecting wildlife habitat and regulating water flows.
3. Almost 75% of active colonies are located in one of two wetland areas: the Millar Wetlands and the ROGD-Rainbow-Wildlife Refuge complex. Such strong, long-established populations no doubt provide the largest source of out-migration that keeps beavers active in less-productive habitats.
4. The area of beaver-affected wetlands (an important measure of wetland habitat) has remained mostly stable since the first estimate in 2018. With these updated numbers, approximately two-thirds (100.7 of 150.7 ha) of the RMOW's remaining wetlands have been created and/or maintained by beavers.

Northern Goshawks:

Stable with Caution (Limited Data)

1. Northern Goshawks are threatened forest predators that require old forest habitat for successful breeding. Although logging and other urban development have led to a significant decline in the goshawk population throughout BC, surveys over the past decade (including by this program) have shown Whistler to be an important breeding area for them. Their inclusion in this program is meant to (a) identify and protect breeding areas; and (b) provide an indicator of the availability of the low-elevation old forest habitat required by goshawks and many other unsurveyed species.
2. The 2022 surveys were the most extensive yet conducted for this program. The most important result was the discovery of two recent (though inactive) nests in old forests on Lower Blackcomb Mountain. This discovery brings the total number of breeding areas known in Whistler to four, and further confirms the long presence of breeding goshawks in a significant proportion of Whistler's remaining old forests.
3. Although no active breeding was detected in 2022, other evidence suggests breeding probably occurred but that cold weather through early July 2022: (a) prevented the detection of active nests; and/or, (b) caused goshawks to abandon their nest(s) due to incomplete egg development.
4. The number of breeding areas now documented provides encouraging evidence that: (a) goshawks continue to maintain a strong presence in Whistler; and therefore that, (b) enough low-elevation forest remains to prevent their extirpation from the area. As continued surveys contribute more data, it will be possible to make stronger statements about population trends of Northern Goshawks and their old growth habitat in the Whistler area.

Coastal Tailed Frogs – Tadpole Surveys:

Stable: Whistler, Sproatt, and Van West Creeks	**Stable with Caution: Archibald Creek**

1. Coastal Tailed Frogs are commonly used in monitoring programs since they require clean, cold streams and are sensitive to disturbances caused by logging and in-stream alterations. The 2022 survey was the 10th year of monitoring in a varying selection of 11 creeks. As in past years, results showed no cause for concern in the creeks sampled in 2022, other than a slight downward trend in Archibald Creek. Tadpole detections in Archibald Creek did not decline enough to conclude there was an ongoing deterioration of this habitat caused by operations in the neighbouring Whistler Bike Park or by other factors. Concerns about this creek will be alleviated if 2023 surveys see a return to past detection levels.
2. While scouring caused by recent floods (especially in 2017) is still obvious, especially on west-side creeks, it does not seem to have affected tailed frog detections. In contrast, the impacts of logging debris at mid-elevation creeks on the west side of Whistler Valley persist and, especially on Van West Creek, are the probable cause of low detections each year.
3. For the third consecutive year, tadpoles have been detected at higher elevations than previously known. Before 2020, the highest site this program detected tadpoles was at 1180 m. BioBlitz events at Brandywine Meadows in 2020 and 2021 found tadpoles at 1435 m and 1440 m, respectively. In 2022, a lichen researcher found a large tadpole population at 1485 m near Brew Creek, just south of the RMOW. These recent findings mean potential habitat for tailed frogs in the Whistler area is larger and higher than previously known.

Coastal Tailed Frogs – eDNA Sampling

Inconclusive (Data deficient)

1. Since Blackcomb and Nineteen-Mile Creeks are Whistler's only major creeks where tailed frog tadpoles have never been found, eDNA testing was employed to confirm whether or not they are present.
2. Due to its strong glacial input, Blackcomb Creek is colder than other creeks known to have tailed frogs, and may be too cold for egg development. With continued glacial melt due to climate change, glacier-fed creeks will become warmer which may then allow tailed frogs to colonize previously uninhabited creeks (which Blackcomb and Nineteen-Mile Creeks appeared to be). eDNA testing was meant to provide a baseline in case this hypothesis was correct.
3. Somewhat surprisingly, eDNA testing confirmed Coastal Tailed Frogs were present in Blackcomb Creek, even though they haven't been detected by tadpole surveys. And while the amount of DNA found in Nineteen-Mile Creek water samples was too low to provide certainty, it was enough to conclude tailed frogs are probably present there as well. These results disprove the hypothesis above.
4. The relatively low density of DNA in both creeks (especially Nineteen-Mile) may nonetheless reflect lower populations than other creeks in Whistler Valley, and that may still increase with warming streams. Further eDNA testing would be required to monitor the situation, and is probably beyond the scope of this program.

Western Toads and Red-legged Frogs

Inconclusive (Data deficient)

1. Since Western Toads and Red-legged Frogs are species of local interest, it is important to identify and protect their breeding habitats. In spite of past efforts by this program to locate these habitats, Lost Lake was the only confirmed site for Western Toads. The 2022 surveys were the first year of a three-year plan to expand the search effort to all suspected ponds in the valley bottom south of Function Junction.
2. A total of 11 ponds were surveyed in spring for egg masses, and traps were set in four ponds in July. As in recent years, no evidence of breeding of either Western Toads or Red-legged Frogs was detected.
3. The most important finding in 2022 came from Whistler BioBlitz which confirmed Western Toad breeding in the Whistler Olympic Park (just outside of the RMOW boundary). This is the first breeding site documented in the Whistler area in more than 10 years and becomes the only known site other than Lost Lake.
4. It is still likely there are other breeding sites for Western Toads south of Function Junction and within the RMOW boundary. Until all possible sites are surveyed in that area (ideally by the end of 2026), there is not enough information to detect any trends.

Benthic Invertebrates

Inconclusive

1. Benthic invertebrates are easily assessed by collecting and sorting through stream substrate. The many species that inhabit these habitats have a wide range of tolerances to pollution and other changes in habitat conditions and are, therefore, good indicators of stream health.
2. Through a well-established protocol in Canada (the Canadian Aquatic Biomonitoring Network or CABIN) biologists compare the invertebrates they find in a given stream to what is found in healthy, undisturbed streams in that region (which is called the ""Reference Condition"). In general, a stream in Reference Condition has a benthic community that includes a higher proportion of species that are intolerant of pollution and other habitat alterations. As these species are replaced by other species that are increasingly tolerant of impaired habitat, CABIN will classify a stream as (from slightly impaired to much worse): Mildly Divergent, Divergent, or Highly Divergent.
3. Fewer invertebrates and fewer species were found at most sites than in previous years, possibly due to colder and wetter weather conditions through early July 2022. In addition, some problems emerged with CABIN models that should be resolved for the 2023 report. As a result, any conclusions from 2022 results should be considered tentative and subject to confirmation next year.
4. In 2022, there was a general trend towards lower rankings. Five of six creeks were assessed as 'Mildly Divergent," and the upper River of Golden Dreams (ROGD) site was assessed as "Divergent." The surprising exception to the downward trend was in Jordan Creek where its ranking of "Mildly Divergent" was actually an improvement from past years.
5. Further analysis in 2023 is expected to clarify some of the ambiguity of the 2022 results and help determine whether any results are truly a cause for concern or just data-related anomalies.

Water Temperature and Quality

Water Temperature: Possible worsening **Water Quality: Stable**

1. Temperature records for 2022 were not available because logger batteries failed in late 2021. Stream records that were available generally showed stable trends, with two exceptions: (i) high temperatures during the summer 2021 caused by the heat dome last year; and (ii) concerningly high temperatures in Jordan Creek that were nearing the threshold that could harm fish.
2. Two of the six temperature loggers installed in 2016 are no longer functional, at Alpha Creek and Lower Crabapple Creek. We suggest that the RMOW purchase and install new loggers to allow continued monitoring of stream temperatures, especially Whistler Creek and/or other creeks that flow south.
3. Temperature loggers need to be maintained on a regular basis. We recommend that the RMOW download the temperature data on a regular schedule (e.g., every three to four months) and replace batteries on scheduled dates to prevent loss of data.
4. All water quality parameters examined were similar to previous years and were within Provincial water quality standards. Trends in water quality data are generally stable, with no evidence of significant change in any stream.

Fish and Fish Habitat

Fish Populations: Inconclusive (Data deficient) **Fish Habitat: Stable**

1. Due to the low quality of data supplied by the RMOW (much of it collected by volunteers), it was not possible to reliably estimate the population of Kokanee and Rainbow Trout. Further analyses could not reveal any population trends; again, primarily due to issues of data quality and survey consistency. At this point, this data is useful only for confirming presence/absence and in-stream distribution.
2. An expanded and program would be required to achieve the goal of accurate population monitoring, and would include methods such as mark-recapture, estimates of survey life (residence time of spawning fish), and measures to ensure consistent measurements by surveyors (e.g., repeatable observer efficiency). Whether an expanded effort makes sense within this program needs to be discussed with the RMOW.
3. Bull Trout are the salmonid species most likely to be impacted by climate change due to their demonstrated sensitivity to elevated stream temperatures. Continued collection of temperature data is therefore a critical part of monitoring fish habitat for Bull Trout. Better distribution and spawning data would also be useful, but are likely outside the scope and budget of this program.
4. Surveys in 2022 confirmed good fish habitat conditions in all streams other than two exceptions: (a) the Twenty-One Mile site where habitat was compromised by a lack of canopy cover (it is under the power lines); and (b) the lower ROGD site which has a streambed comprised of fines and organic materials that are inappropriate for salmonid spawning. In both cases, these conditions have been present for many years (if not decades), and therefore are not a new cause for concern.

Climate Indicators

Alta Lake: Trending to a shorter duration of Ice	**Twenty-One Mile Creek Depths: Trending to lower minimums of longer duration**

1. An incomplete record of dates for ice-on (freezing) and ice-off (thawing) on Alta Lake was analyzed for two periods: early (1942 to 1976) and recent (2001 to 2022). Results for 2022 are consistent with those from recent years and continue the trend towards a shorter duration of ice.
2. The average duration of ice on Alta Lake has been almost one month shorter in recent years than in the mid-1900s.
3. Earlier melting in spring has been the strongest contributor to the shorter duration of ice, and is consistent with warming temperatures caused by climate change that have especially affected non-winter months.
4. Depths in Twenty-One Mile Creek recorded by Karl Ricker since 2001 were entered and analyzed for the first time. Though the data is somewhat intermittent (due to an inconsistent number and timing of readings each year), it showed a clear trend towards longer and more severe periods of low-water. Lowest water levels consistently occurred during September, and sometimes stretched back into August and/or well into October. This timing has potential ramifications for the planning of river closures to protect spawning fish.
5. The negative impacts of the July to October drought on water levels downstream in the River of Golden Dreams were mostly offset by higher-than normal beaver dams, which corroborates results and conclusions from beaver monitoring (Section 2).
6. Note that the trend for the duration of ice on Alta Lake is coloured red to indicate it is worsening (Section 1.5). This evaluation is based on the premise that climate change in general is undesirable, and that it also has obvious negative implications for biodiversity (which is more the focus of this program). There may be positive aspects to having no ice on Alta Lake, e.g., for recreation, which are not considered here.

Table of Contents

1. Introduction

1.1 Overview

This report describes ecosystem monitoring conducted during 2022 in the Resort Municipality of Whistler (RMOW) by Snowline Ecological Research (Snowline). The purpose of the RMOW's Ecosystems and Species Monitoring Program is to monitor the health of ecosystems and species over time through ecological indicators (proxies) that guide the conservation and inform sustainable land use planning and development in Whistler. The 2022 study was the tenth year of the program.

1.2 Background

The Whistler Biodiversity Project (WBP), funded in significant part by the RMOW from 2006 through 2012, began surveys in late 2004. This work led to the first publicly documented record of several important and/or at-risk species, including Coastal Tailed Frog (*Ascaphus truei*), and Red-legged Frog (*Rana aurora*), initiated the first beaver census, and greatly enhanced the inventory of species documented within Whistler. The report summarizing early results (Brett 2007) recommended further inventory work, as well as the identification and monitoring of indicator species. This work was the precursor to a report the RMOW commissioned that proposed a framework for the establishment and application of ecological monitoring in Whistler (Askey *et al*. 2008).

The Ecosystem and Species Monitoring Program was initiated by the RMOW in 2013. The program design was based on the use of species, habitat, and climate indicators to identify temporal and spatial trends in the overall condition of ecosystems.

Cascade was contracted to conduct the first three years of the program (Cascade 2014-2016). In 2016 and again in 2019, Palmer Environmental Consulting Group and Snowline were contracted to conduct the three-year program (Palmer and Snowline 2017 to 2021; Snowline 2021; Palmer 2022). Major changes were made to the study design in 2016 to make it more scientifically robust (e.g., adopting data collection methods which allowed for statistical analysis) while maintaining comparability and consistency with previous years to the greatest extent possible. The work plan has continued to evolve since 2016 as results are evaluated and priorities re-assessed in consultation with RMOW staff, including some redirection in survey effort that resulted from an analysis of conservation priorities (Brett 2018). The 2022 program builds on these past results.

1.3 Study Area

The RMOW is located in the southern Coast Mountains of British Columbia, approximately 100 km north of Vancouver. The study area, defined by the extent of the RMOW municipal boundaries (Figure 1-1), contains a range of aquatic and terrestrial ecosystems at montane to alpine elevations. Most development (within the municipal "Development Footprint"[1]) is located in the valley bottom, from Function Junction to Green Lake. The Development Footprint is the main focus of the program, though some efforts go beyond its boundary.

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1 *More formally termed the "Whistler Urban Development Containment Area" in the Official Community Plan (https://www.whistler.ca/ocp).*

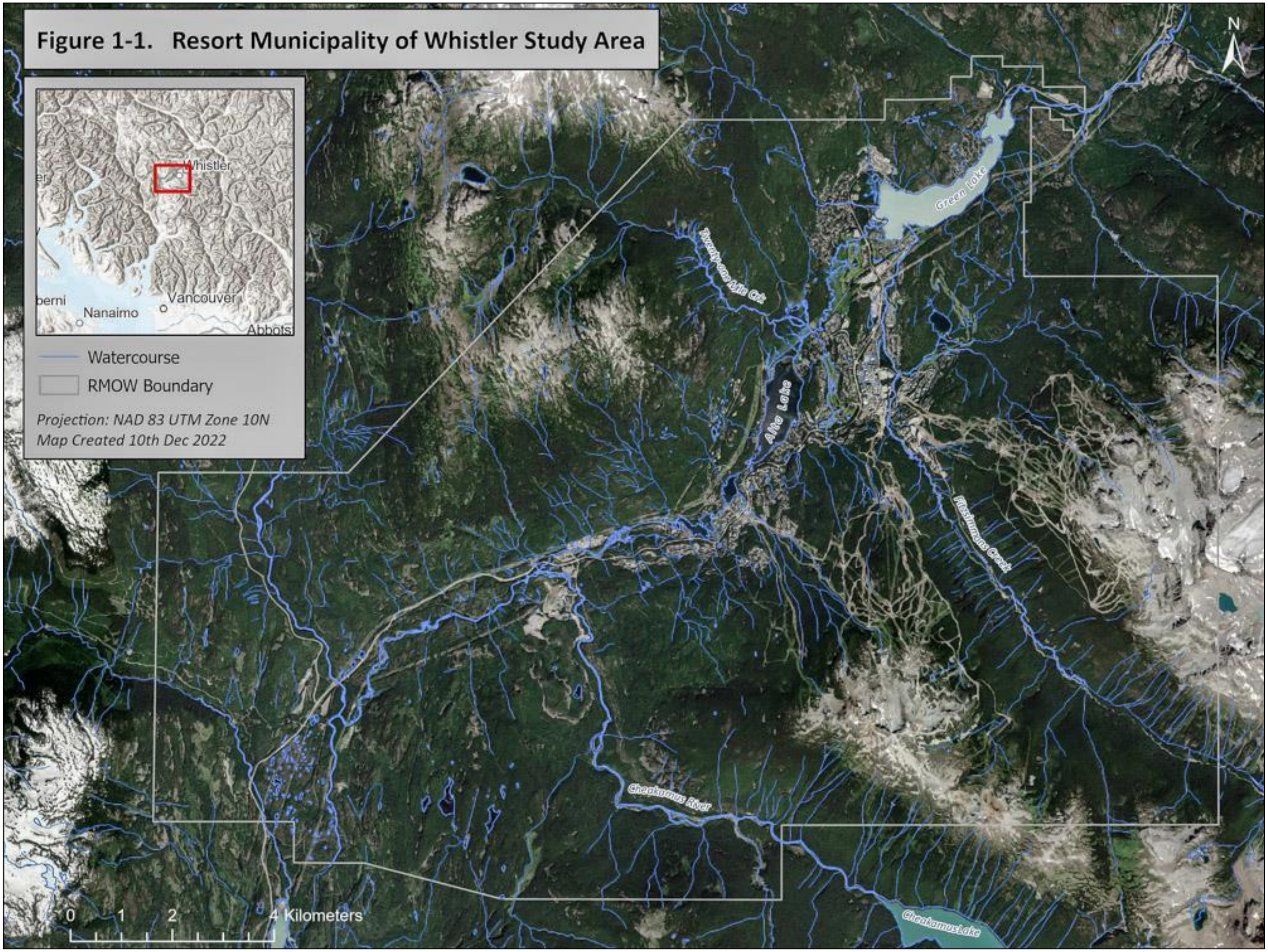


Figure 1-1. Study Area.

1.4 Indicators in the 2022 Program

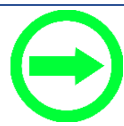
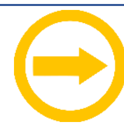
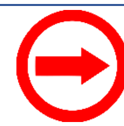
Table 1-1. Indicators included in the 2022 program.

Section	Indicator	Ecological Significance	Preferred Trend
2	Active Beaver Colonies	Beavers create/ maintain wetland habitat and regulate water flows.	Stable or increasing number of colonies (lodges and burrows).
2	Area of Beaver-Affected Wetland	Gives an areal value of the impact of beavers that can be monitored	Stable or increasing area.
3	Northern Goshawks	Old forests at low elevations are necessary for successful breeding of goshawks.	Stable or increasing number of active nests (and/or stable or increasing area of old forest)..
4	Coastal Tailed Frogs – Tadpole Surveys	Tailed frogs require cool, clean mountain streams.	Stable or increasing number of tadpoles in sampled creeks.
5	Coastal Tailed Frogs - eDNA sampling	A more costly, but more powerful way to detect presence of tailed frogs in stream where tadpoles have not been detected.	Stronger eDNA readings for tailed frogs in (e.g.) Blackcomb Creek may be negative if related to warming stream temperatures caused by glacial recession.
6	Pond Amphibians	Western Toads and Red-legged Frogs are local species of interest. Monitoring/confirming breeding sites aids in conservation planning.	Stable or increased number of breeding sites.
7	Benthic Invertebrates	The community composition of benthic invertebrate changes with pollution and other deleterious habitat alterations.	Stable or increased proportion of pollution-sensitive organisms. CABIN results that reflect “Reference” conditions.
8	Stream Temperature	Cool streams are necessary for salmonids but expected to increase with climate change.	Stable or decreasing summer stream temperature (<15° C).
8	Water Quality	Various water quality parameters measure habitat quality for fish and other aquatic life.	Water quality within all provincial and federal guidelines for the protection of aquatic life.
9	Fish Habitat Metrics	Various metrics are used to describe habitat attributes required by fish.	Maintain in “Good” condition.
10	Alta Lake Ice-on/Ice-off	Dates of ice-on and ice-off (freezing and thawing) are indicators of changes in fall and spring weather (cf. climate change).	Stable trend in ice-on and ice-off dates.
10	Low water levels in Twenty-One Mile Creek	Lower water levels and prolonged droughts are predicted by climate change. These in turn affect stream temperature and fish habitat.	Stable number of days with depths lower than 0 cm (i.e., the length of droughts should not increase.

1.5 Pictorial Representation of Trends

Icons which summarize trends observed in 2022 have been added to each section in an effort to better convey results (Table 1-2). Icons are meant to evaluate monitoring results as of 2022 compared to preferred trends (Table 1-1). All trends presented in this report are deemed either green (desired) or amber (caution). Note that a trend coded as amber should be interpreted with caution since the results are inconclusive due to ambiguous or limited data.

Table 1-2. Icons used to summarize trends in each section.

Trend	**Desired Trend**	**Inconclusive Result and/or Data Deficient**	**Worsening Trend**
Increasing			
Stable			
Decreasing			

2. Beavers

Key Takeaways

Active Colonies: Stable	Beaver-affected Wetlands: Stable

1. The same number of active beaver colonies (48) were detected in 2022 as in 2021. This is the first year of the program which: (a) represents a complete or near-complete census of all colonies; and (b) allows a reliable evaluation of population trends.
2. The beaver population has been stable between 2021 and 2022 at approximately 273 individuals (the estimated range is from 197 to 307).
3. The unusual drought between July and October 2022 resulted in dramatically low water levels throughout the valley bottom. Water levels in beaver-affected areas, however, were either equivalent or even higher than in previous years. The ability of beavers to impound water, potentially even more in drought conditions, highlights their importance in protecting wildlife habitat and regulating water flows.
4. Almost 75% of active colonies are located in one of two wetland areas: the Millar Wetlands and the ROGD-Rainbow-Wildlife Refuge complex. Such strong, long-established populations no doubt provide the largest source of out-migration that keeps beavers active in less-productive habitats.
5. From an ecological and habitat perspective, wetlands are not only very important but rarer than before human development. At least 72% of Whistler's original wetland has been lost since development began. The majority of the remaining "beaver-affected wetlands" were created by and/or maintained by beavers. Monitoring the area of beaver-affected wetlands provides a direct measurement of wildlife habitat.
6. The area of beaver-affected wetlands (an important measure of wetland habitat) has remained mostly stable since the first estimate in 2018. The only exception was the loss of approximately 0.1 ha to Valley Trail construction between Alta Lake Road and Function Junction completed in 2021. No negative effect on the beaver population was detected in this area in 2022.
7. With these updated numbers, approximately two-thirds (100.7 of 150.7 ha) of the RMOW's remaining wetlands have been created and/or maintained by beavers.

2.1 Introduction

Beavers (*Castor canadensis*) are a keystone species that literally shaped North America's landscapes, especially before European settlers drastically reduced their numbers (Goldfarb 2018). They are commonly referred to as ecosystem and wetlands engineers (e.g., Müller-Schwarze and Sun 2003) in recognition of their immense impact on landscapes that is second only to that of humans. The life history of beavers is predicated on altering landscapes to provide shelter, food, and security which thereby creates the dams, ponds, wetlands, channels, and wetland vegetation that provides critical habitat for countless other species (Morgan 1986; Müller-Schwarze and Sun 2003; Runtz 2015; Goldfarb 2018; Romansic et al. 2020).

Beavers no doubt exerted a vast impact on the Whistler area before the railway opened in 1913. The Whistler Valley contains five lakes in a flat pass that, even now, are connected by creeks and wetlands impacted by beavers. Before European settlement, that habitat would have been much larger and would have stretched north in a mostly continuous swath from what is now Function Junction through Meadow Park and the Nicklaus North Golf Course beside Green Lake. The first, and significant reduction of Whistler's beaver population was caused by so much trapping that Racey and McTaggart-Cowan (1935) noted beavers had already been "completely trapped out in the district for over twenty years" (p. 24), even though their dams and meadows persisted.

Though the area covered by wetlands is approximately 72 percent smaller than before Whistler was developed (McBlane 2007), beavers still inhabit such notable wetlands as the Millar Wetlands, the Rainbow Wetlands, the Wildlife Refuge, and the River of Golden Dreams wetland complex. And although other former beaver habitats have been replaced by housing developments, golf courses and other developments, beavers continue to maintain their presence throughout the valley bottom.

Due to their critical role in creating and maintaining wetland habitats, beavers have the most positive impact on the quantity and quality of those habitats of any species in Whistler. They also play an important role in flood management, erosion control, and water quantity and quality. Their dams raise the water table to keep areas inundated even through dry summer months, and reduce erosion by slowing streamflow (Goldfarb 2018). From an ecological perspective, it would be difficult to have too many beavers on the landscape.

Many land managers, however, view beavers as pests to be trapped, killed, or otherwise dissuaded from their normal activities. In Whistler, the conflict between humans and beavers has been concentrated in the valley bottom. Much of the valley bottom habitat that once housed beavers has been transformed into low-lying developments where beavers are not welcome due to their propensity to cut valuable trees, raise water levels, and generally cause trouble for property owners. The ongoing challenge for the RMOW (among other land managers) is to balance the enormous ecological benefit of beavers on the landscape with other priorities such as protecting property and infrastructure.

Beavers are colonial animals. They maintain a family lodge which typically houses the adult parents, two yearlings, and two young-of-the-year (Müller-Schwarze and Sun 2003). Two-year-old beavers generally disperse to form new colonies, except when dispersal is delayed by the lack of suitable habitat and they remain with the family lodge. Some lodges can remain active indefinitely, especially in prime habitats, while others are periodically inactive or abandoned permanently. As a result, many of Whistler's lodges have been occupied for many years or even decades, while others are only active for one or a few years.

Beavers provide a unique situation for field biologists because, given enough effort and accumulation of data, it is possible to document all colonies (overwintering lodges) in a valley the size of Whistler. This information, when combined with an estimated number of beavers per colony, provides a population census that can be monitored without the statistical analysis required in most surveys (i.e., through statistical sampling).

The Whistler Biodiversity Project initiated Whistler's first beaver census in 2007 (Brett 2007; Mullen 2008). Surveys continued through 2011, the last two of which were in conjunction with RMOW staff (Mullen 2009; Pevec 2009; Tayless 2010; Tayless and Burrows 2011). The survey was reinitiated in 2013 as part of this program but focussed only on a subset of lodges (Cascade 2014-2016). The 2016 surveys returned to a full census approach where as many active lodges as possible were enumerated (Palmer and Snowline 2017). The greater survey effort and geographic range that began in 2016 increased the number of documented colonies from nine in 2015 to 46 in 2021 (Snowline 2021), and greatly expanded the geographic range of known colonies. Each year since 2015, these surveys have come closer to a full census of all beaver colonies in Whistler.

Field work in 2022 was again led by Bob Brett with assistance from long-time surveyor, Kristen Jones. Anecdotal information from the following people also helped ensure the most comprehensive survey: Kristina Swerhun, Eric Crowe, Birken Mehta, Liz Barrett, Eric Wight (Backroads), Keenan Moses (WET), Dan Nash (Chateau GC), Geoff Barnett (Whistler GC), and Aaron Mansbridge (Nicklaus North GC).

2.2 Methods

2.2.1 Survey Design

Fieldwork began in 2016 towards (re-) building a full census of Whistler's beavers, with the recognition that this goal could only be achieved with intensive and cumulative effort. It started with lodges still documented as of 2015 and resurveyed other areas where the Whistler Biodiversity Project had earlier documented them. Surveys were also directed into areas that had anecdotal reports of beaver activity, as well as suitable habitats that were yet known to house beavers. This general approach has continued since, and each year benefits from knowledge accumulated in previous years. Consistency is further assured since surveys since 2016 have been conducted by the same people (Bob Brett and Kristen Jones).

The goal of the survey is to enumerate all active, overwintering colonies in Whistler Valley, between Function Junction and the north end of Green Lake. While the vast majority of these colonies overwinter in lodges, a minority are sometimes documented overwintering in bank burrows. From that number of active colonies (lodges plus burrows), population estimates are made by multiplying with an average number of beavers that typically occupy a lodge or burrow (Section 2.2.2). Annual fieldwork therefore resurveys sites active in past years, as well as investigates other areas for current activity and potential new colonies. Physical structures (lodges, dams, bank burrows) are mapped, and their activity status is recorded.

In most cases, it is possible to confidently identify where a lodge, burrow, or dam is active based on observations that include:

- Sightings of beavers, especially if entering and exiting structures (Photo 2-1);
- New construction or repair of lodges, especially in the fall when it shows a colony will overwinter in that lodge (Photo 2-2a);

- Functioning and freshly-maintained dam(s);
- Fresh food caches submerged at the entrance to a lodge or burrow;
- Beaver tracks (Photo 2-2b);
- Well-worn paths (tunnels and slides) through vegetation for feeding (Photo 2-2c) and/or
- Evidence of extensive clippings and cuttings along those paths.

Signs of inactivity include the absence of: beaver sightings, a structurally sound lodge; functioning or freshly-maintained dam(s); and/or other fresh signs.

Photo 2-1. Beaver sightings are the strongest evidence of presence. This beaver was observed at Lost Lake in May 2022.

Photo 2-2. Other evidence of recent beaver activity: (a) a lodge freshly mudded before winter; (b; beaver tracks; and (c) a runway through adjacent vegetation.

Until 2019, lodges and burrows for which activity status was unclear were recorded as having "Unknown" status. Starting in 2019, this uncertainty has instead been recognized by question marks beside a record, that is, "Active?" or "Inactive?" This change forced surveyors to choose which of the two classifications was most probable. While those designations have typically been correct, any errors are generally corrected in the subsequent year. For example, a lodge recorded as "Active?" will typically be confirmed active in the subsequent year or, less often, confirmed inactive.

For the first time, 2022 surveys included two other categories: “Probable” and “Possible.” The reason for these additions was to capture information about areas where beaver activity was obvious but the lodge(s) associated with that activity was not detected. The presence of a lodge was deemed to be “Probable” if the level of activity and distance from another lodge provided compelling evidence for an undetected lodge. The expectation for these areas is that a lodge will eventually be located (as happened in 2022 near Meadow Park; Section 2.3.5). The “Possible” category includes similar situations that may or may not be associated with a lodge nearby, that is, the evidence for an undetected lodge is weaker. Both categories are meant to flag areas for further investigation the following year.

2.2.2 Data Analysis

Three factors introduce uncertainty into the reliability of population estimates of Whistler’s beavers. Firstly, it is not always possible to conclude whether a colony will overwinter in a given lodge or burrow. Secondly, not all occupied lodges or burrows are detected each year (though the number of undetected lodges decreases each year due to accumulated knowledge). Thirdly, while it would be ideal to actually count each beaver in Whistler, it is not possible within the scope of this program. As a result, the number of active lodges and burrows is instead used as a proxy for the number of colonies. The total beaver population is then derived by multiplying the number of colonies by an estimated number of individuals per colony.

Among other factors, habitat suitability and beaver density can affect the number of beavers within a colony. The 2008 beaver survey (Mullen 2008) applied a multiplier of 5.8 beavers per lodge from five studies elsewhere and this is the multiplier that has been used since to estimate Whistler’s total beaver population. This multiplier continues to be a reasonable estimate because of two reasons:

1. It is consistent with the studies cited by Mullen, and also within the middle of the range of averages from studies in 12 locations reported in Müller-Schwarze and Sun (2003; Table 2-1); and,
2. It is consistent with a typical colony that contains two adults, two yearlings, and two young-of- the-year (Section 2.1).

Regardless of the multiplier chosen, it is still necessary to realize that this proxy only provides an approximation of the true population. For that reason, surveys since 2016 have included a range of multipliers that includes the middle half of the reported averages in Müller-Schwarze and Sun (2003; Table 2-1): a low estimate of 4.2 beavers per colony; a middle estimate of 5.8 beavers per colony; and a high estimate of 6.4 beavers per colony.

Table 2-1. Number of beavers per family in various locations (Müller-Schwarze and Sun 2003).

Location	Avg. No. per Family	Location	Avg. No. per Family
Alaska	4.1	Alleghany	5.4
Montana	4.1	Ohio	5.9
Newfoundland	4.2	Colorado	6.3
Adirondacks	4.3	Isle Royale	6.4
California	4.8	Massachusetts	8.1
Michigan	5.1	Nevada	8.2

2.3 Results and Discussion

2.3.1 Number of Lodges and Burrows

Surveys in 2022 documented 47 active lodges and one active burrow (Table 2-2; Figure 2-1; Appendix A). The total of 48 active colonies is the same as in 2021, and the first time since the beginning of this program that number did not increase (in spite of additional search effort; Section 2.3.2). This result supports the 2021 report's conclusion that the number of active colonies in 2021 (and now 2022) is a reasonable estimate of the total that inhabit Whistler Valley. As such, the lack of change from 2021 to 2022 shows that the beaver population has remained more or less stable in that time.

Table 2-2. Lodges and Burrows by activity status, 2007 to 2022.

Status	2007	2008	2009	2010	2011	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Lodge - Active(?) + Probable	9	27	16	16	17	10	10	7	13	9	18	27	34	46	47
Burrow - Active(?)	0	0	0	0	0	0	0	0	0	6	5	4	3	2	1
Total Active	**9**	**27**	**16**	**16**	**17**	**10**	**10**	**7**	**13**	**15**	**23**	**31**	**37**	**48**	**48**
Lodge - Inactive(?) + Possible	9	12	13	7	21	5	14	18	11	25	31	35	43	55	66
Summer Only	0	0	0	0	0	0	0	0	2	1	1	0	1	1	0
Unknow n	1	4	4	4	0	8	1	3	3	8	9	NR	NR	NR	NR
Total Surveyed	**19**	**43**	**33**	**27**	**38**	**23**	**25**	**28**	**29**	**49**	**64**	**66**	**81**	**104**	**114**

Notes: Based on results from other years, 2008 totals are likely over-estimated. No surveys were conducted in 2012.

It becomes clearer each year that lodges can remain active for many years (Photo 2-3), presumably with the same mating pair and possibly even their descendants. While only four lodges have been deemed active each year since 2017 (Table 2-3), the true number is certainly higher since many well-established lodges now listed as active were first detected since 2017, including seven newly recorded lodges in 2022. The eighth was the ROGD4-1 Lodge which was recolonized after two years of dormancy (Photo 2-4).

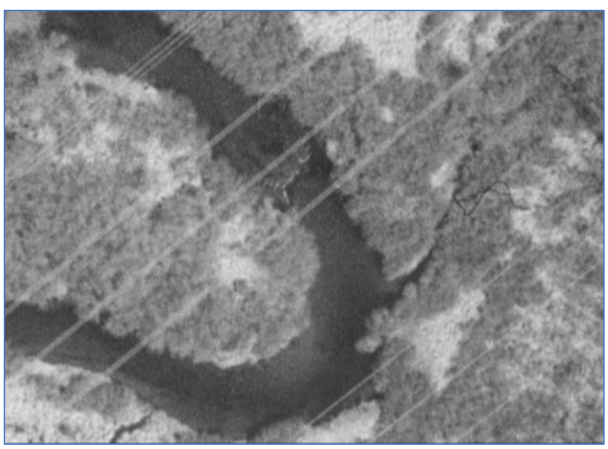


Photo 2-3. RMOW imagery of dam ROGD4-1 in 1995 (left) and 2018 (right). The dam is near the middle of the photo, under the middle power line.

Table 2-3. Active Lodges and burrows, 2017 to 2022. New lodges are highlighted in blue.

Location and ID Number	2022	2021	2020	2019	2018	2017	Easting	Northing
Alpha Lake Lodge 1	Active	Active	Active	Active	Active	NR	499208	5549034
Alpha Lake Lodge 5	Active?	Active?	NR	NR	NR	NR	499913	5548986
Alta Lake Lodge 1	Active?	Active	NR	NR	NR	NR	500934	5550767
Alta Lake Lodge 2	Active	Active	NR	NR	NR	NR	500919	5550750
Alta Vista Lodge 1	Active	Active?	Active	Active	Active	Active	501458	5550235
Chateau GC-18 Lodge 1	Active	Active	Active	NR	NR	NR	504228	5552240
Cheakamus Crossing - Lodge?	Probable	NR	NR	NR	NR	NR	496833	5547905
Fitz Cr Back Channels Burrow 1	Active	Active	Active	NR	NR	NR	504142	5554607
Fitz Pond Lodge 1	Active	Active	Inactive?	Active	Active	NR	503275	5552571
Fitz Pond Lodge 2	Active?	Active	Inactive	Inactive	NR	NR	503300	5552575
Fitz Pond Lodge 3	Active	NR	NR	NR	NR	NR	503287	5552516
Millar Creek Lodge 1	Active	Active	Active	NR	NR	NR	496821	5548379
Millar Wetlands 1-1 Lodge	Active	Active	Active	Active	Active	NR	497706	5548388
Millar Wetlands 1-2 Lodge	Active	Active	Active	NR	NR	NR	497737	5548390
Millar Wetlands 1-3 Lodge	Active	Active?	Active	Active	Active	NR	497796	5548408
Millar Wetlands 3-1 Lodge	Active	Active?	Active	Inactive	NR	NR	497931	5548588
Millar Wetlands 5-1 Lodge	Active?	Active	NR	NR	NR	NR	498270	5548912
Millar Wetlands 5-2 Lodge	Active	Active	Active	Active	Inactive?	NR	498284	5548908
Millar Wetlands 6-1 Lodge	Active?	Active?	Active	Active	NR	NR	498321	5548863
Millar Wetlands 6-2 Lodge	Active	Active	Active	Active	NR	NR	498328	5548894
Millar Wetlands 6-3 Lodge	Active	Active	Active	Active	NR	NR	498398	5548903
Rainbow Park Lodge 1	Active	Active	Active?	Inactive	Inactive	Inactive	501145	5551850
Rainbow Wetlands 1-1 Lodge	Active	Active?	NR	NR	NR	NR	501096	5552182
Rainbow Wetlands 3-1 Lodge	Probable	NR	NR	NR	NR	NR	501523	5552527
Rainbow Wetlands 4-1 Lodge	Active	Active	NR	NR	NR	NR	501702	5552711
Rainbow Wetlands 4-2 Lodge	Active?	Active	NR	NR	NR	NR	501694	5552718
Rainbow Wetlands 5-1 Lodge	Active	Active	NR	NR	NR	NR	501848	5552721
Rainbow Wetlands 5-2 Lodge	Active	Active	Active?	Active	Active	Active	501848	5552727
Rainbow Wetlands 6-1 Lodge	Active?	Active	Active	NR	NR	NR	501777	5552792
Rainbow Wetlands 6-2 Lodge	Active?	Active	NR	NR	NR	NR	501790	5552801
ROGD 03-1 Lodge	Active?	NR	NR	NR	NR	NR	501719	5552450
ROGD 04-1 Lodge	Active	Inactive	Inactive?	Active	Active	Active	501744	5552517
ROGD 10-2 Lodge	Active?	Active	Active?	Active	NR	NR	502126	5553026
ROGD 15-2 Lodge	Active?	Active	Active	Active	NR	NR	502312	5553204
ROGD 15-3 Lodge	Active?	Active	Active	Active	Active	NR	502327	5553188
ROGD 15-5 Lodge	Active	Active	Active	Active	Active?	NR	502349	5553202
ROGD 15-6 Lodge	Active?	Active?	Inactive?	Inactive	Inactive	NR	502355	5553222
ROGD 21-1 Lodge	Active	Active	Active	Active	NR	NR	502406	5553403
ROGD 25-1 Lodge	Active	Active	Active	Inactive	Inactive	NR	502311	5553661
ROGD 25-2 Lodge	Active	Active	Active	Inactive?	Inactive	NR	502308	5553673
ROGD 27-1 Lodge	Active?	Active	Active	NR	NR	NR	502294	5553771
ROGD 31-1 Lodge?	Probable	NR	NR	NR	NR	NR	502607	5554167
ROGD 35-1 Lodge	Active	NR	NR	NR	NR	NR	502846	5554565
ROGD 41-1 Lodge	Active	Active	Active	Active	Inactive?	NR	503187	5554830
Wedge Pond Lodge 4	Active?	NR	NR	NR	NR	NR	503233	5555757
Wildlife Refuge 3-1 Lodge	Active?	Active	Active	NR	NR	NR	501750	5553298
Wildlife Refuge 3-2 Lodge	Active?	Active	NR	NR	NR	NR	501709	5553226
Wildlife Refuge 4 1-Lodge	Active?	Active	Active	Active	Active	Active	501825	5553543

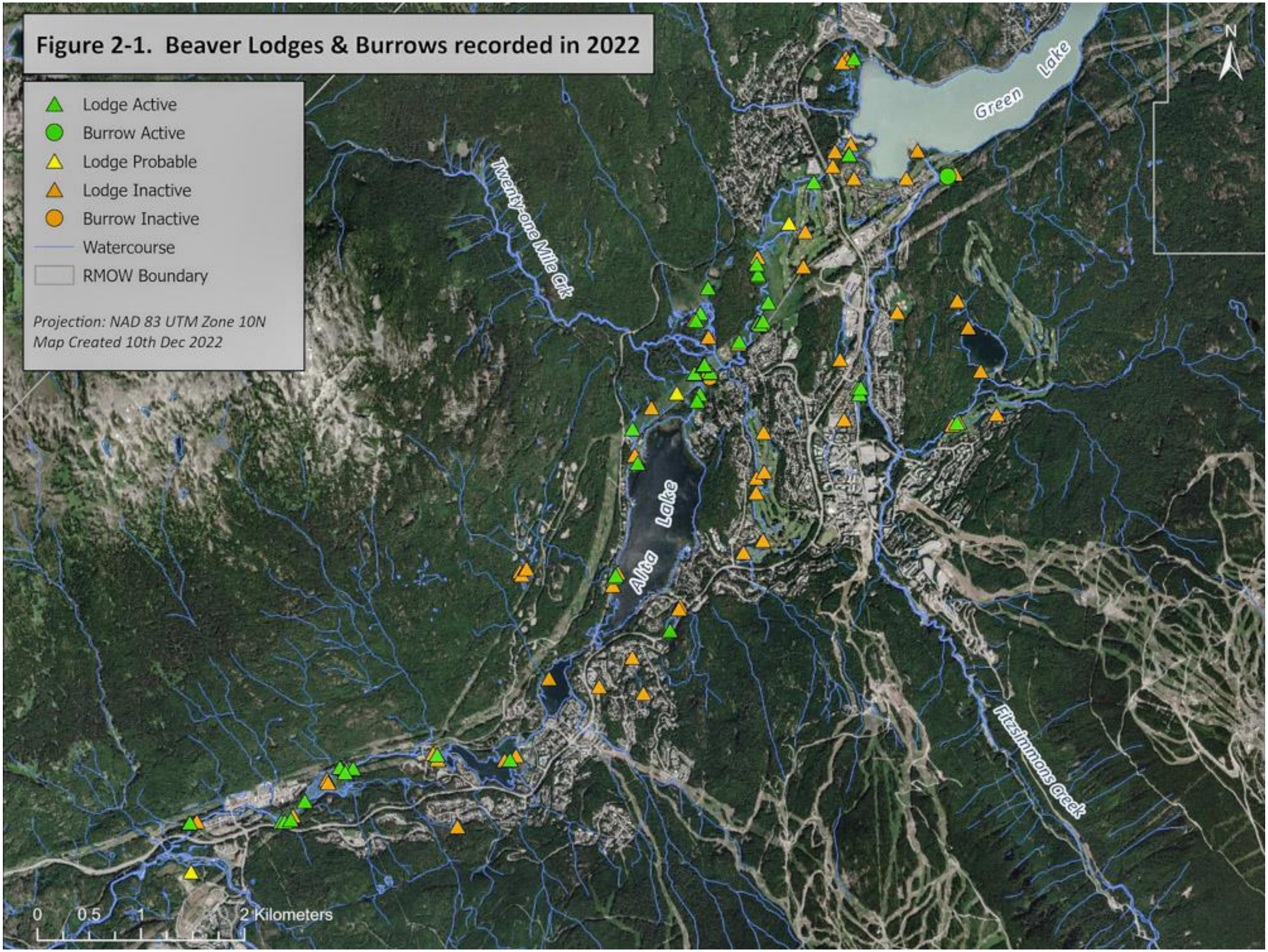


Figure 2-1. Beaver Lodges and Burrows.

2.3.2 Search Effort and Detections

While the number of active lodges and burrows remained the same as in 2021, the search effort continued to increase, from 28 sites in 2015 to 114 sites in 2022 (Table 2-2; Figure 2-2). The main reason for the increase in both search effort and detections has been expanded surveys in the hardhack meadows in the Rainbow Wetlands, Wildlife Refuge, and Millar Wetlands, especially since 2019. Hardhack and other tall shrubs in these wetlands can completely hide a lodge, which is why they are often hidden even when viewed from only a few metres away. Surveys later in the fall was the other main change, and this also increased the number of detections. For example, most of the 2022 surveys were conducted in November, after snow helped flatten the vegetation that can so effectively hide lodges.

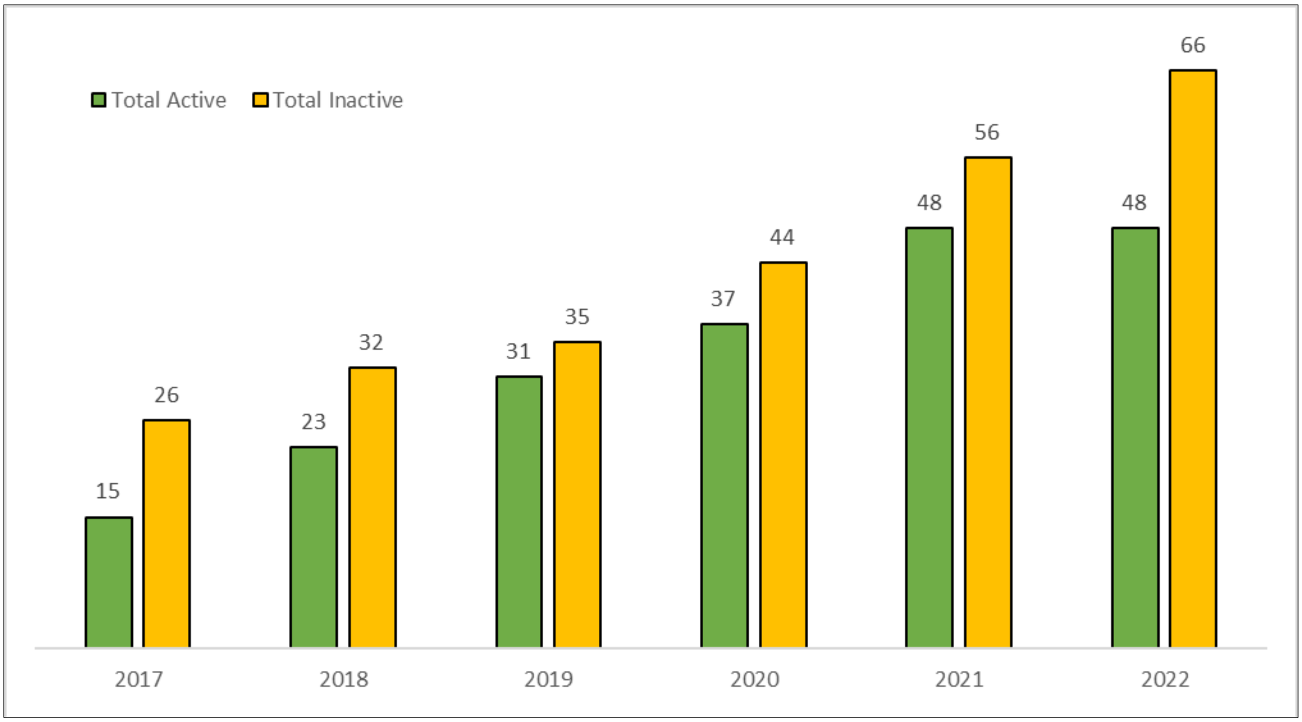


Figure 2-2. Number of active and inactive colonies (lodges and burrows) detected since 2017.

2.3.3 Estimated Beaver Population

The estimated number of beavers living in the 48 colonies detected in 2022 is 273 individuals, with a possible range from approximately 197 to 307 individuals (Table 2-4; Figure 2-3). As mentioned in the previous section, this means that the population has remained stable since at least 2021. While it is not possible to determine the number of beavers for previous years, it is possible to project the pre-settlement population based on McBlane's (2007) calculation that almost three-quarters of Whistler's wetlands have been lost to development since the railway opened in 1913. If Whistler's wetlands were intact, it is therefore conceivable that over 1,000 beavers (four times the current population), inhabited Whistler Valley.

Table 2-4. Estimated number of beavers in Whistler, 2007-2022. The rational for estimates of the number of beavers per colony is described in Section 2.2.2.

	2007	2008	2009	2010	2011	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Active colonies	9	27	16	16	17	10	10	7	13	15	23	31	37	48	48
4.2 beavers/colony	38	113	67	67	71	42	42	29	55	63	97	130	155	197	197
5.8 beavers/colony	52	157	93	93	99	58	58	41	75	87	133	180	215	273	273
6.4 beavers/colony	58	173	102	102	109	64	64	45	83	96	147	198	237	307	307

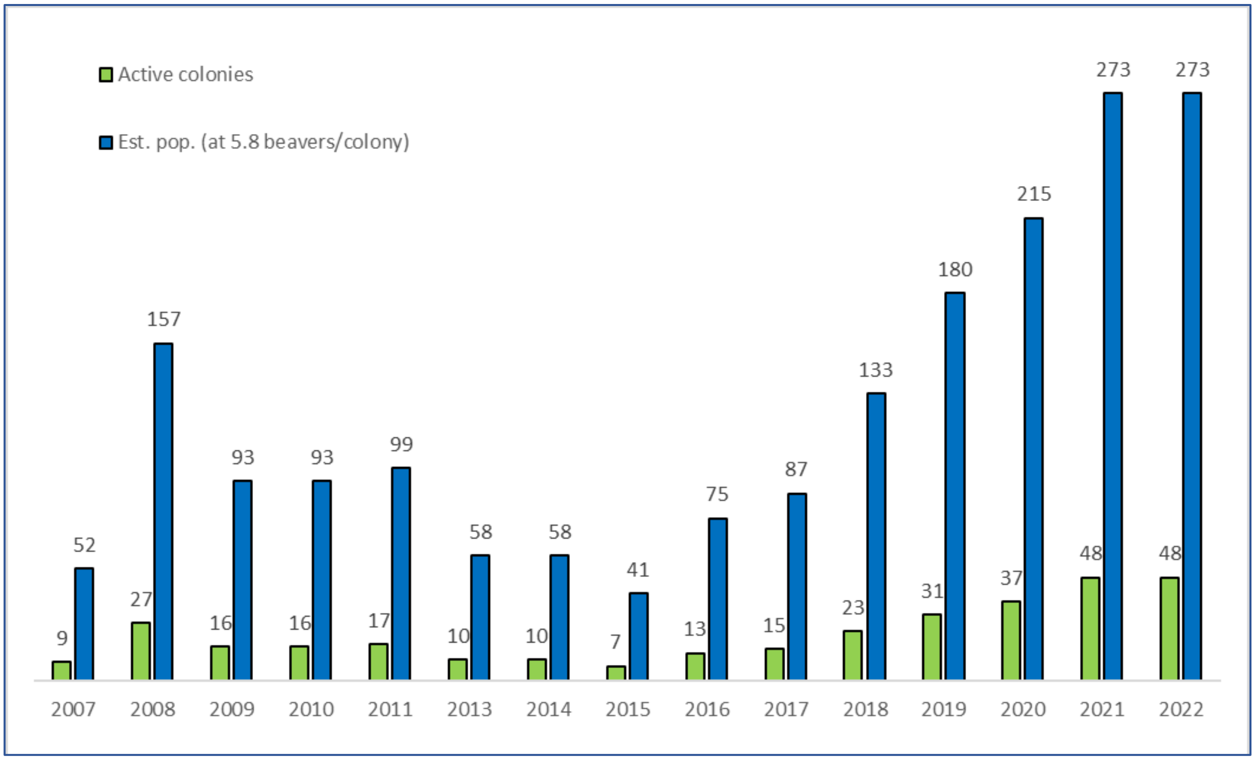


Figure 2-3. Estimated beaver population from 2007-2022 based on 5.8 beavers per colony.

2.3.4 Importance of ROGD-Rainbow-Wildlife Refuge Complex and Millar Wetlands

The impact and presence of beavers in Whistler was well-known long before annual surveys began (e.g., Racey and McTaggart-Cowan 1935). Before these surveys, perhaps the most obvious habitat was on the River of Golden Dreams (ROGD) where paddlers had to navigate multiple beaver dams. It was therefore not surprising when the first decade of beaver surveys confirmed that at least half of known lodges in Whistler were on the ROGD. While the ROGD still provides important beaver habitat, expanded surveys since 2019 have discovered that other areas provide a similar amount of beaver habitat, notably in the Millar Wetlands, the Rainbow Wetlands, and the Wildlife Refuge.

Ambitious surveys in 2019 covered the entire Millar Wetland area, including parts of the hardhack meadows that were very difficult to access. That effort was rewarded with the discovery of seven previously unknown lodges and brought the total for that area to nine active lodges. In 2021, a similar effort discovered an additional five previously unknown lodges in the Rainbow Wetlands and a further two in the Wildlife Refuge. Surveys in 2022 mostly confirmed results from the previous year, and reinforced the importance of these wetland complexes. As in 2021, these two wetland complexes (ROGD-Rainbow-Wildlife Refuge and Millar Wetlands), support almost three-quarters (35 out of 48) active colonies in the Whistler Valley (Figure 2-4).

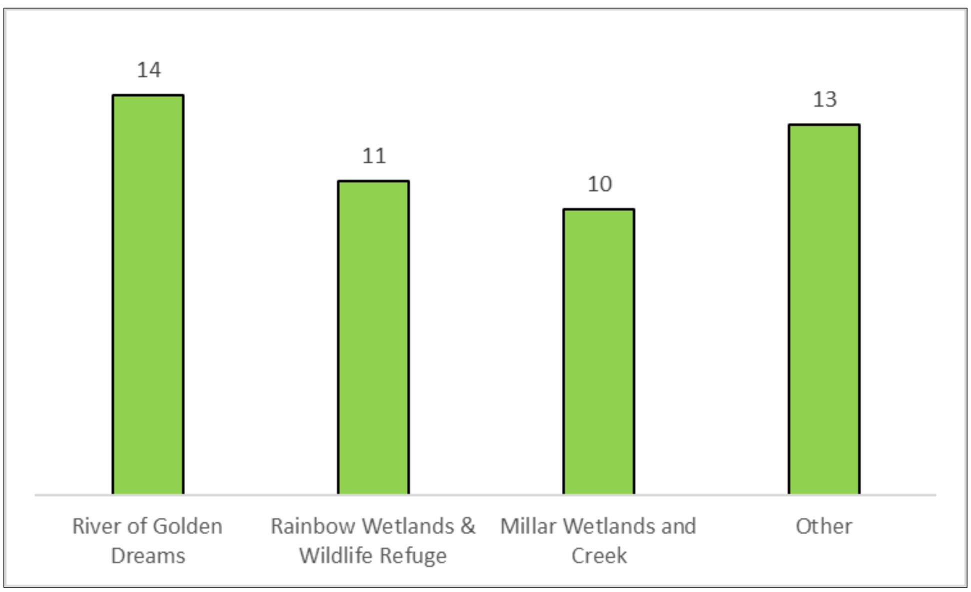


Figure 2-4. Colonies by major activity area, 2022.

River of Golden Dream (ROGD)[2]

Each year, this survey confirms the importance of the River of Golden Dreams (ROGD) to beavers. In 2022, almost one-third (14 of 48) active colonies were documented on the ROGD, while over one-half (25 of 48) active colonies were found in wetland complex that joins the ROGD with the Rainbow Wetlands, and Wildlife Refuge (Figure 2-3). This year the survey benefitted from the latest-ever annual canoe survey, on November 6th, when snow had flattened much of the vegetation and helped reveal some otherwise hidden lodges.

ROGD4-1 Lodge

One of the best-known lodges in the valley is visible upstream from the Valley Trail bridge over the ROGD that is nearest Rainbow Park (Photo 2-4). While it was active for many years, it was vacated in 2020 and remained unoccupied in 2021. It was reoccupied, probably early in summer 2022 (based on dam construction), and overwintering was confirmed by recent mudding in late fall. In addition, a previously undocumented, and likely active lodge was found just upstream. The 2020 report surmised that the colony in the older lodge relocated to Rainbow Park in fall 2020. In 2021, two to three newly active lodges were detected nearby on Alta Lake, beside the outlet of Scotia Creek. It is likely the beavers in these three areas include inter-family linkages.

Photo 2-4. Lodge ROGD 4-1 is visible just upstream of the Valley Trail bridge (middle right of this photo). It was active for many years, inactive 2020 to 2021, then recolonized in 2022.

[2] *Numbering: Note that features on the River of Golden Dreams (lodges, burrows, dams, and caches) are named according to the nearest, sequentially-numbered river bend. Bend 1 is closest to Alta Lake and Bend 41 is closest to the outlet into Green Lake.*

Large Dams and Large Caches

The presence of beavers on the ROGD was particularly noticeably during the November canoe survey. Firstly, dams were impounding more water than observed in previous years, apparently as a strong response to the three-month drought between July and October, 2022. (These large dams, and their impacts on wildlife habitat and water management in a changing climate, is discussed further in Section 2.3.7.)

Secondly, there were two very large caches, one at Bend 19 and one at Bend 31 (Photo 2-5). The cache at Bend 19 may be located to a lodge just downstream, or possibly an undetected lodge near an area of extensive beaver feeding at Bend 17. The even-larger cache at Bend 31 is far from any lodge detected since 2016 and therefore likely associated with an undetected lodge (hence, it's classification as a "Probable" lodge; Table 2-3, Figure 2-1).

Photo 2-5. This large food cache, near the 31st bend in the River of Golden Dreams, was far from any of the lodges detected upstream and downstream. Since the cache must be related to a lodge, the area was classified as a "Probable" active colony (Figure 2-1).

Meadow Park Area

There has been obvious beaver activity in the Meadow Park section of the ROGD for at least two years. Until this year, the associated lodge could not be found. Starting in early fall 2022, beavers built an unusually large dam upstream of Highway 99 near Meadow Park Sports Centre. By November, the height of the unbreached section of the dam was approximately 130 cm (Photo 2-6). The previously undetected lodge associated with this dam was finally found in November 2022 (Photo 2-7).

Photo 2-6. This new dam (ROGD 35-1) is the largest currently on the River of Golden Dreams. It is associated with the newly-detected lodge shown in Photo 2-7, below.

Photo 2-7. This large lodge (35-1) was finally detected under snow in November, 2022. Based on older branches on top of the lodge and sustained activity in the area in past years, it has likely been active at least since 2020, and probably longer.

ROGD Outlet to Green Lake

The large lodge just upstream of the outlet into Green Lake has been active for at least four years, and possibly much longer (Photo 2-8; Table 2-3). The colony in this lodge is almost certainly responsible for beaver cuttings and other evidence of activity closer to the Nicklaus North boardwalk. There was a lodge active for many years on the east side of the float plane base on Green Lake, but it has been inactive since 2018 (Appendix a).

Photo 2-8. Lodge ROGD 41-1 is located just upstream of Green Lake on the River of Golden Dreams. It is one of the largest and most obvious lodges in Whistler.

Rainbow Wetlands[3]

The most notable change in the Rainbow Wetlands in 2022 was that water levels were noticeably higher than in previous years (Photos 2-9 to 2-13). The ditches that would otherwise drain the area were impounded by at least three large dams – dams that would normally be removed by CN Rail.

Another change for the 2022 survey was the use of a drone to investigate the area which was especially helpful given that travel by foot is more difficult in higher water levels. The drone was helpful in a number of ways: (a) understanding better the connection between channels; (b) checking for new lodges; and (c) confirming the status of lodges (e.g., Photo 2-9).

[3] *Numbering: Note that features in the Rainbow Wetlands (lodges, burrows, dams, and caches) are named according to the nearest sequentially-numbered channel, so that Channel 1 is closest to Rainbow Park and Channel 6 to the northeast is closest to Twenty-One Mile Creek.*


Photo 2-9. RW1-1 Lodge and RW1-1 Dam. (Left) The pond is created by a dam on the right-hand side of the pond. The lodge is in the middle of the photo. (Right) The drone allowed confirmation of an open channel at the far side of the lodge (bottom middle of photo).

Photo 2-10. There are two lodges hidden in the middle of this photo (RW5-2 and RW5-1). Unusually large dams increased the depth and surface area of water linking with the lodge

Photo 2-11. Aerial view facing north of RW5 channel (foreground) and RW6 channel (top left). The ditch (right side) parallels the adjacent rail line, and is impounded by three large dams.

Photo 2-12. Aerial view facing south of RW6 channel. RW6-1 Lodge and RW6-2 Lodge active~ hidden under snow right midground

Photo 2-13. Aerial view facing north of RW6-1 and RW6-2 lodges (mid foreground), both mostly hidden under snow. This area is very difficult to access on foot.

Wildlife Refuge[4]

The Wildlife Refuge is connected via Twenty-One Mile Creek and associated wetlands to the Rainbow Wetlands and the River of Golden Dreams that provide habitat for half of Whistler's beaver lodges (Photo 2-14; Figure 2-3). Three lodges were confirmed active in 2022, mostly through the use of a drone (Photos 2-14 to 2-16). While the drone provided information that would not have been possible without it, one of the conclusions from this first drone test is that surveys on foot are often needed to confirm activity status for particularly cryptic lodges.

Photo 2-14. Aerial view of the Wildlife Refuge looking southeast (towards Blackcomb Mountain). Zone 1 (WR1) is centered on the snow-covered opening and pond at the top right of the photo. Zone 2 (WR2) is the main pond in the middle left accessed via Bird Box Trail next to the Emerald Forest. Zone 3 includes the pond at the bottom right of the photo. Zone 4 extends northwest (left) at the bottom left of the photo.

4 *Numbering: Note that features in the Wildlife Refuge (lodges, burrows, dams, and caches) are grouped into different zones to help describe their location. Zone 1 is at the south end of the wetlands, Zone 2 includes the open water closest to Bird Box Trail and the Emerald Forest, Zone 3 is west of Zone 2, and Zone 4 includes the northern part (Photo 2-14).*

Photo 2-15. Pond 3 in the Wildlife Refuge includes an active lodge (middle left) below the dammed pond and another next to the pond (top middle of photo).

Photo 2-16. Zone 4 (WR4) is northwest of the main part of the Wildlife Refuge (Photo 2-14). This small, dammed pond is associated with a large lodge directly to its right.

Millar Wetlands (including Millar Creek downstream)

It wasn't until the first extensive surveys in the Millar Wetlands that the importance of this beaver habitat was documented. In 2022 there were nine active lodges within the main wetlands, and a tenth downstream in Millar Creek. This area is by far the largest concentration of beavers in the south end of Whistler Valley (Figure 2-3).

Millar Wetlands

Two observations from 2022 surveys were notable:

- A large new dam (Figure 2-17) was built in 2022, possibly as a response to the drought between July and October. If so, it would appear to be a similar response to beavers in the ROGD, Fitz Creek Pond, and the Rainbow Wetlands (Section 2.4).

Photo 2- 17. This new dam (MW1-3) is directly downstream from three active lodges.

- No negative impacts from the 2018-21 construction of the Fortis gas line and new Valley Trail were detected, even though the right-of-way extended into the edge of the wetland (Figure 2-18).

Figure 2-18. This long-present dam (MW5-3) was not visible before 2018-2021 construction.

Millar Creek downstream

In 2021, there were two active lodges on Millar Creek downstream of the Millar Wetlands, and near the west end of Function Junction. When visited in late fall 2021, the beavers had felled all the small cottonwoods in preparation for the winter (the adjacent alders were surprisingly left standing). At the time it appeared they had removed most of their food source, at least until the cottonwoods could grow back. As of November 2022, there was much less obvious activity that consisted only of some slides on snow, minor gnawing of alders, and a cache in front of the only active lodge (the other lodge was apparently vacated since last fall; Photo 2-19).

This area would be an obvious destination for juveniles migrating out from the nine active lodges in Millar Creek, and it is possible other lodges could be built even farther downstream (which hasn't been surveyed).

Photo 2- 19.   There was a fresh cached in front of this Millar Creek lodge in November 2022.

2.3.5 Other Notable Activity in 2022 (Alphabetical)

Cheakamus Crossing

Extensive beaver activity was found north of the Cheakamus Crossing neighbourhood during surveys for pond amphibians in (Photo 2-20; Figure 2-1). The most activity was found in a square pond manufactured during construction of the original Athletes' Village development and coded as SP1. The area was mapped as containing an undetected lodge (hence coded as "Probable) since such activity is highly unlikely to be related to the nearest known lodges in the Millar Wetlands and the Cheakamus River (Section 2.3.6). Further surveys in 2023 will help confirm if there is actually a lodge in the area.

Photo 2- 20. This manufactured pond (SP1) in Cheakamus Crossing had large piles of branches cut by beavers (foreground) when visited in May 2022. No associated lodge was found.

Fitz Creek Pond

The remnant wetland between the north end of Blackcomb Way and Fitzsimmons Creek ("Fitz Creek Pond'' has become one of the most active beaver habitats in Whistler Valley. While previous surveys confirmed extensive use of the area long ago, it was only in 2018 that beaver surveys confirmed recolonization. The 2018 lodge was joined by a second lodge in 2020 (Photo 2-21), and a third this past year (Photo 2-22).

Beaver activity in this area is important for wildlife habitat for a number of reasons:

1. The construction in the 1980s of the high berm which supports Blackcomb Way has greatly changed drainage patterns. In 2005, botanist and wetland specialist Adolf Ceska[5] remarked that, without intervention, the only remaining natural wetland would eventually fill in with cattails.
2. While cattails have indeed encroached on the open water in the intervening years, damming by beavers has helped maintain at least some open water.
3. Damming on the downstream edge of the wetland, next to the Fitzsimmons Nature Trail and where it drains into Fitzsimmons Creek, was higher than in past years. This is another example where beavers appear to have responded to the 2022 drought by raising water levels (Section 2-4).
4. Even though this is a very small wetland, it still provides enough open water for Ring-necked Ducks and other waterfowl. Without the beavers, the open water would be likely be covered with vegetation.

Alta Vista Pond

The large main lodge in Alta Vista Pond (Photo 2-23) is one of the most visible in Whistler Valley. It has been active for more than 5 years. Two other lodges in the pond have meanwhile been inactive since at least 2020 (when they were first recorded). While the pond provides important habitat for beavers, who maintain water levels with two large dams, it also provides habitat for salamanders, waterfowl, and other wildlife. The RMOW lowered water levels in Alta Vista Pond in 2018 due to concerns about the roadbed on the north side of the pond. Although it is unclear if that work impacted the two, now inactive lodges, it does not appear to have had any impact on the main lodge.

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[5] *Personal communication to Bob Brett during August 2005 surveys for the Whistler Biodiversity Project.*

Photo 2- 21. Fitz Creek Pond: (foreground) 2020 lodge; (background) 2018 lodge.

Photo 2- 22. Fitz Creek Pond: (left) the 2022 is at the southwest end of the pond, to the right of the tall spruce in this photo; (right) the lodge was freshly mudded in late 2022.

Photo 2- 23. Two large dams to the right of this lodge maintain water levels in Alta Vista Pond.

Alta Lake and Rainbow Park

Just after a colony vacated the long-active ROGD4-1 Lodge (Photo 2-24) in fall 2020, the old lodge at Rainbow Park was reactivated (Photo 2-25). It is therefore likely to be the same colony involved with both lodges. In late 2021, three new lodges were built at the edge of Alta Lake, beside the outflow of Scotia Creek. In 2022, the ROGD4-1 Lodge was again reinhabited. While there is no genetic data available, it is likely the colonies involved include at least some beavers related to each other.

Alta Lake

Only two of three lodges built in 2021 were still active in fall 2022. There was extensive falling of alders adjacent to these lodges in late 2021, at a scale similar to the cottonwood cutting near the Millar Creek lodges (Section 2.3.4). And, as with those lodges, there was almost no cutting visible in fall 2022 and no apparent reason for this change in behaviour.

Photo 2- 24. Alta Lake Lodge 2 is just south of the Scotia Creek outlet to the lake.

Rainbow Park

The main lodge at Rainbow Park remained active in 2022. This lodge is of potential concern to the RMOW since the associated dams, if not managed, have the potential to cause flooding of the Rainbow Park fields. Given the lodge has now been active for three or more years, it shows that it is possible to co-exist with beavers, even in such a human-dominated landscape.

Photo 2- 25. Rainbow Park, Lodge 1, west side upstream of Alta Lake.

Fitzsimmons Overflow Channel

The only colony found inhabiting a bank burrow in 2022 has dammed the overflow channel at the north end of Fitzsimmons Creek, and built a burrow into the berm that creates the channel. Without the dam, this channel would be dry in most non-winter months. The presence of permanent water presumably increases habitat for aquatic plans and some wildlife (though no waterfowl or other animals were seen in numerous visits over the past seven years) summer/fall months The only active burrow detected in 2022. It's a bit of a hybrid since the beavers have dug into a flood control berm and dammed the overflow channel. The activity status of this burrow was unclear in 2021, but confirmed with the presence of a fresh cache outside the burrow in November 2022.

Photo 2- 26. Fitzsimmons Creek overflow channel Dam 1. An overwintering burrow is located just upstream, in the middle right of this photo.

Golf Courses

Much of the area on which in the two valleybottom golf courses (Whistler and Nicklaus North) were built was previously beaver habitat, and at least some wetlands (at the south end) were replaced by the otherwise upland Chateau Golf Course. Beavers continually migrate into these areas to establish lodges, as documented by past beaver surveys, but lodge activity has been less in recent years, especially on the Whistler and Nicklaus North Golf Courses. As in the past several years, only the Chateau Golf Course has an active colony

Chateau Golf Course

The lodge on the main pond beside the #18 fairway (Photo 2-27) has been active since 2019 and is now larger than ever – large enough that it possibly houses more beavers than the expect six individuals (two adults, two one year-olds, and two young-of-the-year). When this lodge was inactive for two years (2017 and 2018), the pond dried up, thereby reducing wildlife habitat. Although the still-sound lodge on the #2 pond has not been occupied since 2017, the beaver dam impounding water on that pond is periodically maintained, presumably by the colony in the #18 pond.

Photo 2-27. Chateau GC #18 main lodge

Whistler Golf Course:

In spite of a long history of beaver lodges in the ponds and creeks on the Whistler Golf Course, there have been no active lodges on the course since 2019 (when there were three). This lack of lodges is apparently not related to control efforts by golf course staff,[6] though any dams on Crabapple Creek are breached by staff when they raise water levels too much. As in fall 2021, the fall 2022 survey found some evidence that at least one beaver had recently been on the course as shown by a recently gnawed alder and a recently constructed and cleared dam (Photo 2-28)

Photo 2-28. (left) Minor feeding in fall 2022 on an alder beside Whistler GC #4 pond; (right) Recent dam building was removed by WGC staff in fall 2022.

Nicklaus North Golf Course

Nicklaus North Golf Course has had no active lodges since 2016. This course and the Whistler course were both built on top of wetlands, with very little height above the water table. As a result, beaver damming is a constant concern, especially in the outlet from the #5 pond where it drains into the River of Golden Dreams. Since there is a very active colony in that area (the ROGD35-1 lodge), there is potential for conflict.

[6] *Whistler GC Superintendent Geoff Barnett personal communication with Bob Brett.*

Lost Lake and Old Mill Pond

Lost Lake and the adjacent Old Mill Pond are another area with extensive evidence of past occupation by beavers. Surveys since 2007 have shown that colonies are less stable than in other areas, and that lodges are only active for one or two years (for unknown reasons). A new lodge was constructed at the north end of the lake in late fall 2021, and was still active in May 2022 (as shown by the beaver in Photo 2-1). No further activity was detected in late fall 2022 and, in spite of the apparent soundness of the lodge, it appears to be inactive (Photo 2-29). A second intact lodge closer to the main beach also appeared to be inactive.

Surveying the new lodge at the north end of the lake provided another example of why late-season and/or multiple surveys are essential for accuracy. The lodge was totally covered by hardhack and other shrubs in early November, enough that it was not found in spite of accurate coordinates.[7] When surveyed again at the beginning of December, enough of the leaves had fallen that the lodge became visible (Photo 2-29).

Lost Lake

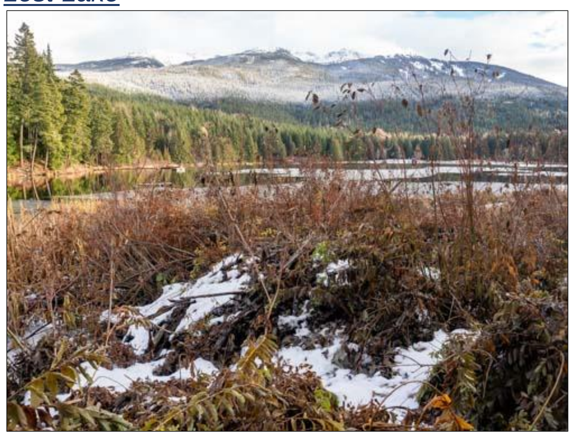

Photo 2- 29. (left) Lost Lake Lodge 1 at the north end of the lake; (right) Lost Lake Lodge 3 is nearer the main beach at the outlet to Blackcomb Creek. While structurally sound, it has not been occupied since 2020.

Old Mill Pond

While Old Mill Pond hasn't had an active beaver lodge for many years, there are at least three old lodges in the wetland just north of the main pond that prove its beaver history. The beaver dam that maintains the pond is still intact, and there is evidence of feeding in the area (possibly from earlier in 2022). While thin ice prevented a full survey of this area in November 2022, drone footage revealed a possible lodge (Photo 2-30) that will be investigated in 2023.

Photo 2-30 (right).

[7] The drought that extended into late fall 2022 meant that leaves stayed on shrubs and trees much later than usual, thereby hiding beaver lodges into November.

Wedge Pond

There is abundant evidence of the impact of beavers in the Wedge Pond area, including the wetlands surrounding it that join with Green Lake. There are old channels, beaver meadows, and old channels throughout. Confirming which lodge(s) are active or not as been a challenge in past surveys. For example, the 2021 survey could not confirm that there was an overwintering colony due to the lack of recent evidence. The November 2022 survey, however, found enough evidence to confirm that a previously undetected lodge (Wedge Lodge 4) was active (Photo 2-31). This confirmation suggests that there was likely an active colony on the pond in 2021 after all. The long, low dam that creates the pond (Photo 2-32) is still being maintained by beavers.

Photo 2- 31. Freshly cut alders (left) and beaver slides on the newly-detected Wedge Pond Lodge 4 (right) confirmed it contained an over-wintering colony.

Photo 2- 32. The beaver dam on the south side of Wedge Pond creates the pond.

2.3.6 Newly Documented Lodges Outside the Development Footprint

While beavers in Whistler's valley bottom are the focus of this program, beavers also inhabit other areas within the RMOW, two of which were recently detected during other work for this program. The first is in the pond just south of the Callaghan Forest Service Road, on the west edge of Highway 99 (UTM 0492923E 5546160N). A large lodge in this pond (Photo 2-33) was first discovered during amphibian surveys in 2021. A second active lodge was confirmed on the opposite side of the pond in 2022.

Photo 2- 33. The large, active lodge on the pond south of the Callaghan FSR.

The second beaver area documented outside the RMOW Development Footprint in 2022 is on a side channel of the Cheakamus River, south of Function Junction (UTM 0493378E 5547059N) and beside the Runaway Train bike trail. This large lodge (Photo 2-34) has been active for at least two and probably more years, given a number of past anecdotal reports as well as extensive damming nearby. The location of this lodge shows great ingenuity since the beavers have used strategic damming and the shape of the river at that point and to create a pond. This design is clearly resilient enough to survive periods of high water on the Cheakamus River.

Photo 2- 34. A large lodge on a side channel of the Cheakamus River near the Runaway Train bike trail.

2.4 The Beavers' Response to the 2022 Drought – Higher Dams

The Highlighted Importance of Beaver Dams in 2022

Dams are the main reason beavers are so ecologically important. Without them, there would be much less area covered by wetlands, and therefore much less of this species-rich habitat (Section 2.5). Dams are also important from a human perspective by storing water through dry summer months and reducing the rate of streamflow. In 2022, the importance of beavers in water management become even clearer.

The extended drought from July through October 2022 revealed a surprising response from beavers throughout Whistler Valley – their dam maintenance and building not only maintained water levels throughout the drought, they actually increased water levels in some areas. The beavers' response to the 2022 drought has a number of implications:

1. It demonstrates that the ecological importance of water impoundment by beavers is even higher during drought (low-water) conditions. This is an important consideration given that a prediction of climate change is that summer droughts will become more common.
2. It shows that beavers are very aware of water conditions, and respond strongly to threats to their desired water levels.
3. The beavers' response not only helps protect wildlife habitat, it also ensures more water storage in the valley bottom that helps regulate the RMOW's water management, maintain water levels high enough to allow recreation on the River of Golden Dreams, and (among other habitat benefits) ensure enough water for spawning fish.

Examples of Larger Dams in 2022

There were at least four areas where beavers built large new dams, and/or increased the size of existing dams: (i) the River of Golden Dreams; (ii) the Rainbow Wetlands; (iii) Fitz Pond; and (iv) Millar Wetlands (Figure 2-5). Brief descriptions of each are included with the photos below.

River of Golden Dreams (ROGD)

The extremely large dam near Meadow Park Sports Centre (Photo 2-35), built in late summer/fall 2022, is perhaps the most obvious example of what seems to be the local beavers' response to the drought. It is approximately 130 cm high, near double the height of any other dam measured during the November 6, 2022 canoe survey. The dam increased depths even upstream of Meadow Park.

Photo 2- 35. The large dam built on the ROGD upstream of Highway 99. (left) On October 27, 2022, after recent rain; and (right) on November 6, 2022, showing scale.

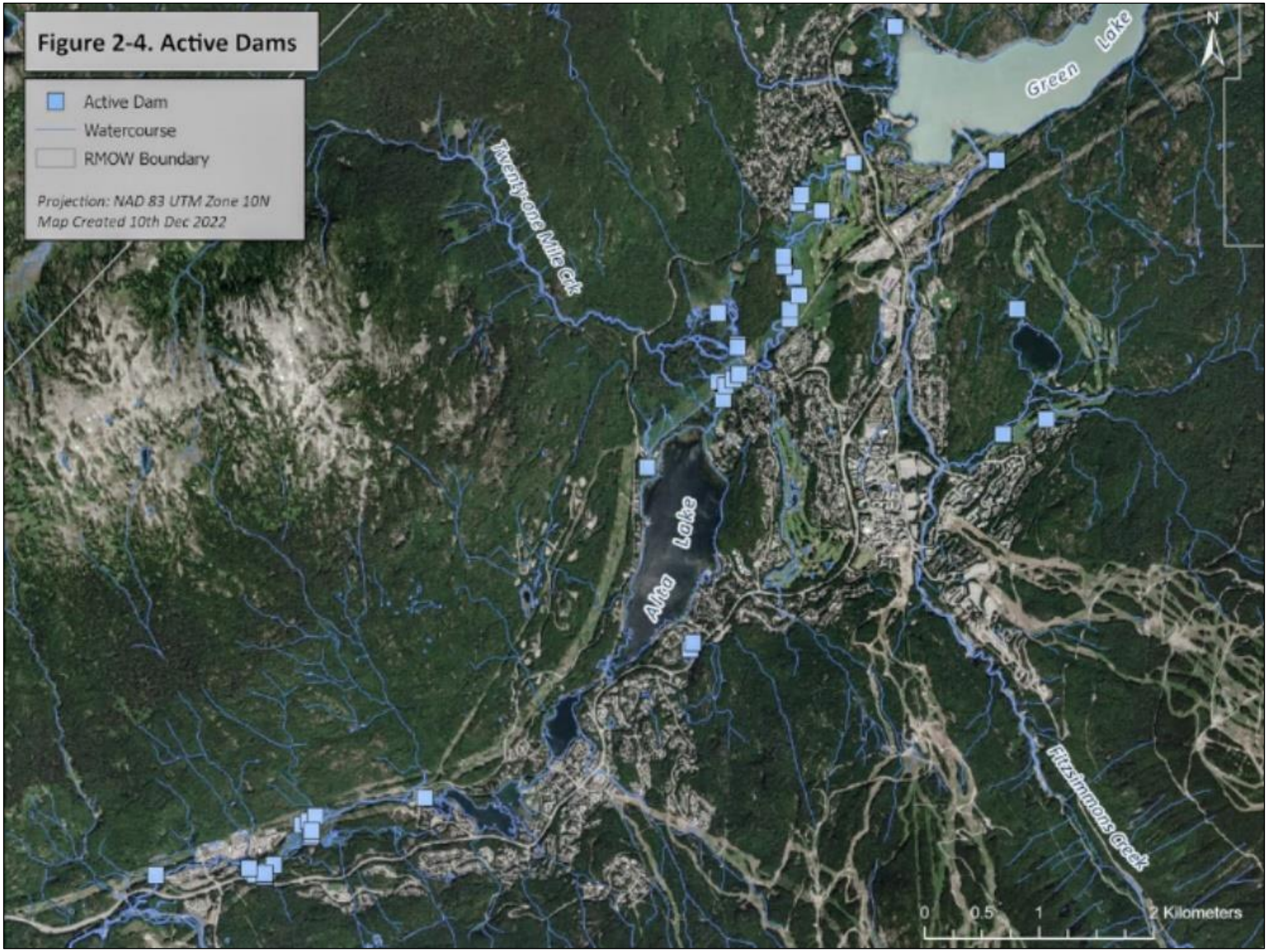

Figure 2-5. Dams active in Whistler Valley in 2022.

Other dams on the ROGD were also higher and impounded more water than in past years, which contrasted sharply with reaches without dams. In late fall, for example, when there was not enough water to float a canoe near the Lorimer Road bridge, ponds above many of the dams were deeper than in previous years (Photo 2-36).

Photo 2- 36. (left) Low water on the ROGD at the base of Lorimer Road; (right) elsewhere on the ROGD, larger than usual dams created deeper pools than observed in past years.

Rainbow Wetland:

As mentioned in Section 2.3.4, there was much more water impounded in the Rainbow Wetlands by beaver dams in 2022 in the ditch beside the railway track (Photo 2-37). It is not clear whether this is because CN Rail did not do their usual removals, or whether it was a response to the drought.

Photo 2-37. This dam (RW5-Ditch-2) is impounding more than one metre of water.

Fitz Pond:

The dams that create this pond between Fitzsimmons Creek and the north end of Blackcomb Way were high enough during 2022 to nearly flood the adjacent Nature Trail. As with the Rainbow Wetlands, it is may or not be related to the late summer drought. Either way, however, the higher water levels (Photo 2-38) provide an important ecosystem function by reducing the incursion of cattails and thereby maintaining open water for waterfowl.

Photo 2- 38. Water levels in the Fitz Pond were higher than in past years.

Millar Wetlands:

The largest dam in the Millar Wetlands was built in 2022 (Photo 2-39), again possibly as a response to the long July to October drought. Since there are two long-active dams just downstream, it seems reasonable to assume this new dam was a response to otherwise low water levels in 2022.

Photo 2- 39. This new dam (MW1-3) is directly downstream of three active lodges.

2.5 Beaver-affected Wetlands

2.5.1 Introduction

A beaver's life is inextricably involved in creating its own habitat – their incredible ability to alter and saturate landscapes is why they are sometimes called ecosystems engineers. By creating and maintaining wetlands, beavers provide habitat for countless plants and animals, reduce erosion, and mitigate floods (Müller-Schwarze and Sun 2003; Goldfarb 2018). The first attempt to quantify this effect of beavers on Whistler's landscape was included in the first mapping of "beaver-affected wetlands" (Palmer and Snowline 2019), a term coined for this project that refers to wetlands that have been created and/or directly affected by beavers within Whistler Valley.

Monitoring the area covered by beaver-affected wetlands is meant to add a spatial complement to the lodge surveys and population estimates described above (Section 2-3). The two measures – number of beavers and areal extent of beaver-affected wetlands – are of course connected. More beavers mean more dams and impounding of water and, hence, more wetland area. Increases or decreases in wetland area likewise reflect the number of beavers present on the landscape.

2.5.2 2022 Update

Based on results described above (Section 2-4), larger dams in 2022 impounded more water than in recent years. Although that meant more open water in 2022 than in 2021, it did not affect the actual area of beaver-affected wetlands, which remained unchanged at 100.7 ha (Table 2-5; Figure 2-6). When combined with the additional open water created by beaver dam at the outflow of Alpha Lake, the total beaver effect is 107.8 ha. The River of Golden Dreams contains almost half (47%) of all beaver-affected wetlands, while the other three main beaver population centres in the Millar Wetlands (13%), Rainbow Wetlands (15%), and Wildlife Refuge (10%) account for most of the rest.

Table 2-5 Location and area of beaver-affected wetlands in Whistler, 2021.

Wetland (South to North)	2022 Area (ha)	2022 Area (%)
Millar Creek Wetlands	13.2	13%
Beaver Lake	1.8	2%
Alta Vista Pond	1.3	1%
Rainbow Wetlands	15.2	15%
Fitzsimmons Wetlands	1.4	1%
Chateau GC #18 Pond	0.7	1%
Wildlife Refuge	10.4	10%
Spruce Grove Wetland	0.3	0%
Lost Lake - Saw mill Wetland	1.6	2%
Buckhorn Pond	0.5	0%
River of Golden Dreams	47.9	47%
Fitzsimmons Creek Outflow Channel	0.9	1%
Wedge Pond	5.5	5%
Total beaver-affected wetlands	**100.7**	**100%**

Alpha Lake (flood effect of dam)	7.1
Total beaver effect	**107.8**

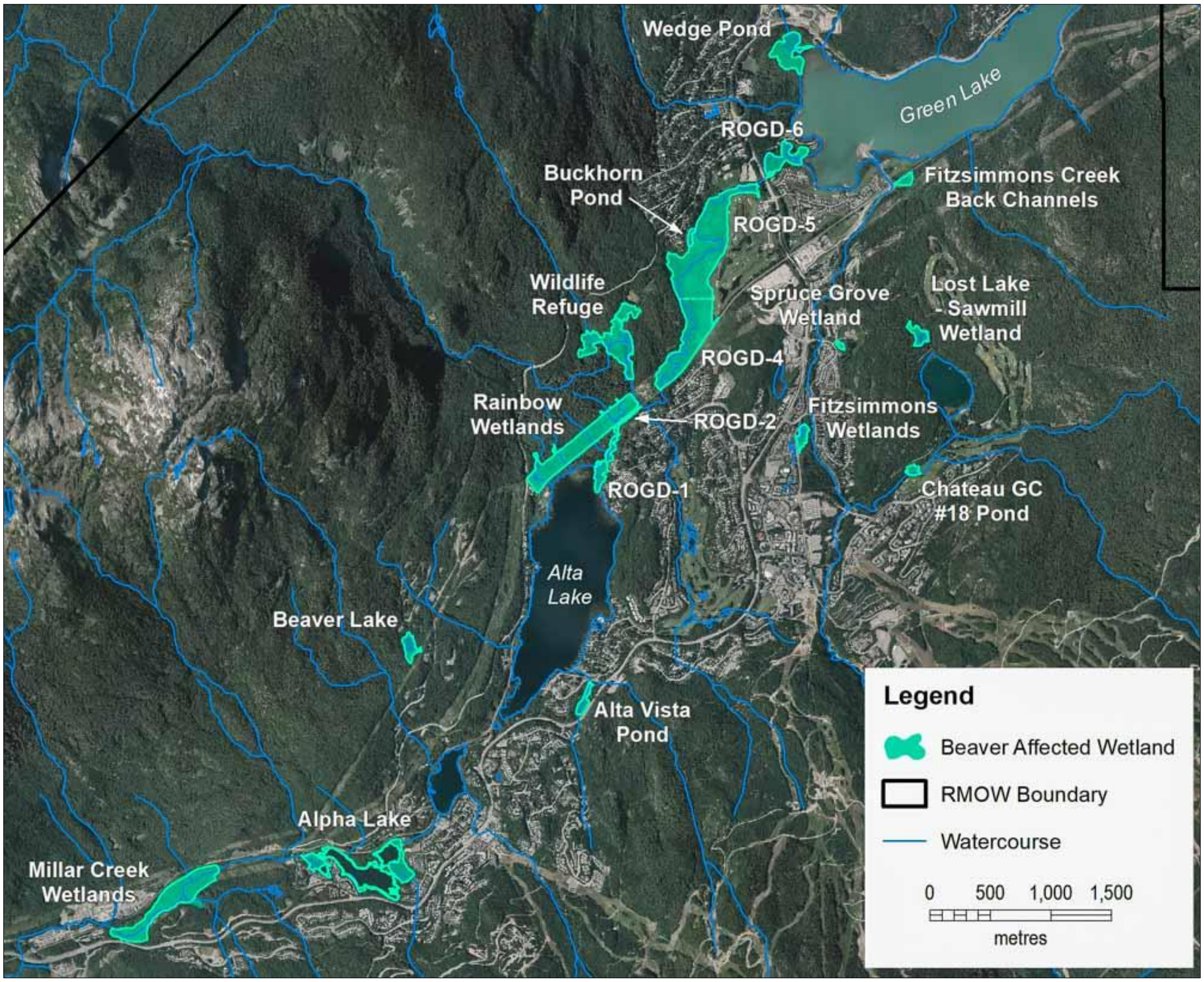

Figure 2-6: The area of beaver-affected wetland has not changed since 2021. [8]

2.5.3 Historic Context

Among other impacts, there were four main changes that that significantly impacted beavers since the railway was built in 1913:

1. The railbed raised water flows in some areas and lowered them elsewhere.
2. The railway facilitated the development of Whistler which brought more people.
3. Beavers were mostly extirpated from the valley within a few years after the railway opened, presumably due to trapping for pelts (Racey and McTaggart-Cowan 1935); and,
4. The expanded development that began with the opening of Whistler Mountain in 1966 and significant loss of beaver habitat since (e.g., McBlane 2007).

The railway bisected the large ROGD-Rainbow-Wildlife Refuge wetland complex which changed the hydrology and reduced the connectivity of that area. As Whistler's population started to grow in the 1960s and 1970s, wetlands were increasingly replaced by subdivisions, golf courses and other urban

[8] *Figure from Snowline (2021). Data from Bob Brett, mapped by Brodie Elder (Palmer Environmental Consulting Group.)*

developments. By 2003, at least 72% of the original area covered by wetlands was lost to development (McBlane 2007; Table 2-6; Figure 2-6). The loss of wetlands has definitely slowed since McBlane's (2007) calculations, though it is not possible with current data to provide exact figures. The RMOW's most recent mapping in 2014 showed that approximately 25% of the original wetland area remained below 800 metres and within the Development Footprint[9] (Table 2-5).

Table 2-6. Wetland area in the RMOW by year and scope.

Year	Wetland Scope	Area (ha)	Compared to 1946	Source
1946	All RMOW	604.4	100%	McBlane 2007
2003	All RMOW	169.9	28%	McBlane 2007
2014	All RMOW	193.4	32%	Palmer and Snowline (unpublished data)
2014	All RMOW <800 m	169.7	28%	Palmer and Snowline (unpublished data)
2014	<800 m, study area only	150.7	25%	Palmer and Snowline (unpublished data)
2018	Beaver-affected, study area only	94.7	16%	Palmer and Snowline 2019
Current	Beaver-affected, study area only	100.7	17%	Palmer and Snowline 2021

Notes: The current study area is equivalent to the RMOW Development Footprint, from Function Junction to the north end of Green Lake. McBlane (2007) compared air photos taken in 1946 and 2003 within a similar but not exact scope. The 2014 data is based on the RMOW's most recent mapping of wetlands.

Based on map these calculations, beavers have created and/or maintain approximately two-thirds of all wetlands (100.7 of 150.7 ha) in Whistler's Development Footprint: as of 2022.

[9] *Roughly from Function Junction north to Emerald Estates and mostly below 800 metres.*

3. Northern Goshawks

Key Takeaways

Stable with Caution (Limited Data)

1. Northern Goshawks are threatened forest predators that require old forest habitat for successful breeding. Although logging and other urban development have led to a significant decline in the goshawk population throughout BC, surveys over the past decade (including by this program) have shown Whistler to be an important breeding area for them. Their inclusion in this program is meant to (a) identify and protect breeding areas; and (b) provide an indicator of the availability of the low-elevation old forest habitat required by goshawks and many other unsurveyed species.
2. The 2022 surveys were the most extensive yet conducted for this program. The most important result was the discovery of two recent (though inactive) nests in old forests on Lower Blackcomb Mountain. This discovery brings the total number of breeding areas known in Whistler to four, and further confirms the long presence of breeding goshawks in a significant proportion of Whistler's remaining old forests.
3. Although no active breeding was detected in 2022, other evidence suggests breeding probably occurred but that cold weather through early July 2022: (a) prevented the detection of active nests; and/or, (b) caused goshawks to abandon their nest(s) due to incomplete egg development.
4. The number of breeding areas now documented provides encouraging evidence that: (a) goshawks continue to maintain a strong presence in Whistler; and therefore that, (b) enough low-elevation forest remains to prevent their extirpation from the area. As continued surveys contribute more data, it will be possible to make stronger statements about population trends of Northern Goshawks and their old growth habitat in the Whistler area.

3.1 Introduction

The population of BC's Northern Goshawks (*Accipiter gentilis*) has declined precipitously in recent years, mainly due to the loss of old forest habitat (BC MFLNRO 2018). The subspecies resident in Whistler, *A. gentilis laingi* (MFLNRO and Madrone 2014, 2015; CDC 2021) is particularly threatened, which is why it is Red-listed in BC (CDC 2022) and ranked as Threatened under the Canadian Species At Risk Act (Government of Canada 2022).[10] Surveys over the past decade have established that Whistler includes

[10] *See Brett (2020) for an update and discussion of the taxonomic and conservation status of Northern Goshawk.*

some of the most active breeding habitat for goshawks on BC's South Coast (MFLNRO and Madrone 2014, 2015; Brett 2020; Snowline 2021), presumably due to the availability of old forest habitat in this area.

No records have yet been found of goshawk nests in the Whistler area prior to a 2011 survey for the BC Government that reported an active nest uphill and west of the current Whistler RV Park.[11] Surveys in advance of construction of an Independent Power Project (IPP) on Wedge Creek found active nests near Comfortably Numb Trail in 2014 and 2015 (MFLNRO and Madrone). Another active nest was recorded in 2016 and 2017 in a patch of old forest above Millar's Pond by this program (Palmer and Snowline 2017, 2018). Evidence of an active nest next found near the Comfortably Numb Trail in 2019 by a separate project (Brett 2020). In 2021, successful breeding was found in two locations: near Comfortably Numb Trail and Lower Sproatt Mountain (Snowline 2021). These records confirm the continued presence of Northern Goshawks within the Whistler area.

The goal for the 2022 survey was to again search for active and inactive goshawk nests. Documenting active nests provides confirmation of continued breeding, while documenting inactive nests extends our knowledge of the Whistler habitats recently used by goshawks.

3.2 Methods

Call-playback is an established survey method that is meant to evoke a response from nearby birds. For surveys in the early nesting season, responses are elicited best with the playback of an adult alarm call. Goshawks nesting or planning to nest in that area will have a territorial response to that recording, and ideally be detected by sound and/or sight. Detections are meanwhile maximized in the later nesting season by broadcasting juvenile begging calls meant to elicit a response from hungry juveniles begging for food.[12]

Recordings by Erica McLaren (BC Government) of both adult alarm and juvenile begging calls, supplied by Brent Matsuda, were used for all call-playbacks. Formal surveys generally followed established protocols (e.g., MFLNRO and Madrone 2014, 2015; Erica McClaren, undated), though were spaced more closely than the recommended 400m between stations. The closer spacing was meant to take advantage of intensive surveys in a relatively well-studied area.

Calls separated by 30 seconds were repeated six times at each station, and faced downhill on the first calls then turning 90 degrees for each subsequent one. All nests and signs were recorded, including whitewash, plucking posts, and prey remains. Stand conditions and notes about any wildlife responses were also recorded. In addition, the following goshawk habitat conditions were subjectively rated: availability of nesting platforms, presence of flyways, access to the forest floor (for hunting), and overall habitat suitability.

The timing of surveys was based on results from Brett (2020) which suggested dates earlier in July might elicit stronger and more reliable responses. This intention was confounded by abnormally cold and wet weather, since birds are unlikely to as responsive in extreme weather conditions.[13]

[11] BC Conservation Data Centre (CDC) Species Occurrence Report Shape ID 106601. This area was recorded as Brew Creek.

[12] Trystan Willmott, personal communication to Bob Brett.

[13] In contrast, 2021 surveys were instead hampered by unusually hot weather in late June and early July.

The 2022 surveys included three areas with past goshawk detections: Millar's Pond, Danimal Middle (Lower Sproatt), and Comfortably Numb. Lower Blackcomb was added for the first time for two reasons: (a) the presence of low-elevation old forest; and (b) its placement midway between the known Millar's Pond and Comfortably Numb nest sites. The spacing of five to six kilometres from Lower Blackcomb to these two nests sites is also ideal since its within the territorial range documented elsewhere,[14] The Rainbow Loop site was chosen for the same reasons: it is approximately four kilometres north of the Danimal Middle site, and includes stands with appropriate structural characteristics (either unlogged or mildly highgraded old forests).

While Bob Brett was the sole surveyor in 2022, a number of local residents provided information that aided the project. Bruce Worden first reported suspected goshawk activity in the Danimal Middle area of Lower Sproatt Mountain in 2020, and videoed juveniles in 2021 nearby. He also found and reported an actual (inactive) nest in that area in May 2022. During that timespan, Liz Barrett has also reported sightings of goshawks flying in the Creekside area, which provided confirmation of birds that were likely resident (and possibly breeding) nearby. More recently, Millar's Pond resident Paul Girodo reported possible goshawk activity in the old forest uphill.

3.3 Results and Discussion

A total of 78 stations at seven sites were surveyed using call-playback in 2022 (Figure3-1; Appendices B and C). This is the most extensive search effort yet for this program, and the most since a similar but separate project (Brett 2020). In spite of this effort, there was there was no goshawk response to 2022 call-playback surveys (Appendix C), for three possible reasons:

1. Goshawk breeding only occurred in areas not included in the surveys.
2. No goshawks actually bred in Whistler in 2022 (that is, the surveys were accurate);
3. Weather-related problems with the timing of surveys precluded detections; and/or,
4. The cold, wet spring prevented successful egg development and any nests were abandoned.

The first two reasons are a potential result for any survey. That is, surveys can miss detections because of site selection, since animals move and all sites cannot be surveyed. And it is also possible there was no breeding, though that seems unlikely given all the activity and nests documented in recent years. The two breeding pairs active in 2021 would presumably have also bred in 2022, not to mention that some of the juveniles produced in past years would have also entered breeding age. In addition, new detections of inactive but sound nests in 2022 (Section 3.4) show that at least four areas have been used for breeding, likely within the last decade at most.

The second two reasons are related to weather. The best timing for surveys in Whistler is still not confirmed, and vastly varying conditions year-to-year complicate that determination (e.g., the heat dome in 2021 and the cold, wet start to the 2022 breeding season). For that reason, a broader range of survey dates will be employed in 2023. The fourth potential reason, nest abandonment, is certainly possible but impossible to confirm without direct evidence. Nest abandonment by Bald Eagles, presumably due to the cold spring, was observed in Vancouver,[15] and Whistler's goshawks could have responded similarly.

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[14] *In undisturbed forests in other parts of BC, goshawks maintain relatively predictable spacing of four to six kilometres between nests (Frank Doyle webinar prepared for BC Government staff, May 10, 2022).*

[15] *Reported by a Metro Vancouver Parks biologist to Thibault Doix.*

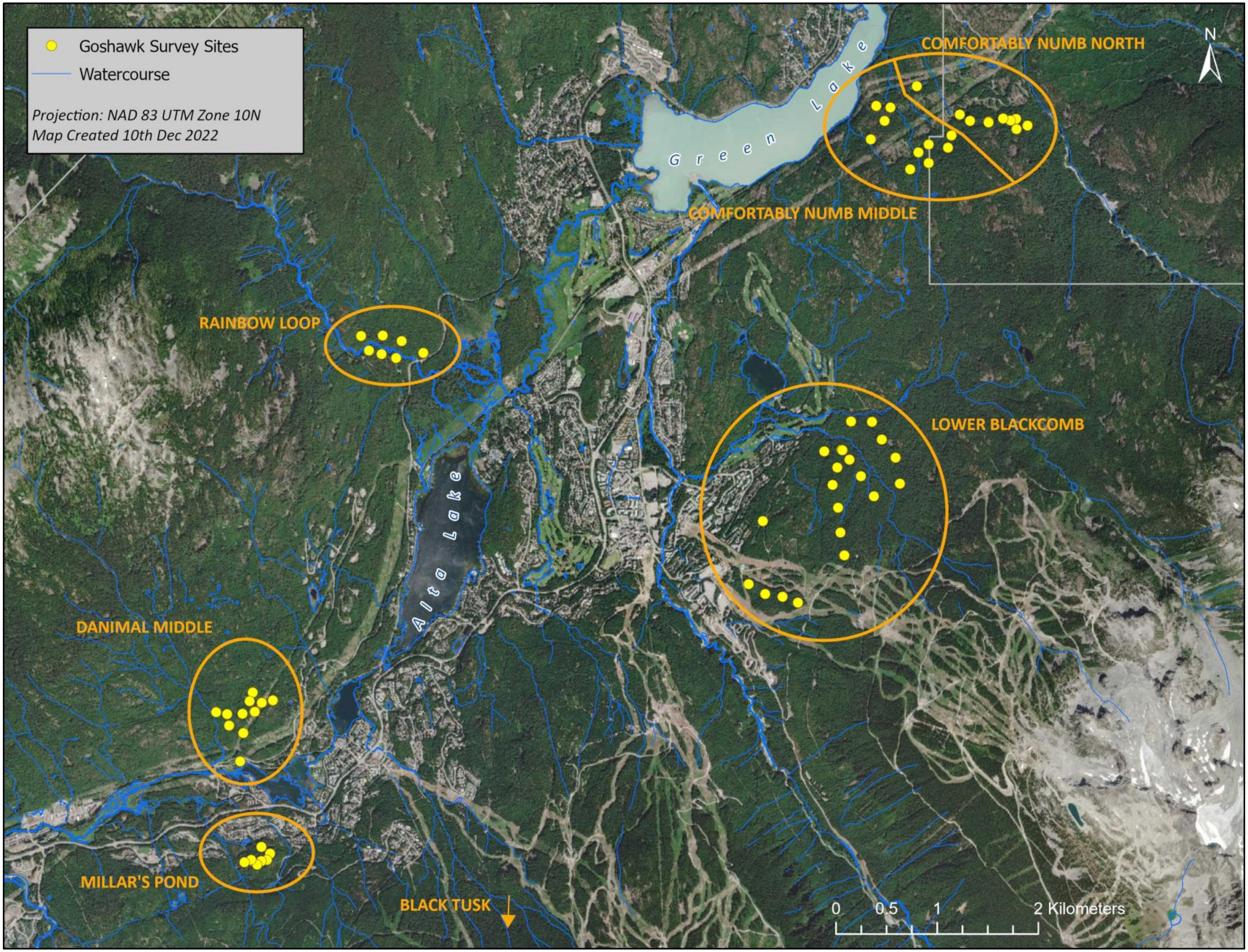

Figure 3-1. Northern Goshawk Survey Sites

3.4 Nest Detections and Bird Sightings

3.4.1 Goshawk Nests

Three new but inactive nests were detected in 2022. There are now seven goshawk nests in four distinct areas documented within Whistler Valley (Table 3-1). Although these nests were inactive in 2022, at least six are structurally sound and likely to have been used in the past five to ten years. The seventh, on the Blackcomb Ascent Trail, is less structurally sound, and was presumably used less recently. [16]

Table 3-1. Northern Goshawk nest sites documented to date. Note: although no nest was detected at the 2022 Comfortably Numb site, the presence of an adult bird with juvenile(s) calling nearby is confirmation of a nest close by.

Valley Side	Location	Feature	1st Detected	Last Active	Elev. (m)
West	Danimal Mid	Nest	2022	2021?	780
East	Millar's Pond	Nest	2016	2017	720
East	Lower Blackcomb - Ascent Trail	Likely Nest	2022	?	973
	Lower Blackcomb – Hey Bud	Nest	2022	?	865
East	Comfortably Numb	Nest	2014	2014	827
	Comfortably Numb	Nest	2015	2015	813
	Comfortably Numb	Adult/Juv. Sighting	2021	2021?	857

The detection of the Danimal Mid nest in 2022 makes it the first one so far located on the west side of the valley. The detection in two nests on Lower Blackcomb is noteworthy because the area is midway between the previously documented nests at Millar's Pond and Comfortably Numb.

The spacing of the three breeding areas on the east side of Whistler Valley (Comfortably Numb, Lower Blackcomb, and Millar's Pond; Figure 3-1) fits almost exactly with the expected spacing of four to six kilometres found in other, relatively undisturbed habitats.[17] This observation still needs to be tested since there are no doubt more undetected nests within the ca. 10 km that separates the Millar's Pond breeding area from the Comfortably Numb breeding area. If future nests are found within or near those areas, it will show that there is breeding frequent enough to maintain a territorial response and therefore that spacing.

In contrast to the regular four- to six-kilometre spacing that appears to occur on the east side of the valley, the Danimal Mid and Millar's Pond nests are separated cross-valley by only 1400 m, or about one-third of the minimum spacing expected. Further surveys will be required to investigate possible explanations, for example:

1. Breeding does not occur in both areas in the same year, hence there is no territorial response; and/or,
2. The breeding pairs are related (offspring or siblings) which reduces the territorial response.

The following sections describe nests and bird detections within the four documented breeding areas.

[16] *This nest is most probably an older goshawk nest given its size, placement on the tree, and lack of other local forest birds that build such large nests inside an old stand. It is, however, the only one that could have possibly been built by another species.*

[17] *Frank Doyle webinar prepared for BC Government staff, May 10, 2022.*

Comfortably Numb Trail Nest

A total of 21 stations were surveyed in 2022 near Comfortably Numb Trail (Figure 3-1; Appendix C), including stations near the two previously-documented nests (e.g., the 2014 nest in Photo 3-1), and one next to the adult/juvenile sighting from 2021 (Table 3-1; Photo 3-2). Based on presence confirmed in the area by 2019 and 2021 surveys, it is very possible or even probable this area included a breeding pair again in 2022. Surveys were nonetheless unable to detect any active nests or other sightings that confirmed breeding.

Photo 3-1. This nest was active in 2014 and is the oldest documented in the Comfortably Numb area.

Photo 3-2. This adult goshawk responded to a juvenile begging call beside the Comfortably Numb trail in 2021. One or possibly two juveniles were also calling nearby, which confirmed the presence of an (undetected) nest.

Danimal Mid

Local resident Bruce Worden first reported hearing goshawk calls on Lower Sproatt Mountain in 2020. A call-playback survey in 2021 elicited a response from an adult goshawk that flew high above the survey station, presumably to check the source of the call. But breeding in the area was only confirmed in September 2021 when Bruce recorded video footage of two juveniles just downhill of Danimal Mid bike trail.[18] In spring 2022, Bruce found an inactive nest nearby. Although it was not possible to confirm this was the nest used in 2021, a May 6th site visit revealed it is structurally sound and could have been used recently. The nest was on the west side of a Douglas-fir in an old forest on a southwest-facing slope, and approximately 14 m above the forest floor.

Trees in this area are relatively small (the nest tree was 40 cm diameter) which means nesting platforms are limited. That is the probable explanation for the placement of this nest that is situated on a branch from that tree, and supported by a hemlock snag that is resting on the tree (Photo 3-3).

Photo 3-3. The nest near the Danimal Mid bike trail was inactive in 2022. Two juveniles were sighted just downhill in September 2021 which indicates this or another nest nearby was active last year.

Two early season call-back surveys around this nest on May 20th and June 7th did not elicit any response and prolonged viewing of the nest also confirmed it was inactive in 2022. The main call-playback survey on July 14th included 11 stations in the same vicinity and also failed to detect any activity (Appendix C).

[18] The two birds likely fledged nearby since juveniles typically remain close to their natal nest for weeks or months after fledging (Wiens et al. 2006; COSEWIC 2013).

Lower Blackcomb

A total of 21 stations were surveyed for the first time on Lower Blackcomb Mountain (Figure 3-1; Appendix C). This area includes old forest habitat conditions very similar to the breeding areas found near Comfortably Numb Trail (Photo 3-4). Similar to Comfortably Numb, the old forest is situated above lower-elevation elevation clearcuts but is mostly continuous at slightly higher elevations from the ski area north to Wedge Creek. The forest on the Lower Ascent Trail differs from the forest farther north and is mostly second-growth interspersed with patches of unlogged forest. This area was included due to past goshawk sightings nearby (Snowline 2021). Lower Blackcomb was also chosen for surveys since it is midway between the two known breeding areas at Millar's Pond and Comfortably Numb, and meets territorial requirements of goshawks (see p. 43).

The Hey Bud nest found during call-playback surveys in 2022 is in ideal forest habitat (Photo 3-4). The nest is very large (Photo 3-5) and appears to be structurally sound. Although no activity was detected either by the call-playback survey or prolonged viewing of the nest itself, it is a priority for re-survey in 2023.

Photo 3-4. 2022 NOGO Lower Blackcomb Hey Bud near LB-09 inactive nest

Photo 3-5. 2022 NOGO Lower Blackcomb Hey Bud near LB-09 inactive nest

Lower Blackcomb, Ascent Trail

A second nest on Lower Blackcomb was first discovered during a reconnaissance visit on June 10th, 2022. The nest is in worse condition and possibly smaller than the other six so far documented (Photo 3-6; Table 3-1). It is approximately 12 m above the forest floor, on the south (uphill) side of a 35 cm western hemlock, and within a small, remnant patch of old forest. Based on the size of the nest and the unusually small patch of old forest, it is the only one of the seven nests that could be anything other than a goshawk nest. However, its placement on the tree branch and general appearance are still consistent with goshawk nesting.

Photo 3-6. This nest beside the Blackcomb Ascent Trail is in disrepair.

Millar's Pond

Although the Millar's Pond nest has not been active since 2017, it is still structurally sound (Photo 3-7). It is the nest most frequently checked for activity in the past five years. Five surveys were again conducted in that area in 2022: on May 20, June 1, July 13, August 15, and August 16 (Appendix C). The reason for the August surveys was that local resident Paul Girodo reported that a goshawk had dive-bombed his daughter in the forest on August 14th. This record confirms the presence of at least one goshawk in the area and, based on Paul's description of its colouration, was likely a juvenile which would confirm breeding in the area in 2022. In spite of all repeated surveys in 2022, no other evidence of goshawk activity was detected.

Photo 3-7. This goshawk nest near Millar's Pond has been inactive since 2017.

4. Coastal Tailed Frogs – Tadpole Surveys

Key Takeaways

Stable: Whistler, Sproatt, and Van West Creeks	Stable with Caution: Archibald Creek

1. Coastal Tailed Frogs are commonly used in monitoring programs since they require clean, cold streams and are sensitive to disturbances caused by logging and in-stream alterations. The 2022 survey was the 10th year of monitoring in a varying selection of 11 creeks. As in past years, results show no cause for concern in the creeks sampled in 2022, other than a slight downward trend in Archibald Creek. Tadpole detections in Archibald Creek did not decline enough to conclude there was an ongoing deterioration of this habitat caused by operations in the neighbouring Whistler Bike Park or by other factors. Concerns about this creek will be alleviated if 2023 surveys see a return to past detection levels.
2. While scouring caused by recent floods (especially in 2017) is still obvious, especially on west-side creeks, it does not seem to have affected tailed frog detections. In contrast, the impacts of logging debris at mid-elevation creeks on the west side of Whistler Valley persist and, especially on Van West Creek, are the probable cause of low detections each year.
3. For the third consecutive year, tadpoles have been detected at higher elevations than previously known. Before 2020, the highest site this program detected tadpoles was at 1180 m. BioBlitz events at Brandywine Meadows in 2020 and 2021 found tadpoles at 1435 m and 1440 m, respectively. In 2022, a lichen researcher found a large tadpole population at 1485 m near Brew Creek, just south of the RMOW. These recent findings mean potential habitat for tailed frogs in the Whistler area is larger and higher than previously known.

Note: *No tadpoles were detected in 2022 at the three Blackcomb Creek site or the two Nineteen-Mile Creek sites. Discussion of follow-up environmental DNA (eDNA) sampling in those creeks is included in Section 5.*

4.1 Introduction

Amphibians have long been used as indicators of ecosystem health. They have physiological constraints and sensitivities due to subcutaneous respiration, specialized adaptations and microhabitat requirements, as well as a dual life cycle that includes aquatic and terrestrial habitats. These characteristics make them susceptible to perturbations in both habitat types and suitable as indicator species of ecosystem health.

Stream-dwelling amphibians such as Coastal Tailed Frog (*Ascaphus truei*) serve a vital role as indicators of stream health as they require flowing, clear, cold water throughout their lifecycle (Matsuda et al. 2006) and are vulnerable to habitat alteration and degradation such as siltation and algal growth. They are also highly philopatric,[19] long-lived, and maintain relatively stable populations. For these reasons, tailed frogs can be a useful indicator of stream condition (Welsh and Ollivier 1998).
Ideal habitats for tailed frogs are small, steep (usually >10% grade), mountainside streams that are cool (typically 10 to 15ºC in late summer, but at least 5º C for egg development), have a cobble-boulder substrate with rounded to subangular-shaped rocks, and a cascade or step pool morphology (Matsuda et al. 2006; BC MOE 2015). These characteristics describe many of the streams that drain into the Whistler Valley so it is unsurprising tadpoles have been detected in most Whistler streams surveyed to date (Wind 2005-2009; Cascade 2014-2016; Palmer and Snowline 2017-2021; Snowline 2021).

Prior to 2004, the only documentation of Coastal Tailed Frogs near the RMOW was in Brandywine Creek (Leigh-Spencer 2004), presumably from surveys before the construction of the Independent Power Project built on that creek. In late 2004, the Whistler Biodiversity Project began the first valley-wide survey Since then, tadpoles have been found in over 40 local creeks (Wind 2005-2009; Brett 2007; Cascade 2013-2015; Palmer and Snowline 2017-2021; Snowline 2021).

In 2017, Coastal Tailed Frogs were down-listed in BC from Blue (Special Concern) to Yellow ("least risk of being lost"), but still has some protection through its classification as Identified Wildlife under the Provincial Forest and Range Practices Act (CDC 2022). It remains a species of Special Concern under the Species at Risk Act (Government of Canada 2022) and was identified as a species of local concern (Brett 2018).

4.2 Methods

4.2.1 Site Selection

The selection of tailed frog survey sites has been modified each year to maximize the ability to detect changes in stream habitats: (a) between years, and (b) between east and west sides of the valley. Since 2013, a total of 11 creeks have been surveyed for this program, most in more than three of the survey years (Table 4-1). More sites have been surveyed on the east than west side of the valley for two main reasons: (a) the creeks on the east side of the valley tend to be easier to survey due to higher and more predictable flows; and, (b) they are generally in areas with more development and therefore more potential impacts to monitor.

Since 2016, the three reaches surveyed on each creek are chosen to represent (as much as topography and surveyability allows), three elevations:

1. The toe slope just above the valley bottom;
2. Mid-elevations at ca. 800 m; and
3. At approximately 1000m.

This elevational range is meant to include one site within the development footprint, one at its upper end, and a third above the development footprint (as a control), respectively.

The 2022 tadpole surveys were again led by Bob Brett with helpful assistance from Hillary Williamson and Rebecca Merenyi (RMOW), and conducted under BC Government Wildlife Permit SU22-722725.

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19 Adults typically breed in the stream in which they hatched.

Table 4-1. Coastal Tailed Frog sampling sites, 2013 to 2022 (Cascade 2016 to 2020; Palmer and Snowline 2017 to 2021; Snowline 2021; Snowline 2021).

Creek	Valley Side	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Total Sites	Survey Years
Alpha Creek	East	3	3	3	3							12	4
Archibald Creek	East		3	3	3	3	3	3	3	3	3	27	9
Blackcomb Creek	East							1	3	2	2	8	4
Horstman Creek	East					3						3	1
Whistler Creek	East				4	3	3	3	3	3	3	22	7
Agnew Creek	West					3	3					6	2
FJ West Creek	West						2	3	2			7	3
Nineteen Mile Cr.	West		2	2							3	7	3
Scotia Creek	West	3	3	3	3		1					13	5
Sproatt Creek	West						1	3	3	3	3	13	5
Van West Creek	West						2	2	3	3	2	12	5
Total East		**3**	**6**	**6**	**10**	**9**	**6**	**7**	**9**	**8**	**8**	**72**	**10**
Total East		**3**	**5**	**5**	**3**	**3**	**9**	**8**	**8**	**6**	**8**	**58**	**10**
Grand Total		**6**	**11**	**11**	**13**	**12**	**15**	**15**	**17**	**14**	**16**	**130**	**10**

The inclusion of a similar number of east- and west-side creeks increases the geographic range of sampling. At least as importantly, the inclusion of sites on both sides of the valley means creeks with different hydrological regimes are represented since most east-side creeks are glacier-fed while most west-side creeks are not. Creeks with a glacial source typically have higher and more sustained flows than those relying solely on snowmelt and rainwater. They are also more sensitive to climate change since glacier melt reduces the volume and timing of water flows.

As of 2021, no tadpoles had been detected in three creeks surveyed in this program: Agnew and Nineteen Mile Creeks (on the west side of the valley), and Blackcomb Creek (on the east side). Topography has limited the ability to survey at higher elevations on the first two creeks. As a result, they may support a tailed frog population that has not yet been detected. While also challenging to survey due to steep chasms, the absence of detections on Blackcomb Creek may be related more to low temperatures resulting from its reliance on meltwater from the Blackcomb Glacier.

Survey sites for 2022 were chosen partly for continuity with past years, and partly to try again to detect tadpoles in Nineteen-Mile Creek and Blackcomb Creek (Table 4-1; Figure 4-1). Of these latter two creeks, Blackcomb has been the subject of speculation since extremely cold water (4° to 6° C) was detected in Whistler Biodiversity Project surveys in 2006 (Brett 2007). Reports for this program (e.g., Snowline 2021) have suggested that eDNA sampling on this creek could test the hypothesis of whether cold water has prevented the colonization by tailed frogs, or whether the sampling method was not sensitive enough to detect tadpoles.

In July, eDNA expert Jared Hobbs said he could possibly visit Whistler in mid-September 2022 to take eDNA samples on Blackcomb and possibly Nineteen-Mile Creek, after the tadpole surveys which would provide an excellent opportunity to compare tadpole detections and eDNA results within a short time span. Jared was fortunately able to visit Whistler to sample eDNA from both creeks and results are included below (Section 5).

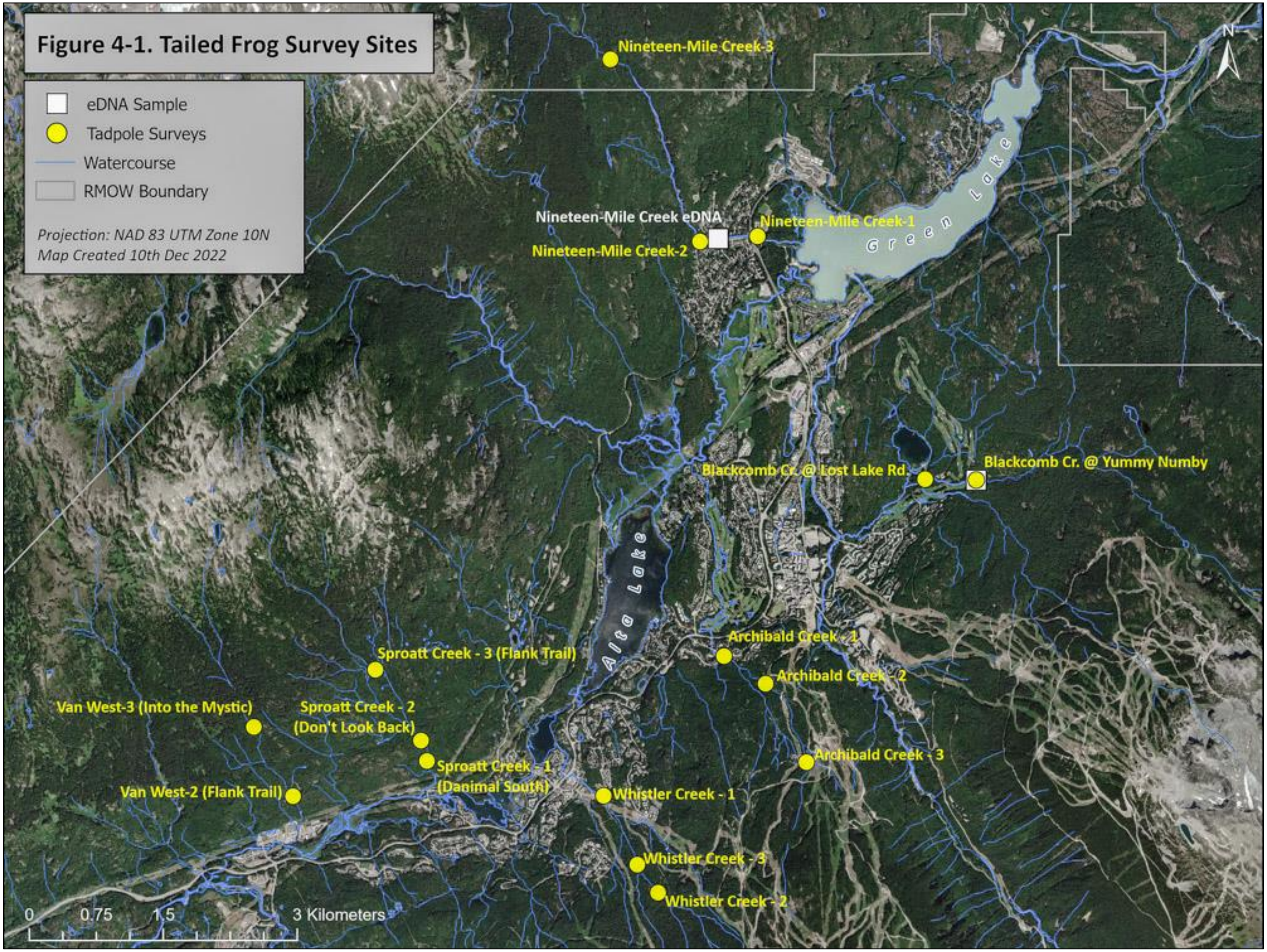

Figure 4-1.Tailed Frog Survey Sites.

4.2.2 Sampling Design

Almost all previous surveys for tailed frog tadpoles in the RMOW study area by the Whistler Biodiversity Project (Wind 2005-2009; Brett 2007) and this program (Palmer and Snowline 2017-2021; Snowline 2021) have used the same time-constrained method. The only exception occurred in surveys from 2013 to 2015 which used area-constrained surveys (Cascade 2014-2016).

The BC Resource Inventory Committee (BC MELP 2000) originally recommended that area-constrained approach for measuring relative abundance. Based on this guidance, the 2013 to 2015 surveys sampled in fixed 5 m stream lengths for a total of 30 minutes (Cascade 2014-2016). Far fewer tadpoles were detected using this method compared to previous WBP surveys (Wind 2005-2009).[20] The return of surveys since 2016 to a time-constrained approach greatly increased detections (Palmer and Snowline 2017-2021) and therefore statistical power (Malt et al. 2014a, 2014b).

In spite of the change back from area- to time-constrained surveys, it has still been possible to make comparisons between these years since both methods sampled for the same amount of time (30 minutes). It is also noteworthy that the total area surveyed at each site since 2016 using the time-constrained approach remained remarkably similar to that surveyed using the area-constrained approach (Palmer and Snowline 2017 to 2021; Snowline 2021).

Data collection methods were otherwise the same for all tailed frog surveys since 2004 and followed recommendations of the BC Resource Inventory Committee (BC MELP 2000). The in-stream surveys consisted of overturning rocks and other unembedded cover objects with dipnets held immediately downstream to catch any dislodged animals (Photos 4-1 and 4-2). Rocks were also swept by hand to detect any clinging tailed frog tadpoles before being set back in their original positions, as were large anchored rocks and large woody debris. Data collected at each site included:

- Site characteristics including location, weather, overhead cover and stand type;
- Stream characteristics including morphology, substrate size/ shape, slope, and wetted width;
- Overhead canopy cover, forest type (coniferous, deciduous, or mixed) and forest successional stage;
- Water and air temperature (measured at the sampling site); and
- Total survey area (measured with a cloth tape to the nearest 0.1 m).

Data collected for tadpole captures also followed standard methods, including a measurement of total length for tadpoles and snout to ventral length for later stages. From 2013 to 2015[21] and again in 2016, tadpoles were classed into cohorts defined by Malt et al (2014a, b) which served as proxies for age classes (e.g., first year - T1; second year - T2, etc.) as follows:

- T0 (hatchling <15 mm);[22]
- T1 (tadpole, no visible hind legs);
- T2 (tadpole, hind legs with knees not extending beyond the anal fold (Photo 4-3);
- T3 (tadpole, conspicuous hind legs with knees that extend out from body (Photo 4-4); and
- Non-tadpole – metamorph (tail plus front legs), juvenile (no tail, small, no nuptial pads); and adult (larger than juvenile, male has tail and nuptial pads, females larger than males).

[20] Bruce Bury (in a 2016 email to Brent Matsuda and Bob Brett) recommends that detections should be >2 tadpoles/m² to ensure statistical power. Virtually all sites sampled to date in Whistler have revealed densities far lower.

[21] Candace Rose-Taylor, 2016 email to Bob Brett.

[22] No hatchlings have been reported to date in Whistler surveys conducted in late August and September.

Photo 4-1. Hillary Williamson from the RMOW Environmental Stewardship Department dipnetting for tadpoles in Whistler Creek (2019 photo).

Photo 4-2. Captured tadpoles are transferred to a bucket until they are measured, classified to cohort and development stage, then released upstream.

Doubts about this classification scheme emerged in 2016 regarding how accurately these classes acted as reliable proxies for age cohorts, especially across different streams. The relationship between length and cohorts (as defined above) was weaker than expected, for example, many longer tadpoles were placed into early cohorts based on morphology, and vice-versa, Pre-survey tests in 2017 again showed overlaps between length and developmental stages within and between streams. These observations intensified questions about whether "cohorts" were reliable proxies for the number of years since hatching, especially between streams that have different growing conditions. This doubt was later strengthened by Pierre Friele[23] who emphasized that the link between developmental stage, length and age is even more tenuous when applied across large geographic gradients in which climate and water temperature regimes differ. As a result, surveys since 2017 measured the length of each tadpole and classified them by more detailed developmental stages as follows:

Table 4-2. Tadpole Developmental Stages and Classifications

Developmental Stage	Cohort (Malt 2014a,b)
DS0 – Hatchling <15 mm	T0
DS1 - No visible hind legs	T1
DS2 - Bulge only, hind legs not defined	
DS3 - Hind legs visible but covered	T2
DS4 - Hind feet protruding	
DS5 -Hind knees protruding outside body	T3

Note: No hatchlings (DS0, T0) have been observed in September surveys in Whistler.

[23] Pierre Friele email to B. Brett and follow-up phone conversation, December 2017.

Photo 4-3. Tadpole Cohort 2 (T2). This individual's developmental stage is transitional between developmental stages DS1 and DS2 2 and 3 (hind legs covered but just starting to be defined).

Photo 4-4. This tadpole's hind knees protrude outside its body and its legs are clearly free from previously enclosing skin. It is in Cohort T3 and its equivalent developmental stage DS5.

For consistency with past reports, the classes above were grouped according to Malt et al.'s (2014a, b) cohorts during data analysis. That is, Developmental Stages 1 and 2 (DS1 and DS2) were grouped into Malt's T1 cohort, and Developmental Stages 3 and 4 (DS3 and DS4) were grouped into Malts' T2 cohort. Future analyses may be able to use these detailed classifications to calibrate a reliable relationship between age and developmental stage in Whistler-area creeks. For the purposes of this report, most of the analysis and discussion is based on Malt et al.'s cohorts.

To prevent recaptures, all tadpoles were placed in buckets and released after measurements were complete (Photo 4-2; BC MELP 2000). Non-tadpoles, or post metamorphosis individuals, were classed as metamorphs (non-resorbed tail), juveniles (no tail, smaller than adults, no nuptial pads on males) or adults (larger than juveniles, males have a cloacal "tail," nuptial pads, and are smaller than females; Corkran and Thoms 1996; Jones et al. 2005). Surveys were scheduled for early September when low streamflows would increase the detectability of tadpoles.

4.2.3 Data Analysis

The total number of tadpoles per site (reach) detected in 2022 was compared to surveys since 2015 (the last year of the time-constrained approach). Results were also reported as detections per unit area (per 100 m^2) to permit comparisons between the 2015 area-constrained method and the time-constrained method used for past surveys.

4.2.4 Quality Assurance/Quality Control

Although the ideal way to ensure consistency between sites and years would be to use the same surveyor(s), that is seldom achievable due to changes in available personnel. To maximize consistency, surveys since 2017 have included at least two surveyors from the previous year. A trial survey was conducted beforehand to ensure consistency between surveyors. Special care was taken to ensure that cohort classes and developmental stages (see above) were recorded consistently. Photos of representative tadpoles in each class were used as guides to improve consistency between surveyors (e.g., Photos 4-3 and 4-4).

4.3 Results and Discussion

4.3.1 Study Sites

Sixteen sites were surveyed from September 6 to 9, 2022 (Table 4-3; Appendix A). As in past years, water was slightly colder (by 0.9° C) at east-side sites, a result that is consistent with less direct sun and a greater influence of glacial water on that side of the valley.

Table 4-3. Coastal Tailed Frog sampling sites, 2022.

Valley Side	Site	Date	Surveyors	Easting	Northing	Elev. (m)	Wea-ther	Water Temp. (°C)	Air Temp. (°C)	pH
East	Archibald Creek-1	2022-09-07	BB, RM	502387	5550606	695	Sun	10.4	16.0	7.0
	Archibald Creek-2	2022-09-07	BB, RM	502854	5550298	835	Sun	9.2	13.4	6.9
	Archibald Creek-3	2022-09-07	BB, RM	503310	5549422	1026	Sun	8.2	12.8	6.8
	Blackcomb Cr. @ Lost Lake Rd.	2022-09-06	BB, HW, RM	504641	5552586	692	Sun	8.0	19.0	6.8
	Blackcomb Cr. @ Yummy Numby	2022-09-06	BB, HW, RM	505211	5552576	762	Sun	6.8	11.0	6.8
	Nineteen-Mile Creek-1	2022-09-07	BB, RM	502764	5555303	648	Sun	9.7	11.0	7.0
	Nineteen-Mile Creek-2	2022-09-07	BB, RM	502121	5555246	692	Sun	9.5	12.3	7.0
	Nineteen-Mile Creek-3	2022-09-09	BB	501114	5557282	1095	Sun	8.0	14.0	7.0
West	Sproatt Creek-1 (Danimal South)	2022-09-08	BB, RM	499063	5549434	692	Sun	11.0	17.0	6.5
	Sproatt Creek-2 (Don't Look Back)	2022-09-08	BB, RM	498996	5549662	790	Sun	11.0	15.0	6.5
	Sproatt Creek-3 (Flank Trail)	2022-09-08	BB, RM	498483	5550455	996	Sun	10.0	12.0	6.2
	Van West-2 (Flank Trail)	2022-09-08	BB, RM	497563	5549038	706	Sun	10.0	12.0	6.5
	Van West-3 (Into the Mystic)	2022-09-08	BB, RM	497125	5549816	1036	Sun	9.5	14.0	6.8
	Whistler Creek-1	2022-09-06	BB, HW, RM	501041	5549045	692	Sun	10.0	20.0	7.5
	Whistler Creek-2	2022-09-06	BB, HW, RM	501649	5547961	879	Sun	8.0	10.0	6.8
	Whistler Creek-3	2022-09-06	BB, HW, RM	501417	5548276	972	Sun	7.0	8.0	6.8
							East-side Average	8.7	13.7	6.9
							West-side Average	9.6	13.5	6.7
							Average (All Sites)	**9.1**	**13.6**	**6.8**

4.3.2 Tadpole Detections

A total of 52 tadpoles were detected in 2022, but no juveniles (metamorphs) or adults (Table 4-4; Appendix B). Although it may be reassuring that this total is similar to previous years (Figure 4-2), the aggregated data is not directly comparable since it comes from a different assemblage of creeks each year. Direct comparisons are therefore discussed by individual creeks below (Section 4.3.5), and it should be noted that averages were depressed by non-detections at five sites on Blackcomb and Nineteen-Mile Creeks.

Metrics from tailed frog sampling since 2015 have remained mostly the same (Figure 4-2), with two main exceptions. Firstly, the total number of tadpoles and density (in tadpoles/100m^2) both increased markedly in 2016, when surveys returned to a time-constrained approach instead of a area-constrained approach. Secondly, the average survey area in 2021 was much smaller than in other years, presumably because of a different way of defining it rather than actually surveying that much less area. As a result, the density of tadpoles in 2021 was reported to be much higher than in other years. Average survey area in 2022 returned to the range seen in years other than 2021, and are therefore more representative.

Another notable difference between years is the average temperature of the creeks. While east-side creeks have consistently been colder than west-side creeks (Table 4-3), the average has ranged from 8.1 to 10.8° C. Part of this variation may be due to the previous use of a handheld electronic instrument that, in retrospect, was not always accurate (all readings now use an analogue thermometer). But there is definitely a strong effect of recent weather changes when, for example, measurements on subsequent days have shown markedly cooler stream temperatures even after only one day of colder weather.

Table 4-4. Tadpoles detected in 2022 by creek and cohort.

Valley Side	Site	Cohort T1	Cohort T2	Cohort T3	Total tadpoles	Meta-morphs /adults
East	Archibald Creek - 1	2	1	1	4	0
East	Archibald Creek - 2	1	0	2	3	0
East	Archibald Creek - 3	5	0	1	6	0
East	Blackcomb Cr. @ Lost Lake Rd.	0	0	0	0	0
East	Blackcomb Cr. @ Yummy Numby	0	0	0	0	0
East	Nineteen-Mile Creek-1	0	0	0	0	0
East	Nineteen-Mile Creek-2	0	0	0	0	0
East	Nineteen-Mile Creek-3	0	0	0	0	0
West	Sproatt Creek - 1 (Danimal South)	0	1	0	1	0
West	Sproatt Creek - 2 (Don't Look Back)	0	1	0	1	0
West	Sproatt Creek - 3 (Flank Trail)	1	6	1	8	0
West	Van West-2 (Flank Trail)	1	0	0	1	0
West	Van West-3 (Into the Mystic)	0	3	3	6	0
East	Whistler Creek - 1	0	5	1	6	0
East	Whistler Creek - 2	7	1	0	8	0
East	Whistler Creek - 3	5	3	0	8	0
	Total tadpoles	22	21	9	52	0
		42%	40%	17%	100%	

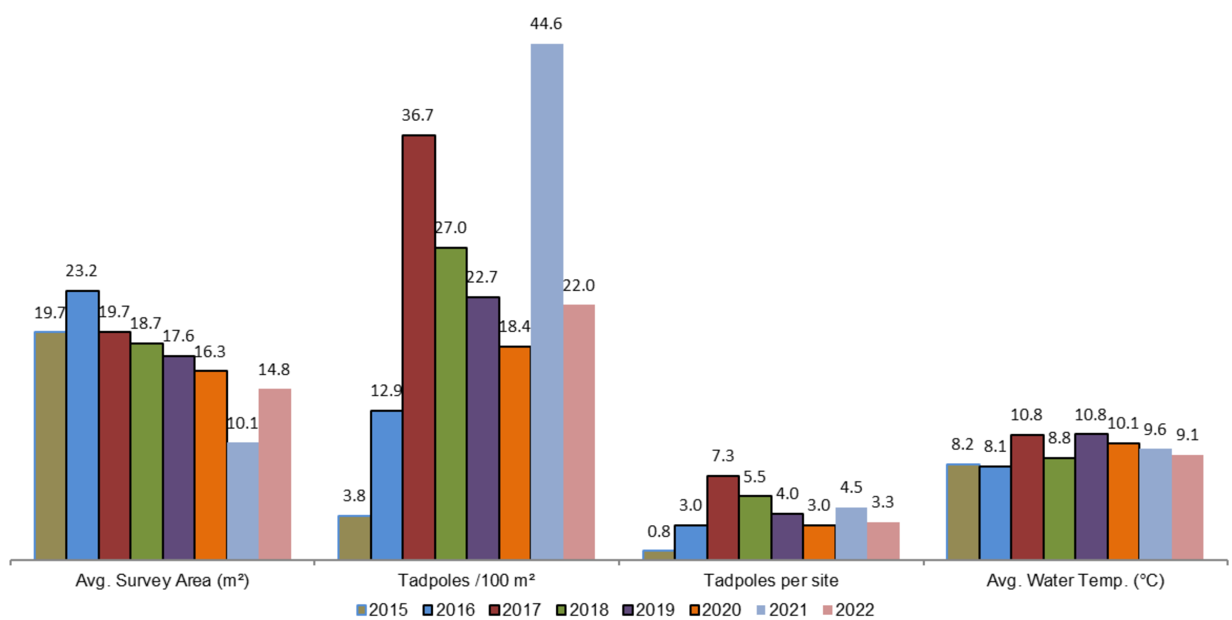

Figure 4-2. Average area, tadpoles per 100 m2, tadpoles per site, and average water temperature of Coastal Tailed Frog Surveys, 2015 to 2022.

4.3.3 Detections by Valley Side (East and West)

Since 2016, more than twice as many tadpoles have been detected per site on the east-side than on the west-side of Whistler Valley (Table 4-5). As discussed above (Section 4.2.1), glacier-fed creeks are predominantly on the east side of Whistler Valley where glacial run-off increases overall volume and provides more mid-summer flow than in creeks reliant solely on rainwater. Creeks on the east side of the valley are therefore more likely to be larger and, as found in these surveys, apparently have better habitat characteristics such as more cobbles, less embeddedness, and more riffles. These are preliminary conclusions that need to be further tested, especially since the predominance of detections from two creeks (Whistler and Archibald; Section 4.3.5) affect the totals so much.

Table 4-5. Tadpoles detected in east-side versus west-side creeks, 2016 to 2021.

Valley Side	No. Sites	Eleva-tion (m)	Survey Area (m2)	Tad-poles /Site	Tad-poles /100m2	Water Temp. (°C)
East	57	847	18.1	6.0	35.2	9.3
West	45	811	16.6	2.7	21.0	10.2
East to West Ratio	1.3	1.04	1.1	2.2	1.7	(0.9)

4.3.4 Detections by Cohort

Survivorship curves for all animal populations lead to the expectation that there will be fewer individuals at later ages/stages, and this has generally been the case for tailed frog surveys (Figures 4-3 and 4-4). Although any interpretations of these results must be tempered by the fact that detectability is not constant (that is, that weather and other contingencies are involved), it is reassuring that: (a) younger stage tadpoles continue to enter the population; and (b) latest-stage tadpoles in Cohort T3 consistently represent a significant minority of all detections. A strong proportion of T3 tadpoles ensures a higher likelihood of new individuals surviving until metamorphosis and breeding age.

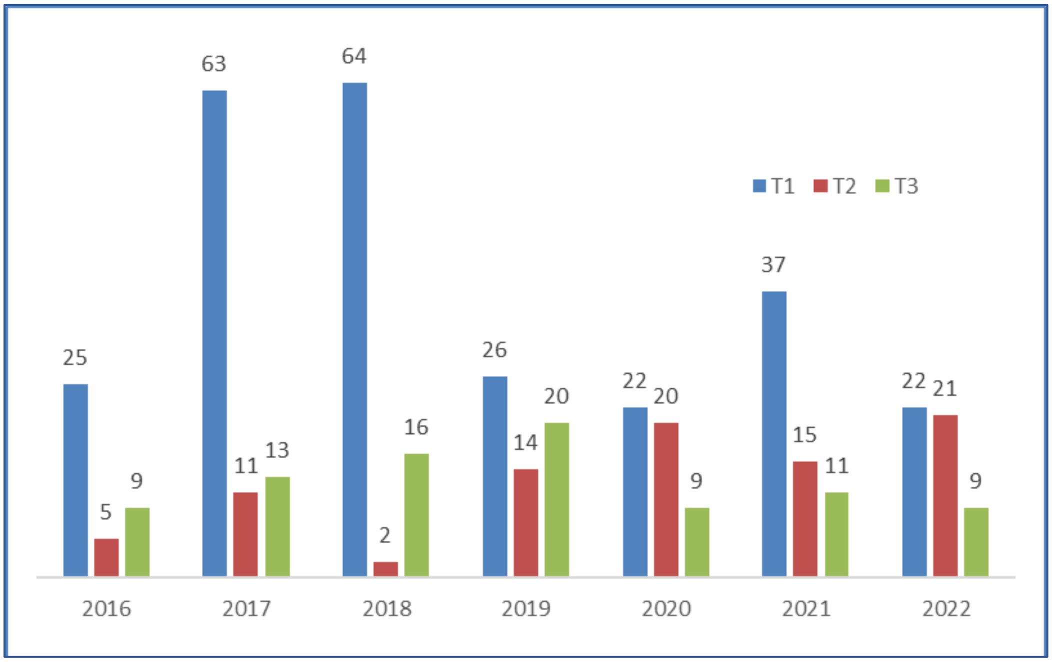

Figure 4-3. Number of tadpoles by cohort and year.

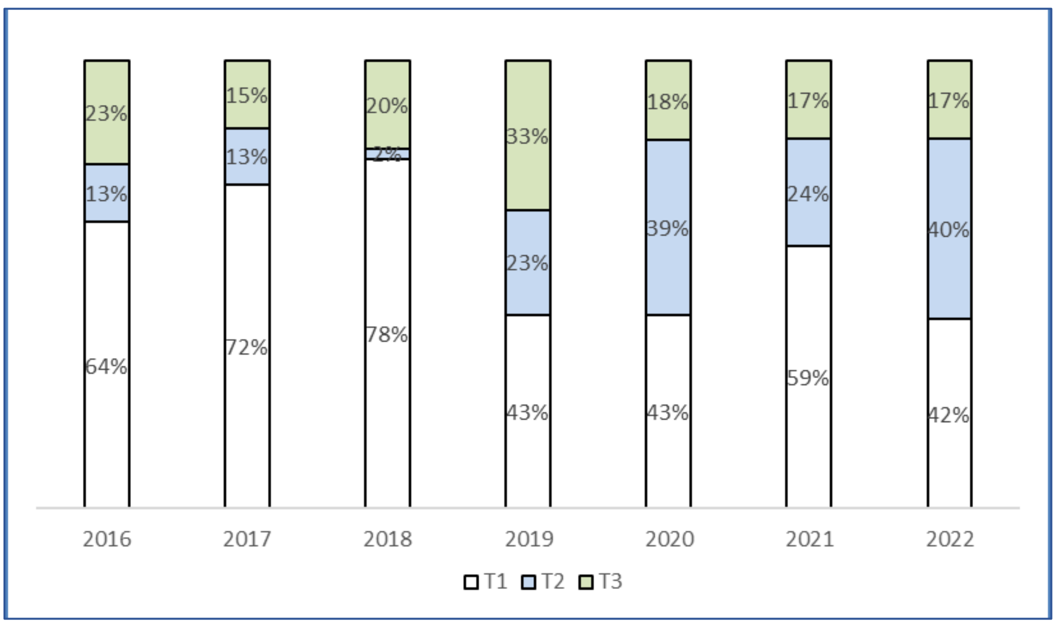

Figure 4-4. Percentage of tadpoles by cohort and year.

4.3.5 Tadpole Detections by Creek

Archibald Creek

Stable with Caution

Archibald Creek is one of only two systems surveyed in all six years since 2016 (Whistler Creek is the other). Three observations emerge from the seven years of data from this creek (Figure 4-5):

1. Detections were abnormally low in 2016 and 2020.
2. Tadpole detections have been most variable at Site 1 (located in Brio at 695 m) – they were highest from 2017 to 2019 and have been much lower since.
3. Tadpole detections at the other two sites have rebounded since the 2020 low.

The 2016 report (Palmer and Snowline 2017) suggested that the reason for low detections that year was recent sedimentation of fines following the end of a long drought (Photo 4-5). When numbers rebounded in 2017, it provided evidence that the population probably hadn't decreased in 2016 after all, but rather that sedimentation reduced detectability (that is, undetected tadpoles were present in 2016 after all).

Site 1 was already well-known before this program due to the Whistler Biodiversity Project (WBP) and Whistler BioBlitz. This site is an outlier in the Whistler area since tadpoles can be seen in the open, attached to smooth bedrock with a thin layer of water overtop. First detected by the WBP (Brett 2007), this site was commonly used to introduce people to tailed frogs during the annual Whistler BioBlitz. In recent years, tadpoles have been less common on the bedrock, maybe because streamside shrubs have increasingly shaded the site and reduced the attractiveness of the exposed bedrock for feeding.

Trend:
Lower detections in the past three years may accurately reflect a lower population in the creek, especially at Site 1, or may be an artefact of changing habitat conditions and detectability at that site. Due to this uncertainty, the trend is "Stable with Caution."

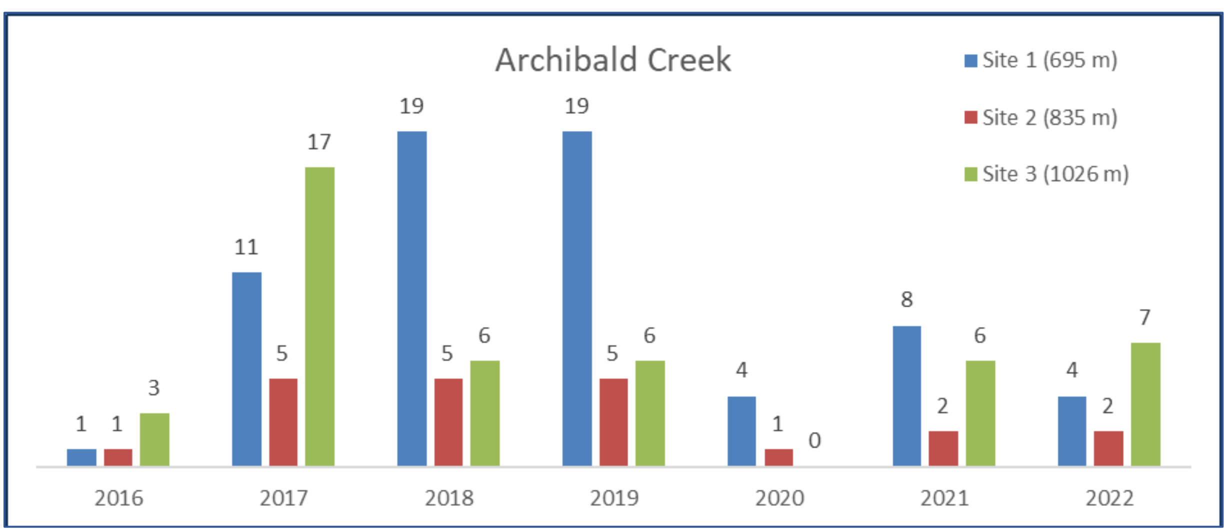

Figure 4-5. Tadpole detections in Archibald Creek by site, 2016-2022.

Photo 4-5. Sedimentation in 2016 at Archibald Creek-1.

Whistler Creek

Stable

Since being added to the program in 2016, more tadpoles have been detected in Whistler Creek than any other (Figure 4-6). Habitat on this creek and its tributaries is mostly unaltered and the watershed probably supports a higher tailed frog population than any other sampled in the greater Whistler area. One of the main reasons to resurvey Whistler Creek in 2016 was to measure possible impacts of the Whistler Bike Park, which started expanding into the watershed at that time. With the exception of unusually high detections at Site 2 in 2017, detections have remained consistent for the seven years of surveys.

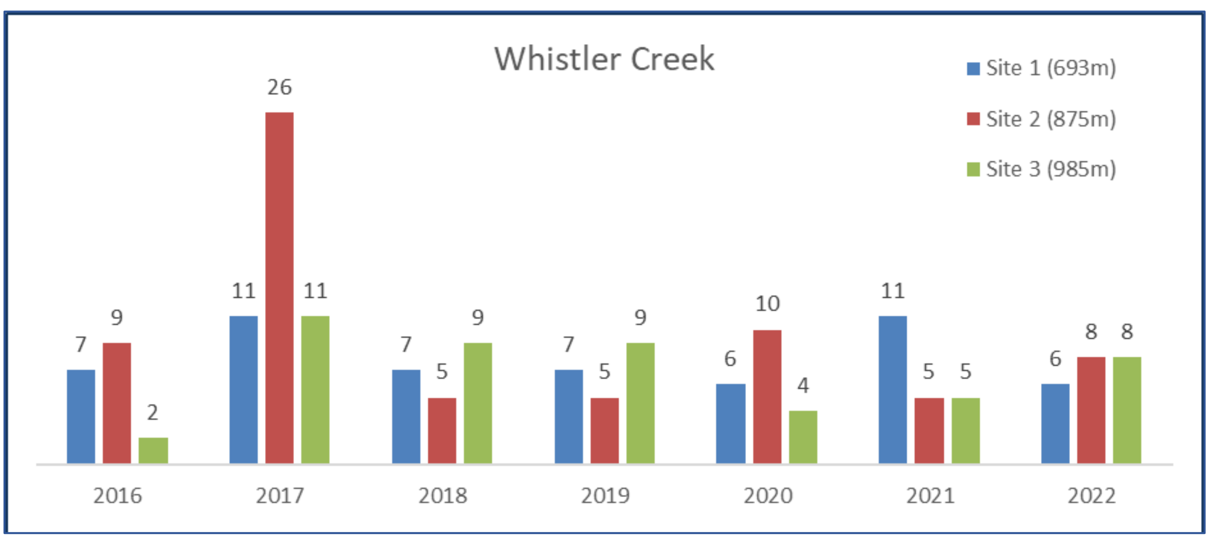

Figure 4-6. Tadpole detections in Whistler Creek by site, 2016-2022.

Sproatt Creek

Stable

Sproatt Creek was added to the program in 2018 (Figure 4-7), the first year after major scouring occurred on this and many neighbouring creeks during a fall 2017 flood (Photo 4-6). Only one site was surveyed that year, near Into the Mystery bike trail (996 m). Two lower-elevation sites were added in 2019. Detections have remained mostly consistent in that time span.

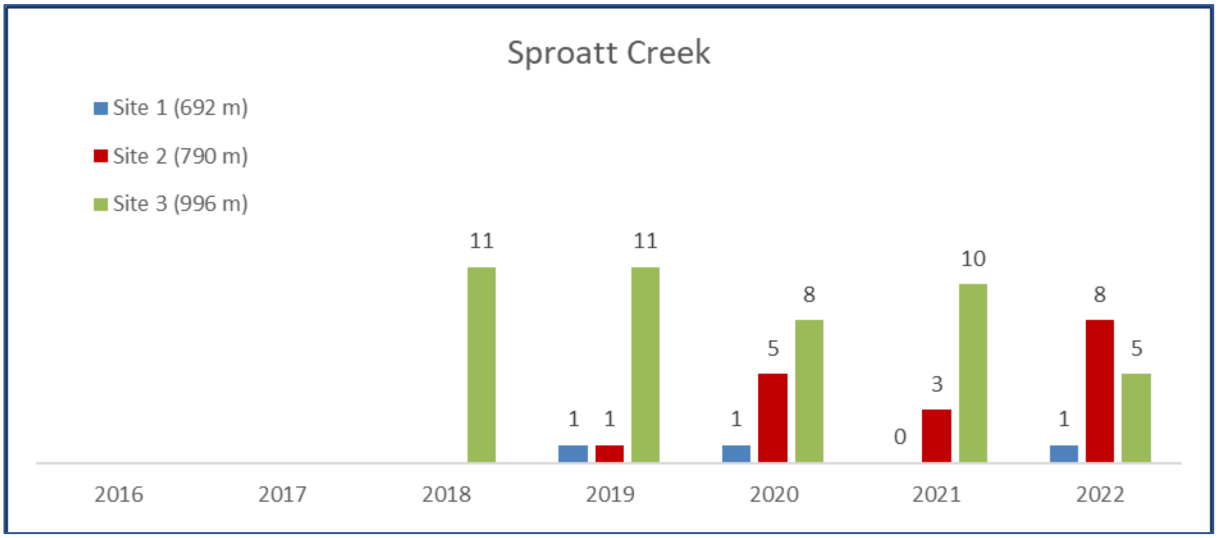

Figure 4-7. Tadpole detections in Sproatt Creek by site, 2018-2022 (only Site 3 surveyed in 2018).

Photo 4-6. Sproatt Creek-2 upstream 2022. Effects of 2017 flood still visible.

Van West Creek

Stable

Like many other creeks in the program, the uppermost site on Van West Creek is surrounded by old forest, while the lower, logged sites have varying levels of in-stream disturbance. The highest site (Site 3) on Van West provides ideal habitat for tailed frogs (Photo 4-7), so it is not surprising detections are consistently high (Figure 4-8). Site 2, meanwhile, includes poor habitat conditions for tailed frogs as a result of extensive logging disturbance (Photo 4-8). Only three tadpoles have been surveyed at Site 2 since 2018. Site 3 is in Function Junction and not surveyable in 2022 due to low water. No tadpoles have yet been detected in the disturbed habitat at Site 1, though small salmonids have been found (Snowline 2021).

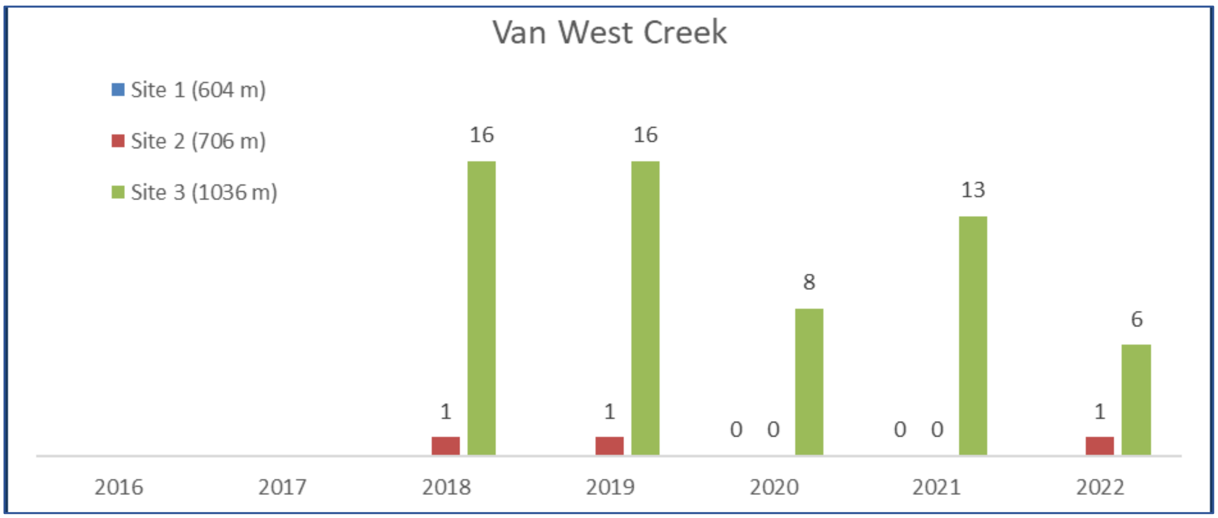

Figure 4-8. Tadpole detections in Van West Creek by site, 2018-2022 (no surveys at Site 2 in 2018, 2019, or 2022).

Photo 4-7. Van West Creek-3 is below the bridge near Into the Mystic trail (2021 photo).

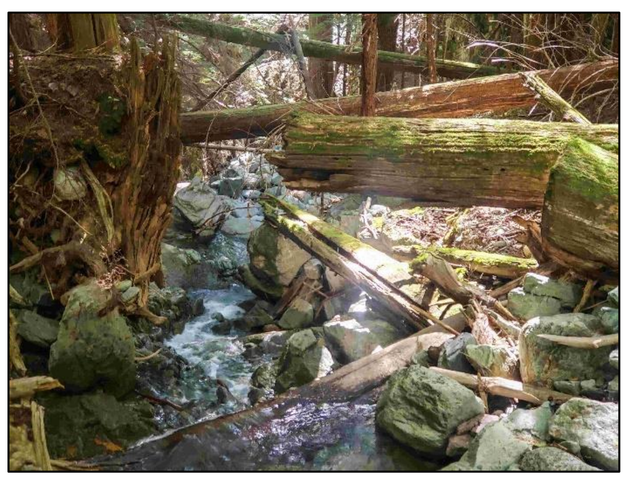

Photo 4-8. Logging debris in Van West Creek-2 (2020 photo).

4.4 Local Range Extensions of Coastal Tailed Frog

Prior to 2020, the highest elevation recorded for Coastal Tailed Frog tadpoles was at 1180m on Horstman Creek (in 2016) where the water temperature was 7° C. Based on that data, it was reasonable to conclude that this site was near the upper elevation limit for frogs since stream temperatures cool with increasing elevation enough to delay egg development (Section 4.1). This hypothesis was disproved during the 2020 Whistler BioBlitz at Brandywine Meadows, when Christopher Stinson discovered a tadpole at 1435 m in the mainstem of Brandywine Creek. Since that mainstem is shallow, slow-moving, and has a sand/silt streambed, it made sense at that time to assume the main habitat was in small side streams that drain into the meadows. This hypothesis was proved when Zeke Gilmore found a tadpole in a side creek, at 1440 m. Given this tadpole was near the bottom of the stream, where it drains into the meadows, it supported the possibility that tadpoles could be present even higher in that stream.

In 2022, tadpoles were detected by Paula Bartemucci at even higher elevations, up to 1485 m, next to Brew Lake and just south of the RMOW border (Figures 4-9, 4-10). Paula was surveying for a red-listed lichen, northwest waterfan (*Peltigera gowardii*; Brett 2022), and found both species in that area. Photo 4-9 shows one of the many late-stage, Cohort 3 tadpoles she found, which shows the breeding population in that area is likely robust (since later-stage tadpoles are more likely to enter the breeding population). Paula's observations further extend the elevational limit for tailed frogs in the Whistler area.

Photo 4-9. Ascaphus truei Brew Lake Creek from Paula Bartemucci

Figure 4-10. The yellow line shows where Paula Bartemucci found tailed frogs near Brew Lake.

5. Coastal Tailed Frogs – eDNA Sampling

Key Takeaways

Inconclusive (Data deficient)

1. Since Blackcomb and Nineteen-Mile Creeks are Whistler's only major creeks where tailed frogs have never been found, eDNA testing was employed to confirm whether or not they are present.
2. Due to its strong glacial input, Blackcomb Creek is colder than other creeks known to have tailed frogs, and may be too cold for egg development. With continued glacial melt due to climate change, glacier-fed creeks will become warmer which may then allow tailed frogs to colonize previously uninhabited creeks (which Blackcomb and Nineteen-Mile Creeks appeared to be). eDNA testing was meant to provide a baseline in case this hypothesis was correct.
3. Somewhat surprisingly, eDNA testing confirmed Coastal Tailed Frogs were present in Blackcomb Creek, even though they haven't been detected by tadpole surveys. And while the amount of DNA found in Nineteen-Mile Creek water samples was too low to provide certainty, it was enough to conclude tailed frogs are probably present there as well. These results disprove the hypothesis above.
4. The relatively low density of DNA in both creeks (especially Nineteen-Mile) may nonetheless reflect lower populations than other creeks in Whistler Valley, and that may still increase with warming streams. Further eDNA testing would be required to monitor the situation, and is probably beyond the scope of this program.

5.1 Introduction

Ever since the Whistler Biodiversity Project (WBP) first surveyed them in 2006, no Coastal Tailed Frogs have been detected in either Blackcomb Creek or Nineteen-Mile Creek. In 2006, the WBP surveyed five reaches on Blackcomb Creek and three on Nineteen-Mile Creek (Brett 2007). Surveys for this program included three reaches in Nineteen-Mile Creek in 2014 and 2015 (Cascade 2015, 2016) and another three this year (Table 4-4). Eight reaches since 2019 have meanwhile been surveyed in Blackcomb Creek (Palmer and Snowline 2020, 2021; Snowline 2021), including three this year. Surveys have therefore not found tadpoles in 12 attempts in Nineteen-Mile Creek, and 13 attempts in Blackcomb Creek.

While both creeks are primarily fed by a glacier, Blackcomb Creek is the only creek cold enough that it may hamper tailed frog colonization and egg development. The past several reports for this program (e.g. Snowline 2021) have therefore recommended eDNA testing to determine whether or not Coastal Tailed

Frogs actually inhabit Blackcomb Creek (and, by extension, Nineteen-Mile Creek). One of the main goals was to establish a baseline to monitor the effects of climate change on these two creeks
Testing for tailed frog eDNA is particularly appealing because this species is so genetically distinct from other amphibians that could be present in their habitat. In BC, Coastal Tailed Frogs only share similar DNA with Rocky Mountain Tailed Frogs (*Ascaphus montanus*), but are geographically separated from them.[24] Decreasing costs in the last five years have also increased the appeal of eDNA testing.

In summer 2022, amphibian biologist Brent Matsuda (who participated in the 2016 program) introduced Jared Hobbs to Bob Brett. Jared is an acknowledged expert in eDNA sampling and analysis (e.g., Hobbs et al. 2019, 2020) who offered to lead eDNA sampling in September 2022. Bob Brett and Brent Matsuda acted as field and lab assistants.

Blackcomb Creek

From a structural perspective, Blackcomb Creek should provide excellent habitat for tailed frogs. The stream morphology and streambed composition appear to be ideal for tadpoles due to frequent step pools that contain the size and rounded texture of rocks cobbles favoured by tailed frogs (Photo 5-1). There are three characteristics of Blackcomb Creek that could nevertheless reduce habitat suitability:

1. Cold temperatures caused by the mostly glacial input;
2. The steep cascades that predominate much of the creek at middle elevations; and,
3. Suspended glacial flour that may impair tadpole functions.

The WBP suggested that cold temperatures might be the main reason why tadpoles might not be present in Blackcomb Creek (Brett 2007). The surveys took place on August 25, 2006 when the water was 6.3°C at 859 m (at the RMOW water intake) and only 4.0°C at 1377 m. (Those temperatures remain the coldest yet recorded during Whistler tailed frog surveys.) Since water colder than 5.0°C is inhospitable for egg development (Section 4.1), it was reasonable at that time to assume Blackcomb Creek might have been be too cold to support tailed frogs. If so, it would also be reasonable to assume that tailed frogs would eventually colonize Blackcomb Creek once it warmed enough due to climate change (that is, when accelerated melting due to climate change decreased run-off from the melting Blackcomb Glacier enough to reduce its cooling effect).

The 2020 surveys on Blackcomb Creek, however, found much warmer temperatures than expected. Ranging from 8.0° to 10.0°, the 2020 temperatures were comfortably within the range of other creeks known to support healthy tailed frog populations. In 2021, temperatures returned to values more similar to 2006, e.g., the temperature at the Yummy Nummy site (Photo 5-1) was 6.5° C in early September. The reason for cold water in 2021 is somewhat counterintuitive since it was almost certainly caused by last year's heat dome (Section 8.3.1). The heat caused extensive glacial melting and therefore more and colder runoff than usual. This pattern was repeated in 2022 which also had hot, dry conditions (starting in July). The stream temperature at the Yummy Nummy site in early September was 6.8° C and the abundant glacial flour reflected glacial melt.

This temperature data is yet another reflection of a warming climate, especially in summer months. Assuming warming trends continue, the glacial influence in local creeks will continue to diminish and eventually result in lower flows and warmer water. How these changes will affect tailed frogs and other

[24] *The only other close relative of tailed frogs is a genus (*Leiopelma*; New Zealand Primitive Frogs) containing four species, all endemic to New Zealand. (https://en.wikipedia.org/wiki/Leiopelma).*

species is of course difficult to predict. But having baseline data makes detecting any changes much more feasible. That is the rationale for eDNA testing of tailed frogs in these creeks.

Photo 5-1. Tailed frog survey at the Blackcomb Creek at Yummy Nummy site.

Nineteen-Mile Creek

The general morphology of Nineteen-Mile Creek is somewhat similar to Blackcomb Creek, especially its steep cascades at middle elevations (which are steeper and even more incised than on Blackcomb Creek). Unlike Blackcomb Creek, however, the water is not noticeably colder than other streams with a healthy population of tailed frogs, nor is there noticeable turbidity from glacial flour. Both factors suggest the glacial influence are likely less than in Blackcomb Creek. The composition of the streambed is likewise similar in that it features the size and shape of cobbles and flat rocks that favour tailed frogs in other creeks (Photos 5-2 and 5-3).

Photo 5-2. Apparently excellent tailed frog habitat at the highest Nineteen-Mile Creek site, under the Flank Trail bridge.	Photo 5 3. The streambed morphology at the lowest elevation site on Nineteen-Mile Creek, beside the Highway 99 bridge, also appears to be excellent tailed frog habitat.

5.2 Methods

Water samples for eDNA testing were collected from Blackcomb Creek and Nineteen-Mile Creek on September 17, 2022. Jared Hobbs was lead surveyor with assistance from Bob Brett and Brent Matsuda. Water samples were collected in sterilized one-litre Nalgene bottles. Three field replicates, each consisting of three litres, were collected from Blackcomb Creek (Photo 5-4). Due to limited supplies, only two field replicates were collected from Nineteen-Mile Creek.

The three litres in each field replicate were pumped through a paper filter until all water ran through, or until transmission through the filter paper was prevented by the build-up of sediments (Photo 5-5). In the latter case, the volume of water that passed through the filter paper was noted. A separate control ("field blank") consisted of three litres of distilled water. Once finished, each filter paper was removed from the pump apparatus (Photo 5-5) and stored in a sterile bag for shipment to Bureau Veritas Laboratory in Guelph, Ontario. The lab process involved a number of steps, summarized as follows:

- The five field replicates and one control were tested for contamination (e.g., from improper cleaning of the Nalgene bottles) through an amplification process.
- Since not contamination was detected, the lab could proceed without other measure to divide the field replicates into eight technical (lab) replicates.
- The technical replicates ("runs") were subjected to a qPCR process that exponentially multiplied the template DNA from the focal taxon (in this case, Coastal Tailed Frog) in a thermocycler. Cycling continued until the concentration of eDNA exceeded a set threshold (a positive result) or reached 50 cycles without exceeding the threshold (a negative result).

The number of cycles (Ct) was reported for any positive results, in which a lower Ct indicates a higher density of eDNA. See the Results section below for more discussion of how to interpret these numbers.

Photo 5-3. Collecting water samples from Blackcomb Creek for eDNA testing. Jared Hobbs (right) is labelling one of the three litre bottles that comprise one field replicate.

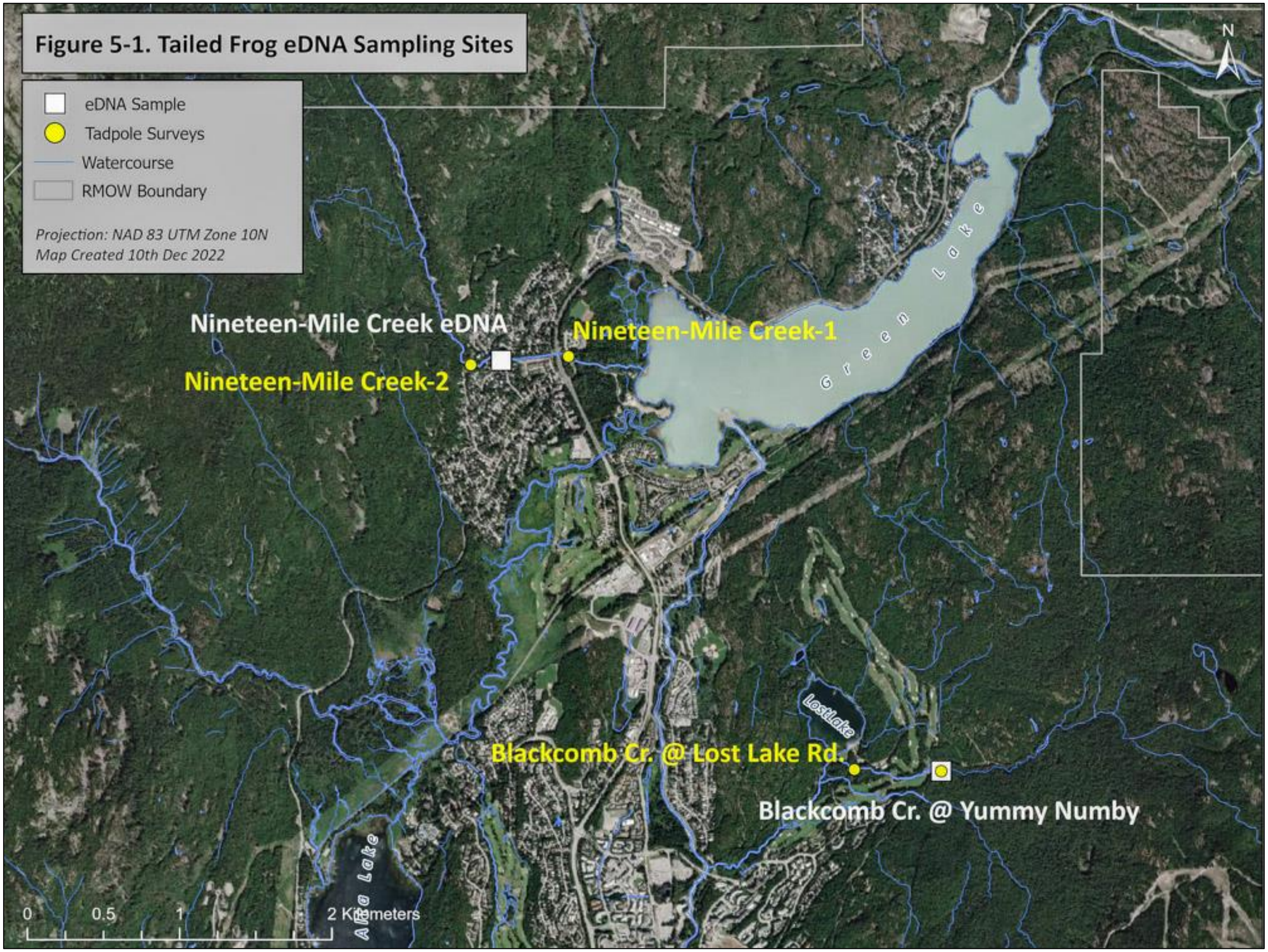

Figure 5-1. Tailed frog eDNA sampling sites.

Photo 5-4. (left) Water from field replicates is filtered. (right) Once pumping is finished, the filter paper is removed and prepared in sterile packaging for shipment to the lab.

5.3 Results and Discussion

Testing for contamination of the five field replicates and one field control (distilled water) confirmed the samples were suitable for qPCR analysis without further preparation (see the "InetgritE-DNA" column in Appendix E). The qPCR process returned positive hits for 2 of 8 technical (lab) replicates from Blackcomb-A and Blackcomb-B samples, but 0 of 8 for Blackcomb-C (Table 5-2; Appendix E). The qPCR process returned only one positive hit (1 of 8) for Nineteen-Mile Creek-A and 0 of 8 for Nineteen-Mile-B.

Table 5-2. Summary of lab results (presented in full as Appendix E).

Creek - Field Replicate	Ct Value	Frequency	Assessment
Blackcomb Creek - A	44.54 45.14	2 of 8	Positive
Blackcomb Creek - B	49.03 43.81	2 of 8	Positive
Blackcomb Creek - C	N/A	0 of 8	Negative
Nineteen-Mile - A	48.08	1 of 8	Suspected
Nineteen-Mile - B	N/A	0 of 8	Negative

The Ct value (cycle number) is related to the density of tailed frog DNA in each replicate, and is only reported when there is a "hit," that is, when the target DNA exceeded a set threshold. Jared Hobbs reports that Ct values between approximately 40 and 45 are a strong result, which includes three of four of the Blackcomb Creek technical replicates. And even though only 4 of 24 replicates from Blackcomb Creek exceeded the threshold value, Jared is confident that this result confirms the presence of tailed frogs in that system. The result from Nineteen-Mile Creek is more equivocal. With only 1 of 16 total replicates exceeding the threshold value (and barely, at 48.08 out of 50 maximum cycles), water at this site is shown to have a low (barely detectable) density of tailed frog DNA. Jared nonetheless interprets this result as a probable positive signal (listed in Table 5-2 as "suspected" to show there is a possibility of a false positive).

It is important to note that eDNA testing only reports the density of tailed frog eDNA at the sampling site rather than the actual number (abundance) of tailed frogs in each steam. Low eDNA density can therefore reflect low total abundance, high streamflows (i.e., dilution), and/or a population far upstream. Further eDNA testing at upstream sites would be needed to clarify whether and where there are tailed frogs in Nineteen-Mile Creek.

6. Western Toads and Red-legged Frogs

Key Takeaways

Inconclusive (Data deficient)

1. Since Western Toads and Red-legged Frogs are species of local interest, it is important to identify and protect their breeding habitats. In spite of past efforts by this program to locate these habitats, Lost Lake was the only confirmed site for Western Toads.
2. A total of 11 ponds were surveyed in spring for egg masses, and traps were set in four ponds in July. As in recent years, no evidence of breeding was detected.
3. The most important finding in 2022 came from Whistler BioBlitz which confirmed Western Toad breeding in the Whistler Olympic Park (just outside of the RMOW boundary). This is the first breeding site documented in the Whistler area in more than 10 years and becomes the only known site other than Lost Lake.
4. It is still likely there are other breeding sites for Western Toads south of Function Junction and within the RMOW boundary. Until all possible sites are surveyed in that area (ideally by the end of 2026), there is not enough information to detect any trends.

6.1 Introduction

In spite of occasional sightings in most parts of the RMOW, the only known annual breeding site for Western Toads (*Anaxyrus boreas*) is at Lost Lake. The only known records of breeding sites (i.e., tadpoles) were ephemeral and prior to 2010, and included one near of the stormwater drainage ponds at the north end of Cheakamus Crossing, one record in Eva Lake, and one at a small, manufactured wetland in the Brandywine snowmobile parking lot. Even though breeding was observed at these sites for only one year, they provided evidence of a breeding population of Western Toads outside of Lost Lake.

One goal of the program has therefore been to further investigate the south end of Whistler (south of Function Junction) for breeding sites, but searches by this program have so far been unsuccessful (Palmer and Snowline 2021; Snowline 2021). The revised goal of the current, three-year cycle of the program is to search approximately one-third of potential breeding sites south of Function Junction each year. That approach should help confirm if and where Western Toads breed and, incidentally, record other species of local interest, notably Red-Legged Frogs (*Rana aurora*).

Red-legged Frogs are blue-listed in BC (CDC 2022) and ranked as Special Concern under the Canadian Species At Risk Act (Government of Canada 2022). The Whistler Biodiversity Project first found a breeding site in 2006 (Brett 2007), inside what became the northward expansion of Brandywine Falls Provincial Park. Although they have been recorded in the lower Callaghan Valley by BioBlitz scientists, Leslie Anthony, and Liz Barrett since then,[25] no other breeding sites have yet been documented farther north.

[25] *Personal communication with and photos sent to Bob Brett.*

6.2 Methods

Pond surveys consisted of egg mass surveys in early spring and trapping in early July. Egg mass surveys were conducted at 11 sites between April 28 and May 2 (Table 6-1). Trapping included four sites where traps were placed in the evening on July 8 and retrieved in the morning of July 9. Trapping was conducted by Bob Brett with assistance from Kristina Swerhun under BC Government Wildlife Permit SU22-722725.

Egg surveys consisted of shoreline searches for egg masses. July trapping used standard minnow traps (Photo 6-1) that were placed at the edge of target ponds in the evening and retrieved the next morning. Care was taken to ensure a part of the trap was out of the water in case air-breathing animals were trapped. Once retrieved, amphibians were identified and measured, and aquatic invertebrates were recorded to the lowest possible taxonomic level. Traps were sterilized in mild bleach and left to dry in the sun before and after trapping to prevent contamination between ponds.

Table 6-1. Pond amphibian survey sites.

Location	Date	Easting	Northing	Elev (m)	Water (°C)	Air (°C)	Survey Type	No. Traps	Amphibians
Brandywine Falls North, RAAU Pond	2022-04-28	491742	5544742	512		12	egg	n/a	RAAU?
Callaghan FSR Pond 1	2022-04-28	493120	5546429	512		12	(visual)	n/a	
Hwy 99 Callaghan North Pond (beavers)	2022-04-28	492947	5546215	508		12		n/a	
Hwy 99 Callaghan South Pond	2022-04-28	492818	5546057	508		12		n/a	
McGuire Pond	2022-04-28	492188	5545136	497		12		n/a	
Cheakamus Crossing Oikos Pond (SP2)	2022-05-02	497044	5547288	603		14		n/a	PSRE
Cheak. Crossing Power Line Pond (SP4 North)	2022-05-02	496789	5547594	594		14		n/a	
Cheak. Crossing Power Line Pond (SP4 South)	2022-05-02	496769	5547554	593		14		n/a	
Cheakamus Crossing: Square Pond (SP1)	2022-05-02	496829	5547902	591		14		n/a	
Cheak. Crossing: Keyhole Pond (w. of SP1)	2022-05-02	496625	5547940	591		14		n/a	
Millar's Pond	2022-05-02	499368	5548340	667		14		n/a	
Callaghan FSR Pond 1	2022-07-09	493120	5546429	512	14	11	tadpole	2	AMGR
Hwy 99 Callaghan North Pond (beavers)	2022-07-09	492947	5546215	508	16	11	(trapping)	4	AMGR
Cheak. Crossing: Keyhole Pond (w. of SP1)	2022-07-09	496625	5547940	591	15	15		4	PSRE, AMGR
Cheakamus Crossing: Square Pond (SP1)	2022-07-09	496829	5547902	591	11	15		4	

Photo 6-1. (left) a minnow trap set in the Hwy 99 Callaghan North Pond; (right) checking an amphibian trap at Callaghan FSR Pond 1.

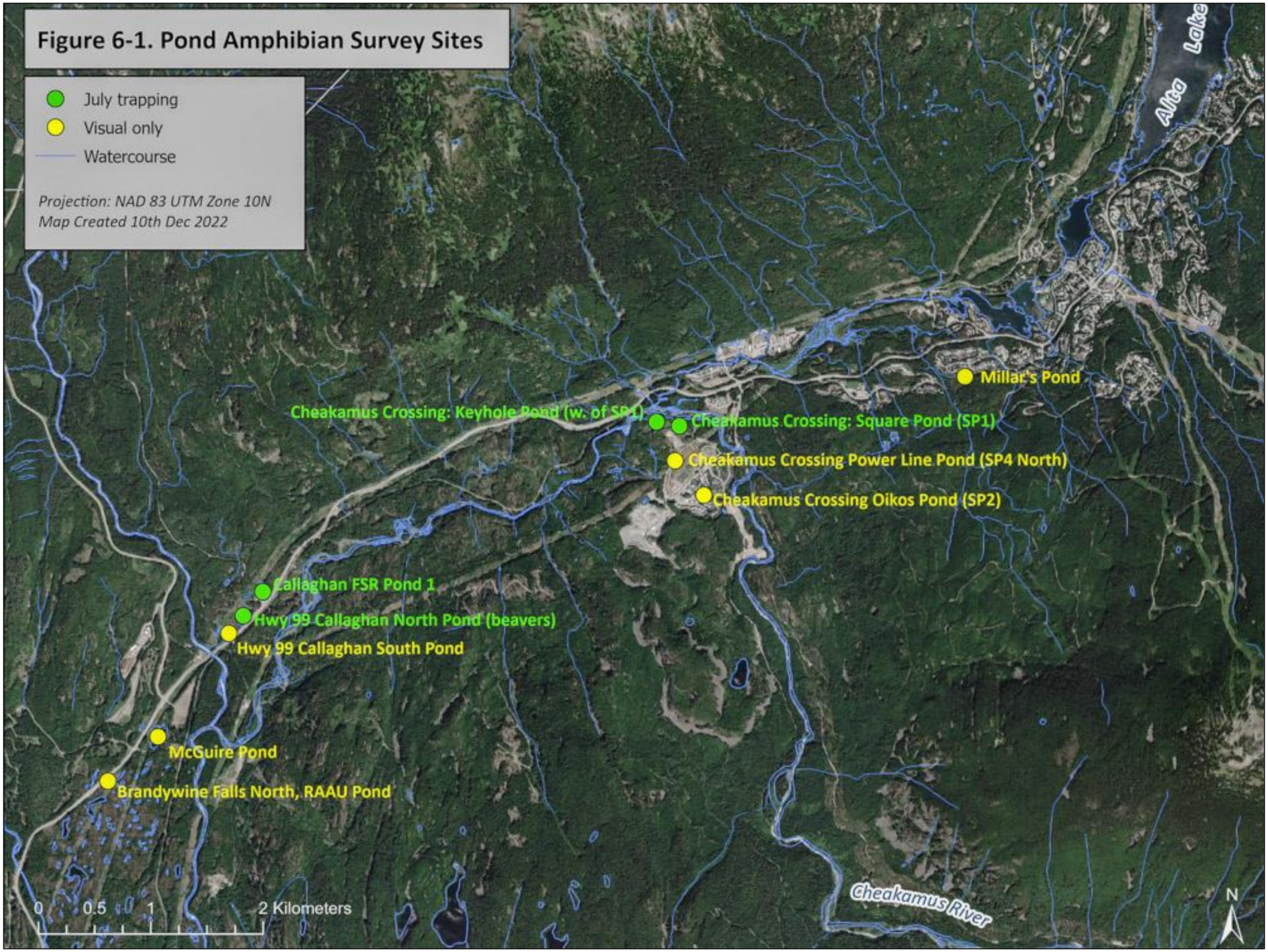

Figure 6-1. Pond Amphibian Survey Sites

6.3 Results and Discussion

6.3.1 Egg Mass Surveys (Spring)

While no egg masses were detected in spring surveys, a suspected Red-legged Frog adult was seen briefly before it submerged in the Brandywine “RAAU” pond (Table 6-1). This was not a surprising observation since the WBP first discovered these frogs breeding here in 2005 (Brett 2007). Breeding in this ponds has been reconfirmed many times since, including at BioBlitz events. Pacific Treefrog tadpoles were also detected during egg mass surveys in the Cheakamus Crossing Keyhole Pond (Photo 6-2).

6.3.2 Pond Trapping (July)

No Western Toads or Red-legged Frogs were detected during July trapping (Table 6-2). Consistent with results from pond surveys during the Whistler Biodiversity Project, Northwestern Salamanders (*Ambystoma gracile*) were common in three of four ponds (Photo 6-3). Pacific Treefrogs (*Pseudacris regilla*) was the only other amphibian species recorded (Photo 6-3). They are also a common species in ponds, especially warm ones such as the Cheakamus Crossing Keyhole Pond (Photo 6-2) – it was 15° C on the same day that the Callaghan ponds (were only 11° C.

Table 6-2: Pond trapping results, 2022.

	Callaghan FSR Pond 1		Hwy 99 Callaghan North				Cheakamus Crossing Keyhole Pond				Cheakamus Crossing Square Pond			
Amphibian Species	**Trap 1**	**Trap 2**	**Trap 1**	**Trap 2**	**Trap 3**	**Trap 4**	**Trap 1**	**Trap 2**	**Trap 3**	**Trap 4**	**Trap 1**	**Trap 2**	**Trap 3**	**Trap 4**
NW Salamander	1	3	2	1	0	10	4	3	2	7				
Pacific Treefrog							30	50	18	40				
Long-toed Salamander														
Ambystoma sp.														
Western Toad														
Rough-skinned Newt														
Red-legged Frog														
	1	**3**	**2**	**1**	**0**	**10**	**34**	**53**	**20**	**47**	**0**	**0**	**0**	**0**
Length (mm)														
NW Salamander	90	110 90 80	130 100	80	120	n/a	30-40	30-40	30-40	30-40	n/a	n/a	n/a	n/a
Pacific Treefrog	n/a	n/a	n/a	n/a	n/a	n/a	15-25	8-30	15-30	15-30	n/a	n/a	n/a	n/a

Legend: AMGR (Ambystoma gracile, NW Salamander); PSRE (Pseudacris regilla, Pac. Treefrog); RAAU (Rana aurora, Red-legged Frog).

Photo 6-2. Cheakamus Crossing Keyhole Pond.


Photo 6-3. Northwestern Salamander (left) and Pacific Treefrog (right).

The only pond in which no amphibians were trapped was the “Cheakamus Crossing Square Pond” (Photo 6-4), a pond manufactured to manage stormwater during the construction of that area in preparation for the 2010 Olympics. This pond was checked for egg masses on May 2, 2022 but the only obvious animals using the pond were beavers (Section 2.3.5). By July 8th, the pond was very overgrown, filled with algae, and trapping sites were very difficult to find. Given the general appearance of this pond, including the algae, it was unsurprisingly the only pond surveyed in July in which snails (eight of them) were trapped, presumably because they are more tolerant of poor water quality.

Photo 6-4. Cheakamus Crossing Square Pond on May 2, 2022.

6.4 Discovery of Western Toad Breeding in the Callaghan Valley

Even thought targetted surveys did not find Western Toad breeding sites within the RMOW, Kristina Swerhun discovered one in the middle of July during reconnaissance for the Whistler BioBlitz in Whistler Olympic Park. Her sighting of tadpoles in a small pond south of Lunch Lake (UTM 0491266E 5555826N; Figure 6-2) is the first confirmed breeding site south of Function Junction recorded in at least 10 years.

Figure 6-2. The green pin marks the Western Toad breeding site in Whistler Olympic Park.

During the actual BioBlitz event, scientists recorded many juvenile and adult frogs in that area, including a large adult that emerged out of a rotten log being examined for fungi, spiders, slime moulds, and insects (Photo 6-5).

Photo 6-5. This large Western Toad emerged out of a rotten log during the 2022 BioBlitz, just south of the tadpole pond shown above (Photo 6-5).

7. Benthic Invertebrates

Key Takeaways

Inconclusive

1. Benthic invertebrate abundance and species richness was generally lower at all monitored sites as compared with previous years. The relatively wetter and colder temperatures during spring and early summer 2022 and delayed onset of the freshet may have impacted benthic communities through delayed/slower development and frequent disturbance of the substrate. These factors would increase the drift of invertebrates early in the development cycle when they are more vulnerable to higher velocities.
2. Lower densities of invertebrates also lower their detectability (i.e., higher probability of not collecting a taxon that is typically present at the site) which lowers taxonomic richness and, in turn, impairs the analysis of benthic communities.
3. No taxa considered to be intolerant to degradation of habitat and water quality was observed at any of the sites; however, the abundance of pollution-tolerant taxa was generally moderate, not showing any substantial evidence of habitat degradation.
4. Whistler Creek was included in the program for the first time. The results of the CABIN analysis show some moderate disturbance of the benthic communities, which are considered to be 'Mildly Divergent' from Reference Condition.
5. For the first time since 2016, the (lower) River of Golden Dreams saw some slight alteration of the benthic communities and was not deemed to be in Reference Condition in 2022 (Mildly Divergent from Reference Condition). The relatively low invertebrate abundance as compared with the previous years has likely affected specimen detectability, and therefore, species richness. It is noted that the on-going streambed disturbance from recreational users and to a lesser extent by dogs within the sampling site could also be a contributing factor.
6. Results from some of the past years of sampling in Jordan Creek have shown elevated numbers of pollution-tolerant organisms. These observations and accompanying water quality data that also showed some cause for concern were not seen in 2022 where the creek was deemed to be in Mildly Divergent from Reference Condition. Based on this result, Jordan Creek appears to be recovering from past anthropogenic disturbance.
7. Despite all sampling sites being geographically close to each other, Jordan Creek and Whistler Creek are part of the Howe Sound drainage (flowing south), whereas the River of Golden Dreams, Twenty-One Mile Creek and Crabapple Creek (flowing north) are situated within the Fraser River watershed.

7.1 Introduction

Benthic invertebrates are an important component of freshwater ecosystems. They are a food source for fish, amphibians, and birds. They play a major role in the decomposition of organic material and, therefore, affect nutrient availability and plant productivity in the water. Aquatic insects have a wide range of water quality tolerances and requirements, and exist within a wide variety of environments. Aquatic invertebrates have long been used as an indicator of water quality and aquatic health. Their benefits as bioindicators include their relatively restricted range during the aquatic lifetime, the short length of their life span (from a few months to several years) and their varied requirements for water quality. Undisturbed aquatic systems generally have high insect species richness with elevated densities of species sensitive to habitat and water quality alterations from anthropogenic disturbance. Conversely, disturbed streams generally have comparatively lower species richness with elevated densities of species more tolerant to pollution and/or low habitat complexity and quality. Cold, fast flowing watercourses may have limited species richness but a higher proportion of species sensitive to disturbance of habitat or water quality, including changes in water temperature (stenothermic species).

In BC, benthic invertebrate sampling is analyzed in conjunction with water quality and set protocols, such as the Canadian Aquatic Biomonitoring Network (CABIN) or the Benthic Index of Biotic Integrity (B-IBI). The health of benthic invertebrate communities has been monitored by this program since 2016 using the CABIN protocol.

7.2 Methods

7.2.1 The CABIN Protocol

The Canadian Aquatic Biomonitoring Network (CABIN) is an aquatic biological monitoring program for assessing the health of freshwater ecosystems in Canada. CABIN is based on the network of networks approach that promotes inter-agency collaboration and data sharing to achieve consistent and comparable reporting on freshwater quality and aquatic ecosystem conditions in Canada. The program is maintained by Environment Canada to support the collection, assessment, reporting and distribution of biological monitoring information. CABIN allows partners to take their observations and make a formalized scientific assessment using nationally comparable standards.

The CABIN program primarily uses the Reference Condition Approach (RCA; Bailey et al., 2004) for evaluating whether a test site is in Reference Condition, and if not, then determine how divergent it is from Reference Condition. Reference sites are considered to be minimally affected by human activity. These sites provide the basis on which to compare the health of any given test sites. This approach relies on the establishment of a large database of biological and habitat data from a wide range of reference sites. The wide range of reference sites provides the data to develop empirical models that explain the variability among the different benthic communities based on environmental characteristics (e.g., location, hydrology, substrate, bedrock geology, and climate).

An empirical Model (see Section 7.2.5), typically at a watershed scale (e.g., Fraser River, Skagit River, etc.), subsequently predicts the benthic community that should be observed at a test site if that site was in '*Reference Condition.*' The further the test site is from the predicted group of reference sites, the more different it is. The assumption of RCA is that if a site is different from what is expected, there must be some anthropogenic stress exerted on the benthic community.

7.2.2 Benthic Invertebrate Sample Collection

The macro-invertebrate sample collection was performed at 6 sites over a two-day period between July 22nd and 23rd (Table 7-1 and Figure 7-1), in accordance with the *CABIN Field Manual* (Environment Canada, 2012) by Jason Macnair, CABIN-certified for field sampling, and assisted by Bob Brett (Snowline) and Rebecca Merenyi (RMOW).

Table 7-1. 2022 Benthic Invertebrate Sampling Locations and Dates.

Site	UTM Location (Zone 10)		Aquatic Site ID	Access (Bridge Crossing)	Date Sampled
	Easting	Northing			
Twenty-one Mile Creek	501910	5552856	21M-DS-AQ21	Lorimer Road	July 22, 2022
Crabapple Creek	502030	5552670	CRB-DS-AQ01	Lorimer Road	July 22, 2022
Jordan Creek	500242	5549278	JOR-DS-AQ31	Lake Placid Road	July 23, 2022
River of Golden Dreams (Upper)	502066	5552829	RGD-US-AQ11	Lorimer Road	July 22, 2022
River of Golden Dreams (Lower)	503035	5554687	RGD-DS-AQ12	Off Nicklaus North Golf Course	July 22, 2022
Whistler Creek	500534	5549592	WHI-DS-AQ01	Lake Placid Road	July 23, 2022

Samples were collected using a 400µm kick-net over a period of exactly three minutes to standardize the level of effort. Sampling was initiated at the downstream end of the study area and moved upstream to avoid potential contamination of the lower sites when invertebrates are dislodged during sampling. A zigzag sampling pattern across the stream is used to integrate benthic macro-invertebrates from various stream microhabitats within the erosional zone in proportion to their occurrence in a sample reach. Sampling should also include stream habitats directly adjacent to the stream bank as these areas may have microhabitats such as leaf litter that support a unique fauna. Each sampling kick area and path was pre-defined before entering the creek, and targeted riffle habitats with cobble/gravel substrate.

The content of the kicknet was emptied into a 400µm sieve before being transferred into a 500mL plastic jar. Each sample was preserved in the field by addition of an 85% ethyl alcohol solution. Care was taken to remove as much creek water as possible to avoid preservative dilution. In some cases, the 'bucket-swirling' method, as described in the CABIN Field Manual, was used to remove excess sand from the sample before preservation. Bucket swirling, or elutriation, is a common method used by to remove large amounts of inorganic material (sand/gravel) from a sample. During elutriation the sample is agitated or swirled in a bucket with water to create a vortex. Swirling causes lighter organic material and macroinvertebrates to float in the water column while the heavier inorganic sand and gravel remains at the bottom of the bucket. This process also reduces the risk of damage to specimens during transport to the taxonomy lab, since the larger substrate is removed. As recommended in the CABIN Field Manual, the removed substrate was kept for QA/QC purposes and to check that no organisms were left behind.

Photo 7-1. Invertebrate sampling in Twenty-One Mile Creek.

Photo 7-2. Invertebrate sampling in Whistler Creek

7.2.3 *In Situ* Habitat Data Collection

Habitat data was collected *in situ* at each of the six sampling sites following the CABIN field sheets.

- **Primary Site Data**: Basin name, estimate of site location coordinates, ecoregion, and stream order are all recorded.
- **Site Description**: a broad characterization of the site. It includes a site drawing and written description, site coordinates, and surrounding land use classification.
- **Reach characteristics**: a description of aquatic habitat types, canopy coverage, macrophyte coverage, streamside vegetation and canopy coverage in a defined sampling reach (site).
- **Water chemistry**: measurement of certain physical-chemical water quality parameters which are required by CABIN such as dissolved oxygen and saturation, pH, water temperature and conductivity. Most can be collected with in-situ field meters.
- **Substrate characteristics**: a 100-pebble count is used to characterize the substrate. The degree of embeddedness of substrate and the size of surrounding material are also determined.
- **Channel measurements**: characterization of the stream channel at current flow and estimate of peak flow conditions. This includes measurements of channel width (bankfull and wetted), depth, velocity and slope. Velocity measurements were collected using a Swoffer unit.

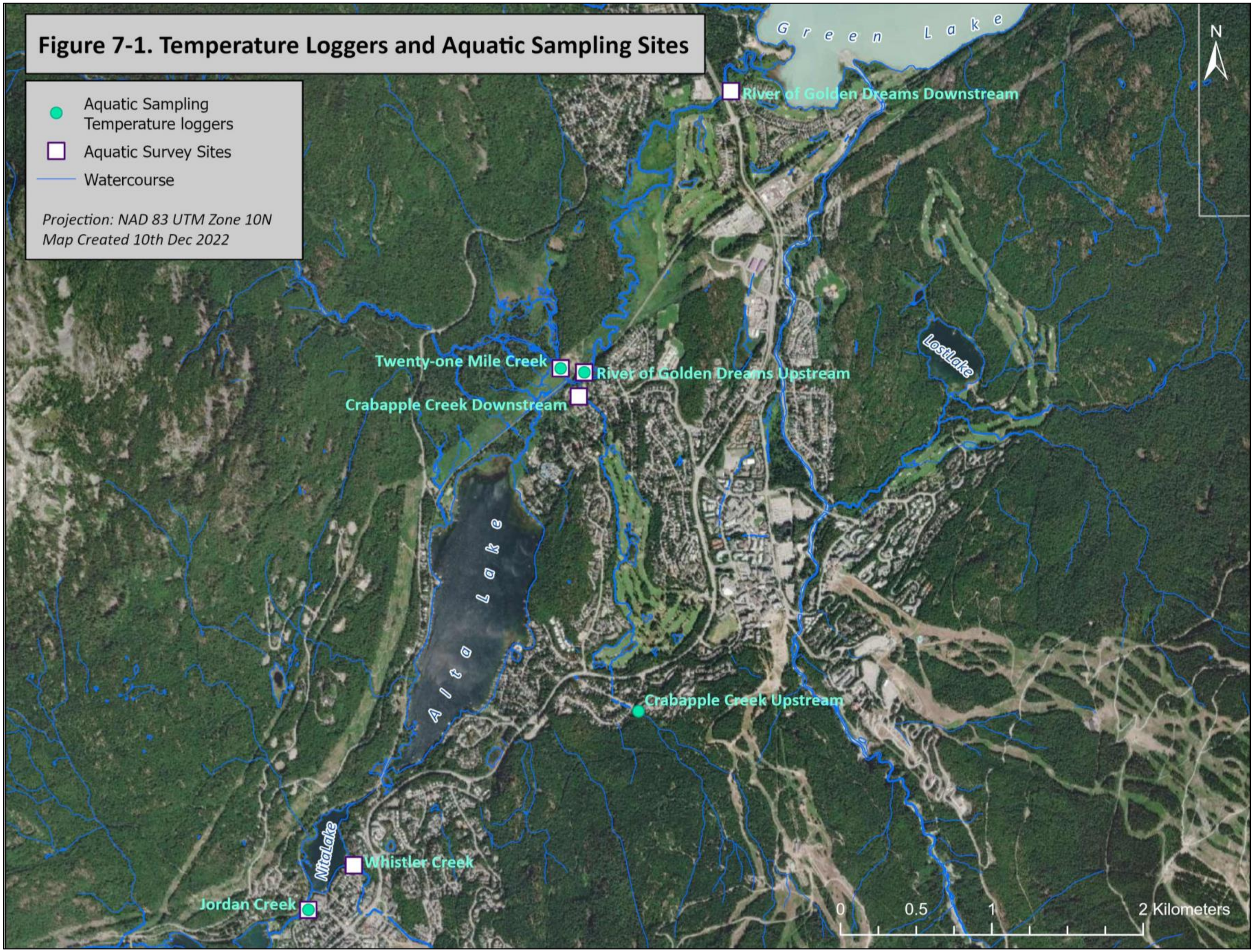

Figure 7-1. Temperature Loggers and Aquatic Sampling Sites.

7.2.4 Sample Sorting and Taxonomic Analysis

Benthic invertebrate sample sorting and taxonomic analysis was conducted by Thibault Doix, Certified Taxonomist with the Society for Freshwater Science. The sample sorting process consists of removing all the benthic invertebrates from the sample matrix prior to taxonomic identification. Each sample was processed as follow:

- The whole sample (i.e., all the jars constituting one sample) was washed with water into a 320µm sieve (smaller than the kicknet mesh size) to remove preservative.
- Large materials, rocks, twigs, and macrophytes were gently and thoroughly washed over. Washed large material was placed in a white tray for further examination and to make that sure no organisms were left behind.
- The sieve content was transferred into a white tray for a first sorting under a hands-free magnifier to remove large and conspicuous specimens.
- The tray content was subsequently split into smaller fractions and progressively transferred into a Petri dish for fine sorting under a dissecting microscope. Sorted debris was set aside and preserved in 85% ethanol.
- Removed specimens were separated into coarse family groupings in multi-well plates.
- All organisms removed from the white tray were identified, tallied and recorded on a bench sheet.
- The specimen vial and sorted debris jars were labeled, preserved in 85% ethanol and retained for Quality Assurance/Quality Control (QA/QC) audits of sorting and identification efficiency, as required.
- Each organism was identified using dissecting (10x-90x magnification) or compound microscopes (40x-1000x magnification) and appropriate taxonomic identification keys. The taxonomic identification was performed to the lowest level possible (generally genus/species level for insect taxa and family/genus for non-insects). Different life stages (e.g., larvae, nymphs) were identified and enumerated separately. If the condition of a specimen did not allow for a correct identification, it was discarded.

7.2.5 CABIN Database and Data Analysis

The CABIN database analysis uses the Reference Condition Approach (RCA) to assess anthropogenic disturbances. A large database of benthic macroinvertebrate communities was established by Environment Canada from a wide range of minimally disturbed sites ('*Reference Sites*') throughout various watersheds (e.g., Fraser River, Skagit River, etc.). Reference Sites were subsequently grouped based on their habitat characteristics, biogeoclimatic zones, etc. Using multivariate statistical techniques, empirical Models were developed from the information collected to predict the '*expected*' invertebrate assemblage using the habitat characteristics at a particular site (Sylvestre et al., 2005). The assumption is that if the observed community at a given test site was not what was expected, then the stream must experience some level of anthropogenic stress.

These Models comprises five to six different reference site groups that the benthic invertebrate communities of each test site can be compared to. Test sites are plotted with the appropriate group of reference sites on two or three axes, each axis representing a group of benthic community attributes. Each test site is assigned to the farthest band to which it resides in the three plots. The CABIN database assessment is summarized based on where the test site fell within the confidence ellipses (Figure 7-2):

- A site falling within the 90% confidence ellipse is designated '*Similar to Reference*'.
- A site falling within the 90% and 99% confidence ellipses is designated '*Mildly Divergent'*.
- A site falling within the 99% and 99.9% confidence ellipses is designated '*Divergent*'.

- A site that falls outside of the 99.9% confidence ellipses is designated *'Highly Divergent'*.

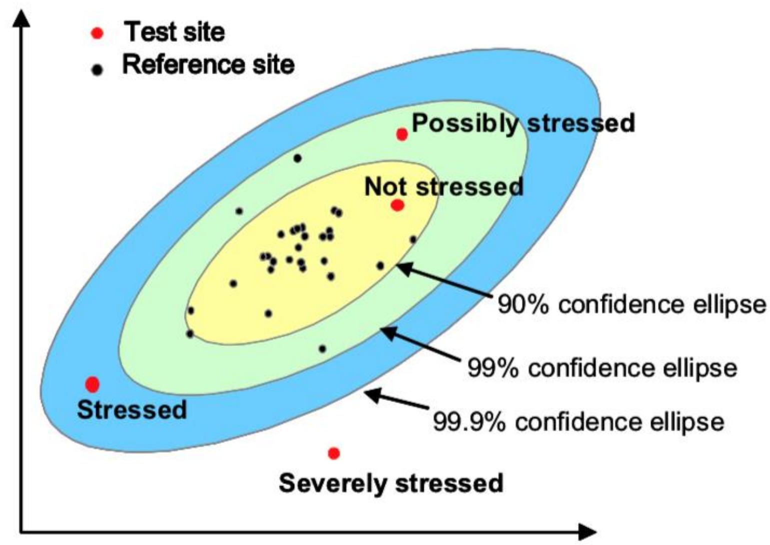

Figure 7-2. Ordination of invertebrate communities at reference sites and test sites. Different bands surrounding the cloud of reference sites represent the assessment criteria for a test site based on the distance the test site falls away from the cloud of reference sites (Source: Sylvestre et al., 2005).

The multivariate ordination used in the RCA was developed using Bray-Curtis Index (BCI) data calculated for the RCA as a complete data matrix. For the test sites, the BCI was calculated based on the expected relative abundance of the taxa present for that reference group. These BCI data were then used to locate each site on the ordination.

For the BCI, a value of 0 indicates that a site is identical in community structure to the Reference Condition and a value of 1 indicates a site is entirely different from the Reference Condition with no species in common. Within that range, between site variability is considered low if BCI values are less than 0.40, moderate if BCI values are between 0.40 and 0.80, and high if BCI values are greater than 0.80. The latter category is also problematic because the correlation between BCI values and ecological 'distance' becomes sharply non- linear above approximately 0.80 (Beals 1984). Site comparisons with BCI values greater than 0.80 should therefore be interpreted with caution. For the reference sites, the mean BCI values ranged from 0.41 to 0.55 and were therefore considered, on average, moderately variable (Table 3-2).

The CABIN database assessment was further developed through comparison of test sites with reference sites using the River Invertebrate Prediction and Classification System (RIVPACS). The RIVPACS compares the *observed* taxonomic richness at each test site, to the *expected* taxonomic richness from the group of Reference sites predicted from the reference model, which is then reported as an Observed:Expected (O:E) ratio. O:E ratios are calculated to assess the potential loss of highly expected taxa that have more than a 70% chance of occurrence (O:E p>0.7) at the Reference sites. A low O:E (p<0.7) score indicates taxa loss as compared with expected benthic communities at Reference sites and is indicative of some form of anthropogenic stress.

The expected taxa richness is calculated from the sum of all taxon probabilities of occurrence in comparison with the average of the Reference sites of a given group. O:E ratios are examined to investigate the loss of highly expected taxa that have more than with more than a 70% chance of occurrence (O:E p>0.7). Ratios were calculated by summing up the total number of observed taxa (taxa present with probabilities of occurrence greater than 70%) and divided by the expected number of taxa from the group of reference sites (with sum of probabilities greater than 70%). A ratio <1 indicates fewer of the taxa with high probability of presence than expected at a site in Reference Condition (i.e., sign of potential alteration) and a ratio >1 indicates a greater taxonomic richness.
Each taxon found at the Reference sites is attributed a probability of occurrence based on the results of the various assessments conducted at these sites. A taxon with a high probability of presence at the group of reference sites that is not found at a test site can substantially affect the results of the CABIN assessment, same as the presence of a higher number of pollution tolerant taxa (i.e., not present at the reference sites).

7.3 Results and Discussion

7.3.1 Reference Model and Reference Group Assignment

The probability of the test site belonging to each of the reference site group is calculated using the habitat variables for the specific Model being used. The Fraser River 2014 Reference Model was used for the River of Golden Dreams (2 sites), Crabapple Creek, and Twenty-Mile Creek as they are part of the Lillooet River drainage (tributary to the Fraser River), while Whistler Creek and Jordan Creek were assessed using the Fraser River Georgia Basin 2005 Model (Sylvestre et al., 2005) as they ultimately drain into Howe Sound. It is noted that Jordan Creek was assessed using the Fraser River 2014 Model (Strachan et al., 2014) in previous years and a comparison of the results using the two Models is provided in Table 7-3 below. A summary of the Reference Model Group assignment probability is summarized in Appendix F.

An updated Fraser River Model (Reynoldson, 2021) does exist, but it requires a complete re-analysis of the predictive habitat metrics and the calculation of some new ones. Thus, it is proposed to be included in next year's analysis as it cannot be included in the present report.

7.3.2 Taxonomic Identification and CABIN Database Analysis

The results of the CABIN database analysis shows that the benthic communities at most sites were Mildly Divergent from Reference Condition while the (upper) River of Golden Dreams was Divergent from Reference Condition (Table 7-2). It is noted that the CABIN analysis was performed once again for all the sites since 2016 as some discrepancies were identified with previous data. Table 7-2 below shows the updated results.

Detailed results of the taxonomic analysis and CABIN database analysis will be provided to RMOW under a separate cover.

Table 7-2. Summary of CABIN Database Output and Site Assessment Results.

Site	Reference Model	Year	Reference Group #	Test Site BCI	Reference BCI (Mean ± SD)	RIVPACS O:E (p>0.7)	CABIN Assessment Results
Twenty-one Mile Creek	Fraser River 2014	2016	4	0.48	0.41 ±0.17	1.17	Reference
		2017	3	0.78	0.41 ±0.17	0.93	Divergent
		2018	5	0.87	0.55 ±0.22	1.20	Mildly Divergent
		2019	3	0.75	0.41 ±0.17	1.16	Mildly Divergent
		2020	4	0.36	0.53 ± 0.14	1.20	Reference
		2021	3	0.85	0.41 ±0.17	1.16	Mildly Divergent
		2022	3	0.67	0.41 ±0.17	0.93	Mildly Divergent
Crabapple Creek	Fraser River 2014	2016	1	0.71	0.48 ± 0.15	0.96	Mildly Divergent
		2017	1	0.37	0.48 ± 0.15	0.96	Reference
		2018	1	0.43	0.48 ± 0.15	1.15	Reference
		2019	4	0.79	0.55 ±0.22	0.56	Mildly Divergent
		2020	5	0.74	0.55 ±0.22	1.11	Mildly Divergent
		2021	5	0.88	0.53 ± 0.14	0.90	Mildly Divergent
		2022	5	0.81	0.53 ± 0.14	0.94	Mildly Divergent
Jordan Creek	Fraser River – Georgia Basin 2005	2016	4	0.78	0.53 ± 0.14	0.82	Divergent
		2017	4	0.76	0.53 ± 0.14	0.82	Mildly Divergent
		2018	4	0.73	0.53 ± 0.14	0.95	Mildly Divergent
		2019	4	0.57	0.53 ± 0.14	0.82	Reference
		2020	4	0.74	0.53 ± 0.14	0.47	Divergent
		2021	4	0.83	0.53 ± 0.14	0.95	Divergent
		2022	5	0.67	0.55 ±0.22	0.90	Mildly Divergent
River of Golden Dreams (Upper)	Fraser River 2014	2016	3	0.70	0.41 ±0.17	1.16	Mildly Divergent
		2017	3	0.70	0.41 ±0.17	1.16	Mildly Divergent
		2018	5	0.94	0.55 ±0.22	1.20	Divergent
		2019	3	0.71	0.41 ±0.17	1.16	Mildly Divergent
		2020	4	0.48	0.53 ± 0.14	1.19	Reference
		2021	5	0.86	0.55 ±0.22	0.91	Mildly Divergent
		2022	5	0.96	0.55 ±0.22	0.90	Divergent
River of Golden Dreams (Lower)	Fraser River 2014	2016	4	0.57	0.53 ± 0.14	1.18	Reference
		2017	5	0.72	0.55 ±0.22	1.22	Reference
		2018	5	0.59	0.55 ±0.22	1.17	Reference
		2019	5	0.39	0.55 ±0.22	1.21	Reference
		2020	5	0.58	0.55 ±0.22	1.21	Reference
		2021	4	0.59	0.53 ± 0.14	1.18	Reference
		2022	5	0.89	0.55 ±0.22	0.54	Mildly Divergent
Whistler Creek	Fraser River – Georgia Basin 2005	2022	4	0.94	0.5 ± 0.2	1.18	Mildly Divergent

Table 7-3 below shows a comparison of the CABN database analysis results for Jordan Creek using the Fraser River 2014 Reference Model and the Fraser River – Georgia Basin 2005 Model.

Table 7-3 Comparison of the CABIN Database Output for Jordan Creek using different Models.

Site	Year	Fraser River 2014 Model Analysis Results	Fraser River - Georgia Basin 2005 Model Analysis Results
Jordan Creek	2016	Mildly Divergent	Divergent
	2017	Mildly Divergent	Mildly Divergent
	2018	Mildly Divergent	Mildly Divergent
	2019	Reference	Reference
	2020	Mildly Divergent	Divergent
	2021	Reference	Divergent
	2022	Reference	Mildly Divergent

The Fraser River – Georgia Basin 2005 Model showed either similar or slightly worse benthic invertebrate community health as compared with the Fraser River 2014 Model, which seemed more consistent with some alteration in water quality observed in the past.

7.4 Discussion and Recommendations

Most benthic invertebrate sampling sites (4 out of 6) were observed to be Mildly Divergent from Reference Condition in 2022 while Jordan Creek was assessed to be in Reference Condition or Mildly Divergent (depending on the Reference Model used) and the (lower) River of Golden Dreams was Divergent from Reference Condition. Results from some of the past years of sampling on Jordan Creek have shown elevated numbers of pollution-tolerant organisms. These observations and accompanying water quality data that also showed some cause for concern were not seen in 2022 where the creek was deemed to be Mildly Divergent from Reference Condition. Based on this result, Jordan Creek appears to be recovering from past anthropogenic disturbance and benthic invertebrate communities even reached Reference Conditions in 2019, confirming some level of resiliency. It is noted, however, that Jordan Creek had the highest proportion of Chironomids (approximately two-thirds of the invertebrate assemblage), which are as a group relatively more tolerant to water quality as compared with some other taxonomic groups. In addition, *Heptageniidae* (a family of Mayflies) which typically live in the interstitial spaces of fast-flowing creeks with unembedded, coarse substrate, were entirely absent from this sampling site but present elsewhere.

The (upper) River of Golden Dreams shows a certain level of variability in the CABIN assessment results over the years, with communities ranging from Divergent from Reference Condition (2018 and 2022) to Reference Condition in 2020. Such variability may be linked to low densities of some of the expected taxa which are not collected every year, and will be further assessed during the next year of monitoring.

Specimen abundance was observed to be low in 2022 in comparison to previous sampling years, with most sites requiring the sorting of the entire sample to achieve the minimum of 300+ specimens required by CABIN. The lower site on the River of Golden Dreams did not achieve this minimum number of specimens, which has likely affected the CABIN assessment results. The relatively cold and wet spring and early summer in southwestern BC in 2022 could have potentially impacted specimen abundance through increased frequency of creekbed disturbance from higher flows and consequently increased specimen drift.

No taxa considered to be intolerant to degradation of habitat and water quality was observed at any of the sites; however, the abundance of truly pollution-tolerant taxa was generally moderate thereby not showing any substantial evidence of habitat degradation.

Despite all sampling sites being geographically close to each other, Jordan Creek and Whistler Creek are part of the Howe Sound drainage (flowing south), whereas the River of Golden Dreams, Twenty-One Mile Creek and Crabapple Creek (flowing north) are situated within the Fraser River watershed. This affects the CABIN Reference Model used to analyze the data and Jordan Creek was erroneously included in a Fraser River-specific Model in previous years (Fraser River 2014). The invertebrate data for this creek was re-processed using a more adequate Model, including the Georgia Basin (Fraser River – Georgia Basin 2005).

We intend to incorporate the following recommendations into the 2023 work plan, after consultation with RMOW staff:

- Upon preliminary review of historical data, it appears that the assignment of each test site to a Reference Group Number (see Table 7-3) varies from one year another. Within a given Model, the assignment to a specific Reference Group is typically based on habitat variables (e.g., slope, dominant substrate, bankfull width, stream order, etc.) that remain relatively consistent from one year to another, except when high morphogenic flows changes stream morphology. We propose to check for inconsistencies in predictive habitat metrics entered for all the sites since 2016. It is noted that some issues with units have already been identified during this year's comparison to previous years.
- Creating summary lists of all the invertebrate taxa identified at each site would improve comparisons of benthic invertebrates year over year and identify taxa that may have disappeared or appeared since the beginning of the invertebrate surveys. This would require integrating functional feeding traits and/or known pollution tolerance levels (e.g., through taxon-specific Hilsenhoff Biotic Tolerance Index). Additionally, a more in-depth review of which *expected* taxa present in the Reference Sites are missing from the test sites, with a review of their ecological requirements, would help understanding any divergence from Reference Condition.
- It is proposed that one additional benthic invertebrate sample be collected at each site in 2023, specifically targeting micro-habitat types that cannot not be sampled during the three-minute kick period as described in the CABIN Field Manual. The objective of this additional sample would be to detect some new invertebrate taxa that may be missed during the standard three-minute kick sampling by specifically targeting depositional areas with coarse organic debris, riparian vegetation in contact with water, and other areas difficult to access. Some taxa in depositional areas may bring relevant additional information regarding the health of the benthic communities and help draw conclusions with the long-term trends.
- An updated Fraser River Model was recently released (2021) and all information will be re-assessed using this new Model in 2023. This re-assessment requires the calculation or research of new predictive variables, which will be added next year due to time constraints in 2022.

As climate change has increase the frequency and intensity of extreme weather events, it is anticipated that taxa with a narrow ecological niche will be replaced by more ubiquitous species. Changes in species assemblage (i.e., species richness) have traditionally been assessed to detect impairment or evidence of change, but more recent advances in in the application of functional traits (e.g., feeding type), have provided an alternative approach to assess the functional structure of communities (Mouillot et al., 2013) that will be investigated further in 202

8. Water Temperature and Quality

Key Takeaways

Water Temperature: Possible worsening	Water Quality: Stable

1. Temperature records for 2022 were not available because logger batteries failed in late 2021. Stream records that were available generally showed stable trends, with two exceptions: (i) high temperatures during the summer 2021 caused by the heat dome last year; and (ii) concerningly high temperatures in Jordan Creek that were nearing the threshold that could harm fish.
2. Two of the six temperature loggers installed in 2016 are no longer functional, at Alpha Creek and Lower Crabapple Creek. We suggest that the RMOW purchase and install new loggers to allow continued monitoring of stream temperatures, especially Whistler Creek and/or other creeks that flow south.
3. Temperature loggers need to be maintained on a regular basis. We recommend that the RMOW download the temperature data on a regular schedule (e.g., every three to four months) and replace batteries on scheduled dates to prevent loss of data.
4. All water quality parameters examined were similar to previous years and were within Provincial water quality standards. Trends in water quality data are generally stable, with no evidence of significant change in any stream.

8.1 Introduction

The ongoing objectives of water quality monitoring and fish habitat within this program is to collect meaningful long-term data that can be used to assess the overall health of aquatic biological communities within the RMOW. In addition, this data will inform other components of the program as well as assist in charting long term climatic changes within the local area.

8.2 Methods

The 2022 stream water temperature monitoring program provided data from four sites (Figure 7.1 & Table 8.1) using Onset® HOBO® MX2201 Pendant wireless loggers set to record stream temperature at hourly intervals. Due to issues with batteries and logger damage, no temperature data is available for all sites for the first half of 2022. The most recent data available covers the period May 2020 to December 2021. Data for previous years dating back to 2016 is also included but is only available for the Jordan Creek, Upper Crabapple Creek and the ROGD US site. Sampling locations and most recent period of record is shown in Table 8-1.

Additional in situ water quality measurements including dissolved oxygen (DO), pH, and conductivity were measured in 2022 using a hand-held YSI Pro plus meter. Measurements were taken as part of fish habitat surveys conducted alongside CABIN benthic invertebrate sampling. In addition, a new benthic/fish habitat site on Whistler Creek was selected for 2022 monitoring (Figure 7-1).

Fish habitat data was collected according to BC Resource Information Standards Committee Criteria (RIC 2008) for fish habitat sampling. Fish habitat data was collected by lead surveyor Jason Macnair and field assistants: Bob Brett (Snowline) and Rebecca Merenyi (RMOW)

Table 8-1. Temperature logger location and data range for the monitoring period.

Site	Easting	Northing	Data Range	Notes
Crabapple Creek Downstream	502030	5552670	n/a	Missing
Crabapple Creek Upstream	502426	5550589	May 2020-Dec 2021	
Jordan Creek	500258	5549255	May 2020-Dec 2021	
River of Golden Dreams	502066	5552829	May 2020-Nov 2021	
Scotia Creek	499199	5548227	n/a	Plugged (unreadable)
Twenty-one Mile Creek	501910	5552856	May 2020-Nov 2021	

8.3 Results and Discussion

8.3.1 Stream Temperatures

Average monthly stream temperatures for the most recent period of record (May 2020 – December 2021) ranged from a low of 0.3°C in February 2021 in Crabapple Creek to a high of 18.4 °C at Jordan Creek for the month of August 2021. Daily maximum temperature was 20.4 °C on August 13, 2021, in Jordan Creek and the daily minimum temperature was -0.2 °C on December 18, 2021, at Crabapple Creek U/S. For the 2016-2021 period of record the average monthly stream temperatures varied from a low of -0.21°C in January 2017 at Crabapple Creek D/S to 18.4 °C at Jordan Creek in August 2021 (Appendix G).

With the exception of Jordan Creek, water temperature in the streams examined were all within approved British Columbia Water Quality Guidelines (BC WQGS) with respect to supporting aquatic life. Jordan Creek has been the warmest creek throughout the study period, possibly due to the fact that it is immediately downstream of a lake – Nita Lake – which receives strong solar radiation in the summer months and then feeds Jordan Creek from this warm surface water (Figure 7-1; Figure 8-1). There is ample evidence elsewhere for this lake heat influence on downstream temperatures (e.g., Mellina 2002, Moore 2006, Dripps 2013). It would be helpful to have temperature data for Nita Lake to test its influence on downstream water temperatures in Jordan Creek, but none was found in the preparation of this report. If it is not already being recorded by the RMOW or other agency, perhaps a local citizen group would be willing to measure temperatures for future analysis.

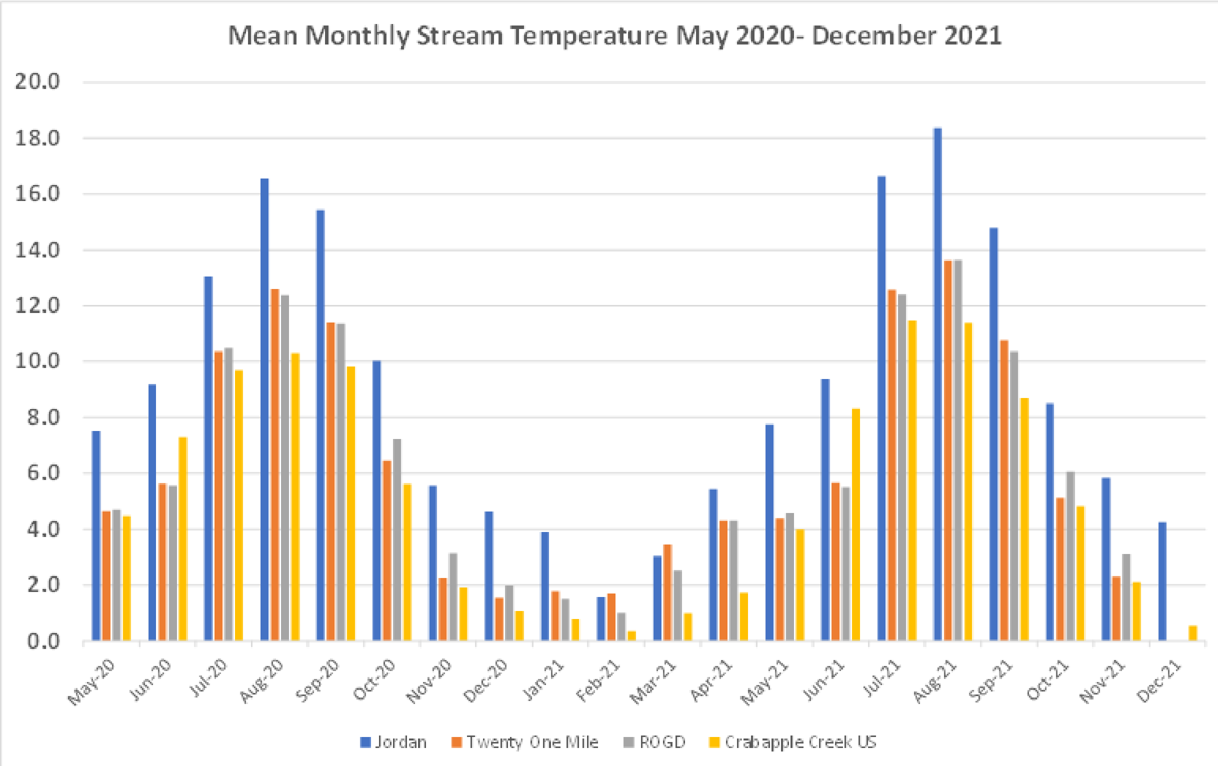

Figure 8-1. **Mean monthly stream temperature (°C) for May 2020 to December 2021.**

Another area of concern, detected from the stream temperature monitoring, was a near month-long period (July 28-August 22) where the daily mean in Jordan Creek was above 18 °C and daily highs were close to or above 20 °C (Appendix G). Temperatures in this range are above provincial guidelines for all age classes of salmonid species known to inhabit the RMOW watershed, and can lead to undue stress in juvenile and adult salmonids that can cause increased mortality under extended exposure periods of as little as two weeks (Crossin 2008, Dill 2011). Resident Cutthroat and Rainbow Trout are more than likely able to tolerate these temperatures, but more heat-sensitive fish such as Kokanee and Bull Trout could see their productivity impacted (Verhille, 2016, Decker 2011).

Evidence for the potential impact of extreme climatic events on aquatic species within the RMOW is demonstrated by examining stream data from 2021 against previous years. In the summer of 2021, the Pacific Northwest of North America was affected by an extreme heat event – referred to as a “heat dome” – that most strongly impacted the region from late June to early July, but also extended into mid-August (Sjoukje et. al. 2021). Table 8-2 shows the mean combined July-August temperatures for four creeks with available data from 2021. In 2021, all creeks examined had a record high mean temperature for the period of record. Despite the limited scope of the stream temperature data presented, it does demonstrate the potential impact of such events, which are only predicted to become more frequent and with increased intensity due to climate change (Falke 2015).

Table 8-2. **Mean July-August temperature 2016-2021 showing evidence of impact of the 2021 heat dome on stream temperature.**

Year	Jordan Ck	ROGD	Twenty One Mile	Crabapple Ck U/S
2016	15.9	12.3		10.8
2017	15.4	10.7		10.7
2018	16.4	11.7		
2019	17.2	12.9		
2020	14.8	11.4	11.5	10.0
2021	**17.5**	**13.0**	**13.1**	**11.4**

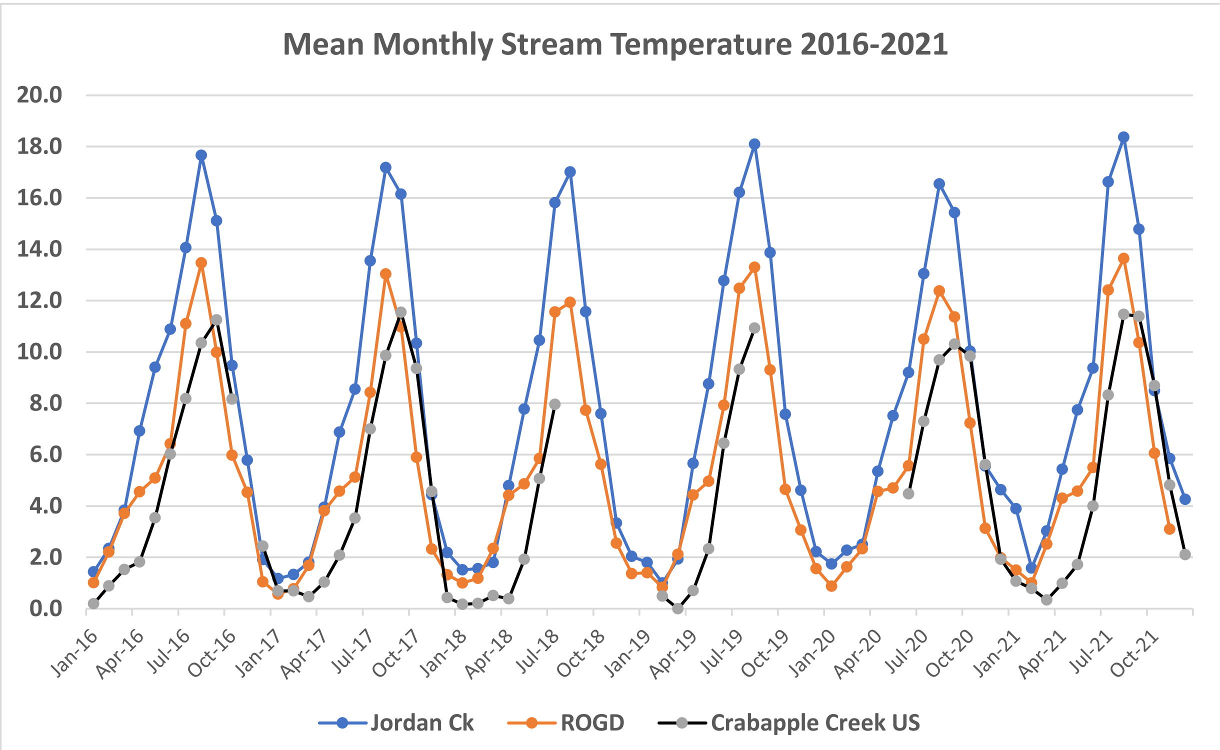

Figure 8-2. **Monthly mean temperatures for Jordan, Crabapple and River of Golden Dreams Upstream site, Jan 2016-Dec 2021. Note the consistently higher temperature in Jordan Creek compared to the others, as well as the peak high July-August 2021 period for all sites.**

8.3.2 Water Quality

All in situ, instantaneous water quality data collected in 2022 was within all Provincial and Federal guidelines for the protection of aquatic life (BC WQG MOE, 1997; Table 8-3). Potential incorrect measurements are marked with an asterisk in Table 8-3, as these results are likely a result of operator or instrument error and are therefore not included in any discussion of the results. Results that are outside of provincial WQGS are in italics.

Dissolved oxygen (DO) varied from 9.3 mg/L to 11.6 mg/L across all sites in 2022, and saturation ranged from 97 to 104 percent. Across all years DO has been between 7.5 mg/L to 11.7 mg/L. Dissolved oxygen at all sites in all years was above the BC WQG instantaneous minimum of 5 mg/L (BC MOE, 1997) for all fish life stages. In some year a number of measurements were below the BC WQG instantaneous minimum guideline of 9 mg/L for buried embryo/alevin life stages.

Stream pH varied from 6.4 to 7.3 across all sites in 2022 (Table 8-3). The pH of 6.4 at Crabapple Creek is slightly below the BC pH guideline of 6.5, otherwise all results conformed to the pH guidelines for the support of aquatic life. Across all sites and years and the stream pH has varied from 6.2 to 7.8. These estimates align with expected values of pH for streams along the coast of British Columbia.

Conductivity, which represents the ability of water to conduct electricity by measuring dissolved salts and is therefore an indirect way to measure how saline water may be, is represented in Table 8-3 as Specific Conductance (SC) in microsiemens per centimetre, (µS/cm). In 2022 the SC ranged from 15.3 µS/cm to 54 µS/cm for all sites with the exception of Crabapple Creek at 190 µS/cm. Instantaneous estimates of SC on Crabapple Creek have been well above that of all other creeks sampled since 2016 and ranged from 190 µS/cm to 336 µS/cm (Table 8-3). There is no confirmation of the reason for the elevated SC on Crabapple Creek, though an anthropogenic source is possible as the creek passes through residential areas as well as a golf course. There are no provincial or federal standards for SC with respect to the protection of aquatic life, as each lake and stream tends to have a relatively constant range of conductivity that may vary from others but is suitable for the local environment. However, most literature recommends that in our region a SC of over 1000 µS/cm might be cause for concern, and under 200 µS/cm is generally considered to be excellent conditions.

Table 8-3. In situ water quality results 2016-2022

Site ID	Date	Oxygen (mg/L)	Dissolved Oxygen (%)	pH	Specific Conductance (µS/cm)	Temperature (°C)
Jordan Creek	03-08-16	9.3	94	7.1	64	15.8
	26-07-17	*8.9*	88	7.1	105	14.9
	01-08-18	*7.7*	83	7.1	65	18.8
	30-07-19	9.4	98	7.7	78	17.4
	05-08-20	*8.1*	83	7.7	63	16.7
	27-07-21	9.2	105	7.2	55	18.3
	23-07-22	10.2	104	7.0	51	13.0
Crabapple D/S	02-08-16	9.4	89	7.6	218	12.7
	25-07-17	11.6	108	7.4	336	12.0
	01-08-18	*7.5*	76	7.5	194	16.0
	30-07-19	10.0	97	7.6	235	13.9
	04-08-20	9.1	87	9.0*	218	13.3
	28-07-21	10.8	99	6.9	200	18.6
	22-07-22	9.3	97	*6.4*	190	14.0
Twenty One Mile	03-08-16	9.4	87	*6.3*	40	12.0
	25-07-17	11.3	104	7.1	40	11.6
	31-07-18	14.6*	160*	*6.2*	38	19.9
	30-07-19	9.8	94	7.0	52	13.3
	04-08-20	*8.0*	77	9.4*	47	13.9
	28-07-21	11.7	113	7.0	55	14.2
	22-07-22	11.6	98.5	7.3	15	8.0
ROGD US	03-08-16	*8.3*	76	7.3	64	11.7
	25-07-17	11.0	99	7.1	50	10.5
	31-07-18	*7.5*	75	7.2	36	15.5
	30-07-19	9.8	92	6.8	33	12.8
	05-08-20	*8.2*	79	7.7	42	13.6
	28-07-21	10.6	100	7.1	46	13.1
	22-07-22	10.8	99	7.0	20	11.5
ROGD DS	05-08-16	9.9	99	7.8	69	15.2
	25-07-17	9.8	93	7.0	73	13.0
	01-08-18	*8.2*	86	6.7	48	17.8
	31-07-19	9.9	94	7.6	61	13.1
	05-08-20	9.1	93	7.5	71	16.3
	27-07-21	11.5	118	7.3	74	16.6
	22-07-22	10.4	100.2	7.1	29	10.5
Whistler Creek	23-Jul-22	10.9	99.6	6.8	37.3	8.4

The Canadian Water Quality Guidelines for the Protection of Aquatic Life state the lowest acceptable dissolved oxygen concentration, for a cold-water aquatic ecosystem, as 9.5 mg/L for early life stages, and 6.5 mg/L for other life stages. The Canadian Water Quality Guidelines for the Protection of Aquatic Life, state the guideline range for pH as 6.5 to 9.0.

9. Fish and Fish Habitat

Key Takeaways

Fish Populations: Inconclusive (Data deficient)	Fish Habitat: Stable

1. Due to the low quality of data supplied by the RMOW (adult escapement data, much of it collected by volunteers), it was not possible to reliably estimate the population of Kokanee and Rainbow Trout. Further analyses could not reveal any population trends; again, primarily due to issues of data quality and survey consistency. At this point, this data is useful only for confirming presence/absence and in-stream distribution.
2. An expanded and program would be required to achieve the goal of accurate population monitoring, and would include methods such as mark-recapture, estimates of survey life (residence time of spawning fish), and measures to ensure consistent measurements by surveyors (e.g., repeatable observer efficiency). Whether an expanded effort makes sense within this program needs to be discussed with the RMOW.
3. Bull Trout are the salmonid species most likely to be impacted by climate change due to their demonstrated sensitivity to elevated stream temperatures. Continued collection of temperature data is therefore a critical part of monitoring fish habitat for Bull Trout. Better distribution and spawning data would also be useful, but are likely outside the scope and budget of this program.
4. Surveys in 2022 confirmed good fish habitat conditions in all streams other than two exceptions: (a) the Twenty-One Mile site where habitat was compromised by a lack of canopy cover (it is under the power lines); and (b) the lower ROGD site which has a streambed comprised of fines and organic materials that are inappropriate for salmonid spawning. In both cases, these conditions have been present for many years (if not decades), and therefore are not a new cause for concern.

9.1 Introduction

Fish habitat and water quality data were collected during fish habitat surveys in order to provide baseline information on fish and fish habitat in the RMOW study area. Streams were assessed using methods based on the Reconnaissance 1:20,000 Fish and Fish Habitat Inventory Protocol (RISC 2001) and the Reconnaissance 1:20,000 Fish and Fish Habitat Inventory: Site Card Field Guide (RISC 1999b). This involved characterizing fish habitat over a section of stream by measuring physical attributes such as: gradient, channel width, temperature and water quality, describing cover types, cover abundance and substrate quality and describing stream morphology. Based on the attributes collected at the monitoring sites, professional judgement was used to rate habitat suitability for all fish life history stages (spawning, incubation and rearing). All fish habitat data along with site photos are found in Appendix G.

9.1.1 Stream Temperature and Fish Habitat

A crucial step in tracking the impact of climate change in the RMOW is the long-term collection of local stream temperature regimes. Stream temperature changes resulting from modifications to the natural landscape and climate change can potentially have a negative impact on aquatic ecosystems, particularly for cold-water species such as salmonids (Beschta et al., 1987; Eaton and Scheller, 1996). In recent years there has been increasing attention in the Pacific Northwest and elsewhere to identify "temperature-sensitive streams" (Ruesch, A.S. 2012, Nelitz, 2009).

Research across the entire range of Bull Trout habitat in British Columbia increasingly shows that stream temperature should be treated as the primary indicator of habitat suitability, and that stream temperatures >15°C likely indicate poor or marginal suitability (Haas 2001; Decker and Hagen 2007). Furthermore, climate change, because of its direct and potentially wide-ranging impact on stream temperature regimes, should be regarded as the most important future threat to Bull Trout across the province as a whole, although other threats may be more important at a local level (Falke, 2015, Decker Hagen 2011).

Bull Trout in the are a blue listed species in BC (CDC 2022). This species is particularly vulnerable to habitat and climate shifts due to its sensitivity to changes in water temperature and habitat loss. Climate and landscape change might isolate small patches of Bull Trout habitat, often in the headwaters of watersheds, and precisely where the RMOW is situated (Falke 2015).

Stream temperatures in excess of 15° C are most likely to impact local Kokanee and Bull Trout populations as their sensitivity to elevated water temperature is much greater than Rainbow or Cutthroat Trout (Verhille 2016, Bear 2011). More stringent temperature guidelines have been recommended for streams and rivers inhabited by Bull Trout, as Bull Trout are known to have the highest thermal sensitivity of salmonids native to British Columbia (Decker 2011).

Stream temperature data collected over the past several years shows that all creeks, with the exception of Jordan Creek, currently have a suitable year-round temperature regime for Bull Trout. The mean July-August temperatures in Jordan Creek have been well above what Bull Trout are known to tolerate (Table 8-2; Figure 8-1). We could find no record of Bull Trout in Jordan Creek or Nita Lake, but populations of Bull Trout are confirmed in the Daisy Lake and Cheakamus River 14km downstream (Hagen & Decker, 2011). The possibility exists that Bull Trout are seasonally excluded from this area of the headwaters due to the warmer summer temperature regime. In addition, the warmer temperatures could also impact Kokanee which are known to inhabit Nita Lake and spawn in Whistler Creek, which is the main tributary to Nita Lake.

It is entirely possible that the elevated temperatures in Jordan Creek are localized and do not extend any further downstream than Alpha Lake, which is where Jordan Creek flows into. Jordan Creek is a short stretch of creek – approximately 350 metres in length – and its discharge is small enough that the warmer temperatures from it would likely be reduced by downstream watercourses fed directly from glacier and snow melt.

9.1.2 Fish Habitat Surveys

All fish habitat data collected in 2022 confirmed that monitoring sites were in Good to Fair condition for all life stages of fish inhabiting the RMOW area. Table 9-1 shows the ranking criteria and how each ranking is determined. Habitat characterises are grouped into five broad categories for evaluation, these are: Water quality, site area and substrate, water depth and velocity, stream morphology, and instream cover.

Professional judgement was used to assess the habitat criteria at each site. All fish habitat data collected with accompanying rating is shown in Appendix G.

With respect to the criteria outlined in Table 9-1, two sites had a Fair rating under the habitat category of instream cover and substrate. Twenty-one Mile Creek had a “Fair” rating under instream cover as a result of the monitoring site location being directly underneath a powerline right of way. Due to this proximity, vegetation along the right-of-way must be constantly pruned to keep it clear of the overhead transmission cables. This situation means that this site will not be able to be adequately shaded due to constant pruning of larger trees and shrubs. Lack of this type of larger vegetation may also reduce the amount of woody debris that enters the stream. The ROGC D/S site also received a “fair” rating in the category substrate category as the streambed had a dominant cover of fines and organic material which is unsuitable for spawning salmonids.

Table 9-1. Showing ranking criteria for fish habitat monitoring

Overall Fish Habitat Quality	
Rank	**Criteria**
Poor	The necessary physical/biological components for healthy fish habitat at all life stages are missing or severely defficient
Fair	Some of the necessary physical/biological components for healthy fish habitat are present, but some important components are missing or defficient
Good	All of the necessary physical/biological components for healthy fish habitat are present at the monitoring site.

9.2. Population Estimates for Adult Rainbow Trout and Kokanee

9.2.1 Introduction

Adult escapement observations for Rainbow Trout for the years 2011-2021 and Kokanee data for 2017 was provided by the RMOW. The intent of examining this data was to determine if it could be realistically applied to a standard estimator of escapement (defined in this case as the number of adult fish that enter local rivers to spawn), with the goal of providing accurate year-over-year estimates of Rainbow and Kokanee populations. Within this context, it is important to note that existing data provided by the RMOW was not collected with a budget or design that would lend to rigorous statistical estimates of spawning or resident salmonid populations. Depending on the goals of a sampling program, there are many ways to measure adult salmon populations, from measurements of abundance using peak counts, or peak count plus carcass counts, to complicated statistical approaches involving intensive tagging and mark-recapture programs. Outlined here are possible approaches for future monitoring and recommendations on improving enumeration techniques in order to produce adult spawner population estimates that can be compared year over year.

9.2.2 Methods Kokanee

Weekly counts of spawning Kokanee from 2017 surveys on the River of Golden Dreams (ROGD) were applied to an area-under-the-curve analysis used to estimate adult escapement for anadromous salmon in small to medium streams. This method is commonly used in surveys of this kind, and is most simply defined as:

Equation 1

$$N = AUC / r \bullet v$$

Where:
N = total estimated number of individuals in the system
AUC = the "area under the curve": $A_1 + A_2 + A_3 + \ldots + A_n$
A_n = number of spawners counted for visit n * time between visits
r = estimate of stream residence time or "survey life" during spawning. Defined as the number of days a fish is in the river to spawn, from the moment of entry to death.
v = visibility, an estimate of observer efficiency using a maximum value of 1.0

Results of the escapement estimate are seen in Table 9-3. This estimate was generated using a modified version of the method shown in Equation 1 where r is represented as "survey life" (SL) and follows a slope corresponding to date of entry of spawning fish rather than a fixed value throughout the run. (Korman 2002; Decker et el. 2003). This model incorporates research indicating that stream residence times for spawning salmon are not uniform throughout the escapement period. This trend has been noted by a number of studies that demonstrate a pattern of longer residence times for adults entering early in the run, and shorter residence times for those that enter later (Perrin and Irvine 1990, English et al. 1992, Korman et al. 2002). This equation is as follows:

Equation 2

$$S_t = S_{max}\left\{1 - \frac{t}{S_{half} + t}\right\}$$

Where:

S_t = survey life in days for fish entering on day t
S_{max} = maximum survey life possible
S_{half} = the day at which the survey life is half the maximum
S_l = the slope of the relationship

For the example used here, all values input into the model, with the exception of start of run timing, are considered to be a "best guess" as there is no local empirical data to use for any of the parameters. We chose the following values to input into the model, shown below and in Table 9-2:

- "SL" was set at 15 days
- "v" was set at 0.50
- Start of run timing was set August 30, 2017
- End of run timing was set at October 10, 2017

For Equation 2, S_{max} was set as 15 days, S_{half} was set at 20 days (in this case the mid-point in the escapement curve), and the S_l was set at 1.0.

9.3 Results and Discussion

(Note: This escapement estimate is used to demonstrate how this model functions and is not intended to be an estimate of actual Kokanee escapement for 2017.)

The example used gave an escapement estimate of 487 Kokanee in the ROGD for the 2017 survey period. Survey start timing is well defined as there is a confirmed "0" date prior to fish entering the system, though end of run timing was not, as there was no survey date confirming that all fish had completed spawning, therefore, the end date of October 10, 2017, had to arbitrarily applied. A necessary component of defining the extent of the AUC is a defined start period, where no fish have entered the system, and end period, where all fish are assumed to have left the system and no more fish are expected to enter. Additional problems arose with visibility and survey life which also had to be guessed at.

Table 9-2. Summary of escapement estimate for Kokanee. Final estimate is the sum of all dAUC values. "Days" is the gap in days between surveys.

2017 Kokanee River of Golden Dreams						
Total Count	**SL**	**AUC**	**dAUC**	**Days**	**v (1.0)**	**Date**
0	15.0	0	0	0	0.50	30-Aug-17
100	10.3	1800	174	9	0.50	8-Sep-17
115	8.8	1150	130	5	0.50	13-Sep-17
125	7.7	1250	163	5	0.50	18-Sep-17
8	6.4	128	20	8	0.50	26-Sep-17
0	4.9	0	0	14	0.50	10-Oct-17
348		4328	487			
Escapement Estimate			**487**			

While the values input into this example do fit the model and do return an estimate of escapement, issues with the lack of accurate data make the estimate too imprecise to be used as a valid tool to represent adult Kokanee population in the ROGD at this time. Table 9-3 demonstrates how sensitive the model is to alterations in the values for SL and v. The "v" is set at 0.50 in the example in Table 9-1, but by simply altering it to 0.25 or 0.75 it causes the escapement estimate to vary from 974 and 325 respectively (Table 9-2). Further changes in SL can return estimates as high as 1217 and as low as 270. These examples highlight the potential uncertainty in the estimate in the absence of accurate data.

Another shortcoming of the adult survey data provided is a lack of information on what portion of the stream was surveyed. Population estimates need to be adjusted based on how much of the potential spawning habitat is being surveyed. For example, If the portion of the river that is surveyed on each date amounts to only 50% of the entire available habitat, then yearly calibration surveys that cover the entire stream length would also be needed in order to adjust for adults located outside of the normal survey area. If the goal is to track yearly trends in the population of an entire stream, accurate information on the extent of spawning populations within the entire stream is required.

Table 9-3. The wide range of escapement estimates generated by applying different values to the SL (residence time) and "v" observer efficiency.

SL	v	Escapement Est.
15	0.25	974
15	0.75	325
12	0.25	1217
12	0.75	406
18	0.25	811
18	0.75	270

Using a standard or modified AUC method it was possible to generate an estimate of escapement for Kokanee; however, due to the demonstrated data gaps and missing information, the estimates it generates could not be considered accurate enough to present in this report. As discussed, the predominant issues with the data were related to a lack of information on stream residence time, arrival and run end timing, and observer efficiency. Variations in run timing, survey timing interval, and stream residence times from year to year seriously reduce accuracy and consistency of the resulting estimates (Thomas 1982). Perrin and Irvine (1990) and Schwarz and Manke (2000) also concluded that stream residence times and observer efficiency should not be extrapolated between years or species on the same stream. To quote Perrin and Irvine (1990): “Survey life (residence time) should be determined on a site-specific basis each time the AUC method is used to estimate escapement.”

Despite these challenges, and with better defined end of run timing and a more accurate representation of visibility and survey life, the use this model could make valid year-over-year escapement estimates feasible. Existing survey methods and level of effort used by the RMOW could easily capture accurate start and end of run dates by ensuring that spawning surveys always cover the full extent of the run.

In addition, applying a repeatable measure of visibility for each survey (such as using a measurement of water clarity and/or discharge at survey time) could provide a repeatable metric of visibility that does not rely on surveyor bias alone. Although this would not be considered a complete representation of observer efficiency, it would provide an improvement on merely a best guess value.

An improvement on estimating survey life is also possible without additional time in the field or an expansion of sampling efforts. An extensive literature search on Kokanee spawner survey life could provide useful analogues from other streams, which could help to refine the SL value used in the model.

Though these improvements would make the AUC model more accurate, they could not replace a mark-recapture program that could much more precisely estimate critical variables of survey life and observer efficiency. Without the yearly accurate assessment of these variables, the AUC estimate used would be considered an index of abundance as opposed to an estimate of the population. However, depending on a programs goal, an exact population value might be unnecessary, as trend monitoring using indexes of abundance are usually more logistically feasible with limited resources (Caughly, 1977).

9.3.1 Rainbow Trout

Adult Rainbow Trout escapement data was provided by the RMOW for the years 2011-2021. Data included weekly counts of spawning Rainbow Trout for 10 creeks: Write-off, Jordan, Lakeside, Scotia, ROGD, Millar, Crabapple, Gonzales, Whistler, and Blackcomb. Of the data provided, only three creeks had sufficient information to be worth examining: Crabapple Creek, Lakeside Creek and Jordan Creek. Rainbow Trout spawner stream counts by RMOW staff provided information on the cumulative number of spawners observed, number of surveys, as well as the yearly peak count and Catch Per Unit Effort (CPUE) determination (Table 9-3).

Unfortunately, it is not possible to calculate a population estimate from the data provided. AUC estimates are not appropriate for resident Rainbow Trout as they do not have the die-off associated with Kokanee or other sea-run Pacific salmon. Accurate annual estimates of resident Rainbow Trout populations require some form of extensive, annual mark-recapture program, or more intensive options such as electronic stream counters or fish fences (Thomas 1982). Current survey methods using peak counts or a CPUE may be suitable for representing a yearly index of abundance only. Although we cannot use quantitative population modelling on indices, it may be that an index of abundance is sufficient for the goals of the monitoring program.

The spawner count data presented in Table 9-4 has a few inefficiencies that makes employing it as a yearly index of abundance problematic. The main issue is the fact that the number of surveys completed each year for each creek are wildly inconsistent. For example, Jordan Creek, the only site that has data for the entire 2011-2021 period, has yearly survey efforts ranging from 1 to 22 days. This inconsistency of effort provides limited confidence in any annual comparisons of Rainbow Trout spawners. Data for Crabapple and Lakeside Creeks also suffer from this, as well as having a number of years where no data is available.

Table 9-4 Showing peak count, CPUE and the number of surveys performed for Rainbow Trout spawner surveys 2011-2021

	Jordan Creek			Crabapple Creek			Lakeside Creek		
Year	**Peak Count**	**CPUE**	**# Surveys**	**Peak Count**	**CPUE**	**# Surveys**	**Peak Count**	**CPUE**	**# Surveys**
2021	2	2.0	1	20	19.0	2	21	18.5	2
2020	4	4.0	2	34	23.0	3	18	11.0	2
2019	4	1.9	10	36	18.7	6	n/s	n/s	n/s
2018	11	1.4	15	15	7.6	5	15	15.0	1
2017	5	0.8	21	28	15.9	8	43	20.7	19
2016	14	1.3	22	n/s	n/s	n/s	5	5.0	1
2015	21	7.2	9	20	6.8	9	8	2.6	12
2014	21	0.0	4	n/s	n/s	n/s	46	18.5	12
2013	8	1.7	11	9	6.3	3	n/s	n/s	n/s
2012	7	1.8	6	n/s	n/s	n/s	n/s	n/s	n/s
2011	15	8.5	6	13	2.4	8	n/s	n/s	n/s
Average	**10.2**	**2.8**	**9.7**	**21.9**	**12.5**	**5.5**	**22.3**	**13.0**	**7.0**

Figure 9-1 graphically illustrates the yearly peak counts and CPUE for Jordan Creek. The trendline calculated for this data set indicates a trend towards decreasing Rainbow Trout spawners for both variables examined. However, when one considers the survey effort in Table 9-4, it shows only one survey was performed in 2021 and only two in 2020. By comparison, there were 22 surveys in 2016 and 21 surveys in 2017. Unless survey efforts are reasonably consistent across years, there will not be much confidence in tracking population trends across years.

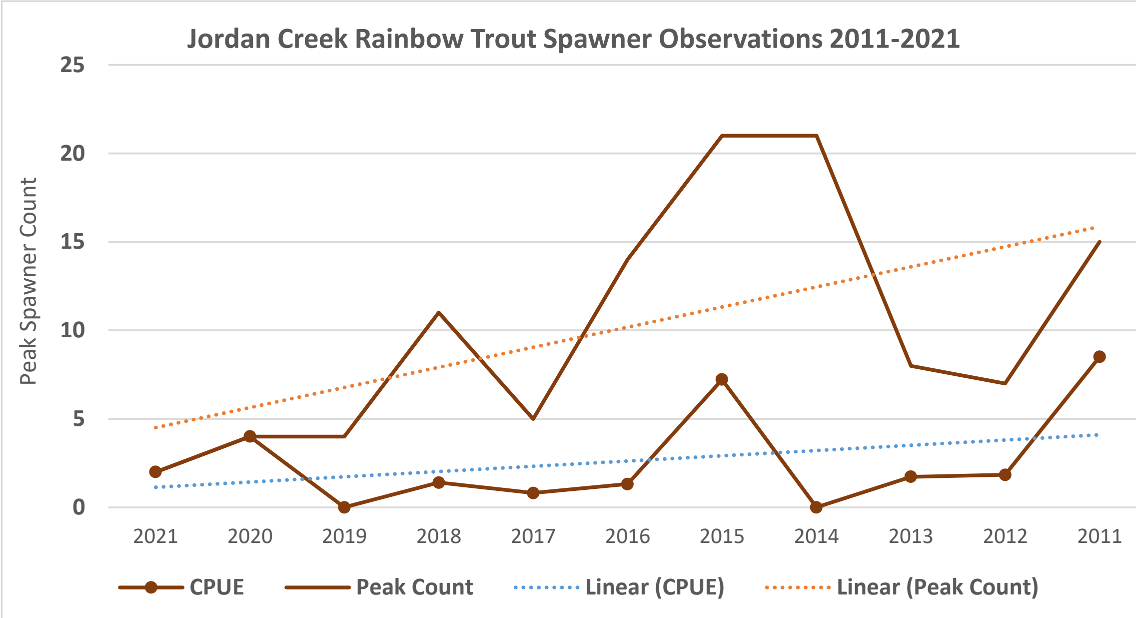

Figure 9-1. Yearly peak count of Rainbow Trout spawners, plus CPUE and linear trendlines for both variables. Inconsistent data collection renders year-over-year trend analysis invalid.

9.4. Recommendations

1. Continue with stream temperature data collection on as many creeks as possible. Consider expanding temperature monitoring to include Whistler Creek, Nita Lake and further downstream of Jordan Creek in order to investigate the possible causes of elevated temperature in Jordan Creek. This information should be considered critical with respect to monitoring Bull Trout and Kokanee habitat. Bull Trout population vulnerability may depend on the extent to which climate effects can be at least partially offset by managing factors such as reproductive habitat protection and maintenance of suitable stream and lake temperatures.
2. Rainbow Trout populations are likely the most well-adapted to any landscape and climate changes in the Whistler area, therefore if resources are put into monitoring adult or spawning populations, it is recommended that Kokanee and Bull Trout be the focus. These species are the most sensitive to shifts in climate and landscape change in the area and there is a lack of good information about the distribution of Bull Trout within the RMOW. Available information on spawning, distribution, age class and Bull Trout type is spotty and very little is available, particularly for the last 10 years.
3. Collect data on observer efficiency and water clarity in order to increase reliability of Kokanee spawner surveys. Clearly define what portion of the stream is being surveyed. Population estimates need to be adjusted based on how much of the potential spawning habitat is being surveyed.
4. Clearly define goals of collecting adult spawner data. If the goal is to generate useful estimates of the adult population in order to identify trends and overall abundance, then a much more rigorous approach must be taken to data collection and analysis. If the goal is simply to confirm presence/absence and instream distribution, then current methods of data collection may suffice.
5. Aside from the Jordan Creek temperature issue, all water quality characteristics examined continue to be in a healthy range for coastal streams in respect to the protection of aquatic life. Continued annual monitoring to track water quality is recommended.
6. Continue to collect yearly baseline fish habitat data, in order to support ongoing monitoring of landscape and climate change impacts on aquatic habitat with the RMOW area.

10. Climate Indicators

Key Takeaways

Alta Lake: Trending to a shorter duration of Ice	**Twenty-One Mile Creek Depths: Trending to lower minimums of longer duration**

1. An incomplete record of dates for ice-on (freezing) and ice-off (thawing) on Alta Lake was analyzed for two periods: early (1942 to 1976) and recent (2001 to 2022).
2. The average duration of ice on Alta Lake has been almost one month (27 days) shorter in recent years than in the mid-1900s.
3. Earlier melting in spring has been the strongest contributor to the shorter duration of ice, a result consistent with warming summer temperatures caused by climate change.
4. Depths in Twenty-One Mile Creek recorded by Karl Ricker since 2001 were entered and analyzed for the first time. Though the data is somewhat intermittent (due to an inconsistent number and timing of readings each year), a clear trend has emerged towards longer and more severe periods of low-water.
5. The negative impacts of the July to October drought on water levels downstream in the River of Golden Dreams were mostly offset by higher-than normal beaver dams, which corroborates results and conclusions from beaver monitoring (Section 2).

10.1 Alta Lake Ice-On and Ice-Off Dates

Data Source: Stephen Vogler, The Point Artist-Run Centre[26]

The timing and duration of ice on Alta Lake was introduced as a climate indicator in this program in 2013 (Cascade 2014). The discontinuous dataset includes at least one record (ice on and/or ice-off) for a total of 33 winters between 1942-43 and 1975-76 (“early years”), and 19 winters between 2001-02 to 2019-20 (“recent years”). Although the data is incomplete, some trends can be seen (Table 10-1):

1. There is a clear trend in recent years towards a shorter duration of ice on Alta Lake.
2. On average, Alta Lake freezes seven days later in recent years (averaging December 19th versus December 12th in the early years).
3. The lake thaws an average of 17 days earlier for the corresponding periods (April 5th vs. April 22nd).
4. The resulting duration of ice on Alta Lake has shortened by 27 days in recent years.
5. The minimum duration of ice in recent years is 30 days shorter than in the early years, while the maximum duration is 43 days shorter.

All five of these trends lead to the same conclusions – that in recent years, Alta Lake usually freezes later and melts earlier than during the years from 1942 to 1976.

[26] *Annual data has been supplied by Stephen Vogler. The 2020 data was emailed by him to Bob Brett on January 10, 2020.*

Table 10-1. Summary of available ice records from Alta Lake.

		Early (1942-1976)		Recent (2001-2022)		
		Date	Day Count	Date	Day Count	Recent vs. Early Records
Ice-On	No. of Records	n/a	31	n/a	15	19 records fewer
	Earliest	1945-11-08	312	2006-11-30	334	22 days later
	Latest	1970-01-15	380	2006-01-06	371	9 days earlier
	Median	Dec. 12th	346	Dec. 21st	351	9 days later
	Average	Dec. 12th	346	Dec. 19th	352	7 days later
Ice-Off	No. of Records	n/a	31	n/a	20	13 records fewer
	Earliest	1963-03-23	82	2015-02-20	51	31 days earlier
	Latest	1952-05-21	142	2008-04-29	120	22 days earlier
	Median	April 22nd	113	April 10th	100	12 days earlier
	Average	April 22nd	113	April 5th	96	17 days earlier
Days Frozen	No. of Records	29		14		17 records fewer
	Median	133		110		24 days shorter
	Average	134		107		27 days shorter
	Minimum	81		51		30 days shorter
	Maximum	163		120		43 days shorter

Notes: No records are available for winters from 1976/77 through 2000/01. Ice-on and ice-off dates were not recorded for all years; days frozen was calculated only for those years in which both were recorded.

These observations should be considered within the context of the incomplete and noisy data, especially since 1976 (Figure 10-1). The duration of freezing was relatively consistent in the early years – ice on Alta Lake lasted from 120 to 160 in all but five of the 29 years. While the average duration in the recent period is clearly shorter (Table 10-1), it is also much more variable. Combined with the lack of records for years in the intervening period, this variability precludes the meaningful use of statistical analysis (e.g., regression) to detect trends.

Even taking this variability into account, a scatterplot of ice duration (Figure 10-1) nonetheless shows the clear trend towards a shorter duration of ice on Alta Lake. Consistent with this observation, nine of ten years in which Alta Lake remained frozen for more than 140 days occurred in the early years, and all but three of the years with the shortest duration of ice occurred in recent years.

Digging deeper into this data, it turns out that earlier thawing (in spring) is much more of a factor than later freezing (in fall) when explaining why ice duration has shortened in recent years (Figure 10-2). Ice-on (freezing) dates have remained comparatively stable in recent years compared to early years. Meanwhile, ice-off (thawing dates) are noticeably earlier. And while the ice-on date has been relatively stable and within a similar range in the two reporting periods (usually occurring in December or early January), the ice-off date in recent years is clearly earlier. These records indicate that the main change in Whistler's winters has been earlier (warmer) springs rather than late winters, at least in the valleybottom.

Although Alta Lake records are not on their own enough to conclude with certainty that Whistler's climate has warmed since the mid-1900s, the warming trends they reveal are consistent with other local observations, notably the rapid retreat of local glaciers in that period (e.g., Blackcomb Glacier, Section 5). In addition, the fact that Alta Lake appears to be melting earlier in the spring may be related to the overall trend towards a longer, warmer summer which has resulted in more evidence of climate change in summer months than in winter months.[27]

[27] For example, Arthur DeJong's analysis of glacier data and temperatures on Whistler Mountain showed that rising overnight temperatures in the summer were the main cause of glacial recession (personal communication with B. Brett).

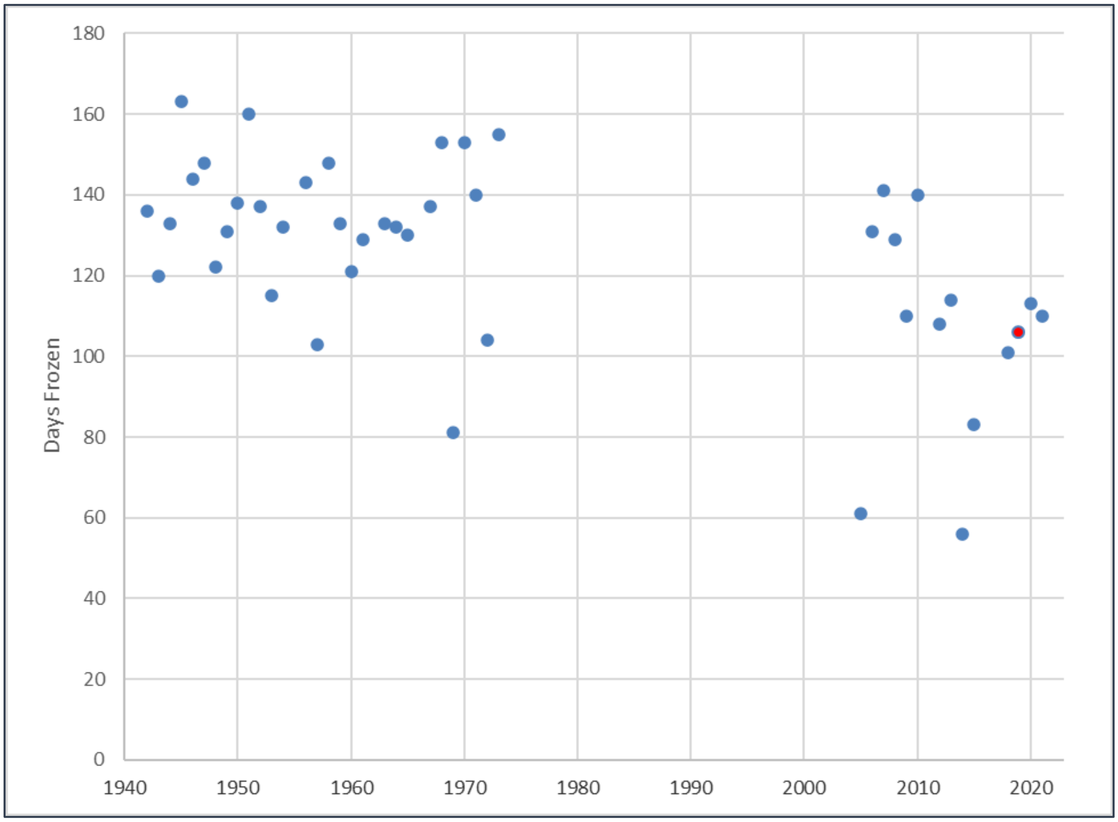

Figure 10-1. Number of days Alta Lake was frozen, 1942/43 to 1975/76 and 2000/01 to 2021/22.

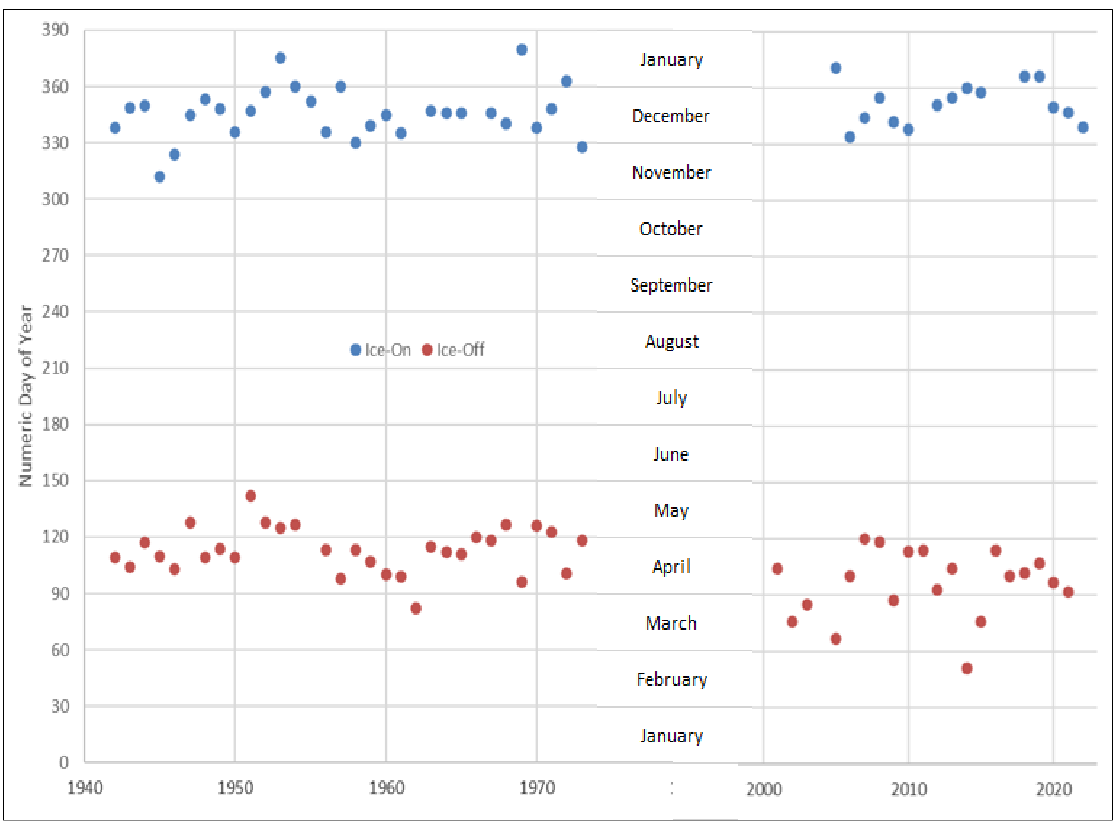

Figure 10-2. Alta Lake Ice-on (top) and ice-off (bottom) by numeric day of year.

10.2 Twenty-One Mile Creek Depths Since 2001

Data Source: Karl Ricker.

10.2.1 Introduction

Karl Ricker has recorded depths on the Twenty-One Mile Creek gauge intermittently since December 1, 2001 (Photo 10-1). In fall 2022, he provided his hand-written notes for data entry and analysis. The resulting dataset spans the period from December 2001 to November 11, 2022 and consists of 1349 records (Table 10-1). While the number of records per year and their timing is inconsistent, there are generally more records for ice-free months and for more recent years. The main goal in analyzing this dataset for the 2022 report was to investigate whether the prolonged drought from July to October 2022 caused unusually low water levels.

Photo 10-1. Since December 2001, Karl Ricker has been recording the depth of Twenty-One Mile Creek just upstream of its confluence with the outflow from Alta Lake.

Table 1-2. Number of records per year (Twenty-One Mile Creek depth data).

Year	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	Total
No. Records	4	84	78	62	65	57	54	34	27	43	53	42	26	36	20	30	36	28	52	163	183	172	1349

10.2.3 Results and Discussion

A simple scatterplot of depths recorded each year (Figure 10-2) shows:

1. There are lower depths recorded in 2021 and 2022 than in the previous 19 years.
2. Although the limited number of records do not reveal conclusive results, there appears to be a trend towards longer and more severe periods of low water (i.e., negative readings at the gauge shown in Photo 10-1).

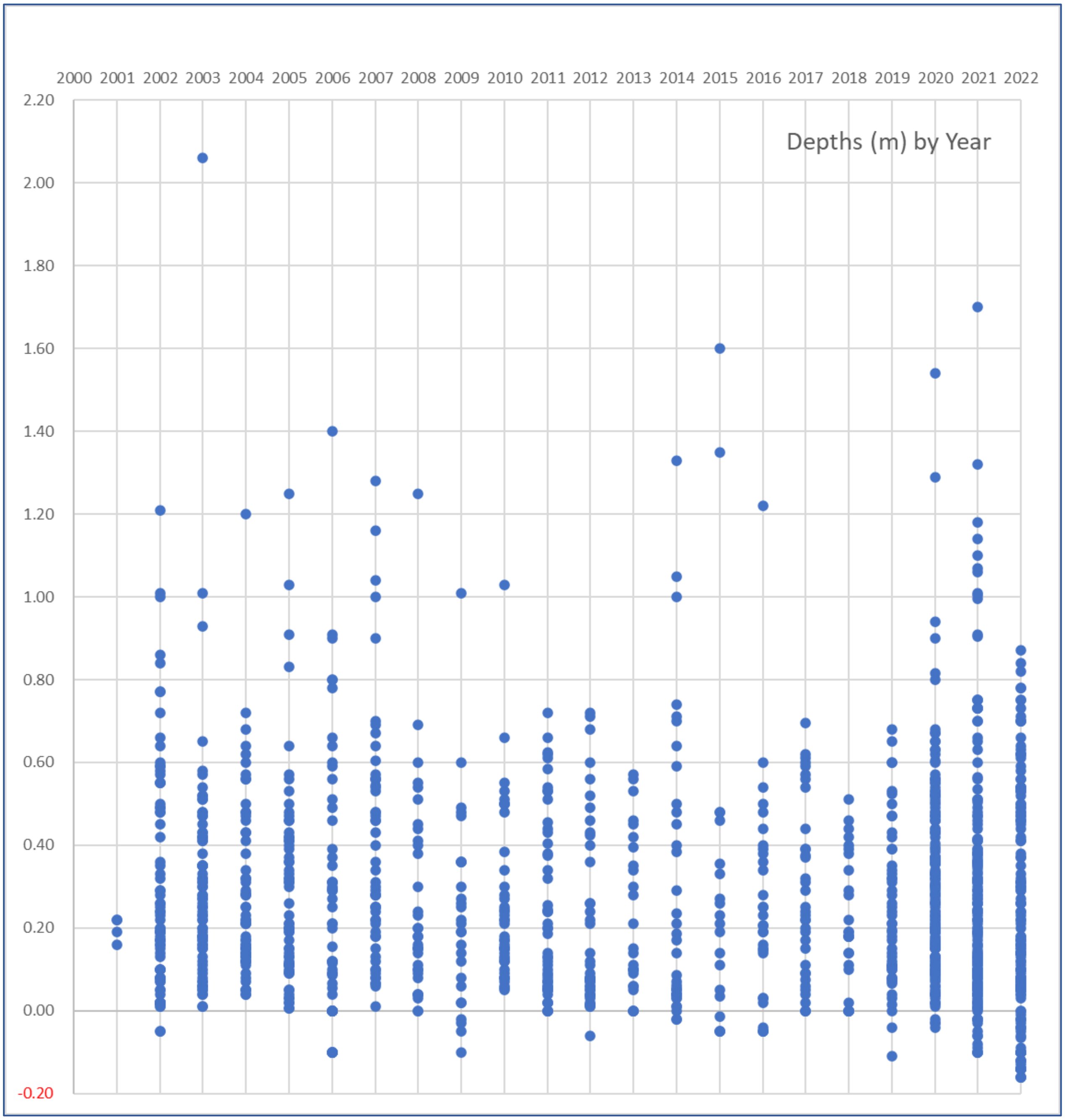

Figure 10-3.`Annual readings of Twenty-One Mile Creek depths (m) since December 1, 2001. The 2001 data is not included in this analysis since there are only four records.

The two observations above are corroborated by a summary of the dataset by year (Table 10-3):

1. The longest recorded periods with negative depths were in 2021 (39 days), 2016 (42 days), and 2022 (53 days).
2. The lowest maximum depth of -0.16 m was recorded in 2022.
3. Negative depths were recorded in only half (11 out 22) of the years in the dataset.
4. The lowest depths mostly occur between late August and early October, which are often drier periods of the year.

Table 10-3. Summary of lowest depths in Twenty-One Mile Creek since 2001.

		Consecutive Days <0 cm			Mininum Depth		
Year	Rec-ords	Start Date of <0 cm	End Date of <0 cm	No. Days	Depth (cm)	Date(s)	Notes
2001	4	n/a		0	0.16	10-Dec-01	Records started Dec. 1, 2001
2002	84	20-Oct-02	05-Nov-02	17	-0.05	Oct 20 - Nov 5	
2003	78	n/a		0	0.04	Aug 28 - Sept 4	
2004	62	n/a		0	0.04	Oct 4	
2005	65	n/a		0	0.01	Aug 23 - Aug 29	
2006	57	18-Aug-06	13-Sep-06	26	-0.10	Aug 18 - Sept 13	Stayed at 0.00 until Nov 4
2007	54	25-Sep-07	25-Sep-07	1	0.01	25-Sep-07	
2008	34	26-Sep-08	26-Sep-08	1	0.04	26-Sep-08	
2009	27	22-Aug-09	25-Sep-09	35	-0.10	10-Oct-09	No intervening readings, could be over-estimate
2010	43	n/a		0	0.05	20-Oct-10	
2011	53	n/a		0	0.07	08-Sep-11	
2012	42	06-Oct-12	06-Oct-12	1	-0.06	06-Oct-12	
2013	26	n/a		0	0.06	Sept 3 and Oct 26	
2014	36	11-Sep-14	22-Sep-14	12	-0.02	Sept 11 - Sept 22	
2015	20	01-Aug-15	21-Aug-15	21	-0.05	Aug 1 - Aug 15	Also negative (-0.02) on Oct 6)
2016	30	26-Aug-16	06-Oct-16	42	-0.05	Aug 26 - Oct 6	
2017	36	n/a		0	0.00	Sept 5 - Oct 7	
2018	28	n/a		0	0.00	Oct 20 - Oct 23	
2019	52	07-Sep-19	10-Sep-19	4	-0.11	10-Sep-19	
2020	163	10-Sep-20	18-Sep-20	9	-0.04	Sept 10 - Sept 18	One +0.03 reading during drought (Sept 15)
2021	183	05-Aug-21	12-Sep-21	39	-0.10	Aug 5 - Sept 12	Date range incl.: +0.04 (Aug 7) and +0.16 (Aug 17)
2022	172	06-Sep-22	28-Oct-22	53	-0.16	Sept 6 - Oct 28	Depths <0 cm through Nov 11 (end of records)

Notes: Winter months not included due to: (i) incomplete records; and (ii) difficulty of assessing depths due to ice. Some winter readings can be near 0.00 but somewhat unreliable due to ice.

10.2.4 Stream Depths, Beavers, and Fish Habitat

The section of the River of Golden Dreams downstream of the depth gauge in Photo 10-1 was the shallowest part of that system in 2022 (and likely in most years). The reason why low water was not seen farther downstream was because of the extensive damming by beavers (Section 2.4).

Overall, the trends described in this report and elsewhere show that climate change is impacting Whistler's habitats in various ways, including a reduction in summer stream flow and a consequent warmer of water. Observations in 2022 showed that beaver dams more than offset the negative impacts of the drought conditions seen this past year (and likely to be more common in the future). There is a clear interaction between beavers, climate change, stream depth and warming, fish habitat, recreation, and water storage. This 2022 report helped quantify some of those interactions and will help guide future monitoring efforts.

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Appendix A: Beaver Surveys, 2017 to 2022

Location	Easting	Northing	Date	Survey-or(s)	2022 Status	2021 Status	2020 Status	2019 Status	2018 Status	2017 Status
Alpha Lk Dam 1	499157	5549046	2022-11-13	BB	Active	Active	Active	Active	Active	NR
Alpha Lk Lodge 1	499208	5549034	2022-11-13	BB	Active	Active	Active	Active	Active	NR
Alpha Lk Lodge 2	499970	5549027	2022-11-14	BB	Inactive?	Inactive?	Active	Active	Active	Active
Alpha Lk Lodge 3	499214	5548991	2022-11-13	BB	Inactive	Inactive	Inactive	Inactive	Inactive	NR
Alpha Lk Lodge 4	499172	5549048	2022-11-13	BB	Inactive	Inactive	Active	Active	Active	NR
Alpha Lk Lodge 5	499913	5548986	2022-11-14	BB	Active?	Active?	NR	NR	NR	NR
Alpha Lk Lodge 6	499861	5548981	2022-11-14	BB	Inactive	Inactive	Inactive	Inactive	Inactive	NR
Alta Lake Lodge 1	500934	5550767	2022-11-13	BB	Active?	Active	NR	NR	NR	NR
Alta Lake Lodge 2	500919	5550750	2022-11-13	BB	Active	Active	NR	NR	NR	NR
Alta Lake Lodge 3	500906	5550670	2022-11-13	BB	Inactive	Active?	NR	NR	NR	NR
Alta Lake Lodge 4	500954	5550790	2022-11-13	BB	Inactive	Inactive?	NR	NR	NR	NR
Alta Vista Dam 1	501471	5550344	2022-11-14	BB	Active?	Active	Active	Active	Active	Active
Alta Vista Dam 2	501495	5550399	2022-11-14	BB	Active?	Active	Active	Active	NR	NR
Alta Vista Lodge 1	501458	5550235	2022-11-14	BB	Active	Active?	Active	Active	Active	Active
Alta Vista Lodge 2	501544	5550444	2022-11-14	BB	Inactive?	Inactive?	Inactive	NR	NR	NR
Alta Vista Lodge 3	501552	5550477	2022-11-14	BB	Inactive	Inactive	Inactive	NR	NR	NR
Beaver Lk Lodge 1	500012	5550828	2022-11-11	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
Beaver Lk Lodge 2	500012	5550802	2022-11-11	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
Beaver Lk Lodge 3	500027	5550773	2022-11-11	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
Beaver Lk Lodge 4	500072	5550831	2022-11-11	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
Bottomless Lodge 1	500774	5549695	2022-11-05	BB	Inactive	Inactive	Inactive	Inactive?	Inactive	Inactive
Buckhorn Dam 1	502412	5554235	2022-11-06	BB; KJ	Active?	Active?	Active?	Active?	Active	NR
CGC-02 Dam 1	504575	5552349	2022-05-12	BB	Active?	Active	Inactive	Inactive	Inactive	Active
CGC-02 Lodge 1	504612	5552324	2022-11-01	BB	Inactive?	Inactive	Inactive	Inactive?	Inactive?	Active
CGC-18 Dam 1	504205	5552210	2022-11-09	BB	Active	Active	Active	Active	Inactive	Inactive?
CGC-18 Dam 2	504199	5552217	2022-11-09	BB	Active	Inactive	NR	NR	NR	NR
CGC-18 Lodge 1	504228	5552240	2022-11-09	BB	Active	Active	Active	NR	NR	NR
CGC-18 Lodge 2	504181	5552219	2022-11-09	BB	Inactive	Active?	Inactive	Inactive	Summer?	Summer?
CGC-18 Lodge 3	504184	5552221	2022-11-09	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
CGC-18 Lodge 4	504245	5552249	2022-11-09	BB	Inactive	Inactive	Inactive	Inactive?	NR	NR
Cheak Cross - Lodge?	496833	5547905	2022-05-02	BB	Probable	NR	NR	NR	NR	NR
Eva Lake	501094	5549975	2022-11-05	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
Fitz Back Burrow 1	504142	5554607	2022-11-11	BB	Active	Active	Active	NR	NR	NR
Fitz Back Dam 1	504144	5554608	2022-11-11	BB	Active	Active	Active	NR	NR	NR
Fitz Back Lodge 1	504212	5554643	2022-11-11	BB	Inactive	Inactive	Inactive	Inactive?	Active	NR
Fitz Fan Lodge 1	503847	5554866	2022-11-11	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
Fitz Pond Lodge 1	503275	5552571	2022-11-09	BB	Active	Active	Inactive?	Active	Active	NR
Fitz Pond Lodge 2	503300	5552575	2022-11-09	BB	Active?	Active	Inactive	Inactive	NR	NR
Fitz Pond Lodge 3	503287	5552516	2022-11-09	BB	Active	NR	NR	NR	NR	NR
Green Lake Lodge 1	503740	5554600	2022-10-28	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Active
Lost Lake Lodge 1	504337	5553160	2022-11-27	BB	Inactive?	Active	NR	NR	NR	NR
Lost Lake Lodge 2	504333	5553154	2022-11-27	BB	Inactive	Inactive?	NR	NR	NR	NR
Lost Lake Lodge 3	504458	5552740	2022-11-02	BB	Inactive?	Inactive?	Active	Active	Active	Unknown
Millar Cr Dam 1	496855	5548395	2022-11-02	BB	Inactive?	Active	Active	NR	NR	NR
Millar Cr Dam 2	496809	5548372	2022-11-05	BB	Active?	Active	Active	Active	check	check
Millar Cr Lodge 1	496821	5548379	2022-11-05	BB	Active	Active	Active	NR	NR	NR
Millar Cr Lodge 2	496812	5548373	2022-11-05	BB	Inactive?	Active	Active?	NR	NR	NR
Millar Cr Lodge 3	496888	5548391	2022-11-05	BB	Inactive	Inactive	Inactive	NR	NR	NR
Millars Pond	499405	5548341	2022-08-14	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
MW1-1 Dam	497622	5548431	2022-11-15	BB	Active?	Active?	Active	NR	NR	NR
MW1-1 Lodge	497706	5548388	2022-11-15	BB	Active	Active	Active	Active	Active	NR
MW1-2 Dam	497649	5548401	2022-11-15	BB	Active	Active?	Active	NR	NR	NR
MW1-2 Lodge	497737	5548390	2022-11-15	BB	Active	Active	Active	NR	NR	NR

Location	Easting	Northing	Date	Survey-or(s)	2022 Status	2021 Status	2020 Status	2019 Status	2018 Status	2017 Status
MW1-3 Dam	497674	5548378	2022-11-15	BB	Active	NR	NR	NR	NR	NR
MW1-3 Lodge	497796	5548408	2022-11-15	BB	Active	Active?	Active	Active	Active	NR
MW1-4 Lodge	497818	5548447	2022-11-15	BB	Inactive?	Inactive?	Inactive	Active	Inactive	NR
MW1-5 Dam	497778	5548405	2022-11-15	BB	Active	Active	Active	NR	NR	NR
MW1-6 Dam	497839	5548459	2022-11-15	BB	Active	Active	Active	NR	NR	NR
MW2-1 Burrow	497803	5548350	2022-11-15	BB	Inactive?	NR	NR	NR	NR	NR
MW2-1 Dam	497758	5548358	2022-11-15	BB	Active	NR	NR	NR	NR	NR
MW2-2 Dam	497759	5548384	2022-11-15	BB	Active	NR	NR	NR	NR	NR
MW3-1 Lodge	497931	5548588	2022-11-27	BB	Active	Active?	Active	Inactive	NR	NR
MW4-1 Dam	498156	5548703	no 2022 data	n/a	ND	ND	Inactive	NR	NR	NR
MW4-1 Lodge	498156	5548764	no 2022 data	n/a	Inactive?	Inactive?	Active?	Active?	NR	NR
MW4-2 Dam	498169	5548719	no 2022 data	n/a	ND	ND	Inactive	NR	NR	NR
MW4-2 Lodge	498146	5548795	no 2022 data	n/a	Inactive?	Inactive	Inactive	Inactive	NR	NR
MW4-3 Dam	498168	5548759	no 2022 data	n/a	ND	flooded	Active	NR	NR	NR
MW5-1 Dam	498083	5548812	2022-11-27	BB	Active	NR	NR	NR	NR	NR
MW5-1 Lodge	498270	5548912	2022-11-27	BB	Active?	Active	NR	NR	NR	NR
MW5-2 Dam	498143	5548844	2022-11-27	BB	Active	NR	NR	NR	NR	NR
MW5-2 Lodge	498284	5548908	2022-11-27	BB	Active	Active	Active	Active	Inactive?	NR
MW5-3 Dam	498201	5548886	2022-11-27	BB	Active	NR	NR	NR	NR	NR
MW6-1 Dam	498371	5548896	no 2022 data	n/a	Inactive	Inactive	Active	Active	NR	NR
MW6-1 Lodge	498321	5548863	no 2022 data	n/a	Active?	Active?	Active	Active	NR	NR
MW6-2 Lodge	498328	5548894	no 2022 data	n/a	Active	Active	Active	Active	NR	NR
MW6-3 Lodge	498398	5548903	no 2022 data	n/a	Active	Active	Active	Active	NR	NR
Nesters Pond	503099	5552852	2022-11-11	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
Nita Lake Lodge 1	500290	5549772	2022-11-14	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
NNCG-15 Lodge	503235	5554601	2022-07-11	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
NNGC-10 Lodge	502764	5554086	2022-07-11	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
NNGC-12 Lodge	502746	5553748	2022-07-11	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
Old Mill Dam 1	504321	5553311	2022-11-27	BB	Active	Active	Active	Active	Active	NR
Old Mill Dam 2	504340	5553261	2022-11-27	BB	Inactive?	Inactive	Inactive	NR	NR	NR
Old Mill Lodge 1	504223	5553409	2022-11-27	BB	Inactive	Inactive	NR	NR	NR	NR
Old Mill Lodge 2	504232	5553421	2022-11-27	BB	Inactive	Inactive	NR	NR	NR	NR
Old Mill Lodge 3?	504238	5553287	2022-11-27	BB	Possible	NR	NR	NR	NR	NR
ROGD 03-1 Lodge	501719	5552450	2022-05-06	BB	Active?	NR	NR	NR	NR	NR
ROGD 04-1 Dam	501758	5552522	2022-05-06	BB	Active	Inactive	Inactive?	Active	Active	Active
ROGD 04-1 Lodge	501744	5552517	2022-05-06	BB	Active	Inactive	Inactive?	Active	Active	Active
ROGD 06-1 Burrow	501840	5552670	2022-05-06	BB	Inactive?	Summer?	Summer?	NR	NR	NR
ROGD 10-1 Lodge	502120	5553004	2022-11-06	BB; KJ	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
ROGD 10-2 Lodge	502126	5553026	2022-11-06	BB; KJ	Active?	Active	Active?	Active	NR	NR
ROGD 15-1 Dam	502340	5553225	2022-11-06	BB; KJ	Active	flooded	Active	Active	NR	NR
ROGD 15-1 Lodge	502302	5553208	2022-11-06	BB; KJ	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
ROGD 15-2 Lodge	502312	5553204	2022-11-06	BB; KJ	Active?	Active	Active	Active	NR	NR
ROGD 15-3 Lodge	502327	5553188	2022-11-06	BB; KJ	Active?	Active	Active	Active	Active	NR
ROGD 15-4 Lodge	502334	5553183	2022-11-06	BB; KJ	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
ROGD 15-5 Lodge	502349	5553202	2022-11-06	BB; KJ	Active	Active	Active	Active	Active?	NR
ROGD 15-6 Lodge	502355	5553222	2022-11-06	BB; KJ	Active?	Active?	Inactive?	Inactive	Inactive	NR
ROGD 17-1 Dam	502340	5553309	2022-11-06	BB; KJ	Active	flooded	Active	Active	NR	NR
ROGD 17-1 Lodge?	502347	5553288	2022-11-06	BB; KJ	Possible	NR	NR	NR	NR	NR
ROGD 19-1 Cache	502356	5553352	2022-11-06	BB; KJ	Active	NR	NR	NR	NR	NR
ROGD 21-1 Lodge	502406	5553403	2022-11-06	BB; KJ	Active	Active	Active	Active	NR	NR
ROGD 21-1-Dam	502421	5553430	2022-11-06	BB; KJ	Active	flooded	Active	Active	NR	NR
ROGD 23-1 Dam	502377	5553591	2022-11-06	BB; KJ	Active	flooded	Active	Active	NR	NR
ROGD 25-1 Dam	502291	5553684	2022-11-06	BB; KJ	Active	flooded	Active	Active	NR	NR
ROGD 25-1 Lodge	502311	5553661	2022-11-06	BB; KJ	Active	Active	Active	Inactive	Inactive	NR
ROGD 25-2 Lodge	502308	5553673	2022-11-06	BB; KJ	Active	Active	Active	Inactive?	Inactive	NR
ROGD 27-1 Dam	502283	5553770	2022-11-06	BB; KJ	Active	flooded	Active	Active	NR	NR
ROGD 27-1 Lodge	502294	5553771	2022-11-06	BB; KJ	Active?	Active	Active	NR	NR	NR

Location	Easting	Northing	Date	Survey-or(s)	2022 Status	2021 Status	2020 Status	2019 Status	2018 Status	2017 Status
ROGD 28-1 Lodge	502304	5553839	2022-11-06	BB; KJ	Inactive?	Inactive?	Inactive?	Inactive?	Inactive	NR
ROGD 30-1 Dam	502429	5553974	2022-11-06	BB; KJ	Inactive?	flooded	Active	Active	NR	NR
ROGD 31-1 Cache	502607	5554167	2022-11-06	BB; KJ	Active	NR	NR	NR	NR	NR
ROGD 31-1 Dam	502621	5554167	2022-11-06	BB; KJ	Active?	flooded	Active	Active	NR	NR
ROGD 31-1 Lodge?	502607	5554167	2022-11-06	BB; KJ	Probable	NR	NR	NR	NR	NR
ROGD 32-1 Dam	502439	5554305	2022-11-06	BB; KJ	Active?	flooded	Active	Active	NR	NR
ROGD 35-1 Dam	502898	5554585	2022-11-06	BB; KJ	Active	NR	NR	NR	NR	NR
ROGD 35-1 Lodge	502846	5554565	2022-11-06	BB; KJ	Active	Active NR	Active NR	NR	NR	NR
ROGD 37-1 Dam	503032	5554681	2022-11-06	BB; KJ	Inactive	flooded	Active	Active	NR	NR
ROGD 37-1 Lodge	503029	5554719	2022-11-06	BB; KJ	Inactive	Inactive	Inactive	NR	NR	NR
ROGD 38-1 Dam	502996	5554792	2022-11-06	BB; KJ	Inactive	flooded	Active	Active	NR	NR
ROGD 38-1 Lodge	503050	5554860	2022-11-06	BB; KJ	Inactive	Inactive?	Inactive	Inactive	Inactive	NR
ROGD 40-1 Dam	503127	5554905	2022-11-06	BB; KJ	Inactive	flooded	Active	Active	NR	NR
ROGD 40-1 Lodge	503202	5554930	2022-11-06	BB; KJ	Inactive	Active?	Active?	Inactive?	Unknown	NR
ROGD 40-2 Dam	503125	5554906	2022-11-06	BB; KJ	Inactive	flooded	Active	Active	NR	NR
ROGD 41-1 Lodge	503187	5554830	2022-11-06	BB; KJ	Active	Active	Active	Active	Inactive?	NR
ROGD 41-2 Lodge	503185	5554836	2022-11-06	BB; KJ	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
Rainbow Park Lodge 1	501145	5551850	2022-11-11	BB	Active	Active	Active?	Inactive	Inactive	Inactive
Rainbow Park Lodge 2	501118	5551927	2022-11-11	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
RW1-1 Dam	501096	5551929	2022-11-11	BB	Active?	Active	NR	NR	NR	NR
RW1-1 Lodge	501096	5552182	2022-11-11	BB	Active	Active?	NR	NR	NR	NR
RW2-1 Lodge	501278	5552385	2022-11-11	BB	Inactive?	Inactive?	NR	NR	NR	NR
RW3-1 Lodge	501523	5552527	2022-11-11	BB	Probable	NR	NR	NR	NR	NR
RW4-1 Dam	501718	5552677	2022-11-15	BB	Active	NR	NR	NR	NR	NR
RW4-1 Lodge	501702	5552711	2022-11-15	BB	Active	Active	NR	NR	NR	NR
RW4-2 Lodge	501694	5552718	2022-11-15	BB	Active?	Active	NR	NR	NR	NR
RW4-Ditch-1 Dam	501780	5552643	2022-11-15	BB	Active	Active	NR	NR	NR	NR
RW5-1 Lodge	501848	5552721	2022-11-15	BB	Active	Active	NR	NR	NR	NR
RW5-2 Lodge	501848	5552727	2022-11-15	BB	Active	Active	Active?	Active	Active	Active
RW5-Ditch-1? Dam	501848	5552696	2022-11-15	BB	Active	Active	NR	NR	NR	NR
RW5-Ditch-2? Dam	501898	5552741	2022-11-13	BB	Active	Active	Active	Active	Active	Active
RW6-1 Lodge	501777	5552792	2022-11-13	BB	Active?	Active	Active	NR	NR	NR
RW6-2 Lodge	501790	5552801	2022-11-13	BB	Active?	Active	NR	NR	NR	NR
Spruce Grove Lodge 1	503652	5553307	2022-11-09	BB	Inactive	Active?	Active	Active	Active	Active
Tennis Club Dam 1	503101	5552253	2022-11-11	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
Tennis Club Dam 2	503127	5552267	2022-11-11	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
Tennis Club Lodge 1	503139	5552271	2022-11-11	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
Wedge Pond Dam 1	503258	5555777	2022-11-09	BB	Active?	Inactive?	Active?	Active?	Active?	Active?
Wedge Pond Lodge 1	503156	5555770	2022-11-09	BB	Inactive	Inactive	NR	NR	NR	NR
Wedge Pond Lodge 2	503176	5555733	2022-11-09	BB	Inactive	Inactive	Active	Active	Active	Inactive
Wedge Pond Lodge 3	503121	5555719	2022-11-09	BB	Inactive	Inactive	NR	NR	NR	NR
Wedge Pond Lodge 4	503233	5555757	2022-11-09	BB	Active?	NR	NR	NR	NR	NR
WGC-10 Lodge 1	502293	5551708	2022-11-08	BB	Inactive	Inactive	Inactive	Active?	Active	Active
WGC-10 Lodge 2	502290	5551566	2022-11-08	BB	Inactive	Inactive	Inactive	Inactive?	Active	NR
WGC-15 Lodge 1	502167	5550989	2022-11-08	BB	Inactive	Inactive	Inactive	Inactive?	Inactive	Inactive
WGC-15 Lodge 2	502346	5551092	2022-11-08	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
WGC-15 Lodge 3	502356	5551107	2022-11-08	BB	Inactive?	Inactive	Inactive	Active?	Active	Active
WGC-5 Lodge 1	502367	5551766	2022-11-08	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
WGC-7 Lodge 1	502361	5552148	2022-11-08	BB	Inactive	Inactive	Inactive?	Active	NR	NR
Wolverine Lodge 1	501201	5549629	2022-11-05	BB	Inactive	Inactive	Inactive	Inactive	Inactive	Inactive
WR1-1 Dam	501887	5553000	2022-11-13	BB	Active	Active?	Active	Active	Active	Active
WR1-1 Lodge	501830	5553068	2022-11-13	BB	Inactive?	Active?	NR	NR	NR	NR
WR1-2 Dam	501884	5552978	2022-11-13	BB	Active?	Active?	Active?	NR	NR	NR
WR3-1 Dam	501713	5553278	2022-11-13	BB	Active?	Active	Active	NR	NR	NR
WR3-1 Lodge	501750	5553298	2022-11-13	BB	Active?	Active	Active	NR	NR	NR
WR3-2 Lodge	501709	5553226	2022-11-13	BB	Active?	Active	NR	NR	NR	NR
WR3-3 Lodge	501693	5553232	2022-11-13	BB	Inactive	Inactive	NR	NR	NR	NR
WR4 1-Lodge	501825	5553543	2022-11-13	BB	Active?	Active	Active	Active	Active	Active

Appendix B: Northern Goshawk Site Data

Site Location	Date	Site Code	Elev. (m)	Tree Species	CWHms1 Site Series	Struct. Stage	Tree Ht. (m)	Avg. DBH (cm)	Canopy Closure (%)	Slope Position	Slope (%)	Nesting Platforms	Flyways	Understorey (<10m)	Habitat Rating
Danimal Middle	2022-05-06	DM-Nest 1	780	FdHw (Cw)	03	7(6)	20-26	50	60	Middle	30	3+	3	3+	3
Danimal Middle	2022-05-06	DM-Nest 1	780	FdHw (Cw)	03	7(6)	20-26	50	60	Middle	30	3+	3	3+	3
Millar's Pond	2022-05-20	Millar's Pond Nest 1	720	Fd (Hw)	01(03)	7	20-26	55	60	Middle	20	2.5	4	4	3
Lower Blackcomb	2022-06-10	LB/Ascent Nest 1	973	HwFdCw	03	6	14-20	40	50	Upper	40	2+	2	2+	2+
Millar's Pond	2022-07-13	Millar's Pond Nest 1	720	Fd (Hw)	01(03)	7	20-26	55	60	Middle	20	2.5	4	4	3
		MP-01	688	Hw (Fd,Cw)	01(03)	7	20-26	45	60	Middle	30	2	4	4	5
		MP-04	735	Hw (Fd,Cw,Ba)	01(03)	7	20-26	45	60	Upper	10	2.5	4	4	3-
		MP-06	718	HwFd (CwBa)	04	7	20-26	50	55	Middle	15	2.5	3	3	3-
Danimal Middle	2022-07-14	DM-01	743	broadcast only											
		DM-02	751	HwFd	03	6/7	20-26	40	60	Middle	15	2	2+	3-	2
		DM-03	784	FdHw (Cw)	03	7(6)	20-26	45	60	Middle	40	2+	3	3+	2+
		DM-04	793	FdHw (Cw/Act)	01	7(6)	>26	55	65	Middle	15	3	3	3+	3
		DM-05	783	FdHw (Cw)	03	7(6)	20-26	50	60	Middle	30	3+	3	3+	3
		DM-06	803	broadcast only											
		DM-07	808	HwFd (Cw,Ba)	01	7	>26	55	50	Middle	30	3+	3	3+	3+
		DM-08	828	broadcast only											
		DM-09	832	FdHw (Ba,Cw)	03	5	14-20	30	40	Crest	0	1+	2	2	2
		DM-10	829	HwFd (Cw)	01	6/7	20-26	40	65	Upper	10	2	2	2	2
		DM-11	776	Fd (Hw,Cw,Pw)	03	7	20-26	35	40	Upper	40	2+	3+	3	2
Comf. Numb Middle	2022-07-15	CNM-01	830	CwHw (Fd)	06	7	>26	75	60	Flat	0	2	3	3	2+
		CNM-02	830	FdHw (Cw,Ba)	01	7	>26	80	50	Middle	10	3+	3+	3+	3+
		CNM-03	841	HwFd (Ba,Cw)	01	7	20-26	50	30	Upper	10	2	3	3	2
		CNM-04	880	HwFd (Ba,Cw)	01	7	20-26	45	35	Upper	10	2	3	3	2
		CNM-05	899	HwFd (Cw,Yc,Ca)	01	7	>26	65	60	Middle	15	3	3+	3	3+
		CNM-06	812	broadcast only											
		CNM-07	785	FdHw (Pl,Yc)	06	6	14-20	35	20	Upper	20	2-	3+	3+	2
		CNM-08	730	FdHw (Pl,Pw)	03	6	14-20	35	20	Middle	20	2-	3	3	2-
		CNM-09	730	HwFd (Cw)	03/01	7	20-26	40	30	Middle	25	2+	2+	2+	2+
		CNM-10	723	HwFd (Cw)	01	6	20-26	45	60	Middle	20	2+	2	2	2
Comf. Numb North	2022-07-15	CNN-01	807	FdHw (Ba)	01	7	>26	70	60	Middle	5	3	3+	3	3+
		CNN-02 (2021 sighting)	857	HwFd(Cw)		7	>26	45	50	Upper	40	3-	3-	3	3-
		CNN-03	859	HwFd (Ba,Cw)	01	7	>26	60	40	Middle	20	2+	3+	3	3
		CNN-04	854	HwFd (Cw,Ba)	01	7	>26	50	40	Middle	30	2+	2+	2+	2+
		CNN-05	835	HwFd (Cw,Ba)	01	7	>26	70	50	Middle	20	3+	4	4	3+
		CNN-06	830	HwFd(Cw,Ba)		7	>26	55	60	Middle	25	3+	3+	3+	3+
		CNN-07	832	Hw (Fd,Cw,Pw,Ba)	01/03	7	>26	55	40	Middle	35	2+	3+	3	2+
		CNN-08 (2021 sighting)	857	HwFd(Cw)		7	>26	45	50	Upper	40	3-	3-	3	3-
		CNN-09	855	HwFd (Cw,Ba)	01	7	>26	50	50	Middle	25	2+	3	3	2+
		CNN-10	842	FdHw (Cw, Se)	01	7	>26	60	50	Middle	30	3	3+	3	3
		CNN-11	838	HwFd (Cw,Ba)	01	7	>26	60	50	Middle	15	3	3	3	3
Danimal Middle	2022-07-15	DM-Nest 1	780	FdHw (Cw)	03	7(6)	20-26	50	60	Middle	30	3+	3	3+	3

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Appendix B (cont.)

Site Location	Date	Site Code	Elev. (m)	Tree Species	CWHms1 Site Series	Struct. Stage	Tree Ht. (m)	Avg. DBH (cm)	Canopy Closure (%)	Slope Position	Slope (%)	Nesting Platforms	Flyways	Understorey (<10m)	Habitat Rating
Rainbow Loop	2022-07-23	RL-01	691	Hw (Cw,Ba,Fd,Dr)	01	6	20-26	40	60	Lower	15	2	2	2	2
		RL-02	707	FdHwBa (Dr, Cw)	01 (05)	6	>26	50	65	Lower	15	2+	2	2	2+
		RL-03	747	Hw (CwBaFdPwAct)	05	6	>26	50	65	Lower	15	2+	2	2	2+
		RL-04	778	HwFd (Cw,Ba)	01	6	>26	55	60	Middle	30	2+	2	2	2+
		RL-05	740	Hw (Fd,Cw)	01	7	>26	40	60	Middle	40	2+	3	3	3
		RL-06	718	HwFd (Cw)	01 (03)	7	>26	40	60	Upper	60	2+	3	2+	2+
		RL-07	698	Hw (Cw,Fd)	03	7	>26	45	60	Middle	60	3	3	3	3
Lower Blackcomb	2022-07-24	LB/Ascent Nest 1	973	HwFdCw	03	6	14-20	40	50	Upper	40	2+	2	2+	2+
		LB/Hey Bud Nest 1	865	HwFd (Ba,Cw)	01	7	>26	55	50	Middle	25	3	4	3+	3+
		LB-01	802	HdFd (Cw,Ba,Yc)	01/03	6/7	20-26	50	60	Lower	20	3	2+	2+	3
		LB-02	862	HwFd (Cw)	01/03	7	20-26	45	50	Middle	35	2+	4	4	3
		LB-03	921	BaHwFd (CwYc)	03	6	14-20	30	40	Middle	35	2	2	2	2
		LB-04	973	Ba(05) + HwFdCw(06)	03	6/5	14-20	40	50	Upper	40	2+	2	2+	2+
		LB-05	1063	HwBaCW (FdBaHm)	01	7	20-26	65	50	Middle	25	2+	3	3	3
		LB-06	1004	HwBaCW (FdBaHm)	01 (05)	7	>26	65	50	Middle	20	2+	3	3	3
		LB-07	965	HwFd (Yc)	01	7	>26	55	60	Middle	10	3	3+	3	3+
		LB-08	924	Hw (BaYcFdCw)	01	7	20-26	60	50	Middle	20	3	3+	3+	3+
		LB-09	876	HwFd (Ba,Cw)	01	7	>26	55	50	Middle	25	3	4	3+	3+
		LB-10	827	HwFdCw (Ba)	01	7	>26	65	50	Middle	25	3+	4	3	3+
		LB-11	793	Hw (FdHwBa)	01	7/6	14-20	40	70	Lower	25	2+	3	3	2+
Black Tusk	2022-07-25	BT-01	945	HwBaHm (Yc,Cw)	01/05	7/6	20-26	60/30	60	Middle	35	2	2	2	2
Lower Blackcomb	2022-07-30	LB-12	782	HwBa (Cw)	01	5	14-20	25	70	Middle	35	2-	2-	2	2-
		LB-13	829	HwFdCw (Ba)	01	7	>26	70	50	Middle	30	3	4	4	3+
		LB-14	867	Hw (FdBaCw)	03 (01)	7	14-20	40	40	Middle	50	2+	3+	3	3-
		LB-15	930	HwFd (BcBa)	01	7	>26	60	60	Middle	20	3	3+	3+	3+
		LB-16	983	Hw (FdYcBa)	01	7	20-26	55	45	Middle	20	3	3+	3+	3+
		LB-17	999	HwBaCw (Yc)	01	7	20-26	60	45	Middle	25	2+	2+	2+	2+
		LB-18	961	Hw (FdCwBa)	01	7	>26	60	60	Middle	10	3	3+	3+	3
		LB-19	930	HwFdCw (Ba)	01	7	>26	70	60	Middle	10	3+	3	3	3
		LB-20	883	HwFd (Cw)	01	7	>26	70	60	Middle	15	3+	3	3	3
		LB-21	808	FdHw (CwBa)	01	7	>26	80	50	Middle	10	3+	2	2	2+
Millar's Pond	2022-08-16	Millar's Pond Nest 1	720	Fd (Hw)	01(03)	7	20-26	55	60	Middle	20	2.5	4	4	3
		MP-01	688	Hw (Fd,Cw)	01(03)	7	20-26	45	60	Middle	30	2	4	4	5
		MP-02	714	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
		MP-03	736	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
		MP-05	737	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
		MP-07	708	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

Appendix C: Northern Goshawk Survey Details

Site Location	Date	Site Code	Survey-ors	Adult or Juvenile Call	Bird/mammal response?
Danimal Middle	2022-05-06	DM- 1	BB, BW	Visual only	No
Danimal Middle	2022-05-20	DM- 1	B.Brett	Adult	No
Millar's Pond	2022-05-20	MP-1	B.Brett	Adult	No
Lower Blackcomb	2022-06-10	LB/Ascent 1	B.Brett	Visual only	No
Millar's Pond	2022-07-13	MP-1	B.Brett	Visual only	No
		MP-01	B.Brett	Juvenile	No
		MP-04	B.Brett	Juvenile	No
		MP-06	B.Brett	Juvenile	No
Danimal Middle	2022-07-14	DM-01	B.Brett	4xJ, 2xA	No
		DM-02	B.Brett	4xJ, 2xA	RBNU
		DM-03	B.Brett	4xJ, 2xA	No
		DM-04	B.Brett	4xJ, 2xA	No
		DM-05	B.Brett	4xJ, 2xA	No
		DM-06	B.Brett	Adult	No
		DM-07	B.Brett	4xJ, 2xA	No
		DM-08	B.Brett	4xJ, 2xA	No
		DM-09	B.Brett	4xJ, 2xA	SOGO
		DM-10	B.Brett	4xJ, 2xA	No
		DM-11	B.Brett	4xJ, 2xA	No
Comf. Numb Middle	2022-07-15	CNM-01	B.Brett	4xJ, 2xA	No
		CNM-02	B.Brett	4xJ, 2xA	No
		CNM-03	B.Brett	4xJ, 2xA	No
		CNM-04	B.Brett	4xJ, 2xA	No
		CNM-05	B.Brett	4xJ, 2xA	CAJA
		CNM-06	B.Brett	2xJ, 4xA	No
		CNM-07	B.Brett	4xJ, 2xA	VATH, RBNU
		CNM-08	B.Brett	4xJ, 2xA	NOFL
		CNM-09	B.Brett	4xJ, 2xA	No
		CNM-10	B.Brett	4xJ, 2xA	No
Comf. Numb North	2022-07-15	CNN-01	B.Brett	4xJ, 2xA	No
		CNN-02	B.Brett	4xJ, 2xA	No
		CNN-03	B.Brett	5xJ, 2xA	CAJA
		CNN-04	B.Brett	4xJ, 2xA	HETH
		CNN-05	B.Brett	4xJ, 2xA	HETH
		CNN-06	B.Brett	4xJ, 2xA	No
		CNN-07	B.Brett	4xJ, 2xA	CAJA
		CNN-08	B.Brett	4xJ, 2xA	CAJA
		CNN-09	B.Brett	4xJ, 2xA	No
		CNN-10	B.Brett	4xJ, 2xA	No
		CNN-11	B.Brett	4xJ, 2xA	No
Danimal Middle	2022-07-15	DM- 1	B.Brett	from DM-05	No

Appendix C (cont.)

Site Location	Date	Site Code	Survey-ors	Adult or Juvenile Call	Bird/mammal response?
Rainbow Loop	2022-07-23	RL-01	B.Brett	6xJ, 2xA	No
		RL-02	B.Brett	6xJ, 1xA	Unidentified
		RL-03	B.Brett	6xJ	No
		RL-04	B.Brett	6xJ	STJA
		RL-05	B.Brett	6xJ	No
		RL-06	B.Brett	6xJ	No
		RL-07	B.Brett	6xJ	No
Lower Blackcomb	2022-07-24	LB/Ascent 1	B.Brett	from LB-04	No
		LB/Hey Bud 1	B.Brett	from LB-09	No
		LB-01	B.Brett	6xJ	No
		LB-02	B.Brett	6xJ	No
		LB-03	B.Brett	6xJ	No
		LB-04	B.Brett	6xJ	No
		LB-05	B.Brett	6xJ	CORA
		LB-06	B.Brett	6xJ	CAJA, STJA, TTWO
		LB-07	B.Brett	6xJ	STJA
		LB-08	B.Brett	6xJ	RBNU
		LB-09	B.Brett	6xJ	DOSQ
		LB-10	B.Brett	6xJ	No
		LB-11	B.Brett	6xJ	No
Black Tusk	2022-07-25	BT-01	B.Brett	6xJ	No
Lower Blackcomb	2022-07-30	LB-12	B.Brett	6xJ	RBNU
		LB-13	B.Brett	6xJ	No
		LB-14	B.Brett	6xJ	No
		LB-15	B.Brett	6xJ	No
		LB-16	B.Brett	6xJ	STJA, CAJA?
		LB-17	B.Brett	6xJ	No
		LB-18	B.Brett	9xJ	CORA/NOGO?
		LB-19	B.Brett	6xJ	No
		LB-20	B.Brett	6xJ	No
		LB-21	B.Brett	6xJ	No
Millar's Pond	2022-08-16	MP-01	B.Brett	Juvenile	No
		MP-01	B.Brett	Juvenile	No
		MP-02	B.Brett	Juvenile	No
		MP-03	B.Brett	Juvenile	No
		MP-05	B.Brett	Juvenile	No
		MP-07	B.Brett	Juvenile	No

Abbreviations:

CAJA: Canada Jay

CORA: Common Raven

DOSQ: Douglas Squirrel

HETH: Hermit Thrush

NOFL: Northern Flicker

NOGO: Northern Goshawk

RBNU: Red-breaster Nuthatch

SOGO: Sooty Grouse

STJA: Steller’s Jay

TTWO: Three-toed Woodpecker

VATH: Varied Thrush

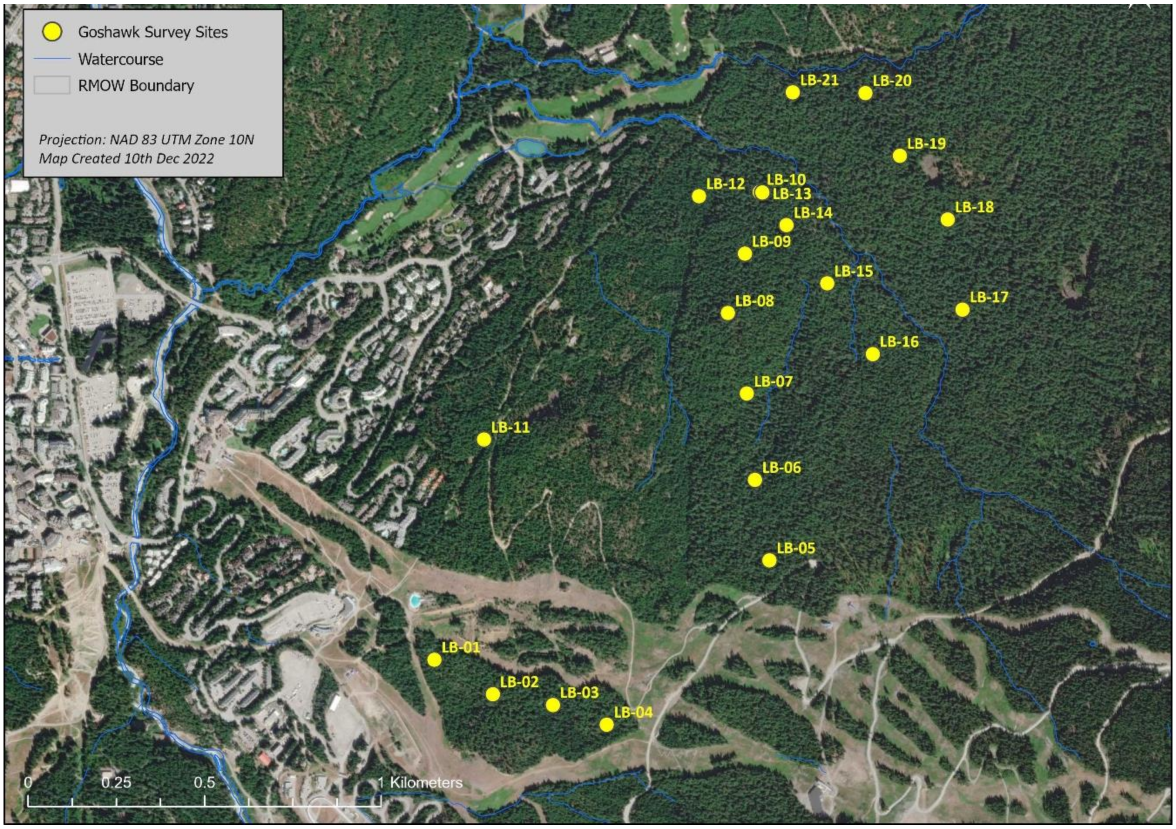

Figure C-1. Northern Goshawk Surveys – Lower Blackcomb (LB)

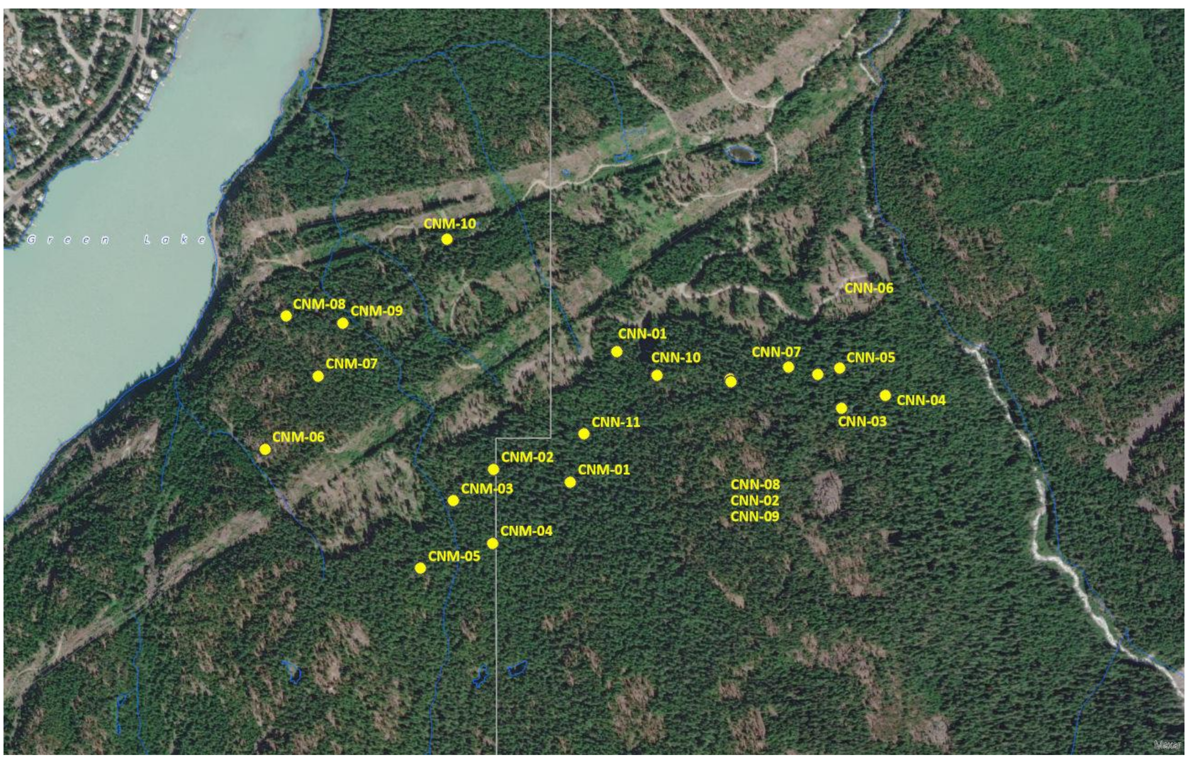

Figure C-2. Northern Goshawk Surveys – Comfortably Numb (CNN and CNM)

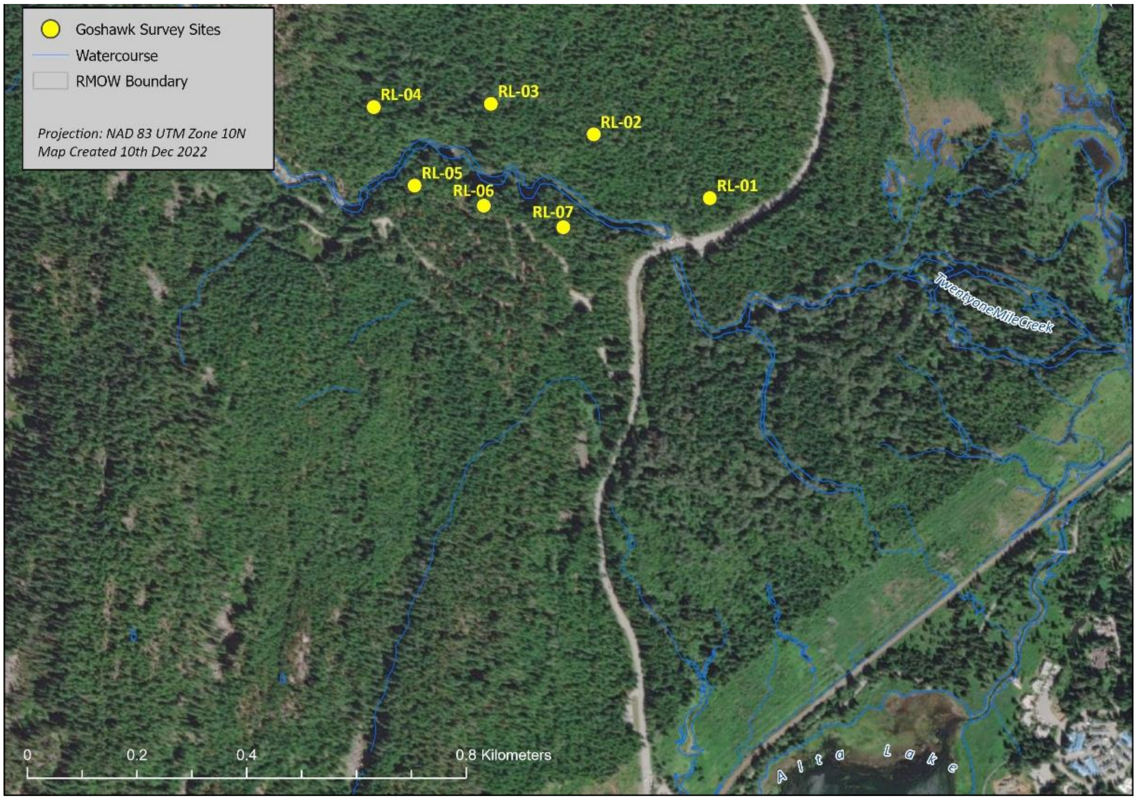

Figure C-3. Northern Goshawk Surveys – Rainbow Loop (RL)

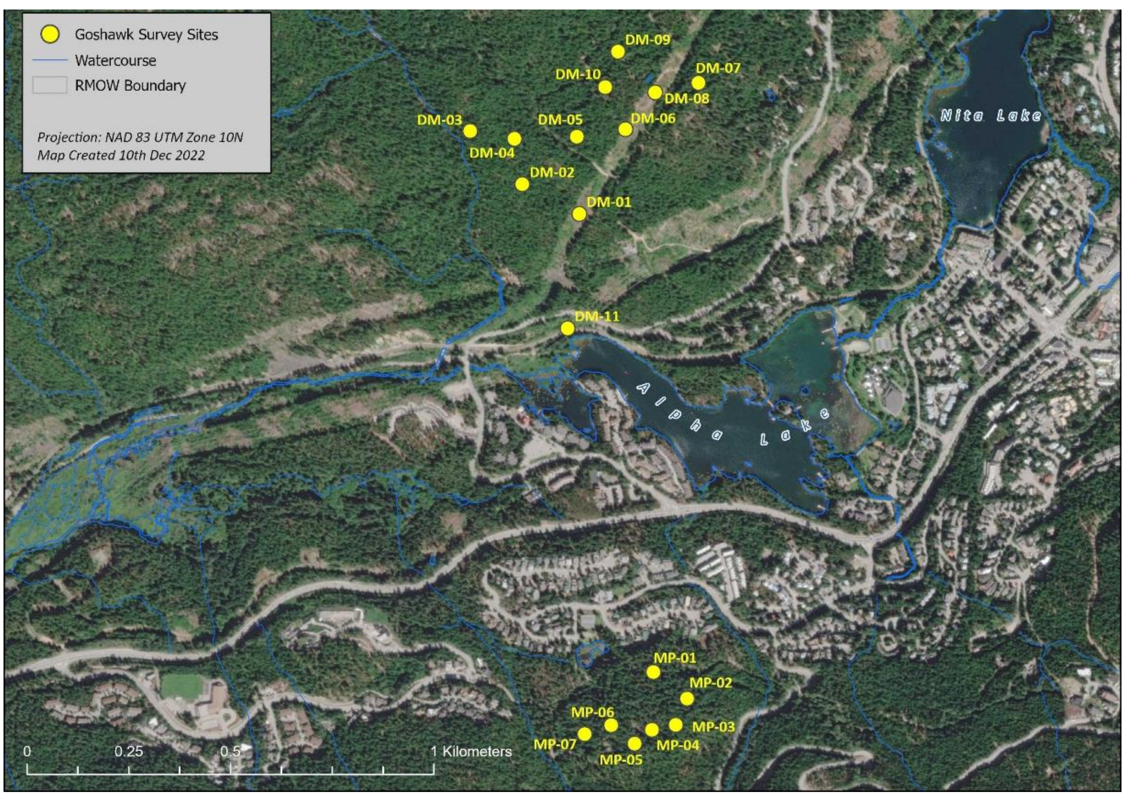

Figure C-4. Northern Goshawk Surveys – Danimal- Middle (DM) and Millar's Pond (MP)

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Appendix D: Tailed Frog Site and Capture Data

Valley Side	Site	Date	Easting	Northing	Elev. (m)	Slope (%)	Channel Width (m)	Wetted Width (m)	pH	Flow (rel.)	Stream Disturb-ance	Mean Depth (cm)	Embedd-edness	Survey-ability	Subj. Hab. Rating
East	Archibald Creek - 1	2022-09-07	502387	5550606	695	17	4.0	2.2	7.0	Low	Med.	12	4	3	3
East	Archibald Creek - 2	2022-09-07	502854	5550298	835	18	2.7	1.9	6.9	Low	High	11	3	3	3
East	Archibald Creek - 3	2022-09-07	503310	5549422	1026	12	2.2	2.4	6.8	Low	Low	12	2	4	3
East	Blackcomb Cr. @ Lost Lake Rd.	2022-09-06	504641	5552586	692	25	10.0	4.0	6.8	Low	Low	17	2	4	3
East	Blackcomb Cr. @ Yummy Numby	2022-09-06	505211	5552576	762	15	8.4	6.8	6.8	Low	Med.	19	3	3	4
East	Whistler Creek - 1	2022-09-06	501041	5549045	692	14	6.2	5.2	7.5	Low	High	12	3	3	4
East	Whistler Creek - 2	2022-09-06	501649	5547961	879	14	5.1	5.3	6.8	Low	Low	11	1	5	5
East	Whistler Creek - 3	2022-09-06	501417	5548276	972	25	4.1	6.1	6.8	Low	Low	14	3	3	4
West	Nineteen-Mile Creek-1	2022-09-07	502764	5555303	648	4	NR	3.9	7.0	Low	Low	12	2	4	4
West	Nineteen-Mile Creek-2	2022-09-07	502121	5555246	692	8	NR	5.1	7.0	Low	Low	16	3	2	4
West	Nineteen-Mile Creek-3	2022-09-09	501114	5557282	1095	3	NR	4.3	7.0	Med	Low	20	1	5	5
West	Sproatt Creek - 1 (Danimal South)	2022-09-08	499063	5549434	692	25	6.6	2.1	6.5	Low	Low	11	3	3	4
West	Sproatt Creek - 2 (Don't Look Back)	2022-09-08	498996	5549662	790	32	7.8	4.2	6.5	Low	High	8	3	3	5
West	Sproatt Creek - 3 (Flank Trail)	2022-09-08	498483	5550455	996	24	5.0	2.2	6.2	Low	High	9	3	3	4
West	Van West-2 (Flank Trail)	2022-09-08	497563	5549038	706	18	5.1	2.6	6.5	Low	High	11	4	2	2
West	Van West-3 (Into the Mystic)	2022-09-08	497125	5549816	1036	25	4.2	1.5	6.8	Low	Low	10	1	5	5

Valley Side	Site	Date	Surveyors	Easting	Northing	Elev. (m)	Wea-ther	Water Temp. (°C)	Air Temp. (°C)	T1	T2	T3	Tad-poles	Tad-poles /100m2	Meta+ Adults
East	Archibald Creek - 1	2022-09-07	BB, RM	502387	5550606	695	Sun	10.4	16.0	2	1	1	4	28.6	0
East	Archibald Creek - 2	2022-09-07	BB, RM	502854	5550298	835	Sun	9.2	13.4	1	0	2	3	30.0	0
East	Archibald Creek - 3	2022-09-07	BB, RM	503310	5549422	1026	Sun	8.2	12.8	5	0	1	6	44.4	0
East	Blackcomb Cr. @ Lost Lake Rd.	2022-09-06	BB, HW, RM	504641	5552586	692	Sun	8.0	19.0	0	0	0	0	0.0	0
East	Blackcomb Cr. @ Yummy Numby	2022-09-06	BB, HW, RM	505211	5552576	762	Sun	6.8	11.0	0	0	0	0	0.0	0
East	Whistler Creek - 1	2022-09-06	BB, HW, RM	501041	5549045	692	Sun	10.0	20.0	0	4	2	6	42.9	0
East	Whistler Creek - 2	2022-09-06	BB, HW, RM	501649	5547961	879	Sun	8.0	10.0	7	1	0	8	53.3	0
East	Whistler Creek - 3	2022-09-06	BB, HW, RM	501417	5548276	972	Sun	7.0	8.0	5	3	0	8	57.1	0
West	Nineteen-Mile Creek-1	2022-09-07	BB, RM	502764	5555303	648	Sun	9.7	11.0	0	0	0	0	0.0	0
West	Nineteen-Mile Creek-2	2022-09-07	BB, RM	502121	5555246	692	Sun	9.5	12.3	0	0	0	0	0.0	0
West	Nineteen-Mile Creek-3	2022-09-09	BB	501114	5557282	1095	Sun	8.0	14.0	0	0	0	0	0.0	0
West	Sproatt Creek - 1 (Danimal South)	2022-09-08	BB, RM	499063	5549434	692	Sun	11.0	17.0	0	1	0	1	9.5	0
West	Sproatt Creek - 2 (Don't Look Back)	2022-09-08	BB, RM	498996	5549662	790	Sun	11.0	15.0	0	0	1	1	10.5	0
West	Sproatt Creek - 3 (Flank Trail)	2022-09-08	BB, RM	498483	5550455	996	Sun	10.0	12.0	1	0	7	8	55.2	1
West	Van West-2 (Flank Trail)	2022-09-08	BB, RM	497563	5549038	706	Sun	10.0	12.0	1	0	0	1	11.1	0
West	Van West-3 (Into the Mystic)	2022-09-08	BB, RM	497125	5549816	1036	Sun	9.5	14.0	0	1	5	6	80.0	0

Surveyors: BB (Bob Brett); HW (Hillary Williamson; RM (Rebecca Merenyi)

Appendix E: Tailed Frog Site eDNA Sampling

		InetgritE-DNA™					Target Species -ASTR				
BV Case ID	**Sample Name**	**qPCR Run**	**Well**	**Ct Value**	**Score**	**Frequency**	**qPCR Run**	**Well**	**Ct Value**	**Score**	**Frequency**
SN20220001	BC1-A	220929Q5	A1	19.56	1	4/4	220930Q9	A01	N/A	0	**2/8**
Blackcomb Creek - A		220929Q5	B1	19.77	1		220930Q9	B01	N/A	0	
		220929Q5	C1	19.93	1		220930Q9	C01	**44.54**	**1**	
		220929Q5	D1	19.84	1		220930Q9	D01	N/A	0	
							220930Q9	E01	N/A	0	
							220930Q9	F01	**45.14**	**1**	
							220930Q9	G01	N/A	0	
							220930Q9	H01	N/A	0	
SN20220002	BC1-B	220929Q5	E1	20.22	1	4/4	220930Q9	A02	N/A	0	**2/8**
Blackcomb Creek - B		220929Q5	F1	20.29	1		220930Q9	B02	N/A	0	
		220929Q5	G1	20.18	1		220930Q9	C02	N/A	0	
		220929Q5	H1	20.01	1		220930Q9	D02	N/A	0	
							220930Q9	E02	**49.03**	**1**	
							220930Q9	F02	N/A	0	
							220930Q9	G02	N/A	0	
							220930Q9	H02	**43.81**	**1**	
SN20220003	BC1-C	220929Q5	A2	20.61	1	4/4	220930Q9	A03	N/A	0	**0/8**
Blackcomb Creek - C		220929Q5	B2	19.80	1		220930Q9	B03	N/A	0	
		220929Q5	C2	20.70	1		220930Q9	C03	N/A	0	
		220929Q5	D2	20.56	1		220930Q9	D03	N/A	0	
							220930Q9	E03	N/A	0	
							220930Q9	F03	N/A	0	
							220930Q9	G03	N/A	0	
							220930Q9	H03	N/A	0	
SN20220004	NM-A	220929Q5	E2	20.31	1	4/4	220930Q9	A04	N/A	0	**1/8**
Nineteen-Mile - A		220929Q5	F2	20.35	1		220930Q9	B04	N/A	0	
		220929Q5	G2	20.25	1		220930Q9	C04	N/A	0	
		220929Q5	H2	20.23	1		220930Q9	D04	**48.08**	**1**	
							220930Q9	E04	N/A	0	
							220930Q9	F04	N/A	0	
							220930Q9	G04	N/A	0	
							220930Q9	H04	N/A	0	
SN20220005	NM-B	220929Q5	A3	20.21	1	4/4	220930Q9	A05	N/A	0	**0/8**
Nineteen-Mile - B		220929Q5	B3	20.19	1		220930Q9	B05	N/A	0	
		220929Q5	C3	20.14	1		220930Q9	C05	N/A	0	
		220929Q5	D3	20.21	1		220930Q9	D05	N/A	0	
							220930Q9	E05	N/A	0	
							220930Q9	F05	N/A	0	
							220930Q9	G05	N/A	0	
							220930Q9	H05	N/A	0	
SN20220006	WDI-A	220929Q5	E3	32.77	0	0/4					
(Distilled Water Control)		220929Q5	F3	33.07	0						
		220929Q5	G3	33.05	0						
		220929Q5	H3	32.74	0						

Appendix F: Benthic Invertebrates / CABIN

Fraser River 2014 Reference Model Group Assignment Probability (%)

Site	Year	Assigned Reference Group #	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Twenty-one Mile Creek	2016	4	6%	4%	29%	***29%***	21%	12%
	2017	3	10%	5%	***33%***	24%	17%	10%
	2018	5	10%	5%	22%	17%	***39%***	6%
	2019	3	10%	5%	***33%***	24%	17%	10%
	2020	4	0%	0%	0%	***56%***	33%	11%
	2021	3	10%	5%	***34%***	24%	17%	10%
	2022	3	9%	4%	***40 %***	21%	17%	10%
Crabapple Creek	2016	1	***45%***	26%	0%	18%	9%	2%
	2017	1	***45%***	26%	0%	18%	8%	2%
	2018	1	***45%***	26%	0%	18%	8%	2%
	2019	4	0%	0%	0%	***88%***	12%	0%
	2020	5	0%	0%	0%	10%	***90%***	0%
	2021	5	30%	17%	0%	10%	***42%***	1%
	2022	5	27%	11%	0%	4%	***58%***	0%
Jordan Creek	2016	4	13%	8%	0%	***55%***	2%	21%
	2017	4	19%	10%	0%	***51%***	2%	19%
	2018	4	9%	7%	0%	***58%***	8%	18%
	2019	4	7%	6%	0%	***63%***	3%	21%
	2020	4	7%	6%	0%	***63%***	3%	22%
	2021	4	9%	7%	0%	***58%***	8%	19%
	2022	5	9%	6%	0%	33%	***43%***	9%
River of Golden Dreams (Upper)	2016	3	9%	5%	***38%***	22%	17%	10%
	2017	3	8%	4%	***41%***	21%	16%	10%
	2018	5	9%	4%	27%	16%	***38%***	7%
	2019	3	9%	5%	***39%***	22%	17%	10%
	2020	4	0%	0%	0%	***61%***	33%	6%
	2021	5	9%	4%	21%	18%	***41%***	7%
	2022	5	0%	1%	0%	0%	***99%***	0.20%
River of Golden Dreams (Lower)	2016	4	17%	8%	16%	***27%***	23%	9%
	2017	5	16%	7%	10%	17%	**46%**	5%
	2018	5	12%	4%	5%	8%	**68%**	2%
	2019	5	18%	7%	10%	16%	**44%**	5%
	2020	5	18%	7%	10%	16%	***41%***	5%
	2021	4	17%	9%	13%	***29%***	23%	9%
	2022	5	0.4%	0.5%	0%	0.3%	**99%**	0.2%

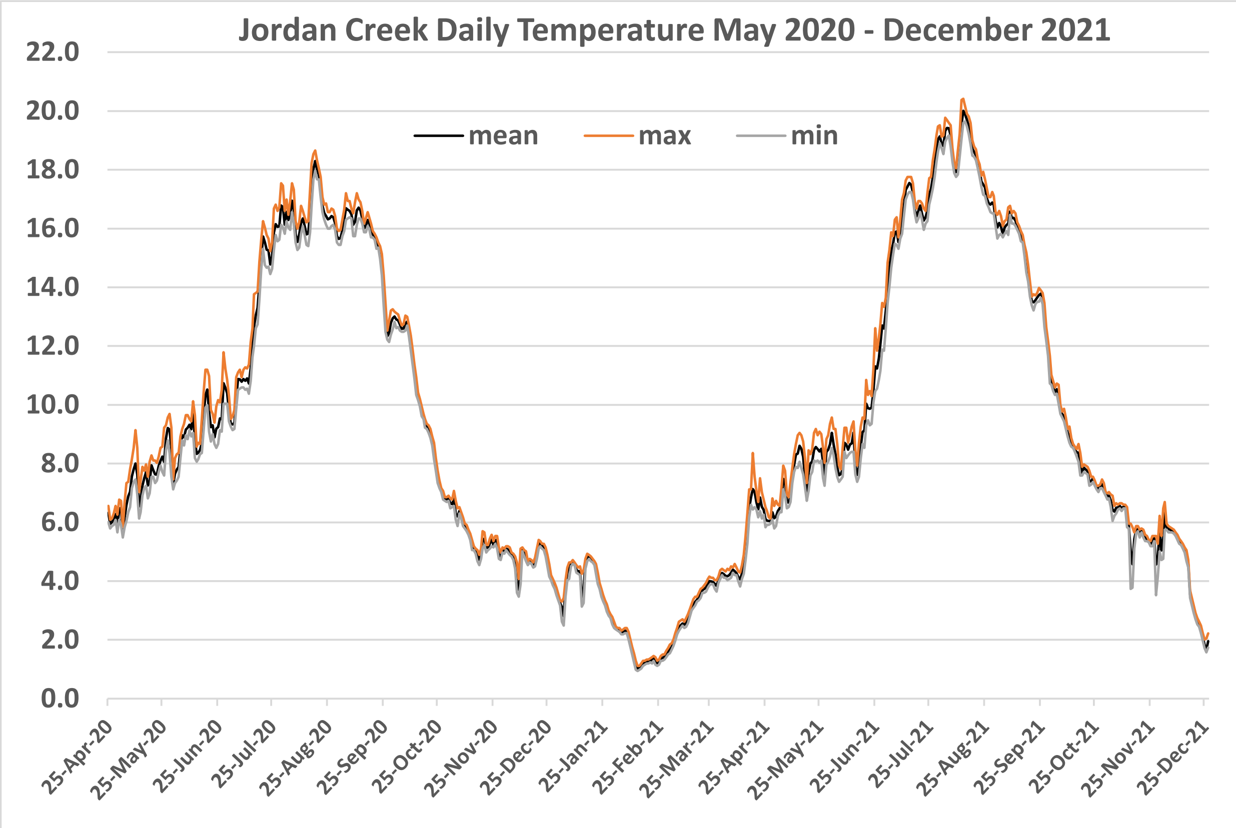
Fraser River – Georgia Basin 2005 Reference Model Group Assignment Probability (%)

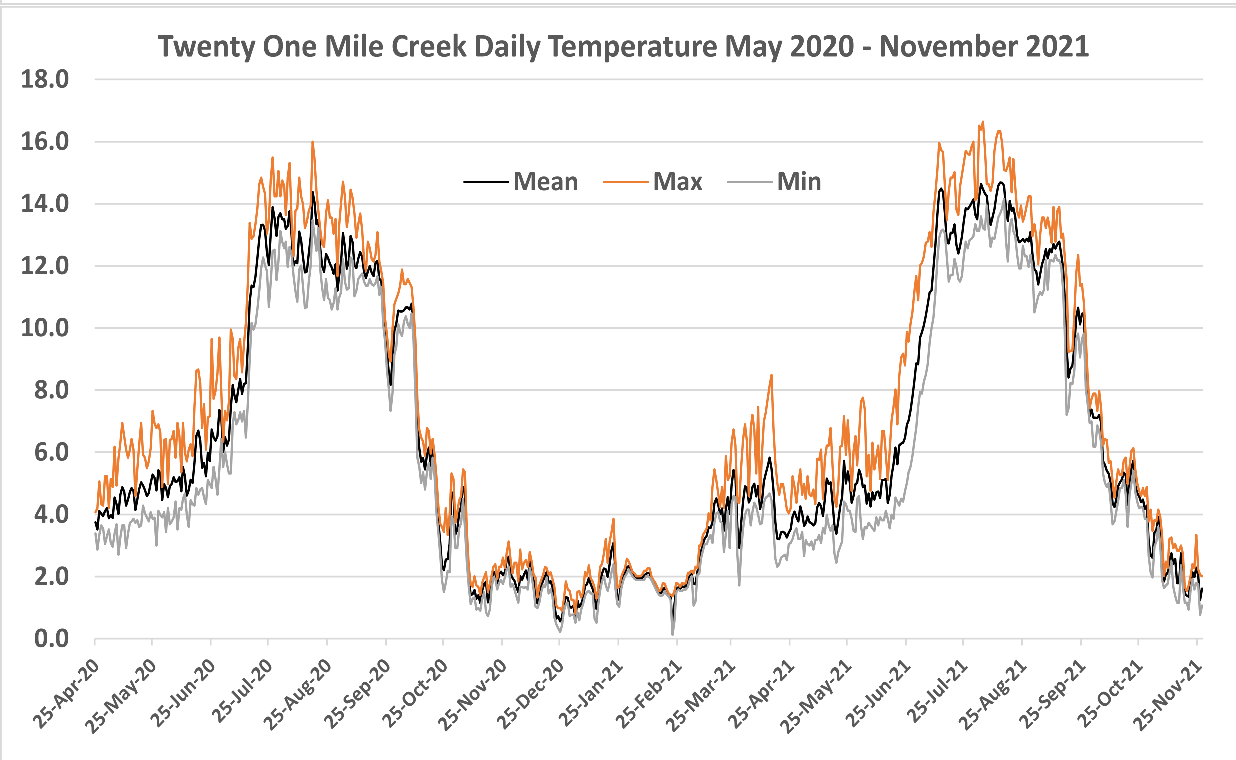
Site	Year	Assigned Reference Group #	Group 1	Group 2	Group 3	Group 4	Group 5
Jordan Creek	2016	1	***71%***	0.3%	21%	0.3%	7%
	2017	1	***95%***	0.2%	4%	0.0%	1%
	2018	1	***93%***	0.2%	6%	0.3%	1%
	2019	1	***91%***	0.1%	8%	0.0%	1%
	2020	1	***87%***	0.1%	11%	0.1%	2%
	2021	1	***50%***	0.4%	30%	10%	10%
	2022	1	***48%***	0.1%	8%	42%	2%
Whistler Creek	2022	4	27.8%	0.6%	19.8%	***35.3%***	16.5%

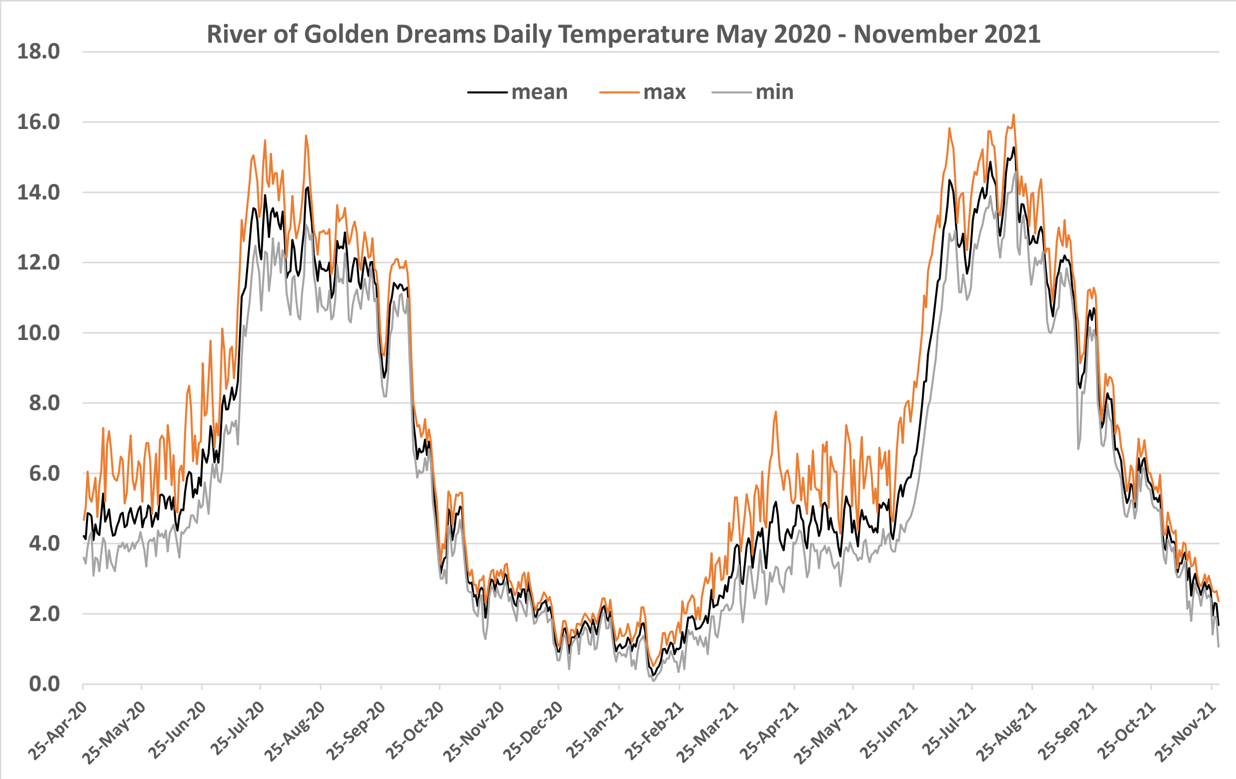
Results of the 2022 Taxonomic Analysis

Phylum	Class	Order	Family	Genus/Species	ROGD	ROGD	21 Mile Creek	Whistler Creek	Jordan Creek	Crabapple Creek
				Site Code	RGD-US-AQ11	RGD-DS-AQ12	21M-DS-AQ21	WHi-AQ-01	JOR-DS-AQ31	CRB-AQ-01
				Sampling Date	22-Jul-22	22-Jul-22	22-Jul-22	23-Jul-22	23-Jul-22	23-Jul-22
				Sorting Date	02-Nov-22	26-Oct-22	27-Oct-22	31-Oct-22	01-Nov-22	02-Nov-22
				Sorted Fraction	100%	100%	100%	38%	100%	41%
ANNELIDA	CLITELLATA	Lumbriculida	Enchytraeidae	(unidentified)		1				
			Lumbriculidae	(unidentified)	51	41	65		8	
		Tubificida	Naididae							1
MOLLUSCA	GASTROPODA	Basommatophora	Planorbidae						1	
ARTHROPODA	ARACHNIDA	Trombidiformes	Lebertiidae	*Lebertia sp.*				1	1	2
			Torrenticolidae	*Torrenticola sp.*						2
	INSECTA	Ephemeroptera	Ameletidae	*Ameletus sp.*	2	1	1			
			Baetidae	*Baetis sp.*	74	5	54	76	5	82
				Baetis bicaudatus		2	24			
				Baetis rhodani group		9				5
				Diphetor hageni					12	
				Procloeon sp.		1				
			Ephemerellidae	(Immature)		9				
				Drunella coloradensis				20		
				Drunella spinifera		5		2		
				Serratella sp.		10		4	15	
			Heptageniidae	*Damaged/Immature*		10				
				Cinygma sp.						3
				Cinygmula sp.	101	17	87	13		
				Epeorus sp.	151	15	153	62		1
				Rhithrogena sp.	93	5	81	1		
			Leptophlebiidae	(damaged)				1		
				Paraleptophlebia sp.					23	16
		Plecoptera	Chloroperlidae	(Immature)				2		
				Suwallia sp.	27	2	28	39		
				Sweltsa sp.		5		2	11	107
			Leuctridae	*Despaxia augusta*				1		
				Paraleuctra sp.	1					
			Nemouridae	*Visoka cataractae*				3		
				Zapada sp.			1	8	10	1
				Zapada cinctipes					1	
				Malenka sp.						2
			Perlidae	(Early instar)	2					
				Calineuria sp.			1	2		
			Perlodidae	(Immature)	3					
				Kogotus sp.	2		3	25	1	
		Trichoptera	Glossosomatidae	*Glossosoma sp.*			1			
			Hydropsychidae	*Arctopsyche sp.*				1		
			Lepidostomatidae	*Lepidostoma sp.*					2	7
			Leptoceridae	*Mystacides sp.*					1	
			Limnephilidae	*Onocomoescus sp.*					2	2
				Psychoglypha sp.		2			1	1
			Rhyacophilidae	*Rhyacophila sp.*	1	2		4		
				Rhyacophila angelita	1		1	1	6	4
				Rhyacophila betteni group				4		
		Coleoptera	Dytiscidae	*Oreodytes sp.*						4
			Elmidae	*Narpus sp.*				1		1
		Megaloptera	Sialidae	*Sialis sp.*					2	
		Diptera	Ceratopogonidae	*Mallochohelea sp.*	1	1		4		
			Chironomidae	Orthocladiinae (Early instar)		7				
				Brillia sp.	1	1			3	1
				Corynoneura sp.					84	
				Cricotopus/Orthocladius		3		14		
				Diamesa sp.			1		1	
				Eukiefferiella sp.		2			1	
				Macropelopia sp					1	2
				Micropsectra sp.	1					
				Pagastia sp.				6		
				Parametriocnemus sp.	1	2		1		
				Pseudodiamesa sp.						1
				Rheocricotopus sp.	1		1		**3**	
				Stempellinella sp.		2			2	
				Tanytarsus sp.		15			106	1
				Thienemannimyia gro	2	3				
				Tevtenia sp.	2	11	1		1	31
				Zavrelimyia sp.						26
			Empididae	*Chelifera sp./ Metachela sp.*		1				
				Clinocera sp.				3		
				Neoplasta sp.		2				
			Simuliidae	*Simulium sp.*	3	13	10			4
			Tipulidae	*Dicranota sp.*	1		1		3	2
				Hexatoma sp.	1		1		2	4
				Limnophila sp.			1			1
				Tipula sp.						1
CRUSTACEA	MALCOSTRACA	Amphipoda	Crangonyctidae	*Crangonyx sp.*		12		1	12	
				Total Number of Organisms	**523**	**217**	**516**	**302**	**321**	**315**
				Total Number of Taxa	**23**	**32**	**20**	**28**	**29**	**28**

Appendix G: Water Temperatures and Fish Habitat






River of Golden Dreams Daily Temperature May 2020 - November 2021
mean
max
min
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
25-Apr-20
25-May-20
25-Jun-20
25-Jul-20
25-Aug-20
25-Sep-20
25-Oct-20
25-Nov-20
25-Dec-20
25-Jan-21
25-Feb-21
25-Mar-21
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25-Jun-21
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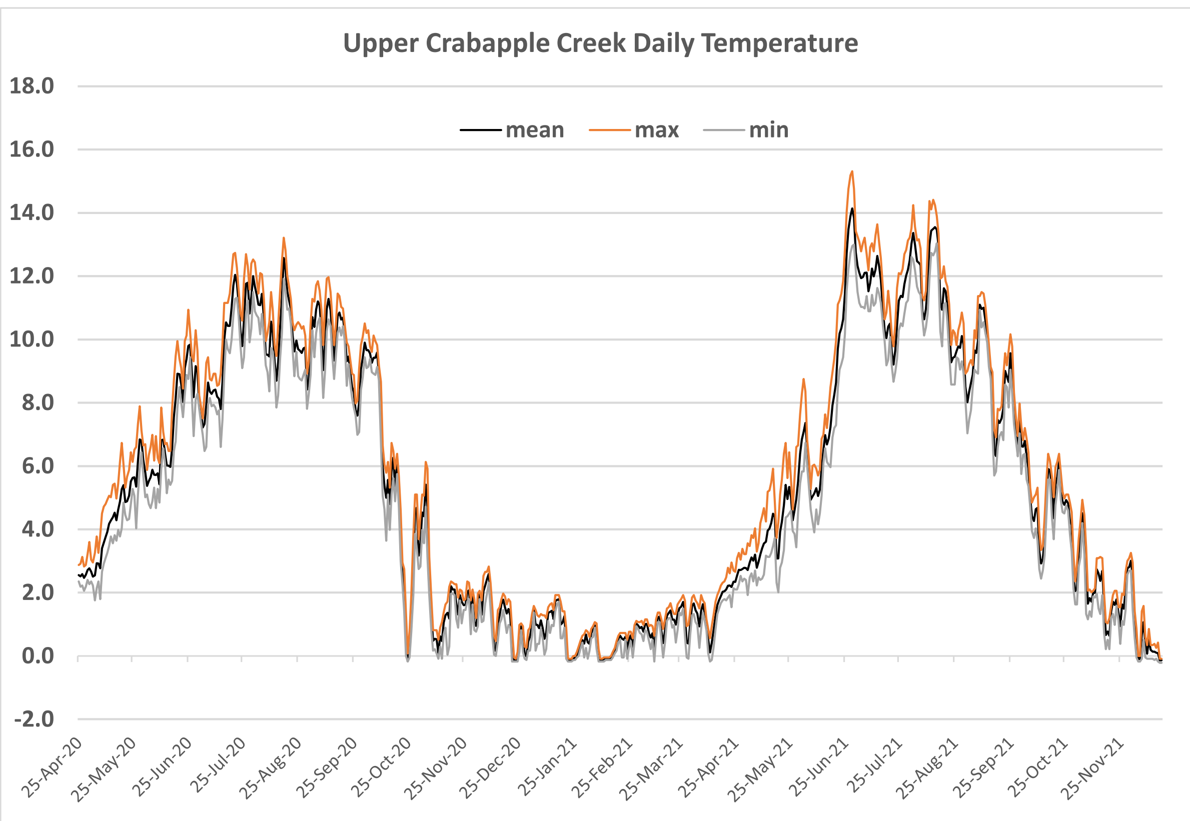
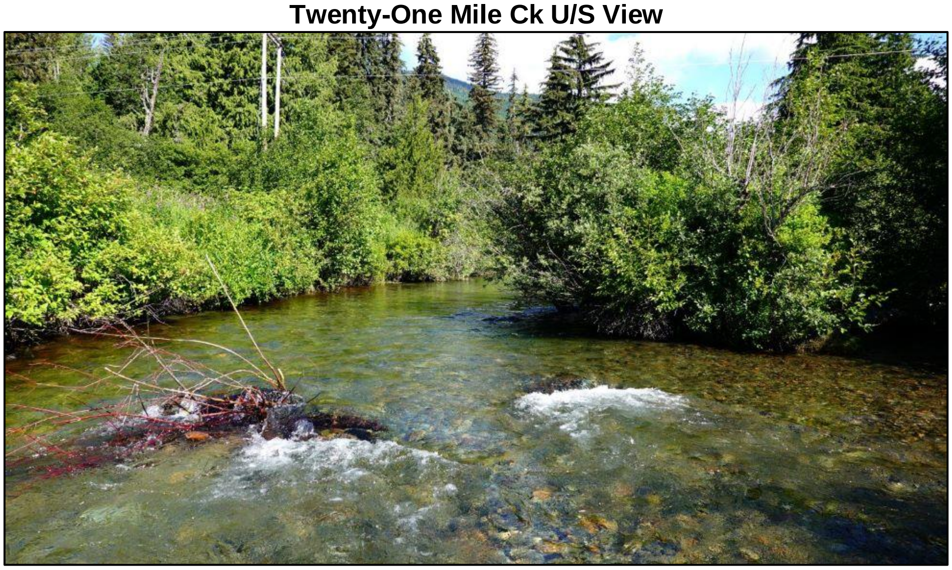
25-Sep-21
25-Oct-21
25-Nov-21


Upper Crabapple Creek Daily Temperature
mean
max
min
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
25-Apr-20
25-May-20
25-Jun-20
25-Jul-20
25-Aug-20
25-Sep-20
25-Oct-20
25-Nov-20
25-Dec-20
25-Jan-21
25-Feb-21
25-Mar-21
25-Apr-21
25-May-21
25-Jun-21
25-Jul-21
25-Aug-21
25-Sep-21
25-Oct-21
25-Nov-21

Date	22-Jul-22	Stream		21 Mile Creek					
Water quality		Area and Substrate		Depth and velocity (m)		Site Cover		Vegetation and Channel	
Habitat type	Riffle-Run	Gradient	1%	Avg Dep	0.31	OH%	1-25%	Grass	Y
Site type	Full x-sec	Width 1 (m)	11.5	Avg Vel	0.85	Turb%	1-25%	Shrub	Y
Turbidity NTU	1.16	Width 2 (m)	16.1	Depth 1	0.31	Deep%	1-25%	Decidiuous	Y
do%	98.5	Width 3 (m)	13.4	Depth 2	0.17	Bol%	0%	Conifer	n
do mg/l	11.6	Length (m)	82	Depth 3	0.28	UC%	76-100%	Dom Veg	S
TDS	10	Wet area m2	1124	Depth 4	0.36	Macro%	1-25%	Sub Veg	D
Conductivity	10	max depth(m)	1.22	Depth 5	0.41	LWD m2	0	Channel Pat	S
SC/cm	15.3	%bol	5	Depth 6	0.28	SWD m2	6	Islands	O
ph	7.3	%cob	15	Vel 1	0.49	Dmax(m)	0.70	Bars	N
Stream Temp ^{0}C	8.0	%grv	60	Vel 2	0.84	D90 (m)	0.15	Riparian Stg	SHR
		%fines	20	Vel 3	1.13				
		%Org	0	Vel 4	1.10				
				Vel 5	0.33				
				Vel 6	1.23				
Good		Good		Good		Fair		Good	

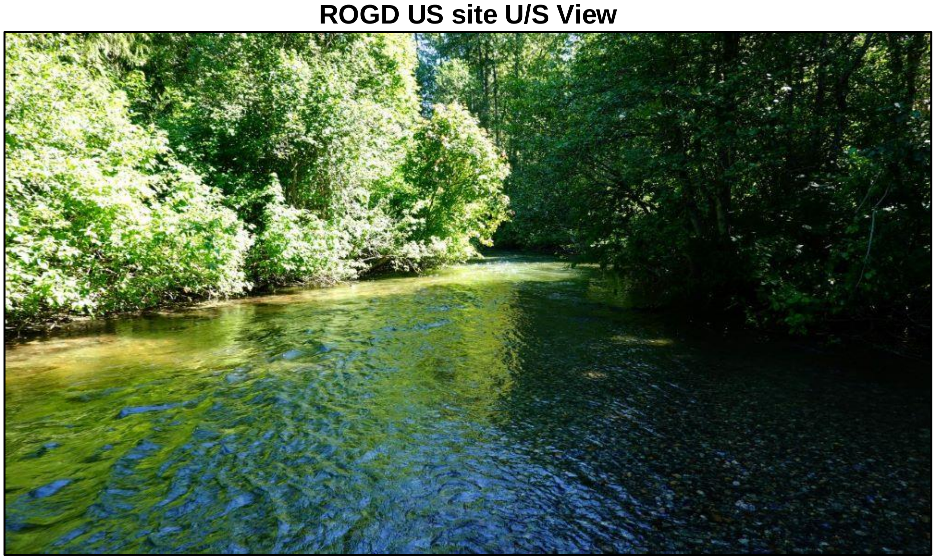
Twenty-One Mile Ck U/S View



Twenty-One Mile Ck D/S View

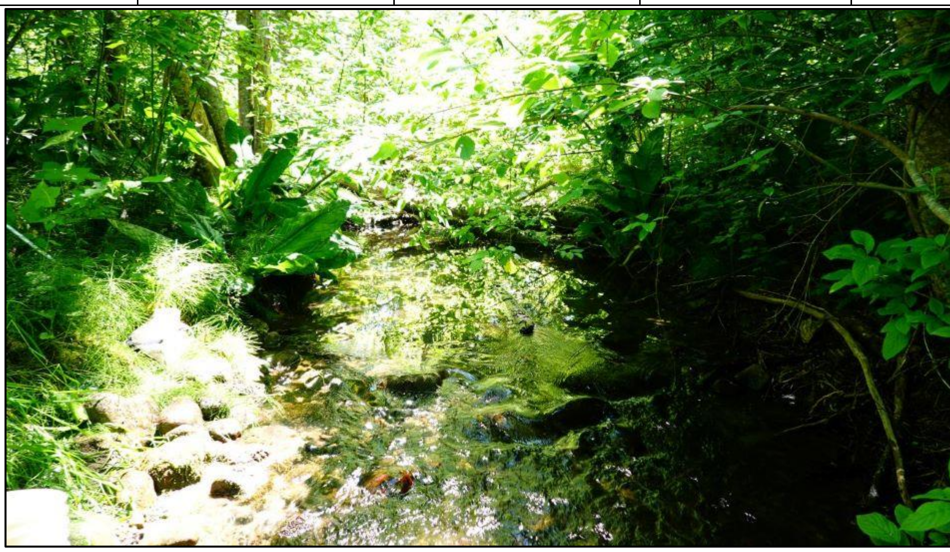
Date	22-Jul-22	Stream		ROGD U/S					
Water quality		Area and Substrate		Depth and velocity (m)		Site Cover		Vegetation and Channel	
Habitat type	Pool-Riffle	Gradient	<1%	Avg Dep	0.32	OH%	26-50%	Grass	Y
Site type	Full x-sec	Width 1 (m)	13.4	Avg Vel	0.90	Turb%	1-25%	Shrub	Y
Turbidity NTU	1.17	Width 2 (m)	12.5	Depth 1	0.22	Deep%	26-50%	Decidiuous	Y
do%	98.8	Width 3 (m)	11.8	Depth 2	0.12	Bol%	0%	Conifer	Y
do mg/l	10.8	Length (m)	75	Depth 3	0.34	UC%	76-100%	Dom Veg	S
TDS	24	Wet area m2	945	Depth 4	0.54	Macro%	0%	Sub Veg	D
Conductivity	14	max depth(m)	1.62	Depth 5	0.36	LWD m2	2	Channel Pat	IM
SC/cm	20.2	%bol	0	Depth 6	0.33	SWD m2	8	Islands	N
ph	7.0	%cob	10	Vel 1	0.42	Dmax(m)	0.45	Bars	S
Stream Temp ^{0}C	11.5	%grv	60	Vel 2	0.48	D90 (m)	0.15	Riparian Stg	YF
		%fines	30	Vel 3	1.21				
		%Org	0	Vel 4	1.26				
				Vel 5	1.26				
				Vel 6	0.79				
Good		Good		Good		Good		Good	

ROGD US site U/S View

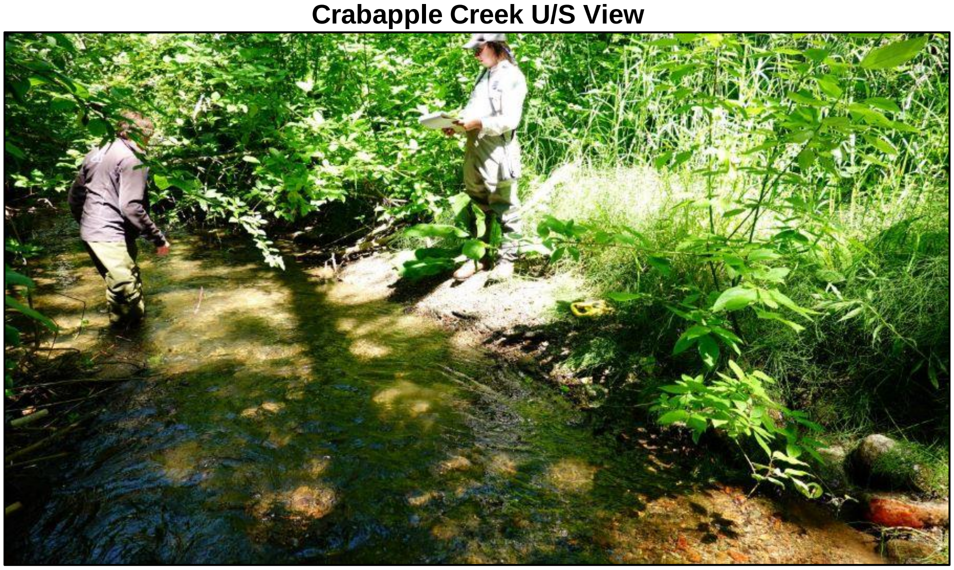


ROGD US Site D/S View

Date	22-Jul-22	Stream		Crabapple Ck					
Water quality		Area and Substrate		Depth and velocity (m)		Site Cover		Vegetation and Channel	
Habitat type	Pool-Riffle	Gradient	1%	Avg Dep	0.15	OH%	76-100%	Grass	Y
Site type	Full x-sec	Width 1 (m)	3.6	Avg Vel	0.14	Turb%	1-25%	Shrub	Y
Turbidity NTU	1.6	Width 2 (m)	5.3	Depth 1	0.13	Deep%	0%	Decidiuous	Y
do%	97	Width 3 (m)	2.9	Depth 2	0.35	Bol%	1-25%	Conifer	Y
do mg/l	9.3	Length (m)	23	Depth 3	0.08	UC%	26-50%	Dom Veg	C
TDS	122	Wet area m2	92	Depth 4	0.05	Macro%	0%	Sub Veg	S
Conductivity		max depth(m)	0.41	Depth 5		LWD m2	6	Channel Pat	S
SC/cm	190	%bol	5	Depth 6		SWD m2	4	Islands	N
ph	6.4	%cob	10	Vel 1	0.15	Dmax(m)	0.75	Bars	N
Stream Temp ^{0}C	14.0	%grv	40	Vel 2	0.33	D90 (m)	0.25	Riparian Stg	YF
		%fines	30	Vel 3	0.06				
		%Org	10	Vel 4	0.00				
				Vel 5					
				Vel 6					
Good		Good		Good		Good		Good	



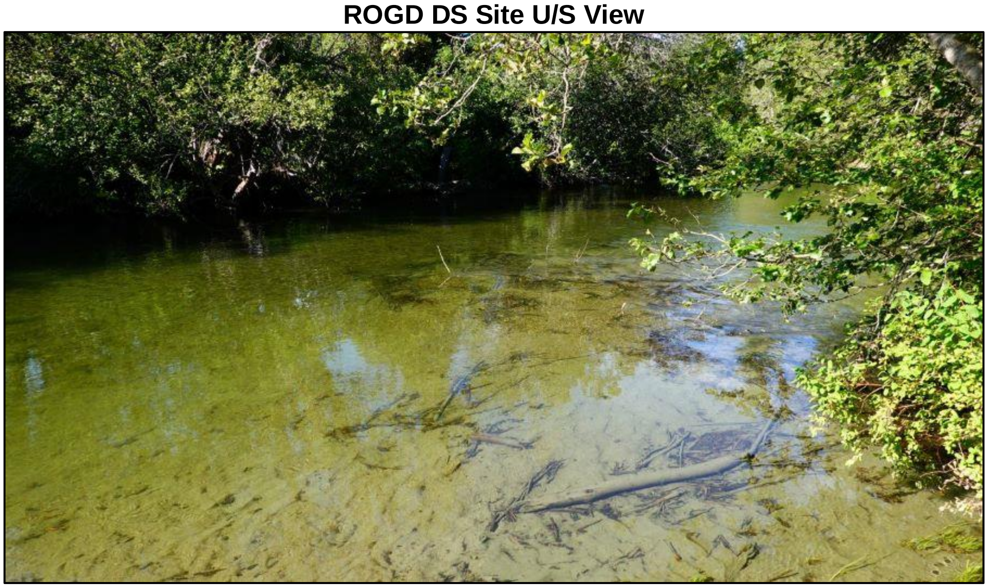
Crabapple Creek U/S View



Crabapple Creek D/S View

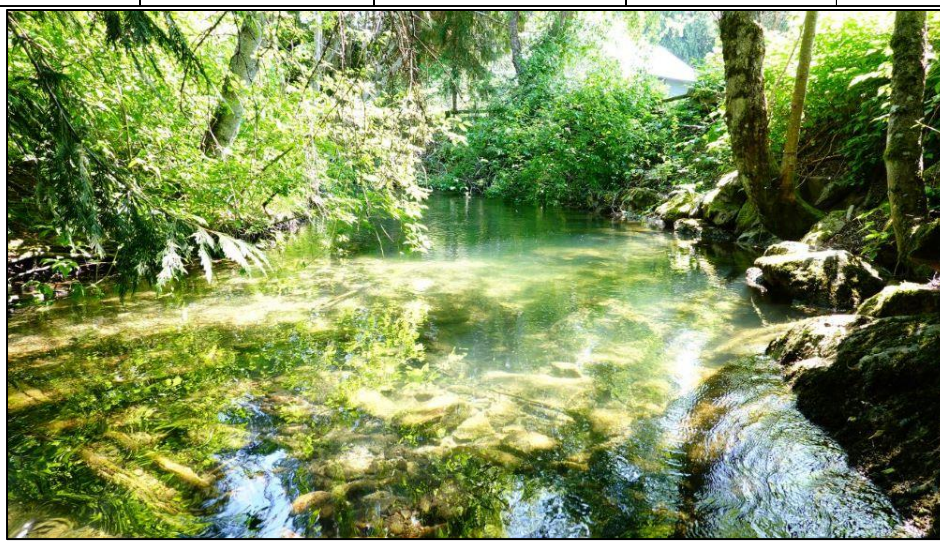
Date	22-Jul-22	Stream		ROGD DS					
Water quality		Area and Substrate		Depth and velocity (m)		Site Cover		Vegetation and Channel	
Habitat type	Pool-Riffle	Gradient	<1%	Avg Dep	0.73	OH%	1-25%	Grass	n
Site type	Full x-sec	Width 1 (m)	16.6	Avg Vel	0.44	Turb%	1-25%	Shrub	Y
Turbidity NTU	1.5	Width 2 (m)	14.9	Depth 1	0.63	Deep%	26-50%	Decidiuous	Y
do%	100.2	Width 3 (m)	13.8	Depth 2	0.46	Bol%	0%	Conifer	Y
do mg/l	10.4	Length (m)	90	Depth 3	0.88	UC%	76-100%	Dom Veg	S
TDS	19	Wet area m2	1359	Depth 4	0.87	Macro%	1-25%	Sub Veg	D
Conductivity	20.9	max depth(m)	1.55	Depth 5	0.79	LWD m2	6	Channel Pat	IM
SC/cm	28.8	%bol	0	Depth 6	0.48	SWD m2	2	Islands	N
ph	7.1	%cob	5	Vel 1	0.22	Dmax(m)	0.30	Bars	S
Stream Temp ^{0}C	10.5	%grv	50	Vel 2	0.22	D90 (m)	0.15	Riparian Stg	YF
		%fines	35	Vel 3	0.60				
		%Org	10	Vel 4	0.65				
				Vel 5	0.59				
				Vel 6	0.38				
Good		Fair		Good		Good		Good	

ROGD DS Site U/S View



ROGD DS Site U/S View

Date	23-Jul-22	Stream		Jordan Creek					
Water quality		Area and Substrate		Depth and velocity (m)		Site Cover		Vegetation and Channel	
Habitat type	Pool-Run	Gradient	1%	Avg Dep	0.55	OH%	76-100%	Grass	Y
Site type	Full x-sec	Width 1 (m)	6.8	Avg Vel	0.21	Turb%	1-25%	Shrub	Y
Turbidity NTU	1.16	Width 2 (m)	5.6	Depth 1	0.38	Deep%	26-50%	Decidiuous	Y
do%	103.8	Width 3 (m)	5.4	Depth 2	0.43	Bol%	1-25%	Conifer	Y
do mg/l	10.2	Length (m)	36	Depth 3	0.58	UC%	76-100%	Dom Veg	D
TDS	33	Wet area m2	212	Depth 4	0.79	Macro%	0%	Sub Veg	C
Conductivity	39.7	max depth(m)	1.46	Depth 5	0.59	LWD m2	4	Channel Pat	S
SC/cm	51.4	%bol	25	Depth 6	0.51	SWD m2	6	Islands	N
ph	7.0	%cob	40	Vel 1	0.24	Dmax(m)	1.80	Bars	N
Stream Temp ^{0}C	13.0	%grv	25	Vel 2	0.65	D90 (m)	0.40	Riparian Stg	YF
		%fines	10	Vel 3	0.12				
		%Org	0	Vel 4	0.09				
				Vel 5	0.13				
				Vel 6	0.02				
Good		Good		Good		Good		Good	



Jordan Creek U/S View

Jordan Creek D/S View

Date	23-Jul-22	Stream		Whistler Creek					
Water quality		Area and Substrate		Depth and velocity (m)		Site Cover		Vegetation and Channel	
Habitat type	Pool-Run	Gradient	1%	Avg Dep	0.24	OH%	51-75%	Grass	Y
Site type	Full x-sec	Width 1 (m)	5.9	Avg Vel	0.67	Turb%	1-25%	Shrub	Y
Turbidity NTU	1.3	Width 2 (m)	7.9	Depth 1	0.1	Deep%	1-25%	Decidiuous	Y
do%	99.6	Width 3 (m)	7.3	Depth 2	0.12	Bol%	1-25%	Conifer	Y
do mg/l	10.9	Length (m)	42	Depth 3	0.2	UC%	76-100%	Dom Veg	C
TDS	36	Wet area m2	295	Depth 4	0.38	Macro%	0%	Sub Veg	S
Conductivity	37.3	max depth(m)	0.65	Depth 5	0.42	LWD m2	8	Channel Pat	S
SC/cm	54.8	%bol	5	Depth 6	0.25	SWD m2	6	Islands	N
ph	6.8	%cob	15	Vel 1	0.46	Dmax(m)	1.40	Bars	N
Stream Temp ^{0}C	8.4	%grv	60	Vel 2	0.57	D90 (m)	0.25	Riparian Stg	YF
		%fines	15	Vel 3	0.81				
		%Org	5	Vel 4	0.74				
				Vel 5	0.91				
				Vel 6	0.51				
Good		Good		Good		Good		Good	

Whistler Creek U/S View

Whistler Creek D/S View