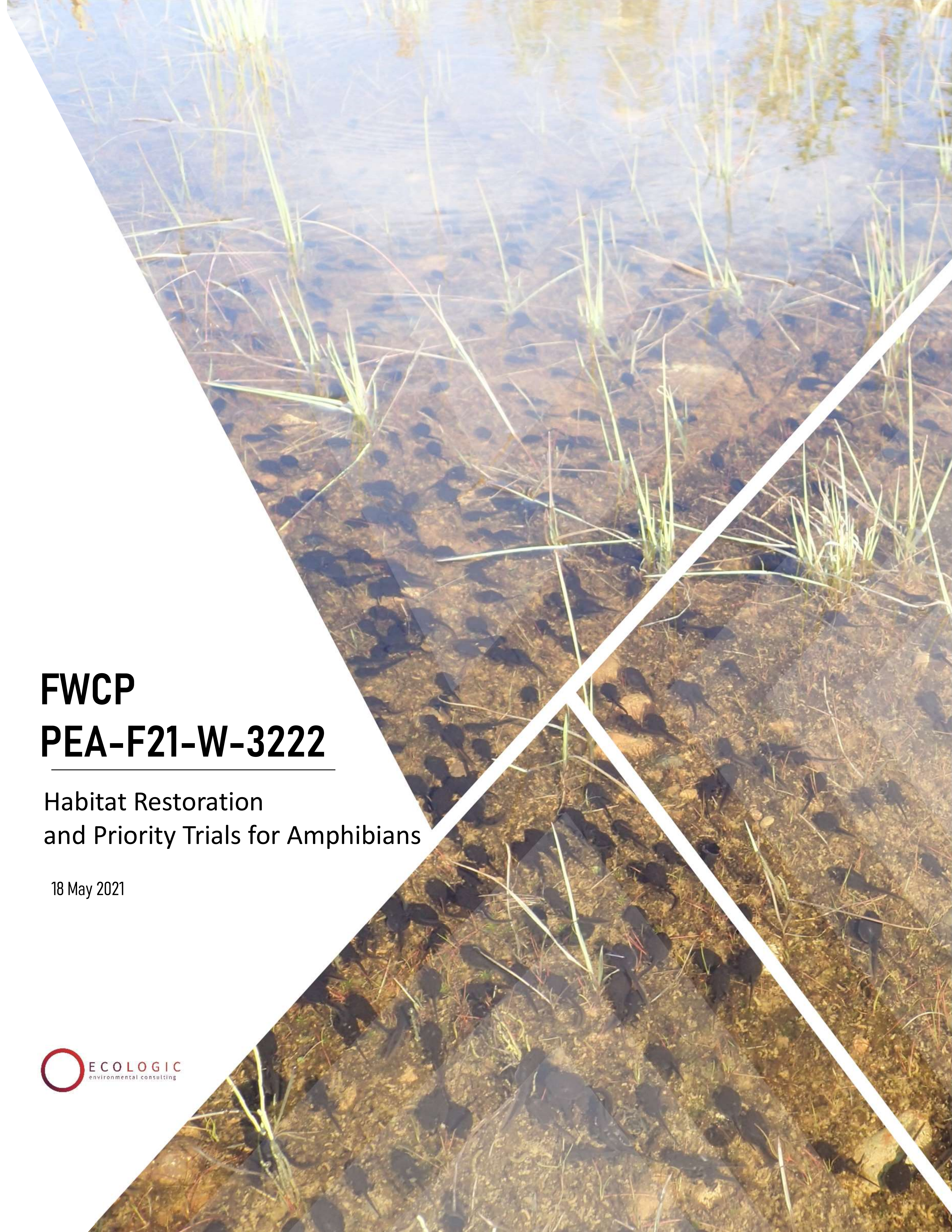

FWCP PEA-F21-W-3222

Habitat Restoration and Priority Trials for Amphibians

18 May 2021

ECOLOGIC
environmental consulting

Habitat Restoration and Priority Trials for Amphibians: FWCP - PEA-F21-W-3222

DATE: MAY 18, 2021

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REVISION HISTORY

Rev. No.	Date	Author	Description	Details
1	March 15, 2021	Mark Thompson	Submission to FWCP	Submitted
2	May 18, 2021	Mark Thompson	Address FWCP technical review	Point-by-point redress of review comments.

EXECUTIVE SUMMARY

This is the year one report of a multi-year FWCP Peace Region Amphibian Habitat Restoration project. A three-year baseline study is being used to trial restoration prescriptions for amphibian populations in select study sites. This project is focused on the restoration of amphibian metapopulations within a forest harvest disturbance area. The third year is scheduled to include the final year of baseline monitoring and the first year of restoration actions. Our upland restoration action involes the installation of an artificial hibernacula within a radio-tracked migration route. The artificial hibernacula will be constructed in the summer while animals are using different seasonal habitat. Aquatic and riparian restoration components will be installed in the fall of year three as animals move away from these warm-season habitats into overwintering habitat.

Partnerships with the First Nation communities of Nak'azdli whut'en and Tsay Keh Dene, and collaborations with government and industrial stakeholders have been integral in the success of efforts to date. The objectives of this project align with FWCP Peace Region Action Plans: to conserve or enhance the integrity of ecologically important habitats, and implement projects identified through approved recovery strategies, action plans, and management plans. Specifically, this project falls under the FWCP Action Plan objectives and priority actions as follows:

- **Objective:** Riparian and Wetland Action Plan
    - **Conservation sub-objective 4:** maximize the population viability of priority riparian and wetland species
    - **Action Type:** Research and Information Acquisition,
    - **Priority Action:** PEA.RWE.SO4.RI.09, Identify and prioritize locations for amphibian habitat restoration - P2.
- **Objective:** Uplands Action Plan
    - **Conservation sub-objective 1:** maintain and/or increase the resilience of uplands ecosystems to habitat disturbances, including climate change and other cumulative effects
    - **Action Type:** Habitat-Based Action
    - **Priority Action:** PEA.UPD.SO1.HB.02), Implement habitat based actions-P1

This report provides a summary of the year one outcomes, an outline into our baseline sampling plan as it relates to our objectives, planning directions for the next phases of work, and initial development into a restoration guidelines framework for amphibians. This first-year overview into the project provides a simple presentation of the data that was collected. Further details into the nature of this project and its outcomes will be presented in subsequent years. This will include deeper levels of analysis as more data are gathered in future years of study. The final year-four report will include a completed analysis of the baseline study and presentation of the restoration actions and outcomes. The discussion of this year-one report provides literature and context into our sampling plans, survey methods, and considerations for restoration planning in future years.

Multiple methods are used to survey amphibian presence, abundance, and movement at multiple study locations as part of the baseline. Repeated surveys were completed between the end of May and August in 2020. The methods include visual-auditory encounter surveys, time-to-detect surveys, wetland surveys, capture-recapture, double-observer egg counts, and fluorescent dye tracking. Each of these methods are used to provide a better understanding into seasonal habitat use and migration, scheduled phenology of key life-history events (e.g., egg laying, metamorphosis, and overwintering), and to provide a suite of metrics that may be used to estimate biomass, abundance, occupancy, or metapopulation size.

However, there are well-known challenges associated with providing statistical estimates of amphibian demographic metrics due to the cryptic nature of these creatures. Techniques are being developed and continuously refined to make the work more systematic and compatible with what is learned about the local amphibians populations, specifically their distributions and timing of habitats used. In 2020, electronic GIS-based data collection forms were in the process of being designed for field tables using QField; the QField forms were completed for the 2021 field season as this report was being developed.

Written field notes were used to complete the systematic baseline survey work in 2020, which was primarily focused in the Chuchi Lakes study area. Direct and high-rates of mortality in tadpoles and disease are key reasons for prioritizing the Chuchi Lakes study area for restoration action. The local Nak'azdli whut'en keyoh-territory members of the lusilyoo-frog clan have also voiced support for redress of amphibians impacted by forest harvest activities in this local area. The Chuchi Lakes study area is approximately 80 km north of Fort St. James and is accessed by the Webberly Forest Service Road (FSR). Road ponds along a small forestry road branch off the main Webberly FSR leading toward Webberly Lake were mapped. Georeferenced data and illustrations of these road ponds was collected to allow for repeated systematic sampling in the second year of our baseline. This report provides a clear description of what is meant by road ponds, by metapopulations, and why the road ponds are importantly implicated in the metapopulation ecology of amphibians in the area.

Our work in Tsay Keh Dene territory, Finlay Reach, remains primarily focused on restoration site selection, assessment, and collaborative planning. We worked in partnership with Chu Cho Environmental and Tsay Keh Dene community members to identify areas for restoration action. Reconnaissance and sampling of amphibians at sites of interest was completed. However, discussions and negotiations on the location and timing of potential restoration work in Tsay Keh Dene territory is ongoing. Chu Cho Environmental has recently prioritized a Teeth Creek location and our year-two work will focus on this location in addition to Middle Creek to maintain continuity with previous work at this location.

Tamasgale Lake was considered a new study site selection in the Chuchi Lakes area through negotiated discussions between Nak'azdli whut'en and British Columbia Timber Sales (BCTS) for a biodiversity management and protection area. However, it was learned at the time of writing this report that harvesting has already occurred in the proposed Tamasgale Lake location. Hence, a new location is being proposed at Mudzenchoot Lake that is located within two area based tenures, the Fort St James

Community Forest, and the Nak'azdli First Nation Woodland License. Mudzenchoot Lake is being targeted in the 2021 baseline as we initiate discussions with the tenure holders and has the advantage of adjoining a provincial park, which works well with ecological and provincial strategies related to spatial colocation.

Disturbance from forestry operations that create new types of aquatic environments requires an expanded characterization of wetland types. These anthropogenic wetlands are ecologically unique as they become occupied by amphibians and other creatures and include road ponds, ponds in cut blocks flooded ditch line habitat. Survey of amphibian occupancy into road ponds and flooded roadside ditches in harvest blocks at the Webberly site is included in the baseline study into the metapopulation ecology of amphibians inhabiting these locations. The baseline and restoration surveys are designed to address metapopulation connections between habitats in harvest areas and the surrounding landscape. Hence, migration is an important part of our investigations.

Dye tracking was found to be very effective for mapping short-term movement patterns. Our plan is to use both dye and radio-telemetry tracking on Western Toads in 2021. Tracking amphibian movements will be used to monitor population responses to our restoration trials. Tracking is used to identify critical habitat and migratory corridors that are necessary parts of amphibian life history. Managing these areas by means of restoration may add resilience to populations being threatened by industrial activities and climate change.

Another goal of this project is to develop a restoration guideline for amphibians in the Peace region and determine the parameters to evaluate the effectiveness of restorative efforts. A seven-point restoration assessment tool (SPRAT) has been developed for this purpose and is appended in this report to frame an initial restoration guidelines document that is being developed through this initiative. SPRAT is introduced in this report as a way to strategize project objectives and it is used to establish our study plan with explicit goals and measureable outcomes. Illustrations are being created to communicate complex life-histories and an introductory overview into the metapopulation ecology of northern amphibians as is applicable to our restoration goals. These were created for the restoration guideline and management framework document. The illustrations simplify complex ideas and concepts about amphibian ecology and are used to explain the points of consideration in restoration ecology that our SPRAT approach addresses.

ACKNOWLEDGEMENTS

This project was advanced through funding and in-kind support, including letters of support from First Nation partners, non-profit organizations, government, and businesses who have contributed various levels of commitment to this project. We wish to acknowledge and thank the following people and organizations for their contributions and involvement in this project:

- John Degagne and Marc Steynen – Society for Ecosystem Restoration of Northern BC (SERNbc)
    - Kindly provided a $5,000 seed grant that was key to getting this project initiated.
- Melissa Todd –Coast Area Research Section, BC Ministry of Forests Land, Natural Resource Operations, and Rural Development (MFLNRORD), with whom we are working collaboratively on the development and application of radio telemetry protocols - Melissa partnered on this project in Year 1, providing $5000 is Research Program support for a complimentary toad genetics component.
- Chu Cho Environmental (CCE) and Tsay Keh Dene – We wish to thank Nathan French (field technical assistance), Sean Rapai, Michael Tilson, Arshad Khan, and Sina Abad for their continued engagement in this work.
    - EcoLogic is working in partnership with CCE on wetland restoration efforts in Tsay Keh Dene. CCE has provided field technicians who are assisting with data collection and logistics in Tsay Keh Dene territory. Mr. French (CCE) has shown great aptitude and skill for tracking amphibians.
- We thank BC Timber Sales - Bruce Middleton, Planning Officer Stuart-Nechako Business Area for their support and communciation on harvest planning and potential use of road rehabilitation funds to advance restoration trials.
- Dr. Kari Stuart-Smith (Senior Forest Scientist, Woodlands Canada, Canadian Forest Products Ltd.) has offered her kind support to assist in the development of restoration guidelines.
- EcoLogic thanks the staff at FrontCounter BC, animal care review, and permitting staff including Ray Pillipow (Resource Manager Fish, Wildlife and Landbase Stewardship, MFLNRORD), Dave Merritt (Omineca Area Supervisor) and Melanie Veres (Area Supervisor – Upper Fraser) of BC Parks and Conservation Officer Service Division, Ministry of Environment and Climate Change Strategy for permit application review and authorization.
- Dr. Dede Olsen - Research Ecologist, Pacific Northwest Research Station, US Forest Service, kindly provided review and constructive feedback on our amphibian illustrations and embedded written content.
- The kind support from Rosemarie Sam, Colleen Erickson, Stuart Nash, Nadine Sam, and Anastasia Sam of Nak'azdli whut'en has been integral to this project.

- Members of Naka'azli whut'en have been very supportive of this work, shared their knowledge, and have worked in partnership with our team in the field and provided field technicians who have greatly assisted with surveys and data collection.

EcoLogic would like extend our thanks for the support we have received from First Nations who have invited this work into their respective territories. It is believed that the high level of support that has been directed to this project has been garnered in recognition of the problems that amphibians are facing globally and the threats that amphibians may be facing in northern BC.

EcoLogic would like to gratefully acknowledge the large grant contribution from the BC Fish and Wildlife Compensation Program (FWCP), Peace Region. This work would not be possible without FWCP's financial support. In particular, we thank Chelsea Coady and Lorraine Ens of FWCP for their assistance.

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ACRONYMS AND ABBREVIATIONS

Term	Definition
AMMA	*Ambystoma Macrodactylum* (Long-Toed Salamander)
ANBO	*Anaxyrus Boreas* (Western Toad)
BCTS	BC Timber Sales
CANFOR	Canadian Forest Products Ltd.
CCE	Chu Cho Environmental
DO	Dissolved Oxygen
EIA	Environmental Impact Assessment
FWCP	Fish and Wildlife Compensation Program
FSR	Forest Service Road
GIS	Geographic Information System
GRTS	Generalized Random Tessellation Stratified
GW	Gape Width
LISY	Wood Frog (*Lithobates sylvaticus*)[1]
MFLNRORD	Ministry of Forests, Lands, Natural Resource Operations & Rural Development
MOE	Ministry of Environment
PARC	Partners in Amphibian and Reptile Conservation
QGIS	Quantum GIS
RALU	*Rana luteiventris* (Columbia Spotted Frog)
SARA	Species at Risk Act
SBS	Sub-boreal Spruce
SERNbc	Society for Ecosystem Restoration in Northern British Columbia
SPI	Wildlife Species Inventory System
SPRAT	Seven-Point Restoration Assessment Tool
SVL	Snout-to-Vent Length
TDS	Total Dissolved Solids
TTD	Time-to-Detect
VAES	Visual Auditory Encounter Surveys
VHF	Very High Frequency
VRI	Vegetation Resource Inventory

[1] The species name has been recently updated back to the historical name, *Rana Sylvatica* (Wood Frog) – RASY; see AmphibiaWeb (2020).

1. INTRODUCTION

Amphibian and reptile populations are widely distributed across the Canadian landscape. Ecosystems occupied by herpetofauna in British Columbia (BC) are largely the result of post-glacial colonization that expanded the ranges of many species into newly exposed areas after the Holocene transition to a warmer climate, 10,000 to 14,000 years ago (Pielou 1991). Amphibians and reptiles migrated, dispersed, and colonized habitats northward from refugia south of the last glacial maximum. They ultimately spread into their present distributions across northerly latitudes to occupy a diverse range of aquatic ecosystems across the boreal forests of the western Cordillera (Thompson and Russell 2005).

Five amphibian and two reptile species inhabit the FWCP Peace Region (Table 1-1), and these species have been the subjects of previous investigations through the FWCP of Peace Williston projects (i.e., Hengeveld 2000; Thompson 2019). These small-bodied creatures are often understudied in northern boreal regions (Venier et al. 2014); however, some of the expected ecological patterns may be inferred from other study regions, where late-seral closed-canopy forests have been found to harbor a greater biomass of amphibian populations (e.g., Dupuis et al. 1995). There is substantial evidence to infer widespread amphibian declines in northern B.C., in a trend that is consistent with global patterns of decline (see Grant et al. 2020); however, it is challenging to collect data on population trends that are able to quantify the scale of these declines (Thompson 2019).

Table 1-1. Herpetofauna in the FWCP Peace Region, their spatial overlap with this project, and their provincial and federal listing rank and status

Common Name	Scientific Name	Spatial Overlap	BC Status Rank	SARA Status
Common garter snake	*Thamnophis sirtalis*	Yes	S5[1] (2018)	-
Western terrestrial garter snake	*Thamnophis elegans vagrans*	No	S5 (2018)	-
Long-toed salamander	*Ambystoma macrodactylum*	Yes	S5 (2016)	-
Boreal chorus frog	*Pseudacris maculata*	No	S4S5 (2010)	-
Columbia Spotted frog	*Rana luteiventris*	Yes	S5?[3] (2015)	-
Wood frog	*Rana sylvatica*	Yes	S4S5 (2016)	-
Western Toad	*Anaxyrus boreas*	Yes	S4 (2016)	1-SC[2] (2018)

[1]S = Maintained by BC CDC. 1 = Critically imperiled, 2 = Imperiled, 3 = Special concern, vulnerable to extirpation or extinction, 4 = Apparently secure, with some cause for concern, 5 = Demonstrably widespread, abundant and secure.
[2]Listed on Schedule-1. SC = Special Concern.
[3]Occurence and population data lacking, expert threat assessment needed. Degree of threat is unknown.

Modern transitions to large-scale forestry operations in northern British Columbia are rapidly altering ecological conditions for amphibian communities and their supporting ecosystems. For example, logging has removed a high proportion of productive old-growth forests (Price et al. 2020) from the 22 million-ha provincial timber land base (BC Ministry of Forests, Mines and Lands 2010). Amphibians tend to react adversely to open canopy harvest conditions (Ferguson 2000; Haggerty et al., 2019; Semlitsch et al. 2009; Loehle et al., 2021), and forestry clear-cuts can reduce population sizes by as much as 50% (Harper et al. 2015). Canopy removal results in a number of complex consequential effects, including: alterations to the rates and distances travelled during migration and dispersal; parasite loads and infection rates; rates of growth and development; predation; and intraspecific competition (Cayuela et al., 2020; Todd, Luhring, Rothermel, and Gibbons, 2009; Veysey, Powell and Babbitt, 2017). Microhabitats encountered in managed stands also have reduced volumes of woody debris habitat (Bunnell and Houde 2010), which adds risk of dehydration as these creatures rely on moisture for safe travel and overall survival. The issue of amphibian declines as they relate to restoration ecology is therefore an increasingly pressing land management issue, both globally and in British Columbia.

Amphibian habitats are also changing due to climate change, which is predicted to be more extreme in northern Canadian latitudes (Bush and Flato 2019). On a global scale, there are more than 8,224 amphibian species (AmphibiaWeb 2020) with 2,700 (33%) species ranked as Threatened (i.e., at risk of extinction)[2]. Of particular concern for amphibians in northern regions is the trend toward significant reduction in snow season duration and snowpack depth across the interior of B.C. (Allchin and Déry 2017). Reduced snowpack has been shown to reduce survival of Western Toads (Muths et al. 2020), and forest harvesting activities may add to the level of environmental stress in amphibians (Thompson and Donnelly 2018) by altering migration routes and dispersal patterns (Todd et al. 2009). As a result of these various stressors on the populations, restoration guidelines and efforts are expected to be highly beneficial for amphibians across the north.

This report focuses on the outcomes from 2020 that were particularly noteworthy and promising, such as the results of fluorescent dye tracking. The discussion is organized around the objectives and is systematically organized to link a set of seven focal areas of research that are explicitly linked to each of the methods that we use to collect a baseline index to evaluate restoration outcomes. A number of illustrations have been developed to help frame the theory and scope of work that this project aims to manage to ensure that direct and effective answers can be achieved. The illustrations have been developed to simplify complex ideas and concepts about amphibian ecology and are used to explain key points of consideration for the baseline work and restoration ecology advances in this project.

This report provides context to the large, multi-stakeholder process that facilitated the study, provides a scientific framework for our investigations, and details the logistics involved. This project has been designed to create an effective baseline for any potential future monitoring and is organized to ensure that this project connects to a growing understanding of how herpetofauna link importantly into the natural resources sector of our province. As such, a primary aim of this project is to investigate herpetofaunal populations in a forestry resource setting where we can trial potential restoration techniques that may be broadly applicable to their management and recovery in the region. Therefore,

[2] The IUCN Red List of Threatened Species (https://www.iucnredlist.org/resources/summary-statistics) provides a best estimate of percentage threatened amphibians species (with lower and upper estimates) = 40% (34-50%).

from this initiative we hope to find potential ways to proactively intervene by finding ways that may improve management decision for amphibians in the Peace Region and northern BC.

1.1 OBJECTIVES

Our 2019 proposal application aligned this project with the FWCP Peace Region Action Plans. The primary *Peace Action Plan* that this proposed project was identified to align with was the *Uplands Action Plan*. This project was primarily identified as a *Habitat-based Action*. Updates were made to the FWCP Peace Region Action Plans and this project was re-aligned to those updates (Table 1.1-1).

Table 1.1-1. Updated 2021 FWCP action plan priorities and objectives

Primary Peace Action Plan	Riparian and Wetland
Conservation Sub-objective	Maximize the population viability of priority riparian and wetland species
Action Type	Research and information acquisition.
Priority Action	PEA.RWE.SO4.RI .09 Identify and prioritize locations for amphibian habitat restoration - P2.
Secondary Peace Action Plan	**Upland**
Conservation Sub-objective	Maintain and/or increase resilience of riparian and wetland ecosystems to habitat disturbances, including climate change and other cumulative effects.
Action Type	Habitat-based action
Priority Action	PEA.UPD.SO1.HB.02 Implement habitat based actions-P1.

1.1.1 First Nations Partnerships

To achieve the identified FWCP Peace Region objectives (Table 1.1-1), EcoLogic has prioritized capacity-building and relationships with First Nations as a necessary part of the planning and execution processes. Therefore, an important goal of this project is to coordinate our efforts in collaboration and partnership with First Nations in the Peace Region where territories overlap with our study sites. Indigenous representatives from the First Nations communities of Nak'azdli whut'en and Tsay Keh Dene—via Chu Cho Environmental (CCE)—are employed and trained in field data collection and monitoring. Our objective is to raise the profile of amphibians and reptiles in land management discussions and practices, including the voice of Indigenous communities, with respect to these creatures and their habitats.

1.1.2 Engagement with Government, Industrial, and other Stakeholders

Government and industry are important stakeholders that are also integrated into the planning process. Nak'azdli whut'en connected us to BCTS in 2019 to initiate discussions on harvesting plans in the target Webberly FSR site (TSL TA0280, R19081A – Webberly FSR hereafter; see Section 2, *Methods* – for complete study site overview and descriptions). It was communicated during the initial meeting that no further harvesting was planned within the selected study location. However, harvesting was initiated in winter 2020/2021 in some of the study area. This report outlines some of the discussions that have since occurred between BCTS, EcoLogic, and Nak'azdli whut'en on the dynamics of site stability and this research project. EcoLogic has also been in communication with Dr. Kari Stuart-Smith, Senior Forest Scientist, Canadian Forest Products Ltd. (CANFOR) who is collaborating on a restoration framework and guidelines document that this year 1 report briefly touches upon.

Components of this project are being run collaboratively with Ms. Melissa Todd (Research Wildlife Ecologist, Coast Area Research Section, BC Ministry of FLNRORD) on the development and application of radio-telemetry protocols. The telemetry equipment was used for previous work on coastal populations of the Western Toad. Melissa partnered on this project in Year 1, which also included a complementary toad genetics study component. Western Toad tissue samples were collected at the Webberly FSR study site for this project and delivered to Ms. Todd as part of the collaboration deliverable.

Government and academic research ties are part of the stakeholder network that forms an important part of the capacity-building process. Data has been submitted into the BC Ministry of Environment Wildlife Species Inventory (SPI) system as part of our general wildlife permit (permit #: PG20-605083) requirements. EcoLogic has also submitted details of this project to the Ministry of Environment and Climate Change Strategy's Species Conservation Science Section data collection tool, which has been designed to capture herpetology projects done in the province over the past decade. The lead project manager (Mr. Thompson) has networked with additional MFLNRORD herpetolgists, including Purnima Govindarajulu (Unit Head) and Leigh Anne Isaac (Small Mammal and Herpetofauna Specialist) to share information about this project and gave a presentation of this work as part of a provincial toad workshop, scheduled for March 17, 2021.

Mr. Thompson also organized a 2021 herpetology conference through partnerships with the BC Association of Professional Biology (APB) and Northwest Partners in Amphibian and Reptile Conservation (NW PARC); he is a director in both organizations. A presentation on this project, titled "Understanding Climate Threats to Amphibians in Northern Climates" was given during the joint 2021 conference on "Amphibians and Reptiles: Stressors, Threats, and Solutions"; FWCP was gratefully acknowledged during these events. Mr. Thompson is also supervising two students to analyze previous data on FWCP Peace Region amphibian projects (PEA-F18-W-2569 DCA and PEA-F21-W-3222).

In addition to Western Toad genetic work, tissue samples from Wood Frogs were also collected in 2020 as part of a wider academic collaboration including researchers from Yale University and University of Lethbridge. This Wood Frog study is being completed in collaboration with Dr. Julie Lee-Yaw (Assistant Professor–Herpetologist, Department of Biological Sciences, University of Lethbridge); additional studies are being advanced on Long-toed Salamanders through this collaborative tie. Mr. Thompson recently published a peer-reviewed paper on Western Toad parasites in the Herpetological Review (In Press – a direct result of fieldwork associated with this program), and submitted another paper (In Press) on avian predation on amphibians to Northwestern Naturalist. These communications, engagements, and publications are an extension of a broader stakeholder engagement process that is a necessary part of advancing restoration activities.

1.1.3 Multi-Year Baseline

A multi-year baseline is being established to study the effects of different restoration designs and approaches on amphibian populations at multiple trial sites. Populations are to be systematically monitored for three years prior to trialing restoration methods. In year three, populations will be surveyed from May until September and restoration work will commence in September of that same year. The same populations will be monitored in years following the restoration interventions at the impacted and reference sites. Webberly FSR has been established as our first restoration trial site.

Survey work was completed in 2020 to identify other potential restoration trial sites in Tsay Keh Dene territory; this work was done in collaboration with CCE and Tsay Keh Dene members, including elders. Our objective is to establish at least two priority sites where restoration trials can be launched. Having more than one study site may allow for comparison of methods with the understanding that different outcomes can be landscape and community context dependent.

Phase 1 is a three-year baseline monitoring study, which ends and then transitions in the fall of the third year into Phase 2 in 2022. Phase 1 also includes capacity-building with stakeholders and considerations for what kinds of restoration study design options might work within the context of what is learned in the process. Phase 2 includes finalizing the design, construction, and installing the restoration actions. Schematic illustrations and mapping of restoration design options will be presented at the end of year 2 (Phase 1) to share and discuss with stakeholders. Phase 3 will address the post-installation monitoring after the restoration trial physical components have been installed. The phases are summarized as follows:

- **Phase 1:** Three-year baseline (2020-2022) including restoration capacity-building, stakeholder investigations into restoration design.
- **Phase 2:** Restoration actions (2022-2023): design, construction, and installation. Installation of different restoration components shall commence in 2022 with some components that may need to be finalized in spring 2023 (e.g., revegetation).
- **Phase 3:** Post-restoration monitoring (2023-onward): continuation of baseline monitoring in trial sites and ecological reference site.

1.1.4 Amphibians: Habitats, Conservation, and Enhancement

The restoration techniques to be trialed will be specifically tailored to the ecology of amphibians in northern BC. A variety of research methods are being advanced in this project (see Methods, Section 2) because there is a large gap in scientific knowledge about the ecology of amphibians and their habitats in northern BC. This report addresses some of the questions about what management or restoration techniques might work, how these might be investigated per our study design components, and what steps are needed to advance the restoration trials (financial, logistical, and experimental). Hence, the studies tied to this project are listed as trials as we seek to link research to restoration methods.

The concepts of habitat and habitat restoration have varied over time and different authorities have favored different interpretations (e.g., Krausman and Morrison, 2016; Miller and Hobbs, 2007; Mitchell, 2005). For example, Thompson and Donnelly (2018) note that "[s]econdary forests provide *suitable habitat* for many amphibian and reptile species, but there is substantial variation in time to recovery of the animal community" (p. 14, emphasis added), where secondary forests may be defined as a harvested forest. However, Krausman and Morrison (2016) note that "*suitable habitat* is redundant and *unsuitable habitat* is a misnomer; if it was unsuitable it would not be habitat" (p. 1143, emphasis added). Amphibians are known to occupy a variety of sites that have been anthropogenically modified (Valdez et al., 2021), including "road puddles and roadside ditches" (deMaynadier and Hunter Jr, 2011; p. 245) that are often labelled as artificial habitat types.

Sites described in Thompson (2019) and in this study are larger than the term road puddle can cover. Hence, water accumulation on forestry roads that become occupied by amphibians or other community associates (e.g., aquatic vegetation and invertebrates) are called road ponds. These road ponds and roadside ditches provide habitat for the species that occupy them. They are a unique type of disturbance habitat distinct from natural wetlands classified in the province of BC as fens, marshes, swamps, bogs, or open water (Mackenzie and Moran 2004). As such, understanding and mitigating the effect of these artificial wetland habitats, road ponds and roadside ditches, on the amphibian metapopulations linked by the occupancy, immigration, and emigration from these aquatic sites into surrounding areas is importantly tied into the restoration framework and objectives of this project.

The outcomes from this project may have potential applications for the management of amphibians across the province, including advances in research into amphibian habitats, conservation, and enhancement through restoration. However, it is important to highlight that the amphibian populations at the Webberly FSR site have been prioritized for restoration due to signs of stress (disease) and mortality (pond drying) that has been observed at this location. As such, this project is designed to align with the FWCP Peace Region Uplands Action Plan – "to conserve and/or restore upland habitats" – by way of restoring connectivity through and stability within the Webberly Lake site.

2. METHODS

2.1 Study Areas and Project Phases

Six study locations selected for this project (Figure 2.1-1) spatially overlap with previous work from 2015 to 2018 (see Thompson 2019). Carp Lake Provincial Park was added as a reference site to the study area in our 2019 proposal and was visited in 2020 along with Chuchi Lakes, Tsay Keh Dene, and Middle Creek. Research methods and recommendations from the previous project (Thompson 2019) are being integrated into the baseline of this restoration trial study with a number of added improvements to the systematic survey components.

Chuchi Lakes is in Nak'azdli whut'en territory and within the keyoh-territory of the lusilyoo-frog clan. It is in the sub-boreal spruce SBS mk1 variant (DeLong, Tanner and Jull 1993). The mean stand age in the Chuchi Lakes study area, from the provincial Vegetation Resource Inventory (VRI) database, is 115 years and 30% crown closure, with few stands reaching 214 years in age and 60% crown closure. Most sites are covered in spruce hybrid mix (Sx = *Picea* cross), with subalpine fir (BL = *Abies lasiocarpa*) in a minority of sites, and trembling aspen (AT = *Populus tremuloides*) least represented. The Chuchi Lakes area is an active harvesting area with over 880 ha of forests cleared in the local vicinity with additional harvesting occurring in winter 2020 (BCTS personal communication). There is also very little coarse woody debris throughout the area (Thompson 2019). The elevation has a gentle NW slope and ranges from 990 to 940 metres above sea level (m asl).

The Chuchi Lakes study area has 6.11 km^2 of aquatic habitat (i.e., Freshwater Atlas Lakes, buffered streams, and wetlands plus data from Filatow et al. 2020; Figure 2.1-1, left panel). The aquatic-to-terrestrial ratio of this site equals 0.31 (6.11 km^2/19.63 km^2). Wetland types (from Filatow et al. 2020) that occur in the study area are as follows, in order of prominence: fens, bogs, shallow open water, and marsh.

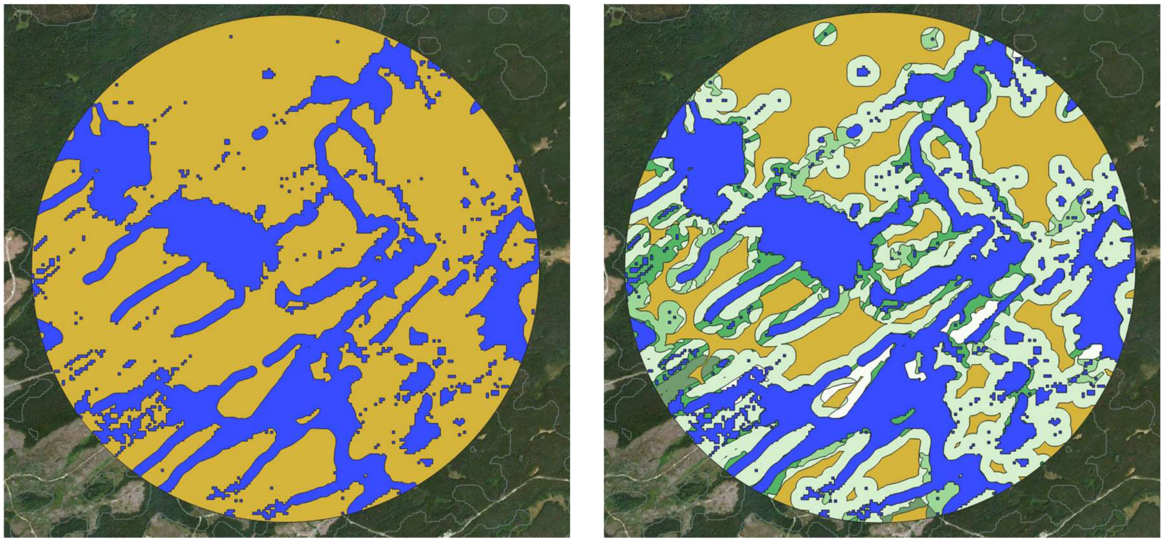

Figure 2.1-1. Images of the Chuchi Lakes study area (yellow circle) and aquatic features merged into a single layer are shown (blue polygons). The left panel is not buffered and the right panel shows a 100 m buffer around the wetland polygon and is classified by a dissolved VRI soil moisture polygon (green colour ramp, right-panel)

Aquatic buffer layers and stratification around the wetland polygons for Chuchi Lake and Mudzenchoot Lake study areas have been created. The 100-m buffer around the wetland polygons (Figure 2.2-1, right panel) has been stratified by VRI soil moisture and these polygons are being imported into the *spsurvey* package (Kincaid et al. 2020) to establish the 2021 generalized random tessellation stratified (GRTS; see Stevens & Olsen, 2004) sampling plan. There are five soil moisture polygons (VRI SOIL_MST_1 = 3-7) stratified for Chuchi Lakes (Figure 2.2-1, right panel). Data for Mudzenchoot Lake is not shown as this study area was selected late in the season after several meetings were held, a mapping exercise was completed, and ongoing discussions occurs between BCTS, Nak'azdli whut'en, and tenure holders. The Mudzenchoot Lake study area is located approximately 15 km SW from Webberly Lake (Figure 2.1-2). Study sites from previous baseline work (see Thompson 2019) are retained on the map as data from these locations provide information that is applicable to the context of the study locations and what is known about amphibian populations in the Peace Region.

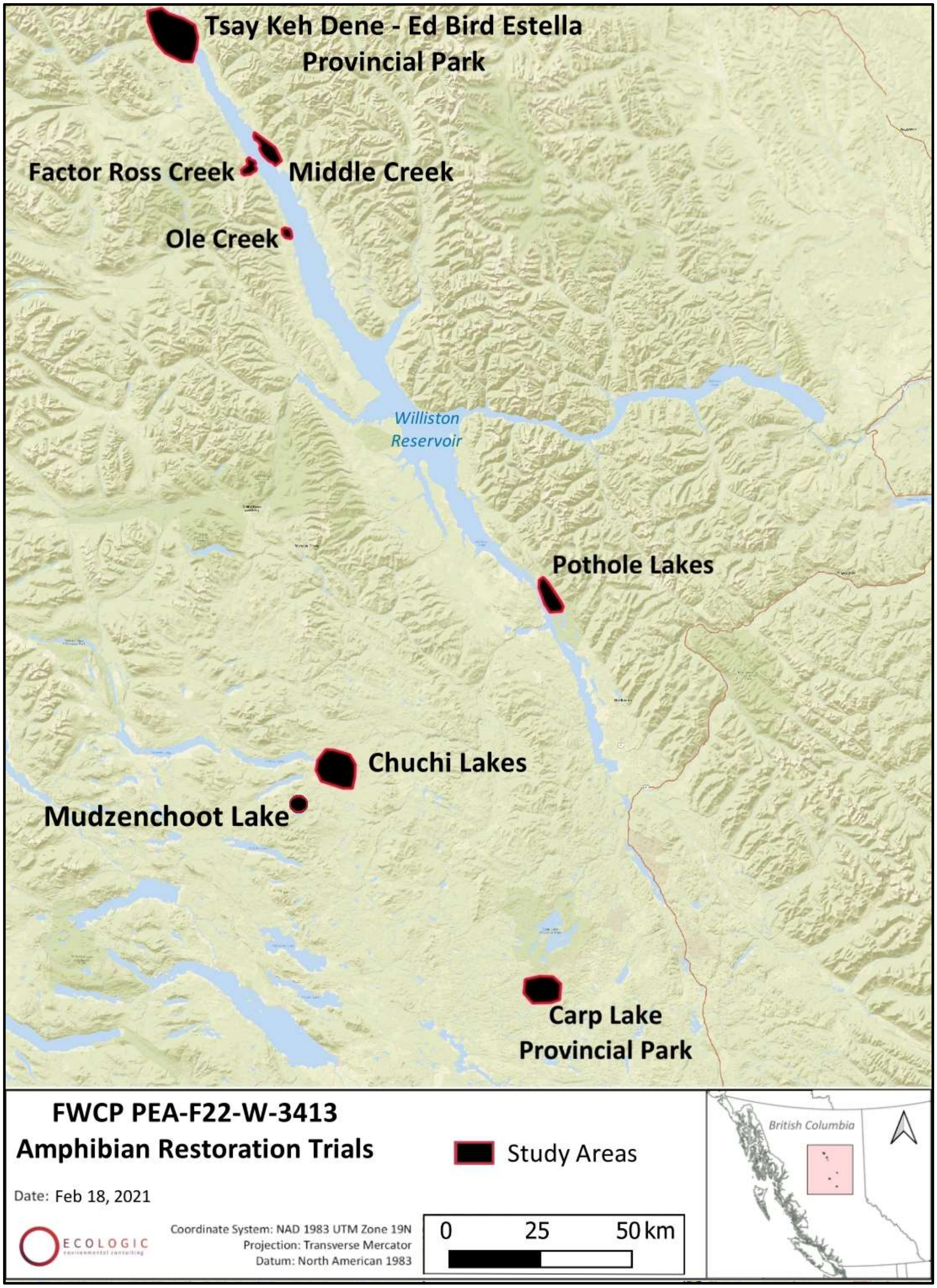

Figure 2.1-2. Study areas that were investigated in Thompson (2019) are shown; Carp Lake Provincial Park was added in 2020 an ecological reference site, but was removed due to poor access. Mudzenchoot Lake was added in 2021 as an ecological reference site.

The main focus area for the 2020 baseline was the Webberly FSR, within the Chuchi Lakes study area (Figure 2.1-1). Field work was executed at the other sites, but the bulk of sampling and study design was aimed at Webberly FSR. Therefore, given that this is year-one of a multi-year project endeavor, we only provide descriptions into the key characteristics of the work completed at the Webberly FSR study site where most of the work was concentrated. Details into the Webberly FSR study site and summary information from environmental data collected in the field were used to establish the sampling design and plan.

An accessible ecological reference site (i.e., 2.5 km radius area with flat terrain and no harvest) could not be located in the northern Tsay Keh Dene territory. Teeth Creek was recently selected as a restoration priority site through a project recently completed by CCE (FWCP Project: PEA-F20-W-2966) and is located approximately 10 km south of Tsay Keh Dene on the western shore of the Williston Reservoir. In lieu of a northern no-disturbance ecological reference site, Middle Creek is retained as a comparison. There is harvesting in the Middle Creek area and comparisons may be made between smaller scale undisturbed patches within the Teeth Creek and Middle Creek radial study areas. Some of the planning considerations in Tsay Keh Dene may involve small scale restoration trials in both Teeth Creek and Middle Creek (hand shoveling / vegetation removal) options, but this is part of an ongoing discussion with the community.

2.2 Project Management: Scheduling, Permits, and Communications

A field gear list was prepared (Appendix A) and all equipment was checked prior to heading into the field. A safety management plan and emergency response plan was prepared with fillable forms that were completed by crew members. A safety plan and safety forms were reviewed with all field staff and signed off as part of the daily tailgate and overall safety awareness program. Adjustments were made for project start-up with respect to the COVID-19 pandemic, including changes to hiring, staff roles, safety, and accessing research sites. Permission and an access pass were required to access research sites in Tsay Keh Dene territory. Field crews could not enter into the Tsay Keh Dene village to purchase fuel and supplies, so extra supplies were brought into the field to address the added constraint.

Applications were submitted for a General Wildlife and Provincial Park permit and obtained prior to heading into the field. The applications included animal care review and approval. Field equipment was prepared to ensure that provincial hygiene protocols and data collection and submission standards could be followed. A schedule was developed prior to heading into the field, including a plan on sites to visit and sampling protocols to execute at each site. Communications took place with First Nations and other project stakeholders prior to heading into the field, through the field season, and as this report was being drafted.

2.3 Sampling Plan

The radial sampling design described here for Webberly FSR is part of an active analytical process to establish sampling plans in other areas for 2021. A centre point was selected at the study sites, judgmental sampling was used at this stage (see Krebs 2014), and a 2.5-km radius was used to define a radial study area. A 2.5 km sample radius was selected (Figure 2.2-1), because this is both near the average of dispersal distances of frogs and salamanders and within the range of distance most frequently travelled (Cayuela et al. 2020). National, provincial, and published data layers including polygon and data tables on harvest areas, roads, vegetation, and wetlands were imported into a r-stats (R Core Team 2020) and a geographic information system (QGIS) –integrated as RQGIS (Muenchow et al., 2017)—and used to assist with digitizing of satellite imagery and summarizing landscape features within the study sites.

Descriptive statistics of terrestrial-to-aquatic ratios within the established radial study area were calculated using functions in QGIS (QGIS Development Team 2021) and custom script in r-stats (R Core Team 2020~~, version?~~). The 3-class wetland classification raster of Filatow et al. (2020) was converted into a vector polygon and clipped to the study area. Freshwater atlas (FWA) data layers for streams, lakes, and wetlands (British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development 2012) were imported and clipped to the study areas. The FWA streams were buffered by 50 m and these aquatic data sets were merged into a single polygon using custom script in r-stats. A 100-m buffer was also established around the aquatic polygons within each study area radius. The provincial Vegetation Resource Inventory (VRI: British Columbia Ministry of Forests and Range, 2016) data layer was clipped to the 100-m buffer and sites were stratified by soil moisture regime.

Recent and cloud-free Sentinel-2 satellite data layers were used to cross-reference the provincial Forest Tenure Cutblock Polygons (FTA 4.0; Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2020) to map and extract recent harvest activity in the study areas. Sample polygons were digitized over the Sentinel-2 raster using GoogleEarth to help with the interpretation of ground features. The digital polygons were used as training data in a random forest model classification of the Sentinel-2 raster. Sample polygons were digitized into eight stratification features:

1. Road Pond
2. Bog
3. Fen
4. Shallow Open Water
5. Lake
6. VRI Soil Moisture Regime 3
7. VRI Soil Moisture Regime 4
8. Cut Block

A custom r-script was developed to create a randomly stratified sampling plan in the riparian buffer areas using the *spsurvey* package (Kincaid et al. 2020). Additional r-script and geospatial analytical work was advanced in 2020 as part of an in-progress sampling plan development. The stratified sampling plan was not fully developed prior to commencing the 2020 field season, but was completed in 2021 in addition to development of customized QField (The QField Project/OPENGIS.ch, 2020) forms for systematic electronic data collection (see Nowak et al., 2020). Field crews primarily focused on mapping of the road ponds to allow for baseline development of a systematic sampling plan in 2021.

2.4 Amphibian Handling and Processing

Provincial hygiene protocols were followed including sterilization of equipment with disinfection spray and bleach wipes when moving between study sites. Amphibians at all life stages were captured by net or hand and placed into a small plastic container or breathable plastic bag. Adult amphibians were anaesthetized using liquid Oragel™ (10% benzocaine) to assist with handling and processing (see Hinrich and Green 2001). The health status of each animal was monitored during processing; heart rates of western toads and adult salamanders were recorded by time interval counts of palpitations of the throat.

Processing time of all animals that were captured and handled was generally complete in less than an hour, but several processing hours were sometimes needed if many animals were captured at once. All adult animals were kept moist and out of direct solar exposure. All larvae were maintained in loosely covered plastic water baths using water from their place of capture; all invertebrate predators were removed to ensure their safety while being processed. All amphibians were carefully examined for signs of injury or parasites.

Data recorded on adults included weights (with digital scale ±0.05 g), length measurements (GW = Gape Width and SVL=Snout-to-Vent length; with calipers ±0.05 cm), and photography (dorsal and ventral side) within a camera box equipped with a scale bar. All sides of the captured adult animals were photographed, including detailed shots of the dorsal and ventral skin patterns, front view head and forearms, each hand and foot, and the venter. Grey standards were used for photography of adults and the images were saved in raw format. Images were imported into a multispectral toolbox for spectral analysis (Troscianko and Stevens 2015). Larvae were photographed (dorsal side only) in a water-filled tray with a scale bar. Total length (with calipers ±0.05 cm) of sub-samples of larvae from select wetland sites were recorded. When large enough to register on the scale later in the field season, the larvae were spooned onto the scale and weighed.

Tissue samples for DNA analysis were taken from Western Toad tadpoles and Wood Frogs (adults and tadpoles) using sterile forceps, tweezers; samples were stored in vials filled with an alcohol preservative. Bactine™ spray was applied to the injured clipped toes of Wood Frog adults per animal-care protocols. All animals were released to their immediate place of capture after being processed.

2.5 Visual-Auditory Encounter Surveys

Consistent workdays were established to coincide with the known behaviour and prime activity times of amphibians. Both day and night visual auditory encounter surveys (VAES) were completed for most of the 24-hour cycles that crews were camped at study sites. Crews worked in 10- to 12-hour split shifts that variably ran in the time ranges of 11 am to 6 pm and 9 pm to 3 am; the timelines were adaptively varied according to the scale of amphibian activity and associated work to record the activity. Field crews were instructed to report any sightings of amphibians in between systematic surveys (e.g., double-observer egg counts or time-to-detect surveys) and while other work was being completed (e.g., one person recorded water chemistry while another searched in the riparian areas). Eyes and ears were consistently trained on the ground on route to pre-planned target locations.

Crews stopped to capture detected animals and processed them to record the data; hearing the scuffle of Western Toads through grasses and shrubs is a reliable detection and capture method during these types of surveys. Signs of different habitat features, tracks, animal behaviours, parasites, or predators (i.e., natural history observations) were recorded in field notes. Crews were encouraged to discuss the observations of each day while reviewing field notes and planning next-steps.

2.6 Time-to-Detect Surveys

Time-to-detect (TTD) methods of Garrard et al. (2008) and Halstead et al. (2018) were trialed during the 2020 field season. A wrist stopwatch was used to initiate start-stop times for terrestrial and aquatic TTD surveys. Field crews were instructed to remain quiet after the survey commenced. Night-time terrestrial TTD surveys were completed using spotlight (>400 lumen) searches while walking along the Webberly FSR study site. Audible detections of Western Toads rustling in the grass or the splash of amphibians into water were noted or used to confirm their presence by observation. The stopwatch was stopped during capture and processing of adults and restarted until the next detection occurred while walking along the road. Wetland TTD surveys were completed in daylight with the wrist-stopwatch start-stop times as we recorded species and life stages (eggs, larvae, metamorphs, or adults) observed.

2.7 Wetland Surveys

In addition to VAES and TTD surveys at wetlands, data was collected on the chemical and physical properties of a select sample of wetlands. Guidebooks on wetland surveys (Olson et al. 1997) and descriptions (e.g., MacKenzie and Moran 2004; Delesalle et al. 1998) were used as references during the surveys. A Hanna instruments water chemistry reader was used in the early season for temperature and pH; this tool was loaned as we waited for order of a newer chemistry kit delayed by Covid-19. An ExStick® EC500 (Extech Instruments) meter was used to collect temperature, dissolved oxygen, pH, salinity, and total dissolved solid readings at select wetland sites.

The Webberly FSR road ponds were sketched at the beginning of the study season and later in the season. A rangefinder was used to measure length and width. Coordinates were taken and deepest depth was measured using a stick and measuring tape. Depth in deeper wetlands in upland areas was recorded by wading into the depths. A Welch Two Sample t-test was applied using r-stats to independently compare early to late season values of width, length, and depth.

Dip nets and small plastic containers were used to capture larvae in smaller wetlands, such as the road ponds on Webberly FSR. Net sweeps were used to sample for larvae of all amphibian species in deeper wetland sites that were waded into for sampling. A target of 10 larvae of each species were sampled from a subset of the wetlands surveyed. The larvae were processed using procedures outlined in Section 0.

2.8 Capture-Recapture

The photographic data on Western Toads and Long-toed Salamander skin patterns are organized for upload into Wild-ID software for photographic mark-recapture analysis (Bolger et al. 2012). The software was trialed using a few Western Toad images from the 2020 capture data. Images from previous work (Thompson 2019) that were analyzed using I3S (see Matthé et al., 2017) are being transferred and entered into the software database.

2.9 DOUBLE-OBSERVER EGG COUNTS

Long-toed Salamander eggs were surveyed using a double-observer count along the Webberly FSR road ponds where detected; detections of other species eggs were noted, but not counted. Polarized lens sunglasses were used to reduce glare and increase visibility during counts. Personnel crouched or laid on the shoreline to see into the depth of the water to count or estimate the number of eggs within clutches or laid individually, while being careful not to disturb, stir, or add sediment into the water to keep the view clear for the second count. This required estimation of the number of eggs within a mass in the deeper zones of the water to feasibly count what could be seen and estimate the rest. A piece of red flagging tape was dropped onto counted egg masses or tied to pieces of nearby vegetation to indicate that they had been counted. The second observer repeated the count, but separated the counts of eggs flagged and eggs missed by the first counter. A Lincoln-Peterson index (see Winne 2013) was used to estimate population size (see Krebs 2014):

$$N = \frac{(M * C)}{R}$$

where M is the number of eggs that were flagged and counted by the first person, C is the number of eggs counted by the second person, and R is the number of eggs counted by the second person that were flagged by the first. The per-capita capture probability (see Young and Young 2013) is:

$$P = \frac{R}{C}$$

2.10 FLUORESCENT DYE TRACKING

Orange fluorescent dye powder (Radiant Color, Richmond, California, USA) was used to track movements of Western Toads and Long-toed Salamanders. Adults or metamorphs captured during the day were dipped into the orange dye powder mixed with mineral oil (Williams et al. 2014); the dye is harmless to amphibians (see Rittenhouse et al. 2006). Several mixture recipes were trialed varying the amount of powder-to-oil ratio to find an optimal viscosity of the solution that would remain on the animal but release onto substrates for tracking purposes. The animals were submerged into the fluorescent mixture, keeping only their eyes and head from being covered. New dye mixtures were made in sterile containers between study sites. Animal capture and release sites were revisited after dark, usually after 9:30 pm at night. A 1,100-lumen rechargeable UV flashlight and additional lower-lumen UV lights were used to locate and follow the pathway of illuminated tracks.

Meandering distances were measured with a tape measure for smaller linear movements (i.e., less than 50 m); a hip-chain was used to measure distances through shrub and forest; and GPS tracking was used for longer distances. A crew of two searched carefully with body to the ground to locate spots of fluorescent dye marking the route followed by the animal. Individuals switched off on roles with one individual taking notes while the other tracked, allowing time for eyes to rest from the strain of looking with UV for extended hours in the dark. Each route was sketched into the field notebook with observations on what features were crossed, moved into, or if the animal was relocated. The start and end of identifiable trails were marked and the straight linear distance between these points was recorded. Field notes and illustrations were later hand-sketched to provide summary details of tracks.

2.11 Data Entry and Quality Review

Field notes were scanned and saved as electronic images for back-up storage. Multiple Microsoft Excel™ spreadsheets were used to enter different analytical components of the study plan and design. Every amphibian detection is given a unique identifier and entered into the main central database. A metadata form is saved in the second tab of the Excel™ files that provides a description of each column header for each respective database. There are a total of six databases in different stages of progress (Table 2.11-1); analysis and progress on the results will be updated annually as we near toward execution of the restoration actions and have multi-year data for analysis.

Table 2.11-1. Project database structure

Database	Function	Status (2021)	Results Presented in this Report
Herp_Detections_ MainDB_2020	This is the central hub of data and is the first database to be created. Each amphibian detection is assigned a unique identifier and handwritten notes in the field book are transcribed along with the field form data.	Entered, quality reviewed by senior biologist, reviewed in GIS, and submitted to MOE SPI as a general survey.	Yes (complete)
Wetlands_2020	Assigns a unique identifier for each wetland and gives binary presence/ absence for species detected at the site and life stages observed. Water chemistry and measurements of the wetlands are included in this database.	Entered, quality reviewed by senior biologist, and reviewed in GIS.	Yes (partial)
Digital photos	All photographic records are saved in separate folders assigned to date. Photos of individuals are copied into separate folder databases for entry into fingerprinting software (e.g., Wild-ID; Bolger et al. 2012). Photos include spectral data on amphibian colours – defensive or cryptic traits.	Photographic records are organized by date and have been reviewed. Fingerprinting software analysis has not been initiated. Spectral analysis has commenced – approximately 2% images analyzed.	Yes / No (partial)
Systematic_Surveys_ 2020	Time-to-detect, double observer egg counts, or larval counts are entered into the database, which includes formulas and formatting for export into r-stats.	Approximately 80% complete.	Yes (partial)

Database	Function	Status (2021)	Results Presented in this Report
Dye_Tracking_2020	Includes data for each tracked individual. Data include locations, dates, and times of tracking activities. Also includes distance measurements between the starts and ends of traceable dye.	Base information complete, but new data fields will be created to better summarize the tracking information.	Yes (complete)
Adult_Morphometrics_2020	Includes field measurements on adult amphibians' snout-vent-length, gape width, and weights. Includes fields for entry of morphometrics obtained from digital photo records.	Approximately 10% completed. Measurements are in field notes and images have scale bars for digital measure.	No
Larval_Morphometrics_2020	Includes field measurements on larval amphibians' total lengths and weights. Includes fields for entry of morphometrics obtained from digital photo records.	Approximately 10% completed. Measurements are in field notes and images have scale bars for digital measure.	No
Invertebrates_2020	Includes fields for aquatic and terrestrial invertebrates.	Approximately 5% completed. Notes on invertebrates observed are in field notes.	No

A fully systematic stratified sampling plan was not completed prior to heading into the field in 2020. However, a field plan was developed on where and how to sample as we had to inventory and map different parts of the study areas for stratification purposes. Some of the baseline data gathered in the field in 2020 is being used to refine the sampling plan for 2021, which is described in greater detail in the discussion section of this report. Results are presented below on the different database components listed in Table 2.11-1, but we cover only the parts that have been sufficiently developed in this year 1 baseline for analysis and presentation with plans to advance the other work in future project years.

3. RESULTS

3.1 Study Areas and Field Survey Schedules

Six potential study sites were visited between May and August 2020 (Table 3.1-1; Figure 2.1-1). The field work effort in 2020 was primarily focused on Webberly FSR. Attempts were made to establish Carp Lake as an ecological reference site, but beetle kill and dead trees made access too challenging and unsafe. A new reference study area, Mudzenchoot Lake, is being planned for 2021 and particulars of this site are addressed later in the discussion of this report. Teeth Creek is another site identified by CCE for restoration that we are in the process of incorporating into the study plan and this is also addressed in a separate memo report (Appendix B).

Table 3.1-1. Study locations field deployment schedule

Location	Date	Location	Date
Webberly FSR	May 26-27	Webberly FSR	Jul 7-12
Carp Lake	May 29-30	W7	Aug 5
Rat Lake	Jun 5	W9	Aug 4-5
Blue Lake	Jun 5-7	Rat Lake	Aug 6
W9	Jun 6	Middle Creek	Aug 6-7
Middle Creek	June 7-9	Webberly FSR	Aug 24-28

3.2 Wetlands

Forty-two road ponds along the Webberly FSR were visited and illustrated and water chemistry data were collected (Figure 3.2-1 and 3.2-2, Table 3.2-1). Two fens were surveyed in the upland area of the Chuchi Lakes study area and additional wetlands were surveyed in study areas of the northern Finlay Reach; details on wetland surveys for restoration potential in other areas are covered in our wetland restoration report to CCE on behalf of Tsay Keh Dene (Appendix B). Information on wetland depth, width, and length on Webberly FSR are presented in Table 3.2-1. There is no significant difference between the measurements for wetland:

- depth early (Mean = 31.5 cm, SD = 18.26) and late (Mean = 29.27 cm, SD = 14.09) season , $t(39.44) = 0.46$, $p = 0.65$,
- width early (Mean = 6.36 m, SD = 3.79) and late (Mean = 7.00 m, SD = 4.97) season, $t(44.90) = -0.51$, $p = 0.61$, and
- length early (Mean = 27.78 m, SD = 23.77) and late (Mean = 27.02 m, SD = 19.83) season, $t(46.50) = 0.12$, $p = 0.90$[3].

[3] These are two-tailed test outputs. There is also no significance in one-tailed greater or lesser than comparisons.

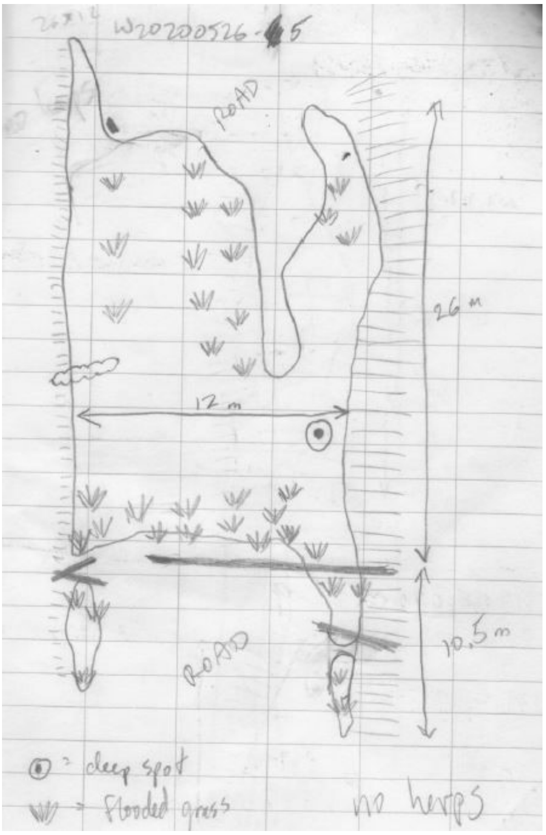

Figure 3.2-1. Sample wetland (WL265.20) illustration from May 26, 2020.

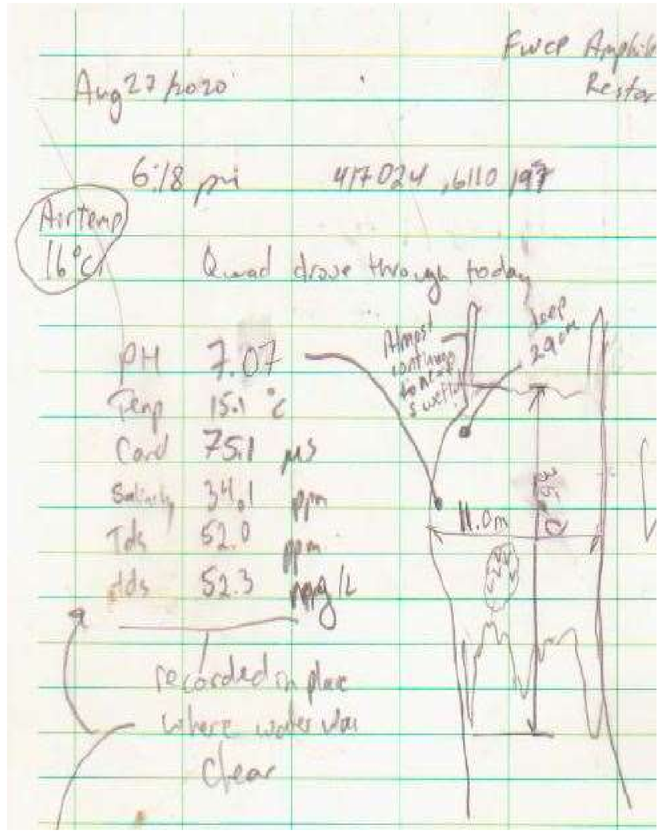

Figure 3.2-2. Sample wetland (WL265.20) illustration from August 276, 2020.

Table 3.2-1. Summary of wetland dimensions and water chemistry data types collected from surveyed Webberly FSR wetlands. V = Visits

#	Site Code	# of Visits	Depth (cm)		Width (m)		Length (m)		Water Chemistry Data	
			V1	V2	V1	V2	V1	V2	V1	V2
1	WL261E.20	2	66	54	12	8	23	22	T, pH, C	T, pH, S, C, TDS
2	WL261W.20	1	NA	NA	3.3	NA	21	NA	None	None
3	WL264.20	2	NA	18	1	1.3	24.5	44	None	T, pH
4	WL265.20	2	NA	29	12	11	36.5	35	None	T, pH, S, C, TDS
5	WL268.20	2	NA	50	3	3	9.3	9.2	None	T, pH
6	WL269.20	1	NA	NA	0.9	NA	3	NA	None	None
7	WL271.20	1	73	NA	10	NA	38	NA	T, pH, C	None
8	WL2710.20	2	28	18	5.4	NA	20	26.7	None	T, pH
9	WL2711.20	1	15	NA	1.7	NA	2.3	NA	None	None
10	WL2712.20	2	38	53	9.5	3	6	49	None	T, pH
11	WL2712b.20	2	NA	33	NA	5.9	NA	19.8	None	T, pH

#	Site Code	# of Visits	Depth (cm) V1	Depth (cm) V2	Width (m) V1	Width (m) V2	Length (m) V1	Length (m) V2	Water Chemistry Data V1	Water Chemistry Data V2
12	WL2712c.20	2	NA	37	NA	13.2	NA	7	None	T, pH
13	WL2713.20	2	8	14	4	5.6	25	20	None	T, pH
14	WL2714.20	2	60	50	3.75	5.2	27.5	26.5	T, pH, C	T, pH, S, C, TDS
15	WL2715.20	1	11	NA	1.1	NA	8.5	NA	None	None
16	WL2716.20	1	8	NA	5	NA	7.5	NA	None	None
17	WL2717.20	2	13	19.5	2.3	8.6	13	9.2	None	T, pH
18	WL2718.20	2	38	35	8.5	7	24	8	None	T, pH
19	WL2719.20	2	46	NA	10.5	3.5	32	18	None	T, pH
20	WL271b.20	1	NA	NA	2.3	NA	7.6	NA	None	None
21	WL272.20	2	12	23	3.8	8.5	15.5	30	None	None
22	WL2720.20	1	18	NA	NA	NA	13	NA	None	None
23	WL2721.20	2	19	15	8.5	8.2	12.5	16.9	None	T, pH
24	WL2722.20	2	11	9	5	5.5	5.1	7.2	None	None
25	WL2723.20	2	19	23	1.5	0.5	17.5	17	None	T, pH
26	WL2724.20	2	19	15	9	6	39	45	None	T, pH, S, C, TDS
27	WL2725.20	2	20	20	1.6	2.3	50	23	None	None
28	WL2726.20	2	23	23	2	3	13	19	None	T, pH
29	WL2727.20	2	49	40	9.5	13	120	90	None	T, pH
30	WL2728.20	2	55	44	10.1	11	67	59.2	None	T, pH, S, C, TDS
31	WL272b.20	1	NA	NA	1.2	NA	13.2	NA	None	None
32	WL2727c.20	1	50	NA	7.5	NA	27	NA	None	None
33	WL273.20	2	40	40	8.3	8	38	49	None	T, pH
34	WL274.20	1	8	NA	1.1	NA	2.5	NA	None	None
35	WL275.20	1	9	NA	1.3	NA	9.4	NA	None	None
36	WL276.20	2	45	30	9	9.1	17	18.2	None	T, pH
37	WL277.20	2	21	10	4.2	1.2	17.5	6.5	None	T, pH
38	WL278.20	2	55	NA	12.5	23.5	23	NA[2]	None	T, pH
39	WL279.20	2	8	NA	2.1	NA	18.5	NA	None	None
40	WL27b.20	1	18	NA	3	NA	12.5	NA	None	None
41	WL2529.20	1	90	NA	12.9	NA	97	NA	T, pH, S, C, TDS	None

#	Site Code	# of Visits	Depth (cm) V1	Depth (cm) V2	Width (m) V1	Width (m) V2	Length (m) V1	Length (m) V2	Water Chemistry Data V1	Water Chemistry Data V2
42	WL2530.20	1	45	NA	9.7	NA	69.5	NA	T, pH, S, C, TDS	None
43	CLW1.18[1]	1	60	NA	NA	NA	NA	NA	T, pH, S, C, TDS	None
44	CLW2.18[1]	1	NA	NA	NA	NA	NA	NA	T, pH, S, C, TDS	None

[1]These wetlands are not on the Webberly FSR. They are fens in the adjacent forested area. The measurements for these sites are not included in the statistical calculation of averages and SD that we did for the forest road ponds. The geometry (width and length) is estimated using remote sensing imagery.
[2]The field notes stated > 5 m because it was too difficult to determine the start-end perimeter for this road pond.

Western Toads occupied 55% of surveyed Webberly FSR road ponds, Wood Frogs occupied 43%, Long-toed Salamanders occupied 31%, Columbia Spotted Frogs occupied 29%, and unidentified frogs occupied 17% (Table 3.2-2). Long-toed Salamanders were confirmed to be breeding in 29% of wetlands, Western Toads, 24%, Wood Frogs, 7.1%, Columbia Spotted Frogs, 4.8%, and unidentified frogs were confirmed to be breeding in 4.8% of the Webberly FSR roadside wetlands (Table 3.2-2). Amphibian samples were only taken from 4 of the 42 wetlands (Table 3.2-2). Two fens in the adjacent forested area were also assessed for occupancy. Long-toed Salamanders, Western Toads, and Wood Frogs were confirmed to be breeding in CLW1.18, whereas only Wood Frogs were confirmed to be breeding in wetlands CLW2.18.

Table 3.2-2. Summary of amphibian occupancy by species and life stage at each surveyed Webberly FSR wetland. Sampled sites included adult tissue samples for DNA analysis or a sub-sample of larvae that were measured. (E=Eggs, L=Larvae, J=Juvenile, A=Adult). Sites where eggs or larvae were detected have dark shading to confirm the location as a breeding site.

Site Code	Date	AMMA	ANBO	RALU	LISY	RANID	Sampled (Y/N)
WL261.20[1]	26-May-20	E			A		
	9-Jul-20		A				
	11-Jul-20		A		J, A	A	Y (Adult)
	27-Aug-20				A		
WL2712b.20	27-May-20		L	A			
	25-Aug-20					A	
	26-Aug-20				J, A		
WL2724.20	27-May-20	E	L				
	10-Jul-20	L					
	25-Aug-20				J		
	26-Aug-20			A	L, J, A		

Site Code	Date	AMMA	ANBO	RALU	LISY	RANID	Sampled (Y/N)
	27-Aug-20				A		
WL2725.20	8-Jul-20		A				
	28-Aug-20		A		J		
WL2727.20	26-May-20	J					
	27-May-20	J					
	25-Aug-20	L	L, J				
	26-Aug-20		L, J				
	27-Aug-20		A		A		
	28-Aug-20				J, A		
WL2727c.20[2]	28-Aug-20		L				
WL276.20	27-May-20	E		L, A			
	9-Jul-20		A	A	L		
	10-Jul-20			A	L		
	25-Aug-20		J		J	A	
WL265.20	10-Jul-20	L	L		A	L	
	11-Jul-20		L				
	24-Aug-20		A				
	25-Aug-20				J, A		
	26-Aug-20				A		
	28-Aug-20		J	A			
WL269.20	8-Jul-20		J				
WL2714.20	27-May-20	E			A	E	
	9-Jul-20		A				
	10-Jul-20	L					
WL2715.20	8-Jul-20			A			
WL2728.20	27-May-20		L				
	8-Jul-20		A		A		
	27-Aug-20		J				
	28-Aug-20				J		
WL2710.20	10-Jul-20				A		Y (Adult)
	25-Aug-20				A		
	26-Aug-20			A			

Site Code	Date	AMMA	ANBO	RALU	LISY	RANID	Sampled (Y/N)
WL2712.20	27-May-20	E	L	L			
	25-Aug-20					A	
WL2713.20	27-May-20			A			
	26-Aug-20		J				
WL2718.20	27-May-20			A			
	8-Jul-20				J		
	25-Aug-20				J, A		
	26-Aug-20				A		
WL271.20	27-May-20	E, L					
	9-Jul-20		A				
WL2716.20	27-May-20				A		
WL2712c.20	27-May-20	E					
	8-Jul-20			A			
	25-Aug-20			A	A		
	26-Aug-20		J				
WL273.20	27-May-20	E					
	9-Jul-20		A				
WL2629.20	24-Aug-20	A					
WL2529.20	10-Jul-20	L					
	25-Aug-20		L				
WL2530.20	9-Jul-20	L	L	A			Y (ANBO)
	25-Aug-20		L				
WL277.20	25-Aug-20				J		
WL2717.20	26-Aug-20					A	
WL2720.20	8-Jul-20				A		
	26-Aug-20		A				
WL2721.20	9-Jul-20		A				
WL2722.20	9-Jul-20		A				
WL2723.20	27-May-20						
	26-Aug-20				J		
WL278.20	9-Jul-20				A		Y
	10-Jul-20			A	L		Y (Larvae)

Site Code	Date	AMMA	ANBO	RALU	LISY	RANID	Sampled (Y/N)
WL279.20	8-Jul-20		A				
	9-Jul-20		J				
CLW1.18[2]	8-Jul-20	L	L				Y (ANBO)
	11-Jul-20	L			L		Y (LISY)
	12-Jul-20				J		Y
	27-Aug-20		L		L		
CLW2.18[3]	12-Jul-20				J		
	27-Aug-20				L		Y
Occupied - road ponds:		13/42	23/42	12/42	18/42	7/42	
Breeding Site Count – road pond:		12/42	10/42	2/42	3/42	2/42	
Breeding Site Count – wetland:		1/2	1/2	0/2	2/2	0/2	

[1]Occupancy data for WL261E.20 and WL261W.20 have been combined.
[2]Note that wetlands with b and c in the code were separate at the time of survey but are close enough in proximity that they may be hydrologically connected seasonally. Hydrologically, it is possible that such locations transition from a single pond into a pond complex with multiple fragments. So site WL2727.20 and WL2727c.20 are hydrologically connected and the presence of breeding may be a single occurrence that seasonally splits into the wetland complex.
[3]These wetlands are not on the forest road, but are fens in the upland forested area.

3.3 Egg and Larvae Counts

A single count estimate of 6,500 Western Toad larvae was completed at WL271.20 in the Webberly FSR. Double-observer Long-toed Salamander egg counts were completed at two wetland sites (Table 3.3-1). Eggs (30 total, in three clusters of 8 to 10) were counted at the same location where the Western Toad larvae were counted; all the eggs could be seen directly, so a consensus agreement on the number was used. Eggs were detected in eight Webberly FSR road ponds in total and larvae were detected in one road pond, for a total of nine breeding ponds. Assuming at least one breeding female per breeding pond and 150 eggs per female (per estimates from Fukumoto 1995) a minimum of 14 females are breeding in the road ponds. Count estimates were completed at other locations (e.g., Middle Creek), but only data for Webberly is complete to date. Time-to-detect surveys (Halstead et al., 2018) were also completed at select wetlands, but the data and analysis for this is not yet analyzed.

Table 3.3-1. Double observer egg count results with Lincoln-Petersen parameters

Wetland ID	Survey Date	M	C	R	N
WL261E.20	May 26, 2020	103	83	78	109.60
WL2714.20	May 27, 2020	465	393	208	878.58

3.4 Adult Amphibian Captures

Data was submitted to MOE SPI[4] including the full capture history from visual encounter and time to detect surveys. We provide a summary of the number of adults captured according to species and their location (Table 3.4-1). No garter snakes were observed in 2020. Digital photographs for each captured adult have been organized into a searchable image database to index skin patterns (Figures 3.4-1 to 3.4-4). A total of 16 road pond TTD surveys were completed and a total of 2 double-observer egg count surveys were completed; results from the egg count surveys are provided (Table 3.3-1).

Table 3.4-1. Adult capture and detection history by species. Counts include everything terrestrial that has metamorphosed, including sub-adults

			Species		
Location	AMMA	ANBO	RALU	LISY	Ranidae
Webberly FSR	1	32	15	48	5
Carp Lake	0	10	0	1	0
Rat Lake	0	1	0	2	0
Blue Lake	0	9	0	2	1
W7	1	0	0	1	0
W9	0	0	0	11	0
Middle Creek	0	30	3	5	0
Totals:	2	82	18	70	6

[4] http://a100.gov.bc.ca/pub/siwe/details.do?id=5890

Figure 3.4-1. Dorsal view of Western Toad (an065-20) captured and measured July 8, 2020 in the Webberly FSR study area.

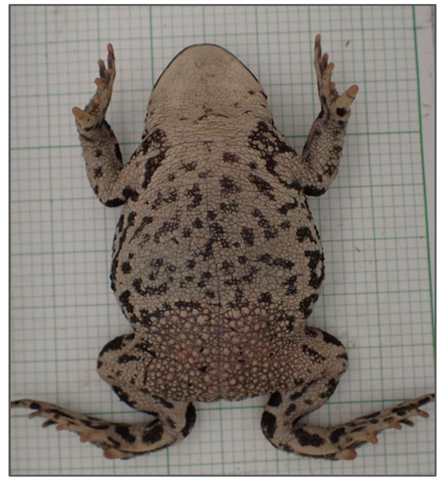

Figure 3.4-2. Ventral view of Western Toad (an065-20) captured and measured July 8, 2020 in the Webberly FSR study area.

Figure 3.4-3. Dorsal view of Wood Frog (li097-20) captured and measured July 10, 2020 in the Webberly FSR study area.

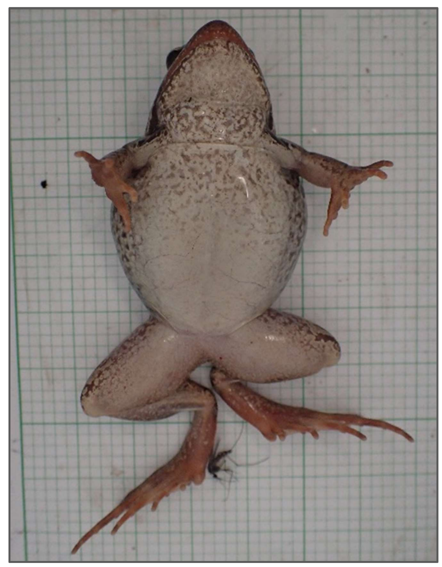

Figure 3.4-4. Dorsal view of Wood Frog (li097-20) captured and measured July 10, 2020 in the Webberly FSR study area.

3.5 Amphibian Tracking

A total of 30 individuals were tracked at four study sites: Blue Lake, Carp Lake, Middle Creek, and Webberly Lake. Collectively, 1,307.6 m of distance was tracked (Table 3.5-1). Dye-tracking diagrams for each individual are illustrated in Appendix D; note, tracking diagrams are not provided for a salamander and a toad (am002-20 and an003-20) because they remained local to the point of capture. The salamander (am002-20) migrated 1.5 m to the water and returned to the log where it was captured. A video (view here: https://www.youtube.com/watch?v=D7b6CwoR0qk) was recorded for the dye-tracking of am002-20. The toad (an003-20) migrated approximately 3 m from the place of capture.

Table 3.5-1. Number of individuals tracked at each study area and total distances tracked

Location	Dates (2020)	# Tracked	Species	Total Distance (m)
Blue Lake	June 6, August 4-5	6	ANBO	244
Carp Lake	May 30	2	ANBO	169.3
Middle Creek	June 8-9, August 6	9	ANBO	625.26
Webberly Lake	May 27, July 7,9-11, August 25-26, 28	13	AMMA (1), ANBO (12)	269.04
Total		30		1307.6

4. DISCUSSION

The first baseline year for an amphibian habitat restoration trial study was completed in 2020. Road ponds along Webberly FSR were mapped and data were collected on each to allow for repeated systematic sampling in the second year of our baseline. The repeated systematic sampling will ensure that sampling effort is spread equally between the road pond sites. The road ponds create a unique set of circumstances in the landscape as they introduce many small aquatic sites that are not otherwise patterned into a forested landscape. They are also unique as they have not had time to mature into a bog, fen, or marsh type of wetland where early colonizers and community assembly processes are taking place.

The unique spatial heterogeneity of each study site makes it challenging to create a sampling plan that results in equal but random sampling to give unbiased comparison of disturbed to non-disturbed habitat. Different spatial juxtapositions of land cover types cause obvious variation in detection probabilities. Survey at the road ponds, for example, generates a different type of data from what can be collected in areas away from disturbance. It is easier to spot and count eggs and capture larvae quickly at these sites. Many road ponds can be surveyed in comparatively less time than surveys of natural wetlands in upland forests. Therefore, we need to ensure that our sampling design does not give a biased inference of higher amphibian richness due to ease of capture in road ponds.

The challenges we identify not only extend to issues of comparison of different populations in different areas for systematic control and replicability, but obtaining tractable estimates of population abundance or occupancy is highly challenging in herpetology research even under ideal conditions (Rodda et al. 2015). Nonetheless, critical data is being gathered in the road pond habitat (a disturbance site) and will be continued as we advance baseline investigations into future years. The road ponds provide a baseline on disturbance ecology to contrast against patterns within metapopulations extending into the surrounding landscape and patterns within populations in other study areas, such as our reference site, Mudzenchoot Lake, or in northern areas of Tsay Keh Dene territory. A number of methods are being co-deployed in our baseline to provide a more comprehensive assessment of the populations as we seek to estimate and predict the range of ecological responses to land development and restorative action.

Information gathered in our pre-restoration baseline assessment will be used to make reasoned inference on types of restoration or management strategies to deploy. The baseline data will be compared post-intervention so that we can assess the outcomes and evaluate their effectiveness. There are two types of inferences that the baseline assessment is designed to test. The first is the primary goal and it is where we direct our main attention to provide an understanding into the metapopulation ecology of amphibians in areas where restoration treatments are planned for comparison with populations in areas where no restoration action is taken. This is a comparative inference to know if restoration treatments are having a measurable and identifiable effect, positive, negative, or varied by species. The second is a more specific inference and is more challenging to test. The baseline may be used to observe or quantify specific kinds of restoration actions that are more likely to produce a predictable outcome. For example, occupancy can be related to certain wetland habitat characteristics, such as shoreline condition, water depth, bottom firmness, organic content in bottom substrate matter, etc. (Hoffman et al., 2003). If specific conditions are identified to favor occupancy, then restoration methods may be developed to mimic these conditions for desired outcomes.

However, the second inference is more challenging to test, because ecological processes can operate at multiple scales. Habitat patches across a landscape can have a greater influence on occupancy than local scale attributes at the scale of individual wetlands (Scherer et al., 2012). Survey methods deployed into areas away from disturbance in both the Chuchi Lakes study area and our reference site Tamasgale Lake can be used for fair comparison, while the road-pond study within the Chuchi Lakes study area, along Webberly FSR, is set to provide a more localized measure of disturbance impact. How far the localized impact spreads into the adjacent landscape remains unknown and we anticipate that radio-telemetry will be the most informative tool to address this question.

4.1 Findings: A First Glimpse

Our results provide an introductory overview into amphibian populations at Webberly FSR. Amphibian populations were sampled at other locations, including Carp Lake, around Tsay Keh Dene, and Middle Creek. However, the sampling was most intensive at Webberly FSR where a firm commitment to restoration trials has been established. The process of selection of potential restoration trial sites is being completed in partnership with CCE and community members of Tsay Keh Dene; we have been informed that the priority has been narrowed down to their Teeth Creek site, which we did not survey in 2020. The sampling process for 2020 focused our efforts on sites we have targeted for restoration and comparison sites. The wetland restoration assessment work in the north is addressed in a separate report that was submitted to CCE (Appendix B). A new record for a long-toed salamander on the west side of the Finlay River stands out in that report.

The stage of analysis for our 2020 data is preliminary. This project is planned to be multi-year where we anticipated and planned for deeper levels of analysis as more data is gathered in future years of study. This first year established the foundations to systematically integrate new data across study years. Data collected in previous work (Thompson 2019; FWCP project: PEA-F18-W-2569 DCA) is also being integrated as applicable (spatially proximal and systematically feasible) into this study baseline. For example, it is important to note that breeding activity was observed in some of the road ponds or wetlands studied in previous years, but these locations appeared empty (no detection) during the 2020 survey.

The relative effectiveness of survey methods in herpetology monitoring programs can vary widely between species. A range of sampling methods can improve demographic or other quantifiable estimates about the study populations. There are different methods being used in this study that may give an index of abundance or occupancy, including simple VAES, natural history observation, capture-recapture digital fingerprinting, double-observer egg counts, and time-to-detect surveys. The fluorescent dye tracking has so far proven effective for mapping out local-scale diel (24-hour period) patterns of migration, which we detail further below.

4.1.1 Visual-Auditory Encounter Surveys

The low-effort VAES has provided some of the first insights into the populations under investigation. Long-toed Salamanders and Western Toads apparently take advantage of—are selecting— road ponds as breeding sites; this is indicated by a higher index of population richness for these species (Table 3.2-2). There is lower population richness for Wood Frogs and Columbia Spotted Frogs that use the road ponds during their adult phase (Table 3.2-2), presumably migrating from adjacent wetland areas (bogs and fens). Tadpoles of Wood Frogs have been identified in wetlands in surrounding forested areas in previous years (Thompson 2019) and Wood Frog larvae were recorded in two upland fens in 2020 (Table 3.2-2).

One egg mass belonging to Ranidae was observed in one of the road ponds (Id: WL2714.20), but it is difficult to key out the distinction between Wood Frog and Columbia Spotted Frogs at that stage. No larvae were observed during a return visit to WL2714.20, which either indicates present but not detected—unlikely given the size and high visibility in the road ponds—or failure to survive. Road ponds may provide an abundance of breeding habitat for long-toed salamanders and western toads and may even provide high-quality habitat per the standardized definitions of habitat (Krausman and Morrison 2016). However, the determination of high-quality habitat depends on habitat in the surrounding areas (e.g., Mudzenchoot Lake, reference study area Figure 3.2-1) to comparatively rank habitat quality.

4.1.2 Natural History Observation

Some of the methods employed in this study may not be intuitively applicable to restoration. Digital photography for spectral analysis of amphibian skin colour reflectance or as a record of body condition can provide high-information content while also requiring low effort to collect. Skin colouration, for example, is an important adaptive trait in amphibians (Thompson, Bolek, and Rea 2021). Photography and measurement of larvae sampled from select ponds to track the seasonal phenology of growth and development is another monitoring tool offering high-information content and relatively low effort. Comparative analysis of traits can be used as a monitoring indicator of stress. Stress can cause deleterious mutations or developmental anomalies to reduce the effectiveness of traits that are otherwise adapted for survival. Hence, higher rates of mortality occur in stressful environments and this can be quantified by comparative analysis of biological traits.

The lead author of this report (MDT) published a paper (Thompson, Bolek, and Rea 2021) on parasitism in a Western Toad (Calliphorid fly larvae) from an observation within one of our study sites. An additional paper is being prepared on observations of fungal infections, potentially *Saprologenia* sp., that continues to infect eggs in road ponds at the Webberly FSR study sites. Other deadly diseases have spread through BC's northern amphibian populations, including high prevalence of chytrid disease in the Peace Region (e.g., Brunette et al. 2020). Disease is understood as an environmental stress that is being exacerbated by climate change, habitat loss, and disturbance (Blaustein et al. 2010). The natural history and observation of these diseases is an important consideration on the habitat quality of the road ponds.

4.1.3 Capture-Recapture

While our capture-recapture fingerprinting data has yet to be analyzed, previous work has shown this to be an effective method for tracking amphibians in the region (Thompson 2019). Images are being processed to ensure that a capture-recapture history can be traced across study years and organized in relation to our abundance monitoring and tracking with dye and radio-telemetry. Use of fluorescent dye with radio-telemetry provides more precise information on diel home range and microhabitat preference in amphibian studies (Eggert 2002).

4.1.4 Tracking

The illustrations of our fluorescent dye tracked individuals (Appendix D) provide a clear way of presenting the findings. They can allude to the sequence and trajectory of the individual as well as speed, step length, turning angle, and the time the animal remains at a certain location (Pasquaretta et al. 2021). Many of the dye-tracking diagrams are representative of this. The diel activity pattern is generally restricted in close proximity—usually within 5 m—of the forestry road edge where Western Toads find refuge under debris piles or rocks. Some individuals ventured farther and switched movement patterns on their journey.

A goal for 2021 is to track animals away from areas of disturbance so that we can compare activity patterns in the different habitats; specifically, we wish to focus on sampling adults from the riparian edges of larger breeding sites (e.g., Webberly Lake) to study movement behaviour. Literature on telemetry studies involving western toads is being carefully investigated and our team is corresponding with other herpetologists who have experience with Western Toad telemetry to ensure that we are being effective in our data collection methods. More quantifiable data can be extracted from our tracking data (e.g., tortuosity, straight distance, change of direction between successive steps; Pasquaretta et al. 2021), which we will investigate further in future years for comparative analysis. Lessons were learned in 2020 to take more specific note on resting points evidenced by the accumulation of fluorescent dye.

4.1.5 Egg and Larvae Counts

Importantly, egg counts can give a reliable index on the number of active breeding females in a given population (Grant et al. 2005). The double-observer egg count method builds on the methods of Grant et al. (2005), however, the use of the Lincoln-Petersen population estimator is a new adaptation. This estimation procedure is used to account for imperfect detection and obtain estimates of detection probabilities. The assumptions hold for this estimation procedure (see Krebs 2014; Young and Young 1998) as used in the current salamander egg-count adaptation and are promising for future study years.

Fukomoto (1995) dissected female Long-toed Salamanders from roadkill and counted one with 110 eggs and another with 173 eggs and estimated an average of 24 eggs per cluster with a range of 4 to 64 eggs per cluster. In the Webberly FSR road ponds we identified eight locations that had salamander eggs and seven site that had larvae. We derive a conservative minimal estimate of 14 female Long-toed Salamanders, using a base estimate of 150 eggs per breeding female (Fukumoto 1995), inhabiting the

Webberly FSR road ponds. The double-observer egg count for long-toed salamanders is relatively quick (less than two hours per wetland) to complete; it seems reliable as the eggs can be seen in the water, but there are issues with this approach in vegetated wetlands in the surrounding area where standard net sweeps or time-to-detect surveys may be more appropriate. Counting of other species eggs require considerations for the different egg morphology (strings = Western Toads, globular masses = Long-toed Salamanders, and densely compact masses = Ranidae frogs).

Calculations of confidence (see Krebs 2014) in the initial estimate of 14 breeding salamander females will be calculated in future study years as new data is gathered. Additional egg counts were also completed in Thompson (2019) using this technique, but the data needs to be integrated for analysis. Simple double-count estimates on the number of tadpoles in a pond were also used, but the reliability and precision in these counts cannot be quantified. Other survey methods would have to be employed to increase reliability of tadpole count estimates that are described in applicable inventory guidelines (e.g., Graeter et al. 2013), but this would require a significant increase in the amount of survey effort.

4.1.6 Time-to-Detect Surveys

Our field notes include data on time-to-detect surveys per methods of Halstead et al. (2018), but the mechanics of executing this approach were being trialed under our unique set of field circumstances (e.g., seeing amphibians in shallow road ponds versus observations in fen wetlands with greater vegetation cover and near-zero visibility). However, the time-to-detect occupancy modelling approach is reported to have many advantages that require fewer survey replicates compared to estimates obtained from repeat site-visit occupancy surveys (Henry, Lee, and Altwegg 2020).

Our time-to-detect occupancy data will be modelled and coupled with mark-capture-recapture and telemetry tracking data to address some of the practical challenges (i.e., multiple site visits) as required for spatial occupancy modelling. A digital wrist watch was used for the stop-start timing, but the method can be improved with a stopwatch attached to a clipboard. Different ways of completing time-to-detect surveys were trialed during the 2020 field season. Data were collected and have been partially entered from the field notes as we evaluate the effectiveness of the approaches trialed. Our goal is to yield more information for less effort as we seek to improve on estimations of abundance or occupancy. Based on our experience trialing various time-to-detect method (e.g., along roads during night-time surveys or while surveying wetlands) it seems that the approach is better suited for surveys in complex natural habitats. Therefore, the time-to-detect surveys are likely to prove more effective in our stratified sampling design (Figure 3.2-1) in upland-riparian areas and natural wetlands.

4.1.7 Wetland and Road Pond Surveys

Wetlands are differentiated from road ponds and ditch line habitat. Mackenzie and Moran (2004) provide a framework for detailed classification of wetlands in the adjacent forested areas or in locations surveyed prior to clearing. Field notes are being collected, including digital photography of the primary aquatic plants at each wetland site surveyed, but sampling to classify to site series is not being adopted as this would require a level of effort to the project design that may not be required for our goals. An estimate on site series can be achieved using visual surveys as field crews sample soils and list aquatic plants. Filatow et al. (2020) provide an estimate of wetland classification that is of broader interest to the scope of this project and we are monitoring water chemistry to assist in the process. Wetland pH, canopy cover, hydroperiod, and adjacent forest cover are predictors of wetland use by amphibians (Lannoo and Stiles 2020; Scherer et al., 2012; Simpson et al., 2021) and these are the types of variables that we focus on to test our primary inference that restoration actions will have an ecological effect.

The second more challenging inference about predictable outcomes, such as finding a wetland depth that increases occupancy of Western Toads, is desired in the baseline analysis. However, there are inherent constraints in doing more targeted tests, such as the short-seasons in northern BC, research timelines involved and landscape context; For example, Brodman (2008) suggests >10 years are needed to characterize phenological timelines, such as onset or peak times of breeding, as may be related to climate or local-scale environmental effects. The degree of focal research that is needed to generalize findings or be more specific in predictions requires cost-benefit considerations for information gains versus a pragmatism of implementing restorative action while climate change and wide-scale forest harvesting is likely having big effects on the status of northern BC's amphibians.

Road ponds measurements seem to indicate that they got shallower but larger in width and length, but statistically the early and late season average values are equivalent. Some of the differences in measurement are due to decisions made in the field as the wetland morphology is complex; it is difficult to sometimes distinguish one site from another as there are shallow gradients or connections through roadside ditches. Further, maximum depth values are taken from the shoreline to avoid wading into the water, which would disturb the sediment and make the water turbid. This created an issue for standardizing the data recorded in repeated surveys. The illustrations of the road ponds and assigned code for each will help to standardize the methods. A flag will also be placed at each road pond and illustrations from previous surveys will be input into a tablet device with instructions on standard measurement.

It is known that Western Toad tadpoles move into water shallows to seek the warmest portions of the water (Blaustein et al. 1995) and they have been observed to feed on falling pollen in the shallows or to cannibalize (Thompson 2019). This increases the threat of becoming isolated as the ponds dry and sections become isolated. While none of the Webberly FSR road ponds became completely dry before amphibians reached maturity, the small peripheral lacuna became occupied by Western Toad tadpoles that have been observed to become isolated and perish (Figures 4.1-1 to 4.1-2), which reduces rates of survivorship in such habitats. The road ponds and wetlands in the upland areas create different admixtures and clusters of breeding sites. The stratification technique we have adopted to measure aquatic-to-terrestrial ratio (Figure 2.1-1) was inspired by the work of Burgett and Chase (2015) to define the landscape context of different study sites. However, a different type of index is likely needed to characterize the road pond clustering for comparison that we have attempted to advance through our illustrative technique (Figures 3.2-1, 3.2-2); costlier drone flights may be a consideration in future.

Figure 4.1-1. Representative photos of Western-Toad tadpoles isolated in peripheral road pond lacuna.

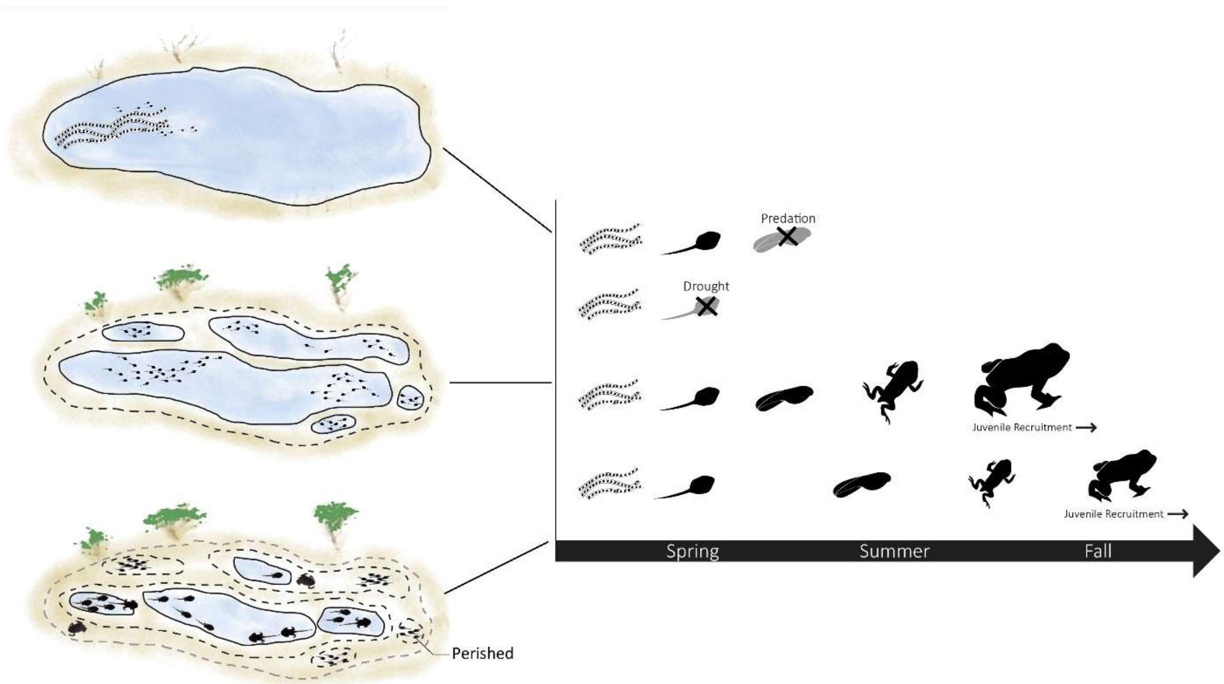

Figure 4.1-2. A schematic illustration of road pond seasonal hydrodynamics as it ties into the phenology of growth, development, and life-history survivorship of amphibians that occupy them.

4.2 Sampling Plan and Considerations for 2021

EcoLogic understands that adequate sample sizes are needed for estimation of power and error in the parameters of measured interest. However, in prospective analysis on how to sample, it is also important to differentiate statistical from research hypotheses (Hurlbert and Lombardi 2009). In both we can ask if the study is designed well enough to answer research questions, but statistical hypotheses require quantified estimates of randomized and unbiased samples. There has been a seismic paradigm shift in ecology from describing to modelling nature. In recognition of the rise in and value of statistical modelling in ecological research, many researchers continue to echo the message that observation studies in the field remain a vital part of the science (Lannoo and Stiles 2020).

4.2.1 Power Analysis and Sample Design

An *a priori* power analysis requires pre-planning and understanding of the experimental setup, the parameters of interest and their anticipated effect sizes, the scale of interest (spatial or temporal boundary of the sample population), and random effects. ''Power analyses … occasionally can be very useful' (Ecological Society of America Statistical Ecology Section 2012), but it requires correct application of the statistics where standard analytical power analysis methods (e.g., Cohens d) are often inadequate for ecological research studies (Johnson et al. 2015). Simulations and mixed-model information-theoretic approaches can be used to ask questions about the power of statistical inference based on sample size and there are recent advances in mixed-effects simulation that can be used to address the more complex realities of ecological study design (e.g., Green and MacLeod, 2016).

In previous years of amphibian baseline studies (FWCP project: PEAF17-W-1310; Thompson 2016) simulations were run with the software package rSPACE (Ellis et al. 2015) with the intent to provide a spatial power analysis for design of an amphibian monitoring program. The rSPACE package was designed to address questions about sample effort required for detectable change in sample size and abundance. However, it was learned in communication with the author of that paper that the program was not equipped to deal with the realities of a clumped distribution or small metapopulation spatial structure of amphibians.

Previous work of populations in the Peace Region (Thompson 2019) noted on the challenges of gathering effective data on occupancy or abundance. An estimate on occupancy of 0.2 was calculated in Thompson (2019) for forest plots in study sites around Williston Reservoir. This estimate can be cross-referenced with Guillera-Arroita and Lahoz-Monfort (2012) who provides power plots on survey effort (number of sites sampled x replicated survey). At the 0.2 occupancy estimate, survey effort using forest plots would have to be greater than 480 to achieve a power of 0.8 to track an occupancy decline equal to 0.5. Hence, a three-year study would require a minimum of 80 upland plot sites sampled two times per season:

- 80 plots x 2 sample times = 160
- 160 x 3 years = 480

There are challenges with sampling in upland areas in terms of the time it takes to get to new locations and what can be achieved for some of the different parameters of interest. These challenges are not unknown in herpetology, where it is recognized that there are inherent constraints in obtaining reliable demographic estimates due to the cryptic nature of these creatures (e.g., Rodda et al. 2015). Amphibian behaviours are complexly tied to their ecothermic physiology requiring movement to thermoregulate and even moon-cycles can change activity levels (Walls 2007). Shorter active seasons with protracted winter hibernation reduces opportunity to collect data on amphibians when they are most active. They respond quickly to the spring thaw to aggregate, breed, lay eggs, and then migrate into surrounding areas where they become difficult to find in underground retreats, such as mammal burrows or within decaying logs (Thompson and McDermot-Fouts 2015). The shorter seasonal transitions with bursts of aggregated activity followed by dispersion into the micro- crevasses of forested lands poses a great challenge to the tractable study and monitoring of amphibians in northern parts of this province.

The complex nature of amphibian life-history adds to the challenge of prospective power analysis. Therefore, our team is advancing statistical models and establishing a sampling design that will allow for estimations on sampling power. We commit to remain engaged in this problem to assess sampling by exploring simulations using a mixed-model information-theoretic approach (e.g., use of SIMR; Green and MacLeod, 2016) or other approaches for occupancy analysis (e.g., Southwell et al., 2019). However, power-analyses require considerable investment in time, effort, and technical skill to integrate the outcomes into a study. Different methods are being used to collect the data, generate estimates, and formulate predictions into the ecology of amphibian populations within our study areas. Each method may require different levels of sampling intensity.

A key step that we have adopted into the baseline is the development of a combined approach that is working toward hybrid between design and model-based sampling (Williams & Brown, 2019). Stratification (Figure 2.1-1) is the first step that is followed by allocating sampling effort to each strata to avoid bias and achieve spatially balanced sampling (Kincaid et al. 2020). In previous years, Thompson (2019) established 7.99 m radial survey plots with set survey times (2 people for 10 minutes); other sampling methods were explored (e.g., Bury and Corn 1990), but did not work under different circumstances encountered (e.g., lack of coarse woody debris at Chuchi Lakes study site). The sampling plan integrated into this baseline is based on trial and error from exploring different methods to establish what might work best in our study locations. Our plan is to keep the effort more general in the more difficult to access upland strata using a combination of time-to-detect and timed visual encounter surveys.

To standardize sampling effort, transects (100 x 2 m) will be established in each stratum using a random start point and a bearing that avoids transitions (e.g., into a wetland, beetle kill area) along the length. Each transect will be flagged during daylight hours and surveyed after dusk for 1 hour. Visual encounter and time-to-detect surveys will occur during daylight at the aquatic sites of each stratum, including implementation of the egg, larval, and adult survey methods. Adult Western Toads will be captured, processed, and potentially tagged with telemetry per our spatial and sample targets (described further below). A target will be set to survey 5 strata in each study area. Strata within the surrounding landscape of the Chuchi Lakes study area (Figure 2.1-1), and strata within the proposed Mudzenchoot Lake reference area (see below) have recently been completed using GIS and r-stats processing. Additional 2.5-km radial study areas and stratification is in progress for Teeth Creek and Middle Creek study areas in Tsay Keh Dene territory.

Investigation into movement patterns was selected as one of the more promising monitoring approaches (per recommendations in Thompson 2019). Investigations into migration may be more effective in measuring and quantifying effects from restoration actions. Therefore, more effort will be allocated to tracking of animals as we set to achieve our targets for strata sampling, but will adaptively adjust and re-allocate efforts if more time is needed to track animals. Tracking has the added benefit of giving a better understanding into the habitat and range of amphibians in northern parts of the province. Western Toads have been selected as the focal species for tracking, due to their Schedule 1 SARA status as a species of Special Concern. Initial work with fluorescent dye tracking of diel activity patterns has provided some initial insight into the movements of adult Western Toads that tend not to migrate too far from their night-time foraging spots along forestry resource roads.

4.2.2 Commitments for 2021

Stratification will be completed prior to heading into the field in 2021. Our methods describe custom r-script that was developed to create our GRTS sampling plan in riparian buffer areas using the *spsurvey* package (Kincaid et al. 2020). A spatially balanced draw of 60 upland points is calculated, which is based on what can be accomplished on schedule and budget across the multi-year baseline. Field crews will complete night-time surveys in the upland areas and daytime surveys into the adjoining wetland site that was stratified into the plan. Work plans were developed prior to heading into the field in 2020, but our team did not have time to execute random sampling in upland areas as emphasis was directed toward counting, measuring, and inventorying the road ponds on Webberly FSR. Some of the upland survey work was completed for the Chuchi Lakes study area in 2020, but harvesting occurred within the study area. Our team has met with Nak'azdli whut'en and BCTS to ensure that the most up-to-date harvesting block information is supplied to assist with the study design.

The baseline work in 2020 gives us a better picture into what can be accomplished in 2021. Western Toads will be captured at target locations within the stratified polygons (Figure 2.1-1, right-panels) during time-to-detect surveys for tracking purposes. Time will be allocated to survey along the Webberly Lake shoreline to see if Western Toad tadpoles occur in this primary location (the largest aquatic site in the study area), with an interest in capturing adults at this location to look at their linkage into the broader landscape. Radio-telemetry will be used to track toads from wetland sites into overwintering habitat to understand metapopulation connections and corridors of interest.

Both dye and telemetry tracking will be used in parallel. Individuals given a telemetry back-pack (Very High Frequency - VHF transmitters) will be dye marked so that we can study the first 24 hours of diel movement in finer resolution. These individuals will be relocated using radio telemetry in the days following their release within the expected lifetime of the transceiver battery; depending on the transmitter and size of animal, battery life can extend across the season. A total of 30 transmitters is our target by year 3 in the baseline; preferably, we would like two sets of smaller and larger transmitters to separately target metamorphs and larger adults respectively. It is planned to have at least 10 individuals dye-tracked at each study site and 5-10 individuals tracked through radio-telemetry at the Webberly FSR and Mudzenchoot Lake study areas (Table 4.2-1).

Table 4.2-1. Target sample sizes (2021) for dye and radio-telemetry by study site

Study Site	Dye Tracking Target Sample Size	Telemetry Target Sample Size
Webberly FSR	10	5–10
Mudzenchoot Lake	10	5–10
Teeth Creek	10	0

Middle Creek	10	0

While it is generally recognized that radio-telemetry is one of the only feasible ways to reliably map home ranges of amphibians, there is no general set of guidance on sample sizes for this type of work. The telemetry work of Browne and Paszkowski (2010, 2014; see also Long and Prepas, 2012) gives comparative point of reference. Across three years of study Browne and Paszkowski (2014) radio-tracked 116 toads, but sampled opportunistically. They were able to use land-cover data to model habitat use and selection and identify hibernation sites, and they concluded that their “results can help land managers identify essential land-cover types and habitat features for Western Toads in their northern range” (Browne and Paszkowski 2014, p. 424). Therefore, our targets across baseline years 2022 and 2023 will aim to increase the number of animals tracked:

- 2020 = 30 fluorescent dye, 0 radio telemetry
- 2021 = 30 to 40 fluorescent dye, 5-10 radio telemetry
- 2022 = 30 to 40 fluorescent dye, 10-20 radio telemetry
- 2023 = 30 to 40 fluorescent dye, 20 radio telemetry

The targets above will give a total of 35 to 50 individuals included in the radio-telemetry component, but this is also supported by dye tracking. While the telemetry numbers are lower than Browne and Paszkowski (2014), the sample size is in the range of other herpetology tracking studies (e.g., Baldwin et al. 2006). Further, the support of fluorescent dye tracking coupled with radio-telemetry increases the sample size of animals sampled. Advantages of coupling of information collected from dye-tracking to radio-telemetry is described in Eggert (2002).

The full suite of parameters that can be measured with our water chemistry probe was collected on only a subset of road pond habitats and a few natural wetlands (Table 3.2-1). The process adds time to the survey process and it is not feasible to collect chemistry data on each location. Furthermore, drainage patterns are anticipated to have modified road-pond configurations in the southern part of Webberly FSR where active logging has occurred over winter 2020/2021, which may require an adjustment to target sampling in that area. A target of six road ponds and six natural wetlands in the forested matrix will have their water chemistry tested (temperature, DO, pH, TDS, conductivity, and salinity). The selection of six road ponds is based on breeding of western toads (Table 3.2-2). All other road ponds will be surveyed using VAES and measured for width, length, depth, temperature, and pH. All Long-toed Salamander eggs observed in road ponds will be counted using double-observer egg counts for the Lincoln-Peterson estimation method described earlier in this report.

A sampling plan has been developed for 2021 and field work preparation is already under way. EcoLogic has purchased new tablet devices that will be used for this project. Field forms are being pre-developed and are being based on our GIS and Excel databases. QField (The QField Project/OPENGIS.ch 2019) will be used as a geospatial tool as it free to use and modify and it has been flagged for its field form applications that can be seamlessly imported into a desktop environment and saved into popular geodata formats like

Shapefile or TIFF (Nowak et al. 2020). Pre-planning with QField and our sampling design is expected to increase efficiency in field and office and may improve on the reliability of data being collected. Multi-species (Hamer, Schmera, and Mahony 2021) and conditional occupancy design methods (Specht et al. 2017) will also be considered in our sampling effort as they may offer estimations on occupancy and abundance as we gather data on adult migration.

Future restoration work will be completed by hand with use of shovels, other simple low-cost equipment (e.g., saws or shears to remove vegetation or collect willow stakes), and assistance from community volunteers. Local nursery plantings may be considered along with translocation of vegetation, logs, or rocky materials from surrounding areas. We have reviewed and are using the Conservation Evidence actions for amphibians (Smith, Meredith, and Sutherland 2020) as a guide on what kinds of restoration actions have been trialed (e.g., Deepen, de-silt or re-profile ponds) or not-trialed but considered (e.g., Create refuge areas in aquatic habitats) as we plan trial studies for 2022-2023. Specific budgeting will be developed with the actions identified and logistics will be planned as we move forward to implement the restoration actions.

5. CLOSING

A successful year 1 baseline was completed. The outcomes have helped chart the path forward for two more years of baseline monitoring. EcoLogic worked closely and in partnership with Nak'azdli whut'en and Tsay Keh Dene (through CCE) band members, providing training, sharing knowledge, and executing the sampling methods. Webberly FSR in Nak'azdli whut'en territory was our primary focus for describing wetland habitat and collecting baseline data on amphibian populations in 2020. This location is where we intend to launch restoration actions in fall of 2022. There is active harvesting in the Chuchi Lakes study area but upland environments remain that have been stratified into our sampling design. Considerations for additional restoration actions and target sites are addressed in our separate report, which was provided to CCE in support of their wetland restoration project (FWCP: PEA-F20-W-2966).

EcoLogic has been actively communicating our project objectives and intentions for the Chuchi and Mudzenchoot Lakes study locations with tenure holders managing harvesting activities in these areas.. Reduced baseline work is being completed in Tsay Keh Dene territory as we seek to identify restoration sites and actions in collaboration with CCE and hope to gain additional funding partners for this initiative.

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APPENDIX A. FIELD GEAR LIST

- Permits
- Field notebooks and tablets
- Amphibian photo box
- Calipers
- Measuring Tape
- Clip board
- Pencils and markers
- Tape, string, and glue
- Digital camera(s)
- Field guides
- Stopwatch
- GPS unit, compass, and rangefinder
- Hand lens
- Plastic bags – Ziploc freezer with and without breathable holes, >200 in supply needed
- Dip nets – big and small (aquarium dip net and spoon for tadpoles)
- Thermometers – soil / water / ambient temperature capabilities
- Spring Weight Scale – Pesola 100g
- Digital weight scale with 0.01 level of precision.
- Fluorescent tracking dye (and mineral oil)
- UV flashlight
- UV polarized lenses
- Virkon tablet solution – in spray bottle (anti-viral)
- Chlorox / bleach wipes
- Nitrile gloves
- Oragel – 4 tubes of gel and bottle of liquid with Q-tip applicator
- Paper towels
- Camping Supplies
- First Aid kit + supplies (anti-histamine for wasps)

APPENDIX B. WETLAND RESTORATION REPORT

ECOLOGIC CONSULTANTS LTD.
PO BOX 2012
SALMON ARM, BC V1E 4R1
PHONE: 604 803-7146

MEMORANDUM

DATE:	26 October 2020
TO:	Sean Rapai, Chu Cho Environmental
FROM:	Mark Thompson, R.P.Bio. Ecologist and Project Manager, EcoLogic Consultants Ltd.
SUBJECT:	Wetland Restoration Prescriptions: Amphibian Surveys and Recommendations

INTRODUCTION

Chu Cho Environmental (CCE) suveyed wetlands in 2019 as part of a traditional ecological study with Tsay Keh Dene Members. The assessment process was continued in 2020 at sites that were identified as potential restoration sites. Ecologic Consultants Ltd. (EcoLogic) is managing a separate FWCP project “Amphibian Habitat Restoration and Priority Trials for Amphibians” (PEA-F21-W-3222) that overlaps geographically with the priority sites flagged by CCE. Therefore, it was considered economical and beneficial for EcoLogic to provide input on CCE’s wetland restoration prescriptions in relation to amphibians. CCE made a request for EcoLogic’s amphibian expert (Mr. Thompson) to survey a number of select sites, collect data, and provide recommendations applicable to the management of amphibians for the restoration prescriptions.

Data were collected on amphibians and their aquatic habitats during each site visit. A full description of the methods, data, and analysis from these surveys are included as part of the amphibian FWCP project (PEA-F21-W-3222) reporting and deliverables. In brief, data and notes were collected on amphibians detected during timed surveys (life stage, measurements, and photographs), aquatic invertebrates (orders), vegetation (observations), and water chemistry (measured temperature, disolved oxygen, pH, todal disolved solid, and conductivity. Tissue samples were collected for DNA analysis of wood frogs (*Lithbates sylvaticus*) as part of a partnership study with Dr. Lee-Yaw, University of Lethbridge.

The goal of this report is to provide a broader descriptive overview of what was observed at the wetland sites that is most applicable to the advancement of restoration efforts in context of the local amphibian populations, including both logistical and ecological considerations. Details of amphibian species and their life stages observed during our surveys are included as well as wetland classifications.

WETLAND SURVEYS

Amphibian surveys were completed by Mr. Thompson (EcoLogic – Herpetologist) and Nathan French (CCE – Environmental Technician) at three of the four targetted wetland restoration sites (Table 1). Wetland W5 (Middle Creek) was not included in the amphibian surveys because of flooding access issues . Arshad Khan (CCE) noted that W5 is unlikely to be targetted as a restoration site due to its location near the drawdown zone where priority is focused on inland wetlands. However, additional wetland sites were visited in the Middle Creek area as part of EcoLogic's FWCP project (PEA-F21-W-3222) that are discussed in our closing recommendations as potential target sites of interest for amphibians and their aquatic habitats.

Table 1. Wetland sites and visit dates.

Site	Visit Dates	Location Name
W5	Not visited	Middle Creek
W7	August 5	Finlay FSR 20K
W9	June 6, August 4-5	10K Road
W14	June 5, August 6	Rat Lake

EcoLogic accompanied CCE, members of Tsay Keh Dene, and another wetland consultant (Robin Annschild, Wetland Restoration Consulting) during the August 4-5th visitation dates. Mr. Thompson gave a small field presentation on amphibians and took part in group discussions during the group visits. Amphibians and their respective life stages that were detected during the site visits are listed in Table 2.

Table 2. Amphibian species detections and life stages during wetland surveys.

Site	Survey Date	Species[1]	Life Stage
W7 Finlay FSR 20K	August 5, 2020	Long-toed salamander	Adult
		Wood frog	Adult
W9 10K Road	June 6, 2020	Wood frog	Tadpole
		Ranidae[2]	Adult
	August 4, 2020	Wood frog	Adult
	August 5, 2020	Wood frog	Adult
W14 Rat Lake	June 5, 2020	Long-toed salamander	Egg[3]
		Wood frog	Tadpole and Adult
	August 6, 2002	Wood frog	Juvenile
		Western toad	Adult

[1]Scientific names: Long-toed salamander (*Ambystoma macrodactylum*), wood frog (*Lithobates sylvaticus*), and western toad (*Anaxyrus boreas*).
[2]Animal eluded capture, but this was either a Wood frog or a Spotted frog (*Rana luteiventris*), both belong to Ranidae.
[3]Potential egg casings were identified, but no larvae were detected that would require further investigation to confirm the presense of this species at this location.

W7 - Finlay FSR 20K

Our investigation did not include timed surveys for amphibians at this location. Our team visited this location only once with CCE and others, including members of Tsay Keh Dene. Group discussions were held on location about options for restoration. It was mentioned during the group visit that this location was historically more permanently flooded providing access to traditional medicinal plants. Ms. Robin Annschild (Wetland Restoration Consulting) extracted soil plugs to identify a thin organic layer over top a deep mineral clay soil, indicative of a marsh or swamp class (MacKenzie and Moran 2009). An adult wood frog was observed and an adult long-toed salamander was captured within a decaying log in the riparian buffer strip approximately 20 m from the Finlay FSR.

The BC Williston Wetland Explorer Tool was used to examine the wetland classification across the broader landscape context (Figure 1). The site is classified as a fen with swamp components according to the ten category wetland prediction from the random forest machine learning algorithm of Filatow and Carswell (2018) and Filatow et al. (2020).

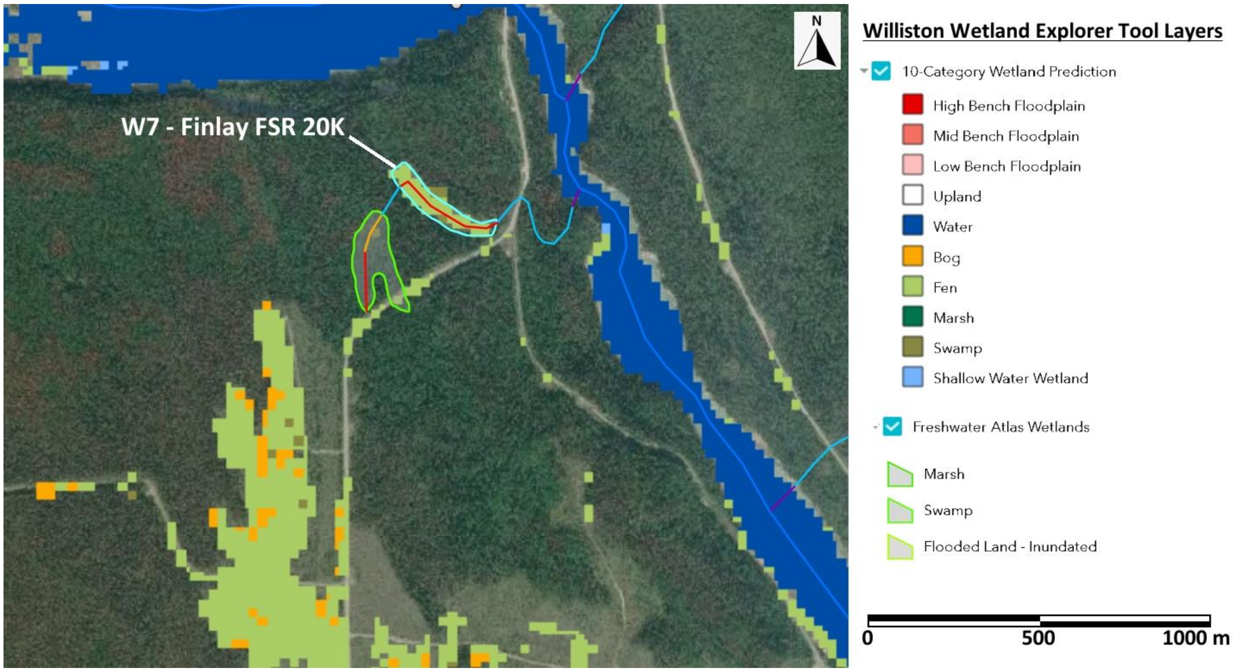

Figure 1. Williston reservoir wetland tool screenshot of landscape surrounding W7 – Finlay FSR 20K wetland site.

A stream is mapped through the area into the Finlay River by the Freshwater Atlas Stream Network that links the W7 site to another wetland area classified as a swamp by Freshwater Atlas. A disturbed logging area is incorrectly classified as a fen-bog, which is part of the understood overcorrection for the ten-category prediction (see Filatow et al. 2020).

The Finlay FSR road was discussed as a potential issue with respect to the hydrological changes that might have caused the amount of flooded area to be reduced within this location. The overlap of the road with part of the fen-bog site south of W7 (Figure 1) supports this inference, but additional investigations would be warranted in the main body of the fen-bog site. A few small shallow water wetlands exist approximately 1.75 km SW of W7 that could harbor additional amphibian breeding as part of a broader metapopulation. The discovery of an adult long-toed salamander at this site is significant, as there are few records of salamanders in this local area. The TKDFN territory is part of the northern range-marginal extent for long-toed salamanders.

W9 - 10K Road

This wetland site (Figure 2) is adjacent to and hydrologically connected to a smaller satellite wetland that has been subject to investigation in Thompson (2019). Only wood frogs have been confirmed at this location and surrounding areas, including smaller wetland areas that have been surveyed in the vicinity. Aquatic vegetation at this site south of the 10 K Rd is dominated by beaked sedges (*Carex utriculata*), marsh cinquefoil (*Comarum palustre*), willows (*Salix* sp.), and horsetails (*Equisetum* sp.). Pine tree seedlings (*Pinus contorta*) are found scattered in the wetland site along with a few dead spruce (*Picea mariana*) snags.

This site was classified as a bog-fen by the Filatow et al. (2020) algorithm and was tentatively identified as a fen in the field by our team. It has a neutral to alkaline pH (measured 8.0 on June 6, 2020), a sluggish hydrodynamic index, and thicker organic soils in the deeper margins of the riparian zone. This site has the characteristics of a Wf01 site association; one of the most common and widespread fen site associations in the province (MacKenzie and Moran, 2009).

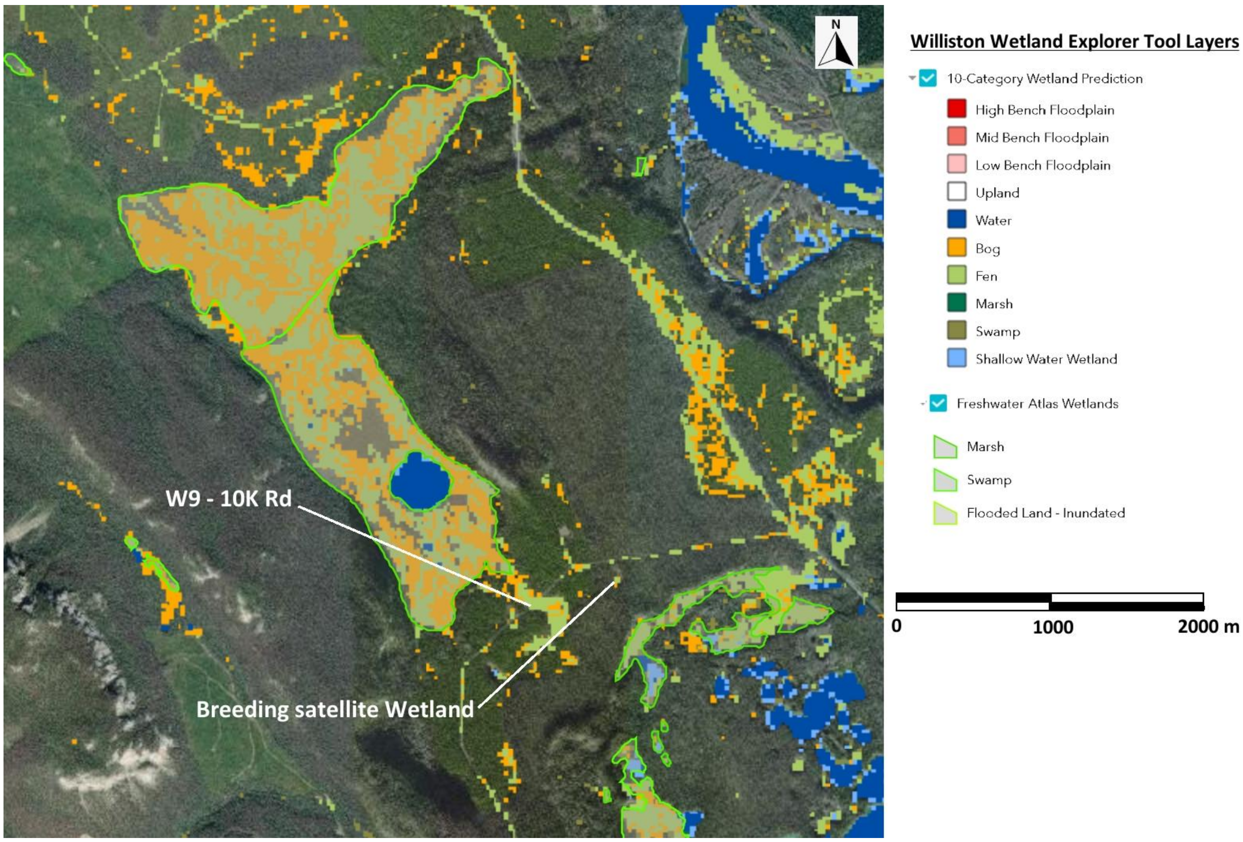

Figure 2. Williston reservoir wetland tool screenshot of landscape surrounding W9 – 10K Rd wetland site.

Concerns were noted about the location of the 10K road crossing, perched culverts, and the apparent effect on the hydrodynamics of this site during the field site visit. It is inferred that groundwater and surface flow drainage ties from southern higher elevation areas is being restricted by the road. This has reduced water levels in the extensive area to the north. The group discussed culvert replacement options as a means to restore some of the local hydrodynamics.

W14 - Rat Lake

This wetland site is highly disturbed. Historic cattle grazing access was noted during group discussions at this location and interest has been expressed in allowing future access for cattle. The Filatow et al. (2020) algorithm identifies this location as an open water site with some bog characteristics in the periphery and is identified as lake by the Freshwater Atlas with a stream channel passing through and connecting to swamp sites northward and west (Figure 3). This location has a thin organic layer overlapping sandy clay that becomes sandy below 1.2 m.

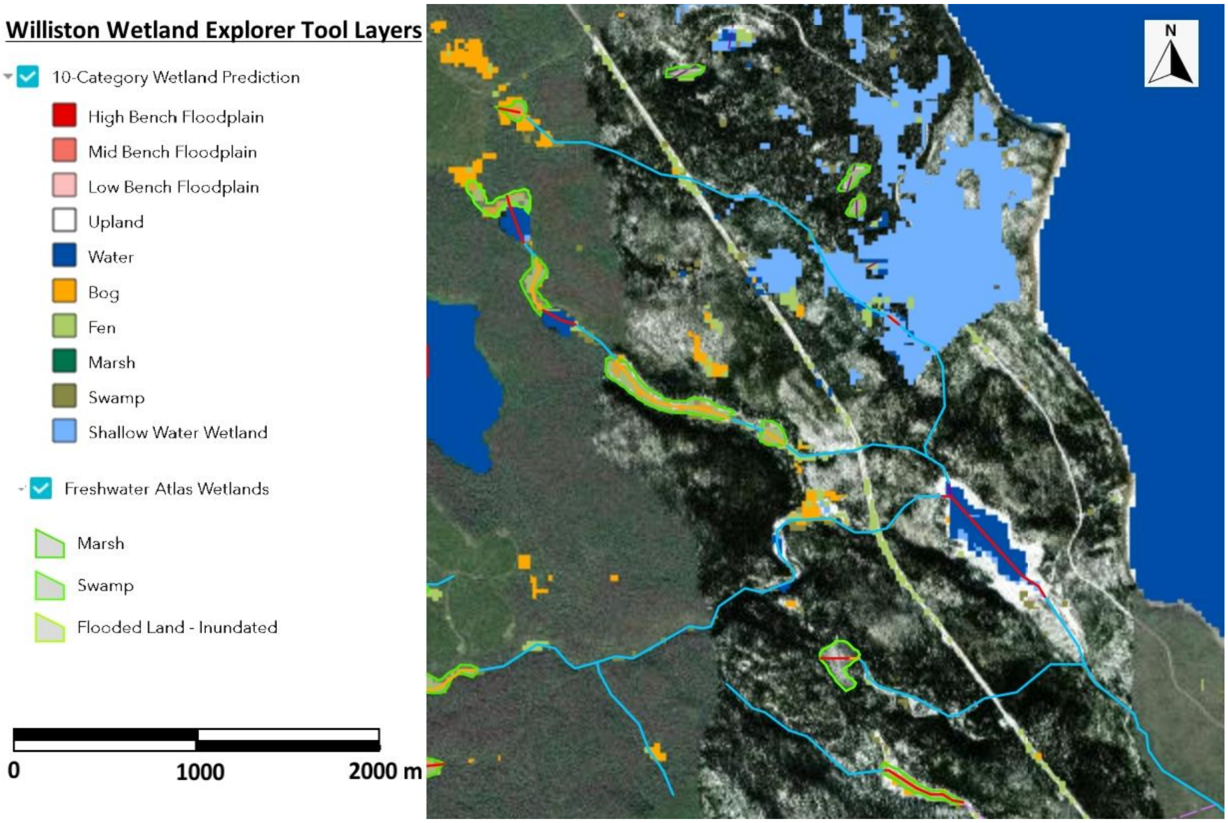

Figure 3. Williston reservoir wetland tool screenshot of landscape surrounding W14 – Rat Lake.

There was beaver activity at this site and it has become infilled by non-native grasses. Despite the historical disturbance at this location, there is an active presence of breeding wood frogs and possibly long-toed salamanders; potential egg casings of the long-toed salamander were identified but this would require further assessment to confirm presence of this species. Our team also documented an active invertebrate community consisting of scuds, snails, predatory diving beetles, caddis fly larvae, and dragon fly nymphs.

RECOMMENDATIONS AND CLOSING

Three of the four amphibian species that inhabit Tsay Keh Dene First Nations territory have been identified to occur in the target restoration wetland sites. There are incidental citizen science records (iMAP BC Frogwatch forms) for the fourth undetected species, spotted frog (*Rana luteiventris*), but local presence of this species may require further scrutiny as it may have been confused with wood frogs. Despite multiple years of survey in the local area, Thompson (2019) found no evidence of spotted frogs locally with the most northern record of this species in the Middle Creek area.

Summary of Wetland Classes by Site

The MacKenzie and Moran (2009) system provides lots of detail into characteristic vegetation associations, but it is not known how these associations relate to amphibian distributions in northern BC. Some data have been collected on invertebrates at these wetlands, but more in-depth systematic investigations are needed to statistically clarify presence/absence site associations. However, an initial inference of wetland classes is provided (Table 3).

Table 3. Inferences on wetland classes.

Site	Algorithm Filatow et al. (2020)	Freshwater Atlas	Local Inference
W5 Middle Creek	Fen-Bog	Swamp	Fen-Bog[1]
W7 Finlay FSR 20K	Fen-Swamp	None	Marsh-Swamp
W9 10K Road	Fen-Bog	Swamp (northern part)	Fen (Wf01)
W14 Rat Lake	Swamp-Bog	None	Disturbed Swamp

[1]The exact location was not visited by our team in 2020. However, Mr. Thompson has visited numerous wetlands in the surrounding local floodplain area and has noted a gradient of Fen-Bog habitats leading toward the reservoir.

Our preliminary classification (Table 3) is based on data we gathered on water chemistry and soil conditions along with observational inferences on the hydrodynamics using the keys within MacKenzie and Moran (2009) as a guide. It is important to note that the Freshwater Atlas is limited to only three classes (marsh, swamp, flooded), which limits its utility for more refined classifications. Wetland classes may provide some guidance on the historical baseline conditions, but the flooding of the reservoir and other developments in the local area have had an effect on the vegetation and soils to alter the trajectories of these systems. It is important that work continue on the ecological site associations of wetlands as may have important bearing on the life-history and habitat requirements of amphibians in terms of survival, fitness, and resilience in context of restoration efforts that are being advanced.

Middle Creek Restoration Potential

The Middle Creek wetland site was not visited by our team in 2020 due to flooding access issues. However, the 2020 report for our EcoLogic FWCP project (PEA-F21-W-3222) will include reference to additional sites within the Middle Creek area as potential restoration targets. One of the potential target sites may be particularly suited for restoration or offsetting of wetlands lost to the reservoir as it is located high above the drawdown zone (Figure 4; 57.5 km on the Davis FSR, UTM: 402819 mE, 6278480 mN). There are two small ponds in the ditchline area adjacent to the road. There is a thick saturated organic layer (10-26 cm) over silty clay and clay mineral soils in small saturated pockets within the upland forested habitat on the east side. The western ditchline has been seasonally occupied by long-toed salamanders breeding, while the eastern ponded area has been variously occupied by all local species and has served as a brooding site for long-toed salamanders in previous years (2015, 2017-2018, 2020).

Figure 4. Location of proposed wetland restoration site (57.5 km Davis) in relation to W5 with a photograph of the site on the east side of the road looking northward (*right panel*).

The local indigenous significance or traditional value of this particular site is unknown in context of the wider landscape and may be of interest to CCE to investigate further should this site be considered in the list of potential restoration priorities. It would be relatively simple to extend the size of the open water on the east side and increase the amount of local breeding habitat by stockpiling the organic layer, the clay base, and take advantage of the groundwater saturated soils to dig at depth and replace the clay and organics.

There is an estimated area of 50-80 m^2 that could be converted into an open water bog-fen and, with planning, an extended riparian system with amphibian migration corridors could be encouraged. This project may serve to offset some of the local wetlands lost due to erosion leading into the reservoir west of the Davis FSR and has potential to improve on the local metapopulation dynamics for amphibians, invertebrates, and other aquatic dependent species. An eco-passage and protection berm would be recommended to facilitate migration at this location as numerous breeding western toad adults are killed along this section of the road (see Thompson 2019).

Amphibian Restoration: Broad Guidelines

Metapopulations

A key recommendation for amphibian restoration planning is to consider the landscape context as amphibian species tend to form metapopulations. Breeding activity of a single connected population can be tied across multiple wetlands. Site occupancy can switch and migration patterns, linking ecological processes across wetlands, form dynamic spatial patterns across years (Petranka and Holbrook, 2006; Lannoo and Stiles, 2020). Different scales of migration must be considered in terms of breeding wetland site availability, patterns of dispersion, and how the local unique context of aquatic and terrestrial conditions influences the structure of and resilience within local amphibian populations.

Restoration Baseline

Species and habitat enhancement is perceived as one of the top methods for success in conservation (Meredith et al. 2018). The Society for Ecological Restoration has established international standards (McDonald et al. 2016) to define restoration as "the process of assisting in the recovery of an ecosystem that has been degraded, damaged or destroyed" (p. 6). Restoration is differentiated from rehabilitation or reclamation projects. Trophic food webs, the physical linkages of ecosystem engineers, and community species compositions that define native ecosystems are utilized as explicit reference in restoration projects (McDonald et al. 2016). Hence, it is recommended that a baseline investigation be established in the local and peripheral wetland context prior to proceeding with restoration activities.

Our initial mapping of the wetland context (Figures 1-3) identifies potential restoration reference sites away from the main impact or restoration target. Thompson (2019) established some baseline data for a small satellite wetland near W9 (Figure 2). The current EcoLogic FWCP project (PEA-F21-W-3222) can assist to provide a baseline context for W7 and W9 with reference to amphibians, but W14 is outside of the current budget and spatial scope of that project. The amphibian baseline monitoring includes an investigation into different scales of migration in addition to a tracking of demographic data on growth, development, and seasonal occupancy in both wetland and upland sites. Additional funds would be required to advance the scope of PEA-F21-W-3222 to cover the additional monitoring requirements at these restoration project sites.

Monitoring Benchmarks

Monitoring statistics on occupancy, abundance, growth, and development are often used as benchmarks on populations to assess population growth and fitness relative to the project. Data on the demographics of amphibians in northern BC habitats (e.g., occupancy and abundance) is very hard to track (see Thompson 2019). It is therefore recommended to continue attempts on tracking demographic data, as per EcoLogic's (PEA-F21-W-3222) project, while also gathering information on the movement patterns of amphibians at different scales (Table 4; see Bailey and Muths, 2019). Demographic data is very important and can help to frame a better understanding of the general ecology. However, data on movement patterns is more likely to be tractable and may offer an effective monitoring approach in terms measuring restoration achievements of landscape connectivity for amphibians.

Table 4. Scales of amphibian movement studies.

Scale	Timeframe	Method	Data
Individual-daily	Daily to weekly	Mark-capture recapture, dye-tracking, and radio-telemetry	Single wetland average migration statistics – increased / decreased
Individuals-seasonal	Seasonally	Mark-capture recapture, radio-telemetry, and occupancy surveys	Single to multi-wetland averaging migration statistics – increased / decreased
Populations-seasonal to annual	Seasonal to multi-annual	Mark-capture recapture, radio-telemetry, occupancy surveys, and population genetics	Multi-wetland landscape migration and demographic statistics – increased / decreased
Lineages	Generational to multi-generational	Phylogeographic DNA	Evolutionary history

Logistics and Planning

A general wildlife permit will be required prior to launching any restoration activities. Additional planning considerations for restoration construction are thoroughly covered in BC's guidelines for mitigation salvage (Ministry of Forests, Lands, and Natural Resource Operations, 2016), including local practices, laws, and recommendations for monitoring. EcoLogic will propose continued monitoring of amphibian populations at W7 and W9, while additional inclusion of W14 would require a fairly large baseline budget request. A multi-year pre-baseline prior to advancing restoration activities (minimal of 2-years) and continued post-monitoring is recommended to understand and evaluate progress in terms of the restoration objectives.

Summary of Recommendations

The following is a summary list of our recommendations:

- Wetland site class and association of each site was not comprehensively surveyed to classify according to the MacKenzie and Moran (2009) system of classification; wetland site classes can form local gradients and mixtures of bogs, fens, and marshes depending on the environmental context. Additional systematic surveys into site associations, including invertebrate communities, would help with baseline studies and evidence gathering with respect to restoration goals.
- Consider multiple smaller satellite wetlands in the restoration targets to support larger systems inclusive of ecosystem services, functions, and traditional use for medicinal plants or spiritual ties.

- Investigate and consider the Davis FSR 57.5 km site for restoration in the Middle Creek area as it is further away from the reservoir influence and is one of the few areas on the east side of the road that could be managed for amphibian restoration purposes.
- Consider metapopulation dynamics between wetlands, including upland connections. Wood frogs inhabiting the W9 10K Rd satellite wetland, for example (see Figure 2), may be more spatially restricted due to pine beetle kill that has likely increased the land surface temperatures and perils associated with travel between sites. This may require considerations for facilitating new canopy growth that ties wetlands into a population of breeding wetlands to add resilience into the project.
- Advance culvert replacements on the W9 10K Rd wetland. Note that our water chemistry analysis identified high levels of total dissolved solids at this location, which may be indicative of road siltation effects. New crossing structures should be developed to consider amphibian migration through the area, such as box culvert design for eco-passage beyond simple considerations for water flow.
- Create and advance baseline studies into wetland sites that are hydrologically connected by groundwater or overland streams but are distant from the impacted effects (e.g., roads, harvesting, reservoir, settlements, etc.) to serve as ecological reference sites.
- Help support EcoLogic's FWCP (PEA-F21-W-3222) project to include amphibians into the scope of restoration targets, including integration of communications monitoring strategies.
- Develop work plans for restoration inclusive of permitting and logistical considerations as may be required for effective management and survival of amphibians at the project sites.

EcoLogic would be pleased to assist and facilitate any further logistical planning and development as may be applicable to these projects, including baseline monitoring and on-location services for amphibian management during restoration construction activities.

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APPENDIX C. WETLAND RESTORATION GUIDELINES

A restoration framework document will be developed as a deliverable through this initiative. This section provides some of the initial restoration philosophy as it applies to the concepts associated with restoration of amphibian metapopulations, which is different from single-site restoration. Some of the terms become complex when discussing habitat, habitat restoration, and if it should be restoration, redress, rehabilitation, or repatriation. Any one of these words may be appropriate in the context of the actionable measures that we are working toward in this initiative. The reality for amphibians in northern BC is dire and we are at high-risk of irrecoverable loss.

Snow-depth provides a good indicator of how severe the risk for amphibians might be. It is an important environmental metric tied to western toad survivorship (Muths et al., 2020), it has been significantly reducted this century (Kang et al., 2016), and is predicted to be reduced even greater (more than double the global average) in the Canadian north (Bush and Flato 2019). This climate change impact is occurring in a regional context where forest harvesting has advanced into many of the corners where amphibians live. Forest management has not traditionally considered amphibians in context of impact to metapopulations and it is for this reason that restoration guidelines and actions for amphibians are necessary. It is further noted that the definitions of wetlands as managed under the province of BC Forest and Range Practices Act has not been managed according to the small aquatic sites where amphibians tend to breed or use for migration corridors nor have the block boundaries been managed according to the new definitions of wetland perimeters as more advance remote sensing technology is able to identify (Filatow et al. 2020). The landscape is being harvested more rapidly than our team can establish a baseline, so it is hoped that this guidelines document will provide the foundation for the type of changes that are needed.

C.1. Restoration Framework and Theory

One of the goals of this project is to use the findings from our research to develop a restoration guideline document for amphibians in the Peace Region. Smith et al. (2020) provide a recent review and cogent summary of methods that have been tested for amphibians by listing 129 actions. Some of these actions align with our project, but there are no studies and no evidence (no assessment) identified for adding woody debris to ponds, adding specific plants to aquatic habitats, deepening ponds to prevent desiccation, or creating habitat connectivity, for example. Other actions, such as clearing of vegetation; constructing artificial hibernacula; deepening, de-silting or re-profiling ponds; or using shelterwood harvesting instead of clearcutting have been assessed and are inferred likely to be beneficial. The Smith et al. (2020) approach looks at different lines of evidence to rank or determine the costs or benefits of different types of actions. Our approach is different as we seek to create a tool that can integrate the different lines of evidence to evaluate the effectiveness of a restoration program.

Considerations for amphibian conservation and restoration extends through landscapes as the life history and survival of amphibians depend on movement between habitats, both aquatic and terrestrial. The implications of restorative efforts and outcomes requires multiple scales of consideration, across species, landscapes, and different time-frames. EcoLogic has developed a seven-point restoration assessment tool (SPRAT) that will be the foundation of our restoration and management guidelines document that this project serves as a test case for. This tool is designed to give a consistent means to evaluate and establish goals and outcomes of a restoration program, including the current amphibian restoration trials or it may more broadly apply to ecosystem restoration more generally. The SPRAT method includes the following assessment parameters:

1. seasonal phenology (e.g., growth, development, reproduction);
2. migration and connectivity;
3. species richness;
4. population richness;
5. abundance;
6. functional community ecology;
7. local community values:
    a. First Nations: Local indigenous knowledge,
    b. traditional local knowledge,
    c. government (permitting and coordination),
    d. industry partners,
    e. non-profit organizations,
    f. citizen naturalists and scientists, and
    g. scientific academia and professionals.

SPRAT is founded on extensive direct professional experience in managing different types of restoration projects. Components of this approach have received guidance from First Nations and other scientists with expertise in restorative ecology, and we have communicated with others in our local community, including ministry personnel and industrial representatives. Each SPRAT parameter provides information about the potential benefits and intended outcomes of a restoration project. SPRAT can be used to assess scales of restoration, from small-local to regional and beyond. It is hoped that the illustrations will help to describe how the SPRAT parameters are being measured under the scope of sampling design, data collection, and analysis. This tool can be used to investigate and evaluate the benefits or costs of engineering (ecological and physical) in restoration planning. Importantly, SPRAT provides a framework for our FWCP sub-objectives, action types, and helps with the priority actions as we seek to "identify and prioritize locations for amphibian habitat restoration" and "identify and prioritize upland habitats for conservation and/or enhancement".

SPRAT is being used to organize the study plan and sampling approach of this project. In the following sections we use illustrations to explain how each parameter that we investigate in this study relates to the biology of the amphibians and gives data on the SPRAT parameters. The images were developed to help illustrate how we are positioning our work—the sampling approach—into the complex life-histories of amphibians in the Peace Region of BC. Our sampling approach links into the first six parameters in the seven-point restoration assessment tool.

C.2. Populations and Metapopulations

Scientists have proposed to raise the importance of maintenance and restoration of intraspecific variation, within and among populations, as a major conservation shift. This population-level priority is where critical ecological functions and nature's contributions to people are known to occur (Des Roches et al., 2021). Are the amphibians that we observe to occupy road ponds in the Webberly FSR a population, part of a larger population, or many small populations? It is important that we understand what the populations are if we hope to improve our aim in restoring the ecosystem in which they reside. Therefore, this section provides a brief introduction into population and metapopulation theory as needed to understand the SPRAT approach and these concepts importantly apply to the baseline sampling and research we are advancing with respect to populations.

Populations may be defined loosely as a group of individuals of the same species inhabiting an area at a specified time (Odum and Barrett 2005). Berryman (2002) added to the definition by stating that "…numerical changes are largely determined by birth and death processes" (p. 441). As such, populations may be given a spatial identity, but this may or may not correspond to what is occurring biologically across a landscape. Populations can also be defined by random mating of groups of individuals that cannot be statistically distinguished through common genealogy to their place of origin (Lawson 2015; Park 1939). However, the spatial identity of a genealogically defined population requires genetic analysis.

Individuals of a species within a study area may be defined as a statistical population (i.e., the ones being sampled; Park 1939; Winther et al. 2015). However, there is likely to be migratory exchange of individuals within adjacent areas that turns boundaries into gradients and threatens the independence of comparative analysis. Thus, a statistical population is not always a discrete sample of individuals in reality, but may be treated as such in an analysis that gives an explicit statement of the assumptions of the model (e.g., no exchange; see Young and Young 1998). However, there are times when groups of individuals are spatially restricted to a particular area, such as amphibian larvae in a pond. The restriction to the pond breaks down when the tadpoles metamorphose into adults to then migrate, disperse, and exchange from one wetland or forest into another. This creates a spatial extension of pond populations into the landscape and gradients of exchange.

Metapopulation theory was developed to imagine populations as a dynamic network of individuals that immigrate, emigrate, and cluster into different areas for different lengths of time. Metapopulations consist of populations structured across a landscape mediated by a process of dispersal facilitating immigration and emigration of individuals and their genes (Cayuela et al. 2020). Metapopulation theory gives scientists a set of conceptual and mathematical tools to systematically characterize and account for the spatial structuring of population dynamics exchanged between patches. Patches are defined as sources or sinks, where a source is productive enough to contribute individuals to other patches in the network, and low productivity in a sink is only capable of receiving immigrants. The source-sink dynamics can be altered across years (Hanski and Simberloff 1997; Hanski and Gaggiotti 2004; Wade 2016).

Metapopulations are not a universal property of species, as they may be organized in some locations but not others (e.g., panmixia; see Smith and Green 2005), while other species of the same community may form metapopulations over top of populations of other species to build an ecological interdependence across a landscape. The interdependence of population-level dispersal helps to maintain ecosystem functions, such as nutrient cycling subsidies (see Semlitsch et al. 2014). An important aspect of metapopulation theory is that it highlights the value of populations for conservation, which is often a neglected part of single-species priorities despite the bulk of ecosystem functions, goods, and services that operate in populations. This has been dubbed the hidden biodiversity crisis (Des Roches et al. 2021).

Therefore, populations are best understood as hypotheses. Not all populations are alike. When an individual is captured, a hypothesis is inferred as to what population it belongs with. Amphibian population types fall broadly into three categories: (1) closed populations that are geographically isolated and cannot be reached by dispersing conspecifics of distinct populations; (2) “metapopulations” consisting of several interacting local populations with occasional gene flow and local extinction and colonization dynamics; and (3) panmictic “patchy populations” with broad gene flow among neighbouring patches” (Sinsch 2014, p. 492). Multiple populations are being monitored in this project at different scales. Each 2.5-km radial study area (Figure 2.1-1) is defined as a sample population, but biologically the boundary likely stretches across multiple genealogical populations that our baseline study can help to map out. Wetlands are sampled as populations of larvae that later extend the reach of that population into the surrounding landscape that may be picked-up by our tracking investigations. The 2.5 km radius was selected, because this is both near the average of dispersal distances of frogs and salamanders and within the range of distance most frequently travelled (Cayuela et al. 2020).

C.3. Growth, Development, and Seasonal Phenology

As ectotherms, amphibians have evolved a number of important physiological adaptations that are tied to the thermal and chemical properties of their environments. They must migrate to meet their physiological needs as their body temperatures and moisture levels are regulated by the varied micro-habitats they occupy. Patterns of growth and development are synchronized by the seasonal phenology of events that unfold in semi-predictable ways, including a range of adaptations to the timing of co-emergence of parasites, predators, and prey (Jara et al. 2019; McDevitt-Galles et al. 2020; Wells 2007). Fitness and survivorship of populations are put at risk as the timing or scale of seasonal transitions become more extreme and less reliably synchronous. Phenological shifts to warmer winters, earlier springs, and drier summers as predicted under climate change, particularly strong in northern Canada (Bush and Flato 2019), is likely to add a significant degree of stress on the populations (Ficetola and Maiorano 2016; Muths et al. 2020).

Climate change is one of the big worrying threats for amphibians globally, but timber harvests are also changing the temperature and moisture conditions in their habitats (Haggerty et al. 2019). Many pathways of environmental stress are identified in review of global amphibian declines that are importantly tied to seasonal change in temperature and precipitation (Blaustein et al. 2010). Their life history is reliant on predictable regularity in seasons and associated weather norms. Therefore, measuring changes in growth and development of amphibians across the seasons in this baseline is being used to set the phenological clock for each species, when they lay eggs and how they grow as they reach different stages of development at different times in their complex life-cycles. This can be used to monitor and understand how or if community structure and survival might be impacted by changes in moisture, humidity, and temperature that can be modified by climate change, forest harvesting, road-building activities, and any measures taken to rehabilitate their habitat.

The seasonal phenology of the Western Toad is illustrated (Figure C-1a-c) as a conceptual demonstration of this SPRAT parameter. Like most amphibians, the Western Toad has a complex life-cycle that transitions between aquatic and terrestrial habitats (Figure C-1a). This transition between environments provides both opportunities and challenges to their survival. Early life stages (eggs, larvae, and metamorphs) are constrained by the quality of their aquatic habitat (Figure C-1b) where mortality rates are highest through crowding and increased susceptibility to disease and predation. Our baseline research is designed and scheduled to mark the timing of egg deposition, record the stage of development, and track growth and development by sampling, measuring, and photographing samples through each habitat and life phase (Figure C-1a-c).

C.4. Restoration in Context of the Baseline

The development of SPRAT has helped us to better organize around the project objectives and to establish a study plan with explicit goals and measureable outcomes. SPRAT is designed to assist in the review of restoration projects and will be used to integrate findings from our restoration baseline and restoration trials as we seek to develop a restoration framework and guidelines document to improve management conditions for amphibians in northern BC. This report and the illustrations we have created to present the conceptual basis behind the SPRAT approach for amphibians will be shared with our partners as we seek to further develop a restoration guidelines and framework document. The parameters used in SPRAT are not new, but integrating this particular list of index parameters into an evaluation bundle is a new and unique approach.

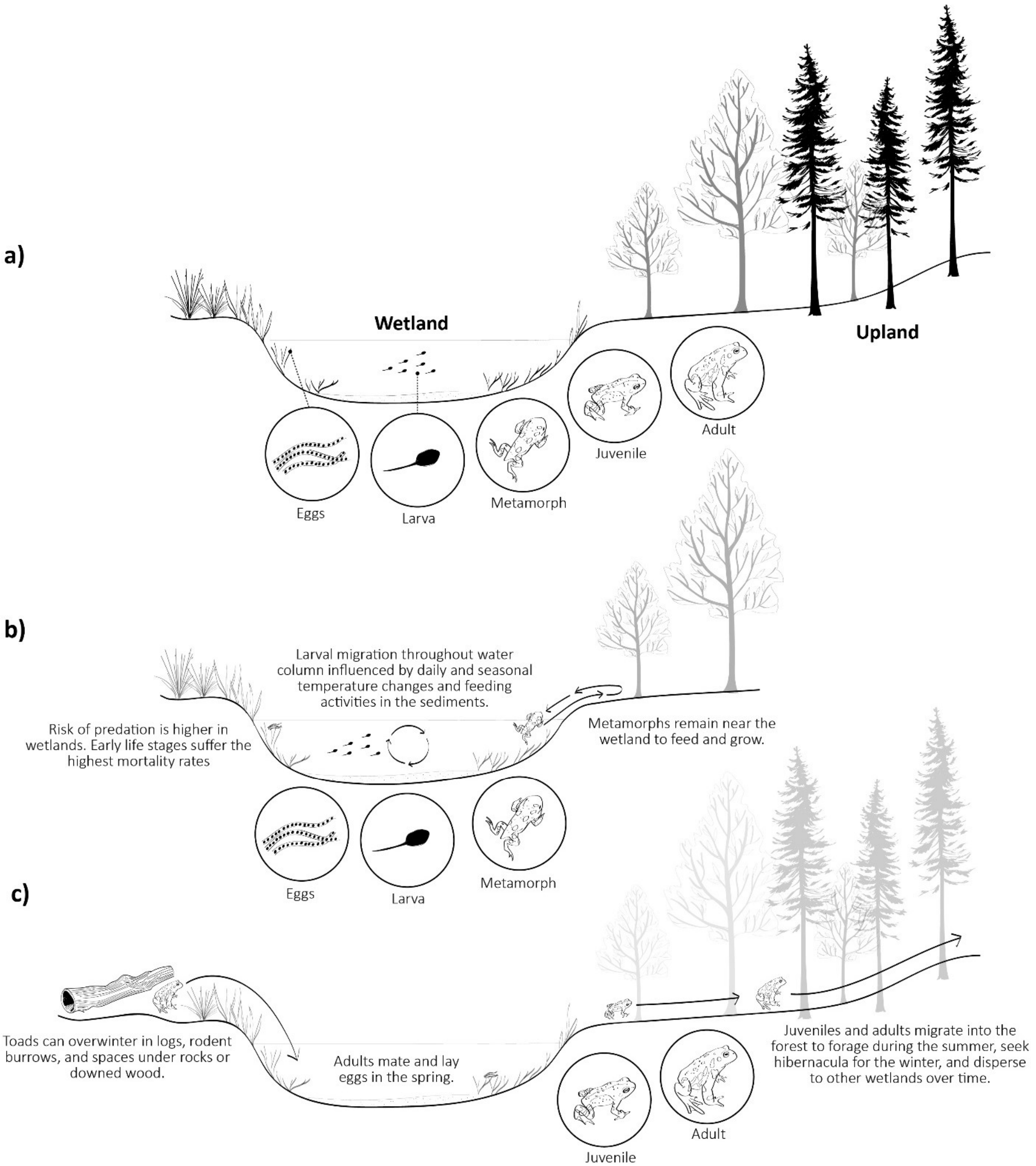


Figure C-1. Illustration of the complex life-history of the western toad showing migratory behaviours within wetlands and between wetlands and upland habitats. a) Early life stages (eggs, larvae, and metamorphs) in the aquatic zone transition to terrestrial habitat as toads mature and metamorphose into juveniles and adults. b) Early life stages localize movement necessary for growth and survival within and near the wetland. Growth and survival is directly influenced by factors such as hydroperiod and water quality. Early life stages are also highly susceptible to predation and parasitism during this period and transition to terrestrial life habits. c) Both juveniles and adults rely upon upland habitat to feed, hibernate, and seek other habitats. Adults return to aquatic areas in the spring to reproduce

Seasonal phenology is an increasing concern for amphibians in context of a changing climate (Ryan et al. 2014). The timing and onset of snow-melt regulates the state of seasonal hydrodynamics in amphibian breeding habitats. Figure C-2 illustrates this concept by presenting how four wetlands at different stages within their hydroperiod have affected the survival and growth rate of individuals. A scenario is presented (right panel) of individuals in ponds 1 and 2 that do not survive past the larval stage, whereas individuals in ponds 3 and 4 survive. However, there is another point of variation with individuals in pond 3 developing quicker and larger than individuals in pond 4. Larger size of emerging adults can enhance fitness (Cabrera-Guzmán et al. 2013). Therefore, it is important that we understand what types of environmental conditions enhance survival, growth, and performance across life stages as may be integrated into restoration planning.

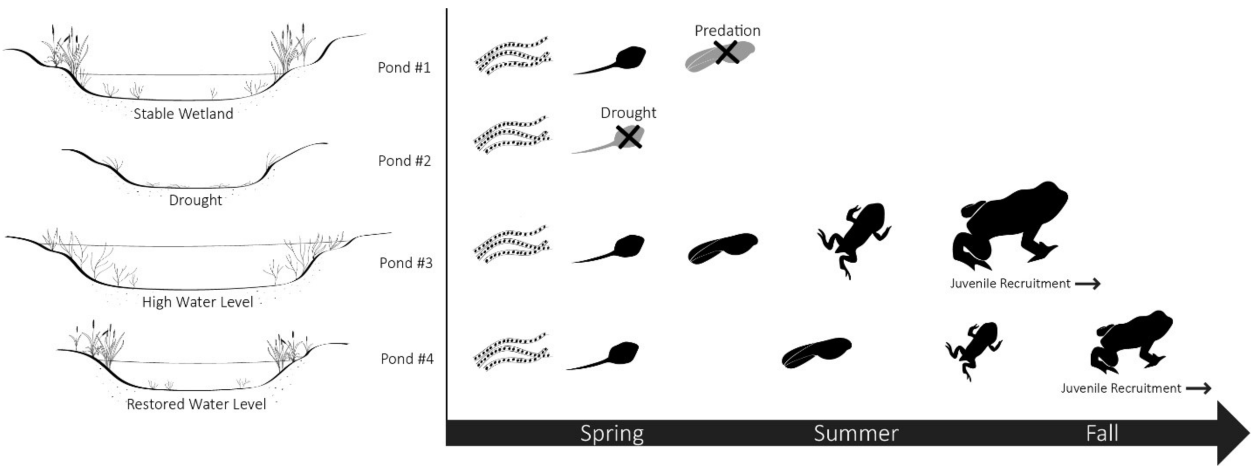


Figure C-2. Varied hydrological states across four ponds are illustrated (left-panel). Water levels may vary between sites, fluctuate seasonally, and vary in duration. Hydroperiod affects the growth and survival of early life stages (right-panel) and influences amphibian metapopulation dynamics. The quality and hydroperiod of aquatic habitats influence the survival and rates of growth for amphibian populations. The illustration presents four hypothetical scenarios where different hydroperiods have affected the survival and growth rate of different individuals, which affect juvenile recruitment into the population

Shifts in amphibian breeding periods and smaller body sizes have been observed as responses to climate change which could further influence population dynamics (Lannoo and Stiles 2020). Amphibians also rely on permanent wetlands during dry years while also being adapted to hypoxic conditions in seasonal and semi-permanent wetlands, providing population refuge from fish predators that perish under states of low dissolved oxygen (Lannoo and Stiles 2020). Baseline data is being collected on water chemistry (Table 3.3-1), hydrological dynamics (Table 3.3-1, Figure 4.2-2), aquatic invertebrates, and natural history observations that will help with restoration planning. Our field team is attuned to search for signs of parasites or predators, such as large invertebrate predators (e.g., dragonfly nymphs), garter snakes, or belted kingfishers (Thompson and Clark 2021; Thompson, Bolek, and Rea 2021).

The type of data collected in our baseline is being used to give a clear understanding on variation in rates of abundance, occupancy, growth, and development in road ponds versus patterns in seasonal and permanent wetlands in the surrounding landscape and at reference sites. Findings from this research will be used to provide guidance on restoration methods and trials, such as increasing water depth (digging down by excavation), planting vegetation, and adding materials (e.g., woody debris).

One of our proposed methods of restoration intervention involves the construction of artificial hibernacula, but the effectiveness has only been trialed in Europe (Latham and Knowles 2008; Neave and Moffatt 2007; Smith et al. 2020). It is anticipated that our radio-telemetry data will lead us to overwintering sites as was accomplished by Browne and Paszkowski (2010). Study of overwintering locations (hibernacula) will be used for consideration of where to locate construction of artificial hibernacula. Detailed information will be gathered at overwintering hibernacula sites, including data on soils, slope, position, micro-habitat, site-series, and canopy cover as may relate to snow-depth to inform design and construction of artificial hibernacula.

5.1.1 Migration and Connectivity

Amphibians move at different rates or distances depending on life stage or season. In the aquatic environments, larval migratory behaviour can alter detection probabilities depending on the time of day as they tend to aggregate in the evening and through the night, and spread as the water temperatures rise. They also traverse the water column to evade predators and feed (Figure C-1b). However, once they metamorphose and leave the pond they move into the surrounding landscape to (Figure C-3). Ponds that do not produce dispersers are called sinks (e.g., Ponds 1 and 2, Figure C-3), whereas ponds that produce an excess of juveniles to disperse into other ponds are defined as sources (e.g., Ponds 3 and 4, Figure C-3).

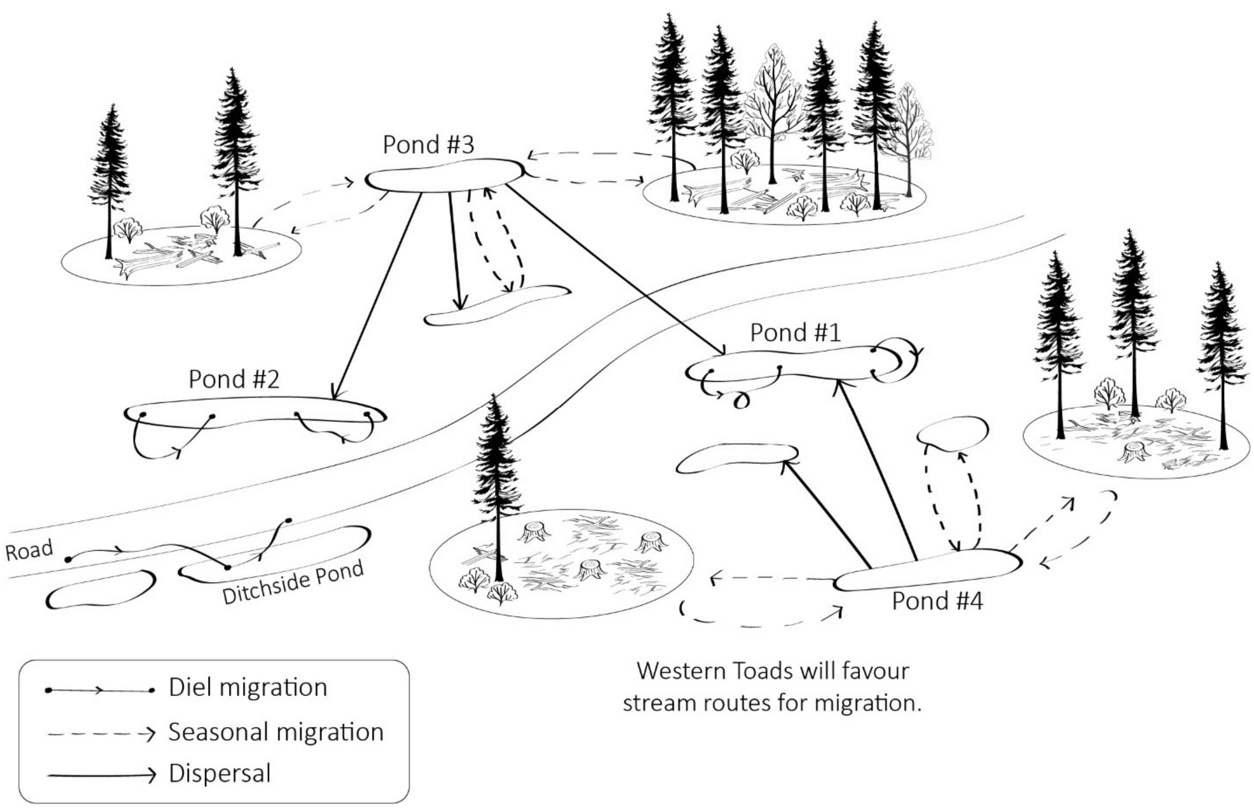


Figure C-3. Generalized landscape representation of daily migration localized within and near aquatic habitat, seasonal migration between aquatic and terrestrial habitats, and dispersal to colonize other wetland habitats. Upland habitats vary in canopy cover and the abundance and type of coarse woody debris.

Seasonal migration represents the journey between overwintering and breeding sites between both upland habitat and other wetlands throughout the year. Dispersal is uni-directional as juvenile or adult toads colonize other habitats to integrate genetically with other populations over time. The rates and distances of migration and dispersal in amphibians is modulated by the landscape pattern (e.g., heterogeneity) and matrix (e.g., dry substrate vs. moist corridor). Amphibian adults migrate into upland habitat to forage, to locate overwintering grounds, and return to wetlands in the spring to find mates and reproduce (Figure C-1c). However, they will encounter different features in the modern landscape, such as different canopy structure, crown closure percentages, and roads (Figure C-3) that have an effect on their behaviour, survivorship, and home range sizes and distributions.

Three categories of movement are illustrated for juvenile and adult toads (Figure C-3). These are categorized as including diel migration, seasonal migration, and dispersal (Table C-1). Table C-1 presents a conceptual framework for scale in relation to movement timeframes, methods, and type of data that are collected at the relative scale. For example, diel migration is illustrated (Figure C-3) as relatively short distances travelled within a day that occurs within and in close proximity to the aquatic habitat of origin, which we are tracking with fluorescent dye. Dispersal is often difficult to detect and is a poorly understood concept in ecology; however, it is an important process to consider in population dynamics (Bailey and Muths 2019). Tracking amphibian movement (e.g., fluorescent dye tracking and radio-telemetry) at multiple scales is recommended to inform many conservation and restoration actions as it can be used to strategically identify key habitat and migratory corridors (e.g., along streams; Bailey et al. 2019) through heterogeneous landscapes (Bailey and Muths 2019; Cayuela et al. 2020). Genetic tissues are being collected as part of collaborative phylogeographic studies into Western Toads (Melissa Todd) and Wood Frogs (Dr. Lee-Yaw), and we are discussing ways to further refine the genetic analysis to a more localized population-level analysis in future years.

Table C-1. Scales of amphibian movement studies and research methods used for data collection and analyses.

Scale	Timeframe	Method	Data
Individual – migration within habitat	Diel	Mark-capture recapture, dye-tracking, and radio-telemetry	Illustrations of tracking and measurements. Movement angles, tortuosity, resting points, and distances.
Individual - migration between some habitats	Weekly	Mark-capture recapture and radio-telemetry	Single wetland migration mapping.
Individuals – migration between all habitats	Seasonal	Mark-capture recapture, radio-telemetry, and occupancy surveys	Single to multi-wetland home range migration statistics.

Scale	Timeframe	Method	Data
Metapopulations – migration and dispersal	Seasonal to multi-annual	Mark-capture recapture, radio-telemetry, occupancy surveys, and population genetics	Multi-wetland landscape migration and demographic statistics – increased/decreased
Lineages	Generational to multi-generational	Phylogeographic DNA	Evolutionary history

5.1.2 Species Richness, Population Richness, and Abundance

Our baseline includes data collection on species and populations. Increases in richness and abundance can be used as indicators of restoration benefits. Species richness data is collected during our VAES and time-to-detect occupancy surveys; species richness is the number of species in a defined area, but there are various ways to calculate this metric (e.g., Fleishman et al. 2006). Population richness is a less familiar concept, but it is defined as the number of genetically distinct populations within a species, across all species, or averaged across multiple species within an area (Lawrence and Fraser 2020). For example, if three of four ponds are occupied by Western Toads and only one pond is occupied by Long-toed Salamanders, then Western Toads have greater population richness in this example. There are additional metrics for population richness that are important to understand in terms of metapopulation ecology and the attendant theory behind it (see Levin 1976; Hanksi and Simberloff 1997). Population richness is a variable that changes with degrees of intraspecific variation and reductions in this may decrease survivorship under environmental stress as the richness adds to the ecological networks and buffers of resilience.

Species richness is another metric for consideration of resilience to disturbance (e.g., Downing and Leibold, 2010). There are many different ways of estimating species richness (see Fleishman et al. 2006) that can be measured by the methods we employ in our baseline. Mark-recapture photo data (skin-pattern fingerprinting), dip net surveys, and double-observer egg counts are also being used to track abundance of each life stage. Skin pattern identification has been used in numerous herpetological studies. This method has outperformed more intrusive marking methods, such as PIT tags or elastomer injection (e.g., Bendik et al. 2013) and can be used to measure distances travelled by relocated animals or to estimate abundance when tied to a controlled survey.

Capture-mark-recapture methods have been used for many years by population ecologists to provide estimates of abundance (see Graeter et al. 2013; Schmidt 2004). Measures of abundance can be tracked in relation to birth and death rates in the metapopulation structure that is to be mapped out by telemetry tracking. Biomass is also indicated by population abundance multiplied by the recorded weights of individual animals. The contrasting of estimates of these multi-SPRAT richness-abundance criteria across wetlands and different upland areas is likely to give a broader, comprehensive, and reliable picture of restoration actions, costs, and benefits.

5.1.3 Functional Community Ecology

Restoration ecologists recognize the great need to focus on habitat diversity in ecosystem restoration to address the different needs of different community members (Lengyel et al. 2020). While in the field, it is important to record observations that can increase knowledge about the roles of different species within a community and ecological processes that may influence population dynamics. Observations of predators and parasites may better inform threats to populations (Thompson and Clark 2021; Thompson, Bolek, and Rea 2021). Anecdotal perceptions about prevalence of prey, predators, and parasites may be indicative of changes in habitat (e.g. after restoration) and environmental conditions (e.g., canopy cover, hydro period and water chemistry). Field observations are part of the scientific process where inferences to hypotheses can be made about potential ecological functions or community dynamics of particular interest for future points of inquiry and investigation.

Some of the data being gathered in our baseline may be used to quantify or gauge different aspects of functional ecology or community dynamics. Methods employed to estimate abundance, for example, may be translated into a quantifiable estimate on the amount of physical work or matter that is being exchanged. The trophic-dynamic exchange of matter and energy is one of the great fundamental theories of ecology (Lindeman 1942). For example, Western Toad tadpoles are defined as ecosystem engineers because they play a significant role in sediment flux in wetland ecosystems (Wood and Richardson 2010). Weight and abundance estimates of Western Toads may give some measure of their relative contributions to wetland functions. Water chemistry is another type of data that may be used to inform on the ecosystem functions operating in natural, disturbed, or restored wetlands. Chemistry may be used as an indicator of the trophic-dynamics and ecosystem functions to answer the question: Are restored versus natural sites comparable?

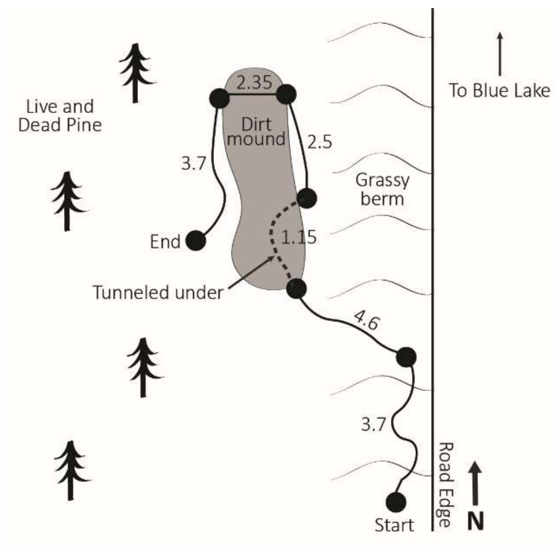
5.1.4 Societal Values (Traditional Local Knowledge, First Nations Values)

> *As scientists working in areas where Indigenous or local knowledge have an important role, we are increasingly aware of the need to learn how best to contribute to inclusive and equitable research and decision-making and how collaboration between multiple knowledge systems can lead to a richer, more effective knowledge base to inform decision-making. (Wheeler and Root-Bernstein, 2020, p. 1634)*

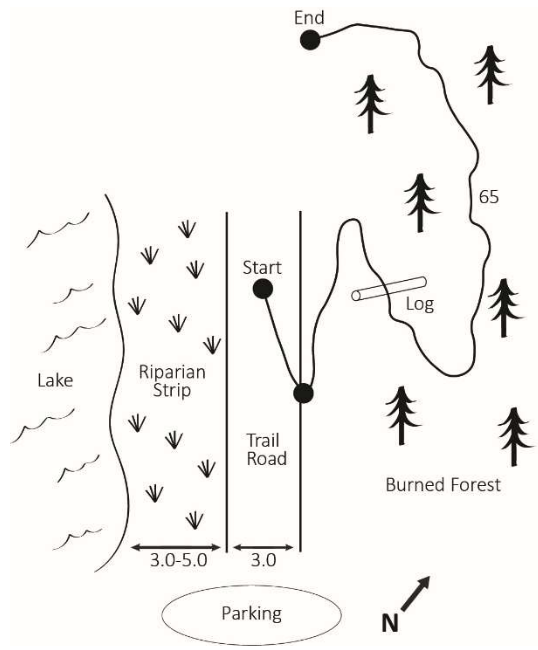
One of the goals of this restoration project is to build strong alliances and partnerships with multiple stakeholders. First Nation partnerships are a high priority as we work in traditional territories of Tsay Keh Dene and Nak'azdli whut'en, including keyoh-territory of the lusilyoo-frog clan. A priority in all our recommendations for restoration actions is how to best integrate cultural values, Indigenous knowledge, and participation into work plans. Poe et al. (2014) provide a set of guiding principles that are evident in the practical example in Heiner et al.'s (2019) study. Although Heiner et al. (2019) was developed in relation to environmental impact assessment (EIA) planning, we believe that their methods and message to "include social and cultural values with systematic frameworks and standards" (p. 2) are applicable.

The SPRAT approach is designed to make multi-criteria parameters explicitly evident so stakeholders can share values and perspectives in the restoration planning and development process. Strengthening partnerships with local peoples can bring sustainability into local communities through actions commensurate with the goals of conservation biology, through an understanding that their knowledge, culture, and practices can both inform stewardship directives, such as restoration, and assist with collective adaptation to climate change and socioeconomic challenges of the future (Wheeler and Root-Bernstein 2020). As such, the SPRAT strategy is designed to involve "…collaboration with local and Indigenous groups who possess critical knowledge on the relationships between intraspecific variation and ecosystem function" (Des Roches et al. 2021, p. 1). How locals perceive, value, and interact with the environment plays a fundamentally critical role in ecosystem interactions and restoration activities.

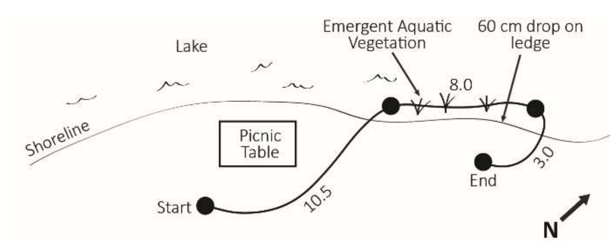
APPENDIX D. DYE TRACKING ILLUSTRATIONS



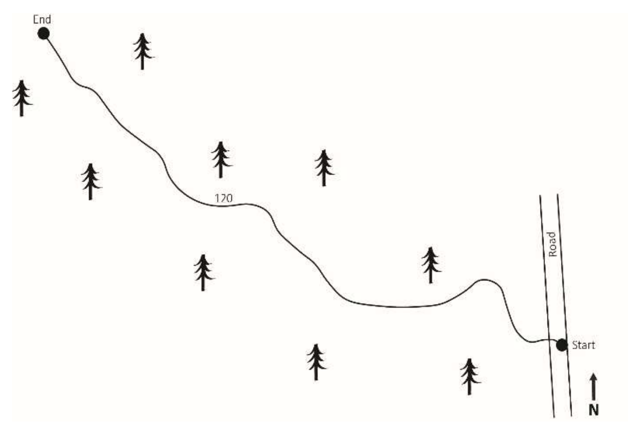
ID: an028-20
Tracking date: June 06, 2020
Total Distance: 18m



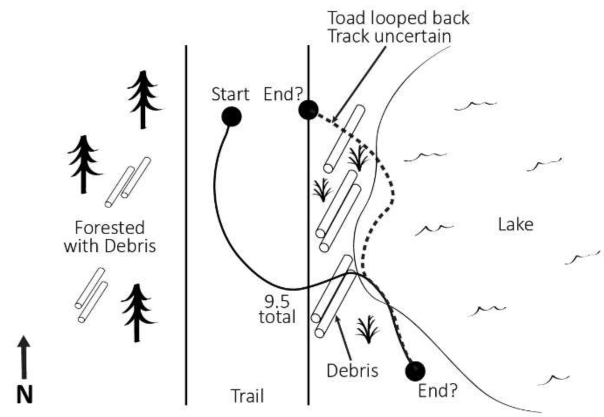
ID: an029-20
Tracking Date: June 06, 2020
Total Distance: 65m

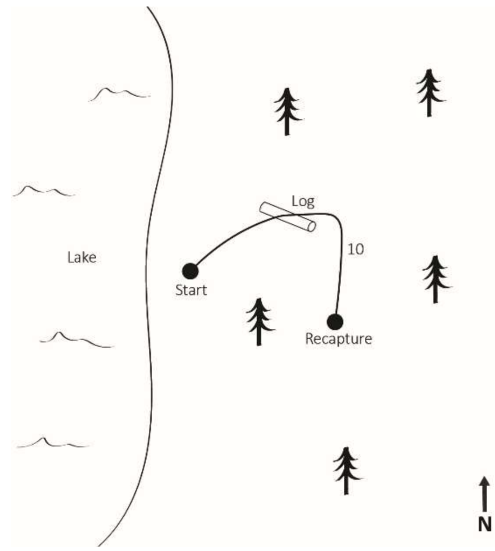


ID: an121-20
Tracking Date: Aug 04, 2020
Total Distance: 21.5m



ID: an123-20
Tracking Date: Aug 05, 2020
Total Distance: 120m

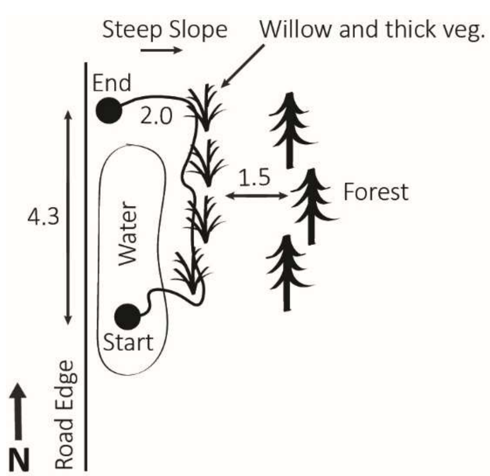


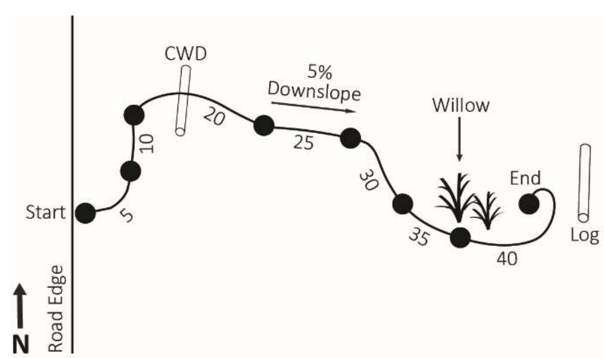


ID: an124-20
Tracking Date: Aug 05, 2020
Total Distance: 9.5m

ID: an203-20
Tracking date: Aug 05, 2020
Total Distance: 10m

Figure D-1. Dye tracking diagrams of individuals captured in the Blue Lake study area. Diagrams show distances in metres. End refers to the end of traceable dye and no recaptured individual

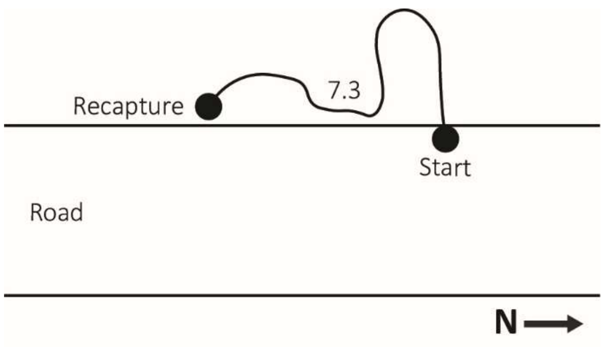




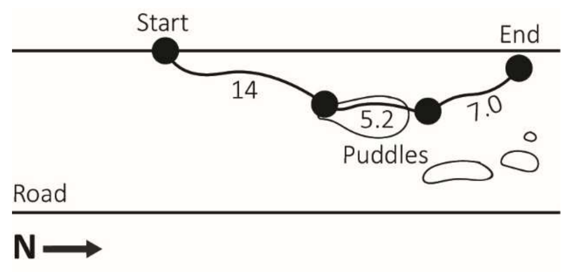
ID: an022-20
Tracking Date: May 30, 2020
Total Distance: 4.3m

ID: an023-20
Tracking Date: May 30, 2020
Total Distance: 165m

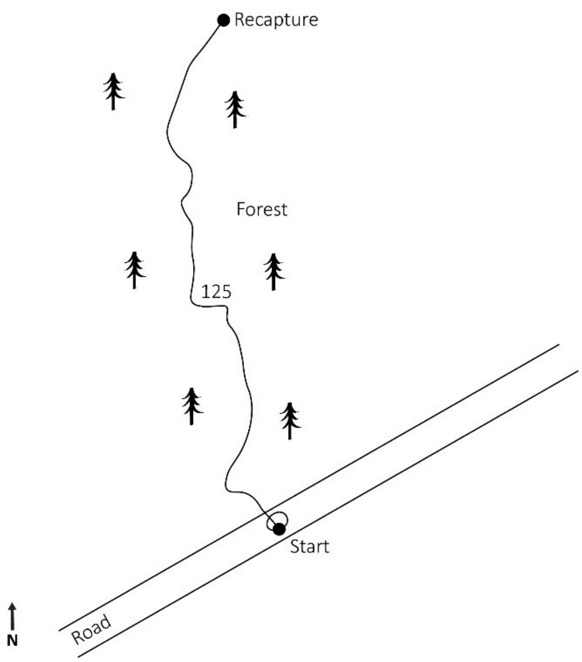
Figure D-2. Dye tracking diagrams of individuals captured in the Carp Lake study area. Diagrams show distances in metres



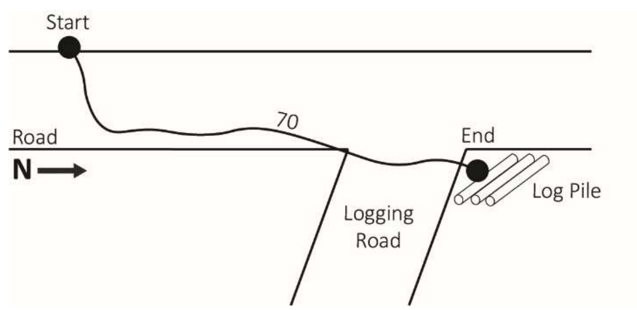
ID: an036-20
Tracking date: June 08, 2020
Total Distance: 7.3m



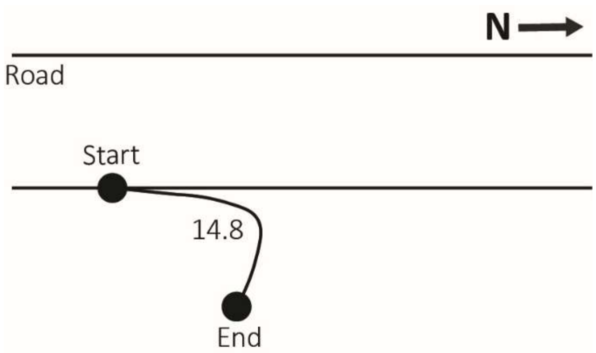
ID: an037-20
Tracking date: June 08, 2020
Total Distance: 26.2m



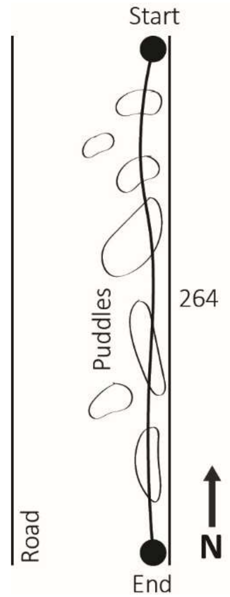
ID: an038-20
Tracking Date: June 08, 2020
Total Distance: 125m



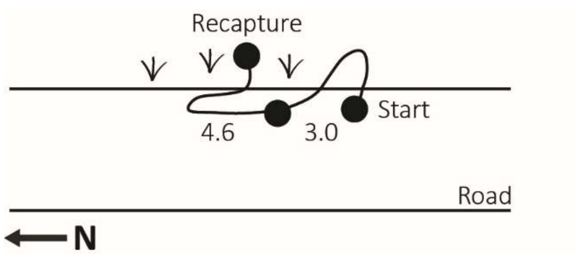
ID: an039-20
Tracking Date: June 08, 2020
Total Distance: 70m



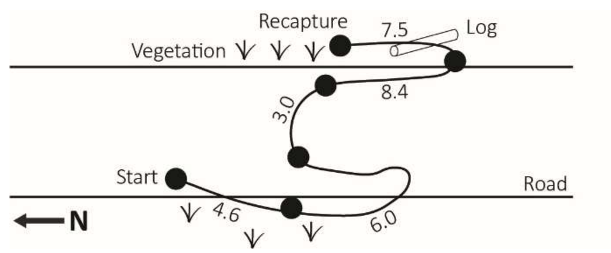
ID: an044-20
Tracking Date: June 09, 2020
Total Distance: 14.8m



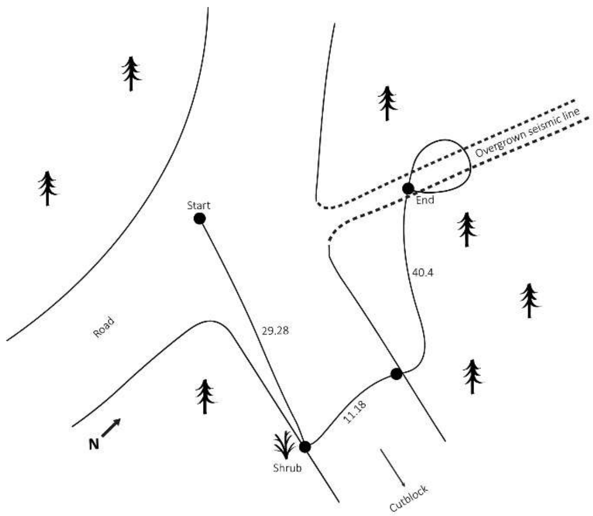
ID: an142-20
Tracking date: Aug 06, 2020
Total Distance: 264m



ID: an144-20
Tracking date: Aug 06, 2020
Total Distance: 7.6m

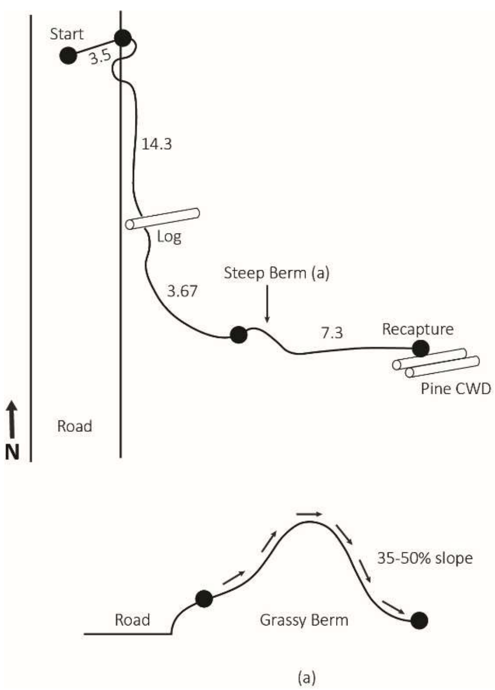


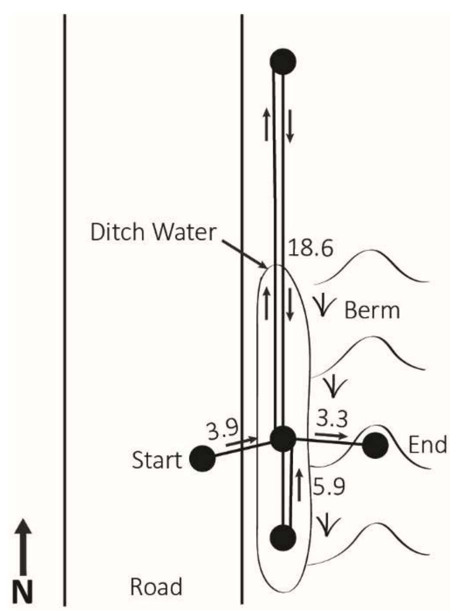
ID: an146-20
Tracking Date: Aug 06, 2020
Total Distance: 29.5m



ID: an149-20
Tracking date: Aug 06, 2020
Total Distance: 80.86m

Figure D-3. Dye tracking diagrams of individuals captured in the Middle Creek study area. Diagrams show distances in metres. End refers to the end of traceable dye and no recaptured individual



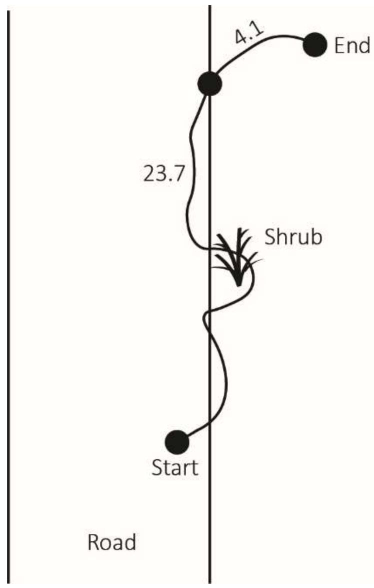


ID: an058-20
Tracking Date: July 07, 2020

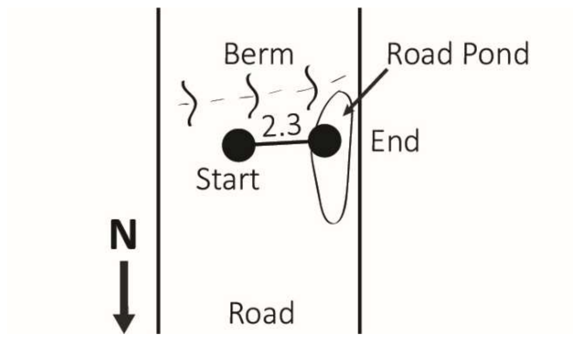
ID: an062-20
Tracking Date: July 09, 2020

Total Distance: 25.27m

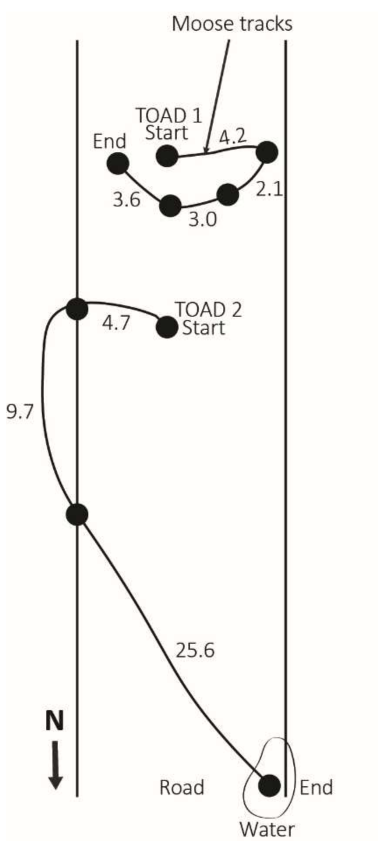
Total Distance: 56.2m



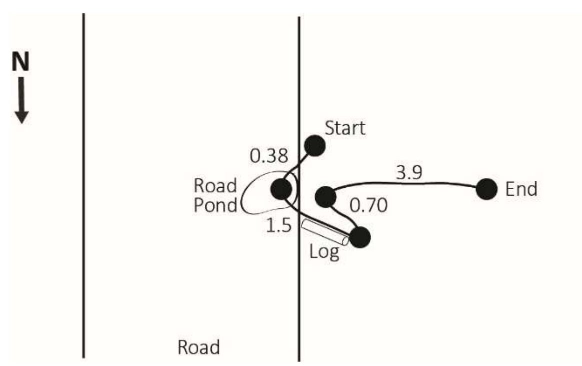
ID: an065-20
Tracking Date: July 09, 2020
Total Distance: 27.8m



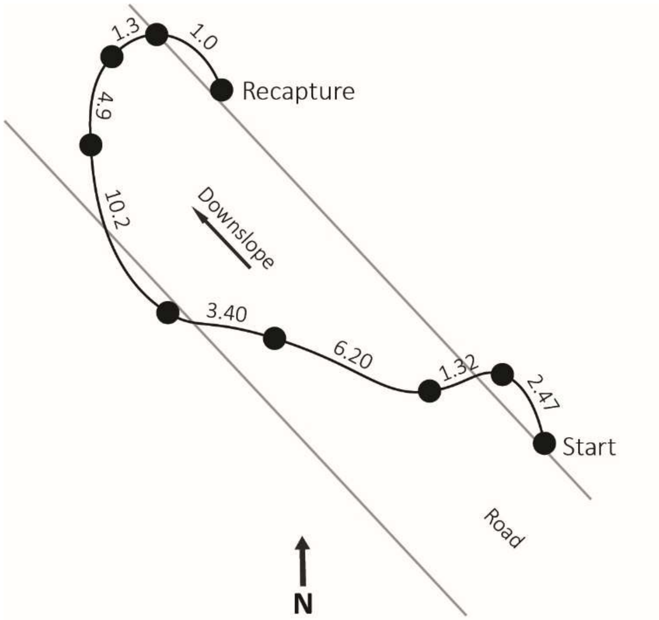
ID: an074-20
Tracking Date: July 09, 2020
Total Distance: 2.3m



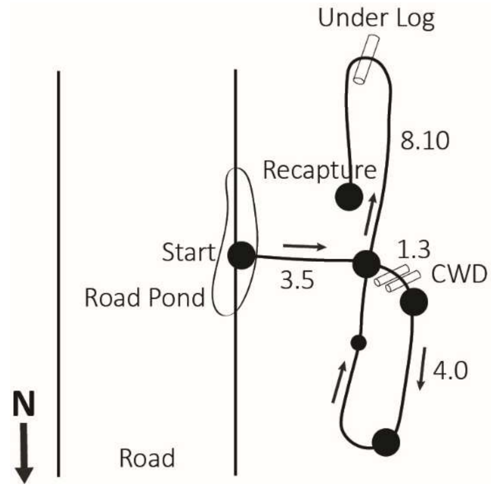
ID: an078-20 (Toad 1), an079-20 (Toad 2)
Tracking Date: July 10-11, 2020
Total Distance: 12.9m (Toad 1) and 40m (Toad 2)



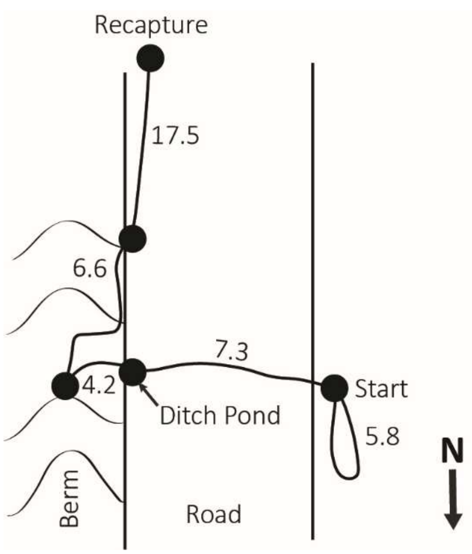
ID: an152-20
Tracking Date: Aug 25, 2020
Total Distance: 6.48m



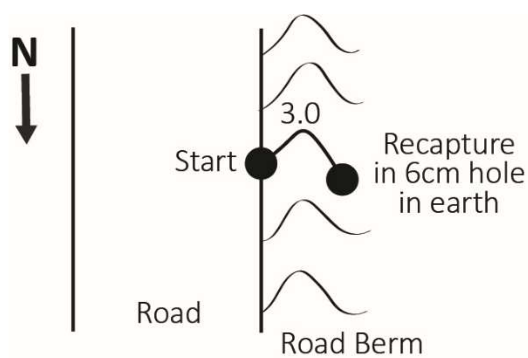
ID: an177-20
Tracking date: Aug 26, 2020
Total Distance: 30.79m



ID: an192-20
Tracking Date: Aug 28, 2020
Total Distance: 16.9m



ID: an198-20
Tracking Date: Aug 28, 2020
Total Distance: 41.4m



ID: an202-20
Tracking Date: Aug 28, 2020
Total Distance: 3m

Figure D-4. Dye tracking diagrams of individuals captured in the Webberly Lake study area. Diagrams unavailable for an002-20 and an003-20. Diagrams show distances in metres. End refers to the end of traceable dye and no recaptured individual