Columbia River Project Water Use Plan

Arrow Lakes Reservoir Operations Management Plan

Amphibian and Reptile Life History

Implementation Year 6

Reference: CLBMON-37

Kinbasket and Arrow Lakes Reservoirs: Amphibian and Reptile Life History and Habitat Use Assessment

Study Period: 2016

Okanagan Nation Alliance, Westbank, BC

and

LGL Limited environmental research associates
Sidney, BC

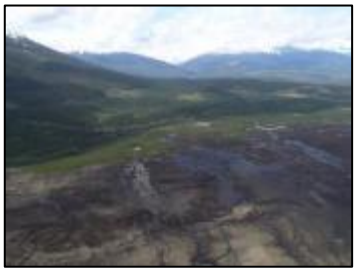
May 14, 2017

EA3533D

KINBASKET AND ARROW LAKES RESERVOIRS

Monitoring Program No. CLBMON-37
Kinbasket and Arrow Lakes Reservoirs: Amphibian and Reptile Life History and Habitat Use Assessment






Final Report 2016

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Cover photos:

From left to right: Columbia Spotted Frog (*Rana luteiventris*), Western Toad tadpoles (*Anaxyrus boreas*); Valemount Peatland © Virgil C. Hawkes, LGL Limited; and Long-toed Salamander (*Ambystoma macrodactylum*) © Krysia Tuttle, LGL Limited.

EXECUTIVE SUMMARY

This year marked the sixth year of CLBMON-37, which is part of a larger 10-year amphibian and reptile life history and habitat use monitoring study in the drawdown zones (DDZs) of Kinbasket and Arrow Lakes Reservoirs (i.e., CLBMON-37). Initiated in 2008, this study is intended to address the relative influence and importance of the current reservoir operating regime (i.e., timing, duration and depth of inundation) on the life history (e.g., abundance, distribution and productivity) and habitat use of amphibians and reptiles occurring in the DDZs of each reservoir. In 2011, an additional study CLBMON-58 was incorporated to specifically address the potential impacts of the installation of Units 5 and 6 at Mica Dam on amphibian and reptile populations in Kinbasket Reservoir. Ten management questions are investigated in this study, with the primary objective being to provide information on how amphibian and reptile communities at the landscape scale are affected by long-term variations in water levels and whether changes to the reservoir's operating regime may be required to maintain or enhance these communities or the habitats in which they occur.

In 2016, through a variety of survey methods (egg mass surveys, visual encounter surveys, auditory surveys, radiotelemetry), we documented the presence of four species of amphibian and five species of reptile in the drawdown zone of Kinbasket and Arrow Lakes Reservoirs. Species documented in Kinbasket included Western Toad (*Anaxyrus boreas),* Columbia Spotted Grog (*Rana luteiventris*) and Western Terrestrial Garter Snake (*Thamnophis sirtalis*). The Long-toed Salamander (*Ambystoma macrodactylumI)* and Western Painted Turtle (*Chrysemys picta*) were not detected in 2016 (but were in 2015). Western Painted Turtle has been detected from only one location in the drawdown zone (at the KM88 study location in 2015). A Western Painted Turtle was outside of the town of Valemount in 2016, the first record of this species in the region. Although the location of the observations was > 4km away from Kinbasket Reservoir, this detection taken with that of 2015 raises questions about the known distribution of Western Painted Turtle in the region. Species documented in the drawdown zone of Arrow Lakes Reservoir include Western Toad, Columbia Spotted Frog, Pacific Chorus Frog, Western Terrestrial Garter Snake, Common Garter Snake (*T.* elegans), Western Painted Turtle, Northern Alligator Lizard (*Elgaria coerulea*), and Western Skink (*Plestiodon skiltonianus*).

In Kinbasket, Western Toad and Columbia Spotted Frog were the most commonly encountered species, usually in wetlands within wool-grass–Pennsylvania buttercup, Kellogg's sedge or willow-sedge habitats. Pond characteristics varied by species with Columbia Spotted Frog using ponds situated at higher elevation and with a higher abundance and per cent cover of aquatic macrophytes compared to Western Toad. Western Toad breed in ponds as low as 734 m ASL in ponds that are typically devoid of vegetation or woody debris. It appears that the water physicochemical parameters measured (dissolved oxygen, conductivity, pH, temperature) do not affect distribution, occurrence or development of either species. In Arrow Lakes, Western Toad and both species of garter snake were the most commonly detected species; these species all use a wide variety of habitats and occur at overlapping elevations (434 to 440 m ASL).

Most amphibian and reptile detections were distributed within an elevation range of 744 to 754 m ASL for Kinbasket Reservoir and 435 to 445 m ASL for Arrow Lakes Reservoir. The influence of reservoir operations on the availability of habitat

in the DDZ was evident; as reservoir elevations increased, the amount of available habitat decreased and the changes in habitat availability was similar in both reservoirs in 2016. In Kinbasket, a subtle difference in reservoir operations was observed, with a decrease in available habitat earlier in June and subsequent lower reservoir levels through August and September, thus more habitat was available during the late season period than in 2010, 2012, and 2014. In 2016 in Arrow Lakes, it was a slightly different year for reservoir operations with reservoir levels reaching an early peak in June and subsequent decrease, which led to increased available habitat in the late summer and fall as compared to 2012 and 2014. Although more habitat was available later in the season, this did not necessarily benefit amphibians as the crucial period for successful breeding is in June when reservoir levels were high (i.e., breeding habitat was inundated). The continued presence of amphibians and reptiles of all life stages in the drawdown zone in consecutive years suggests that these species are not adversely affected by reservoir operations. However, we do not know if populations of these species are affected relative to non-reservoir populations, and we won't know that unless suitable non-reservoir populations are studied.

Radiotelemetry was used in 2016 to determine how Common Garter Snakes use habitats in the drawdown zone and the locations of any overwintering sites in the Valemount Peatland area of Kinbasket Reservoir. The results obtained suggest that Common Garter Snakes use marsh areas within the drawdown zone for summer foraging and thermoregulation and then move into upland habitats for overwintering during September. Data obtained from Common Garter Snakes indicate that there are core areas of use that correspond to locations associated with high densities of amphibians (e.g., Pond 12). More data are required to better assess seasonal habitat use by garter snakes in the drawdown zone of Kinbasket Reservoir.

Because CLBMON-37 was constrained to the drawdown zones of Kinbasket and Arrow Lakes Reservoirs, it is not possible to determine if non-drawdown zone habitats support a similar fauna in similar numbers. What is known, is that all life stages of all expected species of amphibians and reptiles use habitats in the drawdown zone of both reservoirs, which provides an indication of the value of these habitats to the herpetofauna of the region.

The following recommendations, if implemented, will help to answer management questions associated with CLBMON-37:

1. A short term (one season: spring to fall) radio-telemetry study of garter snakes in Arrow Lakes Reservoir would confirm if either species is using the drawdown zone to over-winter;
2. Conduct a hoop-trapping session at Bush Arm KM88 in the spring for 3 to 4 days to sample for Western Painted Turtle;
3. The inundation of elevations between ~735 and 754 m ASL in Kinbasket Reservoir should occur on or as close to the end of the summer (similar to the dates for the period 1978 to 2016 or around 25 August) as possible. This will ensure that amphibians and reptiles using the drawdown zone, particularly those in ponds >751 m ASL, will have enough time to forage for the winter and/or develop through to metamorphosis prior to inundation;
4. Climate change may confound future assessments regarding how reservoir operations affect the distribution and habitat use of amphibians and reptiles in the

drawdown zone of Kinbasket Reservoir. Climate change models relevant to the study area should be reviewed to determine the extent to which climate change might influence the water resources of the drawdown zone, which in turn could affect populations of amphibians and reptiles; and

5. The large deposits of wood debris at Pond 12 (Valemount Peatland) and from the north end of the Bush Arm Causeway (Kinbasket Reservoir) should be considered for removal. These large deposits of wood debris have negatively impacted these areas either through reduced habitat availability or complete exclusion.

The status of CLBMON-37 after Year 6 (2016) with respect to the management questions and management hypotheses is summarized below.

Management Question (MQ)	Able to Address MQ?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
MQ1: Which species of amphibians and reptiles occur (utilize habitat) within the drawdown zone and where do they occur?	Yes	Data collected since 2008 have likely resulted in the documentation of all expected species in the drawdown zone	• None	• Natural annual population variation • Inconspicuous species • Variable reservoir operations
MQ2: What is the abundance, diversity, and productivity (reproduction) of amphibians and reptiles utilizing the drawdown zone and how do these vary within and between years?	Mostly	6 years of site occupancy and detection rates data. Productivity indirectly estimated for some species	• Annual sampling • Intensive productivity data collection for Western Toad and Columbia Spotted Frog	• Natural annual population variation • Inconspicuous species • Mortality difficult to assess • Variable reservoir operations
MQ3: During what portion of their life history (e.g., breeding, foraging, and over-wintering) do amphibians and reptiles utilize the drawdown zone?	Yes	6 years of site occupancy data across multiple sites and seasons; telemetry studies (2015 and 2016)	• None	• Natural annual population variation • Inconspicuous species •
MQ4: Which habitats do amphibians and reptiles use in the drawdown zone and what are their characteristics (e.g., pond size, water depth, water quality, vegetation, elevation band)?	Mostly	6 years of macro and micro habitat data collection; pond and wetland mapping; data from other monitoring programs	• None	• Certain habitats are impacted directly and indirectly by annually by reservoir operations (e.g., deposition of wood debris on wetlands, effects of scour caused by floating wood, habitat erosion, sedimentation), but the effects on amphibians and reptiles and their habitats has not been been studied
MQ5: How do reservoir operations influence or impact amphibians and reptiles directly (e.g., desiccation, inundation, predation) or indirectly through habitat changes?	Mostly	6 years of data collected on the occurrence and distribution of amphibians and reptiles in the drawdown zone	• None	• Natural annual population variation • Variable reservoir operations • Species-specific habitat characteristics are impacted annually by reservoir operations, wood debris, erosion, sedimentation, so habitat characteristics will change from year to year

Management Question (MQ)	Able to Address MQ?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
MQ6: Can minor adjustments be made to reservoir operations to minimize the impact on amphibians and reptiles?	Yes	Longer-term species data (occupancy, presence, distribution)	• None, but see sources of uncertainty	• Variable reservoir operations • Lack of controlled experimentation to assess how varying the time of inundation correlates to the use of the drawdown zone by amphibians and reptiles. It is not possible to manipulate when the reservoirs exceed a given elevation or for how long. • It is not clear what constitutes a minor adjustment. Given the variable nature of reservoir operations, a more informed answer to this question would require understanding how a minor adjustment affects the various types of reservoir operation.
MQ7: Can physical works projects be designed to mitigate adverse impacts on amphibians and reptiles resulting from reservoir operations?	Yes (Kinbasket) and probably for Arrow	Evidence of use of wetlands cleared of wood debris in Kinbasket Reservoir. No data for Arrow Lakes Reservoir.	• Additional assessments of physical works in Kinbasket. • Pre- and post-physical works monitoring in Arrow Lakes Reservoir	• Kinbasket Reservoir was not filled completely in 2016. As such, the ponds that were cleared of wood debris and the mounds that were created were not inundated so the integrity of the mounds following inundation has not been tested. • Physical works have not been implemented in Arrow Lakes Reservoir.
MQ8: Does revegetating the drawdown zone affect the availability and use of habitat by amphibians and reptiles?	No	N/A	• Design physical works and revegetation prescriptions that would benefit amphibians and reptiles.	• Wetland-related plants would need to be planted to benefit amphibians and reptiles. Work is not applicable to this study.
MQ9: Do physical works projects implemented during the course of this monitoring program increase amphibian and reptile abundance, diversity, or productivity?	Kinbasket: Possible for Productivity; no for abundance and diversity. Arrow Lakes Reservoir: uncertain for all.	Same as MQ7	• Additional assessments of physical works in Kinbasket. • Pre- and post-physical works monitoring in Arrow Lakes Reservoir	• Physical works have not been implemented in Arrow Lakes Reservoir. • Limited scope of physical works in Kinbasket. Results to date are site-specific (i.e., can't infer results to entire reservoir).

Key Words: amphibian, reptile, life history, habitat use, reservoir elevation, drawdown zone, Kinbasket Reservoir, Arrow Lakes Reservoir

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1.0 INTRODUCTION

Dams regulate the flow regime in most of the world's large river systems, and the flooding resulting from dam construction and water storage creates a complex disturbance that can modify entire ecosystems (Nilsson and Berggren 2004; Eskew et al. 2012). These impacts are not restricted to the direct flooding and loss of riparian and wetland habitats upstream of dams, but also extend downstream of dams through disturbance of annual flooding regimes needed to maintain the health of floodplain environments (MacKenzie and Shaw 2000; Nilsson and Berggren 2004; Kupferberg et al. 2011; Eskew et al. 2012). To date, most studies of the effects of impoundment have focused primarily on the instream and riparian effects on fish and wildlife downstream of dams (e.g., Burt and Munde 1986; Hayes and Jennings 1986; Kupferberg 1996; Ligon et al. 1995; Lind et al. 1996; Wright and Guimond 2003; Nilsson et al. 2005; García et al. 2011). The need to understand the operational aspects of reservoir effects upstream of dams on wildlife and their habitat remains high (Brandão and Araújo 2008; Eskew et al. 2012), and that is the focus of this study.

Most major rivers in British Columbia have been dammed, and such hydroelectric developments have had numerous negative impacts on wetland ecosystems throughout the province (Hawkes 2005). This is particularly true for the Columbia River in southeastern B.C., which has been extensively altered by dams built for flood control and hydroelectric power production in both Canada and the United States. There are 14 dams on the Columbia River, three of which are in B.C. (Mica, Revelstoke, and Hugh Keenleyside); the remainder are in the U.S. Kinbasket Reservoir was created when the Columbia River was impounded by Mica Dam in 1973. Mica Dam was built under the Columbia River Treaty to provide water storage for power generation and flood control. The creation of Kinbasket Reservoir flooded ~42,650 ha resulting in the loss or alteration of eight broad habitat types (lakes: 2,343 ha; rivers: 4,897 ha; streams: 192 ha; shallow ponds: 555 ha; gravel bars: 236 ha; wetlands: 5,863 ha; floodplain [riparian]: 15,527 ha; and upland forest: 13,036 ha; Utzig and Schmidt 2011). Arrow Lakes Reservoir was created when the Columbia River was impounded by the Hugh Keenleyside Dam in 1968 for flood control. Prior to this, the Arrow Lakes consisted of two smaller water bodies separated by a 32 km section of the Columbia River. The 240 km reservoir extends north to Revelstoke Dam and includes the Revelstoke Reach and Beaton Arm sections of the Columbia River drainage. The creation of Arrow Lakes Reservoir flooded ~51,270 ha resulting in the loss or alteration of eight broad habitat types (lakes: 34,992 ha; rivers: 2,022 ha; streams: 51 ha; shallow ponds: 103 ha; gravel bars: 3,623 ha; wetlands: 3,432 ha; floodplain [riparian]: 3,564 ha; and upland forest: 3,844 ha; Utzig and Schmidt 2011).

During the Columbia River Water Use Planning process (WUP), the Consultative Committee expressed concerns about potential impacts of the operations of the Kinbasket and Arrow Lakes Reservoirs on wildlife and vegetation, including amphibians and reptiles. However, a lack of information on the abundance, distribution, life history and habitat use of these animals made it difficult to assess the impact of current operations and operating alternatives on them. In 2008, BC Hydro initiated a long-term monitoring program (CLBMON-37) to assess the life history and habitat use of amphibian and reptile populations in the Arrow Lakes and Kinbasket Reservoirs of the Columbia Basin. In 2011, an additional monitoring study (CLBMON-58) was initiated to assess whether the incremental increase in

reservoir levels impact amphibian or reptile populations in Kinbasket Reservoir (Hawkes and Tuttle 2012). Monitoring populations of amphibians and reptiles in the drawdown zone will provide the necessary information to address management questions related to (1) their life history and habitat use, (2) the effects of reservoir operations on those populations, and (3) the potential to mitigate those impacts by using physical works (as per CLBMON-37).

This report summarizes the findings of Year 6 (2016) monitoring surveys for BC Hydro's Monitoring Program CLBMON-37: *Kinbasket and Arrow Lakes Reservoirs: Amphibian and Reptile Life History and Habitat Use Assessment*. Data collected from 2008 to 2016 are used to assess whether any trends are apparent in the data.

1.1 Study Species

Of the 16 species of amphibians and reptiles that occur in the Columbia Basin, eight species of amphibians and six species of reptiles potentially occur along the impounded waters of the Columbia River (Table 1-1). In 2015, a Pacific Chorus Frog (*Pseudacris regilla*) was heard calling in Canoe Reach, but the presence of this species has not been verified. One species of amphibian is considered to be at risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC): the Western Toad is currently (November 2012) listed as Special Concern. The Intermountain–Rocky Mountain Population of the Western Painted Turtle is blue-listed in British Columbia and is a SARA Schedule 1 species of Special Concern. One individual of this species was documented in 2015 using the drawdown zone of Kinbasket Reservoir at the mouth of the Bush Arm River (KM88), and in 2016 one individual was found crossing a road near Valemount BC, north of the Valemount Peatland, Kinbasket Reservoir.

Table 1-1: Provincial and federal status of species of amphibians and reptiles that occur in the Columbia Basin. Species names in bold are known to occur in the drawdown zone of Kinbasket and Arrow Lakes Reservoirs

Group and Species	Species Code	Region	Status†	
			CDC	COSEWIC*
AMPHIBIANS				
Northern Leopard Frog (*Lithobates pipiens*)	A-LIPI	KIN	R	E
Columbia Spotted Frog (*Rana luteiventris*)	**A-RALU**	KIN/ARR	Y	
Wood Frog (*Lithobates sylvatica*)	A-LISY	KIN	Y	
Pacific Chorus Frog (*Pseudacris regilla*)	**A-PSRE**	ARR	Y	
Western Toad (*Anaxyrus boreas*)	**A-ANBO**	KIN/ARR	Y	SC
Long-toed Salamander (*Ambystoma macrodactylum*)	**A-AMMA**	KIN/ARR	Y	
Coeur d'Alène Salamander (*Plethodon idahoensis*)	A-PLID	ARR	Y	SC
Rocky Mountain Tailed Frog (*Ascaphus montanus*)	A-ASMO	N/A	R	
REPTILES				
Western Painted Turtle (*Chrysemys picta*)	**R-CHPI**	ARR	B	SC
Western Terrestrial Garter Snake (*Thamnophis elegans*)	**R-THEL**	KIN/ARR	Y	
Common Garter Snake (*T. sirtalis*)	**R-THIS**	KIN/ARR	Y	
Rubber Boa (*Charina bottae*)	**R-CHBO**	ARR	Y	SC
Racer (*Coluber constrictor*)	R-COCO	ARR	B	SC
Pacific Northern Rattlesnake (*Crotalus oreganus*)	R-CROR	ARR	B	T
Western Skink (*Plestiodon skiltonianus*)	**R-EUSK**	ARR	B	SC
Northern Alligator Lizard (*Elgaria coerulea*)	**R-ELCO**	ARR	Y	

†Status: CDC = British Columbia Conservation Data Centre: B = blue-listed; Y = yellow-listed; *COSEWIC = Committee on the Status of Endangered Wildlife in Canada/SARA Schedule: SC = Special Concern; E = endangered; T = threatened

2.0 STUDY OBJECTIVES

2.1 Study Design

In 2008, BC Hydro initiated a long-term monitoring program (CLBMON-37) to assess the life history and habitat use of amphibian and reptile populations in the Arrow Lakes and Kinbasket Reservoirs of the Columbia Basin. Monitoring populations of amphibians and reptiles in the drawdown zone will provide the necessary information to address management questions related to (1) their life history and habitat use, (2) the effects of reservoir operations on those populations, and (3) the potential to mitigate those impacts by using physical works (as per CLBMON-37). Monitoring efforts specific to Kinbasket Reservoir (as per CLBMON-58) will enable an assessment of the impacts of Mica Units 5 and 6 on amphibians using habitats in the drawdown zone of Kinbasket Reservoir. Table 2-1 summarizes the annual implementation schedule for CLMBON-37 and CLBMON-58 in Kinbasket Reservoir only.

Table 2-1: Monitoring years for CLBMON-37 and CLBMON-58 in Kinbasket and Arrow Lakes Reservoir (2007 to 2018). The current year is indicated in bold

Year	CLBMON-58	CLBMON-37	Reference
2008		Year 1	Hawkes and Tuttle 2009
2009		Year 2	Hawkes and Tuttle 2010a
2010		Year 3	Hawkes et al. 2011
2011	Year 1		Hawkes and Tuttle 2012
2012		Year 4	Hawkes and Tuttle 2013a, b

Year	CLBMON-58	CLBMON-37	Reference
2013	Year 2		Hawkes and Wood 2014
2014		Year 5	Hawkes et al. 2015
2015	Year 3		Hawkes and Tuttle 2016
2016		**Year 6**	**Annual report**
2017	Year 4		Annual report
2018*	Year 5	Year 7	Final comprehensive report

2.2 Management Questions and Hypotheses

In 2008, BC Hydro developed nine management questions (MQs) to determine the impacts of reservoir operations on amphibians and reptiles that use habitats in the drawdown zones of Kinbasket and Arrow Lakes Reservoirs (as per CLBMON-37). In 2011, a tenth management question asked how the installation of Mica Units 5 and 6 would affect amphibian populations in the drawdown zone of Kinbasket Reservoir. The ten MQs are grouped into four broad themes, the first nine are considered under CLBMON-37 with MQ10 considered under CLBMON-58:

CLBMON-37/58 – Theme 1: Life History and Habitat Use

MQ1: Which species of amphibians and reptiles occur (utilize habitat) within the drawdown zone and where do they occur?

MQ2: What is the abundance, diversity, and productivity (reproduction) of amphibians and reptiles utilizing the drawdown zone and how do these vary within and between years?

MQ3: During what portion of their life history (e.g., breeding, foraging, and over-wintering) do amphibians and reptiles utilize the drawdown zone?

MQ4: Which habitats do amphibians and reptiles use in the drawdown zone and what are their characteristics (e.g., pond size, water depth, water quality, vegetation, elevation band)?

CLBMON-37/58 – Theme 2: Reservoir Operations and Habitat Change

MQ5: How do reservoir operations influence or impact amphibians and reptiles directly (e.g., desiccation, inundation, predation) or indirectly through habitat changes?

MQ6: Can minor adjustments be made to reservoir operations to minimize the impact on amphibians and reptiles?

CLBMON-37/58 – Theme 3: Physical Works

MQ7: Can physical works projects be designed to mitigate adverse impacts on amphibians and reptiles resulting from reservoir operations?

MQ8: Does revegetating the drawdown zone affect the availability and use of habitat by amphibians and reptiles?

MQ9: Do physical works projects implemented during the course of this monitoring program increase amphibian and reptile abundance, diversity, or productivity?

CLBMON-58 – Theme 4: Effects of Mica Units 5 and 6

MQ10: Do increased reservoir levels in Kinbasket Reservoir during the summer months resulting from the installation of Mica 5 and 6

negatively impact amphibian populations in the drawdown zone through increased larval mortality or delayed development?

Hypotheses were developed to address the four themes of management questions.

H_1 Annual and seasonal variation in water levels in Kinbasket and Arrow Lakes Reservoirs (due to reservoir operations), the implementation of soft operational constraints in Arrow Lakes Reservoir, and the effects of Units 5 and 6 in Mica Dam on Kinbasket Reservoir, do not directly or indirectly impact reptile and amphibian populations.

- H_{1A} Reservoir operations do not result in a decreased abundance of amphibians or reptiles in the drawdown zone.
- H_{1B} Reservoir operations do not increase the stage specific (e.g., larval, juvenile, or adult) mortality rates of amphibians or reptiles in the drawdown zone.
- H_{1C} Reservoir operations do not result in decreased site occupancy of amphibians or reptiles in the drawdown zone.
- H_{1D} Reservoir operations do not result in decreased productivity of amphibians or reptiles in the drawdown zone.
- H_{1E} Reservoir operations do not reduce the availability and quality of breeding habitat, foraging habitat and over-wintering habitat for amphibians or reptiles in the drawdown zone.

H_2 The physical works projects and revegetation efforts do not increase the utilization of habitats by amphibians or reptiles in the drawdown zone.

- H_{2A} Revegetation and physical works do not increase species diversity or seasonal (spring/summer/fall) abundance of amphibians or reptiles in the drawdown zone.
- H_{2B} Revegetation and physical works do not increase amphibian or reptile productivity in the drawdown zone.
- H_{2C} Revegetation does not increase the amount or improve habitat for amphibians and reptiles in the drawdown zone.

3.0 STUDY AREA

3.1 Physiography

The Columbia Basin in southeastern British Columbia is bordered by the Rocky, Selkirk, Columbia, and Monashee Mountains. The headwaters of the Columbia River begin at Columbia Lake in the Rocky Mountain Trench, and the river flows northwest along the trench for about 250 km before it empties into Kinbasket Reservoir behind Mica Dam (BC Hydro 2007). From Mica Dam, the river continues southward for about 130 km to Revelstoke Dam. The river then flows almost immediately into Arrow Lakes Reservoir behind Hugh Keenleyside Dam. The entire drainage area upstream of Hugh Keenleyside Dam is approximately 36,500 km^2.

The Columbia Basin is characterized by steep valley side slopes and short tributary streams that flow into Columbia River from all directions. The Columbia River valley floor elevation extends from approximately 800 m near Columbia Lake to 420 m near Castlegar. Approximately 40 per cent of the drainage area within the Columbia Basin

is above 2,000 m elevation. Permanent snowfields and glaciers predominate in the northern high mountain areas above 2,500 m elevation. About 10 per cent of the Columbia River drainage area above Mica Dam exceeds this elevation.

3.2 Climatology

Precipitation in the basin is produced by the flow of moist, low-pressure weather systems that move eastward through the region from the Pacific Ocean. More than two-thirds of the precipitation in the basin falls as winter snow. Snow packs often accumulate above 2,000 m elevation through the month of May and continue to contribute runoff long after the snow pack has melted at lower elevations. Summer snowmelt is reinforced by rain from frontal storm systems and local convective storms. Runoff begins to increase in April or May and usually peaks in June to early July, when approximately 45 per cent of the runoff occurs. The mean annual local inflow for the Mica, Revelstoke and Hugh Keenleyside projects is 577 m^3/s, 236 m^3/s and 355 m^3/s, respectively (BC Hydro 2007). Air temperatures across the basin tend to be more uniform than is precipitation. The summer climate is usually warm and dry, with the average daily maximum temperature for June and July ranging from 20 to 32°C.

3.3 Kinbasket Reservoir

Located in southeastern B.C., Kinbasket Reservoir is surrounded by the Rocky and Monashee Mountain ranges, and is approximately 216 km long. The Mica hydroelectric dam, located 135 km north of Revelstoke, B.C., spans the Columbia River and impounds Kinbasket Reservoir. The original Mica powerhouse, completed in 1973, has a generating capacity of 1,805 MW, and Kinbasket Reservoir has a licensed storage volume of 12 million acre feet (MAF; BC Hydro 2007). The addition of the new turbines at Mica Dam will increase the generating capacity of Kinbasket Reservoir by roughly 1,000 megawatts (BC Hydro, 2007). The normal operating range of the reservoir is between 707.41 m and 754.38 m elevation, but can be operated to 754.68 m ASL with approval from the Comptroller of Water Rights. The biogeoclimatic (BEC) zones that occur in the lower elevations of Kinbasket Reservoir are the Interior Cedar-Hemlock (ICH) zone and the Sub-Boreal Spruce (SBS) zone (Figure 3-1).

Specific habitats in the drawdown zone of Kinbasket Reservoir are sampled under CLBMON-37. These areas were selected because of the presence of wetlands and ponds in the drawdown zone and the use of those sites by reptiles and amphibians (e.g., breeding). Sites studied include habitats at the east end of Bush Arm (i.e., the Bush Arm Causeway), areas on the north side of Bush Arm including habitats at KM79 (i.e., ~79.5 km along Bush FSR) and KM88 (i.e., the mouth of Bush Arm, Bear Island), and sites in Canoe Reach in the Valemount Peatland and at Ptarmigan Creek (Figure 3-1; see Appendix 11-1 for maps of each study site).

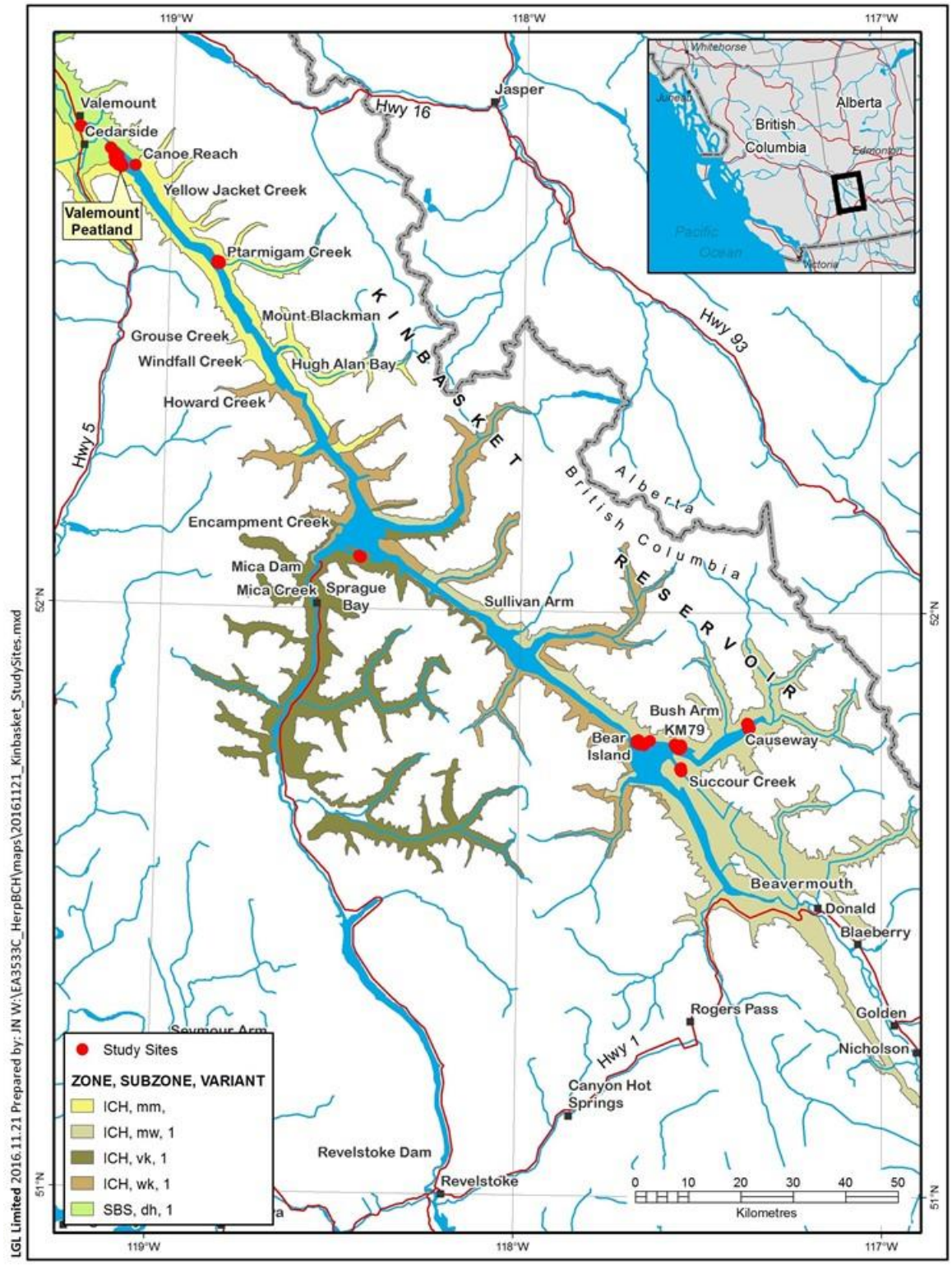

Figure 3-1: Location of Kinbasket Reservoir in British Columbia and locations sampled for CLBMON-37 in 2016. Naming of study sites follows Hawkes et al. (2007)

Kinbasket Reservoir fills in the spring and is typically full by the mid- to late-summer (Figure 3-2). Although there is some year to year variation, the general pattern is consistent.

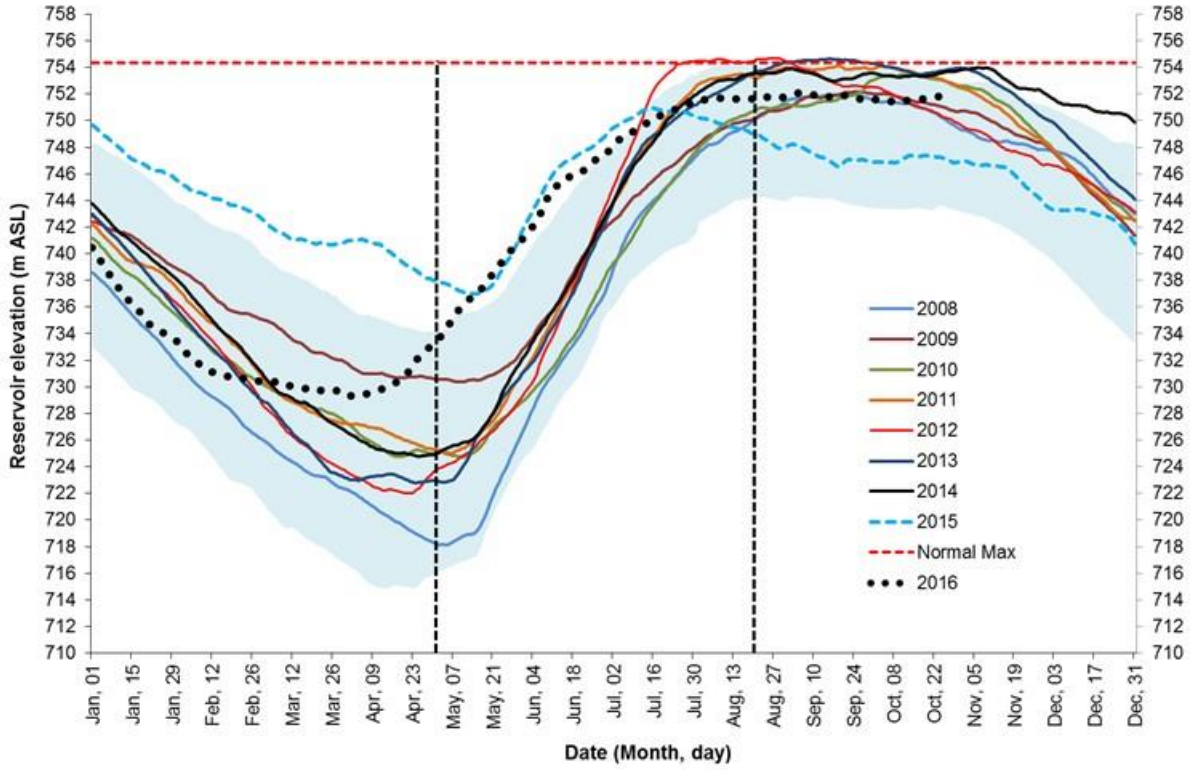

Figure 3-2: **Kinbasket Reservoir hydrograph for the period 2008 through October 25, 2016.** The shaded area represents the 10th and 90th percentile for the period 1976 to October 25, 2016; the dashed red line is the normal operating maximum. Vertical dashed lines indicated start and end dates of sampling in 2016.

3.4 Arrow Lakes Reservoir

Arrow Lakes Reservoir is an approximately 230 km long section of the Columbia River drainage between Revelstoke and Castlegar, BC (Figure 3-3). Two biogeoclimatic zones occur within the study area: the Interior Cedar Hemlock (ICH) and the Interior Douglas-fir (IDF). The reservoir has a north-south orientation and is located in the valley between the Monashee Mountains in the west and Selkirk Mountains in the east. The Hugh Keenleyside Dam, located 8 km west of Castlegar, spans the Columbia River and impounds Arrow Lakes Reservoir. Arrow Lakes Reservoir has a licensed storage volume of 7.1 MAF (BC Hydro 2007). The normal operating range of the reservoir is between 418.64 and 440.1 m elevation (Figure 3-4).

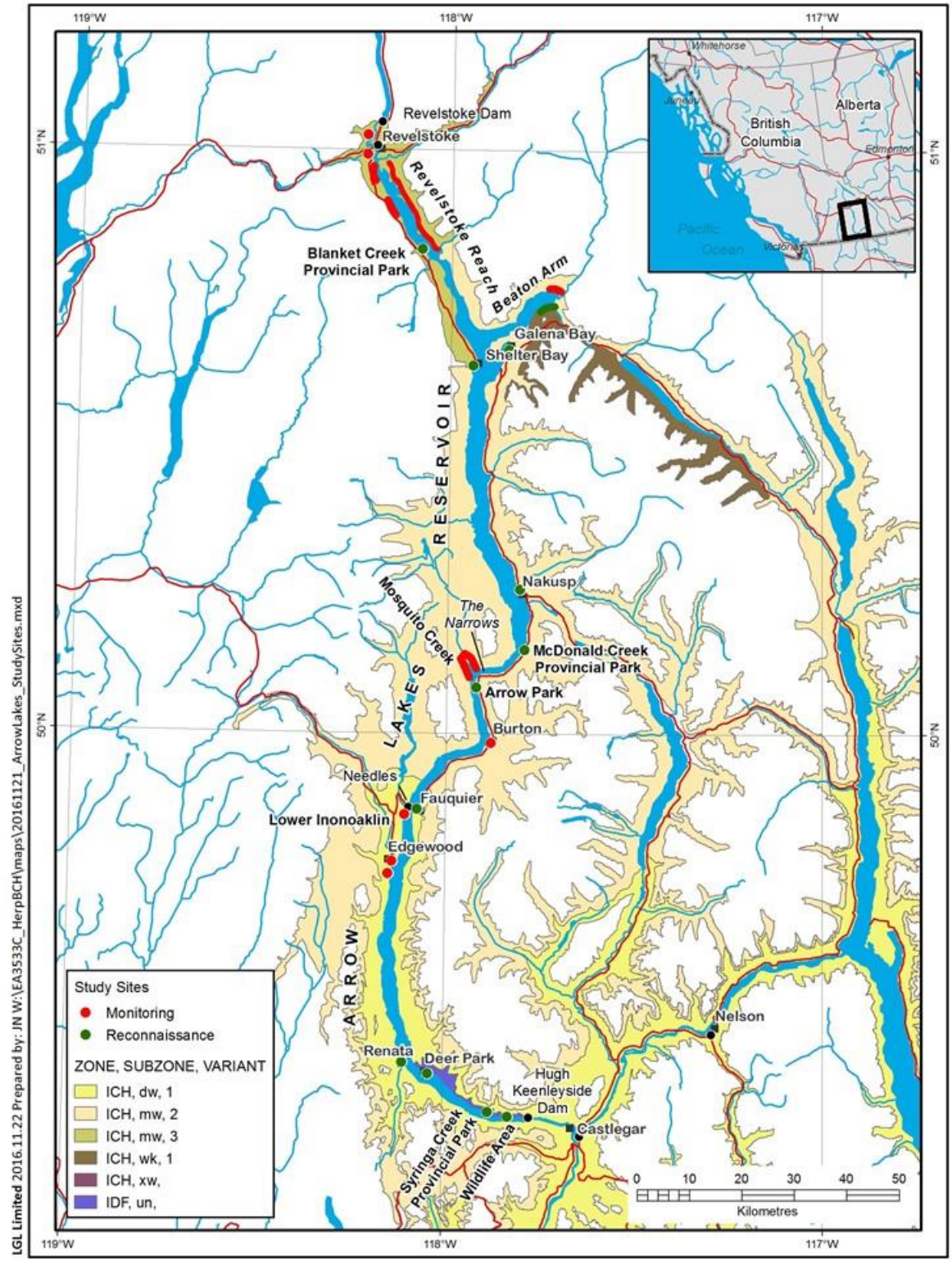

Figure 3-3: Location of Arrow Lakes Reservoir in British Columbia, and locations sampled for CLBMON-37 in 2016. Place names in bold are either monitoring sites or reference sites (see Hawkes and Tuttle 2013b)

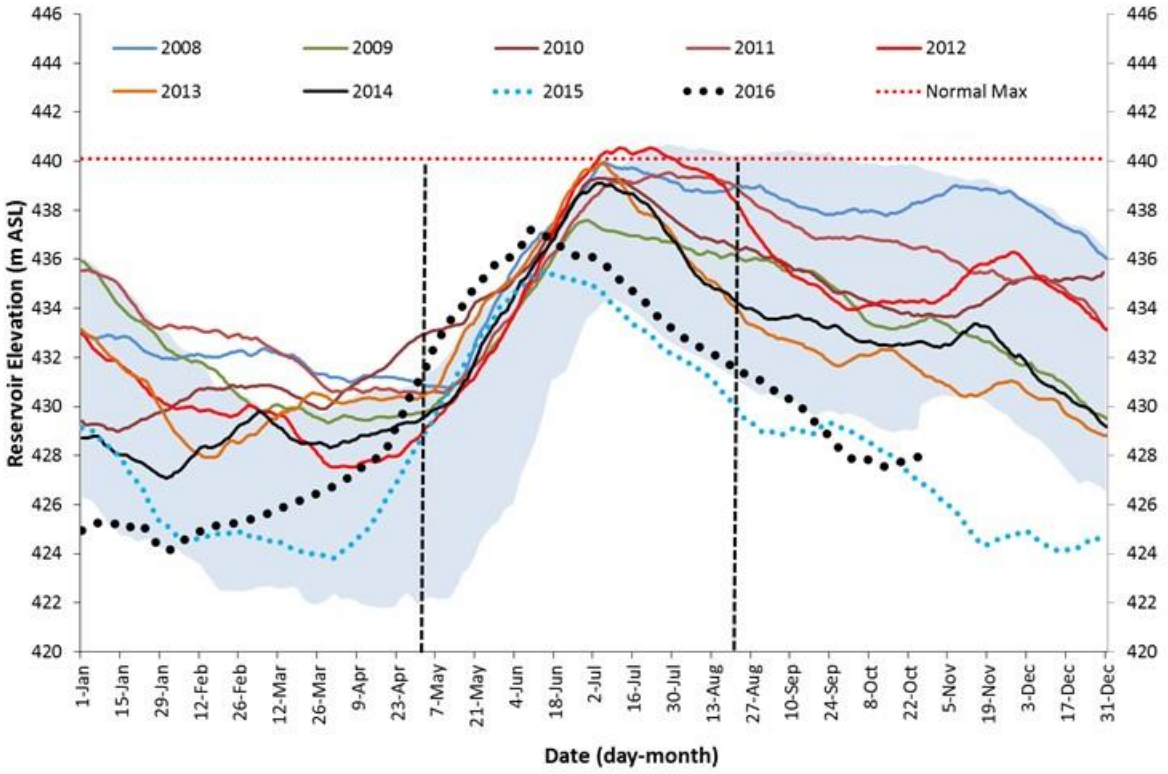

Figure 3-4: **Arrow Lakes Reservoir hydrograph for 2008 through October 25, 2016.** The shaded area represents the 10th and 90th percentile for the period 1969 to October 25, 2016; the dashed red line is the normal operating maximum. Vertical dashed lines indicated start and end dates of sampling in 2016

Fourteen sites within the DDZ of Arrow Lakes Reservoir were selected for monitoring to document the presence of amphibians and reptiles. The site selection process followed that of previous years and was closely tied to a typical 10 m change in elevation (430–440 m) as well as to areas associated with the proposed physical works within Revelstoke Reach (i.e., Cartier Bay). Sites studied include habitats at in Revelstoke Reach (e.g., Montana Slough, Cartier Bay, etc.), up Beaton Arm, and areas on the east and west sides of mid Arrow Lakes including habitats at Burton Creek and Edgewood (e.g., north site, south site, Lower Inonoaklin) (see Appendix 11-1 for maps of each study site).

4.0 METHODS

4.1 Field Schedule

In 2016, field sampling was conducted between May and August to coincide with the active period of amphibians and reptiles. Field sampling in Canoe Reach was more extensive due to UVic Master's of Science student (Jillian McAllister) continuing the radiotelemetry study in the Valemount Peatland. Sampling occurred weekly from May 1 to October 8. The 2016 field sampling schedule followed a similar timeline as that implemented in other years of this study to facilitate data comparison between years. Predicted reservoir levels obtained from BC Hydro were incorporated into field scheduling to determine how much of the DDZ would be available for sampling.

Table 4-1: Variation in reservoir elevation during each sample session in Kinbasket and Arrow Lakes Reservoir in 2016

Date			Kinbasket			Arrow Lakes		
Sample	Start	End	Min elev (m)	Max elev (m)	Change (m)	Min elev (m)	Max elev (m)	Change (m)
1	01-May-16	06-May-16	733.48	734.85	1.37	431.06	432.40	1.34
2	30-May-16	06-Jun-16	740.89	742.82	1.93	435.90	436.53	0.63
3	22-Jun-16	30-Jun-16	746.34	747.65	1.31	436.09	436.40	0.31
4	23-Jul-16	28-Jul-16	750.80	751.25	0.45	433.36	433.91	0.55
5	15-Aug-16	22-Aug-06	751.62	751.85	0.23	431.42	432.00	0.58

4.2 Permits

Work was conducted under Wildlife Act Permit MRCB16-225769, which is valid through March 31, 2017. This permit was amended in 2016 to permit the non-surgical application of transmitters to toads and the surgical application of transmitters to snakes.

4.3 Data Collection

4.3.1 General Survey Data

A variety of techniques (telemetry, auditory call surveys, egg mass surveys [EMS], larval surveys [LVS] and visual encounter surveys [VES]) were used to survey amphibians and reptiles (VES and telemetry only) in the DDZ of Kinbasket and Arrow Lakes Reservoirs in 2016. Of these methods, VES surveys were the most appropriate method to sample amphibians and reptiles of all life stages. Total survey time per person was recorded to calculate catch per unit effort time (i.e., detection rate) for each survey site, field session and species. Surveys for egg masses, tadpoles and larvae were conducted in the spring at various wetland sites, but are considered to be a subset survey type of VES and are reported with those results.

All previously mapped ponds and wetlands were surveyed in the Valemount Peatland, at Ptarmigan Creek, throughout Bush Arm (KM88, Causeway, and KM79), Revelstoke Reach, and mid to lower Arrow Lakes (Burton Creek, Lower Inonoaklin Road, Edgewood). Ponds were numbered at each site and were monitored during the active season (late April through August) to determine amphibian and reptile occupancy and use (provided access to the wetlands or ponds was not hindered by inundation from the reservoir or other access issues).

All amphibian and reptile observations and captures, including incidental observations, were georeferenced to associate each observation with a given wetland or pond, elevation, and vegetation community (as defined in Hawkes et al. 2007).

Annual differences in species richness (q), diversity (H) and evenness (J) were assessed. Species richness was defined as the number of species of amphibians and reptiles recorded in the drawdown zone. Diversity was computed as Shannon's entropy and corresponded to a measure of species composition, combining both the number of species and their relative abundances (Legendre and Legendre 1998). For each transect, diversity was computed as:

$$\sum_i p_i \log \frac{1}{p_i}.$$

where pi is the relative proportion of species i.

A value of 0 means that the sampling unit contains only one species; H then increases along with the number of species recorded in the sampling unit. A high value of H means that many species were recorded.

4.3.2 Species Morphometric Data

The Resources Inventory Standards Committee (RISC) protocols for sampling and handling of amphibians and reptiles (RISC 1998a, b) were followed. All captured animals were weighed and measured, and sex was determined when possible. The marking scheme used in previous years was continued in 2016 (e.g., photo identification for adult amphibians and subcaudal scute clipping in snakes).Most captured animals were photographed, and UTM coordinates were obtained for each observation.

Amphibian Morphometric Data—Snout-urostyle length (SUL) was measured using Vernier callipers to the nearest 0.1 mm. Mass (to the nearest 0.1 g) was obtained using Pesola spring scales. The sex of each animal was determined (where possible) based on longer tail and enlarged vent in male salamanders and presence of nuptial pads on forelimbs of male frog and toad species during the breeding season. Larval amphibians were staged according to the Gosner (1960) or Harrison (1969) indexing standards.

Reptile Morphometric Data—Snout-vent length (SVL [mm]), tail length (TL [mm]) were measured using foldable metric rulers (2 m) and mass (to the nearest 0.1 g) was obtained with a Pesola spring scale. Sex in snakes was determined by probing for the spaces that contain the male reproductive organs.

For a more detailed description of the methods used to sample amphibians and reptiles in 2016, refer to the CLBMON-37 Year 1 report (Hawkes and Tuttle 2009) and revised monitoring program sampling protocols (Hawkes and Tuttle 2012).

4.3.3 Habitat Data

Habitat data were collected in a standardized manner at all locations where amphibians were observed as well as at locations where they were not. Habitat data collected included characteristics at both the macro and micro scales. The vegetation community types (from CLBMON-10 and CLBMON-12/33) in which species were observed was determined by relating the species observation location to the vegetation polygon on a GIS map. For a detailed description of the methods used to sample habitat (micro and macro) in 2016, refer to the CLBMON-37 Year 1 report (Hawkes and Tuttle 2009) and revised monitoring program sampling protocols (Hawkes and Tuttle 2010b).

Water chemistry point data (dissolved oxygen in mg/L, conductivity in µs, temperature in °C, and pH) were collected at all pond and reservoir sampling locations at each study site. A YSI Pro2030 multi-function metre was used to measure dissolved oxygen, conductivity, and temperature. An Oakten waterproof pH Tester 30 was used to obtain pH data.

Water physicochemical dataloggers were deployed in selected wetlands in drawdown zone and upland habitats in Kinbasket and Arrow Lakes Reservoir (four in each reservoir) to record dissolved oxygen (mg/L; PME MiniDOT, Precision Measurement Engineering, Vista California), specific conductivity (µS/cm; ONSET HOBO U24), and water temperature (°C). Physicochemical data were sampled between May and October, although some dataloggers were not collected due to high reservoir levels. To assess the internal temperature of presumed garter snake hibernacula, HOBO UTBI-001 Tidbit v2 temperature data loggers were placed in suspected snake overwintering locations and in adjacent (and presumed) unused wintering habitat. Data collection began in September 2016 and the data loggers will be collected in spring 2017. HOBO tidbit dataloggers were also inserted into the ground in known Western Painted Turtle nesting locations and elsewhere in the drawdown zone of Revelstoke Reach (n=4 locations). Dataloggers were installed in late September 2016 and will be deployed through fall 2017.

Temporal habitat availability (i.e., the time of year when habitats are available and how long they are available) is likely to have a greater effect on amphibian and reptile populations than spatial habitat availability (i.e., the size of the habitat that may be used). This is particularly true for pond-breeding amphibians. This is based on an assessment of the distribution of amphibians and reptiles observed since 2008 and on our understanding of where important amphibian and reptile habitats occur in the drawdown zone of Kinbasket Reservoir. Temporal habitat availability was assessed based on the duration of the active season (i.e., the number of days between April 1 and September 30) during which the drawdown zone was available to amphibians and reptiles. This was accomplished by correlating reservoir elevation (in 1 m increments) to the number of days between April 1 and September 30 (n = 183) that each 1 m elevation band was exposed (i.e., not inundated) and therefore available for use.

4.3.4 Radiotelemetry

Radiotelemetry of Common Garter Snake continued in 2016 in the Valemount Peatland. Radio telemetry transmitters (Model SB-2, 5.0 g, Holohil Systems Ltd.) with whip antennas (approximately 15 cm) were surgically implanted in the peritoneal cavities of female snakes (n=10) by David Sedgman, D.V.M. or Janet Jones, D.V.M. Surgical procedures followed Reinert and Cundall (1982) while anaesthetic procedure followed isoflurane protocol developed by Thompson Rivers University. Transmitters weighed no more than 5 per cent of the mass of each snake (range: 0.9 to 3.7 per cent; average 2.1 per cent) as per Millspaugh and Marzluff (2001) and Jepsen et al. (2003). Snakes were monitored post-operatively for a minimum of 24 hours during which they were provided with water, cover, and a heat gradient in a ventilated enclosure. Special attention was given to the condition of the surgical site and behaviour of recovering snakes to ensure that they were prepared for release at their capture site. Snakes were located the day following release to confirm that they were behaving normally (i.e., moving adequately with appropriate thermoregulatory and defensive behaviours without any signs of pain or stress).

Telemetry sessions for snakes were conducted every few days between May and September 2016. The location of each animal on each visit was determined either visually, by getting to the closest assumed location without seeing the animal, or via triangulation. All snakes fitted with transmitters were tracked until they

remained in the same location for approximately one week, signalling that they had selected a site to overwinter.

4.4 Data Analysis

4.4.1 Site Occupancy

Monitoring amphibians can lead to biased population estimates and inaccurate interpretations of habitat relationships when imperfect detections of the species are not considered (Bailey et al. 2004; Mackenzie et al. 2006). Site occupancy modelling and probabilistic sampling are methods that help overcome this deficiency (Hansen et al. 2012). Site occupancy was assessed in two ways: (1) the presence of any life stage of a species at a survey site; and (2) the naïve occupancy rate (MacKenzie et al. 2006), or the proportion of mapped sites (ponds and wetlands nested within each survey site) in which a species was detected at least once in any year of study (i.e., 2011 to 2015).

4.4.2 Habitat Availability

Habitat availability was assessed through graphical presentation of total area available (i.e., habitats that have not been inundated yet) relative to use (breeding, foraging, and overwintering occurrences). Overwintering locations were determined by tracking snakes to upland habitats. When snakes did not move from an upland location for ≥ 7 consecutive days, the site was considered an over-wintering location. For each study location we created polygons to define the area searched and calculated the total area available relative to reservoir elevations based GIS and DEM (digital elevation models) and reservoir elevation data. Pearson's correlation coefficients were used to assess the associations between total available habitat, reservoir elevation and time of year (month) and linear regression was used to assess the relationships between reservoir elevation and the amount of foraging habitat available to amphibians and reptiles.

4.4.3 Habitat Associations

Habitat associations were assessed for Western Toad and Columbia Spotted Frog through graphical presentation of the distribution of pooled life stages of each species by vegetation community. Each area sampled was delineated as per above and the vegetation communities mapped for CLBMON-10 were correlated with species recorded in the drawdown zone. To account for annual differences in sampling effort, occurrence data (e.g., catch per unit effort) were used and standardized by species totals within each year.

4.4.4 Animal Movements

We examined the relationship between the daily movements of radio transmitter-tagged snakes by month and inundation period in the Valemount Peatland. Animal movement was expressed as the linear distance (in metres) between telemetry detections. Linear distance was calculated using the Pythagorean Theorem and UTM position of snake locations. The distance between telemetry locations was then standardized by the number of days between subsequent surveys to generate measures of distance traveled (m) per day. The home range of each transmittered snake was derived in a GIS from the utilization distribution of each tracked animal. The utilization distribution was calculated using a kernel density estimation using

a binormal kernel. It represents the probability (90% for this exercise) of finding the tracked animal inside its boundaries (Calenge 2006).

5.0 RESULTS

5.1 Kinbasket Reservoir

Our ability to observe possible effects of reservoir activity depends upon the availability of robust occurrence data (i.e., multiple confirmations of species identifications over multiple years), which for this study relates to Western Toad and Columbia Spotted Frog. In 2016, as part of the radiotelemetry component of the study, we also collected data from several Common Garter Snakes in the Valemount area.

5.1.1 Environmental Data

Weather conditions are known to affect the surface activity of amphibians. Thus, air temperature and precipitation were obtained from Environment Canada's Mica Dam weather station (11U: UTM_E: 391261 UTM_N: 5766272; 579.10 m ASL) to evaluate the influence of weather conditions on species detectability and measures of relative abundance (Figure 5-1). The level of variation in precipitation and temperature was not sufficient to affect surface activities of amphibians, and thus, is not likely to have influenced detectability measures (Olson 1999; Hawkes and Gregory 2012). Further, temperatures were within the range of conditions considered suitable for amphibian sampling (Olson 1999; Hawkes and Gregory 2012).

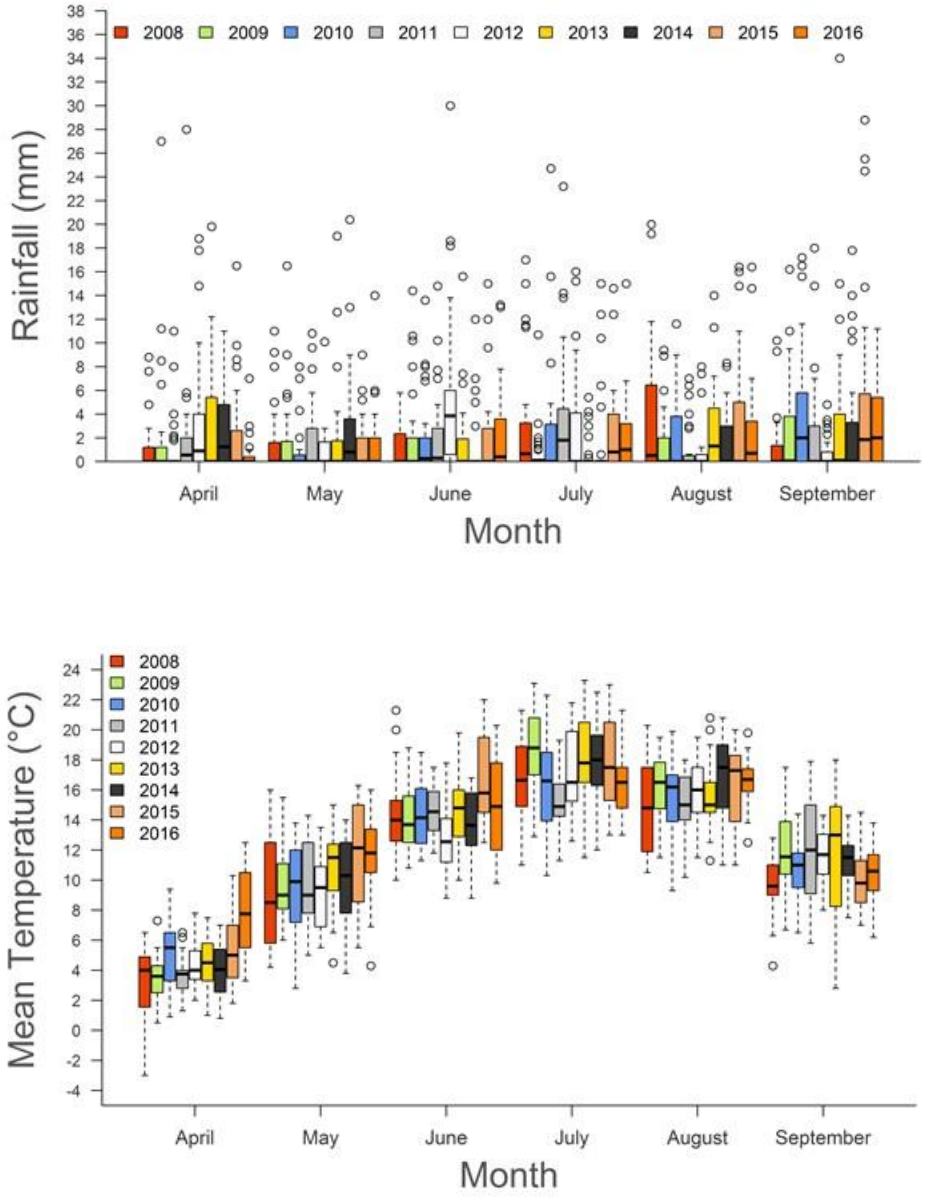

Figure 5-1: Daily precipitation (mm, above) and temperature (°C, below) for April through September, 2008 to 2016 as measured at Mica Dam. Data source: Environment Canada (http://climate.weather.gc.ca/index_e.html)

5.1.2 Water Physicochemical Data

Point data [Conductivity (µS/cm), Dissolved Oxygen (mg/L), pH, and Temperature (°C)] are summarized for all ponds and wetlands sampled and the detection/non-detection of amphibians recorded (Table 5-1). Water physical chemistry varied by location, but was similar regardless of amphibian presence. In general, water physical chemistry is believed to play a minor role in affecting the species richness of amphibians (e.g., Hecnar and M'Closkey 1996) and our data suggest that most values are characteristic of sites with relatively low dissolved oxygen, neutral pH,

low conductivity, and warm spring and summer temperatures; these conditions are not likely to influence the presence of amphibians in the drawdown zone of Kinbasket Reservoir.

Table 5-1: Summary of water physicochemistry data collected from pond and wetland habitats in which amphibians were either present or absent in the drawdown zone of Kinbasket Reservoir in 2016. Average and standard deviation values are provided, N = number of measurements from ponds/wetlands

Pond/Wetland Location		N	Conductivity		Dissolved Oxygen		pH		Temperature	
			Avg	SD	Avg	SD	Avg	SD	Avg	SD
Amphibian Detected	Bear Island	15	133.8	72.6	11.2	1.7	8.5	0.3	13.9	2.2
	Causeway	19	261.8	107.1	9.7	3.7	8.6	0.8	19.4	4.6
	KM 79	14	99.2	46.1	10.0	2.5	8.3	0.8	18.0	5.1
	KM 79 Perched Wetland	1	209.1	N/A	3.1	N/A	7.1	N/A	23.5	N/A
	Ptarmigan Creek	27	78.4	14.1	2.3	2.0	7.7	0.5	17.3	3.9
	Valemount Peatland	91	78.2	36.7	4.1	3.1	7.1	0.5	17.0	4.3
	Total	**167**	**106.7**	**78.0**	**5.6**	**4.2**	**7.6**	**0.8**	**17.2**	**4.4**
Amphibian Not Detected	Bear Island	16	255.4	99.3	9.9	2.4	8.3	0.4	15.6	3.5
	Causeway	12	243.0	110.1	9.5	4.6	8.4	0.7	21.9	4.5
	KM 79	9	102.2	39.2	9.5	2.8	8.2	1.0	17.8	4.6
	KM 79 Perched Wetland	1	182.2	N/A	2.0	N/A	7.4	N/A	16.2	N/A
	Ptarmigan Creek	6	79.7	17.0	3.3	2.8	7.9	0.3	16.6	3.8
	Valemount Peatland	231	68.6	35.7	4.3	2.7	6.8	0.5	16.1	4.0
	Total	**275**	**88.8**	**72.1**	**5.0**	**3.4**	**7.1**	**0.7**	**16.4**	**4.2**
Grand Total		**442**	**95.6**	**74.8**	**5.2**	**3.7**	**7.3**	**0.8**	**16.7**	**4.3**

In 2016 the maximum elevation for Kinbasket Reservoir was 752.85 m ASL, and therefore not all ponds monitored in the drawdown zone were inundated. A seasonal trend of decreasing dissolved oxygen observed throughout the study period was observed, with water becoming hypoxic (i.e., DO < 2.0 mg/L) late in the season (Figure 5-2). Dissolved oxygen and water temperature were measured from two locations in the drawdown zone in 2016. For ponds that were inundated at KM79, post-inundation conditions showed overall lower dissolved oxygen levels (Figure 5-3). Overall, pre- and post-inundation conditions in water temperature were similar, but with a seasonal trend of increasing temperatures peaking in late summer (near time of inundation) and subsequently decreasing. For ponds at the Bush Arm Causeway that did not get inundated in 2016, water temperatures showed a similar increase until late summer and dissolved oxygen levels remained fairly stable.

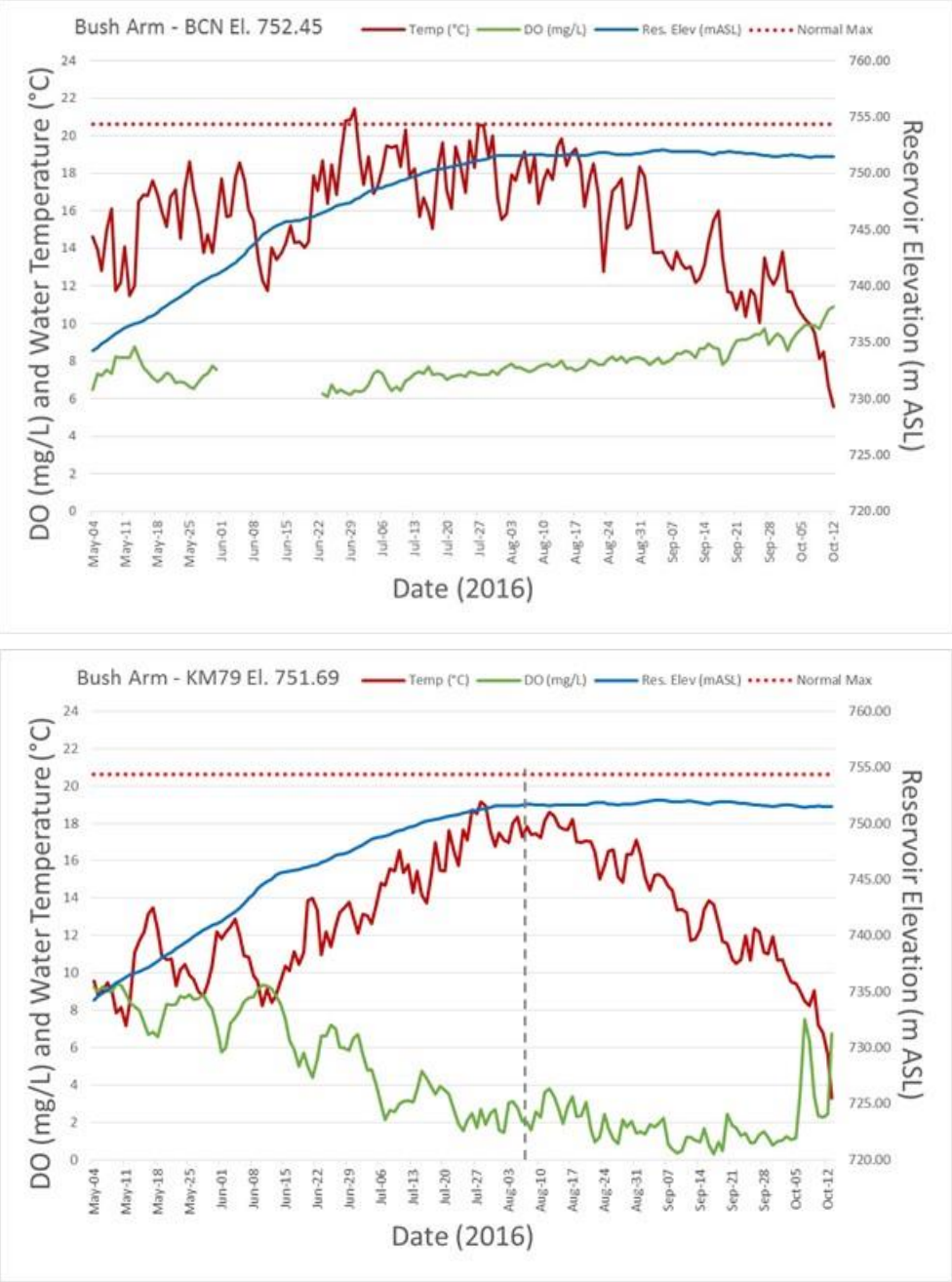

Figure 5-2: **Mean daily variation in dissolved oxygen (DO; mg/L) and water temperature (°C) relative to reservoir elevation (m ASL) for wetlands at two locations in the drawdown zone of Kinbasket Reservoir for 2016.** The dashed vertical line on the bottom panel represents the date of inundation. Missing DO data for BCN (top panel) represents a period when data logger was exposed.

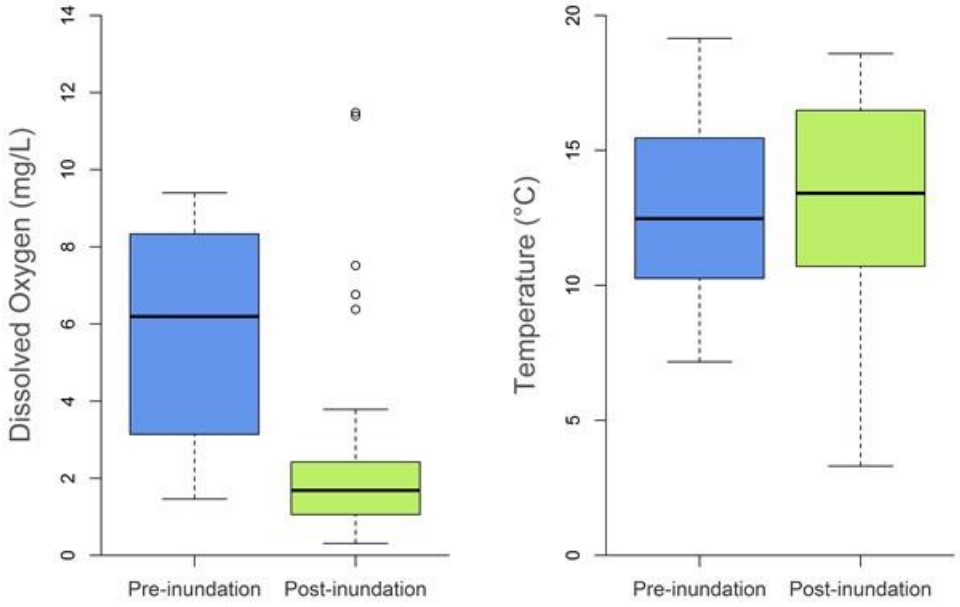

Figure 5-3: Differences in dissolved oxygen (DO; mg/L) and water temperature (°C) before and after reservoir inundation at KM79 in the drawdown zone of Kinbasket Reservoir in 2016

Based on the data presented above, environmental conditions would not have negatively influenced amphibian and reptile surface activity during field surveys. Although DO and water temperature at the depth of the data logger might influence developmental rates of amphibian larvae, tadpoles tend to congregate at the edges of ponds where both DO and water temperature would be higher. Collectively the environmental and water physicochemical conditions associated with field surveys are unlikely to have negatively influenced the species of amphibians and reptiles being studied. Any potential differences in species detectability are therefore unlikely to have been a result of environmental or water physicochemical conditions.

5.1.3 Species Occurrence and Distribution

Site Occupancy

At the landscape level, three species of amphibians and one species of reptile were observed in the DDZ of Kinbasket Reservoir in 2016 (Table 5-2). Two sites supported all three species of amphibians in 2016, the perched wetland at KM79 and Valemount Peatland. Western Toad and Columbia Spotted Frog occupied most of the sites surveyed in all years and accounted for most of the observations. Of the two garter snakes species documented, Common Garter Snake is more widely distributed than the Western Terrestrial Garter Snake with the former documented in multiple years in most survey locations. Mapped occurrences of all species observed in 2016 are included in Appendix 11-1.

Table 5-2: **Site occupancy (shaded cells) of amphibians and reptiles observed in the drawdown zone of Kinbasket Reservoir for 2008, 2009, 2010, 2012, 2014, and 2016.** A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-RALU = Columbia Spotted Frog, R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake. Blanks indicate species not detected in a given year and survey location

	A-AMMA						A-ANBO						A-RALU						R-THEL						R-THSI						No. of Species					
Survey Sites	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**
Bush Arm Bear Island																															2	1	3	3	3	3
Bush Arm Causeway																															3	2	5	4	2	3
Bush Arm KM79 (DDZ)																															3	4	4	2	3	3
Bush Arm KM79 (UPL)																																	2	1	2	3
Ptarmigan Creek																															4	3	3	2	3	3
Valemount Peatland																															4	4	4	4	4	4
Total Sites Occupied	**1**	**1**	**2**	**2**	**1**	**2**	**4**	**5**	**5**	**5**	**6**	**6**	**5**	**4**	**6**	**6**	**6**	**6**	**1**	**1**	**2**				**5**	**3**	**6**	**3**	**4**	**5**						

Detection Rate

Between May and August, ~491 hours of visual encounter surveys were conducted at monitoring sites within the DDZ of Kinbasket Reservoir, during which 418 detections of more than 309,242 individuals across multiple life stages of all species were made (Table 5-3). To assess species-by-site relationships, we pooled all life stages and examined species observations to identify sites where the detection of a given species was the highest regardless of age class. Aggregations of tadpoles (or metamorphs) were treated as a single observation per location or pond, so as not to skew numbers. We examined the detection rates for six areas in Kinbasket Reservoir of which Ptarmigan Creek, the Bush Arm Causeway, and Bush Arm KM79 had the highest rates of detections. Western Toad and Columbia Spotted Frog were the species with the highest detection rates.

Table 5-3: **Total survey effort (hours multiplied by number of surveyors) for visual encounter surveys and species detections by survey location for Kinbasket Reservoir in 2016.** Blanks indicate the species was not detected. A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-RALU = Columbia Spotted Frog, R-THSI = Common Garter Snake. CPUE (catch per unit effort) = the number of observations per site and per species divided by the survey effort

Survey Location	Effort (hrs)	A-AMMA	A-ANBO	A-RALU	R-THSI	Total	CPUE
Bear Island	28.3		24	3	1	28	**0.99**
Causeway	28.6		49	2	3	54	**1.89**
KM 79	28.2		20	25	2	47	**1.67**
KM 79 Perched Wetland	5.6	1	1	2		4	**0.72**
Ptarmigan Creek	24.3		46	7	5	58	**2.38**
Valemount Peatland	375.8		98	108	21	227	**0.60**
Totals: Effort (hrs); #obs	**490.8**	**1**	**238**	**147**	**32**	**418**	**0.85**
CPUE (#obs/hr)		**0.00**	**0.48**	**0.30**	**0.07**	**0.85**	

We examined the detection rates by species for six survey areas in Kinbasket Reservoir (Figure 5-4). Both Western Toad and Columbia Spotted Frog were detected at all sites, with Western Toad having a higher detection rate at all sites with the exception of the upland perched wetland at KM79. The Bush Arm Causeway had the overall highest detection rates for Western Toad. The lowest detection rates were associated with Long-toed Salamander, which was only found at the KM 79 perched wetland in 2016. Detection rates of Common Garter Snakes were also low rates compared to the other species, although they were detected at all sites except the perched wetland.

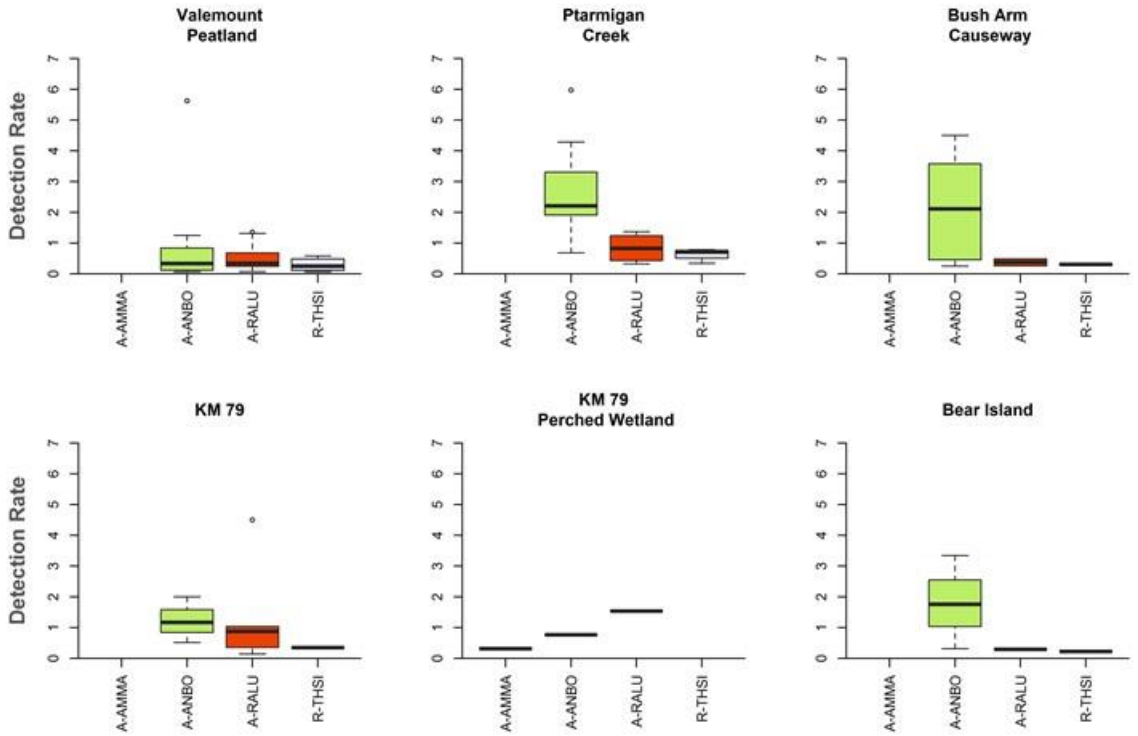

Figure 5-4: Detection rate for amphibian and reptile species in Kinbasket Reservoir in 2016. Detection rate = the number of times a species was detected (all life stages pooled)/the total time spent searching at a study site. A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-RALU = Columbia Spotted Frog, R-THSI = Common Garter Snake

Elevation

In 2016, amphibians and reptiles were found across a wide range of elevations the upper elevation bands of Kinbasket Reservoir (Figure 5-5). Most observations (all life stages combined) were between 749 and 754 m ASL, a trend observed in previous years (Figure 5-5). Western Toad detections spanned the widest range of elevations, while observations of Common Garter Snake spanned the narrowest range. Comparing across the years, Western Toad and Columbia Spotted Frog were distributed across an elevation range of 734 to 757 m ASL. The majority of observations of all species occurred between 748 and 754 m ASL, which is related to the distribution of wetlands in the drawdown zone (see Figure 5-6). However, Columbia Spotted Frog consistently used a narrower range of elevations (752 to 754 m ASL) than Western Toad (750 to 754 m ASL). Salamanders occupied only

the highest elevation ponds (752 to 754 m ASL), which may be related to the proximity of these ponds to upland forest where this species typically lives.

The distribution of snakes in Kinbasket Reservoir overlapped that of amphibians in most cases: Common and Western Terrestrial Garter Snake were typically found between 748 and 754 m ASL, with Common Garter Snakes detected in a greater range of elevations. Differences between the species could be due to habitat availability (e.g., habitats at higher elevations were available for longer periods than those at lower elevations), or animals could have preferentially selected habitats based on specific features (e.g., ponds that do not get inundated until later in the season, availability of foraging or basking sites, predation risk, etc.). A Western Painted Turtle was detected once at 754 m ASL in 2015.

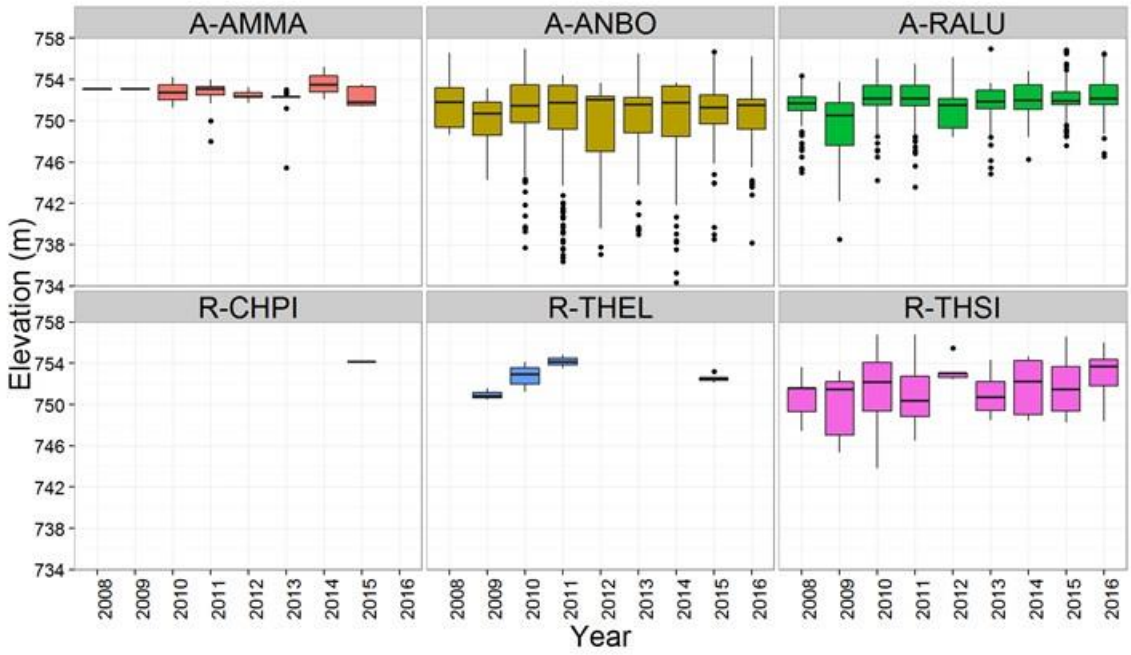

Figure 5-5: Elevation distribution of amphibians and reptiles (number of observations, all life stages combined) documented in and adjacent to the drawdown zone of Kinbasket Reservoir by year of study. A- = Amphibian; R- =Reptile. AMMA = Long-toed Salamander, ANBO = Western Toad, RALU = Columbia Spotted Frog, CHPI = Painted Turtle, THEL = Western Terrestrial Garter Snake, THSI = Common Garter Snake

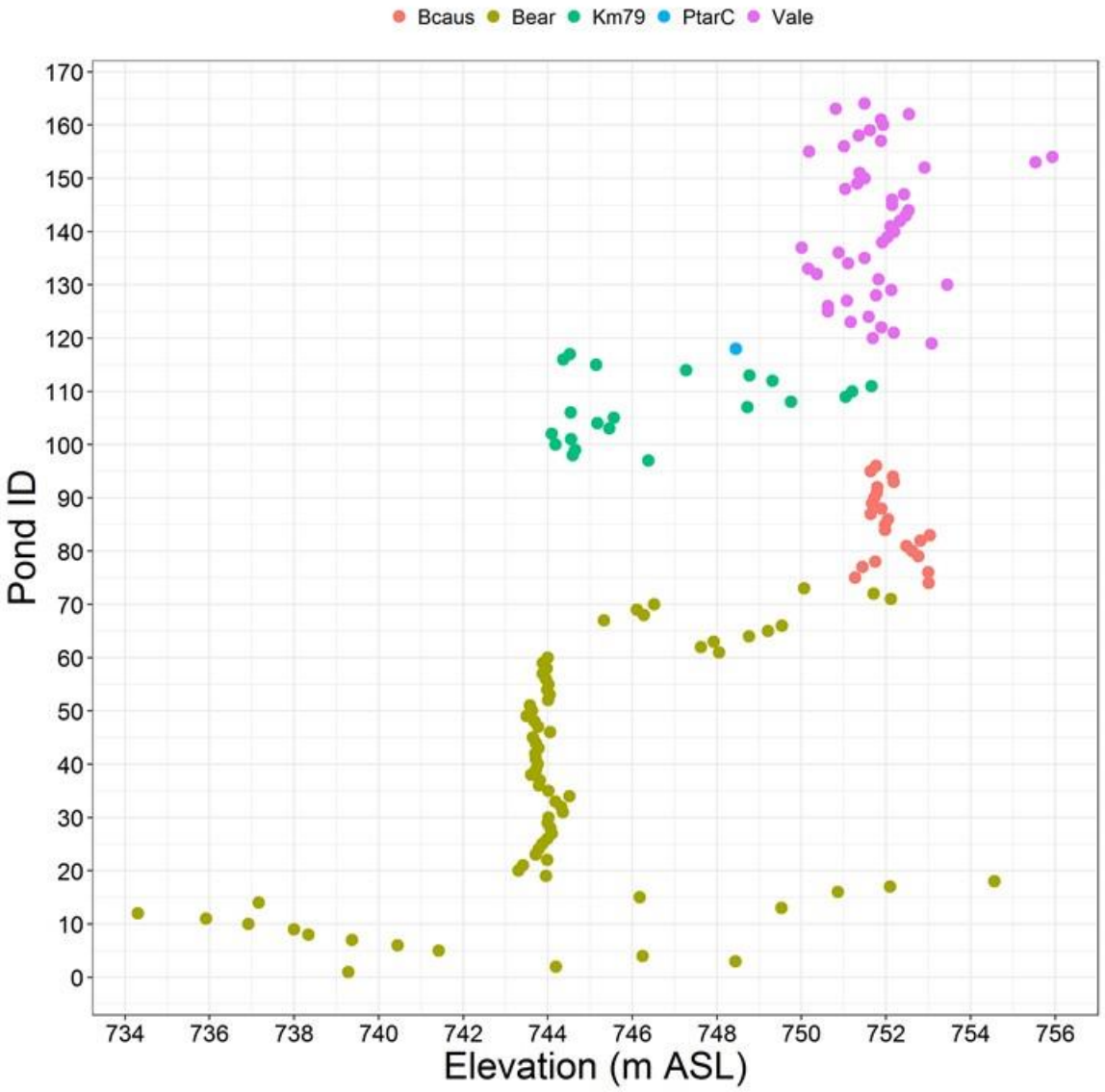

Figure 5-6: Elevation distribution of ponds and wetlands (n=164) sampled in the drawdown zone of Kinbasket Reservoir. BCaus = Bush Arm Causeway, Bear = Bear Island, Km79 = Km79, PtarC = Ptarmigan Creek, Vale = Valemount Peatland

Vegetation Community Associations

Habitat use by Western Toad and Columbia Spotted Frog was compared to the vegetation community mapping that was completed for CLBMON-10 (Figure 5-7). Overall, Western Toad are generalists in terms of their habitat use, and detections were made across multiple habitat types, whereas Columbia Spotted Frog were found most often in the wetter wool-grass–Pennsylvania buttercup (WB) and Bluejoint Reedgrass (BR) habitats. Vegetation communities in which amphibians were found were distributed between ~740 m and 754 m ASL (Figure 5-7).

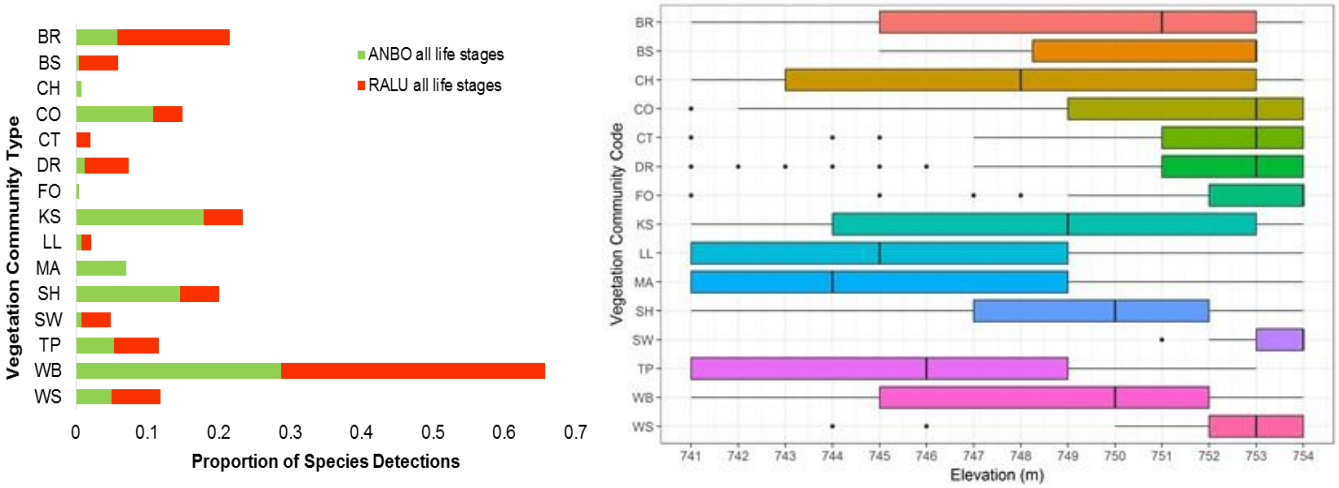

Figure 5-7: **Distribution of Western Toad and Columbia Spotted Frog (all life stages grouped) by vegetation community class in the drawdown zone of Kinbasket Reservoir in 2016 (left panel) and elevation distribution of the same VCCs (right panel).** ANBO = Western Toad, RALU = Columbia Spotted Frog; BR = Bluejoint reedgrass, BS = buckbean-slender sedge, CH = common horsetail, CO = clover–oxeye daisy, CT = cottonwood-trifolium, DR = driftwood, FO = forest, KS = Kellogg's sedge, LL = lady's thumb-lamb's quarter, MA = marsh cudweed–annual hairgrass, SH = swamp horsetail, SW = shrub willow, TP = toadrush-pond water starwort, WB = wool-grass–Pennsylvania buttercup, WS = willow–sedge. See Hawkes et al. (2013) for descriptions of each habitat type

The vegetation communities with the most detections for Western Toad and Columbia Spotted Frog (WB and BR) were situated between ~744 and 753 m ASL (Figure 5-7). A large proportion of all ponds mapped in the drawdown zone (48.4 per cent; 5.5 ha) occurred in these two vegetation communities (WB: 29.9 per cent; 3.4 ha; KS: 10.7 per cent; 1.2 ha), so the presence of amphibians in these communities is not surprising. Few observations occurred in the lady's thumb-lamb's quarter (LL) community despite >10 per cent of all ponds occurring there. The lack of observations is likely because the LL community typically occurs at lower elevations than the other communities (Figure 5-7).

The general use of habitats in the drawdown zone by both amphibian species suggests that even if vegetation communities change over time, the patterns of amphibian use of the drawdown zone are likely to persist. This is because species distributions are more likely a reflection of suitable breeding habitat (i.e., pond areas) and determinants of habitat quality (i.e., suitable habitat for purposes other than breeding) rather than vegetation community alone. In general, amphibians tend to use breeding ponds that are small, shallow, and warm. Columbia Spotted

Frog tend to breed in more specific habitats, such as in wet habitats associated with the WB or KS vegetation communities (Figure 5-8). In contrast, Western Toad tends to use a wide range of elevations and was most often observed breeding in ponds in the marsh cudweed-annual hairgrass community (MA). Ponds used by Western Toad for breeding were typically devoid of vegetation.

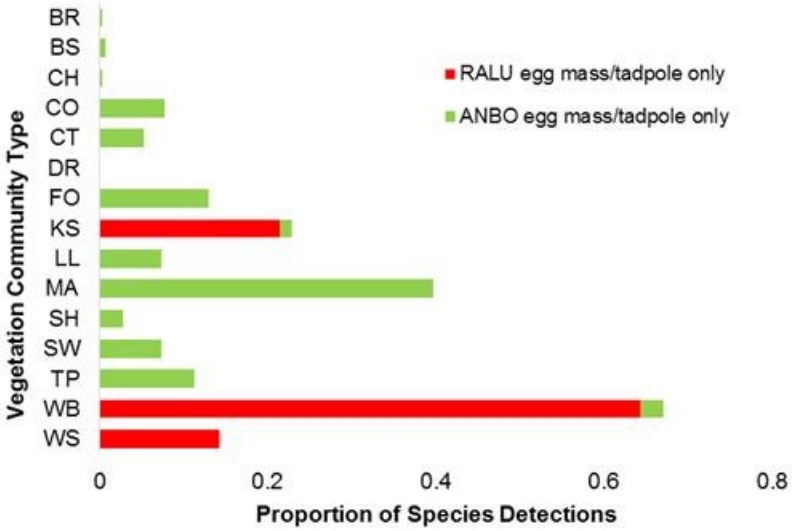

Figure 5-8: Distribution of Western Toad and Columbia Spotted Frog (egg masses and tadpoles only) by vegetation community class in the drawdown zone of Kinbasket Reservoir in 2016. ANBO = Western Toad, RALU = Columbia Spotted Frog; BR = Bluejoint reedgrass, BS = buckbean-slender sedge, CH = common horsetail, CO = clover–oxeye daisy, CT = cottonwood-trifolium, DR = driftwood, FO = forest, KS = Kellogg's sedge, LL = lady's thumb-lamb's quarter, MA = marsh cudweed–annual hairgrass, SH = swamp horsetail, SW = shrub willow, TP = toadrush-pond water starwort, WB = wool-grass–Pennsylvania buttercup, WS = willow–sedge. See Hawkes et al. (2013) for descriptions of each habitat type

Radiotelemetry

In 2016, ten Common Garter Snake (all adult females) were captured and fitted with radio transmitters in the Valemount area. Five of the snakes captured were tagged in Cranberry Marsh complex located outside the Kinbasket DDZ. Four individuals were tagged in the DDZ in proximity to Pond 12 and one individual was tagged outside the DDZ in upland habitat west of the Valemount town site. Snakes ranged in size from 648 to 947 mm SVL and 128 to 512 g. Animals were tagged and tracked between June 11th and October 8th (Table 5-4). Individual snakes were tracked to between 10 and 44 locations (average = 33; R12R3L4 was only tracked to 10 locations before it was killed, presumably by a muskrat, and was left out of some analyses). The average daily distances travelled were similar between females (range = 34.3 to 57.0 m), whereas a greater range in total successive distance moved was observed, with differences exceeding one kilometer (range = 2173.9 to 3866.5 m). Snakes were actively tracked between 71 and 104 days (excluding the predated individual) before reaching their overwintering location and ceasing activity between September 16th and October 4th.

Table 5-4: Summary of radiotelemetry activities (movement distances and tracking period) for Common Garter Snakes near or in the drawdown zone of Kinbasket Reservoir for 2016.

		Daily Movement (m)				Total	No. of	Active Tracking Period		
Location	Snake ID	Avg.	SD	Max	Min	Distance (m)	Detections	First Day	Last Day	No. of Days
Valemount Peatland	R11L6	39.7	42.0	157.3	2.5	3682.1	44	11-Jun	16-Sep	97
	R12L6	35.1	45.4	135.8	0.0	2674.6	31	16-Jul	26-Sep	72
	R12L7	47.7	73.9	285.8	0.5	3374.7	36	17-Jul	4-Oct	79
	R12R3	29.0	57.8	272.2	0.0	2173.9	30	21-Jul	30-Sep	71
Cranberry Marsh	R10L9	40.0	68.3	286.2	0.0	3471.0	40	21-Jun	27-Sep	98
	R12L10	57.0	98.7	416.3	0.0	3824.4	35	18-Jul	29-Sep	73
	R12L4	51.6	80.7	256.0	0.0	3574.2	33	16-Jul	1-Oct	77
	R12L5	36.9	43.6	153.2	1.5	2491.5	33	16-Jul	25-Sep	71
	R12R3L4	34.3	39.7	96.5	1.1	713.5	10	26-Jul	19-Aug	24
Upland	R11L9	56.3	99.6	387.9	0.0	3866.5	39	20-Jun	2-Oct	104

Distances travelled between detections averaged 88.7 m (range = 71.3 to 109.3 m) with individual R10L9 travelling the furthest distance of 858.6 m between detections (Figure 5-9). Although time and distances between detections varied by snake, the median values were similar.

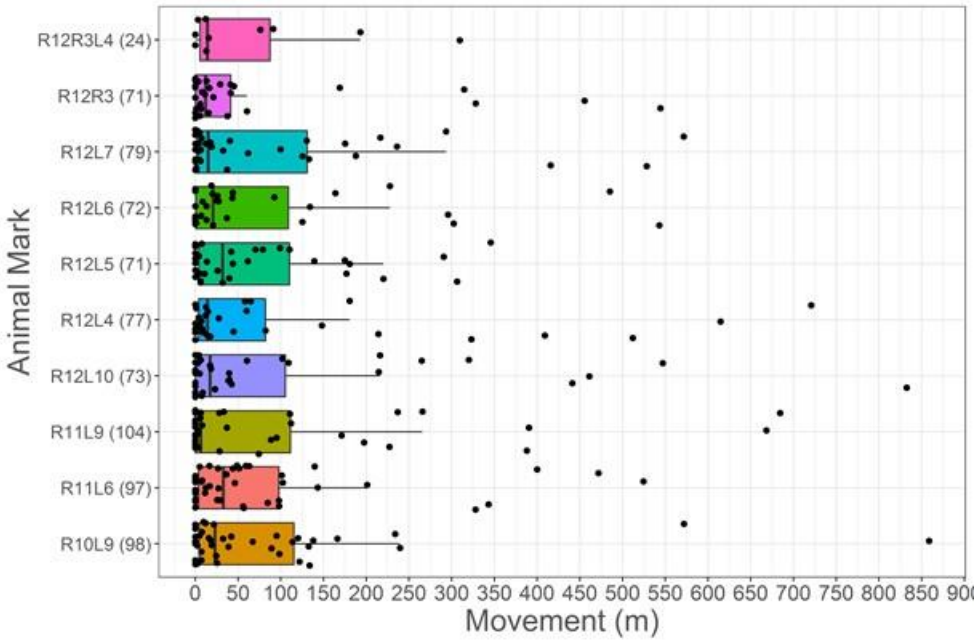

Figure 5-9: Total movements made by female Common Garter Snakes in the Valemount area, between June 11th and October 8th 2016. Actual movement data are represented by black dots. Total days tracked are shown in parentheses

All four of the Common Garter Snakes tagged in the drawdown zone at Valemount Peatland showed similar movement patterns, moving from the DDZ into upland habitat during the survey period (Figure 5-10). The final overwintering location of the four individuals were in relative proximity to one another (range = 18.0 to 532.3 m) and much of their home ranges overlapped (Appendix 11-2).

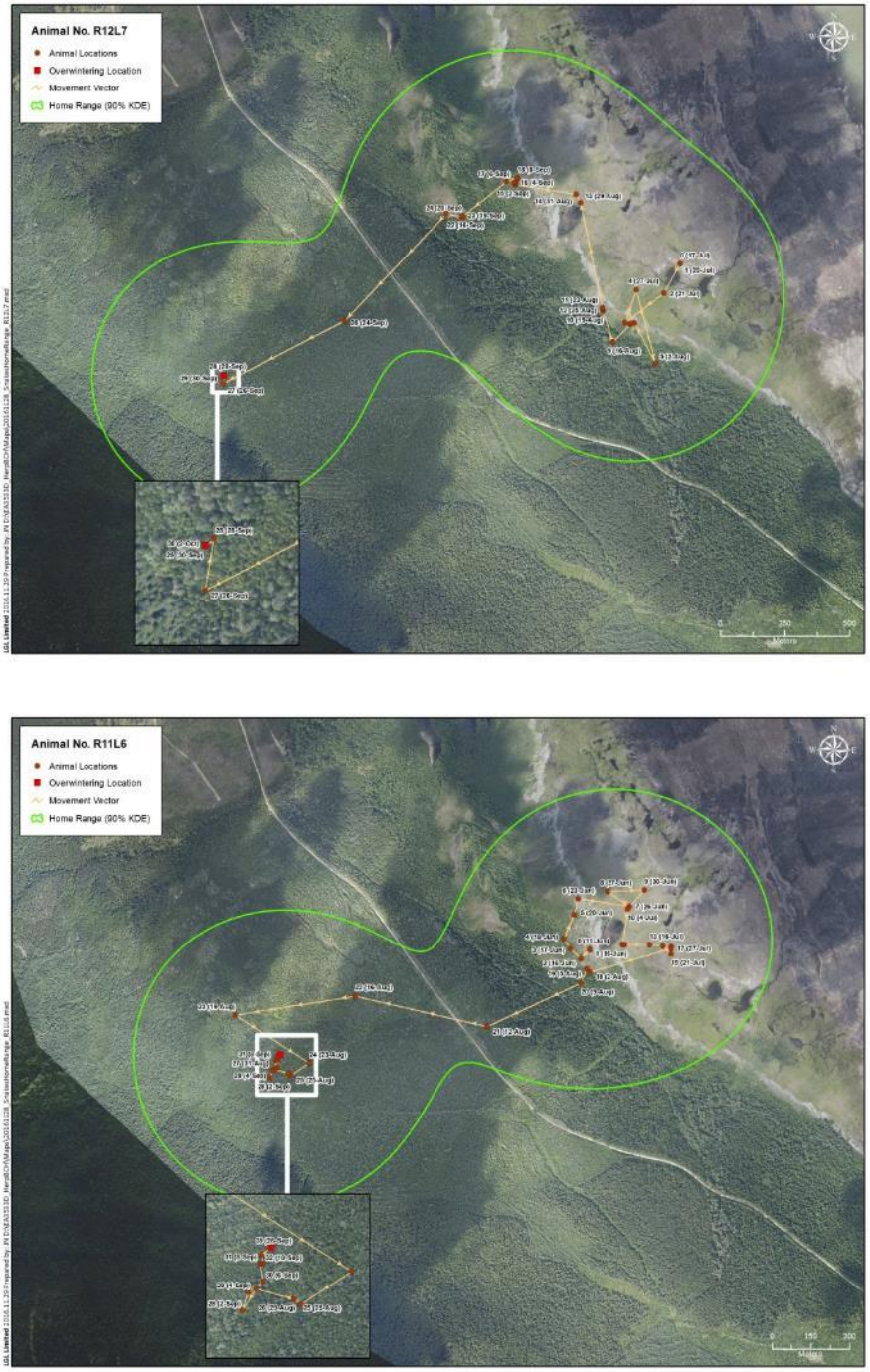

Figure 5-10: Examples of successive movements by tagged female Common Garter Snakes in Canoe Reach, Valemount Peatland 2016. Dates indicate location dates. Vectors indicate presumed (straight-line) direction of movement. The green polygon is the 90% kernel density estimation used to calculate home range.

The five snakes tagged in Cranberry Marsh were more variable in their general movements and final overwintering detection sites with some moving into forested habitat peripheral to the marsh and others remaining within the aquatic marsh habitat (Figure 5-11; Appendix 11-2). The one snake tagged in upland habitat west

of Valemount moved further west and overwintered in forested habitat (Appendix 11-2).

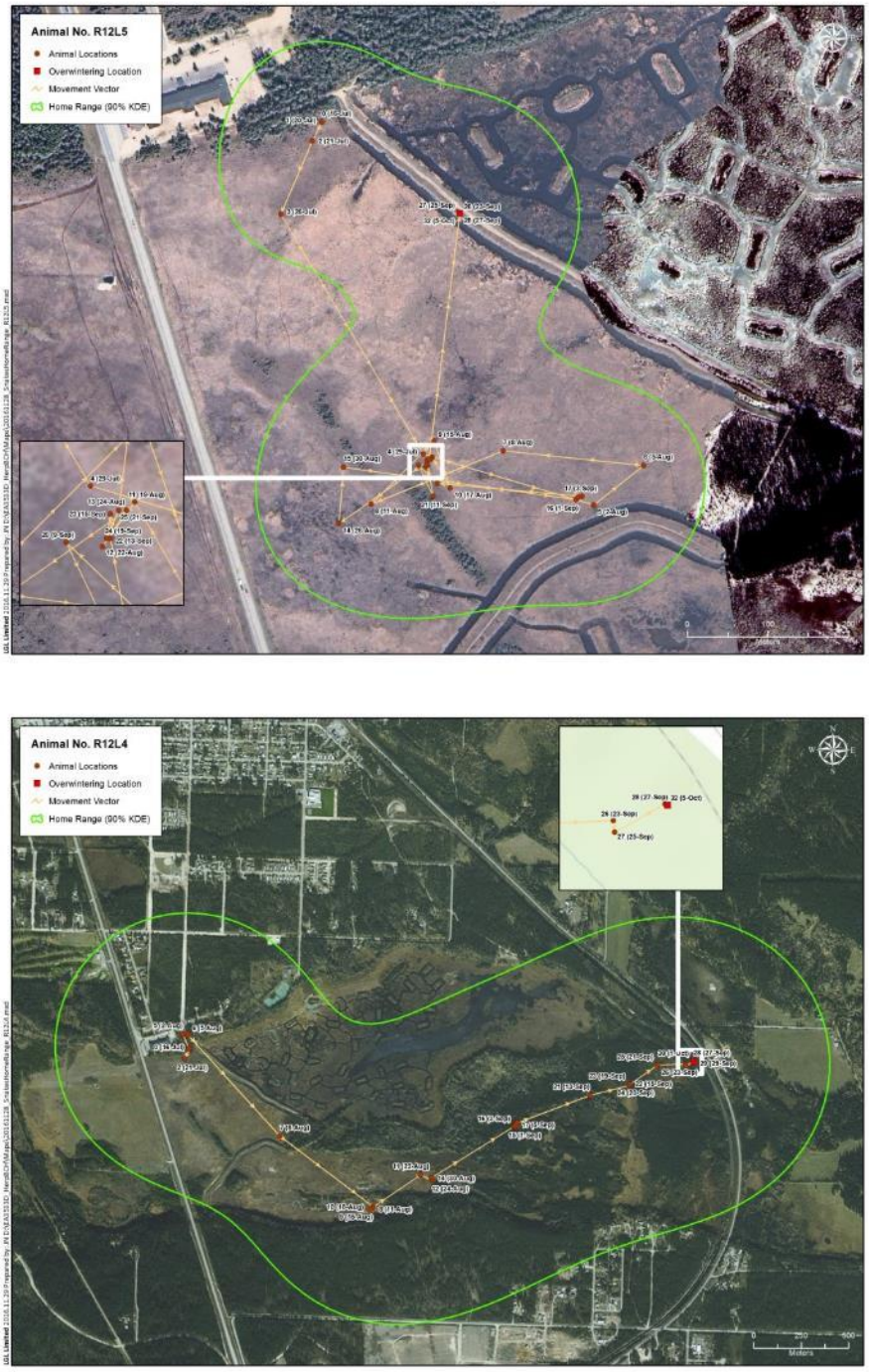

Figure 5-11: **Examples of successive movements by tagged female Common Garter Snakes in Cranberry Marsh, Valemount 2016**. Dates indicate location dates. Vectors indicate presumed (straight-line) direction of movement. The green polygon is the 90% kernel density estimation used to calculate home range.

5.1.4 Hypotheses Testing

H1: Annual and seasonal variation in water levels in Kinbasket and Arrow Lakes Reservoirs (due to reservoir operations) and the implementation of soft operational constraints in Arrow Lakes Reservoir, do not directly or indirectly impact reptile and amphibian populations

Soft Operational Constraints

Section 4.4.1.1 of the Columbia River Water Use Plan (BC Hydro 2007) indicates that the Consultative Committee did not recommend any operational constraints on Kinbasket Reservoir. As such, an assessment of the implementation of soft constraints is relevant to Arrow Lakes Reservoir only.

The following sections test each of the hypotheses associated with CLBMON-37.

$H1_A$: Reservoir operations do not result in a decreased abundance of amphibians or reptiles in the drawdown zone.

The annual variability associated with reservoir operations influences the detectability of amphibians and reptiles in the drawdown zone, but not in a consistent manner. In 2016, Western Toad, Columbia Spotted Frog, and Common Garter Snake detection rates (as a proxy for abundance) were not influenced by reservoir elevation (correlation coefficients = 0.13, 0.08, 0.41 respectively; Figure 5-12). For all species the range of elevations across which they were observed was consistent with previous years of study.

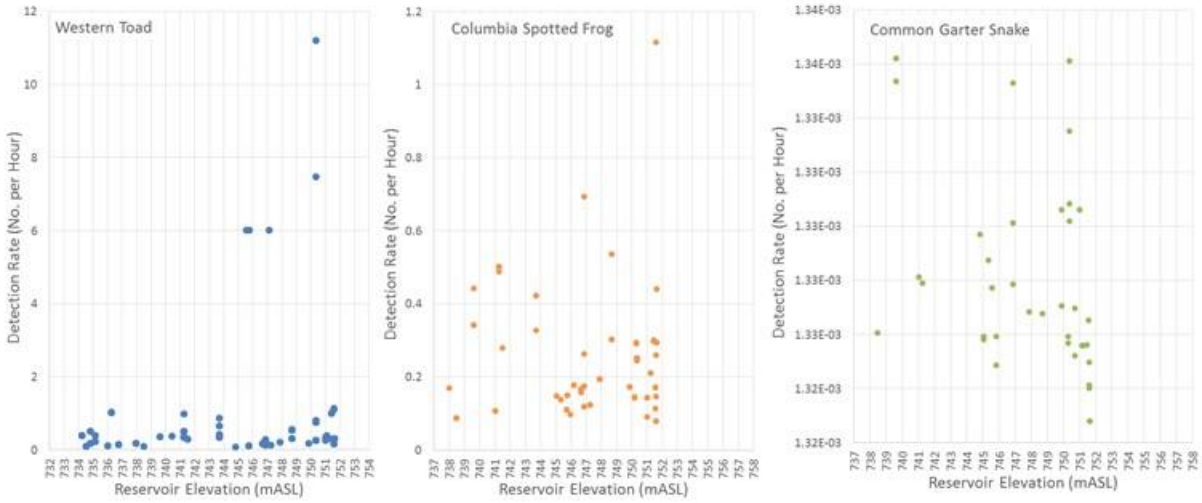

Figure 5-12: Relationship between reservoir elevations and detection rates (number per hour) for Western Toad, Columbia Spotted Frog, and Common Garter Snake in Kinbasket Reservoir, 2016. Note different scales on vertical axes

$H1_B$: Reservoir operations do not increase the stage specific (e.g. larval, juvenile, or adult) mortality rates of amphibians or reptiles in the drawdown zone.

Our current understanding of the use of the drawdown zone by amphibians and reptiles is that certain species use the DDZ to fulfill most of their life history stages (e.g., Western Toad, Columbia Spotted Frog), while others (e.g., Long-toed

Salamander and garter snakes) appear to use the DDZ to fulfill specific stages (Table 5-5).

Table 5-5: Observed life history activity of amphibian and reptile species in the drawdown zone of Kinbasket Reservoir. Any 'Yes' indicates a direct observation of the life history activity or stage, whereas the rest are inferences

Species	Life History Activity			
	Breeding	Growth	Foraging	Overwintering
Columbia Spotted Frog (A-RALU)	Yes	Yes	Yes	Unknown
Western Toad (A-ANBO)	Yes	Yes	Yes	Unlikely
Long-toed Salamander (A-AMMA)	Yes	Yes	Likely	Unlikely
Western Terrestrial Garter Snake (R-THEL)	Unknown	Yes	Yes	Unlikely
Common Garter Snake (R-THSI)	Unknown	Yes	Yes	Unlikely

Life stage-specific mortality rates have not been directly measured for any species, but instances of mortality have been observed and can be related to natural causes (e.g. Western Toad depredation). For example, there are times when toad egg strings are not fertilized (see previous years reports), which could lead to reduced fecundity, but not mortality. We have not observed depredation or unfertilized egg masses of Columbia Spotted Frog. Egg string, egg mass, and tadpole stranding have also been observed at various locations in the drawdown zone (e.g., KM88). The number of Western Toad egg strings and Columbia Spotted Frog egg masses that were stranded were difficult to accurately count, but were fewer than 10 for each species in all years of study. Egg mass stranding is usually related to decreasing hydroperiod at oviposition sites, which can be a major cause of death to developing embryos or tadpoles. The egg mass stranding phenomenon is not unique to drawdown zones (e.g., Marco and Blaustein 1998). Local environmental conditions can influence the hydroperiod of breeding ponds and are likely to confound reservoir effects that may be linked to egg mass stranding.

$H1_C$: Reservoir operations do not result in decreased site occupancy of amphibians or reptiles in the drawdown zone.

Proportion of Sites

In sampling years between 2008 and 2016, six main locations in the drawdown zone have been consistently surveyed for amphibians and reptiles (Table 5-6). The proportion of these sites occupied by each species (i.e., in which a species was detected at least once in a given location per year) ranged from zero per cent for Western Terrestrial Garter Snake in multiple years to 100 per cent for Western Toad, Columbia Spotted Frog, and Common Garter Snake. Occupancy for Long-toed Salamander appears to be low; however, this species can be cryptic and is likely present at more sites than our data suggest. Of the garter snakes detected, Western Terrestrial Garter Snake are rarely found in the drawdown zone, with few individuals detected in three of the six years. Common Garter Snake were observed each year with annual occupancy ranging from 50 to 100 per cent. For some species and years occupancy will be a function of survey effort. For example, in 2016 surveys focused on the Valemount Peatland. In general, the proportion of sites occupied by each species does not indicate a decrease across years and the general patterns of occupancy are similar, with toads and frogs more widely distributed and more readily detectable than all other species.

Table 5-6: Proportion of sites occupied at each survey site for each species of amphibian and reptile known to use habitats in the drawdown zone of Kinbasket Reservoir in 2008 to 2012, 2014 and 2016. A = amphibian, R = reptile; AMMA = Long-toed Salamander, ANBO = Western Toad,), RALU = Columbia Spotted Frog, THEL = Western Terrestrial Garter Snake, THSI = Common Garter Snake. Numbers in table refer to detections of all life stages of each species

	A-AMMA						A-ANBO						A-RALU						R-THEL						R-THSI					
Survey Sites	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**
Bush Arm Bear Island								1	14	22	38	24	1		2	11	12	3							1		6	1	4	1
Bush Arm Causeway			1	10			2	3	32	45	79	50	5	1	6	2	4	2			1				2		5	2		4
Bush Arm KM79 (DDZ)							3	5	15	8	15	20	59	45	47	1	4	22		3	1				8	6	13		1	2
Bush Arm KM79 (UPL)						1					11	1			10	7	21	2									1			
Ptarmigan Creek							10	8	116	4	18	45	4	7	7	3	2	7	4						6	2	51		8	5
Valemount Peatland	2	1	1	1	4	1	7	6	448	3	57	77	23	7	376	12	83	106							1	3	84	2	12	31
Total Locations	**1**	**1**	**2**	**2**	**1**	**2**	**4**	**5**	**5**	**5**	**6**	**6**	**5**	**4**	**6**	**6**	**6**	**6**	**1**	**1**	**2**				**5**	**3**	**6**	**3**	**4**	**5**
Proportion of Locations	**16.7**	**16.7**	**33.3**	**33.3**	**16.7**	**33.3**	**66.7**	**83.3**	**83.3**	**83.3**	**100.0**	**100.0**	**83.3**	**66.7**	**100.0**	**100.0**	**100.0**	**100.0**	**16.7**	**16.7**	**33.3**	**0.0**	**0.0**	**0.0**	**83.3**	**50.0**	**100.0**	**50.0**	**66.7**	**83.3**

$H1_D$: Reservoir operations do not result in decreased productivity of amphibians or reptiles in the drawdown zone.

Amphibian productivity (i.e., through daily monitoring of multiple ponds throughout the breeding period [egg laying through to metamorphosis]) has not been explicitly studied in Kinbasket Reservoir. The data collected thus far indicate that three species of pond-breeding amphibian, Western Toad, Columbia Spotted Frog and Long-toed Salamander, are using habitats in the drawdown zone for breeding. The detection of amphibian egg masses varies between locations, but the observed variation is expected. Although we can calculate detection rates for these species, most of the information we have is based on qualitative observations. We have observed most life stages of these species (i.e., eggs, tadpoles, toadlets, and adults), with the exception of Long-toed Salamander where only egg masses and adults have been recorded.

Western Toad productivity does not appear to be affected by reservoir operations. For example, Western Toad metamorphs have been observed at Ptarmigan Creek, various locations in the Valemount Peatland (e.g., Pond 12), and from the Bush Arm Causeway in most years of study. Each spring, numerous adult Western Toad are documented in the drawdown zone, and egg strings are observed in many of the same locations each year. Adult male to female ratios calculated for each year are consistent with values reported in the literature (Olson et al. 1986), lending support to a stable population of toads in the areas of Kinbasket Reservoir being studied.

Qualitatively, it appears that the productivity of both Western Toad and Columbia Spotted Frog has been consistent between years. However, we are currently only assessing these species in the drawdown zone of the reservoir. In the absence of a suitable control or baseline data, we cannot know for certain how the productivity of any species of amphibian might be affected by reservoir operations.

Reptile productivity is not being assessed via CLBMON-37. Assessing reptile productivity (e.g., garter snakes) would require an intensive study involving the capture of numerous female snakes to determine reproductive state, counting eggs, observing where females give birth (i.e., drawdown zone or upland habitats), and assessing to what extent these species use the drawdown zone. Our current understanding of reptile use of the drawdown zone is limited to opportunistic observations (i.e., dictated by our present level of effort), and more recently, telemetry, made during the spring and summer only and these observations are generally of basking or foraging adults.

$H1_E$: Reservoir operations do not reduce the availability and quality of breeding habitat, foraging habitat and overwintering habitat for amphibians or reptiles in the drawdown zone.

Habitat availability was assessed by delineating the total area sampled each year (i.e., terrestrial and aquatic habitat at each survey site) and calculating how much of that area was available on a monthly basis relative to reservoir operations (i.e., timing of reservoir inundation at each particular elevation = unavailable). As expected, a negative relationship exists between the availability of habitat and reservoir elevations, with habitat availability decreasing with time. The change in habitat availability is most evident in June and July, when reservoir elevations are increasing (Figure 5-13). A subtle difference in 2016 is the decrease in available habitat earlier in June, but with subsequent lower reservoir levels through August and September, more habitat was available during the late season period than in 2010, 2012, and 2014.

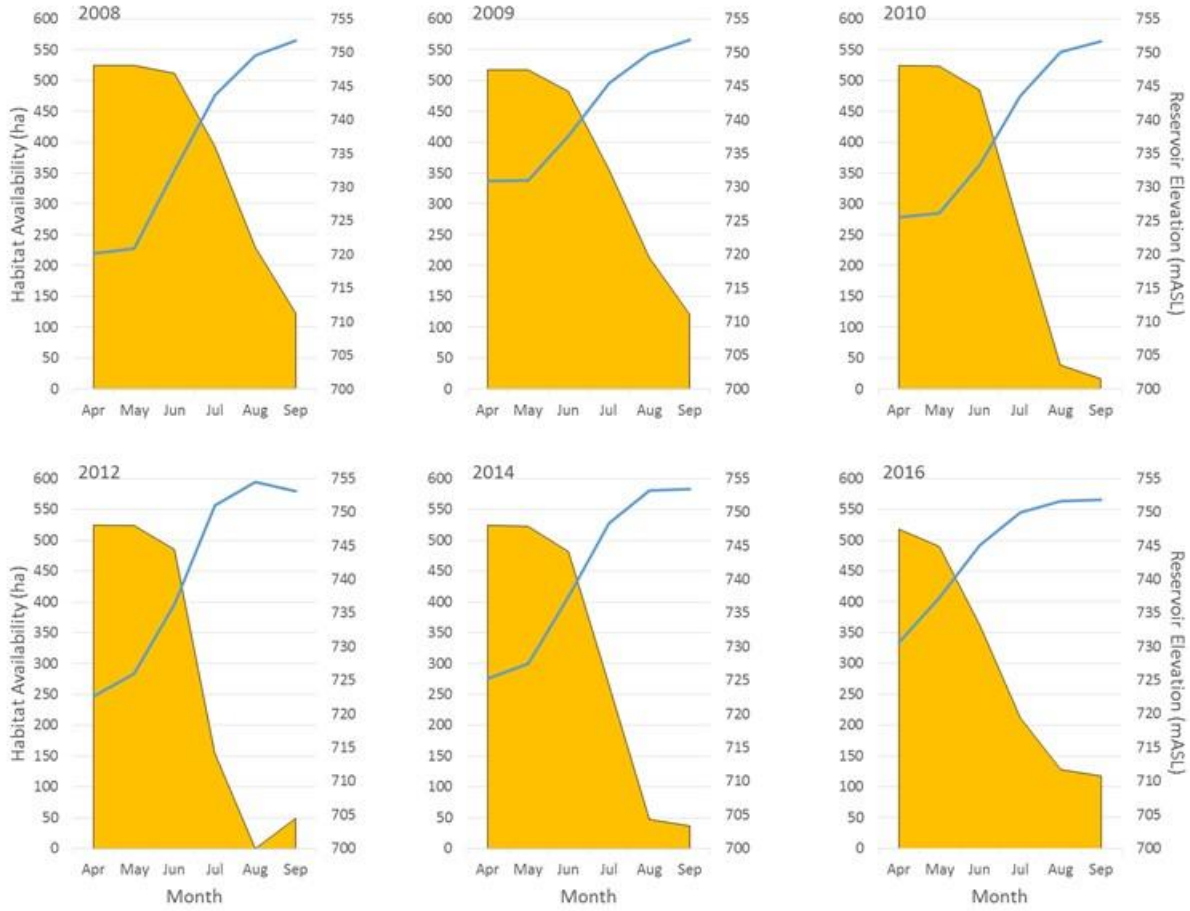

Figure 5-13: Relationship between habitat availability and reservoir elevation (i.e., inundation) in the drawdown zone of Kinbasket Reservoir for 2008, to 2010, 2012, 2014 and 2016. The average reservoir elevation is shown (blue line).

The availability of amphibian and reptile habitat in the drawdown zone is discussed in the context of (1) breeding habitat, which is defined as those habitats in which amphibian egg masses are deposited, (2) foraging habitat, where amphibians and reptiles obtain prey, which includes both aquatic and terrestrial habitats, and (3)

overwintering habitat, or those habitats necessary for the overwinter survivorship of amphibians and reptiles.

Breeding Habitat

The amphibian species using the drawdown zone of Kinbasket Reservoir are pond-breeding amphibians that breed in wetlands, ponds, quiescent backwaters of streams, and sometimes lake margins. In 2016, 161[1] ponds, representing 11.16 ha, were delineated in the drawdown zone in five distinct survey sites. Total pond area per site ranged from 0.94 ha at Ptarmigan Creek (*N* = 1 pond) to 4.6 ha in the Valemount Peatland (*N* = 46 ponds) and most ponds are situated at elevations between 745 m and 753 m ASL (9.49 ha).

Although two species of reptiles are common in the drawdown zone, only one species (*Thamniphis sirtalis*, the Common gartersnake) is documented on a regular basis. Young of the year Common gartersnakes have been observed in the drawdown zone, but it is unknown if birthing occurs there. Several recent observations of snakes giving birth have occurred in upland habitats near the Valemount Peatland, but no such observations have occurred in the drawdown zone.

The quantity of breeding habitat is affected by reservoir elevation on an annual basis. To demonstrate how reservoir elevation affects the availability, and hence quality of breeding habitat, habitat availability was plotted relative to reservoir elevation in all sampling years. In 2008 to 2010, the majority of ponds (i.e., those situated between 745 and 753 m ASL) were available until mid-July. Beyond this point, the amount of breeding habitat steadily declined until late August, at which time ~1-1.7 ha of the pond habitat remained. In 2012 and 2014, the majority of ponds were inundated earlier in the season (between late June and early July) and breeding habitat steadily declined until mid-July and early August when all of the pond habitats were inundated. In 2016, inundation of ponds situated between 745 and 753 m ASL began earlier still in mid-June, but reservoir levels did not reach the same levels as in previous study years and breeding habitat in ponds above 752 m ASL did not get inundated and were available throughout most of the season (Figure 5-14).

[1] Only ponds with mean elevations <754.38 m are considered here, which is why the number of ponds differs slightly from those discussed in previous sections.

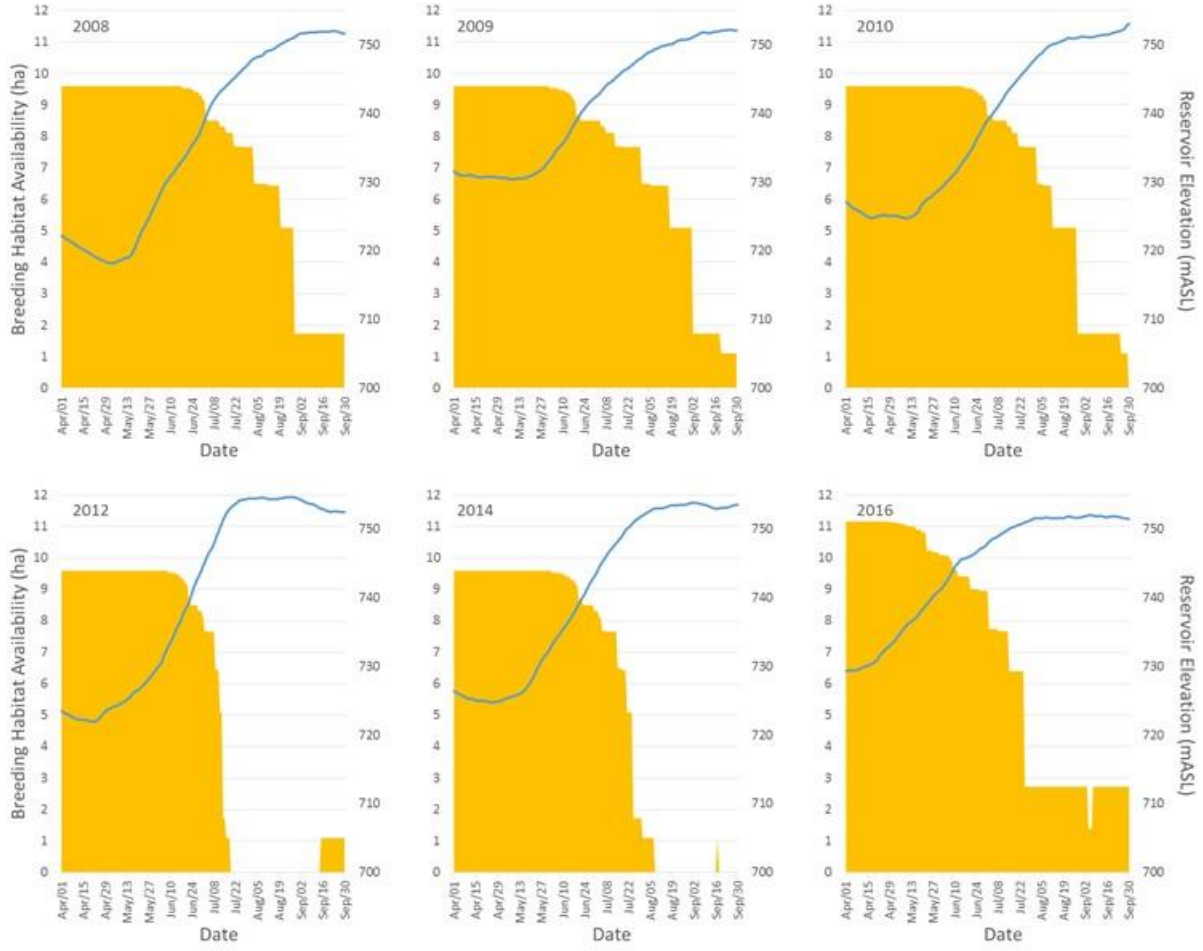

Figure 5-14: Relationship between amphibian breeding (and rearing) habitat availability (pond area) and reservoir elevations for the period April 1 through September 30, 2008 to 2010, 2012, 2014 and 2016 in Kinbasket Reservoir

The timing of inundation and occupancy of ponds coupled with the observation of breeding toads and frogs and egg masses indicates that reservoir operations do not preclude toad and frog breeding in ponds in the drawdown zone. Most pond-breeding amphibian egg masses were laid prior to inundation but not before metamorphosis; however, based on our observations of all life stages of Western Toad (eggs, tadpoles, metamorphs, and adults), the reduction in habitat availability associated with inundation does not appear to be associated with reduced reproductive success. Observations of metamorphosed toads at the Valemount Peatland, Ptarmigan Creek, Bush Arm Bear Island, the Bush Arm Causeway in through July and August suggests that toad egg strings and tadpoles can tolerate some level of disturbance from reservoir operations at lower levels, and ponds that didn't get inundated by the reservoir also had metamorphosed toads. However, the degree to which reservoir operations might affect the success of observed breeding (in terms of the proportion of eggs that survive to metamorphosis) is not well understood and cannot currently be quantified (without following egg mass/tadpole development through to metamorphosis – extremely difficult and labour intensive).

Foraging Habitat

Amphibians and reptiles forage in a variety of aquatic and terrestrial habitats and both of these general habitat types occur in the drawdown zone of Kinbasket Reservoir. A similar trend to pond habitat is observed for foraging habitat (i.e., terrestrial and aquatic) and as expected there is a strong negative relationship between inundated reservoir elevation and habitat availability (Figure 5-13). During each year, the availability of foraging habitat decreased rapidly as soon as reservoir elevations reached ~740 m ASL (Table 5-7). In 2016, a typical proportion of habitat was inundated consistent with previous years and annual trends are similar with only the timing and duration of inundation of each elevation band varying (Table 5-7).

Table 5-7: Proportion of time between April 1st and September 30th (n = 183 days) that Kinbasket Reservoir exceeded a given range of elevations from 2005 to 2016. Shading indicates the reservoir did not exceed a given elevation in that year

m ASL	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
741-742	0.55	0.59	0.55	0.48	0.53	0.46	0.54	0.54	0.52	0.54	0.70	0.67
742-743	0.54	0.58	0.54	0.46	0.51	0.45	0.52	0.53	0.51	0.52	0.67	0.65
743-744	0.51	0.56	0.52	0.44	0.48	0.43	0.51	0.52	0.50	0.51	0.65	0.63
744-745	0.50	0.54	0.50	0.42	0.46	0.42	0.49	0.50	0.49	0.49	0.64	0.62
745-746	0.48	0.52	0.49	0.39	0.43	0.39	0.48	0.50	0.49	0.48	0.62	0.61
746-747	0.46	0.51	0.48	0.37	0.40	0.37	0.46	0.49	0.47	0.46	0.61	0.56
747-748	0.41	0.49	0.46	0.34	0.37	0.35	0.45	0.47	0.46	0.45	0.54	0.53
748-749	0.35	0.48	0.44	0.32	0.34	0.33	0.43	0.46	0.44	0.43	0.38	0.50
749-750	0.28	0.45	0.43	0.27	0.31	0.31	0.42	0.45	0.42	0.41	0.28	0.46
750-751	0.16	0.43	0.42	0.23	0.24	0.27	0.40	0.44	0.38	0.39	0.16	0.43
751-752		0.37	0.40	0.18	0.16	0.19	0.38	0.43	0.35	0.37		0.37
752-753			0.36		0.06	0.03	0.35	0.42	0.30	0.34		0.02
753-754			0.19			0.01	0.32	0.32	0.25	0.29		
>754.38								0.17	0.14			

Overwintering Habitat

Field work for CLBMON-37 occurs during the snow-free period, usually between the middle to end of April and end of September each year. The availability or quality of amphibian overwintering habitat in the drawdown zone of Kinbasket Reservoir has not been extensively assessed. Questions related to the availability and quality of overwintering habitat are difficult to answer using existing data. However, the telemetry data collected in 2014 and 2015 suggest that Western Toad are not using the drawdown zone during the winter period and that more likely, they are wintering in upland habitats, which is consistent with what is generally known for this species (e.g., Browne and Paszkowski 2010).

In 2016, all Common Garter Snakes radio transmitters in the drawdown at Valemount Peatland travelled to upland affixed with habitats outside of Kinbasket Reservoir to their presumed overwintering locations (see section 5.1.3 Radiotelemetry).

$H2_A$: Revegetation and physical works do not increase species diversity or seasonal (spring/summer/fall) abundance of amphibians or reptiles in the drawdown zone.

Revegetation

The revegetation prescriptions applied were never considered relevant or beneficial to amphibians and reptiles nor were they implemented explicitly to benefit amphibians and reptiles. The planting of sedge plugs and live stakes in mostly upland habitats did not appear to improve habitat around important breeding habitats or improve habitat connectivity between upland over-wintering habitats and drawdown zone habitats (see results in Hawkes et al. 2013). Although the hypothesis asks whether revegetation increases species diversity or abundance, we did not test this for the aforementioned reasons. It is the opinion of the authors that revegetation did not, at least in the years covered by this report, increase amphibians and reptiles diversity or abundance in the drawdown zone. This observation is consistent with the findings of Fenneman and Hawkes (2012) and Hawkes et al. (2013). Further, the fall abundance of amphibians and reptiles has not been assessed as the high reservoir level precludes surveys in the drawdown zone during that season.

Physical Works

Prior to 2015, all physical works projects in Kinbasket Reservoir were focused on revegetating the drawdown zone with sedges and cottonwoods. In 2015, a physical works pilot project was implemented that included the creation of wood debris and soil mounds along with the removal of wood debris from wetlands in the drawdown zone near the Bush Arm Causeway (Hawkes 2016, draft). Owing to limited scale, it was not expected that any of the work completed in 2015 would change species diversity or abundance of amphibians and reptiles in the drawdown zone. However, clearing wood from wetlands did increase the suitability of those wetlands for wildlife by removing wood the prevented access to the water and by improving water quality (Figure 5-15). Aquatic macrophytes and pond-breeding amphibians (Western Toad; Figure 5-16) were documented from the wetlands in 2016 and early indications are that the habitat suitability of the wetlands has improved.

Figure 5-15. Differences in water clarity and habitat quality between a wetland choked with wood debris and one that was cleared of wood debris in fall 2015. Both wetlands occur in the drawdown zone at the Bush Causeway North site. Photo Date: 12 October 2016. The wetland cleared in fall 2015 was used by pond-breeding amphibians (Western Toad) in 2016 and native aquatic macrophytes (*Myriophyllum spp*) were starting to grow. Wetland-associated sedges (*Carex utriculata*, *C. aquatilis*, and *C. lasiocarpa)* were also growing around the margin of the cleared wetland.

Figure 5-16. Western Toad egg string in one of the wetland that was cleared of wood debris in fall 2015. Photo date May 3, 2016.

$H2_B$: Revegetation and physical works do not increase amphibian or reptile productivity in the drawdown zone.

Revegetation

The revegetation prescriptions applied were never considered relevant or beneficial to amphibians and reptiles nor were they implemented explicitly to benefit amphibians and reptiles. The relationship between revegetation prescriptions applied in the drawdown zone and amphibian and reptile productivity has not been assessed. There is a potential link between increasing food

resources (e.g., invertebrates and small mammals) and productivity and aspects of this are being studied as part of the Kinbasket Reservoir Wildlife Effectiveness study (CLBMON-11A). However, amphibians and reptiles are not focal taxa in those studies.

Physical Works

Early indications suggest that productivity has improved as a result of the clearing of wood debris from wetlands in the drawdown zone at Bush Arm Causeway (see above). With further wood debris removal and cleaning of wood debris from wetlands in the drawdown zone, additional pond-breeding amphibian habitat could be made available, thereby increasing productivity of habitats in the drawdown for amphibians. Because amphibians (particularly Western Toad) are the primary prey for Common Garter Snake, it is possible that an increase in food resources could result in increased predator productivity, but this has not been studied.

$H2_C$: Revegetation does not increase the amount or improve habitat for amphibians and reptiles in the drawdown zone.

As stated above, the revegetation prescriptions applied were never considered relevant or beneficial to amphibians and reptiles nor were they implemented explicitly to benefit amphibians and reptiles.

5.2 Arrow Lakes Reservoir

Our ability to observe possible effects of reservoir activity depends upon the availability of robust occurrence data i.e., multiple confirmations of species identifications over multiple years), which for this study relates primarily to Western Toad, Columbia Spotted Frog, Pacific Chorus Frog and both species of garter snakes.

5.2.1 Environmental Data

Weather conditions are known to affect the surface activity of amphibians. Thus, air temperature and precipitation were obtained from Environment Canada's Revelstoke Airport weather station (11U: 416897.80 m E, 5646166.90 m N; 444.7 m ASL) to evaluate the influence of weather conditions on species detectability and measures of relative abundance (Figure 5-17). The level of variation in precipitation and temperature was not sufficient to affect surface activities of amphibians, and thus, is not likely to have influenced detectability measures (Olson 1999; Hawkes and Gregory 2012). Further, temperatures were within the range of conditions considered suitable for amphibian sampling (Olson 1999; Hawkes and Gregory 2012).

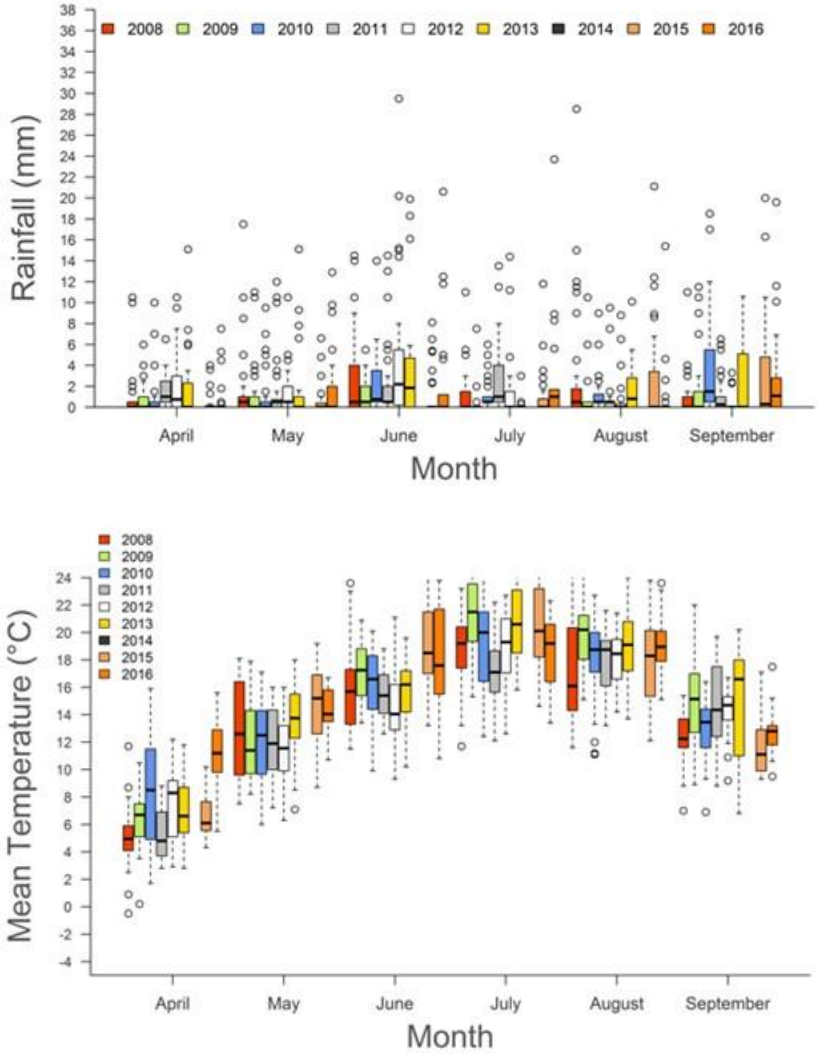

Figure 5-17: Daily precipitation (mm, above) and temperature (°C, below) for April through September, 2008 to 2016 as measured at Revelstoke Airport. Data source: Environment Canada (http://climate.weather.gc.ca/index_e.html)

5.2.2 Water Physicochemical Data

Point data [Conductivity (µS/cm), Dissolved Oxygen (mg/L), pH, and Temperature (°C)] are summarized for all ponds and wetlands sampled and the detection/non-detection of amphibians recorded (Table 5-8). Water physical chemistry varied between location, but was similar in regard to whether amphibians were detected or not. In general, water physical chemistry is believed to play a minor role in affecting the species richness of amphibians (e.g., Hecnar and M'Closkey 1996) and our data suggest that most values are characteristic of sites with relatively low dissolved oxygen, neutral pH, low conductivity, and warm spring and summer temperatures. These conditions are not likely to influence amphibian populations in the drawdown zone of Arrow Lakes Reservoir.

Table 5-8: Summary of water physicochemistry data collected from pond and wetland habitats in which amphibians were either present or absent in the drawdown zone of Arrow Lakes Reservoir in 2016. Average and standard deviation values are provided, N = number of measurements from ponds/wetlands

	Pond/Wetland Location	N	Conductivity		Dissolved Oxygen		pH		Temperature	
			Avg	SD	Avg	SD	Avg	SD	Avg	SD
Amphibian Detected	12 Mile	1	103.6	N/A	8.7	N/A	8.7	N/A	18.0	N/A
	9 Mile	0								
	Airport Marsh	4	155.6	39.2	11.5	2.0	9.0	0.6	23.2	2.4
	Beaton Arm	4	120.9	2.4	7.6	4.2	7.5	0.4	23.1	3.2
	Burton Creek	3	35.4	61.4	8.9	3.5	8.2	0.8	16.8	0.8
	Cartier Bay	3	78.7	68.9	12.0	4.7	8.8	1.2	22.7	6.6
	Downie Marsh	0								
	Edgewood north	2	43.4	46.8	10.1	0.6	8.7	0.2	18.6	1.0
	Edgewood South	3	70.2	60.9	14.4	10.2	7.8	1.2	20.7	3.3
	Lower Inonoaklin	1	203.5	N/A	20.9	N/A	10.3	N/A	31.6	N/A
	Machete Island	4	54.8	109.7	13.1	3.3	8.7	0.4	18.4	1.6
	Montana Slough	2	55.7	78.8	11.6	0.4	8.6	0.8	22.4	5.2
	Total	**27**	**88.3**	**70.6**	**11.4**	**4.8**	**8.5**	**0.9**	**21.1**	**4.2**
Amphibian Not Detected	12 Mile	0								
	9 Mile	5	91.8	85.1	9.4	2.1	8.1	0.7	20.5	6.0
	Airport Marsh	2	272.6	119.1	7.1	0.9	8.3	0.9	20.0	2.7
	Beaton Arm	5	120.0	17.5	6.0	4.2	7.5	0.5	22.6	2.8
	Burton Creek	6	143.2	24.8	8.9	4.0	7.9	0.8	21.8	5.9
	Cartier Bay	11	178.8	90.5	12.6	5.2	8.9	0.5	26.1	3.9
	Downie Marsh	10	214.7	77.6	9.0	4.1	10.3	5.5	22.6	6.2
	Edgewood north	0								
	Edgewood South	2	105.1	1.6	6.4	0.1	6.9	0.6	19.2	5.1
	Lower Inonoaklin	1	118.8	N/A	10.0	N/A	7.6	N/A	19.8	N/A
	Machete Island	4	141.7	101.8	10.7	4.6	8.7	0.7	18.5	1.8
	Montana Slough	8	126.0	25.0	7.4	2.3	7.8	0.6	18.6	4.4
	Total	**54**	**157.1**	**78.8**	**9.2**	**4.2**	**8.6**	**2.5**	**21.9**	**5.1**
Grand Total		**81**	**134.1**	**82.4**	**9.9**	**4.5**	**8.5**	**2.1**	**21.6**	**4.8**

In 2016, the maximum elevation for Arrow Lakes Reservoir was 437.24 m ASL in 2016, and therefore not all ponds in the drawdown zone were inundated. For ponds at Airport Marsh and Edgewood South that did not get inundated in 2016, water temperatures remained fairly stable (started to decrease at end of summer) and dissolved oxygen levels were similar throughout the study period (Figure 5-18).

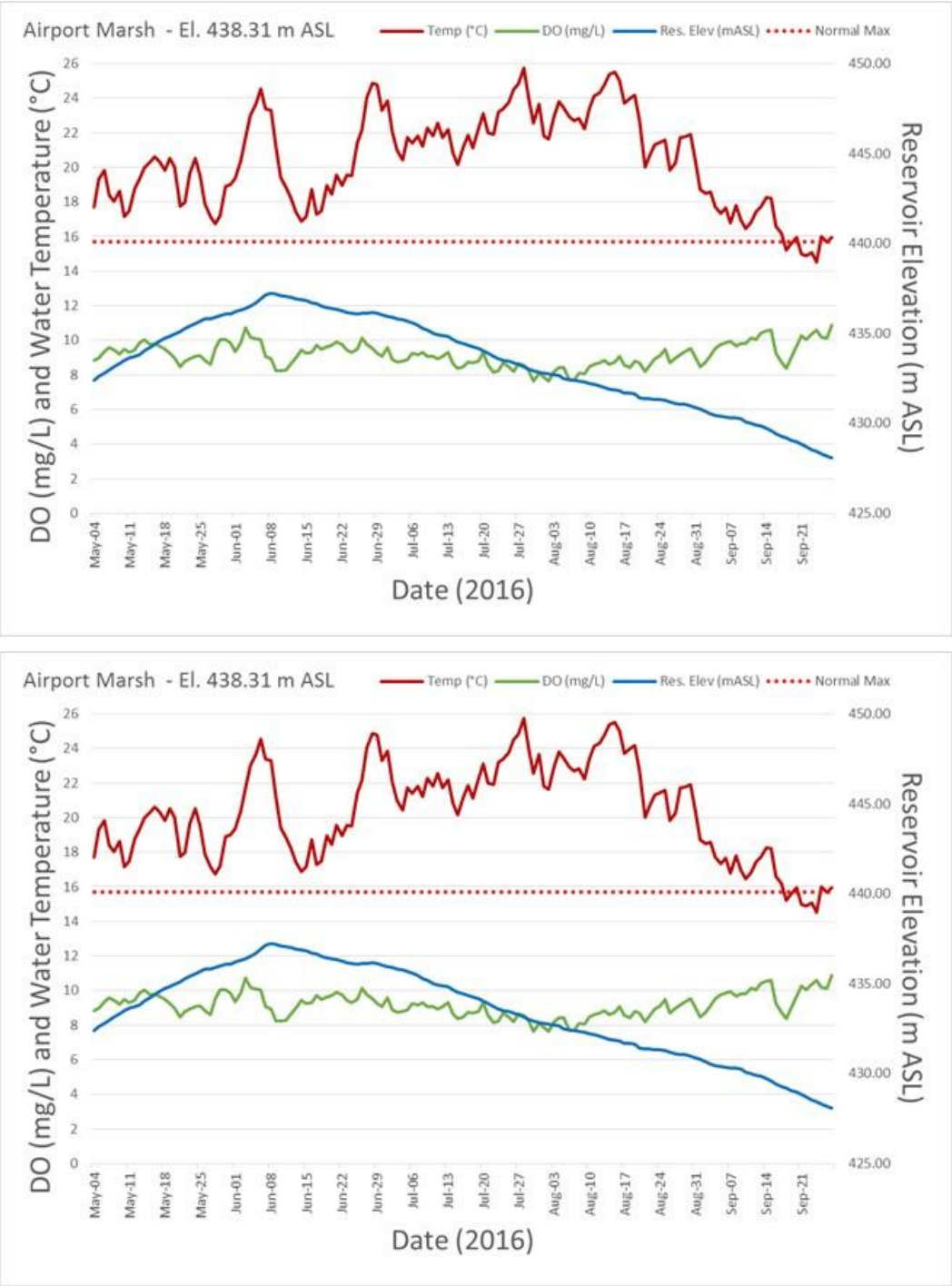

Figure 5-18: Mean daily variation in dissolved oxygen (DO; mg/L) and water temperature (°C) relative to reservoir elevation (m ASL) for wetlands at two locations in the drawdown zone of Arrow Lakes Reservoir for 2016. Data loggers were set at a depth of 30 cm below the surface when first installed.

Based on the data presented above, environmental conditions would not have negatively influenced amphibian and reptile surface activity during field surveys. Although DO and water temperature at the depth of the data logger might influence developmental rates of amphibian larvae, tadpoles tend to congregate at the edges

of ponds where both DO and water temperature would be higher. Collectively the environmental and water physicochemical conditions associated with field surveys are unlikely to have negatively influenced the species of amphibians and reptiles being studied. Any potential differences in species detectability are therefore unlikely to have been a result of environmental or water physicochemical conditions.

5.2.3 Species Occurrence and Distribution

Site Occupancy

At the landscape level, four species of amphibians and five reptiles were observed in the Arrow Lakes Reservoir in 2016 (Table 5-9). Three sites supported three species of amphibians in 2016: Burton Creek, Edgewood south, and Lower Inonoaklin. Western Toad occupied most of the sites surveyed in most years and accounted for the majority of observations. For reptile observations, three of the sites supported four species in 2016: Cartier Bay, Edgewood North, and Lower Inonoaklin. Common Garter Snake was the most widely distributed over all years, followed by Western Terrestrial Garter Snake and Northern Alligator Lizard. Western Skink was observed for the first time at Lower Inonoaklin in 2016. Mapped occurrences of all species observed in 2016 are included in Appendix 11-1.

Table 5-9: Site occupancy (shaded cells) of amphibians (top panel) and reptiles (bottom panel) observed in the Arrow Lakes Reservoir for 2008, 2009, 2010, 2012, 2014, and 2016. Data includes all incidental observations from past years including road and upland habitat in proximity to DDZ. A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-PSRE = Pacific Chorus Frog, A-RALU = Columbia Spotted Frog, R-CHPI = Painted Turtle, R-ELCO = Northern Alligator Lizard, R-PLSK = Western Skink, R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake. Blanks indicate species not detected in a given year and survey location

	A-AMMA						A-ANBO						A-PSRE						A-RALU						No. of Species					
Survey Sites	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**
ARR 12 Mile																									2	1	2	1		1
ARR 9 Mile																									3	2	2	2	2	1
ARR Airport Marsh																										2	2		1	2
ARR Beaton Arm																										2	3	2	2	2
ARR Burton Creek																									3	3	3	2	3	3
ARR Cartier Bay																									3	3	4	1	2	2
ARR Downie Marsh																										1	1	1	1	
ARR Edgewood north																											1		1	2
ARR Edgewood south																											3	2	2	3
ARR Lower Inonoaklin																											2	1	2	3
ARR Machete Island																										1	1			2
ARR Montana Slough																									1	2	3	3	2	2
ARR Mosquito Creek																										2	1			1
ARR Revelstock Reach Hwy.																									2	3			1	2
Total Sites Occupied	**1**	**3**	**2**			**2**	**5**	**10**	**10**	**7**	**10**	**12**	**6**	**7**	**11**	**4**	**5**	**5**	**2**	**2**	**5**	**4**	**4**	**7**						

	R-CHPI						R-ELCO						R-PLSK						R-THEL						R-THSI						No. of Species					
Survey Sites	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**
ARR 12 Mile																															1	1	1	2		1
ARR 9 Mile																															3	4	2	1	2	3
ARR Airport Marsh																															1	1	3		2	3
ARR Beaton Arm																																2	2		1	1
ARR Burton Creek																															2	2	2	1	1	2
ARR Cartier Bay																															2	3	3		2	4
ARR Downie Marsh																																2	2	2	2	
ARR Edgewood north																																2	4	2	2	4
ARR Edgewood south																																2	4	1	3	3
ARR Lower Inonoaklin																																	1		1	4
ARR Machete Island																																2	2			1
ARR Montana Slough																															2	2	4	4	2	3
ARR Mosquito Creek																																2	2			
ARR Revelstock Reach Hwy.																															2					
Total Sites Occupied	**1**	**2**	**2**	**1**	**2**	**3**	**3**	**4**	**6**	**2**	**5**	**6**		**1**	**2**		**1**	**2**	**3**	**9**	**10**	**6**	**4**	**7**	**6**	**9**	**12**	**4**	**6**	**11**						

Detection Rate

Between May and August, ~178 hours of visual encounter surveys were conducted at monitoring sites within the DDZ of Arrow Lakes Reservoir, during which 241 detections of more than 1,592,330 individuals across multiple life stages of all species were made (Table 5-10). To assess species-by-site relationships, we pooled all life stages to identify sites where the detection of a given species was the highest regardless of age class. Aggregations of tadpoles (or metamorphs) were treated as a single detection per location or pond, so as not to skew numbers. We examined the detection rates for 11 areas in Arrow Lakes Reservoir of which Edgewood North, Burton Creek, and Beaton Arm had the most consistently high rates of detections (Table 5-10). Western Toad, Western Terrestrial Garter Snake, and Common Garter Snake were the species with the highest detection rates.

Table 5-10: Total survey effort (hours multiplied by number of surveyors) for visual encounter surveys and species detections by survey location for Arrow Lakes Reservoir in 2016. Blanks indicate the species was not detected. A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-PSRE = Pacific Chorus Frog, A-RALU = Columbia Spotted Frog, R-CHBO = Rubber Boa, R-CHPI = Painted Turtle, R-ELCO = Northern Alligator Lizard, R-PLSK = Western Skink, R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake. CPUE (catch per unit effort) = number of observations per site and per species divided by survey effort in hours.

Survey Location	Effort (hrs)	A-AMMA	A-ANBO	A-PSRE	A-RALU	R-CHPI	R-ELCO	R-PLSK	R-THEL	R-THSI	Total	CPUE
12 Mile	3.78		3							2	5	**1.32**
9 Mile	15.53		5				1		3	1	10	**0.64**
Airport Marsh	16.41				4	2			4	10	20	**1.22**
Beaton Arm	9.33		14		2					2	18	**1.93**
Burton Creek	18.13		11	1	2				18	4	36	**1.99**
Cartier Bay	41.77	7	22		1		12		3	6	51	**1.22**
Edgewood north	6.88		2		1		3	4	1	3	14	**2.03**
Edgewood South	19.19		6	1	5		2		15	5	34	**1.77**
Lower Inonoaklin	10.93		4	2			2	1	4	2	15	**1.37**
Machete Island	7.10		3	1						4	8	**1.13**
Montana Slough	13.84		2		4		1				7	**0.51**
Totals: Effort (hrs); #obs	**162.91**	**7**	**72**	**5**	**19**	**2**	**21**	**5**	**48**	**39**	**218**	**1.40**
CPUE (#obs/hr)		**0.04**	**0.44**	**0.03**	**0.12**	**0.01**	**0.13**	**0.03**	**0.29**	**0.24**	**1.34**	

We examined the detection rates for five areas in Arrow Lakes Reservoir (Revelstoke Reach sites pooled; Figure 5-19), Revelstoke Reach and Edgewood had the most consistent detection rates among the species, as well as the highest numbers of species detected at each site. Beaton Arm and Burton Creek had the highest overall detection rates for Western Toad and Western Terrestrial Garter Snake, respectively. Both Western Toad and Common Garter Snake were detected at all sites. Western Painted Turtles had the lowest detection rate and was only found in Revelstoke Reach.

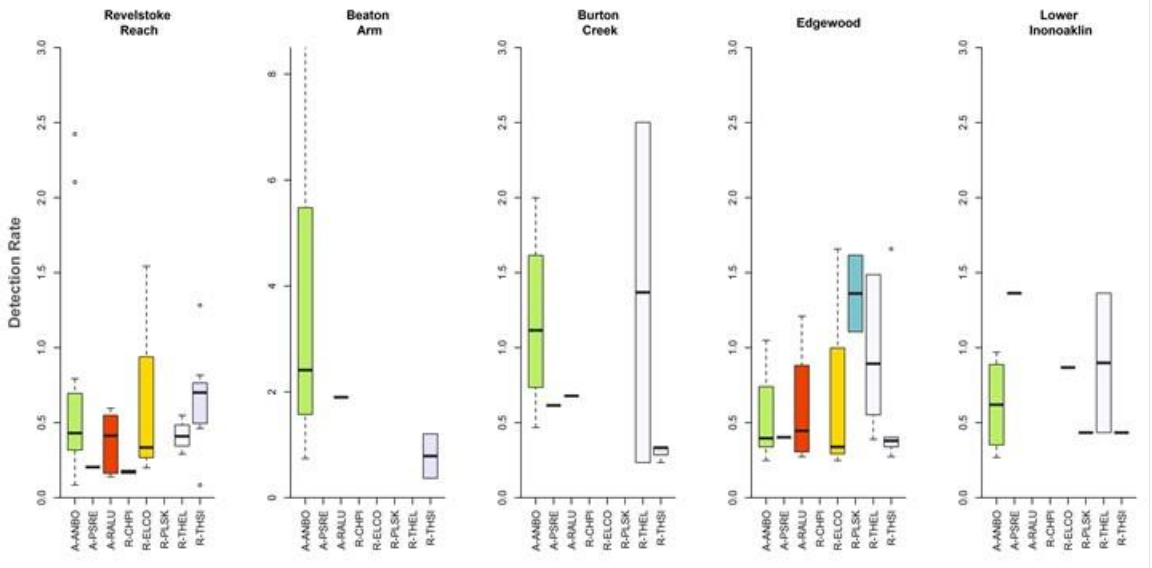

Figure 5-19: Detection rate for amphibian and reptile species in Arrow Lakes Reservoir in 2016. Detection rate = the number of times a species was detected (all life stages pooled)/the total time spent searching at a study site. A-ANBO = Western Toad, A-PSRE = Pacific Chorus Frog, A-RALU = Columbia Spotted Frog, R-CHPI = Painted Turtle, R-ELCO = Northern Alligator Lizard, R-PLSK = Western Skink R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake

Elevation

Amphibians and reptiles were found across a wide range of elevations in Arrow Lakes Reservoir in 2016 (Figure 5-20). Most observations (all life stages combined) were between 436 and 452 m ASL, a trend observed in previous years. Western Toad and Western Skink spanned the widest range of elevations, while observations of Long-toed Salamander and Columbia Spotted Frog spanned the narrowest range; however, detectability issues between the species or ontogenetic variation likely affect these relationships.

Comparing across the years, anuran species (i.e. frogs and toads) were distributed across an elevation range of 432 to 448 m ASL (Figure 5-20). The largest aggregations of frog and toad species occurred between 433 and 440 m ASL, which is likely related to the distribution of wetlands in the drawdown zone. For example, the elevation range of 30 wetlands mapped in the drawdown zone of Revelstoke Reach, Lower Inonoaklin Road, and Edgewood South range from 434 to 439 m ASL. However, Columbia Spotted Frog (435 and 440 m ASL) and Pacific Chorus Frog (434 and 438 m ASL) consistently used a narrower range of elevations than Western Toad (433 and 442 m ASL). Salamanders were not detected in most years, and with the exception of 2016 (438 m ASL), occupied only the highest elevation ponds (443 to 447 m ASL), which may be related to the proximity of these ponds to upland forest where this species typically lives.

The distribution of reptiles in Arrow Lakes Reservoir overlapped that of amphibians in most cases. Western Skink and Northern Alligator Lizard both typically occurred at the higher elevation bands (438 and 444 m ASL) associated with upland species. Common and Western Terrestrial Garter Snake were typically found between 437 and 431 m ASL. Western Painted Turtle are almost exclusively detected in the pond areas of the drawdown zone in Revelstoke Reach between 434 and 440 m ASL.

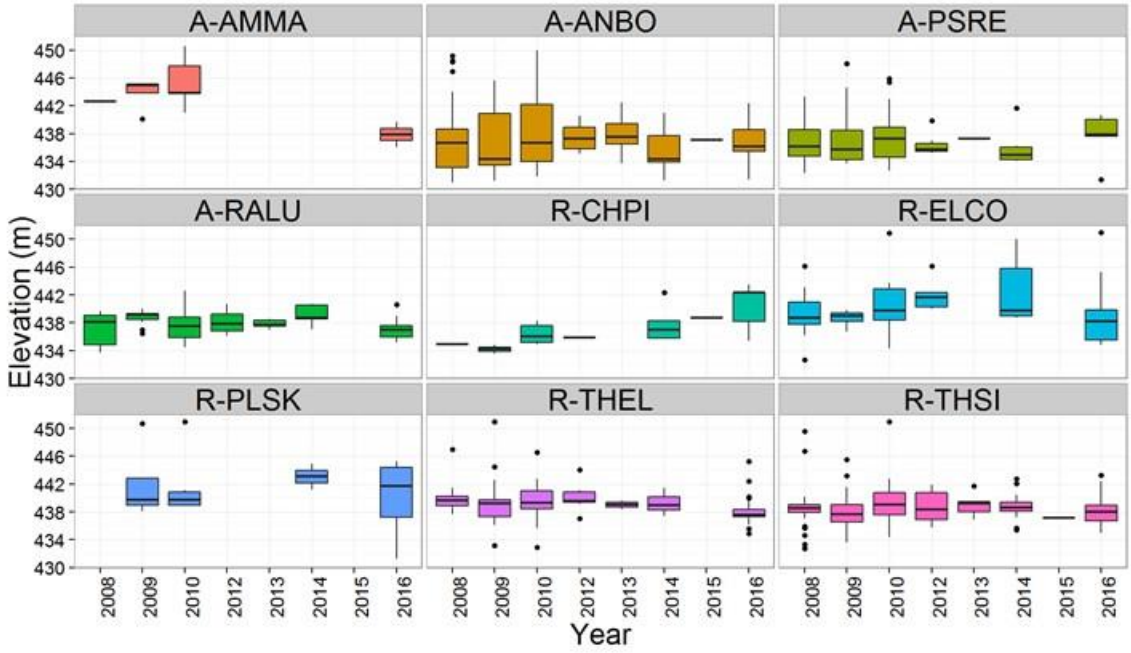

Figure 5-20: Elevation distribution of amphibians and reptiles (number of observations, all life stages combined) documented in and adjacent to the drawdown zone of Arrow Lakes Reservoir across all years of study. A- = Amphibian; R-=Reptile. A-AMMA = Long-toed Salamander, ANBO = Western Toad, A-PSRE = Pacific Chorus Frog, A-RALU = Columbia Spotted Frog, R-CHPI = Painted Turtle, R-ELCO = Northern Alligator Lizard, R-PLSK = Western Skink R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake

Vegetation Community Associations

Habitat use by Western Toad and Columbia Spotted Frog was compared to the vegetation community mapping that was completed for CLBMON-33 (Figure 5-21). Both species used multiple habitat types, with Western Toad being the more generalist species of the two, and Columbia Spotted Frog found most often in the wetter habitats water lily – Potamogeton open water (PO) and river (WR). Vegetation communities in which amphibians were found were distributed between ~434 m and 441 m ASL.

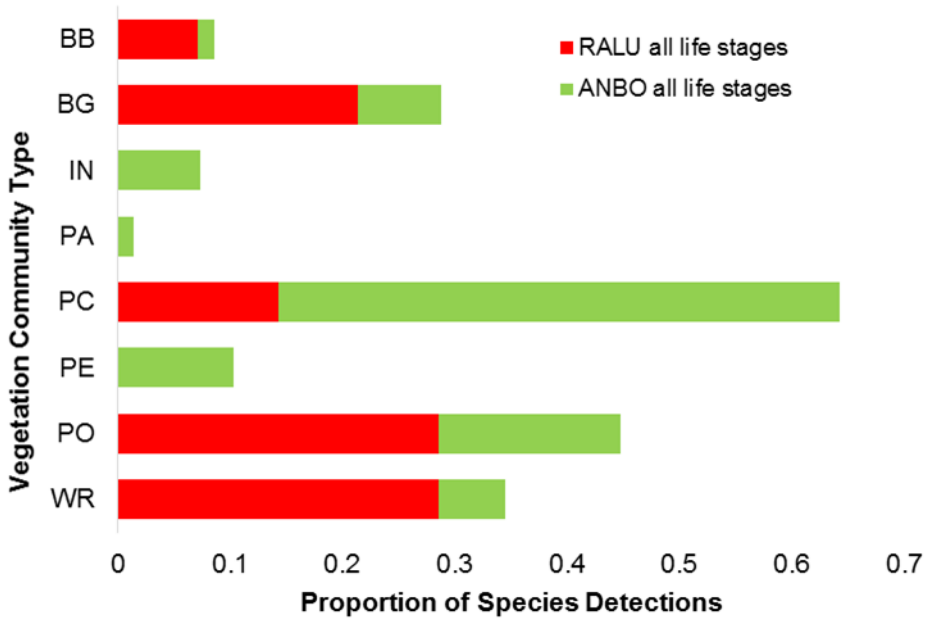

Figure 5-21: Distribution of Western Toad and Columbia Spotted Frog (all life stages grouped) by vegetation community class in the drawdown zone of Arrow Lakes Reservoir in 2016. ANBO = Western Toad, RALU = Columbia Spotted Frog; BB = non-vegetated boulders, steep slope, BG = non-vegetated boulders/gravel, gentle slope, IN = industrial/residential/recreational, PA = reed canary grass – redtop upland, PC = = reed canary grass – lenticular sedge (mesic), PE = reed canary grass – horsetail, PO = water lily – Potamogeton open water, WR = river. See Miller and Hawkes (20) for descriptions of each habitat type

5.2.4 Hypotheses Testing

H1: Annual and seasonal variation in water levels in Kinbasket and Arrow Lakes Reservoirs (due to reservoir operations) and the implementation of soft operational constraints in Arrow Lakes Reservoir, do not directly or indirectly impact reptile and amphibian populations

Soft Operational Constraints

The Columbia Water Use Plan (BC Hydro 2007a) does not specifically address amphibian and reptile populations in relation to the implementation of soft operational constraints. The reference to wildlife specifically discusses birds (nest mortality and fall migration). Similarly, in the Columbia Water Use Plan addendum for Revelstoke Unit 5 (BC Hydro 2007b), only the impacts to birds (as a proxy for wildlife) are discussed. Based on this, it appears that monitoring implemented under CLBMON-37 was not intended to address the impacts to amphibians and reptiles (or their habitat) as a result of the implementation of soft operational constraints. The number of days that the soft operational constraints were met on an annual basis were reported in the Columba River Updates[2] and are summarized below (Table 5-11). Soft operational constraints are not held constant for fixed periods of time and as such, this hypothesis cannot be formally tested directly. The perceived benefit to wildlife can be discussed retrospectively, but this does not assist in testing this hypothesis. Some of the hypotheses related to seasonal and annual variation in amphibian and reptile abundance, diversity, productivity, and habitat use can be tested (because they are not linked to soft constraints), and these are discussed below.

The spring soft constraints (April 30 to July 16; Table 5-11) are more likely to affect amphibians and reptiles as this coincides with the reproductive period for these taxa. Habitats in some parts of the drawdown zone that are situated at or below 435 m ASL are important for pond-breeding amphibians and are flooded between May 31 and June 11, suggesting that the implementation of soft constraints would not mitigate for potential impacts of reservoir operations on amphibian and reptile populations.

[2] http://www.bchydro.com/about/sustainability/conservation/water_use_planning/southern_interior/columbia_river.html

Table 5-11: Summary of the total time (days and percent of total) that soft constraints were met in Arrow lakes Reservoir between 2007 and 2014 to mitigate for potential impacts to birds using the drawdown zone. CLBMON-37 monitoring years are in shaded and bold

Year	Season	Target	Rationale	Date Start	Date End	Days	Days Met	Percent
2007	Spring	<434 m ASL	Nesting Birds	30-Apr	16-Jul	78	31.2	0.40
	Fall	<437.9 m ASL	Fall Migratory Birds	07-Aug	31-Oct	86	73.96	0.86
2008	**Spring**	**<434 m ASL**	**Nesting Birds**	**30-Apr**	**16-Jul**	**78**	**28.08**	**0.36**
	Fall	**<437.9 m ASL**	**Fall Migratory Birds**	**07-Aug**	**31-Oct**	**86**	**26.66**	**0.31**
2009	**Spring**	**<434 m ASL**	**Nesting Birds**	**30-Apr**	**16-Jul**	**78**	**37.44**	**0.48**
	Fall	**<437.9 m ASL**	**Fall Migratory Birds**	**07-Aug**	**31-Oct**	**86**	**86**	**1.00**
2010	**Spring**	**<434 m ASL**	**Nesting Birds**	**30-Apr**	**16-Jul**	**78**	**20.28**	**0.26**
	Fall	**<437.9 m ASL**	**Fall Migratory Birds**	**07-Aug**	**31-Oct**	**86**	**86**	**1.00**
2011	Spring	<434 m ASL	Nesting Birds	30-Apr	16-Jul	78	35.88	0.46
	Fall	<437.9 m ASL	Fall Migratory Birds	07-Aug	31-Oct	86	65.36	0.76
2012	**Spring**	**<434 m ASL**	**Nesting Birds**	**30-Apr**	**16-Jul**	**78**	**35.88**	**0.46**
	Fall	**<437.9 m ASL**	**Fall Migratory Birds**	**07-Aug**	**31-Oct**	**86**	**68.8**	**0.80**
2013	Spring	<434 m ASL	Nesting Birds	30-Apr	16-Jul	78	23	0.29
	Fall	<437.9 m ASL	Fall Migratory Birds	07-Aug	31-Oct	86	86	1.00
2014	**Spring**	**<434 m ASL**	**Nesting Birds**	**30-Apr**	**16-Jul**	**78**	**33**	**0.42**
	Fall	**<437.9 m ASL**	**Fall Migratory Birds**	**07-Aug**	**31-Oct**	**86**	**86**	**1.00**

The following sections test each of the hypotheses associated with CLBMON-37.

$H1_A$: Reservoir operations do not result in a decreased abundance of amphibians or reptiles in the drawdown zone.

The annual variability associated with reservoir operations influences the detectability of amphibians and reptiles in the drawdown zone, but not in a consistent manner. In 2016, Western Toad, Columbia Spotted Frog, and both species of garter snake detection rates (as a proxy for abundance) were not influenced by reservoir elevation (correlation coefficients: ANBO = -0.05, RALU = -0.16, THEL = -0.37, THIS = -0.19; Figure 5-22). For all species the range of elevations across which they were observed is consistent with previous years of study.

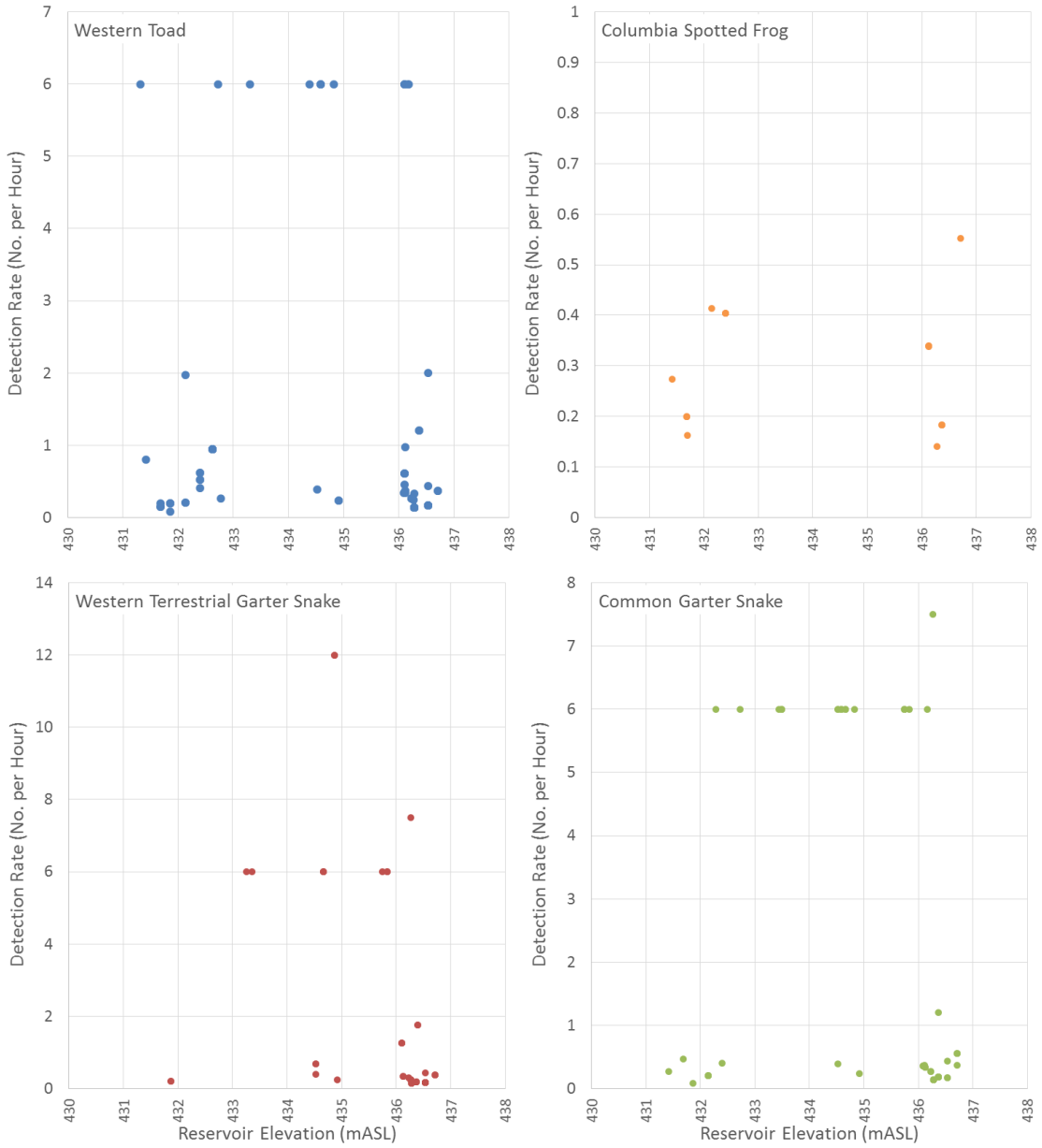

Figure 5-22: Relationship between reservoir elevations and detection rates for Western Toad, Columbia Spotted Frog, Western Terrestrial Garter Snake, and Common Garter Snake in Arrow Lakes Reservoir, 2016. Note different scales on vertical axes

$H1_B$: Reservoir operations do not increase the stage specific (e.g. larval, juvenile, or adult) mortality rates of amphibians or reptiles in the drawdown zone.

Our current understanding of the use of the drawdown zone by amphibians and reptiles is that certain species use the DDZ to fulfill most of their life history stages (e.g., Western Toad and Columbia Spotted Frog), while others (e.g., Long-toed Salamander, garter snakes, painted turtles) appear to use the DDZ to fulfill specific stages (Table 5-12). At this point, we have a good sense of when and how Western Toads, Pacific Chorus Frogs, Western Painted Turtles, and Common Garter

Snakes are using the DDZ; however, for all other species we do not have enough data to determine how they are using the DDZ.

Table 5-12: Observed life history activity of amphibian and reptile species in the drawdown zone of Arrow Lakes Reservoir from 2008 to 2016. Any 'Yes' indicates a direct observation of the life history activity or stage, whereas the rest are inferences

Species	Life History Activity			
	Breeding	Growth	Foraging	Overwintering
Columbia Spotted Frog (A-RALU)	Yes	Yes	Yes	Unknown
Western Toad (A-ANBO)	Yes	Yes	Yes	Unlikely
Pacific Chorus Frog (A-PSRE)	Yes	Yes	Likely	Unlikely
Long-toed Salamander (A-AMMA)	Yes	Yes	Likely	Unlikely
Coeur d'Alene Salamander (A-PLID)	No	No	No	No
Rubber Boa (R-CHBO)	No	Unlikely	Likely	No
Western Painted Turtle (R-CHPI)	No	Yes	Yes	Yes
Northern Alligator Lizard (R-ELCO)	Unlikely	Unlikely	Likely	Unlikely
Western Skink (R-PLSK)	No	Unlikely	Likely	Unlikely
Western Terrestrial Garter Snake (R-THEL)	Unknown	Yes	Yes	Unlikely
Common Garter Snake (R-THSI)	Unknown	Yes	Yes	Unlikely

Although we have a good general sense of how amphibians and reptiles are using the drawdown zone, breeding failures have not been directly measured and the relationships between reservoir operations and breeding failures are not clear. For some species our data do not support a quantitative effect of increased stage-specific mortality rates. For example, we know that all life stages of Western Toads use the drawdown zone at different times during the active season (April through September). In all years of study, we have documented adult toads breeding at the same locations (e.g., Revelstoke Reach, Beaton Arm and Burton Creek) and individuals migrating to and from certain ponds from late April to late June (Cartier Bay, Montana Slough, Burton Creek). Metamorph toads have also been documented emerging from the same drawdown zone locations (e.g., Cartier Bay, Beaton Arm) in multiple years, which provides an indication of how this species uses (and possibly relies upon) habitats within the drawdown zone to fulfill its life requisites; however, assessing mortality rates is not possible using the data collected to date. At issue is the inability to track individual egg masses over time given the spatial scale of CLBMON-37, which currently covers both Kinbasket and Arrow Lakes Reservoir. This results in a frequency of sampling that is too low to permit intensive data collection. As such mortality rates are unlikely to be accurately measured or reported. For all other species, we do not have enough (or any) data to accept or reject this hypothesis. For Western Painted Turtle, a separate study is being implemented to assess the relationship between populations of that species and reservoir operations (CLBMON-11B3) and those results are not reported here.

Life stage-specific mortality rates have not been directly measured for any species, but instances of mortality have been observed and can be related to natural causes (e.g. Western Toad depredation). For example, there are times when toad egg strings are not fertilized (see previous years reports), which could lead to reduced fecundity, but not mortality. We have not observed depredation (but see comment on fish predation concurrent with inundation in Hawkes and Tuttle 2016) or unfertilized egg masses of Columbia Spotted Frog. Egg string, egg mass, and

tadpole stranding have also been observed at various locations in the drawdown zone (e.g., Revelstoke Reach). The number of Western Toad egg strings and Columbia Spotted Frog egg masses that were stranded were difficult to accurately count, but were fewer than 10 for each species in all years of study. Egg mass stranding is usually related to decreasing hydroperiod at oviposition sites, which can be a major cause of death to developing embryos or tadpoles. The egg mass stranding phenomenon is not unique to drawdown zones (e.g., Marco and Blaustein 1998). Local environmental conditions can influence the hydroperiod of breeding ponds and are likely to confound reservoir effects that may be linked to egg mass stranding.

$H1_C$: Reservoir operations do not result in decreased site occupancy of amphibians or reptiles in the drawdown zone.

Proportion of Sites

In sampling years between 2008 and 2016, 14 locations in the drawdown zone have been surveyed for amphibians and reptiles. The proportion of these sites occupied by each species (i.e., was detected at least once in a given location per year) ranged from 0 per cent for Long-toed Salamanders in some years to 85.7 per cent for Columbia Spotted Frog (Table 5-13). Site occupancy was highest for Western Toad (A-ANBO) and Pacific Chorus Frog (A-PSRE) in most years averaging 64.3 per cent for Western Toad and 45.3 per cent for Pacific Chorus Frog. Occupancy for Long-toed Salamanders appears to be low; however, this species can be cryptic and is likely present at more sites than our data suggest. Of the reptiles detected in the drawdown zone, both species of garter snake occupied the most sites in all years (Western Terrestrial Garter Snakes, R-THEL: 46.4 per cent; Common Garter Snake, R-THSI: 57.2 per cent). Northern Alligator Lizards (R-ELCO) were present at two to six sites while Western Painted Turtle (R-CHPI) and Western Skink (R-PLSK) were present at fewer sites; however, both of these species are known to have limited distributions in the Arrow Lakes area, so this is not unexpected. In general, the proportion of sites occupied by each species does not indicate a decrease across years.

Table 5-13: Proportion of sites occupied at each survey site for each species of amphibian and reptile known to use habitats in the drawdown zone of Arrow Lakes Reservoir in 2008 to 2012, 2014 and 2016. A = amphibian, R = reptile; A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-PSRE = Pacific Chorus Frog; A-RALU = Columbia Spotted Frog, R-CHPI = Western Painted Turtle; R-ELCO = Northern Alligator Lizard; R-PLSK = Western Skink; R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake. . Numbers in table refer to detections of all life stages of each species

	A-AMMA						A-ANBO						A-PSRE						A-RALU					
Survey Sites	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**
ARR 12 Mile							1	2	15			3	2		2	3								
ARR 9 Mile	1	1	2				33	11	18	5	9	6	8			2	1							
ARR Airport Marsh								3	5		5	1		1	2									4
ARR Beaton Arm								8	8	1	15	13		1	2						13	1	5	2
ARR Burton Creek							5	13	10	1	15	12	3	1	1		1	1	5	20	10	1	3	2
ARR Cartier Bay		2	16				22	13	54	3	64	24	5	6	2		3		5		1			1
ARR Downie Marsh								3	2	1	11													
ARR Edgewood north												2			2								1	1
ARR Edgewood south									4		2	6			8	1		1			1	1	1	5
ARR Lower Inonoaklin						2			1	1	9	8			2		2	3						
ARR Machete Island												3		2	4			1						
ARR Montana Slough								2	3	3	5	3	3	2	4	1	1				4	1		4
ARR Mosquito Creek								3							2			1		1				
ARR Revelstock Reach Hwy.		4				7	29	8			4	22	4	1										
Total Locations	**1**	**3**	**2**			**2**	**5**	**10**	**10**	**7**	**10**	**12**	**6**	**7**	**11**	**4**	**5**	**5**	**2**	**2**	**5**	**4**	**4**	**7**
Proportion of Locations	**7.1**	**21.4**	**14.3**	**0.0**	**0.0**	**14.3**	**35.7**	**71.4**	**71.4**	**50.0**	**71.4**	**85.7**	**42.9**	**50.0**	**78.6**	**28.6**	**35.7**	**35.7**	**14.3**	**14.3**	**35.7**	**28.6**	**28.6**	**50.0**

	R-CHPI						R-ELCO						R-PLSK						R-THEL						R-THSI					
Survey Sites	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**	**08**	**09**	**10**	**12**	**14**	**16**
ARR 12 Mile																						2			1	5	1	4		2
ARR 9 Mile		1					11	3	4			1							4	2			1	5	26	5	8	4	3	4
ARR Airport Marsh			2		2	11															1			4	1	1	7		1	13
ARR Beaton Arm																				1	1					5	8		2	2
ARR Burton Creek																			14	7	11	1	2	19	6	6	8			4
ARR Cartier Bay						1	1	2	2		2	11								2	1			3	6	3	6		1	7
ARR Downie Marsh																				2	27	3	2			4	47	14	6	
ARR Edgewood north									12	1	12	3		4	6		3	6		1	3	1		1			2			3
ARR Edgewood south								1	3		1	3			1					1	19	2	1	18			14		7	10
ARR Lower Inonoaklin									1		1	3						1						7						2
ARR Machete Island																				1	4					1	7			4
ARR Montana Slough	3	1	4	1	3	4	3	1	3	6	2	3									3	1					3	2		1
ARR Mosquito Creek																				1	3					3	5			
ARR Revelstock Reach Hwy.																			1						20					
Total Sites Occupied	**1**	**2**	**2**	**1**	**2**	**3**	**3**	**4**	**6**	**2**	**5**	**6**		**1**	**2**		**1**	**2**	**3**	**9**	**10**	**6**	**4**	**7**	**6**	**9**	**12**	**4**	**6**	**11**
Proportion of Locations	**7.1**	**14.3**	**14.3**	**7.1**	**14.3**	**21.4**	**21.4**	**28.6**	**42.9**	**14.3**	**35.7**	**42.9**	**0.0**	**7.1**	**14.3**	**0.0**	**7.1**	**14.3**	**21.4**	**64.3**	**71.4**	**42.9**	**28.6**	**50.0**	**42.9**	**64.3**	**85.7**	**28.6**	**42.9**	**78.6**

$H1_D$: Reservoir operations do not result in decreased productivity of amphibians or reptiles in the drawdown zone.

Amphibian productivity has not been explicitly studied in Arrow Lakes Reservoir. The data collected thus far indicate that four species of pond-breeding amphibian, (Western Toad, Columbia Spotted Frog, Pacific Chorus Frogs, and Long-toed Salamander) are using habitats in the drawdown zone for breeding. The detection of amphibian egg masses varies for all species by site, but the observed variation is expected. Although we can calculate detection rates for these species, most of the information we have is qualitative and based on loose count observations. We have observed all life stages of these species (i.e., eggs, tadpoles, toadlets, subadults, and adults).

Western Toad, productivity does not appear to be affected by reservoir operations. For example, Western Toad metamorphs have been observed in Revelstoke Reach (e.g., Cartier Bay), Beaton Arm, and although there have been no observations for Burton Creek yet, it is assumed because of the numerous

tadpoles (both numbers and Gosner stages) that metamorphs occur there as well. Each spring, numerous adult Western Toads are documented in the drawdown zone, and egg strings are observed in many of the same locations each year. Adult male to female ratios calculated in earlier years of this study are consistent with values reported in the literature (Olson et al. 1986), lending support to a stable population of toads in the areas of Arrow Lakes Reservoir being studied.

Qualitatively, it appears that the productivity of certain species is not directly affected by reservoir operations. However, we are currently only assessing these species in the drawdown zone of the reservoir. In the absence of a suitable control or baseline data, we don't know for certain how the productivity of any species of amphibian might be affected by reservoir operations.

Assessing reptile productivity (i.e., garter snakes) would require an intensive study involving the capture of numerous female snakes to determine reproductive state, counting eggs, observing where females give birth (i.e., drawdown zone or upland habitats), and assessing to what extent these species use the drawdown zone. Our current understanding of reptile use of the drawdown zone is limited to opportunistic observations made during the spring and summer only and these observations are generally of basking or foraging adults.

$H1_E$: Reservoir operations do not reduce the availability and quality of breeding habitat, foraging habitat and overwintering habitat for amphibians or reptiles in the drawdown zone.

Habitat availability was assessed by delineating the total area sampled each year (i.e., terrestrial and aquatic habitat at each survey site) and calculating how much of that area was available on a monthly basis relative to reservoir operations (i.e., timing of reservoir inundation at each particular elevation = unavailable). As expected, a negative relationship exists between the availability of habitat and reservoir elevations, with habitat availability decreasing with time. The change in habitat availability is most evident in June and July, when reservoir elevations are increasing (Figure 5-23). A notable difference in 2016 is the early peak in reservoir levels in June and subsequent decrease, which lead to overall increased available habitat in the late summer and fall as compared to 2012 and 2014.

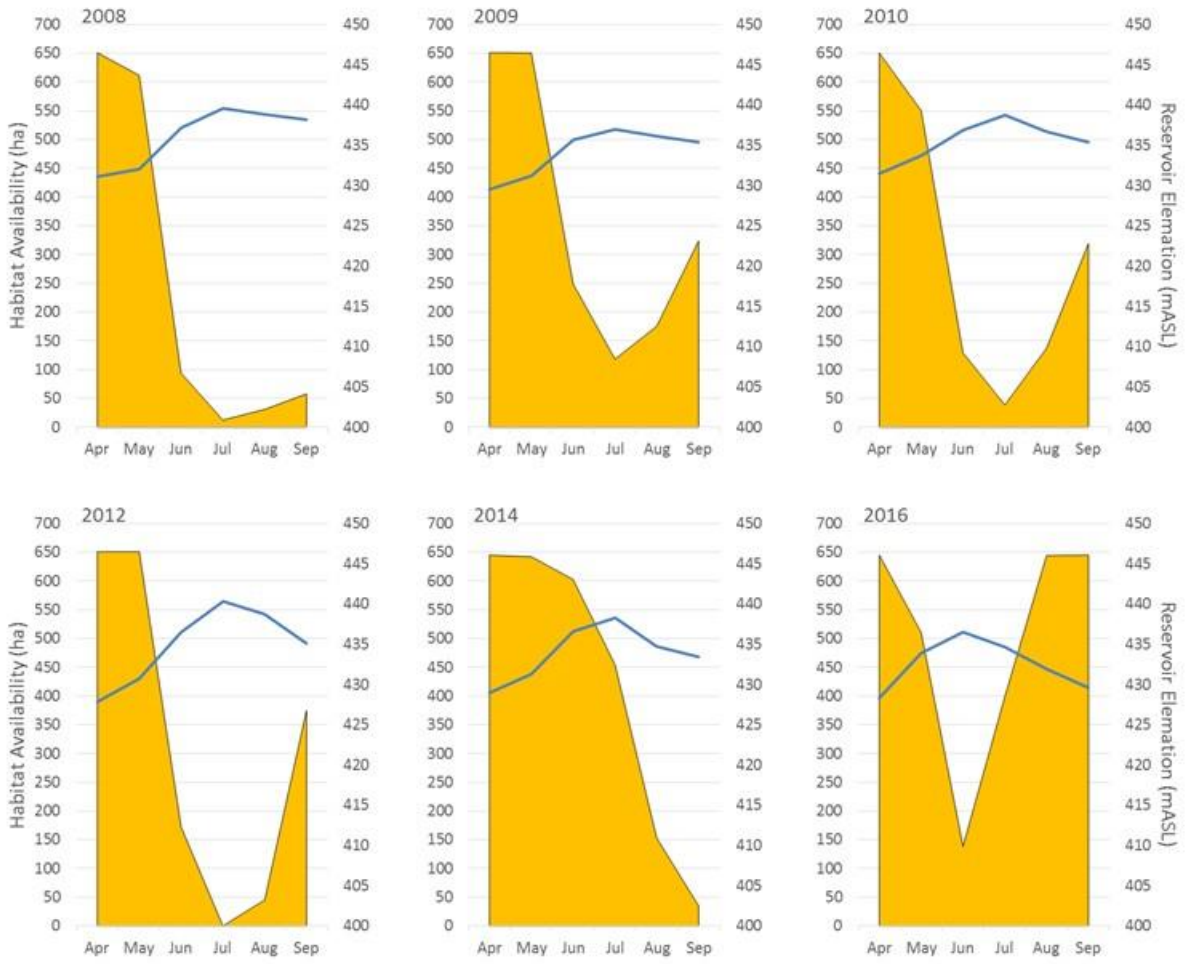

Figure 5-23: Relationship between habitat availability and reservoir elevation (i.e., inundation) in the drawdown zone of Arrow Lakes Reservoir for 2008 to 2010, 2012, 2014 and 2016. The average reservoir elevation is shown (line)

The availability of amphibian and reptile habitat in the drawdown zone is discussed in the context of (1) breeding habitat, which is defined as those habitats in which amphibian egg masses are deposited or where reptiles give birth, (2) foraging habitat, where amphibians and reptiles obtain prey, which includes both aquatic and terrestrial habitats, and (3) overwintering habitat, or those habitats necessary for the overwinter survivorship of amphibians and reptiles.

Breeding Habitat

The amphibians using the drawdown zone of Arrow Lakes Reservoir are pond-breeding amphibians that breed in wetlands, ponds, quiescent backwaters of streams, and sometimes lake margins. Reservoir operations affect the availability of breeding habitat. The quality of breeding habitat is assumed to be high when it is available, mainly because amphibians are observed using those habitats on an annual basis. The degree to which specific areas in the drawdown zone are affected depends on reservoir elevations in any given year and month. To demonstrate the relationship between reservoir elevation and habitat availability, data for Cartier Bay / Montana Slough in Revelstoke Reach is used. This location

provides important breeding habitat for Western Toads. In 2016, 30 ponds were delineated in the drawdown zone in this location ranging in size from 0.01 ha to 14.3 ha ($\bar{x}$ = 2.18; SD = 4.2 ha). Most of the pond area (~60 per cent, 35.3 ha) is situated at ~433 m ASL, an additional ~17 per cent (~10.1 ha) at 435 m ASL and ~ 11 per cent (~6.3 ha) at 436 m ASL. Over the last three years of study (2012, 2014, and 2016), the majority of the ponds in this location were inundated between May, 10 (2016) and May, 31 (2012). The remaining potential breeding habitat was inundated between June 6 (2014) and June 9 (2012 and 2016) (Figure 5-24). Most pond-breeding amphibian egg masses were laid prior to inundation, and based on our observations of all life stages of Western Toads (eggs, tadpoles, toadlets, sub-adults, and adults), the reduction in habitat availability associated with inundation does not appear to be associated with reduced reproductive success, but this has not been explicitly studied in Arrow Lakes Reservoir.

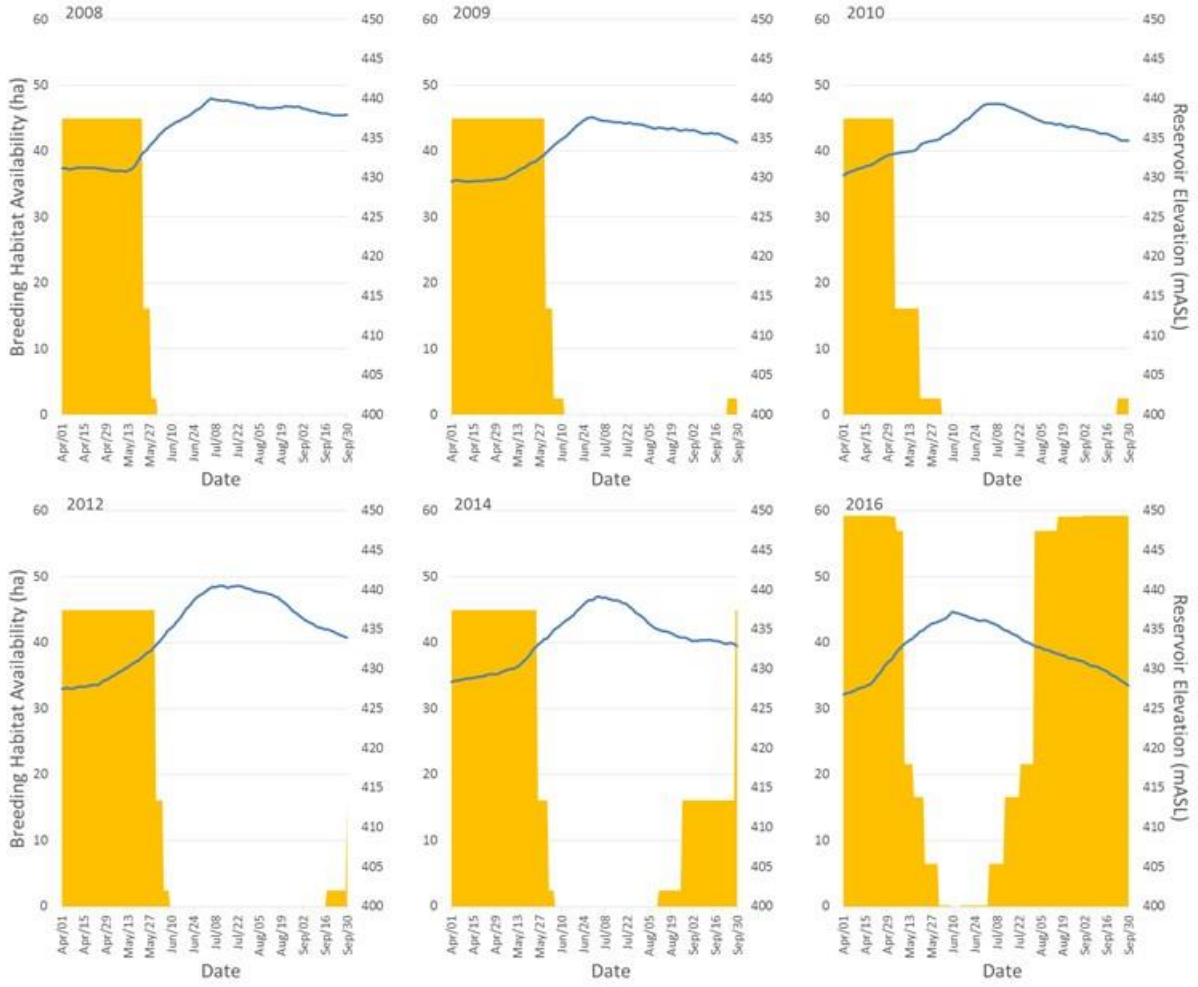

Figure 5-24: Relationship between amphibian breeding (and rearing) habitat availability (pond area) and reservoir elevations for the period April 1 through September 30, 2008 to 2010, 2012, 2014 and 2016 in Arrow Lakes Reservoir

The timing of inundation and occupancy of ponds coupled with the observation of breeding toads and frogs and egg masses indicates that reservoir operations do not preclude breeding in ponds in the drawdown zone. Most pond-breeding amphibian egg masses were laid prior to inundation, and based on our

observations of all life stages of Western Toads (eggs, tadpoles, toadlets, subadults, and adults), the reduction in habitat availability associated with inundation does not appear to be associated with reduced reproductive success. Observations of egg strings were made at Cartier Bay in May of 2012 and 2014 prior to inundation (In 2016, no observations of egg strings were made at this location. It is believed that, due to unseasonably warm temperatures and toads travelling to breeding ponds earlier than normal, the timing of surveys missed the core breeding window for toads in this area). Coupled with observations of metamorphosed toads at Cartier Bay post-inundation in July and August post-inundation (2012, 2014, and 2016) suggests that toad egg strings and tadpoles can tolerate some level of disturbance from reservoir operations. However, the degree to which reservoir operations might affect the success of observed breeding (in terms of the proportion of eggs that survive to metamorphosis) is not well-understood and cannot currently be quantified.

Foraging Habitat

Adult amphibians consume terrestrial and aerial insects, tadpoles are algae grazers, and toadlets eat small invertebrates and insects. Reptiles (snakes and lizards) consume insects, worms, and gastropods, while snakes also consume small mammals and amphibians. Amphibians and reptiles forage in a variety of aquatic and terrestrial habitats and both of these general habitat types occur in the drawdown zone of Arrow Lakes Reservoir. A similar trend to pond habitat is observed for foraging habitat (i.e., terrestrial and aquatic) and as expected there is a strong negative relationship between inundated reservoir elevation and habitat availability (Figure 5-23). The annual trends are similar with only the timing and duration of inundation of each elevation band varying (Table 5-14).

Table 5-14: Proportion of time between April 1st and September 30th (n = 183 days) that Arrow Lakes Reservoir exceeded a given range of elevations from 1997 to 2016. Shading indicates the reservoir did not exceed a given elevation in that year

m ASL	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
427-428	0.78	0.81	0.74	0.80	0.48	0.83	1.00	0.86	1.00	0.85	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.87	0.49
428-429	0.76	0.79	0.70	0.75	0.36	0.72	0.90	0.83	0.93	0.81	1.00	1.00	1.00	1.00	1.00	0.87	1.00	1.00	0.85	0.42
429-430	0.75	0.77	0.68	0.72	0.25	0.69	0.84	0.81	0.87	0.77	1.00	1.00	1.00	1.00	1.00	0.83	1.00	0.90	0.73	0.39
430-431	0.73	0.75	0.65	0.70	0.15	0.68	0.79	0.77	0.80	0.74	0.95	1.00	0.81	1.00	1.00	0.78	1.00	0.79	0.57	0.37
431-432	0.70	0.73	0.63	0.67		0.66	0.72	0.72	0.60	0.73	0.83	0.91	0.76	0.95	0.75	0.74	0.79	0.75	0.50	0.34
432-433	0.68	0.70	0.60	0.64		0.63	0.69	0.68	0.48	0.69	0.76	0.73	0.70	0.88	0.71	0.70	0.72	0.72	0.41	0.32
433-434	0.67	0.67	0.58	0.62		0.61	0.68	0.56	0.31	0.63	0.72	0.72	0.67	0.82	0.69	0.67	0.59	0.69	0.32	0.30
434-435	0.65	0.65	0.57	0.57		0.54	0.63	0.41	0.14	0.56	0.60	0.69	0.64	0.73	0.64	0.64	0.50	0.46	0.23	0.26
435-436	0.62	0.61	0.56	0.55		0.46	0.57	0.22		0.49	0.50	0.67	0.57	0.61	0.62	0.55	0.41	0.36	0.13	0.22
436-437	0.60	0.57	0.54	0.49		0.38	0.49	0.10		0.43	0.43	0.64	0.38	0.47	0.58	0.45	0.31	0.28		0.17
437-438	0.52	0.42	0.49	0.42		0.31	0.35			0.38	0.34	0.60	0.11	0.28	0.48	0.39	0.25	0.22		0.03
438-439	0.42	0.24	0.37	0.33		0.25	0.23			0.31	0.21	0.48		0.19	0.36	0.34	0.15	0.16		
439-440	0.29		0.18	0.16		0.18	0.07			0.19		0.19		0.09	0.26	0.29	0.10	0.04		
440-441	0.09		0.02	0.02												0.15				

Overwintering Habitat

Field work for CLBMON-37 occurs during the snow-free period, usually between the middle to end of April and end of September each year. The availability or quality of amphibian and reptile overwintering habitat in the drawdown zone of Arrow Lakes Reservoir has not been assessed. Questions related to the availability and quality of overwintering habitat cannot be answered using existing data. However, the telemetry data collected in 2014 suggests that Western Toads are not using the drawdown zone during the winter period and that more likely, they are wintering in upland habitats, which is consistent with what is generally known for this species (e.g., Browne and Paszkowski 2010). For the areas assessed in Arrow Lakes Reservoir, it appears that habitats upslope of Cartier Bay provide important overwintering habitat, but more data are required to verify this. Similarly, we are not currently able to confirm where garter snakes overwinter relative to the drawdown zone and although we suspect that they overwinter in upland habitats, data are required to verify this.

$H2_A$: Revegetation and physical works do not increase species diversity or seasonal (spring/summer/fall) abundance of amphibians or reptiles in the drawdown zone.

Revegetation

The revegetation prescriptions applied were never considered relevant or beneficial to amphibians and reptiles nor were they implemented explicitly to benefit amphibians and reptiles. In certain areas (e.g., Lower Inonoaklin Road) the density of sedges around wetland habitat has increased, but there is no indication that increasing sedge densities are contributing to increases in species diversity or seasonal abundance. Although the hypothesis asks whether revegetation increases species diversity or abundance, we did not test this for the aforementioned reasons. It is the opinion of the authors that revegetation did not, at least in the years covered by this report, increase species diversity or abundance of amphibians and reptiles in the drawdown zone. Further, the fall abundance of

amphibians and reptiles has not been assessed as the high reservoir level precludes surveys in the drawdown zone during that season.

Physical Works

Physical works have not been implemented in Arrow Lakes Reservoir and as such, we are unable to test this hypothesis. Given that we have documented all expected species from most areas, it is unlikely that physical works will increase species diversity. If wetlands were constructed in or adjacent to the drawdown zone (as per Hawkes and Tuttle 2016) and those wetlands were protected from inundation through tadpole metamorphosis, the abundance of certain species may increase over time, but this is speculative.

$H2_B$: Revegetation and physical works do not increase amphibian or reptile productivity in the drawdown zone.

Revegetation

The revegetation prescriptions applied were never considered relevant or beneficial to amphibians and reptiles nor were they implemented explicitly to benefit amphibians and reptiles. The relationship between revegetation prescriptions applied in the drawdown zone and amphibian and reptile productivity has not been assessed. There is a potential link between increasing food resources (e.g., invertebrates and small mammals) and productivity and aspects of this are being studied as part of the Arrow Lakes Reservoir Wildlife Effectiveness study (CLBMON-B1). Amphibians and reptiles are not focal taxa in that study.

Physical Works

At present we are unable to test this hypothesis as there have not been any physical works implemented in the drawdown zone of Arrow Lakes Reservoir. If wetlands were built as a physical works and those wetlands were protected from inundation through tadpole metamorphosis, the productivity of certain species may increase over time, but this is speculative. The removal of woody debris from specific areas of the drawdown zone is likely to improve habitat suitability for amphibians and reptiles, but this has not been directly studied.

$H2_C$: Revegetation does not increase the amount or improve habitat for amphibians and reptiles in the drawdown zone.

As stated above, the revegetation prescriptions applied were never considered relevant or beneficial to amphibians and reptiles nor were they implemented explicitly to benefit amphibians and reptiles.

6.0 DISCUSSION

The relationship between habitats occurring in the drawdown zone of hydroelectric reservoirs and their use by wildlife has not been well-studied (but see Swan et al. 2015). While suitable habitat may exist in the drawdown zone of these reservoirs, reservoir operations can affect the suitability and availability of those habitats within and between years. In Kinbasket and Arrow Lakes Reservoirs, the relationship between reservoir operations and the distribution and occurrence of amphibians and reptiles has been studied since 2008.

Reservoir operations do affect the availability and suitability of habitats in the drawdown zone, with large reductions in total available habitat (due to inundation) occurring on an annual basis. Despite a seasonal reduction in total available habitat as a result of increasing reservoir elevations and the associated changes in some water physicochemical parameters, amphibian and reptile populations are persisting in the drawdown zone of Kinbasket and Arrow Lakes Reservoirs. This is likely due to the timing of breeding in the spring and the timing of inundation of breeding habitats which happens late enough in the year to permit larval development. However, there are likely to be direct effects on amphibian habitat resulting mainly from the vertical and horizontal movement and depositions of large rafts of wood debris.

To better assess the within and between season use of the drawdown zone by amphibians and reptiles, a radiotelemetry study was piloted in 2014 and continued in 2015 and 2016 (snakes only in the northern Kinbasket Reservoir). The results to date indicate that Common Garter Snake use the drawdown zone for spring and summer foraging, with all tagged individuals retreating to upland habitat for overwintering. Although we have not documented overwintering locations used by Western Toad, we presume they occur in upland habitats, consistent with other studies (e.g., Bull 2006). More data are required to characterize the seasonal habitat (especially winter) use for other species in both reservoirs.

6.1 MQ1: Which species of amphibians and reptiles occur (utilize habitat) within the drawdown zone and where do they occur?

All expected species have been documented using the drawdown zones and adjacent upland habitats of Kinbasket (Table 5-2) and Arrow Lakes Reservoirs (Table 5-9). The most commonly occurring species are Western Toad, Columbia Spotted Frog and Common Garter Snake. These three species are widespread across B.C. (Matsuda et al. 2006) and are locally abundant at most of the monitoring locations. The most productive sites in Kinbasket Reservoir are Bush Arm KM79 marshes, Bush Arm Causeway and Ptarmigan Creek. In past years, Valemount Peatland has been very productive, but detection rates decreased in 2016 due to increased, daily survey efforts of the Masters project in the peatland. The most productive sites in Arrow Lakes Reservoir are Edgewood areas, Beaton Arm and Burton Creek. In certain years, Cartier Bay is also very productive.

There are historical records of Wood Frog (*Lithobates sylvaticus*) from the drawdown zone of Kinbasket Reservoir, but this species has not been observed during field work for this or other studies (e.g., CLBMON-37, 10, 9, and 61). The currently understood range of Wood Frog (Matsuda et al. 2006) may not overlap the drawdown zone of Kinbasket Reservoir.

The most surprising observation was that of a Western Painted Turtle in the drawdown zone of Kinbasket Reservoir at Bush Arm. The closest known record of a Western Painted Turtle is at Reflection Lake near Golden, B.C., and approximately 140 linear km away.

6.2 MQ2: What is the abundance, diversity, and productivity (reproduction) of amphibians and reptiles utilizing the drawdown zone and how do these vary within and between years?

6.2.1 Amphibian Abundance, Diversity and Productivity

Amphibian abundances (detection rates) vary from year to year and in general, there are more detections in the spring than in the summer or early fall. In 2016, unseasonably warm spring temperatures led to a shift in the breeding window for pond breeding amphibians. As a result, regularly scheduled spring surveys missed the peak of the breeding season when most adults are migrating to and from breeding ponds and are therefore more conspicuous and the detection of egg masses and strings are detectable. In previous years, there was an apparent trend of higher amphibian detection rates in the spring and in particular, for Western Toad. The seasonal variation observed in the drawdown zone may be similar to the seasonal variation associated with non-reservoir populations of toads and frogs, but this has not been confirmed.

Amphibian species diversity has not varied substantively by year, which is related primarily to the total number of detections made in a given year combined with within season differences that contribute to inconstant detectability. Although diversity has not varied, detection rates have (see previous section), which is not surprising. Amphibian populations naturally exhibit large degrees of variation with the number detected a function of current environmental conditions, overwinter survival, and predation pressure (Hansen et al. 2012). Some species (e.g., Long-toed Salamander) are often difficult to locate because they have an early breeding period and are inconspicuous during the remainder of the year (Wilkinson and Hanus 2002). Although Long-toed Salamander have been documented from only a few locations, they are likely distributed throughout Kinbasket and Arrow Lakes Reservoirs and adjacent upland habitats, particularly in areas with suitable breeding habitat. Auditory surveys and additional visual encounter surveys will have to be conducted to confirm presence of Pacific Chorus Frog in the Valemount Peatland or elsewhere in the reservoir.

Amphibian productivity has not been explicitly studied in either reservoir. We currently know which amphibian species (Western Toads, Columbia Spotted Frogs, Pacific Chorus Frogs [Arrow only confirmed], and Long-toed Salamanders) use the DDZ for reproduction (a proxy of productivity) and data collected for two species (Western Toad and Columbia Spotted Frog) indicate that all life stages of this species (i.e., eggs, tadpoles, toadlets, subadults, and adults) use habitats in the drawdown zone. However, too few data on Pacific Chorus Frogs and Long-toed Salamanders exist to discuss how reservoir operations might affect their productivity. To better assess the variation in amphibian productivity across time, increased effort is required to measure reproductive success and survivorship of eggs and tadpoles of pond-breeding amphibians at various elevations in the drawdown zone. This would require intensive site-specific monitoring of ponds used by pond-breeding amphibians, particularly Western Toad and Columbia

Spotted Frog, to determine their productivity and survival in various habitats in the drawdown zone.

Qualitatively, it appears that the productivity of both Western Toad and Columbia Spotted Frog is consistent and stable between years, as egg masses and adults have been repeatedly detected at the same pond locations in all previous years and some in 2016 (e.g., Ptarmigan Creek, Valemount Peatland-Pond 12, KM 79, Cartier Bay, Burton Creek). Further, in the absence of a suitable control or baseline data from ponds outside of the drawdown zones of Kinbasket or Arrow Lakes Reservoirs, we cannot know for certain how productivity is affected by reservoir operations. Species-specific and individual fecundity has not been assessed and is therefore not discussed.

6.2.2 Reptile Abundance, Diversity and Productivity

Reptile abundances (detection rates) vary annually and seasonally; however, small samples sizes limit our ability to discuss within-season trends.

Reptile species diversity consists of two species in Kinbasket and five (possibly six) in Arrow Lakes that occur in and adjacent to the drawdown zones. Common Garter Snake has been observed annually using habitats in the drawdown zone of Kinbasket Reservoir (especially at Ptarmigan Creek, in the Valemount Peatland near Pond 12, and in Bush Arm at the causeway, Bear Island and KM 79) and Arrow Lakes Reservoir (Revelstoke Reach, Burton Creek, Beaton Arm and Edgewood). Western Terrestrial Garter Snakes are more often documented in the drawdown zone of Arrow Lakes than Kinbasket Reservoir. However, this species is more frequently associated with upland habitats immediately adjacent to the drawdown zone. In 2015, a surprising observation of a single adult Western Painted Turtle was made at KM88 (near the mouth of Bush Arm) and in 2016 near the town of Valemount); however it is not known 1) if more than one turtle is present at these or other sites, or 2) whether this animal was released from the Revelstoke population or has immigrated on its own into Kinbasket Reservoir. No other reptile species are expected to occur in Kinbasket Reservoir, but Arrow Lakes Reservoir also has Northern Alligator Lizards (Edgewood to Revelstoke, Western Skinks and Rubber Boas (only detected at the Edgewood and Lower Inonoaklin sites) that are associated with rocky upland habitats at several locations. Western Painted Turtles have been studied in Revelstoke Reach since 2009, and information on this species can be found in the CLBMON-11B3 reports.

Reptile productivity is not readily assessed under CLBMON-37, largely because reptile productivity is not linked to the presence or absence of water. Reproduction for snakes and lizards often occurs near overwintering sites (Garstka et al. 1982; Kromher 2004) which are located outside of the DDZ (as determined via telemetry studies in Valemount Peatland in 2016; J. McAllister, unpublished data, but see Figure 5-9 and Appendix 11-2). However, because of the value of DDZ habitats to pond-breeding amphibians, which snakes use as a primary food resource, reservoir operations could impact snake populations. While it is relatively easy to measure direct productivity in captured female snakes (e.g., counting eggs internally in gravid females), it does not follow that females are necessarily using the DDZ in the same way foraging snakes are, as females generally do not feed as frequently during pregnancy (Tuttle and Gregory 2009).

6.3 MQ3: During what portion of their life history (e.g., breeding, foraging, and over-wintering) do amphibians and reptiles utilize the drawdown zone?

Our current understanding of the use of the drawdown zone by amphibians and reptiles is that Western Toads, some species of frogs and Painted Turtles use the DDZ to fulfill most of their life history stages (e.g., breeding, foraging and, in the case of turtles and possibly frogs, overwintering), while other species (e.g., Long-toed Salamander, garter snakes) appear to use the DDZ to fulfill specific life stages. We do not have enough data for Long-toed Salamander or other species of reptile (e.g., garter snakes, lizard species) to determine how they are using the DDZ. Long-toed Salamander are not always easy to detect, so their perceived lower levels of use of the DDZ (e.g., mainly restricted to egg mass and incidental upland observations) may be related to their cryptic nature and not necessarily to their absence from the DDZ. Use of the drawdown zone for overwintering is considered unlikely for most species, with the exception of Western Painted Turtles and possibly Columbia Spotted Frogs. Water bodies that are deep enough that they do not freeze on the bottom are required for overwintering frog adults, juveniles and possibly larvae (Bull and Hayes 2002; Bull 2005). Freezing depth has not been assessed for ponds in the drawdown zone of Kinbasket and Arrow Lakes Reservoirs, but radiotagged frogs could be monitored during winter to assess overwintering habits and would be necessary to answer this part of Management Question 3. Data from telemetry studies (2014, 2015 and 2016) strongly suggest that Western Toads and confirm that Common Garter Snakes use a portion of the drawdown zone during some or most of their active season (breeding period for toads in the spring, foraging or basking sites for snakes, which coincides with spring and summer) and subsequently move into upland habitat later in the summer or early fall for overwintering.

6.4 MQ4: Which habitats do reptiles and amphibians use in the drawdown zone and what are their characteristics (e.g., pond size, water depth, water quality, vegetation, elevation band)?

Many species of amphibians and reptiles that occur in and adjacent to the drawdown zone depend on aquatic habitats to fulfill their life requisites (Duellman and Trueb 1986; Duellman 2007; Wells 2007). The species of amphibians using the drawdown zone of Kinbasket and Arrow Lake Reservoirs are all pond-breeders. In the spring, these species migrate to ponds, breed, lay eggs, and then move into their spring and summer foraging habitat. Small, isolated wetlands can be critical to the persistence of amphibians that possess complex life cycles (Hopkins 2007). These habitat features are common in the drawdown zones of both reservoirs and are affected on an annual basis to varying degrees depending on the elevation at which they are situated and on reservoir operations (Figure 5-6; Figure 5-14; Figure 5-24) and on reservoir operations (Figure 3-2; Figure 3-4).

In Kinbasket Reservoir amphibians and reptiles use habitats in proximity to wetlands and ponds that occur in the drawdown zone. In Kinbasket Reservoir 164 ponds were assessed for the presence of pond-breeding amphibians (all life stages) and reptiles. These ponds occur in both Canoe Reach [Valemount Peatland (n=46) and Ptarmigan Creek (n=1)] and Bush Arm [Bear Island, (n=73) KM 79 (n=21), and at the Causeway (n=23)]. In total, these ponds cover an area of only 11.1 ha and range in size from 0.0007 ha (7 m^2) to 0.992 ha (9,662 m^2). The total area of wetlands at each of the five main areas ranges from 0.9445 ha at Ptarmigan Creek to 4.729 ha at the Valemount Peatland. The pre-inundation depth

of all 164 wetlands was not measured, but most are < 1 m deep with many < 50 cm. The depth of egg mass deposition was general between 10 and 30 cm, providing an indication that shallow wetlands provided highly suitable habitat for pond-breeding amphibians.

The water physicochemical parameters (DO, conductivity, pH and temperature) are within acceptable levels for amphibians (Crowder et al. 1998; Ultsch et al. 1999). Ponds and wetlands used by pond-breeding amphibians span an elevation range of 734 to 755 m ASL with that range varying by location (see Figure 5-6).

At elevations between 740 and 742 m ASL, most wetlands have very little to no emergent vegetation and only low abundance (cover) of submergent vegetation. As elevation increases, the vegetation structure and composition of wetlands also increased. Wetlands with higher cover of vegetation tend to be used to a greater degree by Columbia Spotted Frog and Long-toed Salamander whereas ponds with little to no negation are favoured by Western Toad. In Kinbasket, most species were found in the wetland-associated habitat types (wool-grass–Pennsylvania buttercup and Kellogg's sedge). Western Toad used a wider range of elevations (740–754 m ASL) than did Columbia Spotted Frog (748–756 m ASL). Columbia Spotted Frog tends to be found at higher elevations, in wet habitats associated with the wool-grass–Pennsylvania buttercup vegetation community. Ponds occurring at elevations < ~739 m ASL were typically unvegetated and can be characterized as shallow ponds with fine mud and organic sediment comprising the bottom substrate. These ponds were used only by Western Toad.

In Arrow Lakes pond-breeding amphibians were associated with most wetland habitat occurring in the drawdown zone with the majority of those habitats occurring in Revelstoke Reach (e.g., Airport marsh, Cartier bay, Montana Slough). Although not as prevalent in mid- and lower Arrow Lakes, important wetland habitats that were monitored occur at Burton Creek, Lower Inonoaklin Road, and Edgewood South. Like Kinbasket, wetland habitats occurring the drawdown zone of Arrow Lakes Reservoir were used by both pond-breeding amphibians and reptiles and had water physiochemical parameters suitable for aquatic life. Wetland habitats tended to occur between 434 and 439 m ASL and most could be characterized as having complex vegetation and substrate characteristics with varying degrees of open water, soft substrates, and emergent/submergent vegetation. The wetlands that occur in the drawdown zone of Arrow Lakes Reservoir provide habitat for all pond-breeding amphibian species including Western Toad, Columbia Spotted Frog, Long-toed Salamander, and Pacific Chorus Frog. Wetland habitats in Cartier Bay are likely the most important for pond-breeding amphibians in Revelstoke Reach. The beaver pond complex at Beaton Arm provides highly suitable habitat for Western Toad as do the gravel excavations at Burton Creek.

Reptile species occurring in both reservoir drawdown zones require both aquatic and terrestrial habitat. Turtles rely on aquatic habitats to fulfil foraging, basking and overwintering needs, and use terrestrial habitats for nesting, thermoregulation and migration between pond habitats. Snakes, on the other hand, use habitats in the DDZ mainly for foraging because amphibians are their primary prey.

6.5 MQ5: How do reservoir operations influence or impact amphibians and reptiles directly (e.g., desiccation, inundation, predation) or indirectly through habitat changes?

Direct impacts of reservoir operations on amphibians and reptiles have not been observed in the drawdown zones of Kinbasket and Arrow Lakes Reservoir. We have observed desiccation at breeding ponds, but this is likely related to natural causes (e.g., rapid pond drying rate, absence of rain, etc.). Egg string and egg mass stranding have been observed at various locations in the drawdown zone and is usually associated with decreasing hydroperiod at oviposition sites, which can be a major cause of death to developing embryos. This phenomenon is not unique to drawdown zones (e.g., Marco and Blaustein 1998). Local environmental conditions can influence the hydroperiod of breeding ponds and are likely confounding any potential reservoir effects that may be linked to egg mass stranding. The normal operating regime of both reservoirs is to fill in the spring between April and June (Figure 3-2, Figure 3-4) and because this coincides with the egg-laying period for amphibians, it is unlikely that reservoir-caused desiccation is an issue.

Water physicochemical parameters measured in ponds in the drawdown zone suggest little evidence of an effect of dissolved oxygen, pH, water temperature, or conductivity on amphibian use or development. Of these parameters, water temperature can influence tadpole development to some degree (Crowder et al. 1998; Ultsch et al. 1999). However, the effects of reservoir inundation on water temperature and subsequent tadpole development are equivocal with no apparent direct effect on amphibians using the drawdown zone of Kinbasket Reservoir. The ability to directly measure the potential effects of changing physicochemical parameters on amphibians is confounded by reservoir operations, which vary annually. Similar physicochemical data are not currently available for Arrow Lakes Reservoir.

Reservoir operations do impact habitat through changes in availability of breeding and foraging habitat of amphibians and reptiles using the drawdown zone, both directly and indirectly. Habitat availability varies by month and year relative to reservoir operations, and is a function of reservoir elevation. The number of amphibian and reptile observations often decreases as reservoir elevations increased. The seasonal changes in habitat availability affect the distribution of amphibians and the additive effects of annual displacement are currently unknown. Because amphibians are persisting in the drawdown zone, we can speculate that the annual reduction of habitat availability does not dramatically effect local amphibian populations; however, we do not know if the populations are supressed relative to populations in non-reservoir habitats.

Hawkes and Gibeau (2015) reported that the vegetation communities defined in the DDZ of Kinbasket Reservoir had not changed since 2007, at least not at the landscape scale, but that the composition of certain species and communities had changed. These changes are believed to be related to reservoir operations, but it is not clear how they might affect reptile and amphibian populations over time. Similarly, Vegetation communities in Arrow Lakes Reservoir have remained stable over time (Miller et al. 2015), and although some change inn vegetation character was noted, there is nothing to indicate that these changes will affect the availability or quality of habitats used by amphibians and reptiles.

A recent assessment of the effects of inundation on vegetation in the drawdown zone of Kinbasket Reservoir and Arrow Lakes Reservoir was conducted in the fall of 2015. Preliminary results suggest that the vegetation will benefit from some level of inundation. Too much inundation or none at all results in reduced plant vigour and increased mortality. These results apply mainly to terrestrial habitats and it is not clear what the effects (if any) on wetland vegetation might be., However, results from a wetland study in Kinbasket Reservoir (CLBMON-61; Adama et al. 2014) indicate that longer periods of inundation of wetlands by the reservoir contribute to increases in wood debris in the wetland, which has been shown to reduce wetland productivity for amphibians (Hawkes 2016, draft). Wetlands in the drawdown zone of Arrow Lakes Reservoir are not impacted by wood debris as they are in Kinbasket, but there is a negative correlation between increasing reservoir elevation and habitat availability.

6.6 MQ6: Can minor adjustments be made to reservoir operations to minimize the impact on amphibians and reptiles?

The present operation of Kinbasket and Arrow Lakes Reservoirs does not appear to directly impact amphibians and reptiles, as evidenced by the year-over-year use of the drawdown zone by pond-breeding amphibians and their predators (i.e., garter snakes). Western Painted Turtles (the focus of another longer-term study, CLBON-11B3) have also continued to use habitats in the drawdown zone of Arrow Lakes, apparently without consequence (Wood et al. 2016).

Given that the present operating regime of both reservoirs is associated with the persistence of all expected species of amphibians and reptiles, in often high numbers at some locations (e.g., Cartier Bay, Valemount Peatland, and in several areas of Bush Arm), there does not appear to be a need to consider minor changes to reservoir operations at this time. However, if larger, much different reservoir operations are considered (e.g., stable Arrow at 434 m ASL), the potential effects of these different management regimes on amphibians and reptiles and their habitats must be carefully considered.

It is evident that there have been large-scale reductions in habitat availability on a seasonal basis in both reservoirs, with the total change varying on an annual basis. If future reservoir operations are consistent with historical trends, there will continue to be seasonal changes in habitat availability that will continue to vary annually as a result of reservoir management. Given the range in elevation over which highly suitability amphibian and reptile habitats occur in both reservoirs, minor changes (as yet undefined, but presumed to not deviate from the average operation in each reservoir) would likely have little to no effect on the current use of the drawdown zone by amphibians and reptiles.

If a new operating regime that included a stable reservoir elevation in one reservoir (e.g., Arrow Lakes) were envisioned, this could have unintended consequences on habitats in both Arrow Lakes and Kinbasket Reservoir. For example, if Arrow lakes Reservoir were maintained at a stable elevation of 434 m ASL, there is a high probability that wetlands located at elevations greater than this could decrease in size and even dry out in some years, as was observed at Lower Inonoaklin Road and Edgewood South in 2015 and 2016, years when Arrow Lakes Reservoir reached maximum elevations of 435.48 and 437.24 m ASL, respectively. Although the maximum elevation exceeded 434 m ASL, the duration of exceedance was relatively short and the reservoir was below 434 m ASL for most

of the year in 2015 (323 days) and 2016 (272 days, measured through December 6, 2016). The potential reduction in total wetted area of wetlands in the drawdown zone would be related to a lack of recharge[3] associated with inundation. Without this recharge, certain wetland habitats may be impacted in Arrow Lakes Reservoir, just as they appeared to have been in 2015 and 2016.

Conversely, if Arrow Lakes Reservoir were maintained at a lower, stable elevation, reservoir elevations in Kinbasket Reservoir would likely need to remain higher longer, which would negatively impact the availability of habitats in the drawdown zone of Kinbasket Reservoir.

6.7 MQ7: Can physical works projects be designed to mitigate adverse impacts on amphibians and reptiles resulting from reservoir operations?

The answer to this question is "yes". The removal of wood debris from wetlands, which was done as part of a physical works project in Kinbasket Reservoir improved the suitability of those wetlands for amphibians. Although not measured, the improvement of wetland suitability on the drawdown zone Kinbasket Reservoir is expected to benefit reptiles through increased food viability. Current planning for physical works at Lower Inonoaklin Road in Arrow Lakes Reservoir is underway to increase the persistence of wetland habitat at that location, which should benefit amphibians and reptiles (and other species of wildlife). Similarly, the physical works proposed for Cartier Bay in Revelstoke Reach will ensure that the wetland at that location continues to provide high quality habitat for amphibians and reptiles.

6.8 MQ8: Does revegetating the drawdown zone affect the availability and use of habitat by amphibians and reptiles?

For Kinbasket the answer is no, revegetating the drawdown zone does not affect the availability and use of habitat by wildlife. Portions of the DDZ of Kinbasket Reservoir were revegetated using a variety of techniques, including live staking, seeding, seedlings and fertilizers (CLBWORKS-1). The revegetation program did not include improvements to amphibian and reptile habitat suitability as a primary objective. As of 2016, the majority of the revegetation treatments applied in the drawdown zone of Kinbasket Reservoir have failed (Hawkes and Miller 2016). The one area showing signs of success was not revegetated to benefit amphibians and reptiles and the longer-term survival of those plants has yet to be determined.

For Arrow Lakes Reservoir, the answer is also no, revegetating the drawdown zone does not affect the availability and use of habitat by wildlife. The revegetation program in Arrow Lakes has had variable success with modest levels of survivorship in some treatment areas. There is currently no evidence that revegetating the drawdown zone of Arrow Lakes has affected the availability and use of habitats by amphibians and reptiles. The revegetation prescriptions applied in the drawdown zone were intended to increase the cover and diversity of non-wetland habitats, providing only minimal potential benefit to amphibians and reptiles.

[3] In this context, recharge refers to the addition of water into a wetland that would occur as a result of inundation.

6.9 MQ9: Do physical works projects implemented during the course of this monitoring program increase the abundance of amphibians and reptiles abundance, diversity, or productivity?

The physical works implemented in Kinbasket Reservoir in 2015 have resulted in Western Toad using previously unavailable wetlands for breeding. As such, there is evidence to support an increase in productivity for certain species via the removal of wood debris from wetlands. There is no expectation that the diversity of amphibians or reptiles will change as a result of physical works in Kinbasket Reservoir and abundance may increase in previously unused habitats, but it is unknown if this increase will result in a net change in abundance over time.

Physical works have not been implemented in the areas monitored for amphibians and reptiles in Arrow Lakes Reservoir so this question cannot be answered at this time. Both of the physical works projects planned for Arrow Lakes Reservoir (Cartier Bay and Lower Inonoaklin Road) are intended to maintain existing habitats. As such, it is unlikely that the abundance, diversity, or productivity of amphibians and reptiles will change.

6.10 MQ10: Do increased reservoir levels in Kinbasket Reservoir during the summer months resulting from the installation of Mica 5 and 6 negatively impact amphibian populations in the drawdown zone through increased larval mortality or delayed development?

See the CLBMON-58 2015 annual report[4].

6.11 Management Questions - Summary

Our ability to address each of the management questions is summarized below (Table 6-1). The methods used are appropriate for collecting data that can be used to answer certain questions. For others, a different approach is required. Continued monitoring of amphibian and reptile populations in the drawdown zone should provide the necessary information to answer most management questions. To be sure we can answer some of the questions, recommended modifications to CLBMON-37 are provided below.

Table 6-1: Relationships between management questions (MQs), methods and results, sources of uncertainty, and the future of project CLBMON-37

MQ	Able to Address MQ?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
MQ1: Which species of amphibians and reptiles occur (utilize habitat) within the drawdown zone and where do they occur?	Yes	Data collected since 2008 have likely resulted in the documentation of all expected species in the drawdown zone	• None	• Natural annual population variation • Inconspicuous species • Variable reservoir operations

[4] Available at https://www.bchydro.com/about/sustainability/conservation/water_use_planning/southern_interior/columbia_river/arrow-operations.html

MQ	Able to Address MQ?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
MQ2: What is the abundance, diversity, and productivity (reproduction) of amphibians and reptiles utilizing the drawdown zone and how do these vary within and between years?	Mostly	6 years of site occupancy and detection rates data. Productivity indirectly estimated for some species	• Annual sampling • Intensive productivity data collection for Western Toad and Columbia Spotted Frog •	• Natural annual population variation • Inconspicuous species • Mortality difficult to assess • Variable reservoir operations
MQ3: During what portion of their life history (e.g., breeding, foraging, and over-wintering) do amphibians and reptiles utilize the drawdown zone?	Yes	6 years of site occupancy data across multiple sites and seasons; telemetry studies (2015 and 2016)	• None	• Natural annual population variation • Inconspicuous species
MQ4: Which habitats do amphibians and reptiles use in the drawdown zone and what are their characteristics (e.g., pond size, water depth, water quality, vegetation, elevation band)?	Mostly	6 years of macro and micro habitat data collection; pond and wetland mapping; data from other monitoring programs	• None	• Certain habitats are impacted directly and indirectly by annually by reservoir operations (e.g., deposition of wood debris on wetlands, effects of scour caused by floating wood, habitat erosion, sedimentation), but the effects on amphibians and reptiles and their habitats has not been been studied
MQ5: How do reservoir operations influence or impact amphibians and reptiles directly (e.g., desiccation, inundation, predation) or indirectly through habitat changes?	Mostly	6 years of data collected on the occurrence and distribution of amphibians and reptiles in the drawdown zone	• None	• Natural annual population variation • Variable reservoir operations • Species-specific habitat characteristics are impacted annually by reservoir operations, wood debris, erosion, sedimentation, so habitat characteristics will change from year to year
MQ6: Can minor adjustments be made to reservoir operations to minimize the impact on amphibians and reptiles?	Yes	Longer-term species data (occupancy, presence, distribution)	• None, but see sources of uncertainty	• Variable reservoir operations • Lack of controlled experimentation to assess how varying the time of inundation correlates to the use of the drawdown zone by amphibians and reptiles. It is not possible to manipulate when the reservoirs exceed a given elevation or for how long. • It is not clear what constitutes a minor adjustment. Given the variable nature of reservoir operations, a more informed answer to this question would require understanding how a minor adjustment affects the various types of reservoir operation.

MQ	Able to Address MQ?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
MQ7: Can physical works projects be designed to mitigate adverse impacts on amphibians and reptiles resulting from reservoir operations?	Yes (Kinbasket) and probably for Arrow	Evidence of use of wetlands cleared of wood debris in Kinbasket Reservoir. No data for Arrow Lakes Reservoir.	• Additional assessments of physical works in Kinbasket. • Pre- and post-physical works monitoring in Arrow Lakes Reservoir	• Kinbasket Reservoir was not filled completely in 2016. As such, the ponds that were cleared of wood debris and the mounds that were created were not inundated so the integrity of the mounds following inundation has not been tested. • Physical works have not been implemented in Arrow Lakes Reservoir.
MQ8: Does revegetating the drawdown zone affect the availability and use of habitat by amphibians and reptiles?	No	N/A	• Design physical works and revegetation prescriptions that would benefit amphibians and reptiles.	• Wetland-related plants would need to be planted to benefit amphibians and reptiles. Work is not applicable to this study.
MQ9: Do physical works projects implemented during the course of this monitoring program increase amphibian and reptile abundance, diversity, or productivity?	Kinbasket: Possible for Productivity; no for abundance and diversity. Arrow Lakes Reservoir: uncertain for all.	Same as MQ7	• Additional assessments of physical works in Kinbasket. • Pre- and post-physical works monitoring in Arrow Lakes Reservoir	• Physical works have not been implemented in Arrow Lakes Reservoir. • Limited scope of physical works in Kinbasket. Results to date are site-specific (i.e., can't infer results to entire reservoir).

7.0 CONCLUSIONS

7.1 Kinbasket Reservoir

Amphibians and reptiles use habitats in the drawdown zone of Kinbasket Reservoir to fulfill some of their life history requisites. Although wetland habitats are limited in the drawdown zone and much reduced relative to pre-impoundment conditions, the wetland habitats that do occur are used annually by Western Toad, Columbia Spotted Frog, Long-toed Salamander, and Common Garter Snake – all species expected to occur in the region. Western Terrestrial Garter Snakes occur in upland habitats adjacent to Kinbasket Reservoir, but are rarely observed in the drawdown zone. The unexpected observation of a Western Painted Turtle in the drawdown zone of Kinbasket Reservoir at Bear Island in 2015 raises questions about the distribution and occurrence of this species relative to other sites in the drawdown zone of Kinbasket Reservoir that were monitored under CLBMON-37. The more recent observation of a Western Painted Turtle near Valemount (and ~4 km away from Kinbasket Reservoir) raises additional questions about the known distribution of Western Painted Turtle in this part of the province, but this is ancillary to the objectives of CLBMON-37.

In general, and as has been discussed in this report, reservoir operations affect the availability and suitability of habitats in the drawdown zone of Kinbasket Reservoir and this occurs on a seasonal and annual basis. Without substantive changes to how Kinbasket Reservoir is managed, the impacts to habitats resulting

from the management of Kinbasket Reservoir will continue. Of the effects of the annual filling or near filling of Kinbasket Reservoir, the accumulation of wood debris on terrestrial habitats or in wetlands, along with the associated effects of wood debris scouring, appear to have the greatest negative impact on amphibians and reptiles and their habitats. While considerable effort has occurred to remove wood debris from the drawdown zone of Kinbasket Reservoir (via CLBWORKS-16), there continues to be large volumes of wood debris input into Kinbasket Reservoir through avalanches, debris flows, and from erosion associated with reservoir operations.

The results of the CLBMON-37 monitoring program suggest that amphibians and reptiles can persist in an environment that, to the untrained eye, appears to be constantly impacted due to varying reservoir elevations. Between 2008 and 2016, the elevation of Kinbasket Reservoir has changed by more than 30 m during a single year (2012 and 2013) with an average change of more than 27 m (2008 to 2016). However, the continued documentation of all expected species of amphibians and reptiles, along with continued high abundance of conspicuous species (Western Toad, Columbia Spotted Frog, and Common Garter Snake), provide evidence of successful breeding. There is also a lack of evidence that any mortality was related directly to reservoir operations supporting an assessment of no direct effects of reservoir operations on amphibian and reptile species using the drawdown zone of Kinbasket Reservoir. There are, and will continue to be, impacts to habitat availability and suitability associated with reservoir operations. However, all species of amphibians and reptiles that occur in and use habitats in the drawdown zone appear to be adaptable with respect to these impacts. Unless reservoir operations change drastically, there are currently no data to support an assessment of longer-term impacts to relative to the current operation of Kinbasket Reservoir.

7.2 Arrow Lakes Reservoir

As many as 11 species of amphibians and reptiles occur in and adjacent to the drawdown zone of Arrow Lakes Reservoir. One species, the Western Painted Turtle, is represented by a relatively large population in Revelstoke Reach, near the northern limit of the species range in BC. Other species (Rubber Boa and Western Skink), typically upland species that occur in dry open forests, have been documented in the drawdown zone in several locations. These species, along with Western Toad, Long-toed Salamander, Columbia Spotted Frog, Pacific Chorus Frog, Northern Alligator Lizard, Common garter snake, and Western Terrestrial Garter Snake have been documented in the drawdown zone of Arrow Lakes Reservoir since 2008.

Arrow Lakes Reservoir is managed in a similar manner to Kinbasket, with sometimes large changes in reservoir elevation occurring on an annual basis (max: 13 m; average 10 m). Although the magnitude of change is not as great as in Kinbasket, changes in reservoir elevation do impact habitat availability and suitability in similar manner, with large-scale reductions in available habitat associated with increasing reservoir elevations. Despite this, all previously listed species continue to persist in the drawdown zone of Arrow Lakes Reservoir, with large breeding populations of Western Toad occurring in Cartier Bay, Beaton Arm, and Burton Creek.

As with Kinbasket Reservoir, the longer-term monitoring of amphibians and reptiles in Arrow Lakes Reservoir has provided unique insights into the ecology of hydroelectric reservoirs, but it has not resulted in a determination that reservoir operations directly impact amphibians and reptiles. While habitats may be unavailable for part of the year, most species continued to use habitats in the drawdown zone to fulfill their life requisites, particularly pond-breeding amphibians, on an annual basis.

Because the study area of CLBMON-37 was constrained to the drawdown zones of Kinbasket and Arrow Lakes Reservoirs, it is not possible to determine if non-drawdown zone habitats support a similar fauna in similar numbers. What is known is that all life stages of all expected species of amphibians and reptiles continue to use habitats in the drawdown zone of both reservoirs and the persistence of these habitats in the drawdown zones is considered paramount for the maintenance and persistence of all species documented in each reservoir relative to their currently understood distribution and relative abundance.

8.0 RECOMMENDATIONS

The objective of CLBMON-37 is to monitor trends in amphibian and reptile populations (relative abundance, detection rates and productivity), determine the impact of reservoir operations on amphibians and reptiles, determine their habitat use, and assess the impacts of any revegetation and physical works on species that use habitats within the drawdown zone of Kinbasket Reservoir. Recommendations are made regarding how amphibians are sampled in the drawdown zone and regarding reservoir operations:

1. A short term (one season: spring to fall) radio-telemetry study of garter snakes in Arrow Lakes Reservoir would confirm overwintering habitats of the two species using the drawdown zone; and
2. Conduct a hoop-trapping session at Bush Arm KM88 in the spring for 3 to 4 days to sample for Western Painted Turtle;
3. The inundation of elevations between ~735 and 754 m ASL in Kinbasket Reservoir should occur on or as close to the end of the summer (similar to the dates for the period 1978 to 2016 or around 25 August) as possible. This will ensure that amphibians and reptiles using the drawdown zone, particularly those in ponds >751 m ASL, will have enough time to forage for the winter and/or develop through to metamorphosis prior to inundation.
4. Climate change may confound future assessments regarding how reservoir operations affect the distribution and habitat use of amphibians and reptiles in the drawdown zone of Kinbasket Reservoir. Climate change models relevant to the study area should be reviewed to determine the extent to which climate change might influence the water resources of the drawdown zone, which in turn could affect populations of amphibians and reptiles.
5. The large deposits of wood debris at Pond 12 (Valemount Peatland) and from the north end of the Bush Arm Causeway should be considered for removal. These large deposits of wood debris have negatively impacted these areas either through reduced habitat availability or complete exclusion.

9.0 Additional Reporting Requirements

9.1 Data Deliverables

The following data deliverables have been or will be provided to BC Hydro and/or the B.C. Ministry of Environment to fulfill the Terms or Reference associated with CLBMON-37 or to fulfill the requirements of the wildlife sundry permit provided to LGL Limited for CLMON-37:

1.	Draft technical report	Submitted December 28, 2016
2.	300 word abstract	February 2017
3.	Revised sampling protocol	February 2017
4.	Copies of notes, maps, photos	February 2017
5.	Digital appendix (data)	February 2017

9.1.1 Data Provided to BC Hydro

A database containing all 2008 through 2016 data will be provided to BC Hydro with the submission of the final report. This database conforms to the standards established by the B.C. Ministry of Environment for wildlife species inventories.

9.1.2 Data Provided to the Ministry of Environment

Data collected under CLBMON-37 will be submitted to the B.C. Ministry of Environment Ecosystems Information Section as per the requirements of the Terms of Reference associated with CLBMON-37/58 and the Wildlife Sundry Work was conducted under Wildlife Act Permit MRCB16-225769, which is valid through March 31, 2017.

9.2 SARA-listed Species

Location data for SARA-listed species and all other amphibians and reptiles observed in and adjacent to the drawdown zone will be provided to the B.C. Ministry of Environment as per the requirements of our wildlife sundry permit.

The only amphibian at risk documented in the drawdown zone of Kinbasket Reservoir is the Western Toad, which is a SARA Schedule 1 species of Special Concern. Western Toad is also found in the drawdown zone of Arrow Lakes Reservoir. Additionally, Coeur d'Alene Salamander (*Plethodon idahoensis*) is a SARA Schedule 1 species of special concern and occurs in the drawdown zone of Arrow Lakes Reservoir (Revelstoke Reach in 2009). The Columbia Spotted Frog is a 'mid priority candidate' species for a COSEWIC status report (as of December 2013) candidate species. The status of this species remains not assessed and populations are considered to be stable throughout its range.

The Intermountain–Rocky Mountain Population of the Western Painted Turtle (*Chrysemys picta*) is blue-listed in British Columbia and is a SARA Schedule 1 species of Special Concern. Western Painted Turtle is being monitored in Revelstoke Reach of Arrow Lakes Reservoir under CLBMON-11B3. Two individual have been spotted in the DDZ of Kinbasket Reservoir (Bush Arm, Bear Island [2015], near Valemount [2016]). Additionally, Northern Rubber Boa (*Charina bottae*) and Western Skink (*Plestiodon skiltonianus*) are SARA Schedule 1 species of Special Concern and occurs in the drawdown zone of Arrow Lakes Reservoir.

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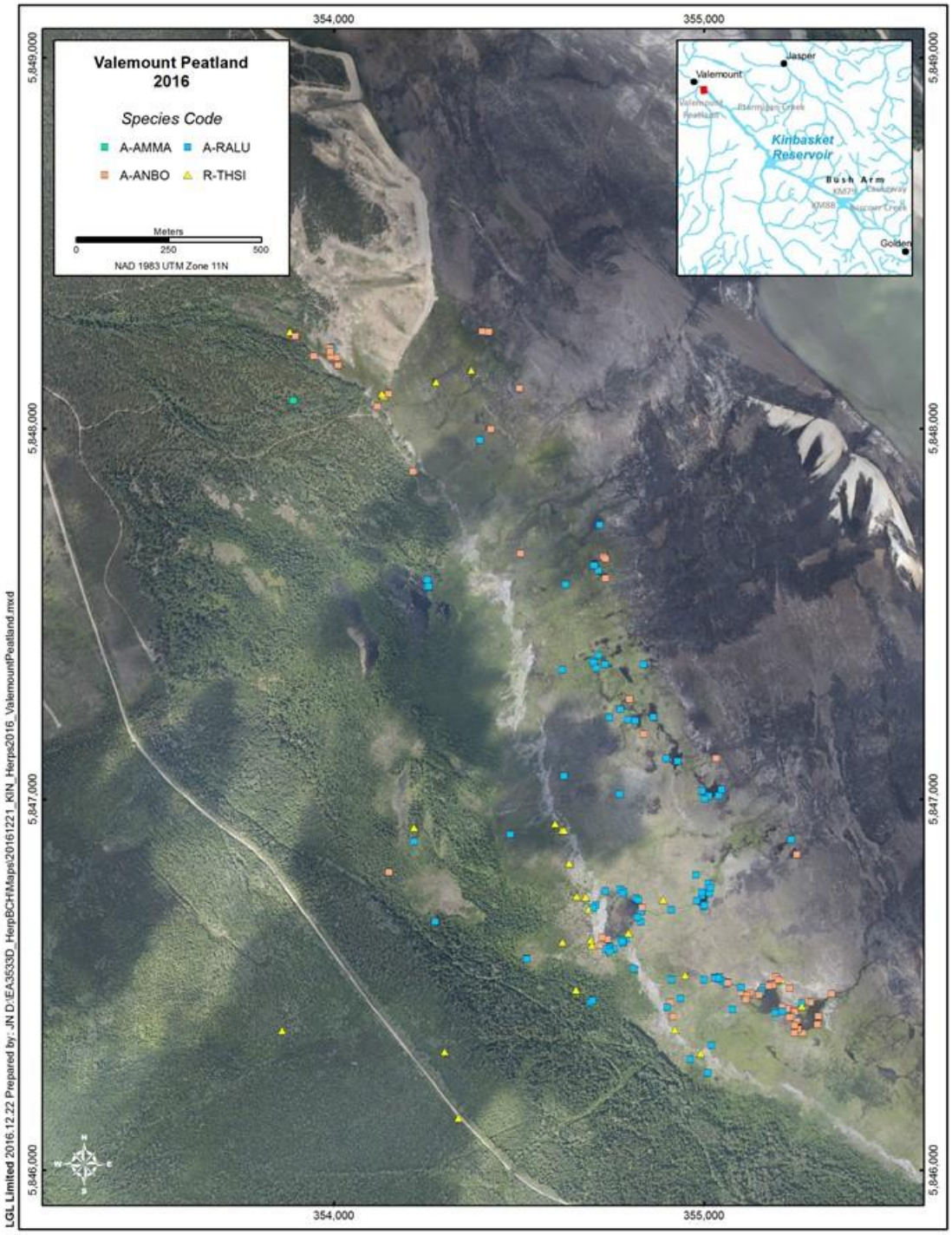
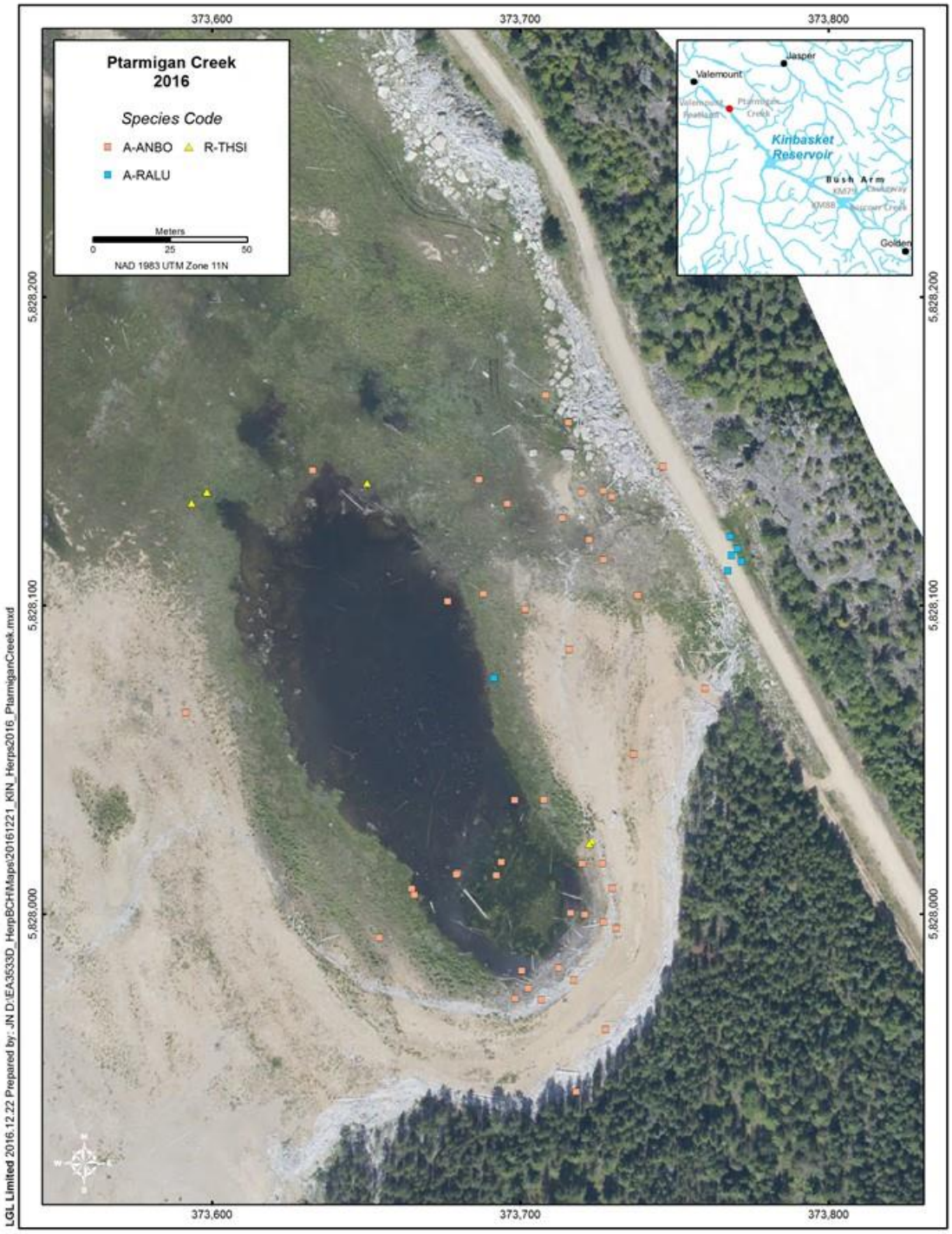
11.0 APPENDICES

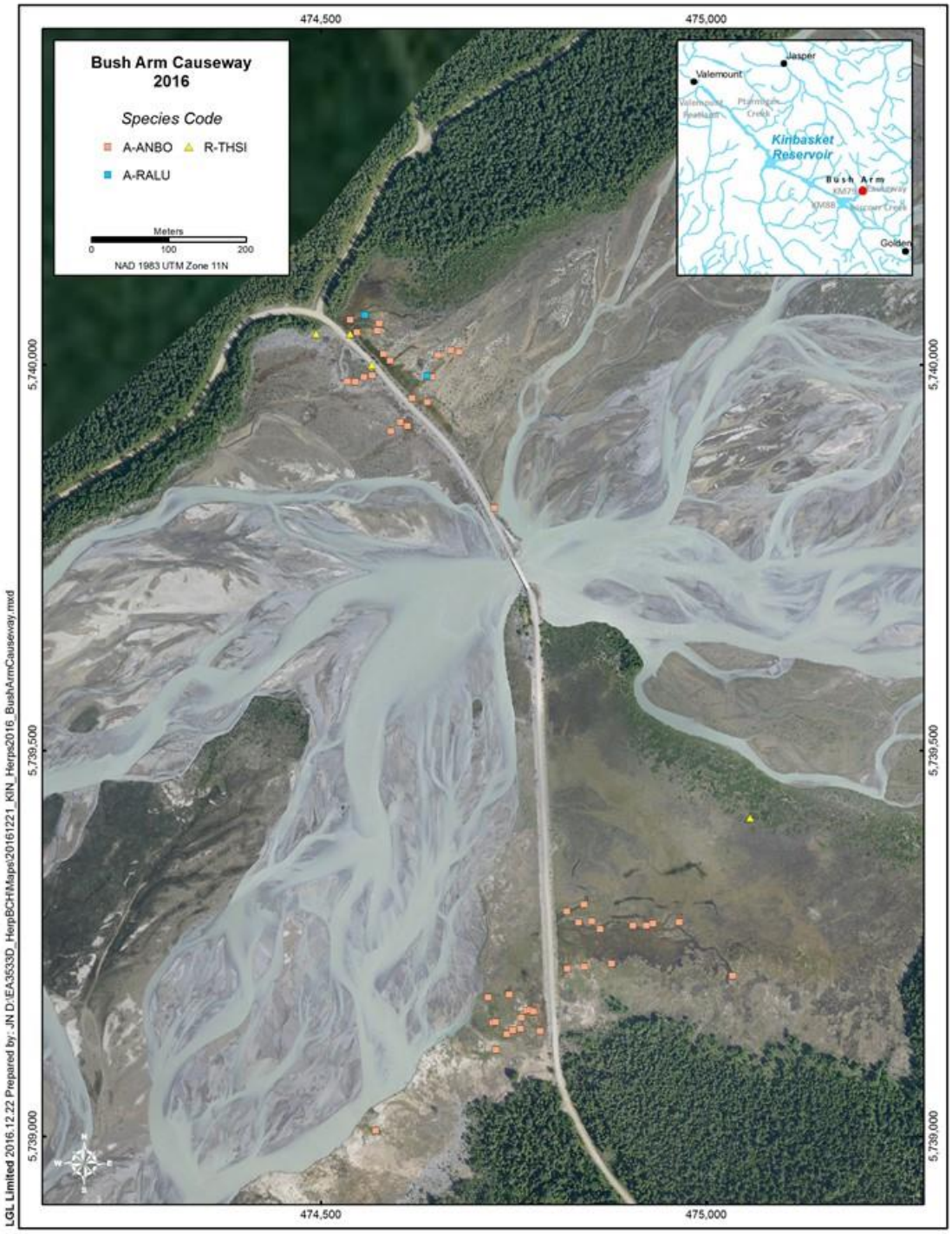
Appendix 11-1: Survey locations and amphibian and reptile captures made in the drawdown zone of Kinbasket and Arrow Lakes Reservoirs in 2016



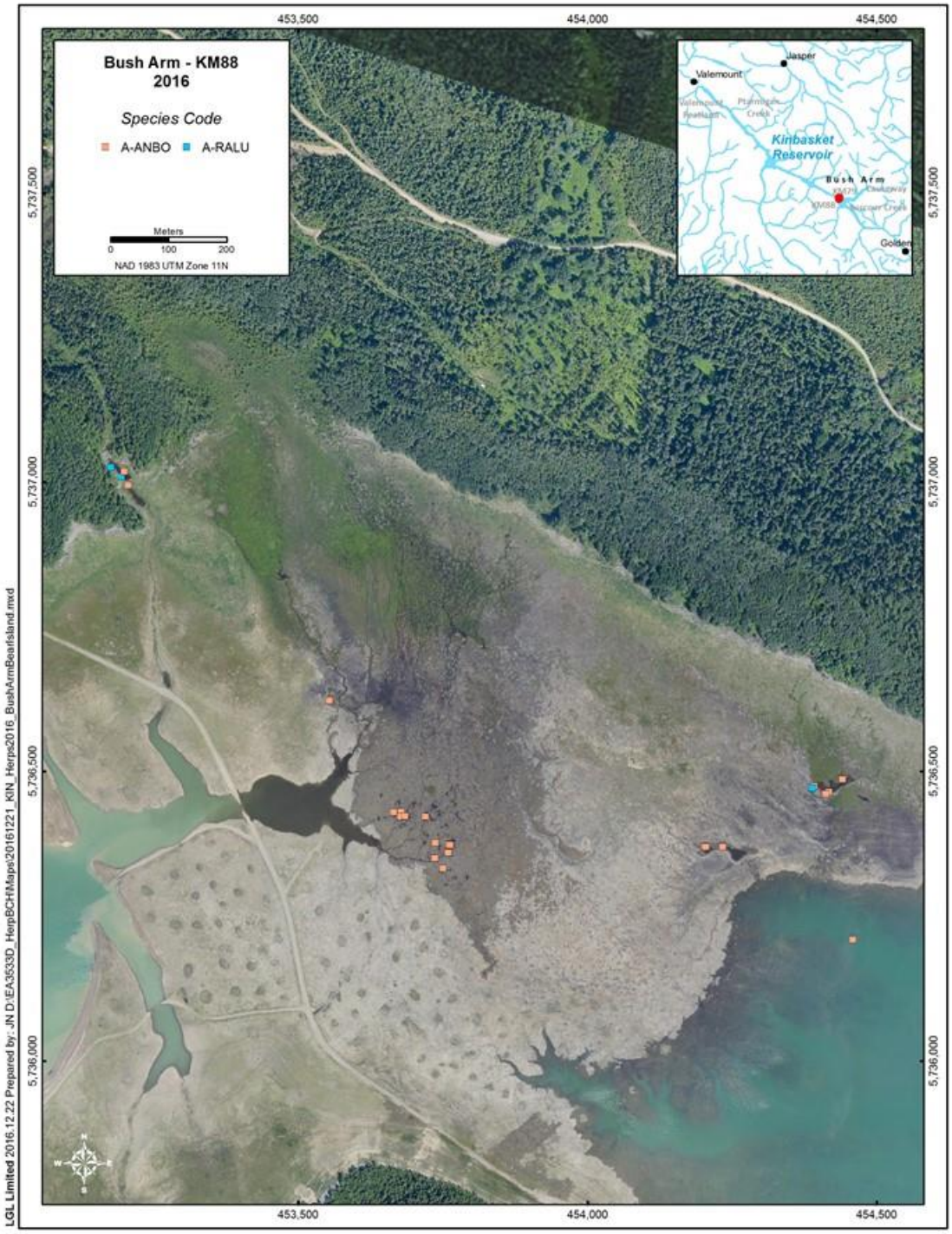
Map 11-1: Species documented in the Valemount Peatland, Kinbasket Reservoir. Species codes can be found in Table 1-1



Map 11-2: **Species documented at Ptarmigan Creek, Kinbasket Reservoir.** Species codes can be found in Table 1-1

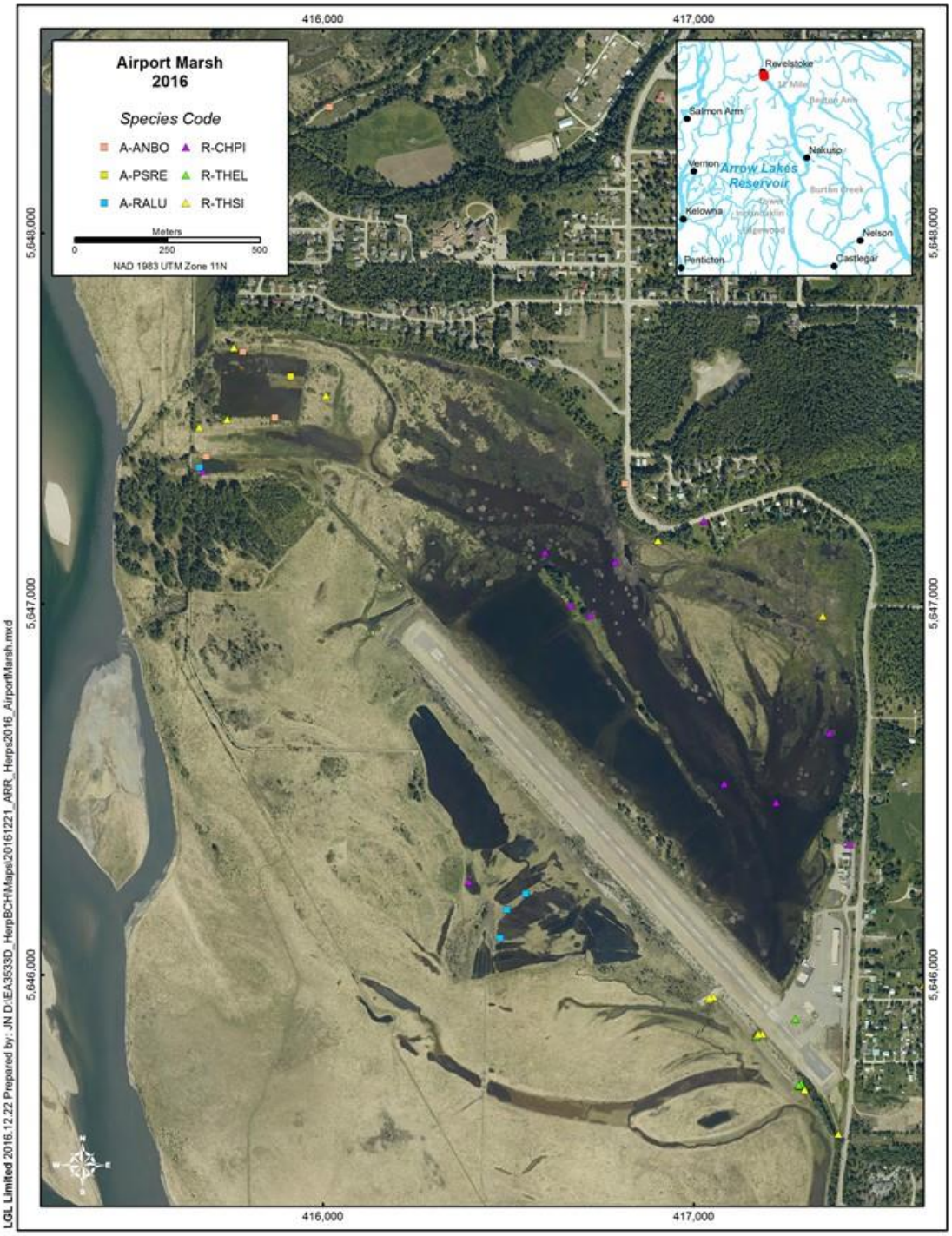


Map 11-3: **Species documented at Bush Arm Causeway, Kinbasket Reservoir.** Species codes can be found in Table 1-1



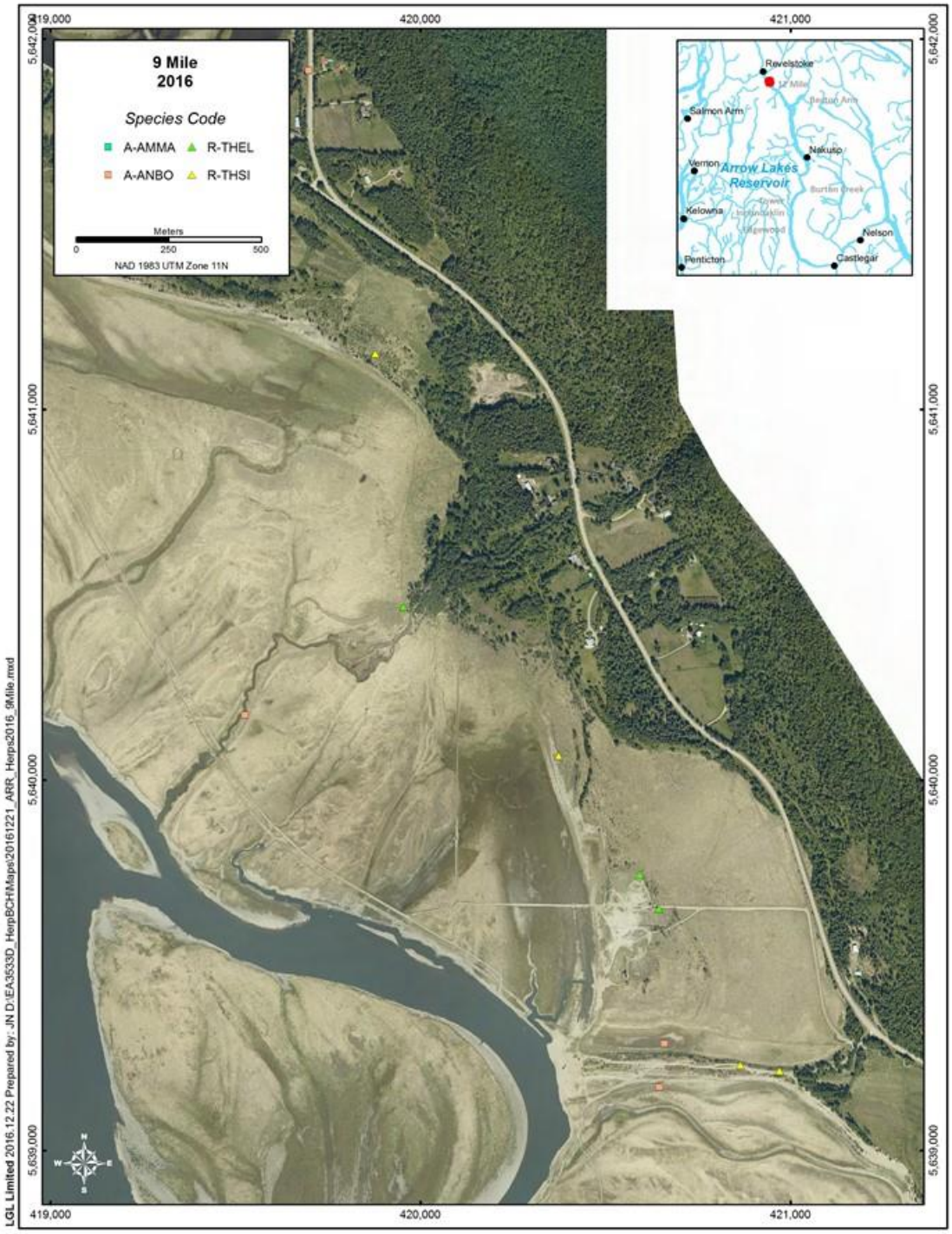
Map 11-4: **Species documented at Bush Arm KM88 (Bear Island), Kinbasket Reservoir.** Species codes can be found in Table 1-1

Map 11-5: **Species documented at Bush Arm KM79, Kinbasket Reservoir.** Species codes can be found in Table 1-1



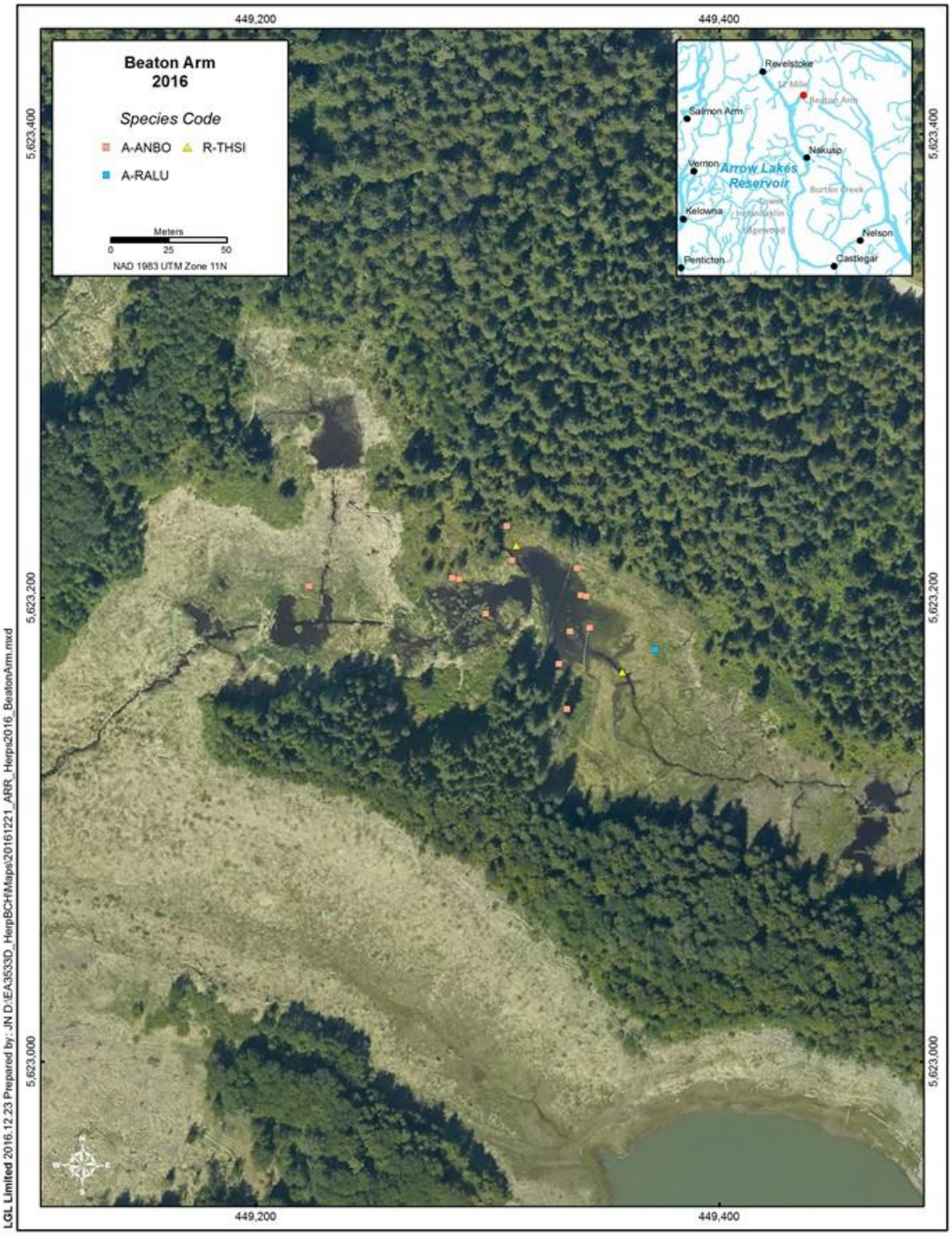
Map 11-6: **Species documented at Airport Marsh, Arrow Lakes Reservoir.** Species codes can be found in Table 1-1

Map 11-7: **Species documented at Montana Slough and Cartier Bay, Arrow Lakes Reservoir.** Species codes can be found in Table 1-1

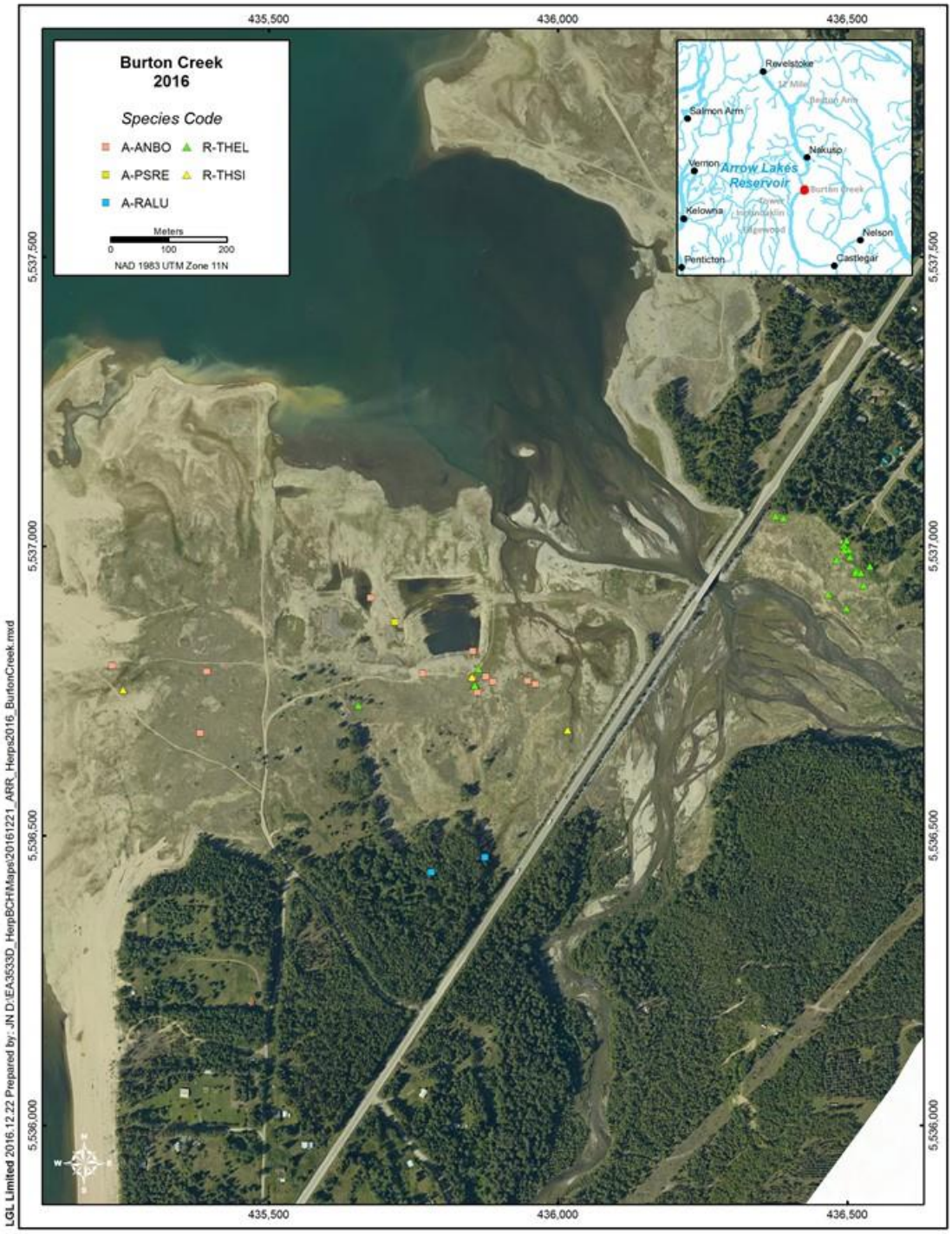


Map 11-8: **Species documented at 9 Mile, Arrow Lakes Reservoir.** Species codes can be found in Table 1-1

Map 11-9: **Species documented at 12 Mile, Arrow Lakes Reservoir.** Species codes can be found in Table 1-1

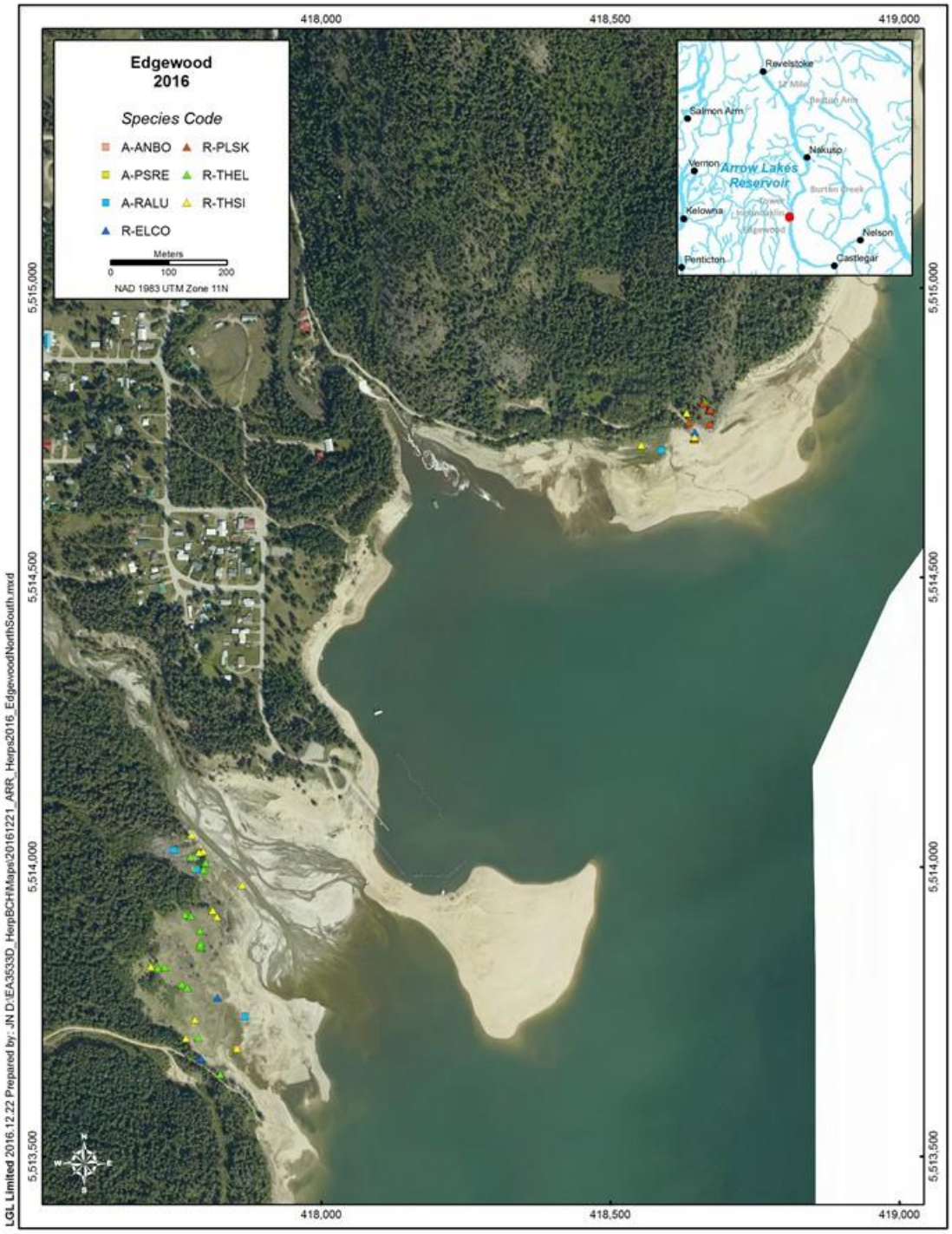


Map 11-10: **Species documented at Beaton Arm, Arrow Lakes Reservoir.** Species codes can be found in Table 1-1



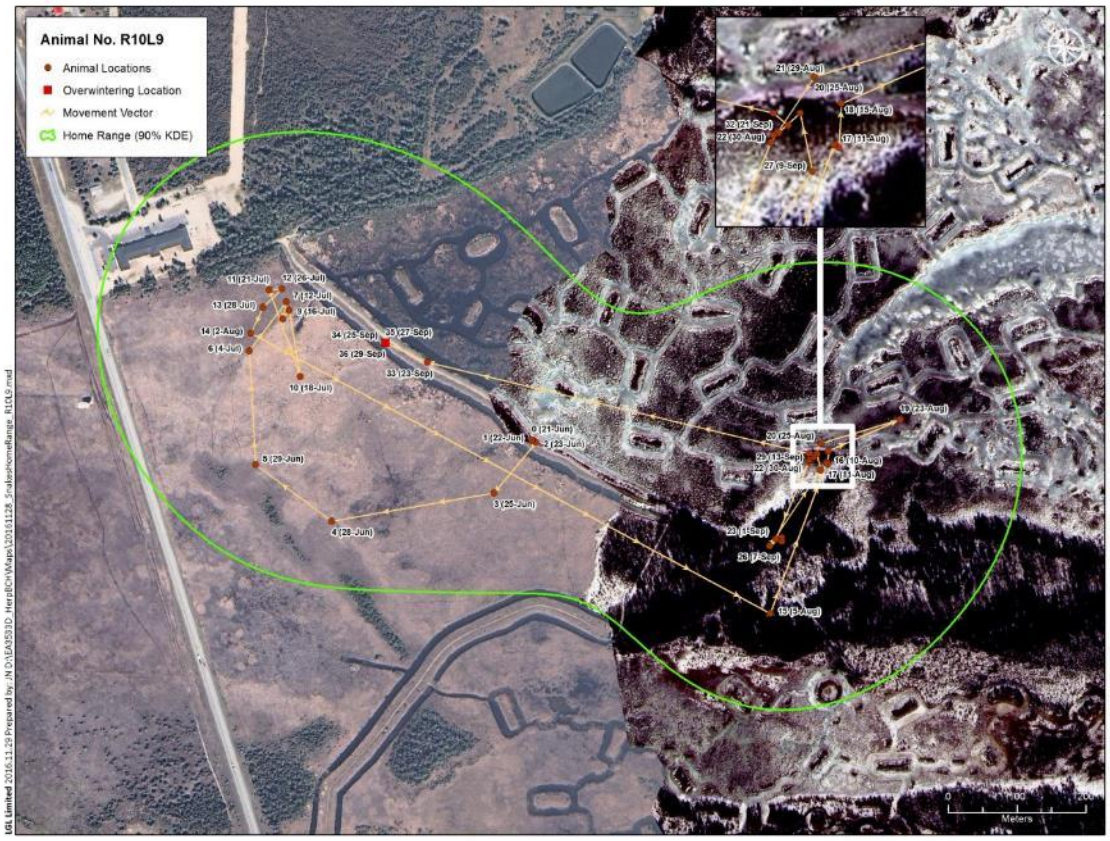
Map 11-11: **Species documented at Burton Creek, Arrow Lakes Reservoir.** Species codes can be found in Table 1-1

Map 11-12: Species documented at Lower Inonoaklin, Arrow Lakes Reservoir. Species codes can be found in Table 1-1

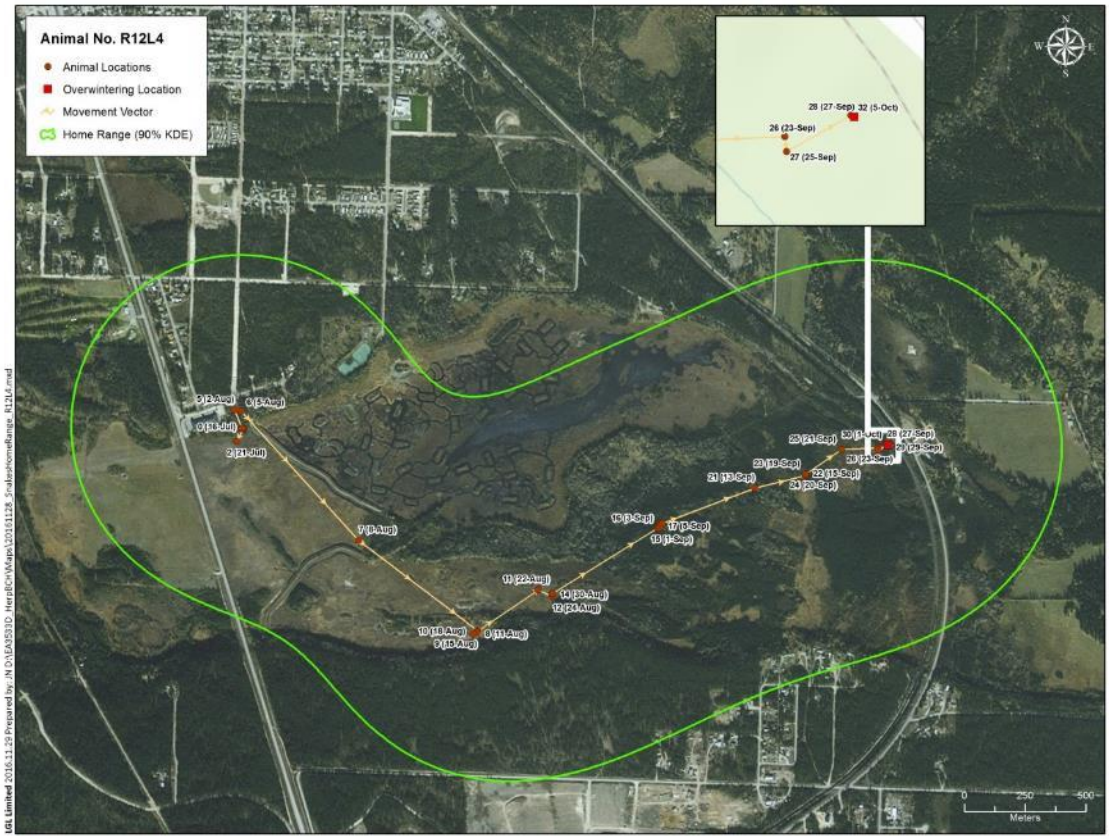


Map 11-13: **Species documented at Edgewood, Arrow Lakes Reservoir.** Species codes can be found in Table 1-1

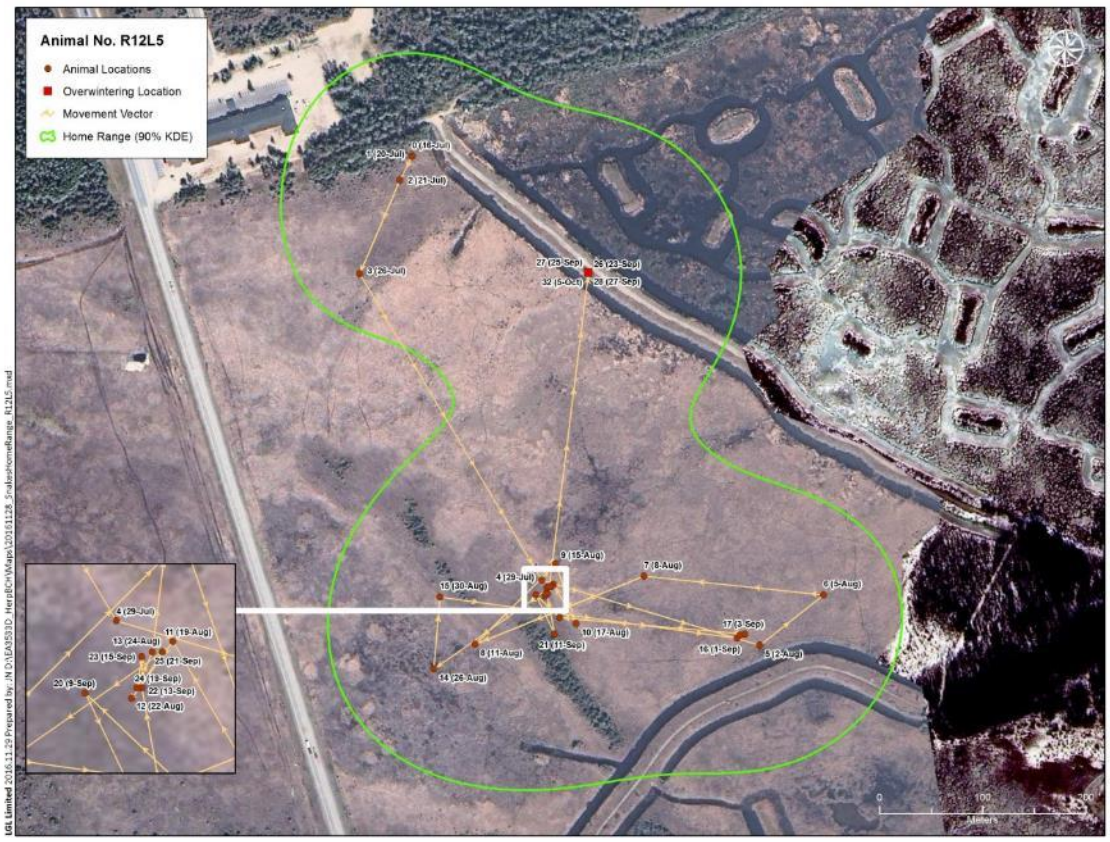
Appendix 11-2: Common Garter Snake movements and home ranges in the drawdown zone and surrounding area of Kinbasket Reservoir in 2016



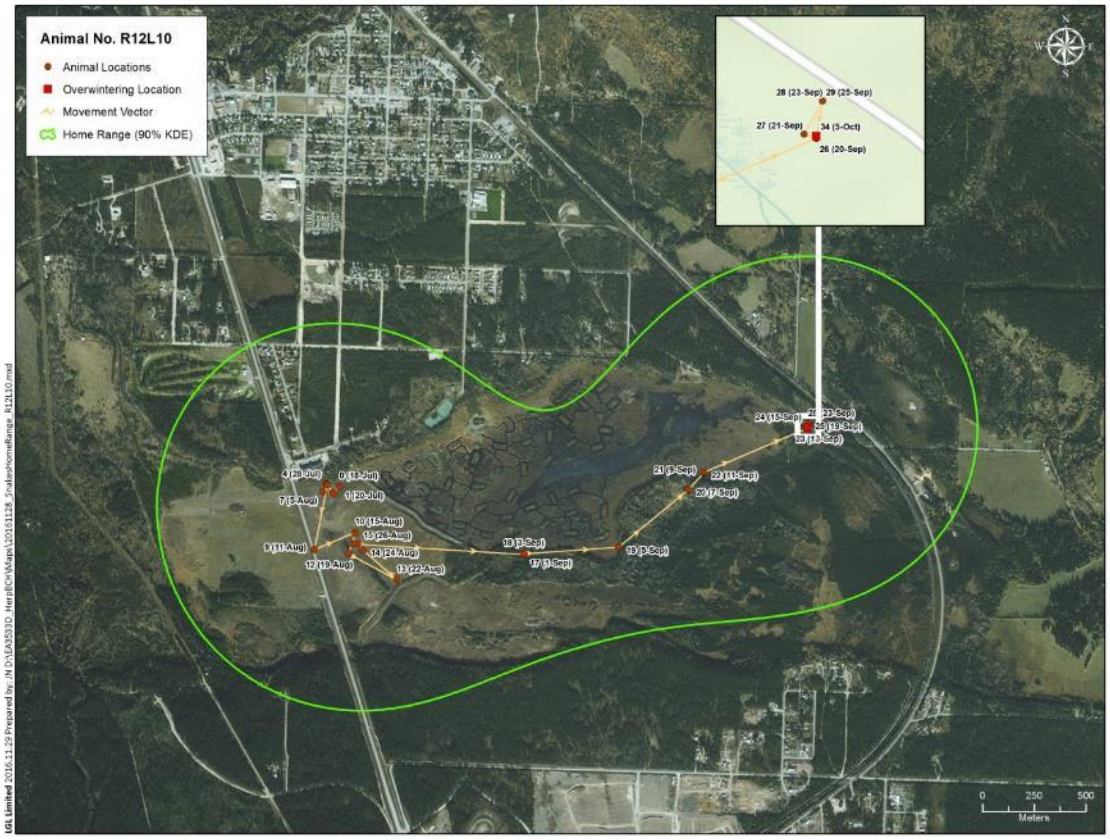
Map 11-14: **Successive movements by tagged female Common Garter Snake R10L9 in Cranberry Marsh, Valemount B.C., 2016.** Dates indicate location dates. Vectors indicate presumed (straight-line) direction of movement. The green polygon is the 90% kernel density estimation used to calculate home range



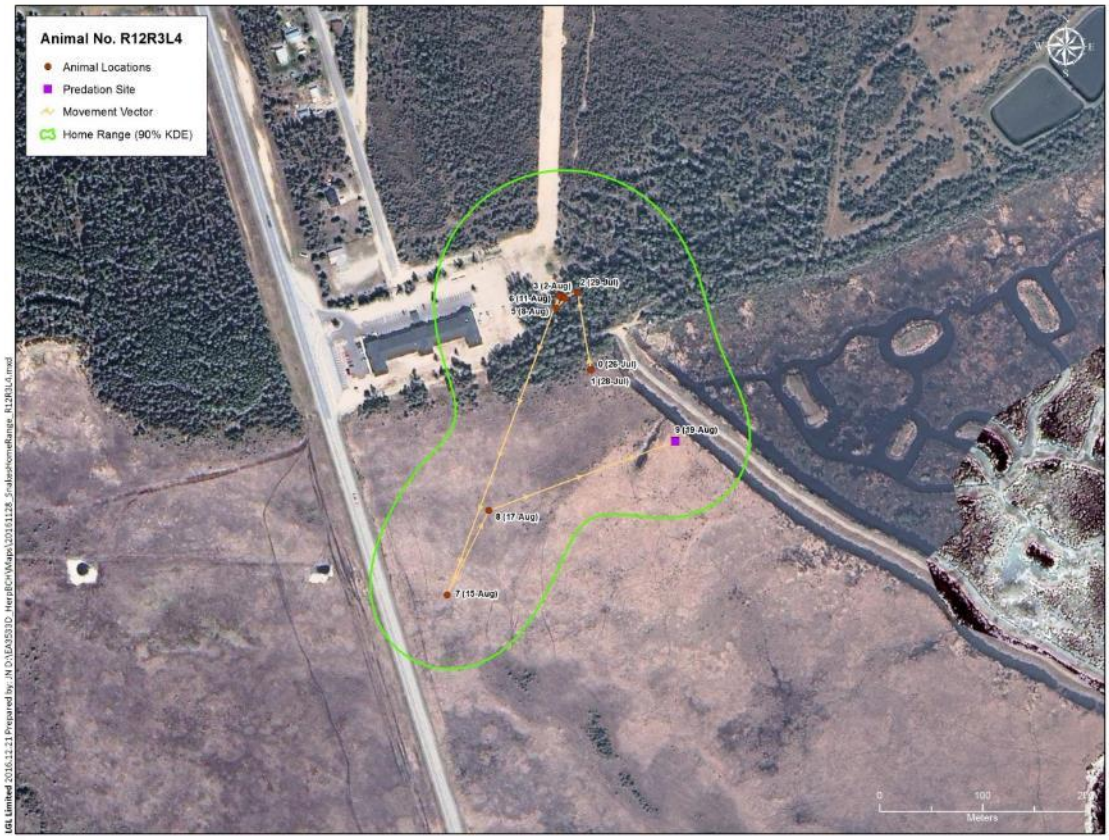
Map 11-15: **Successive movements by tagged female Common Garter Snake R12L4 in Cranberry Marsh, Valemount B.C., 2016.** Dates indicate location dates. Vectors indicate presumed (straight-line) direction of movement. The green polygon is the 90% kernel density estimation used to calculate home range



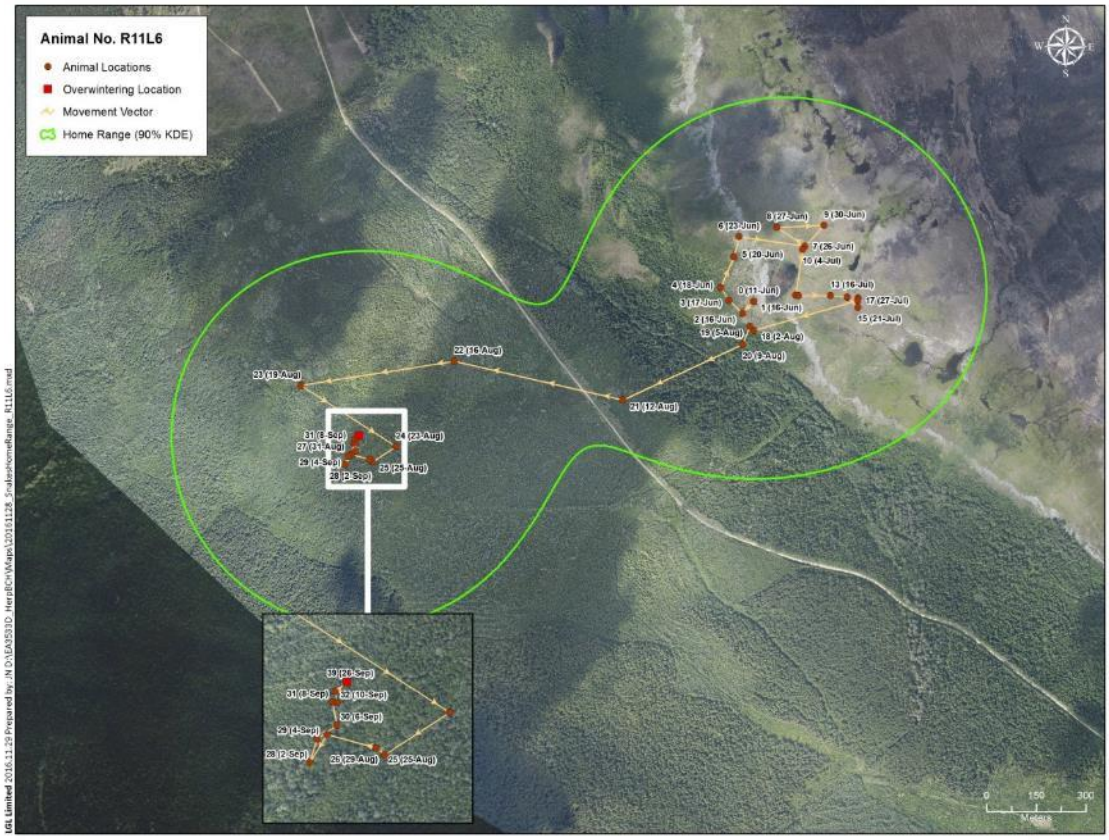
Map 11-16: **Successive movements by tagged female Common Garter Snake R12L5 in Cranberry Marsh, Valemount B.C., 2016.** Dates indicate location dates. Vectors indicate presumed (straight-line) direction of movement. The green polygon is the 90% kernel density estimation used to calculate home range



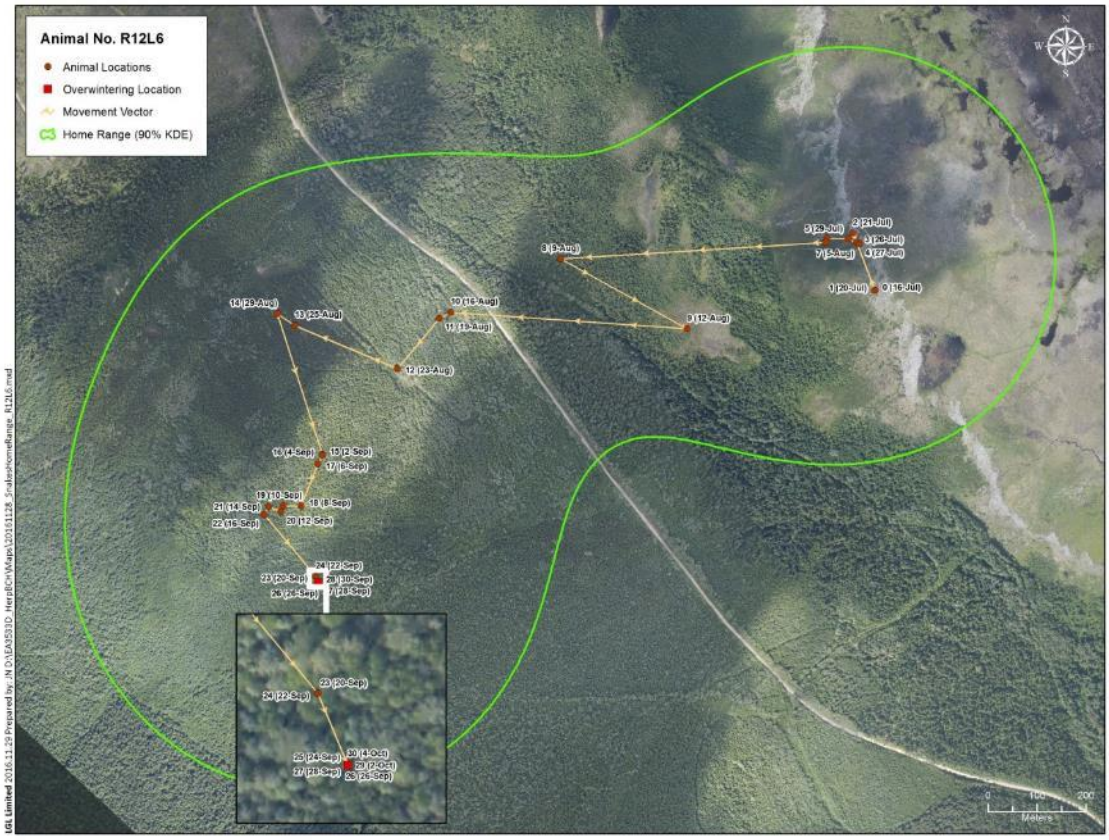
Map 11-17: **Successive movements by tagged female Common Garter Snake R12L10 in Cranberry Marsh, Valemount B.C., 2016.** Dates indicate location dates. Vectors indicate presumed (straight-line) direction of movement. The green polygon is the 90% kernel density estimation used to calculate home range



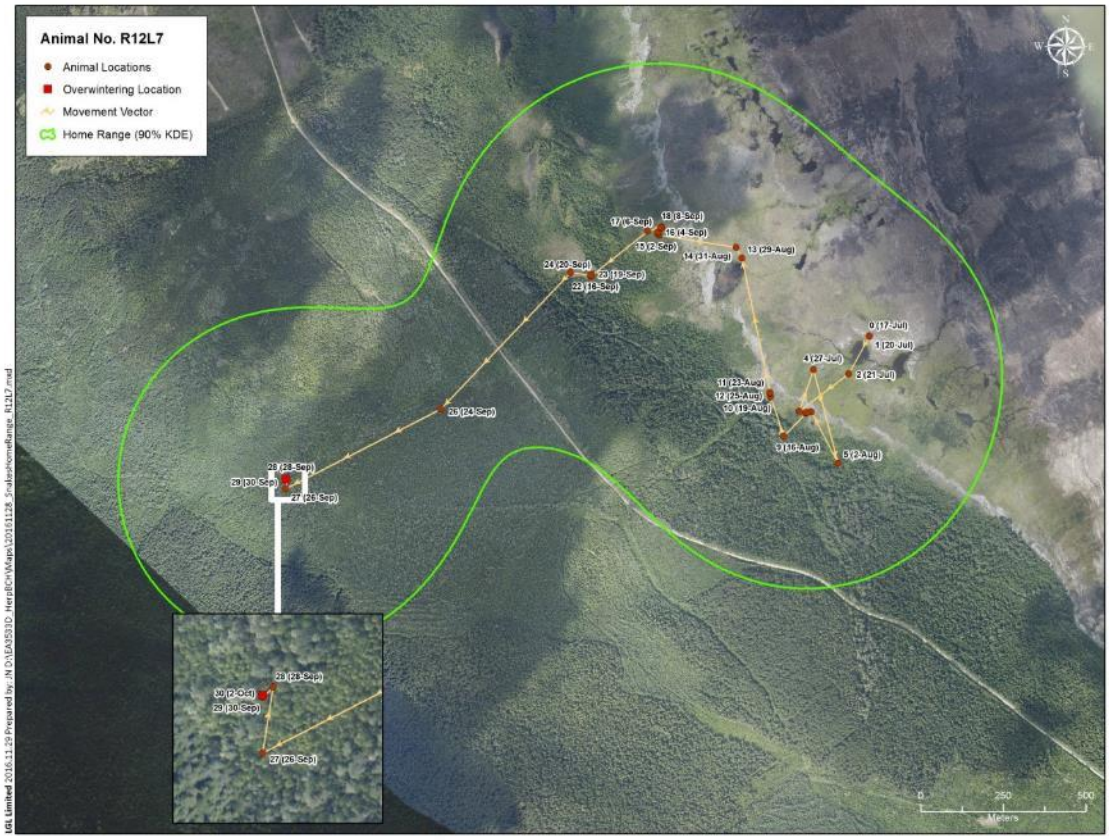
Map 11-18: Successive movements by tagged female Common Garter Snake R12R3L4 in Cranberry Marsh, Valemount B.C., 2016. Dates indicate location dates. Vectors indicate presumed (straight-line) direction of movement. The green polygon is the 90% kernel density estimation used to calculate home range



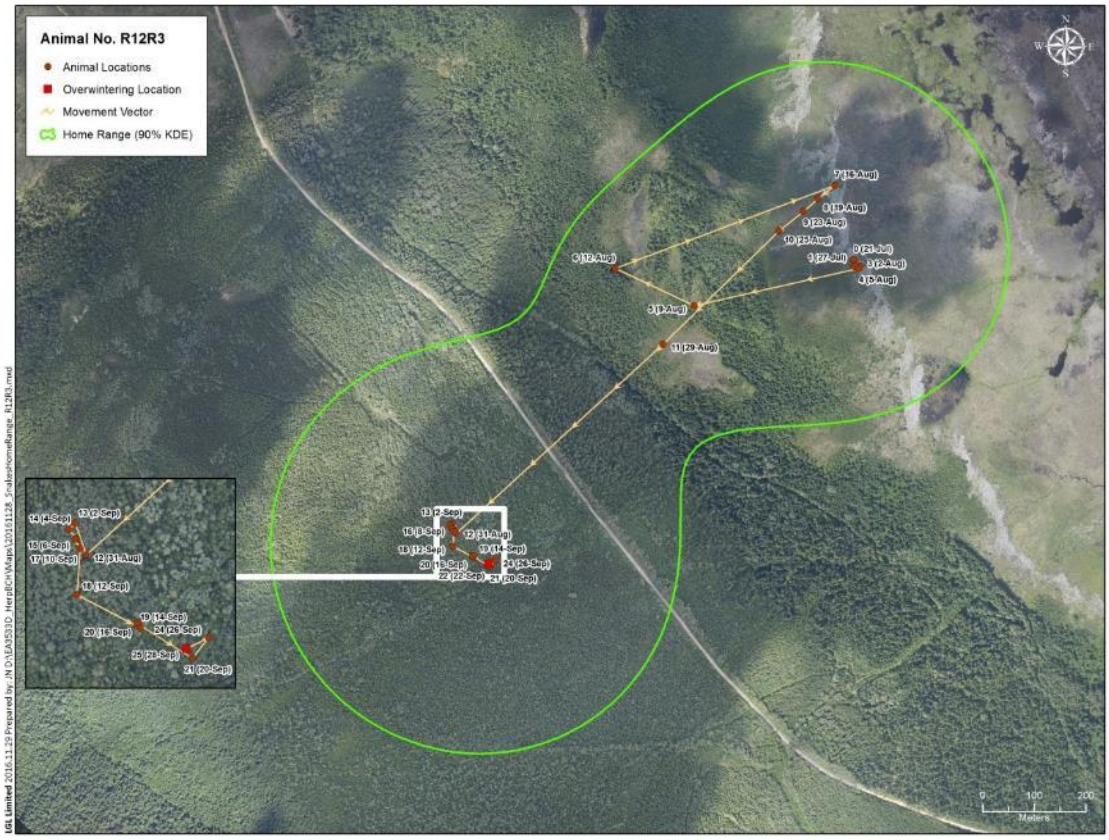
Map 11-19: **Successive movements by tagged female Common Garter Snake R11L6 in Canoe Reach, Valemount Peatland, 2016.** Dates indicate location dates. Vectors indicate presumed (straight-line) direction of movement. The green polygon is the 90% kernel density estimation used to calculate home range



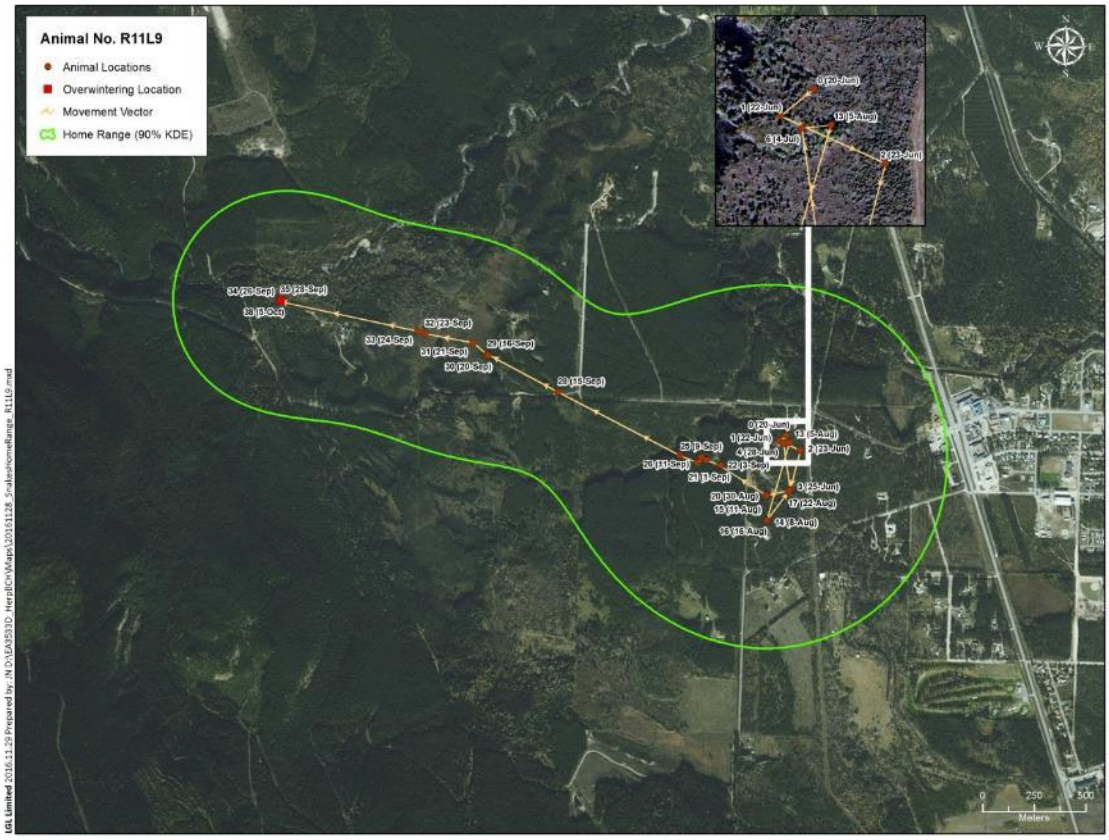
Map 11-20: Successive movements by tagged female Common Garter Snake R12L6 in Canoe Reach, Valemount Peatland, 2016. Dates indicate location dates. Vectors indicate presumed (straight-line) direction of movement. The green polygon is the 90% kernel density estimation used to calculate home range



Map 11-21: **Successive movements by tagged female Common Garter Snake R12L7 in Canoe Reach, Valemount Peatland, 2016.** Dates indicate location dates. Vectors indicate presumed (straight-line) direction of movement. The green polygon is the 90% kernel density estimation used to calculate home range



Map 11-22: Successive movements by tagged female Common Garter Snake R12R3 in Canoe Reach, Valemount Peatland, 2016. Dates indicate location dates. Vectors indicate presumed (straight-line) direction of movement. The green polygon is the 90% kernel density estimation used to calculate home range



Map 11-23: **Successive movements by tagged female Common Garter Snake R11L9 in upland habitat, Valemount B.C., 2016.** Dates indicate location dates. Vectors indicate presumed (straight-line) direction of movement. The green polygon is the 90% kernel density estimation used to calculate home range