Columbia River Project Water Use Plan

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

Reference: CLBMON-37

Comprehensive Report

Study Period: 2008 – 2018

Okanagan Nation Alliance, Westbank, B.C.

and

LGL Limited environmental research associates
Sidney, B.C.

June 8, 2020

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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




Final Report - Draft

Prepared for

BC Hydro

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Water Licence Requirements
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Cover photos:

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

EXECUTIVE SUMMARY

This year marked the final year of CLBMON-37, an 11-year amphibian and reptile life history and habitat use monitoring study in the drawdown zones of Kinbasket and Arrow Lakes Reservoir. Initiated in 2008, CLBMON-37 was designed to address the relative contribution 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 drawdown zones of each reservoir. In 2011, a second component to the program was added: CLBMON-58, which specifically addressed 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 were investigated in this study, including how amphibian and reptile communities using habitats in the drawdown zone of hydroelectric reservoirs 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.

Using a variety of survey methods (e.g., visual encounter surveys, call surveys, road surveys), we documented the presence of three amphibian and two reptile species in Kinbasket Reservoir and four amphibian and six reptile species in Arrow Lakes Reservoir. Western Toad (*Anaxyrus boreas*), Columbia Spotted Frog (*Rana luteiventris*), and Common Garter Snake (*Thamnophis sirtalis*) were the most commonly encountered species in Kinbasket Reservoir, usually in wetlands within wool-grass-Pennsylvania buttercup, Kellogg's sedge, or swamp-horsetail habitats. The most detected species in Arrow Lakes Reservoir included Western Toad, Pacific Chorus Frog (*Pseudacris regilla*), Western Terrestrial Garter Snake (*Thamnophis elegans*), and Common Garter Snake, which were typically observed in reed canary grass mesic habitat.

Most species were widely distributed and abundant in each reservoir. Certain species (e.g., Western Skink [*Plestiodon skiltonianus*]; Rubber Boa [*Charina bottae*], and Western Painted Turtle [*Chrysemys picta belli*]) were more limited in their distribution with Western Skink and Rubber Boa constrained to lower Arrow Lakes Reservoir south of Lower Inonoaklin Road and Western Painted Turtle found primarily in Revelstoke Reach. An incidental observation of a Western Painted Turtle at KM88 - Bear Island (Bush Arm, Kinbasket Reservoir) was unexpected and is currently considered an anomaly. Of the amphibian species detected, one (Western Toad) is considered to be at risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and is a SARA Schedule 1 species of Special Concern (November 2012). For reptiles, the Intermountain-Rocky Mountain Population of the Western Painted Turtle is blue-listed in British Columbia and is a SARA Schedule 1 species of Special Concern, as is the Western Skink. The Rubber Boa is yellow-listed in B.C. but is also a SARA Schedule 1 species of Special Concern.

The continued presence of amphibian and reptile species in the drawdown zone of each reservoir suggested there were important habitat features in these zones that contributed to the ability of these species to fulfill their life requisites. Indeed, in some places (e.g., Revelstoke Reach in Arrow Lakes Reservoir and Valemount Peatland in Kinbasket Reservoir), the drawdown zone provided important breeding habitats for pond-breeding amphibians such as Western Toad, Long-toed

Salamander, and Columbia Spotted Frog that were of limited local availability. These habitats (ponds and wetlands) were used year-over-year for breeding during this study.

The limited availability of these habitats underscored their importance for the continued persistence of amphibians and reptiles in the drawdown zones of both reservoirs. By the study's conclusion, there was limited evidence of direct effects of reservoir operations (timing, duration, frequency of inundation) on most of the species using these habitats. There was evidence of reduced seasonal habitat availability resulting from the variable yet predictable[1] manner in which Kinbasket and Arrow Lakes Reservoir were managed. As each reservoir filled in the spring and summer, the amount of useable habitat available to amphibians and reptiles decreased. Thus, there was a direct relationship between increased reservoir elevations and the reduced seasonal distribution and habitat use of amphibians and reptiles. Data collected over 11 years indicate that as the reservoir fills, amphibians and reptiles continue to occupy pond habitats that have not yet been inundated. They also occupy habitats at the leading edge of the reservoir until there is either no drawdown zone left (i.e., if reservoir reaches full pool), the reservoir begins to recede, or amphibians and reptiles return to their wintering habitats, which are primarily above the normal high-water mark of each reservoir.

In general terms, and except for direct effects on the seasonal distribution and habitat use of amphibians and reptiles in the drawdown zone, we found little evidence of direct effects of varying annual reservoir operations on amphibian and reptile abundance, diversity, or productivity in either Kinbasket Reservoir or Arrow Lakes Reservoir. For species that bred in the drawdown zone (i.e., pond-breeding amphibians), breeding occurred in ponds and wetlands prior to inundation from either reservoir. However, in certain areas of Kinbasket Reservoir (e.g., Km 88, Bush Arm), Western Toads using lower elevation (~736m ASL) ponds for breeding may have been impacted by reservoir inundation, but no direct observations of possible impacts were made. As noted above, foraging habitat (or habitat availability in general) was affected throughout the season as a result of increasing reservoir operations. Western Painted Turtle was the only species confirmed to overwinter in the drawdown zone (Revelstoke Reach, Arrow Lakes Reservoir) and there was no indication of adverse effects of reservoir operations on wintering individuals.

We found no indication of negative effects on habitat availability from increased reservoir elevations in Kinbasket Reservoir as a result of the installation and operation of Mica Units 5 and 6. The lack of effect was related to the predicted timing of increased reservoir elevations, which was associated with the summer months (i.e., July and August) in three of every ten years of operations. Pond-breeding amphibians laid eggs in early spring with hatching and development into free-swimming tadpoles occurring in early summer. As such, the timing of amphibian development into free-swimming tadpoles preceded the timing of inundation of breeding habitats in the drawdown zone of Kinbasket Reservoir. The tadpoles continued to develop for a period of several weeks before transforming into froglets or toadlets, all the while occupying the shallow leading edge of the

[1] Variable and predictable refers to the way Kinbasket and Arrow Lakes Reservoirs are managed. Its predictable in that the reservoirs are drawn down in the winter and spring, filled through the spring and summer, and maintained at their highest elevations through the fall. It is variable in that the elevations achieved on a given data can vary considerably. See Figure 2-1and Figure 2-4.

reservoir. Our observations indicated that the rate of advancement (filling) of the reservoir was slow enough that tadpoles could transform into froglets or toadlets before all useable habitat in the drawdown zone was inundated. This observation remained even with a predicted increase in maximum reservoir elevations associated with the installation and operation of Mica Units 5 and 6.

The findings from this 11-year initiative have greatly increased the current understanding regarding the occurrence and distribution of amphibians and reptiles in habitats in and adjacent to Kinbasket and Arrow Lakes Reservoir. The variable yet predictable manner in which these reservoirs were managed did not appear to adversely affect local populations of the species documented, although habitat impacts were obvious and expected. Through various initiatives, such as physical works (e.g., wood debris removal and wetland creation) completed in parts of Kinbasket and Arrow Lakes Reservoir, there were opportunities to enhance the habitat suitability of the drawdown zone for amphibians and reptiles and future initiatives in this regard are encouraged.

A summary of key findings relative to the management questions asked under CLBMON-37 and -58 is provided below. Included for each management question is a summary of key results for each question along with remaining sources of uncertainty (or limitations).

Management Question (MQ)	Summary of Key Results
MQ1: Which species of amphibians and reptiles occur (utilize habitat) within the drawdown zone and where do they occur?	<u>Summary of Findings</u> Over an 11-year period, we observed all species of amphibian and reptile predicted to occur in the region making use of both reservoir drawdown zones and the surrounding upland areas. Site occupancy of species varied by reservoir and study sites. The most common amphibian species observed in the drawdown zones were Western Toad (Kinbasket and Arrow Lakes Reservoir) and Columbia Spotted Frog (Kinbasket and Arrow Lakes Reservoir), followed by Pacific Chorus Frog (Arrow Lakes Reservoir) and Long-toed Salamander (Kinbasket and Arrow Lakes Reservoir). Coeur d'Alene Salamander were observed using upland habitats adjacent to the drawdown zone (Arrow Lakes Reservoir) but not within the drawdown zone. Common Garter Snake were the most abundant reptile documented in both reservoirs, followed by Western Terrestrial Garter Snake (more abundant in Arrow Lakes Reservoir). Western Painted Turtles were common in Revelstoke Reach (Arrow Lakes Reservoir) and three other reptile species were documented using habitats in the upper elevations of the drawdown zone (Western Skink, Northern Alligator Lizard, Rubber Boa). Arrow Lakes Reservoir had higher species richness than Kinbasket Reservoir. Sites with the highest species richness included Revelstoke Reach (Airport Marsh, Cartier Bay, Montana Slough), Burton Creek, and Beaton Arm for Arrow Lakes Reservoir, and Bush Arm (Causeway, KM79, KM88) and Valemount Peatland for Kinbasket Reservoir. <u>Sources of Uncertainty/Limitations</u> Data collection focused primarily on visual encounter surveys (as well as early spring auditory call surveys and road surveys) to monitor amphibians and reptiles during their active seasons (approx. May to September). Many of the target species were easily located and identified via these survey methods; however, some species (e.g., Long-toed Salamanders, lizards, turtles) may have been underestimated due to their inconspicuous nature (e.g., Long-toed Salamander), natural annual population variation, or inconsistent use of the drawdown zone (upland-associated species). Due to the large geographic range of this study, reconnaissance surveys across both reservoirs were conducted in 2008 to narrow down the study sites that were deemed suitable monitoring sites (based on pond/wetland habitat and species observations), therefore it is possible that certain species (especially if inconspicuous) were not observed at sites that were only periodically visited (e.g., Hugh Allan Bay, Mosquito Creek). <u>Comments</u> Two incidental observations of Western Painted Turtle occurred at Kinbasket Reservoir in 2015 (Bush Arm KM88) and 2016 (Canoe Reach, near Cranberry Marsh, Valemount). Each observation was a solitary turtle that was verified to species by hand capture and/or photos of the plastron. These observations were unexpected due to the current known range of this species. Turtle-specific surveys (e.g., hoop-trapping) were not conducted at either of these sites. Wood Frog has historic records for the Kinbasket region; however, no drawdown zone observations were made during our study. This species has been documented in several wetlands in the Robson and McBride Valleys, but the current range of this species may not overlap with Kinbasket Reservoir. Species-specific targeted surveys for Western Skink, Rubber Boa, Long-toed Salamander, Coeur d'Alene Salamander, and Western Painted Turtle are recommended for certain sites if additional data are desired or required for future physical works projects.

Management Question (MQ)	Summary of Key Results
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?	Summary of Findings Abundance: Our data showed Western Toad, Columbia Spotted Frog, and Common Garter Snake were the most abundant species in both reservoirs. Western Painted Turtle were abundant only in Revelstoke Reach (Arrow Lakes Reservoir), and Pacific Chorus Frog occurred only in Arrow Lakes Reservoir. Other species were less abundant across the monitoring sites, especially Long-toed Salamander, although this was largely attributed to their inconspicuous nature. Edgewood North and South were the only drawdown zone locations for Western Skink, whereas the only drawdown zone location recorded for Rubber Boa was Lower Inonoaklin (an incidental observation). As upland-associated species, these were expected to occur only at the very edges of the drawdown zone. Diversity: Species diversity was highest in Montana Slough and Edgewood South in Arrow Lakes Reservoir. Airport Marsh and Beaton Arm were also high diversity monitoring sites. For Kinbasket Reservoir, species diversity was highest for Valemount Peatland, followed by Bush Arm KM79. Productivity: Breeding amphibian populations, a productivity indicator, were documented for most monitoring sites, with Revelstoke Reach (Airport Marsh, Cartier Bay, Montana Slough), Bush Arm KM79, and Valemount Peatland being the most productive. Western Toad were documented breeding at six of seven monitoring sites in Kinbasket Reservoir and 11 of 12 monitoring sites in Arrow Lakes Reservoir. Large aggregations of Western Toad tadpoles were recorded at several sites over multiple years, including Ptarmigan Creek, Pond 12 in Valemount Peatland, Bush Arm Causeway, KM88 (Bear Island), and Sprague Bay in Kinbasket Reservoir, and Cartier Bay, Beaton Arm, Burton Creek, and Lower Inonoaklin in Arrow Lakes Reservoir. Out-migrating metamorph toads were documented at several of those sites (typically in early to mid-July), with Ptarmigan Creek and Cartier Bay being the most productive with thousands of toads leaving the drawdown zone. Nocturnal call surveys documented large breeding choruses of Pacific Chorus Frogs in Revelstoke Reach (Airport Marsh, Cartier Bay, Montana Slough) in all study years. Ponds in the drawdown zone at Bush Arm KM79 and Valemount Peatland were notably productive for Columbia Spotted Frog. Cartier Bay was the most productive site for Long-toed Salamanders, documented by both egg masses and early spring moving adults. Reptile productivity was difficult to measure with small sample sizes; however, we did observe gravid females of Common Garter Snake and Western Terrestrial Garter Snake (both reserovirs), and Northern Alligator Lizard in the drawdown zone of Arrow Lakes Reservoir. Annual variation in amphibian breeding was not expected to be high between or across the years; however, there were a couple of years of early breeding (end of April 2016) and early inundation (June 2012) that may have affected the estimates of abundance and productivity in those years. Sources of Uncertainty/Limitations Data collection focused primarily on visual encounter surveys to monitor amphibians and reptiles during their active seasons (approx. May to September). Many of the target species were easily located and identified via these survey methods; however, some species (e.g., Long-toed Salamanders, lizards, turtles) may not have been recorded, due to their inconspicuous nature (e.g., Long-toed Salamander), natural annual population variation, or inconsistent use of the drawdown zone (upland-associated species).

<table>
<tr><th>Management Question (MQ)</th><th>Summary of Key Results</th></tr>
<tr><td>MQ3: During what portion of their life history (e.g., breeding, foraging, and overwintering) do amphibians and reptiles utilize the drawdown zone?</td><td><u>Summary of Findings</u>

Surveys were conducted across the active season (late April to October) for amphibian and reptiles, using multiple survey methods, to document life history stages. All amphibian species (except for Coeur d'Alene Salamander, which were never observed in the drawdown zone) were documented using ponds and wetlands in the drawdown zone for breeding (mating, egg laying, tadpole development). Larval stages of amphibians were observed utilizing these ponds for foraging (frogs, Western Toad, and Long-toed Salamander), but because stomach contents were not examined for adults, we can only infer that subadult and adult amphibians use drawdown zone areas for foraging. Western Toads were observed moving out of the drawdown zone after the breeding period, as well as confirmed (via radio telemetry) moving into upland habitats for hibernation. Based on knowledge of the life history of Columbia Spotted Frogs, it is likely that they use some ponds in the drawdown zone to overwinter.

In Canoe Reach (upland of Valemount Peatland), Common Garter Snakes were observed (via radio telemetry) mating in upland areas and giving birth close to the drawdown zone. Gravid females were also observed using drawdown zone sites to bask during the spring and summer. Garter snakes regularly foraged in the drawdown zone of both Kinbasket and Arrow Lakes Reservoir, eating a variety of prey items including all stages of Western Toad. Common Garter Snakes that used Valemount Peatland for summer habitat overwintered at upland hibernating sites on the lower slopes of Canoe Mountain. Northern Alligator Lizards were observed foraging along the edges of Arrow Lakes Reservoir.

<u>Sources of Uncertainty/Limitations</u>

The sources of uncertainty/limitations for MQ1 and MQ2, above, also apply to this MQ. While it is assumed that Columbia Spotted Frog overwinter in ponds in the drawdown zone, this has not been confirmed.</td></tr>
</table>

Management Question (MQ)	Summary of Key Results
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)?	<u>Summary of Findings</u> Multiple survey types were conducted to determine the habitats being utilized by each species and their characteristics. Habitat data were collected when an animal was detected. Species distributions were compared to known elevation ranges of existing habitat mapping (Vegetation Community Codes [VCC]) produced under CLBMON-10 and CLBMON-33. The percentage of species detections in each vegetation community type varied by species. Utilized vegetation communities in Kinbasket Reservoir were distributed between ~736 and 764 mASL. Most species were found in wetland-associated habitat types such as wool-grass-Pennsylvania buttercup (Columbia Spotted Frog), Kellogg's sedge (Common Garter Snake, Western Terrestrial Garter Snake), and swamp-horsetail (Long-toed Salamander, Western Toad). Other vegetation community types with frequent detections included clover-oxeye daisy (Long-toed Salamander, Western Toad, Western Terrestrial Garter Snake), driftwood (Common Garter Snake) and willow-sedge (Columbia Spotted Frog). Occupied vegetation communities in Arrow Lakes Reservoir were distributed between ~430 and 451 mASL. For most species, detections were most frequent in the reed canary grass mesic habitat type. Other frequented vegetation communities included reed-rill (Columbia Spotted Frog), industrial/urban/recreational (Pacific Chorus Frog), vegetation poor ponds (Western Toad, Western Painted Turtle), sandy beach (Common Garter Snake), redtop upland (Western Terrestrial Garter Snake), and gravelly beach (Northern Alligator Lizard). In Arrow Lakes Reservoir, pond-breeding amphibians including Western Toad, Columbia Spotted Frog, Long-toed Salamander, and Pacific Chorus Frog were mainly associated with wetland habitats, with the majority of those habitats occurring in Revelstoke Reach (Airport Marsh, Cartier Bay, Montana Slough). Wetland habitats were characterized as having varying degrees of open water, soft substrates, and complex vegetation that included both emergent and submergent vegetation. In Kinbasket Reservoir, most wetlands had very little to no emergent vegetation and low abundance (cover) of submergent vegetation. Wetlands with higher cover of vegetation were found at high elevations and tended to be used to a greater degree by Columbia Spotted Frog and Long-toed Salamander whereas low-elevation ponds with little to no vegetation were favoured by Western Toad. Over the study period, water physicochemical parameters (dissolved oxygen, pH, water temperature, or conductivity) were within acceptable levels for amphibians in both reservoirs (Crowder et al. 1998; Ultsch et al. 1999). Ponds and wetlands in and around Kinbasket and Arrow Lakes Reservoir used by pond-breeding amphibians spanned an elevation range of 734 to 763 mASL and 433 to 450 mASL, respectively (range varied by location). <u>Sources of Uncertainty/Limitations</u> The sources of uncertainty/limitations for MQ1 and MQ2, above, also apply to this MQ. Additionally, the digital elevation model (DEM) used for CLBMON-58 was based on a non-LiDAR dataset. The available LiDAR DEM should be used to reassess the elevation at which amphibians and reptiles occurred and to characterize the habitats they used. Certain habitats were impacted directly and indirectly annually by reservoir operations (e.g., via deposition of wood debris on wetlands, effects of scour caused by floating wood, habitat erosion, sedimentation), but the effects on amphibians and reptiles and their habitats were not studied.

Management Question (MQ)	Summary of Key Results
MQ5: How do reservoir operations influence or impact amphibians and reptiles directly (e.g., desiccation, inundation, predation) or indirectly through habitat changes?	Summary of Findings Eleven years of data collected on the occurrence and distribution of amphibians and reptiles in the drawdown zone suggested little evidence of a direct effect on amphibians and reptiles though there were assumed indirect effects on habitats. Life-stage specific mortality rates were not directly measured for any species, but instances of mortality were observed in both drawdown zones (likely related to natural causes). Water physicochemical parameters measured in ponds in the drawdown zone suggested little evidence of an effect of dissolved oxygen, pH, water temperature, or conductivity on amphibian habitat use or development (see Hawkes et al. 2018b). Of these parameters, water temperature can influence tadpole development to some degree (Crowder et al. 1998; Ultsch et al. 1999). However, the effects of reservoir inundation on water temperature and subsequent tadpole development were equivocal with no apparent direct effect on amphibians using the drawdown zone of Kinbasket and Arrow. The ability to directly measure the potential effects of changing physicochemical parameters on amphibians was confounded by reservoir operations, which varied annually. Sources of Uncertainty/Limitations Variable reservoir operations were present throughout the study period; different operational regimes likely affected habitat availability differently. See previous comment (MQ4) regarding the use of the DEM based on the 2014 LiDAR dataset. Additionally, natural annual population fluctuations likely contributed some uncertainty. An additional limitation was the difficulty in determining stage-specific mortality in small, inconspicuous species in a dynamic environment (i.e., fluctuating reservoir).
MQ6: Can minor adjustments be made to reservoir operations to minimize the impact on amphibians and reptiles?	Summary of Findings Our study found little to no evidence that reservoir operations needed to be adjusted to minimize the impacts on amphibians and reptiles. This was based only on data collected during the snow-free period and we have no data with which to draw any conclusions regarding reservoir operations and the suitability of overwintering pond habitats for Columbia Spotted Frogs, or other species that may overwinter in the drawdown zone. Using the 11 years of data collected on site occupancy, seasonal elevational distribution, and habitat use of amphibians and reptiles in the drawdown zones of Kinbasket and Arrow Lakes Reservoir, it is the opinion of the authors that only minor adjustments to reservoir operations could be made to theoretically minimize the effects of dam impacts on these species. In general, inundation of drawdown zone habitats during the active season for pond-breeding amphibians and garter snakes led to a displacement of these species into other habitats (e.g., upland areas); therefore, delaying high reservoir elevations until further in the season (August) could hypothetically allow for longer larval development periods in drawdown zone ponds, increased foraging opportunities in drawdown zone ponds for garter snakes, and minimize significant habitat changes during the active season for species that used those habitat areas. Sources of Uncertainty/Limitations The sources of uncertainty/limitations for MQ6 include the variable reservoir operations that were present throughout the study, a lack of experimentation to assess how varying the time of inundation correlated to the use of the drawdown zone by amphibians and reptiles, and the lack of control/reference site study design that would enable a comparison of populations of amphibians and reptiles unaffected by reservoir operations with those in the drawdown zones. Additionally, it was not possible to manipulate variables such as when the reservoirs exceeded a given elevation or for how long. It is not clear what constitutes a minor adjustment. Given the variable nature of reservoir operations, a more informed answer to this question would require understanding how a minor adjustment affects the various types of reservoir operations.

Management Question (MQ)	Summary of Key Results
MQ7: Can physical works projects be designed to mitigate adverse impacts on amphibians and reptiles resulting from reservoir operations?	<u>Summary of Findings</u> The primary impact of reservoir operations to amphibians and reptiles was through direct effects on habitat either through loss or alteration. Two physical works projects that could potentially mitigate for these impacts were completed in Kinbasket Reservoir during this study: Bush Arm Causeway site modifications and wood debris removal in Valemount Peatland. Project outcomes included the removal or exclusion of wood debris to expose previously covered habitats and the installation of log booms around these cleared habitats to protect them from future wood debris accumulation. Mitigation is limited in terms of location, spatial extent, and scale; however, initial evidence of amphibian utilization of wetlands cleared of wood debris supports the notion that physical works can mitigate for some of the adverse impacts. Other physical works, using similar approaches, could theoretically be designed to mitigate adverse impacts on amphibians and reptiles resulting from reservoir operations. <u>Sources of Uncertainty/Limitations</u> Kinbasket Reservoir did not fill completely between 2015 and 2019, meaning that the ponds that were cleared of wood debris and the mounds that were created were not inundated. As a result, the integrity of the mounds following inundation have not been tested. Comparable physical works have not been implemented in Arrow Lakes Reservoir.
MQ8: Does revegetating the drawdown zone affect the availability and use of habitat by amphibians and reptiles?	<u>Summary of Findings</u> We were unable to address this MQ for Kinbasket Reservoir or Arrow Lakes Reservoir, as the relationship between revegetation prescriptions applied in the drawdown zone and amphibian and reptile use of habitat, increased abundance, or productivity was not assessed. The revegetation prescriptions applied were not considered particularly relevant or beneficial to amphibians and reptiles (other than assisting with initial site selection for this study) nor were they implemented explicitly to benefit amphibians and reptiles. It is the opinion of the authors that it is unlikely that revegetation on its own will contribute to an increase in the amount or improvement of habitat for amphibians or reptiles as the revegetation prescriptions were applied at a scale that is unlikely to elicit a population-level response. The type of revegetation was also more consistent with upland, as opposed to wetland, revegetation and therefore not likely to influence the use of most areas of the drawdown zone by amphibians or reptiles. It is also unlikely that revegetation increased species diversity or abundance of amphibians and reptiles in the drawdown zone. <u>Sources of Uncertainty/Limitations</u> Given the nature of the revegetation work that has occurred (not intended to benefit amphibians and reptiles), this MQ was not applicable to this study (CLBMON-37/58). Wetland-related plants would need to be planted to benefit amphibians and reptiles and a habitat use study in restored areas would need to be completed.

Management Question (MQ)	Summary of Key Results
MQ9: Do physical works projects implemented during the course of this monitoring program increase amphibian and reptile abundance, diversity, or productivity?	<u>Summary of Findings</u> Amphibians were monitored (under CLBMON-37 and CLBMON-58) at two sites associated with physical works during this study: Valemount Peatland (2014) and the Bush Arm Causeway (2015). There was some evidence of amphibian use of wetlands cleared of wood debris at the north end of Canoe Reach. The Bush Arm Causeway physical works, which cleared wood debris that had accumulated in small ponds, also resulted in the use of cleared wetlands by Western Toads for breeding. As such, there was evidence to support an increase in productivity for certain species via the removal of wood debris from wetlands. Prior to clearing, these wetlands were not available to amphibians as they were clogged with wood and previous visual encounter surveys (prior to 2015) failed to detect any pond-breeding amphibians. There was no expectation that the diversity of amphibians or reptiles would change as a result of physical works in Kinbasket Reservoir. However, the abundance of some species (e.g., Western Toad) may increase as a result of the improvements made to wetland habitat in the drawdown zone resulting from wood debris removal. The authors recommend additional assessments of physical works in Kinbasket Reservoir to better answer this question. Planned physical works at Burton Flats in Arrow Lakes Reservoir could be assessed relative to this management question during planned work for CLMBON-11B1. <u>Sources of Uncertainty/Limitations</u> Limited scope of physical works in Kinbasket Reservoir. Results to date were site-specific (i.e., cannot infer results to entire reservoir). Comparable physical works have not been implemented in Arrow Lakes Reservoir.
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?	<u>Summary of Findings</u> Based on reservoir operations from 2008 to 2018, a periodic increase in reservoir elevation of 0.6 m is unlikely to have a large effect on amphibian populations that use the drawdown zone of Kinbasket Reservoir. This conclusion is somewhat confounded by the fact that Kinbasket Reservoir is managed differently each year. It is the opinion of the authors that if Kinbasket Reservoir was operated at or above full pool every year (i.e., reservoir levels > 754 mASL), amphibian populations could experience negative effects and potentially decline in numbers. <u>Sources of Uncertainty/Limitations</u> The sources of uncertainty/limitations for MQ1, MQ2, and MQ5, above, also apply to this MQ. Mortality rates were difficult to assess, which was related to our inability to track individual egg strings or egg masses at different elevations from the time of deposition to metamorphosis because of changing reservoir elevations. As such, stage-specific transition rates (i.e., hatching rates or percentage of tadpoles that metamorphose) were unlikely to be accurately measured or reported during this study. The potential effects of Mica Units 5 and 6 on vegetation in the drawdown zone are being assessed under CLBMON-57. Once that study is complete, any impacts to wetland-associated plants should be considered in the context of changes to amphibian habitat. At present, the potential impacts of Mica Units 5 and 6 on amphibian habitat was based solely on changes to habitat availability. It is not clear if surcharge can be used as a proxy for increasing the reservoir by 0.6 m in the summer months. There could be effects that remain unaccounted for if Kinbasket Reservoir reaches full pool more regularly as a result of the additional 0.6 m of water. See previous comment regarding the use of the DEM based on the 2014 LiDAR dataset.

KEYWORDS: amphibian, reptile, life history, habitat use, reservoir elevation, drawdown zone, Kinbasket Reservoir, Arrow Lakes Reservoir, hydro.

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1 INTRODUCTION

Dams regulate aquatic flow regimes 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 et al. 2005; Eskew et al. 2012). Reservoirs and dam impacts include both upstream effects such as direct flooding, erosion and dust disturbances, and loss of riparian and wetland habitats, and downstream effects including fish passage barriers and disturbance of annual flooding regimes needed to maintain the health of floodplain environments (MacKenzie and Shaw 2000; Nilsson and Berggren 2000; Kupferberg et al. 2011; Eskew et al. 2012). To date, most studies of the effects of impoundment have focused primarily on the instream and riparian effects on fish and wildlife downstream of dams (e.g., Burt and Mundie 1986; Hayes and Jennings 1986; Kupferberg 1996; Ligon et al. 1995; Lind et al. 1996; Nilsson et al. 2005; García et al. 2011). The need to understand the operational aspects of reservoir effects upstream of dams on fish and wildlife and their habitat remains high (Brandão and Araújo 2008; Eskew et al. 2012), and that is the focus of this study.

The Columbia River Basin in southeastern British Columbia has been extensively altered by dams built for flood control and hydroelectric power in Canada and the United States. The Columbia River Treaty (1964) is a transboundary water management agreement that resulted in the creation of 14 large-scale reservoir and dam systems, three of which are in B.C.: Kinbasket Reservoir (Mica Dam, 1973), Revelstoke Reservoir (Revelstoke Dam, 1984), and Arrow Lakes Reservoir (Hugh Keenleyside Dam, 1968). Footprint impacts from reservoirs and dams have had numerous negative impacts on wetland and riparian ecosystems, including the loss of nearly 7,705 hectares of wetland habitat in the Columbia Basin (Utzig and Schmidt 2011).

Across the world, many amphibian and reptile species are declining (Alford et al 2001; Gibbons et al. 2000; Lesbarrères et al. 2014), and this is in part due to large-scale terrestrial habitat loss, especially for species that are dependent on wetland ecosystems. During the Columbia River Water Use Planning process (WUP), the Consultative Committee expressed concerns about potential impacts of the operations of the Kinbasket and Arrow Lakes Reservoirs on wildlife and vegetation, including amphibians and reptiles. However, a lack of information on the abundance, distribution, life history, and habitat use of these animals made it difficult to assess the impact of current operations and operating alternatives on them.

In 2008, BC Hydro initiated a long-term monitoring program spanning 10 years (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, the Mica 5/6 Core Committee recommended that additional monitoring (CLBMON-58) to assess the potential impacts/effects of the installation of Units 5 and 6 at Mica Dam and an increase of 0.6 m in summer water levels on amphibian populations using habitats in the drawdown zone of Kinbasket Reservoir. Long-term monitoring of amphibian and reptile populations in the drawdown zone of these reservoirs would provide the necessary information to address 10 management questions.

This report is a comprehensive assessment of data collected from 2008 to 2018 to assess amphibian and reptile populations (life histories and habitat use) in the reservoir drawdown zones and how dam operations may have influenced the dynamics of those populations. This report is divided into two main sections: the main body and the appendices. The main body of the report provides an overview of the study, summarizes the methods and locations of work, introduces the data that were collected, and provides answers to each of the ten management questions. The answers to management questions are supported by the detailed analyses presented in the appendices.

1.1 Management Questions

The ten Management Questions (MQs) for CLBMON-37/58 can be grouped into four broad themes:

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

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

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

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

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

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

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

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

CLBMON-37/58 – Theme 3: Physical Works

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

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

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

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

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

1.2 Objectives

CLBMON-37 was implemented in 2008, 2009, 2010, 2012, 2014, 2016, and 2018. The objectives of CLBMON-37 (BC Hydro 2017) were to:

1. Monitor populations (life history and habitat use) of amphibians and reptiles in the drawdown zones;
2. Examine the effects of reservoir operations on amphibian and reptile populations and habitat use; and
3. Address the potential to mitigate for reservoir operations by using physical works.

CLBMON-58 was implemented in 2011, 2013, 2015, and 2017. The main objectives were to assess the potential impacts on amphibian larval survival, metamorph success, life history, and habitat use of amphibians and reptiles in Kinbasket Reservoir as a result of the installation of Units 5 and 6 at Mica Dam. A detailed timeline of the project development is provided in Appendix 1.

2 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. 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, 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 ranges from approximately 800 m near Columbia Lake to 420 m near Castlegar. Approximately 40 percent 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 ten percent 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 from the Pacific Ocean that move eastward through the region. More than two-thirds of the precipitation in the basin falls as winter snow. Snowpacks often accumulate above 2,000 m elevation through the month of May and continue to contribute runoff long after the snowpack 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 percent 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. Air temperatures across the basin tend to be more uniform than precipitation. The summer climate is usually warm and dry, with the average daily maximum temperature for June and July ranging from 20-32°C.

2.1 Kinbasket Reservoir

Located in southeastern B.C., Kinbasket Reservoir is surrounded by the Rocky and Monashee Mountain ranges and is approximately 216 km long. Mica hydroelectric dam, located 135 km north of Revelstoke, B.C., spans the Columbia River and impounds Kinbasket Reservoir. The original Mica powerhouse, completed in 1973, has a generating capacity of 1,805 megawatt (MW), and Kinbasket Reservoir has a licensed storage volume of 12 million-acre feet (MAF; BC Hydro 2007). Mica Dam was originally designed to hold six generating units; however only four were installed at the time of construction in 1973. The installation of the 5th and 6th units commenced in 2011 with a planned operational date of 2014 (Unit 5) and 2015 (Unit 6). To optimize reservoir storage for power generation associated with the new units, it was predicted that reservoir levels would increase by 0.6 m during the summer months. The addition of the new turbines at Mica Dam will increase the generating capacity of Kinbasket Reservoir by roughly 1,000 MW (BC Hydro 2007). The normal operating range of the reservoir is between 707.41 m and 754.38 m elevation but can be operated to 754.68 mASL with approval from the Comptroller of Water Rights. The creation of Kinbasket Reservoir flooded ~42,650 ha resulting in the loss or alteration of eight broad habitat types (lakes: 2,343 ha; rivers: 4,897 ha; streams: 192 ha; shallow ponds: 555 ha; gravel bars: 236 ha; wetlands: 5,863 ha; floodplain [riparian]: 15,527 ha; and upland forest: 13,036 ha; Utzig and Schmidt 2011).

Kinbasket Reservoir was lowest during March to mid-May, filled throughout late spring and early summer, and was typically full by mid- to late-summer (Figure 2-1). Notably, in 2012 and 2013 Kinbasket Reservoir was filled beyond the normal operating maximum (i.e., > 754.38 mASL) for the first time since 1997. Since September 2013, water levels have been kept below the operating maximum.

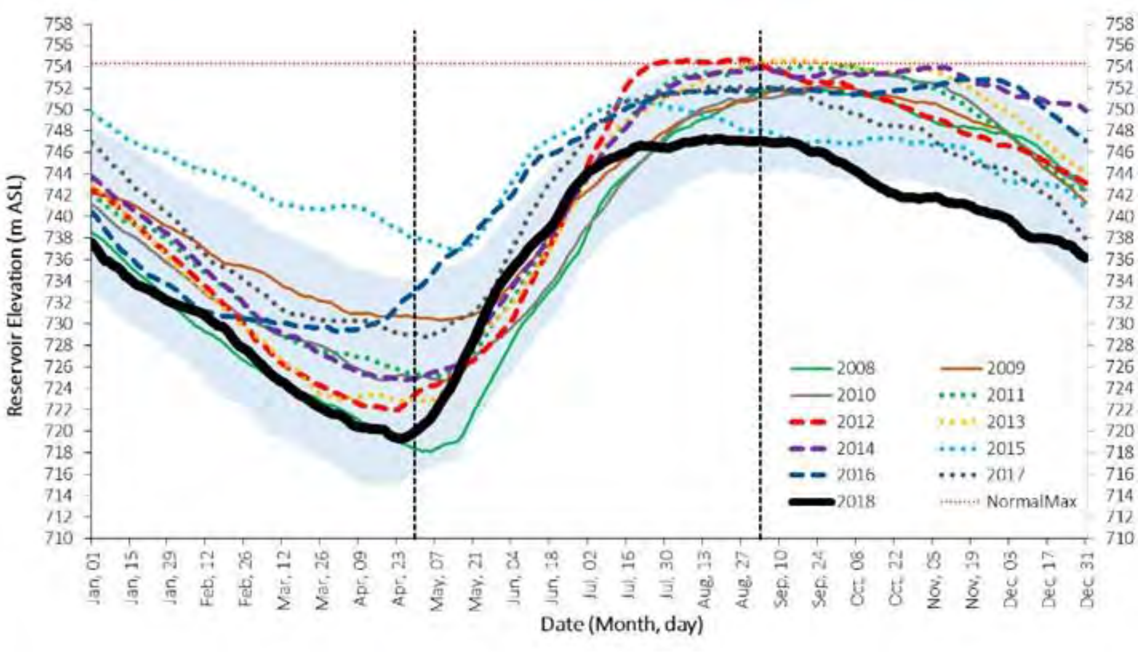

Figure 2-1: Kinbasket Reservoir hydrograph for the period 2008 through 2018. The blue shaded area represents the 10th and 90th percentile for the period 1976 through 2018; the dashed red line is the normal operating maximum; the vertical dotted lines indicates the general survey period which field monitoring was conducted.

The reservoir is located predominately within the Interior Cedar-Hemlock (ICH) Biogeoclimatic (BEC) zone and is represented by four subzone/variants (Table 2-1). The ICH occurs along the valley bottoms and is typified by cool, wet winters and warm dry winters. A small portion of the reservoir extends into the Sub-Boreal Spruce (SBS) BEC zone dh1 variant near Valemount. The climate of the SBS is continental and characterized by moderate annual precipitation and seasonal extremes of temperature that include severe, snowy winters and relatively warm, moist, and short summers.

Table 2-1: Biogeoclimatic zones, subzones, and variants occurring in Kinbasket Reservoir region.

Subzone	Zone Name	Subzone/Variant Description
ICHmm	Interior Cedar - Hemlock	mm: Moist Mild
ICHwk1	Interior Cedar - Hemlock	wk1: Wells Gray Wet Cool
ICHmw1	Interior Cedar - Hemlock	mw1: Golden Moist Warm
ICHvk1	Interior Cedar - Hemlock	vk1: Mica Very Wet Cool
ICHmk1	Interior Cedar - Hemlock	mk1: Kootenay Moist Cool
SBSdh1	Sub-Boreal Spruce	dh1: McLennan Dry Hot

2.1.1 Study Sites

Surveys occurred in three main regions of Kinbasket Reservoir: (1) Canoe Reach (Figure 2-2, top), (2) Bush Arm (Figure 2-2, bottom) and (3) Mica Dam area.

Figure 2-2: Photos of monitoring sites in Kinbasket Reservoir prior to inundation. Top left = Valemount Peatland; top right = Ptarmigan Creek; bottom left = Bush Arm KM79 Marshes; bottom right = Bush Arm Causeway. Photos: © Krysia Tuttle.

1. **Canoe Reach**: includes the northern arm of Kinbasket Reservoir extending from north of Mica Dam to Valemount. The extensive Valemount Peatland at the northern end of the reservoir supports the greatest diversity and abundance

of wildlife in Canoe Reach. Historically, this remnant peatland was likely a combination of sedge and horsetail fen and a swampy forest dominated by spruce (Ham and Menezes 2008). The wildlife habitat in the peatland varies from highly productive riparian and wetland habitat, to highly eroded sand and cobble parent material. Large areas are virtually devoid of vegetation and portions of the peatland are covered by deposits of wood chips from the breakdown of floating logs (Hawkes et al. 2007). Other notable habitats in the northern end of Kinbasket Reservoir include wetlands and ponds on the gently sloping banks along the reservoir's eastern side (e.g., Ptarmigan Creek).

2. **Bush Arm**: includes the eastern arm of Kinbasket Reservoir extending from Bear Island to the Bush River. Bush Arm is characterized by flat or gently sloping terrain that was created by fluvial deposition from Bush River and other inflowing streams. These features are often protected from wind and wave action by the islands and peninsulas that protrude along the shoreline. This combination creates the largest variety of valuable wildlife habitat in the entire reservoir. Extensive fens and other wetlands have been identified, and a high diversity of plants is supported (Hawkes et al. 2007).
3. **Mica Dam Area**: The Mica Dam area itself has little habitat suitable for amphibians and reptiles; however, Sprague Bay (near boat launch) has a network of beaver-created wetlands and bog habitat that extends from upland areas down into the drawdown zone.

Kinbasket Reservoir study sites were defined as monitoring sites or reconnaissance/reference sites; site names, descriptions, and codes are listed in Table 2-2 and shown in Figure 2-3. Eight monitoring sites in or near the Kinbasket Reservoir drawdown zone with varying habitat types were monitored under CLBMON-37 (see Appendix 1 and previous annual reports). These areas were selected because of the presence of wetlands and ponds in the drawdown zone and the use of those sites by reptiles and amphibians, as well as the presence of vegetation monitoring sites associated with CLBMON-10 following Hawkes et al. (2007). A total of 181 ponds were sampled across those sites.

Table 2-2: Study sites surveyed for amphibians and reptiles at Canoe Reach, Bush Arm, and Mica Dam areas of Kinbasket Reservoir. DDZ = drawdown zone, UPL = upland.

Reach	Site	Location	Site Description	Elevation Range (m ASL)
Monitoring Sites				
Canoe Reach	Valemount Peatland	DDZ	Series of peatland ponds / wetlands in DDZ, includes Pond 12, largely vegetated. Most extensive area in Kinbasket (> 500 ha)	747-755
	Ptarmigan Creek	DDZ	One large DDZ pond, sandy soil, sparsely vegetated.	738-755
Bush Arm	Bush Arm Causeway	DDZ	Wetlands and ponds at the mouth of Bush River, north and south end of bridge	749-755
	KM79 Wetlands	DDZ	Beaver dam wetlands and DDZ ponds	738-755
	KM79 Perched Wetland	UPL	Beaver dam wetland above DDZ	N/A
	KM88 Bear Island	DDZ	DDZ ponds and wetlands	738-756
	Succour Creek	DDZ	Narrow river channel that gets inundated	745-766
Mica Dam	Sprague Bay	DDZ/UPL	Beaver dam marshes	753-755
Reconnaissance or Reference Sites				
Canoe Reach	Yellow Jacket Creek	DDZ	DDZ sites associated with CLBMON-10. Sites are sandy or rocky, with little vegetation, and generally unsuitable for amphibians or reptiles.	732-757
	Mount Blackman	DDZ		738-758
	Hugh Allan Bay	DDZ		N/A
	Cranberry Marsh	UPL	Upland wetland near Valemount	N/A
Columbia Reach	Beavermouth	DDZ/UPL	Mouth of the Columbia River into reservoir	744-754
Mica Dam	Encampment Creek	DDZ	Fen habitat and ponds in DDZ	738-757

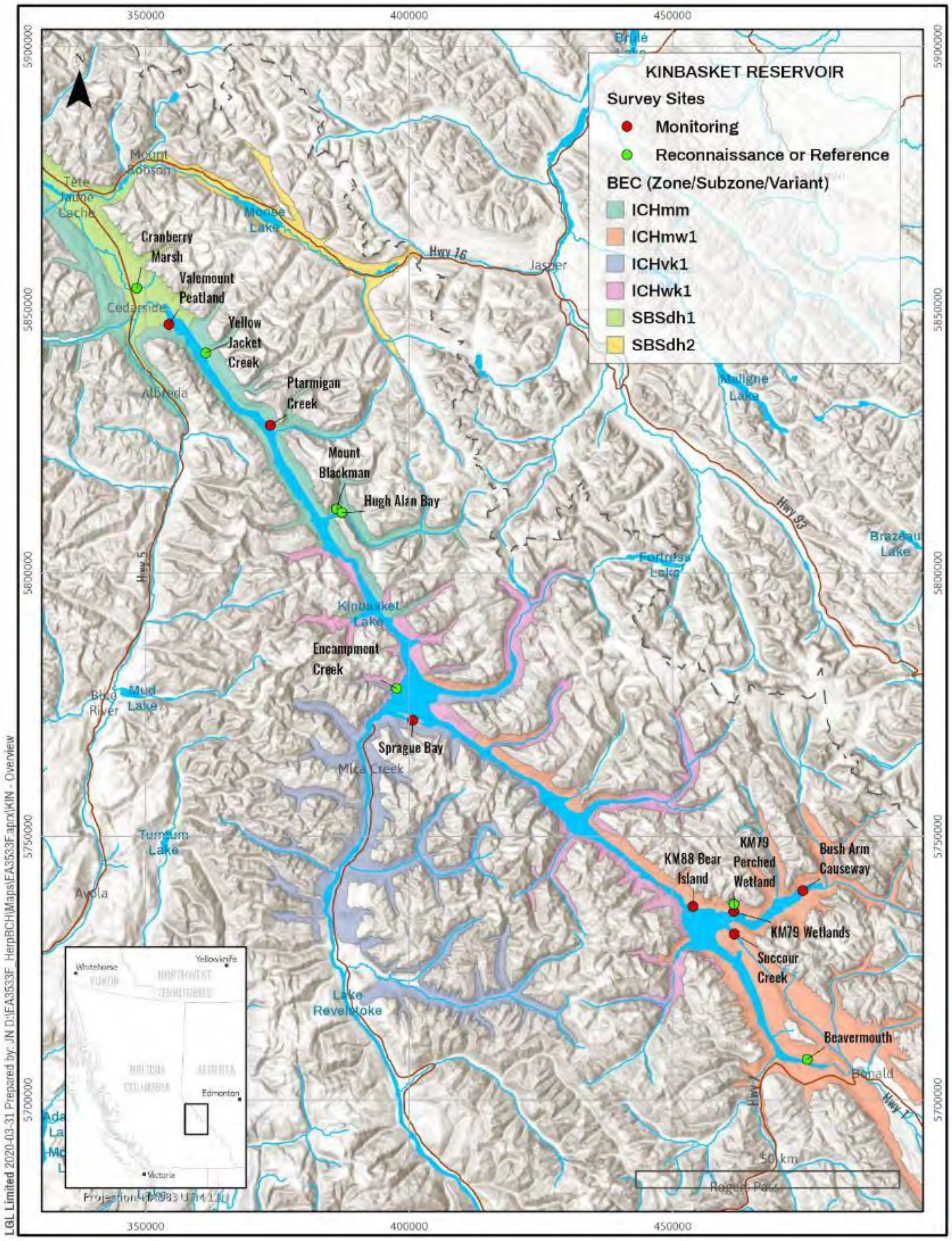

Figure 2-3: Location of Kinbasket Reservoir in British Columbia, and sites sampled for CLBMON-37/58 from 2008 to 2018. Place names in bold are either monitoring sites or reference/reconnaissance sites (see Hawkes and Tuttle 2013b). Refer to Table 2-1 for descriptions of Biogeoclimatic (BEC) zones.

2.2 Arrow Lakes Reservoir

Arrow Lakes Reservoir is an approximately 230 km long section of the Columbia River between Revelstoke and Castlegar, B.C. Two biogeoclimatic zones occur within the study area: Interior Cedar Hemlock (ICH) and 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). During this study, the normal operating range of the reservoir was between 418.64 and 440.1 m elevation (Figure 2-4). The creation of Arrow Lakes Reservoir flooded ~51,270 ha resulting in the loss or alteration of eight broad habitat types (lakes: 34,992 ha; rivers: 2,022 ha; streams: 51 ha; shallow ponds: 103 ha; gravel bars: 3,623 ha; wetlands: 3,432 ha; floodplain [riparian]: 3,564 ha; and upland forest: 3,844 ha; Utzig and Schmidt 2011).

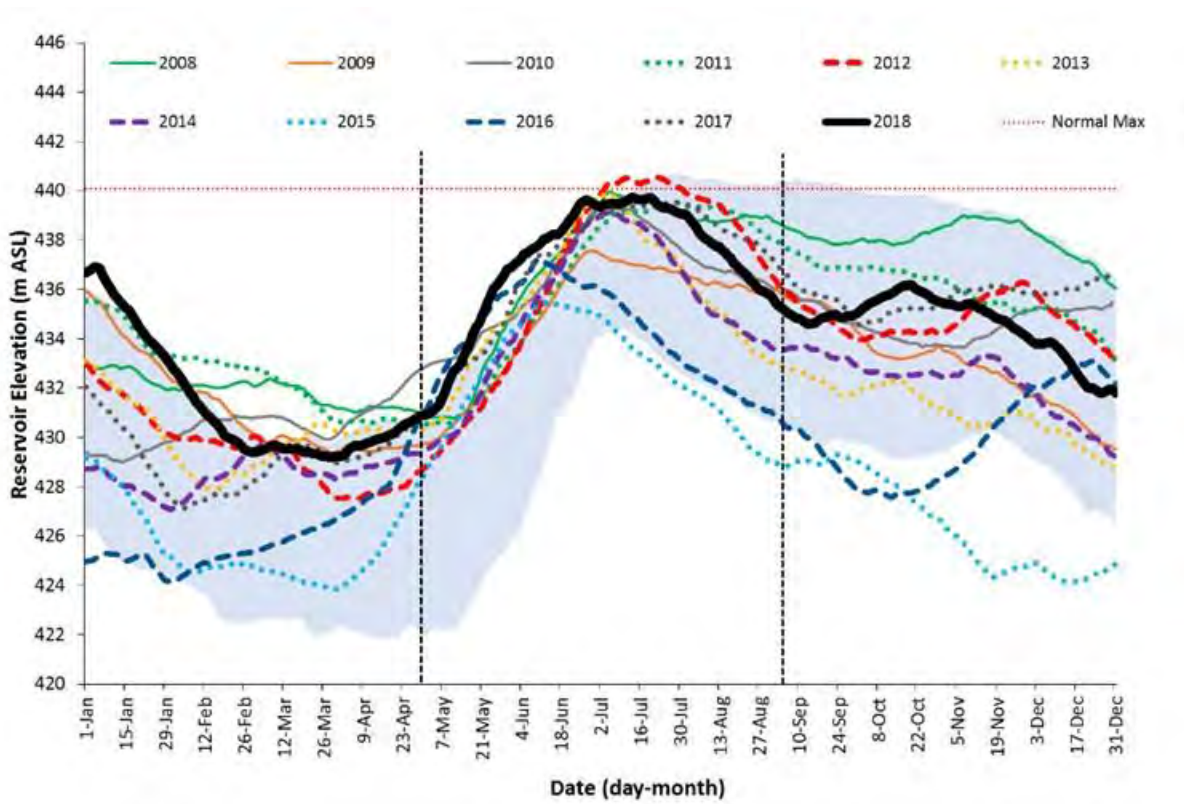

Figure 2-4: Arrow Lakes Reservoir hydrograph for 2008 through 2018. The blue shaded area represents the 10th and 90th percentile for the period 1969 to 2018; the dashed red line is the normal operating maximum. Vertical dashed lines indicate the general survey period for sampling across the years.

Two Biogeoclimatic zones occur within the study area: the Interior Cedar Hemlock (ICH) and the Interior Douglas-fir (IDF; Table 2-3). The majority of the area occurs within the ICH, with three subzones and four variants represented. The IDF is restricted to the southernmost portion of the area and consists of a single subzone (IDFun). The subzones are a reflection of increasing precipitation from the dry southern slope of Deer Park to the wet forests near Revelstoke (Enns et al. 2007).

The Arrow Lakes Reservoir study is primarily situated within the Arrow Boundary Forest District, with a small northerly portion in the Columbia Forest District.

Table 2-3: Biogeoclimatic zones, subzones, and variants occurring in Arrow Lakes Reservoir region.

Subzone	Zone Name	Subzone/Variant Description
ICHdw1	Interior Cedar - Hemlock	dw1: West Kootenay Dry Warm
ICHmw2	Interior Cedar - Hemlock	mw2: Columbia - Shuswap Moist Warm
ICHmw3	Interior Cedar - Hemlock	mw3: Thompson Moist Warm
ICHwk1	Interior Cedar - Hemlock	wk1: Wells Gray Wet Cool
ICHmm	Interior Cedar - Hemlock	mm: Moist Mild
IDFun	Interior Douglas-fir	un: Undefined

2.2.1 Study Sites

Twelve sites within the drawdown zone of Arrow Lakes Reservoir were selected for monitoring to document the presence of amphibians and reptiles (see Appendix 1 and previous annual reports). The site selection process followed that of Kinbasket Reservoir and was closely tied to the typical 10 m change in elevation (430-440 mASL) as well as to areas associated with the proposed physical works within Revelstoke Reach (i.e., Cartier Bay). Sites studied include habitats at Revelstoke Reach (e.g., Airport Mars, Cartier Bay, Montana Slough), up Beaton Arm, and areas on the east and west sides of mid Arrow Lakes Reservoir including habitats at Burton Creek and Edgewood (e.g., Edgewood North, Edgewood South, Lower Inonoaklin; Figure 2-5). Site names, descriptions, and codes are listed in Table 2-4.

Table 2-4: Study sites surveyed for amphibians and reptiles in Arrow Lakes Reservoir. DDZ = drawdown zone, UPL = upland.

Reach	Site	Location	Site Description	Elevation Range (m ASL)
			Monitoring Sites	
Revelstoke Reach	Downie Marsh	DDZ/UPL	Man-made and natural ponds in DDZ, long bank of riprap rock	435-442
	Machete Island	DDZ	Cottonwood stand habitat, ponds	433-450
	Airport Marsh	DDZ/UPL	Large wetland complex, see CLBMON-11B3 for description	433-450
	Montana Slough	DDZ	Multiple ponds in DDZ, Scott Creek and Montana Creek	432-445
	Cartier Bay	DDZ	Multiple ponds in DDZ, immediately below road surveys location	432-444
	9 Mile	DDZ	Ponds in DDZ, willow/shrub habitat	431-448
	12 Mile	DDZ	Drimmie Creek, willow/shrub habitat in DDZ	431-442
Mid Arrow	Beaton Arm wetlands	DDZ/UPL	Beaver wetlands into the DDZ	431-442
	Burton Creek	DDZ/UPL	Series of DDZ ponds (man-made gravel pits), sedge vegetated seep, CWD, field habitat	431-444
Lower Arrow	Lower Inonoaklin	DDZ	Mud-bottomed pond in DDZ	433-443
	Edgewood North	DDZ/UPL	Rocky shoreline along reservoir	431-447
	Edgewood South	DDZ	Shrub habitat, reed-canary grass flat, small pond near Eagle Creek	431-445
			Reconnaissance or Reference Sites	
Upper Arrow / Revelstoke Reach	North of Hwy 1	DDZ	Two gravel pit/mud ponds in DDZ	436-443
	Big Eddy	DDZ	Long channel of water in DDZ	435-443
	Williamson Lake	UPL	Upland Lake (turtle only)	N/A
	Turtle Pond	UPL	Upland wetland (turtle only)	N/A
	Blanket Creek	UPL	Man-made lake in provincial park	N/A
	Shelter Bay	DDZ	Reed Canary-grass area, rocky shoreline along reservoir	431-447
Mid Arrow	Mosquito Creek	DDZ/UPL	Upland habitat, reed canary-grass habitat along creek	432-441
	East Arrow Park	DDZ	Sparsely vegetated sandy habitat along reservoir	431-446
Lower Arrow	Renata Creek	DDZ	Rocky shoreline along reservoir and creek	432-453
	Syringa Park	UPL	Rocky shoreline along reservoir	N/A
	Hugh Keenleyside Dam	UPL	Created wetland wildlife area near dam	N/A

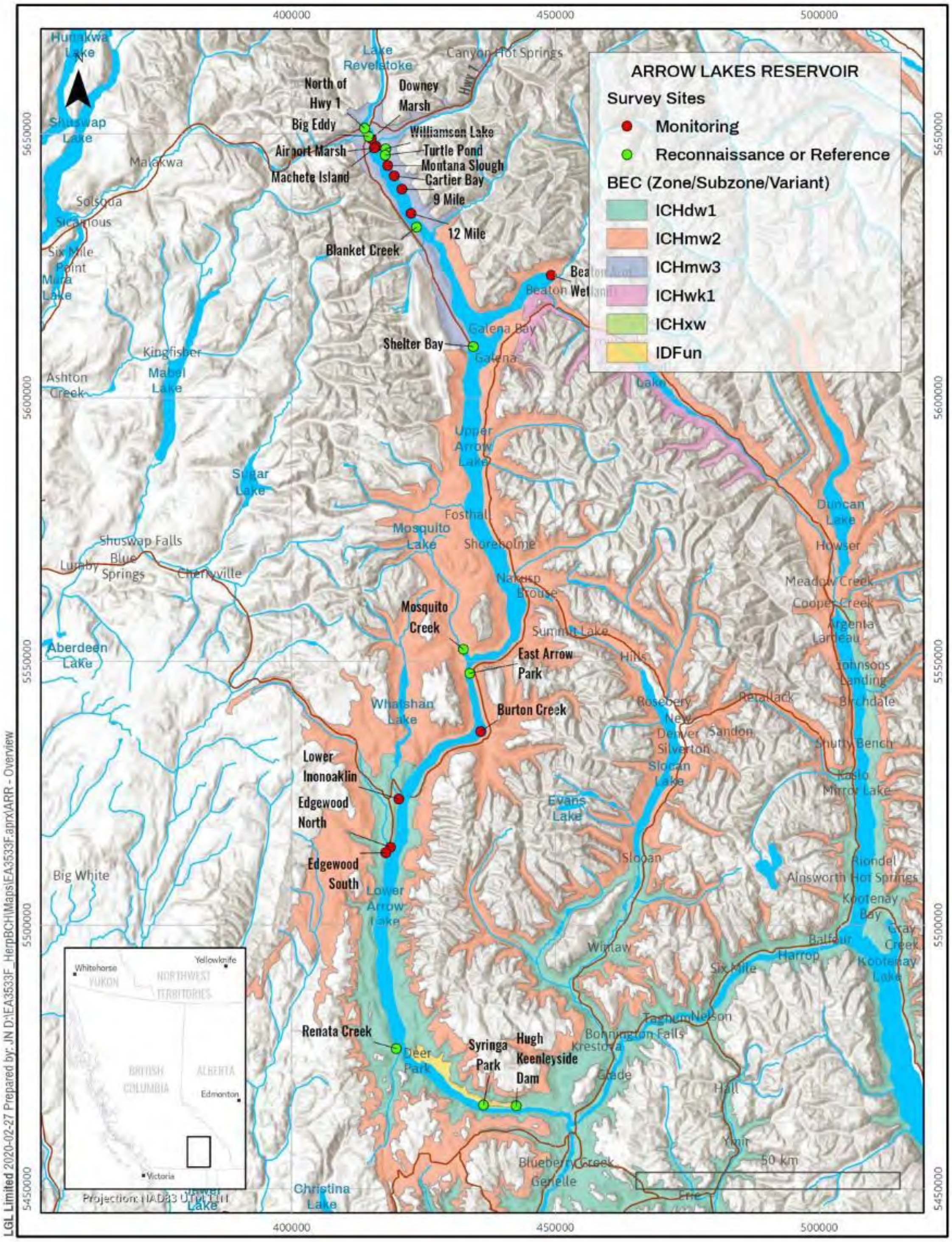

Figure 2-5: Location of Arrow Lakes Reservoir in British Columbia, and sites sampled for CLBMON-37 from 2008 to 2018. Place names in bold are either monitoring sites or reference/reconnaissance sites (see Hawkes and Tuttle 2013b). Refer to Table 2-3 for descriptions of Biogeoclimatic (BEC) zones.

3 METHODS

3.1 Study Overview

CLBMON-37 was a study concerned with the reservoir ecology of amphibians and reptiles spanning 11 years. A variety of sampling techniques were used to survey the drawdown zone study sites annually, from 2008 through 2018. These methods are described below (e.g., Section 3.3); additional detailed methods descriptions are available in the CLBMON-37/58 annual reports (e.g., Hawkes and Tuttle 2009a; Hawkes et al. 2018b) and monitoring program sampling protocols (e.g., Hawkes and Tuttle 2009b; Hawkes and Tuttle 2010b; Hawkes and Tuttle 2012).

3.2 Study Species

Of the 16 species of amphibians and reptiles that occur in the Columbia Basin, eight amphibian species and six reptile species potentially occur along the impounded waters of the Columbia River (Table 3-1). Two of the amphibian species observed are considered to be at risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC); Western Toad and Coeur d'Alene Salamander are currently listed as Special Concern (SARA Schedule 1). In 2015, a Pacific Chorus Frog (*Pseudacris regilla*) was heard calling in Canoe Reach, but the presence of this species has not been verified. The Intermountain-Rocky Mountain Population of the Western Painted Turtle is blue-listed in British Columbia and is a SARA Schedule 1 species of Special Concern.

Table 3-1: Provincial and federal status of species of amphibians and reptiles that occur in the Columbia Basin. Species names in bold are known to occur in the drawdown zone of Kinbasket Reservoir (KIN) and/or Arrow Lakes Reservoir (ARR)**.**

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 sylvaticus*)	A-LISY	KIN	Y	
Pacific Chorus Frog (*Pseudacris regilla*)	**A-PSRE**	ARR	Y	
Western Toad (*Anaxyrus boreas*)	**A-ANBO**	KIN/ARR	Y	SC
Long-toed Salamander (*Ambystoma macrodactylum*)	**A-AMMA**	KIN/ARR	Y	
Coeur d'Alène Salamander (*Plethodon idahoensis*)	A-PLID	ARR	Y	SC
Rocky Mountain Tailed Frog (*Ascaphus montanus*)	A-ASMO	N/A	R	
REPTILES				
Western Painted Turtle (*Chrysemys picta*)	**R-CHPI**	ARR	B	SC
Western Terrestrial Garter Snake (*Thamnophis elegans*)	**R-THEL**	KIN/ARR	Y	
Common Garter Snake (*Thamnophis sirtalis*)	**R-THSI**	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-PLSK**	ARR	B	SC
Northern Alligator Lizard (*Elgaria coerulea*)	**R-ELCO**	ARR	Y	

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

3.3 Sampling Methodology

3.3.1 Sampling Period

Field sampling occurred between May (occasionally April) and August (or September in some years) to coincide with the active period of amphibians and reptiles (Table 3-2). The timing of the sampling sessions was designed to facilitate an assessment of how fluctuating water levels affected amphibian and reptile populations and their use of habitats in the drawdown zone of each reservoir. Due to the large spatial extent of the Kinbasket and Arrow Lakes Reservoirs and the differences in climatic regimes, sample sites were surveyed over general time periods, rather than specific dates. The field sampling schedule followed a similar timeline across the years to facilitate data comparison. Distributing field visits across a four to five-month period also provided an indication of seasonal abundance and habitat use for each species. See Appendix 1 for annual date ranges of field seasons and associated reservoir elevation ranges.

Table 3-2: Timing of field sessions and average reservoir elevations for Arrow Lakes and Kinbasket Reservoirs from 2008 to 2018. Field sessions with an asterisk did not happen in all years. Field session 6 was part of the two Master of Science projects in Valemount Peatland.

Field Session	Season	Field Timing	Average Elevation (m ASL)	
			Arrow Lakes	Kinbasket
1	Early Spring	Early to Mid May	431.1	726.8
2	Late Spring	Early June	435.3	735.68
3	Early Summer	End June / Early July	438.3	744.77
4	Mid Summer	End of July / Early August	437.5	750.1
5*	Late Summer	End of August	435.4	751.6
6*	Fall	September / October	434.5	751.3

Timing of visits to each reservoir varied in some years due to annual differences in the seasonal conditions and temperatures between the Kinbasket and Arrow Lakes Reservoirs. For example, in certain years when reservoir levels were higher than normal (e.g., 2012 and 2013), field sampling was shortened (or late summer sessions cancelled) because less area was available for searching. In 2016, seasonal conditions were earlier than normal and field schedule was adjusted to try and capture early spring amphibian breeding.

In general, early spring field visits were timed to correspond with the breeding season of amphibians and emergence of reptiles from hibernation. This period also corresponded with low reservoir water-levels, which ensured that the lower extent of the drawdown zones could be delineated and surveyed. Early summer visits were timed to include larval amphibian surveys and reptile surveys. In mid to late summer, surveying techniques followed a slightly different sampling scheme, as water levels were near their highest and most of the drawdown zone was unavailable for sampling.

In 2010-2011 and 2015-2017, field sampling in Valemount Peatland was more extensive due to two Master of Science student projects and occurred weekly from late April to mid-October.

3.3.2 General Survey Methods

As the detection of amphibians and reptiles often varies within and among species, by season, and by habitat, several survey methods were used for different species and seasons. In general, daytime surveys for amphibians and reptiles occurred between the hours of 07:30 to 21:00 and night surveys occurred after 22:00 and lasted until around midnight. When daytime temperatures exceeded 25˚C, surveys occurred in the morning prior to 13:00 and in the late afternoon / early evening (e.g., 18:00 to 21:00) to maximize the probability of observing animals.

A variety of survey techniques were used, including radio telemetry, auditory call surveys, egg mass surveys, larval surveys, and visual encounter surveys. Of these methods, visual encounter surveys were deemed the most appropriate method to sample amphibians and reptiles of all life stages. Total survey time per person was recorded to calculate catch per unit effort (CPUE) time (i.e., detection rate) for each survey site, field session, and species.

The following sections briefly describe the methods associated with each survey type and the relevant species targeted by each method:

Visual Encounter Surveys: Visual encounter surveys (VES) were conducted throughout the active season described above. Visual encounter surveys are a commonly used technique for the detection and capture of conspicuous species (e.g., Columbia Spotted Frog, Western Toad, Common Garter Snake, Western Painted Turtle) and involve visually searching an area, typically as a time-constrained search so that equal amounts of time are spent searching various areas or habitat types. VES provided information on presence, species richness, and habitat use.

Egg Mass / Larval Surveys: Surveys for egg masses, tadpoles and larvae occurred in the spring at various wetland sites and are a subset survey type of VES. Data are reported within those results. Egg mass surveys were used to make a count, or estimate, of the number of egg masses of each species deposited in each breeding location and provided information on presence/occupancy, relative abundance, and reproductive output of a species at each sampling area. Egg masses were counted (where possible; Western Toad egg strings noted as individual strings were often overlapping and could not be distinguished) and location data were collected at these sites. Clusters of egg masses and aggregations of tadpoles or metamorphs were treated as a single observation per location or pond, so as not to skew numbers.

Nocturnal Call and Road Surveys: Auditory surveys were conducted at nine call stations in Revelstoke Reach for Pacific Chorus Frogs in most years of CLBMON-37. Call surveys were paired with night road surveys along Airport Road (south of Revelstoke) to document amphibians moving towards or away from the reservoir.

Radio telemetry: A pilot radio telemetry study on Western Toads and Common Garter Snakes occurred in 2014 in Revelstoke Reach, and additional telemetry surveys were conducted in Valemount Peatland starting in 2015, as part of a MSc project studying the movements of Common Garter Snakes in the drawdown zone of Kinbasket Reservoir and upland areas (McAllister 2018). A MSc study assessing turtle ecology and relationships between Western Painted Turtles and reservoir operations in Revelstoke Reach occurred in 2011-2012 (Basaraba 2014) and an overwintering study on Western Painted Turtles occurred between 2014 and 2016

(Duncan 2016). Both studies relied on the use of radio telemetry to track turtles to nesting and overwintering locations (CLBMON-11B3).

3.3.3 Species and Habitat Data

General Survey Data: 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 levels. 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 associate each observation with a given wetland or pond, elevation, and vegetation community (as defined in Hawkes et al. 2007; Enns et al. 2008). Annual differences in species richness, diversity and evenness were assessed by site and reservoir.

Species Data: General Wildlife Permits were granted for each year of work from 2008 to 2018 (see annual reports for specific permit numbers). The Resources Inventory Standards Committee (RISC) protocols for sampling and handling of amphibians and reptiles (RISC 1998a, 1998b) were followed; see previous annual reports for descriptions of morphometric data collected (e.g., weight, size, sex).

Habitat Data: were collected in a standardized manner at all locations where amphibians and reptiles were observed and included characteristics at both the macro and micro scales.

- Vegetation Community: The vegetation community types (from CLBMON-10 and CLBMON-12/33) in which species were observed were determined by relating the species observation location to the corresponding vegetation polygon on a GIS map.
- Water Chemistry: point data (dissolved oxygen in mg/L, conductivity in µs, temperature in °C, and pH) were collected at all pond and reservoir sampling locations at each study site as well as for individual amphibian locations. Water physicochemical dataloggers were also deployed in selected wetlands in drawdown zone and upland habitats in Kinbasket and Arrow Lakes Reservoirs.
- Pond Mapping: All ponds in the drawdown zone were mapped in a GIS to determine both the total area and elevation of ponds. Ponds were numbered at each site and were monitored across the field sessions for amphibian or reptile occupancy and use and to assess within season habitat availability relative to reservoir operations. For more detail on mapping of pond habitat see Appendix 14 and Appendix 17.

4 DATASETS

Sampling in Kinbasket and Arrow Lakes Reservoirs was facilitated via CLBMON-37 (Arrow Lakes Reservoir) and CLBMON-37/CLBMON-58 (Kinbasket Reservoir). Sampling in Arrow Lakes Reservoir under CLBMON-37 occurred in 2008, 2009, 2010, 2012, 2014, 2016, and 2018 for a total of seven sample events in an 11-year period. With the addition of CLBMON-58, sampling in Kinbasket Reservoir occurred in all 11 years (Table 4-1). Below, we provide a summary of the datasets compiled from data collected between 2008 to 2018 including types of data collected, sample sizes, number of sites, temporal replication, number of ponds sampled, etc.

Table 4-1: Years of sampling under CLBMON-37 (black dots) and CLBMON-58 (red dots) in Arrow Lakes and Kinbasket Reservoirs, 2008 to 2018. Blanks indicate no sampling in that reservoir and year.

	Sample Year											
Reservoir	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**Years**
Arrow Lakes	●	●	●		●		●		●		●	7
Kinbasket	●	●	●	●	●	●	●	●	●	●	●	11

4.1 Dataset 1: Visual Encounter Data (All species detected – 11 years)

This dataset was created to summarize the presence–absence (i.e., detection or non-detection) of amphibian and reptile species in the drawdown zone of each reservoir by geographic region (i.e., reservoir or survey location) or habitat distribution. Data pooled across all years of sampling (Table 4-1) were used in most analyses and occasionally partitioned into CLBMON-37 or CLBMON-58 specific analyses. These data assisted in answering MQ1 through MQ4. From this dataset, several measures were extracted, including species-specific abundance and detection rate per site survey (CPUE; Appendix 4), site occupancy (Appendix 2), species richness and diversity (Appendix 5), habitat use (Appendix 10), and elevational distribution in the drawdown zone (Appendix 11).

In total, this dataset contained 888 surveys at eight monitoring sites for Kinbasket Reservoir (Table 2-2) and 12 monitoring sites for Arrow Lakes Reservoir (Table 2-4). We spent 4,582 hours over 435 days surveying study sites within Kinbasket Reservoir and 1,058 hours over 180 days surveying within Arrow Lakes Reservoir between May and August 2008 to 2018 (Table 4-2). In total, we documented 795 egg masses, ~6 million tadpoles, and ~175,589 metamorphs, juvenile or adult amphibians and reptiles of ten species (Appendix 4).

Table 4-2: Survey effort (hours) by year and month and the number of days in the drawdown zone of Kinbasket and Arrow Lakes Reservoirs from 2008 to 2018.

Reservoir	Year	Survey Effort (hrs; [Number of Days])						Total	
		April	May	June	July	August	September	Hours	Days
Kinbasket	2008	0	0	54.33 (7)	47.03 (4)	15.83 (3)	16.2 (2)	133.39	16
	2009	0	10.13 (1)	7.91 (4)	46.27 (7)	24.65 (2)	0	88.96	14
	2010	35.97 (4)	202.47 (21)	163.58 (17)	161.77 (13)	167.9 (15)	12.1 (2)	743.79	72
	2011	45.57 (4)	335.23 (18)	344.07 (22)	309.42 (21)	105.77 (12)	0	1140.06	77
	2012	39.95 (2)	31.63 (4)	42.15 (6)	18.97 (9)	0	0	132.70	21
	2013	0	183.67 (10)	43.47 (6)	17.47 (3)	0	0	244.61	19
	2014	0	72.65 (10)	88.23 (12)	71.3 (6)	4.47 (2)	0	236.65	30
	2015	0	200.67 (20)	225.64 (22)	219.4 (21)	121.66 (11)	0	767.37	74
	2016	0	123.87 (14)	188.62 (17)	106.54 (12)	70.91 (10)	19.93 (4)	509.87	57
	2017	4.97 (2)	133.17 (15)	168.69 (14)	169.6 (10)	3.37 (1)	0	479.80	42
	2018	0	25.09 (4)	38.79 (4)	41.37 (5)	0	0	105.25	13
	Total	126.46 (12)	1318.58 (117)	1365.48 (131)	1209.14 (120)	514.56 (56)	48.23 (8)	4582.45	435
Arrow Lakes	2008	0	45.83 (5)	36.5 (4)	19.25 (2)	18.88 (4)	13.15 (2)	133.61	17
	2009	0	60.18 (6)	35.17 (6)	34.2 (5)	21.87 (4)	0	151.42	21
	2010	44.72 (7)	67.48 (14)	71.73 (12)	37.33 (7)	30.53 (5)	38.83 (6)	290.62	51
	2012	5.42 (1)	37.62 (4)	40.15 (4)	4.87 (3)	12.45 (3)	0.42 (2)	100.93	17
	2014	0	22.52 (5)	40.4 (6)	31.97 (7)	2.68 (1)	0	97.57	19
	2016	0	53.14 (10)	68.64 (14)	16.22 (11)	37.09 (8)	0	175.09	43
	2018	13.79 (2)	23.52 (2)	46.17 (5)	25.39 (3)	0	0	108.87	12
	Total	63.93 (10)	310.29 (46)	338.76 (51)	169.23 (39)	123.50 (25)	52.40 (10)	1058.11	180

4.2 Dataset 2: Call Station Data (Revelstoke Reach Call Stations – 6 years)

This dataset was created to document the presence and relative abundance of calling Pacific Chorus Frog in Revelstoke Reach. Pooled data collected from nine call stations (Table 7-6) were used and consisted of six years of estimated number of calling males per station using the Wisconsin Index (Appendix 3). These data assisted in answering MQ1, MQ2, and MQ3. In total, this dataset contained 48 observation records of Pacific Chorus Frog consisting of approximately 1,357 individuals at nine stations.

4.3 Dataset 3: Road Survey Data (Airport Road, Revelstoke Reach – 5 years)

This dataset was created to summarize the early spring presence and species richness of amphibians moving into the drawdown zone of Revelstoke Reach. These data assisted in answering MQ2. Data collected along sections of Airport Road (~4 km along Montana Slough/Cartier Bay; ~1.5 km along 9 Mile) in six years (2008, 2009, 2010, 2012, 2016, and 2018) were used. Counts of individual amphibians were made to summarize seasonal presence and richness (Appendix 3). In total, this dataset contained 208 observation records of three amphibian species.

4.4 Dataset 4: Life History Data (All components – 11 years)

This dataset was created to examine life history variation (e.g., size, sex ratios, life stage, diet) in seasonal presence, abundance and use of drawdown zone at monitoring sites across all years of study. Morphometric data (e.g., length, mass) were collected from juvenile, subadult, and adult amphibians and reptiles in order to classify individuals into life stages (Appendix 9). Only Western Toad, Columbia Spotted Frog and garter snake species yielded large enough observation numbers to report. These data assisted in answering MQ2 and MQ3. From this dataset, several measures were summarized including species-specific distribution by life stage (Appendix 2), productivity (reproductive population size; Appendix 6), body condition (for Western Toad, Appendix 7), and diet (see MQ3 discussion).

4.5 Dataset 5: Radio Telemetry Data (Canoe and Revelstoke Reaches – 4 years)

This dataset was created to summarize Western Toad, Columbia Spotted Frog, and Common Garter Snake movements and habitat use within drawdown zone and upland habitats from 2014 to 2017 (Appendix 8; Appendix 10). These data assisted in answering MQ3 and MQ4. From this dataset, several measures were summarized including species-specific information on seasonal movements, breeding (courting, mating, and birthing), and the locations of overwintering sites. In total, this dataset contained 62 individuals with tags (37 Western Toads, 2 Columbia Spotted Frogs, and 23 Common Garter Snakes; Table 4-3) and documented 489 locations (locations per individual: range = 1-36, mean = 8, median = 5).

Table 4-3: Sample sizes for radiotagged amphibian and reptile species from 2014 to 2017.

Species	Valemount Peatland				Revelstoke Reach			
	2014	2015	2016	2017	2014	2015	2016	2017
Western Toad	6	20	0	0	11	0	0	0
Columbia Spotted Frog	0	2	0	0	0	0	0	0
Common Garter Snake	6	4	4	7	2	0	0	0

4.6 Dataset 6: Pond Habitat Data (Mapped Ponds in drawdown zone – 9 years)

This dataset was created to summarize pond habitat in the drawdown zone, including pond-specific habitat data (e.g., pond type, water depth, water physicochemistry, dominant vegetation type, percent cover, elevation). Pond mapping occurred in 2009 and 2010 and data collection for ponds with animal observations occurred throughout the 11-year study. These data assisted in answering MQ4 and MQ5 (Appendix 10; Appendix 13, Appendix 14). A total of 209 ponds were mapped (Table 4-4; 181 in Kinbasket Reservoir and 28 in Arrow Lakes Reservoir [Revelstoke Reach area only]), 3,978 physicochemical data points were collected between 2009-2016 (Hawkes et al. 2017, Hawkes et al. 2018b), and data from over 50 data loggers analyzed (Hawkes et al. 2017, Hawkes et al. 2018b).

Table 4-4: Number, area (ha), and elevation (mASL) of mapped ponds in the drawdown zone at monitoring sites sampled for amphibians in Kinbasket Reservoir (KIN) and Arrow Lakes Reservoir (ARR).

			Area (ha)				Elevation (m ASL)		
RES	Site	Ponds	Total	Min	Max	Mean	Min	Max	Mean
KIN	Causeway	24	2.32	0.00	0.97	0.10	750.74	752.89	751.5
	KM79	21	1.01	0.00	0.32	0.05	743.97	751.42	746.45
	KM88	73	2.02	0.00	0.49	0.03	738.33	754.45	744.28
	Ptarmigan Creek	1	0.95	0.95	0.95	0.95	748.97	748.97	748.97
	Valemount Peatland	53	5.36	0.01	0.83	0.10	748.44	753.15	750.28
	Sprague Bay	9	0.16	0.00	0.07	0.02	752.68	754.91	753.76
	Total	**181**	**11.82**						
ARR	Airport Marsh	1	55.80	55.80	55.80	55.80	438.26	438.26	438.26
	Cartier Bay	15	39.75	0.01	14.34	2.65	432.87	434.95	433.81
	Montana Slough	12	19.50	0.06	12.42	1.62	434.86	436.14	435.46
	Total	**28**	**115.05**						

4.7 Dataset 7: Vegetation Community Habitat Data (Vegetation Communities in drawdown zone – 11 years)

This dataset was created to summarize habitat use by documenting the distribution of species within the drawdown zone relative to mapped vegetation community types from 2008 to 2018. Existing habitat maps produced under CLBMON-10 for Kinbasket Reservoir and CLBMON-33 for Arrow Lakes Reservoir were used to define Vegetation Community Codes (VCC). These data were used to describe the habitat use of amphibians and reptiles and assisted in answering MQ4 (Appendix 10). A total of 37 VCC are documented (Kinbasket n = 21; Arrow n = 16) with 17 habitats used in Kinbasket and 14 habitats used in Arrow Lakes Reservoir (Table 4-5).

Table 4-5: Vegetation community codes mapped under CLBMON-33 for Arrow Lakes Reservoir and CLBMON-10 for Kinbasket Reservoir. Arrow Lakes: BB = boulders, BE = sandy beach, BG = gravelly beach, CL = cliffs and rock outcrops, CR = cottonwood riparian, IN = industrial/residential/recreation, LO = log zone, PA = redtop upland, PC = reed canarygrass mesic, PE = horsetail lowland, PO = ponds, RR = reed-rill, RS = willow stream entry, SF = slope failure, SS = steep sand, WR = river entry; Kinbasket: BR = bluejoint reedgrass, BS = buckbean-slender sedge, CH = common horsetail, CO = clover–oxeye daisy, CT = cottonwood-trifolium, DI = disturbed, DR = driftwood, FO = unclassified forest, KS = Kellogg's sedge, LH = lodgepole pine – annual hawksbeard, LL = lady's thumb-lamb's quarter, MA = marsh cudweed–annual hairgrass, MC = mixed conifer, RC = canary reedgrass, RD = common road, SH = swamp-horsetail, SW = shrub-willow, TP = toadrush-pond water starwort, WB = wool-grass–Pennsylvania buttercup, WD = wood debris, WS = willow–sedge

	Vegetation Community Codes																				
Arrow Lakes Reservoir	BB	BE	BG	CL	CR	IN	LO	PA	PC	PE	PO	RR	RS	SF	SS	WR					
Kinbasket Reservoir	BR	BS	CH	CO	CT	DI	DR	FO	KS	LH	LL	MA	MC	RC	RD	SH	SW	TP	WB	WD	WS

The total area of vegetation communities in Kinbasket Reservoir was calculated as part of CLBMON-10 (Table 4-6). Comparable data does not exist for Arrow Lakes Reservoir as the original study design of CLBMON-33 did not allow for the derivation of total area for individual vegetation communities (M. Miller, pers. comm).

Table 4-6: Vegetation community codes and area (hectares) mapped under CLBMON-10 for Kinbasket Reservoir. Data from Hawkes and Gibeau (2017). See Table 4-5 for codes.

	Vegetation Community Code																					
Year	BR	BS	CH	CO	CT	DI	DR	FO	KS	LH	LL	MA	MC	RC	RD	SH	SW	TP	WB	WD	WS	Total
07	16.8	9.3	339.7	161.4	47.0		28.0	21.6	233.6	4.4	569.9	106.1	18.7	9.4		146.9		89.0	4.5	254.3	36.8	2097.3
10	41.5	12.0	280.5	135.7	21.0		36.8	19.0	210.2	0.5	719.1	110.2	0.2	31.5	0.6	52.4		266.9	128.9	70.0	34.5	2171.3
12	40.7	10.7	282.2	125.2	19.6		47.9	16.6	215.6	0.5	713.1	110.4	0.2	28.0	0.6	55.0		265.1	129.7	79.2	32.4	2172.6
14	40.9	10.9	281.2	119.7	16.0	21.6	56.7	45.3	215.1	0.5	707.8	110.4	0.1	25.3	0.5	43.3	22.9	290.2	143.9	56.3	34.7	2243.3
16	39.5	11.2	268.5	130.2	14.9	25.2	45.9	43.2	206.9	0.5	718.2	110.2	0.1	27.8	0.5	44.6	16.1	290.6	143.0	56.3	40.8	2234.0

4.8 Dataset 8: Reservoir Elevation Data (Both reservoirs – historical data and 2008 to 2018)

This dataset was created to summarize reservoir elevations and levels relative to the seasonal distribution and habitat use of amphibians and reptiles from 2008 to 2018. Additionally, data were pooled for all years of reservoir operation (Kinbasket Reservoir: 1976-2018; Arrow Lakes Reservoir: 1968-2018) to examine the effects of reservoir operations on seasonal distribution and habitat use of amphibians and reptiles to assist with answering MQ5, MQ6, and MQ10. From this dataset, several measures were extracted including daily and annual reservoir elevations relative to species distribution (Appendix 11), and seasonal habitat availability (Appendix 12). The operating elevation ranges were 707.41 to 754.38 mASL for Kinbasket Reservoir and 418.64 to 440 mASL for Arrow Lakes Reservoir.

4.9 Dataset 9: Effectiveness Monitoring Data (Four Physical Works Projects)

This dataset was created to document the wildlife physical works that occurred during the study period of CLBMON-37/58 and report the presence and richness of amphibian and reptile species at these physical works sites post construction. Data from four physical works projects were included (Table 4-7). Amphibian and reptile monitoring occurred pre-construction (as part of the CLBMON-37/58 program) and post treatment (Bush Arm and Cartier Bay Physical Works only) to document species' use of the site and to assist with answering MQ7 and MQ9.

Table 4-7: BC Hydro physical works projects and amphibian and reptile monitoring within CLBMON-37 from 2008 to 2018. Year 2019 occurred outside of study period but is shown to indicate other physical works projects that occurred. Pre = pre-treatment monitoring (as per CLBMON-37/58), Post = monitoring the year following treatment or physical work.

		Monitoring by Year					
Reservoir	**Physical Works Project**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Kinbasket	Bush Arm Physical Works	Pre	Treatment	Post	Post	Post	N/A
Kinbasket	Canoe Reach Wood Removal	Pre	Pre	Pre	Pre	Pre	Treatment
Arrow	Cartier Bay Physical Works	Pre		Treatment		Post	N/A
Arrow	Burton Creek Physical Works	Pre		Pre		Pre	Treatment

4.10 Data Analysis

Statistical analyses were performed using R (V3.5.3; R Core Team 2019) and Microsoft Excel Office 365 (© 2019). We used an alpha level of 0.1 to determine significance for most statistical tests. To compare species richness across vegetation communities and landscape units, observation data were standardized by correcting for detection rates (number of observations per hour). Standardized detection rates were also used to assess where amphibians and reptiles were located across the elevation gradient of the drawdown zone. See relevant appendix chapters for specific data analyses associated with each dataset.

5 MANAGEMENT QUESTIONS

Amphibian and reptile life history and habitat use of the Kinbasket and Arrow Lakes Reservoir drawdown zones was studied with reference to ten management questions (MQs). Some questions asked how the use of the drawdown zone by amphibians and reptiles was influenced by reservoir operations. Other questions were aimed at determining whether various revegetation techniques or future physical works projects could improve habitat quality or influence the use of the drawdown zone by amphibians and reptiles.

Below, we summarize our overarching responses to each MQ as per the Terms of Reference (TOR; BC Hydro 2010), with detailed supporting data analysis (based on each dataset) provided in the appendices. In addition to providing information relevant for addressing each MQ, we discuss methodological challenges, associated knowledge gaps, and opportunities for future monitoring.

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

Ten species of amphibians and reptiles were recorded in the drawdown zones of Kinbasket and Arrow Lakes Reservoirs over the 11 years of monitoring, including three amphibians and three reptiles in Kinbasket Reservoir, and four amphibians and six reptiles in Arrow Lakes Reservoir (Table 5-1). All species documented using the drawdown zones (as well as adjacent upland habitats) were expected based on known distributions within B.C. (Matsuda et al. 2006). The sites with the most observed species in Kinbasket Reservoir were Bush Arm KM79 and KM88 (Bear Island) wetlands, Bush Arm Causeway, Ptarmigan Creek, and Valemount Peatland (Figure 5-1; Appendix 15). In Arrow Lakes Reservoir, the most speciose sites were Revelstoke Reach (Cartier Bay, Montana Slough, 9 Mile), Edgewood areas, Burton Creek, and Beaton Arm (Figure 5-2; Table 7-5; Appendix 15).

Table 5-1: Species of amphibians and reptiles that occurred within the drawdown zone of Kinbasket and/or Arrow Lakes Reservoirs from 2008 to 2018.

Group	Species	Kinbasket	Arrow Lakes
Amphibian - Anuran	Columbia Spotted Frog	✓	✓
Amphibian - Anuran	Pacific Chorus Frog		✓
Amphibian - Anuran	Western Toad	✓	✓
Amphibian - Salamander	Long-toed Salamander	✓	✓
Amphibian - Salamander	Coeur d'Alene Salamander		
Reptile - Turtle	Western Painted Turtle	✓	✓
Reptile - Lizard	Northern Alligator Lizard		✓
Reptile - Lizard	Western Skink		✓
Reptile - Snake	Rubber Boa		✓
Reptile - Snake	Western Terrestrial Garter Snake	✓	✓
Reptile - Snake	Common Garter Snake	✓	✓
	Total Species Richness	**6**	**10**

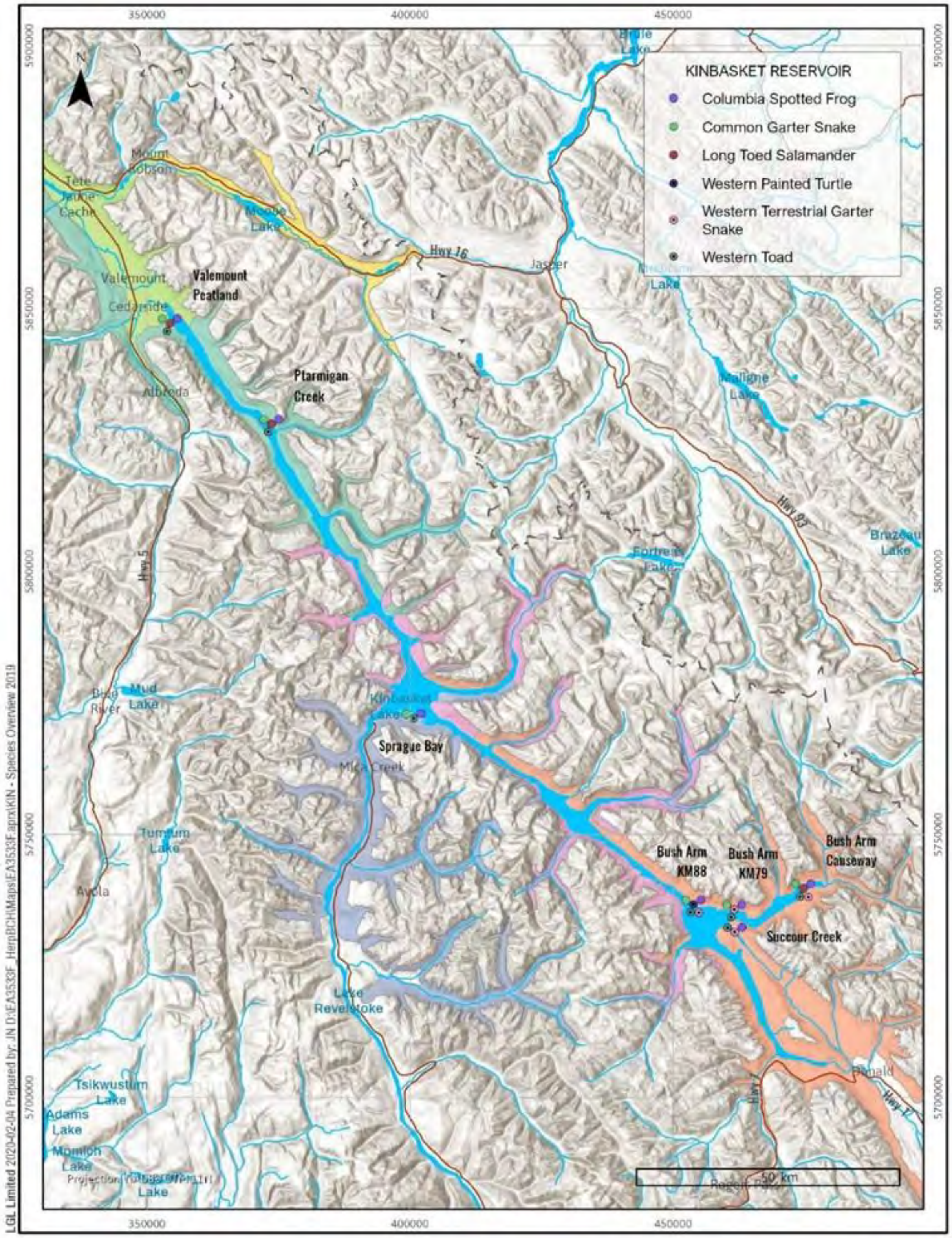

Figure 5-1: Species of amphibian detected in the drawdown zone of Kinbasket Reservoir from 2008 to 2018.

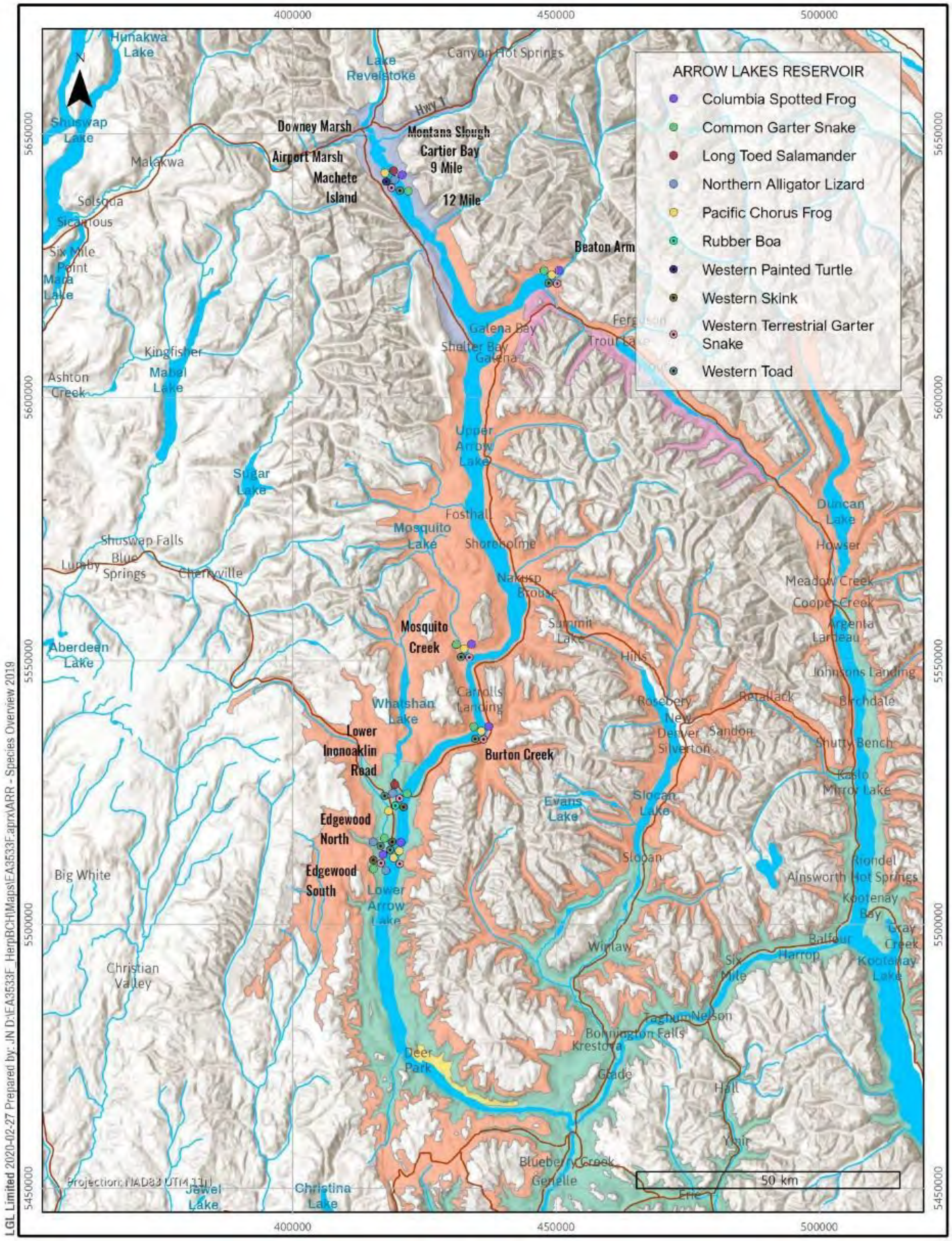

Figure 5-2: Species of amphibian detected in the drawdown zone of Arrow Lakes Reservoir from 2008 to 2018.

Several species observed during this study are widespread across southern B.C. (Matsuda et al. 2006) and occurred at all the monitoring sites (Appendix 2). The most widespread species in Kinbasket Reservoir were Western Toad, Columbia Spotted Frog, and Common Garter Snake, whereas the most widespread species in Arrow Lakes Reservoir were Western Toad, Columbia Spotted Frog, Pacific Chorus Frog, Common Garter Snake, and Western Terrestrial Garter Snake (Appendix 2; Appendix 15).

Additional information regarding the occurrence and distribution of species of amphibians and reptiles in the drawdown zones of Kinbasket and Arrow Lakes Reservoirs is provided in Appendix 2, Appendix 8, Appendix 9, and Appendix 11. Maps of species by reservoir and survey location are provided in Appendix 15 and Appendix 16

Amphibians

Western Toad was by far the most encountered amphibian in the drawdown zone of both reservoirs across all study years. This species is widespread throughout B.C. and uses a variety of pond types as well as nearby upland habitat to fulfill its life history requirements (breeding, foraging and overwintering – see MQ3). Key breeding sites for Western Toad in Kinbasket Reservoir included Valemount Peatland (notably Pond 12), Bush Arm KM79, and Bush Arm Causeway (notably the southeast side of road). Key breeding sites for Western Toad in Arrow Lakes Reservoir include Revelstoke Reach (notably Cartier Bay), Beaton Arm, Burton Creek, and Lower Inonoaklin.

Columbia Spotted Frog is also widely distributed in B.C. and across the study sites for both reservoirs, although to a lesser extent than Western Toad. This species is also pond-breeding. Key breeding sites were Valemount Peatland, Bush Arm KM79, and Sprague Bay in Kinbasket Reservoir, and Beaton Arm and Burton Creek in Arrow Lakes Reservoir. This species is largely tied to pond habitat for breeding, foraging, and overwintering and likely does not move in and out of the drawdown zone during the year (i.e., remains in drawdown zone sites year-round; Matsuda et al. 2006).

Pacific Chorus Frogs were documented in most Arrow Lakes Reservoir sites, expectedly so as its range overlaps with the entire reservoir. This pond-breeding species used multiple pond types and key breeding sites, including Revelstoke Reach (see Appendix 3 for nocturnal call survey results and survey stations), Burton Creek, and Lower Inonoaklin. A possible auditory observation of a Pacific Chorus Frog in the Valemount Peatland was recorded in 2015, but this was not confirmed in any other year. It is the opinion of the authors that this species is unlikely to occur in the Kinbasket Reservoir region due to range constraints.

There are presumed historical records of Wood Frog from the drawdown zone of Kinbasket Reservoir (D. Adama pers. comm.), but this species was not observed during this study or in conjunction with other Columbia River WUP studies (e.g., CLBMON-10, 9, and 61). As currently understood (Matsuda et al. 2006), the present range of Wood Frog may not overlap the drawdown zone of Kinbasket Reservoir and does not overlap with Arrow Lakes Reservoir. Wood Frog have been documented just north of Valemount Peatland in the Robson Valley (near Tete Jaune and McBride; K. Tuttle pers. obs. 2019) and to the west of Kinbasket Reservoir near Avola, BC (Matsuda et al 2006). Northern Leopard Frog has been extirpated from the area and was not expected to occur in either drawdown zone (P. Ohanjanian, pers. comm.).

Long-toed Salamanders were present at several sites in both reservoirs, with Cartier Bay and Bush Arm Causeway being the two main sites for observations. All observations were from breeding ponds; however, this species migrates to upland habitats to overwinter (Matsuda et al 2006). Despite being widespread in B.C., this species is often difficult to locate because it has an early breeding period and animals are inconspicuous during the remainder of the year. Given this, it is possible that Long-toed Salamanders 1) occurred at certain study sites but we failed to observe them, and 2) were more abundant than our detection rates determined.

Coeur d'Alene Salamanders, which have a known range in the Arrow Lakes Reservoir region from Castlegar to north of Revelstoke (Matsuda et al. 2006), were incidentally observed at two locations outside of the drawdown zone of Arrow Lakes Reservoir (Montana Slough, Beaton Arm). This plethodontid species (i.e., lungless salamander) has very specific habitat requirements (e.g., waterfall splash zones, small slow-moving creeks) and was not expected to occur within the drawdown zone (although there was an outside chance of this species occurring at the very margins of the reservoir).

Reptiles

Common Garter Snake were the most widely distributed reptile species and were documented each year at most monitoring sites (Kinbasket and Arrow Lakes Reservoirs). Western Terrestrial Garter Snake were documented less frequently in Kinbasket Reservoir, likely due to northern range limitations and the availability of suitable upland habitat near the drawdown zone (Matsuda et al. 2006). Both garter snake species are typically habitat generalists, have varied diets, and were expected to occur at most sites for both reservoirs.

Western Painted Turtle, a largely aquatic species, were most frequently observed in Revelstoke Reach of Arrow Lakes Reservoir, specifically in Airport Marsh and Montana Slough (Schiller and Larsen 2012; Hawkes and Tuttle 2009a). As part of the ongoing Painted Turtle studies in Revelstoke Reach, LGL Limited and ONA collected data by tracking and documenting use of the drawdown zone and upland habitat by turtles from 2012 to 2016. Data and results pertaining to eight management questions are provided in the annual summary reports (Hawkes et al. 2013c; Wood and Hawkes 2014; Wood and Hawkes 2015; Wood et al. 2016; Challenger and Hawkes 2018).

The most surprising observations of Western Painted Turtle during the study period were two unique turtles observed in the Kinbasket Reservoir region, one in the drawdown zone at Bush Arm-KM88 (Bear Island), and another outside the drawdown zone near the Village of Valemount (Hawkes and Tuttle 2016). More detections of these species at these sites are required to confirm occupancy, as a single detection in one year does not provide conclusive evidence that a species (or population of that species) occurs there (i.e., turtle could have been an introduction by human release). Painted turtles have also been observed near Donald, B.C. (outside of the drawdown zone, near the southeastern arm of Kinbasket Reservoir, Upper Columbia River area; D. Adama pers. comm.). To the best of the authors' knowledge, no other surveys for this species have occurred in Kinbasket Reservoir and this is viewed as a knowledge gap for this blue-listed species.

Several other reptile species were documented only in Arrow Lakes Reservoir or at certain study sites over the 11-year period. These species either have specific habitat requirements not well represented in reservoir drawdown zones or their northern range limits overlap with the study area. Northern Alligator Lizards were detected in the drawdown zone at only a few sites (Montana Slough, Edgewood South/North, Syringa Park, [Cartier Bay (M. Miller pers. obs.)]) and likely only use the periphery of the drawdown zone where suitable habitat occurs (e.g., rocky areas or wood debris present). This species has a northern range limit just north of Arrow Lakes Reservoir (Matsuda et al. 2006) and was not expected to occur in Kinbasket Reservoir area. Western Skink were found only at Edgewood North and South monitoring sites, including three observations in the drawdown zone and several observations during VES in the rocky, treed areas above the drawdown zone (upland immediately adjacent to reservoir). Similarly, Rubber Boa was documented once in the drawdown zone at Lower Inonoaklin and in the upland areas at Edgewood North. All three of these reptile species were expected to inhabit sites only at the very edge of the drawdown zone (immediately adjacent to upland habitat). Both Western Skink and Rubber Boa have northern range limits near the mid-Arrow Lakes Reservoir area (Matsuda et al. 2006) and are primarily associated with rocky and forested upland habitat types.

5.1.1 Challenges and Opportunities

The large dataset collected over the course of CLBMON-37/58 studies (2008 to 2018) has allowed for a detailed characterization of the occurrence and distribution of amphibians and reptiles for the drawdown zone of Kinbasket and Arrow Lakes Reservoirs. For some species and years, site occupancy was influenced by survey effort (i.e., sites inaccessible in certain years, poor survey conditions, alternating years of CLBMON-37/58). Despite this, the general patterns of site occupancy remained consistent, with Western Toad, Columbia Spotted Frog, and Common Garter Snake more widely distributed and more readily detectable than all other species.

Site occupancy was not formally modelled for amphibians or reptiles using habitats in the drawdown zone of either reservoir. In most cases the number of replicates for a given site sampled within a given year were too low to consider occupancy modelling. For the purposes of this report, site occupancy was defined simply as the location where amphibians were documented during each year of study (i.e., the naïve occupancy rate; MacKenzie et al. 2006; Appendix 2). Likewise, detection probabilities were not calculated.

A significant challenge to this study is that small, inconspicuous amphibian species were generally difficult to locate; however, multiple years of surveys across the seasons likely provided an adequate understanding of species occupancy and diversity across all sites in both reservoirs. For example, Long-toed Salamanders possibly occurred at more sites than we reported but went undocumented due to reasons discussed above. This situation could also apply to other species and life history stages in this study including lizard species, neonate snakes, and certain larval stages of pond-breeding amphibians. Nevertheless, the data, while imperfect, provided a good picture of the occurrences and distribution of all the expected species of amphibians and reptiles using the drawdown zone of both reservoirs.

5.2 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?

5.2.1 Abundance

Amphibian populations naturally undergo large fluctuations with the number detected a function of seasonality, current environmental conditions, overwinter survival, and predatory pressures (Hansen et al. 2012). Abundance values for both amphibians and reptiles in this study were not easily estimated due to the large geographic range of this study, limited site access to all reaches and wetlands occurring in the drawdown zone, limited number of site visits per sampling session (e.g., one visit per month per site), and natural population variation. However, below we summarize spatial and temporal relative abundance for most species observed in the drawdown zone from 2008 to 2018.

A total of 8,113 amphibian and 1,166 reptile observations were made in the drawdown zones of Kinbasket and Arrow Lakes Reservoirs between 2008 and 2018. Amphibians were detected more frequently (1.26 CPUE) than reptiles (0.19 CPUE) pooled for both reservoirs and all years combined. If detection rate is regarded as a proxy for relative abundance, the CPUE data indicated that Western Toad (Kinbasket Reservoir = 0.86, Arrow Lakes Reservoir = 0.70), Columbia Spotted Frog (Kinbasket Reservoir = 0.47, Arrow Lakes Reservoir = 0.09), and Common Garter Snake (Kinbasket Reservoir = 0.12, Arrow Lakes Reservoir = 0.23) were the most relatively abundant species in both reservoirs. See Appendix 4 for detection rates by species and location. Overall detection rates for amphibians and reptiles varied slightly from year to year (Figure 5-3; Figure 5-4), most notably in 2018 where numerous observations of Western Toads were made during spring breeding.

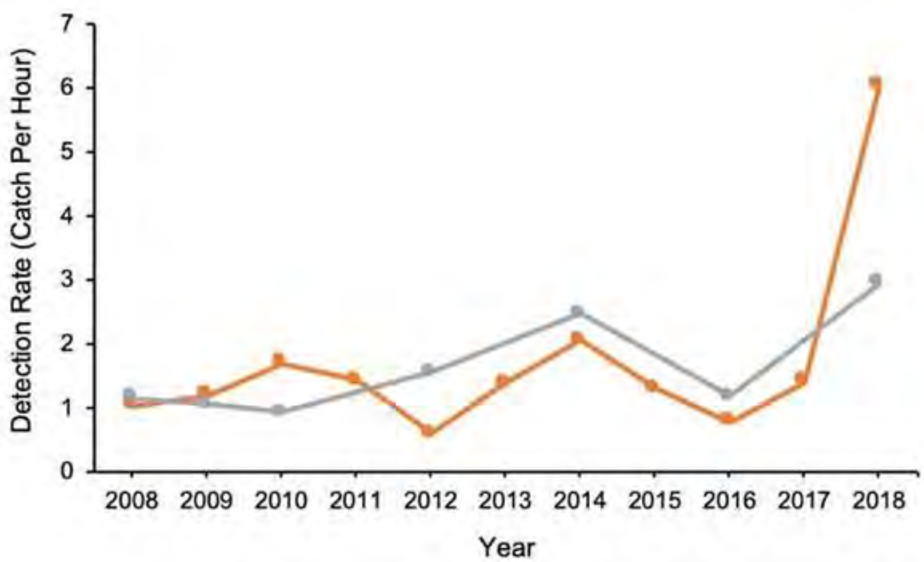

Figure 5-3: Annual variation in detection rate (overall annual rate pooled) for amphibians and reptiles at Kinbasket Reservoir (orange) and Arrow Lakes Reservoir (grey) from 2008 to 2018 Note: Arrow Lakes Reservoir was not surveyed in 2011, 2013, 2015, or 2017.

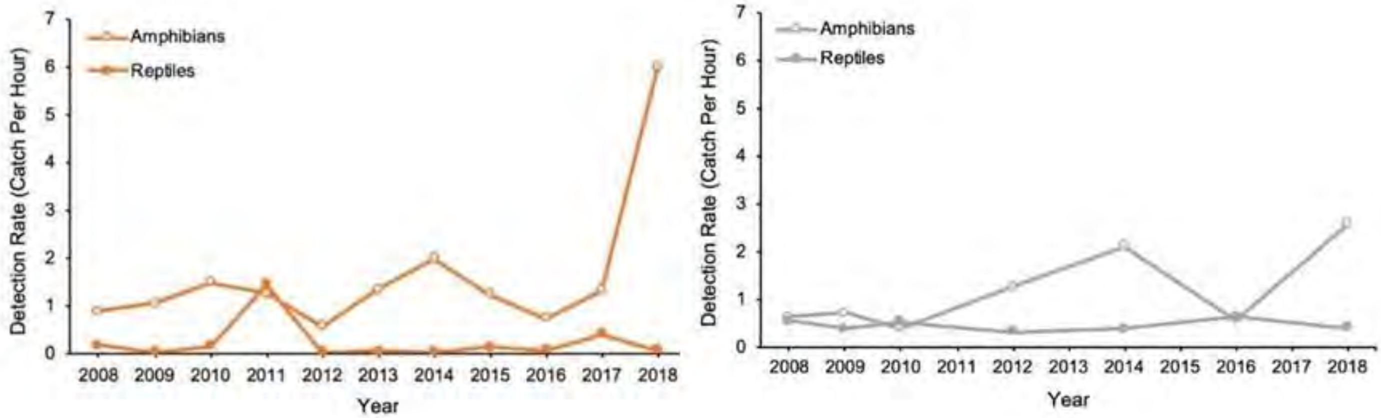

Figure 5-4: Annual variation in detection rate for amphibians (hollow marker) and reptiles (filled marker) at Kinbasket Reservoir (left, orange) and Arrow Lakes Reservoir (right, grey) from 2008 to 2018. Note: Arrow Lakes Reservoir was not surveyed in 2011, 2013, 2015, or 2017.

Amphibian detection rates (overall annual rate pooled) varied within year from 2008 to 2018 (Appendix 4). Overall, there were typically more detections of amphibians in the spring than in the summer or early fall (Appendix 9; Figure 7-2, Figure 7-4). The spring (late April to mid-June) coincided with the peak of the breeding season when most adults were aggregating at and migrating to and from breeding ponds and were therefore more conspicuous. This trend was apparent in all years of study, particularly for adult individuals of Western Toad and Long-toed Salamander and egg masses of all amphibian species. This pattern of high detection rates in the spring is a common phenomenon for amphibian populations occurring at higher latitudes where breeding occurs seasonally rather than year-round (RISC 1998a). Following this general amphibian developmental pattern, tadpole abundance was greater in the spring and early summer (during larval development), metamorph abundance was higher in the summer (once development and emergence was complete), and few amphibian observations overall were made at the end of summer / early fall (as individuals moved into overwintering mode). This seasonal pattern of relative abundance was consistent for both Kinbasket and Arrow Lakes Reservoirs.

Amphibian abundance (detection rates) varied from year to year (Hawkes et al. 2017; Hawkes et al. 2018b; Appendix 4). This variation can likely be attributed to either natural population variability and/or the variable environmental conditions encountered during surveys, which influenced search effort and detectability. Population variability in amphibians can result from annual differences in hydroperiod, larval competition, food availability, and predation (Semlitsch et al. 1996). Timing for field surveys was generally consistent (similar data ranges) across years to facilitate data comparisons; however, environmental conditions or reservoir elevations during surveys were not always ideal for amphibian detections. For example, adult amphibians often move to breeding ponds during the night, when conditions are warm (>8°C) and moist (during or after a period of rainfall). In certain years, the early spring surveys coincided with cooler temperatures (fewer amphibian movements) or wet conditions (increased amphibian movements), both of which likely affected detection rates. For example, in 2012, spring temperatures and conditions occurred earlier than other years and most breeding had occurred for when surveys were conducted in May (i.e., the timing of our surveys in May 2012 did not coincide with the breeding period). In some cases, heavy rains during spring and summer surveys made it difficult to detect amphibians (especially species with more inconspicuous larvae such as Long-toed Salamander and Columbia Spotted Frog).

Western Toad were by far the most encountered and abundant amphibian in the drawdown zone of both reservoirs across all study years. We observed most life stages of toad (see also MQ3) and large annual breeding populations in the drawdown zone of Kinbasket Reservoir at Valemount Peatland, Ptarmigan Creek, Bush Arm (Causeway and Bear Island), and Sprague Bay, and in the drawdown zone of Arrow Lakes Reservoir at Revelstoke Reach (especially Cartier Bay), Beaton Arm, and Burton Creek (Hawkes et al. 2011; Hawkes et al. 2017; Hawkes et al. 2018b). Western Toads are known to have large population sizes in many parts of B.C., with large adult congregations at breeding sites (e.g., Little Cranberry Lake, Summit Lake, Cartier Bay (Revelstoke Reach, pers. obs., Figure 5-5) and numerous, conspicuous (highly visible), aggregations of tadpoles. This was consistent with our observations of the various life stages of this species in the drawdown zones of both Kinbasket and Arrow Lakes Reservoirs.

Figure 5-5: Example of a breeding aggregation of adult Western Toads in Bush Arm (Km 79.5). In this image there are 22 pairs of toads in amplexus (at end of each arrow) in an area of ~3m^2. Photo © Virgil C. Hawkes.

To a lesser extent than Western Toad, Columbia Spotted Frogs were relatively abundant at Valemount Peatland and Bush Arm KM79 in Kinbasket Reservoir and were relatively infrequent in Arrow Lakes Reservoir (except for Beaton Arm). Tadpoles of this species are more difficult to locate due to their preference for feeding and hiding under vegetation (Patla and Keinath 2005). Metamorphs, juveniles, and adults were commonly observed along the edges of ponds in the drawdown zone and readily detected when present. Pacific Chorus Frogs were most abundant in Revelstoke Reach (Appendix 3) and Long-toed Salamanders were most abundant at Bush Arm Causeway in Kinbasket Reservoir and Cartier Bay in Revelstoke Reach. The infrequent detection (and consequently low relative abundance estimate) of Long-toed Salamanders was likely related to their early spring breeding times and inconspicuous nature.

Reptile abundance (detection rates) also varied within and between years, but not to the degree observed among amphibian species. Common Garter Snakes and Western Terrestrial Garter Snakes were relatively abundant in both reservoirs across all study years (the latter to a lesser extent). Snakes were more abundant in the late spring and summer, consistent with their known life history traits:

- ectothermic (require higher day time temperatures to be active; Jones 1986);
- dietary preferences (likely use of drawdown zone for foraging on amphibians and small mammals; Hawkes and Tuttle 2010a; Rossman et al. 1996);
- habitat use (likely hibernated outside of the drawdown zone and thus absent or infrequent from drawdown zone habitats during the early spring and fall, see McAllister 2018 and MQ3).

Year to year variation in detection rates of garter snakes was also likely due to natural population fluctuations and environmental conditions.

Trends in the Western Painted Turtle population in Revelstoke Reach were not assessed as part of CLBMON-37 (this population was the focus of a separate, but related monitoring program, CLBMON-11B3; see annual reports: Hawkes et al. 2013; Wood and Hawkes 2014; Wood and Hawkes 2015; Wood et al. 2016; Challenger and Hawkes 2018; Master's theses: Basaraba 2014; Duncan 2016); however, 31 incidental observations were made by LGL Limited during visual encounter surveys from 2008 to 2018 (n = 1 Kinbasket Reservoir; n = 30 Arrow Lakes Reservoir).

Relative abundance values were low for Northern Alligator Lizard, Western Skink and Rubber Boa in Arrow Lakes Reservoir. This was likely due to the cryptic nature of some species (e.g., Rubber Boa), the ectothermic nature of these taxa (surveys did not always coincide with the optimal environmental conditions for species detections), and the specific habitat preferences of these three species that kept them outside of the drawdown zone and in adjacent uplands habitats. As these species were only expected to occur at the very margins of the drawdown zone (if at all); these values should be interpreted as presence rather than an indication of abundance, population size, or habitat use of the drawdown zone.

5.2.2 Diversity

British Columbia supports a high diversity of amphibians and reptiles, most of which occur in the southern portion of the province (Matsuda et al. 2006. The Columbia/Kootenay region has 16 known or potential species of amphibians and reptiles, 10 of which were observed in this study (n = 4 amphibians, n = 6 reptiles) (see MQ1 for a summary of species richness by reservoir). This level of richness was expected in light of the known range overlaps with the study area (as discussed in MQ1) and the large search effort over multiple seasons and years (Appendix 1). Also as expected, Kinbasket Reservoir had the lower species richness for both taxa groups, as within British Columbia (as well as elsewhere in the northern hemisphere) species richness tends to decrease with latitude (Hillebrand 2004). Kinbasket Reservoir is higher and cooler, and occupies different BEC zones, than Arrow Lakes Reservoir (see Table 2-1; Table 2-3)—geographic differences that might be expected to produce different species assemblages.

Species richness was also higher in Arrow Lakes Reservoir than in Kinbasket Reservoir (Appendix 5). In Kinbasket Reservoir, the number of species observed was greatest Valemount Peatland, followed by Bush Arm KM79. In Arrow Lakes Reservoir, the number of species observed was greatest in Montana Slough/Cartier Bay and Airport Marsh, with four species each of amphibians and reptiles. Beaton Arm and Edgewood South were also high diversity sites, although this is influenced by the presence of upland-associated reptile species detected at the edges of the drawdown zone (e.g., Western Skink and Northern Alligator Lizard).

Amphibian species richness and diversity did not change relative to year or season at the various monitoring sites, nor was it expected to (Appendix 5). Reptile species diversity varied from year to year and was generally low for most sites. As indicated above in the response to MQ1, all species of amphibians and reptiles expected to occur in the drawdown zone of Kinbasket and Arrow Lakes Reservoir were detected. Additionally, most species of amphibians and reptiles show site fidelity (i.e., return to the same sites, year after year, to breed, forage, or overwinter) and were expected each year at the same sites as in prior years (Smith and Green 2005; Gregory and Stewart 1975; Harvey and Weatherhead 2006).

5.2.3 Productivity (Reproduction)

Primary productivity in ecology refers to the rate of photosynthetic generation of biomass within an ecosystem, while secondary productivity is the generation of biomass in animal populations and communities and is related to growth rate, reproduction, and/or survivorship (Krebs 2001). Productivity in this sense was not explicitly studied in the drawdown zones of either Kinbasket Reservoir or Arrow Lakes Reservoirs during CLBMON-37/58. Rigorous productivity estimates for amphibians and reptiles would have called for data on absolute (as opposed to relative) reproductive output (e.g., egg counts within egg masses, larval and metamorph counts, neonate counts), growth rate data (e.g., mark-recapture studies), or survivorship data (e.g., tracking the survivorship of the various life history stages). This level of analysis would have required daily or weekly data collection (especially during the period of reservoir inundation), growth rate measurements (in lab experiments or mark-recapture studies), or assessments of survivorship within and between years, all of which were outside of the scope/capability of this study.

At the study's outset, productivity was defined as "reproduction" occurring within the drawdown zone of either reservoir. Amphibian reproduction was documented in the following ways: evidence of amphibian reproduction at a site (i.e., presence of egg masses, larvae stages, metamorphs, breeding adults, see MQ3), relative abundance of amphibian reproductive stages (Appendix 4), and amphibian sex ratios (Appendix 6). Reproduction in reptiles was documented by mating occurrences and presence of nests, gravid females, and neonates in the drawdown zone of either reservoir. Species-specific and individual fecundity (e.g., number of eggs per female) were not assessed and are therefore not discussed.

The study revealed that four amphibian species (Western Toad, Columbia Spotted Frog, Long-toed Salamander, and Pacific Chorus Frog [Arrow Lakes Reservoir only]) used habitats in the drawdown zones for breeding. We observed most life stages for most species (eggs, tadpoles/larvae, metamorphs, subadults, and adults). Breeding amphibian populations were documented for most study sites, with Revelstoke Reach and Beaton Arm in Arrow Lakes, and Bush Arm KM79, Bush Arm Causeway, and Valemount Peatland in Kinbasket Reservoir being the most "productive" sites (i.e., highest relative abundance values, highest number of breeding species). Qualitatively, it appeared that the productivity of both Western Toad and Columbia Spotted Frog was consistent between years, as egg masses and adults were repeatedly detected at the same pond locations each year (Hawkes et al. 2011; Hawkes et al. 2017; Hawkes et al. 2018b). Too few data exist for the other species of amphibian (Long-toad Salamander, Pacific Chorus Frog) to extensively discuss reproduction within the drawdown zone and how reservoir operations might affect their productivity.

Western Toad, the most widespread and abundant amphibian studied, provided a good basis for discussion of reproduction within the reservoir drawdown zones and how reproduction potentially was influenced by reservoir operations (see also MQ5 for additional detail). This species used multiple habitats in the drawdown zone for reproduction, and all life history stages (eggs, tadpoles, toadlets, subadults, and adults) were observed across the years at most study sites. Although we had 11 years of relative abundance data for Western Toad (Appendix 4), most reproductive information was qualitative and based on surveyor observations.

Our observations suggest that productivity (reproduction) of Western Toad was relatively constant within and across the years. Adults were found breeding at all monitoring sites in May and June of most years, with the most "productive" sites being Valemount Peatland, Ptarmigan Creek, and Bush Arm for Kinbasket Reservoir and Cartier Bay, Beaton Arm, and Lower Inonoaklin for Arrow Lakes Reservoir. Western Toads live for 9 to 11 years (Campbell 1970; Carey 1993) and generally return to the same breeding sites annually even if other suitable habitats are available (Smith and Green 2005). Females may lay eggs every few years (but may only lay eggs once in their lifetime). The male to female ratio has been roughly estimated at 1.6:1 to as high as 5:1 (average: 3.4:1; Hawkes and Tuttle 2013b). The fact that adults returned to the same breeding site each year (as evidenced by the documentation of breeding adults, egg strings, or tadpoles at the same sites annually) suggested that habitats in the drawdown zone provided important habitat breeding habitat for this species. It is not known if habitats in the drawdown zone function as a source or sink for certain amphibian populations (Dias 1996).

Western Toad egg strings and developing tadpoles were observed from May to July when metamorphosis typically occurred. The earliest timing recorded for metamorph emergence was early July for Revelstoke Reach in 2009 (Appendix 4). Large aggregations of Western Toad metamorphs were observed at Valemount Peatland, Ptarmigan Creek, Bush Arm Causeway, Cartier Bay, and Beaton Arm, but not at the remainder of sites (e.g., Burton Creek). Inundation occurred in most years by late June/early July and observations of tadpoles during the July sampling session were frequently single tadpoles, smaller aggregations, or missing altogether. For certain sites, once inundation occurred in drawdown zone ponds, it was difficult to quantify the relative abundance of later life history stages (e.g., larger tadpoles, metamorphs), as the aggregations of tadpoles were dispersed along the reservoir edge, or the fate of the metamorphs was unknown (i.e., no observations were made in later summer field sessions). In cases where no tadpoles were observed for the remainder of that year post-inundation, it was unknown 1) if reproduction failed in that particular year, 2) if tadpoles were present somewhere nearby the original drawdown zone pond location but unobserved, or 3) development to metamorphs had successfully occurred and toadlets had already moved into adjacent upland habitats.

Columbia Spotted Frogs also used the drawdown zones of both reservoirs for reproduction, with Valemount Peatland, Bush Arm KM79, and Beaton Arm as the main sites for egg deposition. Egg laying occurred early in the spring (late April) and often tadpoles had hatched out by May surveys. Very few tadpoles of this species were recorded, but this has more to do with their secretive habits (forage and take cover under vegetation) than low numbers. Metamorph froglets were notably abundant at Bush Arm KM79, where a series of shallow, tiered wetlands (remnant beaver ponds and dams) were present. Long-toed Salamanders were observed breeding at several sites with Bush Arm Causeway and Cartier Bay being the sites with the highest relative abundance of eggs. It was assumed from the presence of calling male Pacific Chorus Frogs that this species bred at several sites in Arrow Lakes Reservoir, although very few egg masses and almost no tadpoles of this species were observed.

As with amphibians, reptile productivity was also not readily assessed under CLBMON-37. In addition to the same reasons stated above, reptile productivity was not linked to the presence or absence of water, and reproduction (in lizards and snakes) likely occurred near overwintering sites (Kromher 2004) which were outside of the drawdown zone (and required intensive telemetry studies to locate the overwintering sites and verify reproductive behaviour; McAllister 2018). Our current understanding of reptile reproduction in the drawdown zone was limited to opportunistic observations made during the spring and summer of mating occurrences and the presence of gravid females or neonate individuals.

Mating in garter snakes typically occurs in the immediate vicinity of overwintering sites (Gregory 1984; Rossman et al. 1996; Shine et al. 2001; Appendix 8), whereby males emerge from hibernation to wait for females, mating occurs nearby once females emerge and then snakes disperse to summer habitats to thermoregulate or forage. Over the 11-year period, we made several incidental observations of garter snake reproduction in the drawdown zone including mating snakes (males and females with intertwined tails) in Revelstoke Reach (Downie Marsh and 12 Mile), multiple gravid (i.e., pregnant) female garter snakes in both Kinbasket and Arrow Lakes Reservoir drawdown zones, and several neonate garter snakes (Common Garter Snake in both reservoirs and Western Terrestrial Garter Snake in Arrow Lakes Reservoir). Garter snakes are viviparous (i.e., live bearing) and females carry their eggs inside their bodies until birth (i.e., parturition; Shine 1983; Rossman et al. 1996). Several females of both species were captured gravid (clutch size ranged between 3 to 22; Appendix 6) and likely used habitats in the drawdown zone to regulate body temperature for developing eggs. Although no observations were made of females giving birth in the drawdown zone, the presence of recently birthed females (loose skin in the abdominal region) and neonate snakes (< 250 mm SVL) suggested that this component of reproduction (i.e., birthing) occurred in the drawdown zone but was simply not observed very often.

Reproduction in Western Painted Turtles was not studied under CLBMON-37; however, neonate turtles were observed in Revelstoke Reach (Airport Marsh) during visual encounter surveys. Female turtles were also observed digging nests at the known nesting site at Red Devil Hill (above the drawdown zone) in the spring in various years. Based on studies of Western Painted Turtles in Revelstoke Reach (as per CLMBON-11B3; Basaraba 2014, Hawkes et al. 2013; Wood and Hawkes 2014; Wood and Hawkes 2015; Wood et al. 2016) it is highly unlikely that turtles nest/reproduce in the drawdown zone.

In Arrow Lakes Reservoir, we made a single observation of a gravid Northern Alligator Lizard in upland habitat (e.g., rocky rip rap) in the Revelstoke Reach region providing some evidence that this species likely breeds outside of the drawdown zone. Other species encountered that were considered unlikely to breed in the drawdown zone include Western Skink (oviparous: lays eggs in nest; no nests were detected during this study) and Rubber Boa (viviparous) and are therefore not discussed.

Additional information on the abundance, diversity, and productivity (reproduction) of species of amphibians and reptiles in the drawdown zones of Kinbasket and Arrow Lakes Reservoirs is provided in Appendix 4 to Appendix 7.

5.2.4 Challenges and Opportunities

As mentioned above, data collection focused primarily on visual encounter surveys to monitor amphibians and reptiles during their active seasons (approx. May to September). Many of the target species were easily located and identified via this survey method; however, some species (e.g., Long-toed Salamander, Northern Alligator Lizard, Western Painted Turtle) may not have been detected, due to their inconspicuous nature (e.g., Long-toed Salamander, neonate snakes), natural annual population variation (all species; Pechmann et al. 1991), environmental conditions, or inconsistent use of the drawdown zone (upland-associated species such as Rubber Boa and Northern Alligator Lizard), affecting both relative abundance and diversity measures. Estimating abundance in amphibians from egg mass and larval counts can be particularly challenging for a number of reasons including varying environmental conditions (e.g., rain affects visibility), species with small egg masses (e.g., Long-toed Salamander, Pacific Chorus Frog), difficulty counting individual egg strings (e.g., Western Toad), or low frequency of sampling (can miss the reproduction window). Estimating abundance in reptiles can be equally challenging due to the difficulties associated with detection and capture of small (i.e., neonate, hatchling) animals in varying environmental conditions (e.g., cold weather, rain, abundant cover of vegetation).

Considering project budgetary constraints and the large geographic extent of this study (Figure 2-3 and Figure 2-5), sampling effort each year was limited to one site visit to each monitoring site per month in varying conditions, which likely compromised both abundance and productivity data values. Assessing amphibian and reptile abundance and productivity in more detail would require more intensive studies using intensive daily/weekly surveys, mark-recapture studies and radio telemetry to determine population estimates and to what extent species used the drawdown zone for reproduction (e.g., mating, growth, brood rearing).

Additionally, this study only assessed abundance and reproduction in the drawdown zone of the reservoirs. In the absence of a suitable control or baseline data, the authors cannot be certain how the abundance or productivity of any species might be affected by reservoir operations compared to natural (i.e., undisturbed) conditions. We can say that amphibians use the drawdown zone for reproduction, but a more intensive (e.g., Master's) study on amphibian biomass and survivorship that focuses more specifically on egg masses (absolute abundance) and larvae (growth and timing of metamorphosis) would likely provide the data necessary to properly test this hypothesis as it relates to amphibians occurring in reservoir affected areas. Our current understanding of reptile reproduction associated with use of the drawdown zone was limited to opportunistic observations (or captures) made during the spring and summer of mating, adult females basking (including several females where number of eggs was determined), and neonate snakes. Determination of clutch size in female garter snakes was only completed for some captures due to 1) difficultly in accurately determining number of eggs early in development, and 2) differences in observer skills (i.e., experience is required to accurately conduct egg counts).

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

Over the 11 years of amphibian and reptile monitoring, ten species were recorded using the drawdown zones of Kinbasket and Arrow Lakes Reservoirs during one or more life history stages. Some species used the drawdown zone to fulfill most of their life history stages (e.g., Columbia Spotted Frog), while others (e.g., Western Toad, garter snakes, Western Painted Turtle) used the drawdown zone to fulfill only specific life stages (Table 5-2 and Table 5-3). For other species, we did not have enough data to fully determine how they used the drawdown zone to fulfill different life stages (e.g., Rubber Boa, Western Skink).

Table 5-2: Observed life history activity of amphibian and reptile species in the drawdown zone of Kinbasket Reservoir from 2008 to 2018. 'Yes' indicates a direct observation of the life history activity or stage, whereas the rest are inferences.

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

Table 5-3: Life history activity of amphibian and reptile species in the drawdown zone of Arrow Lakes Reservoir from 2008 to 2018. 'Yes' indicates a direct observation of the life history activity or stage, whereas the rest are inferences.

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

5.3.1 Breeding

Amphibian and reptile species have vastly different reproductive strategies and are discussed separately in relation to their use (or non-use) of the drawdown zone for breeding. As discussed in MQ2, four amphibian species were confirmed to breed in the drawdown zone of Arrow Lakes Reservoir: Western Toad, Columbia Spotted Frog, Pacific Chorus Frog, and Long-toed Salamander; and three species in

Kinbasket Reservoir: Western Toad, Columbia Spotted Frog, and Long-toed Salamander (Hawkes and Tuttle 2016; Hawkes et al. 2017; Hawkes et al. 2018b). All of these species are classified as pond-breeding species and require the presence of water for 1) laying and fertilizing of eggs (external fertilization of egg masses for anurans, internal fertilization via spermatophore for Long-toed Salamander) and 2) larval/tadpole development (Hopkins 2007).

The variety of wetland and pond types found throughout the drawdown zones offered breeding habitat for amphibians from late April (ice-free period for Kinbasket Reservoir was generally near the end of April, earlier for Arrow Lakes Reservoir) through to reservoir inundation in June or July depending on pond elevation within the drawdown zone. Pond drying occurred prior to inundation by the reservoir in some cases and egg stranding was observed for Western Toad in several ponds in Bush Arm. Large choruses of calling male Pacific Chorus Frog and several egg masses confirmed breeding of this species in Revelstoke Reach drawdown zone ponds (Appendix 3). Notable breeding aggregations of Western Toad were observed at Cartier Bay, 9 Mile, Beaton Arm, and Burton Creek in Arrow Lakes Reservoir and at Bush Arm Causeway, Valemount Peatland, and Ptarmigan Creek in Kinbasket Reservoir.

Western Painted Turtle exhibit internal fertilization and require terrestrial environments (above the water level) for their nests (Matsuda et al. 2006), and as such, nesting was expected to only occur outside of the drawdown zone. Incidental observations were made of female turtles laying nests at Red Devil Hill and Williamson Lake (both sites outside of the drawdown zone); however, copulation (i.e., fertilization of eggs) may have occurred within the drawdown zone near Airport Marsh, as only females were observed climbing the hill at Red Devil Hill to nest. No other reproductive data for turtles were collected under CLBMON-37 (see CLBMON-11B3 reports listed above for additional information relating to breeding in the drawdown zone). It is currently unknown if breeding occurs where a Western Painted Turtle was observed at Bush Arm KM88, as no other observations were made of this species at this location. Hatchling turtles were observed and captured in Airport Marsh; however, the nest locations from which these turtles hatched were unknown.

Garter snakes are viviparous animals, meaning they give birth to live young. We observed breeding (i.e., copulation) in garter snakes a few times in the drawdown zone at Revelstoke Reach (Downie Marsh and 12 Mile) and once near the drawdown zone at Valemount Peatland (approximately 200 m upland); however, as discussed above in MQ2, it is likely that garter snakes (both species) mated near den sites outside of the drawdown zone. Gravid (i.e., pregnant) females of both species were captured in the drawdown zones and likely used habitats in the drawdown zone to regulate body temperature for developing eggs (Gregory et al. 1999; McAllister 2018). Although no observations were made of females giving birth in the drawdown zone, neonate garter snakes were observed in the drawdown zone of both reservoirs suggesting that the drawdown zones provided suitable birthing habitat for this species. It is likely that the use of the drawdown zone by gravid female garter snakes was related to both the availability of basking sites for thermoregulation and birthing sites in areas with high food availability (tadpoles) for neonate snakes. Other species (e.g., Rubber Boa, Northern Alligator Lizard, Western Skink) likely used habitats outside of the drawdown zone for breeding.

5.3.2 Foraging

Amphibians and reptiles likely forage in a variety of aquatic and terrestrial habitats in the drawdown zones; however, since examination of stomach contents was outside the scope of this study, questions relating to time spent foraging in drawdown zone habitats cannot be answered definitively for most species. However, observations of foraging behaviours (e.g., suction feeding by tadpoles of algae on decaying logs, snakes consuming prey) were made on several occasions and can be used in conjunction with what is known about diet (e.g., prey type and size) for most species to develop several hypotheses regarding stage-specific foraging in the drawdown zone. Adult amphibians consume terrestrial and aerial insects; tadpoles are algae grazers; and toadlets eat small invertebrates and insects (Matsuda et al. 2006). Squamate reptiles (snakes and lizards) consume insects, worms, and gastropods, while snakes also consume small mammals and amphibians (Tuttle and Gregory 2009; Swan et al. 2015). Western Painted Turtles feed primarily on plants and small animals such as fish, crustaceans, and aquatic insects (Matsuda et al. 2006).

All species of amphibian and reptile are consuming food (for growth or future years of reproduction) during the active season (between April and September). Therefore, occurrence in the drawdown zone during that time was an indication that species were using the drawdown zone for foraging. At a minimum, pond-breeding amphibians exhibiting successful metamorph stages during any given year were assumed to have had larval stages that foraged in the ponds within the drawdown zone. It is also likely that metamorphs foraged in the immediate area of their natal pond before hibernation, although this was not studied. Some reptile species (e.g., garter snakes) were captured with food in their stomachs (mainly amphibians and small mammals), which confirmed foraging in the drawdown zone. In Kinbasket Reservoir, Common Garter Snakes fed exclusively on Western Toads (Boyle 2012; McAllister 2018), whereas garter snakes in Arrow Lakes Reservoir were confirmed to forage on toads, frogs, birds, and small mammals (incidental observations).

Data on prey choice of both species of garter snakes in Kinbasket and Arrow Lakes Reservoirs were collected opportunistically. Snakes were frequently observed around Western Toad breeding habitats. Because Western Toad females can lay up to 12,000 eggs, most breeding locations contained thousands of tadpoles and these tadpoles provided an important food resource for snakes. When snakes were caught that had recently eaten, their stomachs were palpated, and revealed a diet comprised primarily of Western Toad in Kinbasket Reservoir (Boyle 2012; McAllister 2018) and Western Toad and small mammal species in Arrow Lakes Reservoir (Hawkes and Tuttle, pers. obs.). Small mammal trapping occurred in portions of the drawdown zone of Kinbasket Reservoir between 2008 and 2013. Results from those studies indicated the presence of Deer Mouse (*Peromyscus maniculatus*), Meadow Vole (*Microtus pennsylvanicus*), and Long-tailed Vole (*M. longicaudus*) in the drawdown zone (CBA 2009; CBA 2010; MacInnis et al. 2011; Hawkes et al. 2014); however, neither Boyle (2012) nor McAllister (2018) documented small mammal species in the stomachs of snakes. Small mammal trapping did not occur in the drawdown zone of Arrow Lakes Reservoir, but both Deer Mouse and Meadow Vole have been observed in several sites (e.g., Revelstoke Reach, Burton Creek, and Edgewood), and one observation of a Western Terrestrial Garter Snake consuming a vole was made at Burton Creek in 2010. Common Garter Snakes were also observed foraging in shrubby habitat for nestling birds in Revelstoke Reach (Tuttle, pers. obs.). No comparable observations were made for Northern Alligator Lizards.

Available habitat in the drawdown zone for foraging decreased over the summer months (see MQ5), which likely affected all life stages of amphibians and reptiles. The quality of foraging habitats in the drawdown zone, variation in prey availability throughout the year, and how these affected the life stages of animals, were not assessed in this study.

5.3.3 Overwintering

Field work for CLBMON-37/58 occurred during the active season for amphibians and reptiles, which coincided with the snow-free period between the middle to end of April and end of August each year. This meant that (in most cases) no data were collected during the overwintering period. Therefore, the use, availability or quality of amphibian and reptile overwintering habitat in the drawdown zone of Kinbasket and Arrow Lakes Reservoir was not extensively assessed, and this question (do animals overwinter in the drawdown zone?) was difficult to answer using existing data for most species.

Inferences were limited to the radio telemetry studies conducted between 2014 and 2017; data collected under CLBMON-11B3 for Western Painted Turtle; and identification of potential locations for overwintering based on early spring and late fall observations, combined with our knowledge of the natural history for each species (Appendix 9).

The only species known to overwinter in the drawdown zone is the Western Painted Turtle, with some individuals overwintering in Airport Marsh and Montana Slough of Arrow Lakes Reservoir (Basaraba 2014; Duncan 2016). Radio telemetry data collected from 2014 to 2017 suggested that Western Toads were not using the drawdown zone during the winter period (Hawkes et al. 2018b; Appendix 8) and that, more likely, they were wintering in upland habitats. This is consistent with what is generally known for this species (e.g., COSEWIC 2002a; Browne and Paszkowski 2010; COSEWIC 2012).

Likewise, telemetry data collected from 2015 to 2017 showed that Common Garter Snakes captured in the drawdown zone at Valemount Peatland traveled to upland habitats outside of Kinbasket Reservoir to their overwintering locations (McAllister 2018). Overwintering locations for these snakes were revisited in December to confirm signal and same last known location. Having tracked only a few individuals to overwintering locations (n = 2 toads, n = 4 snakes) at two monitoring sites, we have limited ability to infer overwintering at other sites in Arrow Lakes and Kinbasket Reservoir. However, based on our knowledge of the life histories of this species, we do not currently expect that Common Garter Snakes overwinter in reservoir drawdown zones (Browne and Paszkowski 2010; Gregory and Stewart 1975; Gregory 1977; McAllister 2018).

The overwintering locations of other species (e.g., Northern Alligator Lizard) documented in the drawdown zones during the active period are currently unknown or unconfirmed. Based on the known natural and life history information for these species, it is likely that Columbia Spotted Frogs hibernate in ponds in the drawdown zone (Bull 2005); possible that Long-toed Salamanders overwinter in the drawdown zone in some cases (COSEWIC 2005; Atkinson-Adams et al. 2018); and unlikely that Pacific Chorus Frog and most reptile species overwinter in the drawdown zone (Schaub and Larsen 1978; Rutherford and Gregory 2001; St. Clair and Dibb 2004; Table 5-2; Table 5-3). Multiple years of road surveys conducted in Revelstoke Reach in early spring confirmed the movements of several species of amphibian (Western Toad, Pacific Chorus Frog, Long-toed Salamander) from upland habitats to pond and wetland habitats in the drawdown zone of Arrow Lakes Reservoir. This suggests that at least these three species overwinter in upland habitats, which is supported in part by telemetry data (for toads) collected for CLBMON-37/58.

5.3.4 Challenges and Opportunities

The sources of uncertainty and challenges for MQ1 and MQ2, above, also apply to this MQ, including issues related to the inconsistencies in detection rates among species (and life history stages), challenges to determining abundance (Corn and Bury 1990), challenges to distinguishing natural fluctuations from human disturbances (Pechmann et al. 1991), and no control for data comparisons.

Observing breeding amphibians can be relatively straightforward provided the timing of surveys coincides with the peak of the breeding season. Over 11 years, our surveys were timed to capture these events during each year of monitoring. The two exceptions to this were in 2012 and 2016, when spring conditions were present much earlier than normal (2 to 3 weeks earlier), and consequently the first field sessions documented tadpoles more frequently than breeding adults and egg masses. The 11-year dataset for breeding amphibians has allowed for the description of seasonal patterns of relative abundance and reproductive activities. Conversely, observing reptile breeding activity was a challenge, as most lizard and snake species that occur in the region likely mated near hibernation sites which were unknown (and likely outside of the drawdown zone).

As indicated previously, we did not assess or monitor any prey taxa that might contribute to the diet of amphibians (e.g., aerial insects) or reptiles (e.g., small mammals in the drawdown zone of Arrow Lakes Reservoir) under CLBMON-37. Data from both CLBMON-11A and CLBMON-11B1 indicated that the insect populations in the drawdown zone of both reservoirs were robust and likely provided an adequate food resource for amphibians using habitats in the drawdown zone (CBA 2009; CBA 2010; MacInnis et al. 2011; Hawkes et al. 2012; Wood et al. 2018; Wood et al. 2019). Incidental observations of snakes consuming metamorph and adult toads were made; however quantitative data collection of this relationship was outside of the scope of this study. Further investigation into the diet (e.g., examining stomach contents) and use of foraging habitat relative to the known distribution of breeding habitat could provide additional insight into the overall value of specific habitats in the drawdown zones of Kinbasket and Arrow Lakes Reservoirs for amphibians and reptiles. Additionally, a better understanding of the occurrence, distribution, and density of small mammals in the drawdown zone of both reservoirs, but in particular Arrow Lakes Reservoir, would strengthen our understanding of the suitability of the drawdown zone as foraging habitat for snakes.

Without the use of radio telemetry, it was not possible to determine the overwintering locations of amphibian and reptile species. Telemetry studies can be invasive, costly, and have limited utility in smaller species because battery life of the tiny transmitters is very short, especially in colder months; therefore, this method of monitoring species was possible only in a few cases (mostly due to MSc. funded projects). There is potential to gather additional telemetry data from other monitoring sites (e.g., Bush Arm Causeway, Burton Creek) for Western Toad and

Common Garter Snake to verify that other overwintering sites occur outside of the drawdown zones; however, it is not unreasonable to assume that the observations made were representative of normal overwintering behaviours for the species that were tracked above drawdown zone. While it is assumed that Columbia Spotted Frog overwinter in ponds in the drawdown zone, this has not been confirmed. This species would be a good candidate for using telemetry to determine whether habitats in the drawdown zone are used for overwintering.

5.4 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)?

Eight species of amphibian and reptile consistently used habitats in the drawdown zone of Kinbasket and Arrow Lakes Reservoirs over the 11-year period (Appendix 2). Most of the herpetofauna species in the region are associated with aquatic habitat and were expected to use habitats (both aquatic and terrestrial) in the drawdown zone that contained or occurred near water. Amphibians were expected to occur in wetlands within the reservoir drawdown zones because they are pond-breeders. Garter snakes were expected to occur near aquatic habitats due to their foraging preferences of amphibians. Western Painted Turtles, being aquatic turtles and relying on water to fulfill their life history requirements, were expected to occur near suitable wetland habitat. For this reason, reconnaissance surveys completed in 2008, and sites subsequently selected for monitoring of species' use of the drawdown zones (commencing in 2009), were tied to locations with aquatic habitat nearby (i.e., reaches or arms of the reservoir with wetland or pond habitat present). Northern Alligator Lizards were only expected to be found along the margin of the drawdown zone at sites with rocky habitat. Rubber Boa and Western Skink, being upland habitat-associated species, were only observed a few times and not expected to regularly use drawdown zone habitats.

Most amphibian and reptile observations were made at the periphery of the drawdown zones, where suitable vegetated and wetland areas (e.g., pond habitats) occurred. Pond-breeding amphibian species were most frequently detected at or near pond habitats in the spring, where they bred, laid eggs, and then moved into their spring and summer foraging habitat (either near the same drawdown zone ponds or to adjacent upland habitats, depending on the species). Snakes used habitats in the drawdown zone mainly for foraging (amphibians were their assumed primary prey) or basking (where appropriate habitat was available). Turtles used aquatic habitats to fulfill foraging, basking, and overwintering needs, and used terrestrial habitats (outside of the drawdown zone) for nesting, thermoregulation, and migration between pond habitats. Lizards occupied terrestrial habitats on the margin of the drawdown zone that likely fulfilled thermal and security requirements. Habitat features utilized by amphibian and reptile species were common in the drawdown zones of both reservoirs.

5.4.1 Vegetation Communities

Habitat characterizations were derived from general observations of utilized habitat combined with information from other datasets. For example, vegetation community classifications completed as per CLBMON-10 and CLMBON-33 provided an opportunity to assess whether amphibians or reptiles were more typically associated with one or more of vegetation communities classified for the drawdown zone of each reservoir. Similarly, data collected under CLBMON-11B4 that described Cartier Bay in Revelstoke Reach were used to describe the physical attributes of that location, which is a site used by multiple species of amphibians and reptiles. It should be noted that the vegetation community classifications produced for Kinbasket and Arrow Lakes Reservoir did not consider wildlife usage, including that of amphibians and reptiles. Any identified associations with vegetation community classification are actually tied to the presence of aquatic habitats, which were nested within the community classifications produced for each reservoir. Amphibian and reptiles were likely keying into aquatic habitats present in the drawdown zone, not selecting for specific vegetation communities. However, because certain vegetation communities were associated with wetland or pond habitat it was useful to use the vegetation communities classified for Kinbasket and Arrow Lakes Reservoir when describing habitat associations.

In Kinbasket Reservoir, amphibians and reptiles were documented in 17 of 21 vegetation communities mapped between ~736 and 764 mASL (Hawkes and Gibeau 2017; Appendix 10). Most species detected in the drawdown zone (elevations <754 mASL) were found in wetland-associated habitat types such as WB (wool-grass–Pennsylvania buttercup), KS (Kellogg's Sedge), swamp-horsetail (SH), willow-sedge (WS) and clover-oxeye daisy (CO; Figure 5-6). It should be noted that habitat types are not evenly distributed in Kinbasket Reservoir (Table 4-6); the four most extensive wetland habitat types (WB, SH, TP, and KS) cover more than 70% of the total pond area in the drawdown zone. Conversely, common horsetail (CH), CO, unclassified forest (FO), reed canary grass (RC), shrub-willow (SW) and willow-sedge (WS) habitat types each cover less than 5% of drawdown zone pond area. A large percentage of pond area mapped in the drawdown zone (52.7 percent; 6.2 ha) occurred in two of these vegetation communities (SH: 20.4 percent, 2.4 ha; WB: 32.3 percent, 3.8 ha), thus the presence of amphibians in these communities was not surprising. Few observations occurred in the toadrush-pond water starwort (TP) community despite ~10 percent of total pond area occurring there. The lack of observations is likely because the TP community typically occurs at lower elevations than other communities (Figure 5-7). In addition to appropriate breeding habitat (for amphibians), these habitats (and the others) likely offered cover (from predators), foraging, and/or thermoregulating opportunities for animals at various times of the year.

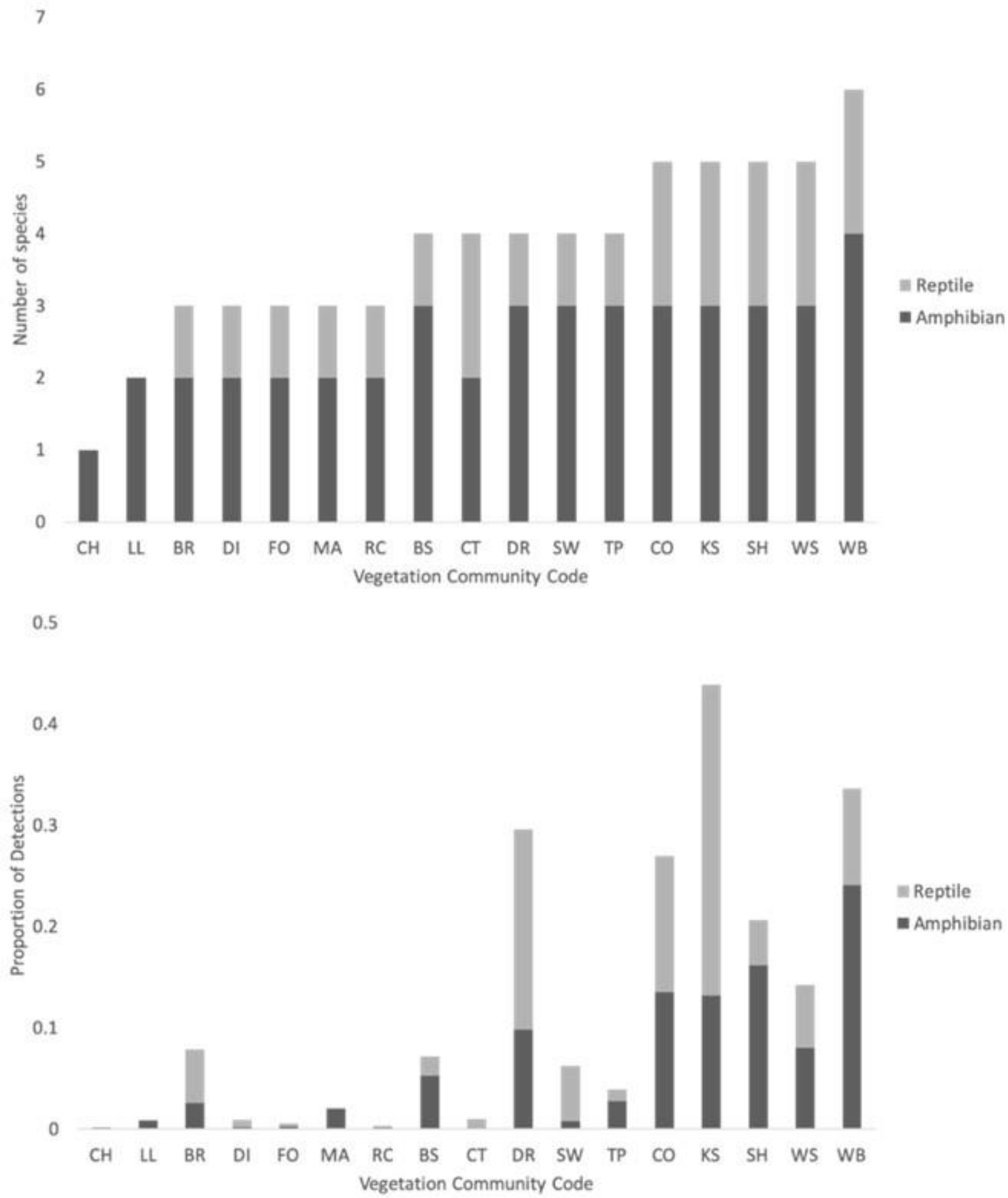

Figure 5-6: Species richness (top) and relative abundance (bottom) of amphibians and reptiles by habitat type (Vegetation Community Code) in Kinbasket Reservoir from 2008 to 2018. BR = bluejoint reedgrass, BS = buckbean-slender sedge, CH = common horsetail, CO = clover–oxeye daisy, CT = cottonwood-trifolium, DI = disturbed, DR = driftwood, FO = unclassified forest, KS = Kellogg's sedge, LL = lady's thumb-lamb's quarter, MA = marsh cudweed–annual hairgrass, RC = reed canary grass, SH = swamp-horsetail, SW = shrub-willow, TP = toadrush-pond water starwort, WB = wool-grass–Pennsylvania buttercup, WS = willow–sedge. See Hawkes et al. (2013a) for descriptions of each habitat type.

Figure 5-7: Elevation range associated with each of the vegetation communities characterized in the drawdown zone of Kinbasket Reservoir in 2007, 2010, 2012, 2014, 2016. Refer to Figure 5-6 for a description of the vegetation communities. Figure from Hawkes and Gibeau (2017).

Areas of the drawdown zone with little to no vegetative cover (i.e., elevations <736 mASL) were not used very often by animals (Figure 7-27). The exception to this was the presence of Western Toad tadpoles in lower unvegetated portions of the drawdown zone at Bush Arm KM79 and KM88 (Bear Island). Tadpoles (and presumably adults to breed) were observed, in multiple years, in a series of ponds connected via small creeks that eventually drained into the reservoir (Map 7-3). Western Toads are known to use shallow, mud-bottomed ponds lacking vegetation for breeding (Matsuda et al. 2006), but in this case, reproductive success was unlikely to be successful at these locations due to lack of sustained food availability for developing tadpoles and early reservoir inundation (see MQ5 for additional discussion).

Species distributions depended to some degree on environmental variables such as vegetation community, site, elevation, pond area, and the year of study. Other variable such as reach, location (drawdown zone or upland), and season were also related to species occurrences (Hawkes et al. 2015). Western Toad used the widest range of elevations (736-763 mASL; Figure 7-27) and was most often present in SH and TP communities in Kinbasket Reservoir (Figure 7-22). This species likely only used the drawdown zone for breeding and foraging then moved out of the drawdown zone into upland habitats for overwintering. In contrast, Columbia Spotted Frog tended to be found at higher elevations (745-756 mASL), in wetter habitats such as those associated with the WB vegetation community at Bush Arm KM79 and Valemount Peatland. Where observations of Long-toed Salamander were made, they were associated with CO vegetation community; however, due to the difficulties with locating this species, there are likely other habitats that this species uses in the drawdown zone (we simply did not observe them there). As expected, Common Garter Snake used a variety of habitats in the drawdown zone, likely for foraging and basking, whereas Western Terrestrial Garter Snake were more associated with habitat types that were closer to upland areas.

In Arrow Lakes Reservoir, the majority of species were detected in the reed canary grass (PC) habitat (Figure 5-8), which is a widespread vegetation community in the drawdown zone (Appendix 10; Miller et al. 2018b). This was particularly true for the main monitoring sites in Revelstoke Reach, Burton Creek, and Lower Arrow Lakes Reservoir (Edgewood and Lower Inonoaklin). Reed-canary grass habitat provided good cover for all species. For example, in the spring when grass mats were flattened from the previous winter's snow, garter snakes were frequently observed basking on sunny patches of grass litter and retreated beneath (i.e., under cover). Other frequented vegetation communities included pond habitat (PO), redtop upland (PA), and industrial/urban/recreational (IN).

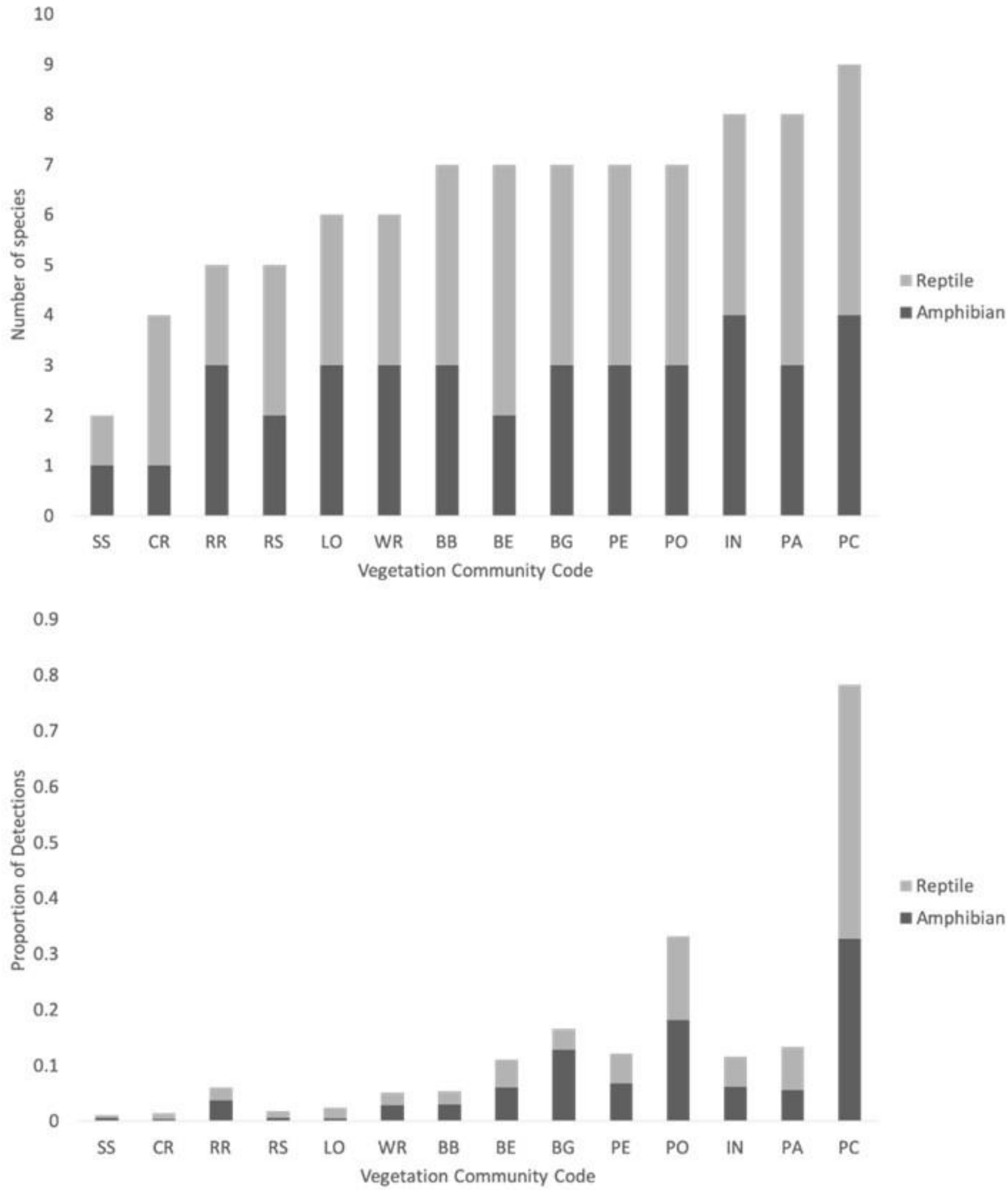

Figure 5-8: Species richness (top) and relative abundance (bottom) of amphibians and reptiles by habitat type (Vegetation Community Code) in Arrow Lakes Reservoir from 2008 to 2018. Note: Arrow Lakes Reservoir was not surveyed in 2011, 2013, 2015, or 2017. BB = boulders steep, BE = sandy beach, BG = gravelly beach, CR = cottonwood-riparian, IN = industrial/residential/recreational, LO = log zone, PA = redtop upland, PC = reed canary grass mesic, PE = horsetail lowland, PO = pond, RR = reed-rill, RS = willow stream entry, SS = steed sand, WR = river entry. See Miller et al. (2018b) for descriptions of each habitat type.

Rocky riprap and nearby upland habitats were considered important habitat for Northern Alligator Lizard (and Western Skink and Rubber Boa at Lower Arrow Lakes Reservoir sites), and while not particularly relevant to the study as these habitats mostly occurred outside of the drawdown zone, are worth mentioning due to the occasional observations of these species in these periphery drawdown zone habitats. Reservoir operations are unlikely to affect these species drastically due to their low use of the drawdown zone; however, in periods of high water (i.e., full pool), riprap areas at the lower elevations (and upland habitat immediately adjacent to the drawdown zone) were often flooded forcing animals out of those habitats. In 2012, nearly 100% of observations of animals in Revelstoke Reach during July surveys in full pool were made outside of the drawdown zone along the periphery edge of the water. Multiple Western Painted Turtles were observed basking on small floating pieces of wood and along the rocky edge of Montana Slough, which was not a typical behaviour (indicating use of habitat) for this species.

Other notable habitats occurring in Revelstoke Reach, which may have represented important refugia areas during periods of higher reservoir levels, included Machete Island, Airport Marsh, and the island in the middle of Montana Slough (refugia on a small scale). Garter snake use of microhabitats within shrub zones in Revelstoke Reach (Downie Marsh, Machete Island/Airport Marsh, 9 Mile, 12 Mile) was also observed frequently as this habitat offered good cover for shelter and thermoregulation.

Finally, cover use by small animals, such as amphibians and reptiles, is a well-documented phenomenon (Gregory and Tuttle 2016 and references therein) and a notable component of habitat use in this study. Cover objects are used by amphibians and reptiles for a variety of reasons including foraging, seeking shelter from predators, and thermoregulating. Cover in drawdown zone aquatic habitats included vegetation (submergent, emergent, or floating) and substrate (mud, algae, or coarse woody debris). Qualitative observations were made on multiple occasions of tadpoles swimming under vegetative cover and of juvenile or adult amphibians jumping into ponds and burying themselves in the mud to avoid observers or predators. Vegetative cover was also a component of terrestrial habitats (e.g., reed canarygrass, sedges, dense horsetail patches, willow or other shrub species), but coarse woody debris was the most common terrestrial cover type in both reservoirs. Coarse woody debris and rocks along the edges of the drawdown zones were frequently used as cover objects by Western Toad (n = 26), Northern Alligator Lizard (n = 12), and both species of garter snake (n = 133). Observations of animals under wood cover (especially small to medium sized garter snakes) were made on multiple occasions in Cartier Bay, Burton Creek, and Edgewood South and this appeared to be an important component of their habitat requirements. Conversely, large deposits of wood debris, such as those occurring at certain sites in Kinbasket Reservoir, did not appear to be used at a high frequency, although these results should be interpreted with caution, as animals may have been present but not detected (see MQ7 for more discussion on coarse woody debris).

5.4.2 Pond-breeding Habitat

Many species of amphibians and reptiles that occurred in and adjacent to the drawdown zone depend on aquatic habitats to fulfill their life requisites (Duellman and Trueb 1986; Duellman 2007; Wells 2007). Small, isolated wetlands (such as those occurring in the reaches and arms of reservoirs) are critical to the persistence of amphibians with complex life cycles (Hopkins 2007). Overall, 217 ponds in Kinbasket and Arrow Lakes Reservoirs were mapped and surveyed over the 11-year period, with ~50% of these supporting amphibians or reptiles

(Appendix 15). Data on pond habitat (e.g., physicochemistry, pond depth, vegetation cover) were compiled from multiple WUP studies including: 1) ponds delineated and assessed for amphibian and reptile occupancy by life stage under this study; 2) pond data collected under CLBMON-61 for Kinbasket Reservoir from 2012 to 2017 (see Adama 2019); and 3) wetland data collected under CLBMON-11B4 for Revelstoke Reach in Arrow Lakes Reservoir (see Miller et al. 2018a). These various information sources were used to relate important pond habitat parameters to species' use. Considerably more ponds, and therefore pond data existed for Kinbasket Reservoir than for Arrow Lakes Reservoir.

For both reservoirs, amphibians generally tended to use breeding ponds that were small, shallow, and warm (Wells 2007; Hawkes and Tuttle 2012). Utilized ponds and wetlands spanned an elevation range of 432 to 440 m and 736 to 755 mASL, respectively, with the elevation of ponds varying by location (Figure 5.5 in Hawkes et al. 2015). Amphibian observations occurred at water depths ranging from surface level to 30 cm, and most observations were made within 100 cm of the shoreline. The pre-inundation depth of all ponds was not measured in the study (see Adama et al. 2013 and Miller et al. 2020 for pond depths), but most were estimated at < 1 m deep with many < 0.5 m. The depth of egg mass deposition was generally between 10 and 30 cm – an indication that shallow wetlands provided highly suitable habitat for pond-breeding amphibians.

Pond habitat in select areas and specific elevations of Kinbasket Reservoir was diverse and extensively characterized, despite its overall scarcity in the drawdown zone (Adama 2019). Based on the spatial extent of the vegetation communities mapped previously (Hawkes et al. 2007, 2010), 102.8 hectares of wetland habitat exist between 751 and 755 mASL. Within this study, a total of 181 ponds were surveyed covering an area of 11.81 ha. Ponds ranged in size from <0.001 ha to 0.9675 ha, and the total area of wetlands varied by site, ranging from 0.16 ha at Sprague Bay to 5.36 ha at the Valemount Peatland (Table 4-4). Pond elevation ranged from 738.33 mASL at KM79 to 754.91 mASL at Sprague Bay. Kinbasket Reservoir drawdown zone ponds were typically vegetated with species such as *Potamogeton pusillus* (Small Pondweed), *Nuphar polysepala* (Rocky Mountain Pond-lily), *Sparganium angustifolium* (Narrow-leaved Bur-reed), *Myriophyllum* spp. (Eurasian Water-Milfoil/Siberian Water Milfoil), and *Equisetum fluviatile* (Swamp Horsetail; Hawkes and Tuttle 2009a). At elevations low in the drawdown zone (between 740 and 742 mASL), most wetlands had very little to no emergent vegetation and only low abundance (cover) of submergent vegetation. As elevation increased, the vegetation structure, composition, richness, and diversity of wetlands also increased (Adama et al. 2013; Hawkes and Gibeau 2017).

Physicochemistry data indicate that amphibians used ponds that were warm (spring and summer temperatures), with relatively neutral pH, low conductivity, and variable dissolved oxygen levels (ranging between 2.0 to 13 mg/L; Hawkes et al. 2015). Data loggers and point data collected from 2008 to 2018 indicated that water physicochemical parameters (DO, conductivity, pH, and temperature) for most drawdown zone ponds were within acceptable levels for amphibians in both reservoirs (Crowder et al. 1998; Ultsch et al. 1999; Hawkes and Tuttle 2013b; B.C. Ministry of Environment & Climate Change Strategy 2018). Some studies have concluded that, in general, water physical chemistry has a minor influence on amphibian richness (e.g., Hecnar and M'Closkey 1996), although our point data comparisons of pond characteristics found differences between ponds used by amphibians versus not used in terms of dissolved oxygen (higher preferred), pH (higher preferred), conductivity (lower preferred) and temperature (higher preferred) (Hawkes and Tuttle 2009a; Hawkes and Tuttle 2010a).

Amphibian use of ponds for breeding in Kinbasket Reservoir varied by species, pond size, elevation, vegetation community, and study location to varying degrees (see regression tree analyses in Hawkes et al. 2015 for additional detail). Western Toad and Columbia Spotted Frog used a wide range of pond sizes and one or both species occurred in more than 50% of the available wetland habitat. Fewer data existed for Long-toed Salamander, although this species bred in ponds used by both Western Toad and Columbia Spotted Frog. Pond habitats with the highest amphibian species richness were in the Valemount Peatland and Bush Arm Causeway. Increased species richness with increasing pond size is a well-documented phenomenon in amphibians (Parris 2006; Semlitsch et al. 2015) and both these sites contained the largest ponds for Kinbasket Reservoir; however, due to low sample sizes for some sites and low species numbers, the size-richness relationship was not explicitly tested.

Wetlands with higher cover of vegetation at higher elevations tended to be used to a greater degree by Columbia Spotted Frog and Long-toed Salamander, whereas Western Toad were typically found breeding at lower elevation ponds with little to no vegetation (Hawkes and Wood 2014). As vegetation cover was linked to elevation in the drawdown zone (Hawkes and Gibeau 2017), we hypothesized that the increased use of ponds at higher elevations was partially related to higher vegetative cover in these areas.

Evidence of pond partitioning among species was seen at monitoring sites (Figure 5-9; Figure 5-10). In areas where only one or a few ponds were available (i.e., pond habitat was a limiting factor), Western Toad and Columbia Spotted Frog egg masses were often found in the same ponds (Swan et al. 2015). For example, egg masses of both species were found in the single large drawdown zone pond at Ptarmigan Creek (see Appendix 15 for maps). At other sites, such as Bush Arm KM79 ponds, KM88 (Bear Island), and the Valemount Peatland, where there were more ponds and a greater variety of pond types (e.g., shallow, mud-bottomed vs. deeper vegetated ponds), Western Toad and Columbia Spotted Frog bred in different ponds. At KM88 (Bear Island) and Bush Arm KM79, Western Toad egg masses were documented in mud-bottomed ponds (with little vegetation) at lower elevations, whereas Columbia Spotted Frog generally laid their eggs in ponds with more vegetation and at higher elevations (see figures and text in Hawkes and Tuttle 2012).

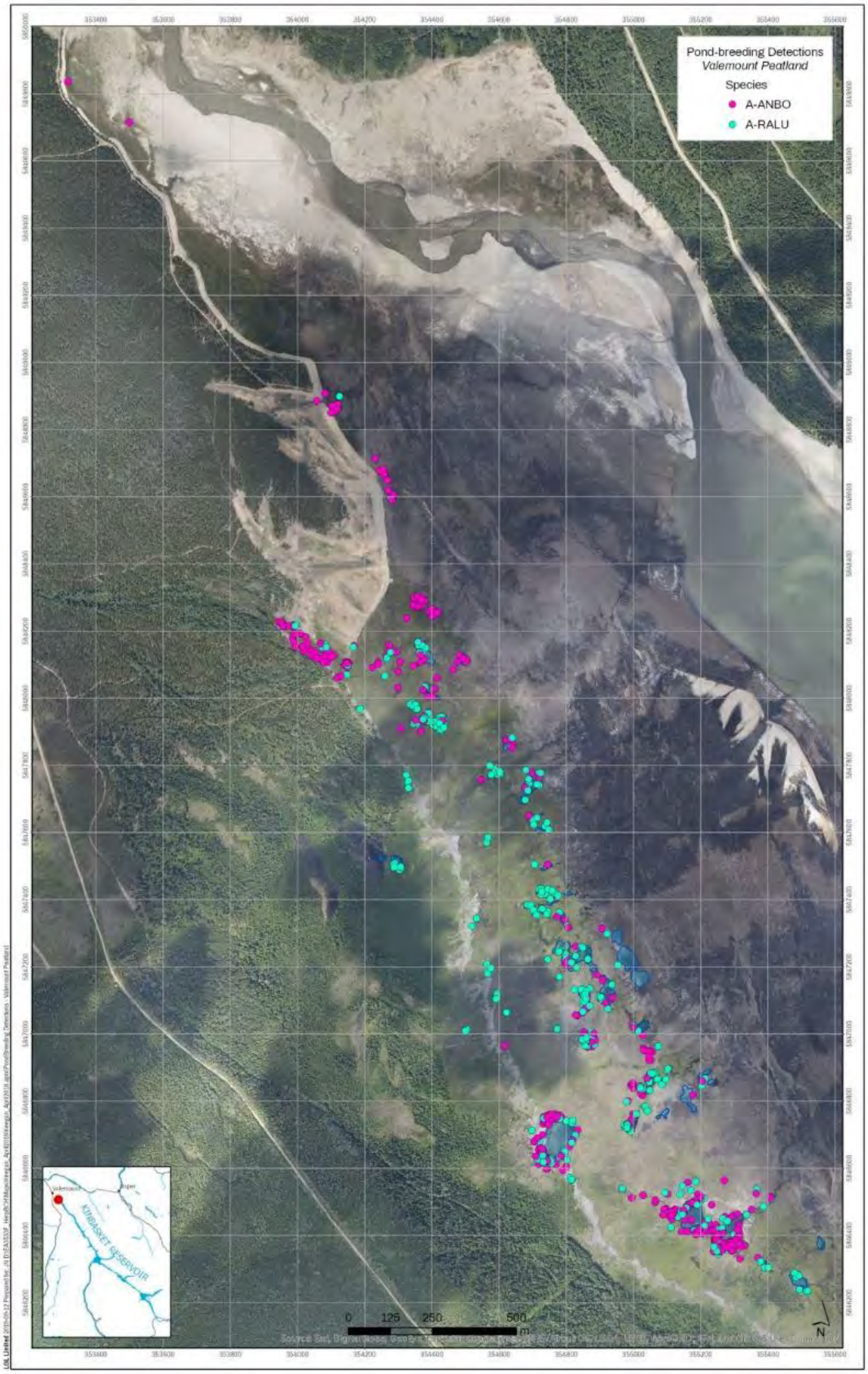

Figure 5-9: Detections of Western Toad and Columbia Spotted Frog in Valemount Peatland (Canoe Reach), Kinbasket Reservoir between 2008 – 2018. A-ANBO = Western Toad, A-RALU = Columbia Spotted Frog.

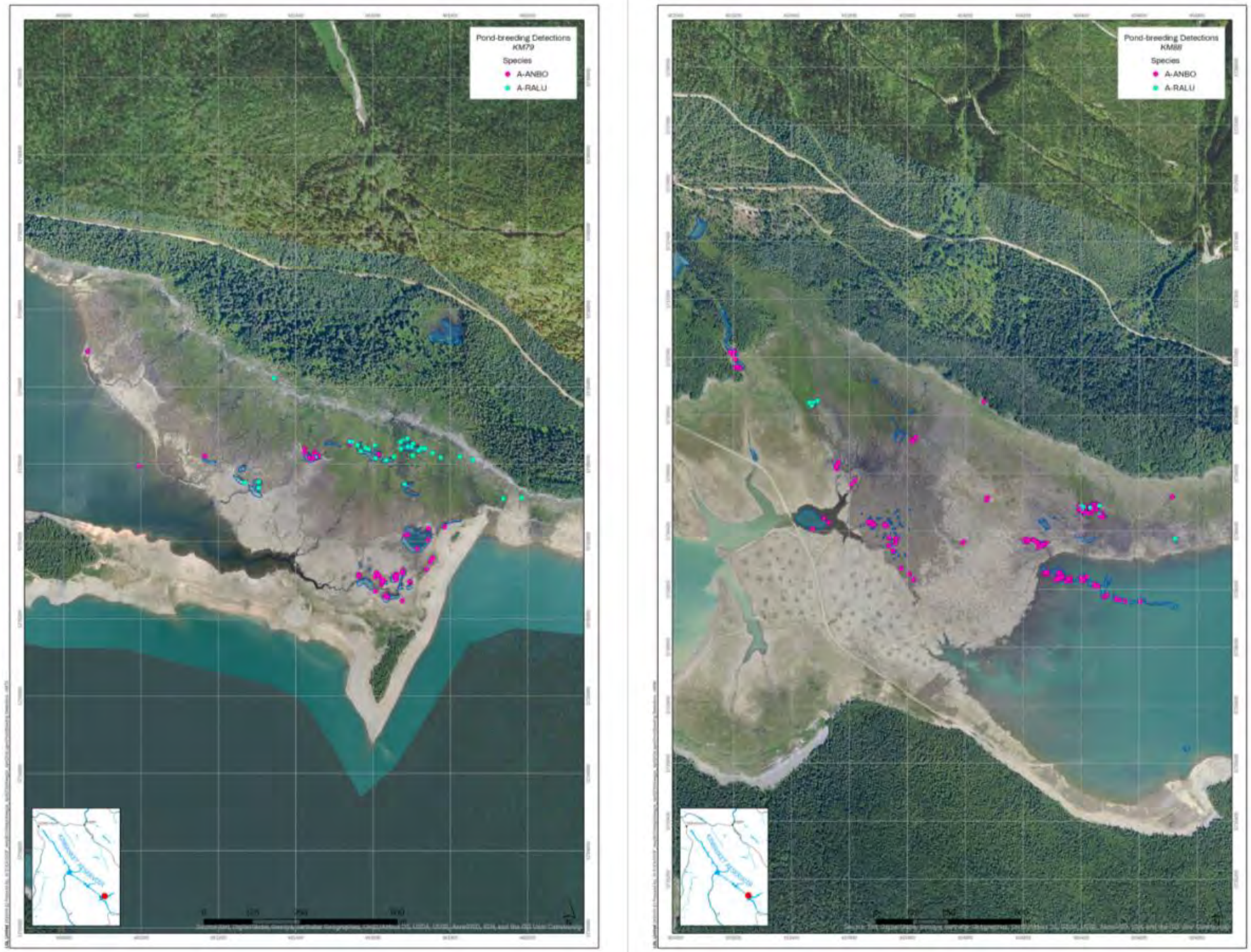

Figure 5-10: Pond-breeding detections of Western Toad and Columbia Spotted Frog at Bush Arm KM79 (left) and KM88 (right) in Kinbasket Reservoir between 2008-2018. A-ANBO = Western Toad, A-RALU = Columbia Spotted Frog.

Columbia Spotted Frog pond use within the drawdown zone for breeding was tested for the Valemount Peatland. This location was selected due to the high number of ponds (n = 95), the large sampling effort in 2011 and 2012 (Master's thesis), and the presence of all three amphibian species (i.e., Western Toad, Columbia Spotted Frog, and Long-toed Salamander) in varying life stages (Hawkes and Tuttle 2012; Boyle 2012). The model showed that pH, water temperature, and the presence of both Western Toad eggs and fish influenced the use of a pond for breeding by Columbia Spotted Frog (Swan et al. 2015). Lack of data precluded similar analyses for other species, sites, and years.

In Arrow Lakes Reservoir drawdown zone, some wetlands provided habitat for all pond-breeding amphibian species including Western Toad, Columbia Spotted Frog, Long-toed Salamander, and Pacific Chorus Frog, as well as Western Painted Turtle (Revelstoke Reach only) and both species of garter snake. Amphibians were associated with most surveyed wetlands, with most of those habitats occurring in Revelstoke Reach (e.g., Airport Marsh, Cartier Bay, Montana Slough). All had water physicochemical parameters suitable for aquatic life (B.C. Ministry of Environment & Climate Change Strategy 2018). Wetland habitats occurred between 434 and 439 mASL and most could be characterized as having complex vegetation and substrate characteristics with varying degrees of open water, soft substrates (e.g., mud or algae-bottomed), and emergent/submergent vegetation (see Hawkes and Tuttle 2008, 2009, and Miller et al. 2018b for plant species lists). The beaver pond complex at Beaton Arm provided highly suitable habitat for Western Toad as did the gravel excavation ponds at Burton Creek. Although not as prevalent in mid- and lower Arrow Lakes Reservoir, important wetland habitats occurred at Burton Creek, Lower Inonoaklin, and Edgewood South.

One of the key Western Toad breeding habitats in Revelstoke Reach was Cartier Bay, which has been the focus of ongoing study under CLBMON-11B4 (e.g., Miller et al. 2018a). In addition to Western Toad, several other species of amphibian (e.g., Long-toed Salamander) and reptile (e.g., Common Garter Snake) used this site throughout the active season making it one of the key sample sites for CLBMON-37 (Figure 5-11). Average water depth at surface sample points, after correcting for daily reservoir elevations, was 0.88 m. Measured depths tended to be greater in the west compartment of Cartier Bay (~1.0 m depth) than in the east compartment (0.83 m) (Miller et al. 2018a). Depths in the east compartment ranged from 0.1–1.5 m: those in the west, from 0.3–1.9 m. The range of depths in both the west and east compartments provided suitable breeding habitat for toads. Similar data for Montana Slough and Airport Marsh (Miller and Hawkes 2013) indicated that water depth in Montana Slough ranged from < 1.0 m to 5.0 m and from 0.15 m to 3.10 m in Airport Marsh. Ponds at Airport Marsh (n = 1), Cartier Bay (n = 15), and Montana Slough (n = 12) covered 55.80 ha, 39.75 ha, and 19.50 ha, respectively (Table 4-4, Appendix 17). Pond elevation in Revelstoke Reach (all locations) ranged from 432.87 mASL to 438.26 mASL.

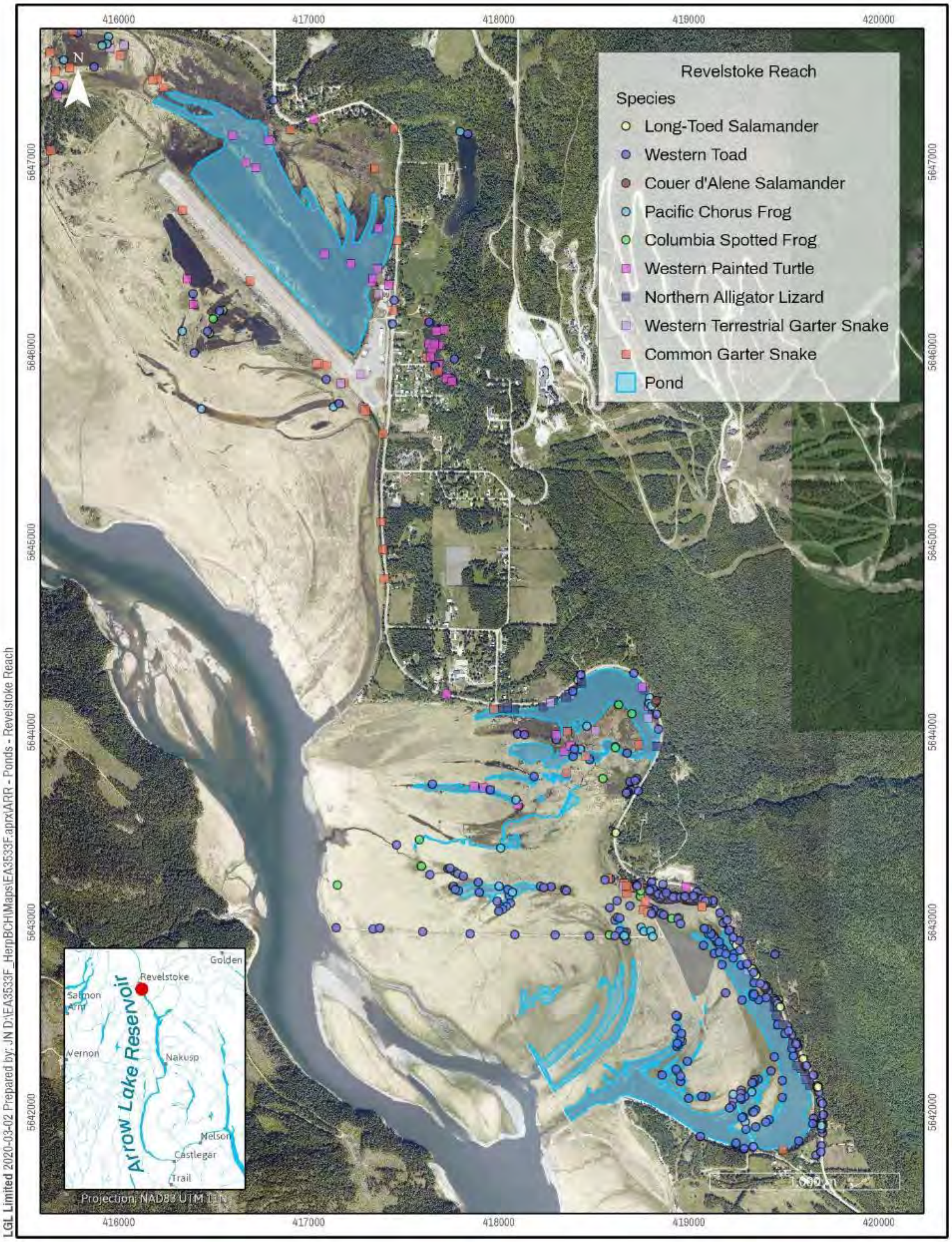

Figure 5-11: Detections of amphibians and reptiles at sites in Revelstoke Reach (i.e., Airport Marsh, Cartier Bay, Montana Slough), Arrow Lakes Reservoir between 2008 – 2018. See Table 3-1 for species codes.

Both species of garter snakes were frequently observed (foraging, swimming, or basking) around the margins of ponds and channels in both reservoir's drawdown zone. Palpation of captured individuals indicated recent prey including metamorphosed and juvenile amphibians. The presence of snakes was likely linked to the presence and abundance of amphibians and/or basking sites (see MQ3).

Western Painted Turtle were observed swimming or basking on logs in ponds at locations throughout Revelstoke Reach (see Figure 5-11). For a detailed description of pond use by Western Painted Turtle at Revelstoke Reach, see reports from CLBMON-11B3 (Schiller and Larsen 2012; Hawkes et al. 2013; Wood and Hawkes 2014; Wood and Hawkes 2015; Wood et al. 2016).

5.4.3 Challenges and Opportunities

Overall, the use of habitat in the drawdown zones of Kinbasket and Arrow Lakes Reservoirs by amphibians and reptiles has been well documented through multiple site visits and sampling of all vegetated habitats in the drawdown zones. Documentation included abundance, elevational, and habitat data. However, care must be taken when generalizing these results.

First, while surveys were conducted during the same general period each year, environmental conditions varied seasonally and annually, which may have affected our ability to detect all species present at each study site in each season and year. For example, if surveys occurred on a cold, rainy day, reptiles that occurred at that site were likely not detected (ectothermic animals typically seek shelter from rain and cooler temperatures; Gregory and Tuttle 2016). However, because data were collected over an 11-year period, this limitation likely had only a small influence on the overall detection and site-occupancy of each species.

Second, associating amphibian and reptile occurrence and distribution with the VCCs derived for both Kinbasket and Arrow Lakes Reservoir may provide somewhat misleading results. Search effort between the habitat types (VCC) was not controlled for because we focused the selection of survey sites on the presence of wetland and pond habitat in the drawdown zone and not on vegetation cover. Where possible we associated observations of amphibians and reptiles with VCC but due to incomplete coverage of vegetation mapping in both reservoirs and more specifically at the sites sampled for CLBMON-37 the results presented should be considered generally.

Third, habitat use was based on detection rates, which can differ based on habitat characteristics (e.g., amount of vegetation cover). Therefore, our assessment of habitat use may have been biased due to detection rates. For example, there were a variety of conditions under which detecting species can be difficult (e.g., tall dense vegetation, cool air temperature, precipitation, rocky substrate with crevices, murky water). Radio telemetry methods are one way to overcome this challenge by allowing surveyors to locate radio-tagged animals regardless of what habitat type they are using (e.g., dense vegetation, underground burrows; Boyle 2012; McAllister 2018). The radio telemetry data collected for Common Garter Snakes, Western Toad, and Western Painted Turtle (CLBMON-11B3) provided a more complete picture of habitat use by these species. Because radio telemetry could not be used for all species occurring in the drawdown zone for reasons discussed above (MQ3), we were unable to definitively quantify habitat use for most species beyond general descriptions of the habitats in which those species were encountered during the active season.

Fourth, annual variation in hydroperiods and pond size confounded our ability to compare amphibian use across the years. For example, in some years certain ponds were unavailable (i.e., not present) for sampling due to water table changes, broken beaver dams, CWD deposits, or because they were inundated by the reservoir. Ephemeral ponds are often used by amphibian species and likely contribute to the overall natural variation observed in many amphibian populations (Hawkes and Gregory 2012) which was a recognized limitation for most MQs within this study.

Finally, while not studied under CLBMON-37/58, yet likely relevant to the persistence of amphibian and reptile populations in reservoirs, was the lack of connectivity between habitats within the drawdown zone. The vast size of both reservoirs, lack of control wetlands outside of the drawdown zone, and limited wetland and riparian habitat across the drawdown zone landscapes put this out of scope for this project, despite it being an important component of population and community ecological monitoring studies. Maintaining connectivity between habitat patches (e.g., within wetland reaches in reservoirs) is important for amphibians, since many species exist in metapopulations and rely on dispersal for persistence (Marsh and Trenham 2001).

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

The influence of reservoir operations on amphibian and reptile populations was investigated from 2008 to 2018 with our data suggesting that reservoir operations influenced amphibians and reptiles in the drawdown zone, both directly and indirectly (Appendix 12). To what degree and in what direction (negative or positive) these impacts occurred on an annual or overall basis was more difficult to determine due to a variety of reasons.

The most direct observed effect of reservoir operations on amphibians and reptiles was the inundation of habitat which in most cases directly displaced animals to the periphery of the drawdown zone (Appendix 12). Other direct effects such as mortality, increased predation, and breeding depression were harder to measure and could only be inferred in most cases (e.g., absence of animal locations from inundated areas). Indirect effects, such as lower water temperatures (which hypothetically affects larval development), changes to habitats (which can affect quality of habitats selected by animals), or decreased food resources (which can affect habitat use or growth in all life stages), were difficult to determine; however, inferences can be drawn using water physicochemistry data (Appendix 13) and changes to other habitat characteristics (see figures and text in Hawkes and Tuttle 2012).

Despite direct effects (reduction in total habitat available due to reservoir inundation) and indirect effects (altered water chemistry) from reservoir inundation, amphibians (Western Toad, Columbia Spotted Frog, Pacific Chorus Frog, Long-toed Salamander) breed successfully in ponds situated in the drawdown zone. This is thought to be largely a function of the timing of breeding, which occurs early enough in the spring to allow for larval development to reach a stage that is less affected by the summer inundation of breeding ponds. Additionally, the high numbers of garter snakes that were observed at monitoring sites such as Valemount Peatland, Revelstoke Reach, and Burton Creek, suggest that these reptiles are also persisting in drawdown zone environments, despite the effects of reservoir inundation.

Our ability to answer this question was based on both a quantitative (data-based) and qualitative (hypotheses-based) approach of direct or indirect effects on amphibian and reptile populations. This information is summarized by species and effect in Table 5-4 and discussed in detail below.

Table 5-4: Hypothesized direct and indirect effects of reservoir operations on amphibians and reptiles found in the drawdown zones of Kinbasket and Arrow Lakes Reservoirs. D = direct, I = indirect, DDZ = drawdown zone.

Group	Species	Hypothesized Effects from Inundation	Hypothesized Severity	Hypothesized Direction	Literature or Study Findings
Pond-breeding Amphibian Species	Columbia Spotted Frog	Inundation of cold water likely slows larval development	Moderate	D	Water temperature decreased after DDZ inundation and no effect was concluded; however, cooler water may have led to reduced rates of development based on results from other studies (Crowder et al. 1998; Ultsch et al. 1999).
	Western Toad	Inundation may change tadpole habitat use	Moderate	D	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).
	Pacific Chorus Frog	Changes to pond habitat	Moderate	D & I	Inundation increased water depth and changes shoreline structure.
	Long-toed Salamander	Possible changes to food availability	Moderate	I	Food availability may change with DDZ inundation due to increased water depth (for tadpoles) and reduced pond/wetland habitat available for foraging (for metamorphs/adults).
Pond Species	Western Painted Turtle	Changes to basking and foraging habitat	Moderate	D	Inundation may change shoreline structure and availability of woody debris utilized for basking. Inundation timing may have an effect on the availability of prey sources such as aquatic insects, tadpoles, and macrophytes.
Upland Species	Coeur d'Alene Salamander	None anticipated	N/A	N/A	Coeur d'Alene Salamander were not observed in the DDZ and therefore inundation should not have any effect.
	Northern Alligator Lizard Western Skink Rubber Boa	Possible decreased availability of basking and foraging habitat	Low Low Low	D & I D & I D & I	Less habitat available due to inundation means there is less area in the DDZ to forage and bask.
Garter Snake Species	Western Terrestrial Garter Snake	Changes to basking and foraging habitat	Moderate	D	Less habitat available in DDZ due to inundation means there is less area to forage and bask.
	Common Garter Snake	Possible changes to food availability	Low	I	Because amphibians are the primary prey for garter snakes in the DDZ, potential impacts to amphibian productivity resulting from inundation of the DDZ could lead to a reduction in prey availability.

Desiccation – The normal operating regimes of both reservoirs was to fill during the egg-laying and larval development stages for amphibians (spring), so it is unlikely that reservoir-caused desiccation of ponds was an issue in the drawdown zone. We observed desiccation at several small breeding ponds, but this was likely related to natural causes (e.g., rapid pond drying rate, absence of rain), and not to reservoir operations. Egg string and egg mass stranding were observed at various sites in the drawdown zone (e.g., Bear Island in 2013) and were associated with pond drying at oviposition sites, which can be a major cause of death to developing embryos. This phenomenon is not unique to drawdown zones, as local environmental conditions can influence the hydroperiod of breeding ponds and were likely confounding any potential reservoir effects that may be linked to egg mass stranding (e.g., Marco and Blaustein 1998).

Predation/Mortality – Life stage-specific mortality rates were not directly measured for any species during this study; however, instances of mortality were observed during the 11-year period. Most of these mortalities were likely related to natural causes (e.g., injuries, senescence) or road mortalities outside of the drawdown zone and were not thought to be directly or indirectly related to reservoir operations. For example, high rates of Western Toad depredation were observed at Ptarmigan Creek in 2012 and 2013 (by an unidentified avian predator), dead garter snakes (unknown cause of death), and toad drownings (multiple males in amplexus with a female and drowning her as a result of her inability to swim and obtain air) were not unusual. There were also times when toad egg strings were not fertilized, which reduced fecundity, but did not increase mortality.

We can only hypothesize that changes to seasonal use of habitats, due to rising reservoir levels (indirect effect), may have exposed certain individuals, life stages, or species to increased risk of predation, because animals were either 1) dispersed in the water away from their original location in a pond (e.g., tadpoles), or 2) forced to move into less preferred habitats within or outside of the drawdown zone. For example, on several occasions, Common Garter Snakes were observed feeding on dispersed Western Toad tadpoles and metamorphs along the leading edges of the drawdown zone (these areas being void of vegetation in some cases and therefore less cover to hide under/in and potentially more likely to be predated). In other incidences, larger fish species (potential predators of amphibians) were detected in ponds post-inundation, thereby introducing a potential predator into an area where it previously did not exist (e.g., carp in Arrow Lakes Reservoir, pers. obs.). In Montana Slough when Arrow was full, Western Painted Turtles were observed along the edges of the reservoir (near the rip rap bolder edge), thereby potentially exposing them to an increased risk of predation from land predators.

Inundation - The decline of some species of amphibians has been attributed to changes to hydrological regimes resulting from hydroelectric developments (see Lind et al. 1996; Brandão and Araújo 2008). The data collected for CLBMON-37/58 suggest that reservoir operations directly reduced the amount of habitat available for breeding and foraging by amphibians and reptiles using the drawdown zone; however, the indirect effects of this annual displacement on reproduction, survivorship, and quality of habitat over the long-term are currently unknown (see also MQ6). Although we had a considerable amount of data (2008 to 2018) regarding the seasonal occurrence, distribution, and relative abundance of Western Toad, Columbia Spotted Frog, and Common Garter Snake that suggested these species were persisting in the drawdown zone (for at least a portion of the year) despite the annual effects of inundation, we did not have sufficient occurrence or abundance data to provide an assessment for any other species using the drawdown zone.

Direct effects of inundation on habitat availability – The direct effects of reservoir operations on amphibians and reptiles were related to temporal and spatial displacement from shallow wetland habitats, which were in short supply in the drawdown zones of Kinbasket and Arrow Lakes Reservoir. The presence of small wetlands has been linked to the persistence of local populations of amphibians (Gibbs 1993, Semlitsch and Bodie 1998). Habitat availability was assessed by delineating the total area sampled each year (i.e., terrestrial and aquatic habitat at each monitoring site) and calculating how much of that area was available on a monthly basis relative to reservoir operations. Habitat availability varied by month and year relative to reservoir operations and was a function of reservoir elevation (see Appendix 12). As expected, a strong negative correlation existed between habitat availability and reservoir elevations with habitat availability decreasing with time (Kinbasket Reservoir: *r* = -0.95, Arrow Lakes Reservoir: *r* = -0.96; Figure 5-12, Figure 5-13). The change in habitat availability was most evident in spring and early summer, when reservoir elevations were increasing. This trend was present in both reservoirs with the number of amphibian and reptile observations decreasing as reservoir elevations increased, and fewer individuals documented at sites when reservoir elevations were high (i.e., post-inundation; Hawkes et al. 2011; Hawkes et al. 2017).

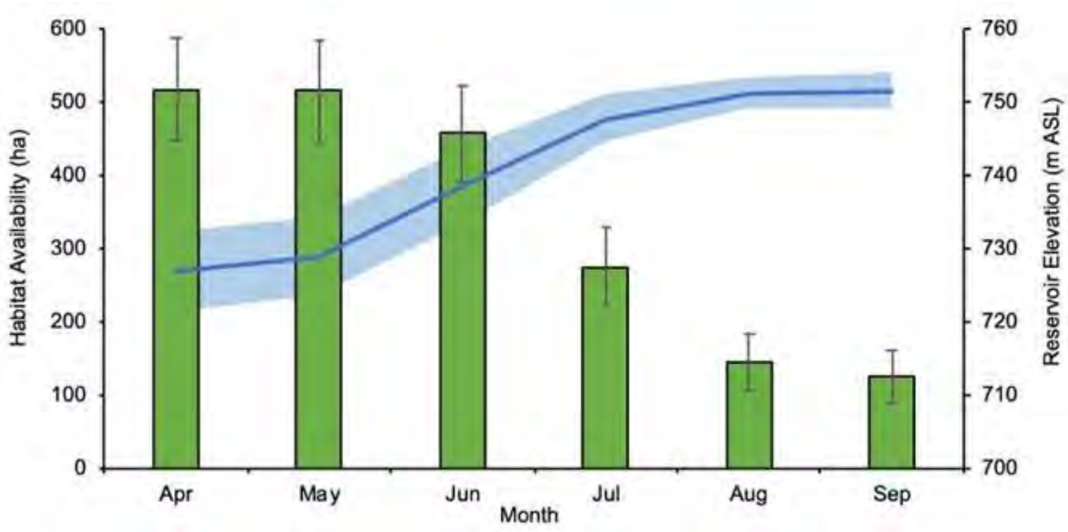

Figure 5-12: Average monthly change in habitat availability (ha) and reservoir elevation (mASL) in the drawdown zone of Kinbasket Reservoir (2008 to 2018). The average reservoir elevation (line) is shown. Error bars and light blue shading show standard deviation.

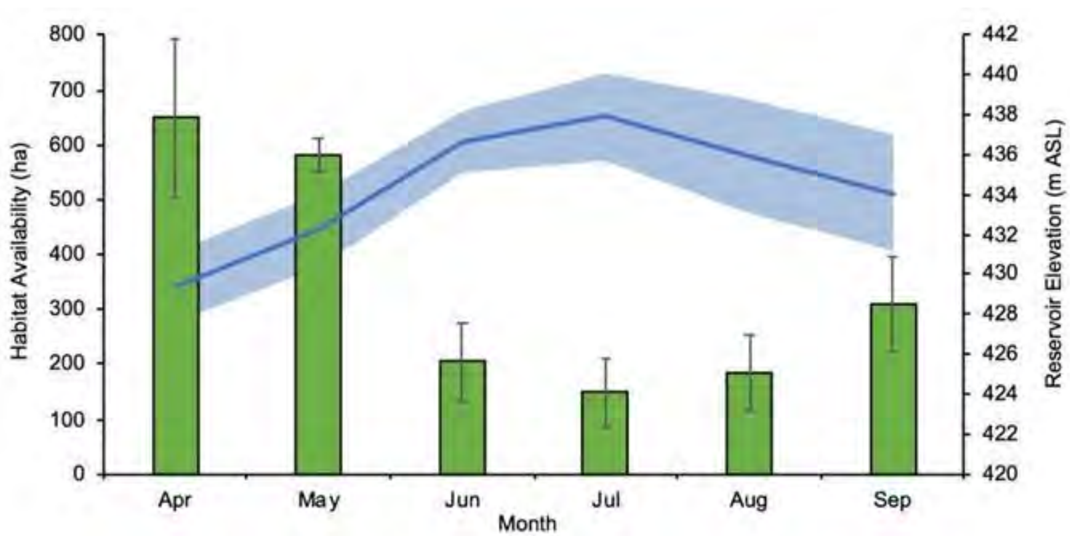

Figure 5-13: Average monthly change in habitat availability (ha) and reservoir elevation (mASL) in the drawdown zone of Arrow Lakes Reservoir (2008 to 2018). The average reservoir elevation (line) is shown. Error bars and light blue shading show standard deviation.

An example of extreme reservoir inundation directly impacting habitat availability of species was documented in 2012 whereby both reservoirs were operated above the normal operating maximum and survey sites normally accessible for surveying in

June and July were inundated. For species such as Western Toad and both species of garter snakes, it was clear that reservoir operations were implicated in a reduction of site occupancy as few to no individuals were observed during surveys at the sites or in the surrounding upland habitat (immediately adjacent to the water's edge). Even in years that were not considered extreme, habitat in the drawdown zone was affected by reservoir inundation, and for some study sites with high species diversity and relative abundance this is noteworthy.

The species most likely to be affected by reservoir operations was Western Toad. This species bred in ponds at lower elevations in the drawdown zone, which were inundated at earlier dates than other ponds. Additionally, since Western Toad tadpoles often formed large aggregations within ponds (anti-predator survival strategy; COSEWIC 2012), displacement and dispersal of tadpoles post reservoir inundation was likely to affect their survival through to metamorphosis. This effect was inferred by observing the difference between ponds that were inundated early, before metamorphosis occurred and where metamorphs were not observed (e.g., Bush Arm KM88 and Burton Creek), and ponds that were not inundated (or only partially inundated) until after metamorphosis had occurred and where numerous metamorphs were observed (Valemount Peatland). The one exception to this was for Cartier Bay / Montana Slough in Revelstoke Reach, which was frequently inundated early in the year yet still produced thousands of metamorphs in most years. This site had a significant population of Western Toad with breeding habitat situated between 433 and 435 mASL (Hawkes and Tuttle 2013). In three of the seven years of monitoring, these habitats were inundated in May and completely flooded by June; however, metamorphs were still detected each year.

Interactions between reservoir operations and the Western Painted Turtle population in Revelstoke Reach were assessed under CLBMON-11B3 (Schiller and Larsen 2012; Hawkes et al. 2013; Wood and Hawkes 2014; Wood and Hawkes 2015; Wood et al. 2016). As expected, reservoir inundation altered spring and summer habitats used by turtles in Montana Slough and Cartier Bay only (Airport Marsh was largely unaffected). In years of high water (2011/2012), turtles were observed along the edges of Montana Slough (using floating logs and shoreline habitat), possibly indicating that other previously used habitats were unavailable. Known nesting sites for this species in this area are located outside of the drawdown zone at Red Devil Hill, Williamson Lake, and near the airport and thus were unaffected by reservoir operations (Basaraba 2014). Winter habitat use by turtles in the drawdown zone was studied by Duncan (2016) who found that turtles overwintered in Airport Marsh and Montana Slough. Duncan (2016) concluded that turtles overwintering in the drawdown zone exhibited differential wintering tactics but did not appear to be impacted by reservoir level fluctuations in winter. Both Basaraba (2014) and Duncan (2016) indicate that the turtle populations in Revelstoke Reach experience potential, seasonal (and temporary) habitat displacement relative to changing reservoir levels but the overall impact of reservoir operations on turtles appears to be negligible.

Overall, inundation affected habitat availability directly; however, it is the opinion of the authors that inundation resulting from normal operations was unlikely to drastically affect species diversity, abundance, or productivity for most monitoring sites. For example, the constant year-to-year abundance of Western Toad egg masses and adults in both reservoirs and Common Garter Snakes in Arrow Lakes Reservoir suggested that the size of the adult populations of these species were stable and likely an indication of a healthy population (Deichmann et al. 2008). Because amphibians and reptiles were persisting in the drawdown zone and in some cases were apparently quite abundant (e.g., garter snakes in Revelstoke Reach, Western Toads in Valemount Peatland and Bush Arm), we can assume that the annual reduction of habitat availability does not dramatically affect local populations; however, we do not know if these populations were supressed relative to populations in non-reservoir habitats. Based on what we have observed regarding the location and elevation of ponds used by amphibians in the drawdown zone for breeding, we suspect the effects of reservoir inundation are mitigated mainly by habitat selection, but this has not been explicitly tested.

Indirect effects of inundation on water physicochemistry - Reservoir operational effects on habitat change were assessed in terms of changes in water chemistry and temperature in several years of CLBMON-37/58 (Hawkes et al. 2018b). Of these parameters, water temperature can influence tadpole development to some degree (Crowder et al. 1998; Ultsch et al. 1999). However, the effects of reservoir inundation on water temperature and subsequent tadpole development were not directly tested due to the inability to continuously monitor development over time. 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 collected from wetlands in the drawdown zone of Kinbasket Reservoir for CLBMON-61 suggested that inundation temporarily reduced water temperature and dissolved oxygen (Adama et al. 2013) but the effects of pond-breeding amphibians were not determined. Other water physicochemical parameters measured in ponds in the drawdown zone of Kinbasket Reservoir suggest little difference between values of dissolved oxygen, pH, or conductivity after inundation (Hawkes et al. 2013); however, other studies have documented a negative relationship between species richness and certain chemical variables (e.g., chloride, magnesium, conductivity: Hecnar and M'Closkey 1996). Physicochemical data for Arrow Lakes were assessed and found to be unlikely to influence amphibian populations (2014 and 2016 CLBMON-37 annual reports).

For garter snakes and turtles, which are ectothermic, a small decrease in water temperature of a few degrees (from inundation of cooler reservoir water into shallow, warm pools) would possibly affect foraging by decreasing body temperature of any individuals swimming in the water. This conclusion is based on literature relating ectothermic performance to temperature (e.g., Huey and Stevenson 1979; Peterson et al. 1993) and only inferred as a potential indirect effect in the case of this study. It is the opinion of the authors that changes to water temperature are unlikely to affect garter snakes. Western Painted Turtles are known to overwinter in Montana Slough with water temperatures ranging from 0.3 ° to 1.8°C in January (Hawkes et al. 2013) and it is unlikely that they would be negatively affected by decreasing water temperatures as a result of inundation in the spring/summer.

Indirect effects of inundation on habitat change – wood debris

A separate, but related, issue to reservoir operations was the presence of wood debris in reservoirs and the effects that wood debris disturbance can have on amphibian and reptile habitat occurring the drawdown zone. The accumulation of wood debris can be detrimental to wetlands for several reasons. First, wood debris displaces existing terrestrial and aquatic vegetation as it accumulates over time, affecting the surface and the bottom of ponds. Second, vertical and lateral movement of large wood debris due to fluctuating water levels can cause mechanical damage to established vegetation. Third, the leachate from the large accumulations of wood material can be highly coloured, acidic, of very high oxygen demand, and toxic to aquatic life (Tao et al. 2005).

Successive years of high water in Kinbasket Reservoir resulted in increased rates of wood debris accumulation on important amphibian breeding habitats (Figure 5-14) which likely reduced the quality of these habitats for amphibians. In some cases, work was undertaken to remove the wood debris from these ponds to make them once again available to amphibians. In the example shown in Figure 5-14, wood debris removal activities in 2015 resulted in the cleared ponds being used by Western Toad for breeding in 2016 (Hawkes 2016). In certain locations, wind and wave action resulted in scouring of vegetation and the ground near the upper elevations of the drawdown zone by woody debris, which contributed to increased rates of plant mortality (Hawkes et al. 2019), particularly in the willow shrub habitat that provided important garter snake habitat.

Wood debris accumulation does not have the same effect on habitats in Arrow. Wood debris at Edgewood South and Burton Creek provided important cover habitat for garter snakes and Western Toad in the early spring and summer and high reservoir levels at these sites has the potential to negatively alter habitat by moving existing debris cover (e.g., by pushing it into upland habitats making it unavailable for use in the drawdown zone, or changing the thermal qualities of existing pieces of wood).

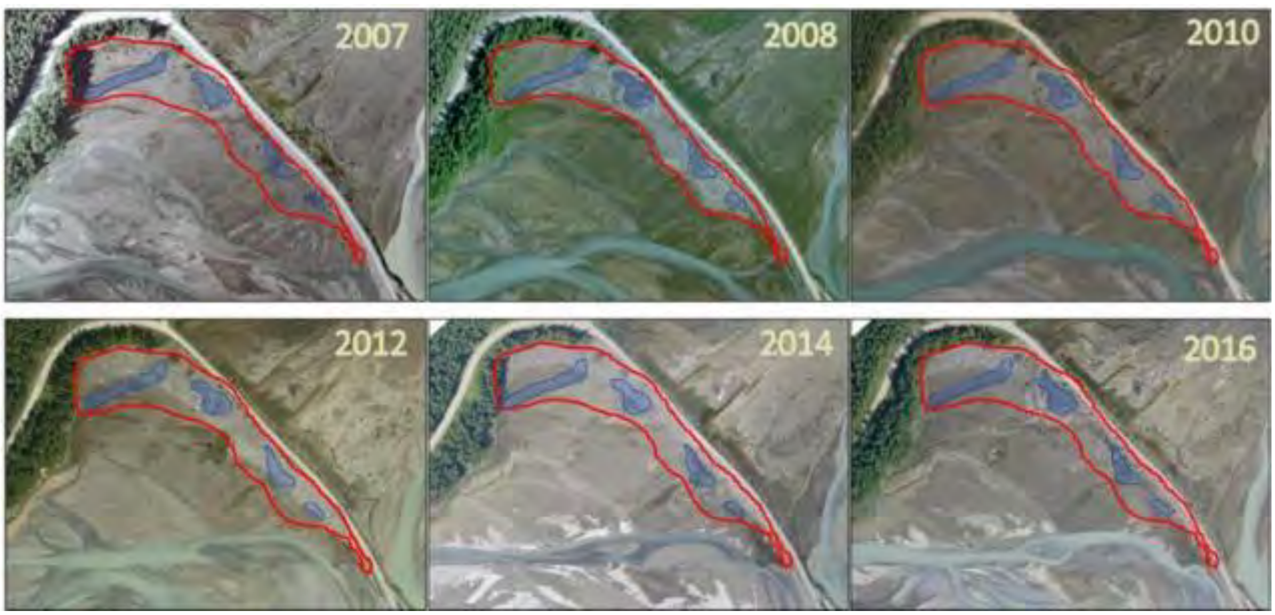

Figure 5-14: Accumulation of wood debris at Bush Arm Causeway following a high water event in 2007. Wood debris accumulated at this site and settled on ponds between 2007 and 2008 rendering them inaccessible to amphibians until they were cleared of wood debris in 2015. The red polygon denotes the distribution of wood debris as measured in 2008. Blue polygons indicate the location of the ponds first mapped in 2007and that were under wood until 2015.

5.5.1 Challenges and Opportunities

The sources of uncertainty and challenges for MQ1 through MQ4 also apply to this MQ. Overall, the effects of reservoir inundation in Kinbasket and Arrow Lakes Reservoirs on amphibians and reptiles have been well documented through multiple site visits and sampling of all occupied habitats in the drawdown zones, which provided abundance, elevational, and habitat data.

Overall, our ability to directly measure the potential effects of changing physicochemical parameters on amphibians was confounded by 1) reservoir operations, which varied annually, and 2) the inability to capture the same individuals over time whilst measuring or manipulating variables such as dissolved oxygen or temperature (i.e., a control/treatment study design was out of scope for this study).

Our data indicate that reservoir operations affect habitat availability, and this occurred in a varied but predictable manner each year. The year-over-year persistence of all expected species of amphibian and reptile in the drawdown zone coupled with high rates of site occupancy (i.e., the same ponds were used each year by the same species) suggests the influence of reservoir operations on amphibians and reptiles was likely short-lived and constrained to within-year effects. However, we were not able to quantify whether amphibian or reptile survivorship was affected by operational regimes that resulted in higher reservoir 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 and neither approach was used extensively in this study. When radio telemetry was used it was to answer specific questions about seasonal habitat use (see Section 5.4).

One limitation associated with assessing the effects of reservoir operations on populations of amphibians and reptiles using habitats in the drawdown zones of large hydroelectric reservoirs is the lack of a non-reservoir control. In the absence of a suitable control or even pre-impoundment baseline data, we cannot predict with confidence how the abundance, diversity or productivity of any species of amphibian might be affected by reservoir operations. This is because we were unable to study non-reservoir populations of the same species to determine if similar patterns in habitat usage were apparent. The data collected for CLMBON-37 and 58 do enable us to comment on the interplay between species occurrence and distribution and habitat use relative to reservoir operations and it is clear that as the reservoir fills, habitat availability declines and amphibians and reptiles no longer have access to those habitats in the drawdown zone.

Our ability to infer reservoir impacts of habitat alteration (inundation) on amphibians and reptiles was confounded by (1) the fact that many populations of amphibians and reptiles experience significant spatial and temporal population fluctuations (McGarigal and Cushman 2002; Cushman 2006), (2) data gaps pertaining to species' patterns of seasonal distribution for foraging and overwintering, and (3) the annual variation of reservoir operations in combination with variable environmental conditions. Additionally, certain drawdown zone habitats were impacted directly and indirectly annually by reservoir operations (e.g., deposition of wood debris on wetlands, scouring caused by floating wood, habitat erosion, sedimentation), and the effects on amphibians and reptiles and their habitats were not studied. The longer-term implications of variable reservoir operations and inundation of important breeding habitats remain unknown.

For upland species not typically associated with the drawdown zone (e.g., Western Skink, Rubber Boa, Coeur d'Alene Salamander), the lack of detections in the drawdown zone was not surprising. These species were typically associated with dry rocky outcrops (Rubber Boa [Matsuda et al. 2006]) or wet seeps and splash zones (Coeur d'Alene Salamander [Matsuda et al. 2006]) – habitats that do not exist in the drawdown zone. Western Skinks typically occupied similar habitats as Rubber Boa; however, they were documented under rocks situated below the normal operating maximum of the reservoir in Edgewood and Deer Park. The rocky habitat at or near 440.1 mASL currently represented the known extent of use of the drawdown zone by this species.

With respect to changing habitat types, data from CLBMON-10 could be used to determine if the habitats that amphibians and reptiles use change over time relative to reservoir operations. Hawkes et al. (2019) reported that the distribution and extent of those communities have varied, but over time there has been a slight (~ 9 percent) increase in the total extent of vegetation in the drawdown zone, which is related (in part) to the reduction in wood debris deposits in the drawdown zone (from ~254 ha in 2007 to ~56 ha in 2016; see also Figure 5-14). However, this slight increase in vegetation cover at the landscape level has been coupled with a decrease in species richness and diversity over time at the site level. Hawkes et al. (2019) also reported that the diversity of communities within each landscape unit, as well as the relative distributions of communities within landscape units, has remained relatively stable with time. This, in combination with the slight but incremental increases over time in the total spatial extent of mapped vegetation, implies that the current operating regime is succeeding in maintaining the general character, composition, and extent of vegetation at the landscape scale. As such there are currently no data to support an indication of habitat change as a result of the operating regime that would directly or indirectly affect amphibian and reptile species or populations that rely on particular drawdown zone habitat attributes to fulfill their life requisites.

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

Based on the findings summarized above, it is the opinion of the authors that minor adjustments to reservoir operations could theoretically be made to minimize the impacts on amphibians and reptiles.

Avoid rapid inundation early in the season - A management strategy that avoids rapid filling of the reservoir at lower elevations in the spring when amphibians are breeding in ponds in the drawdown zone would likely have a positive effect on the annual fecundity of all species of pond-breeding amphibians. Inundation of drawdown zone habitats during the active season for pond-breeding amphibians and garter snakes displaced individuals into other habitats (e.g., upland areas), especially in Arrow Lakes Reservoir which filled earlier than Kinbasket Reservoir. Delaying the draw of Arrow Lakes Reservoir until further in the season (July/August) could hypothetically allow for longer larval development periods in drawdown zone ponds (larvae develop more quickly in warmer water [Ultsch et al. 1999]), increased foraging opportunities in drawdown zone ponds for garter snakes, and reduction of significant habitat changes during the active season for species using those areas.

Additionally, the limited amount of breeding habitat available in the drawdown zones should be considered relative to any adjustments of reservoir operations. For example, some ponds at lower elevations in Bush Arm were used by Western Toads for breeding (e.g., KM88 Bear Island). These ponds are situated between 738 and 744 mASL, and although they comprise a small number of ponds, they could be considered for protection to minimize impacts to toads. By protection, we suggest ensuring that elevations between 737 and 738 mASL are available for use by amphibians into mid to late June. This would ensure that local populations of Western Toad could access important breeding habitat in the drawdown zone.

Adjustments to operations to ensure these elevations were accessible would not need to be considered in all years. For example, between 2008 and 2018, Kinbasket Reservoir exceeded 737 mASL on 16 Jun (average; min: 4 Jun; max: 29 Jun) in 9 of 11 years. As such, hydro operations that mimic the hydrograph observed in these years (i.e., 2008 to 2014; 2017 and 2018; Figure 5-15) support access to lower elevations into June; there would be no need to consider adjusting reservoir operations. In 2015 and 2016, when Kinbasket Reservoir was not drawn down to the same extent as the other years, 737 mASL was exceeded on 1 May (2015; Figure 5-15) and 16 May (2016). In these cases, adjusting operations to expose elevations ≤737 mASL and delay inundation of those elevations until sometime between 4 and 29 June (to align with the operations observed during all other years of study) would benefit species such as Western Toad.

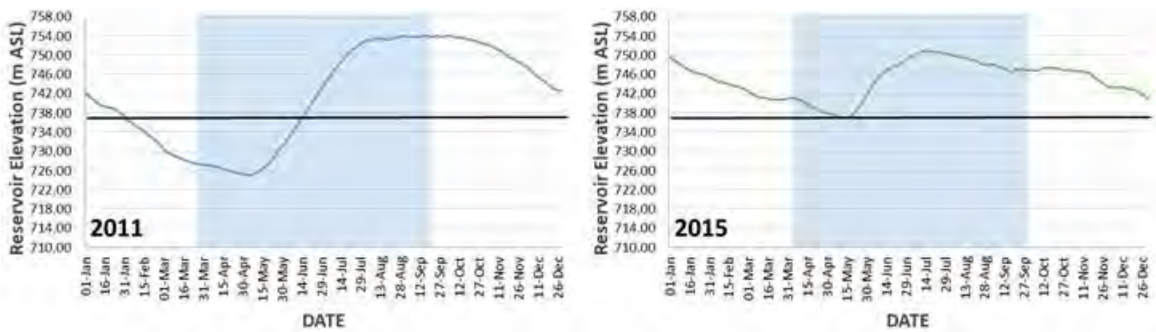

Figure 5-15: Example hydrographs depicting a year when adjustments to reservoir operations would not be required (2011) and one where adjustments could be considered (2015). Horizontal line represents 737 mASL; shaded box indicates period of amphibian activity in most years (April through September).

In Arrow Lakes Reservoir, important Western Toad breeding habitat occurs between 434 and 436 mASL (Table 4-4). On average, 434 mASL was exceeded on 29 May (in 6 of 7 years assessed). In 2016, 434 mASL was exceeded on 24 April. Although inundation occurred considerably earlier in 2016 compared to other years of study, pond-breeding amphibian species including Western Toad continued to occupy habitats in the drawdown zone in subsequent study years (See Appendix 2: Summary of amphibian and reptile site occupancy; Table 7-5). Continued occupancy of study sites such as Cartier Bay by Western Toad and Western Painted Turtle suggests that hydro operations such as those observed in 2016 do not unduly affect the use of habitats in the drawdown zone. However, if reservoir operations such as those observed in 2016 were to occur at an increased frequency, there is in increased probability that the suitability of certain habitats, such as those occurring at Cartier Bay, would be diminished for pond-breeding amphibians and reptiles.

Adjusting reservoir operations to formally adopt the soft constraint targets for wildlife (i.e., target a reservoir level of 434 m or lower from late-April to mid-July) would benefit pond-breeding amphibians and reptiles (in addition to other taxa) that use habitats in the drawdown zone of Arrow Lakes Reservoir. Using the years of study associated with CLBMON-37 as a guide, this could require delaying inundation of 434 mASL by 40 to 82 days (mean: 52.5), but this depends on how Arrow Lakes Reservoir is managed, which is contingent on multiple factors.

Avoid reservoir levels above full pool early in the year and in successive years – The recent management of both Kinbasket and Arrow Lakes Reservoirs has included successive years of high water, which affected habitat availability and the habitats themselves (Hawkes and Gibeau 2017; Miller et al. 2018b). Surveys conducted in July and August of those years documented very few amphibians and reptiles, both due to the lack of survey area (i.e., areas were inundated) and/or presumed dispersal of animals into upland habitats or mortality events from lack of sufficient drawdown zone habitat (e.g., appropriate ponds for larval development). 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 (this species was documented using coarse wood debris deposits in the drawdown zone of Edgewood South and in the rocky rip-rap around reservoir sites in Revelstoke Reach).

A management strategy that avoids filling the reservoir to full pool during the summer months (when the most animals are using the drawdown zone for larval development, foraging, etc.) would likely have a positive effect on all species of pond-breeding amphibians and Western Painted Turtle, as well as species using the periphery of the drawdown zone such as garter snakes and Northern Alligator Lizard. 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.

Additionally, successive years of high water in Kinbasket Reservoir resulted in increased rates of wood debris accumulation on important breeding habitats, which reduced the quality of these habitats for amphibians (see Figure 5-14). Wind and wave action contribute to scouring of vegetation and the ground near the upper elevations of the drawdown zone, which likely contribute to increased rates of plant mortality, particularly in the willow shrub habitat that provided important garter snake habitat. Avoidance of successive years of high water, in combination with monitoring the important wetland habitat in Canoe Reach and Bush Arm, would likely help to mitigate these negative effects of reservoir operations.

5.6.1 Challenges and Opportunities

It is not clear what constitutes a "minor adjustment." Given the variable nature of reservoir operations, a more informed answer to this question would require understanding how a minor adjustment affects the various types of reservoir operations. Because reservoir operation changes from year to year, it is difficult to identify any one management regimen to change. It is unlikely that any future study could control when the reservoirs exceed a given elevation or for how long. The lack of experimentation to assess how varying the timing and duration of inundation correlates to the use of the drawdown zone by amphibians and reptiles, or to abundance, distribution, and productivity values, hampered our ability to answer this question.

The variable manner in which reservoirs were managed created something of a conundrum with respect to this management question. In general, the operation of both reservoirs from 2008 to 2018 did not appear to have direct negative effect on amphibians and reptiles using the drawdown zone, as animals returned year after year to the same sites. However, because reservoir operation changed from year to year, it is difficult to identify any one management regimen to change for a positive effect.

With respect to reptiles, garter snakes (both species) were mobile and frequently used aquatic habitats in the drawdown zone for foraging, security, and thermal habitat (pers. obs.) and were unlikely to be affected by reservoir operations during their active season (April through September). Given that we do not know where snakes are overwintering for most study sites (exception being adult snakes at Valemount Peatland) or whether there is important breeding habitat in the drawdown zone of either reservoir, we were unable to answer whether adjusting reservoir operations would minimize the impacts to these species. Northern Alligator Lizard, Western Skink, and Rubber Boa are unlikely to benefit from minor adjustments to reservoir operations as their preferred habitat did not typically occur in the drawdown zone.

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

Restoration efforts have become an important tool in the recovery of biodiversity and are regularly used to improve, create, and restore habitats that have been degraded or destroyed in North America (Young 2000). Restoration of wetland areas to pre-disturbance conditions or the creation of new wetland habitats are conservation strategies that help mitigate for the decline in aquatic ecosystems in our natural world (Biebighauser 2011). Species of amphibian are of particular interest to wetland restoration projects, in part because of the diversity of species that rely on wetland habitat to fulfil important life history requirements (e.g., breeding, foraging, cover), but also due to their worldwide decline in numbers (Houlahan et al. 2000, Hopkins 2007). Several factors have been shown to influence amphibian recolonization of restored wetlands, including pond hydroperiod, terrestrial buffers, aquatic predators and species' characteristics (e.g., site fidelity, vagilities, conservation status, metapopulation dynamics), all of which need to be factored into restoration designs (Pechmann et al. 2001).

Future physical works designed to mitigate potential adverse impacts on amphibians and reptiles from reservoir operations are a viable option for both reservoirs. Several physical works projects were implemented during the course of this study, providing preliminary data to support their efficacy and suitability. The effectiveness of these projects to mitigate impacts on amphibians and reptiles is discussed in MQ9. Here we focus on designs/methods that are predicted to be the most effective in each reservoir and identify designs that should be considered.

The primary impacts of reservoir operations on amphibians and reptiles are direct inundation of habitats by the reservoir, which decreases habitat availability during the active season, and indirect effects of inundation via habitat change (e.g., water physicochemistry changes or wood debris accumulation; see discussion in MQ5 for more detail). Examples of physical works that could be used to increase habitat availability for amphibians and reptiles or protect important existing habitats include (see Hawkes and Tuttle 2016 for more detail):

- **Creation of permanent wetland habitat** at higher elevations in the drawdown zone or immediately adjacent to the drawdown zone in upland habitat (Hawkes 2007; Hawkes and Fenneman 2010; Tuttle 2013; Hawkes and Tuttle 2016b),
- **Restoration to improve habitat** via the removal or exclusion of wood debris from wetland habitats (installation of log booms around these cleared habitats to protect them from future wood debris accumulation and improve habitat suitability; Hawkes 2016, 2017), and/or

- **Enhancement of selected habitat attributes** directed at amphibian and reptile taxa and designed to mitigate adverse effects of reservoir inundation (e.g., floating islands, specific revegetation prescriptions).

5.7.1 Kinbasket Reservoir

Various factors, alone or in combination, may explain the lack of amphibians and reptiles in many areas of Kinbasket Reservoir: an absence of suitable habitat, due in part to the extensive footprint of the reservoir; its vast draw downs (which can span ~49m but average ~ 25m); fluctuating water levels; and the low vegetation cover in lower reaches/elevations. The amphibian species occurring in the region are all pond-breeders and tied to the presence of water, but the total area of available wetted habitat is small (~12 hectares were mapped in the locations we sampled). Quality of wetland habitat may be further affected by vegetation ingrowth (influenced by water saturation resulting from reservoir inundation), fluctuating water physicochemistry variables (e.g., reduction in dissolved oxygen following inundation [Figure 7-37]), erosion resulting from inundation, and wood debris accumulation (Figure 5-14). Based on our initial reconnaissance surveys in 2008, subsequent field surveys, and reviews of aerial imagery, much of the drawdown zone of Kinbasket Reservoir is an inhospitable place for amphibian and reptile taxa. Much of the drawdown consists of steep rocky shorelines that preclude the development of vegetation and wetland/pond habitat, rendering them of little to no habitat value to amphibians and reptiles.

One way to improve habitat quality for wildlife would be to increase the availability of wetlands, particularly at higher elevations less affected by reservoir operations. For the most part, this includes elevations between ~748 and 754 mASL. There are existing examples of utilized habitats that could be emulated through physical works to improve the overall habitat suitability of the drawdown zone for amphibians and reptiles. For example, in Bush Arm there are a series of old beaver dams that have created a tiered system of ponds ranging in elevation from ~748 mASL to ~752 mASL. These ponds provide habitat for Columbia Spotted Frog, Western Toad, and Common Garter Snake. There is also a connection to an upland (i.e., non-drawdown zone) pond that contributes to the use of the drawdown zone by frogs and toads. Additional tiered wetlands could be created in select locations in Bush Arm including sites at the causeway and sites west of the tiered beaver pond at KM88 (Figure 7-42).

A similar project to create tiered wetlands is underway in Arrow Lakes Reservoir at Burton Creek (Miller and Hawkes 2019) and although the efficacy of that work will not be known until 2020, it is anticipated that the construction of a series of tiered wetlands will improve the suitability of the drawdown zone for wildlife, including amphibians and reptiles. This is based on evidence from a wetland construction project in the drawdown zone of Diversion Reservoir (Jordan River) (Hawkes and Fenneman 2010; Tuttle 2013). There, the creation of wetland habitat in the drawdown zone benefitted Red-legged Frog (*Rana aurora*), Pacific Chorus Frog, and several species of salamander (e.g., Northwestern Salamander, *Ambystoma gracile*), especially when pond habitat in the drawdown zone was in short supply previously.

Restoring habitat through the removal of wood debris from terrestrial, wetland, and pond habitats should benefit amphibians by directly improving wetland function, productivity, and habitat suitability, either by increasing the total area of vegetated habitat or by restoring access to the wetland (see Figure 5-14). The removal of wood debris from the accumulation site at the Bush Arm Causeway in 2015 immediately resulted in those cleared ponds being used by Western Toad for breeding. In this instance, restoring access to ponds in the drawdown zone led to post-wood removal use by amphibians (Hawkes 2017).

A related project occurred in the northern portion of the Valemount Peatland. In this case, wood debris was cleared from a wetland and a log boom installed to prevent future wood accumulation (Figure 5-16). The removal of wood debris promoted the regrowth of wetland-associated plants and was used by Columbia Spotted Frog and Western Toad for breeding the year following clearing. These results indicate that wood removal from wetlands located in the drawdown zone of Kinbasket Reservoir is an effective technique that improves habitat suitability for amphibians. Because amphibians, particularly Western Toad, are one of the main prey sources for garter snakes, improving habitats for amphibians will have a commensurate effect for snakes. As such, there is evidence to suggest that productivity increases could be observed for certain species following the removal of wood debris from wetlands, although it is unknown if this increase will result in a net change in abundance over time.

Figure 5-16: Removal of wood debris from an area of the Valemount Peatland showing the pre (2012) and post (2014) clearing and subsequent ingrowth of vegetation 2016).

Garter snakes in the Kinbasket Reservoir region have slightly different habitat requirements from those of amphibians (i.e., they do not rely on water in the same way), and while they would likely benefit from the creation of wetland habitat via food availability, the creation of artificial hibernacula (i.e., dens) would likely be of greater benefit. Hibernation sites are typically a limiting factor in garter snake populations in northern environments (Macartney et al. 1988, Tuttle 2007, McAllister 2018). Constructing man-made garter snake hibernacula has been used to enhance snake habitat (Zappalorti and Reinert 1994), and artificial dens are relatively easy to install and are not expensive. Implementing this approach just above the drawdown zone (e.g., near Valemount Peatland) could benefit snake populations by creating suitable den habitat and reducing travel distances to existing sites (which are likely the only available options; McAllister 2018).

Although not measured, the improvement of wetland suitability in the drawdown zone of Kinbasket Reservoir was expected to benefit reptiles through increased food viability. There are other areas in the drawdown zone of Kinbasket Reservoir (e.g., Valemount Peatland, Succour Creek, and additional areas at Bush Arm Causeway) that would benefit from wood debris removal to enhance wetland habitat suitability. The use of physical works to mitigate adverse impacts on amphibians and reptiles resulting from reservoir operations will be limited in scale as only certain portions of the drawdown zone can be manipulated to improve habitat suitability. The long-term efficacy of physical works in providing suitable habitat for amphibians and reptiles relative to normal reservoir operations (including filling to the normal operational maximum) requires study.

No other physical works designs directly related to amphibians and reptiles have been proposed since the completion of this study. Based on our professional opinion and on available data showing project success in other aquatic ecosystems (Hawkes and Fenneman 2010; Tuttle 2013), we suggest that the most promising physical works methods for mitigating adverse impacts of reservoir operations on amphibians and reptiles are creation of wetland habitat in the upper elevations of the reservoir (increases availability of breeding habitat for a longer period during the active season) and debris management (increasing the suitability of existing wetland habitat), but there is a finite opportunity for implementing these methods, and it remains unclear what size of benefit can be achieved by their implementation.

5.7.2 Arrow Lakes Reservoir

At Arrow Lakes Reservoir, the effects of wood debris accumulation in the drawdown zone are less severe than at Kinbasket Reservoir. Notably, most of the ponds studied under CLBMON-37 that were used by amphibians and reptiles remain surrounded by vegetation [e.g., reed canarygrass (*Phalaris arundinacea*)] and unaffected by wood debris accumulation. Such vegetation provides cover for amphibians and reptiles during the active season (i.e., spring to fall), and likely promotes food abundance. As at Kinbasket Reservoir, a wood debris removal program was implemented that emphasised creating a safer environment for recreational users. In Kinbasket Reservoir, wood removal had ancillary and positive effects on habitats in the drawdown zone. Because there was less wood in Arrow Lakes Reservoir, its removal was not associated with observable improvements to wildlife habitat in the drawdown zone.

An effort to expand the quality and quantity of vegetation in the drawdown zone between 430 and 440 mASL occurred between 2008 and 2011 (Keefer et al. 2008; 2009; Keefer Ecological Services 2010; 2011). These efforts have achieved mixed success (Enns and Overholt 2013a, Miller et al. 2018c), and there is expected to be minimal benefit to amphibians and reptiles accruing from this approach (see MQ8 for more discussion on revegetation programs). Unless there are site-specific habitat attributes (e.g., wetlands) that could benefit from improved vegetation cover and diversity, there does not appear to be a connection between revegetation efforts and improved habitat suitability for amphibians and reptiles in the drawdown zone of Arrow Lakes Reservoir, as current conditions at the sites sampled under CLBMON-37 support a persistent population of amphibians and reptiles.

Another potential adverse effect of reservoir operation on reptiles and amphibians is the potential loss of habitat, particularly pond features, caused by erosion. Two physical works projects (CLBWORKS-29: WPW-6A and WPW-15A) were implemented in Revelstoke Reach, Arrow Lakes Reservoir during the course of this study (see discussion in MQ9; Miller et al. 2020), both aimed at protecting existing habitat (e.g., reduced changes to hydrology of Cartier Bay) and preventing erosion impacts. It should be noted that, in both cases, the erosion was not entirely caused by reservoir operations (H. van Oort, pers. comm.). Both projects appear to be effective thus far (see MQ9 and Miller et al., 2020), although the WPW-6A project is only half complete as only one of the two head cut features was fortified. WPW-6A and WPW-15A were designed to protect Airport Marsh and Cartier Bay, respectively – both exceedingly important wetlands for reptiles and amphibians. Completing WPW-6A remains as an important physical works project to mitigate adverse impacts of reservoir operations. Monitoring under CLBMON-37 in 2016 and 2018 indicated that there was no evidence of a change in usage by Western Toads or garter snakes at Cartier Bay. These results were based on detection rates from the existing monitoring, not on an effectiveness program designed to measure changes to specific values such as abundance, diversity or productivity.

In 2016, CLBWORKS-29B—the Arrow Lakes Reservoir Feasibility Study of High Value Habitat for Wildlife Physical Works—was produced for BC Hydro to 1) identify high-value habitat along the drawdown zone of lower and middle reaches of the Arrow Lakes Reservoir for protection; 2) identify habitat enhancement opportunities along the drawdown zone of the lower and middle reaches of the Arrow Lakes Reservoir; and 3) provide recommendations for enhancing or protecting high-value wildlife habitat along the drawdown zone of the lower and middle reaches of the Arrow Lakes Reservoir (Hawkes and Howard 2012; Hawkes and Tuttle 2016b). This led to the Burton Creek wetland creation project (implemented in 2019), some early results for which are described in Miller and Hawkes (2019). The efficacy of the Burton Creek wetland construction project with respect to creating wildlife habitat will be assessed beginning in 2020.

5.7.3 Challenges and Opportunities

Available information and observations provide us with moderate confidence when recommending various physical works prescriptions to improve habitat suitability for amphibians and reptiles in the drawdown zones of both Kinbasket and Arrow Lakes Reservoirs. Directed effectiveness monitoring of physical works projects was not undertaken as part of CLBMON-37. Our recommendations around physical works to benefit the abundance, diversity and productivity of amphibians and reptiles come from 1) preliminary evidence from this study (e.g., Bush Arm wood debris removal; Hawkes 2017); 2) other examples of wetland creation and enhancement in large lakes or reservoirs (e.g., Tuttle 2013; Wind 2012); and 3) the probability of success associated with existing prescriptions that were developed for Arrow Lakes Reservoir (Hawkes and Tuttle 2016b).

While promising, it is unclear whether the removal of wood from ponds in the drawdown zone will result in long-term amphibian habitat creation/restoration in the drawdown zone. This is because Kinbasket Reservoir was not filled to its maximum since the physical works were completed (from 2014 to 2018, the reservoir operated under its maximum), meaning that we have been unable to ascertain whether wood would re-accumulate in those locations following a high-reservoir event. This precluded a fulsome assessment of how certain treatment techniques, such as log boom installation, might function to preserve habitat integrity and species richness or diversity in an area following maximum inundation.

As indicated above, wildlife habitat, and in particular amphibian habitat, has been the benefactor of the wood debris removal program in certain areas of the drawdown zone of Kinbasket Reservoir (e.g., Canoe Reach; Valemount Petland, Bush Arm Causeway). However, debris management in general may not be a suitable long-term strategy for improving the suitability of amphibian and reptile habitat in the drawdown zone unless the debris removal sites are associated with log boom installation. In general, wood debris accumulates in the same locations of the drawdown zone year-over-year (which is a function of wood debris inputs, reservoir levels, and prevailing winds). Annual entries into some of the locations (e.g., Packsaddle Creek area in the northeast corner of Canoe Reach) to remove wood debris results in frequent and large-scale disturbance to the drawdown zone. While removing large piles of wood debris from the drawdown zone in these frequent accumulation sites improves safety in the reservoir, it does little to promote the establishment and development of vegetation cover, especially on gravelly beaches like those at Packsaddle, and therefore does little to improve wildlife habitat suitability. Consideration of wood debris removal from habitats in the drawdown zone should be made when 1) wetland habitat has been impacted, and 2) the site is either not in a known wood debris accumulation zone or else a log boom can be installed around the site to protect it from future wood accumulation. Even if all three requirements are met, there is no guarantee that a debris flow or avalanche will not re-impact the habitat.

The proposed physical works at Burton Creek in Arrow Lakes Reservoir will require monitoring to determine whether the constructed wetlands are supporting amphibians and reptiles. The physical works at site 15A in Cartier Bay appears to have met the stated objectives of no measurable biophysical change in the Cartier Bay wetlands (Miller et al., 2020). The physical works completed at site 6A near Airport Marsh is a partial success. The armouring of the east head cut has effectively arrested erosion in that channel. However, the west channel continues to show signs of erosion, which are likely agitated by reservoir operations, and additional armouring is recommended to prevent further erosion (Miller et al., 2020).

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

The relationship between revegetation prescriptions applied in the drawdown zone and use of habitat by amphibians and reptiles was not assessed under CLBMON-37/58. The revegetation prescriptions applied under CLBMON-9 (Kinbasket Reservoir) and CLBMON-12 (Arrow Lakes Reservoir) were not considered particularly relevant or beneficial to amphibians and reptiles (other than assisting with initial site selection for this study) nor were they implemented explicitly to benefit amphibians and reptiles.

It is the opinion of the authors that it is unlikely that revegetation on its own would have contributed to an increase in the amount or improvement of habitat for amphibians or reptiles. The revegetation prescriptions trialled in the drawdown zone were more consistent with upland than wetland habitats (so, less relevant to our study species) and therefore unlikely to influence habitat use by amphibians or reptiles. It is also unlikely that revegetation increased species diversity or abundance of herpetofauna. The efficacy of revegetating physical works locations, such as the one implemented at Burton Creek, has yet to be assessed with respect to improving habitat suitability for amphibians and reptiles.

5.8.1 Kinbasket Reservoir

Despite not specifically monitoring amphibian and reptile population response to the revegetation program implemented in the drawdown zone of Kinbasket Reservoir, we have confidence that revegetating the drawdown zone did not affect the availability and use of habitat by amphibians and reptiles. Although the revegetation program was associated with mixed results, with some locations (e.g., KM88 - Bear Island) showing signs of success, the drawdown zone was not specifically revegetated 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 overwintering habitats and drawdown zone habitats, although this assessment was based solely on observations made in the field. Although revegetation with live staking or sedge plugs had limited success, the removal of wood debris from accumulation sites has in some instances promoted the natural regrowth of vegetation. Protecting the wood debris removal areas with log booms should help vegetation to re-establish and develop naturally.

5.8.2 Arrow Lakes Reservoir

For Arrow Lakes Reservoir, revegetating the drawdown zone likely did not affect the availability and use of habitat by wildlife. Revegetation prescriptions (CLBWORKS-2) were applied between 2008 and 2011 and the total area revegetated in mid- and lower Arrow Lakes Reservoir (i.e., Galena Bay south to Castlegar) per year ranged from a low of 2.13 ha in 2008 to a high of 36.22 ha in 2009 for a total of 70.5 ha (Hawkes et al. 2012). The plug seedling prescription was the most commonly applied prescription (39.84 ha) followed by hand-planted live stakes (23.31 ha). All other prescriptions were either applied over relatively small areas or in one year only (Hawkes et al. 2012). The amount of area revegetated at the CLBMON-37 monitoring sites was 3.72 ha at Edgewood, 17.82 ha at Burton Creek, and 7.91 ha at Lower Inonoaklin. Some revegetation occurred in Revelstoke Reach to provide habitat for songbirds, but that was not quantified by Hawkes et al. (2012).

The revegetation program in Arrow Lakes Reservoir had variable success with modest levels of survivorship in some treatment areas (Miller et al. 2018c). Some overlap occurred between revegetated treatment areas and our survey sites; however, because we did not explicitly monitor the treatments, we cannot conclude or disprove that revegetating the drawdown zone of Arrow Lakes Reservoir 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.

5.8.3 Challenges and Opportunities

This management question was not fully addressed for several reasons. First, we did not assess abundance, productivity, or habitat use relative to revegetation prescriptions. This is mainly because CLBMON-37 was not an effectiveness monitoring program (see Arrow Lakes Reservoir Wildlife Effectiveness study, CLBMON-11B1; Hawkes et al. 2012)

Second, we did not assess the potential link between increasing food resources (e.g., invertebrates and small mammals) as a result of revegetation on abundance/productivity of amphibians or reptiles. Prey studies were not conducted under CLBMON-37 and would require a much more intensive and specific program than what was implemented under CLBMON-37. While evidence of enhanced pond breeding habitat for amphibians was reported (CLBWORKS-1; Hawkes 2017), our monitoring was limited to post-treatment data only.

Third, based on our understanding of the habitat requirements of amphibians and reptiles, the revegetation treatments had little relevance to these taxa. Fourth, the survivorship of revegetation treatments was mixed and did little to increase the cover or diversity of vegetation in the drawdown zones of Kinbasket and Arrow Lakes Reservoirs (Miller and Hawkes 2019; Miller et al. 2018c). And last, any potential effects would likely be very small and would require large resources to monitor and/or measure effectively.

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

Four examples of mitigation-type physical works projects occurred during this 11-year study: two in Kinbasket Reservoir and two in Arrow Lakes Reservoir. Reports for the Canoe Reach wood removal treatment (CLBWORKS-16; Hawkes 2014), Bush Arm debris mounds and wind row construction (CLBWORKS-1; Hawkes 2016, 2017), and two Wildlife Physical Works in Revelstoke Reach, WPW-6A and WPW-15A (CLBWORKS-30A; Watson 2016; Miller et al. 2020), provide in depth details regarding the planning and implementation for these projects. Below we discuss the effects (backed by data where available) of these projects on amphibian abundance, diversity, and/or productivity.

5.9.1 Kinbasket Reservoir

There is evidence that clearing ponds of wood debris in the drawdown zone improves breeding habitat suitability for amphibians. Amphibians were monitored at two physical works sites in Kinbasket Reservoir: Valemount Peatland (CLBWORKS-16, 2014) and the Bush Arm Causeway (CLBWORKS-1, 2015).

In 2014, CLBWORKS-16 (Kinbasket Reservoir debris inventory, management strategy and removal) implemented wood removal and debris exclusion trials in the Valemount Peatland. The cleared wetland at Valemount Peatland North was the second most active breeding site in Canoe Reach after Pond 12 in May 2014 (Hawkes et al. 2017). Western Toad and Columbia Spotted Frog were both observed mating and laying eggs during day and night surveys at this pond. In fall 2015, CLBWORKS-1 implemented physical works trials to construct mounds and wind rows and clear ponds of wood debris in the drawdown zone of Kinbasket Reservoir were implemented at Bush Arm Causeway (Hawkes 2016). This project resulted in Western Toad using previously unavailable wetlands for breeding (Hawkes et al. 2016): two of the three ponds northwest of Bush Arm Causeway, which were choked with wood and devoid of amphibians prior to clearing, were used by Western Toad as breeding habitat immediately the next spring (Figure 5-17).

Figure 5-17: Photo of the treatment area at the Valemount Peatland in 2014 with Western Toad tadpoles and metamorphs developing in the cleared wetland (initial post-treatment breeding season).

As such, there is evidence to support an increase in use and productivity (e.g., presence of egg masses) for certain species via the removal of wood debris from wetlands (Figure 5-18). Abundance may increase in previously unused habitats, but it is unknown if this increase will result in a net change in abundance over time.

Figure 5-18: Photo documentation of Western Toad tadpoles in cleared pond habitat at the Bush Arm Causeway in June 2016 (one year post-treatment).

Between 2007 and 2013, a large portion of Pond 12 in the Valemount Peatland was covered by wood debris. In 2007, the area of Pond 12 was estimated at ~0.94 ha. Based on 2016 imagery, the total pond area was 0.89 ha, amounting to a reduction of 0.05 ha. While this may seem trivial, this represented loss of amphibian habitat in one of the most important ponds in the drawdown zone. In 2016, the total volume of wood debris that had accumulated in this pond was estimated to be ~8,000 m^3. In January 2018, wood debris removal occurred along the western edge of the Valemount Peatland from just south of the initial trial location to Pond 12. The area cleared around Pond 12 (visible in the overhead images in Figure 5-19) covered ~13,000 m^2 of which ~2,900 m^2 was in the pond. By spring 2018, the site had started to recover with evidence of vegetative regrowth (Figure 5-20).

Figure 5-19: Overhead image of Pond 12 in 2014 and 2016, pre-wood debris removal, and in May 2018 following wood debris removal. The silver-grey colouration is the extent of the wood debris in each year.

Figure 5-20: Examples of vegetation recovery at the Pond 12 wood debris removal location in May 2018. The plants growing were native plants common to the Valemount Peatland.

Because sampling under CLBMON-37 ended in 2018, amphibian responses to the clearing of this pond have not been formally assessed. A site visit in the spring of 2019 (under a different project) recorded the presence of Columbia Spotted Frog adults; however, no Western Toad egg strings or tadpoles were observed (K. Tuttle, pers. obs.). The timing of the site visit could have affected the results, and future site visits are suggested to assess the use of this pond by Western Toad.

Elsewhere, further assessments are also needed to document the success of wood debris removal and log boom installation projects on amphibians and reptiles. More data are required to determine if there is a measured increase the abundance and productivity of amphibians and reptiles in the drawdown zone in years after the projects. Given that all expected species of amphibians and reptiles were documented from the drawdown zone of Kinbasket Reservoir, there is no reason to believe that physical works will increase diversity.

5.9.2 Arrow Lakes Reservoir

Two physical works projects (WPW-6A and WPW-15A) were implemented in Revelstoke Reach (Arrow Lakes Reservoir) during the course of this study, both intended to protect existing wetland habitats. These projects were designed to protect habitat for multiple wildlife taxa, including amphibians and reptiles.

The physical works completed at site 6A near Airport Marsh (WPW-6A) is a partial success. The armouring of the east head cut has effectively arrested erosion in that channel. However, the west channel continues to show signs of erosion, which are likely agitated by reservoir operations, and additional armouring is recommended to prevent further erosion (Miller et al., 2020). This work is monitored under CLBMON-11B4 and no specific effectiveness monitoring associated with this physical works was completed under CLBMON-37, other than visual encounters in the general area in 2014, 2016 and 2018. Common Garter Snake has been observed using habitats around rip rap used to armour the east channel (D. Adama, pers. comm).

WPW-15A was designed to ensure that the hydrology of Cartier Bay (pre-inundation) remains unchanged, thereby protecting existing habitat that was considered important to multiple wildlife taxa groups (CLBWORKS-30A; Watson 2016). This physical works project was completed in October 2016 and involved the reinforcing of the existing rail bed at the site of the wood box culvert to prevent Cartier Bay wetland from draining into Arrow Lakes Reservoir when water levels drop. Sampling under CLBMON-11B4 occurred to determine if the physical works at Cartier Bay resulted in no net change to productivity (based on measurements of macrophyte richness and cover). Based on data collected between 2016 and 2019 in Cartier Bay, there was no evidence of a change in usage by Western Toads (still a highly productive breeding habitat) and numerous garter snakes were observed in the area (some foraging on Western Toad tadpoles). These data suggest that the physical works WPW-15A did not alter breeding habitat suitability for Western Toads or relative abundance of other amphibians or reptiles.

A third physical works project planned for Burton Creek was implemented in the fall of 2019. The Burton Creek physical works (KWL 2018) was intended to create shallow wetland habitat for Western Toad, nesting and migratory birds, and other wildlife through excavation of pools and construction of a series of tiered wetlands. The goal was to retain site drainage and groundwater to promote stability of the wetland habitat. Effectiveness monitoring of this site is proposed for 2020. As this project was not completed prior to the end of CLBMON-37, we cannot make any conclusions about its effect on amphibians and reptiles that use this site.

5.9.3 Challenges and Opportunities

The sources of uncertainty and challenges for MQ1 through MQ4, above, also apply to this MQ, including issues related to the inconsistencies in detection rates among species (and life history stages), challenges to determining abundance and productivity (Corn and Bury 1990), challenges to distinguishing natural fluctuations from human disturbances (Pechmann et al. 1991), and no control for data comparisons between pre- and post-project monitoring years.

While promising, it is unclear whether the removal of wood from ponds in the drawdown zone will result in long-term amphibian habitat creation/restoration in the drawdown zone. This is because Kinbasket Reservoir has not filled to full pool since the physical works were completed. Additionally, it is too early to make any conclusions about the treatment application at Pond 12, a site where follow up is suggested. The treatment area at this site was blanketed by a dense cover of wood chips following the wood debris removal work in 2018. We expect that amphibians and garter snakes would use this habitat as this area becomes established with vegetation and changes over time. A site visit to Pond 12 in May of 2019 documented only Columbia Spotted Frog at the site; no Western Toad egg strings or tadpoles were observed. However, further years of monitoring are required to determine the effects if wood debris removal on amphibian occupancy and reproduction at the site.

The creation of habitat such as the debris mounds at Bush Arm Causeway North and South (2015) and Burton wetlands (2019) may provide a benefit to amphibian and reptile species as basking and foraging habitat, but effectiveness monitoring needs to occur over a period of at least five years to determine trends (if present) in any benefits (i.e., increases) to abundance, diversity or productivity are occurring (Block et al. 2003). This represents an opportunity for future study.

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

In 2011, a second component to the program, CLBMON-58, was added to address the specific potential impacts of the installation of Units 5 and 6 at Mica Dam on amphibian populations in Kinbasket Reservoir. The installation of Units 5 and 6 at Mica Creek was predicted to increase reservoir elevations by 0.6 m during the summer months (i.e., July and August) in three out of ten years, which coincides with the period of larval amphibian development. The usual operating regime of Kinbasket Reservoir included a large drawdown in the late winter followed by rapid filling in the spring and early summer, with full pool normally attained by late July or August.

Our data do not support a qualitative prediction of increased larval mortality rates or delayed development for either Western Toad or Columbia Spotted Frog. However, based on reservoir operations observed between 2008 to 2018, a periodic increase in reservoir elevation of 0.6 m is unlikely to have a large effect on amphibian populations that use the drawdown zone of Kinbasket Reservoir (Hawkes et al. 2018b). This conclusion is somewhat confounded by the fact that Kinbasket Reservoir is managed differently each year (Figure 2-1). Further, it is not possible to determine if and/or how often the level of Kinbasket Reservoir has been affected (i.e., increased) due to the installation of Mica Units 5 and 6. As such, our ability to answer this question is based on a qualitative assessment of reservoir elevation effects observed between 2008 and 2018. In our opinion, adding 0.6 m of water to the reservoir elevations observed over the past 11 years is unlikely to compound the already observed effects of reservoir operations on amphibians and reptiles, which is related directly to habitat availability. Similarly, if reservoir operations continue in a manner that mimics historical operations, the future impacts to amphibians and reptiles would be consistent with the observations made in this report.

If the addition of 0.6 m were to increase the frequency and duration of surcharge (see MQ#5), then there could be further impacts to habitat quality resulting from potential impacts to wetland habitats that exist in the upper elevation bands (i.e., those that occur at elevations >751 mASL, which represents ~64% of all currently mapped ponds). Impacts could result from increased rates of erosion, alteration of vegetation communities in and adjacent to those wetlands (Adama 2019), or potentially from the vertical and horizontal movement and depositions of large rafts of wood debris (see MQ#7 and #9; Adama 2019).

Effects of surcharge on amphibians need to be considered relative not only to reservoir elevations and potential associated effects, but to the timing of the maxima (Table 5-5). In general, Kinbasket Reservoir reached its annual maximum elevation between August 2 (1987) and November 9 (2014) with an average date of full pool of August 25. In years when Kinbasket Reservoir was surcharged, the reservoir reached full pool between August 2 (2007) and October 2 (1997) with an average fill date of September 1. By this time (i.e., August 25 or September 1), amphibian eggs have hatched and free-swimming tadpoles are close to being fully transformed into froglets and toadlets. This suggests that reservoir elevations and the current timing of full pool (either via surcharge or normal operations) are unlikely to directly impact amphibian habitat availability more so than currently reported. That said, Kinbasket Reservoir was operated to full pool in 2011 and 2012 and full pool was achieved by mid-July; if an additional 0.6 m of water had been added in those years the reservoir would have exceeded full pool, potentially resulting in adverse effects for the wetland and pond habitat occurring > 751 mASL (Hawkes and Tuttle 2016a; Adama 2019).

If the timing of full pool or surcharge changed relative to historical data, and in particular if reservoir filling occurred earlier in the summer (i.e., late June or early July) there could be impacts to various life stages of amphibians using the drawdown zone including changes to egg and larval development, increased predatory pressure, and potential changes to habitat suitability resulting from wood debris transport or changes to vegetation and physicochemical attributes (assumptions provided in Appendix 13). Given that reservoir elevations are predicted to increase in the summer months, achieving full pool in July is not recommended, and maximum reservoir elevations should be targeted for the current average date of August 25. This would ensure that amphibians using the drawdown zone, particularly those in ponds > 751 mASL, would have enough time to develop prior to inundation.

Table 5-5: Examples of potential effects on amphibians resulting from Kinbasket Reservoir elevations exceeding the normal maximum operating elevation by 0.6 m.

Potential Impact	Effect on Amphibians	Life Stage
Increased rates of erosion	• Increased turbidity leading to reduced water quality, which could affect larval food resources and larval development • Increased sediment deposition leading to a reduction in water depth, pond area, water temperature, and overall pond suitability (as it relates to breeding)	• Egg masses • Larvae
Changes in vegetation composition and structure at upper elevations	• Reduced habitat suitability near the periphery of breeding habitats (e.g., reduced cover), which could increase rates of predation	• Adults • Sub-adults • Juveniles • Metamorphs
Changes in coarse woody debris conditions near or outside of the DDZ	• Changes to microhabitat conditions (e.g., reduced cover, scouring of pond habitat and vegetation). Indirect effects to foraging opportunities due to effects on insect communities	• Adults • Sub-adults • Juveniles • Metamorphs
Changes to aquatic characteristics (e.g., DO, conductivity, temperature, pH) in ponds near the periphery of the DDZ (or those that are not inundated under normal operating conditions	• Potential effects to egg and larval development (e.g., decreased water temperature from inundation). • Potential effects to overall suitability of the pond for breeding leading to pond-abandonment in subsequent years.	• All life stages
Changes to the biological communities of ponds (e.g., introduction of fish, changes in semi-aquatic and aquatic macrophytes)	• Potential for increased predation risk by fish on amphibian eggs and larvae • Potential changes to available food resources required by developing amphibians	• Egg masses • Larvae

One possible and unstudied indirect effect on amphibian populations from reservoir surcharge is the dispersal of aggregations of tadpoles along the periphery of the reservoir, which could force tadpoles into poor quality habitats with subsequent possible effects on survival. Indirect effects of reservoir surcharge are also likely important. Key wetland habitats will be impacted, particularly those ponds situated above 751 mASL (which represents ~64 percent of all ponds mapped in the drawdown zone). Indirect impacts will be mainly related to changes in habitat suitability caused by wood deposition and changes to aquatic and riparian vegetation communities that could affect the primary productivity of wetlands (Table 5-5). The effects of these changes are not likely to result in immediate effects to habitat quality (see final report for CLBMON-61). Data from that program should be examined to determine how wetland productivity is affected by reservoir operations and as a result of the installation of Units 5 and 6 at Mica Dam.

Of the various reservoir management regimes reviewed, surcharge may represent the worst-case scenario with respect to reservoir management. A review of historical reservoir data indicated that Kinbasket Reservoir was surcharged seven times between 1978 and 2018. Adding 0.6 m to each year of historical data (to simulate the addition of Units 5 and 6 at Mica Dam) would have increased the number of surcharge events to 14 over the same period. Given the fact that BC Hydro has the flexibility to control water levels, surcharge at this frequency (35 percent of the time) in the future is unlikely. The anticipated increase in reservoir surcharging is not likely to directly affect amphibian populations if reservoir management in the future is consistent with historical patterns.

5.10.1 Challenges and Opportunities

As mentioned, we were unable to accurately document or model mortality rates in amphibians due to the truncated timing of field sessions and the decreased ability to document amphibian reproduction fully from egg laying to metamorphosis. In this regard we were unable to answer this question fully. It is the opinion of the authors that it is possible that if Kinbasket Reservoir were operated in a manner in which surcharge occurred every year (i.e., reservoir levels exceeded 754 mASL), amphibian populations could experience negative effects and potentially declines in numbers.

A lack of observations of the direct effects of reservoir operations on the development, survival, and mortality of amphibians in the drawdown zone of Kinbasket Reservoir precludes a quantitative answer of MQ10 (i.e., without in situ or lab experiments it is difficult to quantify this relationship). For example, observations of delayed development resulting from temperature changes (reductions) correlated to reservoir filling would be required. Similarly, without observations of mortality events, such as many dead tadpoles at the leading edge of the reservoir as it fills, it is not possible to quantify the direct effect of reservoir operations on amphibians. An assessment of increased predation of tadpoles by fish (via gut analysis) concurrent with reservoir filling could also provide an additional metric of reservoir-related effects on amphibians (Pope 2008). Further, without detailed knowledge of overwintering sites, metamorph habitat use, and overwinter survival, we cannot comment on any quantitative effects that the installation of Mica Units 5 and 6 might have on amphibian larval development.

This conclusion is somewhat confounded by the fact that Kinbasket Reservoir was managed in a predictable yet variable manner each year. Uncertainties around the degree of variation, and the biological impacts of this variation, makes it difficult to answer this question with confidence. Mica Units 5 and 6 were operational in 2016. Given that reservoir operations in 2017 and 2018 were within the range of variation observed between 2008 and 2018 (see Figure 2-1), it may be the effects of the operation of Mica Units 5 and 6 are indistinguishable from those associated with operations over the observed 11-year period. However, it may also be that the observable effects resulting from an increase of 0.6 m during the summer months have not yet manifested themselves. The operational prediction is that the increase in water levels could occur in three of 10 years, but it is not known when this will happen or how the increase would be attributable to the operation of Mica Units 5 and 6. Without knowing when the predicted increases will occur (in terms of the months and years affected), the answer to this question will continue to be elusive.

Similarly, if reservoir elevations are low in the spring and snowpack or rainfall are also low, some ponds in the drawdown zone may not fill, reducing breeding opportunities for pond-breeding amphibians in some years. This may not represent a long-term risk but given climate change and changes to precipitation coupled with predictions for longer, drier, and warmer summers (e.g., Payne et al. 2004), reservoir operations need to be considered in the context of a changing climate and the potential effects on water resources. However, because of the uncertainty associated with most climate change models and the predicted effects on water resources (Christensen and Christensen 2007; Saha 2015), a careful assessment is required to understand how seasonal changes in precipitation might influence wetlands in the drawdown zone of Kinbasket Reservoir.

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7 APPENDICES

A timeline of the CLBMON-37 and CLBMON-58 monitoring program and all 2018 data analyses (including comparisons with all other years of study) are included in the following appendices. These data chapters are presented as individual reports for each response measure under assessment.

Appendix 1: Timeline of CLBMON-37 and CLBMON-58

Background and Timeline for this Study

BC Hydro initiated studies CLBMON-37/58 and LGL Limited environmental research associates completed the first five year of monitoring of these studies. The Okanagan Nation Alliance (ONA), in partnership with LGL Limited, continued monitoring in 2013 through 2018 with methods consistent with the preceding monitoring years. Table 7-1 summarizes the annual implementation schedule and reports to date for CLMBON-37 and CLBMON-58.

Table 7-1: Monitoring years by reservoir for CLBMON-37 and CLBMON-58 and associated annual reports.

Year	Kinbasket / Arrow	Kinbasket only	Annual Report
	CLBMON-37	CLBMON-58	
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 2	Hawkes and Wood 2014
2014	Year 7		Hawkes et al. 2015
2015		Year 3	Hawkes and Tuttle 2016a
2016	Year 9		Hawkes et al. 2017
2017		Year 4	Hawkes et al. 2018
2018	Year 11		**Hawkes et al. 2020**

In 2008, a reconnaissance-level survey of amphibians and reptiles was completed between May and September within and adjacent to the drawdown zones of Kinbasket and Arrow Lakes Reservoir. The goal was to determine the presence of each species within the drawdown zone of each reservoir. As such, systematic surveys were not conducted at each site. Rather, we spent most of our time documenting the location of species, the location of egg masses, or the location of suitable breeding ponds within the drawdown zone of each reservoir. In general, reconnaissance surveys provided information on species presence, species richness, seasonal habitat use, and helped determine the main monitoring sites for the remainder of the study. The data collected were used to develop a long-term amphibian and reptile monitoring program to be implemented from 2009 to 2018.

The study sites and number of surveys conducted across all years of CLBMON-37/58 are summarized in Table 7-2. In 2010-2011 and 2015-2017, field sampling in Valemount Peatland was more extensive due to two Master of Science student projects and occurred weekly from late April to mid-October. In 2016 and 2017, Cranberry Marsh was also visited more frequently due to a Master of Science project.

Table 7-2: Monitoring years and number of visits per study site for CLBMON-37 and CLBMON-58 in Kinbasket and Arrow Lakes Reservoirs, 2008 to 2018. DDZ = drawdown zone, UPL = upland.

	Reach	Site	Location	# Site Visits Per Year										
Kinbasket Reservoir		**Monitoring Sites**		**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
	Canoe Reach	Valemount Peatland	DDZ	5	5	54	59	3	5	6	69	52	34	3
		Ptarmigan Creek	DDZ	5	4	17	17	4	2	4	14	8	4	3
	Bush Arm	Bush Arm Causeway	DDZ	2	3	7	6	3	4	4	4	7	7	3
		KM79 Wetlands	DDZ	5	4	6	5	2	3	4	3	5	6	3
		KM79 Perched Wetland	UPL	3	4	4	4	3	2	4	3	3	4	1
		KM88 Bear Island	DDZ	1	1	5	5	3	3	5	3	5	8	3
		Succour Creek	DDZ	1	1	4	3	1			2		2	
	Mica Dam	Sprague Bay	DDZ/UPL		1	6	2	3		1				
		Reconnaissance or Reference Sites		**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
	Canoe Reach	Yellow Jacket Creek	DDZ	1										
		Mount Blackman	DDZ	1										
		Hugh Alan Bay	DDZ	2			1				1			
		Cranberry Marsh	UPL				1					37	23	
	Columbia	Beavermouth	DDZ/UPL	1		1								
	Mica Dam	Encampment Creek	DDZ	1				1						
Arrow Lakes Reservoir		**Monitoring Sites**		**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
	Revelstoke Reach	Downie Marsh	DDZ/UPL	5	4	6		4		3		4		2
		Machete Island	DDZ		4	2		1				2		
		Airport Marsh	DDZ/UPL	2	4	7				4		12		1
		Montana Slough	DDZ	3	4	6		4		4		7		3
		Cartier Bay	DDZ	5	5	6		3		5		8		3
		9 Mile	DDZ	5	5	6		1		5		7		3
		12 Mile	DDZ	4	4	7		2		1		1		2
	Mid Arrow	Beaton Arm	DDZ/UPL	1	4	7		4		1		4		
		Burton Creek	DDZ/UPL	5	5	10		3		3		9		3
	Lower Arrow	Lower Inonoaklin	DDZ			3		3		4		8		3
		Edgewood North	DDZ/UPL		1	6		3		4		5		2
		Edgewood South	DDZ	1	1	9		2		4		8		3
		Reconnaissance or Reference Sites		**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
	Revelstoke Reach / Upper Arrow	Rev - North of Hwy 1	DDZ		1	1		1						
		Big Eddy	DDZ		1	1		1						
		Williamson Lake	UPL	1				1				1		
		Turtle Pond	UPL					1		1		10		
		Blanket Creek	UPL	1	1	3								
		Shelter Bay	DDZ	2										
	Mid Arrow	Mosquito Creek	DDZ/UPL		3	6		1						
		East Arrow Park	DDZ		2	5								
	Lower Arrow	Renata Creek	DDZ	1										
		Syringa Park	UPL	1										
		Hugh Keenleyside Dam	UPL		1			1						1

Field sampling occurred during the months of May through September to coincide with the period of activity of amphibians and reptiles (Table 7-3). Predicted water levels obtained from BC Hydro were incorporated into field scheduling to determine how much of the drawdown zone would be available for sampling. The field sampling schedule followed a similar timeline across the years to facilitate data comparison between the years. Due to the large spatial extent of the Kinbasket and Arrow Lakes Reservoirs and the differences in climatic regimes, sample sites were surveyed over four or five time periods.

Table 7-3: Timing of field sessions and range (min-max) reservoir elevations (mASL) for Kinbasket and Arrow Lakes Reservoirs from 2008 to 2018.

Year	Reservoir					
	Kinbasket			Arrow Lakes		
	Start Date	End Date	Elevation (m ASL)	Start Date	End Date	Elevation (m ASL)
2008	15-Jun	18-Sep	732.3-751.9	13-May	20-Sep	430.8-440.0
2009	31-May	30-Aug	732.7-750.8	05-May	27-Aug	429.9-437.6
2010	27-Apr	05-Sep	724.7-751.2	15-Apr	06-Sep	431.4-439.3
2011	27-Apr	27-Aug	725.0-753.8	-	-	-
2012	27-Apr	21-Aug	722.9-754.6	30-Apr	17-Sep	428.7-440.5
2013	05-May	28-Jul	722.9-750.9	-	-	-
2014	02-May	19-Aug	725.1-753.5	05-May	15-Sep	429.8-439.1
2015	05-May	26-Aug	737.0-751.0	-	-	-
2016	02-May	04-Oct	733.6-752.1	02-May	26-Aug	431.2-437.2
2017	04-Apr	17-Aug	728.7-752.1	-	-	-
2018	04-May	17-Jul	720.9-746.1	29-Apr	12-Jul	430.8-439.6

Appendix 2: Summary of amphibian and reptile site occupancy

Introduction

We summarized site occupancy to determine what species of amphibians and reptiles occurred within the drawdown zone in Kinbasket and Arrow Lakes Reservoirs to assist with answering MQ1, MQ2, and MQ3. The intent of this summary was to 1) obtain an indication of the number of years each species was detected by site and reservoir, and 2) obtain the proportion of sites that each species was detected at during each year of study.

Methods

Most monitoring sites were surveyed every year, while reconnaissance sites or reference sites were surveyed infrequently (see Table 2-2). Sampling occurred at most monitoring sites on an annual and seasonal basis to document the life stages of species of amphibians and reptiles present. Due to various reasons (e.g., sub-optimal habitat identified, difficult or impossible access due to weather and budget restrictions) some monitoring sites were not sampled during all field visits in a given year.

Datasets

Observations from Dataset 1 (Visual Encounter Data), Dataset 2 (Call Station Data) and Dataset 3 (Road Survey Data) were summarized to determine presence/non-detection of amphibian and reptile species (any life stage) in a given year and monitoring site.

Analysis

Site occupancy was assessed in two ways for each year of study: (1) the presence of a species at a monitoring site; and (2) the proportion of sites (monitoring and reference/reconnaissance sites) in which a species was detected (excluding sites not visited that year). Multiple surveys were conducted to determine the presence/non-detection of a species at a site including visual encounter surveys, egg mass surveys, night call surveys, road surveys, and pitfall trap surveys. A site was considered occupied by a species if detected at least once in a given study year. Sites at which a species was not detected in a given survey year were considered to be unoccupied; however, this does not mean that the species was absent at the site.

We evaluated yearly site occupancy of a given study site and the proportion of sites occupied each year to determine which species were present and which study sites in Kinbasket and Arrow Lakes Reservoirs were being utilized. Site occupancy tables highlight the number of detections of a species at a given site during surveys conducted each year. A detection was defined as an observation of a single individual, pair in amplexus, egg mass or cluster, or aggregation of tadpoles or metamorphs. The proportion of sites occupied was based on the number of sites where a species was detected out of the total number of sites sampled in each reservoir each year.

Results

<u>Kinbasket Reservoir</u>

Three species of amphibian and three species of reptile were observed in the drawdown zone at monitoring sites in Kinbasket Reservoir between 2008-2018 (Table 7-4). The proportion of sites occupied varied by year and species. The proportion of sites occupied by a species in a given year ranged from zero (Western

Painted Turtle and Western Terrestrial Garter Snake) to 1.0 (Columbia Spotted Frog in 2013 and 2016; Common Garter Snake in 2016; Western Toad in 2013, 2016, and 2018). Of all species recorded throughout the study period, Western Toad, Columbia Spotted Frog, and Common Garter Snake had the highest annual occupancy rates, respectively (Table 7-4). Common Garter Snake were observed more frequently than Western Terrestrial Garter Snake with the former documented each year. However, Western Terrestrial Garter Snake were observed at more sites overall but were rarely seen at the same site in subsequent years. Of the species with known populations in Kinbasket Reservoir, Long-toed Salamander and Western Terrestrial Garter Snake had the lowest occupancy rates throughout the study. Species that were difficult to detect such as Long-toed Salamander were likely more present than our data suggest. In 2015, a Western Painted Turtle was found in the drawdown zone at Bush Arm KM88. It is currently unknown whether a population exists in Kinbasket Reservoir.

The following sites supported at least one species of amphibian in each year of study: KM79, KM88 [Bear Island], Causeway, Ptarmigan Creek, and Valemount Peatland. Three sites supported all three amphibian species: Bush Arm Causeway, Ptarmigan Creek, and Valemount Peatland. Valemount Peatland was occupied by all three species every year except 2017. Bush Arm KM88 was the only site that supported all three reptile species. Most years, at least one species of garter snake was detected at sites in Bush Arm. The sites most consistently surveyed during the study period were KM79, KM88 [Bear Island], Causeway, Ptarmigan Creek, and Valemount Peatland.

Table 7-4: Proportion of sites occupied by species of amphibians and reptiles in the drawdown zone of Kinbasket Reservoir between 2008-2018. A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-RALU = Columbia Spotted Frog, R-CHPI = Western Painted Turtle, R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake. Numbers in table refer to detections of all life stages of each species (a detection is equal to an individual adult, pair in amplexus, or a group of egg masses/tadpoles/metamorphs). Blank cells indicate study site not visited in a given year.

(A) Amphibians	A-AMMA											A-ANBO											A-RALU										
Monitoring Site	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Beavermouth	0		0									0		0									0		0								
Bush Arm - Causeway	0	0	1	4	10	52	0	15	0	6	2	2	3	39	45	45	198	217	69	51	228	411	5	1	6	1	2	3	4	4	2	21	1
Bush Arm - KM79	0	0	0	0	0	0	0	0	0	0	0	3	5	15	28	8	28	15	16	20	10	32	59	49	53	73	1	24	4	11	30	52	18
Bush Arm - KM88 (Bear Island)	0	0	0	0	0	0	0	0	0	0	0	0	1	23	59	22	15	62	33	24	12	33	1	0	2	3	11	6	12	9	3	16	6
Encampment Creek					0											1											0						
Hugh Allan Bay	0			0				0				0			0				0				0			0				0			
Old Mill Site				0											1											0							
Ptarmigan Creek	0	0	0	0	0	1	0	0	0	0	0	10	8	127	291	4	131	18	199	68	33	29	4	8	10	25	4	5	2	17	7	2	0
Sprague Bay		0	0	0	0		0						0	7	1	2		0						4	23	5	1		0				
Succour Creek	0	0	0	0	0			0		0		0	0	1	0	0			0		0		0	0	2	0	0			0		0	
Valemount Peatland	2	1	1	18	1	1	10	7	1	0	4	7	6	448	498	3	91	427	306	79	89	20	23	7	376	432	13	35	93	345	115	146	74
Total Sites Occupied	**1**	**1**	**2**	**2**	**2**	**3**	**1**	**2**	**1**	**1**	**2**	**4**	**5**	**7**	**7**	**7**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**7**	**6**	**6**	**5**	**5**	**5**	**5**	**5**	**4**
Proportion of Sites Occupied	**0.13**	**0.14**	**0.25**	**0.22**	**0.25**	**0.60**	**0.17**	**0.29**	**0.20**	**0.17**	**0.40**	**0.50**	**0.71**	**0.88**	**0.78**	**0.88**	**1.00**	**0.83**	**0.71**	**1.00**	**0.83**	**1.00**	**0.63**	**0.71**	**0.88**	**0.67**	**0.75**	**1.00**	**0.83**	**0.71**	**1.00**	**0.83**	**0.80**
(B) Reptiles	R-CHPI											R-THEL											R-THSI										
Monitoring Site	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Beavermouth	0		0									2		5									0		0								
Bush Arm - Causeway	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	2	0	0	0	2	0	5	2	2	3	0	6	4	6	3
Bush Arm - KM79	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	1	0	8	6	15	4	0	2	1	0	2	2	0
Bush Arm - KM88 (Bear Island)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	6	1	1	0	4	4	1	2	0
Encampment Creek					0											0											0						
Hugh Allan Bay	0			0				0				0			4				0				0			0				0			
Old Mill Site				0											0											0							
Ptarmigan Creek	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	6	2	51	131	0	3	8	27	5	13	3
Sprague Bay		0	0	0	0		0						0	0	0	0		0						0	9	1	0		0				
Succour Creek	0	0	0	0	0			0		0		0	0	2	1	0			2		1		0	0	0	0	0			0		0	
Valemount Peatland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	85	53	2	1	12	28	46	37	1
Total Sites Occupied	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**2**	**1**	**4**	**4**	**0**	**0**	**0**	**2**	**0**	**3**	**0**	**5**	**3**	**6**	**6**	**3**	**4**	**4**	**4**	**5**	**5**	**3**
Proportion of Sites Occupied	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.14**	**0.00**	**0.00**	**0.00**	**0.25**	**0.14**	**0.50**	**0.44**	**0.00**	**0.00**	**0.00**	**0.29**	**0.00**	**0.50**	**0.00**	**0.63**	**0.43**	**0.75**	**0.67**	**0.38**	**0.80**	**0.67**	**0.57**	**1.00**	**0.83**	**0.60**

Arrow Lakes Reservoir

At the landscape level, five species of amphibian and six species of reptile were observed at sites in or proximal to the drawdown zone of Arrow Lakes Reservoir during surveys between 2008 and 2018 (Table 7-5). Most detections at monitoring sites were of species that were known to utilize the drawdown zone, including Western Toad, Pacific Chorus Frog, Columbia Spotted Frog, Long-toed Salamander, Western Painted Turtle, Common Garter Snake, and Western Terrestrial Garter Snake. Species mostly detected in habitats along the margin of the drawdown zone and adjacent upland areas included Coeur d'Alene Salamander (never located in drawdown zone), Rubber Boa (observed once in drawdown zone), Northern Alligator Lizard, and Western Skink.

The proportion of sites occupied by amphibians and reptiles varied by year and species. The proportion of sites occupied by a species in a given year ranged from zero (Long-toed Salamander, Northern Alligator Lizard, Western Skink, Rubber Boa, and Western Painted Turtle) to 0.87 (Common Garter Snake). Of all species recorded during the study, Common Garter Snake, Western Toad, Western Terrestrial Garter Snake, and Pacific Chorus Frog had the highest proportion of sites occupied, respectively. Of the anuran species, the proportion of sites occupied ranged from 0.31 to 0.86 for Western Toad, 0.33 to 0.73 for Pacific Chorus Frog, and 0.14 to 0.50 for Columbia Spotted Frog. The proportion of sites occupied by Northern Alligator Lizard ranged from 0.11 to 0.33. Of the two garter snake species, Common Garter Snake were detected more frequently and were more widely distributed than Western Terrestrial Garter Snake, with occupancy rates ranging from 0.33 to 0.87, whereas Western Terrestrial Garter Snake occupancy ranged from 0.23 to 0.73.

Lesser detected amphibian and reptile species had much lower proportions of sites occupied each year. Species such as Rubber Boa and Western Skink, which were found in the drawdown zone at a single site or a few at most, had very low occupancy rates. Detections in and around the drawdown zone of the two salamander species were scarce and occupancy rates of the salamander species appeared to be low. Long-toed Salamander were found at more sites than Coeur d'Alene Salamander, which were found only above the perimeter of Montana Slough. The lack of observations of this miniscule salamander in the drawdown zone is not surprising as plethodontids do not require standing water for breeding and prefer to utilize moist waterfall upland habitat areas, whereas Long-toed Salamander utilize ponds in the drawdown zone during breeding season and were likely present at more sites than our data suggest. Western Painted Turtle were not detected often, and the percentage of sites occupied ranged from 0.0 to 0.15, however, this species was intensively studied as part of the CLBMON-11B3 project and the results of that program indicate that Western Painted Turtle are most often found at Airport Marsh and Montana Sough in Revelstoke Reach.

Sites with the highest occupancy values were Cartier Bay, Montana Slough, 9 Mile, Edgewood areas (Edgewood South, Edgewood North), Burton Creek, and Beaton Arm. Four of the 19 sites were occupied by at least one species of amphibian each year (9 Mile, Burton Creek, Cartier Bay, and Montana Slough) and nine sites supported all three anuran species. Most detections of the two garter snake species were at 9 Mile, Edgewood South, and Burton Creek, which was occupied by both species almost every year.

Table 7-5: Proportion of sites occupied by species of amphibians and reptiles in the drawdown zone of Arrow Lakes Reservoir during study years between 2008 to 2018. A-AMMA = Long-toed Salamander, A-PLID = Coeur d'Alene Salamander, A-ANBO = Western Toad, A-PSRE = Pacific Chorus Frog, A-RALU = Columbia Spotted Frog, R-CHBO = Rubber Boa, R-CHPI = Western Painted Turtle, R-ELCO = Northern Alligator Lizard, R-PLSK= Western Skink, R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake. Numbers in table refer to detections of all life stages of each species (a detection is equal to an individual, pair in amplexus, or a group of egg masses/tadpoles/metamorphs). Numbers in parentheses indicate detections outside of the drawdown zone. Number marked with an * indicate between-year detection not made under CLBMON-37. Blank cells indicate study site not visited in a given year.

(A) Amphibians	A-AMMA							A-PLID							A-ANBO							A-PSRE							A-RALU						
Monitoring Site	08	09	10	12	14	16	18	08	09	10	12	14	16	18	08	09	10	12	14	16	18	08	09	10	12	14	16	18	08	09	10	12	14	16	18
12 Mile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	15	0	0	3	0	2	0	11	3	0	0	2	0	0	0	0	0	0	0
9 Mile	1	1	2	0	0	0	0	0	0	0	0	0	0	0	33	30	33	5	9	6	107	8	0	0	2	1	0	1	0	0	0	0	0	0	5
Airport Marsh	0	0	0		0	0	0	0	0	0		0	0	0	0	3	5		5	1	0	0	2	2		0	0	0	0	0	0		0	4	0
Beaton Arm	0	0	0	0	0	0		0	0	0	0	0	0		0	10	8	1	83	14		0	1	2	0	0	0		0	0	13	1	5	2	
Blanket Creek	0	0	1					0	0	0					0	3	3					0	0	0					0	0	0				
Burton Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	13	11	1	17	12	8	3	1	1	0	1	1	1	5	23	15	1	3	2	1
Cartier Bay	0	2	16	101	0	6	0	0	0	0	0	0	0	0	22	13	55	3	181	24	210	5	11	3	0	8	0	0	5	0	1	0	0	1	0
Downie Marsh		0	0	0	0	0	0		0	0	0	0	0	0		3	2	1	11	0	4		0	0	0	0	0	0		0	0	0	0	0	0
East Arrow Park		0	0						0	0						1	0						1	0						0	0				
Edgewood North		0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	2	0		0	2	0	0	0	0		0	0	0	1	1	0
Edgewood South	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	2	6	1	0	0	8	1	0	1	3	0	0	1	1	1	5	5
Halfway River	0							0							0							0							0						
Illecillewaet River	0					0		0					0		0					1		0					0		0					0	
Lower Inonoaklin Road			0	0	0	2	0			0	0	0	0	0			1	1	9	8	11			2	0	2	3	6			0	0	0	0	0
Machete Island		0	0	0		0			0	0	0		0			0	0	0		3			4	4	0		1			0	0	0		0	
Montana Slough	0	0	0	0	0	1	0	0	(2)	(1)	0	0	0	0	0	2	3	3	5	3	3	3	2	4	1	1	0	0	0	0	4	1	0	4	0
Mosquito Creek		0	0	0		0			0	0	0		0			3	0	0		0			0	3	0		1			1	0	0		0	
Shelter Bay	0							0							0							0							0						
Syringa Provincial Park	0							0							0							0							0						
Total Sites Occupied	**1**	**2**	**3**	**1**	**0**	**3**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**4**	**11**	**11**	**7**	**9**	**12**	**7**	**5**	**7**	**11**	**4**	**5**	**5**	**5**	**2**	**2**	**5**	**4**	**4**	**7**	**3**
Proportion of Sites Occupied	**0.08**	**0.14**	**0.20**	**0.08**	**0.00**	**0.21**	**0.00**	**0.00**	**0.07**	**0.07**	**0.00**	**0.00**	**0.00**	**0.00**	**0.31**	**0.79**	**0.73**	**0.58**	**0.82**	**0.86**	**0.70**	**0.38**	**0.50**	**0.73**	**0.33**	**0.45**	**0.36**	**0.50**	**0.15**	**0.14**	**0.33**	**0.33**	**0.36**	**0.50**	**0.30**

(B) Reptiles	R-CHBO							R-CHPI							R-PLSK							R-ELCO							R-THEL							R-THSI						
Monitoring Site	08	09	10	12	14	16	18	08	09	10	12	14	16	18	08	09	10	12	14	16	18	08	09	10	12	14	16	18	08	09	10	12	14	16	18	08	09	10	12	14	16	18
12 Mile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	5	1	4	0	2	1
9 Mile	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	11	3	7	0	0	1	0	4	2	0	0	1	5	0	26	5	8	4	3	4	5
Airport Marsh	0	0	0		0	0	0	0	0	2		2	11	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	1		0	5	0	1	1	7		1	14	0
Beaton Arm	0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0	1	1	0	0	0		0	5	8	0	2	2	
Blanket Creek	0	0	0					0	0	0					0	0	0					0	0	0					0	0	0					0	0	0				
Burton Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	7	11	1	2	19	12	6	6	8	0	0	4	1
Cartier Bay	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	2	2	0	2	13	1	0	2	1	0	0	3	0	6	3	6	0	1	7	5
Downie Marsh		0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		0	0	0	0	0	0		2	27	3	2	0	3		4	48	14	7	0	3
East Arrow Park		0	0						0	0						0	0						0	1						4	3						1	4				
Edgewood North		0	1	0	0	0	0		0	0	0	0	0	0		4	7	0	3	6	1		0	15	1	13	3	2		1	3	1	0	1	0		0	2	0	0	3	0
Edgewood South	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	3	0	1	3	4	0	1	19	2	1	19	3	0	0	14	0	7	10	8
Halfway River	0							0							0							0							0							1						
Illecillewaet River	0					0		0					0		0					0		0					0		0					0		1					0	
Lower Inonoaklin Road			0	0	1*		0			0	0	0	0	0			0	0	0	1	0			1	0	1	3	0			0	0	0	7	4			0	0	0	2	1
Machete Island		0	0	0		0			0	0	0		0			0	0	0		0			0	0	0		0			1	4	0		0			1	7	0		4	
Montana Slough	0	0	0	0	0	0	0	3	2	11	3	5	5	0	0	0	0	0	0	0	0	3	1	6	6	8	3	0	0	0	3	1	0	0	0	0	0	3	2	0	1	0
Mosquito Creek		0	0	0		0			0	0	0		0			0	0	0		0			0	0	0		0			1	3	0		0			3	5	0		0	
Shelter Bay	0							0							0							0							2							0						
Syringa Provincial Park	0							0							0							1							0							0						
Total Sites Occupied	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**2**	**2**	**1**	**2**	**3**	**0**	**0**	**1**	**2**	**0**	**1**	**2**	**1**	**4**	**4**	**7**	**2**	**5**	**6**	**3**	**3**	**10**	**11**	**6**	**4**	**7**	**4**	**7**	**10**	**13**	**4**	**6**	**11**	**7**
Proportion of Sites Occupied	**0.00**	**0.00**	**0.05**	**0.00**	**0.00**	**0.00**	**0.00**	**0.05**	**0.10**	**0.10**	**0.06**	**0.12**	**0.15**	**0.00**	**0.00**	**0.05**	**0.10**	**0.00**	**0.06**	**0.10**	**0.06**	**0.21**	**0.20**	**0.33**	**0.11**	**0.29**	**0.30**	**0.19**	**0.23**	**0.71**	**0.73**	**0.50**	**0.36**	**0.50**	**0.40**	**0.54**	**0.71**	**0.87**	**0.33**	**0.55**	**0.79**	**0.70**

Discussion

Monitoring sites and reference/reconnaissance sites were surveyed throughout both reservoirs over a period of 11 years providing a sufficient basis for assessing the occurrence (occupancy) and distribution of amphibians and reptiles in Kinbasket and Arrow Lakes Reservoir. Species-specific distributions and preferences for habitat types as well as variable reservoir operations likely contributed to differences in species richness values across the sites and between certain years. While likely imperfect, the data collected for CLBMON-37 and 58 provided a good overview of the occurrences and distribution of all the expected species of amphibians and reptiles utilizing habitats within and adjacent to the drawdown zone of both reservoirs.

Survey effort varied between sites from 2009 onwards as sites with suitable habitat (i.e., monitoring sites) were identified and focussed on to answer the management questions. Some sites (e.g., Sprague Bay) were not surveyed every year for logistic reasons including difficult access, lack of suitable habitat, and budget restrictions. For example, sites such as Beavermouth, Encampment Creek, and Hugh Allan Bay in Kinbasket Reservoir were surveyed intermittently during the early years of the study when appropriate sites were still being identified.

Small, inconspicuous amphibian species were generally difficult to locate; however, multiple years of surveys across the seasons likely provided an adequate understanding of species diversity across monitoring sites in both reservoirs. It is possible that certain species (especially if inconspicuous) were not observed at sites that were only periodically visited. For example, Long-toed Salamanders were often difficult to locate because they have an early breeding period and were inconspicuous during the remainder of the year. Given this, it is possible that Long-toed Salamanders 1) occurred at certain study sites but we failed to observe them, and 2) were more abundant than our detection rates determined. This situation could also have applied to other species / life history stages in this study including lizard species, neonate snakes, and certain larval stages of pond-breeding amphibians.

Appendix 3: Summary of nocturnal call station surveys and road surveys

Introduction

We conducted nocturnal call station surveys to determine breeding locations of Pacific Chorus Frogs and nocturnal road surveys to collect data on amphibian species migrating to and from the drawdown zone in the Revelstoke Reach area of Arrow Lakes Reservoir. Site access precluded these survey types at other monitoring sites. Nocturnal call station surveys paired with road surveys provided insight on the seasonal presence and abundance of amphibian species moving between the drawdown zone of Revelstoke Reach and adjacent upland habitats.

Methods

Nocturnal call and road surveys were conducted in CLBMON-37 years (2008, 2009, 2010, 2012, 2014, 2016, 2018) during the early breeding season to document presence, richness, and distribution of amphibian species in Revelstoke Reach, Arrow Lakes Reservoir (see also Section 3.3.2).

Nocturnal Call Surveys: were conducted at nine call stations in the drawdown zone of Revelstoke Reach for male Pacific Chorus Frogs. Survey sites were chosen based on access and the presence of expected or known breeding ponds in the drawdown zone. Surveys occurred in May during the breeding season, on nights with little to no wind and mild temperatures. A pre-determined amount of time (10 minutes) was spent listening for calling male frogs, with data recording beginning after 3 minutes (sound from vehicle and surveyors' arrival is initially disruptive). Presence/non-detection and relative abundance (i.e., estimated numbers of calling males) were summarized using the Wisconsin Index (RISC 1998a): 0 = no calls; 1 = individual calls can be counted; 2 = calls are overlapping, but still distinguishable; and 3 = full chorus where individuals cannot be distinguished.

Road Surveys: were conducted along Airport Road (south of the city of Revelstoke) in early May. The road survey route was approximately 4.5 km long. These surveys occurred from approximately 21:00 to 01:00, overlapping with wet conditions (e.g., light rain) where possible. All amphibian observations (dead or alive) were documented and morphometric and location data collected.

Datasets

Nocturnal call station observations from Dataset 2 (Call Station Data) were summarized to determine the presence-absence and estimated number of calling Pacific Chorus Frog males. Road survey observations from Dataset 3 (Road Survey Data) were used to summarize presence and relative abundance of species of amphibian moving in and out of the drawdown zone of Arrow Lakes Reservoir along Airport Road during the breeding season.

Analyses

We summarized (raw data only) the Wisconsin Index values and estimated the number of Pacific Chorus Frogs by observation station in each year that the survey took place (n = 6). Similarly, we summarized (raw data only) the number of amphibian species and detections recorded during nighttime road surveys along Airport Road in each year that road surveys occurred (n = 5).

Results

Pacific Chorus Frogs were visually observed occasionally in the drawdown zone of Arrow Lakes Reservoir during the study period, however the bulk of the observations were nocturnal auditory calls from call stations (Table 7-6; Figure 7-1). Airport Marsh, Montana Slough, and Cartier Bay had a Wisconsin Index of at least 2 in every year of study. Site 1 & 2, 9 Mile, 12 Mile, and Machete Island all had years with a Wisconsin Index of 3 and a high number of individuals. At some sites, the number of calling individuals could be easily counted (e.g., < 10 males per location), whereas at other sites, choruses of more than 100 individuals were documented.

Table 7-6: Pacific Chorus Frog observations from nocturnal call stations in Revelstoke Reach, Arrow Lakes Reservoir in 2008, 2009, 2010, 2012, 2016, and 2018. Wisconsin Calling Index (WI): 0 = no calls; 1 = individual calls can be counted; 2 = calls are overlapping, but still distinguishable; and 3 = full chorus where individuals cannot be distinguished. # = estimate number of individuals. Nocturnal call surveys were conducted between April 28 and May 17.

Call Station	Survey Site	UTM Coordinates			2008		2009		2010		2012		2016		2018	
		Zone	Easting	Northing	WI	#	WI	#	WI	#	WI	#	WI	#	WI	#
1	Site 1 & 2	11	413849	5651107	-	-	3	>100	3	>100	0	0	0	-	1	1
2	Big Eddy	11	414551	5650178			1	<10	1	5	1	1	2	-	0	0
3	Downie Marsh	11	415250	5648974	-	-	1	1	1	1	1	1	-	-	0	0
4	Machete Island	11	415689	5648099	-	-	3	>100	0	0	3	>100	2	-	-	-
5	Airport Marsh	11	417346	5645647	3	-	2	10-20	2	~50	3	25-50	2	-	3	>100
6	Montana Slough	11	418830	5644166	3	-	3	>100	3	>100	3	~100	3	-	3	>100
7	Cartier Bay	11	418863	5643200	3	-	2	10-20	3	>100	2	10-20	2	-	3	20-30
8	9 mile	11	420696	5639278	1	-	2	10-20	0	1	0	0	2	-	2	10-20
9	12 mile	11	422681	5635573	1	-	3	~20	1	1	3	50-100	3	-	3	20-30

Road surveys on Airport Road (Figure 7-1) documented three species of amphibian including Long-toed Salamander, Western Toad, and Pacific Chorus Frog (Table 7-7). Western Toad were the most frequently detected species crossing the road into the drawdown zone of Revelstoke Reach; they are known to utilize the upland forested areas adjacent to the reservoir. The majority of detections were on the stretch of Airport Road adjacent to Cartier Bay and Montana Slough near the base of Mount MacKenzie.

Table 7-7: Number of individuals per species during nighttime road surveys on Airport Road in Revelstoke Reach, Arrow Lakes Reservoir in 2008, 2009, 2010, 2012, 2016, and 2018. A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-PSRE = Pacific Chorus Frog. Road surveys were conducted between April 27 and June 26.

Survey Site	Species	Year					
		2008	2009	2010	2012	2016	2018
Airport Road	A-AMMA	0	4	17	1	7	0
	A-ANBO	28	8	52	51	23	11
	A-PSRE	0	1	13	5	11	0

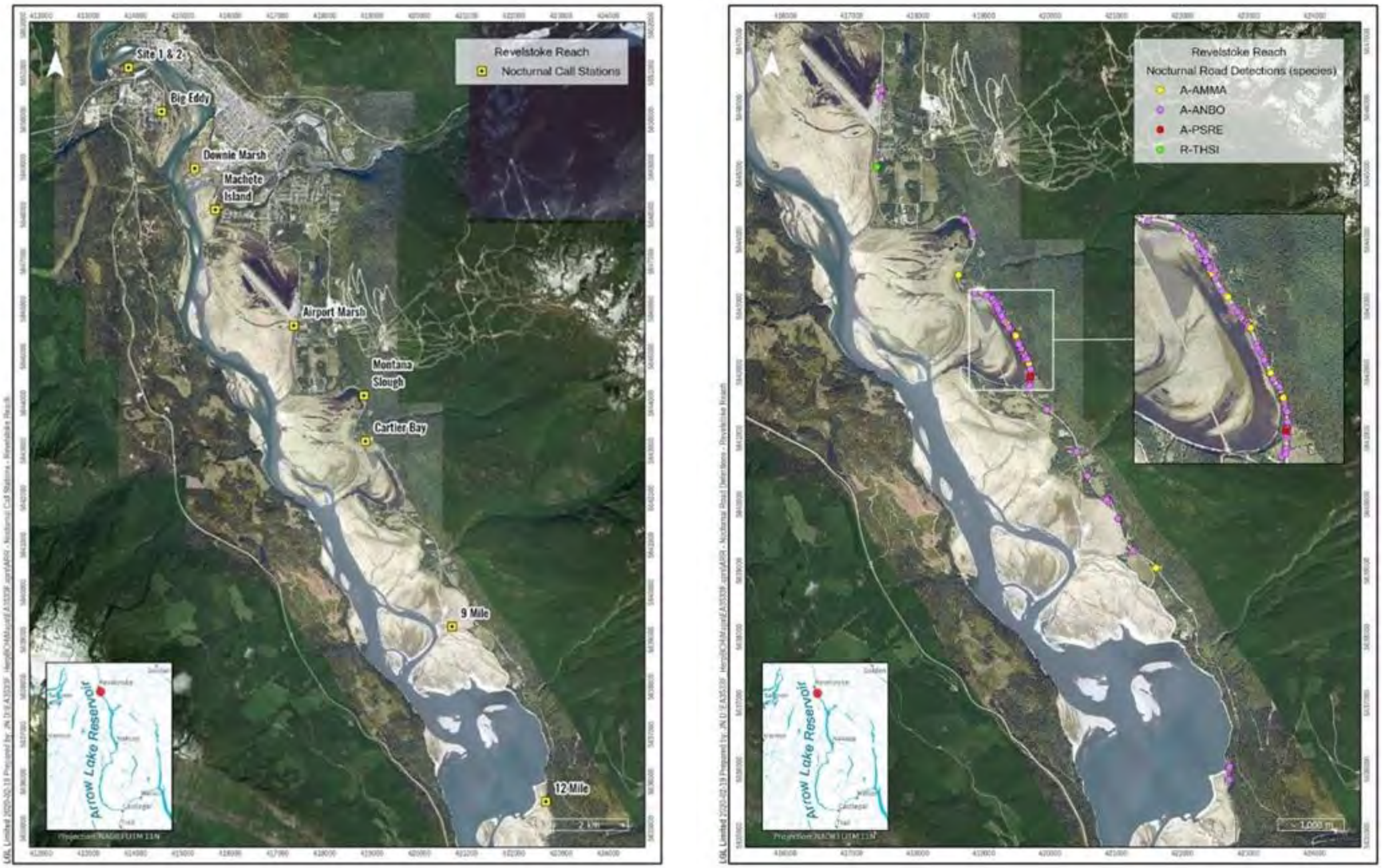


Figure 7-1: Nocturnal call stations (left) and amphibian detections on Airport Road during nighttime road surveys (right) in the Revelstoke Reach area of Arrow Lakes Reservoir. A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-PSRE = Pacific Chorus Frog, R-THSI = Common Garter Snake.

Discussion

Nocturnal call station surveys were useful for locating active breeding areas with Pacific Chorus Frog and other possibly vocal pond-breeding amphibians (e.g., Western Toad in some cases). These surveys provided insight on where to focus monitoring efforts at the various sites in the drawdown zone. We expected sites with wetland and pond habitats in the drawdown zone (Airport Marsh, Cartier Bay, and Montana Slough) to be the most active. Some monitoring sites in Revelstoke Reach were not truly discrete and it is possible that choruses overlapped at sites that were adjacent to one another (e.g., Cartier Bay and Montana Slough, Machete Island and Airport Marsh). It is likely that the number of individuals at these sites varied from our observations, but for the purposes of identifying active breeding areas for Pacific Chorus Frogs and other pond-breeding amphibians in areas that were accessible, these surveys were sufficient.

Paired nighttime road surveys provided insight to the amphibian species crossing Airport Road into adjacent drawdown zone sites from upland habitats. Specifically, it highlighted that Western Toad were the most frequent road-crossing amphibian, and that Cartier Bay was an active breeding site for Long-toed Salamanders (which were typically hard to locate). These findings also identified a potential mortality risk to Western Toad in Revelstoke Reach, which could be useful for future efforts to reduce the impact of road mortality on populations in the area (Mazerolle 2004).

Appendix 4: Analysis of amphibian and reptile abundance

Introduction

We examined the abundance of amphibians and reptiles that occur within the drawdown zone at the monitoring sites in Kinbasket and Arrow Lakes Reservoir. This section assisted in answering Management Question 2 (see Section 5).

Methods

We assessed the abundance of amphibians and reptiles by species, monitoring site, reservoir, and year. To assess species-by-site relationships, we pooled all life stages and examined species observations to identify sites where the detection of a given species was the highest regardless of age class. Clusters of egg masses and aggregations of tadpoles or metamorphs were treated as a single observation per location or pond, so as not to skew numbers. We determined the detection rates for 12 monitoring sites at Arrow Lakes Reservoir of which 9 Mile, Cartier Bay, and Burton Creek had the greatest overall survey effort. Survey effort was greatest at Valemount Peatland in Kinbasket Reservoir due to two graduate student projects with the University of Victoria (2010 to 2011 and 2015 to 2017).

Datasets

Observations from Dataset 1 (Visual Encounter Data), Dataset 2 (Call Station Data), Dataset 3 (Road Survey Data), and Dataset 4 (Life History Data) were summarized and subset by year, monitoring site, species group (i.e., amphibian or reptile), and species.

Analysis

We analyzed abundance through the calculation of detection rates. We calculated detection rates for each amphibian and reptile species at each monitoring site by dividing the number of observations per site and per species by survey effort in hours. Survey effort was calculated as the number of hours surveyed multiplied by the number of surveyors conducting the survey. Mean detection rates were calculated for all sites (pooling data from all years).

Results

<u>Kinbasket Reservoir</u>

From 2008 to 2018, ~4,582 hours of surveys were conducted at seven monitoring sites at Kinbasket Reservoir, during which 7,566 detections across multiple life stages of all species were made (Table 7-8; Table 7-9).

Table 7-8: Summary of amphibian and reptile catch data within the drawdown zone of Kinbasket Reservoir 2008 to 2018. Unknown category represents individuals for which life history stage was not classified. A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-RALU = Columbia Spotted Frog, R-CHPI = Western Painted Turtle, R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake. '-' indicates that the life stage is not applicable to the species group.

Species	Catch						
	Egg Mass	Tadpole	Metamorph / Neonate	Juvenile	Adult	Unknown	Total
A-AMMA	42	16	0	2	66	0	126
A-ANBO	290	1,144	1,342	120	1,723	28	4,647
A-RALU	373	260	193	445	879	57	2,207
R-CHPI	-	-	0	0	1	0	1
R-THEL	-	-	0	6	12	1	19
R-THSI	-	-	18	207	335	6	566
Total	705	1,420	1,553	780	3,016	92	7,566

Table 7-9: Total survey effort (hours multiplied by number of surveyors) by monitoring site in the drawdown zone of Kinbasket Reservoir from 2008 to 2018. Blanks indicate the location was not surveyed.

Monitoring Site	Survey Effort (hrs)											
	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18	Total
Bush Arm Causeway	8.6	10.7	25.4	90.1	22.5	141.4	15.4	13.3	22.2	4.0	19.3	372.8
Bush Arm KM79 (DDZ)	43.5	22.9	37.2	32.0	7.7	16.1	18.1	9.1	28.2	24.8	15.7	255.1
Bush Arm KM88	1.8	2.1	15.4	19.7	17.1	21.2	26.3	17.1	28.3	32.5	20.1	201.5
Ptarmigan Creek	21.7	13.9	142.7	231.1	20.6	7.9	9.3	59.4	24.3	44.6	8.0	583.4
Sprague Bay		5.1	16.9	3.8	6.7		0.9					33.5
Succour Creek	4.0	4.3	9.8	5.5	1.7			1.5		2.3		29.0
Valemount Peatland	53.9	30.0	496.4	757.9	56.5	58.0	166.7	667.1	406.9	371.7	42.1	3107.2
Total	133.4	89.0	743.8	1140.1	132.7	244.6	236.7	767.4	509.9	479.8	105.3	4582.5

Amphibians

Amphibian abundance varied from year to year and, in general, there were more detections in the spring than in the summer (Figure 7-2). This coincided with the peak of the breeding season when most adults were migrating to and from breeding ponds and were therefore more conspicuous. This trend was apparent in all years of study, particularly for Western Toad.

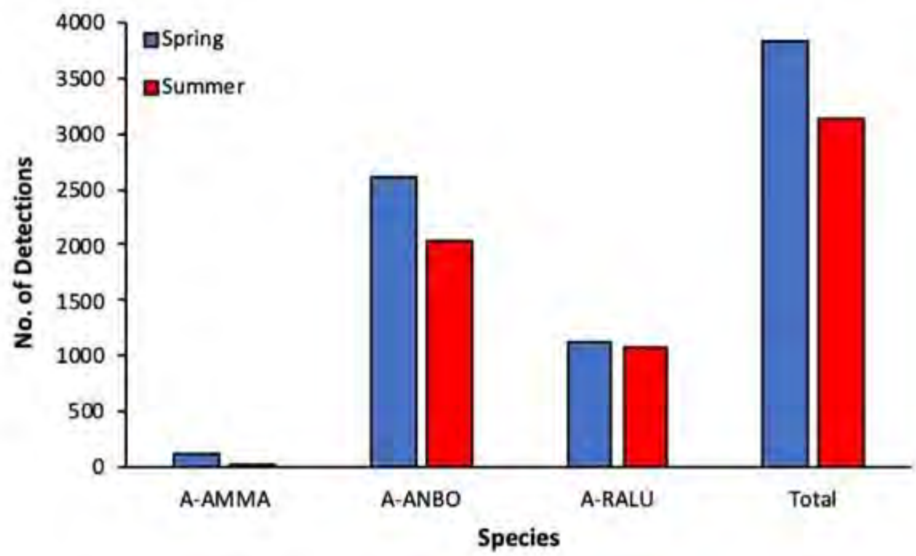


Figure 7-2: Number of amphibian detections in Kinbasket Reservoir drawdown zone by species and by season (all years pooled). A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-RALU = Columbia Spotted Frog.

Western Toad and Columbia Spotted Frog were the amphibian species with the highest detection rates (Table 7-10). From 2010 onwards, detection rates for Western Toad were consistently higher than those for Columbia Spotted Frog. Western Toad and Columbia Spotted Frog were detected at all sites, with Western Toad having a higher overall detection rate at Bush Arm Causeway, Bush Arm KM88, and Ptarmigan Creek. The lowest detection rates for amphibians were associated with Long-toed Salamander, which were found at only three of the seven monitoring sites. Bush Arm Causeway and Ptarmigan Creek had the highest overall detection rates for amphibians, 2.86 and 1.57, respectively, for Western Toad.

Table 7-10: Detection rate by amphibian species and monitoring site in the drawdown zone of Kinbasket Reservoir from 2008 to 2018. Blanks indicate the site was not surveyed. A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-RALU = Columbia Spotted Frog, detection rate = the number of observations per monitoring site and per species (all life stages pooled) divided by the survey effort.

Monitoring Site	Species	Detection Rate											
		'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18	Total
Bush Arm Causeway	A-AMMA	0	0	0.04	0.03	0.13	0	0	1.13	0	1.5	0.1	0.08
	A-ANBO	0.23	0.28	1.49	0.3	0.44	0.11	14.1	4.97	2.21	57	21.3	2.86
	A-RALU	0.58	0.09	0.24	0.01	0.09	0.01	0.26	0.3	0.09	5.25	0.05	0.13
Bush Arm KM79 (DDZ)	A-ANBO	0.07	0.22	0.38	0.88	1.03	0.75	0.83	1.76	0.71	0.4	2.04	0.64
	A-RALU	1.36	2.14	1.34	2.28	0.13	1.37	0.22	1.21	1.06	2.1	1.15	1.45
Bush Arm KM88	A-ANBO	0	0.48	1.3	2.49	1.29	0.52	2.36	1.7	0.85	0.37	1.64	1.31
	A-RALU	0.56	0	0.13	0.15	0.41	0.28	0.46	0.47	0.11	0.49	0.3	0.32
Ptarmigan Creek	A-AMMA	0	0	0	0	0	0.13	0	0	0	0	0	0
	A-ANBO	0.46	0.57	0.89	1.22	0.1	16.5	1.94	3.35	2.79	0.92	3.61	1.57
	A-RALU	0.18	0.57	0.07	0.11	0.15	0.63	0.22	0.29	0.29	0.04	0	0.14
Sprague Bay	A-ANBO		0	0.12	0	0		0					0.06
	A-RALU		0.59	1.13	1.31	0		0					0.81
Succour Creek	A-ANBO	0	0	0.1	0	0			0		0		0.03
	A-RALU	0	0	0.2	0	0			0		0		0.07
Valemount Peatland	A-AMMA	0.04	0.03	0	0.02	0.02	0.02	0.01	0.01	0	0	0.09	0.01
	A-ANBO	0.13	0.2	0.9	0.65	0.05	1.52	0.31	0.4	0.18	0.24	0.47	0.5
	A-RALU	0.43	0.23	0.73	0.56	0.23	0.59	0.48	0.45	0.23	0.39	1.73	0.5
Total by Species	A-AMMA	0.01	0.01	0	0.02	0.03	0.01	0	0.03	0	0.01	0.06	0.01
	A-ANBO	0.16	0.26	0.87	0.77	0.34	1.05	1.53	0.75	0.46	0.8	4.99	0.86
	A-RALU	0.69	0.76	0.61	0.47	0.2	0.28	0.43	0.45	0.27	0.49	0.93	0.47
Total by Year	All Spp.	0.87	1.03	1.48	1.25	0.57	1.34	1.97	1.23	0.73	1.3	5.98	1.35

Reptiles

Common Garter Snake had the highest overall detection rate among the reptiles in Kinbasket Reservoir. They were detected at every monitoring site except Succour Creek and were detected every year at Valemount Peatland (Table 7-11). Ptarmigan Creek had the highest overall detection rate for reptiles in Kinbasket Reservoir whereas the Bush Arm KM88 and Valemount Peatland had the lowest overall detection rates. Low detection rates were also associated with Western Terrestrial Garter Snake and Western Painted Turtle. In 2015, a single observation of an adult Western Painted Turtle was made at KM88 (near the mouth of Bush Arm, the first observation of this species in the drawdown zone of Kinbasket Reservoir).

Table 7-11: Detection rate by reptile species and monitoring site in the drawdown zone of Kinbasket Reservoir from 2008 to 2018. Blanks indicate the monitoring site was not surveyed. R-CHPI = Painted Turtle, R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake, detection rate = the number of observations per monitoring site and per species (all life stages pooled) divided by the survey effort.

Monitoring Site	Species	Detection Rate											
		'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18	Total
Bush Arm Causeway	R-THEL	0	0	0	0.01	0	0	0	0.15	0	0	0	0.01
	R-THSI	0.23	0	0.12	0.01	0.09	0.02	0	0.3	0.05	1.5	0.16	0.07
Bush Arm KM79 (DDZ)	R-THEL	0	0.13	0.03	0	0	0	0	0	0	0.04	0	0.02
	R-THSI	0.18	0.26	0.4	0.13	0	0.12	0.06	0	0.07	0.08	0	0.16
Bush Arm KM88	R-CHPI	0	0	0	0	0	0	0	0.06	0	0	0	0
	R-THEL	0	0	0	0	0	0	0	0	0	0.03	0	0
	R-THSI	0.56	0	0.26	0.05	0	0	0.15	0.23	0.04	0.06	0	0.08
Ptarmigan Creek	R-THEL	0.18	0	0	0	0	0	0	0	0	0	0	0.01
	R-THSI	0.28	0.14	0.36	0.57	0	0.38	0.86	0.45	0.21	0.29	0.37	0.43
Sprague Bay	R-THSI		0	0.24	0	0		0					0.12
Succour Creek	R-THEL	0	0	0.2	0.18	0			1.35		0.43		0.21
Valemount Peatland	R-THSI	0.02	0.1	0.17	0.07	0.04	0.02	0.05	0.03	0.05	0.04	0.02	0.07
Total by Species	R-CHPI	0	0	0	0	0	0	0	0	0	0	0	0
	R-THEL	0.03	0.03	0	0	0	0	0	0.01	0	0.01	0	0
	R-THSI	0.13	0.12	0.22	0.17	0.03	0.04	0.09	0.07	0.06	0.08	0.07	0.12
Total by Year	All Spp.	0.16	0.16	0.22	0.17	0.03	0.04	0.09	0.08	0.06	0.09	0.07	0.12

Summary

Overall, Western Toad had the highest detection rate (0.86) of all amphibian and reptile species in Kinbasket Reservoir, followed by Columbia Spotted Frog (0.47) and Common Garter Snake (0.12; Figure 7-3). The most frequently observed species varied among sites, all of which were amphibians with the exception of Succour Creek where Western Terrestrial Garter Snake were the most commonly detected species.

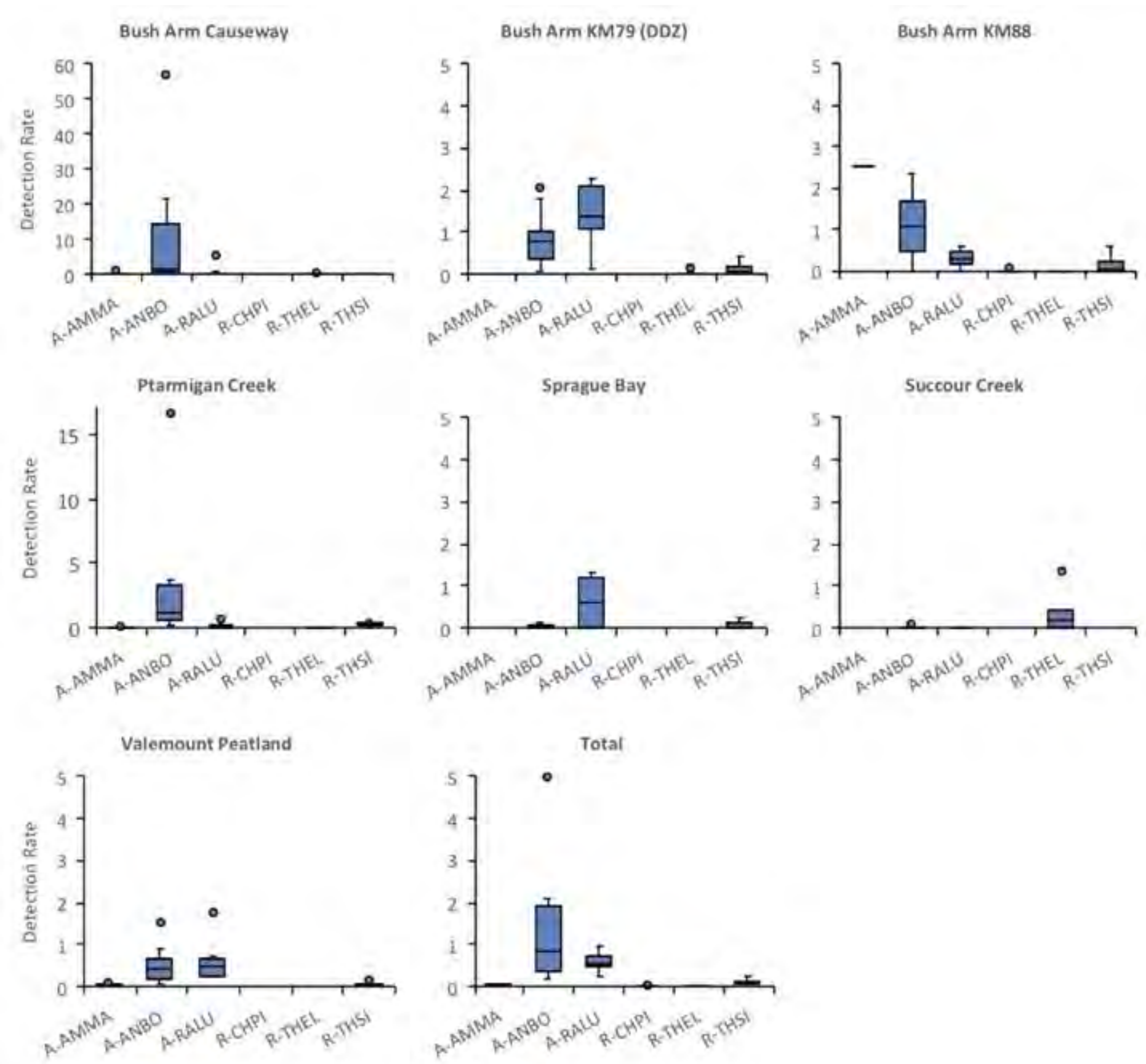


Figure 7-3: Mean annual detection rates (each point represents the mean annual detection rate) for amphibian and reptile species at monitoring sites in the drawdown zone of Kinbasket Reservoir. Detection rate = the number of observations per site and per species (all life stages pooled) divided by the survey effort. A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-RALU = Columbia Spotted Frog, R-CHPI = Painted Turtle, R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake**.** Note: different scales for Bush Arm Causeway and Ptarmigan Creek.

Arrow Lakes Reservoir

From 2008 to 2018, ~1,058 hours of surveys were conducted at 12 monitoring sites in the drawdown zone of Arrow Lakes Reservoir, during which 1,813 detections across multiple life stages of all species were made (Table 7-12; Table 7-13).

Table 7-12: Summary of amphibian and reptile catch data within the drawdown zone of Arrow Lakes Reservoir 2008 to 2018. Unknown category represents individuals for which life history stage was not classified. A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-PSRE = Pacific Chorus Frog, A-RALU = Columbia Spotted Frog, R-CHPI = Painted Turtle, R-ELCO = Northern Alligator Lizard, R-PLSK = Western Skink, R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake. '-' indicates that the life stage is not applicable to the species group.

Species	Catch						
	Egg Mass	Tadpole	Metamorph / Neonate	Juvenile	Adult	Unknown	Total
A-AMMA	100	1	0	2	0	0	103
A-ANBO	77	238	64	15	506	3	903
A-PSRE	6	4	1	1	102	0	114
A-RALU	7	9	3	43	42	9	113
R-CHPI	-	-	5	5	33	1	44
R-ELCO	-	-	0	8	59	9	76
R-PLSK	-	-	0	6	4	0	10
R-THEL	-	-	3	43	121	3	170
R-THSI	-	-	7	67	197	9	280
Total	190	252	83	190	1,064	34	1,813

Table 7-13: Total survey effort (hours multiplied by number of surveyors) by monitoring site for Arrow Lakes Reservoir. Blanks indicate the site was not surveyed.

Monitoring Site	Survey Effort (hrs)							
	'08	'09	'10	'12	'14	'16	'18	Total
12 Mile	16.8	7.7	20.4	5.1	0.5	3.8	7.2	61.5
9 Mile	47.5	33.4	15.0	10.8	17.9	16.0	24.4	165.0
Airport Marsh	16.2	8.7	33.4		13.6	17.4	1.2	90.5
Beaton Arm	2.0	7.0	27.0	19.2	6.3	9.3		70.8
Burton Creek	26.7	25.5	32.6	12.5	8.5	18.5	16.1	140.3
Cartier Bay	14.5	14.3	31.0	14.0	14.9	41.9	23.8	154.4
Downie Marsh		13.1	29.2	12.1	12.8	9.4	6.5	83.1
Edgewood North		1.7	5.5	4.1	2.6	5.8		19.7
Edgewood South	1.9	2.0	41.9	5.3	6.4	19.7	15.8	93.0
Lower Inonoaklin			5.3	3.7	3.4	11.5	9.5	33.3
Machete Island		24.9	11.7	1.7		7.1		45.3
Montana Slough	7.9	13.3	37.8	12.5	10.8	14.6	4.4	101.3
Total	133.6	151.4	290.6	100.9	97.6	175.1	108.9	1058.1

Amphibians

As seen in Kinbasket Reservoir, amphibian abundance in Arrow Lakes varied from year to year and, in general, there were more detections in the spring than in the summer (Figure 7-4). Detection rates of Western Toad were considerably higher than those for other amphibians in this study (Figure 7-4), with the highest detection rates at Cartier Bay (Table 7-14). Burton Creek had the highest detection rates of

Columbia Spotted Frog. Long-toed Salamander were found in the drawdown zone only at 9 Mile and Cartier Bay (Table 7-14). Pacific Chorus Frogs were observed at every monitoring site except Downie Marsh and Edgewood North. When all amphibian species and all survey effort were considered, the overall detection rate was 0.95 (Table 7-14).

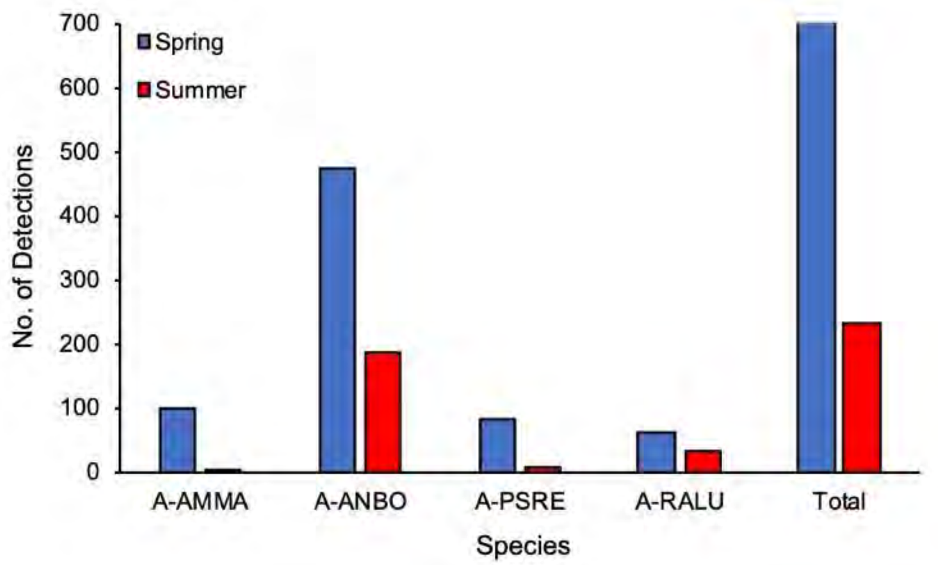


Figure 7-4: Number of amphibian detections in Arrow Lakes Reservoir drawdown zone by species and by season (all years pooled). A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-PSRE = Pacific Chorus Frog, A-RALU = Columbia Spotted Frog.

Reptiles

Common Garter Snake and Western Terrestrial Garter Snake had the highest detection rates and were detected at all monitoring sites in Arrow Lakes Reservoir. Western Painted Turtle were observed only at 9 Mile, Airport Marsh, and Montana Slough, with the most consistent detection at the two latter sites. Northern Alligator Lizard were documented at half of the monitoring sites but were not observed on an annual basis at each of these sites. Western Skink had the lowest detection rates and were found only at Edgewood North and Edgewood South. Although one observation of Rubber Boa was made at the Lower Inonoaklin monitoring site in 2015, it was not made under CLBMON-37 and therefore not included in this analysis. When all reptile species and all effort were considered, the overall detection rate was 0.47 (Table 7-15).

Summary

Overall, Western Toad (0.70) and Common Garter Snake (0.23) had the highest detection rates of any species in Arrow Lakes Reservoir (Figure 7-5). The most frequently observed species varied among monitoring sites; amphibian species were dominant at every monitoring site with the exception of Succour Creek where Western Terrestrial Garter Snake was the most commonly detected species.

Table 7-14: Detection rate by amphibian species and monitoring site in the drawdown zone of Arrow Lakes Reservoir from 2008 to 2018. Blanks indicate the site was not surveyed. A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-PSRE = Pacific Chorus Frog, A-RALU = Columbia Spotted Frog, detection rate = the number of observations per site and per species (all life stages pooled) divided by the survey effort.

		Detection Rate							
Monitoring Site	Species	'08	'09	'10	'12	'14	'16	'18	Total
12 Mile	A-ANBO	0.06	0.26	0	0	0	0.79	0	0.10
	A-PSRE	0	0	0	0.59	0	0	0.28	0.08
9 Mile	A-AMMA	0	0.03	0	0	0	0	0	0.01
	A-ANBO	0.69	0.87	1.94	0.46	0.45	0.31	4.39	1.31
	A-PSRE	0.13	0	0	0.18	0.06	0	0.04	0.06
	A-RALU	0	0	0	0	0	0	0.21	0.03
Airport Marsh	A-ANBO		0.23	0		0.37	0	0	0.08
	A-PSRE		0.23	0.06		0	0	0	0.04
	A-RALU		0	0		0	0.23	0	0.04
Beaton Arm	A-ANBO		0.86	0.18	0.05	13.24	1.50		1.54
	A-PSRE		0.14	0.07	0	0	0		0.04
	A-RALU		0	0.37	0.05	0.80	0.21		0.25
Burton Creek	A-ANBO	0.19	0.51	0.28	0.08	2.00	0.60	0.50	0.46
	A-PSRE	0.11	0.04	0	0	0	0.05	0.06	0.04
	A-RALU	0.19	0.90	0.21	0.08	0.35	0.11	0.06	0.30
Cartier Bay	A-AMMA	0	0	0	7.14	0	0	0	0.65
	A-ANBO	1.45	0.70	0.81	0.21	3.43	0.52	5.25	1.66
	A-PSRE	0.14	0.35	0.03	0	0	0	0	0.05
	A-RALU	0.34	0	0.03	0	0	0.02	0	0.05
Downie Marsh	A-ANBO		0.23	0.07	0.08	0.86	0	0.62	0.25
Edgewood North	A-ANBO		0	0	0	0	0.34		0.10
	A-RALU		0	0	0	0.39	0.17		0.10
Edgewood South	A-ANBO		0	0.05	0	0.31	0.30	0	0.11
	A-PSRE		0	0.12	0.19	0	0.05	0.19	0.11
	A-RALU		0	0.02	0.19	0.16	0.25	0.32	0.14
Lower Inonoaklin	A-ANBO			0.19	0.27	2.66	0.35	1.16	0.78
	A-PSRE			0	0	0.59	0.17	0.63	0.30
Machete Island	A-ANBO		0	0	0		0.42		0.07
	A-PSRE		0.16	0.34	0		0.14		0.20
Montana Slough	A-ANBO	0	0.15	0.08	0.24	0.46	0.14	0	0.15
	A-PSRE	0.25	0.08	0.05	0	0.09	0	0	0.06
	A-RALU	0	0	0.11	0.08	0	0.27	0	0.09
Total by Species	A-AMMA	0	0.03	0	7.14	0	0	0	0.10
	A-ANBO	0.45	0.44	0.26	0.15	1.96	0.41	2.34	0.70
	A-PSRE	0.10	0.09	0.06	0.06	0.04	0.03	0.12	0.07
	A-RALU	0.07	0.15	0.08	0.04	0.10	0.11	0.10	0.09
Total by Year	All Spp.	0.62	0.69	0.40	1.24	2.10	0.55	2.56	0.95

Table 7-15: Detection rate by reptile species and monitoring site in the drawdown zone of Arrow Lakes Reservoir from 2008 to 2018. Blanks indicate the location was not surveyed. R-CHPI = Painted Turtle, R-ELCO = Northern Alligator Lizard, R-PLSK = Western Skink, R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake. Detection rate = the number of observations per site and per species (all life stages pooled) divided by the survey effort.

		Detection Rate							
Monitoring Site	**Species**	**'08**	**'09**	**'10**	**'12**	**'14**	**'16**	**'18**	**Total**
12 Mile	R-THEL	0	0	0	0.39	0	0	0	0.03
	R-THSI	0.06	0.65	0.05	0.78	0	0.53	0.14	0.23
9 Mile	R-CHPI	0	0.03	0	0	0	0	0	0.01
	R-ELCO	0.17	0.09	0	0	0	0.06	0	0.07
	R-THEL	0.06	0.06	0	0	0.06	0.19	0	0.05
	R-THSI	0.55	0.15	0.54	0.37	0.17	0.06	0.21	0.32
Airport Marsh	R-CHPI		0	0.03		0.15	0.11	0	0.06
	R-THEL		0	0.03		0	0.23	0	0.06
	R-THSI		0	0.18		0	0.57	0	0.18
Beaton Arm	R-THSI		0.57	0.22	0	0.32	0.21		0.20
Burton Creek	R-THEL	0.52	0.28	0.12	0.08	0.12	0.97	0.75	0.41
	R-THSI	0.22	0.24	0.12	0	0	0.22	0.06	0.15
Cartier Bay	R-ELCO	0.07	0.14	0.06	0	0	0.31	0.04	0.12
	R-THEL	0	0.14	0.03	0	0	0.07	0	0.04
	R-THSI	0.41	0.21	0.19	0	0.07	0.14	0.21	0.17
Downie Marsh	R-THEL		0.15	0.51	0.17	0.16	0	0.15	0.26
	R-THSI		0.31	0.99	0.75	0.47	0	0.31	0.60
Edgewood North	R-ELCO		0	0.90	0	0.78	0.17		0.41
	R-PLSK		1.80	0.54	0	0	0.34		0.41
	R-THSI		0	0	0	0	0.52		0.15
Edgewood South	R-ELCO		0.50	0.05	0	0.16	0.10	0.13	0.09
	R-PLSK		0	0.02	0	0	0	0	0.01
	R-THEL		0.50	0.31	0.38	0.16	0.81	0.19	0.39
	R-THSI		0	0.21	0	1.09	0.25	0.44	0.30
Lower Inonoaklin	R-ELCO			0.19	0	0.30	0	0	0.06
	R-THEL			0	0	0	0.26	0.21	0.15
	R-THSI			0	0	0	0.17	0.11	0.09
Machete Island	R-THEL		0	0.34	0		0		0.09
	R-THSI		0.04	0.51	0		0.56		0.24
Montana Slough	R-CHPI	0.38	0.15	0.29	0.24	0.46	0	0	0.24
	R-ELCO	0.38	0.08	0.16	0.16	0	0.07	0	0.13
	R-THEL	0	0	0.08	0	0	0	0	0.03
	R-THSI	0	0	0.08	0.16	0	0	0	0.05
Total by Species	R-CHPI	0.02	0.02	0.04	0.03	0.07	0.01	0	0.03
	R-ELCO	0.09	0.05	0.06	0.02	0.04	0.10	0.03	0.06
	R-PLSK	0	0.02	0.01	0	0	0.01	0	0.01
	R-THEL	0.13	0.09	0.14	0.07	0.05	0.27	0.17	0.14
	R-THSI	0.29	0.18	0.27	0.19	0.19	0.22	0.20	0.23
Total by Year	All Spp.	0.53	0.36	0.52	0.31	0.36	0.62	0.39	0.47

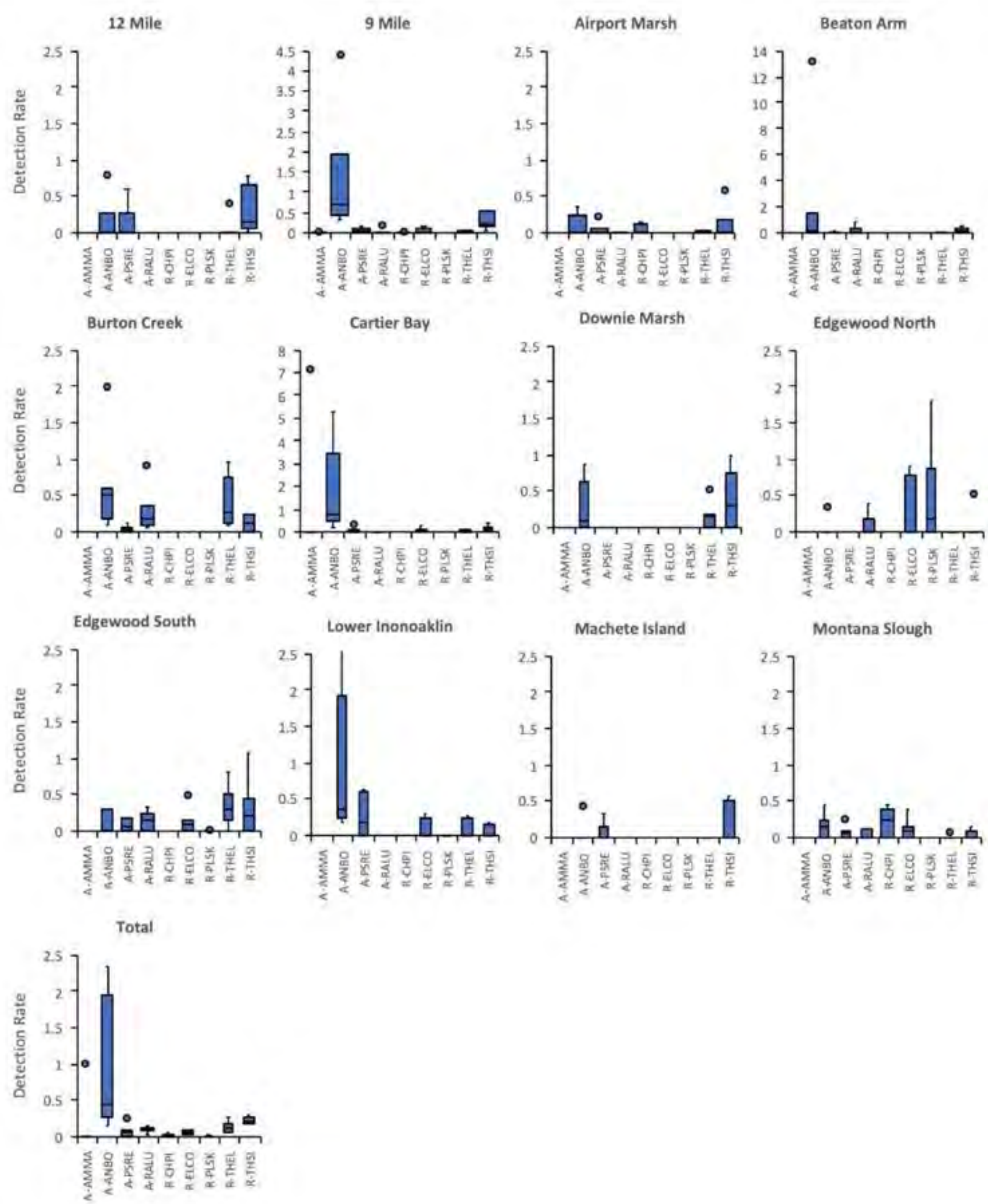


Figure 7-5: Detection rate for amphibian and reptile species at monitoring sites in Arrow Lakes Reservoir from 2008 to 2018 (all study years pooled). Detection rate = the number of observations per site and per species (all life stages pooled) divided by the survey effort. A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-PSRE = Pacific Chorus Frog, A-RALU = Columbia Spotted Frog, R-CHPI = Painted Turtle, R-ELCO = Northern Alligator Lizard, R-PLSK = Western Skink, R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake**.** Note: different scale for 9 Mile, Beaton Arm, and Cartier Bay.

Discussion

Amphibian abundances (detection rates) varied from year to year and in general, there were more detections in the spring than in the summer or early fall, which is consistent with the life history of these species. Spring surveys coincided with the peak of the breeding season when most adults were migrating to and from breeding ponds and were therefore more conspicuous. This trend was apparent in all years and in particular, for Western Toad. It is unknown if the seasonal variation observed in the drawdown zone is similar to the seasonal variation associated with non-reservoir populations of toads and frogs. For example, the timing of metamorphosis (and therefore presence of tadpoles) could be affected by inundation of breeding ponds in the drawdown zone (i.e., cooler water temperatures), which would not affect developing amphibians in ponds above the reservoir's influence.

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

One of the major assumptions of the methodology we used to assess abundance was that our observations were a good representation of the true abundance at each site and that detection rates were not impacted differently across monitoring sites or years. Another assumption was that the animals we observed were unique individuals. For snakes, we used a scale-marking method to identify individuals, however for amphibians we did not tag or mark individuals for identification in the field, and therefore adult individuals could have been counted as new between field sampling sessions and years, when in fact the same adult could have been captured twice.

Appendix 5: Analysis of amphibian and reptile diversity

Introduction

We determined the diversity of amphibians and reptiles that occur within the drawdown zone at monitoring sites in Kinbasket and Arrow Lakes Reservoir. This section assists in answering Management Question 2 (see Section 5).

Methods

The data used to determine diversity were gathered during visual encounter surveys (VES) and egg mass surveys (EMS; see Sampling Methodology section). We assessed the diversity of amphibians and reptiles by species group, monitoring site, reservoir, and year. Clusters of egg masses and aggregations of tadpoles or metamorphs were treated as a single observation per location or pond, so as not to skew numbers. We assessed diversity at seven sites in Kinbasket Reservoir and 12 sites in Arrow Lakes Reservoir. Survey effort was greater at Valemount Peatland in Kinbasket Reservoir due to two graduate student projects with the University of Victoria (2010 to 2011 and 2015 to 2017).

Datasets

Observations from Dataset 1 (Visual Encounter Data) were used to conduct the analysis of species diversity.

Analysis

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

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

where p_i is the relative proportion of species *i*.

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

Results

Kinbasket Reservoir

Three species of amphibian were detected in the drawdown zone of Kinbasket Reservoir between 2008 and 2018: Long-toed Salamander, Western Toad, and Columbia Spotted Frog. All three species were detected every year of the study. Among monitoring sites, amphibian species diversity ranged from 0.11 to 0.32, with an average of 0.21 (Table 7-16). One auditory observation of Pacific Chorus Frog was made in 2015 in Valemount Peatland, but no further observations were made to confirm the presence of this species.

Three species of reptile were detected in Kinbasket Reservoir between 2008 and 2018: Common Garter Snake, Western Terrestrial Garter Snake, and Western

Painted Turtle. Reptile species diversity ranged from 0 to 0.18 among monitoring sites, with an average of 0.07 (Table 7-16).

Table 7-16: Species diversity (Shannon's Entropy) by monitoring site at Kinbasket Reservoir from 2008 to 2018 (all years pooled).

Monitoring Site	Species Diversity		
	Amphibian	Reptile	Overall
Bush Arm Causeway	0.13	0.15	0.18
Bush Arm KM79 (DDZ)	0.27	0.15	0.38
Bush Arm KM88	0.21	0.18	0.31
Ptarmigan Creek	0.13	0.04	0.33
Sprague Bay	0.11	0	0.26
Succour Creek	0.28	0	0.37
Valemount Peatland	0.32	0	0.40
Average	0.21	0.07	0.32
Minimum	0.11	0	0.18
Maximum	0.32	0.18	0.40

Species diversity did not vary substantially between years for amphibians or reptiles (Table 7-17). Overall species diversity ranged from 0.23 to 0.44 on Shannon's Index.

Table 7-17: Species diversity (Shannon's Entropy) by year at Kinbasket Reservoir (all monitoring sites pooled).

Year	Species Diversity		
	Amphibian	Reptile	Overall
2008	0.25	0.21	0.43
2009	0.27	0.23	0.43
2010	0.30	0.04	0.43
2011	0.31	0.03	0.44
2012	0.36	0	0.43
2013	0.24	0	0.29
2014	0.23	0	0.30
2015	0.33	0.14	0.41
2016	0.29	0	0.38
2017	0.31	0.11	0.40
2018	0.21	0	0.23
Average	0.28	0.07	0.38
Minimum	0.21	0	0.23
Maximum	0.36	0.23	0.44

Arrow Lakes Reservoir

Four species of amphibian were detected in the drawdown zone of Arrow Lakes Reservoir between 2008 and 2018: Long-toed Salamander, Western Toad, Pacific Chorus Frog, and Columbia Spotted Frog. Amphibian species diversity in Arrow Lakes Reservoir ranged from 0 to 0.47 across monitoring sites, with an average of 0.28 (Table 7-18). Montana Slough, Edgewood South, and Airport Marsh had the highest amphibian species diversity.

Five reptile species were detected in the drawdown zone between 2008 and 2018: Western Painted Turtle, Northern Alligator Lizard, Western Skink, Western Terrestrial Garter Snake, and Common Garter Snake. Reptile species diversity in Arrow Lakes Reservoir ranged from 0 to 0.49 across monitoring sites, with an average of 0.33 (Table 7-18). Montana Slough, Lower Inonoaklin, and Edgewood (North and South) had the highest reptile species diversity.

Table 7-18: Species diversity (Shannon's Entropy) by monitoring site at Arrow Lakes Reservoir from 2008 to 2018 (all years pooled).

Monitoring Site	Species Diversity		
	Amphibian	Reptile	Overall
12 Mile	0.30	0.16	0.23
9 Mile	0.13	0.35	0.43
Airport Marsh	0.46	0.39	0.71
Beaton Arm	0.22	0	0.34
Burton Creek	0.37	0.25	0.61
Cartier Bay	0.33	0.42	0.50
Downie Marsh	0	0.27	0.44
Edgewood North	0.30	0.44	0.62
Edgewood South	0.47	0.44	0.72
Lower Inonoaklin	0.26	0.45	0.53
Machete Island	0.24	0.25	0.55
Montana Slough	0.45	0.49	0.76
Average	0.29	0.33	0.54
Minimum	0	0	0.23
Maximum	0.47	0.49	0.76

In contrast to Kinbasket Reservoir, species diversity at Arrow Lakes Reservoir was greater for reptiles than for amphibians (Table 7-19). Annual species diversity ranged from 0.36 to 0.76 on Shannon's Index.

Table 7-19: Species diversity (Shannon's Entropy) by year at Arrow Lakes Reservoir (all monitoring sites pooled).

Year	Species Diversity		
	Amphibian	Reptile	Overall
2008	0.36	0.49	0.70
2009	0.40	0.56	0.74
2010	0.38	0.57	0.76
2012	0.41	0.50	0.73
2014	0.13	0.62	0.36
2016	0.30	0.54	0.71
2018	0.15	0.46	0.44
Average	0.30	0.53	0.64
Minimum	0.13	0.46	0.36
Maximum	0.41	0.62	0.76

Discussion

Kinbasket Reservoir had lower species richness for both taxa groups than Arrow Lakes Reservoir, and this was expected, as within British Columbia (as well as other parts of the world) higher numbers of species occur at lower latitudes in the northern hemisphere (Hillebrand 2004). Kinbasket Reservoir occurs at a higher elevation, experiences cooler temperatures, and has different BEC zones than Arrow Lakes Reservoir (see Table 2-1; Table 2-3), all of which contribute to geographic variation which can be hypothesized to influence species assemblages.

Some species (e.g., Long-toed Salamander) were often difficult to locate because they had an early breeding period or were inconspicuous during the remainder of the year. Although Long-toed Salamander were documented from only a few sites, they were likely distributed throughout the drawdown zone and adjacent upland habitats, particularly in areas with suitable breeding habitat. To confirm the presence of Pacific Chorus Frogs or Wood Frogs in the Kinbasket Reservoir, auditory surveys and additional visual encounter surveys would have to be conducted.

Appendix 6: Analysis of amphibian and reptile productivity (reproduction)

Introduction

We examined the productivity (reproduction) of amphibians and reptiles within the drawdown zone at monitoring sites at Kinbasket and Arrow Lakes Reservoir. This section assists in answering Management Question 2 (see Section 5).

Methods

The data used to examine productivity were gathered during visual encounter surveys and radio telemetry surveys (see Sampling Methodology section). The number of breeding amphibian pairs in amplexus was recorded at a given monitoring location annually during the breeding season. We documented the presence of egg masses, tadpoles, and metamorphs. We estimated timing of metamorphosis for Western Toads based on observations of metamorphs across study sites and across years. Although we can calculate detection rates for these species, most of the information we have is based on qualitative observations.

Morphometric data (e.g., length, mass) were collected from juvenile, subadult, and adult amphibians and reptiles in order to classify individuals into life stages. These data contributed to our understanding of the potential for breeding populations. The Resources Inventory Standards Committee (RISC) protocols for sampling and handling of amphibians and reptiles (RISC 1998a, 1998b) were followed. All captured animals were identified to species, weighed and measured, and sex was determined when possible.

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

Reptile Morphometric Data—Snout-vent length (SVL [mm]), tail length (TL [mm]) were measured using foldable metric rulers (2 m) and mass (to the nearest 0.1 g) was obtained with a Pesola spring scale. Sex in snakes was determined by probing for the spaces that contain the male reproductive organs. We palpated the body of female snakes to determine if gravid or not and, if so, we estimated clutch size (i.e., number of eggs) when possible.

Datasets

Observations from Dataset 1 (Visual Encounter Data), Dataset 2 (Call Station Data), Dataset 3 (Road Survey Data), Dataset 4 (Life History Data), and Dataset 5 (Radio Telemetry Data) were summarized and subset by year, monitoring site, and species.

Analysis

We assessed the productivity of amphibians and reptiles by monitoring site, reservoir, and year. Sex ratios were calculated as the number of males observed divided by the number of females observed. Counts of egg masses, tadpoles, and metamorphs were each summed and averaged by study site (all years pooled).

Results

Kinbasket Reservoir

Amphibians

The detection of amphibian egg masses varied between sites, but the observed variation was expected. We observed most life stages of these species in the Kinbasket Reservoir drawdown zone (i.e., eggs, tadpoles, metamorphs, and adults), with the exception of Long-toed Salamander where only egg masses, tadpoles, and adults were recorded.

We captured and measured a total of 1,206 Western Toads of various age and size classes at Kinbasket Reservoir from 2008 to 2018 (mean snout-urostyle length [SUL] = 35.5 ± 30.6 SD mm SUL; range = 3-120 mm SUL). The average SUL of Columbia Spotted Frogs (n = 635) at Kinbasket Reservoir was 47.9 ± 15.2 SD mm and ranged from 3.4 to 86.0 mm.

Breeding amphibian populations, indicating productivity, were documented for most monitoring sites at Kinbasket Reservoir, but not at Succour Creek (only a single metamorph toad and frog were observed at this site to indicate reproductive activity). Bush Arm Causeway and Valemount Peatland appeared to be the most productive sites in the Kinbasket Reservoir drawdown zone. Western Toad were documented breeding at all seven of the monitoring sites in Kinbasket Reservoir. The number of Western Toads observed in amplexus in the drawdown zone of Kinbasket Reservoir ranged over the years and averaged at 37 ± 47 SD pairs (range = 0-154 pairs). Large aggregations of Western Toad tadpoles were recorded at several sites in Kinbasket Reservoir over several years including Ptarmigan Creek, Pond 12 in Valemount Peatland, Bush Arm Causeway, Bush Arm KM88, and Sprague Bay. Out-migrating metamorph toads were documented at several of these sites (typically in early to mid-July), with Ptarmigan Creek being the most productive with thousands of toads leaving the drawdown zone.

We documented egg masses and dense aggregations of toad tadpoles in June and July in several areas of the Kinbasket Reservoir drawdown zone: Ptarmigan Creek, Valemount Peatland, and Bush Arm (Causeway and KM88). Toad tadpoles were of varying sizes and Gosner stages and there appeared to be pronounced variation in timing of metamorphosis between some sites (Table 7-20). In June, we took a sample (n = 100) of recently metamorphosized toadlets ranging in size from 13.1-18 mm SUL (mean = 15.4 ± 1.2 SD mm) and weighing between 0.1-0.6 grams (mean = 0.3 ± 0.08 SD g). Tadpoles of various sizes and stages (Gosner stage 26-30 and 35-40) were captured in the same areas at the same time (Figure 7-6). In July, we took a sample of recently metamorphosized toadlets ranging in size from 11.5-26.6 mm (mean = 16.2 ± 4.2 SD mm).

Figure 7-6: Example of Western Toad tadpoles documented in the drawdown zone of Kinbasket Reservoir. Photos: © Virgil C. Hawkes.

Table 7-20: Timing of metamorphosis of Western Toad by monitoring site in Kinbasket Reservoir from 2008 to 2018. Underlined text indicate that tadpoles were not present at the same time as metamorph emergence. Blanks indicate that the study site was not surveyed. E. = Early, M. = Mid, L. = Late. Asterisks (*) indicate the estimated time of metamorphosis was based on timing of field sessions. Question marks (?) represent an unknown timing of metamorphosis, due to no metamorphs being observed after the tadpole stage. Only monitoring sites with sufficient data were included in this assessment.

Monitoring Site	Timing of Metamorphosis										
	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18
Bush Arm Causeway	Aug. ?	L. Jul.	E. Jul.	?	?	L. Jul.	M. Jul.	E. Jul.	L. Jul.	L. Jun.	L. Jun.
Bush Arm KM79	?	E. Jul.	?	?	?	?	?	?	?	?	?
Bush Arm KM88	?	?	?	?	?	?	E. Jul.	?	?	M. Aug.	L. Jun.
Ptarmigan Creek	M. Jul.	M. Jul.	M. Jun.	M. Jul.	?	?	L. Jul.	L. Jun.	E. Jul.	E. Jul.	M. Jul.
Succour Creek	?	?	Aug. ?	?	?			?		?	
Valemount Peatland	Aug.	Aug.*	L. Jul.	M. Jul.	?	L. Jul.	E. Jun.	M. Jun.	E. Jul.	M. Jul.	M. Jul.

Ponds in the drawdown zone were notably productive for Columbia Spotted Frog at Valemount Peatland and, to a lesser extent, Bush Arm KM79. Columbia Spotted Frogs were observed in amplexus only once between 2008 and 2018, recorded at Valemount Peatland in May 2014. During the study calling males were recorded only at Valemount Peatland (May 2011). In 2016, the early development stages of Columbia Spotted Frog were observed only at Valemount Peatland (Table 7-21). High counts and consistent presence of Columbia Spotted Frog egg masses, tadpoles, and metamorphs were seen at Valemount Peatland (Table 7-21).

Table 7-21: Presence and count rating of Columbia Spotted Frog by age class, offering evidence of reproductive activity and its magnitude, by monitoring site, and by year at Kinbasket Reservoir from 2008 to 2018. E = Egg Masses, T = Tadpoles, M = Metamorphs. Count rating: X = low (1), X = moderate (2-100), X̲ = high (>100).

Monitoring Site	Presence																																
	'08			'09			'10			'11			'12			'13			'14			'15			'16			'17			'18		
	E	T	M	E	T	M	E	T	M	E	T	M	E	T	M	E	T	M	E	T	M	E	T	M	E	T	M	E	T	M	E	T	M
Bush Arm Causeway							X	X					X	X̲			X		X	X̲		X	X					X	X	X	X		
Bush Arm KM79		X	X		X		X	X	X		X̲		X						X									X		X	X		
Bush Arm KM88										X			X	X̲			X		X	X		X						X	X̲	X	X	X	
Ptarmigan Creek		X				X				X	X				X		X						X	X									
Sprague Bay												X																					
Succour Creek									X																								
Valemount Peatland		X	X		X		X̲	X̲	X	X̲	X̲	X				X	X		X̲	X̲		X	X̲	X	X	X̲	X	X	X̲		X	X̲	X

Long-toed Salamanders were not observed breeding at Kinbasket Reservoir; however, some evidence of reproduction (i.e., egg masses, tadpoles, juveniles) was observed in each year of study, with the exception of 2016. Egg masses were recorded at Bush Arm Causeway and Valemount Peatland. Salamander larvae were observed at Bush Arm Causeway, Valemount Peatland, and Ptarmigan Creek. Only two juvenile Long-toed Salamanders were captured at Valemount Peatland.

The relative lack of data for Columbia Spotted Frog and Long-toed Salamander precludes us from completing an assessment of reproduction similar to that provided for Western Toad.

Reptiles

We captured a total of 402 Common Garter Snakes at Kinbasket Reservoir (mean snout-vent length [SVL] = 417.1 ± 189.8 SD mm SVL; range = 30.5-965 mm) and nine Western Terrestrial Garter Snakes (mean = 431.2 ± 187.6 SD mm SVL; range = 178-618 mm) of various age and size classes in the Kinbasket Reservoir drawdown zone from 2008 to 2018.

The average sex ratio (male:female) for Common Garter Snakes at Kinbasket Reservoir was 0.96:1 (i.e., approximately equal numbers of males and females were observed; Table 7-22). In 2013 and 2018, no male Common Garter Snakes were observed.

Table 7-22: Number of Male and Female Common Garter Snake (THSI) observed at Kinbasket Reservoir drawdown zone from 2008 to 2018. Quotient = Number of Male THSI/Number of Female THSI. Ratio = Number of Male THSI:Female THSI.

Year	Number of THSI		Quotient	Ratio
	Male	Female		
2008	8	7	1.14	1.14:1
2009	5	4	1.25	1.25:1
2010	47	55	0.85	0.85:1
2011	82	65	1.26	1.26:1
2012	2	2	1.00	1:1
2013	0	8	0.00	0:1
2014	7	8	0.88	0.88:1
2015	7	10	0.70	0.7:1
2016	5	9	0.56	0.56:1
2017	8	9	0.89	0.89:1
2018	0	1	0.00	0:1
Average	15.55	16.18	0.96	0.96:1

We estimated clutch size for Common Garter Snakes (n = 20) and Western Terrestrial Garter Snakes (n = 2) as 9 ± 5 SD eggs and 8 ± 3 SD eggs, respectively. Gravid snakes ranged in size from 454 to 947 mm snout-vent length (SVL). We did not observe garter snakes giving birth in the drawdown zone, however three parturition events (one observed and two inferred, all radio-tracked individuals) took place near the drawdown zone at Valemount Peatland. We captured neonate snakes of both species in the drawdown zone of Kinbasket Reservoir.

The single observation of Western Painted Turtle in Bush Arm did not allow for an assessment of productivity for Kinbasket Reservoir.

Arrow Lakes Reservoir

Amphibians

At Arrow Lakes Reservoir, we captured and measured a total of 139 Western Toads of various age and size classes in the drawdown zone from 2008 to 2018 (mean = 72.5 ± 24.8 SD mm SUL; range = 2.4-126 mm). Western Toad were documented breeding at 11 out of 12 monitoring sites at Arrow Lakes Reservoir. The number of Western Toads observed in amplexus ranged over the years and averaged at 16 ± 24 SD pairs (range = 0-62 pairs). Large aggregations of Western Toad tadpoles were recorded at several sites over several years including Cartier Bay, Beaton Arm, Burton Creek, and Lower Inonoaklin. Out-migrating metamorph toads were documented at several of these sites (typically in early to mid-July), with Cartier Bay being the most productive with thousands of toads leaving the drawdown (Table 7-23).

Table 7-23: Timing of metamorphosis of Western Toad by monitoring site in Arrow Lakes Reservoir drawdown zone from 2008 to 2018. Underlined text indicate that tadpoles were <u>not</u> present at the same time as metamorph emergence. Blanks indicate that the study site was not surveyed. E. = Early, M. = Mid, L. = Late. Question marks (?) mean timing of metamorphosis is unknown, due to no metamorphs being observed after the tadpole stage. Only monitoring sites with sufficient data were included in this assessment.

<table>
<tr><th rowspan="2">Monitoring Site</th><th colspan="7">Timing of Metamorphosis</th></tr>
<tr><th>'08</th><th>'09</th><th>'10</th><th>'12</th><th>'14</th><th>'16</th><th>'18</th></tr>
<tr><td>9 Mile</td><td>L. Aug.</td><td>?</td><td>?</td><td>?</td><td>?</td><td>?</td><td>L. Jun.</td></tr>
<tr><td>Beaton Arm</td><td>?</td><td>?</td><td>?</td><td><u>L. Jul.</u></td><td>M. Jun.</td><td>?</td><td></td></tr>
<tr><td>Burton Creek</td><td>?</td><td>?</td><td><u>E. Aug.</u></td><td>?</td><td>?</td><td><u>M. Jul.</u></td><td>?</td></tr>
<tr><td>Cartier Bay</td><td>L. Aug.</td><td><u>E. Jul.</u></td><td>E. Jul.</td><td>?</td><td>M. Jun.</td><td>E. Jun.</td><td>M. Jul.</td></tr>
<tr><td>Downie Marsh</td><td></td><td>E. Jul.</td><td>?</td><td>?</td><td>M. Jul.</td><td>?</td><td>?</td></tr>
<tr><td>Lower Inonoaklin</td><td></td><td></td><td>?</td><td>?</td><td>?</td><td><u>Jun.</u></td><td>?</td></tr>
<tr><td>Montana Slough</td><td>?</td><td>?</td><td>?</td><td>M. Jul.</td><td><u>E. Jul.</u></td><td><u>Aug. ?</u></td><td>?</td></tr>
</table>

Columbia Spotted Frog were not observed in amplexus in the drawdown zone of Arrow Lakes Reservoir, however, egg masses, tadpoles, and metamorphs were documented as evidence of spotted frog reproduction in and around ponds in the drawdown zone. The mean SUL of Columbia Spotted Frogs was 44.2 ± 10.3 SD mm (n = 46) and ranged from 20.1 to 66.0 mm. Egg masses were observed only at Beaton Arm, Burton Creek, and Edgewood South monitoring sites (Table 7-24). Tadpoles were recorded between early May and late August and were observed each year of study, with the exception of 2009 and 2018.

Table 7-24: Presence and count rating of Columbia Spotted Frog by age class, offering evidence of reproductive activity and its magnitude, by monitoring site, and by year at Arrow Lakes Reservoir drawdown zone from 2008 to 2018. E = Egg Masses, T = Tadpoles, M = Metamorphs. Count rating: X = low (1), X = moderate (2-100), <u>X</u> = high (>100).

<table>
<tr><th rowspan="3">Monitoring Site</th><th colspan="21">Presence</th></tr>
<tr><th colspan="3">'08</th><th colspan="3">'09</th><th colspan="3">'10</th><th colspan="3">'12</th><th colspan="3">'14</th><th colspan="3">'16</th><th colspan="3">'18</th></tr>
<tr><th>E</th><th>T</th><th>M</th><th>E</th><th>T</th><th>M</th><th>E</th><th>T</th><th>M</th><th>E</th><th>T</th><th>M</th><th>E</th><th>T</th><th>M</th><th>E</th><th>T</th><th>M</th><th>E</th><th>T</th><th>M</th></tr>
<tr><td>Airport Marsh</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>X</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Beaton Arm</td><td></td><td></td><td></td><td></td><td></td><td></td><td>X</td><td></td><td></td><td></td><td></td><td></td><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Burton Creek</td><td></td><td>X</td><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>X</td><td></td><td></td></tr>
<tr><td>Cartier Bay</td><td></td><td>X</td><td>X</td><td></td><td></td><td></td><td></td><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Edgewood South</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>X</td><td></td><td></td><td><u>X</u></td><td></td><td></td><td></td><td></td><td>X</td><td></td><td></td></tr>
</table>

Nocturnal call surveys documented large breeding choruses of Pacific Chorus Frogs in Revelstoke Reach (Airport Marsh, Cartier Bay, Montana Slough) in all CLBMON-37 years (see Appendix 3 for further details). We did not observe any Pacific Chorus Frogs engaged in amplexus over the course of the study. We recorded Pacific Chorus Frog egg masses once at Montana Slough and Airport Marsh, and twice at Lower Inonoaklin and Cartier Bay. We observed tadpoles at both Edgewood sites and Lower Inonoaklin and detected only a single metamorph chorus frog (located at 12 Mile).

Cartier Bay was the most productive site for Long-toed Salamanders, documented by both egg masses and early spring moving adults. Most individuals observed at Arrow Lakes Reservoir were adults found crossing the road upland from the drawdown zone at Revelstoke Reach.

Reptiles

At Arrow Lakes Reservoir, we captured and measured a total of 177 Common Garter Snakes (mean = 480.8 ± 145.8 SD mm SVL; range = 160-835 mm) and 125 Western Terrestrial Garter Snakes (mean = 417.3 ± 101.9 SD mm SVL; range = 160-650 mm) of various age and size classes in the drawdown zone from 2008 to 2018. The average sex ratio (male:female) for Common Garter Snake at Arrow Lakes Reservoir was 0.8:1 (i.e., generally fewer males were observed than females; Table 7-25).

Table 7-25: Number of Male and Female Common Garter Snake (THSI) observed at Arrow Lakes Reservoir drawdown zone from 2008 to 2018. Quotient = Number of Male THSI/Number of Female THSI. Ratio = Number of Male THSI:1 Female THSI.

	Number of THSI			
Year	Male	Female	Quotient	Ratio
2008	11	20	0.55	0.55:1
2009	10	7	1.43	1.43:1
2010	36	28	1.29	1.29:1
2012	6	6	1.00	1:1
2014	4	5	0.80	0.8:1
2016	3	23	0.13	0.13:1
2018	4	3	1.33	1.33:1
Average	11	13	0.80	0.8:1

We observed gravid females of Common Garter Snake, Western Terrestrial Garter Snake, and Northern Alligator Lizard in the drawdown zone of Arrow Lakes Reservoir. We estimated mean clutch size as 8.3 ± 4.4 SD eggs (range = 1-16 eggs, n = 31) for Common Garter Snakes and 7.6 ± 2.2 SD eggs (range = 3-11 eggs, n = 18) for Western Terrestrial Garter Snakes. Gravid Common Garter Snakes ranged in size from 420 to 835 mm SVL (mean SVL = 616 ± 111 SD mm) whereas Western Terrestrial Garter Snakes ranged from 160 to 590 mm SVL (mean SVL = 502 ± 92 SD mm). Neonate individuals were observed in the drawdown zone for Western Painted Turtle, Western Terrestrial Garter Snake, and Common Garter Snake.

Adult and juvenile Western Skink were observed at Edgewood, but no nest sites, neonates, or reproductive behaviours were observed.

Discussion

Data collected over the 11 years indicated that four amphibian species (Western Toad, Columbia Spotted Frog, Long-toed Salamander, and Pacific Chorus Frog [Arrow Lakes Reservoir only]) used habitats in the drawdown zones for breeding and we observed most life stages for most species (eggs, tadpoles/larvae, metamorphs, subadults, and adults). Qualitatively, it appeared that the productivity of both Western Toad and Columbia Spotted Frog was consistent between years, as egg masses and adults were repeatedly detected at the same ponds each year. Annual variation in amphibian breeding was not expected to be high between or across the years; however, there were a couple of years of early breeding (end of April 2016) and early inundation (June 2012) that may have affected abundance and productivity.

Too few data exist for the other species of amphibian (Long-toad Salamander, Pacific Chorus Frog) to extensively discuss reproduction within the drawdown zone and how reservoir operations might affect their productivity. Coeur d'Alene Salamander were not observed in the drawdown zone nor were they expected to be breeding in the drawdown zone, therefore, their reproduction was not assessed.

Reptile productivity was difficult to measure in our study due to small sample sizes; however, the observations of gravid individuals in the drawdown zones of both reservoirs indicated that they were utilizing these habitats during the reproductive period. Determination of clutch size in female garter snakes was only completed for some captures due to 1) difficultly in accurately determining number of eggs early in development, and 2) differences in observer skills (i.e., experience is required to accurately conduct egg counts). Estimated clutch size did not vary considerably between garter snake species or reservoirs, though these comparisons were based on relatively few individuals. Gravid female snakes were not necessarily using the drawdown zone in the same way that foraging, nongravid snakes were, because females generally do not feed as frequently during pregnancy (Tuttle and Gregory 2009). Although neonate snakes were observed in the drawdown zone, it was unclear whether the snakes were born in the drawdown zone or had moved into the drawdown zone from upland parturition sites.

Appendix 7: Analysis of amphibian population health (body condition)

Introduction

We inferred the health of amphibian populations through an assessment of body condition, which can be affected by changes in the environment. These data could 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.

Methods

We assessed body condition as a proxy for amphibian population health. We used amphibian body length and body mass data that were gathered during visual encounter surveys (VES, see Sampling Methodology section). Snout-urostyle lengths (SUL) were measured with a folding ruler and masses were taken with Pesola spring scales.

Datasets

Amphibian morphometric data from Dataset 4 (Life History Data) were used to assess body condition. Tadpole and metamorph amphibians were rarely measured in the field, so our analysis of body condition is based only on observations of adults. Only Western Toad and Columbia Spotted Frog at Kinbasket Reservoir were considered for this analysis; other species had too few data. Due to the low numbers of Western Toad and Columbia Spotted Frog collected and measured in the drawdown zone of Arrow Lakes Reservoir, the same assessment conducted for Kinbasket Reservoir could not be done for Arrow Lakes Reservoir.

Analysis

Linear regressions were conducted for male and female Western Toad at Kinbasket Reservoir. Analysis of covariance (ANCOVA) was used to investigate the relationship between mass (response variable) and snout-urostyle length by year (predictor variables) for male and female Western Toad.

Results

Kinbasket Reservoir

For male and female Western Toads there was a significant effect of length on their body mass ($p < 0.0001$ for male and females, respectively). The year-length interaction term was not significant for either sex, meaning that the slope of mass vs. snout-urostyle length did not vary significantly among years (Figure 7-7, Table 7-26). Western Toad capture data from 2017 and 2018 are not included in Figure 7-7 due to small sample sizes of female toads.

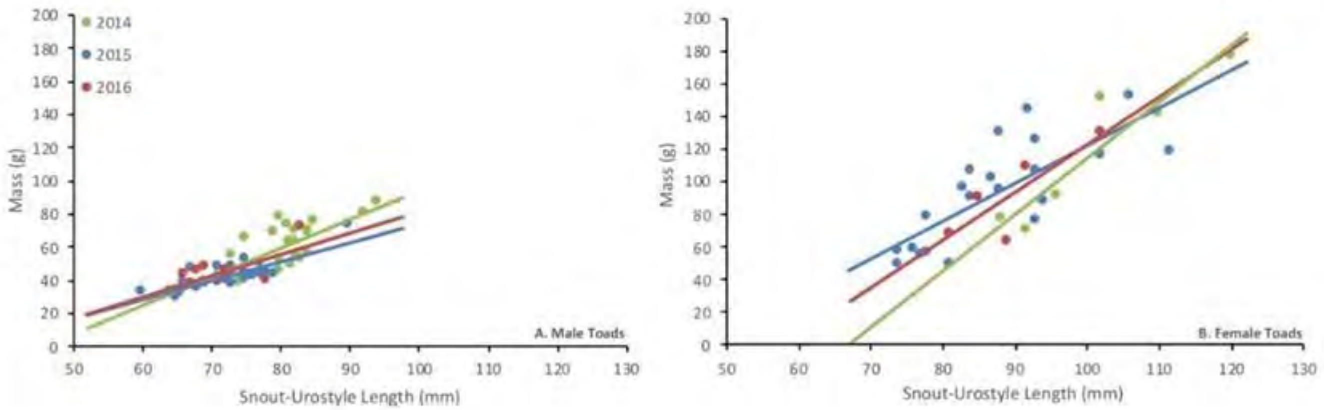


Figure 7-7: Relationship between snout-urostyle length (mm) and body mass (g) for adult male and female Western Toad captured in the drawdown zone of Kinbasket Reservoir 2014, 2015, and 2016. Western Toad capture data from 2017 and 2018 are not included due to small sample sizes of female toads.

Table 7-26: Body size ranges and linear regression coefficients for Western Toad (ANBO) and Columbia Spotted Frog (RALU) at Kinbasket Reservoir. '-' indicates no data or undefined; SUL = snout-urostyle length.

				SUL (mm)		Mass (g)				
Species	**Year**	**Sex**	**N**	**Min**	**Max**	**Min**	**Max**	**R^2**	**Slope**	**Int**
ANBO	2014	Female	6	88.2	120	71.1	178	0.86	3.43	-229
	2014	Male	23	65	94	34	87	0.56	1.72	-78
	2015	Female	21	74	111.5	49.25	152.75	0.58	2.31	-109
	2015	Male	30	60	90	29.75	72.75	0.65	1.14	-40
	2016	Female	5	81	102	63.75	130.25	0.68	2.92	-170
	2016	Male	11	66	83	37.25	71.5	0.46	1.28	-47
	2017	Female	2	81.5	89	76	92	1.00	2.13	-97.9
	2017	Male	32	61.7	91.2	24.5	82	0.46	1.23	-41
	2018	Female	2	88	88	81	93	-	-	-
	2018	Male	9	65	77.5	39	68	0.19	0.89	-7
RALU	2014	Female	0	-	-	-	-	-	-	-
	2014	Male	1	-	-	-	-	-	-	-
	2015	Female	26	61	78	24	53	0.34	0.99	-29
	2015	Male	0	-	-	-	-	-	-	-
	2016	Female	8	61	75	23.75	52.25	0.74	1.82	-88
	2016	Male	19	42	58	6.75	21.5	0.76	0.72	-22
	2017	Female	16	52	71	20.75	48.5	0.57	1.15	-43
	2017	Male	22	39	65.3	6.75	30	0.72	0.74	-22
	2018	Female	6	52.8	57.5	15.5	24	0.18	0.75	-20
	2018	Male	4	44.1	60.9	11.5	25	0.88	0.84	-27

Arrow Lakes Reservoir

Morphometric data collected in 2014, 2016, and 2018 at Arrow Lakes Reservoir are summarized in Table 7-27.

Table 7-27: Body size ranges for Western Toad (ANBO) and Columbia Spotted Frog (RALU) at Arrow Lakes Reservoir drawdown zone. '-' indicates no data; SUL = snout-urostyle length.

				SUL (mm)		Mass (g)	
Species	**Year**	**Sex**	**N**	**Min**	**Max**	**Min**	**Max**
ANBO	2014	Female	2	87.2	88.2	68.7	71
	2014	Male	12	61	88	35	76
	2016	Female	0	-	-	-	-
	2016	Male	8	64.1	95.3	43	136
	2018	Female	4	82.8	106	68	133
	2018	Male	8	60.1	76.7	39	59
RALU	2014	Female	0	-	-	-	-
	2014	Male	0	-	-	-	-
	2016	Female	0	-	-	-	-
	2016	Male	2	56.1	58	16	23.75
	2018	Female	2	41.3	48	8	9
	2018	Male	1	48.1	48.1	13.5	13.5

Discussion

The results suggest that the health of male and female toads sampled each year were similar (i.e., the relationship between mass and length did not vary from year to year). From this we conclude that the toad populations sampled in the drawdown zone of Kinbasket Reservoir were of equivalent health in the years considered for this analysis.

Unfortunately, we do not have similar data from non-drawdown zone habitats to comment on the general health of amphibians using the drawdown zone of hydroelectric reservoirs versus those that do not (and use natural habitats). Further, the limited number of observations from Arrow Lakes Reservoir and for Columbia Spotted Frog precluded similar analyses. However, a review of the data in Table 7-27 suggests that toads and frogs had comparable mass in different years.

Appendix 8: Analysis of radio telemetry data

Introduction

The detailed utilization of the Kinbasket and Arrow Lakes Reservoir drawdown zones by Western Toads and Common Garter Snakes was assessed with the observations of radio-tracked individuals. Of particular interest was the location of overwintering sites and if any occur in the drawdown zones of either reservoir. This section assisted in answering Management Question 3 (see Section 5.0). We used radio telemetry to determine amphibian and garter snake movements and utilization of the drawdown zones of Kinbasket and Arrow Lakes Reservoirs.

Methods

We used radio telemetry to determine amphibian and garter snake movements and utilization of the drawdown zones of Kinbasket and Arrow Lakes Reservoirs. A pilot radio telemetry study occurred in 2014 at Revelstoke Reach and Valemount Peatland (Hawkes et al. 2015), followed by additional work only at Valemount Peatland in 2015, 2016, and 2017 (Hawkes and Tuttle 2016a; Hawkes et al. 2017; Hawkes et al. 2018b; McAllister 2018). See Table 4-3 in Dataset 5 (Radio Telemetry) for sample sizes of each species by year and by site.

In 2014 and 2015, Adult Western Toad and Common Garter Snake were captured (May to July) and fitted with external radio transmitters (Holohil BD-2 for toads and PD-2 for snakes) and released at the site of capture. In 2015, a pilot to assess the utility of radio telemetry for Columbia Spotted Frog was also undertaken, using the same type of transmitters as for toads. We tracked the movements of individuals during the active season (May through August) to determine the use of the drawdown zone by these species. Transmitters had a life expectancy of 4 to 6 months and weighed no more than 5 percent of the mass of each individual (Millspaugh and Marzluff 2001; Jepsen et al. 2003). Transmitters were attached to toads and frogs following the techniques described in Burow et al. (2012) and to snakes using the body method described in Wylie et al. (2011).

Figure 7-8: 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.

To assess transmitter fit, animals were tracked daily for up to three days following the initial application of a transmitter to visually inspect transmitters and monitor the behaviour of the animal (exhibiting appropriate thermoregulatory and antipredator responses). 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.

The 2014 and 2015 telemetry sessions proved that external radio transmitters were not suitable for tracking individuals over long periods of time, as required to locate overwintering sites, as transmitters were dropped frequently by toads, frogs, and snakes (each time a snake shed its skin). Therefore, in 2016 and 2017, as part of a University of Victoria graduate student project, radio-transmitters were surgically implanted in the body cavity of adult female Common Garter Snakes by veterinarians to locate overwintering sites and gather greater detail of seasonal habitat use. Surgical procedures followed methods described in Reinert and Cundall (1982), with a few modifications (Wilson 2013). For greater detail of the surgical methods, post-surgery recovery procedures, and a description of the radio-tracked snakes see the methods section in McAllister (2018). Radio-tracking was conducted from May to October in 2016, with one additional session in mid-December 2016 to confirm the use of presumed overwintering sites. In 2017, telemetry took place from April to the end of August.

Datasets

Observations from Dataset 5 (Radio Telemetry) were used to assess the utilization of the drawdown zone by adult Western Toad, Columbia Spotted Frog, and Common Garter Snake.

Analysis

Radio telemetry observations were summarized to describe the timing and location of breeding, foraging, and overwintering for Western Toads, Columbia Spotted Frogs, and Common Garter Snakes. Radio telemetry was also useful in providing information on the movement patterns of these animals, which were calculated as the distance (m) an individual moved since the previous location. Approximate home ranges were calculated using 90% kernel density estimation.

Results

<u>Kinbasket Reservoir</u>

Western Toad

Most toads selected for radio telemetry were initially captured in the drawdown zone during the breeding period in early spring. Toads stayed in the drawdown zone at Valemount Peatland for two to three weeks and following breeding, many (12 of 26 toads) were tracked moving to adjacent upland (i.e., non-drawdown zone) summer and fall habitat.

Figure 7-9: 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.

Columbia Spotted Frog

Of the two Columbia Spotted Frogs tagged in June 2015, one was re-located and tracked for over two weeks (94 m over 7 locations) whereas the other dropped its transmitter before relocation could occur (transmitter retrieved 10 m from deployment location). The two weeks of tracking showed that the frog remained in the drawdown zone at the same pond.

Common Garter Snake

In 2014, 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 mASL; Hawkes et al. 2015). In 2015, Common Garter Snake moved an average of 7.8 m per day. One individual was captured ~700 m upland from the drawdown zone early in the spring and was then tracked to the higher elevations of the drawdown zone. In 2016, the average daily distances travelled were similar among individuals (range = 29 to 48 m, mean = 38 m, n = 4 snakes); however, when the total successive distance moved was observed, a greater range was observed among snakes, with differences exceeding one kilometer in some cases (range = 2174 to 3682 m). Snakes were actively tracked between 71 and 97 days (mean = 80 days) before reaching their overwintering locations. The onset of overwintering behaviour was estimated to be between September 16th and October 4th. All four snakes tagged in the drawdown zone at Valemount Peatland showed similar movement patterns: they all moved from the drawdown zone into upland habitat (Figure 7-10). The final overwintering locations of the four individuals were in proximity to one another (average = 296 m, range = 18 to 551 m; Figure 7-11) and much of their home ranges overlapped (Figure 7-10). In 2017, the average daily distances travelled varied among radio-tagged snakes (range = 23 to 64 m, mean = 44 m, n = 7 snakes). The total successive distance moved was more varied than total movements calculated in 2016, with differences exceeding a few kilometers (range = 667 to 5894 m, mean = 3263 m). Snakes were actively tracked between 28 and 153 days (mean = 95 days).

Figure 7-10: Examples of successive movements by tagged female Common Garter Snakes in Canoe Reach, Valemount Peatland 2016. Dates indicate location dates. Vectors indicate presumed (straight-line) direction of movement. The green polygon is the 90% kernel density estimation used to calculate home range.

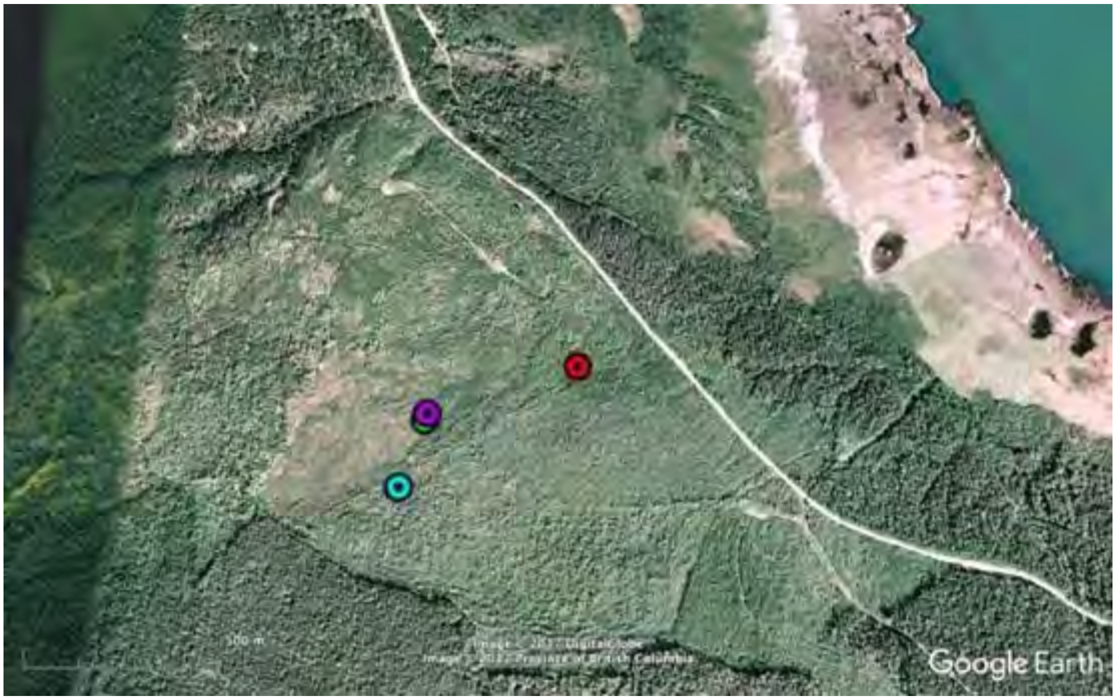


Figure 7-11: Locations of hibernacula (n = 4) used by adult female Common Garter Snakes at Kinbasket Reservoir during the winter of 2016 (October 2016 to April 2017).

Table 7-28: Summary of radio telemetry activities (movement distances and tracking period) for Common Garter Snakes near or in the drawdown zone of Kinbasket Reservoir at Valemount Peatland from 2016 to 2017. '*' indicates the individual was tracked in 2016 and 2017.

		Daily Movement (m)				Total	No. of	Active Tracking Period		
Year	Snake ID	Avg.	SD	Max	Min	Distance (m)	Detections	First Day	Last Day	No. of Days
2016	R11L6	39.7	42	157.3	2.5	3682.1	44	11-Jun	16-Sep	97
	R12L6	35.1	45.4	135.8	0	2674.6	31	16-Jul	26-Sep	72
	R12L7	47.7	73.9	285.8	0.5	3374.7	36	17-Jul	04-Oct	79
	R12R3	29	57.8	272.2	0	2173.9	30	21-Jul	30-Sep	71
2017	R11L6*	57.0	69.0	152.6	0	1045.5	8	11-Apr	09-May	28
	R12L6*	64.7	120.9	431.7	0	4868.8	20	11-Apr	29-Jun	79
	R12L7*	34.3	51.2	207.8	0	5893.8	37	11-Apr	11-Sep	153
	R12R3*	51.9	84.0	358.7	0	5376.3	30	11-Apr	11-Sep	153
	R12R6L5	47.4	65.0	327.1	2.5	4197	25	15-May	11-Sep	119
	R12R7L5	31.6	50.4	198.0	0	789.3	25	08-Jun	10-Sep	94
	R12R7L10	23.5	31.9	118	0	668.6	12	22-Jun	03-Aug	42

Arrow Lakes Reservoir

Western Toad

Five of the toads captured in the drawdown zone of Arrow Lakes Reservoir moved to upland habitats during the survey period and occupied summer habitat on the slopes of Mount MacKenzie or in upland habitat to the south of Cartier Bay. By May 12th some toads had already started to move out of the drawdown zone away from the breeding ponds with all toads moving out of the drawdown zone into upland habitats by May 17th or June 2nd. Some individual toads (n = 6) continued to use the drawdown zone. Examples of toad movements in the drawdown zone and out of the drawdown zone of Arrow Lakes Reservoir at Cartier Bay are shown in Figure 7-12.

Figure 7-12: 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 mASL contour. Locations above this contour are outside of the drawdown zone.

Common Garter Snakes

Garter snake movements ranged from 10.3 m to 206.7 m (mean = 108.5 m). All locations associated with these snakes (n = 2) were within in the drawdown zone, though the duration of tracking was low (mean = 2 days).

Discussion

The radio telemetry data collected in 2014 at Kinbasket and Arrow Lakes Reservoirs and 2015 at Kinbasket Reservoir suggested that Western Toad were not using the drawdown zone during the winter period and that more likely, they were overwintering in upland habitats, which is consistent with what is generally known for this species (e.g., Bull 2005; Browne and Paszkowski 2010). The proportion of toads we observed moving into upland habitat after breeding may be an under-representation of actual toad movement because several individuals dropped their transmitters too quickly to assess for the potential of migratory movements.

It is likely that most snakes were overwintering outside of the drawdown zone at Arrow Lakes Reservoir (evidenced by Valemount Peatland radio telemetry study in Kinbasket Reservoir); however, this was not directly observed in Arrow Lakes Reservoir, which may be attributed to the low sample size obtained and the short duration of tracking permitted by external transmitters. It also remained unknown whether young-of-year garter snakes overwintered in the drawdown zone of either reservoir. The hibernating sites located upland from Kinbasket Reservoir were associated only with observations of adult snakes.

A common assumption associated with radio telemetry methods is that the radio-tracked animals are not significantly impacted by either the weight of the transmitter or the frequent presence of the surveyors. Through the selection of only the largest individuals (minimizing the effect of the transmitter weight) and the high level of caution given while surveyors were tracking, it is unlikely that animal behaviour was significantly altered on account of the study.

Appendix 9: Analysis of seasonal distribution of amphibians and reptiles in the drawdown zone

Introduction

We assessed the use of the drawdown zones in Kinbasket and Arrow Lakes Reservoirs by amphibians and reptiles at various life history stages to determine the seasonal distribution for species from 2008 to 2018. This section assists in answering Management Question 3 relating to life history activities within the drawdown zone and Management Question 5 how reservoir operations influence use by life history stage of amphibians and reptiles (see Section 5.0).

Methods

Visual encounter surveys were conducted across the active season (late April to October) for amphibians and reptiles to document the life history stages of species that occurred in the Kinbasket and Arrow Lakes Reservoir drawdown zones. Data used to analyze amphibian and reptile species at different life history stages were gathered during visual encounter surveys (VES) and call surveys (Datasets 1 and 2). Radio Telemetry data (Dataset 5) presented in Appendix 8 were used to describe seasonal movements towards overwintering sites, including the routes within the drawdown zone, for Common Garter Snakes in Kinbasket Reservoir and Western Toads in Arrow Lakes Reservoir.

Datasets

Observations from Dataset 1 (Visual Encounter Data), Dataset 2 (Call Station Data), Dataset 4 (Life History Data), and Dataset 5 (Radio Telemetry Data) were used to summarize the utilization of the Kinbasket and Arrow Lakes Reservoir drawdown zones by various life history stages of amphibian and reptile species.

Analysis

Observations of amphibians and reptiles in the drawdown zones were summarized for each reservoir, by species, age class, and season.

Results

<u>Kinbasket Reservoir</u>

Amphibians

Western Toad egg masses were observed in the drawdown zone between late April and early June, whereas toad tadpoles and juveniles were detected towards the end of August, with the greatest catch of tadpoles occurring in late June. Adult Western Toad were found in the drawdown zone throughout the active season (April to September) but most observations were made during the spring breeding period (Figure 7-13).

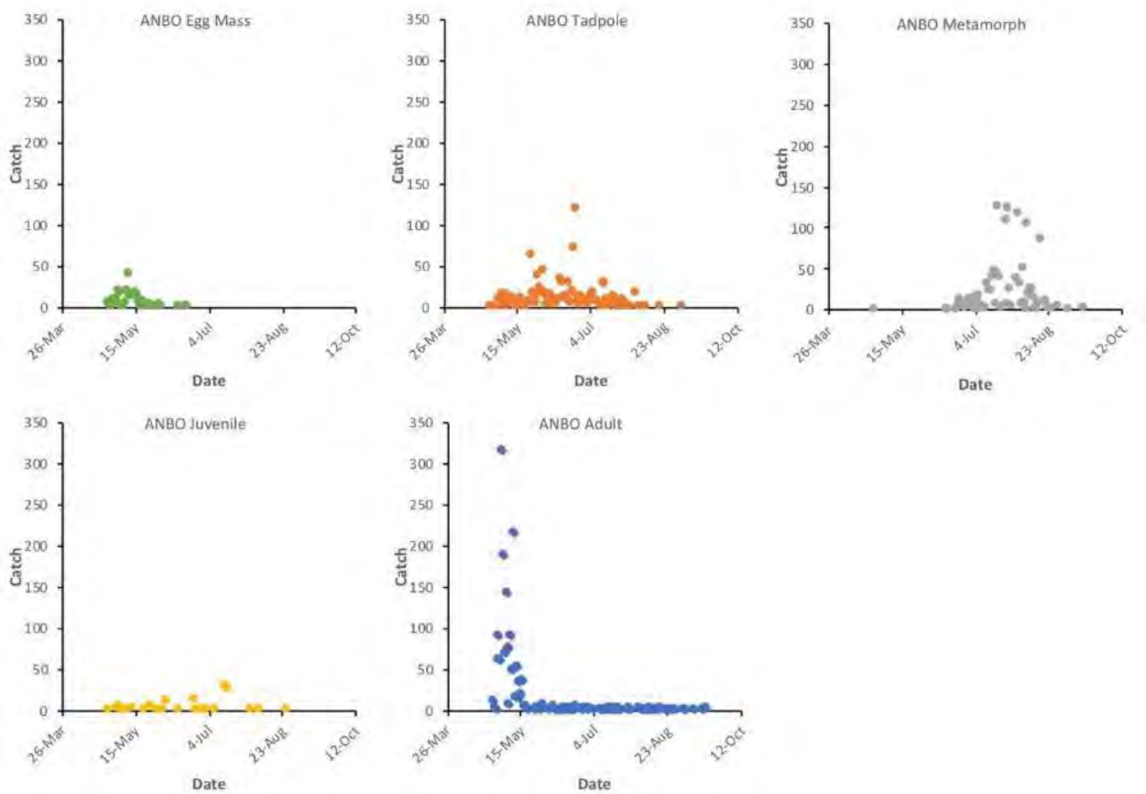


Figure 7-13: Seasonal distribution of daily catch for Western Toad (ANBO) life stages in the drawdown zone of Kinbasket Reservoir (all years pooled).

Columbia Spotted Frog egg masses were observed in the drawdown zone between late April and late May. Tadpoles were detected from early May to late August, with the greatest catch of tadpoles occurring in early July. Most observations of metamorph frogs were between early July and late August (Figure 7-14). Juvenile and adult Columbia Spotted Frogs were found in the drawdown zone throughout the active season (April to September) and observations were more evenly distributed compared to Western Toads.

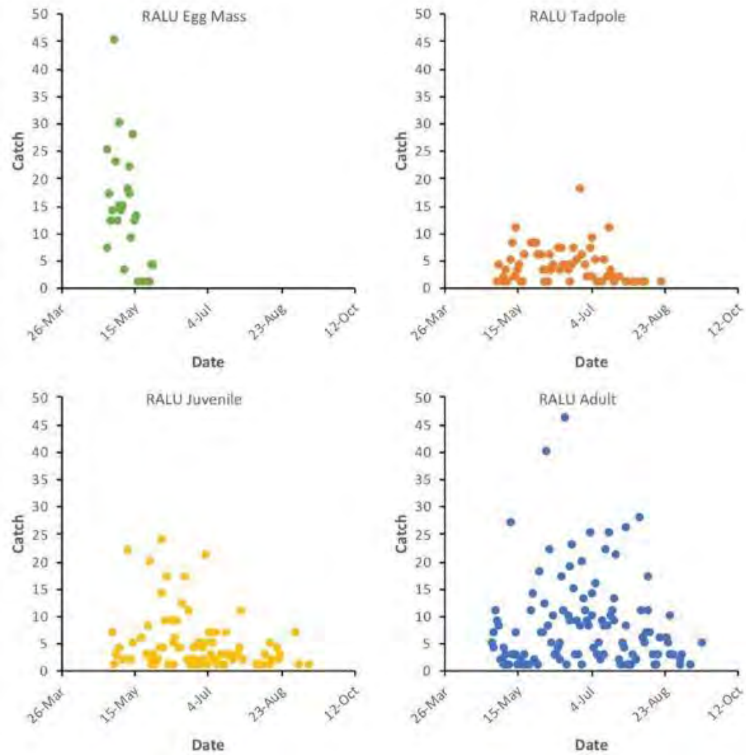


Figure 7-14: Seasonal distribution of daily catch for Columbia Spotted Frog (RALU) life stages in the drawdown zone of Kinbasket Reservoir (all years pooled).

Reptiles

Although three species of reptiles were observed in the drawdown zone, only one species (Common Garter Snake) was documented on a regular basis. Few Western Terrestrial Garter Snake juveniles and adults were observed in the Kinbasket Reservoir drawdown zone, and no neonates of this species were detected (Figure 7-15). Only one observation of Western Painted Turtle was made over the 11 years of study in Kinbasket Reservoir.

Neonate Common Garter Snakes were observed in the drawdown zone between early August and mid-September (Figure 7-16), but it is unknown if birthing occurred there. Several recent observations of snakes giving birth occurred in upland habitats near the Valemount Peatland, but no such observations occurred in the drawdown zone.

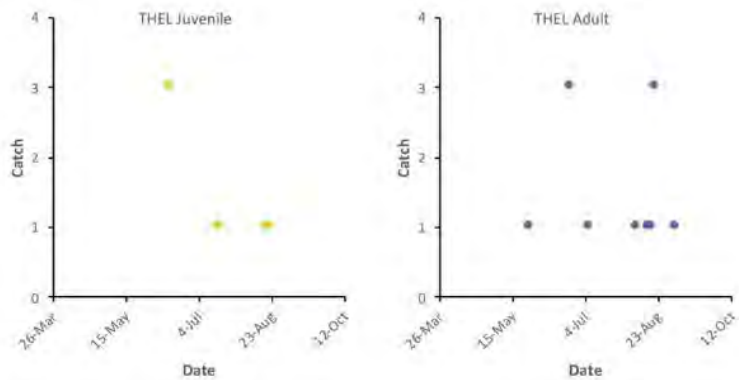


Figure 7-15: Seasonal distribution of daily catch for Western Terrestrial Garter Snake (THEL) in various life stages in the drawdown zone of Kinbasket Reservoir (all years pooled).

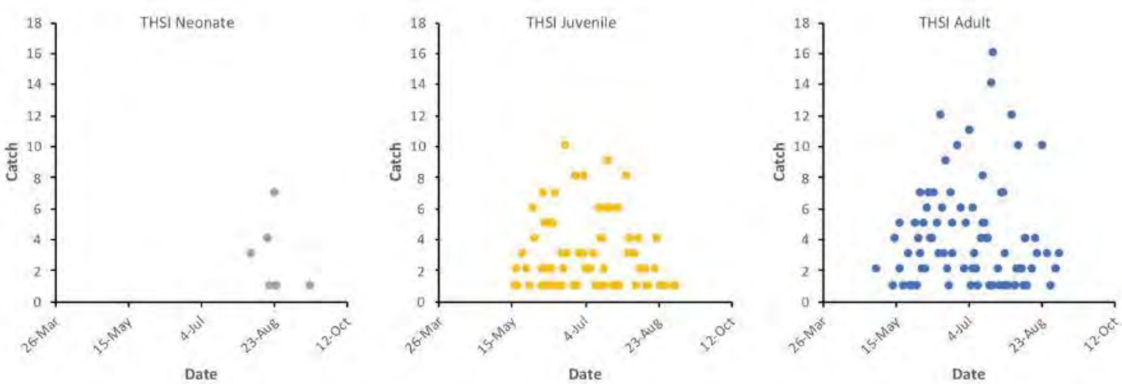


Figure 7-16: Seasonal distribution of daily catch for Common Garter Snake (THSI) in various life stages in the drawdown zone of Kinbasket Reservoir (all years pooled).

Of the 470 snake captures, 169 (4 neonates, 49 juveniles, and 116 adults, with equal numbers of males and females) were observed actively consuming prey or with detectable prey in their gut. Most of these observations in the Kinbasket Reservoir drawdown zone were in June (n = 46) and July (n = 78). Amphibians (adults, metamorphs, tadpoles) were recorded as the most common prey type for garter snakes in the drawdown zone, however, prey were not always identified to species.

Arrow Lakes Reservoir

Amphibians

Western Toads used the drawdown zone at different times during the active season (April through September), depending on their stage of development. Western Toad egg masses and juveniles were observed in the drawdown zone between late April and early June. Tadpoles and metamorph toads were detected from late April to mid-September, with the greatest number of tadpoles occurring in June and July. Adult Western Toads were found in the drawdown zone throughout the active season (April to September) but most were observed during the spring breeding period (Figure 7-17). In all years of study, we documented adult toads breeding at the same sites (e.g., Revelstoke Reach, Beaton Arm, and

Burton Creek) and individuals migrating to and from certain ponds from late April to late June (e.g., Cartier Bay, Montana Slough, and Burton Creek). Metamorph toads were also documented emerging from the same drawdown zone sites (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.

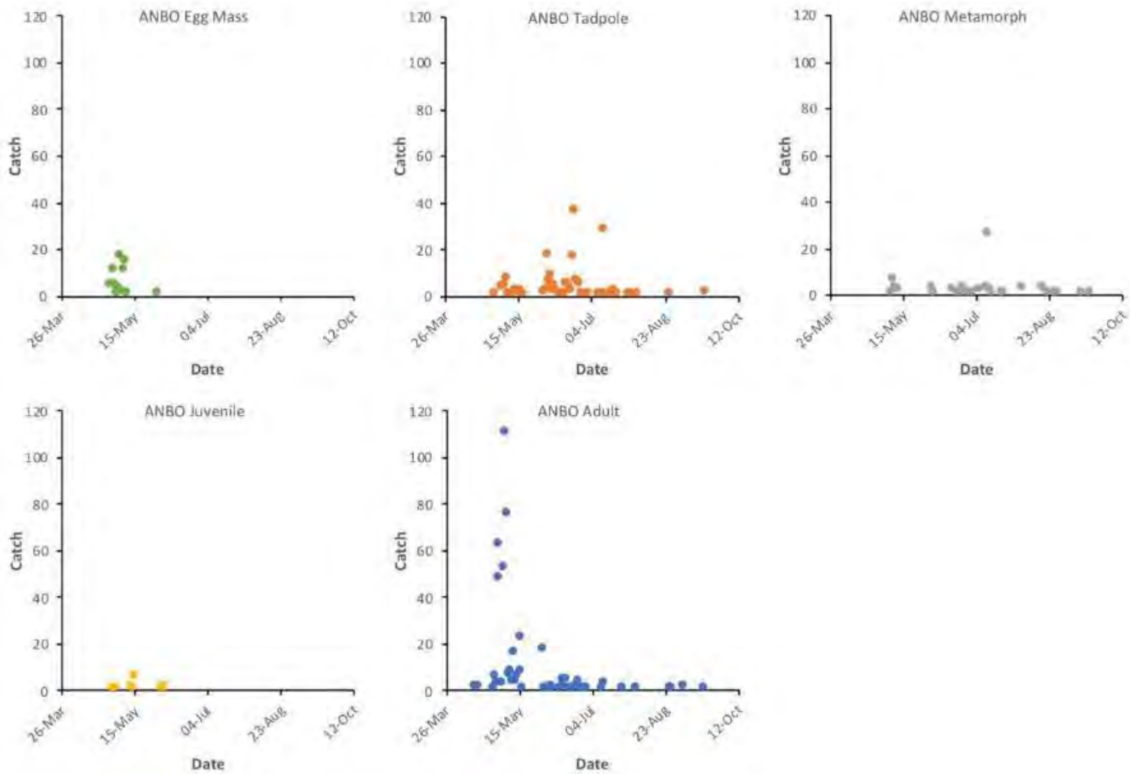


Figure 7-17: Seasonal distribution of daily catch for Western Toad (ANBO) in various life stages in the drawdown zone of Arrow Lakes Reservoir (all years pooled).

Few Columbia Spotted Frog egg masses were observed in the Arrow Lakes Reservoir drawdown zone. Tadpoles were detected from early May to late August, with most observations occurring in June. Metamorph frogs were observed only in early September (Figure 7-18). Juvenile and adult Columbia Spotted Frogs were found in the drawdown zone throughout the active season (April to September) and observations were more evenly distributed in frequency compared to Western Toads.

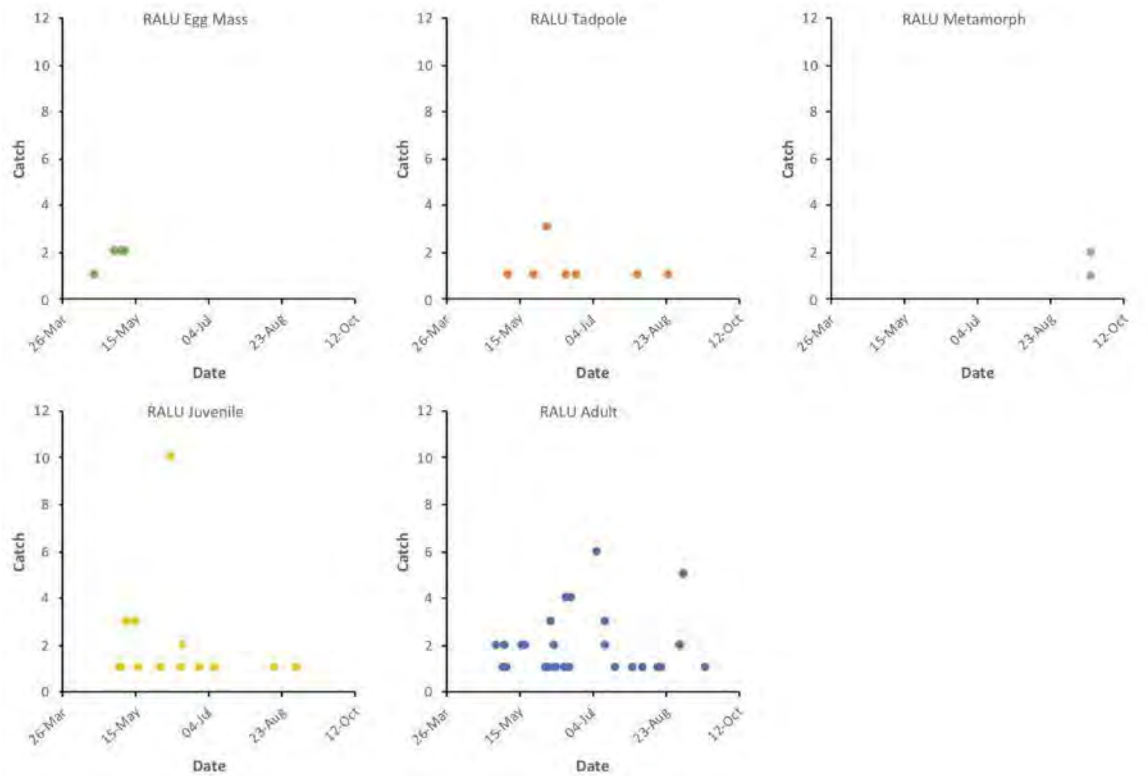


Figure 7-18: Seasonal distribution of catch of Columbia Spotted Frog (RALU) in various life stages in the drawdown zone of Arrow Lakes Reservoir (all years pooled).

Pacific Chorus Frog egg masses were detected in the drawdown zone in early May and tadpoles were observed from late April to mid-June. Only one metamorph and one juvenile Pacific Chorus Frog were detected in the drawdown zone throughout the course of the study. Adults were observed at a much higher frequency throughout the active season, with a marked peak in early spring (Figure 7-19).

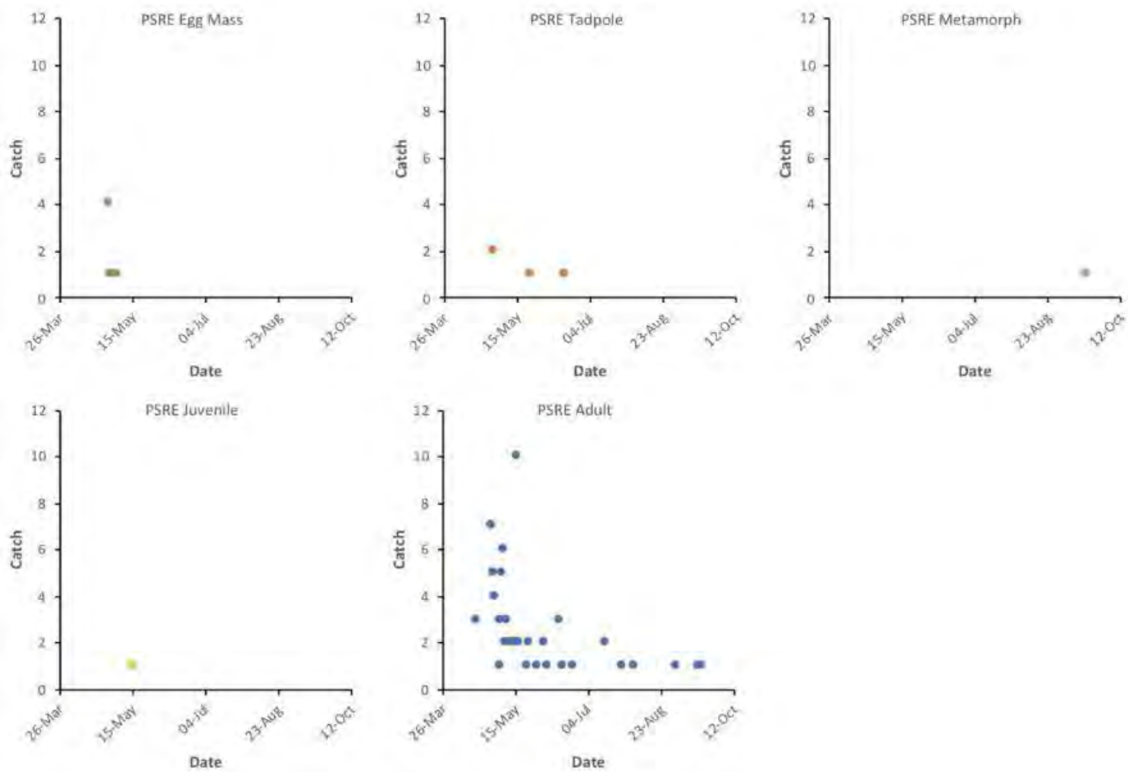


Figure 7-19: Seasonal distribution of catch of Pacific Chorus Frog (PSRE) in various life stages in the drawdown zone of Arrow Lakes Reservoir (all years pooled).

Reptiles

Neonate, juvenile, and adult Western Painted Turtles were observed in the drawdown zone, primarily at Montana Slough and Airport Marsh. Western Painted Turtles utilized the drawdown zone of Arrow Lakes Reservoir for foraging and overwintering, though breeding does not take place in the drawdown zone. For more detailed information on their use of the drawdown zone see CLBMON-11B3 reports (e.g., Wood et al. 2016).

Neonates of both garter snake species were observed in the Arrow Lakes Reservoir drawdown zone in late August to mid-September (with one exception, a neonate Western Terrestrial Garter Snake on June 17th; Figure 7-21). However, it is currently unknown if birthing occurs in the drawdown zone. Juvenile and adult garter snakes were observed more frequently than neonate snakes and were detected throughout the active season.

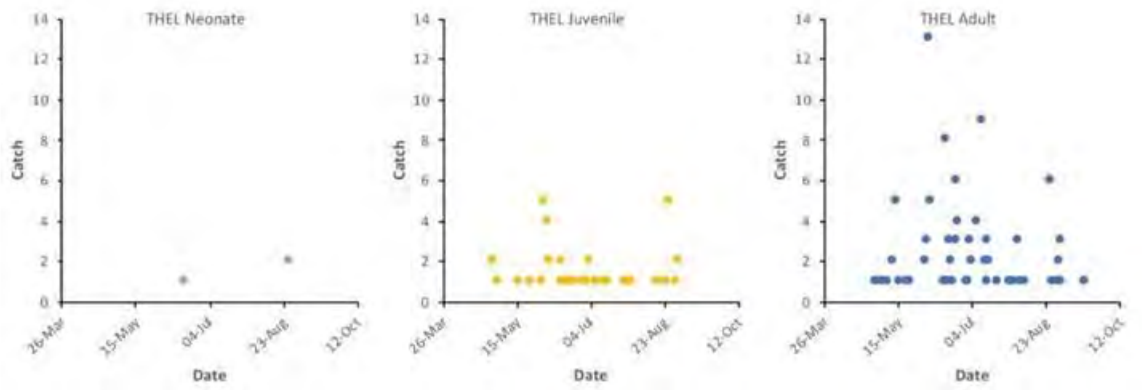


Figure 7-20: Seasonal distribution of daily catch for Western Terrestrial Garter Snake (THEL) in various life stages in the drawdown zone of Arrow Lakes Reservoir (all years pooled).

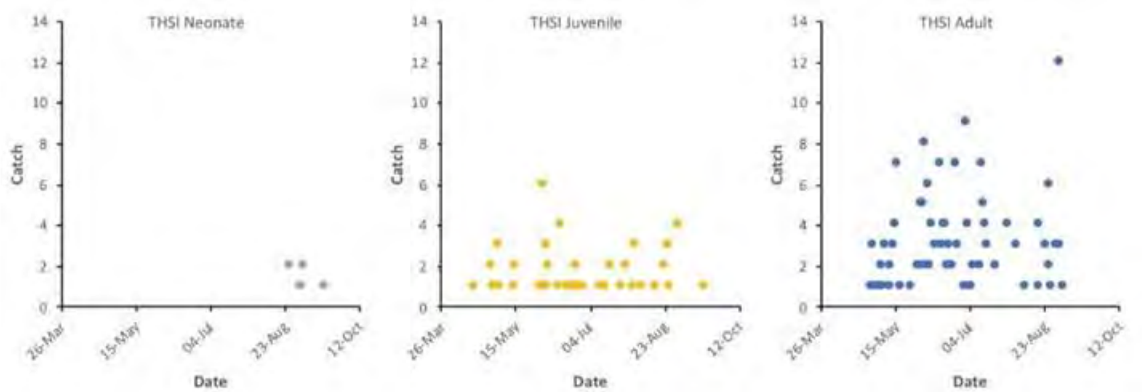


Figure 7-21: Seasonal distribution of daily catch for Common Garter Snake (THSI) in various life stages in the drawdown zone of Arrow Lakes Reservoir (all years pooled).

Of the 446 snake captures in the drawdown zone of Arrow Lakes Reservoir, 56 (3 neonates, 6 juveniles, and 47 adults, including twice as many females as males) were observed actively consuming prey or had detectable prey in their gut. Most of these observations occurred in June (n = 23). Amphibians and small mammals were recorded as prey species consumed by snakes in the drawdown zone of Arrow Lakes Reservoir.

Discussion

Our current understanding of the use of the drawdown zones by amphibians and reptiles is that certain species used the drawdown zones to fulfill most of their life history stages (e.g., Columbia Spotted Frog), while others (e.g., Western Toad, garter snakes, Western Painted Turtle) appeared to use the drawdown zones to fulfill specific stages.

It unlikely that snakes were utilizing the drawdown zones for overwintering habitat, however they used drawdown zone habitat for foraging, and it is possible that they used it for reproduction (parturition), based on observations of neonate snakes in the drawdown zone. Garter snake courting and mating behaviours were also observed upland of Kinbasket Reservoir, near confirmed overwintering sites, and probably also occurred upland of Arrow Lakes Reservoir.

Long-toed Salamander were not always easy to detect, so their perceived lower levels of use of the drawdown zones (e.g., mainly restricted to egg mass observations) may be related to their cryptic nature and not necessarily to their absence from the drawdown zones. Coeur d'Alene Salamander have very specific habitat requirements (e.g., waterfall splash zones, small slow-moving creeks) and were never observed in the drawdown zone, nor were they expected to occur within the drawdown zone (outside chance of this species occurring at the very margins of the reservoir).

Northern Alligator Lizards were only expected to be found along the margin of the drawdown zone at sites with rocky habitat and Rubber Boa and Western Skink, being upland habitat-associated species, were only observed a few times and not expected to regularly use drawdown zone habitats.

Appendix 10: Analysis of amphibian and reptile habitat use in both reservoirs

Introduction

We examined amphibian and reptile habitat use at sites in and adjacent to the drawdown zone of Arrow Lakes and Kinbasket Reservoirs. The intent of this analysis was to determine the types of habitats being utilized by amphibian and reptile species by identifying associations to vegetation communities and the characteristics of habitats where species occur. This section assisted in answering MQ4.

Methods

Amphibian and reptile habitat use was assessed during visual encounter and radio telemetry surveys. Sampling occurred at most monitoring sites on an annual and seasonal basis to document all life stages of amphibian and reptile species and the characteristics of their habitat.

Amphibian and reptile detections at sites (monitoring and reconnaissance sites) in both reservoirs were pooled (all years and life stages) and evaluated relative to mapped vegetation community polygons (i.e., detection intersects polygons classified under CLBMON-33 in Arrow Lakes Reservoir [Miller et al. 2018b] and CLBMON-10 in Kinbasket Reservoir [Hawkes et al. 2007]) using GIS to determine vegetation community associations. Existing habitat maps produced under CLBMON-10 and CLBMON-33 (where such mapping exists) were used to define Vegetation Community Codes (VCC) and the habitat polygons were based on detailed vegetation plots that provide information on species' presence and percentage cover.

Datasets

Observations from Dataset 1 (Visual Encounter Data), and Dataset 5 (Radio Telemetry Data) were compared to Vegetation Community Codes (VCC) from Dataset 7 (Vegetation Community Habitat Data), where such mapping exists.

Analysis

Vegetation Community Habitat Associations: Observations of amphibian and reptile species of all life stages made between 736 and 764 mASL in Kinbasket Reservoir and 430 and 451 mASL in Arrow Lakes Reservoir were mapped relative to vegetation community polygons. Amphibian and reptile habitat association (implying habitat use) within the drawdown zone was summarized by comparing the elevation distribution of species to the distribution of mapped vegetation communities. We calculated the proportion of species detections within a given community type and compared the results to identify potential vegetation community associations. Species that were infrequently detected over the years and observations that did not occur within a mapped vegetation community were excluded from vegetation community association analysis.

TREE Habitat Analyses: We described the distribution of Western Toad, Columbia Spotted Frog, and Common Garter Snake occurrence in habitats of the drawdown zone of Kinbasket 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 are important for determining how complex a tree should be (e.g., how many branches should be included). Large trees generally have lower 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 (V1.6-2; De'ath 2013) in R (V3.1.2; R Core Team 2019). 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.

Results

<u>Kinbasket Reservoir</u>

Vegetation Communities: The proportion of species detections of three species of amphibian and three species of reptile varied compared to 17 vegetation community types found between ~736 and 754 mASL in the drawdown zone of Kinbasket Reservoir (Figure 7-22).

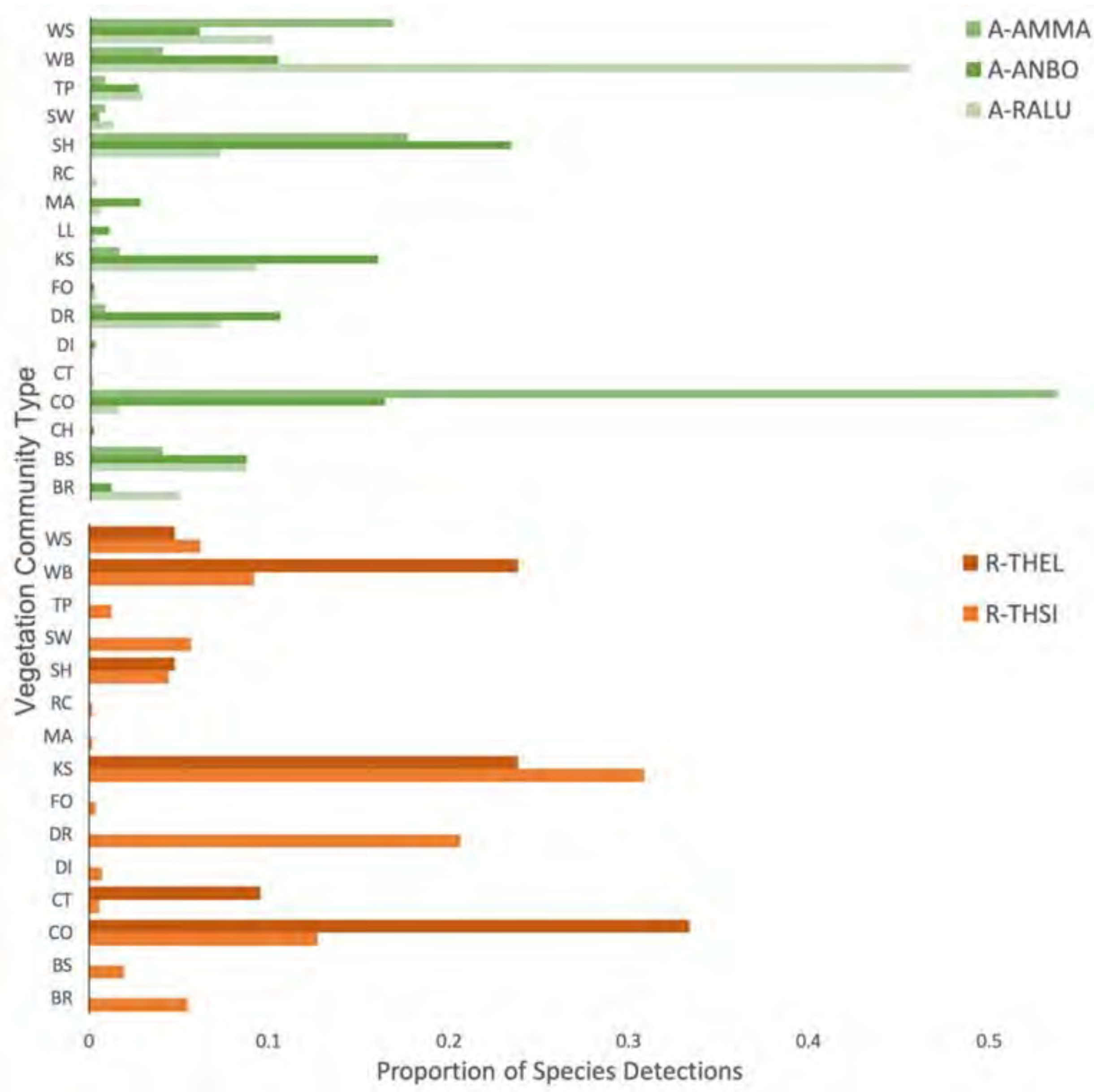


Figure 7-22: Distribution of amphibian (top) and reptile (bottom) species by Vegetation Community Type/Code in the drawdown zone of Kinbasket Reservoir between 2008-2018. A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-RALU = Columbia Spotted Frog, R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake; BR = bluejoint reedgrass, BS = buckbean-slender sedge, CH = common horsetail, CO = clover–oxeye daisy, CT = cottonwood-trifolium, DR = driftwood, FO = forest, KS = Kellogg's sedge, LL = lady's thumb-lamb's quarter, MA = marsh cudweed–annual hairgrass, SH = swamp-horsetail, SW = shrub willow, TP = toadrush-pond water starwort, WB = wool-grass–Pennsylvania buttercup, WS = willow–sedge. See Hawkes et al. (2013a) for descriptions of each habitat type.

All three amphibian species were found in multiple habitat types. The proportion of species detections per vegetation community type ranged from < 0.1 for Long-toed Salamander in multiple habitats and Columbia Spotted Frog in common horsetail (CH) to 0.536 for Long-toed Salamander in clover-oxeye daisy (CO) habitat.

Western Toad and Columbia Spotted Frog were the most generalist species, whereas Long-toed Salamander were detected in the fewest community types. Long-toed Salamander were most detected in CO and swamp-horsetail (SH) vegetation communities, respectively, and had the greatest proportion of detections in a single community type. Western Toad were most detected in SH and CO and Columbia Spotted Frog were most detected in wetter wool-grass-Pennsylvania buttercup (WB) and willow-sedge (WS) vegetation communities.

Western Terrestrial Garter Snake and Common Garter Snake were found across multiple habitat types. The proportion of species detections per vegetation community type ranged from < 0.1 for both species in multiple habitat types to 0.33 for Western Terrestrial Garter Snake in CO habitat. Common Garter Snake appeared to be the most generalist and were detected in 15 different vegetation communities, whereas Western Terrestrial Garter Snake were only detected in six community types. Common Garter Snake were most detected in Kellogg's sedge (KS) and driftwood (DR) habitat types, whereas Western Terrestrial Garter Snake were most detected in CO and KS habitat types.

The vegetation communities with the most detections of amphibian species were KS, SH, and WB, whereas reptiles were most found in CO, DR, and KS habitats. A large percentage of pond area mapped in the drawdown zone (52.7 percent; 6.2 ha) occurred in two of these vegetation communities (SH: 20.4 percent, 2.4 ha; WB: 32.3 percent, 3.8 ha). Few observations of amphibians or reptiles occurred in the toadrush-pond water starwort (TP) community despite > 10 percent of all ponds occurring there. The lack of observations is likely because the TP community typically occurs at lower elevations than the other five communities.

Tree Analyses: 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 (drawdown zone or upland), and season were not found as important variables for any species occurrences (see Hawkes et al. 2015 for full analyses by species). For Western Toad, vegetation community, pond area, site, and elevation were important determinants of occurrences in Kinbasket Reservoir (44.9% of the variance explained; relative error = 0.551, CV error = 0.795; Figure 7-23). 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 and Bear Island. At other sites, elevation further helped explain toad occurrence (4.0% of variance explained), with greater presence found at elevations lower than 746.5 mASL. 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).

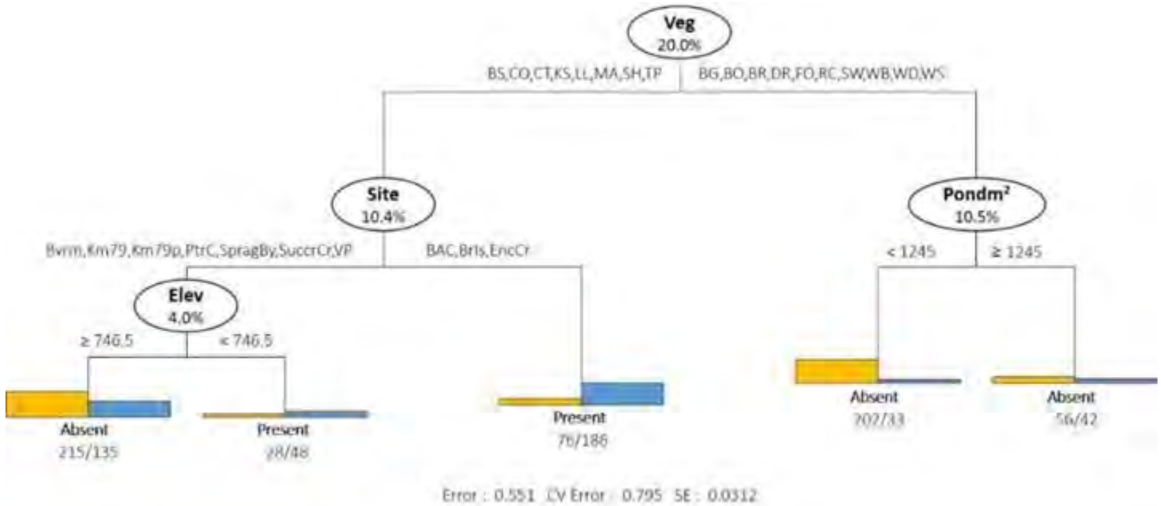


Figure 7-23: Classification tree describing the habitats occupied by Western Toads in the drawdown zone of Kinbasket Reservoir between 2013 and 2014. Major environmental determinants of toad adult and egg mass presence are given in hierarchical order at each node, with the percent of variance explained. 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 = Succour Creek, VP = Valemount Peatland.

For Columbia Spotted Frog, site, year, elevation, and vegetation community were important determinants of adult and egg mass occurrences in the drawdown zone of Kinbasket Reservoir (43.6% of the variance explained; relative error = 0.564, CV error = 0.658). Site explained 16.3% of the variation in frog presence, with most frog occurrences found at KM79 (including perched wetland), Sprague Bay (including perched wetland), and Valemount Peatland. 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 mASL. 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.

Similar to Columbia Spotted Frog, Common Garter Snake occurrence was most predicted by site and year (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.

Pond Habitats: One hundred and eighty-one ponds have been delineated across the years in the drawdown zone of Kinbasket Reservoir (Table 4-4). Pond habitat occurs between approximately 738 and 755 mASL and pond size ranged from < 0.001 ha to 0.968 ha. With the majority of ponds mapped < 0.15 ha, and overall, there was no significant relationship between pond size (area) and elevation ($F_{1,101}$ = 0.17; p= 0.89; Hawkes and Tuttle 2016). Not surprisingly, the elevation distribution of amphibian detections pairs well with the elevation distribution of ponds in the drawdown zone (Figure 7-24 [Figure 5.7 in Hawkes and Tuttle 2016a]).

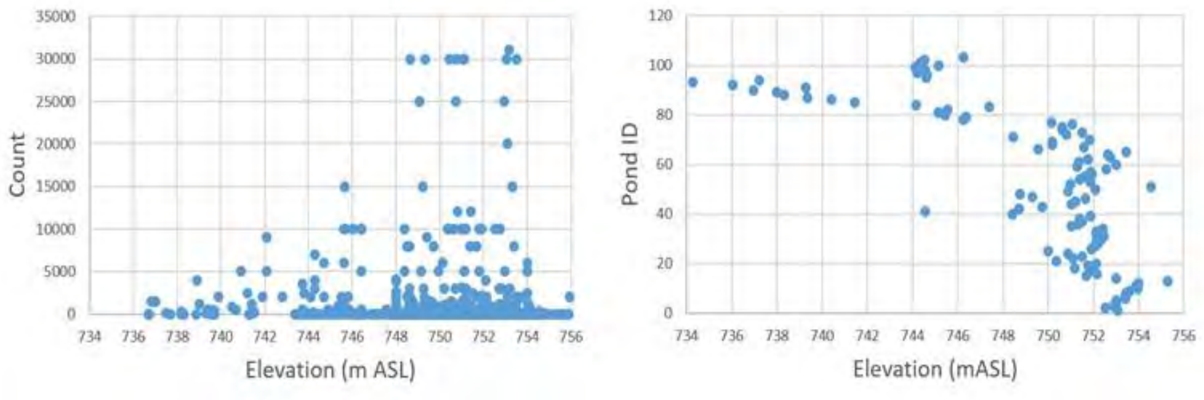


Figure 7-24: Elevation distribution of amphibians and reptiles detected in 2015 (all species pooled; left) and elevation distribution of ponds (right) in the drawdown zone of Kinbasket Reservoir.

In areas where only one or a few ponds were available (i.e., pond habitat was a limiting factor), Western Toad and Columbia Spotted Frog egg masses were often found in the same ponds. For example, egg masses of both species were found in the large pond in the drawdown zone at Ptarmigan Creek. In Valemount Peatland, where many ponds were available, Western Toad and Columbia Spotted Frog were detected together in large ponds or separately in smaller ponds (Figure 5-9). In other sites, such as KM79 and KM88 (Bear Island) where there were more ponds and a greater variety of pond types (e.g., shallow, mud-bottomed vs. deeper vegetated ponds), there was some evidence of pond partitioning between the species. At KM79 and KM88 (Bear Island), Western Toad egg strings were often documented in mud-bottomed ponds (with little vegetation) at lower elevations, whereas Columbia Spotted Frogs tended to lay their eggs in ponds with more vegetation, at higher elevations (Figure 5-10). This was especially noticeable at KM79, where each anuran species appeared to use entirely different portions of the drawdown zone for breeding. In general, amphibian breeding ponds tended to be small, shallow, and warm and often had high levels of dissolved oxygen and abundant vegetation cover at higher elevations, with the exception of several lower elevation ponds used by Western Toads at Bush Arm sites, which were devoid of vegetation.

<u>Arrow Lakes Reservoir</u>

The proportion of species detections of three species of amphibian and four species of reptile varied across the 14 vegetation community types found between ~430 and 451 mASL of Arrow Lakes Reservoir (Figure 7-25).

All three amphibian species were found in multiple habitat types. The proportion of species detections per vegetation community type ranged from < 0.1 for Pacific Chorus Frog and Columbia Spotted Frog in multiple habitat types to 0.37 for Western Toad in reed canary grass mesic (PC) habitat. Western Toad were detected in 14 different vegetation communities and were the most generalist species, whereas Pacific Chorus Frog were detected in the fewest community types. Each species had the greatest proportion of detections in the PC vegetation community type. Other vegetation community types with notable proportions include reed-rill (RR) habitat for Columbia Spotted Frog, industrial/urban/recreational (IN) habitat for Pacific Chorus Frog, and vegetation poor pond (PO) habitat for Western Toad.

All four reptile species were found in multiple habitat types. The proportion of species detections per vegetation community type ranged from < 0.1 for all species in multiple habitat types to 0.54 for Western Painted Turtle in the PC habitat. Of all reptile species found in the drawdown zone of Arrow Lakes Reservoir, Common Garter Snake appeared to be the most generalist and were detected in 13 different vegetation communities, whereas Northern Alligator Lizard and Western Terrestrial Garter Snake were detected in the fewest community types. Each species had the greatest proportion of detections in the PC vegetation community type. Other vegetation community types that included notable proportions include sandy beach (BE) habitat for Common Garter Snake, redtop upland (PA) habitat for Western Terrestrial Garter Snake, gravelly beach (BG) habitat for Northern Alligator Lizard, and PO habitat for Western Painted Turtle.

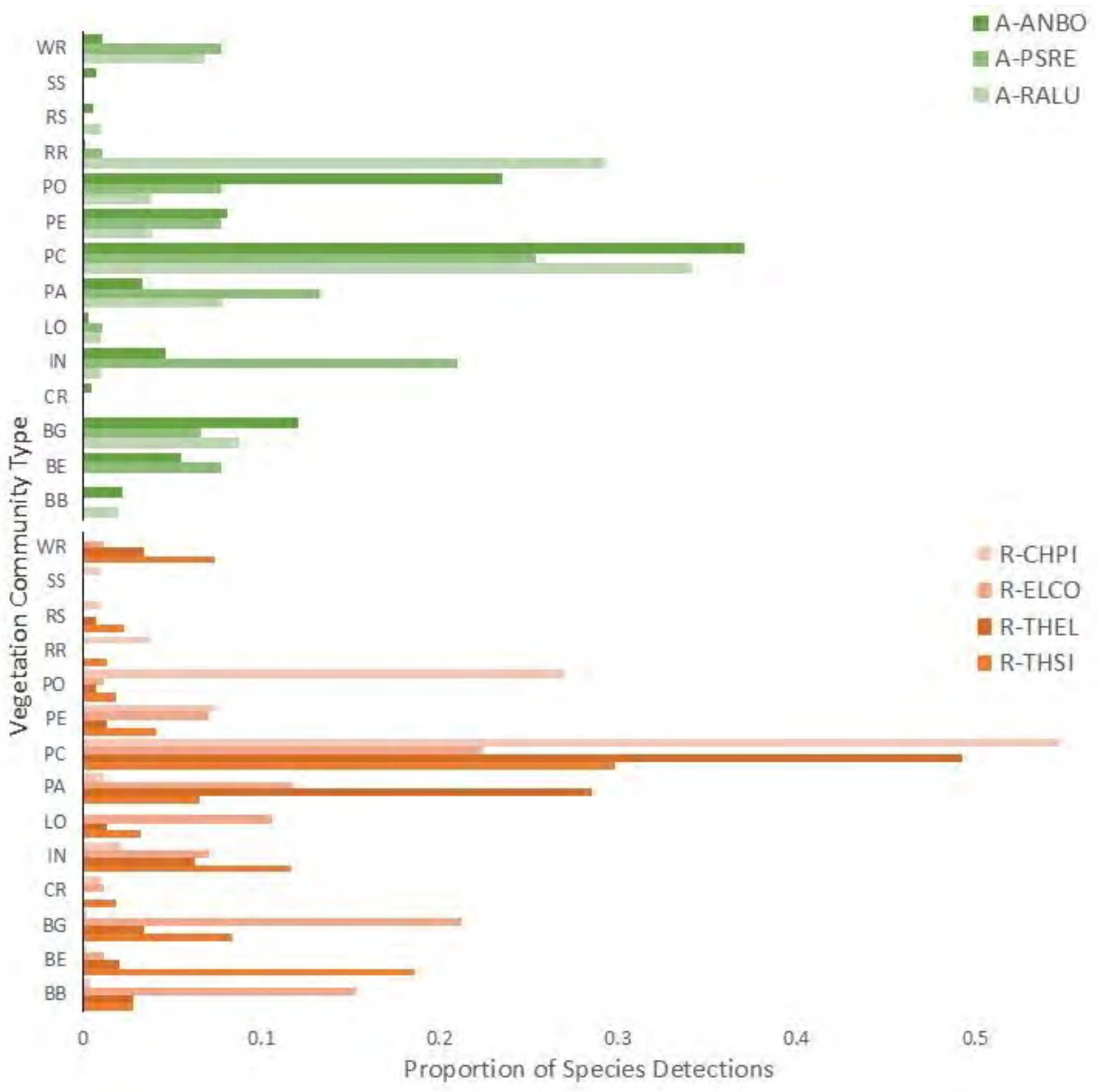


Figure 7-25: Distribution of amphibian (top) and reptile (bottom) species by Vegetation Community Type/Code in the drawdown zone of Arrow Lakes Reservoir between 2008-2018. A-ANBO = Western Toad, A-PSRE = Pacific Chorus Frog, A-RALU = Columbia Spotted Frog, R-CHPI = Western Painted Turtle, R-ELCO = Northern Alligator Lizard, R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake; BB = boulders steep, BE = sandy beach, BG = gravelly beach, CR = cottonwood-riparian, IN = industrial/residential/recreational, LO = log zone, PA = redtop upland, PC = reed canary grass mesic, PE = horsetail lowland, PO = pond, RR = reed-rill, RS = willow stream entry, WR = river entry, See Miller et al. (2018b) for descriptions of each habitat type.

Discussion

We were able to utilize data collected over the 11-year study period to describe the habitats where species were detected. The general use of habitats in the drawdown zone by amphibian and reptile species suggested that even if vegetation communities changed over time, the patterns of use of the drawdown zone are likely to persist. This is because species distributions were more likely a reflection of suitable breeding habitat (i.e., pond or wetland areas) and determinants of habitat quality (i.e., suitable habitat for purposes other than breeding such as foraging) rather than vegetation community alone.

The scale at which vegetation communities were mapped in Arrow Lakes Reservoir was possibly not detailed enough to highlight habitat features selected by amphibians and reptiles or the variation of habitat in and around ponds/wetlands within the drawdown zone. Therefore, microhabitat features being selected by species in the drawdown zone of Arrow Lakes Reservoir may not be accurately described by vegetation community associations.

Despite conducting surveys over the same general time frames each year, environmental conditions varied between years, so we expected to see some variability in habitat use. Habitat use was described using detection rates, which can differ based on habitat characteristics (e.g., percentage vegetation cover, water clarity, reservoir elevation). Search effort could not be standardized between habitat types due to large amounts of area, changing conditions and availability throughout the field season, and focused surveys near pond breeding habitat; therefore, our assessment of habitat use may be biased due to detection rates influenced by which habitats we spent more time searching.

Ponds in Arrow Lakes Reservoir were not delineated similarly to those in Kinbasket Reservoir. Furthermore, the vegetation communities mapped in Arrow Lakes Reservoir were not to a scale sufficient to describe microhabitat features utilized by pond-breeding amphibians. The communities may be too general and not representative of the variation present at sites in the drawdown zone.

We were able to determine the characteristics of ponds utilized by pond-breeding amphibians in the drawdown zone of Kinbasket Reservoir over the 11-year period. We were able to identify pond partitioning at sites where many ponds were available (e.g., ponds where Western Toads would breed in one part of the pond and Columbia Spotted Frogs in another), which provides insight into the behaviour of species with overlapping habitat requirements (see Swan et al. 2015).

Appendix 11: Analysis of the elevational distribution of species detections in the drawdown zone

Introduction

We examined the elevational distribution of species detections at monitoring sites in and around the drawdown zone of both reservoirs to determine the elevation ranges at which species occur. The elevational distribution of detections was compared to the normal operating reservoir maximum for each reservoir (753.48 mASL Kinbasket Reservoir, 440.1 mASL Arrow Lakes Reservoir). This analysis provides insight on the elevation ranges at which species occur with respect to the normal operating reservoir maximum and whether elevational distributions varied annually throughout the study period.

Methods

Elevation data from georeferenced amphibian and reptile observations during surveys at monitoring sites were pooled for each reservoir. Boxplots were created in R (V3.5.3; R Core Team 2019) to plot the elevational distribution of species detections by year and across all study years. The annual and overall elevational distribution of species detections were compared to the normal operating reservoir maximum of each reservoir. To account for annual differences in sampling effort, presence data were used and standardized by detection rates in each year.

Datasets

Georeferenced observations from Dataset 1 (Visual Encounter Data) and Dataset 5 (Radio Telemetry Data) were pooled to determine the elevational distribution of species detected in the drawdown zone at monitoring sites in Arrow Lakes Reservoir and Kinbasket Reservoir over all study years.

Analysis

We evaluated the elevational distribution of amphibian and reptile species detections in and around the drawdown zone at sites (monitoring sites and some reconnaissance sites) in both reservoirs to determine the ranges at which species occur and whether these ranges varied annually. Boxplots were created for both reservoirs to highlight the range in elevation values for each species in a given year and across all study years (pooled). A detection was defined as an observation of a single individual, pair in amplexus, egg mass or cluster, or aggregation of tadpoles or metamorphs.

Results

Kinbasket Reservoir

Over the 11-year study period amphibians and reptiles were found across a wide range of elevations within the upper elevation bands of Kinbasket Reservoir (Figure 7-26). Most observations (all life stages combined) were between 749 and 754 mASL. Of the pond-breeding amphibians, Western Toad detections spanned the widest range of elevations, whereas Long-toed Salamander covered the narrowest range, likely due to a lack of detections and decreased survey effort along the drawdown zone margin and neighboring upland areas. The distribution of snakes overlapped that of amphibians in most cases: Common and Western Terrestrial Garter Snake were typically found between 749 and 754 mASL, with the former species being detected more frequently in the drawdown zone. Western

Terrestrial Garter Snake were found at higher elevations above the drawdown zone at sites where Common Garter Snake were not detected.

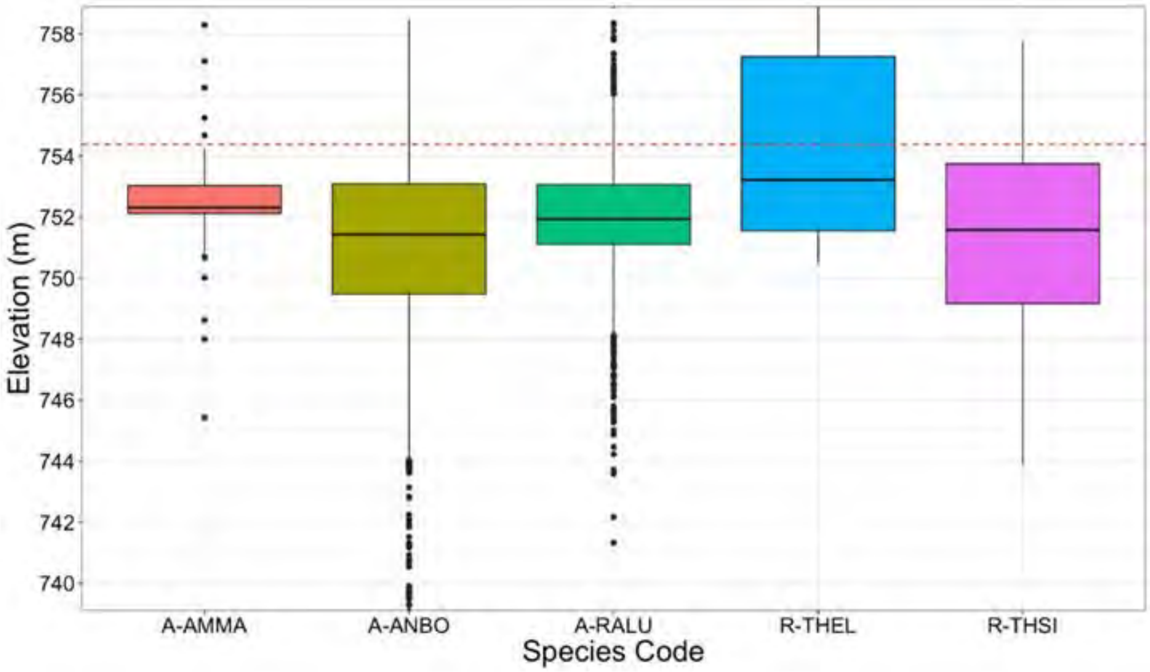


Figure 7-26: Elevation distribution of amphibians and reptiles (number of observations, all life stages combined) documented in and adjacent to the drawdown zone of Kinbasket Reservoir between 2008 and 2018. A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-RALU = Columbia Spotted Frog, R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake. Red-dashed line (elevation = 754.38 mASL) represents normal operating reservoir maximum for Kinbasket Reservoir.

The median elevation associated with species detections in the drawdown zone Kinbasket Reservoir between 2008 and 2018 was typically below the normal operating reservoir maximum of 754.38 mASL (Figure 7-26). The median elevation of most pond-breeding amphibian and reptile observations was between 750 and 754 mASL, which is likely related to the focus of this study (i.e., understanding the occurrence and distribution of amphibians and reptiles using habitats in the drawdown zone of Kinbasket and Arrow Lakes Reservoir) and to the distribution of ponds in the drawdown zone of Kinbasket Reservoir. Of the ponds sampled, ~40 percent (n = 76) occur between 750 and 754 mASL (elevation range of ponds sampled: 738.33 to 753.15 mASL; Table 4-4). Although most of our work was focused on the drawdown zone, it was apparent that limited and potentially suitable pond-breeding habitat occurred above the normal high-water mark in the areas that we sampled. This suggests that the ponds and wetland-associated habitats in the drawdown zone of Kinbasket Reservoir provide important breeding habitat for species such as Western Toad, Columbia Spotted Frog, and Long-toed Salamander. Because both garter snake species documented from the drawdown zone of Kinbasket Reservoir are known predators of amphibians, the important pond-breeding amphibian habitats that occur in the drawdown zone are also considered important foraging habitat for Western Terrestrial and Common Garter Snakes prior to annual inundation.

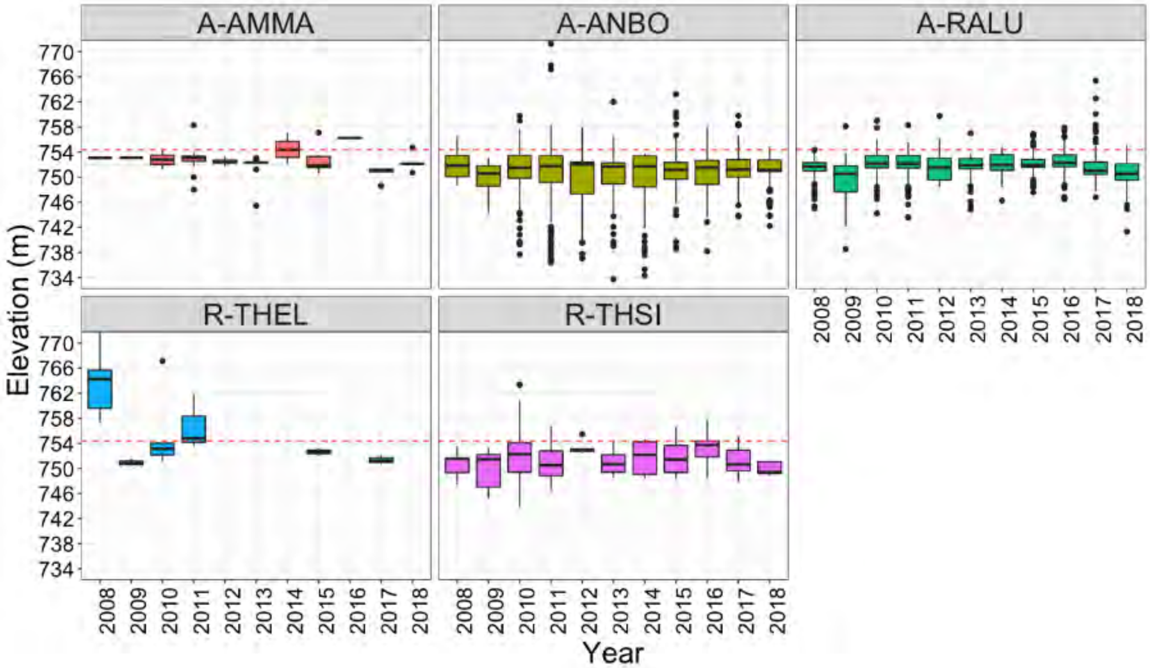


Figure 7-27: Elevation distribution of amphibians and reptiles (number of observations, all life stages combined) documented in and adjacent to the drawdown zone of Kinbasket Reservoir by year of study. A-AMMA = Long-toed Salamander, A-ANBO = Western Toad, A-RALU = Columbia Spotted Frog, R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake. Red-dashed line (elevation = 754.38 mASL) represents normal operating reservoir maximum for Kinbasket Reservoir.

The annual average elevation in which detections were made ranged from 749.83 to 752.02 mASL (2009 and 2008, respectively), with an overall average of 751.48 mASL. In most cases, the majority (~75%) of species detections of pond-breeding amphibians and garter snakes did not appear to vary significantly interannually, except for Western Terrestrial Garter Snake in 2008, which was detected at a seldom visited reconnaissance site outside of the drawdown zone. Differences in average annual elevations were likely due to changes in survey effort and/or survey timing, reservoir elevation and detectability.

Arrow Lakes Reservoir

Amphibians and reptiles were found across a wide range of elevations in Arrow Lakes Reservoir between 2008 and 2018 (Figure 7-29). Most observations (all life stages combined) were between 432 and 445 mASL. Western Toad spanned the widest range of elevations, while Columbia Spotted Frog and Western Painted Turtle covered the narrowest range.

Amphibians in Arrow Lakes Reservoir were distributed across an elevation range of 432 to ~460 mASL. The largest aggregations of frog and toad species occurred between 434 and 440 mASL, which was likely related to the distribution of wetlands in the drawdown zone. In Revelstoke Reach specifically, the elevation of 28 mapped ponds in the drawdown zone ranged from 432.87 and 438.26 mASL (Table 4-4). For pond breeding amphibians, this is indicative that the drawdown zone provides important breeding habitat as surveys occur throughout the breeding season. Long-toed Salamander were infrequently detected, and while our data may suggest that they were not often found in the drawdown zone, egg masses detections (n = 100) at Cartier Bay in 2012 suggest otherwise. Furthermore, nighttime road surveys have corroborated their use of the drawdown zone in Revelstoke Reach. Therefore, the elevation range of Long-toed Salamander was likely a function of detectability and ontogenetic variation.

The distribution of reptiles in Arrow Lakes Reservoir overlapped that of amphibians in most cases. Common and Western Terrestrial Garter Snake were found between 436 and 440 mASL, in locations that likely provide necessary thermal and security cover and foraging habitat. Upland species such as Western Skink and Northern Alligator Lizard both occurred at the higher elevation bands (436 to 444 mASL) along the margin of the drawdown zone. Western Painted Turtle were almost exclusively detected in the pond areas of the drawdown zone in Revelstoke Reach around 436 mASL.

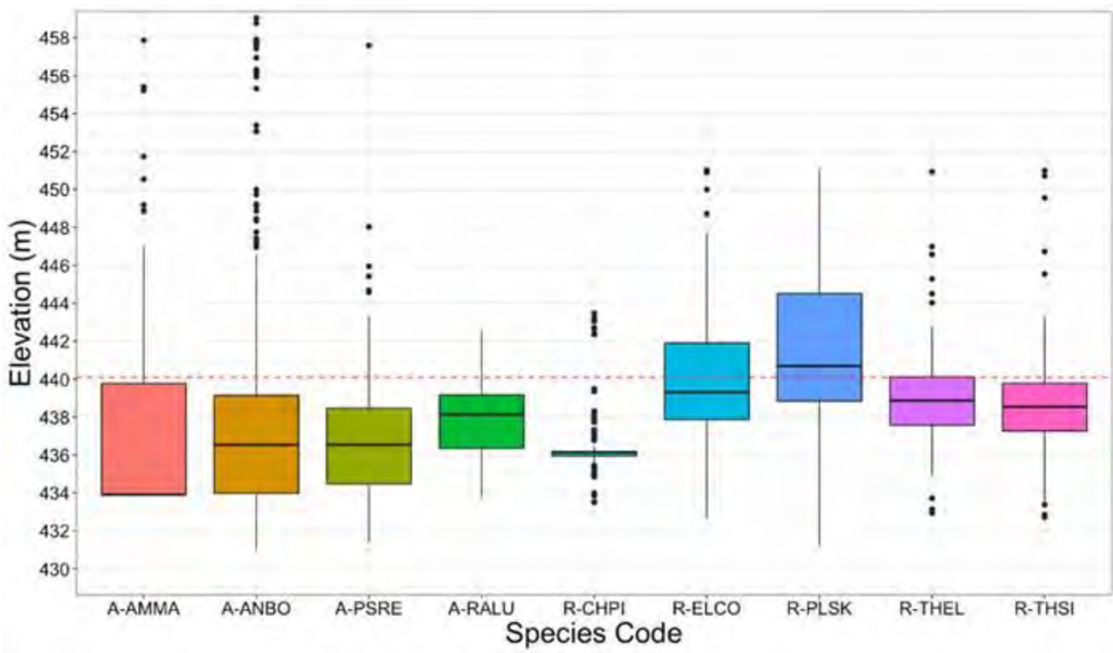


Figure 7-28: Elevation distribution of amphibian and reptile observations (all years pooled) documented in and adjacent to the drawdown zone of Arrow Lakes Reservoir between 2008 and 2018. A-AMMA = Long-toed Salamander, ANBO = Western Toad, A-PSRE = Pacific Chorus Frog, A-RALU = Columbia Spotted Frog, R-CHPI = Painted Turtle, R-ELCO = Northern Alligator Lizard, R-PLSK = Western Skink, R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake. Red-dashed line (elevation = 440.1 mASL) represents normal operating reservoir maximum for Arrow Lakes Reservoir.

Comparing across the years, the average elevation in which detections were made were greatest in 2010 (~439 mASL) and lowest in 2012 (~436 mASL), with an overall average of 438 mASL (Figure 7-29). This is likely due to an increase in survey effort of reconnaissance and reference sites during the early years of the study. The median elevation of all species that were detected between 2008 and 2018 was typically below the normal operating reservoir maximum of 440.1 mASL each year, except for Western Skink (in 2014, 2016 and 2018) and Long-toed Salamander (in 2008, 2009, 2010, and 2016). For most species, the majority

(~75%) of detection elevations did not appear to vary significantly interannually. Differences in average annual elevations were likely due to changes in survey effort and/or survey timing, reservoir elevation, and detectability.

Columbia Spotted Frog (~435 to 440 mASL) and Pacific Chorus Frog (~432 to 440 mASL) consistently used a narrower range of elevations each year than Western Toad (~432 and 458 mASL). Long-toed Salamander were not detected every year and with the exception of 2012 (~434 mASL) and 2016 (~436 mASL), occupied only the highest elevation ponds (440 to 452 mASL), which may be related to the proximity of these ponds to upland forest, which this species typically inhabits.

The median elevation of reptiles such as Western Skink and Northern Alligator Lizard was close to the normal operating maximum reservoir level most years, which is not surprising as these species utilize habitat at the margin of the drawdown zone and were infrequently detected in the drawdown zone. Rubber Boa and Coeur d'Alene Salamander were not included due to being seldom detected. However, Rubber Boa was detected once in the drawdown zone at Lower Inonoaklin in 2015, which suggests that this species may occur in the drawdown zone at more sites than our data suggest. In most years, Western Painted Turtle had the narrowest elevation range and lowest median elevation of all species found in the drawdown zone of Arrow Lakes Reservoir as most detections were from a single site in Revelstoke Reach (Airport Marsh). Both species of garter snakes had similar annual elevation ranges and median elevations below the normal operating reservoir maximum indicating the drawdown zone provides important habitat (e.g., foraging, basking sites) for these species.

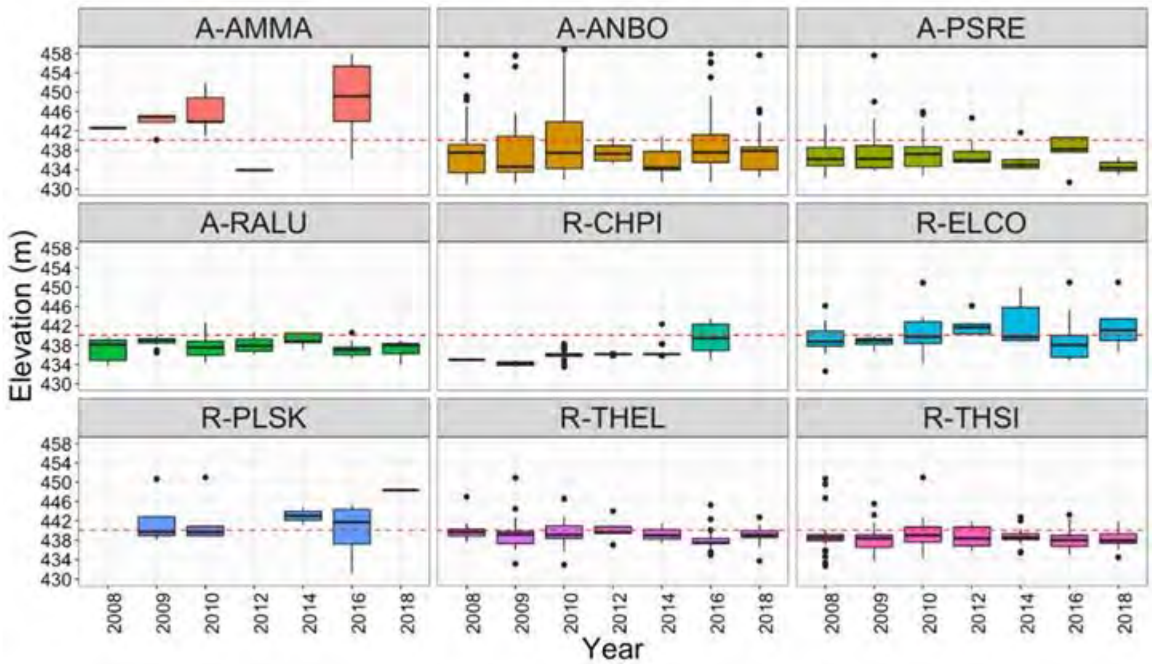


Figure 7-29: Elevation distribution of amphibians and reptiles (number of observations, all life stages combined) documented in and adjacent to the drawdown zone of Arrow Lakes Reservoir across all years of study. A-AMMA = Long-toed Salamander, ANBO = Western Toad, A-PSRE = Pacific Chorus Frog, A-RALU = Columbia Spotted Frog, R-CHPI = Painted Turtle, R-ELCO = Northern Alligator Lizard, R-PLSK = Western Skink, R-THEL = Western Terrestrial Garter Snake, R-THSI = Common Garter Snake. Red-dashed line (elevation = 440.1 mASL) represents normal operating reservoir maximum for Arrow Lakes Reservoir.

Discussion

Using 11 years of data, we described the elevation gradient at which species occurred at sites (monitoring and reconnaissance/reference) in and around the drawdown zone of both reservoirs. Our assessment of the elevational distribution of species was influenced by variable annual reservoir elevations, which influenced the area surveyed each year. Detection rates were typically highest early in the breeding season prior to inundation, when pond-breeding amphibians were utilizing ponds within the drawdown zone. Detection rates for some species (e.g., Western Toad and Common Garter Snake) were also high in the summer when toad tadpoles were metamorphosing, providing an abundant prey source for snakes. Overall, the elevation at which species were detected in each reservoir was a function of annual and seasonal reservoir elevations (e.g., habitats at higher elevations were available for longer periods than those at lower elevations), the availability of pond habitats pre-inundation (animals could have preferentially selected lower elevation habitats based on specific features such as foraging or basking sites, predation cover, etc.) and survey effort. Median elevation values were not expected to vary annually for most species as survey effort was focussed on elevation bands with suitable pond and wetland habitat.

Visual encounter surveys were focused primarily in the drawdown zone; therefore, the apparent absence of animals at higher elevations shown in the boxplots should be interpreted with caution. Survey effort tended to focus on areas at elevations below the normal operating reservoir maximum as these ponds/habitats were typically the first to be inundated and were frequently utilized by pond-breeding amphibians and snakes year after year. We were able to account for a portion of this inequality of effort with the use of radio telemetry for Western Toad and Common Garter Snake, which were tracked outside of the drawdown zone, but smaller-bodied species (e.g., Long-toed Salamander) were unsuitable for this methodology. Furthermore, detectability issues between the species or ontogenetic variation may affect these species-elevation relationships, as some species and life stages are more readily detectable than others. The relationship between elevation and vegetation cover in the drawdown zone (increased vegetation with increased elevation) may also introduce a bias in observation rates, as animals are more easily detected when cover is sparse.

Appendix 12: Analysis of the effect of reservoir operations on habitat availability for amphibian and reptile species

Introduction

We examined amphibian and reptile habitat use in relation to reservoir elevations in the drawdown zones of Kinbasket and Arrow Lakes Reservoir to determine if changing reservoir operations had a direct effect on their use of the drawdown zone by life history stage thereby inferring a potential indirect effect on growth, reproduction, or survivorship. Assessing direct or indirect effects of reservoir operations on amphibian and reptile populations can be accomplished by (1) assessing habitat availability as a function of reservoir elevation, and (2) through hypothesizing how increases to reservoir operations at various times of the year would impact both amphibians and reptiles or their habitats. This section assists in answering Management Questions 5 and 6.

Methods

To assist with answering MQ5, monitoring sites were visited in May to August of each year to document: 1) the distribution and abundance of amphibians and reptiles that used habitats in the drawdown zone; 2) which life history activities species' were conducting in the drawdown zone, and 3) how species' distributions, abundance, and activities changed or were altered by reservoir operations (i.e., inundation). Refer to Methods section in Appendix 2 for information on the survey methods used to collect species presence-absence data and habitat use data.

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 monthly relative to reservoir operations (i.e., timing of reservoir inundation at each particular elevation = unavailable). Temporal habitat availability was assessed based on the duration of the active season (i.e., the number of days between April 1 and September 30) during which the drawdown zone was available to amphibians and reptiles. This was accomplished by correlating reservoir elevation (in 1 m increments) to the number of days between April 1 and September 30 (n = 183) that each 1 m elevation band was exposed and therefore available for use.

Habitat availability was assessed through graphical presentation of total area available (i.e., habitats that have not been inundated yet) relative to use (breeding, foraging, and overwintering occurrences). 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.

Datasets

Dataset 1 (Visual Encounter Data) was used to summarize amphibian and reptile observations (count/abundance) of all life stages by year and monitoring site. Dataset 6 (Pond Habitat Data) and Dataset 7 (Vegetation Community Habitat Data) were used to summarize the yearly breeding habitat and availability of total habitat and Dataset 8 (Reservoir Elevation Data) was used to calculate reservoir elevations by date and monitoring site.

Results

Kinbasket Reservoir

As expected, a negative relationship existed between the availability of habitat and reservoir elevations, with habitat availability decreasing with time. The change in habitat availability was most evident from May to July, when reservoir elevations were increasing (Figure 7-30).

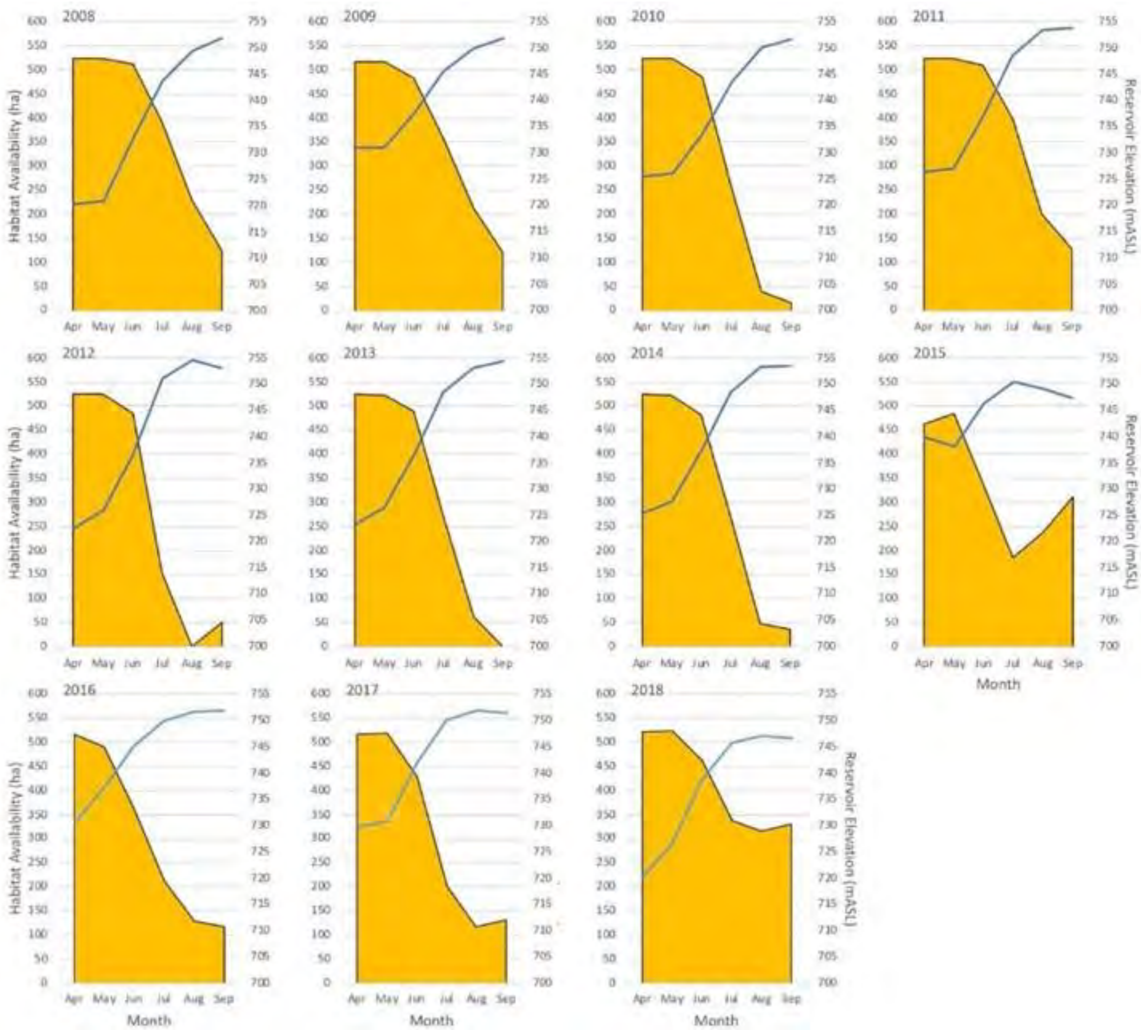


Figure 7-30: Relationship between habitat availability and reservoir elevation (i.e., inundation) in the drawdown zone of Kinbasket Reservoir for the study period of CLBMON-37 (2008 to 2018). The average reservoir elevation is shown (line).

For most years, the majority of breeding ponds (i.e., those situated between 745 and 753 mASL in the available habitat) were available until late June. Beyond this point, the amount of available habitat steadily declined until mid-August, at which time most of the pond habitats (and surrounding areas) were inundated. Seven of the 11 study years followed this general pattern of total availability of habitat high in the spring, decreasing rapidly in June and July as reservoir levels increased, and reservoir level remaining high into September. There were a few years of notable exception: 2012 and 2013 (high water years), and 2015 and 2018 (low water years).

The operation of Kinbasket Reservoir influenced the spatial and temporal availability of habitat for amphibians and reptiles (Figure 7-31). Data collected between 2008 and 2013 represented the period prior to the installation of Units 5 and 6 at Mica Dam. In 2012 and 2013, reservoir levels came up rapidly resulting in decreased habitat availability occurring early in the season. In 2012, a notable year for high water levels in Kinbasket Reservoir, most ponds were only available until mid-June, with all available habitat completely inundated by mid-July. A different situation occurred in 2015 and 2018, whereby reservoir levels were lower than usual and began to decline again in July instead of increasing into September.

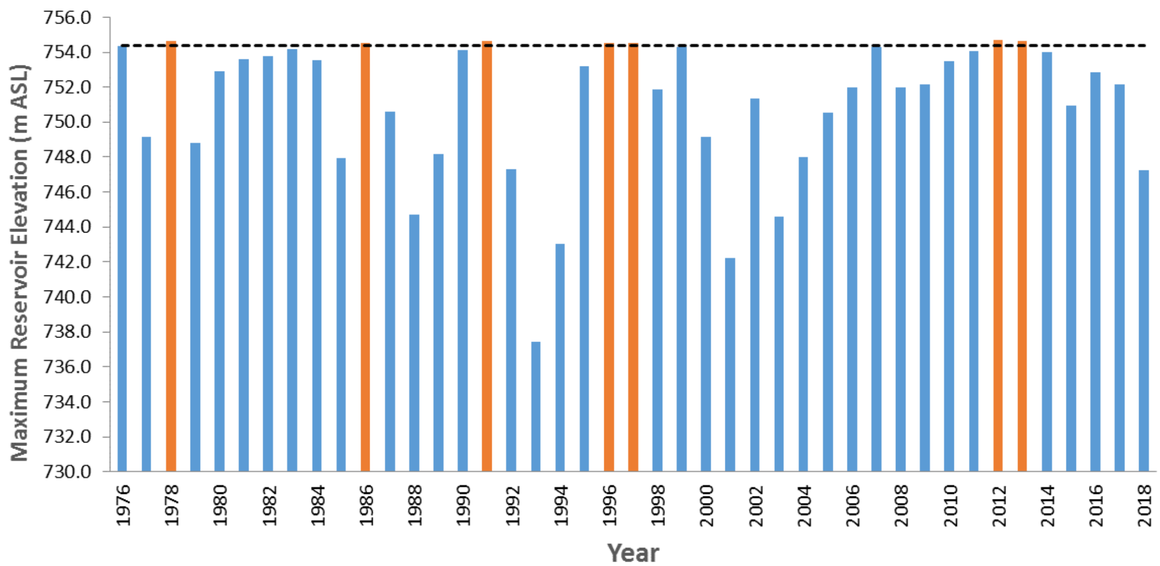


Figure 7-31: Maximum reservoir elevations (metres above sea level, mASL) achieved in Kinbasket Reservoir, 1976 to 2018. Orange bars indicate years when Kinbasket Reservoir was operated beyond the normal operating maximum (black dashed line).

Seasonal changes in documented amphibian and reptile locations in relation to habitat availability and changing reservoir levels are depicted in Figure 7-32 and Figure 7-33. Ponds (and other habitat) were available in May for breeding, foraging and/or emerging from overwintering (where applicable) for all study sites. Reservoir levels began to increase into study areas starting in late June and had typically inundated most habitats by mid to late July. As habitat became inundated (i.e., unavailable), amphibian and reptile observations typically followed the edges of the reservoir or were further upland of the drawdown zone in parts of July and August. This was particularly true for developing tadpoles/larvae: as reservoir levels inundated ponds, tadpole aggregations were documented using the leading edge of the reservoir.

Figure 7-32: Monthly species observations and Kinbasket Reservoir elevations for Valemount Peatland from 2008 to 2018. Dark blue shaded area represents the maximum reservoir elevation that was reached across the 11-year period and light blue shaded areas shows the average reservoir elevation for that month.

Figure 7-33: Monthly species observations and Kinbasket Reservoir elevations for Bush Arm KM79 wetlands from 2008 to 2018. Dark blue shaded area represents the maximum reservoir elevation by month that was reached across the 11-year period and light blue shaded areas shows the average reservoir elevation for May 15, June 1st, and July 1st across all years.

This scenario of habitat becoming unavailable by mid-July and species occurrences shifting to the edges of the reservoir changed by study location, depending on the elevation of the total available habitat and pond habitat at each site. For the Valemount Peatland (Figure 7-32), a site in which the species observations generally occurred in the higher elevation ranges (~747 to 754 mASL), reservoir elevations typically began to impact amphibian and reptile habitat availability in July, with most habitat affected only in high-water years (e.g., 2012, max. elevation = 750.38 mASL). A similar situation was seen at Bush Arm KM79 (Figure 7-33), where only in high water years, where maximum reservoir elevations were attained, were animal observations were either 1) absent in summer months or 2) found typically along the leading edge of the reservoir.

Arrow Lakes Reservoir

Similar to Kinbasket Reservoir, a negative relationship existed between the availability of habitat and reservoir elevations, with habitat availability decreasing with time. The change in habitat availability was most evident from May to July, when reservoir elevations were increasing (Figure 7-34).

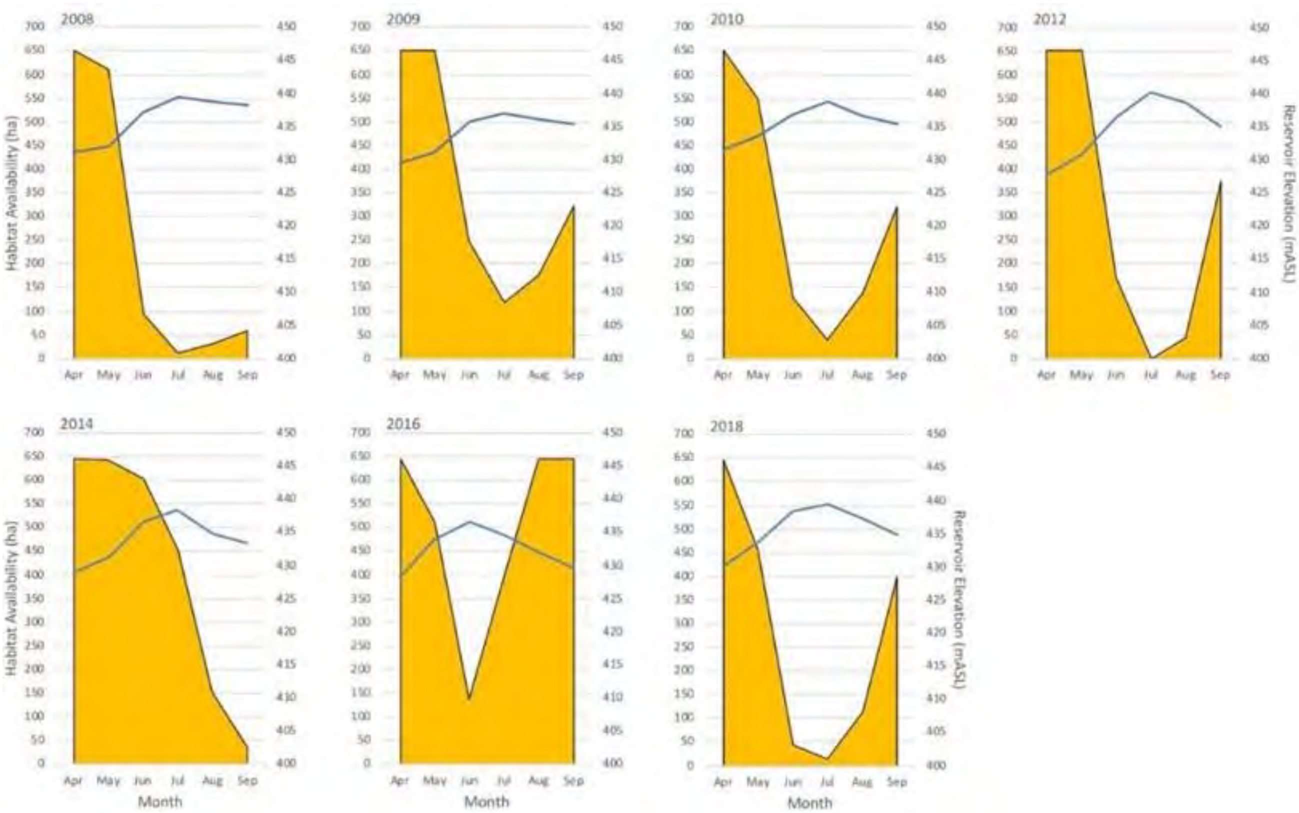


Figure 7-34: Relationship between habitat availability and reservoir elevation (i.e., inundation) in the drawdown zone of Arrow Lakes Reservoir for the study period of CLBMON-37 (2008 to 2018). The average reservoir elevation is shown (line).

Seasonal changes in documented amphibian and reptile locations in relation to habitat availability and changing reservoir levels were examined for a high species distribution area in Revelstoke Reach (Figure 7-36). Habitat was available in May for breeding, foraging, and/or emerging from overwintering (where applicable).

Reservoir levels began to increase into Montana Slough and Cartier Bay starting in early June and had inundated most habitats by early July. As habitat became inundated (i.e., unavailable), amphibian and reptile observations typically followed the edges of the reservoir or were further upland of the drawdown zone during July and August.

This scenario of drawdown zone habitat becoming unavailable by early to mid-July and species occurrences shifting to the edges of the reservoir was typical for most study sites, depending on the elevation of the total available habitat and pond habitat at each site. Burton Creek, Edgewood South, and Lower Inonoaklin all had a similar reservoir inundation pattern, whereas Beaton Arm wetlands remained relatively intact until later in the summer due to the extensive network of beaver dams in the reach of the arm.

Similar to Kinbasket Reservoir, the earlier reservoir levels increased in the season, the less habitat was available to amphibians and reptiles for breeding and foraging. Above full pool reservoir levels during this study only occurred in Arrow Lakes Reservoir in 2012 and very few amphibian and reptile observations were made in July and August of that year. Arrow Lakes Reservoir has been operated above full pool 14 times since the creation of the reservoir; however, years with above full pool reservoir levels decreased after the completion of Revelstoke Dam (1985). In 2012, Arrow Lakes Reservoir was filled beyond the normal operational maximum for the first time in 21 years (Figure 7-35).

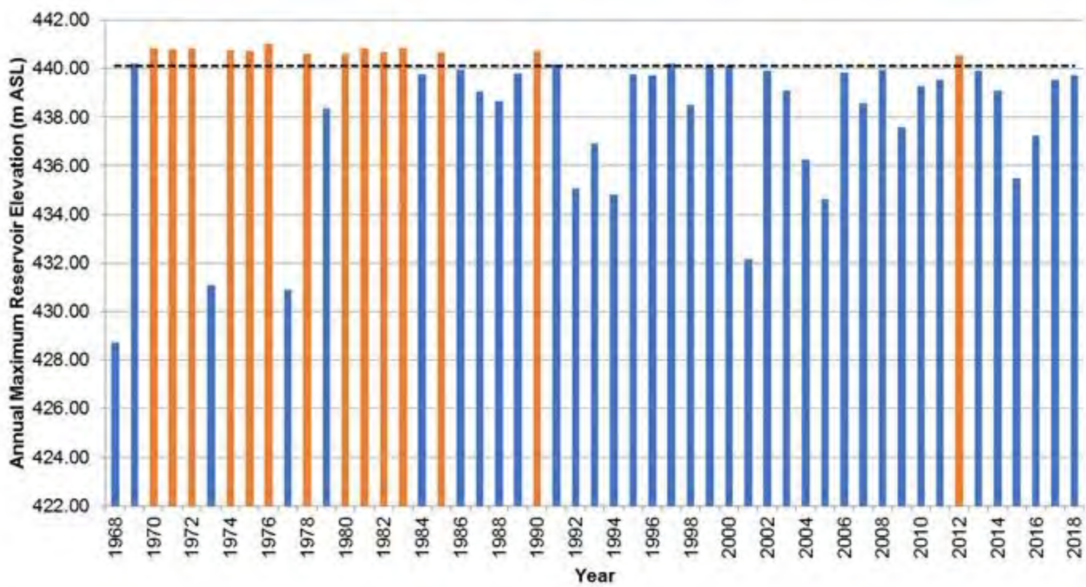


Figure 7-35: Maximum reservoir elevations recorded for Arrow Lakes Reservoir for the period 1968 through 2018. The years during which the reservoir exceeded the normal operation maximum are coloured red. The normal maximum reservoir elevation is depicted by the dashed line.

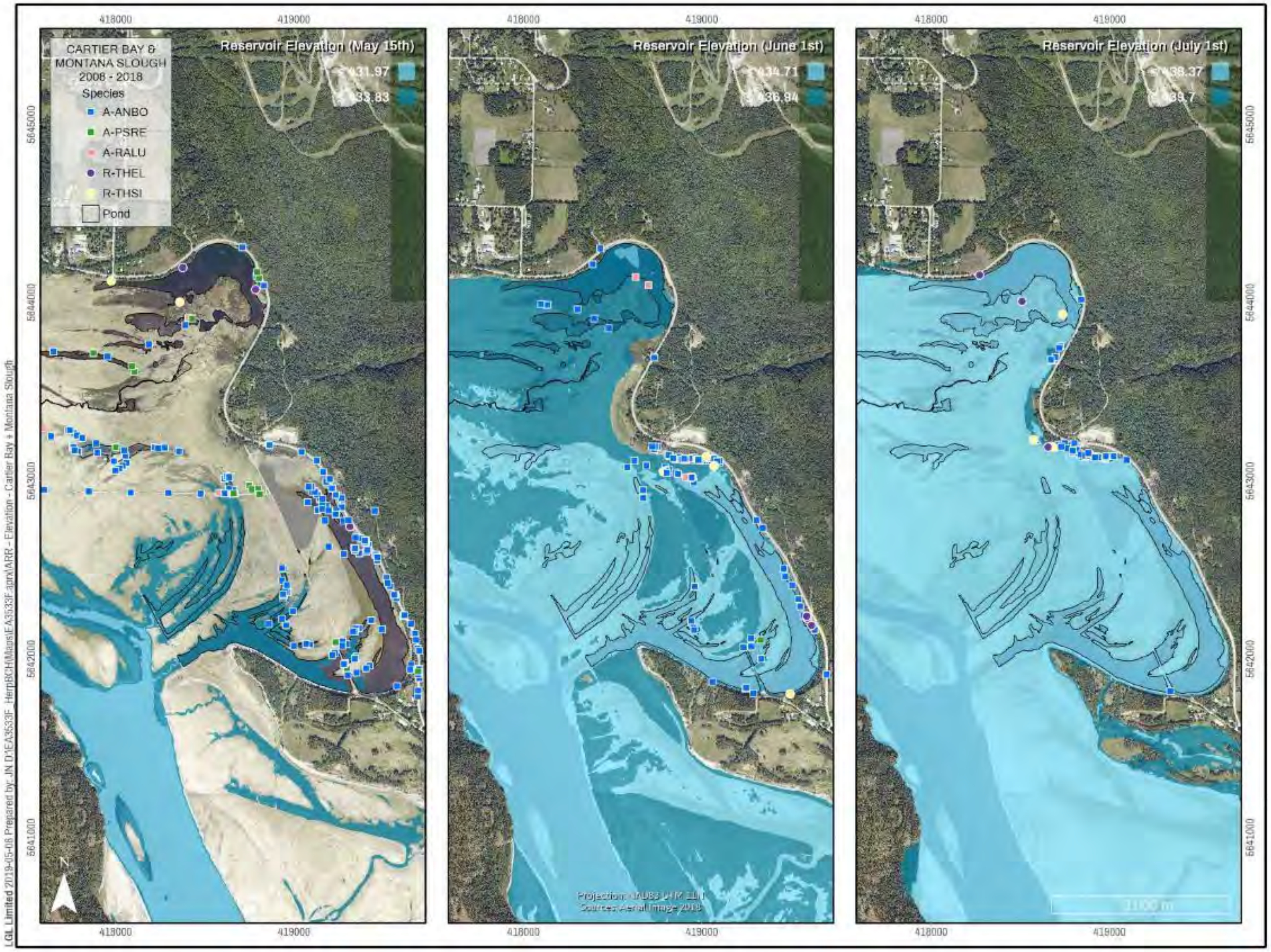


Figure 7-36: Monthly species observations and Arrow Lakes Reservoir elevations for Montana Slough and Cartier Bay (Revelstoke Reach) from 2008 to 2018. Dark blue shaded area represents the maximum reservoir elevation by month that was reached across the 11-year period and light blue shaded areas shows the average reservoir elevation for May 15th, June 1st, and July 1st across all years. Note sampling did not occur in 2013, 2015, or 2017 (CLBMON-58 years – Kinbasket Reservoir only).

Discussion

In the drawdown zone of a reservoir, habitat availability was a function of reservoir elevation. It was apparent that reservoir operations influenced amphibians and reptiles in the drawdown zone, both directly and indirectly. The most direct effect of reservoir operations on amphibians and reptiles observed was the inundation of habitat which in most cases displaced animals to the periphery of the drawdown zone. Other direct effects such as mortality or breeding depression were harder to measure and could only be inferred in most cases. Indirect effects, such as lower water temperatures (which indirectly affects larval development), changes to habitats (which indirectly affects quality of habitat selected by animals) or food resources (which indirectly affects habitat use or the development of all life stages) were also difficult to determine.

The longer-term implications of variable reservoir operations and inundation of important breeding habitats remain unknown. Based on what we have observed regarding the location and elevation of ponds used by amphibians in the drawdown zone for breeding, we suspect the effects of reservoir inundation are mitigated mainly by habitat selection, but this has not been explicitly tested.

The availability of suitable breeding habitat in the reservoirs was variable between years. We did not map all ponds in the drawdown zone in in all years; therefore, we cannot quantify the magnitude of the change to breeding habitat in this study. For example, certain ponds were not present in all years, while others changed in size between years. Despite the changes in available pond habitat, we continued to document the same species of amphibians and reptiles in the drawdown zones of Arrow Lakes and Kinbasket Reservoirs in most years.

The timing of inundation and occupancy of ponds coupled with the observation of breeding toads and frogs and egg masses indicated that reservoir operations did 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 life stages of Western Toad and Columbia Spotted Frog, the reduction in habitat availability associated with inundation did 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 August (for Kinbasket Reservoir) and Revelstoke Reach and Beaton Arm (for Arrow Lakes Reservoir) suggested that egg strings and tadpoles can tolerate some level of disturbance from reservoir operations. However, the degree to which reservoir operations might affect the reproductive (in terms of the percentage of eggs that survive to metamorphosis) was not well understood for this study and could not be quantified.

An additional difficulty to assessing reproductive success was that metamorphs were not always detected in the expected quantities at some sites and in several years (i.e., the vast number of egg masses in the spring did not translate into metamorph detections in mid-summer). Breeding was documented for many sites in the early spring as drawdown zone ponds were available; however, in several cases, very few to no metamorphs were detected at these sites over the 11-year period (Table 7-23). It is currently unknown if 1) breeding failure was occurring on an annual basis, 2) tadpoles were present, but had moved away from original egg mass site after inundation (e.g., followed warmer water along the shoreline) and metamorphosis occurred elsewhere, 3) the timing of metamorphosis (or emigration from the ponds/reservoir's edge) was outside of the timing of field sessions, or 4) toadlets were present, but not detected due to vegetation and reservoir levels reaching into upland habitat.

Appendix 13: Analysis of the effect of reservoir operations on water physicochemistry

Introduction

We examined amphibian habitat use in relation to physicochemical conditions in ponds in the drawdown zones of Kinbasket and Arrow Lakes Reservoir to determine if changing reservoir operations had an indirect effect on their use of the drawdown zone and thereby inferring a potential indirect effect on growth, reproduction, or survivorship. Assessing indirect effects of reservoir operations on amphibian and populations can be accomplished by (1) assessing habitat change (e.g., changing water chemistry and temperatures) as a function of reservoir inundation, and (2) through hypothesizing how these changes would impact developing amphibians or their use of habitats. This section assists in answering Management Questions 5 and 6.

Methods

Visual encounter surveys were conducted to determine amphibian presence and habitat use. Refer to Methods section in Appendix 2 for information on the survey methods used to collect species presence-absence data and habitat use data. Mapped ponds were visited across the season and years to measure pond characteristics relative to reservoir conditions.

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).

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.

Datasets

Observations from Dataset 6 (Pond Habitat Data) were used to assess water physicochemistry variables for ponds in the drawdown zone.

Results

Water physicochemical parameters measured in ponds in the drawdown zone showed evidence of an effect of reservoir operations (inundation). Data from 2013 and 2014 showed a decrease in water temperature following inundation at the Bush Arm Causeway (Figure 7-37). In 2013, temperature dropped by 12.8°Cover 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. Additionally, dissolved oxygen levels were declining prior to reservoir inundation in both 2013 and 2014, which could have been 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). 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.

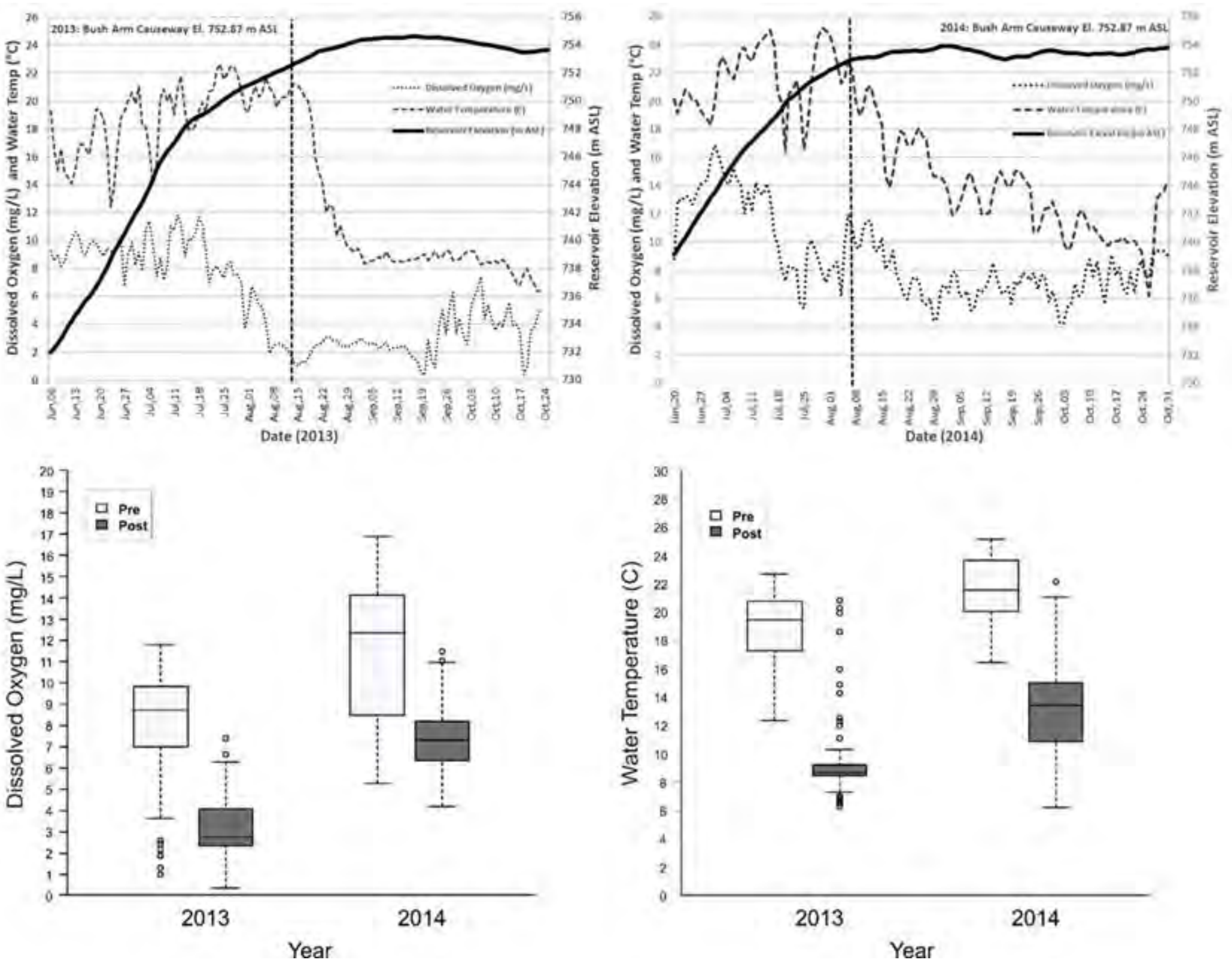


Figure 7-37: Daily variation in dissolved oxygen (DO; mg/L) and water temperature (°C) relative to reservoir elevation (mASL) at the Bush Arm Causeway 2013 and 2014. The dashed vertical line in the top panels represents the date of inundation. The dashed horizontal line in the top panels represents the 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.

Discussion

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

Appendix 14: Analysis of the effect of Mica 5/6 and reservoir operations on habitat availability for amphibian species in Kinbasket Reservoir

Introduction

We examined the potential effects of Mica 5/6 and associated reservoir operations by assessing the predicted impacts of increasing Kinbasket Reservoir elevations by 0.6 m on amphibian abundance, productivity, and habitat use at monitoring sites in the drawdown zone. Assessing direct or indirect effects of reservoir operations on amphibian populations can be accomplished by assessing habitat availability as a function of reservoir elevation and through hypothesizing how increases to reservoir operations at various times of the year would impact amphibians and their habitats. This section assists in answering Management Question 10.

Methods and Analysis

The installation of Units 5 and 6 at Mica Creek was predicted to increase reservoir elevations by 0.6 m during the summer months, which coincides with the period of larval amphibian development. The usual operating regime of Kinbasket Reservoir included a large drawdown in the late winter followed by rapid filling in the spring and early summer, with full pool normally attained by late July or August. Data collected between 2008 and 2013 represented the period prior to the installation of Units 5 and 6 at Mica Dam. During this time, the operation of Kinbasket Reservoir was different than in previous years. Specifically, Kinbasket Reservoir filled more rapidly and was filled beyond the normal operating maximum in 2012 and 2013, an operation that had not been implemented since 1997. This information was used to facilitate a qualitative assessment of the potential effects that the installation of Units 5 and 6 might have on amphibians using the drawdown zone of Kinbasket Reservoir.

Assessing the potential impacts of increasing Kinbasket Reservoir elevations by 0.6 m required a combination of modelling and site-specific studies of pond-breeding amphibian habitat locations in the drawdown zone of Kinbasket Reservoir. Refer to Methods section in Appendix 2 for information on the survey methods used to collect species presence-absence data. To assess the effects of increasing Kinbasket Reservoir elevations, we stratified the drawdown zone into 5-m increments starting at 715 mASL through 755 mASL creating eight strata. Amphibian monitoring occurred at in Kinbasket Reservoir across all available reservoir elevations, but not as treatment/control sampling design. Instead, amphibian detection rates per elevation band using the outlined ponds were reported to assist with answering MQ10.

To address both MQ5 (reservoir operations) and MQ10 (Mica 5/6 effects) and to collect data appropriate for testing the associated hypotheses, the following methods were used:

1. **Map the locations of pond habitat in the drawdown zone of Kinbasket Reservoir**

All ponds in the drawdown zone of Kinbasket Reservoir (monitoring sites) were tracked between 2008 and 2013 using a handheld GPS receiver (Garmin GPSMap 60cSx). These GPS tracks were mapped using ArcMap 10 to determine the location, total area, and elevation of each pond within the drawdown zone. The delineation of each pond was updated in 2015 to the 2012 orthorectified imagery of the drawdown zone of Kinbasket Reservoir and any new ponds were added to this dataset.

2. **Determine use of those pond habitats by amphibians for breeding**

Each year ponds at each monitoring location were visited when reservoir levels were low (May) to determine (1) availability (presence or absence in a given year prior to inundation), (2) amphibian breeding activity, and (3) seasonal use of pond areas as reservoir elevations changed the availability of habitat. Breeding activity was documented for each species by estimating counts of egg masses, larval aggregations, and breeding adults (i.e., numbers of pairs in amplexus and adult males and females). Ponds were classified as used or unused ponds (as defined by the presence of egg masses, tadpoles, or breeding adults).

3. **Assess the timing of development of pond-breeding amphibians from egg deposition through to metamorphosis at various elevations**

The critical life history stage for amphibians that used drawdown zone ponds was the larval stage, because tadpoles/larvae were unable to move out of ponds until metamorphosis was complete. To evaluate how amphibian species were affected by reservoir operations (i.e., how inundation of ponds by the reservoir influenced amphibians), we monitored larval development (e.g., Gosner/Harrison staging) and timing of metamorphosis (where possible) in Canoe Reach and Bush Arm.

4. **Assess the effects of increasing the elevation of Kinbasket Reservoir by 0.6 m on ponds that occur in the drawdown zone (MQ10)**

The installation of Mica Units 5 and 6 was predicted to result in a 0.6 m increase in reservoir elevations during the summer months in three out of 10 years. Changes in amphibian habitat availably resulting from this predicted increase were visually assessed by plotting the observed elevation of amphibians relative to the observed annual hydrograph and to the observed annual hydrograph + 0.6 m. The plots were reviewed to determine if an additional 0.6 m would reduce the amount of habitat available to amphibians at each study site, particularly during the breeding and larval development periods.

To visually evaluate the effects of increasing the elevation of Kinbasket Reservoir by 0.6 m on pond-breeding amphibian habitat in the drawdown zone, we added 0.6 m to reservoir elevations reported during the time of year when ponds would be used by pond-breeding amphibians (April through August) for all historical reservoir elevation data (i.e., 1978 to 2018). This was done because we are unable to attribute changes in reservoir elevations to the operation of Mica Units 5 and 6, nor are we able to discern which years the effects would manifest. As such, we used a conservative approach to assess how adding an additional 0.6 m of reservoir elevation to each observed historical hydrograph (as well as those observed during the period of implementation of CLBMON-37 (2008 to 2018) and the operation of Mica Units 5 and 6 (2016) would affect habitat availability. This is likely a conservative approach as the actual increase of 0.6 m would likely be masked within 'normal' reservoir operations. However, using this retroactive assessment allowed us to visually assess whether an additional 0.6 m on top of observed values would negatively affect habitat availability for pond-breeding amphibians. The assumption made is that future operations would mimic, to some degree, operations observed over the previous 40 years, thereby providing an indication of how adding more water to Kinbasket Reservoir would influence habitat availability.

We also assumed that the effects of adding 0.6 m to Kinbasket Reservoir during the summer months in three out of ten years would vary by time of year and life stage (egg mass, tadpole, larvae, juvenile, and adult). We therefore considered how changes to reservoir elevations would affect those life stages.

The results of the visual assessment (which is qualitative, not quantitative) were summarized by plotting the hydrographs associated with Kinbasket Reservoir for each year that CLBMON-58 was implemented (i.e., 2011, 2013, 2015, and 2017) and overlaying the distribution of amphibian eggs, larvae, and metamorphs by elevation and time of year. This provided a visual indication of the relationship between reservoir elevation, time of year (month) and life stage associated with pond-breeding amphibians. The hydrographs include the actual reservoir elevations and the predicted maximum increase in elevation (0.6 m) resulting from the installation and operation of Mica 5/6.

The years in which reservoir elevations might increase by 0.6 m were unknown. It was also unlikely that any changes associated with reservoir operations following the installation of Mica Units 5 and 6 would be easily attributable to the installation of those units. As such, the effects of the installation of Mica Units 5 and 6 were considered in the context of reservoir effects. If, by adding 0.6 m to observed annual hydrographs, there was a reduction or removal of amphibian breeding habitat in the drawdown zone of Kinbasket Reservoir, a negative impact on amphibian populations in the drawdown zone would be assumed.

Datasets

Dataset 1 (Visual Encounter Data) were used to summarize amphibian observations (count/abundance) of all life stages by year and survey location. Dataset 6 (Pond Habitat Data) and Dataset 7 (Vegetation Community Habitat Data) were used to summarize the yearly availability of total habitat and breeding habitat and Dataset 8 (Reservoir Elevation Data) was used to calculate reservoir elevations by date and study site.

Results

The typical pattern of Kinbasket Reservoir operations was repeated annually with some year-to-year variation. With the exception of 2015 and 2018, where the reservoir was operated at a lower than normal maximum height, the potential of direct impacts to amphibians and loss of suitable habitats had increased relative to 2008 and the previous decade.

A review of historical reservoir data for July and August indicated that Kinbasket Reservoir was surcharged seven times between 1978 and 2017 (Figure 7-38), which is unrelated to any predicted changes related to the operation of Mica Units 5 and 6. However, if future operations are affected by Mica Units 5 and 6 and those operations do result in an increased frequency of surcharge, then there may be implications for pond-breeding amphibian habitat (as discussed above in Section 5.10). The current assessment suggests that if future operations mimic historical (as depicted in Figure 7-38) then the effects on pond-breeding amphibians and their habitats are considered negligible.

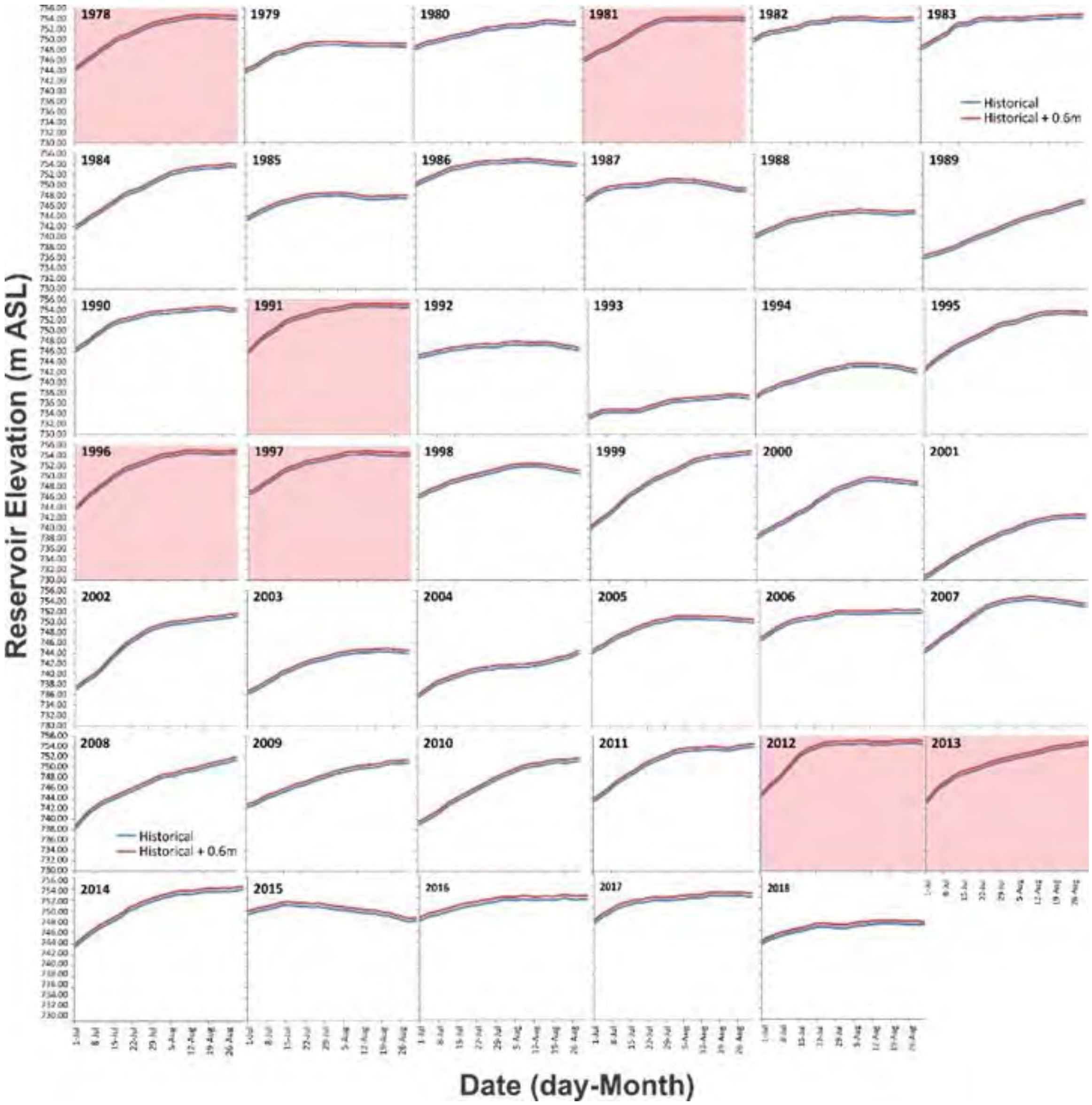


Figure 7-38: Historical reservoir elevations measured in July and August 1978 to 2018, with and without 0.6 m added to simulate the addition of Units 5 and 6 at Mica Dam. Red shading indicates the years Kinbasket Reservoir was filled to elevations > 754.38 mASL (i.e., surcharged).

In the context of typical (i.e., observed historical) reservoir operations, and assuming that similar operations will occur into the future, adding 0.6 m to each year of historical data (to simulate the addition of Units 5 and 6 at Mica Dam) has a negligible effect on the timing of inundation of habitats used by pond-breeding amphibians (Figure 7-38 and Figure 7-39) As indicated above, it was not possible to discern when the elevations of Kinbasket Reservoir were affected by the operation of Mica Units 5 and 6. As such, the approach taken is conservative, but used to emphasize that even if the 0.6 m increase was added to historical hydrographs, the effects on habitat availability, and therefore on pond-breeding amphibians is biologically immeasurable (Figure 7-39). Overall, the impact of reservoir operations on amphibian larval development was likely to be minimal, given that the timing of inundation occurs after eggs have hatched. This appeared to be the case regardless of the annual hydrograph considered because in general, the pattern of reservoir filling was the same, with maximal elevations achieved between the end of June and August, which coincided with the latter stages of tadpole development and transformation to metamorphs.

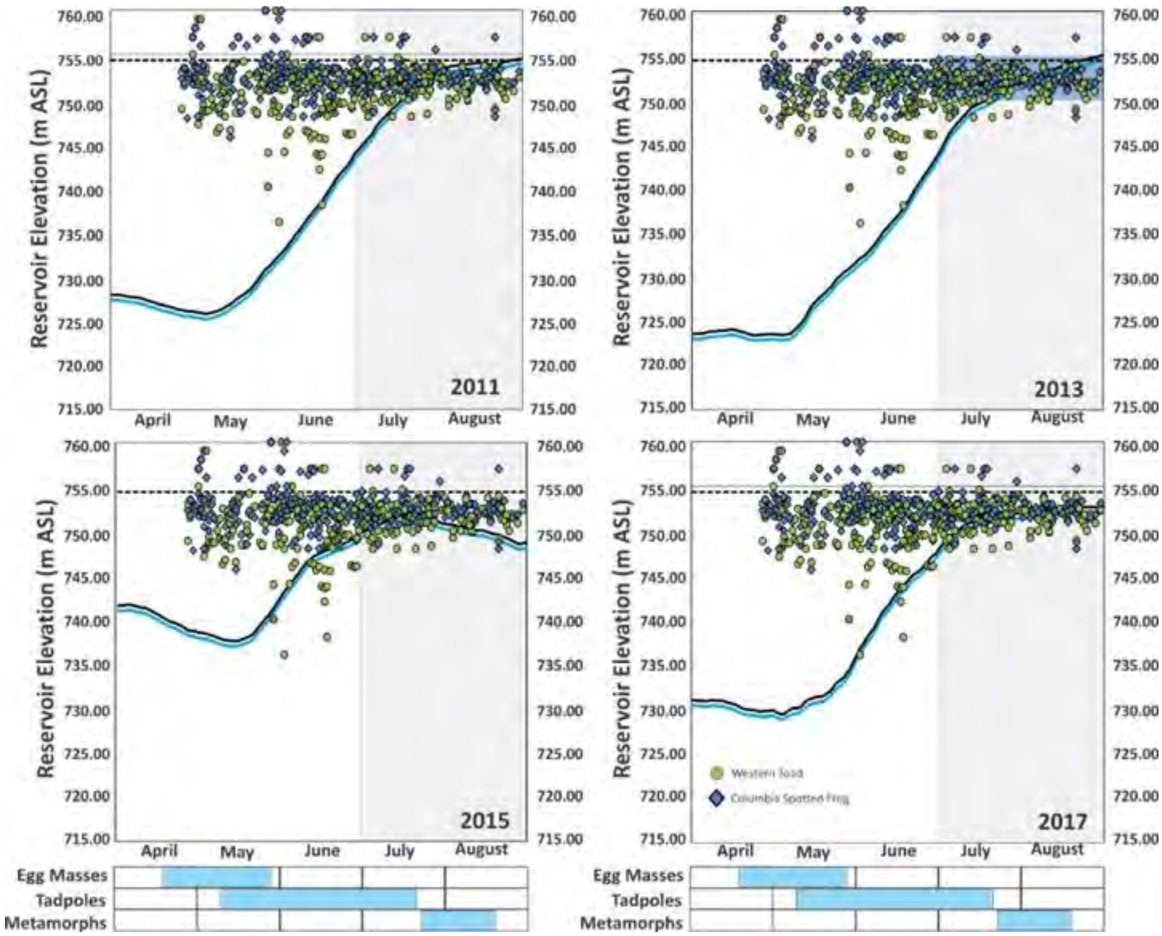


Figure 7-39: Changes in amphibian habitat availability in the drawdown zone of Kinbasket Reservoir relative to actual reservoir operations (blue line) and to a predicted increase of 0.6 m resulting from the installation of Mica Units 5 and 6 (black line) for the period April 1 to August 31, 2011, 2013, 2015, and 2017. The dashed line represents the normal operating maximum of 754.38 mASL. The shading indicates the period during which the predicted increase in reservoir elevation would occur (July and August). The phenology of various amphibian life stages is shown relative to date and elevation. Amphibian observation data from all years is pooled and displayed on each plot.

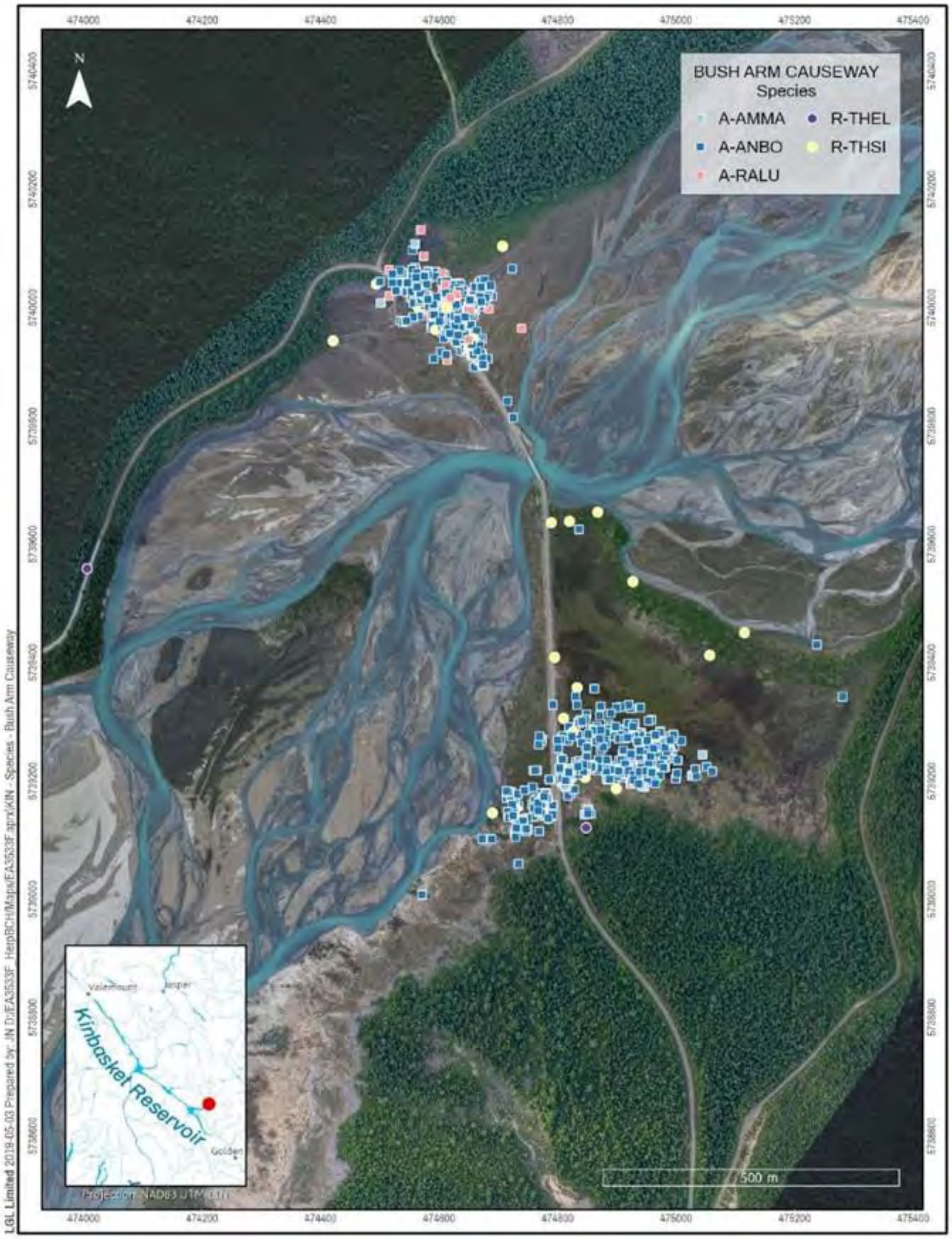
Discussion

In general, from 2008 to 2018, the number of amphibian observations decreased as reservoir elevations increased and were concentrated either around the water's edge (i.e., leading edge of the reservoir) or in nearby upland habitat. In addition to there being a reduced area to search due to increasing reservoir elevations, seasonal habitat use of these habitats by amphibians changes over time with most use occurring in the spring, coincident with the breeding season. Another pulse of activity occurs with the emergence of metamorphs in the summer. As indicated in Figure 7-39 the potential effects of increasing reservoir elevations by 0.6 m during

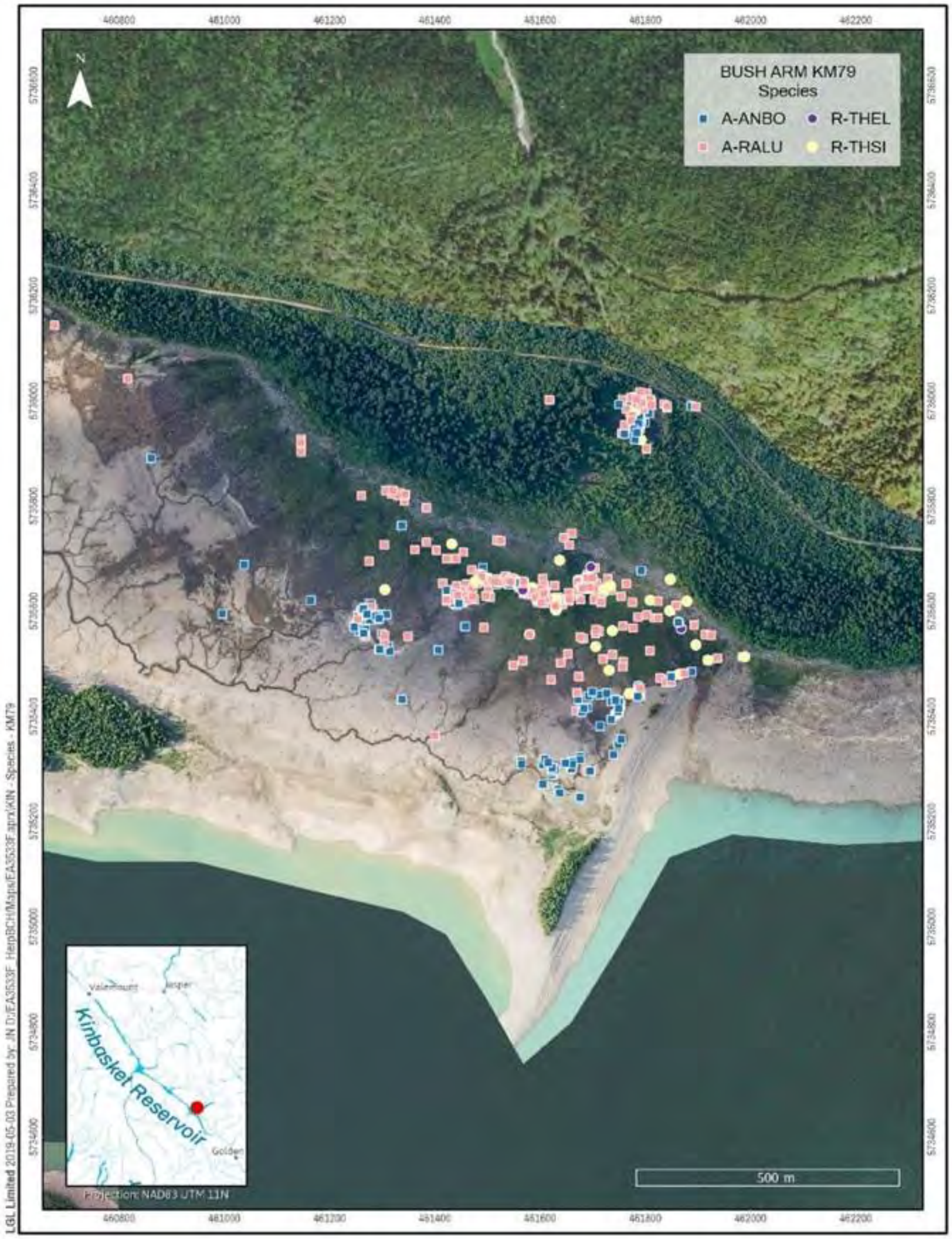
July and August are likely to have biologically immeasurable effects on pond-breeding amphibians. Increasing reservoir levels by 0.6 m due to the installation of Mica Units 5 and 6, would likely have the same effect as “normal” operations, in that it would decrease the total available habitat for amphibians in the drawdown zone, and any potential negative impacts to amphibian populations would depend on the timing of inundation, which would be a function of several factors (snow pack, power demand, flood control, etc.) and not necessarily attributable to the operation of Mica Units 5 and 6.

Appendix 15: Maps of amphibian and reptile locations by study area

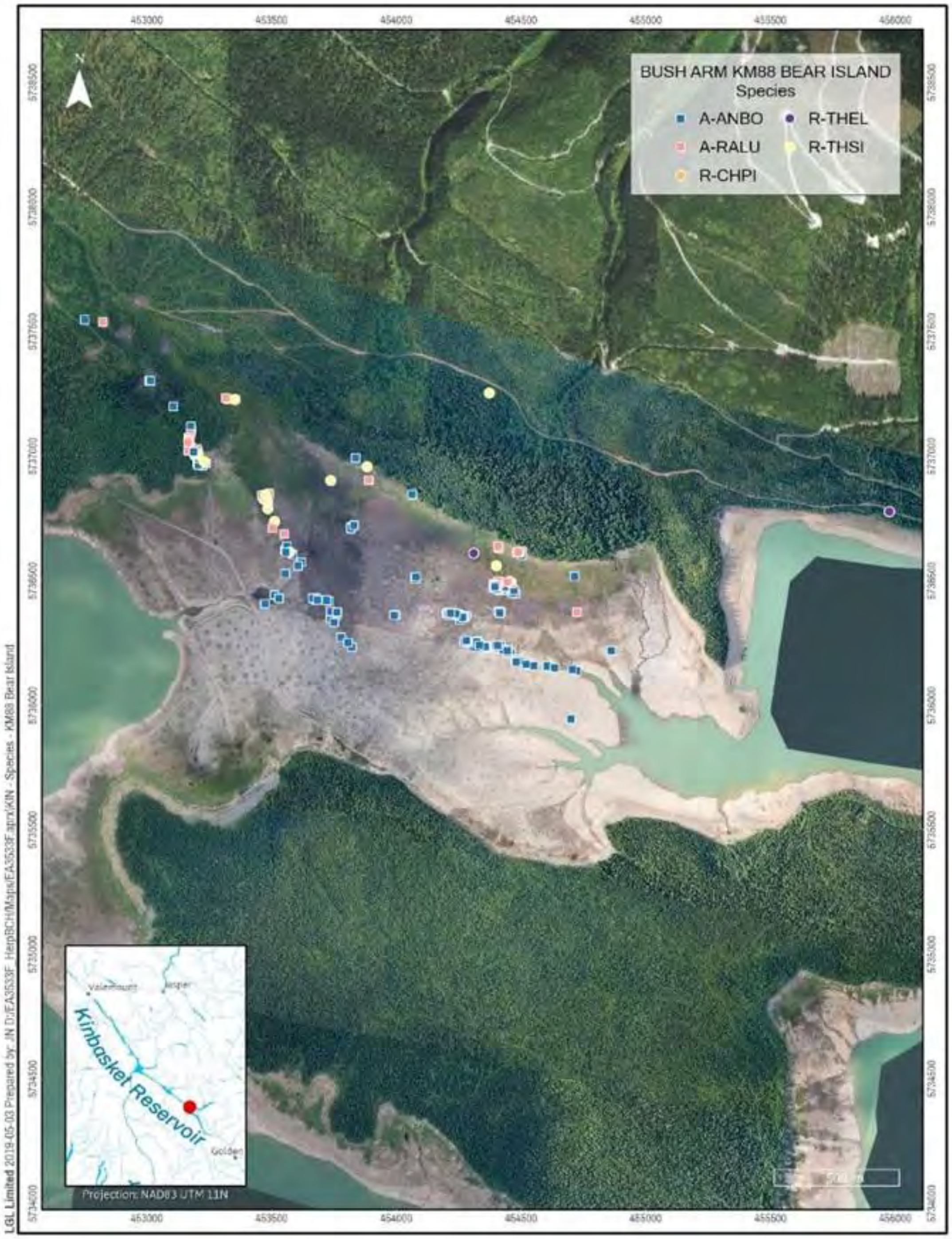
Kinbasket Reservoir



Map 7-1: **Distribution and occurrence of amphibian and reptile species documented around the Bush Arm Causeway, Kinbasket Reservoir between 2008 and 2018.**



Map 7-2: **Distribution and occurrence of amphibian and reptile species documented at Bush Arm KM79, Kinbasket Reservoir between 2008 and 2018.**

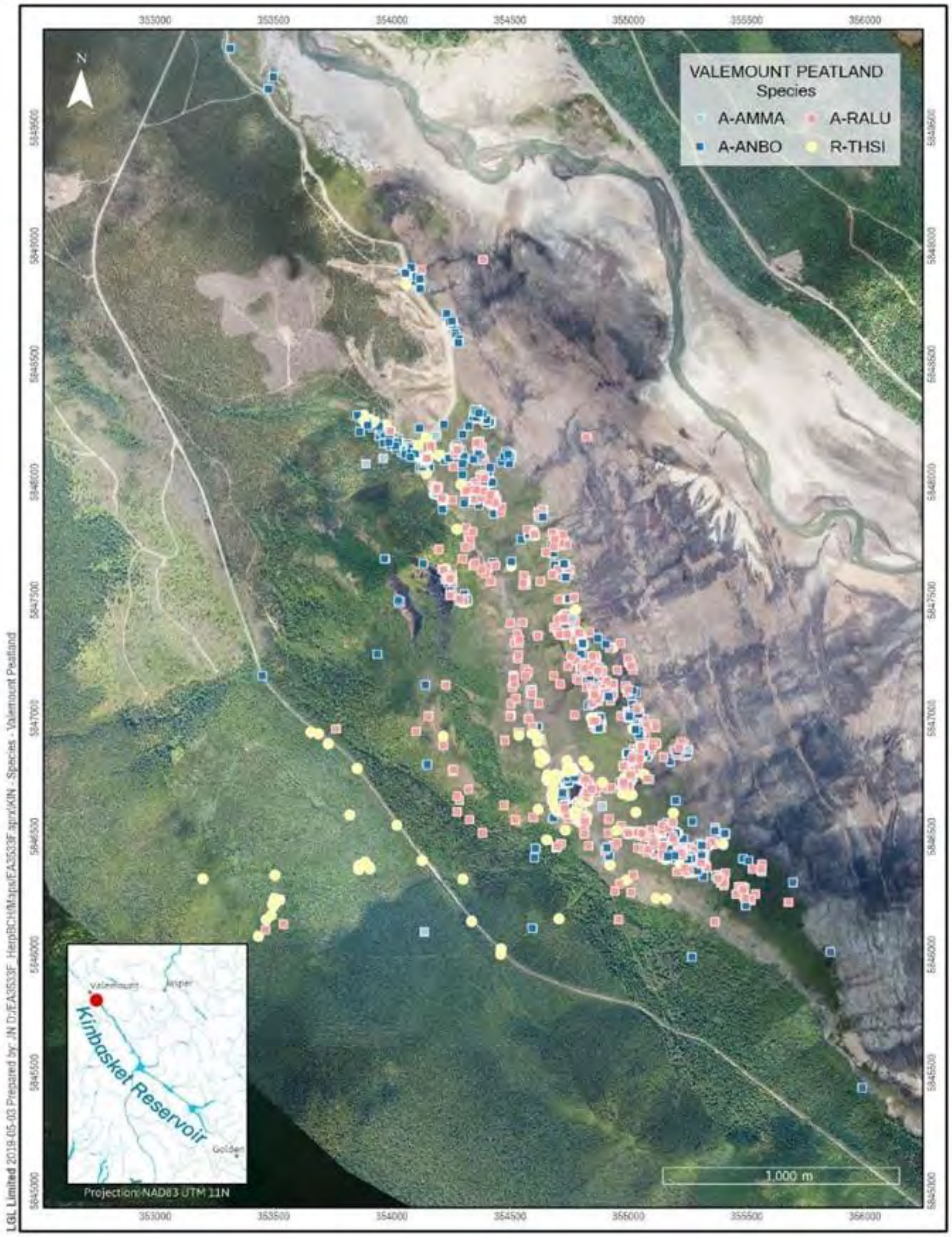


Map 7-3: Distribution and occurrence of amphibian and reptile species documented at Bear Island (mouth of Bush Arm), Kinbasket Reservoir between 2008 and 2018.

Map 7-4: Distribution and occurrence of amphibian and reptile species documented at Succour Creek (Bush Arm), Kinbasket Reservoir between 2008 and 2018.

Map 7-5: Distribution and occurrence of amphibian and reptile species documented at Ptarmigan Creek (Canoe Reach), Kinbasket Reservoir between 2008 and 2018.

Map 7-6: Distribution and occurrence of amphibian and reptile species documented at Sprague Bay (Mica Dam), Kinbasket Reservoir between 2008 and 2018.

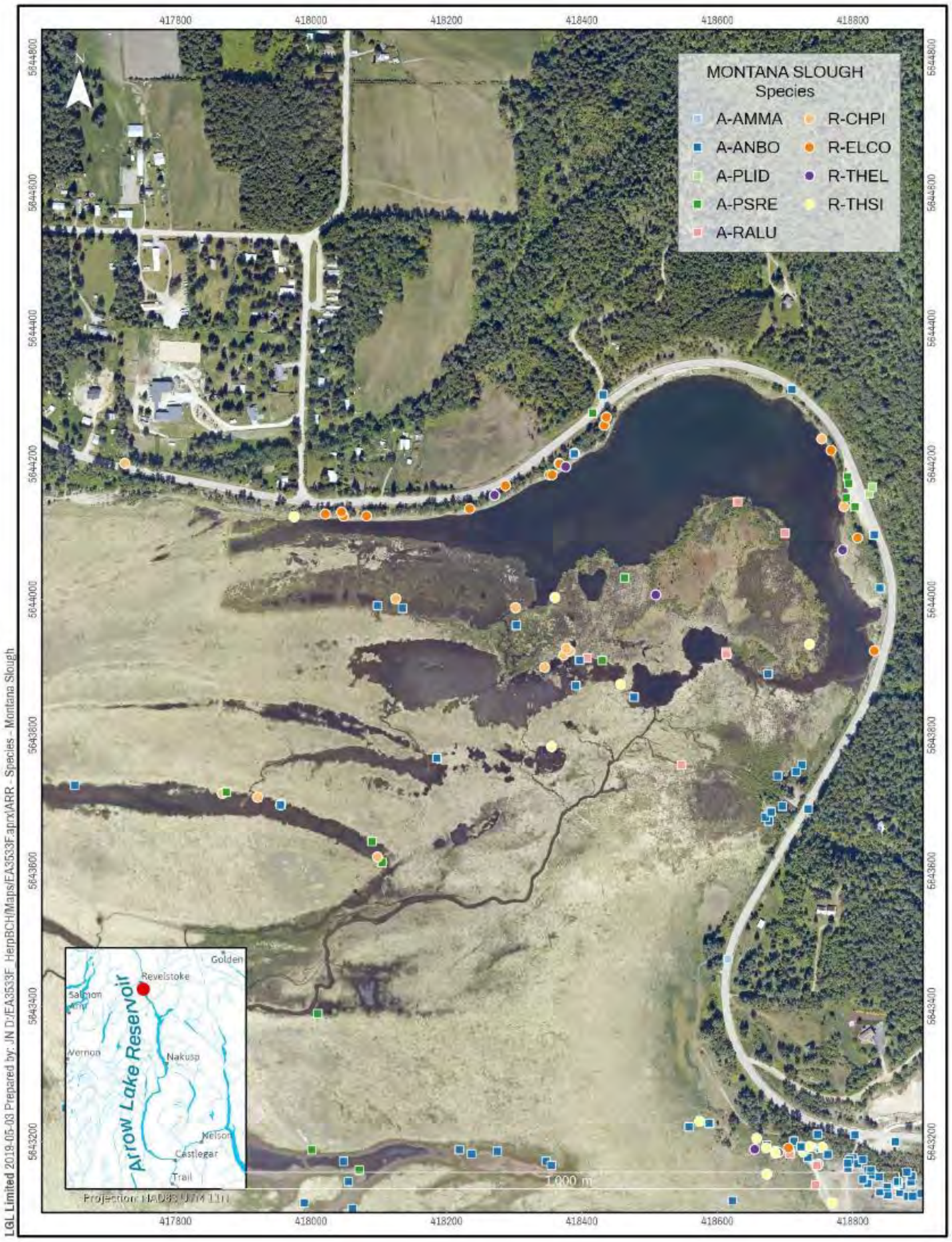


Map 7-7: **Distribution and occurrence of amphibian and reptile species documented in the Valemount Peatland (Canoe Reach), Kinbasket Reservoir between 2008 and 2018.**

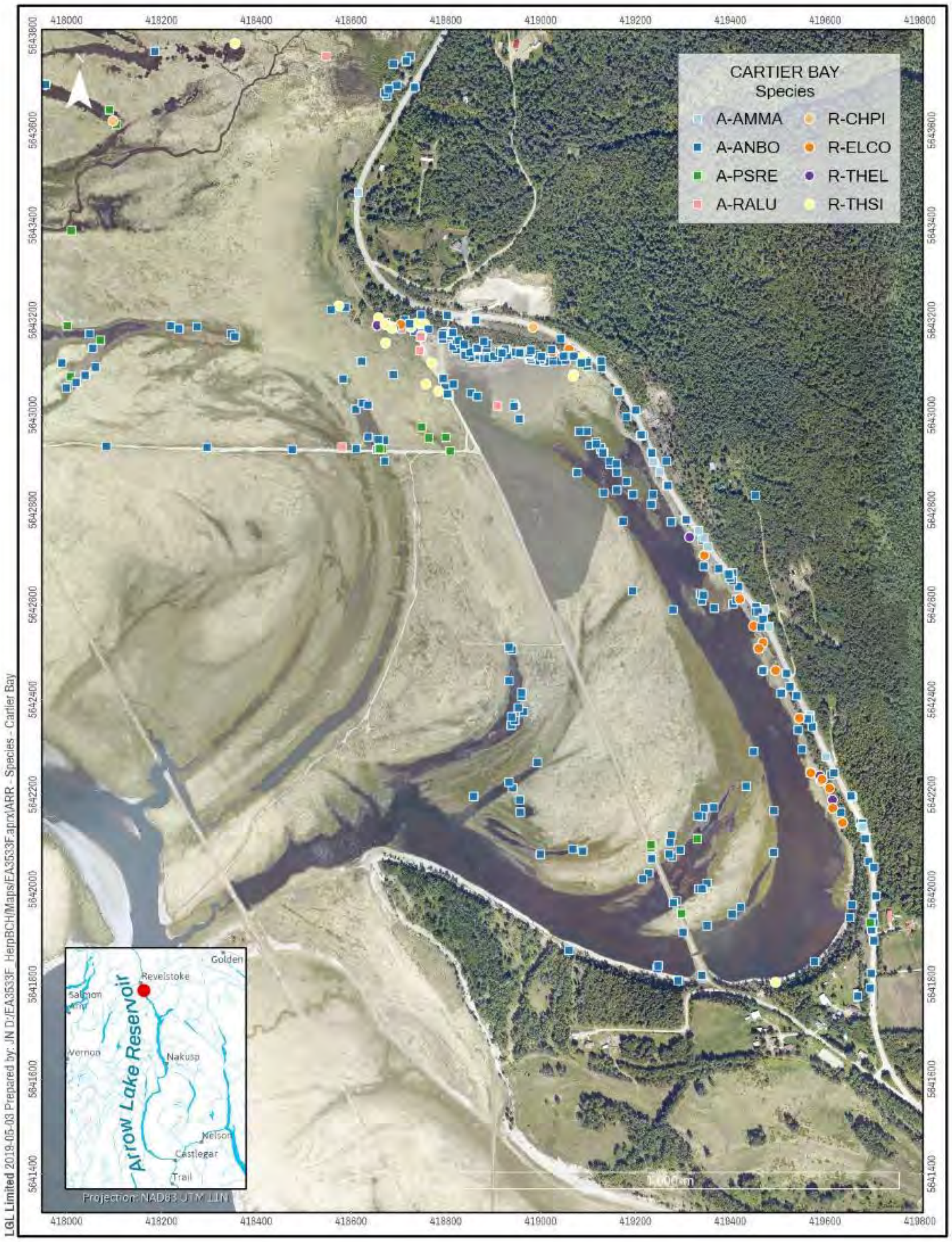
Arrow Lakes Reservoir

Map 7-8: Distribution and occurrence of amphibian and reptile species documented in the Downie Marsh area (Revelstoke Reach), Arrow Lakes Reservoir between 2008 and 2018.

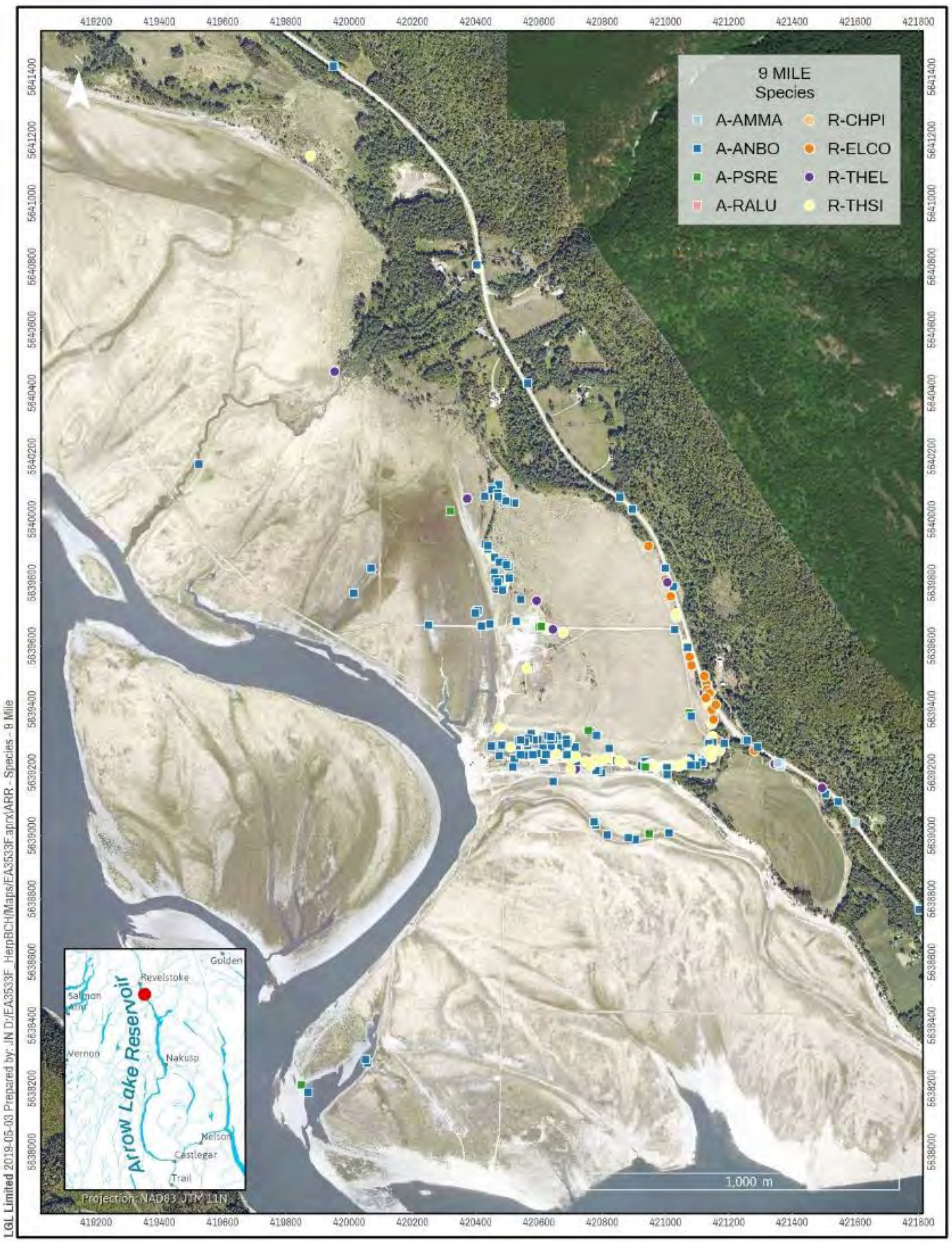
Map 7-9: **Distribution and occurrence of amphibian and reptile species documented in the vicinity of Machete Island (Revelstoke Reach), Arrow Lakes Reservoir between 2008 and 2018.**



Map 7-10: **Distribution and occurrence of amphibian and reptile species documented in the vicinity of Montana Slough (Revelstoke Reach), Arrow Lakes Reservoir between 2008 and 2018.**



Map 7-11: Distribution and occurrence of amphibian and reptile species documented in the Cartier Bay area (Revelstoke Reach), Arrow Lakes Reservoir between 2008 and 2018.



Map 7-12: Distribution and occurrence of amphibian and reptile species documented from the 9 Mile area (Revelstoke Reach), Arrow Lakes Reservoir between 2008 and 2018.

Map 7-13: Distribution and occurrence of amphibian and reptile species documented from the 12-mile area (Revelstoke Reach), Arrow Lakes Reservoir between 2008 and 2018.

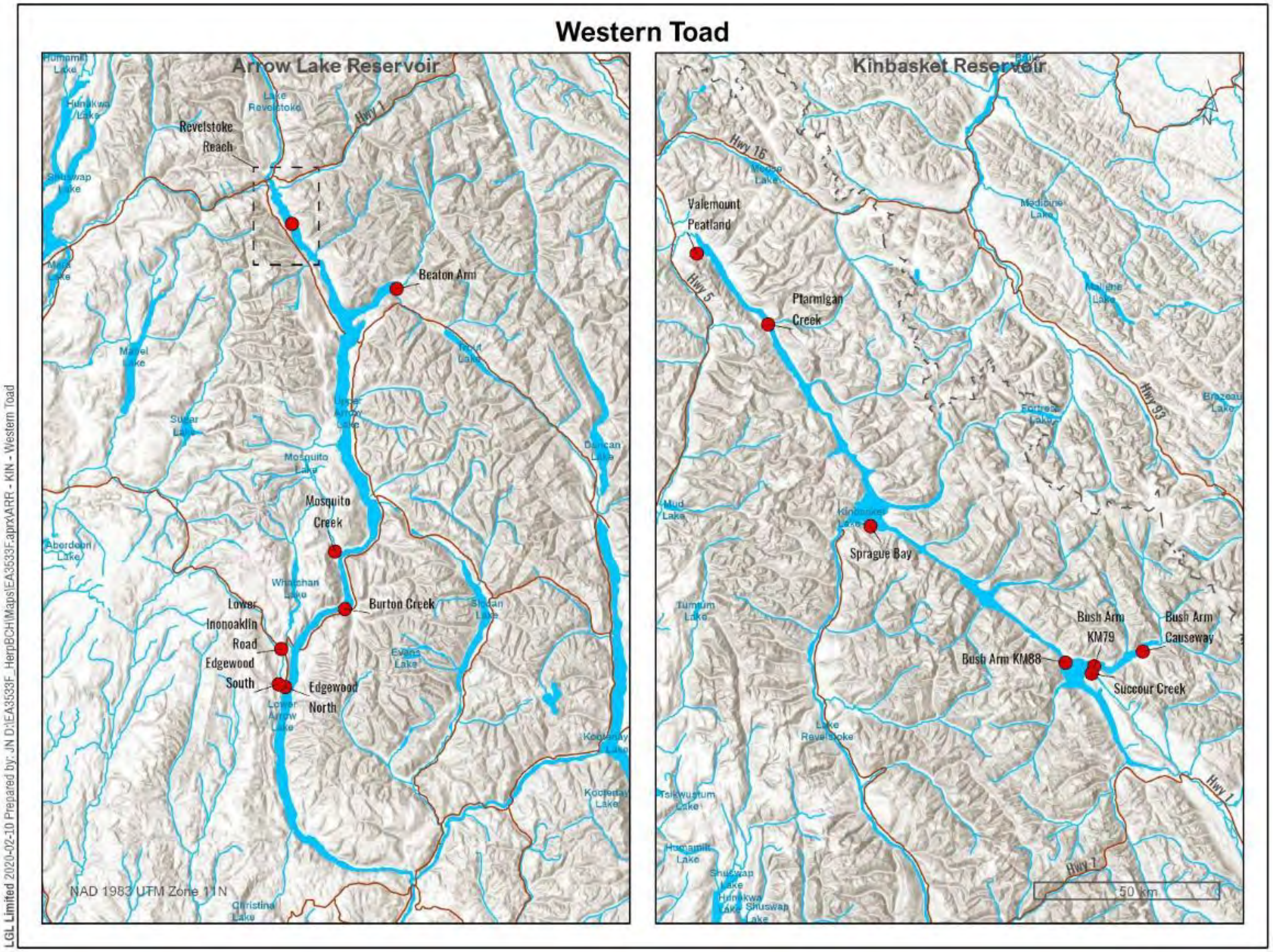
Map 7-14: **Distribution and occurrence of amphibian and reptile species documented at Burton Creek (Burton Flats), Arrow Lakes Reservoir between 2008 and 2018.**

Map 7-15: Distribution and occurrence of amphibian and reptile species documented at the Lower Inonoaklin Road study area, Arrow Lakes Reservoir between 2008 and 2018.

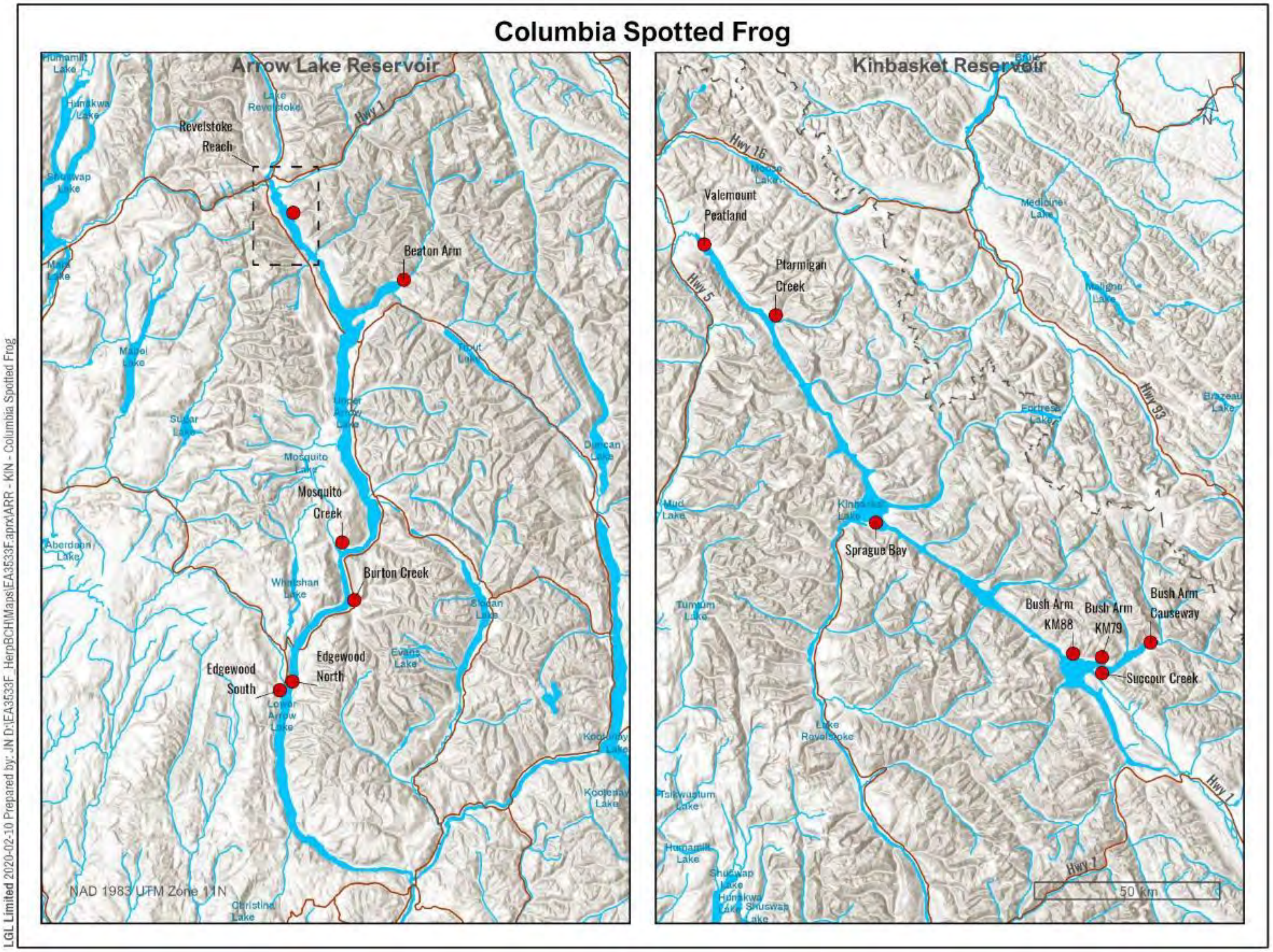
Map 7-16: Distribution and occurrence of amphibian and reptile species documented north of Edgewood (Eagle Creek), Arrow Lakes Reservoir between 2008 and 2018.

Map 7-17: Distribution and occurrence of amphibian and reptile species documented south of Edgewood (Eagle Creek), Arrow Lakes Reservoir between 2008 and 2018.

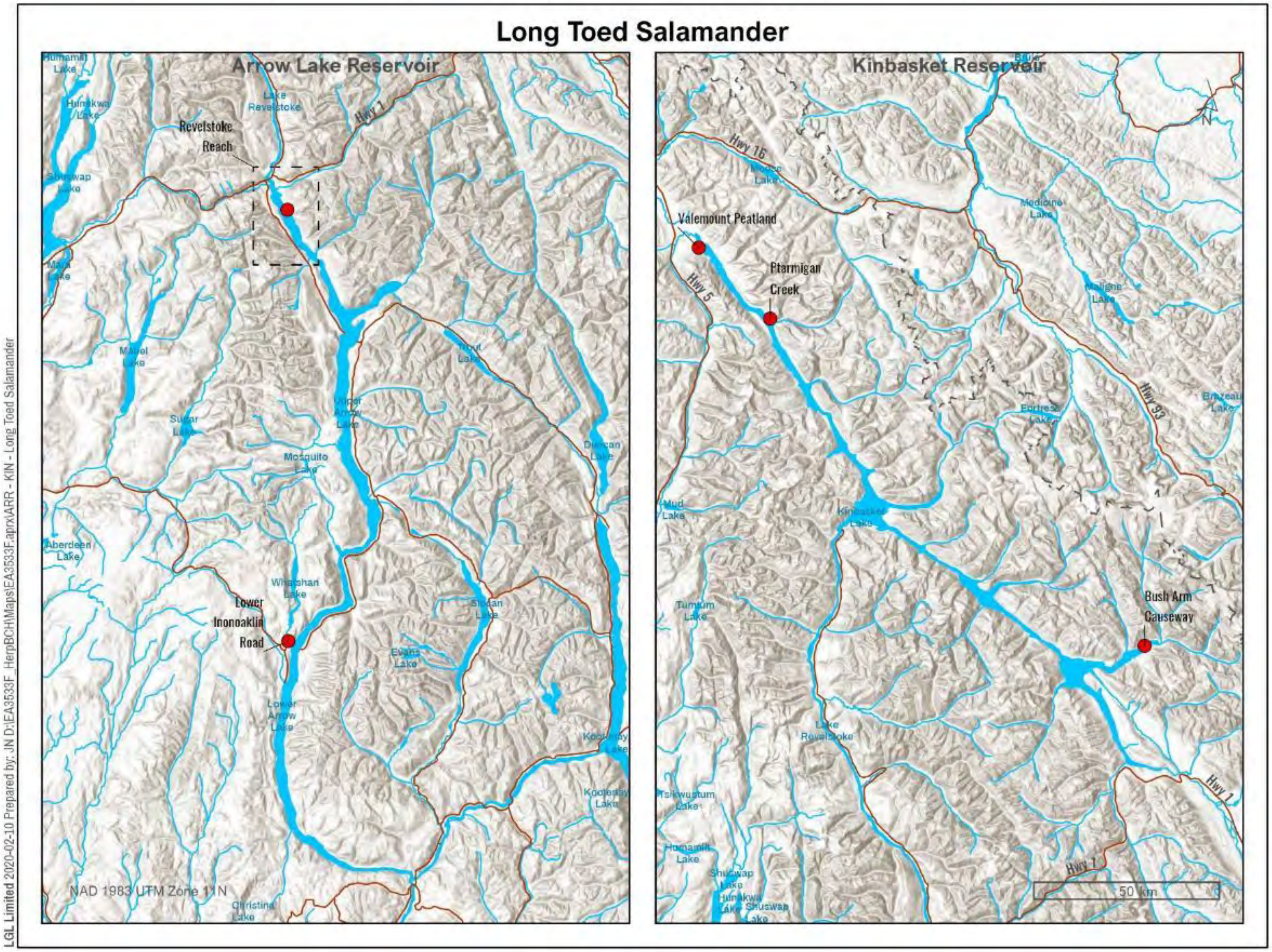
Appendix 16: Maps of amphibian and reptile species by reservoir



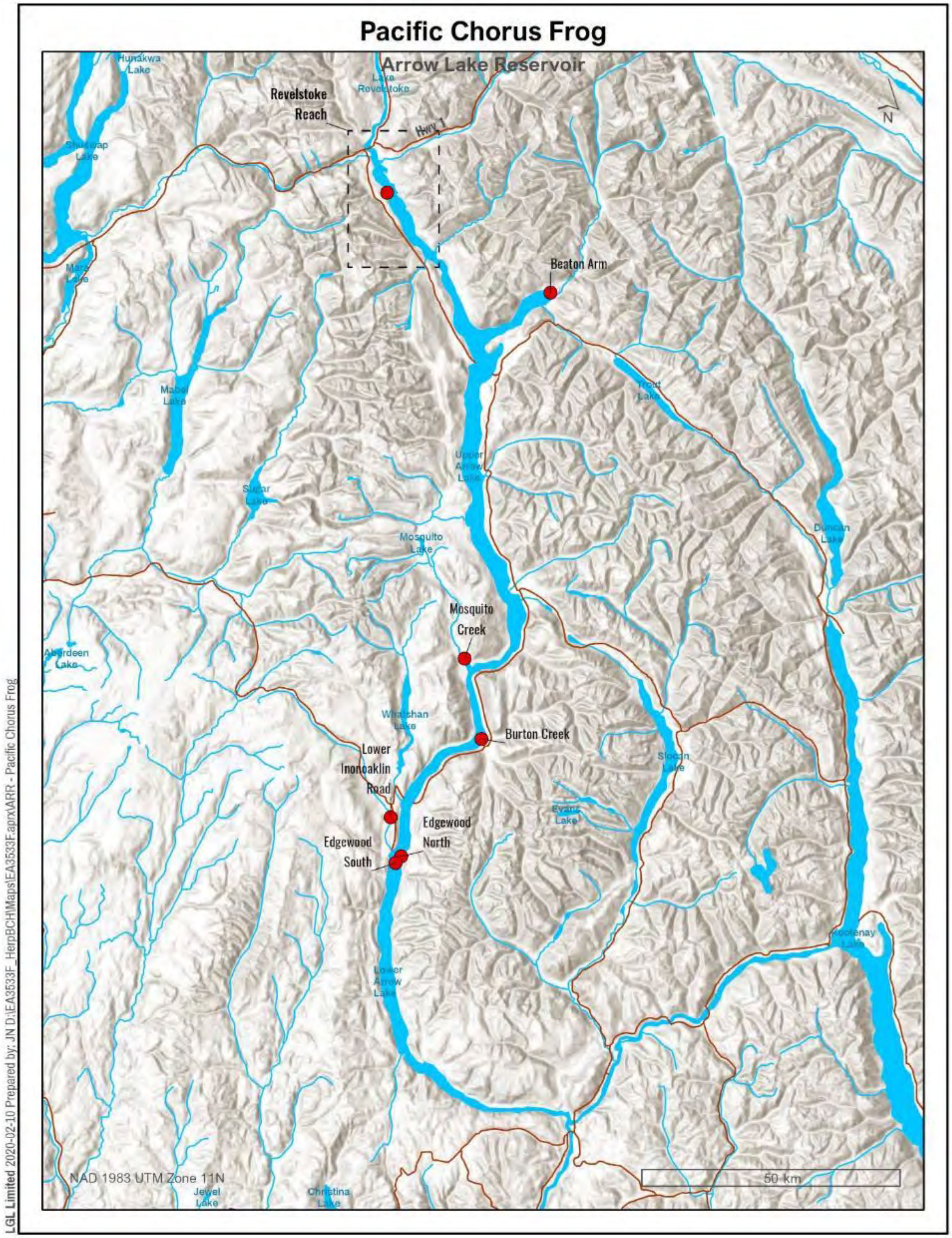
Map 7-18: Distribution and occurrence of Western Toads documented in Kinbasket and Arrow Lakes Reservoirs between 2008 and 2018.



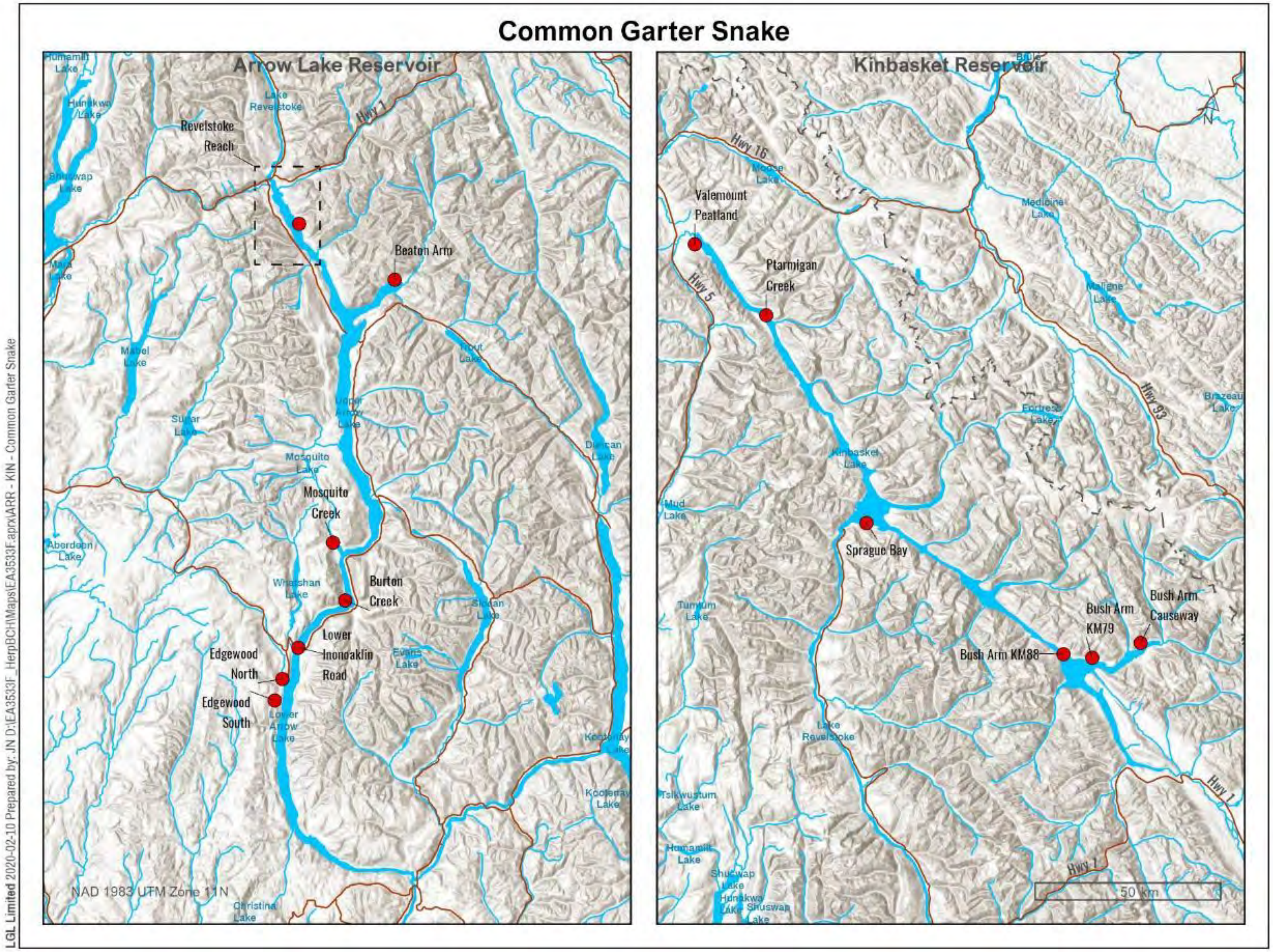
Map 7-19: Distribution and occurrence of Columbia Spotted Frog documented in Kinbasket and Arrow Lakes Reservoirs between 2008 and 2018.



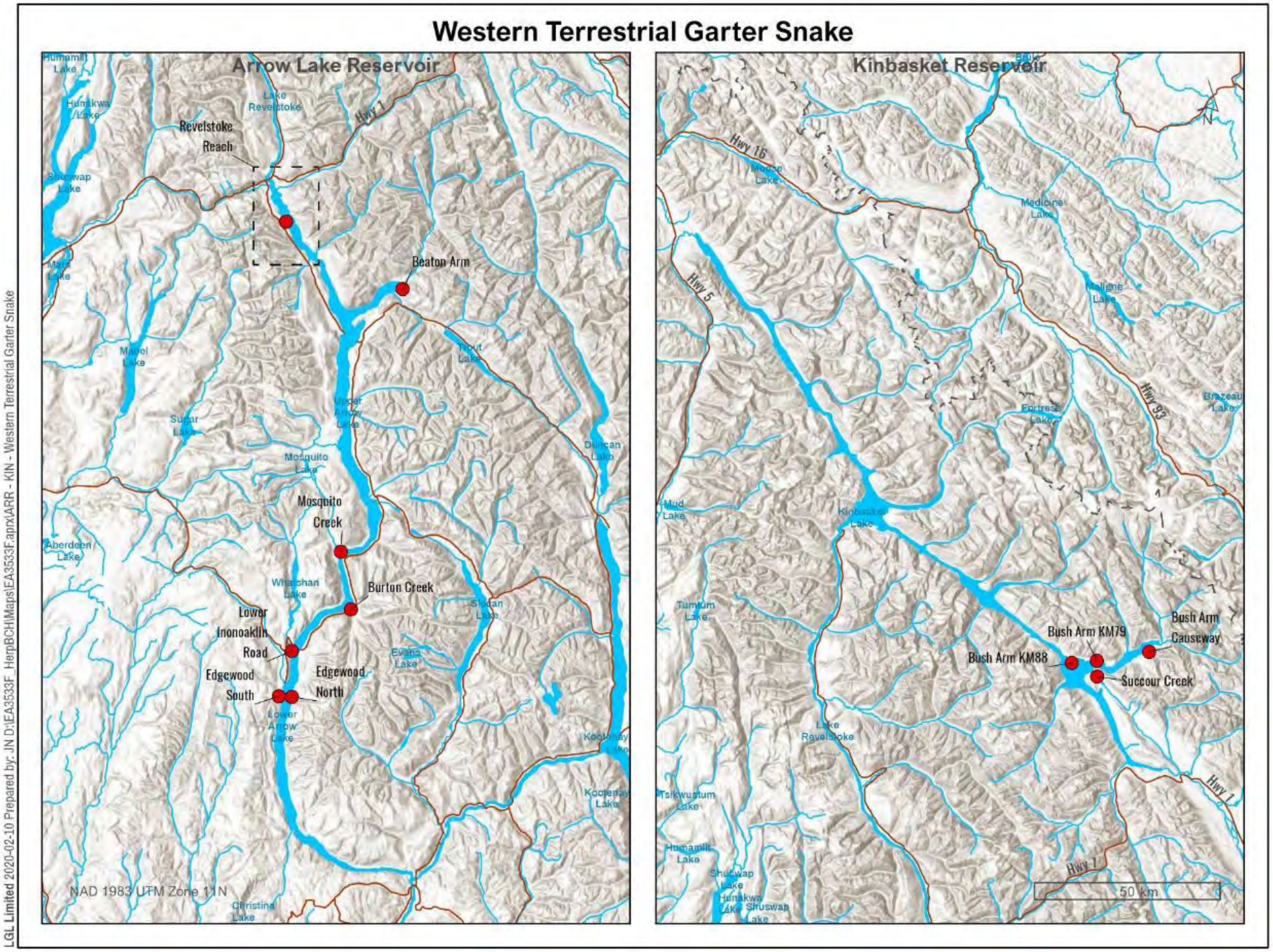
Map 7-20: **Distribution and occurrence of Long-toed Salamander documented in Kinbasket and Arrow Lakes Reservoirs between 2008 and 2018.**



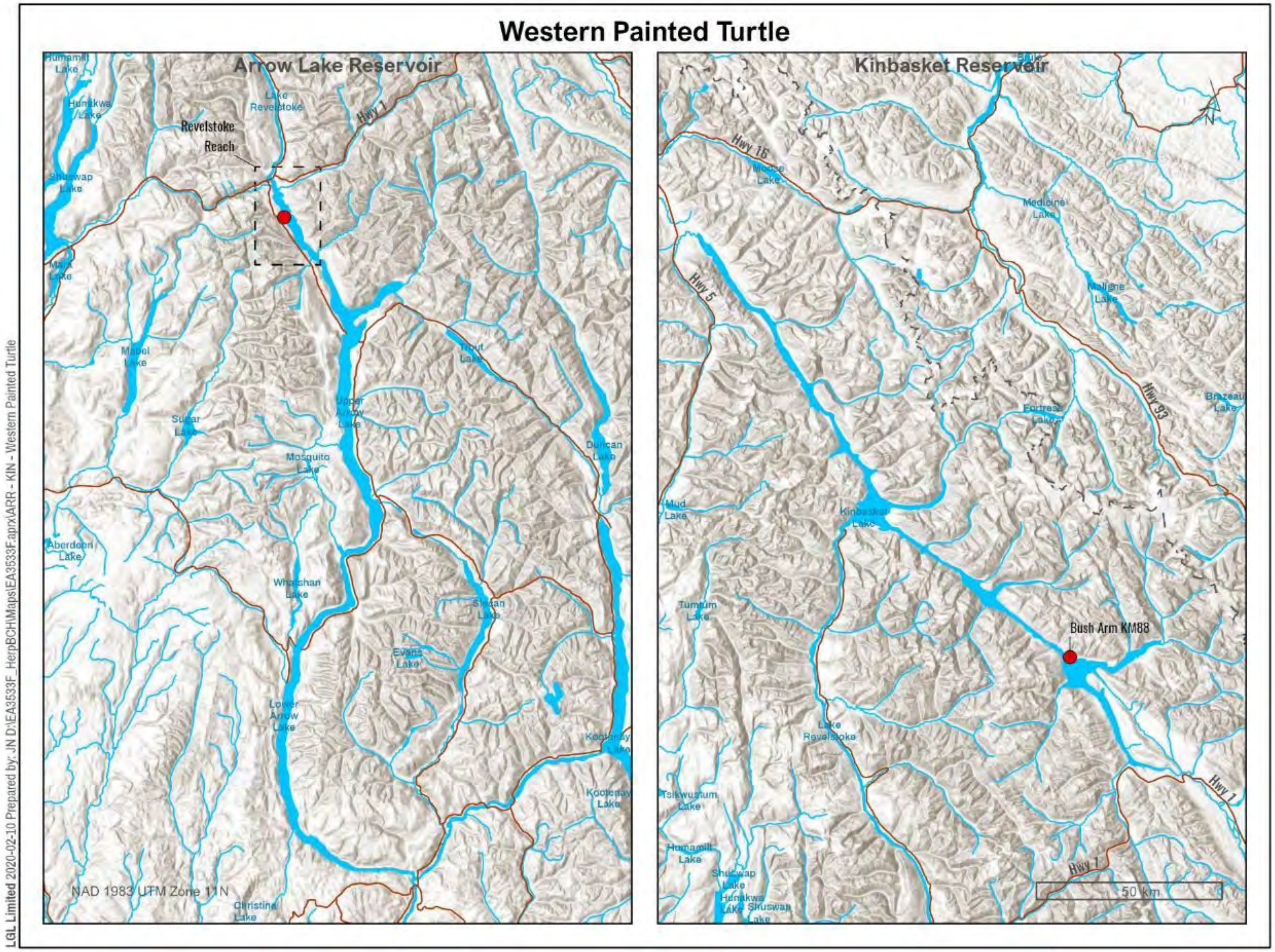
Map 7-21: Distribution and occurrence of Pacific Chorus Frog documented in Arrow Lakes Reservoirs between 2008 and 2018.



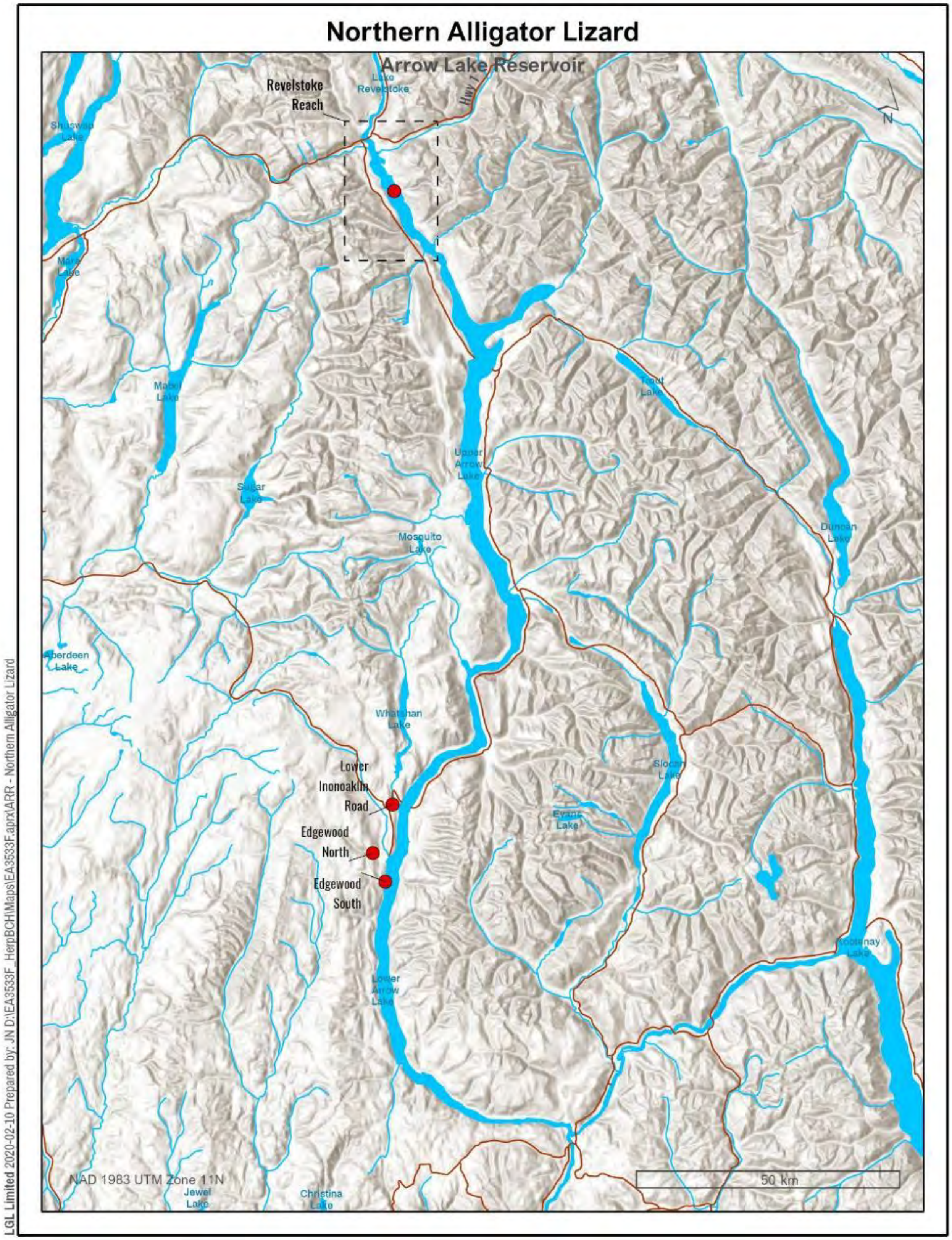
Map 7-22: Distribution and occurrence of Common Garter Snake documented in Kinbasket and Arrow Lakes Reservoirs between 2008 and 2018.



Map 7-23: Distribution and occurrence of Western Terrestrial Garter Snake documented in Kinbasket and Arrow Lakes Reservoirs between 2008 and 2018.



Map 7-24: Distribution and occurrence of Western Painted Turtle documented in Arrow Lakes and Kinbasket Reservoirs between 2008 and 2018.



Map 7-25: Distribution and occurrence of Northern Alligator Lizard documented in Arrow Lakes Reservoirs between 2008 and 2018.

Appendix 17: Maps of ponds at select monitoring sites.

Kinbasket Reservoir

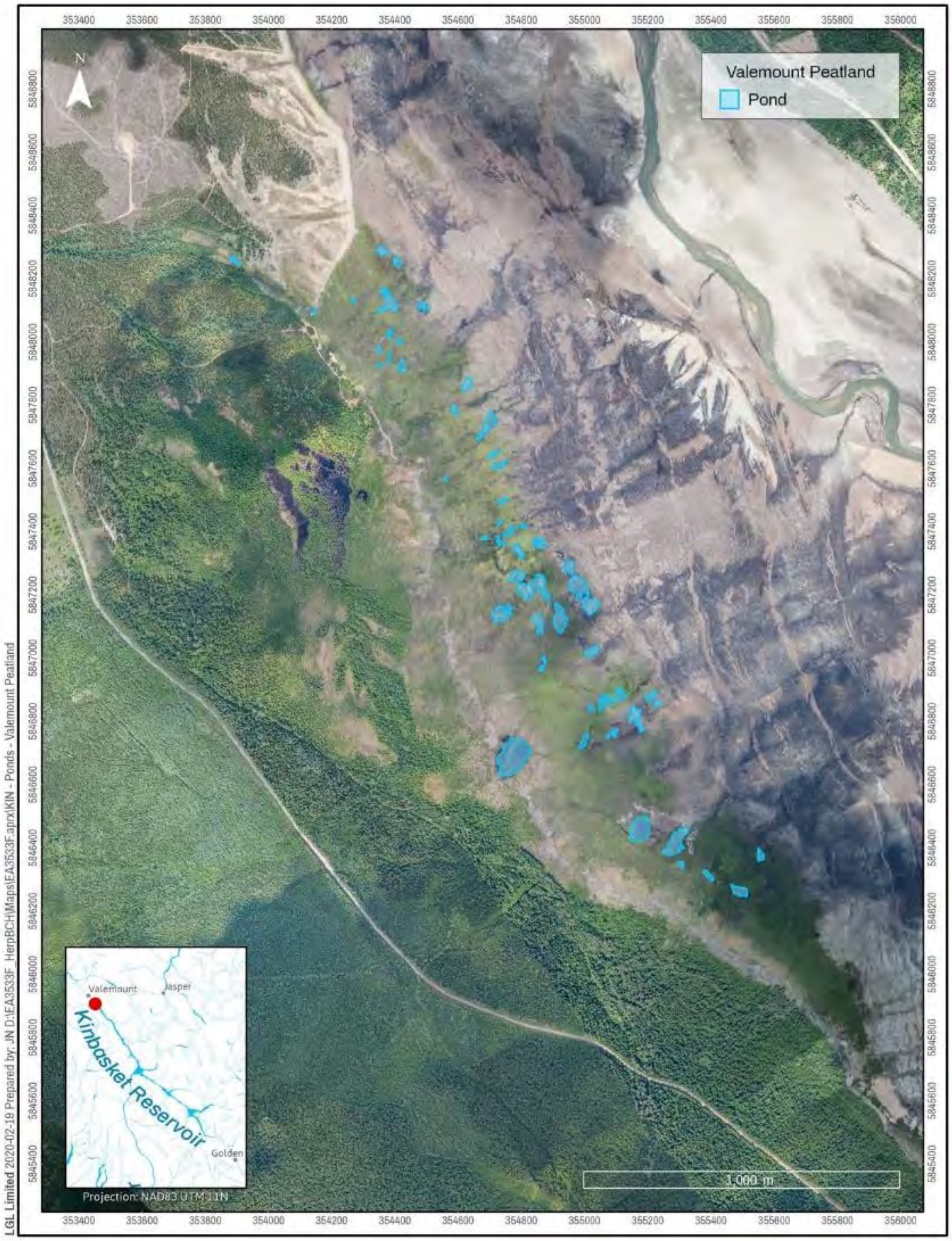


Figure 7-40: Delineated ponds in the drawdown zone at Valemount Peatland, Kinbasket Reservoir.

Figure 7-41: Delineated ponds in the drawdown zone at Bush Arm KM79, Kinbasket Reservoir.

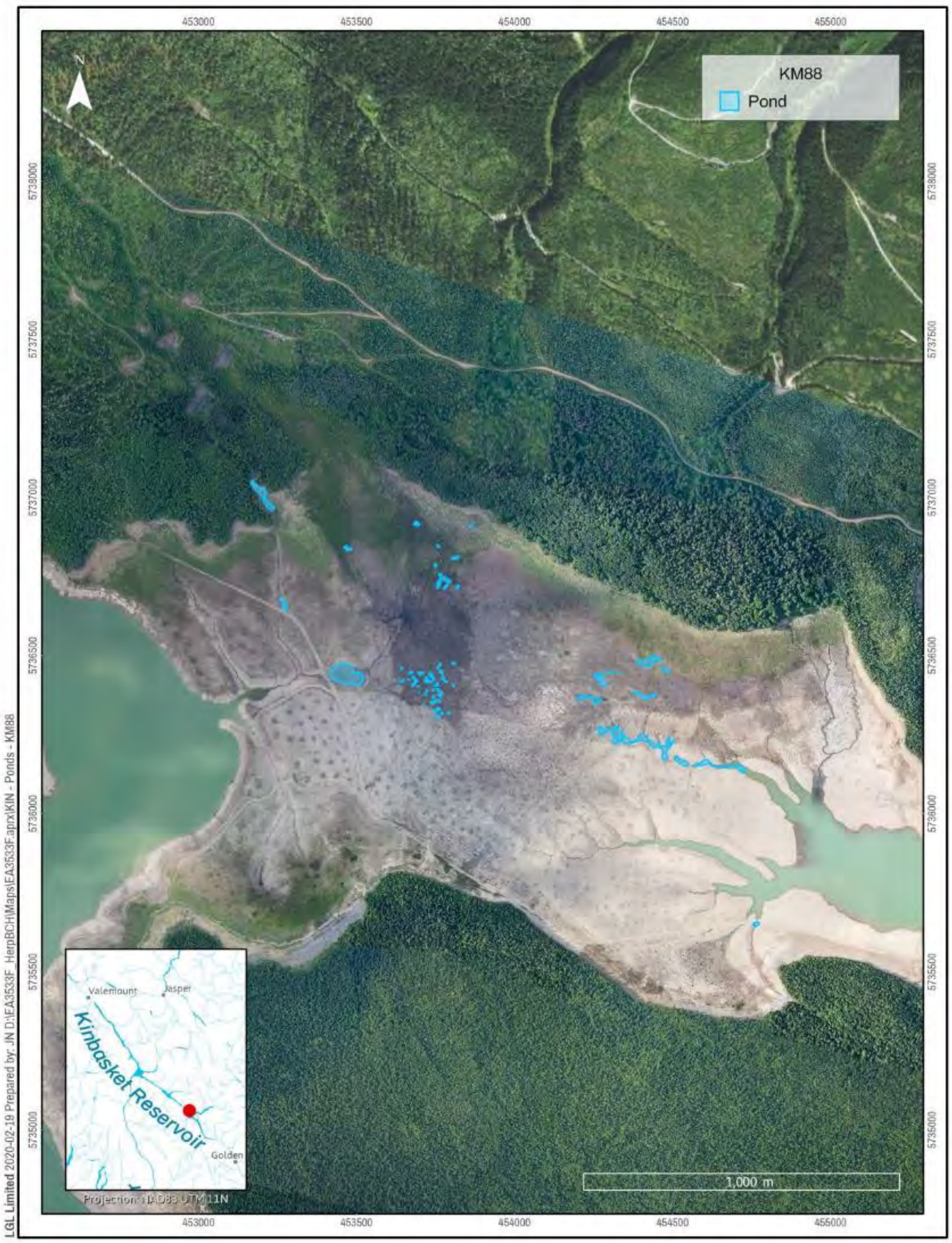


Figure 7-42: Delineated ponds in the drawdown zone at Bush Arm KM88 (Bear Island), Kinbasket Reservoir.

Arrow Lakes Reservoir

Figure 7-43: Delineated ponds in the drawdown zone at Airport Marsh (n =1), Cartier Bay (n = 15) and Montana Slough (n = 12) in Revelstoke Reach, Arrow Lakes Reservoir.