Rapid Response Bullfrog Control and Biodiversity Research in Sensitive Wetlands (HCTF #2-699)

Jennifer Barden, Project Coordinator
April 2021

Fraser Valley Conservancy
Placing lands in trust for our future

Acknowledgements

The Rapid Response Bullfrog Control and Biodiversity Research in Sensitive Wetlands project is coordinated by the Fraser Valley Conservancy after years of monitoring the amphibian populations of the Ryder Lake area through the Ryder Lake Amphibian Protection Program (RLAPP). This project owes its origin to the hard work provided by the RLAPP team and all the associated groups and volunteers that have supported this project along the way.

The Fraser Valley Conservancy would like to thank Matt Morrison, Purnima Govindarajulu, and Kendra Morgan for their support designing and guiding this project. Thank you to Athene Ecological for their monitoring expertise, and to the University of the Fraser Valley for providing research assistance. We are deeply indebted to Pieter Johnson and the University of Colorado for their amazing research on a new parasite discovery.

We are grateful for the generous support of the Habitat Conservation Trust Foundation, who has allowed the Fraser Valley Conservancy to support the biodiversity of the Ryder Lake area for many years. The relationships we have built with this community is invaluable, and we could not do this work without them. Thank you!

Special thanks to Grace and Steve, without whom this project would not be what it is today.

Contents

Figures

Tables

Executive Summary

This project is of critical importance to protect a diverse and unique ecosystem in the Fraser Valley. The Ryder Lake neighbourhood sits up above the valley floor, boasting lush forests and dozens of small wetlands. One of the largest waterbodies, Hornby Wetland, is an important breeding location for the at-risk Western Toad and Northern Red-legged Frog, as well as four other native amphibians. HCTF funding has been used for the past six years to protect these amphibians from road mortality, however, the latest threat may be even more devastating to the entire wetland ecosystem. The American bullfrog was recently discovered in the Ryder Lake neighbourhood.

This project will implement a rapid response control effort while simultaneously gathering as much information about the biodiversity in this area as possible. In year 1, the FVC began the monumental task of documenting bullfrog impacts to amphibians, invertebrates, vegetative communities, and the larger neighbourhood ecosystem. During bullfrog control efforts we removed over 860 bullfrogs and 2 egg masses in the first year of this project and researched bullfrog replenishment into Hornby Wetland and Ryder Lake. Thorough documentation of capture efforts and project milestones are directly informing protocols and standards used by the provincial American Bullfrog Action Team.

The true importance of the FVC's bullfrog control efforts is as a research tool that contributes to bullfrog population/abundance data, native amphibian observations, and habitat use documentation for bullfrogs and native species. These surveys also identify research questions and opportunities beyond the scope of the project, which has led to collaborating with research institutions to preform science-based research to answer bullfrog impact questions. The unique opportunities for research provided by this unfortunate situation will aid in future conservation and management planning for other sensitive wetlands under threat by bullfrogs.

Of note in the first year this project was the discovery of bullfrogs infected with *Ribeiroia* parasites, which are only known to exist in one other location in BC. Future research partnerships will focus on the implications of detecting *Ribeiroia* in the area and the associated impacts to native amphibians. Benefits of this project will be felt not only in the immediate Ryder Lake area, but across the province of BC. Our scientific approach to biodiversity impact assessment, as well as our collaborative partnerships with local and international universities, will reveal important questions and answers we had not even considered.

Overall goals for this project in year 1 include: developing protocols for all activities that can be shared with other groups; creating a biodiversity baseline; identifying priority species for bullfrog impact assessment; research collaborations; and engaging the community in bullfrog education and awareness.

Introduction

Project History

The Fraser Valley Conservancy (FVC) has been working to protect the amphibians of Ryder Lake through HCTF funded projects for over six years. This work focused on preventing road mortality through the installation and monitoring of a specialized culvert. Our latest project began in 2019 with an investigation of what to do about bullfrogs recently discovered in Ryder Lake under the FVC's HCTF #2-642. That investigation led to the creation of the Rapid Response Bullfrog Control and Research in Sensitive Wetlands project in 2020.

Species Information

The American Bullfrog (*Lithobates catesbeianus*, hereafter bullfrog) is North America's largest true frog reaching up to 20 cm in length (Frogwatch, 2018). They have an olive, green or brown dorsal surface that often fades to a light green towards the head and bright gold eyes. There is usually some spotting on the dorsal surface with bands or blotching on the legs. This species does not have dorsolateral folds like the similar Green Frog (*Lithobates clamitans*), instead a skin fold extends from the eye and folds around the back of the tympanum. The "bwaa, bwaa" call of an adult male can be heard up to a kilometer away. Tadpoles can be up to 15 cm long and significantly larger than native BC tadpoles. Freshly metamorphosed bullfrogs are small compared to adults but are larger or similar in size to young adults of other frog species in the area.

Bullfrogs are highly aquatic but can travel up to 1.5 km over land to spread to other water bodies (USFWS, 2013). They prefer quiet water, such as shallow, warm ponds and lakes with thick vegetation. They can be seen in ditches and streams but seem to prefer standing water. Tadpoles are able to forgo metamorphosis in their first year and over-winter as tadpoles for up to two years, so bullfrogs require permanent bodies of water to breed in. A female can lay a large egg mass that could contain up to 20,000 eggs in a sheet on the water's surface and depending on conditions the eggs can hatch within 3-5 days. Bullfrogs reach sexual maturity as early as two years after metamorphosis.

Bullfrog Impacts

Bullfrogs are native to eastern North America from southern Canada to Florida. They were introduced in British Columbia in the 1930's for human consumption (frog legs) (BC Frogwatch, 1993). Many have since escaped and dispersed across the province. While their ranges can naturally expand, within British Columbia they are predominantly distributed by anthropogenic means. Humans move or release bullfrogs into natural areas (SeaGrant, 2020).

Adult bullfrogs are generalist, gape limited predators. Potential prey items vary over the course of their lives and includes a vast range of species. This is concerning when considering the impacts, a bullfrog invasion can have on native amphibian populations outside of their natural range. Bullfrog tadpoles are herbivorous, grazing on algae and detritus. Not only do bullfrogs prey on native amphibians but they compete for food and habitat at all life stages.

A bullfrog invasion into an area with no previous bullfrog presence is often viewed as having a negative influence on the survival of native species and is considered one of the "most ecologically destructive of invasive alien vertebrate species" (Triece et al, 2018). This is due to their adaptability, proliferation, distributional expansion rates and the potential ecological impacts associated with competition and predation (Jancowski & Orchard, 2013). Despite this view of bullfrog invasions, it is hard to conclusively determine if changes in native species population/abundance are directly caused by bullfrogs and documentation of their full impacts remains regionally fragmented (Jancowski & Orchard, 2013). Site-specific investigations of bullfrog impacts are therefore warranted to ensure the best management recommendations can be made.

Study Area

The study area for this project is in the Chilliwack Agriculture Upland Zone of the rural Ryder Lake Neighborhood, southeast of Chilliwack, British Columbia. The study area sits at an approximate elevation of 220 m and, per the Bio-geoclimatic Ecosystem Classification Subzone/Variant Map for the Chilliwack Natural Resource District, is located within the Coastal Western Hemlock dry maritime (CWHdm) subzone. The area is comprised of low-density privately-owned properties with pockets of natural and human-influenced ecological features, including Ryder Lake (Figure 1) and Hornby Wetland (Figure 2). Figure 3 shows the map of the study area including both Ryder Lake and Hornby Wetland.

Ryder Lake

Ryder Lake is a small water body on private property in the Ryder Lake neighborhood. This lake is approximately 2.3 hectares in size and is mostly surrounded by a mixed coniferous forest. Along the southern edge is a small field adjacent to a gravel road and an agricultural field that contains domestic cattle, which sometimes make their way down to the water. The deepest area of the lake measures just over 10 meters. The lake bottom has a steep drop off close to the waters edge leaving a narrow (< 5 m) band of shallow open water habitat along the edge. This edge is dominated by invasive Yellow flag iris (*Iris pseudacorus*).

Hornby Wetland

This site is a shallow wetland (< 2 m water depth) approximately 4.3 hectares in size. It was created on private land by beaver activity in the 1950's, though no beaver activity is currently suspected. A beaver dam was converted to a water level control structure by landowners, creating a permanent water body with consistent water levels throughout the year. Periods of high-water levels can be mitigated by lowering the gate on the water level control structure. The wetland and surrounding properties are owned by multiple stakeholders. The southern half of the wetland is mostly inaccessible by kayak/small boat due to the dense vegetation communities and significant woody debris presence. In the early 2000's, these features were significantly altered or removed in the northern section of the wetland. Aquatic vegetation is removed annually by the landowners for easier access to the wetland for recreational purposes. Along the western and south eastern edges, the mixed coniferous forest comes right to the edge of the wetland and the riparian vegetation on the north western section has been removed and replaced with a mowed grass lawn. The northeastern and southern edges are adjacent to hay fields that are hayed for forage by property caretakers.

Figure 2: (Left) Photo of Ryder Lake.

Figure 1. (Right) Photo of Hornby Wetland.

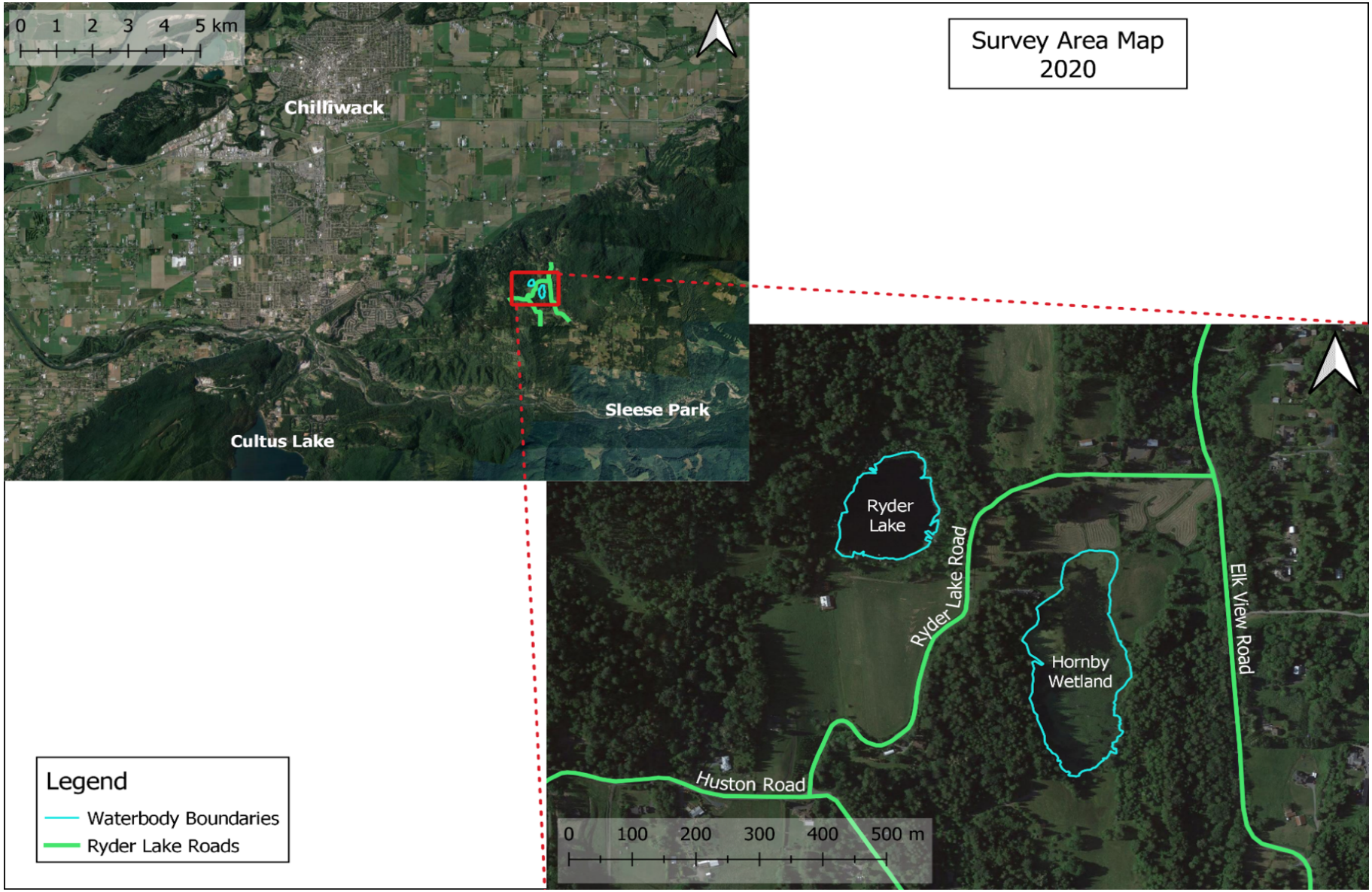


Figure 3: Map of the study area. *The water body boundaries from the survey area map were determined by walking/kayaking along the water body edge.*

Goals and Objectives

The goal of the Rapid Response Bullfrog Control and Biodiversity Research in Sensitive Wetlands Project is to protect the biodiversity of important wetland habitats in the Ryder Lake area. This will be accomplished by engaging in a rapid response bullfrog control program, gathering as much information on biodiversity for this area as possible and researching bullfrog impacts on local biodiversity. This project also aims to create a bullfrog management plan, identifying sustainable bullfrog mitigation strategies and habitat enhancement recommendations. Over the course of this five-year project, the results will lead to the creation of a habitat mitigation strategy for this area that is well informed. Specific objectives of this project include:

- Create a bullfrog control program and develop protocols
- Assess bullfrog control methods and program success
- Research bullfrog ecology and replenishment into study sites
- Create a biodiversity baseline and identify priority species for future monitoring efforts
- Monitor biodiversity and develop protocols
- Research bullfrog impacts on local biodiversity
- Assess wetland habitat and site quality
- Collaborate with research institutions to answer questions beyond project scope
- Develop relationships and educate the Ryder Lake community about bullfrog impacts and control methods

Methods

All field work implemented in year 1 was thoroughly documented, and protocol documents were created as required for activities. These protocols will be refined in subsequent years to ensure method efficacy and will be made available to other groups. Amphibian handling and field gear hygiene protocols followed current standards utilized by the FVC and approved by the Ministry of Forests, Lands, Natural Resource Operations and Rural Development. This work was conducted under the BC Wildlife Permit SU20-609975. Boat surveys were carried out following stratified random sampling and visual encounter methods and all surveys occurring at night were conducted by at least 2 surveyors.

Objective 1 – Bullfrog Control

This objective is focused on removing bullfrogs as quickly as possible to reduce the negative impacts of a bullfrog invasion on biodiversity in the Ryder Lake area. Control efforts were focused on Hornby Wetland and Ryder Lake due to the importance of these waterbodies for native species.

The American Bullfrog is listed as a Schedule C species in the BC Wildlife Act (Wildlife Act, 1996) and Wildlife Act Designation and Exemption Regulation in British Columbia, meaning a permit or hunting license is not required to capture and kill them anywhere and anytime in BC.

1.1 & 1.2 Adult control and juvenile control

The primary focus of control efforts was on sexually mature adults to prevent breeding and the secondary focus was on juveniles, as they could be targeted alongside adults during surveys. Control efforts are most effective at reducing population size when targeting adults and juveniles (Govindarajulu et al., 2005). Adult and juvenile control efforts occurred at least 3 times per week during the active season, May – October (Govindarajulu et al., 2005). Adult control surveys start earlier in the season than juvenile surveys to prevent breeding and the creation of the next generation of bullfrogs.

Bullfrog control surveys began after dark, and surveyors used pit-lamping to stun the bullfrogs from a kayak/boat before using a preferred or situationally appropriate capture method such as: hand-capture, paddle whapper (blunt impact), pellet gun, or dip net. Males could also be captured during surveys by following their calls to the individual and following the same procedure.

Once captured, bullfrogs were placed in a clove oil bath for at least 15 minutes prior to being humanely euthanized and stored in a freezer on site (Figure 4). The Amphibian Euthanasia Procedure can be found in Appendix 1. When a bullfrog was captured or observed, metrics (e.g. age class, sex, gravidity), location of observation (UTM), behaviour, habitat use information and numbers were recorded.

1.3 Tadpole control

The FVC trialed tadpole trapping in September 2020 to determine the efficiency of this method for the Ryder Lake and Hornby Wetland sites. Trapping surveys were conducted using the "Amphibian Trapping Protocol" developed by the FVC (Appendix 1). A total of 80 soft-sided, collapsible minnow traps were placed in each water body. An extra 10 metal traps were placed temporarily in Hornby Wetland and removed after 24 hours. Traps were monitored in Hornby Wetland (September 15th – 19th), removed and moved to Ryder Lake, and monitored

(September 21st – 25th). Soft-sided traps were outfitted with pieces of foam pool noodle to prevent traps from completely submerging.

Traps were placed in areas of the wetlands with expected tadpole/bullfrog presence due to habitat suitability and previous observations. Generally, traps were placed along wetland edges or adjacent to woody debris features (Figure 5), targeting transitional habitats (i.e. in the aquatic vegetation between riparian and open water habitats). In Hornby Wetland, traps were placed in the northern half of the wetland, which is comparatively open habitat, avoiding the hard-to-access southern half of the wetland. In Ryder Lake, traps were placed along the perimeter of the entire wetland (Figure 6). Traps were left in the wetlands for 5 days. Submerged traps were monitored every 12 hours and floating traps every 24 hours.

When checking traps, all vertebrates and macro-invertebrates discovered were recorded, as part of the project's biodiversity focus. Macro-invertebrates were recoded as presence/absence data, and amphibian observations were recorded as precise counts. Photos were taken for species confirmation and later identification purposes if required. Once a trap check was completed the trap was emptied of all living creatures. If a bullfrog was captured during this process the same bullfrog euthanasia protocols used during targeted control surveys were followed. All data was recorded on an iPad using Filemaker Pro databases.

The wetlands are considered connected for the purposes of trapping in the Ryder Lake area, so the traps were not cleaned between uses within the two water bodies. Traps were thoroughly cleaned and disinfected following their use in this area.

Figure 5: Male American Bullfrog captured in 2020. Shows the clove-oil bucket the frogs are put in after being captured.

Figure 4: A soft-sided, collapsible minnow trap deployed in Ryder Lake in 2020. Note the blue "floatation devices" keeping the trap afloat (modified pool noodle).

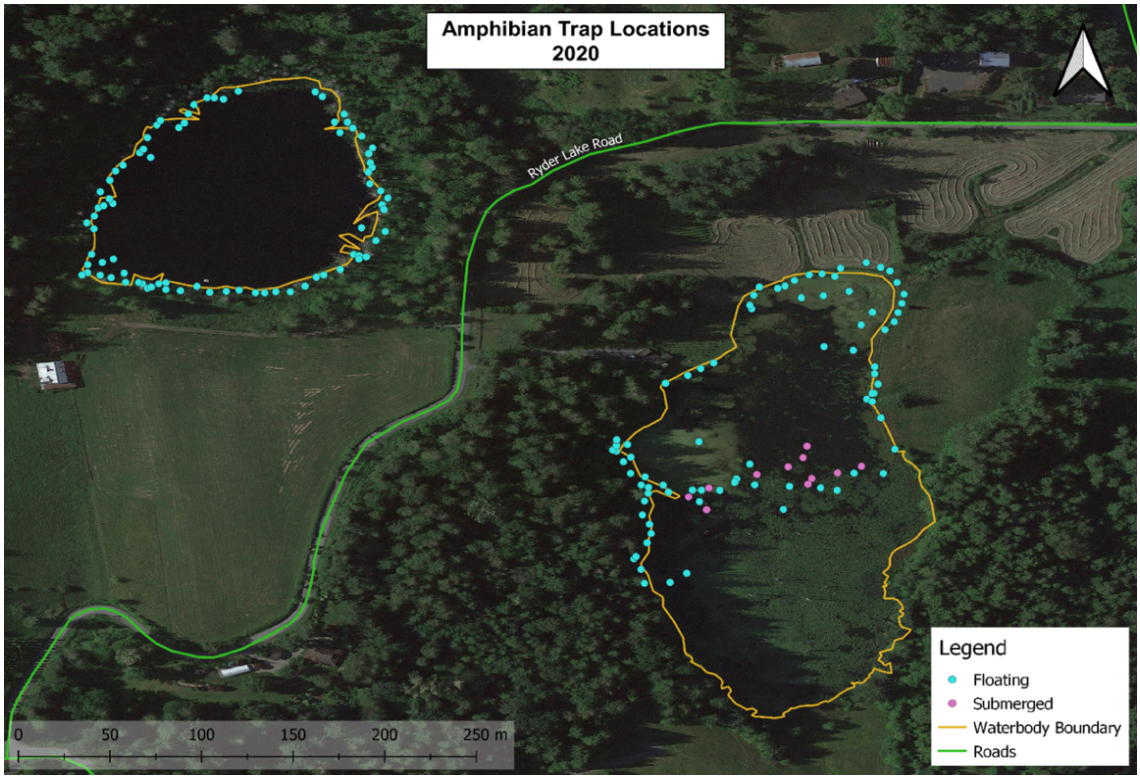


Figure 6: Amphibian trap locations within Ryder Lake (Sept 22-25th, 2020*) and Hornby Wetland (Sept 15-19th, 2020).*

1.4 Egg mass control

Extensive bullfrog egg mass control surveys were conducted in both wetlands an average of 3 times per week between mid-June and the end of August 2020. Bullfrog egg mass surveys were conducted using modified protocols developed by the Oregon Spotted Frog Recovery Team (2015). Surveyors used a small boat/kayak and targeted ideal weather days focusing on clear/partially cloudy days with little to no wind. Some rain was acceptable but heavy rain (2.5 mm/hour) limits visibility.

In Ryder Lake, egg mass surveys focused on the edge vegetation and woody debris features while avoiding the deeper open water at the center of the lake. In Hornby Wetland, surveys focused on the northern half of the wetland in areas with a significant mat of aquatic vegetation. The southern half of the wetland was less accessible and surveyed infrequently to ensure the entire wetland was represented.

If an egg mass was encountered and confirmed to be a bullfrog egg mass, it was removed from the wetland using the FVC "Amphibian Euthanasia Procedure" (Appendix 1). The egg mass location would be recorded, and it was removed using a bilge pump and deposited into a bucket (Figure 7). The removed egg masses were brought to shore and dumped out away from the water (> 5 m ashore) in an area with limited human presence and allowed to desiccate.

Figure 7: An American Bullfrog egg mass removed from Hornby Wetland in 2020.

Objective 2 – Bullfrog Research

This objective focused on understanding bullfrog ecology to effectively plan for future mitigation efforts. While conducting bullfrog control surveys we sought to answer some bullfrog-related questions and investigated alternative bullfrog control methods to ensure that the methods used were the most efficient. To assess where control needs to take place all potential source populations must be identified, and the spread of bullfrogs needs to be continuously monitored. Our project also aims to participate in collaborative science-based projects with research institutions in the hopes of answering more bullfrog-related questions than possible as a single organization and sharing any results with similar groups.

2.1 Call surveys

The source and spread of bullfrogs in the Ryder Lake area must be investigated if mitigation efforts are to be successful. Call surveys were used to monitor bullfrog spread and direction of replenishment into Hornby Wetland and Ryder Lake, and to identify new source populations in the area. Figure 8 shows the call survey routes. Call surveys target calling, mature, male bullfrogs during the breeding season (June – July; Govindarajulu, Price & Anholt, 2006).

In 2019, the Ryder Lake call survey route was established to monitor areas with a known bullfrog presence and in 2020 a new survey route outside of the Ryder Lake area was established (Chilliwack Route) to search for source populations that could be acting as areas of replenishment for this bullfrog infestation. During previous investigations in 2019, potential call

survey stations were identified and refined in 2020 based on data indicating bullfrog presence or sufficient potential habitat (i.e. pond, shallow open-water wetland, or agricultural drainage ditches). Sites were also identified by locating potential habitat on Google Earth and conducting daytime ground-truthing surveys to determine site suitability.

These surveys do not require direct property access. The 33 survey stations were then monitored 3 times each between July and August. FVC staff used the North American Amphibian Monitoring Program (NAAMP) protocol to conduct surveys.

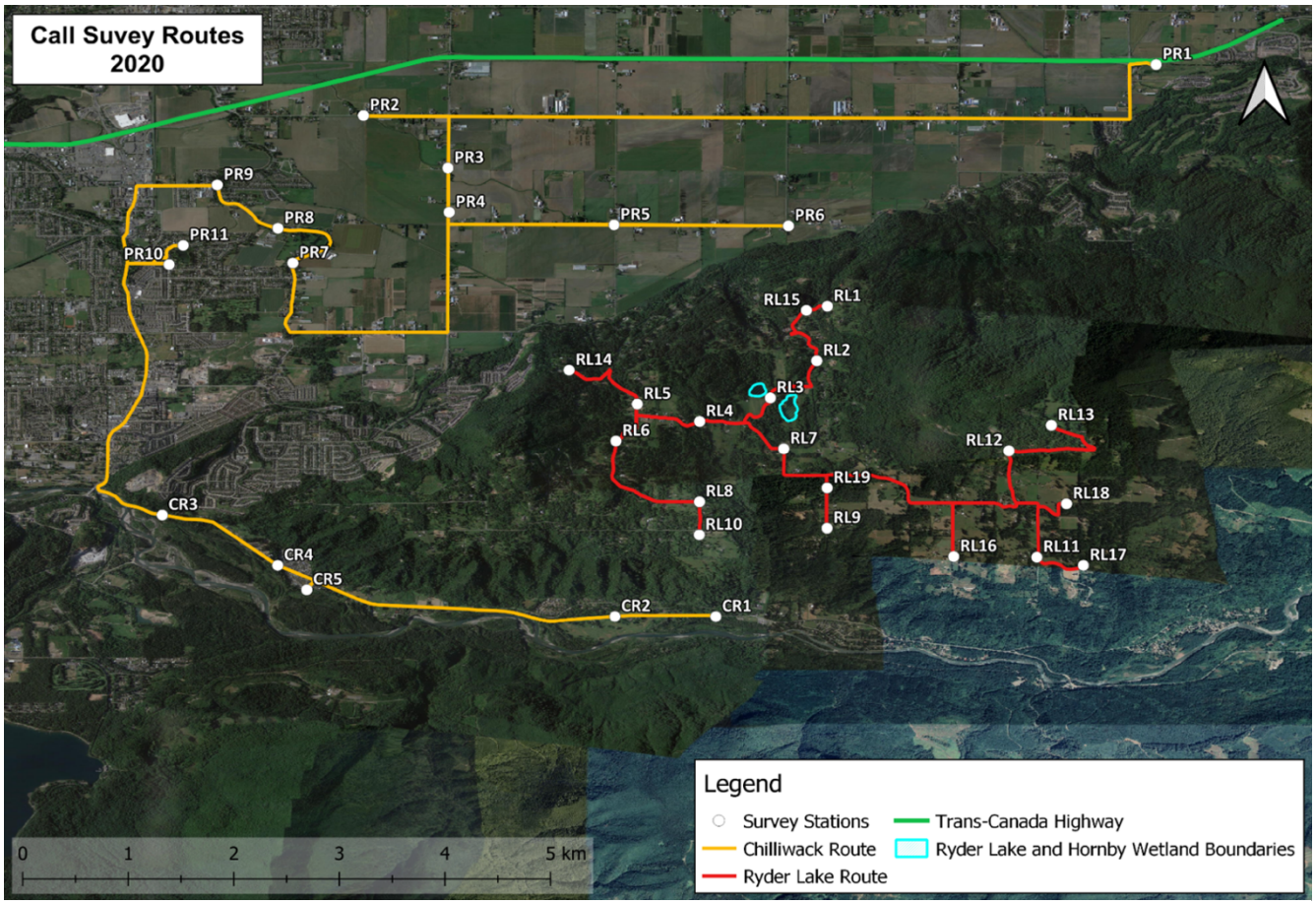


Figure 8: Call survey routes. The Ryder Lake route surround Horny wetland and Ryder Lake, the Chilliwack route follows roads in the valley.

2.2 Eyeshine surveys

Eyeshine surveys were proposed for use as an alternative or addition to call surveys for bullfrog detection but was not pursued due to the methodology's limitations. Areas inaccessible for call surveys are also inaccessible for eyeshine survey methods, which require close contact with detected amphibians to verify species identity. This will not be proposed for future objectives.

2.3 Habitat use documentation

Habitat use information was recorded for bullfrogs and native amphibians when encountered. This information will be mapped to determine habitat preferences and requirements for bullfrogs and native species. This will help direct habitat restoration/enhancement or research projects. When a bullfrog or native amphibian at any life stage was captured or observed the following information was recorded: location, abundance, metrics (e.g. age class, sex, gravidity), and behaviour data. Habitat features were also recorded, including water depth, woody debris, and vegetation presence (surface vegetation only).

2.4 Collaborate on bullfrog research projects

This project aims to support others in conducting well-structured, scientific research projects focusing on answering important bullfrog questions. The goal of this activity is to create a network/partnership with research institutions to answer these questions. This part of the project will change and evolve as more questions arise. In 2020, the University of the Fraser Valley was approached to discuss conducting a gut content analysis on the bullfrogs collected during bullfrog control efforts. Thompson Rivers University and the University of Colorado were approached to discuss amphibian limb deformities.

Gut content analysis

In 2020, two students at the University of the Fraser Valley started conducting a gut content analysis on the frozen bullfrogs. Gut content is removed from the dissected bullfrog stomachs and identified to the level of family/order (to the species level, where possible). Prior to dissection, the bullfrogs underwent a physical external examination, looking for visible deformities (i.e. extra or missing limbs). During the dissection process, the students recorded the following metrics for each bullfrog: age class, sex (based on external and internal anatomical features), gravidity, gape length, snout-vent-length, right shank length, and weight (pre-and post-dissection). The lungs were also removed to look for lung fluke and nematode presence. After completing the dissection, the body was disposed of according to the University of the Fraser Valley lab protocols (incinerated). FVC provided direction and protocols to the University of the Fraser Valley.

Deformity investigation

Another bullfrog research project that began in 2020 was an amphibian limb deformity investigation. The University of Colorado investigated the occurrence of amphibian deformities observed in 2020, which could be an indication of parasitic trematode presence (*Ribeiroia* sp.). Figure 9 depicts some of the deformities observed in the Ryder Lake area in 2020. In 2017, a Northern Pacific Treefrog detected during a road survey had an extra hind-limb as well. Knowing

which parasites are present in the survey areas is an important step in defining all the potential threats to biodiversity in this area, as Ribeiroia sp. for example can infect all frogs. If Ribeiroia is present in the Ryder Lake area it would only be the second known location in Canada, the other location being Isobel Lake, Kamloops, BC.

Figure 9: Deformed amphibians found in 2020. A juvenile bullfrog with an extra pair of hind legs (top left), a juvenile bullfrog missing an eye (top right), a juvenile bullfrog missing a hind leg (bottom left) and a juvenile Northern Red-legged Frog with a fused hind leg, excess webbing (bottom right.

2.5 Alternate control method investigations

Part of this project's bullfrog research initiative is investigating and trialing alternative control methods to ensure the most efficient methods are utilized and to optimize control success. Multiple bullfrog capture methods were investigated in 2020 and their effectiveness was assessed. For the purposes of this project, hand capture is considered to be the main capture method and all other capture methods are considered "alternative". The alternative methods investigated in 2020 included: paddle whapper (Figure 10), pellet gun, and trapping. Descriptions of all control methods used can be found in Appendix 3. More alternative capture methods will be investigated in year 2.

Figure 10: Two different sizes of *"Paddle whapper". Used as a bullfrog control method in year 1.*

Objective 3 – Biodiversity Research

The biodiversity research objective focuses on understanding the potential impacts of a bullfrog invasion in the Ryder Lake area. Biodiversity assessment methodologies will be developed to make realistic bullfrog impact projections, plan mitigation efforts, and demonstrate the effectiveness of the project's bullfrog control efforts.

3.1 Biodiversity baseline

To understand the potential impacts of bullfrogs on biodiversity, a biodiversity baseline needs to be established for the study area. The intention is for this baseline to be a "before bullfrog invasion" list of species present, proceeding with the knowledge that this project started shortly after bullfrog detection. Completing this biodiversity baseline will require collaborating with experts, incorporating local knowledge, and developing biodiversity monitoring techniques. The goal is to document biodiversity in these sensitive wetland habitats, focusing on species that are potentially impacted by a bullfrog invasion. The goal is to complete the baseline in year 2, allowing for a more holistic investigation of bullfrog impacts in future years.

No targeted bird, reptile, or small mammal surveys have been completed for this project; surveyors recorded all incidental observations made while conducting amphibian targeted surveys. With the help of the knowledgeable consultants at Athene Ecological, the FVC conducted bat acoustic surveys and established vegetation and macro-invertebrate survey plots for biodiversity monitoring and habitat quality assessment purposes.

3.2 Monitor priority species

Priority species are species identified as most likely to be negatively impacted by a bullfrog invasion. The FVC will develop specialized protocols and monitoring techniques for these species. In 2020, the following were monitored to add to a biodiversity baseline: aquatic vegetation, macro-invertebrates, native amphibians (especially species at risk), and bats. After year 1 data collection it is anticipated that priority species for monitoring going forward will include amphibians and macro-invertebrates. Priority species will be monitored annually or as protocols dictate.

Control Effort Incidental Herpetofauna Observations

Native amphibians, especially species-at-risk such as the Western Toad and Northern Red-legged Frog were identified as priority species for this project. Surveyors recorded all native amphibian and reptile observations made during and between bullfrog control efforts. The following was recorded for every observed native amphibian or reptile: metrics (e.g. age class, sex, gravidity), location, behaviour, habitat use information, and numbers. Most native

amphibians and reptiles were not captured and were simply observed to avoid contact with clove oil that could be on equipment or surveyor hands during bullfrog control efforts. No targeted reptile surveys were completed in 2020, but surveyors recorded incidental observations made while in the field.

Vegetation and Macro-Invertebrate Surveys

In 2020, Athene Ecological aided in creating vegetation and macro-invertebrate survey plots. Protocols for vegetation and macro-invertebrate sampling are being developed and follow the direction of consultants. Vegetation and macro-invertebrates were surveyed in the same positions for sampling simplicity. Each plot point was identified on Google Earth and ground truthed using a GPS on the survey day. For this reason, some of the survey plot points were not used because they were outside of the wetland perimeter or inaccessible from a boat/kayak (Figure 12). If a point was just outside the water body perimeter the point was still selected but was altered slightly to fit accessibility and habitat needs (see the "adjusted and surveyed" points in Figure 12). In Hornby Wetland, once at a survey plot point, surveyors used a measuring device made of PVC pipe (shown on the right in Figure 11) to measure the water depth and then pushed through the substrate to provide an anchoring point for the floating 1 m by 1 m PVC quadrat laid out over the point. The quadrat was aligned with the top facing north and the anchoring PVC pipe in the bottom right corner (Figure 11).

The PVC pipe used in Hornby Wetland to measure water depth and anchor the quadrat in place could only be used along the edge of Ryder Lake. The plot points in the center of Ryder Lake (RL12, RL14, RL7, RL9, RL2, and RL4 in Figure 12) were too deep to follow the same procedure. For these points, a rock with a string attached was lowered until it reached the bottom of the water body, providing a very rough estimate of water depth. The quadrant was arranged similarly to Hornby Wetland, facing roughly north-south and recordings were made while attempting to maintain the position and avoid the quadrant drifting.

Surveyors took reference photos of each survey plot from the south facing north. The pH was measured using an Oakton PCSTestr35 and recorded. Surveyors recorded the surface vegetation and submerged vegetation (species and percent plot cover). If there was vegetation that could not be identified, photos were taken, and a sample was collected for later identification. Woody debris feature presence and percent cover were also recorded. After recording all vegetation information, three dip nets were completed, emptying the net contents into a bucket. Surveyors counted macro-invertebrates that could be immediately identified, making estimates where numbers were too large to count. If something could not be identified in the field, surveyors collected a sample, and/or photos were taken, for later identification.

Figure 11: Vegetation and macro-invertebrate monitoring plot

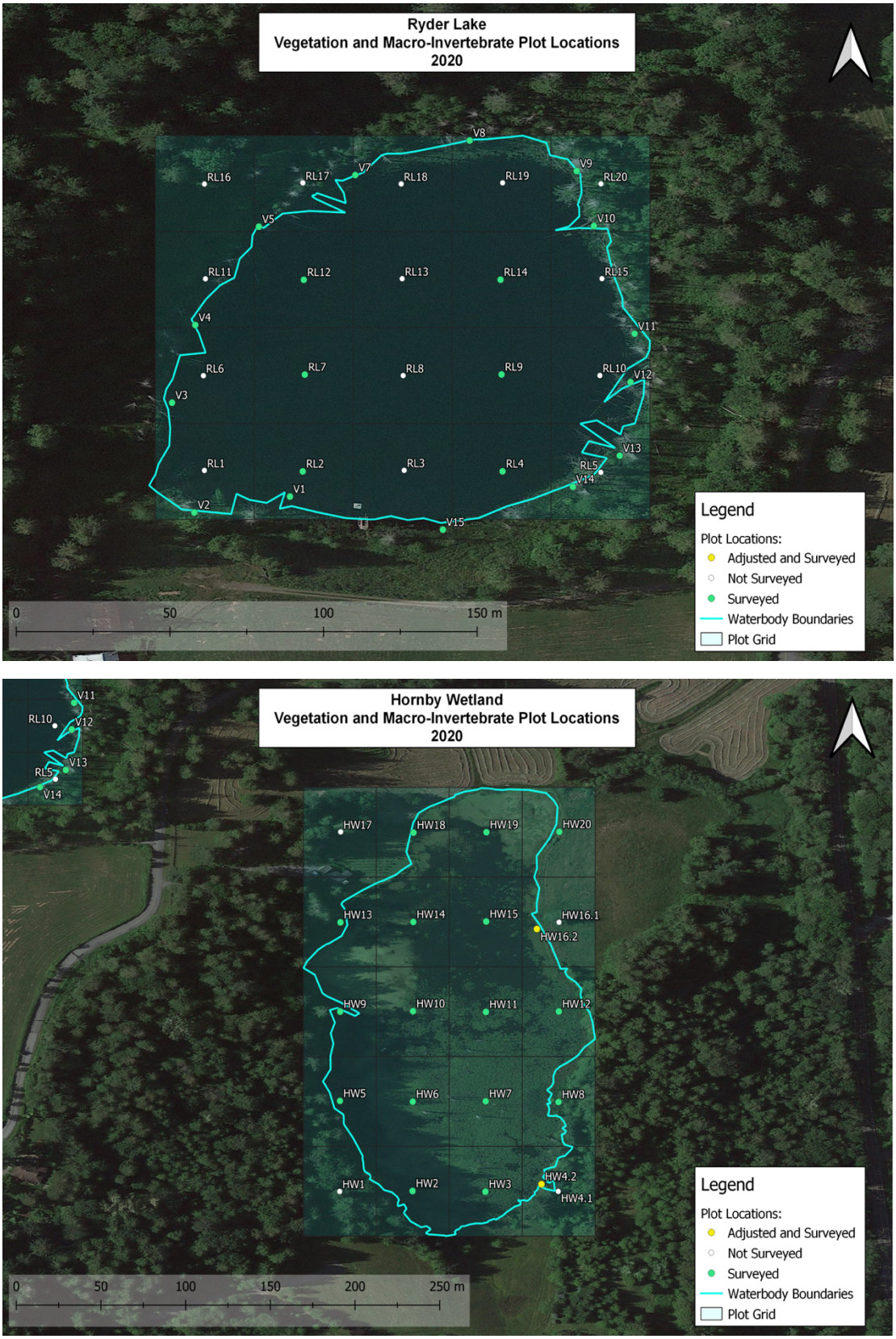


Figure 12: The vegetation and macro-invertebrate plot locations surveyed in 2020 (Ryder Lake = top, Hornby Wetland = bottom).

Artificial Cover Object Surveys

The FVC installed Artificial Cover Objects (ACOs) to monitor adult salamanders in the forest habitat surrounding Hornby Wetland (a breeding site for many amphibian species). The "Artificial Cover Object Specifications" can be found in Appendix 3 and is a modified version of the ACO's used in Davis, 1996. Figure 13 shows one of the ACOs placed around Hornby Wetland in 2020. Figure 14 shows the ACO placement in the forest surrounding Hornby Wetland: two on the west side, two on the east side and two adjacent to the permanent directional fencing installed by the Ryder Lake Amphibian Protection Program in 2020. The following location information was recorded during setup: GPS point, slope (recorded using a phone app; all sites had a less than 10° slope), vegetation present, percent cover, approximate distance to Hornby Wetland edge, and any other features present (i.e. gravel). The ACOs were labelled with the FVC's phone number and an ACO number. Each ACO was monitored three times between September 4th and October 27th, 2020.

Figure 13: One of six artificial cover objects in the forest surrounding Hornby Wetland.

Figure 14: Artificial cover object placement.

Spring Egg Mass Surveys

Spring egg mass surveys were conducted using protocols developed by the Oregon Spotted Frog Recovery Team and refined for this project's purposes ("Egg Mass Survey Protocols for Oregon Spotted Frog and Red-legged Frogs 2018" in Appendix 1). These visual encounter egg mass surveys were targeting native amphibian egg masses in the spring in Ryder Lake and Hornby Wetland. Surveys were conducted on ideal weather days, targeting clear/partially cloudy days with little to no wind and consistent weather from morning to evening. Some rain was acceptable but heavy rain (2.5 mm/hour) limits visibility. Surveyors used a small boat/kayak to conduct egg mass surveys and searched/scanned shallow water with floating mats/edge vegetation within 1-3 m of the surveyor (depending on visibility). Surveyors recorded the following for every detection: the number of egg masses present, species, GPS coordinates, and relevant site conditions.

Amphibian Road Surveys

Fall road surveys were conducted to monitor amphibian migration patterns using protocols adapted from Ryder Lake Amphibian Protection Program road survey protocols. The focus of these surveys was determining a direction of replenishment for the bullfrog population and monitoring the more elusive native amphibians as they cross the roads (i.e. Roughskin Newt). This data could also be used to identify areas that would benefit from direct mitigation efforts in the future. Surveys targeted dead and live adult amphibians. Surveys were conducted starting at dusk on nights with ideal weather conditions and lasted 3-4 hours (October 9th, October 14th, November 3rd). Surveyors targeted the first day of rain after a few dry days; ideally, there would also be precipitation during the survey.

Before and after every survey, the following information was recorded: date, start/end time, surveyor names, wind (Beaufort wind scale), cloud cover (%), precipitation (misty drizzle, light rain, rain, heavy rain), and temperature. Two to four surveyors walked a 3 km route, spread out across both road lanes and backtracking along all sections. Surveyors walked at a steady normal walking pace, scanned the road with headlamps, and recorded all vertebrate observations, alive or dead. For each observation, the following information was recorded: species, sex (if possible), age class, time, dead/alive, GPS point (UTM), and direction of travel (toward/away from Hornby Wetland). Surveyors removed dead bodies from the road to avoid double counting and guided live animals off the road in their direction of travel with minimal touching to avoid double counting and vehicular mortality. This work was conducted under the FVC's BC Wildlife Permit SU19-475035.

Data collected was added to the Ryder Lake Amphibian Protection Program dataset and analyzed for the number of amphibians observed during a survey, the percentage of

observations that were alive, and the average number of amphibians observed per survey and km. The average number of amphibians per survey was also calculated for the area where the FVC installed permanent fencing and compared this data to historical data collected before fence installation. This analysis was not a part of the FVC bullfrog project.

Acoustic Monitoring

In 2020, bats were the only mammals that were actively investigated. Surveyors recorded all other mammal observations during other surveys, including bullfrog control surveys. A consultant from Athene Ecological installed acoustic recording units (Anabat Express) to record the echolocation calls of bats in both Ryder Lake and Hornby Wetland (between July 13th – July 22nd, 2020).

3.3 Assess site quality

Wetland habitat quality can impact biodiversity and can be improved by enhancement (Environment Canada, 2013). In order to direct future restoration or enhancement planning, it is important to understand the current habitat conditions and how species are using the habitat. Site quality assessments can also help rule out other factors that can affect species population changes over time. This will help with bullfrog impact assessments and management recommendations. The focus of this activity is to assess the site quality at Ryder Lake and Hornby Wetland to aid in directing potential habitat enhancement/mitigation measures. In 2020, this included water level and temperature monitoring via installed level loggers (HOBO) and recording the pH during vegetation and macro-invertebrate monitoring surveys. In 2020, 3 level loggers (Figure 15) were installed in the Ryder Lake area (June to October): an ambient air temperature logger in a tree near Hornby Wetland and water level loggers in both Ryder Lake and Hornby Wetland. Wetland habitat quality monitoring protocols were established in 2020 and will be refined in later years.

Figure 15: Level logger installed in Hornby Wetland

3.4 Biodiversity Impact Assessment

All Year 1 biodiversity and bullfrog data was compiled for future assessment of bullfrog impacts on biodiversity. The intent is to create a map of overlaying data layers (bullfrog occurrences, biodiversity baseline, priority species monitoring, research findings, and habitat features) to depict the interface between the species and habitat. The resulting product will allow for better biodiversity analyses and bullfrog mitigation planning as the project progresses. Databases will be updated annually, and the full biodiversity impact assessment will be a 2024 target.

Objective 4 – Project Evaluation and Planning

This objective involves compiling bullfrog and biodiversity information for future comparisons and evaluations. This data will be used to create an eradication evaluation and mitigation plan and contribute to a bullfrog management plan for the Ryder Lake area.

4.1, 4.2 & 4.3 Track bullfrog population trends annually; Eradication evaluation and mitigation plan; Update bullfrog management plan

Bullfrog abundance and population trend data from all surveys and research efforts will be compiled and reported on annually. Year 1 bullfrog control data has been compiled in a database for future population evaluations. This bullfrog capture and relative abundance data will be used to assess the success of the control program. This data will be used to evaluate the efficacy of the bullfrog control efforts and aid in directing future control/mitigation efforts.

All data collected for this project will contribute to a bullfrog management plan for the Ryder Lake area. This management plan will be a priority in year 4 (2024) and will make recommendations for continued bullfrog control efforts or a shift in project focus towards habitat enhancement/mitigation efforts based on the success of eradication efforts.

Objective 5 – Targeted Bullfrog Outreach

This objective focuses on engaging the Ryder Lake community to facilitate control efforts and aid in native amphibian and invasive species identification.

5.1 Secure ongoing access to wetlands on private property

The Ryder Lake area is comprised of low-density privately-owned properties with pockets of natural and human-influenced ecological features, including our study sites, Ryder Lake and Hornby Wetland. Ensuring continued access to study sites and maintaining good relationships with associated landowners and landowner representatives is essential for the continuation of this project. In 2020, a written Research Access Agreement was drafted and shared with residents associated with Ryder Lake and Hornby Wetland. These agreements were tailored to the site and resident input directly influenced the wording of these documents to outline expectations of all parties for the duration of the project ("Research Access Agreement" in Appendix 3). This research access document can be updated and will be reviewed as required to ensure landowners and the FVC agree with the contents.

5.2 Train residents to assist with bullfrog surveys and control

Community engagement efforts in the Ryder Lake neighbourhood are built upon over a decade of FVC outreach programming. This activity focuses on encouraging interested residents and landowners in the Ryder Lake area to help with bullfrog surveys and control efforts. This involves supporting and training residents in amphibian identification and bullfrog control efforts so they can remove bullfrogs from their own properties. In year 1 we hosted a community meeting to share our amphibian knowledge and give project updates to residents.

5.3 Train a local resident to coordinate and facilitate community support

This activity was not pursued in 2020 due to a combination of factors including the COVID-19 pandemic, landowner relationship building, and a change in project direction.

5.4 Utilize partnerships and collaborate with other groups to promote bullfrog identification and control through media and educational resources.

The FVC is an important cornerstone for ecological information distribution in the South Coast region. We aimed to take any opportunity available to grow public awareness of bullfrog issues

through partner groups including local naturalist groups, print media, and television interviews. We created educational resources, a new webpage, and added significant contributions to Metro Vancouver's best management practices guide for bullfrogs. Throughout all of this work, we maintained our message of focusing on creating healthy habitat for native species rather than attempting to control or eradicate bullfrogs. Through our Habitat Stewardship Program funded Frog Finders program, we received bullfrog observations from the community, and were able to provide information and resources. We also updated the American Bullfrog Action Team on our project status and attended their annual general meeting.

Results

Year 1 Field-Based Activity Summary

Table 1: Activities undertaken in the field by the FVC in year 1 (2020/2021) as part of the Rapid Response Bullfrog Control and Biodiversity Research in Sensitive Wetlands project. Includes survey types, timing information and the number.

Activity	Timeframe	Survey Frequency	Number of Surveys Completed in 2020
Adult & Juvenile Bullfrog Control Surveys	May – October.	3 surveys/week	32
Tadpole Trapping	Sept.	Traps monitored for 5 days	5 days/wetland
Call Surveys	July – Late Aug.	3 surveys	3
Bullfrog Research Projects	All Year	n/a	2 research projects investigated
Summer Egg Mass Surveys	June – Late Aug.	Every 2-3 days	50
Spring Egg Mass Surveys	Late March – June	3 surveys	1 survey/wetland
Biodiversity Monitoring	April – Oct.	Alongside all other surveys	n/a
Amphibian Road Surveys	March – April; Sept. – Nov.	3 spring surveys, 3 fall surveys	3 fall surveys
Artificial Cover Object Surveys	May – Oct.	Every 2 weeks	3
Vegetation and Macro-invertebrate Plot Surveys	Sept.	Once per season	1 survey/plot

Objective 1 – Bullfrog Control

1.1 & 1.2 Adult control and juvenile control

The focus of bullfrog control efforts was on adults to prevent breeding and the secondary focus was on juveniles, as they could be targeted alongside adults during surveys. Between June 19th and September 4th, 2020, 32 visual encounter bullfrog control surveys were conducted targeting adults and juveniles. Table 2 shows the percentage of bullfrogs observed that were captured for each age class (including adults, young adults, juveniles, tadpoles, and egg masses). Individuals that were not captured were either attempted captured that resulted in a miss or observations made during other surveys (such as during the day when control was not taking place).

Adult control appears to have been effective in preventing breeding. While only two bullfrog egg masses were discovered and removed (see Results 1.4 Egg mass control), preliminary gut content analysis dissections have identified 8 gravid females were captured before they were able to breed (as of April 8th, 2021). Metamorphs and juveniles were not recorded separately in the field, so metamorphs fall under the juvenile category for this data. Figure 16 shows the age class percentages of captured bullfrogs. 93% of the bullfrogs captured were juveniles, 77% of which were captured in August 2020 (Figure 17), as the bullfrogs began to metamorph from tadpoles to frogs.

The seasonality of bullfrog capture rates presented in Figure 17 reflects the behaviour of adults at the two target sites. The first bullfrog adults were captured at the end of May, right as their breeding season was beginning. Adult captures were high in the month of June as surveyors removed as many bullfrogs as possible from the wetland. Between July and August, bullfrog density alternated as they migrated between Ryder Lake and Hornby Wetland. A few days after all bullfrogs were removed from Hornby Wetland, new bullfrogs would appear. As bullfrog breeding season ended in August, adults were not heard calling or detected by surveying for eye shine. Juveniles/metamorphs were abundant at this time and became the primary control target.

Table 2: The number of bullfrogs captured in 2020 relative to age class.

Age Class	Captured
Adult	34
Young Adult	21
Juvenile	808
Tadpole	4
Egg Mass	2
Total	**869**

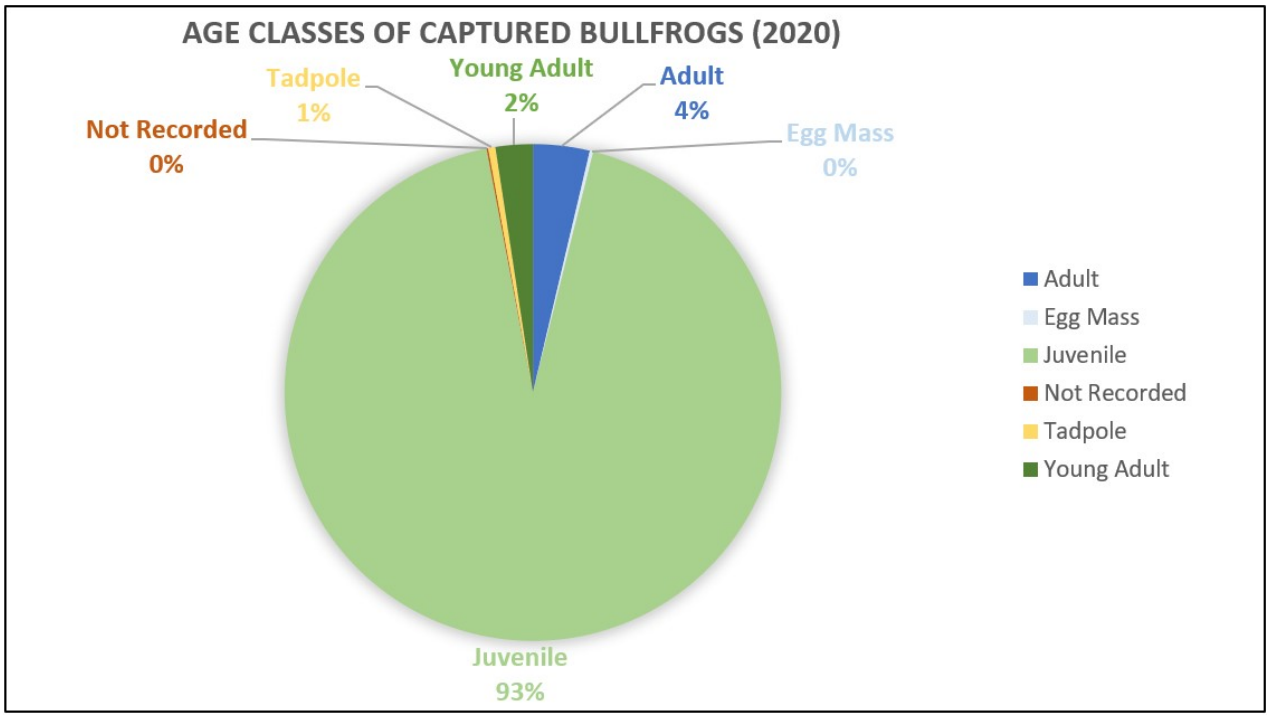


Figure 16: Age class percentages.

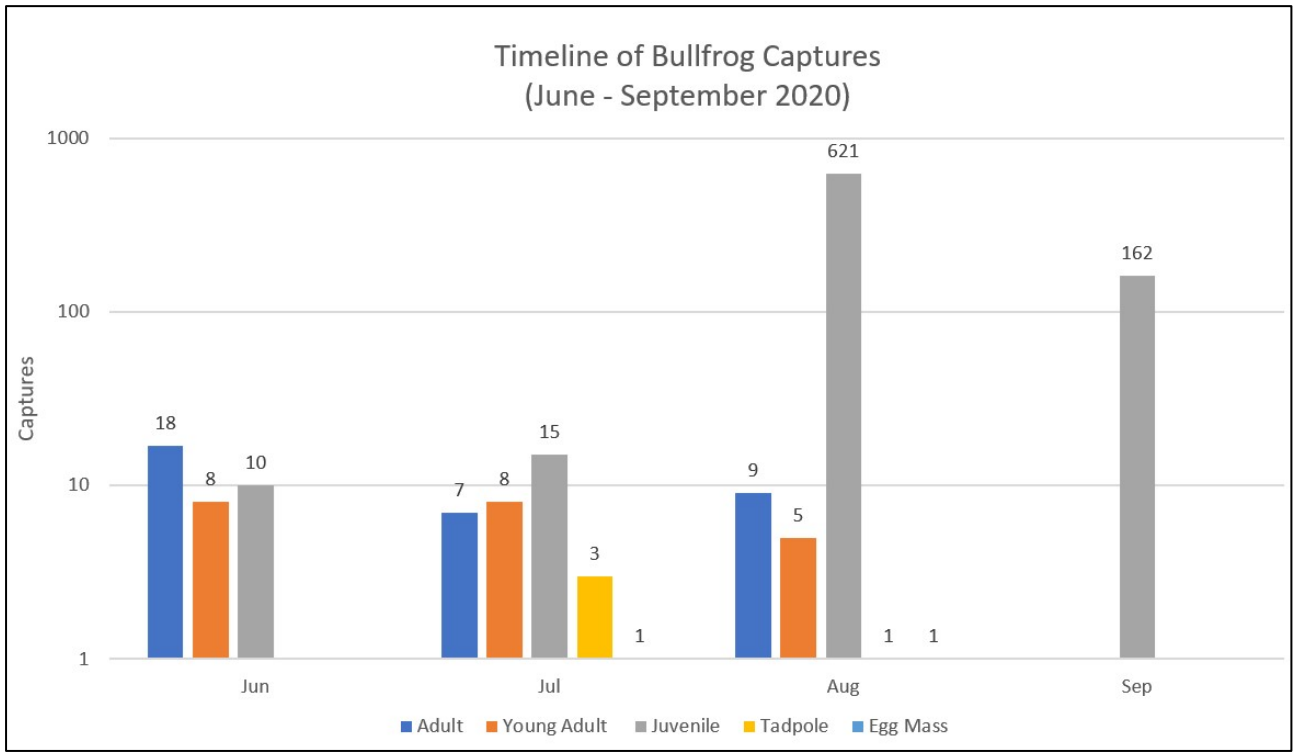


Figure 17: Timeline of bullfrog captures by age class, 2020. Logarithmic scale (base 10).

1.3 Tadpole control

Tadpole trapping involved 170 traps in Hornby Wetland and Ryder Lake (80 soft-sided, collapsible minnow traps in each water body and an extra 10 submerged metal traps in Hornby Wetland). No bullfrog tadpoles were captured during these trapping surveys, but 17 juveniles and 2 adults were captured. Bullfrogs captured during trapping were euthanized following FVC euthanizing protocols. These surveys also resulted in the detection of 44 Northwestern Salamanders, one newt and the first crayfish observation for this project.

The submerged traps in Hornby Wetland were monitored every 12 hours and were removed after only 24 hours due to the incidental capture of a neotenic Northwestern Salamander. Surveyors decided the risk to non-target species was too high to continue submerged trapping.

1.4 Egg mass control

Between June 15th and September 2020, 50 non-linear transect visual encounter surveys targeting bullfrog egg masses were conducted. Only 2 bullfrog egg masses were found and removed (July 8th and August 1st), both in Hornby Wetland (Figure 18). The egg mass discovered and removed on July 8th was detected during a formal egg mass survey performed by the FVC staff. The second egg mass was discovered by the Ryder Lake area resident who lives on the Hornby Wetland property and had received amphibian and specifically bullfrog identification training. This egg mass was partially removed by the resident and removal was finalized by FVC staff. No bullfrog egg masses were discovered in Ryder Lake in 2020.

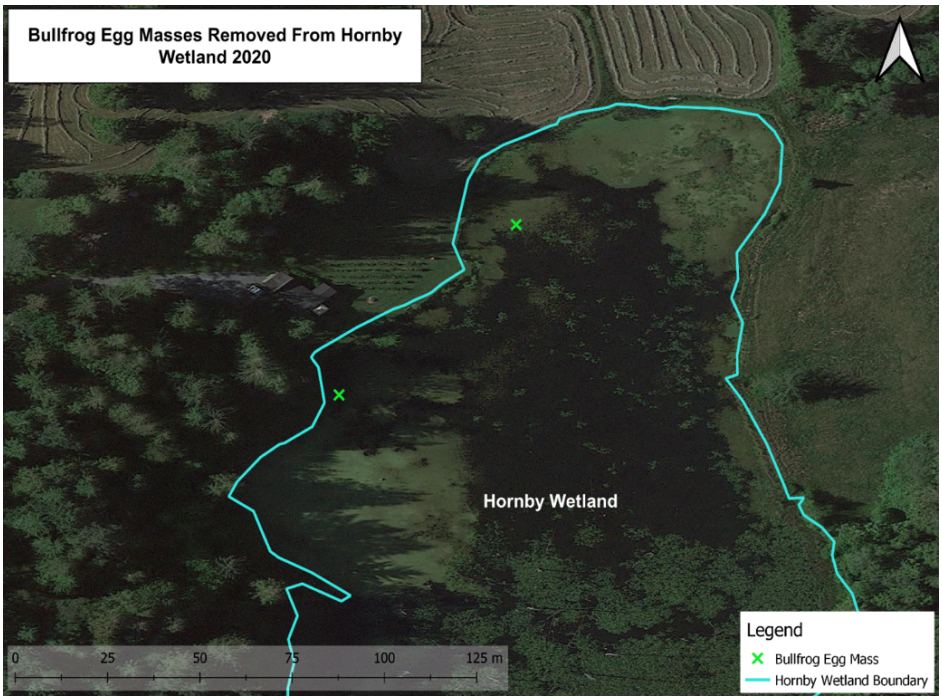


Figure 18: Bullfrog egg mass detection and removal locations in 2020.

Objective 2 – Bullfrog Research

2.1 Call surveys

Three call surveys were conducted at 33 stations in Ryder Lake as well as North and South of the Ryder Lake area, from July 21st to August 5th, 2020. Alternative call survey sites were also investigated, and sites added when new information became available (PR8, PR9, PR10). No novel bullfrog populations were discovered by this survey method in 2020. Green Frogs were detected in the Chilliwack portion of the survey route and Northern Pacific Treefrogs were detected at 8 different survey stations (Figure 19). Bullfrogs were detected at 2 stations, PR10 and RL3 (Hornby Wetland). These locations already had confirmed bullfrog presence prior to 2020. These sites should continue to be monitored in future years to monitor the bullfrog spread in the Ryder Lake area. Table 3 shows the survey station names and locations as well as survey results.

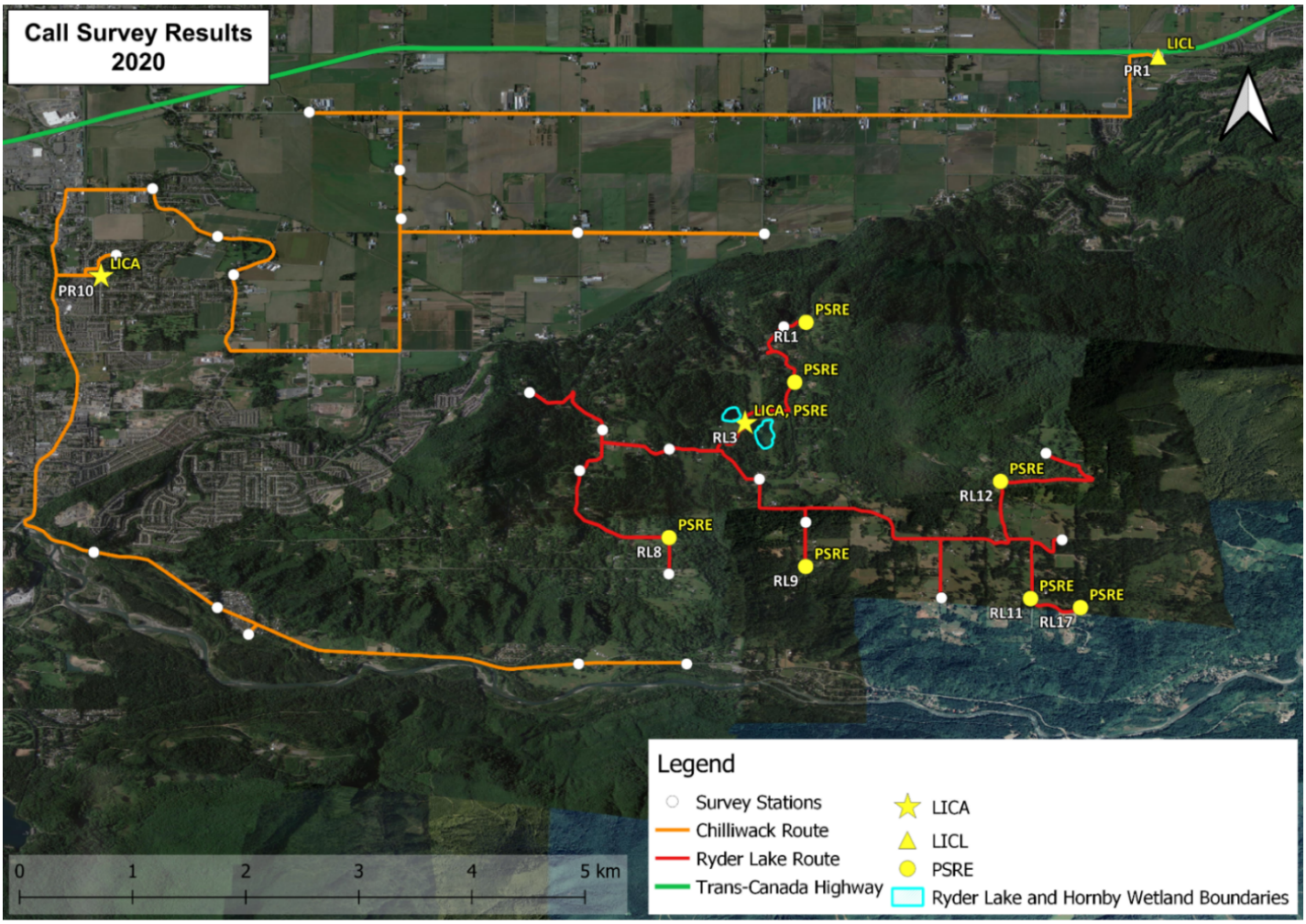


Figure 19: Call survey results, includes all amphibian calls. LICA = American Bullfrog (Lithobates catesbeianus), PSRE = Northern Pacific Treefrog (Pseudacris regilla), and LICL = Green Frog (Lithobates clamitans). American Bullfrog calls were detected at PR10 and RL3 only. Green Frogs calls were detected at PR1 only.

Table 3: Call survey routes, station names, survey dates and results. RL18 and PR4 were deemed unsuitable for surveying and removed (RL18 was removed before formal surveys started and PR4 was removed after 1 survey). PR6 could not be surveyed on 29-July-2020 due to the site being blocked temporarily by road construction. The value in the Bullfrog, Treefrog, and Green Frog score columns is the maximum call score detected during surveys at the associated station in 2020. Refer to the "Call Survey Indices and Code Definitions" and "Call Survey Codes" in Appendix 1 for more details on these numbers.

Survey Station	UTM (Easting)	UTM (Northing)	Survey Dates	Bullfrog Score	Treefrog Score	Green Frog Score
Route 1 - Chilliwack						
CR1	581515	5437001	21-July-2020, 29-July-2020, 04-Aug-2020			
CR2	580636	5436775	21-July-2020, 29-July-2020, 04-Aug-2020			
CR3	576256	5438436	21-July-2020, 29-July-2020, 04-Aug-2020			
CR4	577358	5437703	21-July-2020, 29-July-2020, 04-Aug-2020			
CR5	577638	5437344	21-July-2020, 29-July-2020, 04-Aug-2020			
PR1	585553	5445272	21-July-2020, 29-July-2020, 04-Aug-2020			2
PR2	578075	5444406	21-July-2020, 29-July-2020, 04-Aug-2020			
PR3	578884	5443635	21-July-2020, 29-July-2020, 04-Aug-2020			
PR4	578906	5442977	21-Jul-20			
PR5	580467	5442812	21-July-2020, 29-July-2020, 04-Aug-2020			
PR6	582115	5442821	21-July-2020, 04-Aug-2020			
PR7	577438	5442201	21-July-2020, 29-July-2020, 04-Aug-2020			
PR8	577290	5442716	29-July-2020, 04-Aug-2020			
PR9	576707	5443353	29-July-2020, 04-Aug-2020			
PR10	576269	5442162	29-July-2020, 04-Aug-2020	1		
Route 2 - Ryder Lake						
RL1	582501	5441631	22-July-2020, 27-July-2020, 05-Aug-2020		1	
RL2	584250	5439508	22-July-2020, 27-July-2020, 05-Aug-2020		2	
RL3	581982	5440260	22-July-2020, 27-July-2020, 05-Aug-2020	1	3	
RL4	581318	5439900	22-July-2020, 27-July-2020, 05-Aug-2020			
RL5	580725	5440151	22-July-2020, 27-July-2020, 05-Aug-2020			
RL6	580532	5439598	22-July-2020, 27-July-2020, 05-Aug-2020			
RL7	582120	5439506	22-July-2020, 27-July-2020, 05-Aug-2020			
RL8	581334	5438706	22-July-2020, 27-July-2020, 05-Aug-2020		2	
RL9	582547	5438332	22-July-2020, 27-July-2020, 05-Aug-2020		2	
RL10	581339	5438214	22-July-2020, 27-July-2020, 05-Aug-2020			
RL11	584539	5437929	22-July-2020, 27-July-2020, 05-Aug-2020		1	
RL12	584250	5439508	22-July-2020, 27-July-2020, 05-Aug-2020		2	
RL13	584646	5439894	22-July-2020, 27-July-2020, 05-Aug-2020			
RL14	580073	5440646	22-July-2020, 27-July-2020, 05-Aug-2020			
RL15	582305	5441568	22-July-2020, 27-July-2020, 05-Aug-2020			
RL16	583752	5437927	22-July-2020, 27-July-2020, 05-Aug-2020			
RL17	584982	5437815	22-July-2020, 27-July-2020, 05-Aug-2020		2	
RL19	582539	5438930	22-July-2020, 27-July-2020, 05-Aug-2020			

2.2 Eyeshine surveys

Eyeshine surveys were not pursued due to methodology limitations.

2.3 Habitat use documentation

Habitat use and abundance data was recorded for amphibians observed during all surveys, including: 106 Western Toad, 77 Northern Red-legged Frog and 989 American Bullfrog observations. The following habitat information was recorded when an amphibian was captured or observed: water depth, distance to water edge, woody debris feature and vegetation presence (surface vegetation only). This data is being stored in a database for future investigation.

Figure 20 shows the average water depths that were measured when an amphibian was encountered. Figure 21 and Figure 22 show the vegetation that was observed when a bullfrog (Figure 21) or native reptile/amphibian was observed (Figure 22). "Other features" mentioned in Figure 21 and Figure 22 were notes indicating if something other than the expected five common species or woody debris features was present. This list included: bittersweet nightshade, unknown rush spp., yellow flag iris, unknown cinquefoil spp., unknown grass spp., mowed lawn, gravel, moss, unknown willow spp. These were infrequent observations.

Data is presented in Figure 20 with 95% confidence intervals. Preliminary results suggest there is significant overlap in Western Toad and bullfrog water depth preferences, however more data is needed for true habitat use comparisons for all amphibian species at target sites.

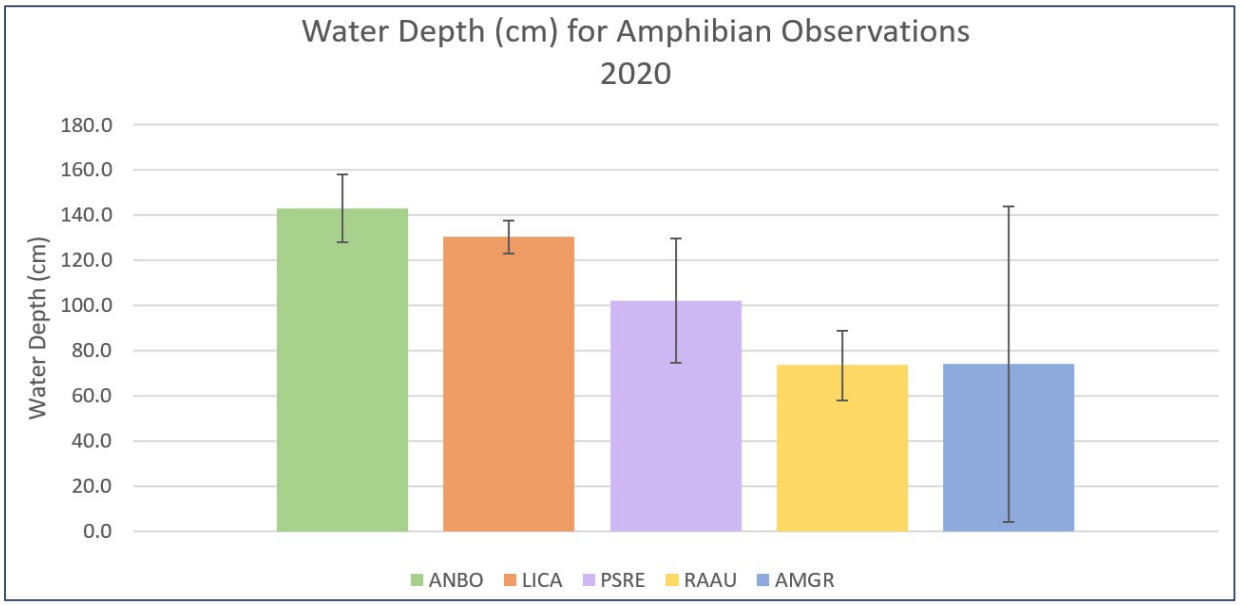


Figure 20: Mean water depth for amphibian observations 2020. This was recorded for the following observations: Western Toad (n=65), American Bullfrog (n=266), Northern Pacific Treefrog (n=22), Northern Red-legged Frog (n=20), Northwestern Salamander (n=3).

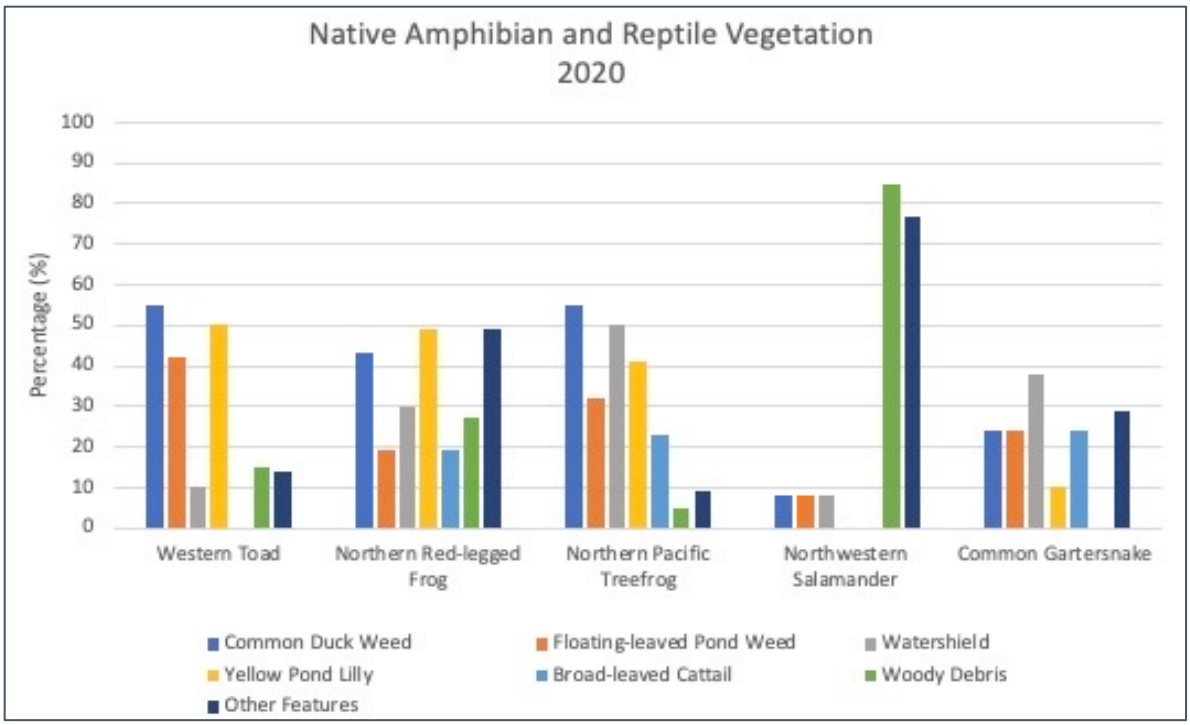


Figure 21: Habitat features present when a native amphibian/reptile was captured/observed. Represented as the percentage of observations with the feature present. This was recorded for the following observations: Western Toad (n=78), Northern Pacific Treefrog (n=22), Northern Red-legged Frog (n=74), Northwestern Salamander (n=13), Red-eared Slider (n=2) and Common Gartersnake (n=21).

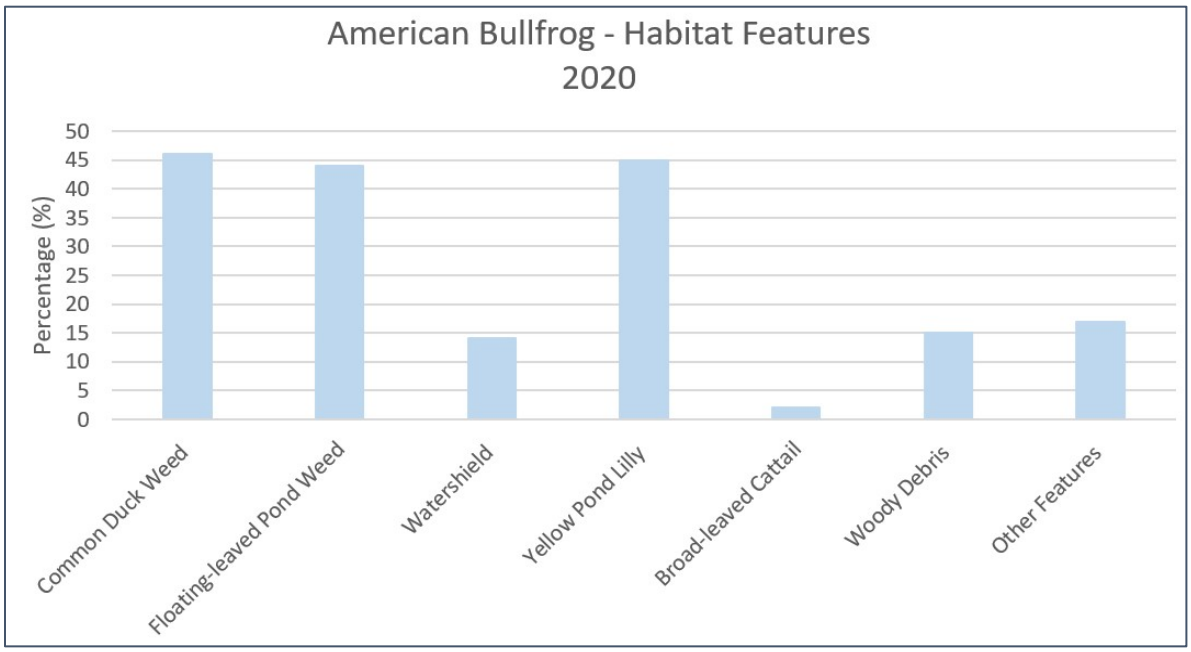


Figure 22: Habitat features present when a bullfrog was captured/observed. Represented as the percentage of observations with the feature present. This was recorded for n=336 bullfrog observations.

2.4 Collaborate on bullfrog research projects

Gut content analysis

In January 2021, the University of the Fraser Valley began conducting a gut content analysis on the bullfrogs collected in 2020. Table 4 shows the preliminary gut content analysis results (n=72 bullfrogs) as of April 1st, 2021. Bullfrogs were selected randomly from the available sample set and contain individuals from both sites across the sampling window. These bullfrogs have mostly been larger adults and young adults.

Table 4: Bullfrog gut content analysis results. Prey items identified to order, family or species. Number of frogs = number of bullfrogs with this prey item in its gut content; Number of Instances = number of times a prey item was detected in gut content.

Order/Family/Species	Number of Frogs	Number of Instances
Coleoptera (Adult)	16	24
Odonata (Adult)	8	16
Unidentified Wings	7	7
Odonata (Nymph)	5	46
Gastropoda - Snail	4	5
Hymenoptera	4	5
Isopod - Malacostraca sp.	3	5
Lepidoptera (Larva)	3	4
Northern Pacific Treefrog	3	6
Coleoptera (Larva)	2	3
Unidentified Insect	2	2
Annelid	1	1
Arachnid	1	1
Diptera (Adult)	1	4
Gastropoda - Slug	1	1
Heteroptera	1	2
Myriapoda - Centipede	1	1
Unidentified Amphibian	1	1
Unidentified Frog	1	1
Unknown Salamander (Adult)	1	1

Out of the 72 frogs that have currently been dissected 92% (n=66) have had something in the gut. Approximately 82% (n=54) of these individuals had gut content that was identifiable. The most represented group observed in the gut content, with respect to the number of frogs that consumed this prey item, was adult Coleoptera (24.2% of bullfrogs; n=16), the majority of which were ground beetles and Asian Ladybird Beetles. Odonate nymphs were the most represented group (33.8% of total prey items; n=46) when considering the number of individual prey items observed. The only frog observed so far is the Northern Pacific Treefrog (0.04% of total prey items).

Deformity investigation

There were fourteen amphibians observed in 2020 with deformities. Only one of the deformities detected in 2020 was not a juvenile bullfrog: a single juvenile Northern Red-legged Frog was observed during a night amphibian road survey in September 2020. This individual was found alive on the road and was released after photos were taken. Thirteen of the deformity observations were bullfrog metamorphs captured between August 23rd and September 4th, 2020. There was one metamorph that had an extra set of hind limbs, one with a half developed hind limb, two with a missing eye and nine with a missing hind limb. The hind limb deformities, and the extra set of hind legs in particular, could be an indication of a parasitic trematode presence (potentially a *Ribeiroia* sp.).

Deformed bullfrogs were selected from the frozen samples, and 18 bullfrogs were shipped to the University of Colorado for investigation (February 2021). There was a problem with shipping that led to a delay in delivery that thawed and compromised the shipped specimens. The bullfrogs were examined upon arrival however the prolonged thawing caused by the delay in shipping made macro and microparasite examination difficult or impossible. The researcher still examined the skin and the tail resorption area (TRS) for signs of parasitic infection. These locations are common areas for detecting *Ribeiroia* in other amphibian species.

Upon examination, the presence of *Ribeiroia* was confirmed in an individual with an extra set of hind limbs that was captured in Ryder Lake on August 26th, 2020. Three well defined *Ribeiroia* cysts were present in the TRS. Shipping conditions compromised the cysts resulting in closer examinations on a microscope impossible.

2.5 Alternate control method investigations

In 2020, four capture methods were utilized to capture adult and juvenile bullfrogs. Hand capture is considered to be the main capture method and all other capture methods are considered “alternative”. The alternative methods investigated in a given year will evolve with project needs and as information becomes available. In 2020, the alternative capture methods that were investigated included: paddle whapper, dip net and pellet gun.

Table 5 shows the number of bullfrogs of each age class that were captured using each capture method. A pellet gun was used a few times but did not result in any captures, so it was not added to this list of capture methods. In one case, a boat paddle was used in a similar manner to a paddle whapper and resulted in the capture of a juvenile bullfrog, leading to its inclusion in this table. The bilge pump was used to remove 2 egg masses from Hornby Wetland, but is not a method used for adult or juvenile captures. Tadpole trapping also resulted in adult and juvenile bullfrog frog; these results are discussed separately in Objective 1.3.

Aside from hand capture, the most used capture method was blunt impact using a custom-made wooden swatting tool, the "paddle whapper" designed by one of our volunteers (Figure 10). The capture method used was determined by bullfrog age class and the situation (e.g. dense vegetation present, bullfrog was sitting on a woody debris feature). The paddle whapper was particularly useful in situations where there was open water or surface vegetation associated with shallow-open water habitats (e.g. Water Lilly or Duck Weed). It was difficult to use the paddle whapper in areas with significant riparian vegetation such as the perimeter of Ryder Lake (due to the Yellow-flag Iris) and in specific areas of Hornby Wetland (i.e. cattails). The preferred method for capture utilized when a bullfrog was on land or resting on a woody debris feature was a dip net or hand capture. Using a paddle whapper in these situations is not recommended as it could lead to injury.

Table 5: Comparison of capture methods

	Capture Method				
Age Class	**Paddle Whapper**	**Hand**	**Dip Net**	**Bilge Pump**	**Boat Paddle**
Adult	28	5	0	0	0
Young Adult	17	4	0	0	0
Juvenile	65	741	1	0	1
Tadpole	1	0	3	0	0
Egg Mass	0	0	0	2	0
Total Captures	**111**	**750**	**4**	**2**	**1**

Table 6: Average capture effort (time in seconds from observation to capture). Capture effort was not recorded every time a bullfrog was captured (n= 241 captures with recorded capture effort

	Capture Method			
Capture Effort (Time to capture in seconds)	**Hand**	**Paddle Whapper**	**Dip Net**	**Boat Paddle**
< 10	133	18		
10 - 19	2	24		1
20 - 29	5	7		
30 - 39	2	13	1	
40 - 49	1	9		
50 - 59		3		
60 - 69	1	6		
70 - 79		4		
80 - 89		2		
90 - 99	2	3		
100 - 109				
110 - 119		1		
120 - 129		2		
130 - 139				
140 - 149		1		
> 150	1	2		

Age class also played a role in determining the preferred capture method for a given situation. For adults and young adults, a paddle whapper was used for 85% (n=28) and 81% (n=17) of captures, respectively. For juveniles, hand capture was used for 92% of captures (n=741). When a juvenile was hit with a paddle whapper it was common that the body was not retrieved because it was pushed under the aquatic vegetation. This resulted in the tendency for surveyors to avoid the use of paddle whappers when encountering juveniles in dense aquatic vegetation.

The capture effort (time from observation to capture) was recorded for 241 bullfrog captures. Table 6 shows the number of bullfrogs captured within different time frames and compares the capture effort between capture methods. Figure 23 shows that most captures occurred less than 10 seconds after the first observation (63%; n=151) and 95% of those captures were juveniles (n=144). Trends like these will be monitored in future years for comparison and capture method efficacy investigations and recommendations.

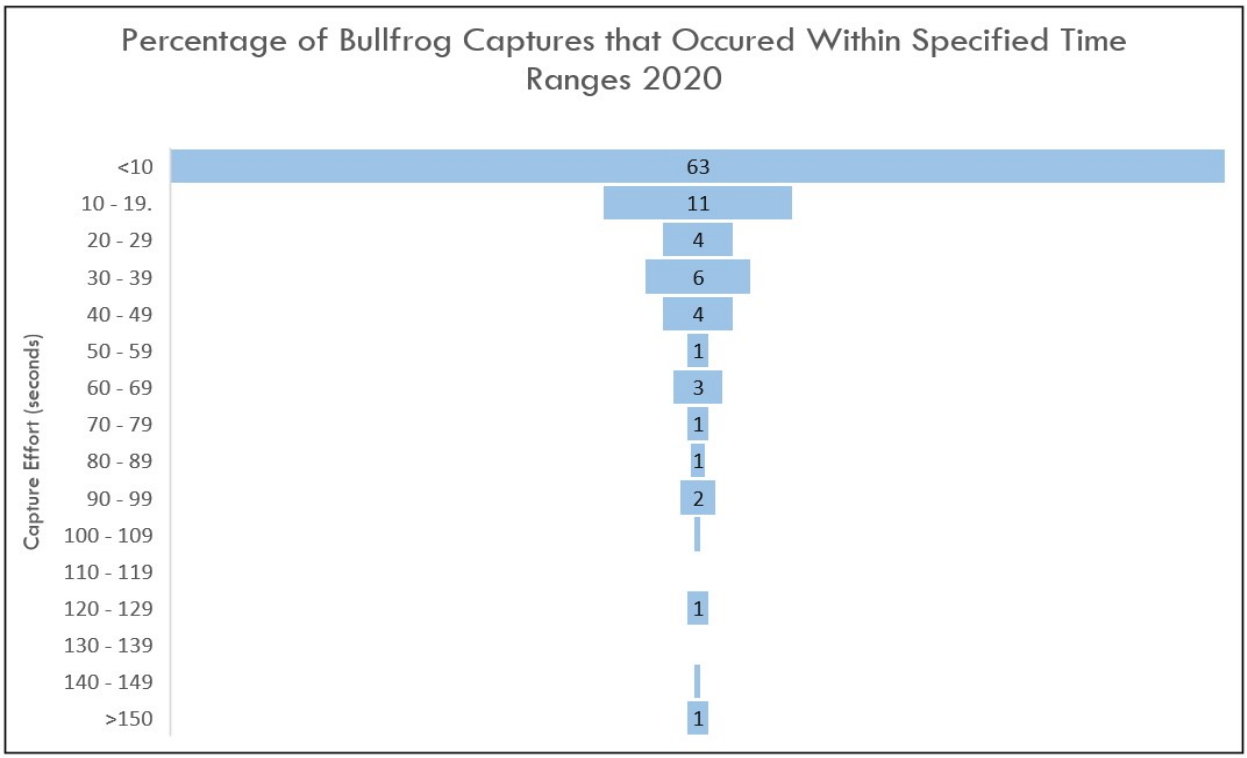


Figure 23: Percentage of captures that occurred within specified time ranges (n=241 captures). 63% of captures took less than 10 seconds.

Objective 3 – Biodiversity Research

3.1 Biodiversity baseline

In year 1, the first phase of biodiversity baseline data collection was completed. This data will be compiled and added to in future years. These observations will reveal species present in the Ryder Lake area that may suffer negative impacts from a bullfrog infestation.

The full Biodiversity Baseline can be found in Appendix 2 – Biodiversity Baseline. This includes status information for detected species and some species that are expected to be in the area but were not observed in 2020.

As of April 2021, the biodiversity baseline includes: 60 species of vegetation, 70 species of invertebrates (including 1 crayfish and 1 bryozoan), 43 bird species, 20 mammal species (including 8 bat species), 2 reptile species (including the invasive Red-Eared Slider) and 7 amphibian species (including the invasive American Bullfrog and 2 species at risk). Protocols will be developed to fill in the knowledge gaps this biodiversity baseline has begun to reveal.

3.2 Monitor priority species

Control Effort Incidental Herpetofauna Observations

All bullfrog-related activities included protocols for data collection if/when native species were encountered. The data below summarizes the herpetofauna encountered in 2020 while conducting bullfrog control. Figure 24 shows the number and age class of species observed. The most recorded subset being adult Western Toads (65 individuals observed) and juvenile Northern Red-legged Frogs (56 individuals observed). Toad tadpoles were not recorded as individuals, rather they were recorded as a group observation due to large numbers. Therefore, the 16 toad tadpole observations listed were sightings of large groups.

Two additional non-native herpetofauna observations were made of Red-eared Slider (*Trachemys scripta elegans*). An empty shell was discovered in the flooded riparian habitat along the eastern edge of Hornby Wetland and a live individual was observed by field staff while it was sitting on a log.

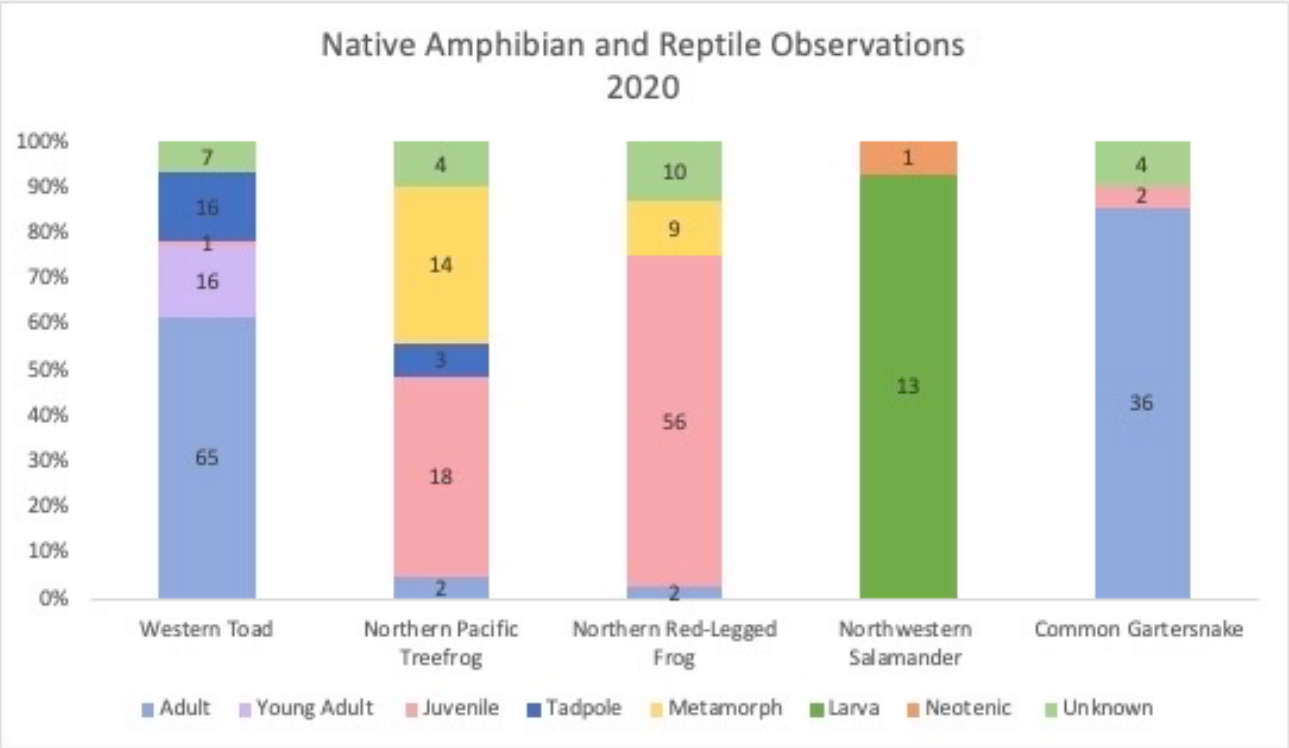


Figure 24: All non-bullfrog reptile and amphibian observations made during the 2020 bullfrog surveys (May-October 2020), showing species and associated age classes. Total count of each amphibian species observed in 2020. Data is stacked by age class. Unknown = age class was not determined in the field.

Vegetation and Macro-Invertebrate Plots

In 2020, vegetation and macro-invertebrate survey plots were created and monitored. Vegetation and macro-invertebrates were surveyed in the same positions for sampling simplicity. Data collected during these surveys will be used to investigate bullfrog impacts on native species over time, compare vegetation and invertebrate observed together and compare this to bullfrog and native amphibian habitat use data. Data collection for year 1 is complete, and a database will be maintained for vegetation and macro-invertebrate data that will be available for investigation/comparison over time. This data is preliminary and will need further data collection and investigation for accurate comparisons. In 2020, 60 species of vegetation and 70 macro-invertebrate species were recorded, and some were only detected due to these surveys.

In 2021, vegetation and macro-invertebrate plots will be monitored again, and the results will be compared over time to determine the impacts that a bullfrog invasion could have on the vegetation communities and macro-invertebrate occurrence/abundance in these sensitive wetland habitats.

Artificial Cover Objects

Artificial cover objects were used to in an attempt to monitor adult native salamanders. No salamanders were found under artificial cover objects (ACOs) in 2020. Although the ACOs did not aid in native salamander monitoring, they were an unintended source of terrestrial macro-invertebrate observations, adding some ground beetle, camel cricket, and spider observations to the biodiversity baseline. These surveys will continue in 2021 and because the cover objects have been left out over the winter it is expected that the micro-habitat underneath the cover object may be more suited to salamander use.

Spring Egg Mass Surveys

Spring visual encounter egg mass surveys were conducted in April 2020 targeting native amphibian egg masses in Ryder Lake and Hornby Wetland. During these surveys the following egg masses were found: 139 Northwestern salamander, 4 Long-toed salamander, 51 Northern Red-Legged Frog, and hundreds of Northern Pacific Treefrog (Table 7). This survey was too early to detect Western Toad egg masses, although surveyors were able to detect tadpoles in Hornby Wetland, but not Ryder Lake. This data will be used to map habitat use and requirements for native species in the future.

*Table 7: Spring egg mass survey results in Hornby Wetland and Ryder Lake, 2020. *Surveys were conducted too early in the season to detect Western Toad egg masses. Tadpole observations from the summer were substituted.*

Species	**Number of egg masses observed**	
	Hornby Wetland	Ryder Lake
Northwestern Salamander	120	19
Long-toed Salamander	4	0
Northern Red-legged Frog	47	4
Northern Pacific Treefrog	51	0
Western Toad*	Tadpoles observed	No tadpoles observed

Amphibian Road Surveys

In total, 3 fall amphibian road surveys were completed (October 9, October 14, November 3). A total number of 174 amphibians were observed, dead and alive, on the 3km road survey route (Figure 25). During these surveys 3 dead juvenile bullfrogs were detected, all on Huston Rd. (south of Hornby Wetland).

This data was compiled in the Ryder Lake Amphibian Protection Program dataset and the bullfrog data will be used to direct future call surveys/acoustic monitoring.

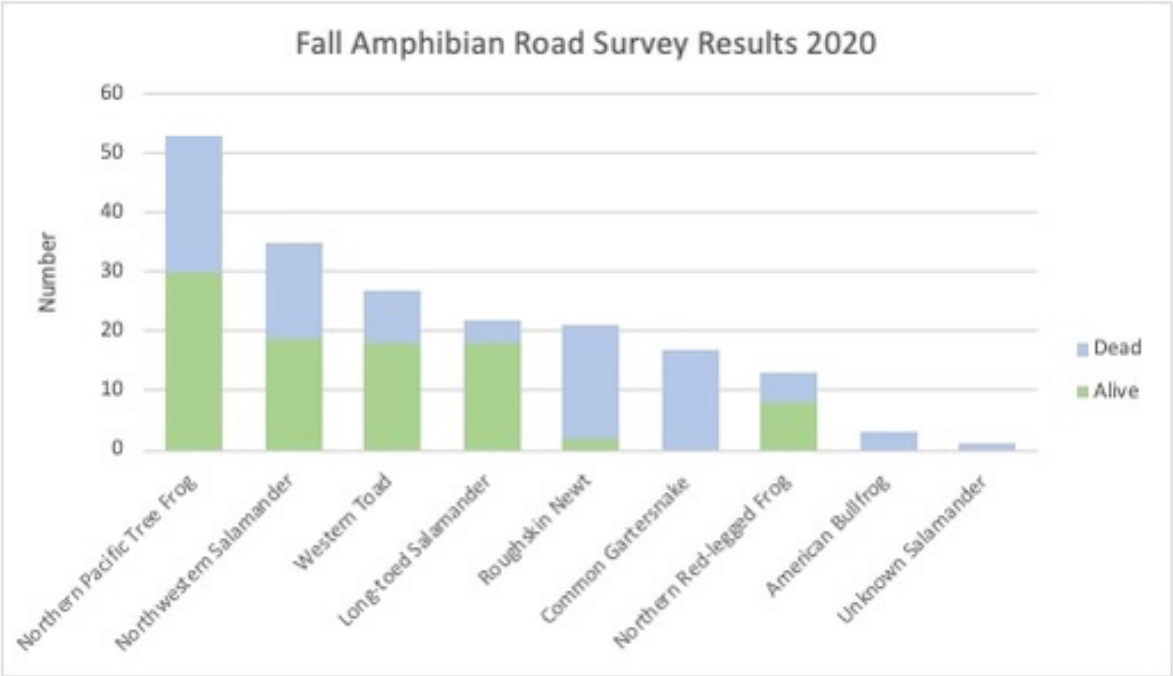


Figure 25: Total number of amphibians observed, alive and dead, during road surveys in fall 2020 (n=3 surveys, n= 174 amphibians).

Acoustic Monitoring

In 2020, bats were the only mammals that were actively investigated and not just observed incidentally. Athene Ecological installed acoustic recording units to record the echolocation calls of bats in both Ryder Lake and Hornby Wetland (between July 13th – July 22nd, 2020). Tables 8 and 9 show the species that were heard in Ryder Lake and Hornby Wetland. This acoustic data revealed that 8 species of bat frequent the Ryder Lake area. The distance between Ryder Lake and Hornby Wetland is negligible for bats but there were 50% more total calls recorded at Hornby Wetland than at Ryder Lake.

The full report is held by the Fraser Valley Conservancy and available upon request.

Table 8: Identified Bat echolocation calls at Ryder Lake 13-31 July 2020.

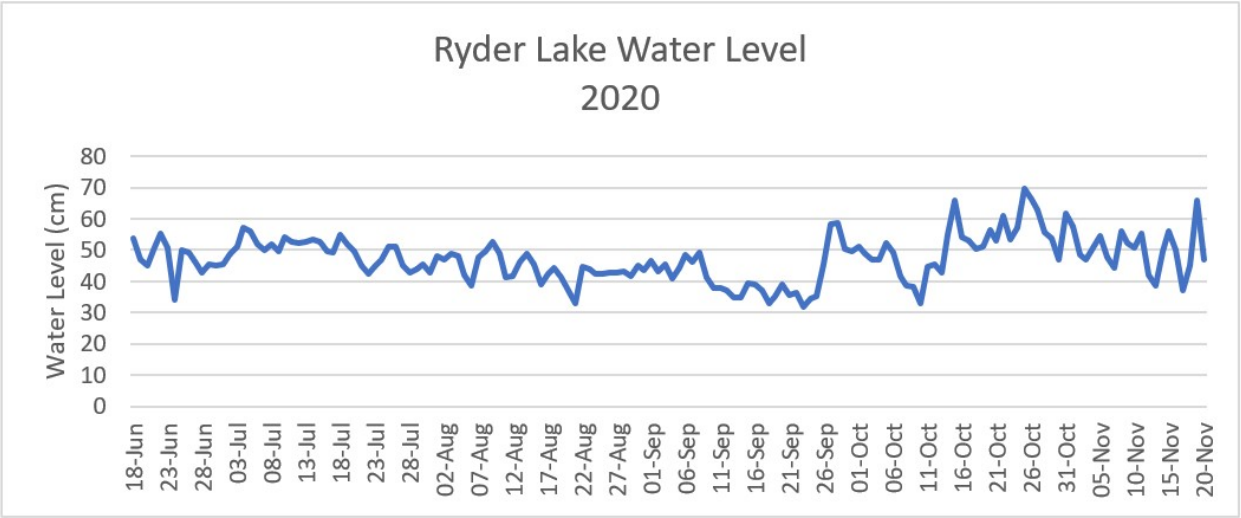
				25 k Frequency difficult to distinguish			40 k Frequency difficult to distinguish			50 k Frewuency Indistinguishable
Date	All Bat Species	Townsends's Big-eared Bat	Hoary Bat	Big Brown Bat	Silver-Haired Bat	Long-eared Myotis	Little Brown Myotis	Long-Legged Myotis	Mexican Free-tailed Bat	California/Yuma Myotis
		COTO	LACI	EPFU	LANO	MYEV	MYLU	MYVO	TABR	MYCA/MYYU
13-Jul-20	10441	23	10	51	89	0	98	0	65	3019
14-Jul-20	9136	28	2	75	73	0	89	0	53	4058
15-Jul-20	10268	30	6	134	126	0	136	0	41	4959
16-Jul-20	11800	42	11	73	117	0	272	2	70	4464
17-Jul-20	17759	54	16	504	55	0	282	2	77	6077
18-Jul-20	9426	25	24	118	53	0	122	0	71	3547
19-Jul-20	11276	42	194	137	22	0	239	0	78	5453
20-Jul-20	8724	57	117	26	96	0	181	6	46	5313
21-Jul-20	12609	67	64	88	38	0	280	0	78	5892
22-Jul-20	16061	53	77	179	19	0	209	0	101	7157
Total	117500	421	521	1385	688	0	1908	10	680	49939
Mean # per day	11750	42	52	139	69	0	191	1	68	4994

Table 9: Identified Bat echolocation calls at Hornby Wetland 13-22 July 2020.

				25 k Frequency difficult to distinguish			40 k Frequency difficult to distinguish			50 k Frewuency Indistinguishable
	All Bat Species	Townsends's Big-eared Bat	Hoary Bat	Big Brown Bat	Silver-Haired Bat	Long-eared Myotis	Little Brown Myotis	Long-Legged Myotis	Mexican Free-tailed Bat	California/Yuma Myotis
Date		COTO	LACI	EPFU	LANO	MYEV	MYLU	MYVO	TABR	MYCA/MYYU
13-Jul-20	2342	0	11	4	90	0	0	0	60	165
14-Jul-20	1649	0	10	3	28	0	2	0	39	305
15-Jul-20	3093	1	46	5	39	0	0	0	92	401
16-Jul-20	7201	16	36	11	69	0	98	0	91	4346
17-Jul-20	5413	3	24	62	68	0	12	0	77	2345
18-Jul-20	3130	0	26	15	45	0	2	0	66	312
19-Jul-20	2648	0	65	5	57	0	0	0	56	441
20-Jul-20	3381	1	128	2	26	0	3	0	89	734
21-Jul-20	5384	7	185	2	56	0	26	0	75	2590
22-Jul-20	9481	19	32	79	57	0	193	4	104	6634
23-Jul-20	7282	16	50	8	14	0	40	0	124	2898
24-Jul-20	4035	2	16	4	10	0	0	0	94	296
25-Jul-20	2025	0	36	0	68	0	0	0	64	166
26-Jul-20	2668	2	219	2	32	0	0	0	32	562
27-Jul-20	3304	2	182	2	37	0	2	0	79	803
28-Jul-20	2066	1	67	0	14	0	2	0	42	193
29-Jul-20	2943	1	135	2	91	0	3	0	75	295
30-Jul-20	4400	0	194	2	69	0	0	0	88	626
31-Jul-20	2559	5	32	0	0	0	14	4	11	2494
Total	75004	76	1494	208	870	0	397	8	1358	26606
Mean # per day	3948	4	79	11	46	0	21	0	71	1400

3.3 Assess site quality

Habitat quality monitoring protocols were developed in 2020. Installed level loggers in both wetlands and an atmospheric logger in a tree next to Hornby Wetland. Figure 26 shows the water level recordings for 2020. Future site quality parameters will be investigated 2021.



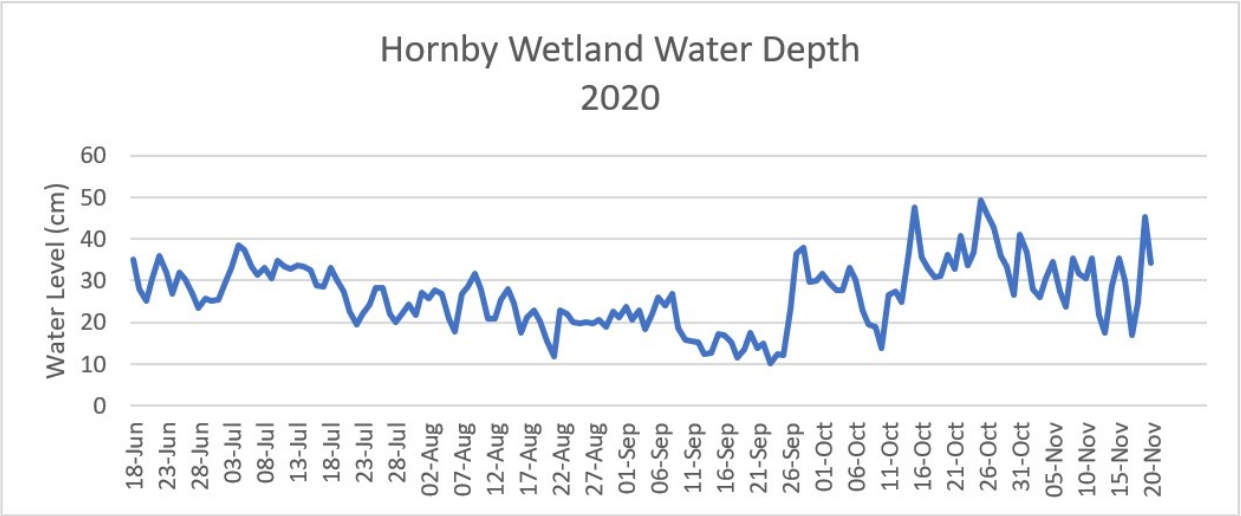


Figure 26: Water levels at Horny Wetland and Ryder Lake in 2020.

3.4 Biodiversity Impact Assessment

All year 1 biodiversity and bullfrog data were compiled for future assessment of bullfrog impacts on biodiversity. Databases will be updated annually, and the full biodiversity impact assessment will be a 2024 target.

Objective 4 – Project Evaluation and Planning

4.1 Track bullfrog population trends annually

Over the 2020 field season there were 989 bullfrog observations recorded by our field team, 868 of which were captures. More data is required for comparison over time. Year 1 data collection is complete, and a database will be maintained as population trend data is compiled.

4.2&4.3 Eradication evaluation and mitigation plan; Update bullfrog management plan

An Eradication Evaluation, Mitigation Plan and a Bullfrog Management Plan were established in 2020, and yearly updates will be contributed to each. The final recommendations (eradication vs habitat enhancement/mitigation) will be made in year 4 of this project for implementation in year 5.

Objective 5 – Targeted Bullfrog Outreach

5.1 Secure ongoing access to wetlands on private property

A landowner/landowner representative agreement was created and signed by 2 landowner representatives in the Ryder Lake area in 2020. Refer to the "Research Access Agreement" in Appendix 3 for details. These research access agreements were signed by landowner representatives and not the landowners themselves as this is preferred by the landowners.

5.2 Train residents to assist with bullfrog surveys and control

The FVC trained the Hornby Wetland property caretaker in amphibian identification and bullfrog control methods. In 2020, one bullfrog egg mass was identified and removed by this resident using FVC bullfrog control protocols. The resident detected the egg mass and contacted FVC field staff for identification confirmation and proceeded to scoop the egg mass into a bucket. Field staff arrived at Hornby Wetland within hours of the initial sighting and finished removing the remains of the egg mass. She also contributed to many native other wildlife observations for the biodiversity baseline and priority species monitoring.

Another resident of the Ryder Lake area conducted bullfrog control surveys in Ryder Lake using a modified version of FVC bullfrog control data collection protocols. This resident conducted visual encounter bullfrog control surveys in Ryder Lake on a volunteer basis during the breeding season and had other residents accompany him on surveys to share bullfrog knowledge and control techniques. Table 8 shows this residents' capture and observation rates for bullfrogs, Northern Red-legged Frogs and Western Toads. This resident conducted 13 visual encounter bullfrog control surveys in Ryder Lake between May 18th and Aug 17th, 2020. The resident also brought volunteers from the neighbourhood out surveying and shared amphibian identification

and bullfrog control techniques. Over the field season, 16 individuals accompanied him on surveys, usually in groups of 3 or 4 at a time. This led to variances in data and frog collecting abilities per survey but was an important way for the project to reach more individuals in the area and led to the capture of an additional 273 bullfrogs (Figure 27). The bullfrog control protocols followed by non-FVC staff can be found in Appendix 1 ("Bullfrog Control Field Work Protocol - Steve Style (Version 1.0)").

Table 8: Ryder Lake volunteer bullfrog control survey and incidental native species observation data. Bullfrogs (n=273) were captured and removed, following FVC euthanasia protocols.

	Species		
Age Class	**American Bullfrog**	**Northern Red-legged Frog**	**Western Toad**
Adult	22		8
Juvenile	192	2	
Metamorph	20		
Sub Adult	24		
Tadpole	15		
Unknown			1
Grand Total	273	2	9

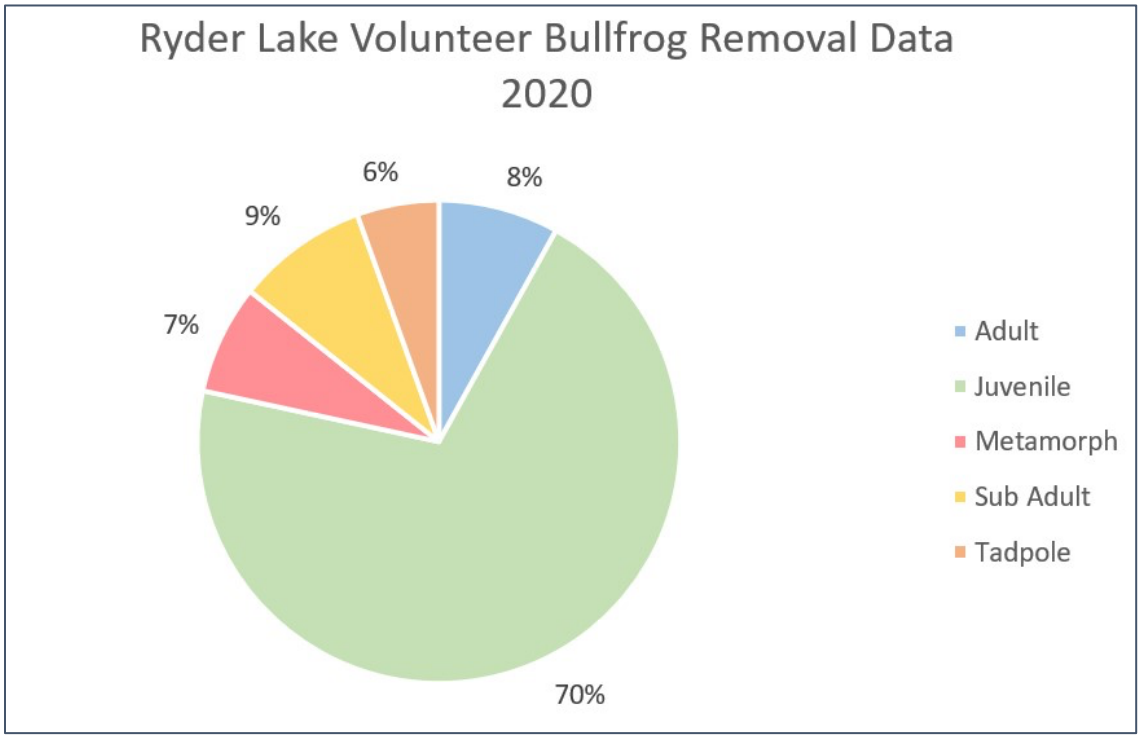


Figure 27: Ryder Lake volunteer bullfrog removal data

RAPID RESPONSE BULLFROG CONTROL AND BIODIVERSITY RESEARCH IN SENSITIVE WETLANDS

Another important component of this activity is our larger Ryder Lake neighbourhood community engagement strategy. We posted new educational materials on our social media to the Ryder Lake community Facebook page (Figure 28) and shared the larger print and television media publications. In addition to this targeted digital engagement, we hosted a community event called "Leap and Learn" alongside the Ryder Lake Amphibian Protection Program project in September (Figure 29). This event aimed to bring awareness of the FVC's newest project to the Ryder Lake residents, and to ensure residents were trained in differentiation between Western Toads and bullfrogs. Unfortunately, due to limitations on gatherings with the COVID-19 pandemic, only 15 Ryder Lake neighbourhood residents were able to participate.

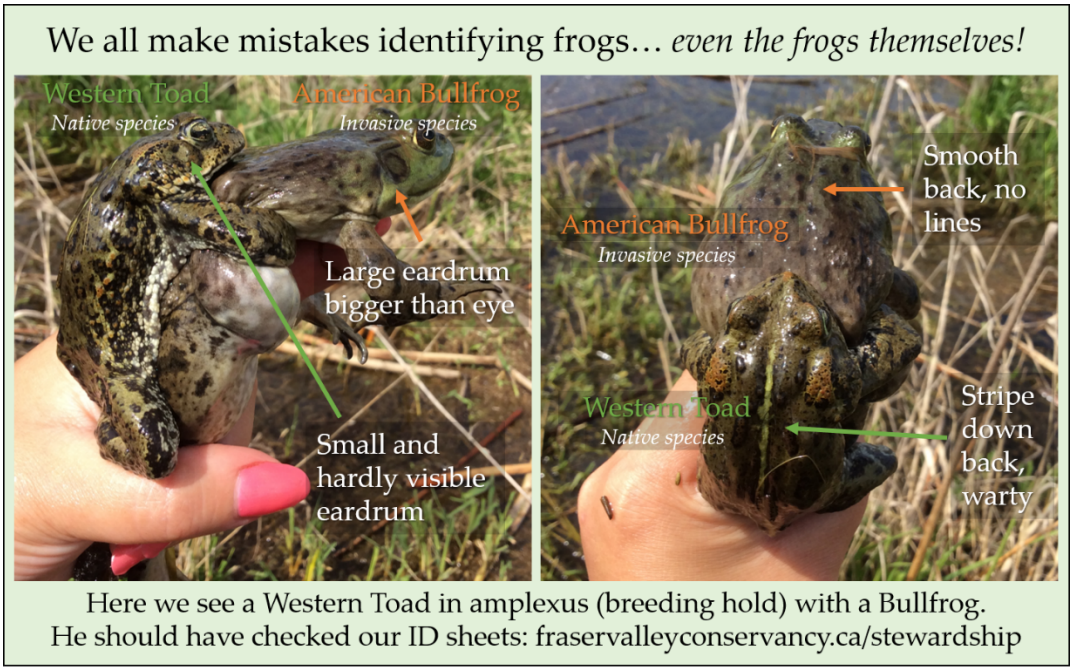


Figure 28: Social media posts for bullfrog awareness

Figure 29: Leap and Learn promotion and event photo

5.3 Train a local resident to coordinate and facilitate community support

A local resident was not identified in 2020 and this activity is not how we want to proceed. This will not be a separate objective in 2021. This activity was changed to creating a community group that will facilitate biodiversity projects in the Ryder Lake area. Refer to the discussion section for more details.

5.4 Utilize partnerships and collaborate with other groups to promote bullfrog identification and control through media and educational resources.

Media outreach

The FVC played reached thousands of people through media in 2020. Our story of bullfrog awareness was picked up by the *Chilliwack Progress* newspaper and shared amongst all other local Black Press Media affiliates including the *Abbotsford News*, *Agassiz-Harrison Observer*, *Aldergrove Star*, *Mission City Record*, *Hope Standard*, and the *Langley Advance Times*. This article reached thousands of people in the Fraser Valley area and received hundreds of social media shares and responses.

https://www.theprogress.com/news/american-bullfrogs-wreaking-havoc-in-fraser-valley-watersheds/

The coverage from this article led to an opportunity to appear on Global TV news for a segment on bullfrogs in the Fraser Valley. From this TV spot we received new amphibian detections in our Frog Finders program, including a Ryder Lake resident who had otherwise not been reached by our programming. He reported juvenile bullfrogs had started appearing in his pond this year.

https://globalnews.ca/video/7208493/american-bullfrogs-pose-threat-to-fraser-valley-ecosystem

We also participated in a radio interview with the local radio station 980 CKNW.

https://omny.fm/shows/the-jill-bennett-show/american-bullfrogs-could-potentially-wreak-havoc

Expert advising and collaboration

Our team participated in the most recent American Bullfrog Action Team (ABAT) meeting (December 9th, 2020) and gave project updates to the group. The effectiveness of the "paddle whapper" and other alternative control methods were also discussed. Due to this massive success of our capture efforts and the detailed data collection, we have been able to provide important contributions to knowledge gaps for other bullfrog control practitioners. It was at the direction of the ABAT team that a comparison of capture methods used on this project and other commonly used control techniques be undertaken. Participation in these meetings is building on the relationship founded prior to the establishment of the FVC bullfrog project.

We were also able to provide significant contributions to Metro Vancouver's *Best Management Practices for American Bullfrog in the Metro Vancouver Region* (contributions cited as both FVC 2020 and Switzer 2020). Our educational material, including the new *A Landowner's Guide to American Bullfrog Management in the Fraser Valley* was a primary source of information for habitat management and practical control advice. Our website hosts a variety of resources on our new *Bullfrog 101* page.

http://www.metrovancouver.org/services/regional-planning/PlanningPublications/AmericanBullfrogBMP.pdf

https://fraservalleyconservancy.ca/wp-content/uploads/2020/06/BullfrogControlLandowners_Final_web.pdf

http://fraservalleyconservancy.ca/bullfrog101/

Community education

The Fraser Valley Conservancy frequently answers questions from the community about bullfrogs, bullfrog control, and habitat enhancement for native species. Through this project we were able to present to approximately 15 people from the Abbotsford Mission Nature Club's meeting to discuss the Ryder Lake project and the trials of bullfrog prevention and management. Many other FVC activities, including our Nature Stewardship School and Frog Finders, raise community awareness of amphibian issues, and this project is often referenced as an example to help explain the difficulties of bullfrog management.

Discussion

Bullfrog Control

Capture methods

The most used capture methods in year 1 of this project were hand capture and the paddle whapper (blunt impact). Hand capture was the most used capture method for juveniles and was especially effective on the relatively naive metamorphs in late August. These individuals had not been the target of previous capture attempts and would sit at the water surface. It was very easy to reach over the side of the boat/kayak and collect them. The paddle whapper was not the preferred method for these individuals, especially when a dense mat of aquatic vegetation present. When used in these situations, the paddle whapper would push the bullfrog under the vegetation and in some cases was not retrieved. When used on an adult in the same situation bullfrog was often large enough to see and retrieve. After year 1, these results are not enough to determine which capture method is the most successful as the method used was situationally dependent and influenced by surveyor biases towards preferred methods.

After consulting with the American Bullfrog Action Team, the FVC bullfrog team trialed the following control methods in 2020: Paddle whapper, pellet gun, and minnow traps. Alternative control methods should be continuously investigated to ensure the most efficient, humane, and cost-effective methods are utilized. Capture method and capture effort (time from observation to capture) require further investigation. This data will aid in making recommendations for control methods to other practitioners.

After trialing tadpole trapping in 2020, it was determined that this was not an efficient method of bullfrog control in the project locations. Although tadpoles were the target of these surveys, no bullfrog tadpoles were captured in traps in 2020. The timing of trapping trials could have affected these results. Traps were installed in September and monitored for 5 days. During the summer bullfrog control, call and egg mass surveys were the focus of surveyor efforts. Tadpole trapping was trialed after the breeding season (September) and targeted the 1–2-year-old tadpoles. While this method was not a significant source of bullfrog tadpole captures it aided in macro-invertebrate and native salamander larval stage investigations. Trapping will not be pursued further as a bullfrog control method. This method will still be used in biodiversity research and native amphibian monitoring. At this point, no efficient method of tadpole control has been identified. Alternative methods targeting this life stage will be investigated but tadpoles are not the main target of the control program.

Success factors

During control efforts, the amount of light pollution observed while conducting surveys seemed to be linked to the success of pit-lamping techniques. Light sources that seemed to affect the success rate of the pit-lamping method: a light turned on at a nearby cabin and when there was a full moon on a clear night. When sufficient alternative light sources were present, bullfrogs were not completely stunned by the light of a headlamp. If they were stunned at all they appeared to be more skittish and easily disturbed. This could have affected capture rates. Adults seem especially sensitive to this. These results were not recorded measurably but surveyors recorded these observations in survey notes.

Bullfrogs learned to avoid the boat or kayak and surveyors' lights if capture attempts were unsuccessful. This is something that can be investigated in later years to determine ideal survey conditions. Perhaps clear full moon nights are not ideal for bullfrog control surveys if it increases the number of failed attempts, especially if the odds of bullfrog capture decrease with each subsequent attempt. Prioritizing quality control activities over quantity may be key to success.

For this project's control efforts to be successful, the network dynamics of bullfrogs within the Ryder Lake neighbourhood must be investigated. Call surveys were used to investigate the source of the bullfrogs and how they were spreading across the landscape. The source of bullfrogs in this area is most likely anthropogenic but there is a possibility that they are spreading into the area from the valley below. Ryder Lake is higher in elevation than the surrounding valley floor and it would be difficult for bullfrogs to spread this way. Currently, there is no evidence that bullfrogs are traveling from the Chilliwack River Valley into the Ryder Lake area. If bullfrog introduction in the Ryder Lake area is anthropogenic in nature, it reinforces the need for public outreach and education to prevent more introductions.

Bullfrog Research

Call survey efficacy

The number of call survey stations in each survey route was limited by the time it takes to complete a survey. Surveyors had to complete survey routes within the most likely window for call detection (between 10 pm and 2 am) (NAAMP, 2015). If the call survey routes were longer, accurate data would not be available. The Chilliwack Route (see Figure 20) ended at CR1 as this survey station was directly next to Lovely Pond. FVC staff identified Lovely Pond as one of the most likely spots in the area for bullfrog detection based on habitat. This location is not directly south of the Ryder Lake survey route but in 2019 and 2020 no bullfrog calls were detected in the eastern section of the Ryder Lake call survey route (no bullfrog calls have been detected east of RL9 and RL19 in 2019 or 2020). This seems to indicate that it is unlikely that a source

population is coming from the southeast (near CR1). This survey route could be altered in later years and expanded towards Slesse park to get a clearer picture of bullfrog presence south of Ryder Lake along the Chilliwack River.

Now that the survey routes are mostly established there is a possibility of farming out these activities to volunteers. The timing of call surveys could also be altered to increase the chances of detecting calls. Surveys started once calls were already being heard in Hornby Wetland and Ryder Lake. Call surveys could start before bullfrog calls are detected at Hornby Wetland (using year 1 and 2019 call survey data to determine start date). No calls were detected during the third set of call surveys in year 1. This seems to indicate that surveys could start earlier. These surveys also did not reveal any novel bullfrog populations in the Ryder Lake or Chilliwack area. The call survey methodology should be evaluated to determine if it is answering the questions being asked about replenishment and bullfrog movement on the landscape. It may be combined with acoustic monitoring to increase the chances of detecting calls. Determining the spread of bullfrogs and their infestation range in the Ryder Lake area is an important action that will influence control efforts and overall management decisions.

Cancelling eyeshine surveys

It was proposed that eyeshine surveys could be used in combination with call surveys to increase the chances of detecting bullfrogs during surveys. Surveyors did not use eyeshine alongside call surveys in 2020 and it has been removed from the project objectives for future years. Trials indicated that this was not a suitable method of bullfrog detection for this project. Bullfrog calls can be heard from great distances so call survey stations were often not visible from the road (i.e. trees between the road and the pond, water was at the bottom of a hill or in an agricultural field) and on private property. Surveyors had limited or no direct access to water bodies on private property. Call surveys were conducted from adjacent roads and pullouts. If eyeshine was detected it would be difficult to distinguish between species from a distance. Shining a light onto private property could also be disruptive late at night (surveys occurred between 10 pm-2 am). For these reasons, eyeshine surveys will not be conducted alongside call surveys in year 2.

Research project collaboration

In year 1, this project reached out to other groups/research institutions to aid in answering bullfrog research questions and these relationships are an integral part of the future of this project.

Gut content analysis

The gut content analysis being performed by students at the University of the Fraser Valley is beginning to reveal what prey items bullfrogs in the Ryder Lake area are consuming, answering

important questions and directing survey and habitat enhancement priorities in the future. Gut content analysis is not a novel research topic, but the unique situation in the Ryder Lake neighbourhood makes it an important endeavour to undertake. Direct, long-term bullfrog impacts to biodiversity are not well documented in literature. Gut content analysis usually takes place long after bullfrog infestations have been established, and many impacts may have already been missed. The FVC's biodiversity baseline and gut content analysis at this early stage in bullfrog infestation will help serve as a record for future research of what was present and what was directly eaten by bullfrogs, allowing for a deeper understanding of bullfrog impacts over time.

This activity is forming an important relationship between the University of the Fraser Valley and the Fraser Valley Conservancy, which can help produce more research collaboration opportunities in the future. Additionally, the formalized protocols and student-friendly research methods can be shared with other groups studying bullfrogs (such as the American Bullfrog Action Team). Well-written protocols do not currently exist, and the FVC is poised to be an important resource generator and distributor for researchers across the province.

Deformity investigation

The ramifications of the new *Ribeiroia* discovery for the Ryder Lake neighbourhood are not well understood. As this is only the second discovery of this parasite in British Columbia, there is little known about how native amphibians will be impacted, and how significant this discovery is to their survival. This new threat only compounds the existing threats of bullfrogs, development, road mortality, and climate change.

The FVC now stands at an important juncture in understanding how to protect biodiversity in the Ryder Lake neighbourhood. Our relationship building with the University of Colorado will allow us to continue the investigation of the prevalence of *Ribeiroia* infections in amphibian populations, and we will serve as an important mentor for other groups in the South Coast region.

Biodiversity Research

Understanding the species interactions between bullfrogs and native species and how they are using these wetlands is integral to the purpose of our control efforts. Bullfrog eradication is not the focus of this project. Control methods are seen as a necessary research tool for investigating the impacts that a bullfrog introduction has on native species. It is also important to implement control efforts early in the infestation process to collect critical information about early impacts. Therefore, the FVC proceeded with bullfrog control efforts while asking bullfrog and biodiversity research questions. This data will be invaluable for creating informed, comprehensive

management plans for the Ryder Lake area, including continued management of the at-risk Western Toad and Northern Red-legged Frog populations the FVC has worked to protect for many years.

A biodiversity impact assessment will be a project priority when more biodiversity data has been compiled. The intent is to create a map where data layers will be overlayed (bullfrog occurrences, biodiversity baseline, priority species monitoring, research findings, and habitat features) to depict the interface between the species and habitat. The resulting product allows for better biodiversity analyses and bullfrog mitigation planning as the project progresses. This involves completing the biodiversity baseline and identifying priority species for monitoring purposes. These findings will be shared with land managers across the province to inform the creation and implementation of informed, adaptive management strategies.

Targeted Outreach

Community coordinator position

One of the year 1 objectives involved hiring a community coordinator who would facilitate community engagement. Due to challenges with creating opportunities for landowner engagement during the COVID-19 pandemic, and the natural evolution of the project's activities, this objective was re-invented. We now intend to create a Ryder Lake biodiversity protection community group trained and supported by FVC staff. This group will allow for more directed citizen science data collection and continuous support from project staff.

Public engagement

The overall public response to the Ryder Lake bullfrog project story was supportive, positive, and energized. The FVC's posts don't typically receive as much media response and public engagement compared to our bullfrog related posts. This issue is still new and exciting to the general public, despite bullfrogs being present in the area for decades. This important outreach work must continue as many people shared that they were either unaware of bullfrogs being invasive, or that they had confused Western Toads with bullfrogs.

Ryder Lake residents have been largely supportive of this new project, with many residents expressing concern for bullfrog impacts and appreciation of our work.

Conclusion

The Fraser Valley Conservancy has been working to protect amphibians in the Ryder Lake area for over six years. In partnership with HCTF, City of Chilliwack municipal staff, and residents of the Ryder Lake neighbourhood, we have managed to affect significant, positive change. The Rapid Response Bullfrog Control and Biodiversity Research in Sensitive Wetlands project adds to this important work and demonstrates a commitment from all involved to care for the future of the Ryder Lake neighbourhood, and by extension of the lessons we learn, the entire Fraser Valley. The primary aim of the first year of this project was to quickly respond to a new bullfrog infestation by engaging in a science-based, research-minded control program. Our thorough data collection, intensive biodiversity surveys, and position as a respected authority on bullfrog information has resulted in a successful first year.

Finalizing the biodiversity baseline started in year 1 will aid in identifying more priority species that could be impacted by bullfrogs in the Ryder Lake area. This will involve targeted surveys and a continuation of incidental monitoring techniques as well as collaborating with landowners, consultants, experts and researchers. Bullfrog control as a tool for biodiversity impact research should continue, answering questions in collaboration with other bullfrog control projects.

New threats to amphibian survival have been revealed by our university partnerships; a *Ribeiroia* cyst detected in a Ryder Lake bullfrog points to more trouble on the horizon. As the front line of protection for biodiversity in this area, the project must continue to investigate the impacts of yet another non-native species to these sensitive wetlands.

The results of this program will be shared with other groups, like the American Bullfrog Action Team, and will have far reaching impacts on invasive amphibian management practices and recommendations for mitigating impacts to native species. Understanding the complex web of wetland life present in the Ryder Lake area will allow us to develop more appropriate, data-driven wetland enhancement recommendations in subsequent years. Together, we can learn how to build a sustainable future for biodiversity in the Fraser Valley.

References

British Columbia Frogwatch Program (BCFP). 2017. American Bullfrog Fact Sheet. 2p. http://www.env.gov.bc.ca/wld/documents/bullfrog_.pdf (Accessed March 1, 2021).

Davis, T.M. 1996. Distribution, Abundance, Microhabitat Use and Interspecific Relationships Among Terrestrial Salamanders on Vancouver Island, British Columbia. Ph.D. dissertation, Univ. Victoria, Victoria, BC.

Environment Canada. 2013. How Much Habitat is Enough? Third Edition. Environment Canada, Toronto, Ontario. https://www.ec.gc.ca/nature/default.asp?lang=en&n=e33b007c-1#_02_1_4

Global Invasive Species Database. 2019. Downloaded from http://www.iucngisd.org/gisd/100_worst.php

Jancowski, K. and S.A. Orchard. 2013. Stomach contents from invasive American bullfrogs Rana Catesbeiana (=Lithobates catesbeianus) on southern Vancouver Island, British Columbia, Canada. *NeoBiota*, 17-37.

Govindarajulu, P., R. Altwegg, and B.R. Anholt. 2005. Matrix model investigation of invasive species control: Bullfrogs on Vancouver Island. Ecological Applications. 15. 2161-2170. 10.1890/05-0486.

Govindarajulu, P., W.S. Price, and B.R. Anholt. 2006. Introduced Bullfrogs (Rana catesbeiana) in Western Canada: Has Their Ecology Diverged? Journal of Herpetology 40(2): 249-260.

Ministry of Environment. 2008. Standard Operating Procedures: Hygiene Protocols for Amphibian Fieldwork.

North American Amphibian Monitoring Program (NAAMP). 2015. NAAMP Protocols: https://www.usgs.gov/centers/pwrc/science/north-american-amphibian-monitoring-program?qt-science_center_objects=0#qt-science_center_objects (Accessed April 14, 2021).

SeaGrant. 2020. *American Bullfrog*. Retrieved from Aquatic Invasions! A Meance to the West - Species Guide: https://seagrant.oregonstate.edu/sites/seagrant.oregonstate.edu/files/bf-species-guide_1.pdf

Triece, K., J. Ehrenberger, and N. Daveport. 2018. Investigating Bullfrog management on the Front Range. Boulder County: Parks and Open Space. https://assets.bouldercounty.org/wp-content/uploads/2018/12/bullfrog-control-techniques.pdf

U.S. Fish and Wildlife Service (USFWS). 2013. Columbia River Fisheries Program Office: American Bullfrog Factsheet. https://www.fws.gov/columbiariver/ans/factsheets/bullfrog.pdf (Accessed April 14, 2021).