Columbia River Project Water Use Plan

Arrow Lakes Reservoir Operations Management Plan

Kin and Arrow Amphibian and Reptile Life History

Implementation Year 5

Reference: CLBMON-37

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

Study Period: 2014

Okanagan Nation Alliance, Westbank, BC

and

LGL Limited environmental research associates
Sidney, BC

February 13, 2015

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KINBASKET AND ARROW LAKES RESERVOIRS

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




2014 Annual Report
Final

Prepared for

BC Hydro Generation
Water Licence Requirements
6911 Southpoint Drive
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Cover photos:

From left to right: Northern Alligator Lizard (*Elgaria coerulea*), Columbia Spotted Frog (*Rana luteiventris*) egg mass, Western Terrestrial Garter Snake (*Thamnophis elegans*), Western Toad (*Anaxyrus boreas*) in amplexus © Virgil C. Hawkes, LGL Limited.

EXECUTIVE SUMMARY

This year marked the fifth year of monitoring under CLBMON-37, a 10-year amphibian and reptile life history and habitat use monitoring study in the drawdown zones (DDZs) of Kinbasket and Arrow Lakes Reservoirs. 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 2014, through a variety of survey methods (egg mass surveys, visual encounter surveys, auditory surveys, radiotelemetry) we documented the presence of four amphibian and five reptile species in Kinbasket and Arrow Lakes Reservoirs. Western Toads (*Anaxyrus boreas*), Columbia Spotted Frogs (*Rana luteiventris*), and Common Garter Snakes (*Thamnophis sirtalis*) were the most commonly encountered species, usually in wetlands within reed canarygrass (*Phalaris arundinacea)* – lenticular sedge (*Carex lenticularis*) mesic habitats (Arrow), or clover-oxeye daisy (*Leucanthemum vulgare*), Kellogg's sedge or willow-sedge habitats (Kinbasket).

Most amphibian and reptile detections in the drawdown zone 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 DDZs was evident: as reservoir elevations increased throughout the season, the total amount of available habitat decreased. As such, the location of amphibians and reptiles in either DDZ was a function of seasonal habitat availability. Direct impacts from reservoir levels in 2014 were observed at all sites in Kinbasket and Arrow Lakes Reservoirs because water levels inundated ponds that still had developing tadpoles. Western Toads (SARA species of Special Concern) were likely the most affected by early inundation, as very few metamorph toads were observed in either reservoir during July compared to previous years.

Radiotelemetry was used in 2014 to determine how long Western Toads and Common Garter Snakes use habitats in the drawdown zone and whether the drawdown zone was used for summer or winter habitat. The results obtained suggest that Western Toads migrate to the drawdown zone to breed between late April and early May. Toads stay in the drawdown zone for two to three weeks and following breeding, most move to adjacent upland (i.e., non-drawdown zone) summer and fall habitat. It is presumed that these summer and fall habitats also represent important winter habitat, but data are required to confirm this assumption. Data obtained for Common Garter Snakes did not provide much insight into seasonal habitat use, which may be related to the length and frequency of telemetry sessions and because snakes dropped transmitters more frequently

than toads. More data are required to better assess the seasonal habitat use of the drawdown zone in both Kinbasket and Arrow Lakes Reservoirs.

Amphibian and reptile monitoring will continue in 2015 (under CLBMON-58) and again in 2016 (under CLBMON-37) and additional methods are recommended to improve the likelihood of answering several management questions regarding how amphibians and reptiles use the drawdown zone to fulfill their life requisites. Several recommendations listed here are carried forward from previous implementation years, and are discussed in more detail in the Recommendations Section.

Sampling

1. Consider annual sampling in Arrow Lakes Reservoir to increase the time series of data. Annual sampling has occurred in Kinbasket Reservoir since 2011 and is facilitated by the implementation of CLBMON-38 and CLBMON-37 in alternating years;
2. Constrain sampling in Arrow Lakes Reservoir to Revelstoke Reach, Beaton Arm, Burton Creek, and Edgewood (Eagle Creek). These sites are the most appropriate to continue monitoring due to the presence of multiple species, relatively large populations, ease of access, and measurable changes to breeding habitat within a year;
3. Consider continuing and/or possibly increasing the amount of pitfall trapping at various monitoring locations (e.g., Bush Arm Causeway) is suggested to determine site occupancy of inconspicuous species of amphibians that migrate to and from breeding ponds;
4. 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 sites used by pond-breeding amphibians, particularly Western Toads and Columbia Spotted Frogs, to determine their productivity and survival in various habitats in the drawdown zone.
5. Consider incorporating and funding Master's students into this study focusing on a variety of topics. This would not only increase the amount of data collection possible over two consecutive years of the study, but would also allow for the in-depth examination of one or more of the management questions. Possible studies could include:
    - Garter snake study focusing on abundance, productivity (gravid and non-gravid female size ranges and egg counts), seasonal habitat use for garter snakes in the drawdown zone and upland habitats compared to reservoir elevations, and interspecific species microhabitat use comparisons;
    - Seasonal habitat use of Western Toads and Columbia Spotted Frogs (via radiotelemetry and mark recapture methods);
    - Amphibian reproduction and development (e.g., characteristics of egg mass deposition sites and consequence survivorship of larvae through to metamorphs, pre and post inundation comparisons, enclosure experiments manipulating varying water physicochemical conditions reflecting pond/reservoir variables)
6. Continue telemetry study on Western Toads and Common Garter Snakes for a few years (e.g., fund a graduate student to implement an intensive telemetry study;

see above). This will provide valuable information on the use of the drawdown zone by these species on a seasonal basis, including the winter period, which will remove uncertainty as to whether the drawdown zone provides overwintering habitat for certain species. A long-term radiotelemetry component will provide additional data to support the existing data for this study in helping to determine:

- What time of year animals are most likely to use the drawdown zone;
- Where animals are overwintering;
- Whether amphibians are returning to the same breeding ponds each year;
- Specific microhabitat use of the drawdown zone by adult animals of each species

Without this information, it will not be possible to determine the effects of normal or adjusted reservoir operations on amphibians and reptiles that use the drawdown zone of Kinbasket and Arrow Lakes Reservoirs.

7. Install continuous data loggers in Arrow Lakes Reservoir to obtain Dissolved Oxygen concentrations and temperature data pre- and post-inundation.

Reservoir Operations

1. The inundation of elevations between ~735 and 754 m ASL (Kinbasket) and ~434 and 440 m ASL (Arrow) should occur on or as close to the end of the summer (similar to the dates from the period 1978 to 2007) as possible.
2. For Kinbasket only, given that reservoir elevations are predicted to increase (by up to 60 cm) in the summer months as a result of the installation of units 5 and 6 at Mica Dam, achieving full pool in July is not recommended and maximum reservoir elevations (~754 m ASL for Kinbasket and 440 m ASL for Arrow) should be targeted for the current average date of August 25. 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.

The status of CLBMON-37 after Year 7 (5th year of monitoring: 2014) with respect to the management questions and management hypotheses is summarized below.

Management Question	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 resulted in the documentation of all expected species in the drawdown zone	• Annual sampling (to assess annual occupancy) • Increased frequency of sampling within a year	• Natural annual population variation • Inconspicuous species (e.g., Long-toed Salamander) • Bi-annual sampling • 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?	Partially	5 years of site occupancy and detection rates data. Productivity estimated for some species	• Intensive productivity data collection for Western Toads, spotted frogs and garter snakes • Annual sampling for select amphibians • Constrain study to Revelstoke Reach and Burton Creek in Arrow • Add other sites as physical works are implemented	• Natural annual population variation • Unknown rate of immigration may confound productivity estimates • Inconspicuous species • Mortality difficult to assess • Bi-annual sampling • 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?	Partially	5 years of site occupancy data across multiple sites and seasons	• Telemetry studies on Western Toads and garter Snakes to assess overwinter habitat use. Ideally this would occur over several years to determine whether this species is using habitats in the drawdown zone to overwinter	• Natural annual population variation • Inconspicuous species • Lack of knowledge regarding the use of the drawdown zone in the winter. Still not resolved after telemetry trial in 2014. • Variable reservoir operations

Management Question	Able to Address MQ?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
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)?	Probably	5 years of macro and micro habitat data collection	• Reduce the number of monitoring sites • Focus on Western Toads, spotted frogs and garter snakes • Continue telemetry study on Western Toads and garter snakes to assess habitat use • Re-evaluate existing habitat mapping and its relevance to amphibians and reptiles	• Inconspicuous species • Habitat mapping is required at a scale relevant to amphibians and reptiles • Frequency of sampling- more intensity required for telemetry studies. • Variable reservoir operations
MQ5: How do reservoir operations influence or impact amphibians and reptiles directly (e.g., desiccation, inundation, predation) or indirectly through habitat changes?	Partially	5 years of data collected on the occurrence and distribution of amphibians and reptiles in the drawdown zones	• None	• Natural annual population variation • Variable reservoir operations • Habitat mapping is required at a scale relevant to amphibians and reptiles • Wetland habitats and conditions may change on an annual basis
MQ6: Can minor adjustments be made to reservoir operations to minimize the impact on amphibians and reptiles?	Possibly	N/A	• Restrict Kinbasket Reservoir elevations for one year to elevations < 751 m ASL to determine whether doing so alters the use of the drawdown zone by amphibians and reptiles. • Arrow Lakes: maintain reservoir elevations < 436 m ALS or delay inundation of habitat > 436 to late August	• Lack of 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.
MQ7: Can physical works projects be designed to mitigate adverse impacts on amphibians and reptiles resulting from reservoir operations?	Partially	N/A	• Implement physical works in Arrow Lakes Reservoir • Assess effectiveness of woody debris removal and log boom installation in Kinbasket Reservoir	• Physical works have not been implemented in Arrow Lakes Reservoir. Until they are we cannot answer this question.

Management Question	Able to Address MQ?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
MQ8: Does revegetating the drawdown zone affect the availability and use of habitat by amphibians and reptiles?	No	Assessments of revegetation effectiveness (CLBMON-9, 12); 5 years of monitoring data	• Kinbasket: revegetate high potential sites using combinations of woody debris removal, log boom installations, and revegetation (or a combination of these). • Arrow Lakes: implement revegetation prescription that will benefit amphibians and reptiles. Focus on habitats adjacent to wetlands or that expand dense shrub habitats.	• Revegetation in Kinbasket has been a failure. • Revegetation in Arrow moderately successful, but not designed to benefit amphibians and reptiles.
MQ9: Do physical works projects implemented during the course of this monitoring program increase amphibian and reptile abundance, diversity, or productivity?	Not at this time	N/A	• Implement physical works in Arrow Lakes Reservoir. • Assess effectiveness of physical works done in Kinbasket Reservoir in 2014.	• Physical works have not been implemented in Arrow Lakes Reservoir. Until they are we cannot answer this question. • No monitoring of physical works installed in Kinbasket Recommend this occurs in 2015 (CBMON-58).

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

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1 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). 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). 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; Eskew et al. 2011; Kupferberg et al. 2011). To date, most studies on the effects of impoundment have focused primarily on the instream and riparian effects on fishes 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; Eskew et al. 2011; Kupferberg 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), and that is the focus of this study (Hawkes and Tuttle 2009a, 2010a; Hawkes et al. 2011).

During the Columbia River Water Use Planning process (WUP), concerns were expressed about potential impacts of the operations of the Kinbasket and Arrow Lakes Reservoirs on 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 any impacts by using physical works.

This report summarizes the findings of Year 7[1] (2014) 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 in 2010 and 2012 are used to assess whether any trends are apparent in the data.

[1] 2014 represents the 5th year of sampling, but the 7th year since project inception. Sampling for CLBMON-37 occurred in 2008, 2009, 2010, 2012, and 2014.

2 STUDY OBJECTIVES & MANGEMENT QUESTIONS

2.1 Study Design

Monitoring populations of amphibians and reptiles in the drawdown zones of Kinbasket and Arrow Lakes 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. 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.

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

Year	CLBMON-58	CLBMON-37	Reference
2008		Year 1	Hawkes and Tuttle 2009a
2009		Year 2	Hawkes and Tuttle 2010a
2010		Year 3	Hawkes et al. 2011
2011	Year 1		Hawkes and Tuttle 2012
2012		Year 5	Hawkes and Tuttle 2013a, b
2013	Year 3		Hawkes and Wood 2014
2014		**Year 7**	**Hawkes et al. 2014 (this report)**
2015	Year 5		Annual report
2016		Year 9	Annual report
2017	Year 7		Annual report
2018	Year 8	Year 11	Final comprehensive report

2.2 Management Questions and Hypotheses

Nine management questions (MQs) were developed in 2008 to determine the impacts of reservoir operations on amphibians and reptiles that use habitats in the drawdown zones of Kinbasket and Arrow Lakes Reservoirs. In 2011, a tenth management question asked how the installation of Mica Units 5 and 6 will affect amphibian populations in the drawdown zone of Kinbasket Reservoir (as per CLBMON-58). Thus, the ten MQs can be grouped into four broad themes:

CLBMON-37 – 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 – 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 – 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. Hypothesis H_1 was modified to include the effect of Units 5 and 6 on amphibians that use habitats in the drawdown zone of Kinbasket Reservoir (CLBMON-58 only):

H_1 Annual and seasonal variation in water levels in Kinbasket or Arrow Lakes Reservoirs (due to reservoir operations), the implementation of soft operational constraints, and the effects of Units 5 and 6 in Mica Dam on Kinbasket Reservoir (CLBMON-58 only), 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 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.

These questions and hypotheses will be tested directly by this monitoring program, which is aimed at determining the habitat use/associations and distribution of amphibians and reptiles in the drawdown zones of Kinbasket and Arrow Lakes Reservoirs relative to reservoir operational regimes, including changing water levels (Table 2-2). The monitoring program is also designed to address whether or not the proposed physical works and/or revegetation programs will enhance habitat suitability for amphibians and reptiles in the drawdown zone.

Table 2-2: Hypotheses addressed by each theme for CLBMON-37. A √ indicates a relationship between the theme and hypothesis

Theme	Hypotheses									
	H_1	H_{1A}	H_{1B}	H_{1C}	H_{1D}	H_{1E}	H_2	H_{2A}	H_{2B}	H_{2C}
Life History and Habitat Use	√	√	√	√	√	√				
Reservoir Operations and Habitat Change	√	√	√	√	√	√				
Physical Works							√	√	√	√

The focus of work in 2014 was to collect data to answer management questions 2, 3, 4, and 5. To do so, two approaches were used: 1) site occupancy assessments; and 2) a telemetry study. Site occupancy assessments were conducted as per previous years. This ensures that data collected in 2014 are comparable to those collected between 2008 and 2012. All sites sampled in previous years (see Hawkes and Tuttle 2013a) were sampled in 2014 to determine the distribution and occurrence of all species of amphibians and reptiles using habitats in the drawdown zone of Kinbasket and Arrow Lakes Reservoir. Work associated with the telemetry pilot study occurred in the Valemount Peatland of Kinbasket Reservoir and in Revelstoke Reach of Arrow Lakes Reservoir. The methods used follow Hawkes and Tuttle (2012). The only modification is the addition of the methods for radio telemetry, which are provided below (see Methods).

3 STUDY AREA

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.

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.

3.1 Kinbasket Reservoir

Located in southeastern B.C., Kinbasket Reservoir is surrounded by the Rocky and Monashee Mountain ranges, and 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 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 normal operating range of the reservoir is between 707.41 m and 754.38 m elevation (Figure 3-1). 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 3-2).

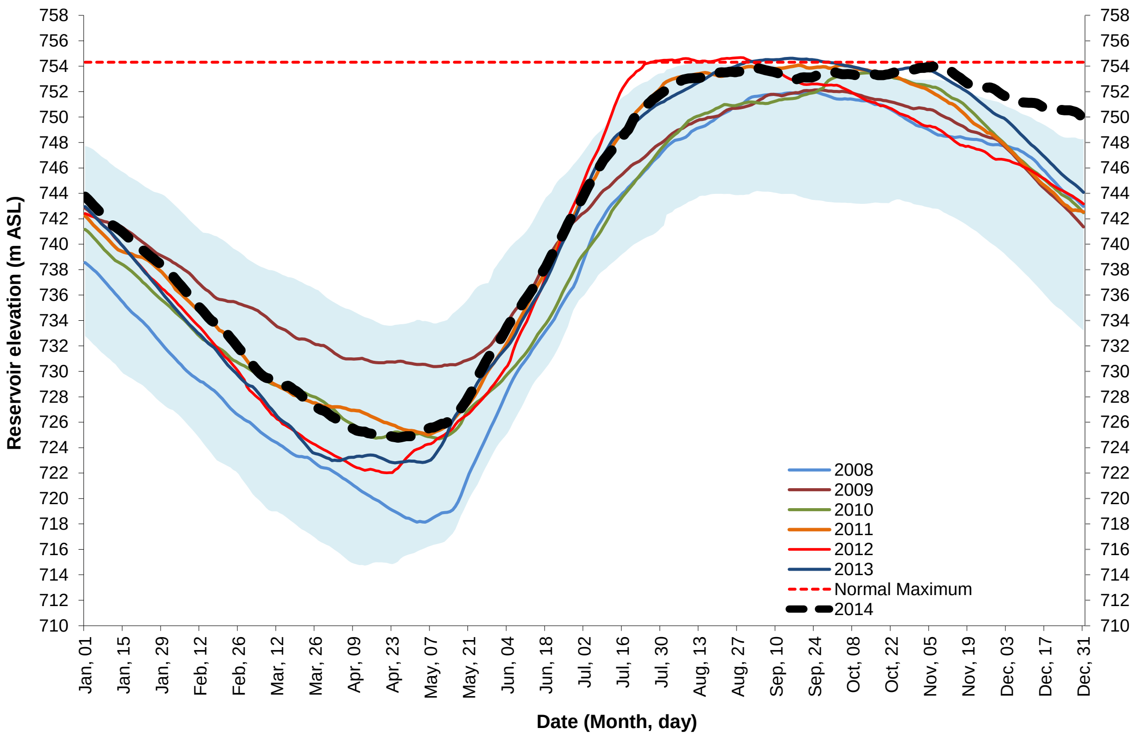

Figure 3-1: **Kinbasket Reservoir elevations for 2008 through 2014.** The shaded region delineates the 10th and 90th percentile in reservoir elevation (1977 to 2014). Field work occurred between April and August 2014

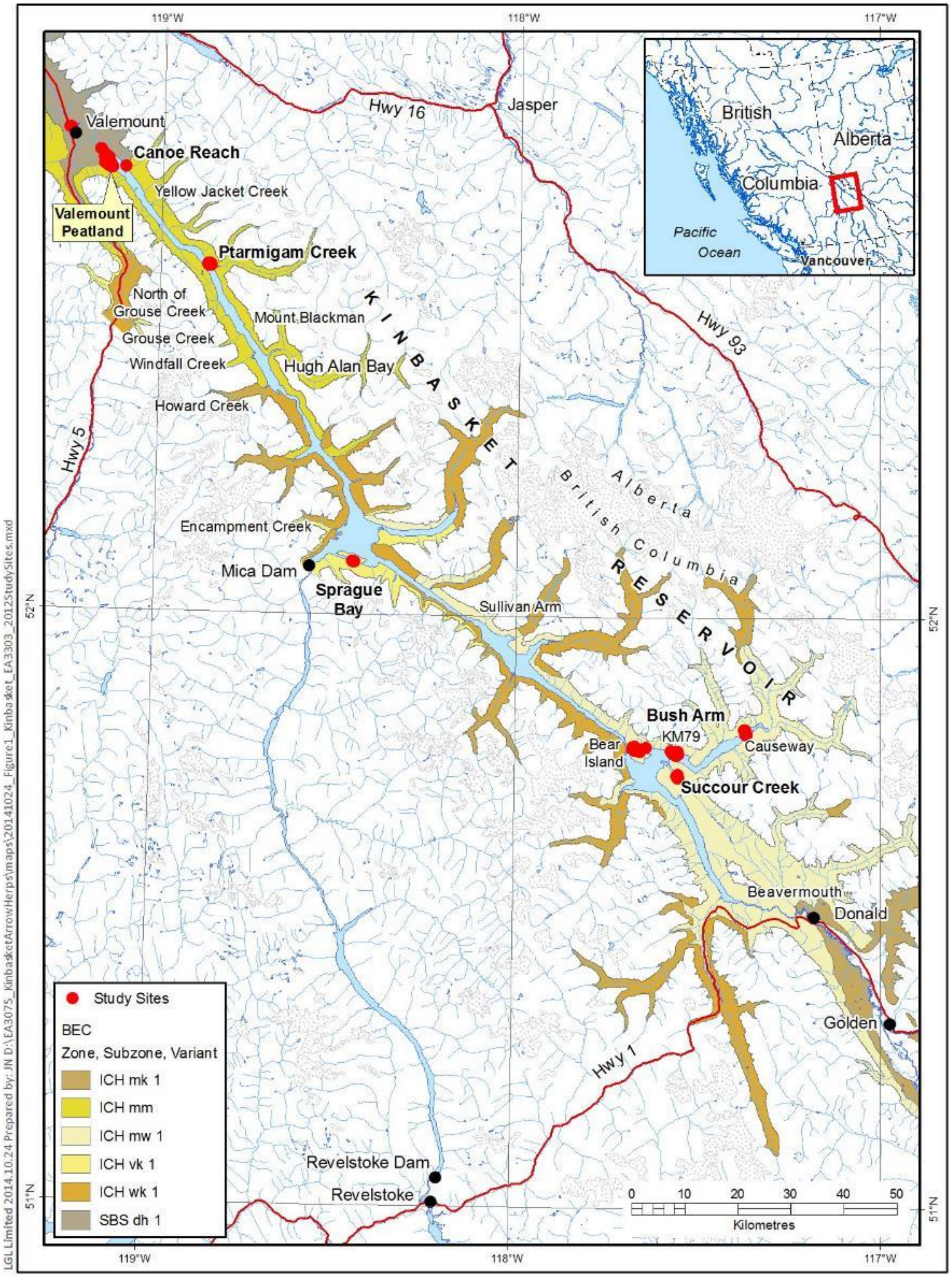

Figure 3-2: Location of Kinbasket Reservoir in British Columbia, and locations sampled for CLBMON-37 in 2014. Place names in bold are either monitoring sites or reference sites (see Hawkes and Tuttle 2013a). Naming follows Hawkes et al. (2007)

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 amphibians and reptiles. 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 ~79.5 km along Bush FSR ("KM 79") and KM 88 (i.e., the mouth of Bush Arm; Bear Island), and sites in Canoe Reach in the Valemount Peatland and at Ptarmigan Creek (see Appendix 10 for maps of each study site).

3.2 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).

Seventeen 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, 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), and sites in lower Arrow Lakes area (see Appendix 10 for maps of each study site).

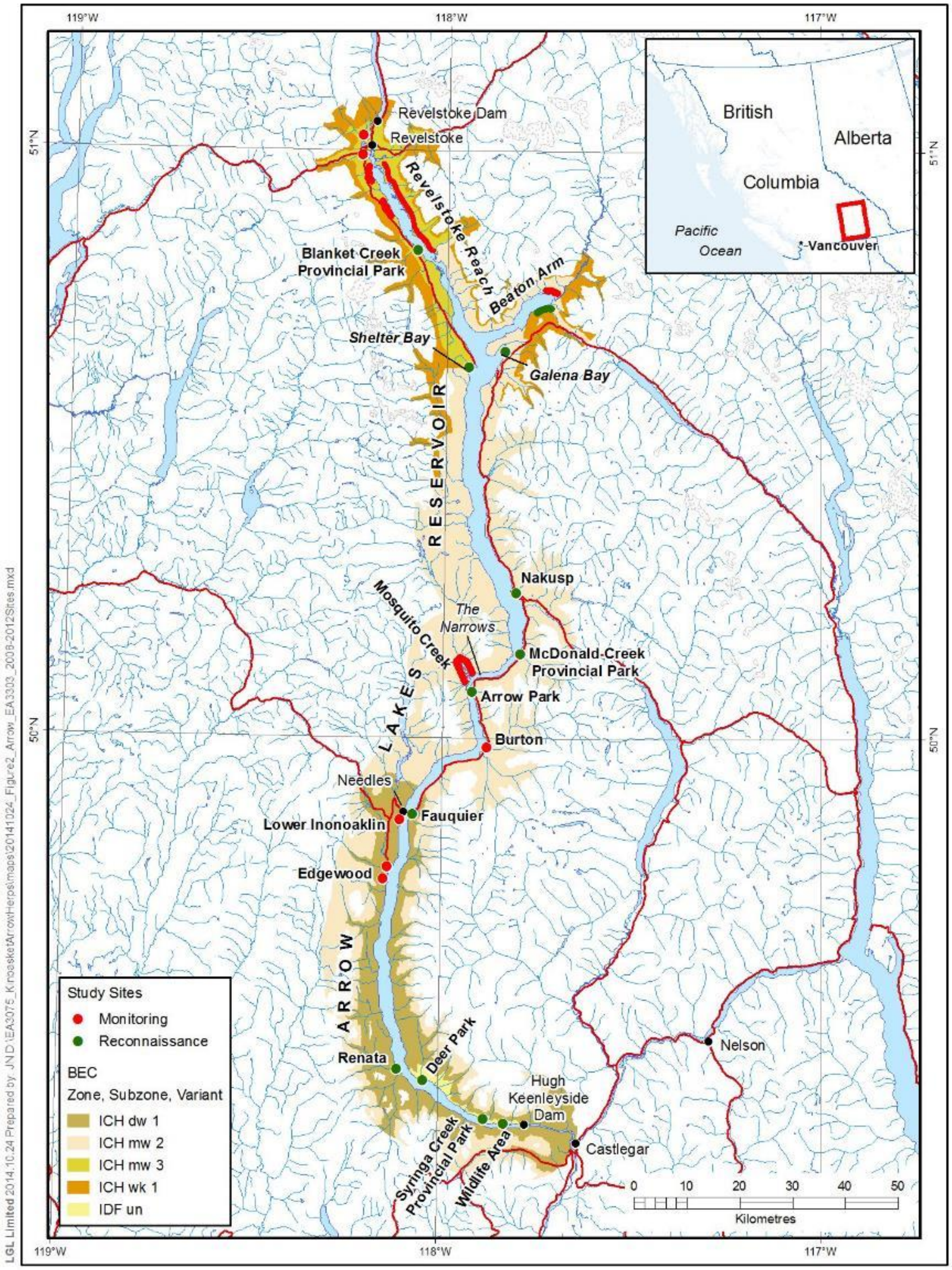

Figure 3-3: Location of Arrow Lakes Reservoir in British Columbia, and locations sampled for CLBMON-37 in 2014. Place names in bold are either monitoring sites or reference sites (see Hawkes and Tuttle 2013b)

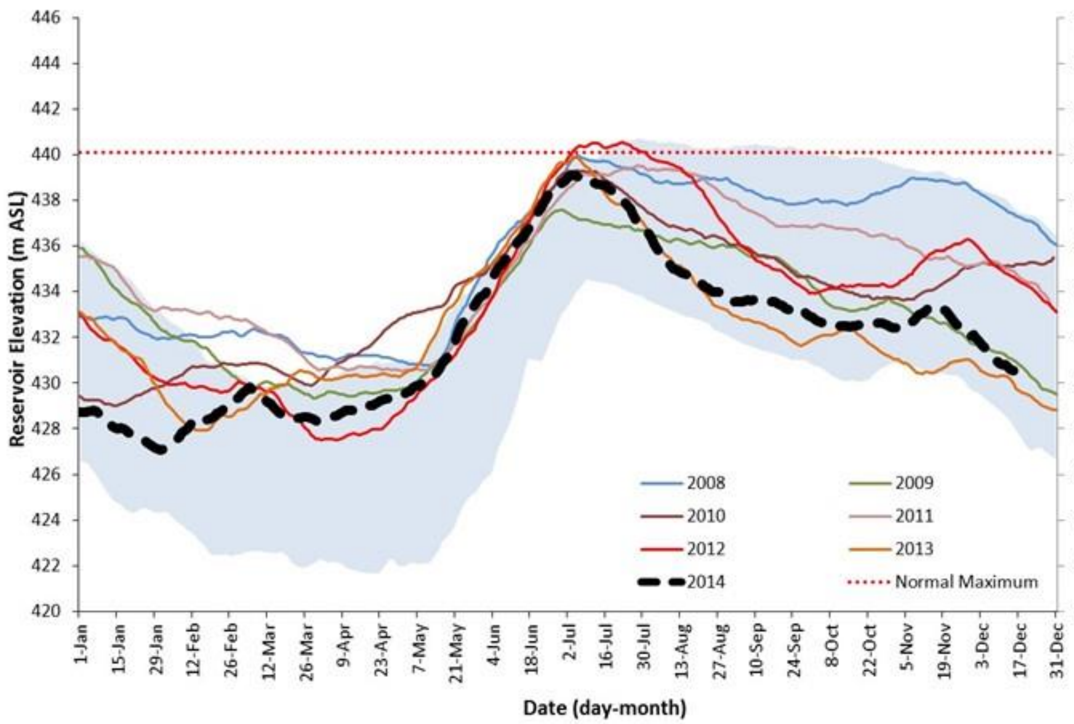

Figure 3-4: Arrow Lakes Reservoir elevations for 2008 through 2014. The shaded region delineates the 10th and 90th percentile in reservoir elevation (1969 to 2014). Field work occurred between April and August, 2014

4 METHODS

4.1 Study Species

Sixteen species of amphibians and reptiles are known to 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 4-1). Life history information for each species can be found in Hawkes and Tuttle (2009a). All species of reptiles and amphibians are monitored under CLBMON-37, with an emphasis on those species that have been typically documented in the drawdown zone of Kinbasket and Arrow Lakes Reservoir (i.e., those in bold in Table 4-1). In addition, Western Toad and Common Garter Snake were targeted for the telemetry study.

Table 4-1: 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 zones (DDZs) of Kinbasket and/or 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**	KIN/ARR	Y	
Western Toad (*Anaxyrus boreas*)	**A-ANBO**	KIN/ARR	Y	SC
Long-toed Salamander (*Ambystoma macrodactylum*)	**A-AMMA**	KIN/ARR	Y	

Group and Species	Species Code	Region*	Status†	
			CDC	COSEWIC
Coeur d'Alène Salamander (*Plethodon idahoensis*)	A-PLID	ARR	Y	SC
Rocky Mountain Tailed Frog (*Ascaphus montanus*)	A-ASMO	N/A	R	
REPTILES				
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	

*KIN = Kinbasket Reservoir; KIN/ARR = Kinbasket Reservoir and Arrow Lakes Reservoir; ARR = Arrow Lakes Reservoir; NA = Not Applicable.
†Status: CDC = British Columbia Conservation Data Centre: B = Blue; R = Red; Y = Yellow; COSWEIC = Committee on the Status of Endangered Wildlife in Canada: E = Endangered; T = Threatened; SC = Special Concern.

4.2 Field Schedule

In 2014, field sampling was conducted between early May and the end of September to coincide with the active period of amphibians and reptiles. Predicted reservoir elevation levels obtained from BC Hydro were taken into account for field scheduling to determine how much of the DDZ would be available for sampling. The 2014 field sampling schedule followed a similar timeline as that implemented between 2008 and 2012 to facilitate data comparison between years.

4.3 Permits

Work was conducted under Wildlife Act Permit VI13-86283, which is valid through March 31, 2015. This permit was amended in 2014 to permit the non-surgical application of transmitters to toads and snakes.

4.4 Data Collection

4.4.1 General Survey Data

A variety of standardized techniques (egg mass surveys [EMS], larval surveys [LVS] and visual encounter surveys [VES]) were used to survey amphibians and reptiles in the DDZ of Kinbasket and Arrow Lakes Reservoir (RISC 1998a,b; see Hawkes and Tuttle 2012; Hawkes and Wood 2013). Of these methods, VES were determined to be the most appropriate, mainly because of the large geographic scale of the study and the need to sample many locations across the active season (i.e., late April to the end of September). Total survey time per person was recorded to calculate detection rates (a proxy for catch per unit effort time or CPUE) for each survey site, field session and species. Detection rates for each species (including the different life stages) and site were calculated by dividing the total number of captures made at each site by the time spent searching the site. Aggregations of tadpoles and metamorph amphibians were treated as a single detection.

At each survey site, as much area (terrestrial and aquatic habitat) as possible was surveyed on each visit and the total area surveyed was a function of reservoir management. Species location data were used to assess site occupancy and annual comparisons were made. All amphibian and reptile observations and captures, including incidental observations, were georeferenced to identify the vegetation community (e.g., per Enns et al. 2007 and Hawkes et al. 2007) and elevation at which they were made. All captured animals were measured, weighed, and marked (e.g., scale clipping or photo identified) and released at the site of capture.

4.4.2 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, most were photographed, and UTM coordinates were obtained for each observation. The sex of an animal was determined where possible. The marking scheme used in previous years was continued in 2014 (e.g., photo identification for adult amphibians and subcaudal scute clipping in snakes).

Amphibian Morphometric Data—Snout-urostyle length (SUL) was measured using Vernier calipers 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 hemipenes (i.e., the probe was inserted farther in males due to the presence of the spaces in which the hemipenes occupy).

For a detailed description of the methods used to sample amphibians and reptiles in 2014, refer to the CLBMON-37 Year 1 report (Hawkes and Tuttle 2009a, b) and revised monitoring program sampling protocols (Hawkes and Tuttle 2011).

4.4.3 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 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), refer to the CLBMON-37 Year 1 report (Hawkes and Tuttle 2009a) and revised monitoring program sampling protocols (Hawkes and Tuttle 2010b).

Water chemistry 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. An YSI 85 multi-function metre was used to measure dissolved oxygen, conductivity, and temperature. An Oakten waterproof pH Tester 30 was used to obtain pH data. Conductivity (Onset U24-001) and dissolved oxygen (PME MiniDOT) dataloggers were installed in select wetlands to collect continuous data. The dataloggers were installed between 30 cm and 50 cm below the water's surface in depths of 65 to 80 cm. The units were affixed to rebar (125 cm in length) using a pipe clamp and the rebar was fitted with an orange plastic safety cap for easy relocation. The dataloggers were factory programmed to record data every 5 minutes and data were downloaded using the manufacture's software (Onset HOBOware and PME miniDOT software). Data collected from the dataloggers spanned 165 days (2013) and 134 days (2014). The dataloggers were deployed May to November in 2013 and June to October 2014.

HOBO temperature data loggers were installed at several locations to track water temperature changes as a result of reservoir inundation. Data loggers were attached to a pin-flag or flagging tape and were weighted down with a brick, and the site was georeferenced and photographed. Data loggers were programmed to record hourly temperatures over a 3-year period. Data are downloaded in the spring and fall of each year.

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 zones. Temporal habitat availability was assessed by evaluating the range of dates that amphibians and reptiles would likely be using in the DDZ of Kinbasket and Arrow Lakes Reservoirs (Matsuda et al. 2006). The temporal assessment was based on the duration of the active season (i.e., the number of days between April 1 and September 30; n = 183) 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 in the active season that each 1 m elevation band was exposed and therefore available for use.

4.4.4 Radio-telemetry

A pilot radio-telemetry study on Western Toads and Common Garter Snakes occurred in 2014. Adult Western Toads and Common Garter Snakes were captured and fitted with radio transmitters (Holohil BD-2 for toads and PD-2 for snakes) and released at the site of capture (Figure 4-1). Transmitters had a life expectancy of 4 to 6 months depending on the model. Transmitters weighed no more than 5% of the mass of each toad or snake (Millspaugh and Marzluff, 2001; Jepsen et al. 2003). Transmitters were attached to toads following the techniques described in Burow et al. (2012) and to snakes using the body method described in Wylie et al. (2011). Transmitters were attached to adult Western Toads and Common Garter Snakes in each of two areas: Valemount Peatland and Revelstoke Reach.

To assess transmitter fit, animals were tracked daily for up to three days following the initial application of a transmitter. Subsequent telemetry sessions were conducted on a weekly or bi-weekly schedule during May through August. 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.

Figure 4-1: Examples of transmitters applied to a Western Toad (left) and Common Garter Snake (right) following the methods of Burow et al. (2012) and Wylie et al. (2011). Camouflage duct tape was used to attach the transmitter on the garter snake. Photos: Virgil C. Hawkes

4.5 Data Analyses

4.5.1 Species Richness

Statistical analyses were performed using R (V3.0.2) and Microsoft Excel 2013 (© 1985–2013). Comparisons of species richness (i.e., the number of species per study site and vegetation community) relative to vegetation communities and landscape units were made by standardizing capture data by correcting for total time surveyed per area (number of observations per hour). For all analyses measures of relative are used. Summary boxplot graphs were produced to describe the dispersion of richness, diversity and evenness per transect according to landscape units, vegetation communities and elevation (Massart et al. 2005). In boxplot graphs, the boxes represent between 25 per cent and 75 per cent of the ranked data. The horizontal line inside the box is the median. The length of the boxes is their interquartile range (Sokal and Rohlf 1995). A small box indicates that most data are found around the median (small dispersion of the data). The opposite is true for a long box: the data are dispersed and not concentrated around the median. Whiskers are drawn from the top of the box to the largest observation within 1.5 interquartile range of the top, and from the bottom of the box to the smallest observation within 1.5 interquartile range of the bottom of the box. Boxplots display the differences between groups of data without making any assumptions about their underlying statistical distributions, and show their dispersion and skewness. Analysis of variance (ANOVA) was used to test for differences in detection rates across survey locations and between years. The critical level of alpha was set to 0.1.

4.5.2 Morphometric Data

Analysis of covariance (ANCOVA) was used to investigate the relationship between mass and snout-urostyle length of Western Toad and Common Garter Snake sex and year (as per Shine 1979 and Duellman and Trueb 1986). Length-weight relationships have been useful in estimating biomass for a variety of organisms (see summary in Deichmann et al. 2008) and such data could be used to document changes in community biomass and serve as a baseline for changes in individual taxa over time. These data may also be used to infer the health of a population relative to environmental stressors, or in this case, changing reservoir elevations.

4.5.3 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., 2008 to 2014).

4.5.4 Habitat Availability

Habitat availability was assessed through graphical presentation of total area available relative to use (breeding, foraging, basking, and overwintering). The area assessed for availability was arbitrarily delineated at each of the monitoring locations to enable this analysis. It is likely that the total area available is being underestimated using this approach. Pearson's correlation coefficients were used to describe 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.

4.5.5 Habitat Associations

Habitat associations were assessed for Western Toads, Columbia Spotted Frogs and Common Garter Snakes through graphical presentation of the distribution of pooled life stages of each species by vegetation community. To account for annual differences in sampling effort, presence data were used and standardized by species totals within each year.

Further, we described the distribution of Western Toad, Columbia Spotted Frog, and Common Garter Snake occurrence in habitats of the drawdown zone of each reservoir through classification (logistic regression) trees (De'ath 2002) Classification and Regression Tree (CART) models have many advantages in comparison to other regression approaches. They are more effective for analysis of complex ecological data that may include unbalanced designs, missing values, non-linear relationships between variables, and high-order interactions (Breiman et al. 1984; De'ath and Fabricius 2000). In comparison to general linear model and general additive model approaches, CART provides better predictions (Franklin 1998; Vayssières et al. 2000).

However, tree models have a tendency to overfit data, and thus trees must be evaluated in order to find the overall best model. The criteria for evaluating variable selection and the model fit is given by cross-validation (CV). This technique involves splitting the data into k-fold partitions (usually 10-fold). Models are fit using 90% of the data ('training data') and tested for goodness of fit on the 10% of the data that was left out during model building ('testing data'). In this way, models trained on 'in-fold' observations are evaluated in their ability to predict the response for 'out-fold' observations. This process is then repeated on all partitions of the data, such that all data is used in both training and testing subsets.

The cross-validation criteria is important for determining how complex a tree should be (e.g., how many branches should be included). Large trees generally have less predictive accuracy due to increased variance and model complexity bias. Thus, the model with the fewest nodes and the lowest predictability error (minimum CV error) is selected as the overall best fit. The convention is to run many trees and select the simplest model (most parsimonious) with the CV error within one standard-error of the lowest attained CV error in all runs. The final tree model is based on all of the data (not just the training data partition).

Trees were generated for each species with the MVPART package (version 1.6-2) in R (De'ath 2013; version 3.1.2; R Core Team 2014). Species presence and non-detection were used as class response variables to biologically relevant environmental variables, such as: vegetation community ('Veg'), pond area ('Pondm2'), elevation ('Elev'), site, location (drawdown zone or upland), study year, and season. We ran 100 trees and used the standard method of model evaluation (10-fold cross-validation; CV error within 1 SE) for each species. Variables that did not improve the variance explained were removed one-at-a-time, such that the final model achieved minimum cross-validation and relative error. Only branches that improve the explained variance in the overall model were included in figures. Animal Movements

We examined the relationship between the daily movements of radio transmitter-tagged toads and snakes by month and inundation period at each site. 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 toad and 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. A Two-Factor Analysis of Variance (ANOVA) was used to test for movement differences among sites occurring within the drawdown zone (DDZ) and upland (UPL) areas of Arrow Lakes Reservoir and across months in 2013. Daily distance data were transformed with a power transformation, where $\lambda = 1$ (Box and Cox 1964) to meet the assumptions of ANOVA (Fox and Weisberg 2011).

5 RESULTS

5.1 Kinbasket Reservoir

5.1.1 Environmental Data

Weather conditions are known to affect the surface activity of amphibians and reptiles. Thus, temperature and precipitation data were obtained from Environment Canada's Mica Dam weather station (52°03'11.000" N 118°35'07.000" W; 579.10 m ASL) to evaluate the influence of weather conditions on species detectability and measures of relative abundance. Daily temperature varied by month from April to September ($F = 118.9$; $p < 0.001$) and between years ($F = 3.3$; $p = 0.01$), which is to be expected. Total rainfall did not vary annually ($F = 1.5$; $p = 0.17$), but did on a monthly basis, which is expected ($F = 2.2$; $p = 0.05$; 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). Environmental conditions during each field session are provided in Table 5-1.

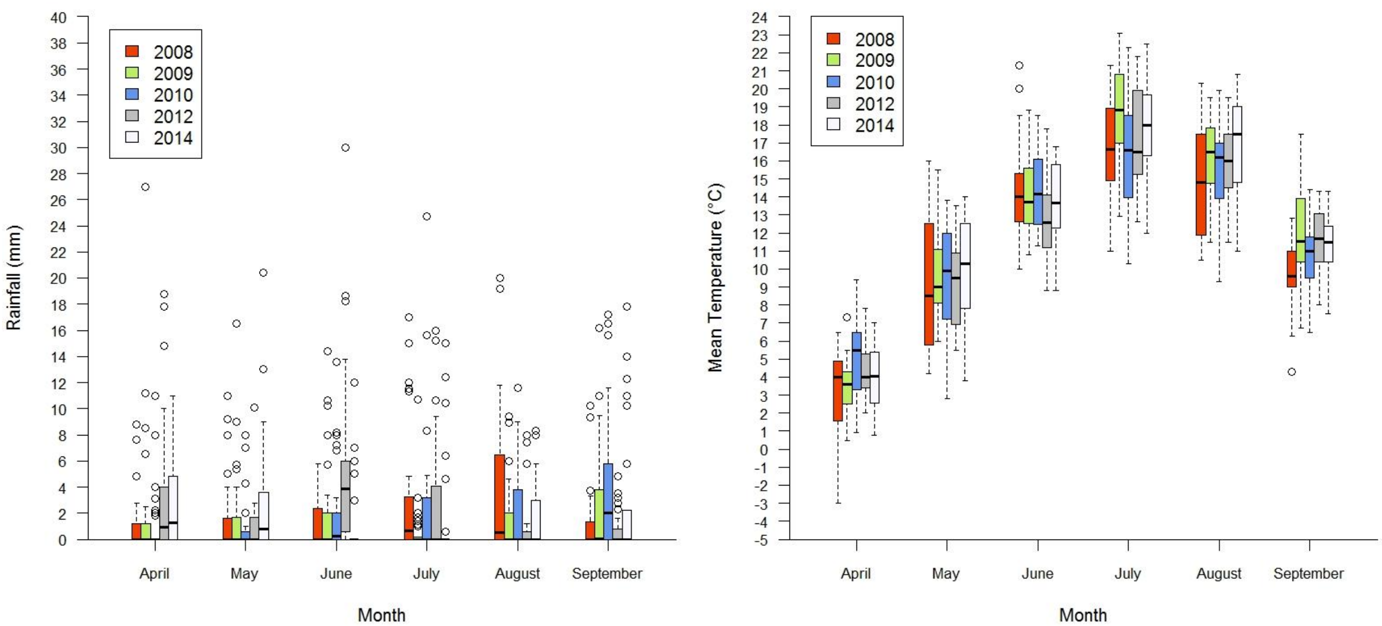

Figure 5-1: Daily precipitation (mm, left) and mean temperature (°C, right) for April through September, 2008-2010, 2012, and 2014 as measured at Mica Dam. Data source: Environment Canada (http://climate.weather.gc.ca/index_e.html)

Table 5-1: Air temperature and precipitation conditions[1] for Kinbasket Reservoir during the 2014 field sessions. Precipitation values are totals by session and by month

		Temperature (°C)			Precipitation (mm)	
Field Session	**Dates**	**Min**	**Max**	**Average**	**Session**	**Monthly**
1	May 1 - 10	-2.5	17.0	6.73	13.7	79.8
2	May 26 - 31	3.0	22.5	11.9	14.1	79.8
3	Jun 6 - 9	1.0	21.5	11.8	12.0	42.0
4	Jun 11 - 20	3.0	25.5	14.2	16.0	42.0
5	Jun 25 - 30	6.5	26.0	15.3	11.0	42.0
6	Jul 7 - 15	7.0	32.0	19.7	0.0	49.4
7	Jul 18 - 25	8.0	26.0	15.3	44.2	49.4
8	Aug 14 - 25	6.0	26.5	16.6	7.4	53.3

[1]Data obtained from BC Wildfire Management Branch

5.1.2 Water Physicochemical Data

Point data [pH, Conductivity (µS/cm), and Temperature (°C)] are summarized for ponds sampled in 2010, 2012 and 2014 (Table 5-2). 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 neutral pH, low conductivity, and warm spring and summer temperatures. These conditions are not likely to influence amphibian populations in the drawdown zone of Kinbasket Reservoir.

Table 5-2: Summary of water physicochemistry data collected at ponds with and without amphibians in the drawdown zone of Kinbasket Reservoir, 2010, 2012, and 2014

WITHOUT		pH				Conductivity (µS/cm)				Temperature (°C)			
Year	*N*	Min	Max	$\bar{x}$	SD	Min	Max	$\bar{x}$	SD	Min	Max	$\bar{x}$	SD
2010	180	6.3	9.19	7.22	0.55	1	804	82.4	75.8	8.2	31.2	16.38	4.63
2012	1	7.45	7.45	7.45	--	88	88	88.0	--	20.9	20.9	20.90	--
2014	202	6.2	10.46	7.36	0.74	26	406.8	112.8	86.6	4.3	29.2	15.44	5.68
WITH													
Year	*N*	Min	Max	$\bar{x}$	SD	Min	Max	$\bar{x}$	SD	Min	Max	$\bar{x}$	SD
2010	274	6.2	9.96	7.39	0.68	1	424	82.7	65.7	7.6	29.3	17.35	4.93
2012	27	5.94	9.45	7.87	0.73	23.1	367	132.1	80.5	11.8	33.1	18.15	4.12
2014	137	6.46	10.9	7.70	0.87	22	411	137.4	89.1	6.7	32.8	17.62	5.63

Data from 2013 and 2014 show the relationships between reservoir inundation and water temperature and dissolved oxygen levels (Figure 5-2). In both 2013 and 2014, water temperature decreased following inundation at the Bush Arm Causeway. In 2013 temperature dropped by 12.8°C over a three week period (21.1 to 8.3°C) and in 2014 water temperature declined by a similar amount following inundation, but over a much longer period of time, taking ~ 80 days for the water temperatures to decrease to ~ 8.3°C. Dissolved oxygen levels were declining prior to reservoir inundation in both 2013 and 2014, which could be a function of increasing water temperature and expected daily and seasonal fluctuations. Following inundation in 2013, the pond at the Bush Arm Causeway became hypoxic (i.e., DO < 2.0 mg/L) following inundation. In 2014 DO decreased from approximately 12 mg/L to near 4 mg/L following inundation. In both 2013 and 2014 DO concentrations showed expected daily and seasonal fluctuation with additional influence of water temperature. The influence of reservoir inundation on DO and water temperature appeared to be more pronounced in 2013, but a similar pattern was observed in both years.

These conditions were measured at the depth of the DO meter, which was installed 30 cm below the surface of the water prior to inundation from 12 mg/L to ~ 4 mg/L before rebounding to pre-inundation levels, a pattern observed in both years.

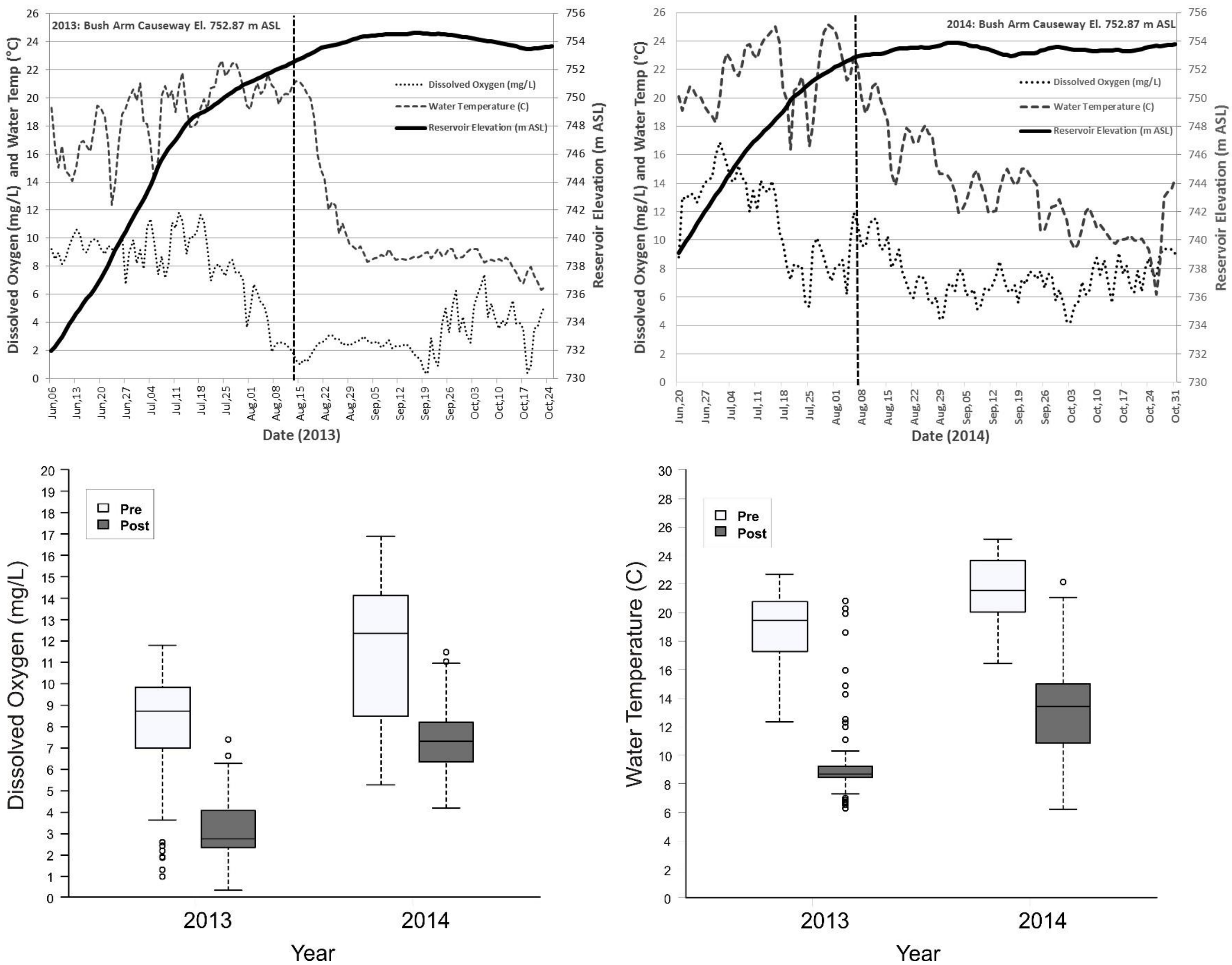

Figure 5-2: Daily variation in dissolved oxygen (DO; mg/L) and water temperature (°C) relative to reservoir elevation (m ASL) at the Bush Arm Causeway 2013 and 2014. The dashed vertical line in the top panels represents the date of inundation. The dashed horizontal line in the top panels represents the point at which the water column becomes hypoxic. Data loggers were set at a depth of 30 cm below the surface when first installed. Box plots depict differences in DO (left) and water temperature (right) before and after inundation

Based on the data presented above (Table 5-2 and Figure 5-2), 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 have 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 differences in species detectability is therefore unlikely to have been a result of environmental or water physicochemical conditions.

5.1.3 Species Occurrence and Distribution

5.1.3.1 Site Occupancy

Three amphibian species and two reptile species have been observed in the DDZ of Kinbasket Reservoir since 2008 (Table 5-3). Long-toed Salamander (AMMA) have been detected only in the Valemount Peatland and Bush Arm Causeway while both Western Toad (ANBO) and Columbia Spotted Frog (RALU) have been documented in most survey locations. The exceptions are Beavermouth and the Bush Arm Forest Service Road (FSR), neither of which contain wetland or pond habitats. Columbia Spotted Frog has not been documented from Canoe East FSR, but this is expected given the aquatic nature of this species. Of the two garter snakes species documented, Common Garter Snake (THSI) is more widely distributed than the Western Terrestrial Garter Snake (THEL) with the former documented each year in most survey locations. Mapped occurrences of all species observed in 2014 are included in Appendix 10-1.

Of the locations surveyed, the Valemount Peatland, Bush Arm Causeway, Bush Arm km 79, and Ptarmigan Creek support the highest number of species. The number of sites occupied in a given year ranges from six to nine, with 2010 associated with the most occupied sites.

Table 5-3: Site occupancy (shaded cells) of amphibians and reptiles observed in the drawdown zone of Kinbasket Reservoir between 2008 and 2014. AMMA = Long-toed Salamander, ANBO = Western Toad, RALU = Columbia Spotted Frog, THEL = Western Terrestrial Garter Snake, THSI = Common Garter Snake. Blanks indicate species not detected in a given year and survey location

	AMMA					ANBO					RALU					THEL					THSI					Species				
Survey Location	08	09	10	12	14	08	09	10	12	14	08	09	10	12	14	08	09	10	12	14	08	09	10	12	14	08	09	10	12	14
KIN Beavermouth																										1		1		
KIN Bush Arm Bear Island																										2	1	3	3	3
KIN Bush Arm Causeway																										3	2	5	4	2
KIN Bush Arm km 79																										3	4	4	2	3
KIN Bush Arm km 79 perched wetland																												2	1	2
KIN Encampment Creek																													1	
KIN Ptarmigan Creek																										4	3	3	2	3
KIN Sprague Bay																											1	3	2	
KIN Succour Creek																												3	1	
KIN Valemount Peatland																										4	4	4	4	4
Location Per Year	1	1	2	2	1	4	5	7	7	6	5	5	8	7	6	2	1	4			5	3	7	4	4	6	6	9	9	6

5.1.3.2 Detection Rates

Between April and August, we spent 285 hours over 42 days surveying monitoring sites within the DDZ of Kinbasket Reservoir (Table 5-4), during which we observed more than 163,000 individuals across multiple life stages.

Table 5-4: Total survey time (hours) and species detections by survey location for Kinbasket Reservoir in 2014. Blanks indicate the species was not detected. AMMA = Long-toed Salamander, ANBO = Western Toad, RALU = Columbia Spotted Frog, THSI = Common Garter Snake. CPUE (catch per unit effort) = the number of observations per site and per species divided by the survey time

Survey Location	Time	AMMA	ANBO	RALU	THSI	Total	CPUE
Bush Arm Bear Island	31.5		38	12	4	**54**	**1.71**
Bush Arm Causeway	17.5		79	4		**83**	**4.74**
Bush Arm km 79	19.5		15	4	1	**20**	**1.03**
Bush Arm km 79 Perched	6.5		11	21		**32**	**4.92**
Ptarmigan Creek	10.5		18	2	8	**28**	**2.67**
Sprague Bay	2						**0.00**
Valemount Peatland	192	2	57	80	12	**151**	**0.79**
Totals (Time = hours; #obs)	**285**	**2**	**218**	**123**	**25**	**368**	**1.29**
CPUE (#obs/hr)		**0.01**	**0.76**	**0.43**	**0.09**	**1.29**	

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 five areas in Kinbasket Reservoir (Figure 5-3), of which Bush Arm Causeway and Ptarmigan Creek had the most consistently high rates of detections.

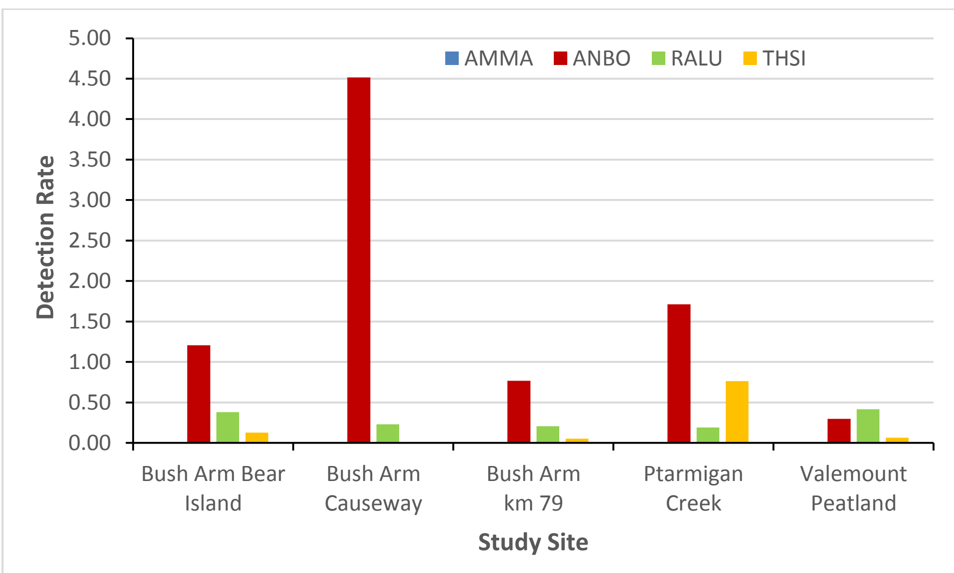

Figure 5-3: Detection rate for amphibian and reptile species in Kinbasket Reservoir in 2014. Detection rate = the number of times a species was detected (all life stages pooled)/the total time spent searching at a study site. AMMA = Long-toed Salamander, ANBO = Western Toad, RALU = Columbia Spotted Frog, THSI = Common Garter Snake

5.1.3.3 Elevation

Amphibians and reptiles of all species and life stages were found across a wide range of elevations in Kinbasket Reservoir in 2014 (Figure 5-4). Most observations (all life stages combined) were between 749 and 755 m ASL, a trend that was also observed in 2010-2012. Western Toad (ANBO) spanned the widest range of elevations, while observations of Long-toed Salamander (AMMA) spanned the narrowest range; however, detectability issues between the species or ontogenetic variation likely affect these relationships. The relationship between amphibian (and reptile) distribution in the drawdown zone is likely a function of habitat availability.

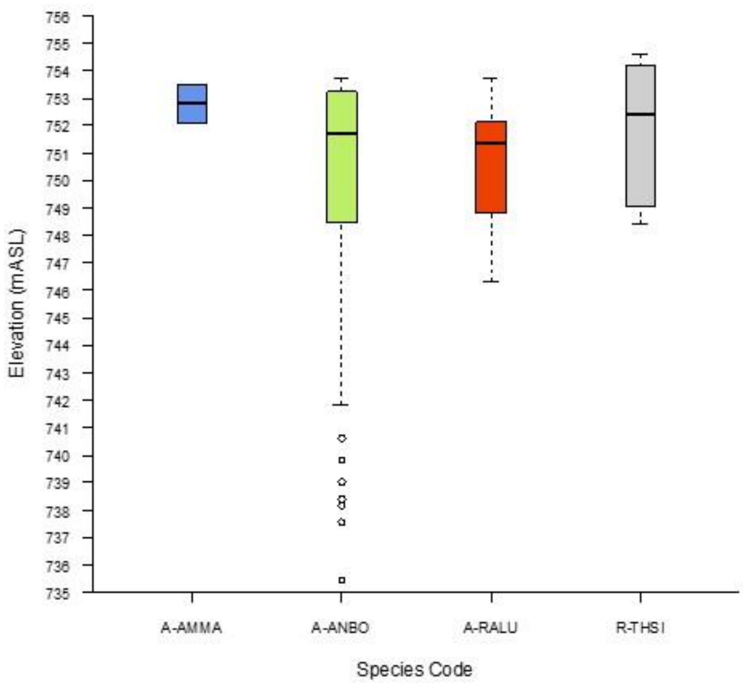

Figure 5-4: Elevation distribution of amphibians and reptiles (number of observations, all life stages combined) documented in the drawdown zone of Kinbasket Reservoir in 2014. A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-RALU = Columbia Spotted Frog, R-THSI = Common Garter Snake

5.1.3.4 Pond and Wetland Habitat in the Drawdown Zone

One hundred and eleven ponds have been delineated across the years in and adjacent to the drawdown zone of Kinbasket Reservoir. Vegetation communities in which amphibians were found were distributed between ~738 m and 754 m ASL (Figure 5-5A). Pond size ranged from 0.003 ha to 0.945 ha. Most ponds mapped were < 0.15 ha (Figure 5-5B), and overall, there was no significant relationship between pond size (area) and elevation ($F_{1,101}$ = 0.17; p = 0.89; Figure 5-5C, D). Not surprisingly, the elevation distribution of amphibian and reptile occurrences aligned well with the elevation distribution of ponds in the drawdown zone (Figure 5-5C, D).

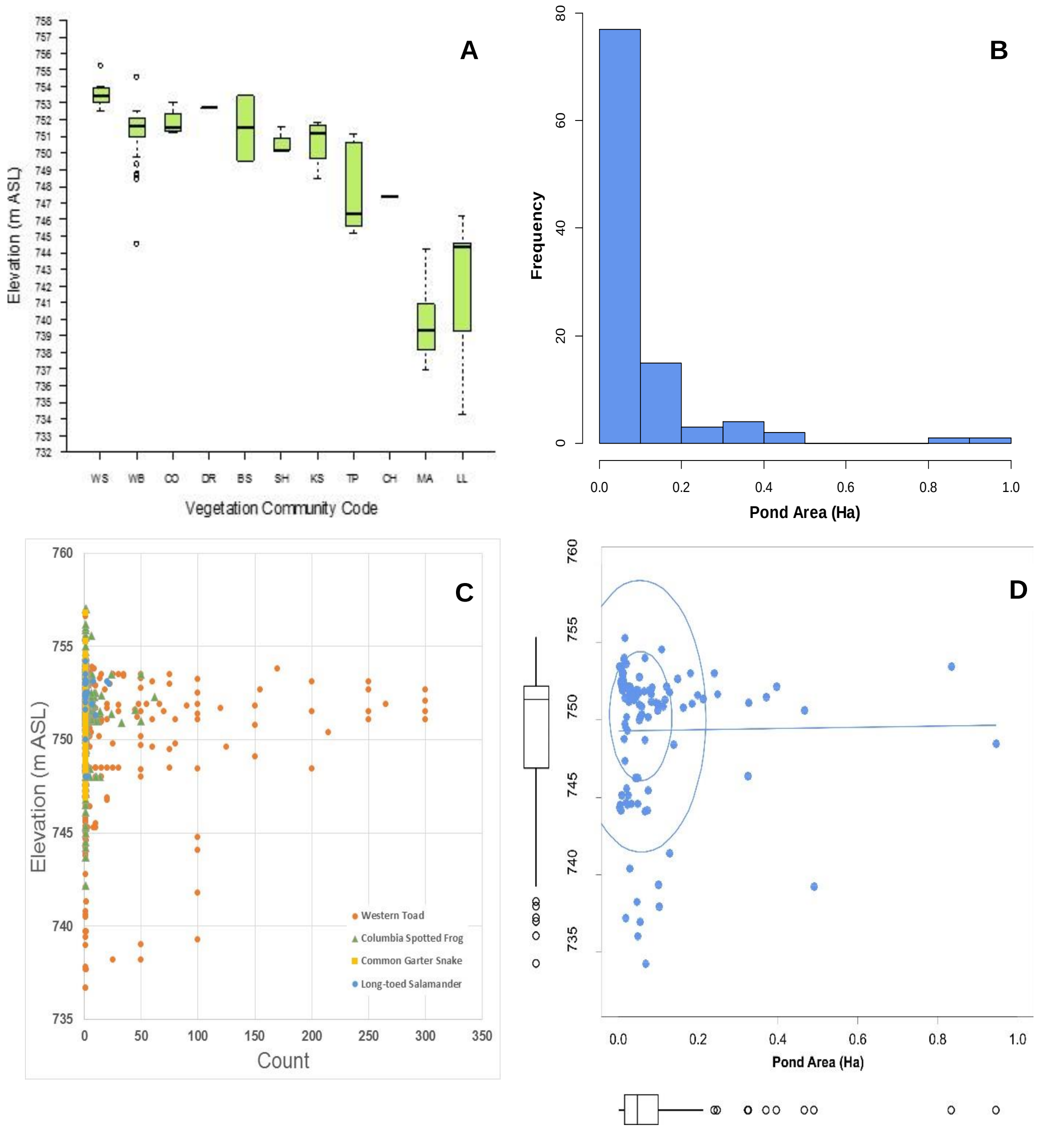

Figure 5-5: Elevation distribution of vegetation communities in which amphibian habitat occurs (A), size-frequency distribution of ponds within those habitats (B), elevation distribution of Long-toed Salamander, Western Toad, Columbia Spotted Frog, and Common Garter Snake adults and egg masses (amphibians only) (C), and elevation distribution of ponds (by area [D]) in the drawdown zone of Kinbasket Reservoir. Ellipses in D represent the normal probability contour over a scatter of the data. Amphibian and reptile data from 2008 to 2014 pooled. See Figure 5-6 for vegetation community codes

5.1.3.1 Vegetation Community Associations

Habitat use by Western Toad, Columbia Spotted Frog and Common Garter Snake was compared to the vegetation community mapping that was completed for CLBMON-10. Associations with vegetation community types varied substantially by year (Figure 5-6), suggesting that these species are fairly general in their selection and use of habitats. Overall, Western Toads detections were most often associated with drier clover-oxeye daisy (CO) and swamp horsetail (SH) habitats, whereas Columbia Spotted Frogs were found most often in the wetter wool-grass–Pennsylvania buttercup (WB) habitats. Neither amphibian species was detected within the shrub-willow (SW[2]) community type. Snakes were found across a variety of habitats, but most commonly in driftwood (DR) or Kellogg's sedge (KS) for 2014. The general use of habitats in the drawdown zone by both amphibian species and by garter snakes 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 and determinants of habitat quality other than vegetation community alone.

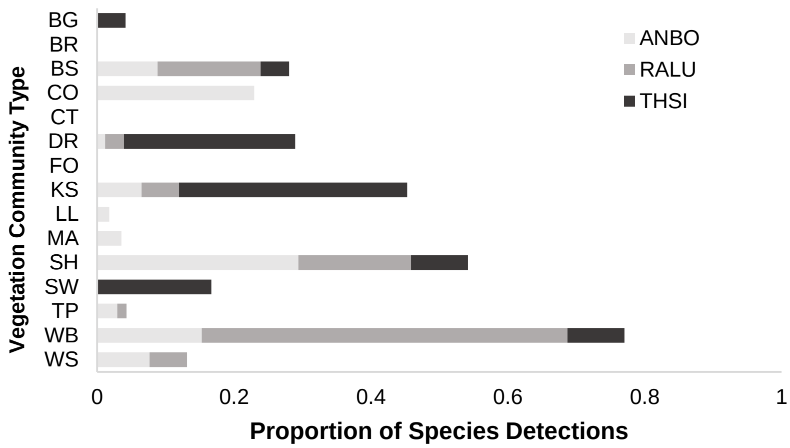

Figure 5-6: Distribution of Western Toads, Columbia Spotted Frogs, and Common Garter Snakes by vegetation community class in the drawdown zone of Kinbasket Reservoir (for adults and egg masses only) in 2014. Presence of adults and egg masses in each vegetation class was standardized by detection totals for each year to account for differences in sampling effort between years. ANBO = Western Toad, RALU = Columbia Spotted Frog, THSI = Common Garter Snake; BG = non-vegetated boulder slopes, BR = bluejoint reedgrass, BS = buckbean-slender sedge, 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 (Western Toad: CO and SH; Columbia Spotted Frog: WB and KS) were situated between ~744 and 753 m ASL (Figure 5-5A and Figure 5-6). A large proportion of ponds mapped in the drawdown zone (48.4 per cent; 5.5 ha) occur in these four vegetation communities (CO: 4.9 per cent; 0.56 ha; SH: 2.9 per cent; 1.2 ha: WB: 29.9 per cent; 3.4 ha; KS: 10.7 per cent; 1.2 ha), so the presence of animals in these communities is not surprising. Few observations occurred in the toadrush-pond water starwort (TP) community despite >10 per cent of all ponds occurring there. The lack of observations is likely because the TP community typically occurs at lower elevations than the other four communities (Figure 5-5A).

In general, amphibians tend to use breeding ponds that are small, shallow, and warm; the size of the ponds used is partially constrained by the availability of ponds

[2] The SW community has not been delineated in its entirety for Kinbasket Reservoir (i.e., it is not one of the 19 communities characterized by Hawkes et al. 2013). This community is situated between 754 m and 756 m ASL.

at each location in the drawdown zone. These ponds typically have high levels of dissolved oxygen and ponds used by Columbia Spotted Frogs tend to have higher per cent cover of aquatic macrophytes. Columbia Spotted Frog tends to be found at high elevations, in wet habitats associated with the wool-grass–Pennsylvania buttercup vegetation community (WB). In contrast, Western Toad tends to use a wide range of elevations and is most often present in drier habitats in association with the clover-oxeye daisy vegetation community (CO). Ponds used by Western Toads for breeding were typically devoid of vegetation.

Species distributions depended to some degree on environmental variables such as vegetation community, site, elevation, pond area, and the year of study, whereas reach, location (DDZ or upland), and season were not found as important variables for any species occurrences. For Western Toads, vegetation community, pond area, site, and elevation were important determinants of occurrences in Kinbasket Reservoir (Figure 5-7; 44.9 per cent of the variance explained; relative error = 0.551, CV error = 0.795). Vegetation was most important in determining toad distribution (20.0% of variance explained), since presences were much greater in BS, CO, CT, KS, LL, MA, SH, and TP vegetation community classes. Within these vegetation types, more toads were present at Bush Arm Causeway, Bear Island, and Encampment Creek sites. At other sites, elevation further helped explain toad occurrence (4.0% of variance explained), with greater presence found at elevations lower than 746.5 m ASL. Consistent with the results of Hawkes and Wood (2014), toads that were present in other vegetation communities of Kinbasket Reservoir were associated with large ponds (≥ 1245 m^2; 10.5% of the variance was explained by pond area).

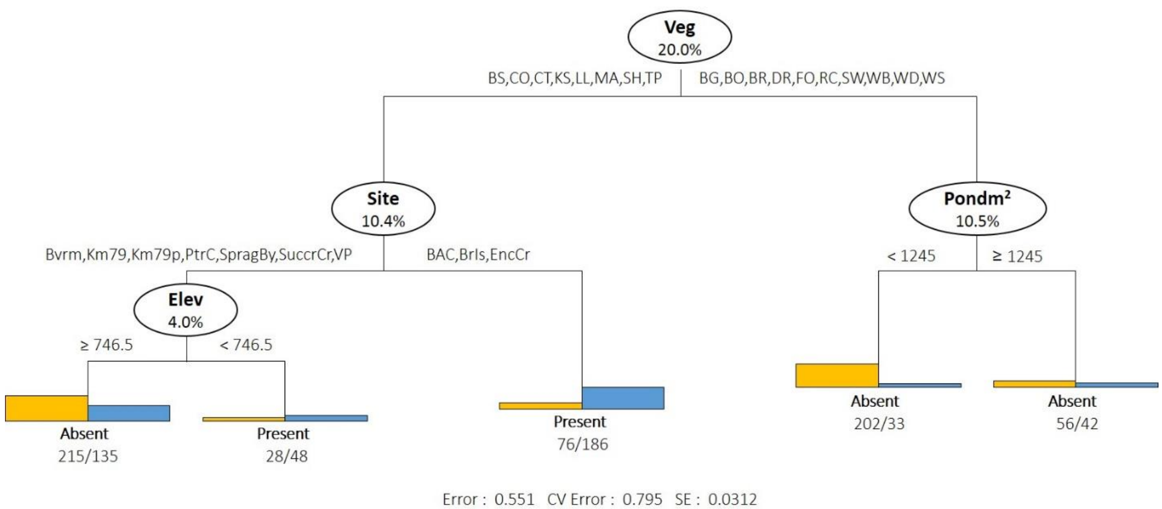

Figure 5-7: Classification tree describing the habitats occupied by Western Toads in the drawdown zone of Kinbasket Reservoir. Major environmental determinants of toad adult and egg mass presence are given in hierarchical order at each node, with the per cent of variance explained. The average predicted response (absent or present) is written at each branch terminus (bold). Bars and number of observed responses are also provided at terminal branches for each combination of variables (where absences are shown by yellow bars and presences by blue bars). BAC = Bush Arm Causeway, Bris = Bear Island, EncCr = Encampment Creek, PtrC = Ptarmigan Creek, SuccrCr = Succor Creek, VP = Valemount Peatland. See Figure 5-6 for vegetation community codes

For Columbia Spotted Frogs, site, year, elevation and vegetation community were important determinants of adult and egg mass occurrences in the drawdown zone of Kinbasket Reservoir (43.6 per cent of the variance explained; relative error = 0.564, CV error= 0.658; Figure 5-8). Site explained 16.3 per cent of the variation in frog presence, with most frog occurrences found at km 79 (including perched wetland), Sprague Bay (including perched wetland), and Valemount Peatland. Fewer frogs were observed in 2014, resulting in year as the second-most important variable explaining frog occurrence (15.6% of variance explained). Within peak years for frog observations, elevation was an important determinant of distribution (7.2% of variance explained), with more frogs present at elevations greater or equal to 746.7 m ASL. At these higher elevations, more frogs were associated with BO, KS, TP, WB, and WS vegetation community classes (4.5% of variance explained). The interactions between environmental variables in these regression trees illustrate the complex nature of habitat associations for both species and supports the notion that species are associated with a wide range of vegetation communities.

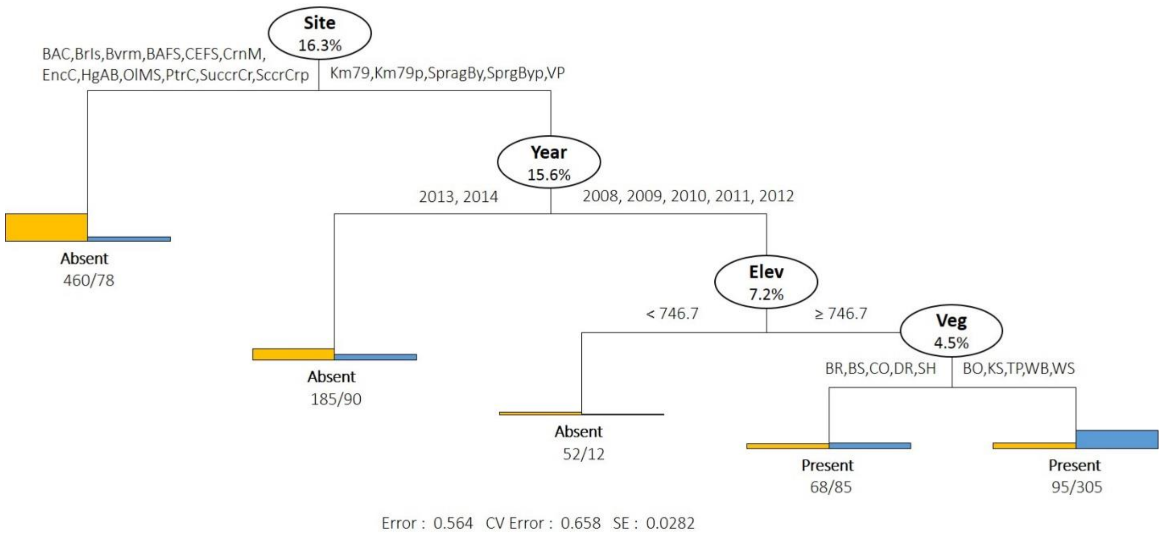

Figure 5-8: **Classification tree describing the habitats occupied by Columbia Spotted Frogs in the drawdown zone of Kinbasket Reservoir**. Major environmental determinants of toad adult and egg mass presence are given in hierarchical order at each node, with the per cent of variance explained. The average predicted response (absent or present) is written at each branch terminus (bold). Bars and number of observed responses are also provided at terminal branches for each combination of variables (where absences are shown by yellow bars and presences by blue bars). See Figure 5-6 for vegetation community codes

Similar to Columbia Spotted Frogs, Common Garter Snake occurrence was most predicted by site and year (Figure 5-9; 28.6% of the variance explained; relative error = 0.714; CV error = 0.747). Snakes occurred most frequently at Ptarmigan Creek and Cranberry Marsh sites (21.2% of variance explained). Occurrences were also structured according to year, with more snakes present in 2008, 2010, and 2011 than any other study years.

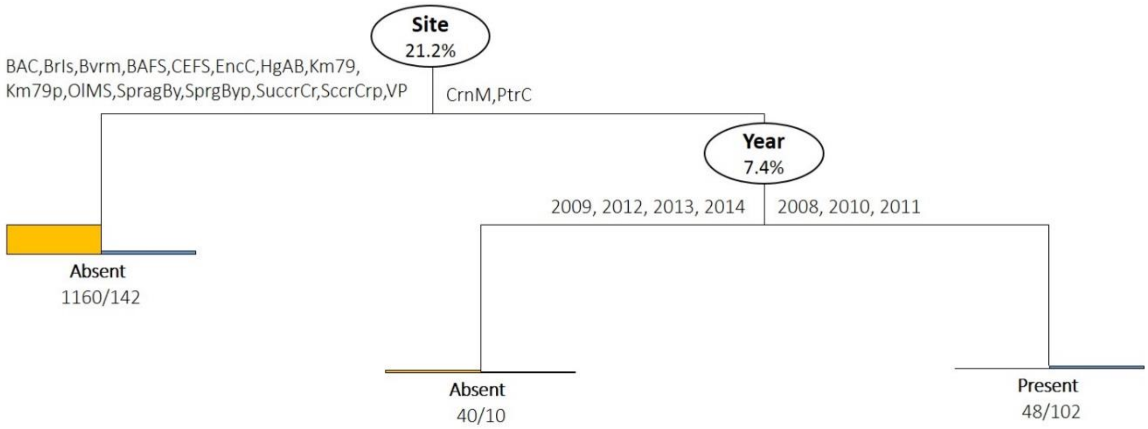

Figure 5-9: Classification tree describing the habitats occupied by Common Garter Snakes in the drawdown zone of Kinbasket Reservoir. Major environmental determinants of toad adult and egg mass presence are given in hierarchical order at each node, with the per cent of variance explained. The average predicted response (absent or present) is written at each branch terminus (bold). Bars and number of observed responses are also provided at terminal branches for each combination of variables (where absences are shown by yellow bars and presences by blue bars). See Figure 5-6 for vegetation community codes

5.1.3.2 Radiotelemetry

In 2014, seven Western Toads and six Common Garter Snakes were captured and fitted with radio transmitters in the Valemount Peatland. Toads were a mix of male (n=4) and female (n=3) and ranged in size from 81.3 mm to 91.8 mm SUL, with all females being larger than males. Snakes ranged in size from 531 mm to 695 mm SVL, with females generally being larger than males in both snout-vent length and mass (5 females, 1 male).

Animals were tagged and tracked between May 8th and August 7th. Some animals dropped their transmitter within the first few days, but in general, transmitters were retained and detected up to a confirmed duration of 29 days on one toad and 23 days on one snake.

Total distances travelled by toads ranged from 18.0 m to 846.8 m with an average of 239.8 m. Female toads had higher average daily movements than males (Figure 5-10). However, actual daily movements are difficult to ascertain due to the varying lengths of time between locating animals. Two of the seven toads captured in the drawdown zone moved to upland habitats during the survey period with one male moving > 840 m upslope to an underground burrow (Figure 5-12). Snake movements ranged from 5.0 m to 87.3 m (Average = 43.8 m), all locations were recorded at the higher elevations of the drawdown zone (> 753 m ASL).

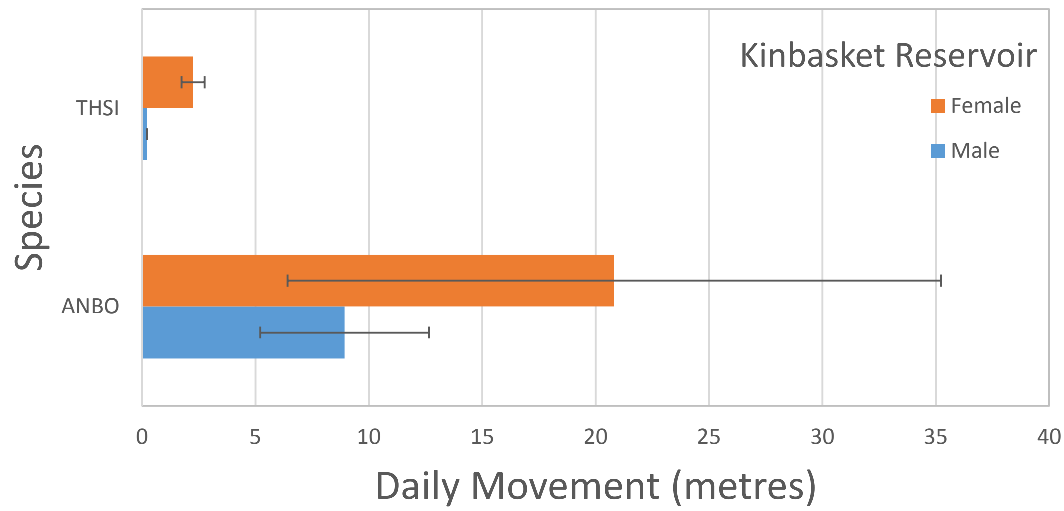

Figure 5-10: Average daily movements (± SE) of Western Toads (ANBO) and Common Garter Snakes (THSI) in the Valemount Peatland, Kinbasket Reservoir, 2014. Sample size for both species was small: ANBO: Males N = 5; Female N = 3; THSI: Males = 1; F = 4

Three of the toads captured in the drawdown zone moved into or towards upland habitats during the survey period with one toad occupying habitat on the lower slopes of Canoe Mountain following the breeding season (Figure 5-11). Between May 8 and June 7, 2014, a male Western Toad (M08) moved ~ 850 m from the drawdown zone to upland summer habitat (see Figure 5-12). All locations associated with snakes were in the drawdown zone at or near the 754 m ASL contour line.

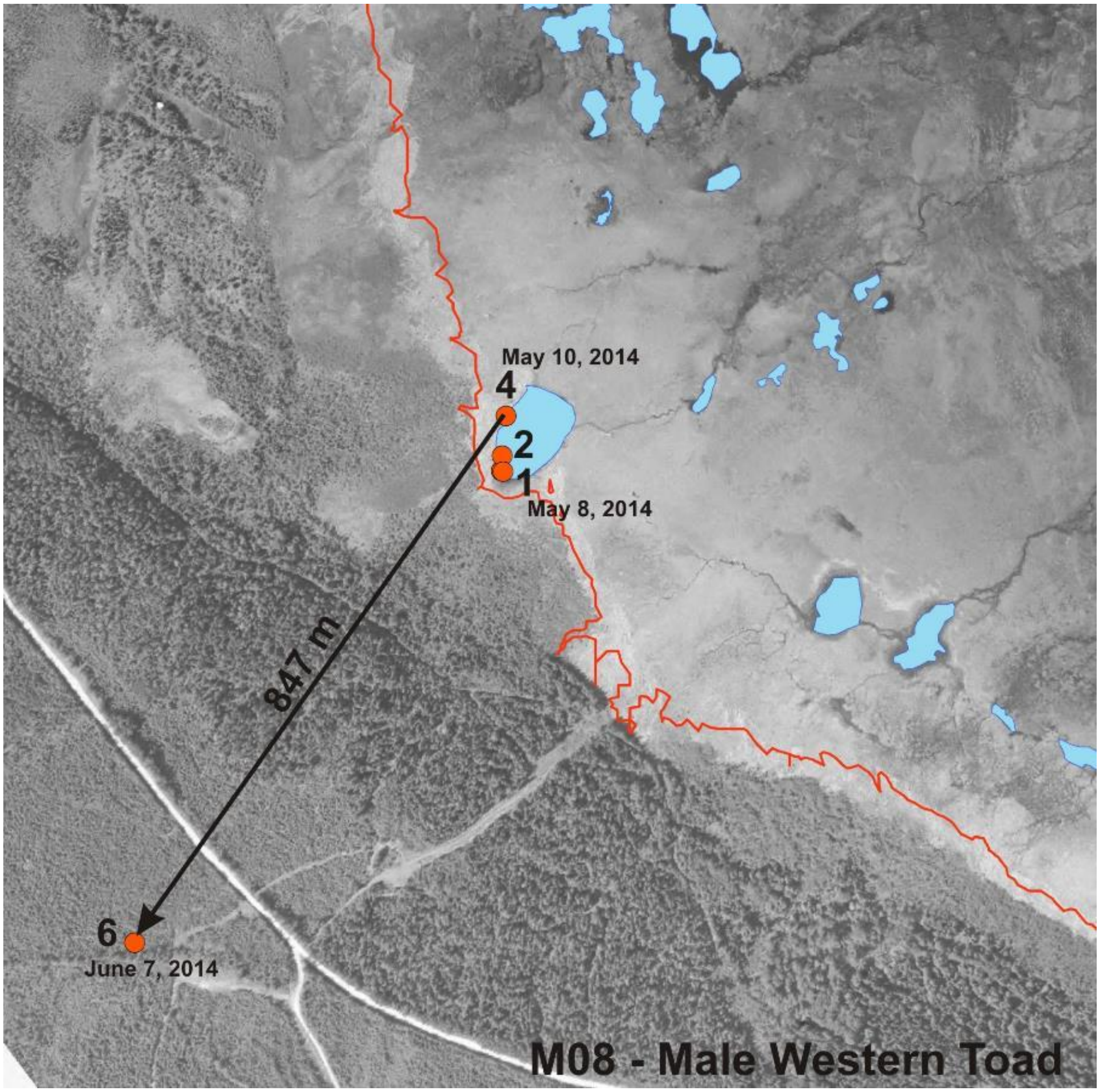

Figure 5-11: Examples of successive movements by one male Western Toad in Canoe Reach, Valemount Peatland 2014. Numbers refer to successive locations with '1' being the capture location. M08 was not detected on location attempts 3 and 5 Dates indicate location dates. Vectors indicate presumed (straight-line) direction of movement. The red line is the 754 m ASL contour. Locations above this contour are outside of the drawdown zone

Figure 5-12: Summer habitat selected by a male Western Toad ~ 850 m upslope from the drawdown zone on the west side of Kinbasket Reservoir in Canoe Reach. Photos: Charlene Wood

Due to small sample sizes, data on toads for Kinbasket and Arrow Lakes Reservoirs were combined to examine size and movement relationships. For both males and females, larger toads appear to move greater distances (Figure 5-13); however, more data for each reservoir are required to substantiate this relationship.

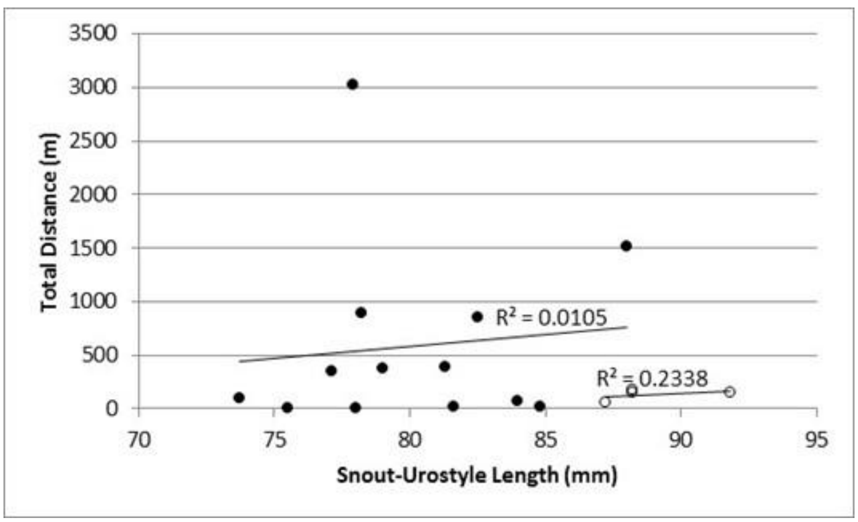

Figure 5-13: Relationship between size and total distance travelled by male and female Western Toads in the Kinbasket and Arrow Lakes Reservoirs, 2014. Males denoted by solid circles; females by open circles

5.1.4 Hypotheses Testing

5.1.4.1 H1: Annual and seasonal variation in water levels in Kinbasket Reservoir (due to reservoir operations), the implementation of soft operational constraints, and the effects of Units 5 and 6 in Mica Dam on Kinbasket Reservoir (CLBMON-58 only), do not directly or indirectly impact reptile and amphibian populations.

Soft 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.

Effects of Mica 5/6

The effects of Mica 5/6 are being investigated under CLBMON-58. See Hawkes and Wood (2014) for the most recent results.

5.1.4.2 H1A: Reservoir operations do not result in a decreased abundance of amphibians or reptiles in the drawdown zone.

The use of the drawdown zone by amphibians and reptiles is influenced by reservoir elevation and time of year. Detection rates (as a proxy for abundance) are negatively correlated with increasing reservoir elevation for both Western Toad (-0.34) and Columbia Spotted Frog (-0.19) while detection rates for Common Garter Snakes appear to be positively correlated with reservoir elevations (0.39; Figure 5-14). In all cases, detection rates are also correlated with season with detection rates of Western Toad peaking in early to late spring and declining with time (correlation -0.37), detection rates for Columbia Spotted Frog stay relatively constant throughout the year, but tending towards a decline over time (-0.23). Common Garter Snakes are more frequently observed late spring and summer (0.40; Figure 5-15). These patterns have been observed during each year of study and although seasonality does influence detectability of each species, the use of the drawdown zone is affected by inundation on an annual basis.

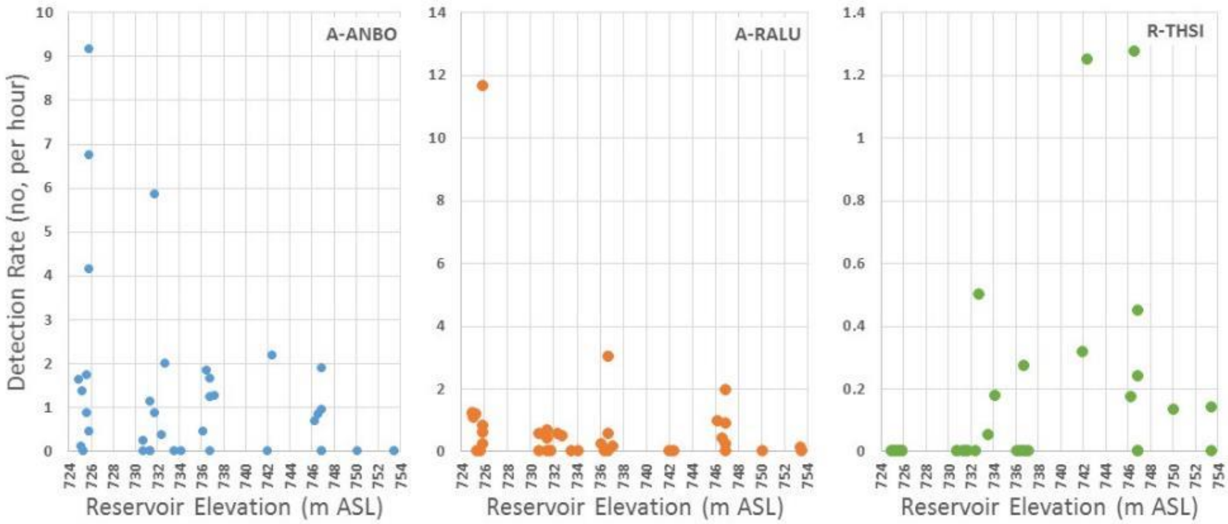

Figure 5-14: Relationship between reservoir elevations and detection rates for Western Toad (A-ANBO), Columbia Spotted Frog (A-RALU), and Common Garter Snake (R-THSI) in Kinbasket Reservoir, 2014. Note different scales on vertical axes

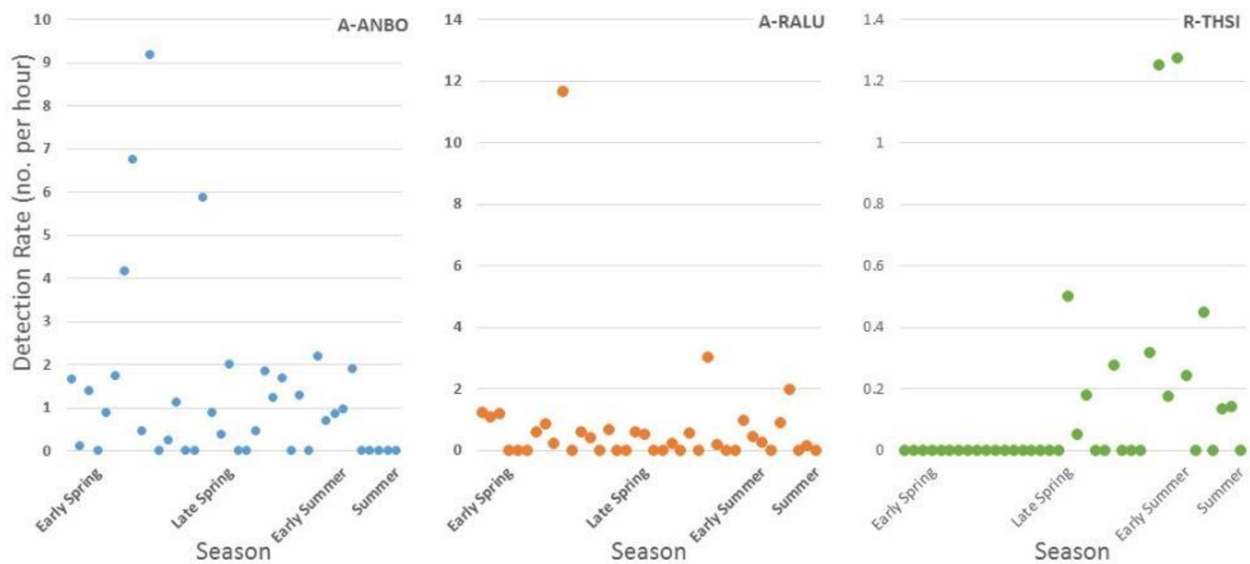

Figure 5-15: Relationship between season and detection rates for Western Toad (A-ANBO), Columbia Spotted Frog (A-RALU), and Common Garter Snake (R-THSI) in Kinbasket Reservoir, 2014. Note different scales on vertical axes (early spring, April 1 to May 18; late spring, May 19 to June 21; early summer, June 22 to July 21; and summer, June 22 to August 19)

5.1.4.3 H1B: 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 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 from 2010 to 2014. Any 'Yes' indicates a direct observation of the life history activity or stage, whereas the rest are inferences

	Life History Activity			
Species	**Breeding**	**Growth**	**Foraging**	**Overwintering**
Columbia Spotted Frog (RALU)	Yes	Yes	Yes	Unknown
Western Toad (ANBO)	Yes	Yes	Yes	Unlikely
Long-toed Salamander (AMMA)	Yes	Yes	Likely	Unlikely
Western Terrestrial Garter Snake (THEL)	Unknown	Yes	Yes	Unlikely
Common Garter Snake (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). There are times when toad egg strings are not fertilized (Figure 5-16), which could lead to reduced fecundity, but not mortality. We have not observed depredation or unfertilized egg masses of Columbia Spotted Frog.

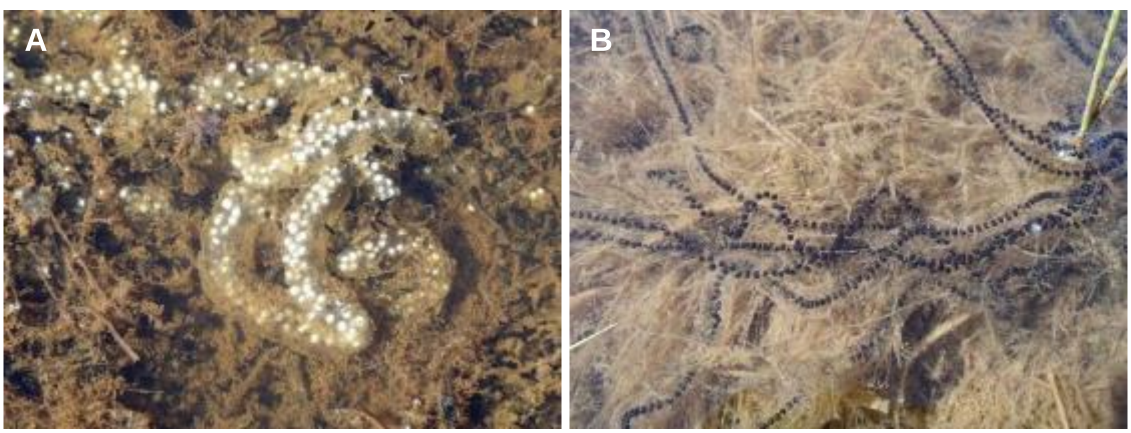

Figure 5-16: Photo of unfertilized Western Toad eggs (A; white orbs) surrounded by recently hatched Western Toad tadpoles (from another egg string) and fertilized Western Toad eggs (B). Photos: Virgil C. Hawkes

Egg string and egg mass stranding have been observed at various locations in the drawdown zone. 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. 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.

Despite not being able to directly measure mortality, we can infer the health of animal populations thorough an assessment of biomass, which can be affected by changes in the environment. For both male and female Western Toads there was a significant effect of length and of year (mean snout-urostyle length and mass varied among years; p <0.0001 for both male and females). For both sexes, the interaction term was significant, meaning that the slope of mass vs. snout-urostyle length varied among years; however, the three lines (one for each year) are approximately parallel (Figure 5-17). For any given snout-urostyle length, toads were heaviest in 2014 and lightest in 2012 (Table 5-6). Given that slopes do not vary greatly among years, it appears that the health of the population has not changed over the three years. Small sample sizes of Columbia Spotted Frogs and garter snakes preclude a similar assessment.

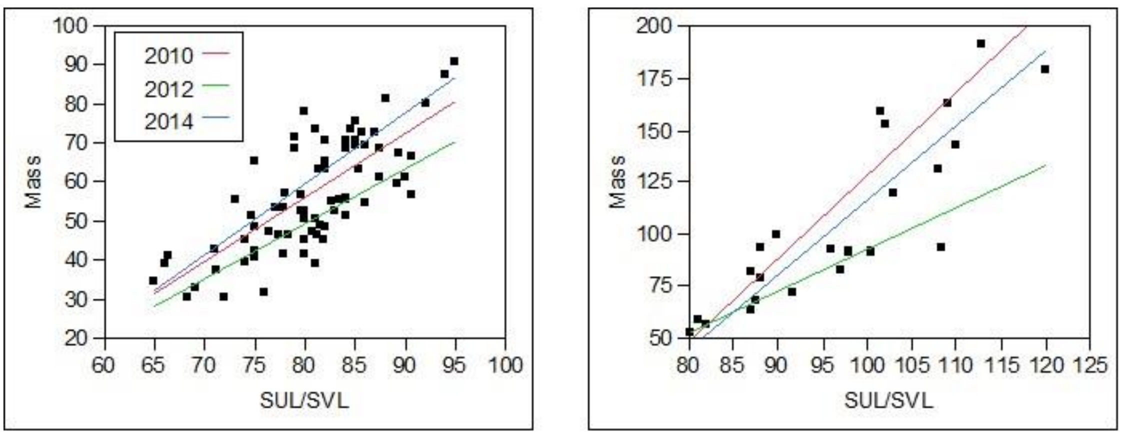

Figure 5-17: Relationship between snout-urostyle length (mm) and body mass (g) for adult male (left) and female (right) Western Toads captured in the drawdown zone of Kinbasket Reservoir 2010, 2012, and 2014

Table 5-6: Size ranges and linear regression coefficients for Western Toad (ANBO), Columba Spotted Frog (RALU) and Common Garter Snake (THSI) males and females. All species regressions were significant (P < 0.001) except for Columbia Spotted Frog females in 2012 (P = 0.3). -- indicates no data; SUL = Snout-Urostyle Length

				SUL (mm)		Mass (g)					
Species	**Year**	**Sex**	**N**	**Min**	**Max**	**Min**	**Max**	**R^2**	**Slope**		**Int**
ANBO	2010	Female	9	82	112.9	56	190	0.839	4.01	*	-272.6
	2010	Male	18	66	90.5	31.5	73	0.599	1.66	*	-76.2
	2012	Female	8	80.2	108.4	52	130	0.826	2.02	*	-109.2
	2012	Male	30	68.2	90.5	30	69	0.684	1.41	*	-63.6
	2014	Female	7	88.2	120	71.1	178	0.863	3.58	*	-242.0
	2014	Male	26	65	95	34	90	0.651	1.83	*	-86.4
RALU	2010	Female	5	57	72.3	14.75	37	0.759	1.34		-60.1
	2010	Male	23	37	80	4	50	0.856	1.00	*	-39.4
	2012	Female	3	72.7	76.2	28	46	0.792	5.28		-353.1
	2012	Male	0	--	--	--	--	--	--		--
	2014	Female	0	--	--	--	--	--	--		--
	2014	Male	5	52	82	17	38	0.971	0.72	*	-21.4

				SUL (mm)		Mass (g)					
Species	**Year**	**Sex**	**N**	**Min**	**Max**	**Min**	**Max**	**R^2**	**Slope**		**Int**
THSI	2010	Female	38	280	965	10	543.5	0.834	0.71	*	-294.7
	2010	Male	28	200	632	4	74	0.845	0.18	*	-42.1
	2012	Female	2	730	800	160	295	1.000	1.93	*	-1247.9
	2012	Male	3	343	525	17.5	52	0.995	0.19	*	-50.4
	2014	Female	7	531	695	60	155	0.886	0.50	*	-192.1
	2014	Male	6	449	580	40	83	0.460	0.26		-78.0

5.1.4.4 H1C: Reservoir operations do not result in decreased site occupancy of amphibians or reptiles in the drawdown zone.

Proportion of Sites

Between 2008 and 2014 13 locations in the drawdown zone have been surveyed for amphibians and reptiles. 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 0 per cent for Western Terrestrial Garter Snake to 61.5 per cent for Columbia Spotted Frog (Table 5-7). Site occupancy was highest for Western Toad (A-ANBO) and Columbia Spotted Frog (A-RALU) in all years, averaging 46.2 per cent for Western Toad and 48.4 per cent for Columbia Spotted Frogs. 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 two species of garter snakes detected, Western Terrestrial Garter Snakes are rarely found in the drawdown zone, having been detected in four of seven years. Common Garter Snakes were observed each year with annual occupancy ranging from 23.1 to 53.8 per cent. For some species and years occupancy will be a function of survey effort. For example, in 2011 and 2013 surveys focused on the Valemount Peatland and Bush Arm. Despite this, the general patterns of occupancy remain with toads and frogs more widely distributed and more readily detectable than all other species.

Table 5-7: 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 between 2011 and 2013. 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						
Survey Locations	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**08**	**09**	**10**	**11**	**12**	**13**	**14**
KIN Beavermouth														
KIN Bush Arm Bear Island									1	14	48	22	15	38
KIN Bush Arm Causeway			1	4	10	52		2	3	32	41	45	134	79
KIN Bush Arm km 79								3	5	15	27	8	26	15
KIN Bush Arm km 79 perched wetland											9		3	11
KIN Encampment Creek												1		
KIN Hugh Allan Bay														
KIN Ptarmigan Creek						1		10	8	108	280	4	25	18
KIN Sprague Bay										6		2		
KIN Sprague Bay Perched Wetland											1			
KIN Succour Creek										1				
KIN Succour Creek Perched Wetland														
KIN Valemount Peatland	2	1	1	18	1	1	2	7	5	444	451	3	49	57
Total Locations	**1**	**1**	**2**	**2**	**2**	**3**	**1**	**4**	**5**	**7**	**7**	**7**	**6**	**6**
Proportion of Locations	**7.7**	**7.7**	**15.4**	**15.4**	**15.4**	**23.1**	**7.7**	**30.8**	**38.5**	**53.8**	**53.8**	**53.8**	**46.2**	**46.2**

	A-RALU							R-THEL							R-THSI						
Survey Locations	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**08**	**09**	**10**	**11**	**12**	**13**	**14**
KIN Beavermouth								2		5											
KIN Bush Arm Bear Island	1		2	3	11	4	12				1				1		6	1	1		4
KIN Bush Arm Causeway	5	1	6	1	2	4	4			1	1				2		5	2	2	3	
KIN Bush Arm km 79	59	45	47	61	1	5	4		3	1					8	6	13	4		2	1
KIN Bush Arm km 79 perched wetland			10	32	7	16	21										1				
KIN Encampment Creek																					
KIN Hugh Allan Bay											4										
KIN Ptarmigan Creek	4	7	7	24	3	3	2	4							6	2	51	131		3	8
KIN Sprague Bay		4	21		1												9				
KIN Sprague Bay Perched Wetland				5														1			
KIN Succour Creek			2							2	1										
KIN Succour Creek Perched Wetland																					
KIN Valemount Peatland	23	7	370	426	12	33	80								1	3	84	53	2	1	12
Total Locations	**5**	**5**	**8**	**7**	**7**	**6**	**6**	**2**	**1**	**4**	**4**				**5**	**3**	**7**	**6**	**3**	**4**	**4**
Proportion of Locations	**38.5**	**38.5**	**61.5**	**53.8**	**53.8**	**46.2**	**46.2**	**15.4**	**7.7**	**30.8**	**30.8**	**.**	**.**	**.**	**38.5**	**23.1**	**53.8**	**46.2**	**23.1**	**30.8**	**30.8**

5.1.4.5 H1D: Reservoir operations do not result in decreased productivity of amphibians or reptiles in the drawdown zone.

Amphibian productivity has not been explicitly studied in Kinbasket Reservoir. The data collected thus far indicate that at least two species of pond-breeding amphibian, Western Toad and Columbia Spotted Frog, are using habitats in the drawdown zone for breeding. The detection of amphibian egg masses varied for both Columbia Spotted Frog and Western Toad, 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 all life stages of these species (i.e., eggs, tadpoles, toadlets, subadults, and adults). Too few data exist for the other species of amphibians to discuss how reservoir operations might affect their productivity.

For at least one species, the 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 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 for each year (2010: 2:1; 2012: 3.8:1; and 2014: 3.7:1) 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 is 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 don't 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 (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.

5.1.4.6 H1E: 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. As expected, a strong negative correlation exists between the availability of all types of habitat and reservoir elevations (2008: r = -0.89; 2009: r = -0.95; 2010: r = -0.92; 2011: r = -0.95; 2012: r = -0.95; 2013: r = -0.93; 2014 r = -0.94) with habitat availability decreasing with time. The change in habitat availability is most evident in June and July, when reservoir elevations are increasing (Figure 5-18).

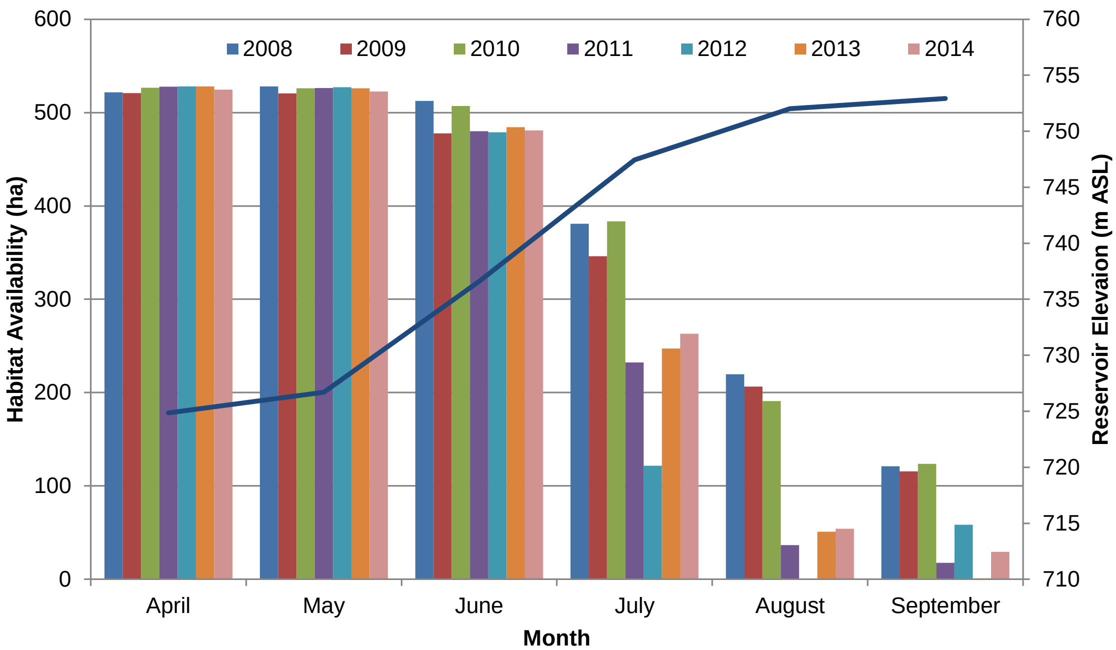

Figure 5-18: Monthly change in habitat availability (bars) in the drawdown zone of Kinbasket Reservoir, 2008 to 2014. The average reservoir elevation is shown (line)

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 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. Ninety five[3] ponds representing 9.59 ha were delineated in the drawdown zone in five distinct survey sites. Total pond area per site ranged from 0.9 ha at Ptarmigan Creek (*N* = 1 pond) to 4.9 ha in the Valemount Peatland (*N* = 48 ponds) and most ponds are situated at elevations between 745 m and 753 m ASL (Figure 5-19).

[3] Only ponds with mean elevations <756 m are considered here, which is why the number of ponds differs from those discussed in Section 5.1.3.

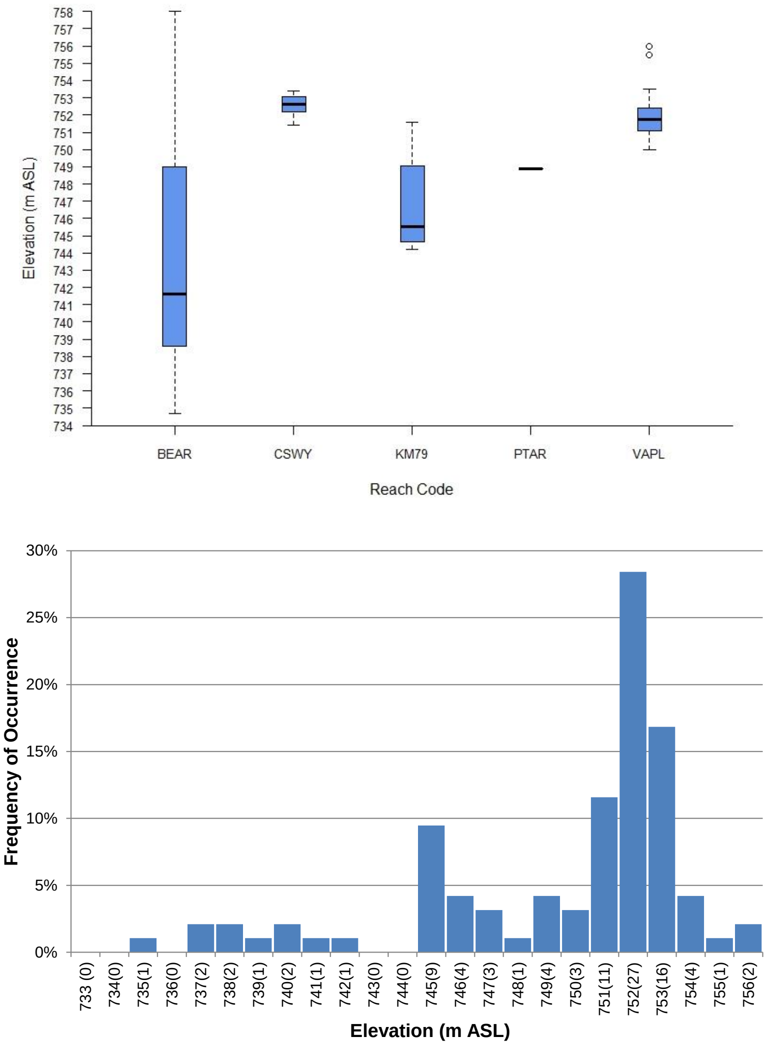

Figure 5-19: Elevation distribution of ponds (top panel) delineated in and adjacent to the drawdown zone at Bear Island (BEAR), the Bush Arm Causeway (CSWY), Bush Arm at km 79 (KM79), Ptarmigan Creek (PTAR) and the Valemount Peatland (VAPL) and the proportion of ponds occurring at elevations ranging from 733 to 756 m ASL (bottom panel). Sample size in parentheses

The quality (i.e., availability) 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 2010, 2012, and 2014. In 2010, the majority of ponds (i.e., those situated between 745 and 753 m ASL) were available until late June. Beyond this point, the amount of breeding habitat steadily declined until August 12, at which time most of the 9.59 ha of pond habitat were inundated. In 2012, most ponds were available until June 13, but were completely inundated by July 17. Similarly, most ponds were available through July 22 in 2014 and were completely inundated by August 7 (Figure 5-20).

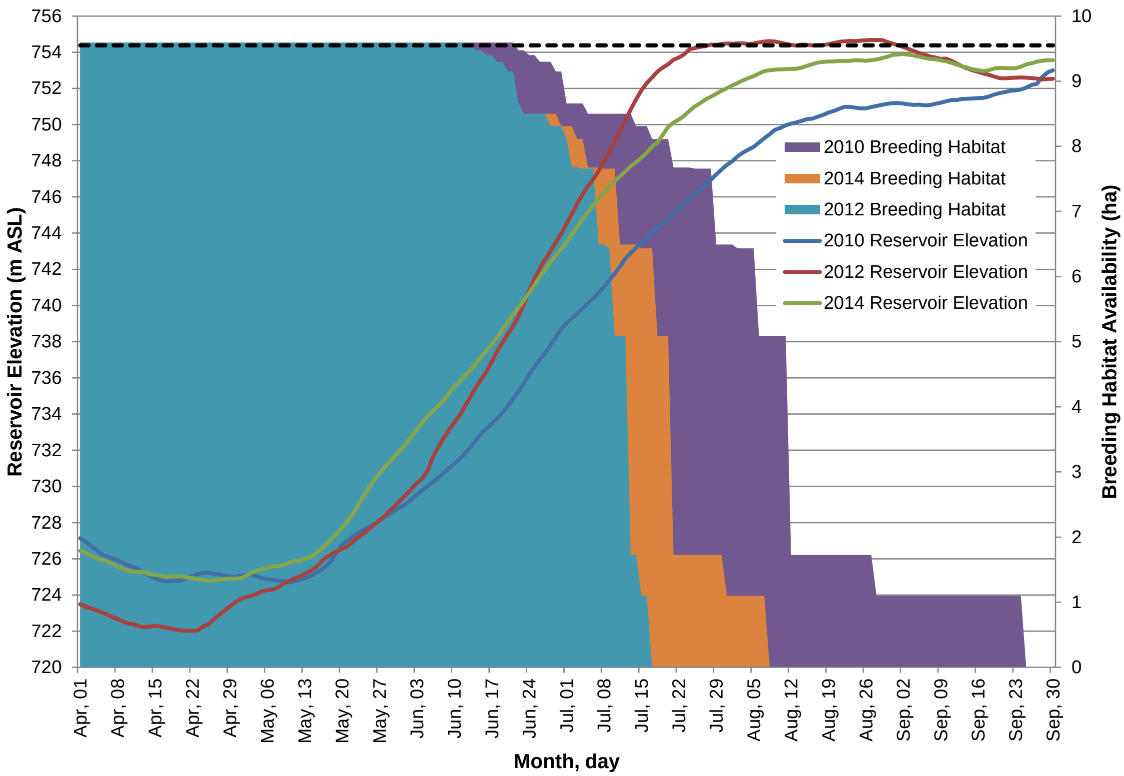

Figure 5-20: **Relationship between breeding habitat availability (pond area) and reservoir elevations for the period April 1 through September 30, 2010, 2012, and 2014**

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 metamorphosed toads at the Valemount Peatland, Ptarmigan Creek, and Bush Arm Causeway in early to late August 2010, 2012, and 2014 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

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. During each year the availability of foraging habitat decreased rapidly as soon as reservoir elevations reached ~740 m ASL (Figure 5-21). Adult amphibians consume terrestrial and aerial insects, tadpoles are algae grazers, and toadlets eat insects and other small invertebrates. Reptiles (snakes) consume insects, worms, gastropods, small mammals, amphibians, and fish. The availability of aquatic (i.e., pond) habitat varies relative to time of year and reservoir operations

(Figure 5-20). A similar trend is observed for all foraging habitat (i.e., terrestrial and aquatic) and as expected there is a strong negative relationship between reservoir elevation and habitat availability (Figure 5-21) with R^2 values close to 1 for all years (see R^2 values in Figure 5-21). The annual trends are similar with only the timing and duration of inundation of each elevation band varying (see Table 5-8).

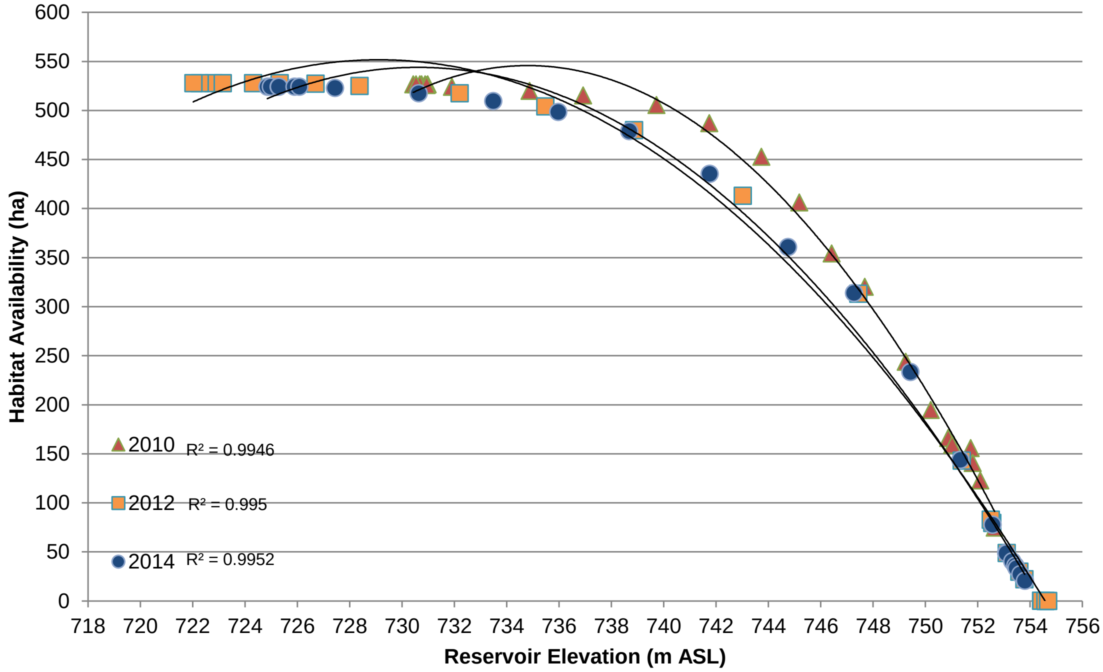

Figure 5-21: The relationship between reservoir elevation and foraging habitat availability in the drawdown zone of Kinbasket Reservoir for the period April 1 to September 30 2010, 2012, and 2014. A 2nd order polynomial trend line was fitted to the data in each year

Table 5-8: Proportion of time between April and September (n = 183 days) that Kinbasket Reservoir exceeded a given range of elevations. Shading indicates that the reservoir did not exceed a given elevation

m ASL	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
741-742	0.58	0.60	0.49	0.44	0.21	0.44	0.40	0.34	0.55	0.59	0.55	0.48	0.53	0.46	0.54	0.54	0.52	0.54
742-743	0.58	0.58	0.47	0.43	0.05	0.44	0.37	0.23	0.54	0.58	0.54	0.46	0.51	0.45	0.52	0.53	0.51	0.52
743-744	0.57	0.56	0.45	0.40		0.43	0.26	0.19	0.51	0.56	0.52	0.44	0.48	0.43	0.51	0.52	0.50	0.51
744-745	0.55	0.54	0.44	0.39		0.42	0.09	0.16	0.50	0.54	0.50	0.42	0.46	0.42	0.49	0.50	0.49	0.49
745-746	0.54	0.52	0.43	0.37		0.40		0.11	0.48	0.52	0.49	0.39	0.43	0.39	0.48	0.50	0.49	0.48
746-747	0.51	0.50	0.42	0.36		0.39		0.07	0.46	0.51	0.48	0.37	0.40	0.37	0.46	0.49	0.47	0.46
747-748	0.49	0.48	0.40	0.30		0.37			0.41	0.49	0.46	0.34	0.37	0.35	0.45	0.47	0.46	0.45
748-749	0.48	0.45	0.39	0.17		0.35			0.35	0.48	0.44	0.32	0.34	0.33	0.43	0.46	0.44	0.43
749-750	0.45	0.40	0.37	0.04		0.32			0.28	0.45	0.43	0.27	0.31	0.31	0.42	0.45	0.42	0.41
750-751	0.44	0.29	0.34			0.23			0.16	0.43	0.42	0.23	0.24	0.27	0.40	0.44	0.38	0.39
751-752	0.42	0.14	0.32			0.06				0.37	0.40	0.18	0.16	0.19	0.38	0.43	0.35	0.37
752-753	0.39		0.28								0.36		0.06	0.03	0.35	0.42	0.30	0.34
753-754	0.34		0.19								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 and reptile overwintering habitat in the drawdown zone of Kinbasket 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). 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.

5.1.4.7 H2A: 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

Physical works are not currently proposed for Kinbasket 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 and those wetlands were protected from inundation through tadpole metamorphosis, the abundance 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.

5.1.4.8 H2B: 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). 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 Kinbasket 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.

5.1.4.9 H2C: Revegetation does not increase the amount or improve habitat for amphibians or 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. Certain types of physical works (e.g., woody debris removal) have the potential to improve habitat for amphibians and reptiles in the drawdown zone. Woody debris removal in specific areas (e.g., Valemount Peatland, Ptarmigan Creek, Bush Arm) are recommended as these areas contain high quality amphibian and reptile habitat and abundant woody debris. Woody debris removal occurred in 2014 in both the Valemount Peatland and Bush Arm. In addition to woody debris removal at the north end of the Valemount Peatland, a log boom was installed around a wetland habitat to protect it from scour and wood debris deposition. Preliminary results suggest that the log boom is protecting the wetland habitat and limiting wood debris accumulation. Protecting important wetland habitats will serve to improve habitat for amphibians and reptiles in the drawdown zone.

5.2 Arrow Lakes Reservoir

5.2.1 Environmental Data

As discussed in Section 5.1.1, weather conditions are known to affect the surface activity of amphibians. Weather data obtained from Environment Canada's Revelstoke weather station (50°57'29.600" N 118°10'34.600" W; 444.70 m ASL) was used to evaluate the influence of weather conditions on species detectability and measures of relative abundance. Daily temperature varied by month from April to September ($F = 2163.9$; $p < 0.001$) and between years ($F = 36.9$; $p < 0.001$), which is to be expected. Total rainfall varied annually ($F = 3.01$; $p = 0.01$), but monthly rainfall was similar between years (F = 1.48; p = 0.19; Figure 5-22). The 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). Environmental conditions during each field session are provided in Table 5-9.

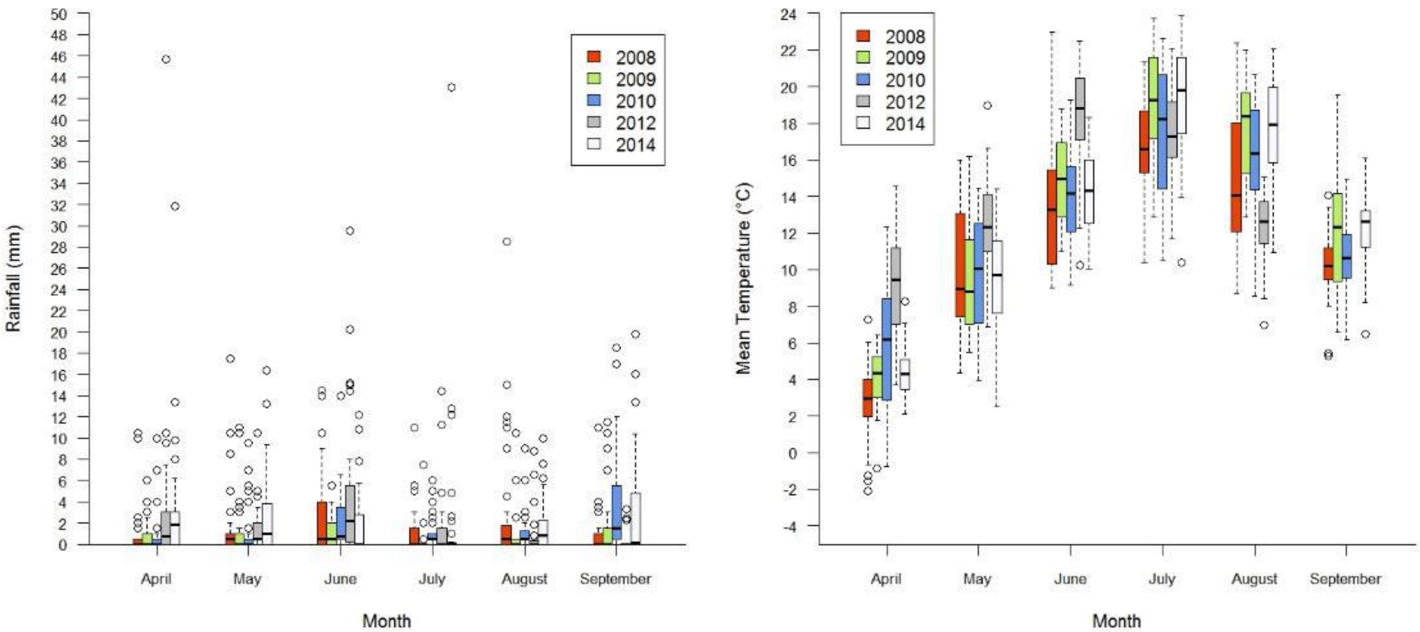

Figure 5-22: Daily precipitation (mm, left) and mean temperature (°C, right) for April through September, 2008-2010, 2012, and 2014 as measured at Revelstoke. Data source: Environment Canada (http://climate.weather.gc.ca/index_e.html)

Table 5-9: Air temperature and precipitation conditions[1] for Arrow Lakes Reservoir during the 2014 field sessions. Precipitation values are totals by session and by month

		Temperature (°C)			Precipitation (mm)	
Field Session	Dates	Min	Max	Average	Session	Monthly
1	May 1 - 10	-2.6	20.1	6.1571	34.0	87.0
2	May 26 - 31	3.6	25.1	10.84	31.4	87.0
3	Jun 6 - 9	1.6	25.0	14.03	3.0	57.8
4	Jun 11 - 20	4.0	27.7	13.732	34	57.8
5	Jun 25 - 30	7.2	28.9	15.193	8.4	57.8
6	Jul 7 - 15	9.0	36.6	21.137	0.0	78.8
7	Jul 18 - 25	7.2	30.6	16.209	75.2	78.8
8	Aug 14 - 25	7.8	27	16.39	29.4	55.4
9	Sep 8 - 15	-1.1	25.3	10.35	5.2	81.6

[1]Data obtained from BC Wildfire Management Branch

5.2.2 Water Physicochemical Data

Point data [pH, Conductivity (µS/cm), and Temperature (°C)] are summarized for ponds sampled between 2010 and 2014 (Table 5-10). In general, water physical chemistry is believed to play a minor role in affecting the species richness of amphibians in certain areas (e.g., Hecnar and M'Closkey 1996) and our data suggest that most values are characteristic of sites with relatively 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 5-10: Summary of water physicochemistry data collected at ponds with and without amphibians in the drawdown zone of Arrow Lakes Reservoir, 2010, 2012 and 2014

WITHOUT		pH				Conductivity (µS/cm)				Temperature (°C)			
Year	*N*	Min	Max	$\bar{x}$	SD	Min	Max	$\bar{x}$	SD	Min	Max	$\bar{x}$	SD
2010	90	7.0	9.8	8.1	0.5	1	383	91.0	99.1	7.4	26.1	15.5	4.2
2012	11	7.5	8.4	7.9	0.3	27	608	147.5	164.5	14.0	23.7	17.3	3.3
2014	69	6.4	10.4	8.2	0.7	18	505	163.1	103.2	7.5	27.9	16.6	4.4
WITH													
Year	*N*	Min	Max	$\bar{x}$	SD	Min	Max	$\bar{x}$	SD	Min	Max	$\bar{x}$	SD
2010	59	6.9	9.9	8.3	0.7	2	309	101.1	77.4	9.1	27.8	18.0	4.2
2012	11	7.3	8.4	7.9	0.3	11	124	79.8	35.3	12.8	23.7	17.5	3.6
2014	71	6.6	9.8	8.5	0.8	23	489	140.6	64.5	9.5	25.4	16.4	3.8

5.2.3 Species Occurrence and Distribution

5.2.3.1 Site Occupancy

At the landscape level, four species of amphibians and five species of reptiles have been observed in the DDZ of Arrow Lakes Reservoir since 2008 (Table 5-11). Long-toed Salamander (AMMA) have been detected only in Revelstoke Reach while both Western Toad (ANBO) and Pacific Chorus Frog (PSRE) have been documented from most survey locations. Columbia Spotted Frog (RALU) occurs at only a few locations. Of the five species of reptile detected, Western Painted Turtle (CHPI) are constrained to Revelstoke Reach, Northern Alligator Lizards are common in the rocky edges of the drawdown zone from Revelstoke south to Deer Park, Western Skink (PLSK) have been detected at Deer Park and Edgewood only and both species of garter snakes are present throughout the reservoir. Mapped occurrences of all species observed in 2014 are included in Appendix 10-1.

Of the locations surveyed, locations in Revelstoke Reach (Cartier Bay, Montana Slough) and near Edgewood and at Burton Creek support the highest number of species. The number of sites occupied in a given year ranges from six to 14, with 2009, 2010, and 2014 associated with the most occupied sites.

Table 5-11: Site occupancy (shaded cells) of amphibians (Top panel) and reptiles (Bottom panel) observed in the drawdown zone of Arrow Lakes Reservoir between 2008 and 2014. AMMA = Long-toed Salamander, ANBO = Western Toad, PSRE = Pacific Chorus Frog, RALU = Columbia Spotted Frog, CHPI = Western Painted Turtle; ELCO = Northern Alligator Lizard; PLSK = Western Skink; THEL = Western Terrestrial Garter Snake, THSI = Common Garter Snake. Blanks indicate species not detected in a given year and survey location

	AMMA					ANBO					PSRE					RALU					Species				
Survey Location	**08**	**09**	**10**	**12**	**14**	**08**	**09**	**10**	**12**	**14**	**08**	**09**	**10**	**12**	**14**	**08**	**09**	**10**	**12**	**14**	**08**	**09**	**10**	**12**	**14**
ARR 12 mile						■	■	■			■		■	■							2	1	2	1	
ARR 9 mile	■	■	■			■	■	■	■	■	■			■	■						3	2	2	2	2
ARR Airport Marsh							■	■		■		■	■									2	2		1
ARR Beaton Arm							■	■	■	■		■	■					■	■	■		2	3	2	2
ARR Burton Creek						■	■	■	■	■	■	■	■		■	■	■	■	■	■	3	3	3	2	3
ARR Cartier Bay		■	■			■	■	■	■	■	■	■	■		■	■		■			3	3	4	1	2
ARR Downie Marsh							■	■	■	■												1	1	1	1
ARR East Arrow Park							■					■										2			
ARR Edgewood north													■							■			1		1
ARR Edgewood south								■		■			■	■				■	■	■			3	2	2
ARR Hugh Kinnleyside Dam Wildlife Area							■					■					■					3			
ARR Lower Inonoakalin								■	■	■			■		■								2	1	2
ARR Machete Island												■	■									1	1		
ARR Montana Slough							■	■	■	■	■	■	■	■	■			■	■		1	2	3	3	2
ARR Mosquito Creek							■						■				■					2	1		
ARR Revelstoke Reach		■				■	■			■	■	■									2	3			1
ARR Syringa Provincial Park																									
Locations Per Year	**1**	**3**	**2**			**5**	**12**	**10**	**7**	**10**	**6**	**9**	**11**	**4**	**5**	**2**	**3**	**5**	**4**	**4**	**6**	**13**	**13**	**9**	**11**

	CHPI					ELCO					PLSK					THEL					THSI					Species				
Survey Location	**08**	**09**	**10**	**12**	**14**	**08**	**09**	**10**	**12**	**14**	**08**	**09**	**10**	**12**	**14**	**08**	**09**	**10**	**12**	**14**	**08**	**09**	**10**	**12**	**14**	**08**	**09**	**10**	**12**	**14**
ARR 12 mile																			■		■	■	■	■		1	1	1	2	
ARR 9 mile		■				■	■	■								■	■			■	■	■	■	■	■	3	4	2	1	2
ARR Airport Marsh			■		■													■			■	■	■		■	1	1	3		2
ARR Beaton Arm																	■	■				■	■		■		2	2		1
ARR Burton Creek																■	■	■	■	■	■	■	■			2	2	2	1	1
ARR Cartier Bay						■	■	■		■							■	■			■	■	■		■	2	3	3		2
ARR Downie Marsh																	■	■	■	■		■	■	■	■		2	2	2	2
ARR East Arrow Park								■									■	■				■	■				2	3		
ARR Edgewood north								■	■	■		■	■		■		■	■	■				■				2	4	2	2
ARR Edgewood south							■	■		■			■				■	■	■	■			■		■		2	4	1	3
ARR Hugh Kinnleyside Dam Wildlife Area																						■					1			
ARR Lower Inonoakalin								■		■																		1		1
ARR Machete Island																	■	■				■	■				2	2		
ARR Montana Slough	■	■	■	■	■	■	■	■	■	■								■	■				■	■		2	2	4	4	2
ARR Mosquito Creek																	■	■				■	■				2	2		
ARR Revelstoke Reach																■					■					2				
ARR Syringa Provincial Park						■																				1				
Locations Per Year	**1**	**2**	**2**	**1**	**2**	**4**	**4**	**7**	**2**	**5**		**1**	**2**		**1**	**3**	**10**	**11**	**6**	**4**	**6**	**11**	**13**	**4**	**6**	**8**	**14**	**14**	**7**	**10**

5.2.3.2 Detection Rates

Between April and August, we spent 117 hours over 49 days surveying monitoring sites within the DDZ of Arrow Lakes Reservoir (Table 5-12), during which we made more than 204 species detection (114,000 individuals across multiple life stages, most of which were tadpoles).

Table 5-12: Total survey time (hours) and species detections by survey location for Arrow Lakes Reservoir in 2014. Blanks indicate the species was not detected. AMMA = Long-toed Salamander, ANBO = Western Toad, PSRE = Pacific Chorus Frog, RALU = Columbia Spotted Frog, CHPI = Painted Turtle, ELCO = Northern Alligator Lizard, PLSK = Western Skink, THEL = Western Terrestrial Garter Snake, THSI = Common Garter Snake. CPUE (catch per unit effort) = the number of observations per site and per species divided by the survey time. RR = Revelstoke Reach

Survey Location	Time	ANBO	PSRE	RALU	CHPI	ELCO	PLSK	THEL	THSI	Total	CPUE
RR 12 mile	1									**0**	**0.00**
RR 9 mile	18	9	1					1	3	**14**	**0.78**
RR Airport Marsh	14.5	5			2				1	**8**	**0.55**
Beaton Arm	7.5	15		5					2	**22**	**2.93**
Burton Creek	10.5	15	1	3				2		**21**	**2.00**
RR Cartier Bay	19	64	3			2			1	**70**	**3.68**
RR Downie Marsh	15	11						2	6	**19**	**1.27**
Edgewood North	9			1		12	3			**16**	**1.78**
Edgewood South	11	2		1		1		1	7	**12**	**1.09**
Lower Inonoaklin	6	9	2			1				**12**	**2.00**
RR Montana Slough	12	5	1		3	2				**11**	**0.92**
Hours; #obs	**123.5**	**135**	**8**	**10**	**5**	**18**	**3**	**6**	**20**	**204**	**1.65**
CPUE (#obs/hr)		**1.09**	**0.06**	**0.08**	**0.04**	**0.15**	**0.02**	**0.05**	**0.16**	**1.65**	

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. We examined the detection rates for five areas in Arrow Lakes Reservoir (Revelstoke Reach sites pooled; Figure 5-23), of which Burton Creek had the most consistently high rates of detections among these five sites.

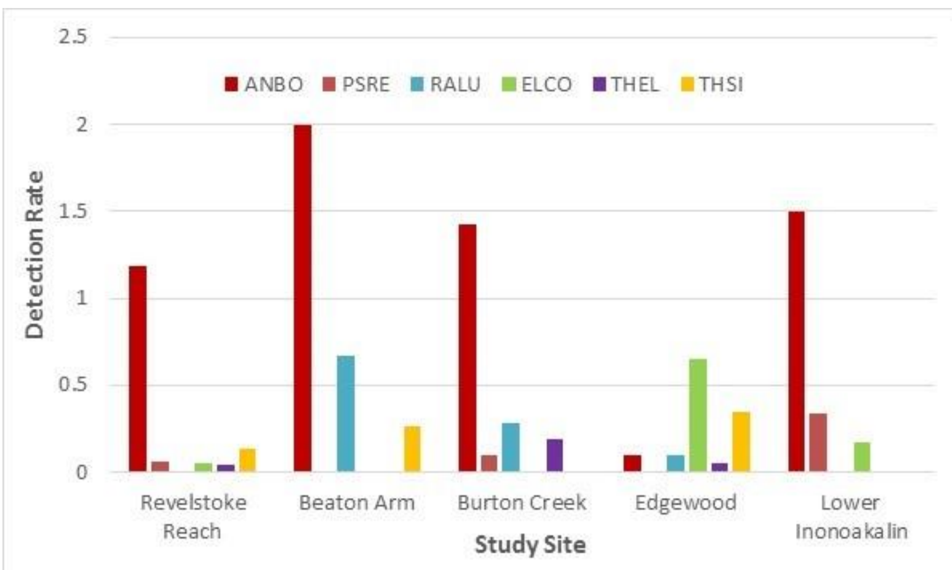

Figure 5-23: Detection rate for amphibian and reptile species in Arrow Lakes Reservoir in 2014. Detection rate = the number of times a species was detected (all life stages pooled)/the total time spent searching at a study site. ANBO = Western Toad, PSRE = Pacific Chorus Frog, RALU = Columbia Spotted Frog, ELCO = Northern Alligator Lizard, THEL = Western Terrestrial Garter Snake, THSI = Common Garter Snake

5.2.3.3 Elevation

Amphibians and reptiles of all species and life stages were found across a wide range of elevations in Arrow Lakes Reservoir in 2014 (Figure 5-24). Most observations (all life stages combined) were between 434 and 441 m ASL, a trend that has been consistently observed across the years (see previous reports). Northern Alligator Lizards (ELCO) spanned the largest range of elevations, while observations of Columbia Spotted Frogs (RALU) spanned the smallest range. The relationship between amphibian (and reptile) distribution in the drawdown zone is likely a function of habitat availability.

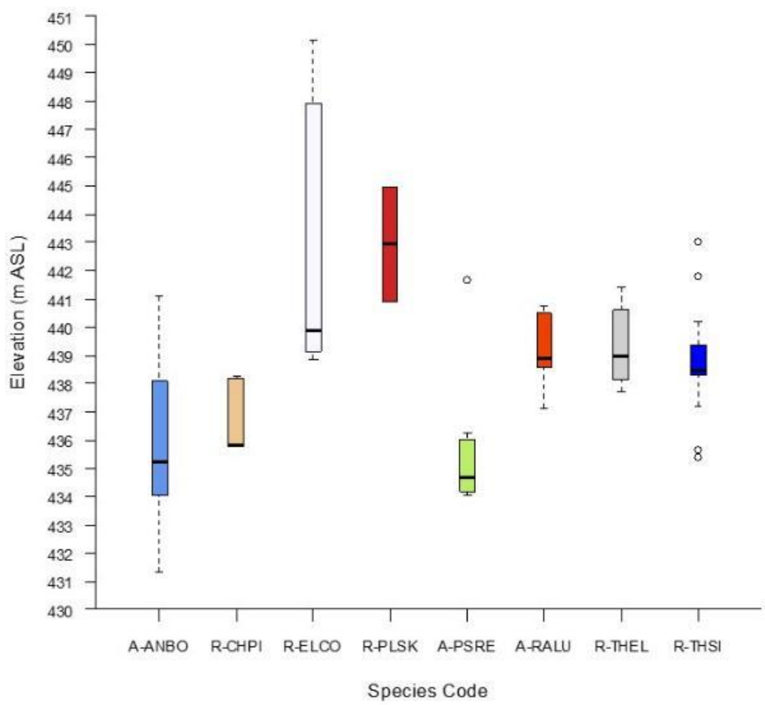

Figure 5-24: Elevation distribution of amphibians and reptiles (number of observations, all life stages combined) documented in the drawdown zone of Arrow Lakes Reservoir in 2014. A-ANBO = Western Toad, R = Painted Turtle, R-ELCO = Northern Alligator Lizard, R-PLSK = Western Skink, A-PSRE = Pacific Chorus Frog, A-RALU = Columbia Spotted Frog, R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake

5.2.3.4 Radiotelemetry

In 2014, 11 Western Toads and two Common Garter Snakes were captured and fitted with radio transmitters in Revelstoke Reach. Toads were a mix of male (n=9) and female (n=2) and ranged in size from 73.7 mm to 88.2 mm SUL, with females being generally larger than males. Two female garter snakes (584 mm and 656 mm SVL) were also tracked.

Animals were tagged and tracked between May 5th and September 11th. As most transmitters were recovered after being dropped by the original animal, it is difficult to assess the maximum number of days a transmitter remained on any individual.

Some animals dropped their transmitters within the first few days, but in general transmitters were retained and detected on subsequent trips up to a confirmed duration of 30 days on a toad and 2 days on a snake. Total distances travelled by toads ranged from 4.2 m to 3019.0 m with an average of 593.2 m. On average male toads had higher average daily movements than females (Figure 5-25). Garter snake movement distances ranged from 10.3 m to 206.7 m ($\bar{x}$ = 108.5 m). However, daily movements are difficult to ascertain due to the varying lengths of time between locating animals

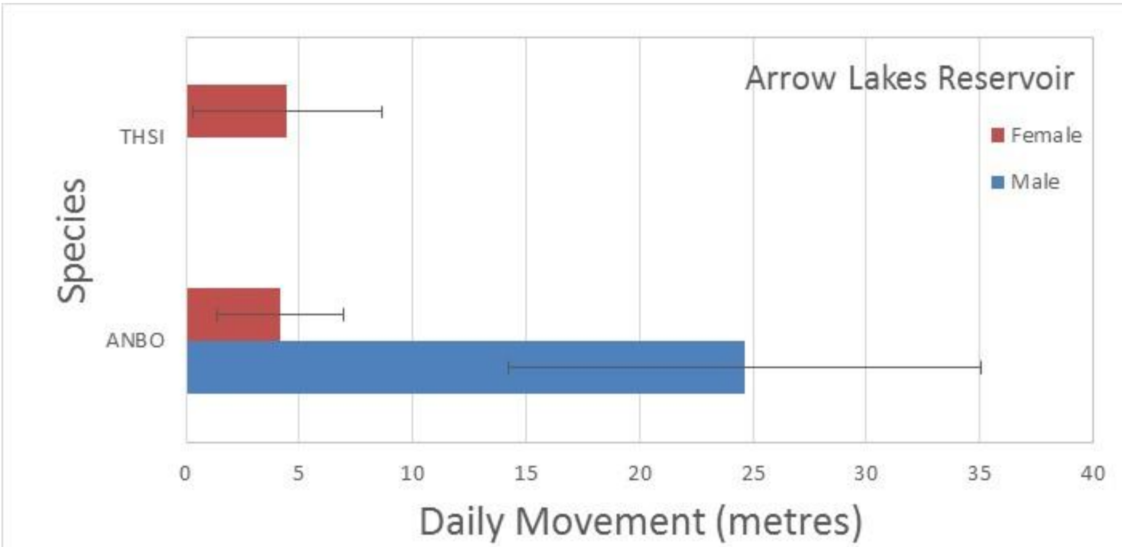

Figure 5-25: Average daily movements (±SE) of Western Toads (ANBO) and Common Garter Snakes (THSI) in Revelstoke Reach, Arrow Lakes Reservoir, 2014
Sample size for both species was small: ANBO: Males N = 9; Female N = 2; THSI: Males = 0; F = 2

Five of the toads captured in the drawdown zone moved to upland habitats during the survey period and occupied summer habitat on the slopes of Mount Revelstoke or in upland habitat to the south of Cartier Bay. Toad capture occurred in early May (May 5, 6, and 7) with all animals caught in the drawdown zone. By May 12 some toads had already started to move out of the drawdown zone away from the breeding ponds with all toads moving out the drawdown zone into upland habitats by May 17 or June 2. Some individual toads continued to use the drawdown zone, but most were in upland habitats. Examples of toad movements in and out of the drawdown zone of Arrow Lakes Reservoir at Cartier Bay are shown in Figure 5-26 and habitat used by M03 at location 4 is shown in Figure 5-27. All locations associated with snakes were in the drawdown zone.

Figure 5-26: Examples of successive movements by two Western Toads in Cartier Bay, Arrow Lakes Reservoir, 2014. Numbers refer to successive locations with '1' being the capture location. Dates indicate location dates. Vectors indicate presumed (straight-line) direction of movement. The red line on each tile is the 440 m ASL contour. Locations above this contour are outside of the drawdown zone

Figure 5-27: Example of upland habitat used by Western Toads M03 in the summer (left) and Western Toad with transmitter inside crevice (right). Photos: Bryce McKinnon

5.2.4 Hypotheses Testing

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

Soft 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[4] and are summarized below (Table 5-13). The implementation of soft operational constraints are not planned 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

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

habitat use can be tested (because they are not linked to soft constraints), and these are discussed below.

The spring (April 30 to July 16) soft constraints 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.

Table 5-13: Summary of the total time (days and percent of total) that soft constraints were met in Arrow lakes Reservoir to mitigate for potential impacts to birds using the drawdown zone. CLBMON-37 implementation 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**

5.2.4.2 H1A: Reservoir operations do not result in a decreased abundance of amphibians or reptiles in the drawdown zone.

The use of the drawdown zone by amphibians and reptiles is influenced by reservoir elevation and time of year. Detection rates (as a proxy for abundance) are negatively correlated with increasing reservoir elevation for Western Toad (-0.20) and Pacific Chorus Frog (-0.42), but positively for Columbia Spotted Frog (0.12), although the correlations tend to be weak. Of the reptiles detected, correlations with reservoir elevations are negative for Western Painted Turtle (-0.18), Northern Alligator Lizard (-0.08), and Western Skink (-0.10) and positive for both species of garter snake (Western Terrestrial Garter Snake: 0.19; Common Garter Snake: 0.23), but again, most of these correlations are weak. Relationships between detection rates and reservoir elevations for two species of amphibian and two reptiles that are representative of all species are shown in Figure 5-28). In all cases, detection rates are also correlated with season, with detection rates of Western Toad peaking in early to late spring and declining with time (correlation -

0.26), detection rates for Columbia Spotted Frogs relatively constant throughout the year (0.05), and both species of snakes tending to be detected more frequently in the summer (Western Terrestrial Garter Snake: 0.13; Common Garter Snake: 0.25; Figure 5-29). However, the data associated with most species documented (except for Western Toad) are zero-inflated, which makes it difficult to interpret these results. In general the findings align with what we would expect regarding the seasonal occurrence of amphibians and reptiles and the relationships between increasing reservoir elevations and the detection of each species. These patterns have been observed during each year of study and although seasonality does influence detectability of each species, the use of the drawdown zone by these species is also affected by inundation on an annual basis.

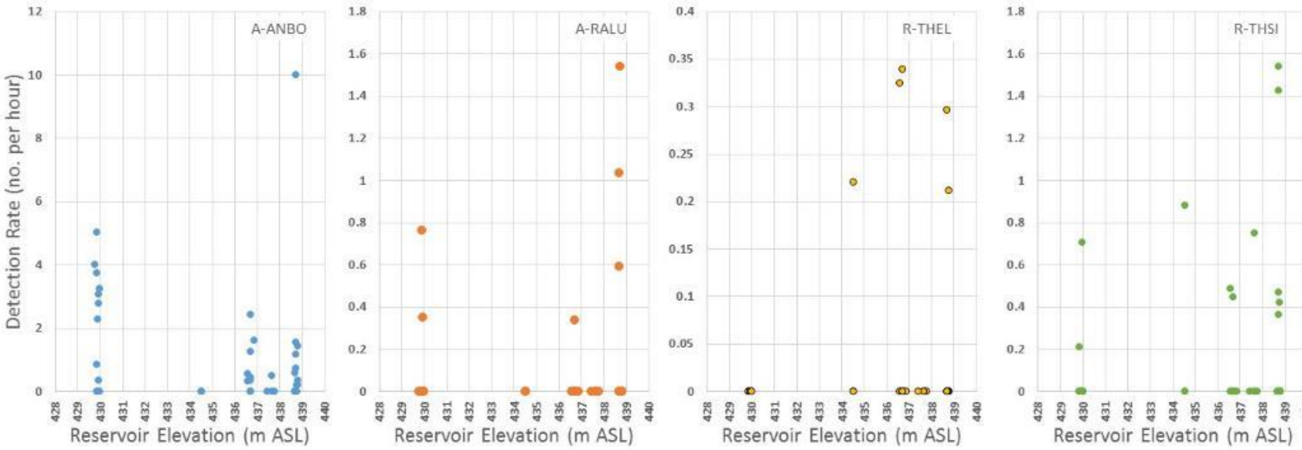

Figure 5-28: Relationship between reservoir elevations and detection rates for Western Toad (A-ANBO), Columbia Spotted Frog (A-RALU), Western Terrestrial Garter Snake (R-THEL) and Common Garter Snake (R-THSI) in Arrow Lakes Reservoir, 2014. Note different scales on vertical axes

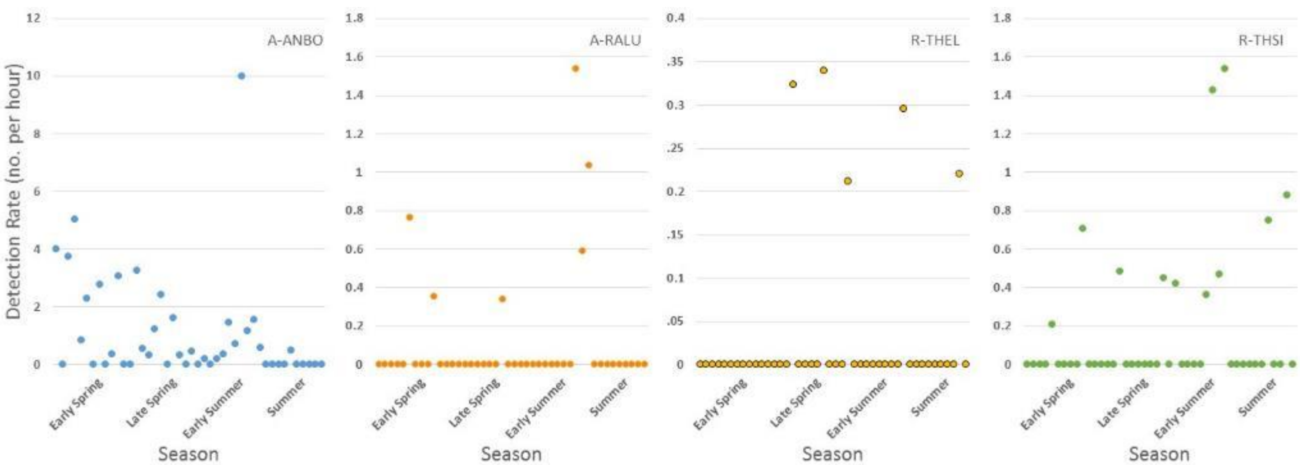

Figure 5-29: Relationship between season and detection rates for Western Toad (A-ANBO), Columbia Spotted Frog (A-RALU), Western Terrestrial Garter Snake (R-THEL) and Common Garter Snake (R-THSI) in Arrow Lakes Reservoir, 2014. Note different scales on vertical axes (early spring, April 1 to May 18; late spring, May 19 to June 21; early summer, June 22 to July 21; and summer, June 22 to August 19)

5.2.4.3 H1B: 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 5-14). 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 5-14: Observed life history activity of amphibian and reptile species in the drawdown zone of Arrow Lakes Reservoir from 2008 to 2012. 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, mortality rates (defined here as breeding failure) have not been directly measured and the relationships between reservoir operations and mortality rates 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.

Despite not being able to directly measure mortality, we can infer the health of animal populations thorough an assessment of biomass (body size), which can be affected by changes in the environment. For both male and female Common Garter Snakes there was a significant effect of length and of year (mean snout-vent length and mass varied among years; p <0.0001 for both male and females). For both sexes, the interaction term was not significant, meaning that the slope of mass vs. snout-vent length did not vary greatly among years: the three lines (one for each year) are approximately parallel (Figure 5-30). For any given snout-vent length, snakes were heaviest in 2012/2104 and lightest in 2010 (Table 5-15). Given that slopes do not vary among years, it appears that the health of the population has not changed over the three years. Unfortunately, small sample sizes for most other species preclude a similar assessment.

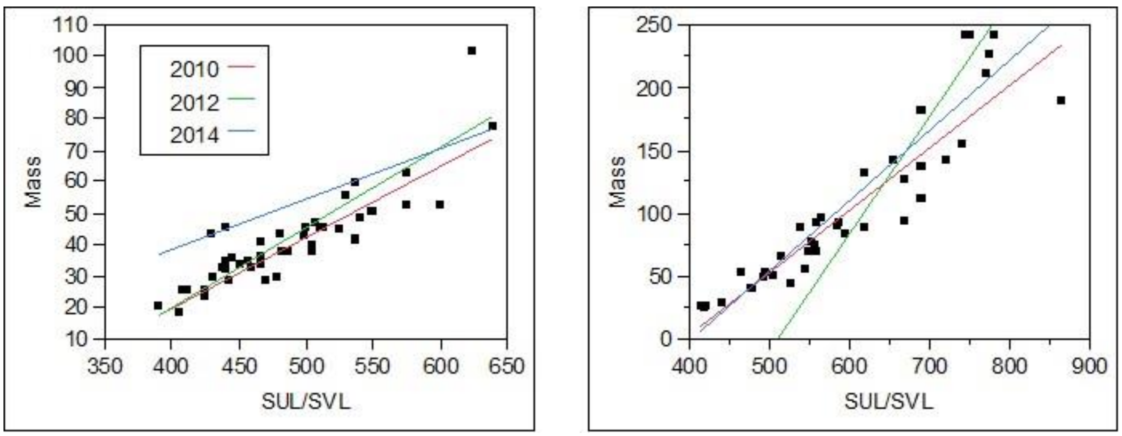

Figure 5-30: Relationship between snout-vent length (mm) and body mass (g) for adult male (left) and female (right) Common Garter Snakes captured in the drawdown zone of Arrow Lakes Reservoir 2010, 2012, and 2014

Table 5-15: Size ranges and linear regression coefficients for Common Garter Snake (THSI) and Western Toad (ANBO) males and females. -- indicates no data; SV/UL = Snout-Vent/Urostyle Length

				SV/UL (mm)		Mass (g)					
Species	**Year**	**Sex**	**N**	**Min**	**Max**	**Min**	**Max**	***R^2***	**Slope**		**Int**
THSI	2010	Female	30	415	865	21.8	240	0.865	0.50	*	-199.1
	2010	Male	38	391	625	20	101	0.755	0.23	*	-71.0
	2012	Female	4	560	745	67	240	0.907	0.94	*	-479.9
	2012	Male	4	405	575	18	62	0.972	0.25	*	-81.3
	2014	Female	5	515	656	65	140	0.939	0.56	*	-225.0
	2014	Male	3	430	640	43	77	1.000	0.16	*	-26.1
ANBO	2010	Female	11	79.5	126	66	185	0.166	1.03		2.5
	2010	Male	49	67.7	98.8	38	110	0.640	2.10	*	-106.9
	2012	Female	0	--	--	--	--	--	--		--
	2012	Male	4	79	89.5	49	86	0.985	3.43	*	-220.5
	2014	Female	2	87.2	88.2	68.7	71	1.000	-2.30	*	271.6
	2014	Male	12	61	88	35	76	0.250	0.98		-26.1

There is evidence of road-based mortality associated with the migratory period in the spring and fall, particularly near Cartier Bay, Montana Slough, and Airport Marsh (F. Maltby, pers. com). These road-based mortalities are not related to reservoir operations, but the proximity of suitable breeding habitat to summer and over-wintering habitat contributes to an increased risk of mortality during the migratory periods each year.

5.2.4.4 H1C: Reservoir operations do not result in decreased site occupancy of amphibians or reptiles in the drawdown zone.

Proportion of Sites

Between 2008 and 2014 16 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 68.75 per cent for both Western Toad and Pacific Chorus Frog (Table 5-16). Site occupancy was highest for Western Toad (A-ANBO) and Pacific Chorus Frog (A-PSRE) in all years averaging 53.8 per cent for Western Toad and 42.5 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 most sites in all years (Western Terrestrial Garter Snakes, R-THEL: 40 per cent; Common Garter Snake, R-THSI: 47.5 per cent). Northern Alligator Lizards (R-ELCO) were present at two to five 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.

Table 5-16: 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 between 2008 and 2014. A = amphibian, R = reptile; AMMA = Long-toed Salamander, ANBO = Western Toad, PSRE = Pacific Chorus Frog; RALU = Columbia Spotted Frog, CHPI = Western Painted Turtle; ELCO = Northern Alligator Lizard; PLSK = Western Skink; THEL = Western Terrestrial Garter Snake, THSI = Common Garter Snake

	A-AMMA					A-ANBO					A-PSRE					A-RALU				
Survey Location	**08**	**09**	**10**	**12**	**14**	**08**	**09**	**10**	**12**	**14**	**08**	**09**	**10**	**12**	**14**	**08**	**09**	**10**	**12**	**14**
ARR 12 mile						1	51	15			2		11	3						
ARR 9 mile	1	1	2			33	27034	25041	5	5724	8			2	1					
ARR Airport Marsh							10101	5		8551		2	6							
ARR Beaton Arm							23007	10506	10000	10730		1	2					15	1	11
ARR Burton Creek						5	7509	1608	500	3630	3	1	1		1	5	23	15	1	3
ARR Cartier Bay		2	16			22	11117	5E+05	50202	67185	5	11	6		8	5		10		
ARR Downie Marsh							503	22	2000	2430										
ARR Edgewood north													51							1
ARR Edgewood south								4		4001			8	25				1	25	280
ARR Hugh Kinnleyside Dam Wildlife Area							23					3					4			
ARR Lower Inonoakalin								4000	1	3614			2		2					
ARR Machete Island												4	4							
ARR Montana Slough							51	502	13	2302	3	2	28	1	1			4	1	
ARR Mosquito Creek							3						3				1			
ARR Revelstoke Reach		4				29	8			5602	4	1								
ARR Syringa Provincial Park																				
Total Locations	**1**	**3**	**2**	**0**	**0**	**5**	**11**	**10**	**7**	**10**	**6**	**8**	**11**	**4**	**5**	**2**	**3**	**5**	**4**	**4**
Porportion of Locations	**6.25**	**18.75**	**12.50**	**0.00**	**0.00**	**31.25**	**68.75**	**62.50**	**43.75**	**62.50**	**37.50**	**50.00**	**68.75**	**25.00**	**31.25**	**12.50**	**18.75**	**31.25**	**25.00**	**25.00**

	R-CHPI					R-ELCO					R-PLSK					R-THEL					R-THSI				
Survey Location	**08**	**09**	**10**	**12**	**14**	**08**	**09**	**10**	**12**	**14**	**08**	**09**	**10**	**12**	**14**	**08**	**09**	**10**	**12**	**14**	**08**	**09**	**10**	**12**	**14**
ARR 12 mile																			2		1	5	1	4	
ARR 9 mile		1				11	3	7								4	2			1	26	5	8	4	3
ARR Airport Marsh			2		2													1			1	1	7		1
ARR Beaton Arm																	1	1				5	8		2
ARR Burton Creek																14	7	11	1	2	6	6	8		
ARR Cartier Bay						1	2	2		2							2	1			6	3	6		1
ARR Downie Marsh																	2	27	3	2		4	48	14	7
ARR Edgewood north								15	1	13		4	7		3		1	3	1				2		
ARR Edgewood south							1	3		1			1				1	19	2	1			14		7
ARR Hugh Kinnleyside Dam Wildlife Area																						2			
ARR Lower Inonoakalin								1		1															
ARR Machete Island																	1	4				1	7		
ARR Montana Slough	3	2	11	3	5	3	1	6	6	8								3	1				3	2	
ARR Mosquito Creek																	1	3				3	5		
ARR Revelstoke Reach																1					20				
ARR Syringa Provincial Park						1																			
Total Locations	**1**	**2**	**2**	**1**	**2**	**4**	**4**	**6**	**2**	**5**	**0**	**1**	**2**	**0**	**1**	**3**	**9**	**10**	**6**	**4**	**6**	**10**	**12**	**4**	**6**
Porportion of Locations	**6.25**	**12.50**	**12.50**	**6.25**	**12.50**	**25.00**	**25.00**	**37.50**	**12.50**	**31.25**	**0.00**	**6.25**	**12.50**	**0.00**	**6.25**	**18.75**	**56.25**	**62.50**	**37.50**	**25.00**	**37.50**	**62.50**	**75.00**	**25.00**	**37.50**

5.2.4.5 H1D: 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).

For at least one species, the 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 for each year (2010: 4.5:1; 2012: 4:0; and 2014: 6:1) 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.

5.2.4.6 H1E: 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 and calculating how much of that area was available on a monthly basis relative to reservoir operations. As expected, a strong negative correlation exists between habitat availability and reservoir elevations (2008: *r* = -0.98; 2009: *r* = -0.95; 2010: *r* = -0.96; 2012: *r* = -0.95; 2014: *r* = -0.90) with habitat availability decreasing with time within each year (not across years). The change in habitat availability is most evident in spring, when reservoir elevations are increasing (Figure 5-31).

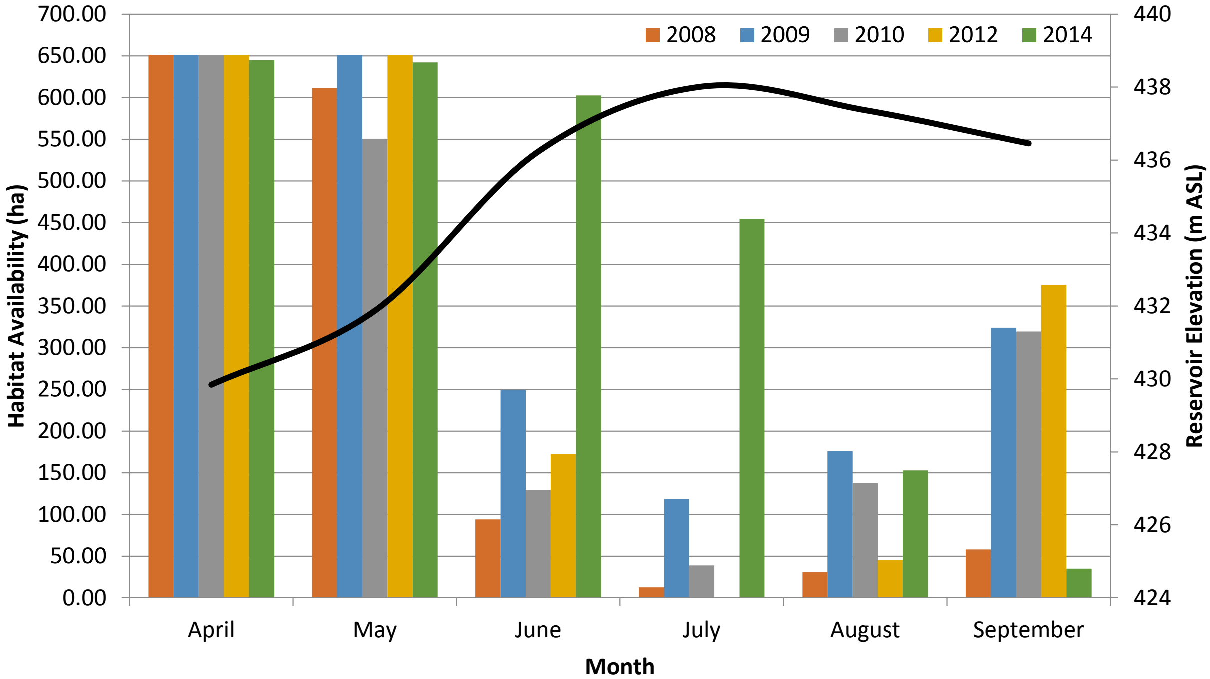

Figure 5-31: Annual Change in habitat availability relative to month and reservoir elevation (solid black line; averaged over each year of sampling)

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. Fifteen ponds were delineated in the drawdown zone in this location ranging in size from 0.05 ha to 25.1 ha ($\bar{x}$ = 2.99; SD = 6.86 ha). Most of the pond area (~64 per cent, 28.8 ha) is situated at ~433 m ASL, an additional 30 per cent (13.6 ha) at 434 m ASL and ~ 5 per cent (~2.5 ha) at 435 m ASL. Over the last three years of study (2012, 2012, and 2014), the majority of the ponds in this location were inundated between May, 3 (2010) and May, 28 (2012). Following the inundation of the 433 m ASL elevation band (and 28.8 ha of breeding habitat), the 434 elevation band (or 13.6 ha) was inundated between May 19 (2010) and June 4 (2012). The remaining 2.5 ha was inundated between June 2 (2010) and June 8 (2012) (Figure 5-32). 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.

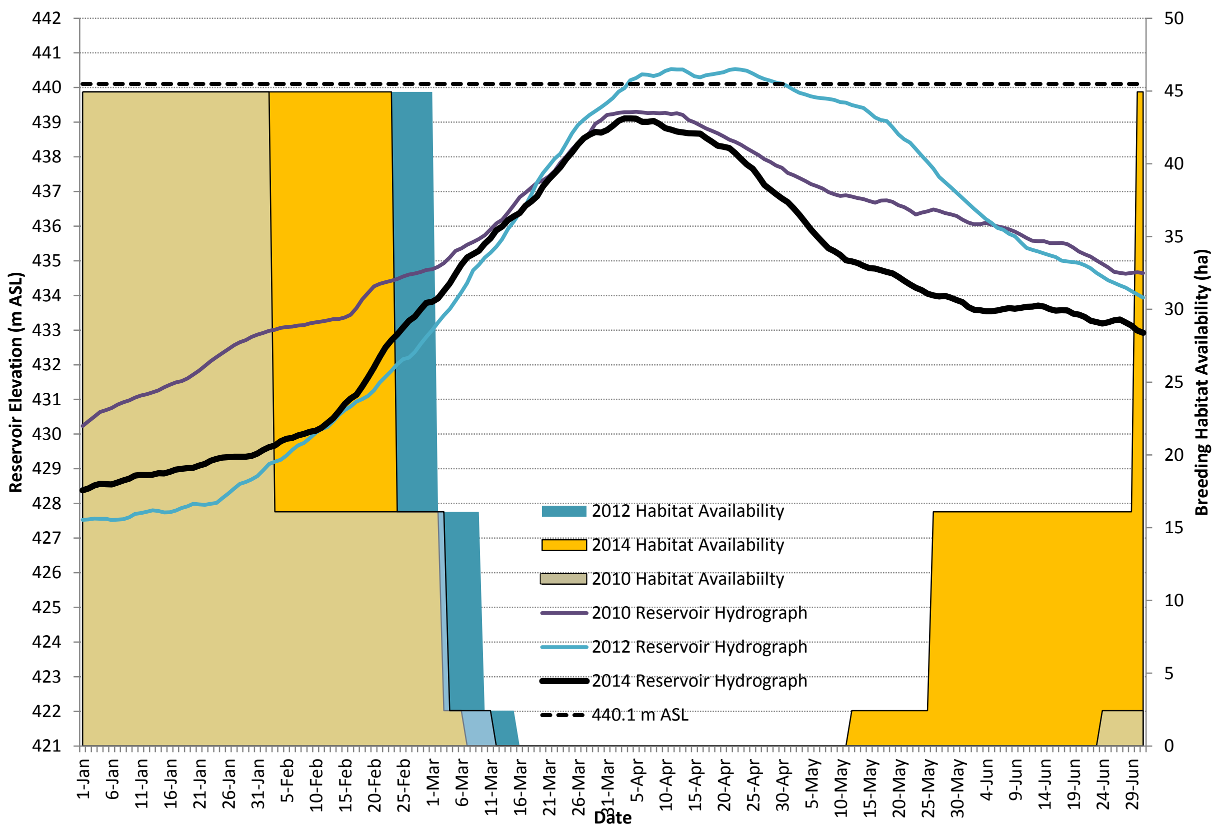

Figure 5-32: Relationship between habitat availability (pond area) and reservoir elevations for the period April 1 through September 30 (2010, 2012, and 2014 only), Arrow Lakes Reservoir

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 (with the possible exception of Burton Creek). Observations of metamorphosed toads at Cartier Bay and Beaton Arm in July and August 2010, 2012, and 2014 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. The availability of aquatic (i.e., pond) habitat varies relative to time of year and reservoir operations (Figure 5-32). A similar trend is observed for terrestrial habitat and as expected there is a strong linear relationship between reservoir elevation and habitat availability with R^2 values close to 1 for all years (see R^2 values in Figure 5-33). The annual trends are similar with only the timing and duration of inundation of each elevation band varying (see Figure 3-4; Table 5-17).

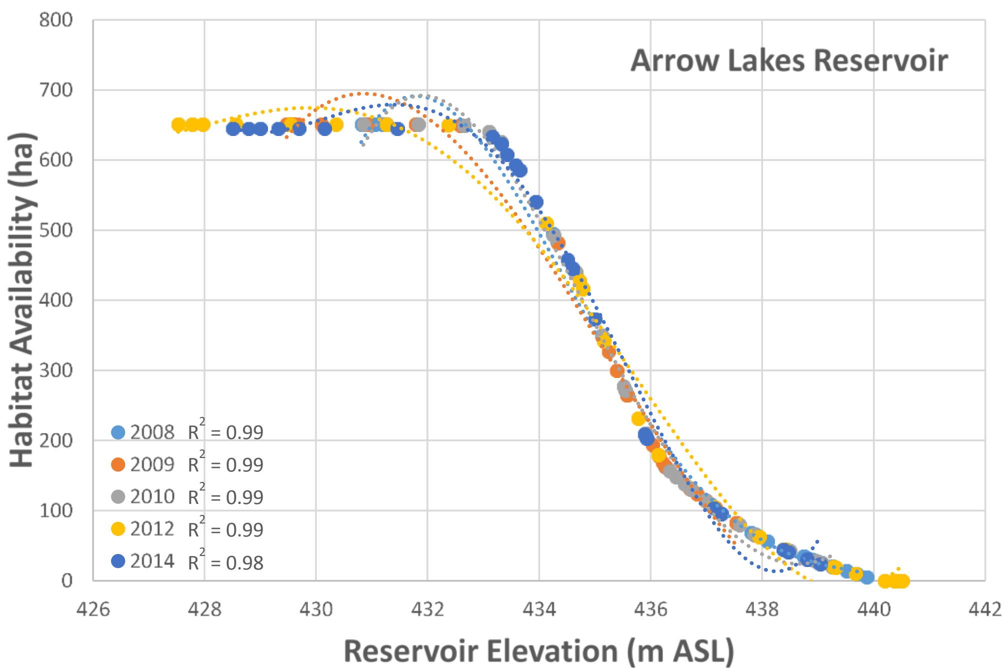

Figure 5-33: The relationship between reservoir elevation and foraging habitat availability in the drawdown zone of Arrow Lakes for the period April 1 to September 30 2008–2014. A 4th order polynomial trend line was fit to the data in each year to obtain the coefficient of determination

Table 5-17: Proportion of time between April and September (n = 183 days) that Arrow Lakes Reservoir exceeded a given range of elevations. 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
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
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
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
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
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
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
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
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
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
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
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
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

5.2.4.7 H2A: 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 Howard 2012) and those wetlands were protected from inundation through tadpole metamorphosis, the abundance of certain species may increase over time, but this is speculative.

5.2.4.8 H2B: 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.

5.2.4.9 H2C: Revegetation does not increase the amount or improve habitat for amphibians or 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 DISCUSSION

The relationship between habitats in the drawdown zone of hydroelectric reservoirs and their use by wildlife has not been well studied. While suitable habitat may exist in the drawdown zone, reservoir operations can affect both the suitability (i.e., quality) and availability (i.e., quantity) 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.

Amphibian and reptile populations appear to be persisting in the drawdown zones of Kinbasket and Arrow Lakes Reservoirs, and our data suggest that the number and size of adult Western Toads, Columbia Spotted Frogs and Common Garter

Snakes is sufficient to maintain these populations under current conditions. Furthermore, the occupancy and detection probability estimates derived for Western Toad and Columbia Spotted Frog are consistent with what is known about the natural variation of amphibian populations because of environmental stochasticity.

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 annual basis. Despite the observed changes in water physicochemical parameters and the reduction in total habitat available, both Western Toad and Columbia Spotted Frog breed successfully in ponds situated in the drawdown zone. This is hypothesized to be largely a function of the timing of breeding occurring early enough in the spring to allow for larval development to reach a stage that is less affected by reservoir inundation of breeding ponds. Preliminary data from an associated study (CLBMON-58) suggest that increasing Kinbasket Reservoir elevations by as much as 0.6 m in the summer months is unlikely to negatively impact Western Toad and Columbia Spotted Frog populations directly. However, there are likely to be direct effects on amphibian habitat resulting from the vertical and horizontal movement and depositions of large rafts of wood debris.

Although we can quantify habitat use by amphibians and reptiles, we are not currently able to quantify whether survivorship will be affected by reservoir operations that result in higher elevations at specific times of the year. Survivorship studies typically involve the use of mark-recapture techniques or radio-telemetry to study the fate of marked/tagged animals over a period of time.

In 2014, a pilot telemetry study examined habitat use of Western Toads and Common Garter Snakes. Valuable information on use of the drawdown zone by these species was gathered; however, without additional data, we will not be able to answer questions relating to overwinter habitat use, whether individuals return to and use the same ponds for breeding annually, and how amphibians and reptiles respond directly to increasing reservoir elevations over time. This topic is discussed in further details below, under Management Questions, and in the recommendations.

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

For the purposes of CLBMON-37 this management question has been answered. All expected species have been documented using the drawdown zones and adjacent upland habitats of Kinbasket Reservoir (Table 5-3) and Arrow Lakes Reservoir (Table 5-11). The most commonly occurring species in both reservoirs 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 km 79 marshes, Valemount Peatland and Ptarmigan Creek. In certain years, the Bush Arm Causeway is also productive. The most productive sites in Arrow Lakes Reservoir are Cartier Bay in Revelstoke Reach, Beaton Arm and Burton Creek.

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. Similarly, the Pacific Chorus Frog (*Pseudacris regilla*) has not been documented from the drawdown zone of Kinbasket Reservoir during field work for CLBMON-37 or 58 and it is assumed not to occur in the study area.

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. Spring surveys coincide with the peak of the breeding season when most adults are migrating to and from breeding ponds and are therefore more conspicuous. This trend was apparent in 2014 (and all previous years) 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 studied.

Amphibian species diversity (i.e., the number of amphibian species) does not vary relative to year or season, but detection rates do (see previous section), which is not surprising. Amphibian populations naturally exhibit large degrees of variation with the number of species 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 Salamanders have been documented from only a few locations (e.g., Valemount Peatland, Cartier Bay), they are likely distributed throughout Kinbasket and Arrow Lakes Reservoirs and adjacent upland habitats, particularly in areas with suitable breeding habitat. For example, during work associated with CLBMON-11A, ten Long-toed Salamanders were documented, eight from upland reference sites and two from the drawdown zone.

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], and Long-toed Salamanders) use the DDZ for reproduction (inferring 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.

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 each year (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. Within year assessments of productivity are not relevant and are 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 and km 79.5) and Arrow Lakes Reservoir (Revelstoke Reach, Burton Creek and Edgewood south). Western Terrestrial Garter Snakes have not been observed in the drawdown zone of Kinbasket, but are regularly documented in the drawdown zone of Arrow Lakes. However, this species is more frequently associated upland habitats immediately adjacent to the drawdown zone. No other reptile species are expected to occur in Kinbasket Reservoir, but Arrow Lakes Reservoir also has Northern Alligator Lizards, Western Skinks and Rubber Boas (Edgewood only) 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 likely outside of the DDZ (and this requires telemetry studies to locate the overwintering sites and verify reproductive behaviour).

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). Assessing reptile productivity requires intensive studies using mark-recapture and radiotelemetry and is well-suited to a graduate program. However, this also requires annual, not bi-annual studies.

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 is that Western Toads, some frog species and Painted Turtles use the DDZ to fulfill most of their life history stages (e.g., breeding, foraging and sometimes overwintering), while Long-toed Salamanders and garter snakes appear to use the DDZ to fulfill specific stages.

We do not have enough data for Long-toed Salamanders or on most species of reptile (e.g., garter snakes, lizards) to determine how they are using the DDZ. Long-toed Salamanders are not always easy to detect, so their perceived use of the DDZ 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.

Data from the 2014 telemetry study strongly suggest that both Western Toads and 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 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 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). Turtles additionally rely on aquatic habitats to fulfil foraging, basking and overwintering needs. Snakes, on the other hand, use habitats in the DDZ mainly for foraging because amphibians are their primary prey.

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 (Figure 5-19; Figure 5-20; Figure 5-32) and on reservoir operations (Figure 3-1; Figure 3-4).

At present we have delineated pond and non-pond habitat for the drawdown zones of both reservoirs; however, this will need to be updated on an annual basis (e.g., some ponds change from year to year, additional ponds are mapped each year). We also are beginning to assess how biotic and abiotic pond qualities are related to amphibian use and vary with respect to reservoir operations.

In Kinbasket, most species were found in the wetland-associated habitat types (swamp-horsetail, wool-grass–Pennsylvania buttercup, clover–oxeye daisy, and Kellogg's sedge) and Western Toads used a wider range of elevations than did Columbia Spotted Frogs. Western Toad and Columbia Spotted Frog both used a wide range of pond sizes and tended to occupy most available habitat.

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 are difficult to assess in the drawdown zones of Kinbasket and Arrow Lakes Reservoir. We have observed desiccation of breeding ponds, but this is likely related to natural causes. 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 regimes of both reservoirs is to fill in the spring between April and June (Figure 3-1; 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 of Kinbasket Reservoir suggest little evidence of an effect of dissolved oxygen, pH, water temperature, or conductivity on amphibian use or development. 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 made in terrestrial or aquatic habitats often decreased as reservoir elevations increased, and no species were documented at some sites in the later stages of summer when reservoir elevations were high. The seasonal changes in habitat availability affects the distribution of amphibians and the additive effects of annual displacement are currently unknown.

Although inundation affects habitat availability directly, we observed only minor changes in water physicochemical parameters and all life stages of both species were observed during each year of study. Similarly, the constant year-to-year size and mass of adult Western Toads in Kinbasket Reservoir and Common Garter Snakes in Arrow Lakes Reservoir suggests that the body size of the adult populations of these species are stable, which could be an indication of a healthy population (Deichmann et al. 2008). Because amphibians and reptiles are persisting in the drawdown zone, we can assume that the annual reduction of habitat availability does not dramatically affect local amphibian populations; however, we do not know if these populations are supressed relative to populations in non-reservoir habitats.

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

In Kinbasket minor adjustments could include maintaining the reservoir at or below elevations of ~751 m ASL year-round or delaying the inundation of habitats above 751 m ASL until late August.

In Arrow Lakes Reservoir, maintaining reservoir elevations at or below 436 m ASL year-round would minimize impacts to important habitats used by amphibians and reptiles. Alternatively, delaying the inundation of areas above 436 m ASL until late August would benefit amphibians and reptiles.

The recent management of both Kinbasket and Arrow Lakes Reservoirs has included successive years of high water, which has affected habitat availability and the habitats themselves (see 2014 results for CLBMON-10 and CLBMON-33). Even without successive years of high water, the annual filling of each reservoir to or near full pool is more likely to impact amphibians than reptiles, although there is considerable uncertainty regarding how some species such as Northern Alligator Lizards in Arrow Lakes Reservoir might be affected by high reservoir elevations.

Garter snakes (both species) are mobile and frequently use aquatic habitats for foraging, security, and thermal habitat and are unlikely to be affected by current reservoir operations during their active season (April through September). Given that we do not know where snakes are overwintering or whether there is important breeding habitat in the drawdown zone of either reservoir, we are unable to answer whether adjusting reservoir operations during winter would minimize the impacts to these species.

A separate study in Arrow Lakes Reservoir (CLBMON-11B3) is underway to assess how reservoir operations affect the Western Painted Turtle population in Revelstoke Reach.

Western Skink and Rubber Boa are unlikely to be affected by minor adjustments to reservoir operations as their preferred habitat does not occur in the drawdown zone.

With respect to amphibians, we know that the rapid inundation of breeding ponds with cold water can significantly slow tadpole development and change tadpole behaviour, which can delay metamorphosis, decrease survival, and reduce reproductive output (Ultsch et al. 1999; Bury 2008). Data for Kinbasket suggest that inundation reduces water temperature and DO and observations of Western Toad metamorphs at this location suggest they are smaller when they transform compared to other locations in the drawdown zone; however, the longer-term effects, if any, are unknown. Similar data are not currently available for Arrow Lakes Reservoir.

Successive years of high water in Kinbasket Reservoir resulted in increased rates of woody debris accumulation on important breeding habitats, which reduces the quality of these habitats for amphibians. Wind and wave action results in scouring of vegetation and the ground near the upper elevations of the drawdown zone, which contributes to increased rates of plant mortality, particularly in the willow shrub habitat that provides important garter snake habitat.

Woody debris does not have a similar effect on habitats in Arrow Lakes Reservoir, but the timing of filling does, with most pond habitat inundated in May and flooded by June. The timing of inundation coincides with the typical period of larval and tadpole development; however, we have not observed direct effects of reservoir management on amphibians or reptiles.

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

Physical works could be designed to mitigate adverse impacts on amphibians and reptiles resulting from reservoir operations. The primary impact to amphibians and reptiles is through direct effects on habitat either through loss or alteration. Examples of physical works that could be used to protect important habitats include the removal or exclusion of woody debris to expose previously covered habitats and the installation of log booms around these cleared habitats to protect them from future woody debris accumulation. This approach was tested in 2014 in one area (see results from CLBWORKS-1 2014): vegetation grew on the site following woody debris removal and the log boom appears to have protected the site from additional woody debris accumulation (V.C. Hawkes, pers. obs.). There are other areas in the drawdown zone that would benefit from a similar approach including ponds in the Valemount peatland and areas near the Bush Arm Causeway.

Hawkes and Howard (2012) developed three physical works for mid- and lower Arrow Lakes. All three projects were centred on the enhancement or creation of wetland habitat within the drawdown zone. Each of these projects would benefit amphibians and reptiles (and other species) and would mitigate the adverse impacts on amphibians and reptiles resulting from reservoir operations. Evidence form other similar projects (e.g., Hawkes and Fenneman 2010, Tuttle 2012) suggest the utility of these types of physical works for providing amphibian habitat to be very high.

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 amphibians and reptiles. As of 2014, the majority of the revegetation treatments applied in the drawdown zone of Kinbasket have failed (Hawkes et al. 2013). The one area showing signs of success (KM88) was not revegetated to benefit amphibians and reptiles and the longer-term survival of those plants has yet to be determined. Although revegetation was not facilitated by way of live staking or sedge plugs, the removal of woody debris has promoted the natural regrowth of vegetation and it is predicted that by protecting the woody debris removal area with a log boom, that vegetation will establish and develop naturally.

For Arrow Lakes Reservoir, the answer is no, revegetating the drawdown zone does not affect the availability and use of habitat by amphibians and reptiles. 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.

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?

See Section 6.7 for Kinbasket Reservoir. More data are required to determine if the woody debris removal and log boom installation increase the abundance and productivity of amphibians and reptiles in the drawdown zone. Given that all expected species of amphibians and reptiles have been documented from the drawdown zone of Kinbasket Reservoir, there is no reason to believe that physical works will increase diversity.

Physical works have not been implemented in the areas monitored for amphibians and reptiles in Arrow Lakes Reservoir. This question cannot be answered at this time.

6.10 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. For example, to answer questions regarding overwinter habitat use by amphibians and reptiles and to determine exactly how snakes are using the drawdown zone in all seasons, a telemetry study is required. Continued monitoring of amphibian and reptile populations in the drawdown zone should provide the necessary information to answer most management questions provided that new methods are used in subsequent years (i.e., beginning in 2015 for CLBMON-58). 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 resulted in the documentation of all expected species in the drawdown zone	• Annual sampling (to assess annual occupancy) • Increased frequency of sampling within a year	• Natural annual population variation • Inconspicuous species (e.g., Long-toed Salamander) • Bi-annual sampling • 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?	Partially	5 years of site occupancy and detection rates data. Productivity estimated for some species	• Intensive productivity data collection for ANBO, RALU and THSI • Annual sampling for select amphibians • Constrain study to Revelstoke Reach and Burton Creek in Arrow • Add other sites as physical works are implemented	• Natural annual population variation • Unknown rate of immigration may confound productivity estimates • Inconspicuous species • Mortality difficult to assess • Bi-annual sampling • 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?	Partially	5 years of site occupancy data across multiple sites and seasons	• Telemetry studies on Western Toads and garter snakes to assess overwinter habitat use. This may only need to occur once to determine whether this species is using habitats in the drawdown zone to overwinter	• Natural annual population variation • Inconspicuous species • Lack of knowledge regarding the use of the drawdown zone in the winter. Still not resolved after telemetry trial in 2014. • Variable reservoir operations
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)?	Probably	5 years of macro and micro habitat data collection	• Reduce the number of monitoring sites • Focus on ANBO, RALU and THSI • Continue telemetry study on Western Toads and garter snakes to assess habitat use • Re-evaluate existing habitat mapping and its relevance to amphibians and reptiles	• Inconspicuous species • Habitat mapping is required at a scale relevant to amphibians and reptiles • Frequency of sampling-more intensity required for telemetry studies. • Variable reservoir operations
MQ5: How do reservoir operations influence or impact amphibians and reptiles directly (e.g., desiccation, inundation, predation) or indirectly through habitat changes?	Partially	5 years of data collected on the occurrence and distribution of amphibians and reptiles in the drawdown zones	• None	• Natural annual population variation • Variable reservoir operations • Habitat mapping is required at a scale relevant to amphibians and reptiles • Better characterization of wetland habitats

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?	Possibly	N/A	• Restrict Kinbasket Reservoir elevations for one year to elevations < 751 m ASL to determine whether doing so alters the use of the drawdown zone by amphibians and reptiles. • Arrow Lakes: maintain reservoir elevations < 436 m ASL or delay inundation of habitat > 436 to late August	• Lack of 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
MQ7: Can physical works projects be designed to mitigate adverse impacts on amphibians and reptiles resulting from reservoir operations?	Partially	N/A	• Implement physical works in Arrow Lakes Reservoir • Assess effectiveness of woody debris removal and log boom installation in Kinbasket Reservoir	• Physical works have not been implemented in Arrow Lakes Reservoir. Until they are we cannot answer this question.
MQ8: Does revegetating the drawdown zone affect the availability and use of habitat by amphibians and reptiles?	Yes	Assessments of revegetation effectiveness (CLBMON-9, 12); 5 years of monitoring data	• Kinbasket: revegetate high potential sites using combinations of woody debris removal, log boom installations, and revegetation (or a combination of these). • Arrow Lakes: implement revegetation prescription that will benefit amphibians and reptiles. Focus on habitats adjacent to wetlands or that expand dense shrub habitats.	• Revegetation in Kinbasket has been a failure. • Revegetation in Arrow moderately successful, but not designed to benefit amphibians and reptiles.
MQ9: Do physical works projects implemented during the course of this monitoring program increase amphibian and reptile abundance, diversity, or productivity?	Not at this time	N/A	• Implement physical works in Arrow Lakes Reservoir. • Assess effectiveness of physical works done in Kinbasket Reservoir in 2014.	• Physical works have not been implemented in Arrow Lakes Reservoir. Until they are we cannot answer this question. • No monitoring pf physical works installed in Kinbasket Recommend this occurs in 2015 (CBMON-58).

7 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 (especially related to the impacts of Mica 5/6 in Kinbasket [CLBMON-58]), determine their habitat use, and assess the impacts of any revegetation and physical works on species that use habitats within the drawdown zones of Kinbasket and Arrow Lakes Reservoirs.

In 2016, we will continue to monitor amphibian and reptile populations in the DDZ using the methods applied in previous years. Recommendations are made regarding how amphibians are sampled in the drawdown zone and regarding reservoir operations:

Sampling

1. Consider annual sampling in Arrow Lakes Reservoir to increase the time series of data. Annual sampling has occurred in Kinbasket Reservoir since 2011 and is facilitated by the implementation of CLBMON-38 and CLBMON-37 in alternating years.
2. Constrain sampling in Arrow Lakes Reservoir to Revelstoke Reach, Beaton Arm, Burton Creek, and Edgewood (Eagle Creek). These sites are the most appropriate to continue monitoring due to the presence of multiple species, relatively large populations, ease of access, and measurable changes to breeding habitat within a year;
3. Consider continuing and/or possibly increasing the amount of pitfall trapping at various monitoring locations (e.g., Bush Arm Causeway) to determine site occupancy of inconspicuous species of amphibians that migrate to and from breeding ponds;
4. 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 sites used by pond-breeding amphibians, particularly Western Toads and Columbia Spotted Frogs, to determine their productivity and survival in various habitats in the drawdown zone.
5. Consider including additional Master's programs into this study focusing on a variety of topics. This would not only increase the amount of data collection possible over two consecutive years of the study, but would also allow for the in-depth examination of one or more of the management questions. Possible studies could include:
    - Garter snake study focusing on abundance, productivity (gravid and non-gravid female size ranges and egg counts), seasonal habitat use for garter snakes in the drawdown zone and upland habitats compared to reservoir elevations, and interspecific species microhabitat use;
    - Seasonal habitat use of Western Toads and Columbia Spotted Frogs (via radiotelemetry and mark recapture methods);
    - Amphibian reproduction and development (e.g., characteristics of egg mass deposition sites and consequence survivorship of larvae through to metamorphs, pre and post inundation comparisons, enclosure experiments manipulating varying water physicochemical conditions reflecting pond/reservoir variables)
6. Continue telemetry study on Western Toads and Common Garter Snakes for a few years (preferably with a graduate student; see above). This will provide valuable information on the use of the drawdown zone by these species on a seasonal basis, including the winter period, which will remove uncertainty as to whether the drawdown zone provides overwintering habitat for certain species. Longer-term radiotelemetry data will help determine:
    - What time of year animals are most likely to use the drawdown zone;
    - Where animals are overwintering;
    - Whether amphibians are returning to the same breeding ponds each year;
    - Specific microhabitat use of the drawdown zone by adult animals of each species

Without this information, it will not be possible to determine the effects of normal or adjusted reservoir operations will be on amphibians and reptiles that use the drawdown zone of Kinbasket and Arrow Lakes Reservoirs.

7. Install continuous data loggers in Arrow Lakes Reservoir to obtain DO and temperature data pre- and post-inundation.

Reservoir Operations

1. The inundation of elevations between ~735 and 754 m ASL (Kinbasket) and ~434 and 440 m ASL (Arrow) should occur on or as close to the historical date calculated for the period 1978 to 2014 as possible.
2. For Kinbasket only, given that reservoir elevations are predicted to increase in the summer months as a result of the installation of units 5 and 6 at Mica Dam, achieving full pool in July is not recommended and maximum reservoir elevations should be targeted for the current average date of August 25. This will ensure that amphibians and reptiles using the drawdown zone, particularly those in ponds >751 m ASL, will have enough time to develop prior to inundation.

8 ADDITIONAL REPORTING REQUIREMENTS

8.1 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.	Final technical report	Submitted February 2015
2.	300 word abstract	Submitted February 2015
3.	Copies of notes, maps, photos	Submitted February 2015
4.	Digital appendix (data)	Submitted February 2015

8.1.1 Data Provided to BC Hydro

An MS Access database and GIS files containing all 2008 through 2014 data will be provided to BC Hydro in February 2015. This database conforms to the standards established by the B.C. Ministry of Environment for wildlife species inventories.

8.1.2 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. This task will be conducted in December 2014.

8.2 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. The **Columbia Spotted Frog** is currently (as of October 2010) a

COSEWIC status report candidate species. The status of this species remains not assessed and populations are considered to be stable throughout its range.

One species of reptile with federal conservation status was documented (**Western Painted Turtle**), either in or near the DDZ of Arrow Lakes Reservoir. Similarly, the Western Toad, which is a SARA Schedule 1 species of Special Concern was detected in various locations of the drawdown zone of Arrow Lakes Reservoir. The **Western Skink** (*Plestiodon skiltonianus*) is blue-listed in British Columbia and is a SARA Schedule 1 species of Special Concern. This species was documented in the drawdown zone of Arrow Lakes Reservoir near Deer Park (2010) and at Edgewood in the west-central portion of the reservoir in 2010, 2012, and 2014. The **Rubber Boa** (*Charina bottae*) is yellow-listed in British Columbia, and is a SARA Schedule 1 species of Special Concern. This species was documented just outside the drawdown zone of Arrow Lakes Reservoir at Edgewood North in the west-central portion of the reservoir in 2010.

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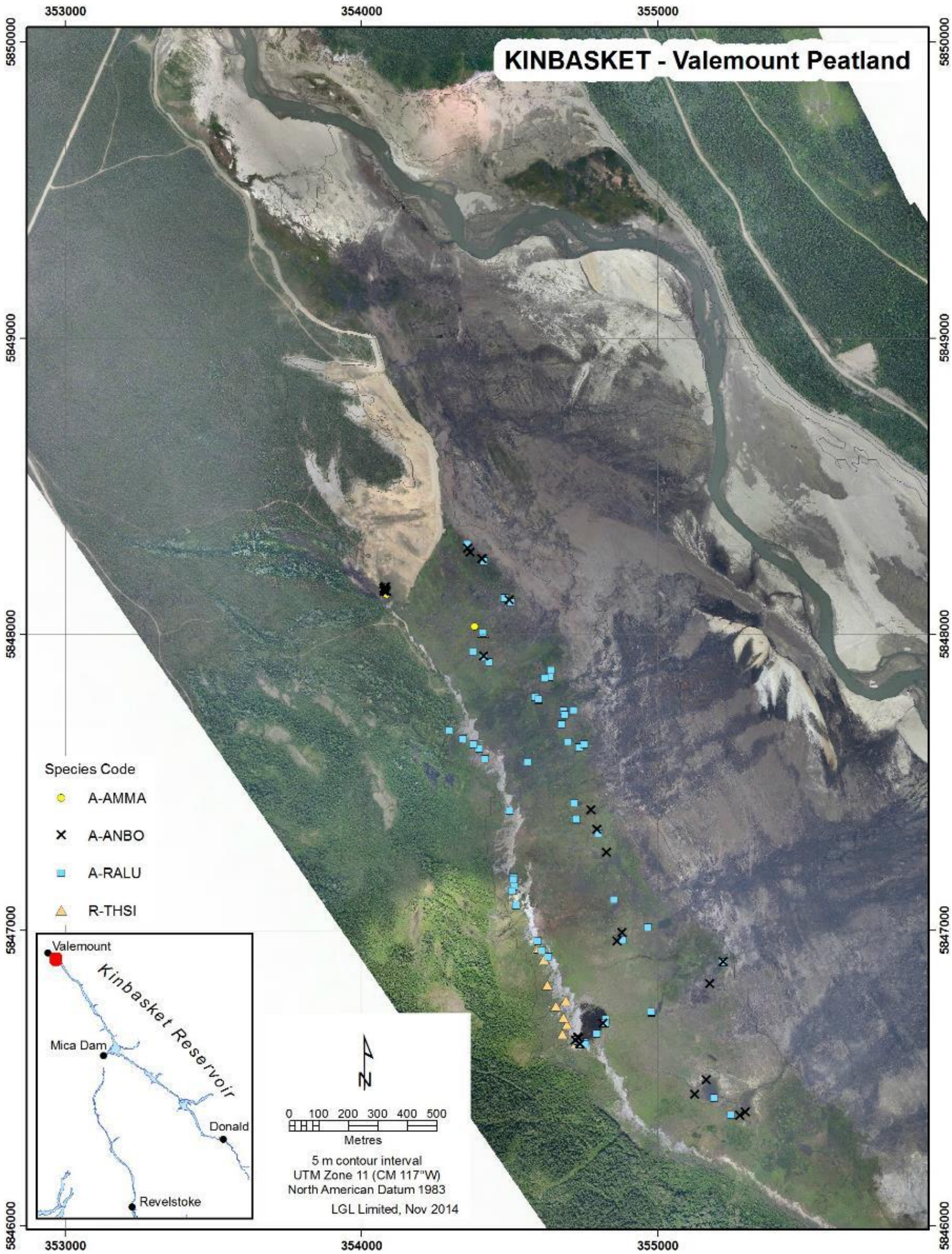
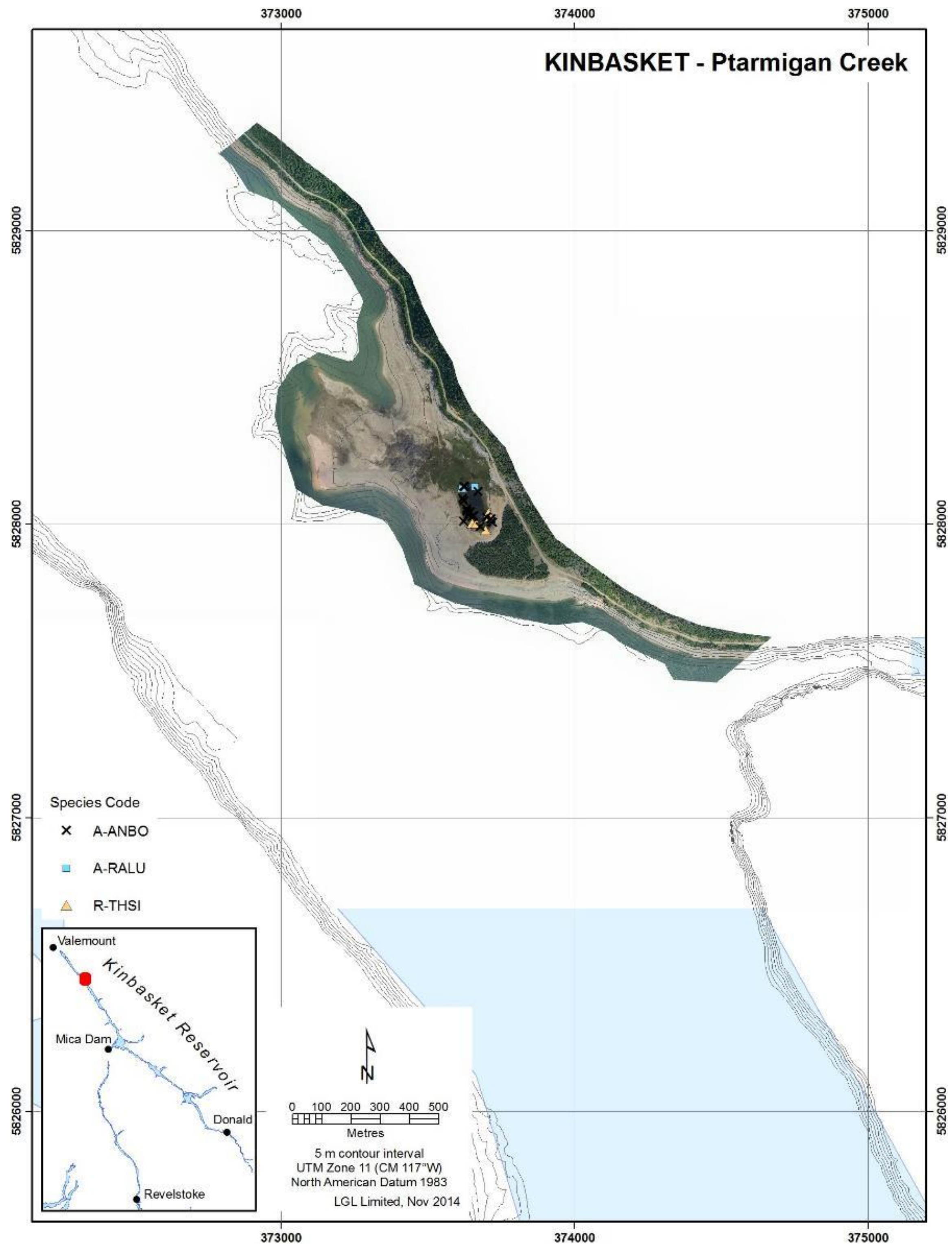
10 APPENDICES

Appendix 10-1: Survey locations and amphibian and reptile captures made during the 2014 life history and habitat monitoring surveys in Kinbasket and Arrow Lakes Reservoirs

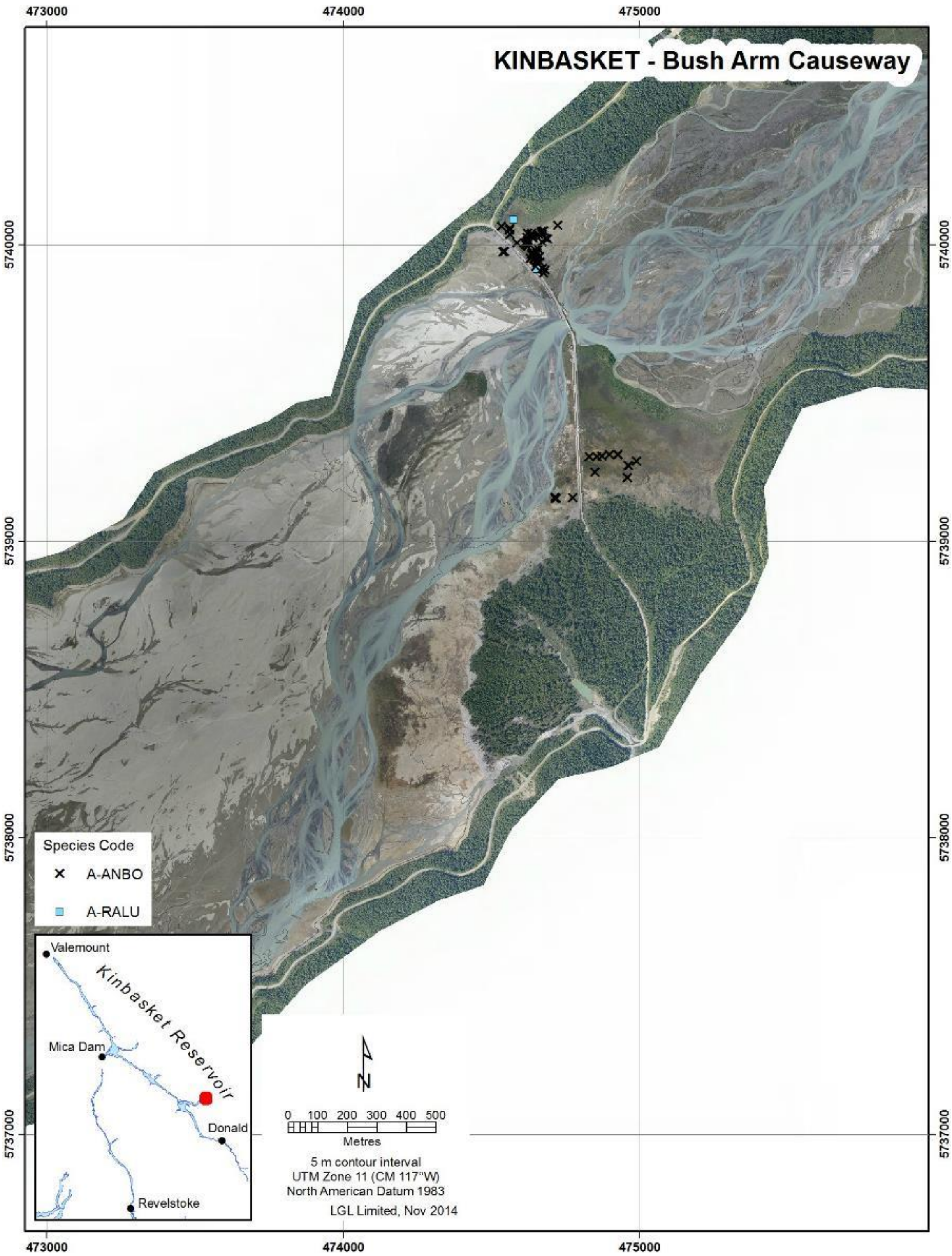
The following maps identify the survey locations visited in each reservoir and the species documented at those locations.



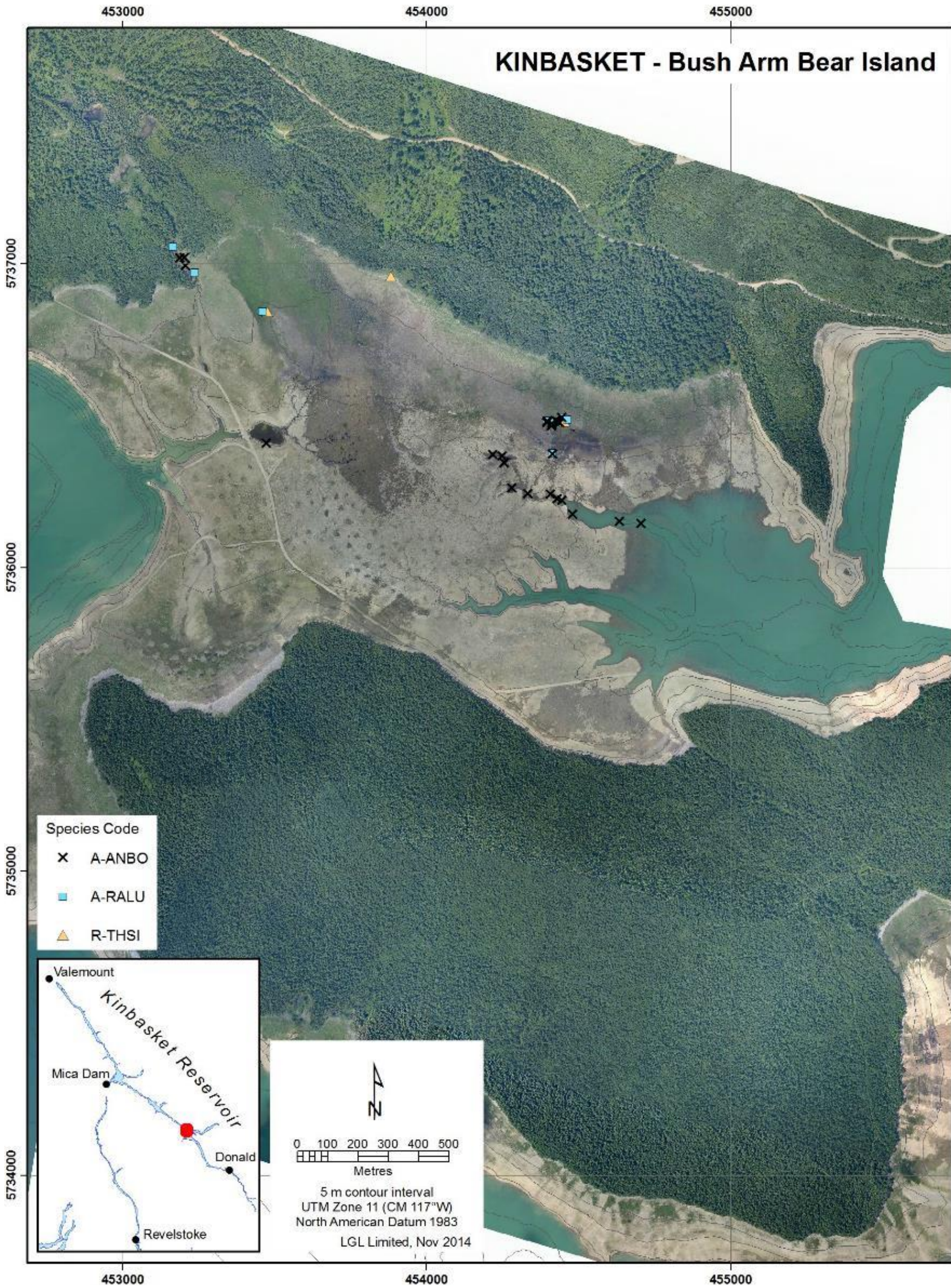
Map 10-1: Species documented in the Valemount Peatland, Kinbasket Reservoir. Species codes can be found in Table 4-1



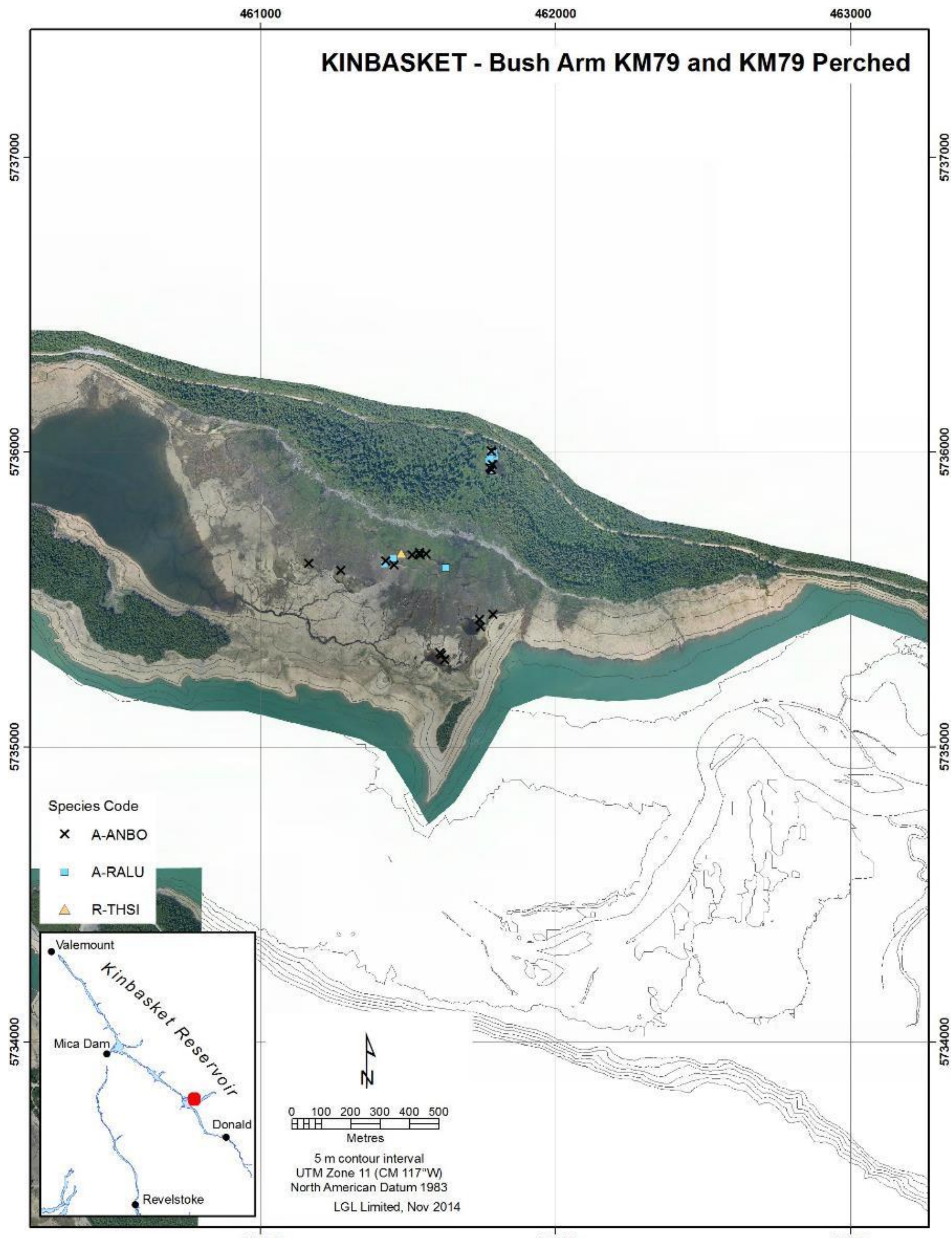
Map 10-2: **Species documented at Ptarmigan Creek, Kinbasket Reservoir.** Species codes can be found in Table 4-1



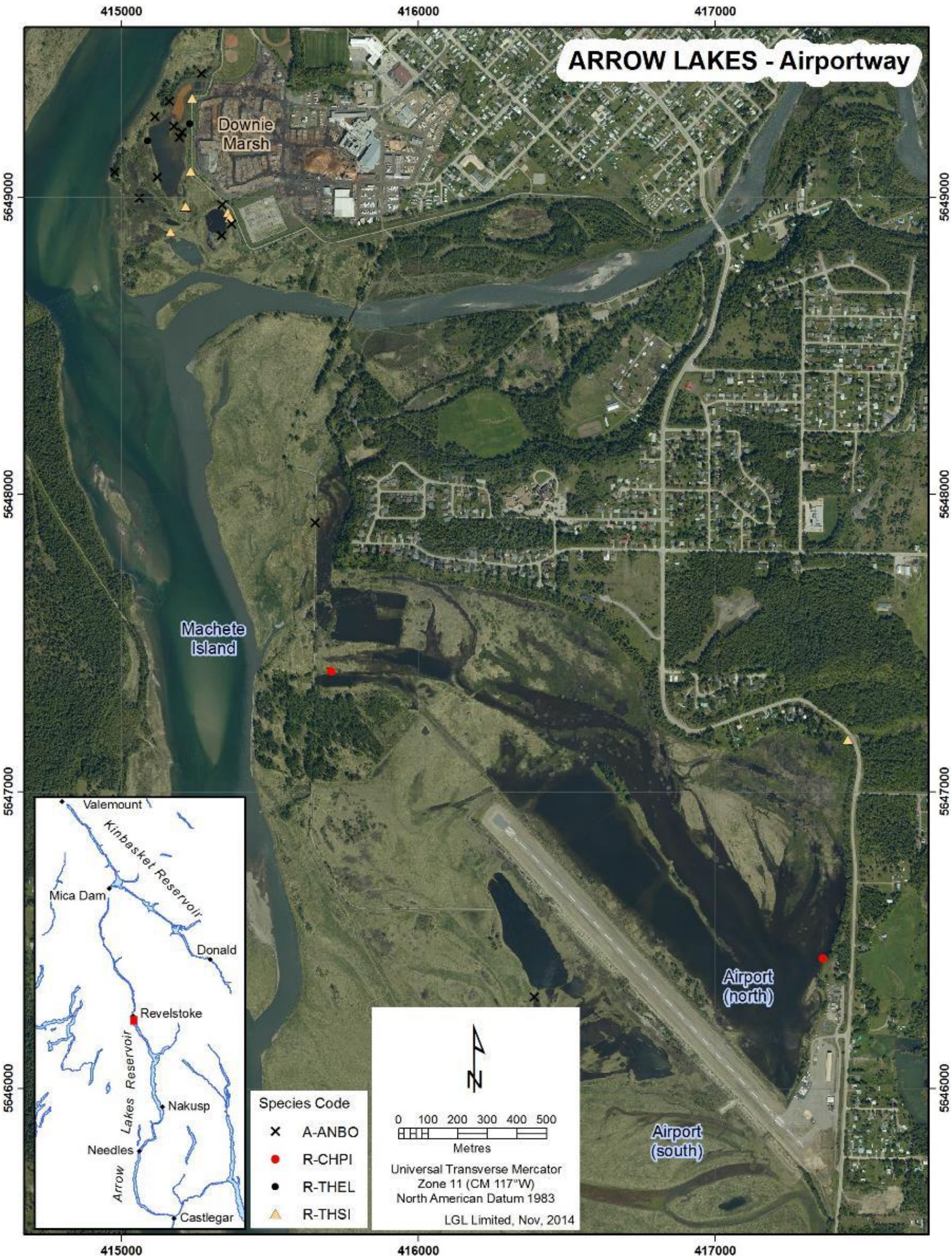
Map 10-3: Species documented at Bush Arm (Causeway), Kinbasket Reservoir. Species codes can be found in Table 4-1



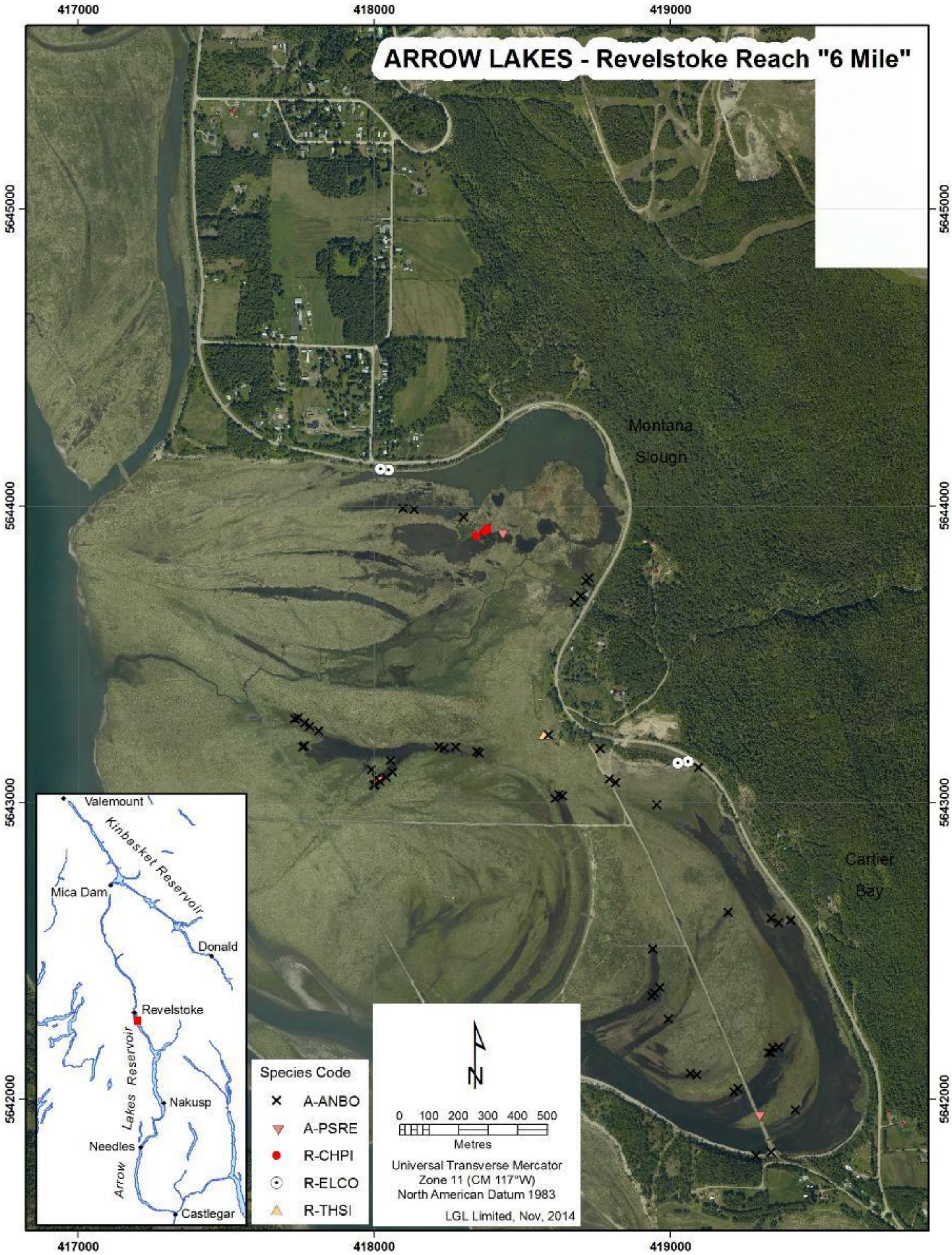
Map 10-4: **Species documented at Bear Island in Bush Arm, Kinbasket Reservoir.** Species codes can be found in Table 4-1



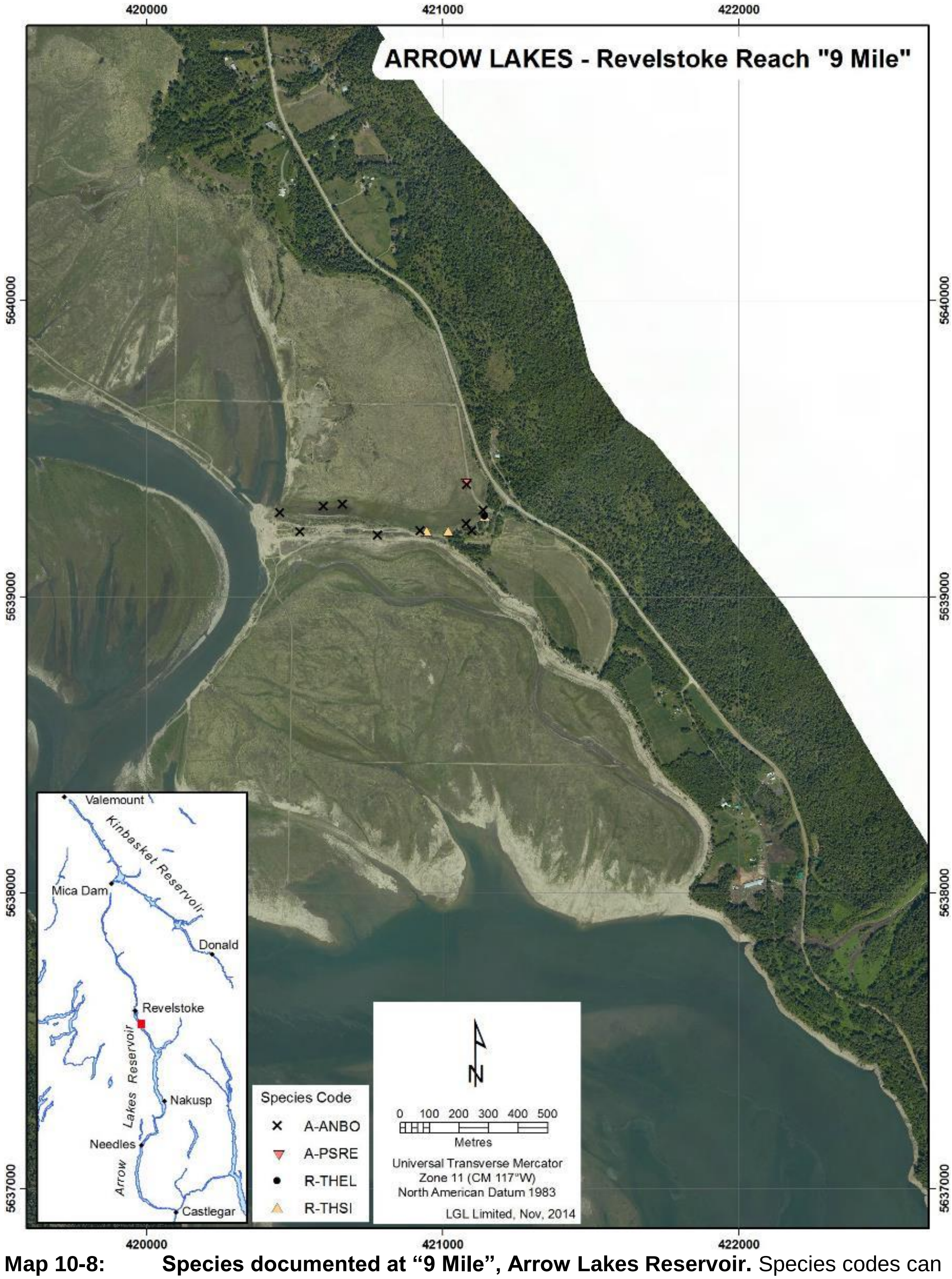
Map 10-5: Species documented at km 79 marshes Bush Arm, Kinbasket Reservoir. Species codes can be found in Table 4-1



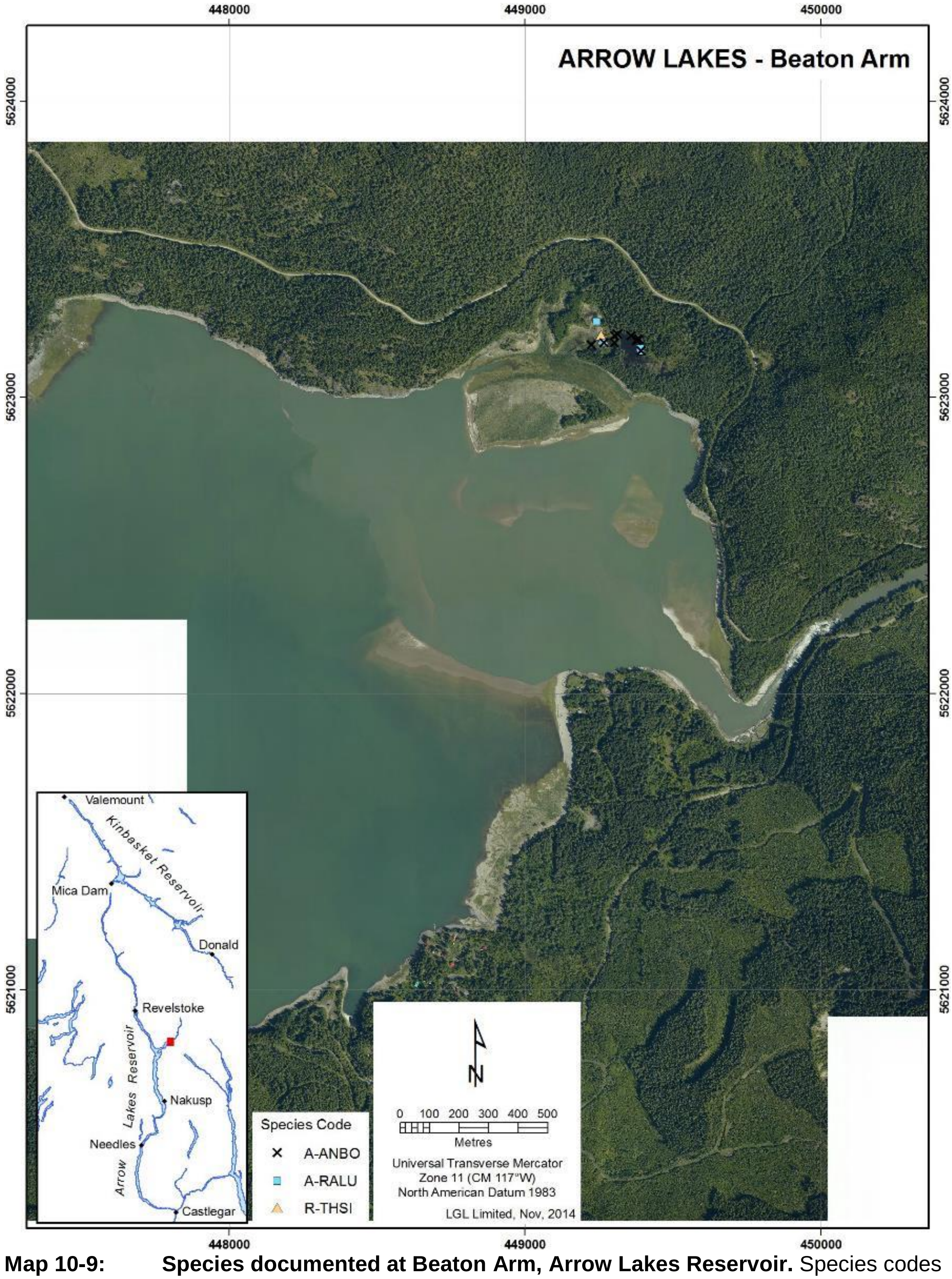
Map 10-6: Species documented at Airport Marsh, Arrow Lakes Reservoir. Species codes can be found in Table 4-1



Map 10-7: **Species documented at "6 Mile", Arrow Lakes Reservoir.** Species codes can be found in Table 4-1

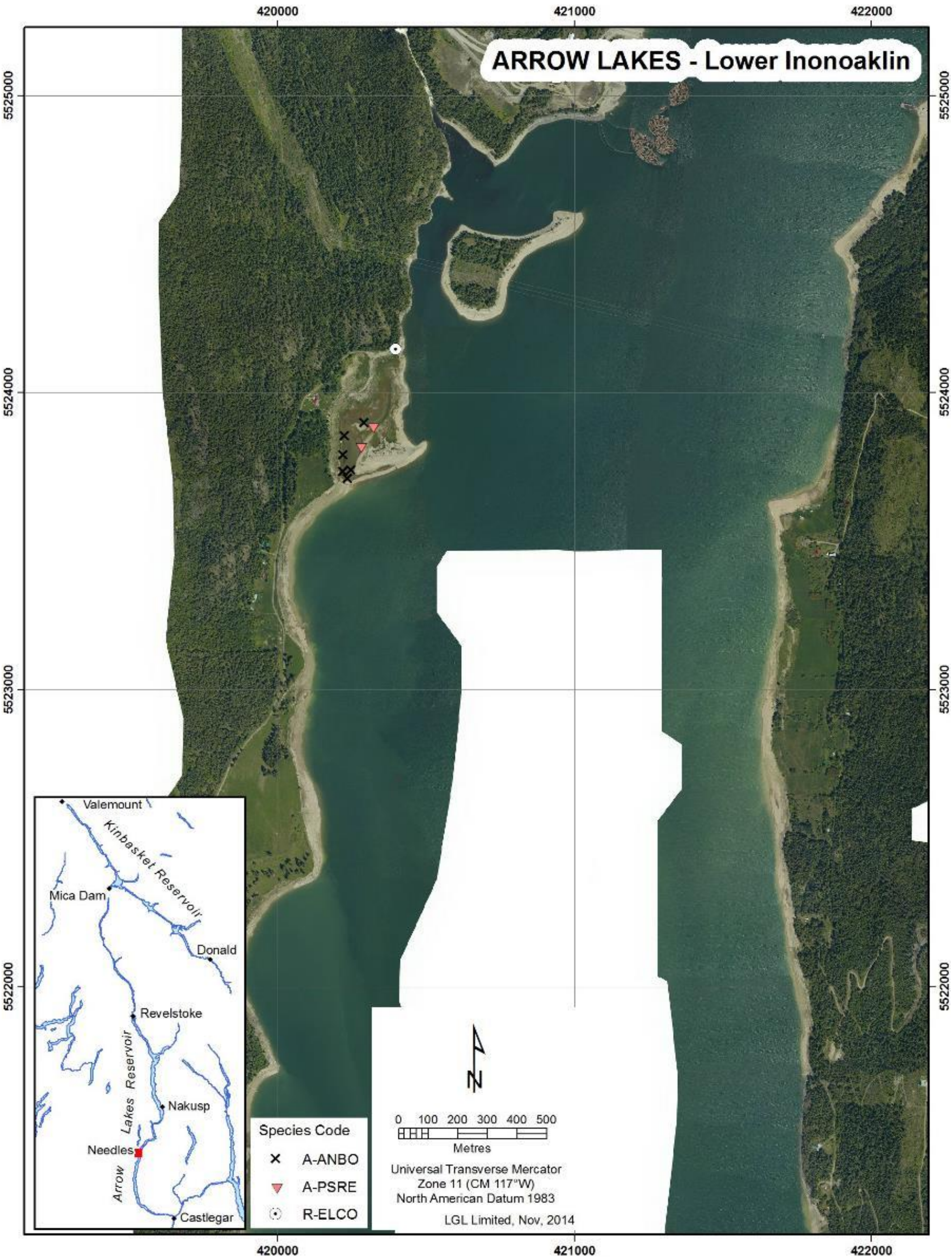


Map 10-8: **Species documented at "9 Mile", Arrow Lakes Reservoir.** Species codes can be found in Table 4-1

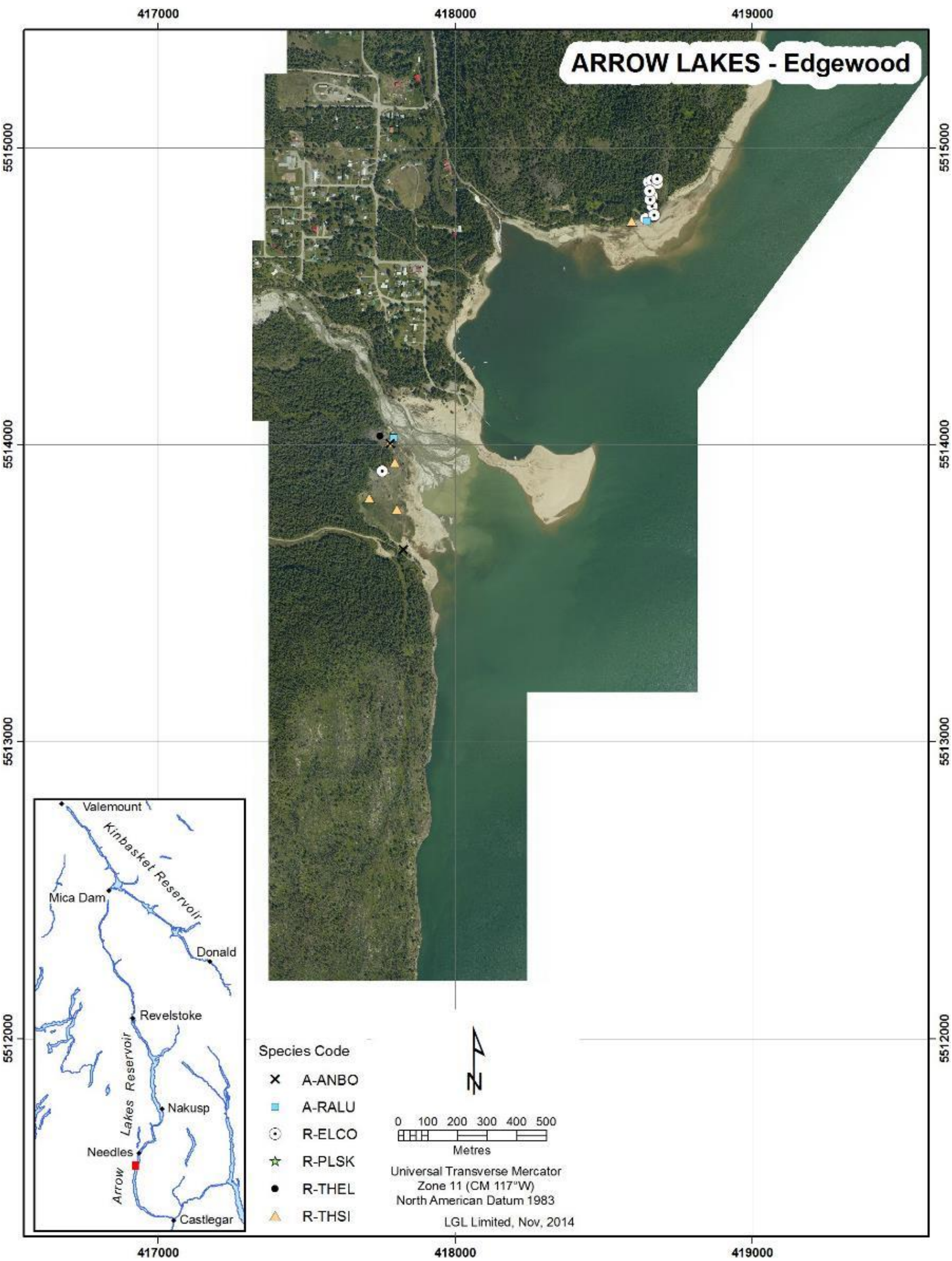


Map 10-9: Species documented at Beaton Arm, Arrow Lakes Reservoir. Species codes can be found in Table 4-1

Map 10-10: Species documented at Burton Creek, Arrow Lakes Reservoir. Species codes can be found in Table 4-1



Map 10-11: Species documented at Lower Inonoaklin Road, Arrow Lakes Reservoir. Species codes can be found in Table 4-1



Map 10-12: Species documented at Edgewood, Arrow Lakes Reservoir. Species codes can be found in Table 4-1