Columbia River Project Water Use Plan

Arrow Reservoir Operations Management Plan

Kinbasket and Arrow Lakes Reservoirs: Nest Mortality of Migratory Birds Due to Reservoir Operations

Implementation Year 8

Reference: CLBMON-36

Study Period: 2015

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Head Office
1250 Winchester Road
Qualicum Beach, BC

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CLBMON-36: Kinbasket and Arrow Lakes Reservoirs: Nest Mortality of Migratory Birds Due to Reservoir Operations

Year 8, 2015

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Cover photo: Nestling Yellow-headed Blackbirds. Airport Marsh, Revelstoke Reach, Arrow Lakes Reservoir, 2015 (photo by Harry van Oort)

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EXECUTIVE SUMMARY

Water Use Planning for the Columbia River provided guidance on the operations of hydroelectric reservoirs to improve ecological and recreational values. During this process, the multi-stakeholder Consultative Committee recognized that impacts of reservoir operations on breeding birds were potentially large, yet poorly understood. As a requirement of their new Water Licence, BC Hydro committed to research the impacts that reservoir operations have on the productivity of birds breeding in the reservoir drawdown zones of Kinbasket (KIN) and Arrow Lakes Reservoirs (ALR). CLBMON-36 is a 10-year monitoring program designed to fulfill this commitment. This report summarizes field study and analysis conducted in **2015**, **Year 8** of CLBMON-36.

At KIN, research has focussed on two regions. Canoe Reach (CR), near Valemount, BC, has been monitored annually since project inception (2008); the more remote Bush Arm (BA) region, closer to Golden, BC, was monitored for three years in order to increase knowledge of breeding birds that utilize vegetation communities in the drawdown zone that were not well-represented at CR. At ALR, only one study area has been monitored - Revelstoke Reach (RR), also monitored annually since project inception. All three study areas contain relatively high amounts of vegetated habitat, and appear to constitute the most important areas for breeding birds within the vast drawdown zones of these two reservoirs.

PROJECT OVERVIEW

Nest mortality: biogeography and site productivity monitoring

In Years 1-5, a focus of field research was to document how avian communities were distributed in the drawdown zones of KIN and ALR, and to document how nesting productivity was influenced by reservoir operations. New sites, stratified among habitat classes, were selected and monitored annually with the goal of finding all nests within 3 m of the ground at each site. Sites with active nests were visited regularly (~ every 3 days) to monitor nest survival.

After field studies for Year 5 were completed, an initial examination of biogeographical and productivity data was made. The Year 5 Interim Report (Y5IR) showed that the cumulative increase in species richness levelled off at both reservoirs after Year 3, indicating that knowledge of the diversity of species nesting in the drawdown zones of both reservoirs was near complete. Nonetheless, nests of additional uncommon species have continued to be located since that time, including Year 8. To date, 30 species have been discovered nesting in KIN's drawdown zone, and 61 species in ALR's. While we are confident that all regular species have been documented, additional rarities are likely to be discovered occasionally in the future.

It was evident by Year 5 that the project had attained a basic understanding of the biogeography of nesting communities within and among the various drawdown zone habitats of ALR and KIN. At both reservoirs, nesting was concentrated at higher elevations in the drawdown zones, where there is greater plant species diversity and a more complex vegetation structure. However, nesting was not restricted to these high elevation habitats, and extended to surprisingly low elevations in the drawdown zones where the habitat is devoid of vegetation. By Year 5, nesting was documented as low as 739.3 m ASL in KIN (~ 16 m below the historic maximum reservoir elevation), and as low as 433.2 m ASL in ALR (~ 8 m below the historic maximum reservoir elevation). The number of nests and diversity of species nesting varied considerably, depending on the habitat classes being monitored. In KIN one habitat class (WS – Willow Sedge Wetland) had a species richness of 13 with an average of 2.4 nest attempts per ha of monitored habitat each year, while other habitats were never observed to be used for nesting. In ALR, one habitat class (BF) had a species richness of 15, and an average of 11.9 nest attempts per ha of monitored habitat. There were also habitat classes in ALR where no nesting was observed (see Y5IR Appendix 1 and 2 for additional detail).

The Y5IR revealed that active nests in the ALR drawdown zone were often submerged by annual reservoir operations (mean = 11.7% of monitored nests observed to have flooded). Nest submergence was less common in KIN (2.8%), and was not observed every year. Nest predation was the leading cause of nest failure in both reservoirs. Overall, nesting success was greater in KIN, compared with ALR due to lower rates of nest predation and submergence.

A major result presented in the Y5IR was the production of the first empirically derived mechanistic model of nest activity as a function of elevation and time, allowing nest flooding rates to be modelled within the mapped parts of the drawdown zone. Although this model was not conceptually complex, its predictions correlated well with field observations.

Focal species research

In addition to the biogeography (community-level) study above, focal species monitoring took place to allow more detailed ecological processes to be explored within particular populations. This research explored how reservoir operations impact all aspects of productivity including nest survivorship and the survivorship of juveniles post-fledging. Focal species were monitored by targeted nest searches and subsequent nest inspections, and by using radio telemetry to track juvenile survivorship. To determine juvenile survivorship, we attached small radio transmitters to nestlings and located them daily to determine each bird’s status allowing us to determine how reservoir inundation of post-fledging habitat affected their prospect of survival. To determine if juvenile survival is impacted in reservoir drawdown zones, our approach was to contrast survival data in dry versus flooded habitats within the drawdown zone, and in drawdown zone habitats versus non-drawdown zone habitats.

Focal species monitoring has been ongoing since project inception for two particular species: the Savannah Sparrow (SAVS) in the CR study area, and the Yellow Warbler (YEWA) in RR. Focal species monitoring has been an increasing focus of field study since Year 5. In particular, radio telemetry work commenced in 2012 following the 5YIR.

Since project inception, we have generated substantive nesting data for the ground-nesting SAVS in KIN. No formal analyses have yet been conducted on the CR SAVS data. The SAVS dataset is now large enough to begin some analyses, but a need remains to continue juvenile monitoring. The YEWA have been studied in collaboration with Dr. D.J. Green (and students) at Simon Fraser University (SFU). Due to the collaboration, three YEWA populations in the ALR drawdown zone have been intensively studied, with most breeding adults and fledged young being colour-banded each year. To date, one peer-reviewed paper has demonstrated that YEWA habitat selection in the ALR drawdown zone is adaptive, indicating that the drawdown zone habitats these birds select are unlikely to function as ecological traps. An additional paper has shown that YEWA (and Willow Flycatcher) are buffered from the effect of nest flooding to some degree because they are compensated for nest flooding by reduced predation rates at non-flooded nests positioned in flooded habitat. Our component study of juvenile YEWA survival using telemetry concluded in Year 7 (2014), with sufficient data to show a negative impact of reservoir operations on juvenile survivorship (summarized in this report).

SUMMARY OF YEAR 8 PROGRESS

In Year 8, field work continued in CR and RR. We located 365 nests from 39 species. In the early breeding season, a census of Canada Goose nests in RR was also made north of 12 Mile; during this census, 32 Canada Goose nests were located, primarily in Airport Marsh but also in Montana Slough. Previously unrecorded species were observed nesting in both reservoirs; Blue-winged Teal in KIN, and Bullock's Oriole in ALR.

The operations of both reservoirs were highly unusual in 2015. Reservoir levels in ALR were considerably lower than normal throughout the breeding season. At KIN, water levels were atypically high and initially filled at normal rates; however, the rate of reservoir fill reduced substantially as the breeding season progressed, and a very low maximum elevation was reached, followed by drafting, much earlier compared with normal operations. Under these non-typical operations, no nests were observed to be flooded in ALR, which is a new result for CLBMON-36. In KIN, there were three cases of nest flooding observed, which is not unusual, but the flooding in KIN occurred earlier than normal. Had KIN continued to be drawn to normal high water elevations with a normal rate of filling, the nest flooding destruction would have been well above what we have observed previously.

In Year 8, 30 Savannah Sparrow nestlings were tagged for juvenile monitoring at CR, with half being located in the drawdown zone, and half located above the drawdown zone.

NEW ANALYSES, RESULTS, AND CONCLUSIONS

In 2015, we laid the groundwork in preparation for a myriad of nest survival analyses. Previous analyses of nest survival for CLBMON-36 utilized the program MARK nest survival model and the logistic exposure approaches; both options were less than ideal in several regards, and neither allowed the flexibility required for the types of analyses required – namely mixed effects models. In 2015, we explored using a Bayesian approach to nest survival modeling. This process involved writing code to format data appropriately once imported from the CLBMON-36 database, and a considerable programming effort, with the aide of published code that we adapted for our purposes. This model was validated using a simulation study. We then performed a draft analysis on duck nesting data to examine if nest site elevation and nesting on the floating bog habitat in the ALR had any effect on nest survival. These analyses controlled for year effects and species using mixed effects models with random intercept terms, although we recognize that given low species diversity in the analysis, and relatively low numbers of years, mixed effect terms were not necessarily suitable. Our analysis indicated that duck nest survival is generally very low in the ALR, and showed support for the idea that floating habitat offers a nest survival advantage, possibly via reduced nest flooding impacts.

The Yellow Warbler juvenile survival data were analyzed by Mathew Hepp (SFU) in 2015, as part of a Master's of Science program. These results indicated that the state of flooding within the post-fledging area negatively impacted juvenile survival. Those results are also summarized in this report, but will be formally presented as an SFU thesis document.

RECOMMENDATIONS FOR 2016

- Site selection in 2016 should continue to focus on filling knowledge gaps.
- We recommend working in Bush Arm in 2016 rather than CR.
- Continue to model predictors of nest survivorship (e.g., habitat, elevation, species nesting 'guilds')

With two years remaining in the CLBMON-36 study, we feel that the project is in a solid position and that each management question, hypothesis and objective will be adequately addressed.

Keywords

River regulation, reservoir operations, nest mortality, habitat distribution, habitat suitability, flooding, submersion, nest monitoring, nest survivorship, juvenile survivorship, Yellow Warbler, *Dendroica petechia*, Savannah Sparrow, *Passerculus sandwichensis*, Arrow Lakes Reservoir, Kinbasket Reservoir, BC Hydro, British Columbia

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CBA collaborates with the Okanagan Nation Alliance (ONA) for delivery of CLBMON-36, with ONA biologists and technicians providing field and technical support, and insight into the perspectives and protocols of the Syilx (Okanagan) people. Bruce Weaver of the Okanagan Indian Band and Karle Zelmer of the ONA contributed to field studies. Al Peatt managed the ONA's involvement and provided a technical review of this report.

Many people contributed to field studies including: Devon Anderson, Corey Bird, Emily Braam, James Bradley, Allan Carson, Catherine Craig, Kate Gibson, Ryan Gill, Michal Pavlik, Vicki Prigmore, Harry van Oort, Bruce Weaver, and Karle Zelmer. Ryan Gill provided GIS mapping. Ryan Gill and Harry van Oort planned the field study program. Suzanne Beauchesne provided overall supervision and monitoring of crews. John Cooper acted as Project Manager and provided a technical review of this report.

CBA worked closely with Simon Fraser University throughout this study. Dr. David Green of Simon Fraser University coordinated some of the Yellow Warbler research in 2014, which was conducted by Michal Pavlik and Kate Gibson. Dr. David Green provided scientific guidance to CBA. Matthew Hepp and Lena Ware collected the Yellow Warbler juvenile survival data.

Matthew Hep conducted the juvenile survival analysis; Harry van Oort conducted all other analyses.

Lesley-Anne Howes and Louise Laurin (Canadian Wildlife Service Bird Banding Office) processed bird banding and capture permits. All procedures followed in this study were approved by the Simon Fraser Animal Care Committee.

CBA would like to thank the communities of Valemount and Revelstoke for providing safe and enjoyable home bases for field crews during the field season.

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1 INTRODUCTION

The regulation and impoundment of river basins causes considerable impact to riparian and wetland wildlife, initially through habitat destruction, and continually via the ongoing regulation of water (Nilsson and Dynesius 1994). The Columbia River is one of the most modified and regulated large rivers in North America (Nilsson et al. 2005), with multiple dam projects existing in both the USA and British Columbia portions of the basin. Water storage reservoirs along the primary course of the Columbia River in BC include the Kinbasket Reservoir (KIN), Lake Revelstoke, and the Arrow Lakes Reservoir (ALR), positioned sequentially along the river's main stem (many other impoundments exist on the tributaries). The footprint impact of Columbia River basin reservoirs has been estimated to cause a loss of 26% of the wetlands, 21% of riparian cottonwood, and 31% of shallow water and ponds in BC portion of the basin (Utzig and Schmidt 2011). In place of these and other natural habitats that were lost, are the substantial drawdown zones of these reservoirs, typically comprised of steep, barren shorelines, with negligible value as habitat for wildlife.

Yet in some parts of reservoir drawdown zones in BC, important wildlife habitats persist, some with significance as nesting habitat for a variety of birds. In particular, the upper four meters of the drawdown zone in Revelstoke Reach (RR) at the north end of ALR is highly vegetated and known to be used by a diversity of birds during the breeding season (Boulanger 2005, Jarvis 2006, Quinlan and Green 2012, CBA 2013). The drawdown zones at Canoe Reach (CR) and Bush Arm (BA), both in KIN, also contain several vegetated areas suitable as nesting habitat (CBA 2010a, 2011, 2013). Because these remnant breeding habitats are located in reservoir drawdown zones, the operation of ALR and KIN reservoirs may have significant impacts on the productivity of resident bird populations (CBA 2013). It is possible that some nesting habitats within the reservoir act as ecological traps (Schlaepfer et al. 2002, Robertson and Hutto 2006, Anteau et al. 2012, CBA 2013), and/or that some drawdown zone populations act as population sinks (Pulliam 1988)[1] caused by the flooding of nesting habitats, and nests during the breeding season (Wolf 1955, Espie et al. 1998, Anteau et al. 2012).

During the Columbia River Water Use Planning process (BC Hydro 2007), nest mortality caused by reservoir operations was identified as a critical issue. The primary concern was that the operations of ALR and KIN may reduce the productivity of breeding bird communities via nest submersion. This concern arose from earlier studies in RR that documented a high diversity of birds using drawdown habitats during the breeding season (Boulanger et al. 2002, Boulanger 2005), and pilot surveys that documented nest mortality resulting from reservoir operations (Jarvis 2003, 2006). Furthermore, the discovery of Short-eared Owl (*Asio flammeus*) nesting within the drawdown zone in 2002 (Jarvis 2003) highlighted the potential for reservoir operations to have negative effects on breeding bird species protected under the federal *Species at Risk Act* (SARA). Under the direction of the Columbia River Water Use Plan, and as one of their Water Licence Requirements (WLR), BC Hydro initiated CLBMON-36, a 10-year program designed to determine the effects of reservoir operations (water level management) on breeding

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[1] Ecological traps occur when populations prefer/select unnatural habitats where reproduction is compromised (misguided preferences). Population sinks are sub-populations in a meta-population with intrinsic productivity that is insufficient to sustain the population size; their existence is sustained by immigration (demographic rescue) from other sub-populations.

success of birds nesting in the drawdown zone of KIN and ALR, and to provide feedback and guidance on the efficacy of methods used to enhance breeding habitats for birds in reservoir drawdown zones (revegetation and wildlife physical works).

1.1 Objectives

The objectives of CLBMON-36 are as follows:

- Identify how drawdown zone habitats are used by breeding birds in Kinbasket Reservoir and Revelstoke Reach.
- Evaluate how the operations of the Kinbasket and Arrow Lakes Reservoirs influence nest survival.
- Evaluate how the operations of the Kinbasket and Arrow Lakes Reservoirs influence juvenile survival.
- Establish a nest flooding risk model for Kinbasket Reservoir and Revelstoke Reach.
- Assess how habitat management in the drawdown zones can be used to increase productivity, or reduce negative impacts of reservoir operations.

1.2 Management questions

To achieve the above objectives, the Terms of Reference (TOR) for CLBMON-36 list Management Questions that the research should address:

A. Which bird species breed in the drawdown zones and how are they distributed among the drawdown zone habitat classes?

B. What are the seasonal patterns of habitat use by birds nesting in the drawdown zones?

C. Do reservoir operations affect nest survival?

D. What are the causes of nest failure in the drawdown zone, and how do they differ among species, among habitat classes, and across elevation (i.e., position in drawdown zone)?

G. Do reservoir operations affect juvenile survival when water levels inundate post-fledging habitat?

H. How can the operations of the Kinbasket and Arrow Reservoirs be optimized to reduce nest submersions and/or improve avian productivity?

K. Can drawdown zone habitats be managed to improve nest survival and/or site productivity? If so, how?

1.3 Management hypotheses

Further to the Management Questions, several hypotheses were drafted to focus data collection and analysis:

H1: Inundation of nesting habitat caused by reservoir operations does not affect nest survivorship.

H1A: Nest survivorship in the drawdown zone is not different from nest survivorship above the drawdown zone.

H1C: Nest survivorship does not differ across elevations in the drawdown zone.

H1D: Rates of nest flooding do not differ across elevations in the drawdown zone.

H2: Inundation of post-fledging habitat does not affect juvenile survival.

H2A: Juvenile survival in the drawdown zone does not differ from juvenile survival above the drawdown zone.

The above **Objectives**, **Management Questions** and **Hypotheses** were refined in the CLBMON-36 TOR revisions in 2014. The TOR re-write addressed several outstanding issues that were highlighted in previous reports (e.g., CBA 2013) and improved clarity. Notably, two Management Questions (E and F) were removed because they were not questions that could be answered by CLBMON-36, and two others (I and J) were amalgamated as one question (K). Similar editing to the objectives and hypotheses also occurred. A table showing how the revised objectives, questions and hypotheses are related is provided in Appendix 6-1.

1.4 Study areas

Field studies in 2015 were conducted at one study area in each of two reservoirs: RR (ALR) and CR (KIN; Figure 1-1).

1.4.1 Canoe Reach, Kinbasket Reservoir

KIN is the upper-most reservoir along the Columbia River. The KIN reservoir impounds a 216-km section of the Columbia and Canoe Rivers, and is operated by BC Hydro for storage (12 MAF), power generation (1805 MW) and flood control downstream (BC Hydro 2007). It extends from Donald, 39 km northwest of Golden, north, down the Columbia River and further north up the Canoe River to ~ 7 km south of Valemount. The reservoir is regulated by outflow at the Mica Dam (input is unregulated) and is licensed to operate between 707.41 m and 754.38 m (BC Hydro 2007). Additional storage may be attained (to an elevation of 754.68 m) with approval from the BC Comptroller of Water Rights.

KIN drawdown zone habitats have been described and mapped by another WLR project (CLBMON-10; Hawkes et al. 2010) and this work informed the design of the CLMBON-36 monitoring regime (i.e., site selection). The first five years of bird studies under CLBMON-36 documented nesting in 13 of the described habitat types (see Appendix 6-2), with annual nest density estimates ranging up to 2.35 nests per hectare (CBA 2013). The habitat with the greatest nest density (WS = Willow-Sedge wetland), had the highest diversity of nesting species (13 species), and a mapped area of ~35 ha within the KIN drawdown zone.

Situated between the Monashee and Rocky Mountains, CR is the northern arm of KIN (Figure 1-1). CR occurs in the Interior Cedar–Hemlock moist mild (ICHmm) biogeoclimatic subzone (Meidinger and Pojar 1991) and receives moderate precipitation, primarily from Pacific frontal systems that shed snow during the winter. The reservoir is surrounded by steep rugged mountain slopes with managed coniferous forests. The study area is approximately 50 km long and extends from the northern end of the reservoir south as far as Hugh Allen Creek on the east shore, and as far as Windfall Creek on the west shore. The drawdown zone of this area is largely comprised of steep, unvegetated shorelines of sand, gravel and cobble, but includes vegetated habitats near seepage sites, which are characterized by grasses and sedges (Figure 1-2). Extensive remnant peat lands occur at the north end of CR.

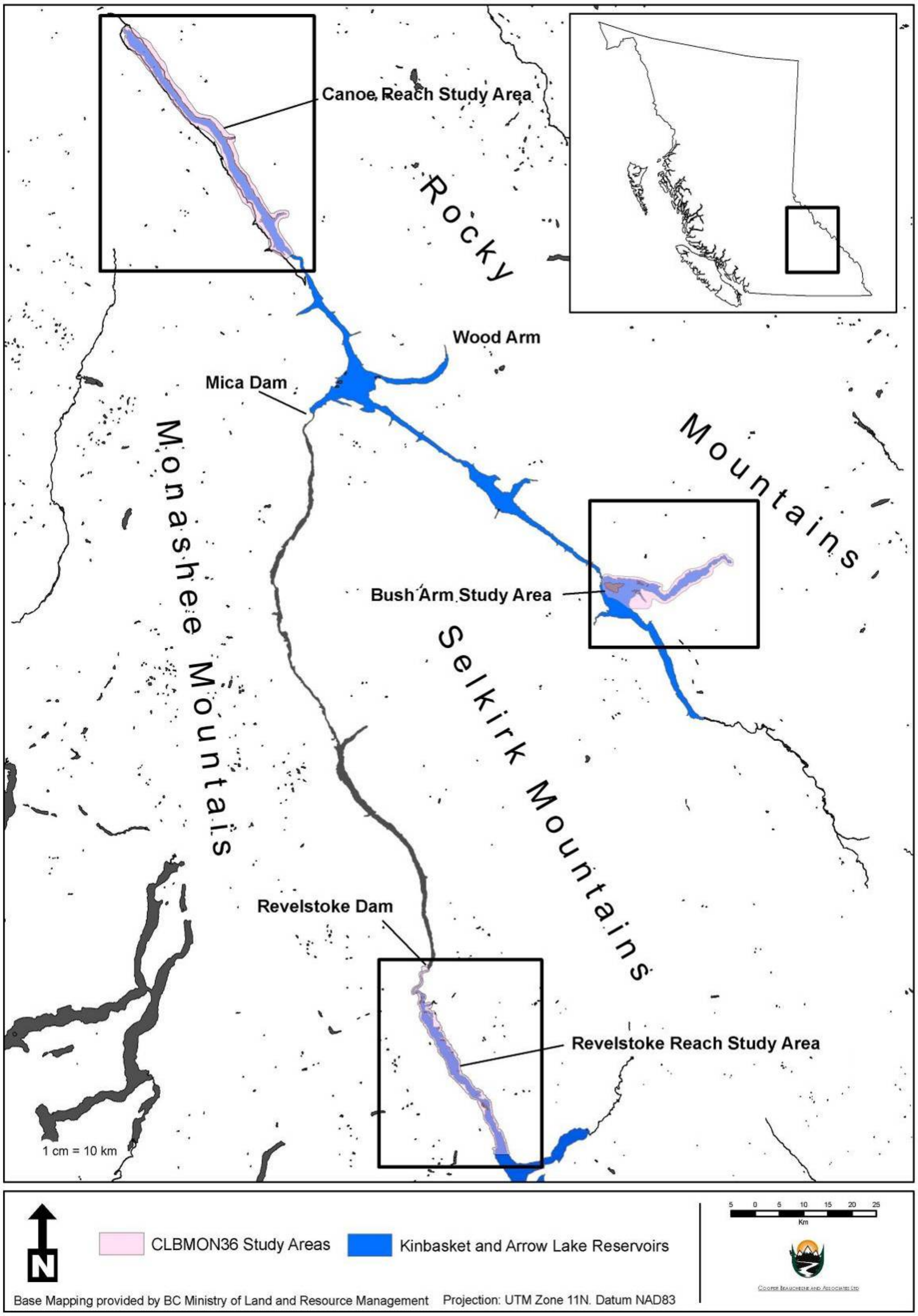

Figure 1-1: Overview map of the three study areas (lakes are shown in black). Bush Arm was not monitored in 2015

Figure 1-2: Relatively well-vegetated drawdown habitat at Hugh Allen Bay, Canoe Reach

1.4.2 Revelstoke Reach, Arrow Lakes Reservoir

The Hugh Keenleyside Dam is located approximately 8 km north of Castlegar. The completion of the dam in 1968 created the Arrow Lakes Reservoir, which extends approximately 240 km north to Revelstoke and has a licensed storage capacity of 7.1 MAF (BC Hydro 2007). The facility is capable of discharging 10,500 m^3/s (BC Hydro 2007) primarily through non-generating ports and spillways. Although the Hugh Keenleyside Dam was created primarily for flood control and water storage for downstream power generation in the U.S. (BC Hydro 2007), a 185-MW generating facility was added in 2002. The Arrow Lakes Reservoir is licensed to operate between 418.6 m and 440.1 m ASL. With approval from the Comptroller of Water Rights, the maximum allowable level is 440.75 m (BC Hydro 2007).

Situated between the Monashee and Selkirk Mountain Ranges, and directly below the Revelstoke Dam, RR forms the northernmost section of the Arrow Lakes Reservoir. From the Trans-Canada Highway, RR extends south for approximately 42 km (Figure 1-1). Habitats within the RR drawdown zone vary with topographic elevation. Grasses (e.g., *Phalaris arundinacea*), sedges (*Carex* spp.) and horsetails (*Equisetum* spp.) become well-established above 434 m ASL; willow (*Salix* spp.) and cottonwood (*Poplar balsamifera*) grow as low as 436 m ASL, but become well-established at 438 m, within a matrix of dense graminoid cover (Figure 1-3). Above 439 m, multi-storied mature cottonwood riparian forests have become established in some areas (e.g., Machete Island).

RR occurs in the ICHmm (variants 2 and 3) biogeoclimatic subzone (Meidinger and Pojar 1991), and receives heavy precipitation, primarily from Pacific frontal systems that shed snow during the winter. The drawdown zone is surrounded by steep slopes with managed coniferous forests.

Figure 1-3: **Shrub savannah habitat in the drawdown zone of Revelstoke Reach (~438 m ASL). This habitat is often subjected to as much as 2 m of habitat flooding in the mid to late breeding season**

1.5 Scope of work in 2015

This annual report presents data collected in Year 8 (2015). Similar to Years 6 and 7, a concentrated effort was made in Year 8 to conduct productivity and telemetry monitoring; in this year we focused this work on Savannah Sparrow (SAVS) in CR. Otherwise, field work continued with regular nest monitoring. On-going multi-year analysis projects continued, with the development of Bayesian hierarchical nest survival models, the development of code required to format data appropriately for these analyses, and testing of the modeling framework using a subset of nests in the database (dabbling ducks).

2 METHODS

The methods followed those used in previous years (CBA 2015).

A large part of the field effort involved ‘Nest Mortality’ monitoring, which is a community-level nest monitoring program aimed at determining biogeographic distributions of communities, the causes of nest failure, and the overall productivity within the reservoir drawdown zones. To accomplish this, field technicians attempted to find and monitor all nests (less than 3 m above ground) at a selection of monitoring sites throughout the entire nesting season. Sites were chosen systematically to maximize spatial replication and stratification among habitat types identified in GIS maps.

In addition to the community-level Nest Mortality monitoring, we also focussed on finding and monitoring nests and the juvenile survival of several 'focal species'. The purpose of focal species monitoring was to examine factors influencing the survivorship of nests and of juveniles post-fledging. Field efforts attempted to generate larger sample sizes of nests for selected species for statistical purposes; there was reduced emphasis on finding every nest at a given site, and site boundaries were of less importance. Focal species monitoring was also conducted over multiple sites including some above the drawdown zone. In 2015, focal species monitoring centred on SAVS in CR, and YEWA in RR. Radio telemetry was implemented for SAVS in CR to monitor juvenile survival.

2.1 Site selection

Habitat categories for both reservoirs are described in Appendix 6-2. Maps of study sites are provided in Appendix 6-3 and Appendix 6-4. Sites with high concentrations of focal species (SAVS and YEWA) were monitored annually, including 2015.

In CR, sites 1, 2, 4, 5, and 16 were monitored at the community level but were also monitored each year because these plots were occupied by SAVS. In RR, colour-banded populations of YEWA were monitored at sites 21 (Drimmie Creek and 12 Mile Island), 28 (Machete Island) and 46 (Illecillewaet riparian shrub) in conjunction with SFU.

In RR, two unique sites were monitored at the community-level annually because they provided particularly interesting time series data. Site 39 (Montana Slough) contained the majority of the floating bog habitat. This habitat is unique, and becomes populated by breeding birds following their displacement by reservoir flooding elsewhere in the drawdown zone. Site 30 (at Airport Marsh) includes some of the best examples of water sedge, cattail and bulrush habitat, and includes the primary colony of Yellow-headed Blackbirds in ALR. This site also provides nesting habitat for other regionally uncommon species such as Pied-billed Grebe, Virginia Rail, Sora, and Marsh Wren.

Most site selection for community-level monitoring followed a systematic sampling design with new sites chosen annually. These sites were selected from each of the available habitat types. Site accessibility and habitat patch size/configuration were considered during site selection, but we did not have or use prior knowledge of the site’s particular suitability for nesting when delineating the sites. Sites were monitored for at least one full breeding season. In KIN, we stratified the drawdown zone habitats by the vegetation communities identified by CLBMON 10 (Hawkes et al. 2010). In RR, we stratified the drawdown zone by vegetation communities identified by a habitat map developed by CBA (CBA 2012).

2.2 Field procedures

2.2.1 Nest searching

Sites were surveyed by walking slowly and systematically while looking for nests or signs of nesting activity. Birds exhibiting nesting behaviour (e.g., giving warning calls; carrying nest material, fecal sacs or food) were watched for clues of nest locations (Martin and Geupel 1993). In grassland habitats, rope dragging was used to flush birds from nests, especially shortly prior to sites becoming submerged. Nest searching effort was adjusted based on the potential to find additional nests. Sites with many singing birds but relatively few known nests were prioritized for nest searching. Sites where no birds were detected were searched less frequently. In some cases (e.g., barren sites without any vegetation), nest searching required minimal effort but multiple visits to the site were made during the season. When active nests were located, sites were re-visited regularly for nest monitoring. In most cases, site visits included some additional nest searching but sometimes the sites were visited only for the purposes of making nest observations.

2.2.2 Nest monitoring

Standard nest site data were collected at all nests (nest position, nest substrate, habitat, etc.). Active nests were monitored every three or four days until young fledged or the nest failed. Evidence of nest outcome was documented for each nest. A nest was considered to be successful if it fledged one or more young. Nest failure was categorized as being caused by nest predators or reservoir operations, or as failed for unknown reasons. Nest outcomes were designated as "unknown" if it was unclear whether the nest had been successful or had failed. Nests that had well-developed young late in the nestling phase were deemed to be successful if the last observation of the active nest was after the minimum number of days recorded for fledging by that species. Information about fledging periods was obtained from *The Birds of North America* species accounts (Poole 2010).

2.2.3 Focal species capture and monitoring

Targeted mist netting with call-playback was undertaken in areas with focal species. Mist nets were set up near territorial males, and an audio recording of the species' territorial song was played to lure the focal species into the nets. Once captured, birds were banded with a metal Canadian Wildlife Service (CWS) leg band inscribed with a unique number. Additionally, unique combinations of coloured plastic leg bands were applied to allow field biologists to identify and track these individual birds. Re-sighting colour banded birds assisted in mapping territories, monitoring juvenile survivorship and documenting local recruitment and dispersal.

To study juvenile survivorship of SAVS, we used radio-telemetry. Lotek PicoPip Aeg 317 (<0.45 g) telemetry transmitters were attached to one nestling per nest. Tagged birds were monitored daily using a Communications Specialists R-1000 receiver equipped with a three element Yagi antenna until ether the bird died, the transmitter battery expired, or the bird could no longer be found. Radio transmitters were attached with a fine elastic filament designed to drop off following expiry of the transmitter battery.

2.3 Data summary and analysis

Historic reservoir data includes all data from KIN (July 1, 1976 to present) and all data from ALR dating from completion of the Revelstoke Dam (January 1, 1985 to present).

All data manipulation, statistical computing and graphing was performed using R (R Core Team 2014). For Bayesian analyses, R was used to drive a separate program WinBUGS using the R2WinBUGS package (Lunn et al. 2000, Sturtz et al. 2005, Kéry 2010).

2.4 Permits

Bird handling and telemetry protocols were approved by the SFU Animal Care Committee (1038B-04). Banding was conducted under Federal Scientific Permits to Capture and Band Migratory Birds issued to John Cooper (#10663), Harry van Oort (#10663 F), and Catherine Craig (#10273 AI).

3 RESULTS

3.1 Year 8 summary

3.1.1 Reservoir operations

The operations of KIN and ALR in 2015 differed greatly from previous years.

The KIN water elevation was ~ 737 m ASL in early May, considerably higher than average historical levels. The surface elevation remained high and increased over the summer, peaking earlier and lower than usual at ~ 751.0 m ASL on July 16. Although still relatively high on July 16, compared with historical operations, water elevations dropped thereafter, to below average levels later in the summer (Figure 3-1).

The ALR water elevation was relatively high in early May (~ 429 m ASL) compared to historical levels, but low compared to other levels during the course of this study. The water elevations increased during the spring with normal progression but reached maximum elevation very early, at just 435.5, on June 16 (Figure 3-1).

3.1.2 Other annual conditions

Relatively low rainfall and warm temperatures were recorded at Revelstoke airport in May and June compared to the previous years of the project (Figure 3-2, Figure 3-3). The weather was relatively normal later in the summer with an absence of major summer wind storms or major rain events.

At RR, Airport Marsh and Machete Ponds had seemingly normal water levels in 2015. Notable observations in bird diversity in relation to previous years included the following:

- Marsh Wren abundance had recovered at the Airport Marsh, after several years of absence
- Yellow-headed Blackbird were present in moderate/low numbers
- Brewer's Blackbird continued to have low abundance in the Revelstoke area compared with what was normal at the initiation of the project
- Unusual species observed included a Brewer's Sparrow, and a Dickcissel (neither breeding)
- Western Meadowlark were present in relatively high numbers
- Cedar Waxwing continued to appear to decline in number

In CR, the bird populations and conditions were comparable to most previous years. One exception was a relatively high occurrence of *Protocalliphora* blow fly parasitism on nestling SAVS compared with 2014. A high prevalence of these parasites was also noted in Year 1 (CBA 2009).

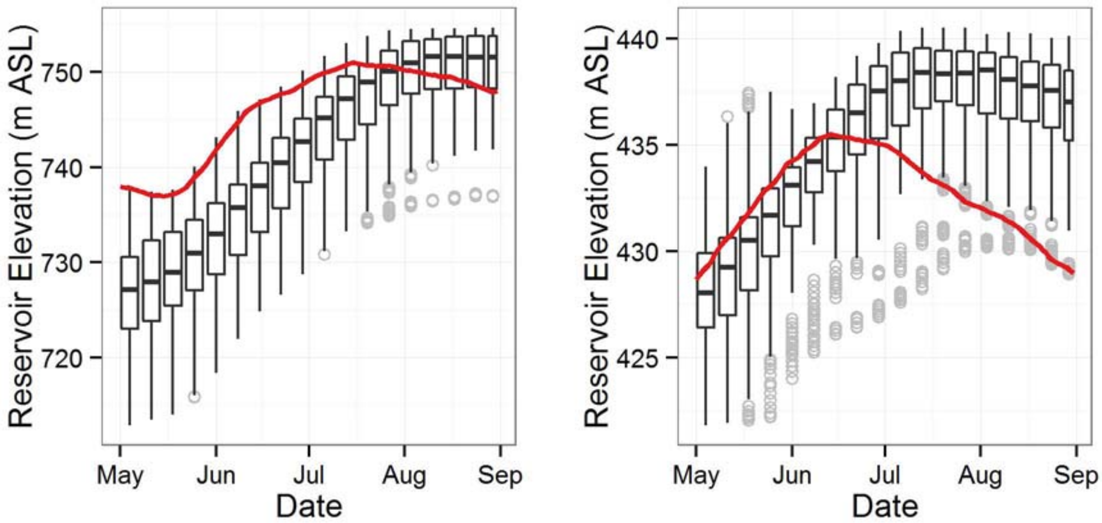

Figure 3-1: **Reservoir elevations at Kinbasket Reservoir (left) and Arrow Lakes Reservoir (right) plotted as weekly boxplots of historical data, with the 2015 elevations plotted in red. Note early transition to drafting phase at both reservoirs in 2015**

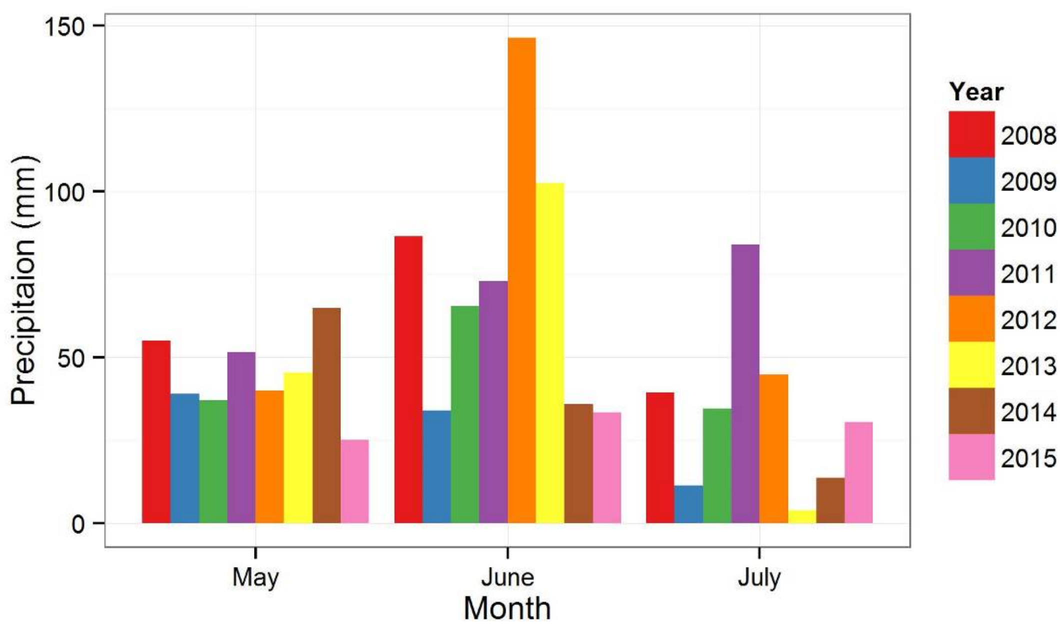

Figure 3-2: **Precipitation measured at the Revelstoke airport weather station over the course of CLBMON-36 monitoring**

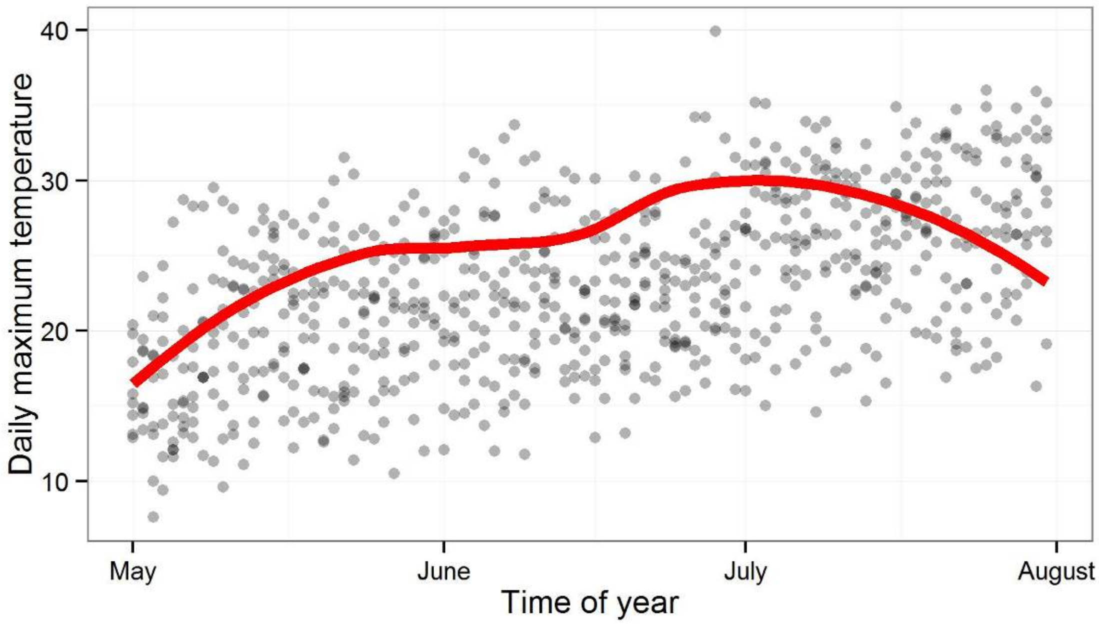

Figure 3-3: **Maximum daily temperatures measured at the Revelstoke airport weather station over the course of CLBMON-36 monitoring. The red smoother line represents maximum daily temperatures in 2015**

3.1.3 Survey effort

In both study areas, crew schedules were coordinated so that surveys were conducted almost daily.

In CR, field sampling was conducted from May 26 to August 3. During this period, we monitored 16 community-level study sites. Additionally, focal species (SAVS) were monitored at another five areas. In total, there were 536 person-hours of survey effort in CR in 2015.

In RR, field sampling was conducted from April 15 to August 14. During this period, 21 community-level study sites were monitored. Focal species (YEWA) were monitored at three additional areas in RR. To continue to improve knowledge of Canada Goose nesting, specific surveys for nesting geese were conducted during the early nesting season. We attempted to find all nests in the wetlands at the north end of the study area (Montana Slough, Airport Marsh). In total, there were 1439 hours of survey effort in RR in 2015.

3.1.4 Nest records

In 2015, 365 nests from 39 confirmed species[2] were located. Of these, 352 nests from 37 species were monitored until young fledged or the nest failed (Table 3-1).

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[2] The species for two duck nests was not confirmed; one was known to be a Teal species, the other likely an American Wigeon. Additionally, one unidentified warbler nest was located.

In CR, 82 nests from 11 species were found which accounted for 22% of the nest records (Table 3-1); 28 (34%) of these nests (4 species) were located in the drawdown zone; the rest were located above the drawdown zone.

In RR, 283 nests from 35 species were found which accounted for 78% of the total nest records (Table 3-1); 273 (96%) of these nests (34 species) were located in the drawdown zone; the rest were located above the drawdown zone.

3.1.5 Bird Species at risk

No species at risk were found breeding in either reservoir.

3.1.6 Nest monitoring results

Of the nests for which outcomes were determined (325 nests, 92% of all monitored nests), 199 (61%) were successful. Of the 126 documented nest failures (39% of nest outcomes), 90 (71%) failed due to predation and three (2%) failed due to reservoir inundation. The cause of failure for the remaining 33 nests (26%) was uncertain.

Within the drawdown zones, nest success rate was highest in CR (67%); RR nests had a considerably lower success rate (51%). At CR, three percent of all monitored nests failed due to reservoir operations; no nests were submerged by reservoir operations at RR.

Table 3-1: Bird species and number of nests found in CR (Kinbasket Reservoir), and in Revelstoke Reach (Arrow Lakes Reservoir)

		Above Drawdown Zone		Within Drawdown Zone	
Common Name	Scientific Name	Canoe Reach	Revelstoke Reach	Canoe Reach	Revelstoke Reach
Pied-billed Grebe	*Podilymbus podiceps*	0	0	0	4
Canada Goose	*Branta canadensis*	0	1	0	31
American Wigeon	*Anas americana*	0	1	0	4
Mallard	*Anas platyrhynchos*	0	0	1	4
Blue-winged Teal	*Anas discors*	1	0	0	0
Unidentified Teal		0	0	0	1
Unidentified Duck		0	0	0	1
Virginia Rail	*Rallus limicola*	0	0	0	14
Sora	*Porzana carolina*	0	0	0	12
Killdeer	*Charadrius vociferus*	2	1	0	12
Spotted Sandpiper	*Actitis macularius*	1	0	3	5
Wilson's Snipe	*Gallinago delicata*	3	0	0	2
Wilson's Phalarope	*Phalaropus tricolor*	0	0	0	1
Long-eared Owl	*Asio otus*	0	0	0	1
Traill's Flycatcher	*Empidonax alnorum/traillii*	0	0	0	3
Willow Flycatcher	*Empidonax traillii*	0	0	0	16
Eastern Kingbird	*Tyrannus tyrannus*	0	0	0	3
Warbling Vireo	*Vireo gilvus*	0	0	0	1
Red-eyed Vireo	*Vireo olivaceus*	0	0	0	1
American Crow	*Corvus brachyrhynchos*	0	0	0	2
Black-capped Chickadee	*Poecile atricapillus*	1	0	0	0
Marsh Wren	*Cistothorus palustris*	0	0	0	4
Veery	*Catharus fuscescens*	0	0	0	3
American Robin	*Turdus migratorius*	0	0	0	1
Gray Catbird	*Dumetella carolinensis*	0	0	0	5

		Above Drawdown Zone		Within Drawdown Zone	
Common Name	Scientific Name	Canoe Reach	Revelstoke Reach	Canoe Reach	Revelstoke Reach
Cedar Waxwing	*Bombycilla cedrorum*	0	1	0	22
Yellow Warbler	*Dendroica petechia*	0	5	0	68
Magnolia Warbler	*Dendroica magnolia*	1	0	0	0
American Redstart	*Setophaga ruticilla*	0	0	0	1
MacGillivray's Warbler	*Oporornis tolmiei*	0	0	0	1
Common Yellowthroat	*Geothlypis trichas*	0	0	0	9
Unidentified Warbler		0	0	0	1
Chipping Sparrow	*Spizella passerina*	4	0	0	0
Clay-colored Sparrow	*Spizella pallida*	0	0	0	3
Savannah Sparrow	*Passerculus sandwichensis*	40	0	23	2
Song Sparrow	*Melospiza melodia*	0	0	0	16
Lincoln's Sparrow	*Melospiza lincolnii*	0	0	1	5
Dark-eyed Junco	*Junco hyemalis*	1	0	0	0
Red-winged Blackbird	*Agelaius phoeniceus*	0	0	0	2
Western Meadowlark	*Sturnella neglecta*	0	0	0	2
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	0	0	0	8
Bullock's Oriole	*Icterus bullockii*	0	1	0	2

3.1.7 Nest submersion in 2015

Reservoir operations flooded three monitored nests from two species (Spotted Sandpiper and Savannah Sparrow; Appendix 6-5). None were nests of species at risk, all were built directly on the ground, and all were located at CR.

3.1.8 Canada Goose population at Revelstoke Reach

Thirty-two Canada Goose nests were found in April and May. Most nests (75%) were located in Airport Marsh, followed by Montana Slough, with seven nests (22%; Figure 3-4). Among all Canada Goose nest records, 66% were successful and predation was determined to cause the failure of 31% of the nests. Nest submersion was not a factor. The first observation of a fledged brood occurred on April 27.

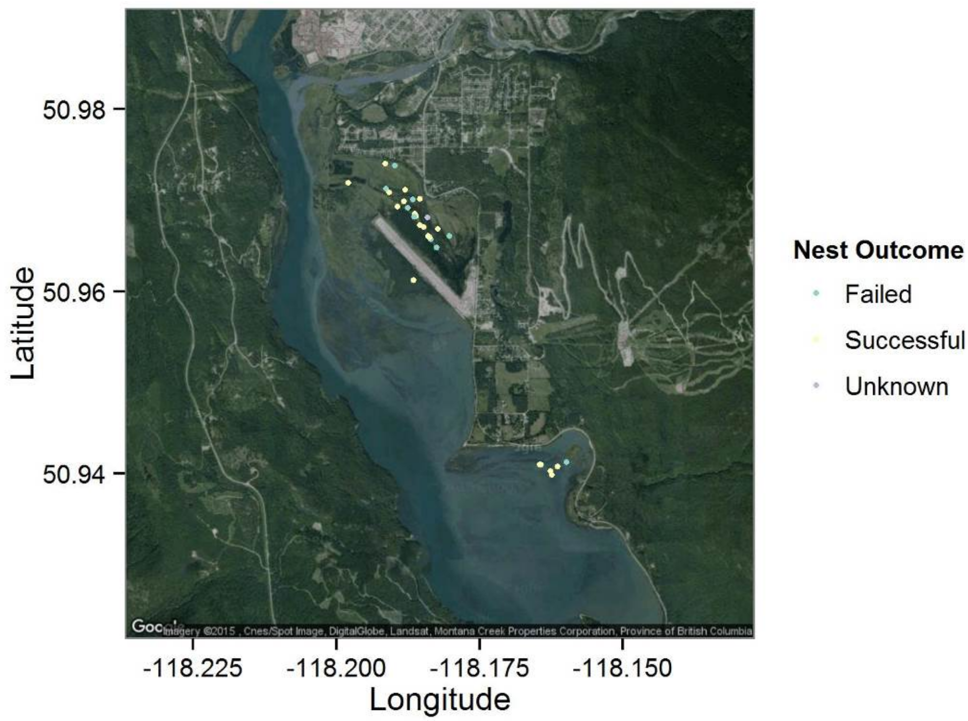

Figure 3-4: Locations of Canada Goose nests located during April and May. These nests likely represent the majority of goose nests in Revelstoke Reach

3.1.9 Juvenile survival

At Canoe Reach, 30 nestling SAVS were tagged for juvenile survival study: 15 from nests above the drawdown zone, and 15 from nests within the drawdown zone. In general, survivorship of the juveniles was high in 2015, both within and above the drawdown zone. Only 6 deaths were recorded, including one juvenile in the drawdown zone that drowned. Two tagged nestlings were predated before fledging. One nestling dropped its transmitter prior to fledging. Seventeen tagged young survived over two weeks post fledging.

3.2 Multi-year progress

3.2.1 Community-level monitoring

In 2015, 40.0 ha of mapped habitat was monitored at KIN and 46.2 ha of mapped habitat was monitored in ALR (Table 3-2 and Table 3-3). At KIN, monitoring sites with DR, FO, and RD habitats helped round out the community data (Table 3-2). At ALR, field efforts improved monitoring coverage of several habitats that had previously low levels of monitoring (e.g., GR, CK, CT, RB, and CW) in addition to also expanding monitoring effort over the most common habitat classes.

Table 3-2: Habitats monitored in Kinbasket Reservoir (CR and BA) from 2008 through 2015

Code	Vegetation Community	Total Area[1]	Monitored Area[2]	Effective 2014[3]	Effective 2015[3]
BR	Bluejoint Reedgrass	41.6	14.5	14.5	14.5
BS	Buckbean–Slender Sedge	12.0	8.4	8.4	8.4
CH	Common Horsetail	287.6	61.6	69.3	69.8
CO	Clover–Oxeye Daisy	136.5	35.4	80.0	84.6
CT	Cottonwood – Trifolium	20.3	4.5	6.1	6.4
DR	Driftwood	36.9	17.7	22.1	22.8
FO	Forest	159.6	2.4	1.9	2.6
KS	Kellogg's Sedge	210.7	38.3	77.3	81.6
LH	Lodgepole Pine–Annual Hawksbeard	0.5	0.5	0.5	0.5
LL	Lady's Thumb–Lamb's Quarter	1299.7	46.6	85.2	89.2
MA	Marsh Cudweed–Annual Hairgrass	140.3	10.3	10.3	10.3
MC	Mixed Conifer	0.2	0.0	0.0	0.0
RC	Reed Canarygrass	31.5	12.1	12.1	12.1
RD	Common Reed	0.6	0.6	0.6	1.2
SH	Swamp Horsetails	52.4	36.0	90.5	98.5
TP	Toad Rush–Pond Water-starwort	310.0	103.7	111.5	112.4
WB	Wool-grass–Pennsylvania Buttercup	128.9	56.3	113.1	122.7
WD	Wood Debris	70.0	27.7	27.7	27.7
WS	Willow–Sedge wetland	34.5	12.2	45.1	50.8
	Total	2973.7	488.8	776.2	816.2

1. 'Total Area' is the sum of mapping for each habitat type within the reservoir.
2. 'Monitored Area' indicates the sum of the mapped area that has been monitored (2008 – 2014).
3. Some sites have been monitored more than one time. Considering sites that have been repeatedly monitored over time, the effective monitored area increases, which is summarized for 2013 and 2014 in 'Effective 2013' and 'Effective 2014' respectively.

Table 3-3: Habitats monitored in Arrow Lakes Reservoir (Revelstoke Reach) from 2008 through 2015

Code	Category	Total Area[1]	Monitored Area[2]	Effective 2014[3]	Effective 2015[3]
BE	Steep bedrock	6	0	0	0
BF	Floating bog	3	3	15	17
BR	Bullrush	13	7	48	55
BS	Submerged buoyant bog	4	4	16	18
CK	Creek	25	7	6	7
CR	Coarse Rocks	0	0	0	0
CT	Cattail	4	4	6	7
CW	Shrub wetland complex	12	8	7	8
EG	Equisetum grassland	57	18	18	18
GR	Gravel	194	5	3	5
LD	Low elevation draw	189	44	62	64
MG	Mixed grassland	1019	80	129	135
PG	Sparse grassland	372	43	43	45
PO	Pond	128	44	64	71
RB	Rocky bank	58	5	7	7
RC	Reed canarygrass	110	39	51	51
RF	Riparian Forest	77	31	58	59
SA	Sand	474	24	24	24
SB	Sand bank	10	3	3	3
SG	Sedge grassland	364	72	92	93
SH	Shrub savannah	324	78	102	110
SI	Silt	710	10	10	10
SR	Riparian shrub	26	8	13	13
SW	Swamp	1	2	2	2
TH	Thalweg	2069	1	1	1
UC	Upland conifer	43	0	1	1
UM	Upland mixed	110	6	10	10
UR	Urban	1	0	0	0
WM	Wet meadow	26	8	13	14
WS	Water Sedge	26	5	10	12
	Total	6453.6	559.9	813.9	860.1

1. 'Total Area' is the sum of mapping for each habitat type within the reservoir.
2. 'Monitored Area' indicates the sum of the mapped area that has been monitored (2008 – 2014).
3. Some sites have been monitored more than one time. Considering sites that have been repeatedly monitored over time, the effective monitored area increases, which is summarized for 2013 and 2014 in 'Effective 2013' and 'Effective 2014' respectively.

3.2.2 Nesting species detections

In 2015, one new species was detected in KIN (Blue-winged Teal); the total number of species known to nest in the KIN drawdown zone was 30. One bird species was found nesting in the ALR drawdown zone which had not previously been recorded (Bullock's Oriole), bringing the total number of species to 61 (Figure 3-5). The orioles were nesting in the mature cottonwoods on the islands in the Airport Marsh.

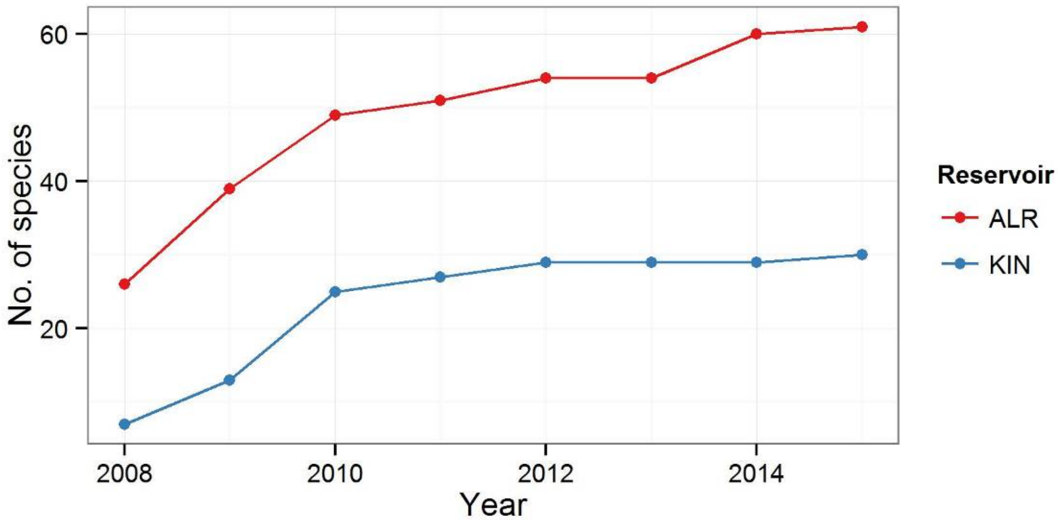

Figure 3-5: Cumulative count of species detected nesting in the drawdown zones of the Arrow Lakes Reservoir (ALR) and the Kinbasket Reservoir (KIN)

3.2.3 Nest submersion

Since 2008, there have been 176 nests (of 34 species) observed to have failed as a direct consequence of reservoir operations (Table 3-4); 16 nests (6 species) in KIN, and 160 nests (32 species) in ALR. At KIN, nest inundation was observed in 2010, 2011, 2012, 2013, and 2015. At ALR, nest inundation was observed in each year of the study except 2015 (Figure 3-6).

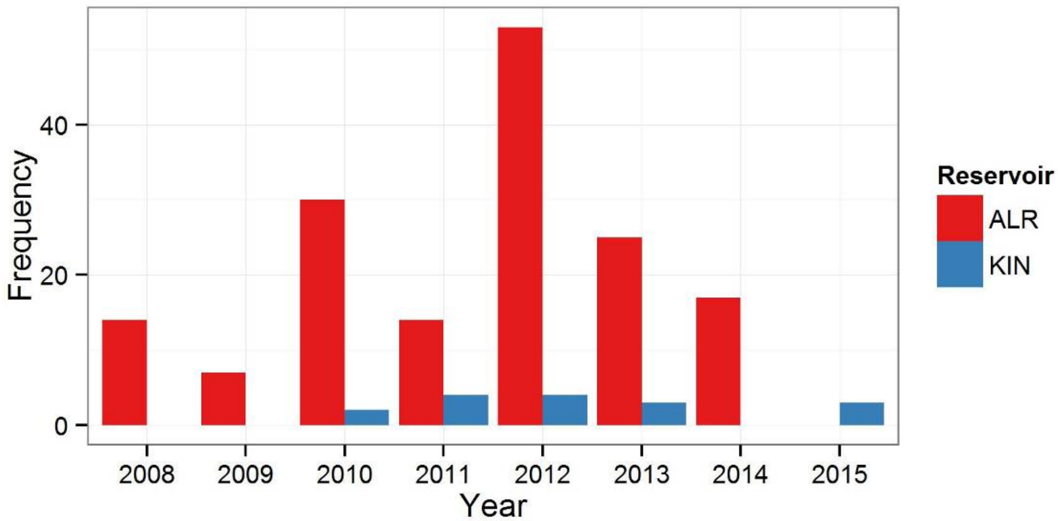

Figure 3-6: **Annual number of observations of nest flooding observed for Kinbasket (KIN) and Arrow Lakes Reservoir (ALR)**

Table 3-4: Observations of nest sumbersion since 2008 by species in Kinbasket (KIN) and Arrow Lakes (ALR) Reservoirs

Type of Nest	Common Name	ALR	KIN
Ground	Common Loon	2	0
	American Wigeon	6	0
	Mallard	8	0
	Green-winged Teal	3	0
	Killdeer	4	0
	American Avocet	1	0
	Spotted Sandpiper	2	4
	Wilson's Snipe	3	0
	Wilson's Phalarope	1	0
	Long-eared Owl	1	0
	Short-eared Owl	1	0
	Savannah Sparrow	7	8
Low in Shrub or Emergent Vegetation	Pied-billed Grebe	2	0
	Virginia Rail	5	0
	Sora	2	0
	Marsh Wren	1	0
	Veery	2	0
	MacGillivray's Warbler	1	0
	Common Yellowthroat	15	1
	Chipping Sparrow	6	0
	Clay-colored Sparrow	2	0
	Song Sparrow	4	0
	Red-winged Blackbird	9	0
	Yellow-headed Blackbird	15	0
Shrub	Traill's Flycatcher	2	0
	Willow Flycatcher	15	1
	Dusky Flycatcher	1	0
	Eastern Kingbird	1	0
	Unidentified Flycatcher	2	0
	Gray Catbird	8	0
	Cedar Waxwing	7	0
	Yellow Warbler	20	0
Canopy	American Robin	0	1
	American Redstart	1	0
Cavity	Mountain Bluebird	0	1

3.2.4 Juvenile survival monitoring

Radio telemetry of juvenile survival began in 2012. The YEWA study focussed on the impact of habitat flooding on juvenile survival, and field work concluded in 2014. Data analysis for YEWA juvenile survival continued in 2015 and is reviewed in Section 3.3.2 below.

The SAVS telemetry study was conceived to assess:

1. whether juvenile survival was influenced by advancing water levels, and
2. how juvenile survival compares between birds fledged in drawdown zone habitats versus those fledged in non-drawdown zone habitats.

To date, 71 SAVS nestlings were tagged, 44 of which were within the CR drawdown zone (27 outside of the drawdown zone environment). Nine of the 44 radio-monitored SAVS in the CR drawdown zone encountered reservoir inundation at their natal territories while we were monitoring them: two prior to fledging (which drowned) and seven post-fledging. Of the seven fledged young, one died as a consequence of drowning four days post-fledging, four survived, and two were predated. One additional SAVS juvenile drowned in a naturally wet habitat when 12 days old, 2 days after fledging. A formal survival analysis to address the research questions (1 and 2 above) has not yet been completed.

Survival of juveniles in the KIN drawdown zone may differ from other habitats for reasons other than drowning; for example, predation pressure may differ. The 27 nests located above the KIN drawdown zone will be used as a ‘control’ group to compare how overall nest survival in the KIN drawdown zone compares with non-drawdown zone habitats.

3.3 New Multi-year Analyses

We present two multi-year analyses below. First, we apply a new modelling framework (Appendix 6-6) to examine two likely predictors of duck nest survival. Second, we provide a more detailed summary of an analysis of Yellow Warbler juvenile survival that is currently part of a M.Sc. thesis at SFU.

3.3.1 Bayesian nest DSR in the drawdown zone – dabbling duck nest example

While analyzing nest survival previously (van Oort et al. 2015), we realized that a more powerful and flexible modelling methodology was required for estimating nest daily survival probability, commonly referred to as daily survival rate (DSR). Given the complexity of the CBLMON-36 dataset, mixed effects models will be appropriate; however, the classical (frequentist) statistical approach using logistic exposure (Shaffer 2004) in R would not allow random effects (e.g., species, year, site) to be modeled. In 2015, we successfully adapted and implemented code for modeling nest survival using Bayesian inference (Appendix 6-6). Here we present a draft analysis of nest data from the community of ducks (mostly dabbling ducks) that nest on the ground in RR using the Bayesian modeling approach. This analysis examined some key themes of interest in CLBMON-36, and provides an example where this approach may be applied.

The questions we considered in this analysis related to nest position in the ALR drawdown zone: (1) do nests at higher elevations have better survival than those at lower elevations? And, (2) does nesting on the floating bog (BF) habitat provide a nest survival advantage? The nesting data included 36 nests positioned on the floating bog (BF) habitat at Montana Slough, and 59 nests positioned elsewhere in the ALR drawdown zone. Nests were also classified as being positioned within BF habitat using a GIS query. Nests were classified as coming from either Mallard (n = 48 nests), American Wigeon (n = 31 nests) or as 'Other' (primarily Green-winged or Cinnamon Teal, and a few nests of unconfirmed species). This species grouping (SPP) was entered into the Bayesian model as a random effect. The effect of YEAR was entered as a random effect. Nest elevation (Digital Elevation Model values - DEM), was examined to assess whether nests positioned higher in the drawdown zone had better survival than those positioned lower in the drawdown zone (Management Hypothesis H1C; Appendix 6-1). This result is to be expected if low elevation nests have a greater chance of being submerged by the reservoir and nest flooding is a major source of nest mortality.

We did two modelling runs, the first considering all 95 nests. In this run, we adjusted the DEM value of nests positioned on the BF habitat to be fixed at the full pool elevation, as their nests elevate to this level when the reservoir is full and they typically suffer less from nest submersion as a result. In the second run, we omitted the BF nests, and examined whether the effect of DEM on DSR was better pronounced by a data subset not complicated by floating habitat. These models indicated an advantage to nesting in the BF habitat and no support was found for an effect of nest elevation. The daily survival probability was estimated as 0.903 to 0.908 in the normal drawdown zone habitats, but improved to 0.936 for nests positioned in the BF habitat (for methods and results details, see Appendix 6-7).

3.3.2 Yellow Warbler juvenile survival

The YEWA juvenile survival study took place over three years at Revelstoke Reach (2012-2014) to address management question G and hypothesis H2 (Appendix 6-1). The goal of this component study was to determine how survival of juvenile birds is affected by reservoir operations during the weeks that follow their fledging from the nest. Specifically, the study examined if the survival of fledglings from successful nests was impacted when their natal nests were positioned in habitat inundated by the reservoir. To address this question, nestlings were fitted with radio telemetry transmitters prior to fledging. Using a radio telemetry receiver to locate the fledglings on a daily basis, we monitored their survival and often determined their fates. Nestlings were tagged in nests that had one of two states: inundated habitat (treatment) or dry habitats (control). The study took place at the three long term study sites monitored by SFU students (Drimmie Creek, Machete Island, and Illecillewaet River) as part of a graduate thesis. Study details will be reported in the project thesis; only methods, results and generalized findings are summarized below.

Ten radios were deployed in 2012, 12 in 2013, and 17 in 2014. Of these 39 deployed radios, 26 nestlings were monitored post-fledging (67%); the non-fledged young either died in the nest or their radios failed to function correctly. Juveniles that survived for the length of the post fledging period were monitored for 18.5 ± 5.1 days.

A Cox's proportional hazards analysis of this survival data was conducted on the fledged young (Cox 1972). Potential explanatory variables included were: inundation (Y/N), date of fledge, site, year, and nestling condition (residual mass; Schulte-Hostedde et al. 2005). Competing models were compared systematically in pairs, using the 'anova()' command in R (Zuur et al. 2009). The model selection process identified the model with inundation as the lone explanatory variable as the top model, indicating that a fledgling's survival probability dropped from ~ 60% when fledging in dry habitat to ~ 20% when fledging from wet habitat (**Error! Reference source not found.**). The time most hazardous to fledged young was one to five days after fledging which was more pronounced for those fledglings in wet habitat.

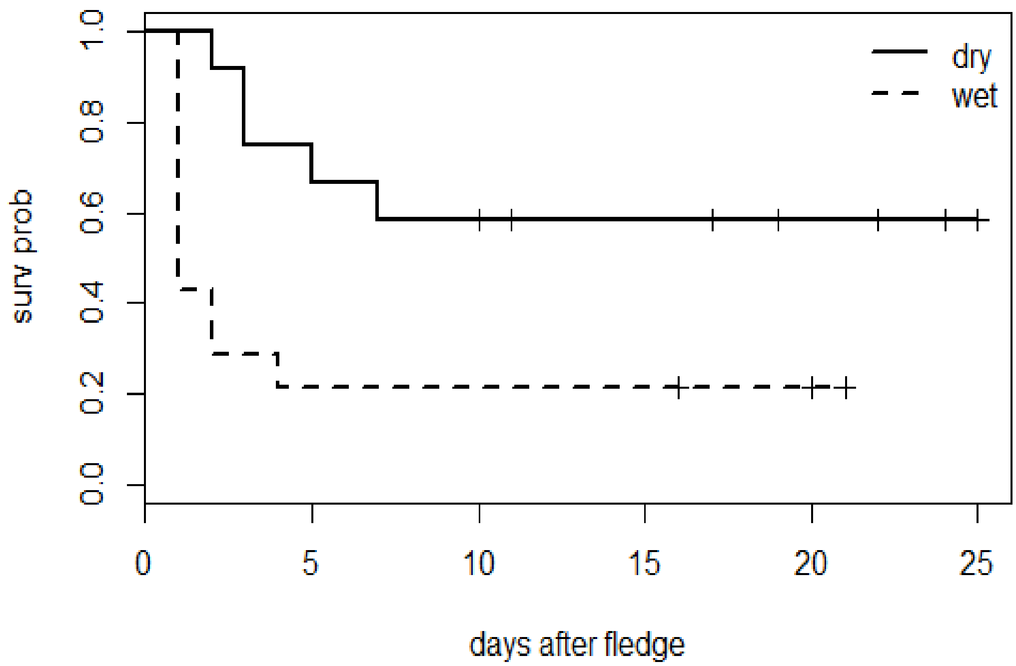

Figure 3-7: Survival probability of fledglings in two habitat states. The days following fledging are plotted on the x axis. The cumulative survival probability is estimated on the y axis. Survival of fledglings in inundated (wet) habitats is diminished compared with survival in dry habitats, not inundated by the reservoir

4 DISCUSSION

CLBMON-36 is a 10-year project addressing knowledge gaps related to the management of reservoirs (their habitat and operation) to enhance avian productivity and minimize incidental destruction of nests caused by reservoir operations. This report summarizes progress made in the CLBMON-36 project in 2015, the 8th year of research. Below, we briefly review progress and observations made in 2015, cumulative multi-year progress since 2008, and the new analyses results.

4.1 Year 8 (2015)

In Year 8, 2015, the spring and early summer was hot and exceptionally dry and the late summer was cooler, and characterized by frequent showers. The most notable environmental difference in Year 8, compared with previous years, were the operations of the two reservoirs. KIN water levels were held exceptionally high in late winter and into spring. Nonetheless, presumably as a result of shallow snowpack (e.g., low reservoir input) and dry spring and summer, the reservoir peaked early (July 16) at a relatively low elevation (751 m asl). The ALR remained so low in 2015 that almost no nesting habitat was submersed during the breeding season. These reservoir operations had large consequences for nest mortality in ALR and relatively low consequences for KIN (see section 4.2.3 below). On the whole, it appeared that nest and juvenile survivorship seemed to be above average in 2015 at both reservoirs. Although true nest survival can only be estimated via analysis of daily survival probability (Mayfield 1961, Shaffer 2004), the proportion of successful nests remains a useful index of survival. In the first five years of CLBMON-36, the proportion of successful nests averaged 62.2% in KIN (unpublished information) and 37.7% in ALR (CBA 2013). In 2015, the proportions were higher; slightly so in KIN (67%) and considerably in ALR (51%). In addition to the loss of the nest flooding impact, the degree to which nest success appeared to improve in the ALR in 2015 could be related to interactions between predation and reservoir operations. It is possible that there are multiple interactions between these factors; for example, predation may increase if nesting density (and nest predator activity) concentrates as habitat availability declines during the season. It will be interesting in Year 10 to examine how overall nest DSR relates to reservoir operations among years.

4.2 Multi-year progress and data gaps

4.2.1 Nest mortality – biogeography

Nest mortality monitoring among representative habitat types will continue to target habitats that are least represented by previous field monitoring effort. However, this is a somewhat challenging task as the poorly represented habitats are often those that are uncommon, and difficult to monitor if they are found in isolated areas with difficult access. In Years 9-10 one option would be to focus on monitoring at Bush Arm rather than at CR, as Bush Arm contains a greater diversity of habitats that are not found at CR, and are somewhat poorly represented in the database.

4.2.2 Nest mortality - species detection

In Year 8, we located nests from two species not previously recorded nesting at either of the two reservoirs. A Blue-winged Teal nest found at CR was the first nest record of this species for KIN and for the project. Duck nests appear to be uncommon in the KIN drawdown zone; previously two Green-winged Teal nests and two Mallard nests were monitored, making the Blue-winged Teal nest the fifth duck nest and the third duck species to be discovered. Blue-winged Teal likely also breed in the ALR, but evidence has been elusive.

In 2015, we also located three Bullock’s Oriole nests in the ALR, the first such nest records for ALR and for the project. This species nests very high in deciduous trees and, although there is no threat of nest submersion, it is a species that has lost habitat via the impoundment of the valley, and would be able to successfully nest in the drawdown zone if given the opportunity. Additional mature cottonwood habitat following natural recruitment, or physical works projects, may help increase abundance of this species by providing more nesting habitat.

At this point in the study, the cumulative count of breeding species detected in the KIN and ALR drawdown zones will only increase by locating rarities. The general breeding bird communities have been well-documented and MQ-A has already been adequately addressed (Appendix 6-1).

4.2.3 Nest mortality – nest submersion

2015 was the first year of CLBMON-36 monitoring where no nest flooding was observed at RR. This outcome reflects the atypical ALR operation where the reservoir surface elevation remained so low that nesting habitats were not flooded.

KIN also had an unusual operation in 2015, howerver we observed a relatively normal number of submersed nests compared with previous years. Under typical operations, the rising water of KIN tends to miss the time/space window of nesting, flooding the most populated high elevation habitats after the nesting season (see for example 2008 and 2010 in Figure 4-1). Typically, the nest flooding at KIN that does occur is observed for late ground nests at high elevations – for example some of the last Savannah Sparrow nests of the year – but can also occur earlier in the season for species that nest at low elevations (e.g., Mountain Bluebirds). The 2015 operations differed from previous years – with an initial trajectory set to inundate nesting habitats in the middle of the breeding season. If this aggressive filling had continued, the level of nest flooding at KIN would have been unprecedented for the CLBMON-36 project; however, in early June, the rate of fill decreased markedly (Figure 4-1). The primary reason why we did not observed many nests being flooded in 2015 was that the reservoir peaked at a low elevation (751 m asl) and therefore did not flood the most densely populated nesting areas at the upper elevations of the drawdown zone.

In 2015, KIN water levels exceeded the low elevation nesting habitat (< 742 m asl) prior to the nesting season (Figure 4-1). To some degree, this created a situation first hypothesized in 2009, where high water levels in spring could reduce mortality risk (nest flooding) by inundating the nesting habitat (removing it) prior to the nesting season (CBA 2010b). In 2015, this type of scenario existed for the low elevation nesting habitat, but at elevations above 742 m asl, our model predicts that every increase in reservoir surface elevation had the potential to drown nests in the KIN drawdown zone.

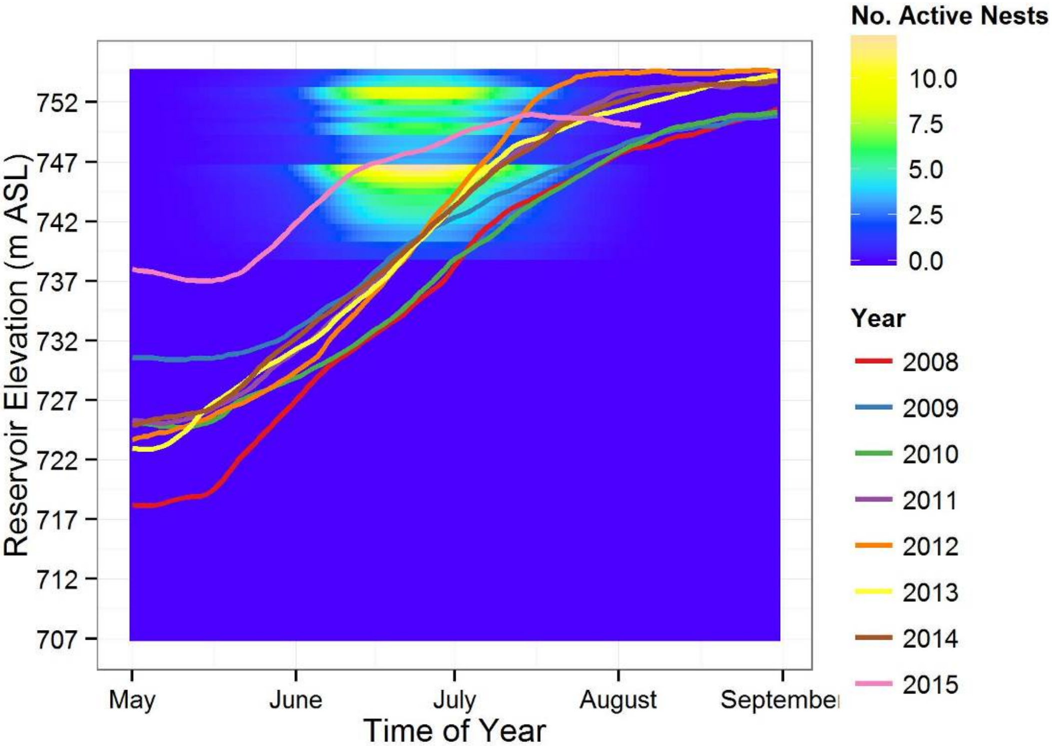

Figure 4-1: Kinbasket Reservoir water surface elevations during each year of the study are plotted against time of year. The background colour indicates the number of active nests modelled within mapped parts of the Kinbasket Reservoir drawdown zone. The area of habitat that has been mapped at each elevation accounts for the disjointed appearance of the modelled nesting activity (i.e., more habitat is mapped at lower elevations)

4.2.4 Focal species - juvenile survival

The juvenile survival component studies are nearing finalization. Data collection and analysis for the YEWA study was completed in 2015 and reporting by SFU is in progress. In 2015, all telemetry study focussed on juvenile survival of SAVS in CR. The primary study design was to test Management Hypothesis 2A (Appendix 6-1), with juveniles tagged for telemetry within and above the reservoir drawdown zone. In 2016, we suggest that it would be beneficial to gather additional survivorship monitoring data by expanding the sampling sites – for example, by conducting new sampling at Bush Arm. The results of the study will be better supported if the sample size of sites is increased, particularly if the difference between survival rates within and outside the drawdown zone is very small. We have not yet analyzed the data, but it appears that the difference in survivorship may be negligible.

4.3 New analyses (2015)

Progress towards multi-year analysis in 2015 was made by acquiring the statistical tools to allow complex modelling of daily survival rate (DSR). Many of the upcoming CLBMON-36 analyses will likely include combining data from multiple species, multiple sites, and multiple years; these variables all potentially contribute to variation in nest DSR, and in most cases, would best be accounted for by modelling as random effects. The previously explored logistic exposure method (Shaffer 2004, van Oort et al. 2015) does not allow mixed effects models in R, and the code to specify the logistic exposure model's link function does not appear to be supported by the most recent versions of R that we have used (3.0.3). Ecological datasets are increasingly being analyzed using Bayesian statistics and it appears that the future of nest DSR modelling will follow this example (Royle and Dorazio 2008, Schmidt et al. 2010, Brown and Collopy 2012, Converse et al. 2013). Several text books now present Bayesian survival modeling approaches using the BUGS language and applications (Royle and Dorazio 2008, Kéry and Schaub 2012), and the application for nest DSR need not be overly complex (Royle and Dorazio 2008). There are several advantages to using Bayesian statistics to estimate DSR of nests, but perhaps the most attractive reason is that mixed effects models can readily be fit. In 2015, we dedicated considerable time writing code to allow the CLMBON-36 data to be readily formatted for a Bayesian nest DSR analysis, and experimented with these modeling approaches. This effort and the results are discussed below in the following section.

It is likely that when the SAVS juvenile survival data collection is completed, we will also consider using Bayesian statistics to model whether juvenile survival differs within and above the KIN drawdown zone. Currently, the YEWA juvenile survival data analyses have been finished (M. Hepp *in preparation*). The initial results from these are discussed further below.

4.3.1 Management Hypothesis 1C: Does nest survivorship differ across elevations in the drawdown zone?

In 2015, our efforts to apply a Bayesian model to the current duck nesting dataset for the ALR were successful and encouraging. Our initial testing showed that the models return very precise and accurate results; using a sample size as small as 100 nests, the Bayesian model was generally able to differentiate even minor differences in DSR (Appendix 6).

Preliminary results indicate that ground-nesting ducks have generally poor nesting success in RR drawdown zone habitats and suggest an advantage to nesting in BF habitat (the floating bog habitat represents non-flooded conditions at all times). American Wigeon (egg incubation = 23 days) that nested in habitats other than BF were calculated to have a nest success rate of about 10 %. The nest success rate for Mallard (28 day incubation) in habitats other than BF was calculated to be about 6 %. In comparison, preliminary results hint that birds nesting in BF habitat are more successful; nest success rate in BF habitat was calculated at 22 percent for American Wigeon and 16 percent for Mallard.

The range DSR/nest success values that we calculated are similar to the ranges observed in other studies. We modeled DSR to range from 0.90 to 0.94. With *Anas spp*. ducks in other populations, Horn et al. (2005) calculated DSR rates of 0.91, 0.92, 0.93, and 0.96 at four different study sites, and another study modeled DSR to vary between 0.80 and 0.97 (Stephens et al. 2005). Walker et al. (2004) reported Mallard having a DSR of 0.95. Hence, the DSR values we measured are not high by any standard, but are certainly not uncommonly poor.

Using DSR values, nest success rates can be derived as we report above, but it should be noted that these calculations may differ based on assumptions about the length of time required for nesting periods. Nest success rates based on DSR varied from 10 to 30 % in one study (Warren et al. 2008), and was commonly between 5 and 10% in another study, which reported a highest success rate of 19% (Klett et al. 1988). It has been hypothesized that the Mallard require nest success of 15% in order to sustain their population (Warren et al. 2008). This latter value suggests that it is possible that the BF habitat could provide nesting habitat that is productive for the population, while the normal drawdown zone habitat does not. We do not make this conclusion, but the example serves the purpose of showing that even a small increase in DSR could potentially have profound differences for productivity. Hence, we do suggest that that the advantage of nesting in BF habitat has ecological importance.

More analysis, including consideration of more species groups than just ducks is needed before conclusions may be drawn about differing nest survivorship across elevations in the ALR drawdown zone. However, the analyses to date demonstrate a promising method of investigation and highlights that ground-nesting ducks may not be very successful at nesting in parts of the ALR drawdown zone. The poor nesting success in RR habitats other than BF may represent an ecological trap (Schlaepfer et al. 2002, Robertson and Hutto 2006, Anteau et al. 2012). It also highlights the possibility that floating islands could mitigate the negative impacts of reservoir operations on nesting birds. Looking forward, the Bayesian method will be applied to further testing of DEM and BF effects for additional species groups; examining the impact of variable reservoir operations and habitat flooding in wetland habitats (e.g., Airport Marsh); and comparing DSR at differing elevations within and above the drawdown zone.

4.3.2 Management Hypothesis 1C: Juvenile survivorship is impacted by habitat flooding

Hypothesis 1C was tested using YEWA as a focal species in Revelstoke Reach. Data collection occurred over three years (2012-2014) and data analysis occurred in 2015. A detailed account of this study will be reported elsewhere (M. Hepp *thesis in preparation*); in this report, we provided an overview of the analysis and results.

Preliminary results are that reservoir operations can continue to impact YEWA productivity even after nests have been successful. Earlier CLBMON-36 analyses demonstrated that YEWA and Willow Flycatcher do not suffer large negative impacts to their productivity when their nesting habitat becomes flooded during the nesting phase (van Oort et al. 2015). The latest analysis indicate a negative impact to YEWA juvenile survival in the first week following fledging.

YEWA is a riparian species whose young may be well-adapted to fledging under conditions of habitat flooding. We have observed flightless YEWA juveniles grabbing branches and narrowly escaping falling into water as they leave the nest (HvO personal observation). Other species that do not normally encounter flooded habitats may be less well-adapted to handling such conditions (e.g., Chipping Sparrow). The detected post-fledging impact on YEWA likely indicates a generalized impact for all shrub-nesting species. The degree of impact is likely greater for those species not adapted to periodic habitat flooding and less for species such as Yellow-headed Blackbird which always nest over water (although this latter species is known to suffer severe nest failure from flooding in the ALR).

The inclusion of juvenile survival monitoring has enhanced the understanding of reservoir ecology with respect to bird productivity. While it would be ideal that a wide array of species are studied, the logistics and invasive nature of telemetry research warrants a measured level of commitment for this kind of field work. We do not recommend that juvenile survival is studied for additional species at this time.

4.4 Final analyses

None to report in Year 8.

4.5 Recommendations for the Year 9 work plan, and future analyses

- Site selection for the 2016 (Year 9) season should review and be informed by section 3.2.1, Table 3-2, and Table 3-3, and attempt to further fill knowledge gaps. Moving field operations to Bush Arm from CR would likely offer enhanced ability to fill knowledge gaps in KIN.
- Continued telemetry research on SAVS should occur at new sites. Working at Bush Arm would be the most efficient and productive option for Year 9.
- The decision to operate in Bush Arm in Year 9 and/or Year 10 should consider access issues and logistics at this remote setting. As observed in 2012, road closures can cause a serious impact to field study success.
- Resources should continue to be allocated toward data analysis in the final years of the 10-year CLBMON-36 project.

4.6 Conclusions

The analysis of YEWA juvenile survival is essentially finished and no additional data are required for that the analysis. We await the publication of the SFU M.Sc. thesis prior to making conclusions about that study. No further conclusions about other aspects of CLBMON-36 are drawn at this time.

5 ADDITIONAL REPORTING REQUIREMENTS

5.1 Banded birds

Birds were banded in accordance with national permit regulations. Only focal species were targeted, although incidental captures of a few non-focal species did occur, so these birds were also banded. All data were entered into Bandit 2.01 software and submitted to the Bird Banding Office of the Canadian Wildlife Service. No mortalities or injuries occurred.

5.2 Provincially- and SARA-listed species

No Species at Risk nests were located.

5.3 Species with provincial jurisdiction

All nest records were reported to the Ministry of Environment following the Wildlife Species Inventory standards.

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Appendix 6-1: Status of management objectives, questions and hypotheses

STATUS OF OBJECTIVES, MANAGEMENT QUESTIONS AND HYPOTHESES

OBJECTIVES	MANAGEMENT QUESTIONS	HYPOTHESES	YEAR 8 STATUS AND SUMMARY
Identify how drawdown zone habitats are used by breeding birds in Kinbasket Reservoir and Revelstoke Reach.	A. Which bird species breed in the drawdown zones and how are they distributed among the drawdown zone habitat classes? B. What are the seasonal patterns of habitat use by birds nesting in the drawdown zones?		• These MQ's have been addressed adequately. Additional rare or uncommon species will undoubtedly be observed with additional work, but we believe that the regular nesting species are well documented • Additional monitoring will improve knowledge of (1) birds nesting in uncommon habitat types, and (2) uncommon birds within habitat types, in addition to improving precision of density estimates. • Densities do appear to vary among years, so there is a benefit to monitoring for an extended period of time • Additional work can be done to summarize the data in new ways (e.g., elevational profiles for each species) • Additional information on seasonal patterns will be beneficial for uncommon species
Evaluate how the operations of the Kinbasket and Arrow Lakes Reservoirs influence nest survival.	C. Do reservoir operations affect nest survival? D. What are the causes of nest failure in the drawdown zone, and how do they differ among species, among habitat classes, and across elevation (i.e., position in drawdown zone)?	H1: Inundation of nesting habitat caused by reservoir operations does not affect nest survivorship. H1A: Nest survivorship in the drawdown zone is not different from nest survivorship above the drawdown zone. H1C: Nest survivorship does not differ across elevations in the drawdown zone. H1D: Rates of nest flooding do not differ across elevations in the drawdown zone.	• H1 has been addressed with a final analysis for shrub nesting species • H1A was addressed in the Interim report, but models need to be re-assessed and fit with new data.
Evaluate how the operations of the Kinbasket and Arrow Lakes Reservoirs influence juvenile survival.	G. Do reservoir operations affect juvenile survival when water levels inundate post-fledging habitat?	H2: Inundation of post-fledging habitat does not affect juvenile survival. H2A: Juvenile survival in the drawdown zone does not differ from juvenile survival above the drawdown zone.	• All data to address H2 for YEWA are now collected, and final analyses and write-up are underway. • Data to address H2 for SAVS are still being collected (success of gaining adequate data will depend on reservoir operations). • Data to address H2A for SAVS are still being collected, and this component study is progressing well.
Establish a nest flooding risk model for Kinbasket Reservoir and Revelstoke Reach.	H. How can the operations of the Kinbasket and Arrow Reservoirs be optimized to reduce nest submersions and/or improve avian productivity?		• Draft models have been created and presented previously. • Improvements and updating will occur prior at Year 10
Assess how habitat management in the drawdown zones can be used to increase productivity, or reduce negative impacts of reservoir operations.	K. Can drawdown zone habitats be managed to improve nest survival and/or site productivity? If so, how?		• One well-supported suggestion for a physical works project has been delivered • The productivity and propensity of drawdown zone shrubs to function as ecological traps is still being assessed (see H1A-D).

Appendix 6-2: Habitat classes / vegetation communities used in Kinbasket Reservoir and Revelstoke Reach

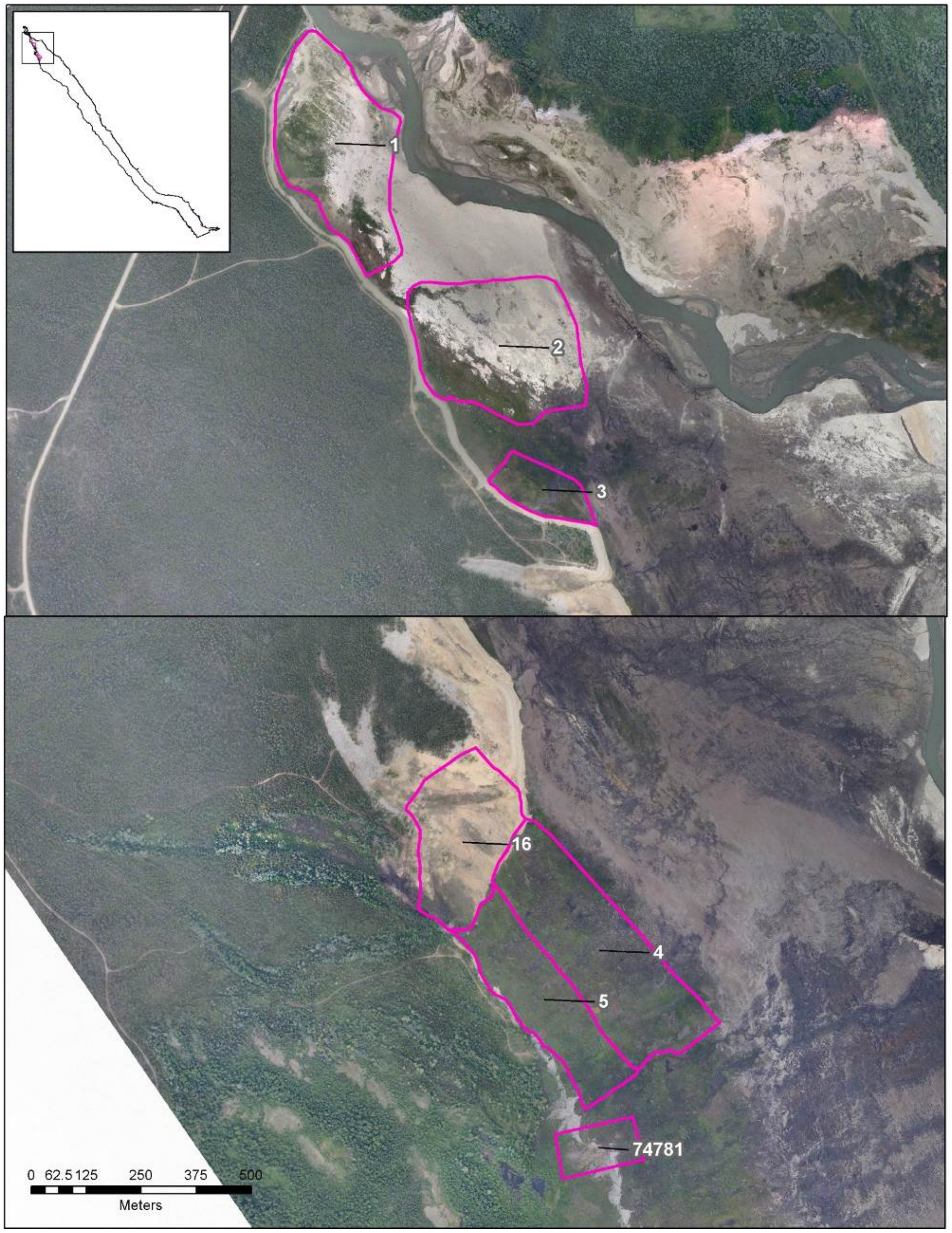
Vegetation communities within the Kinbasket Reservoir drawdown zone mapped by CLBMON 10 (Hawkes et al. 2010)

Code	Vegetation Community	Description
BR	Bluejoint Reedgrass	Above CH, often above KS
BS	Buckbean–Slender Sedge	Very poorly drained, wetland association
CH	Common Horsetail	Well drained, above LL or lower elevation on sandy, well-drained soil
CO	Clover–Oxeye Daisy	Well drained, typical just below shrub line and above KS
CT	Cottonwood – Trifolium	Imperfectly to well drained, above CO, below MC and LH
DR	Driftwood	Long, linear bands of driftwood, very little vegetation
FO	Forest	Any forested community
KS	Kellogg's Sedge	Imperfectly to moderately well drained, above CH
LH	Lodgepole Pine–Annual Hawksbeard	Well drained, above CT along forest edge, very dry site
LL	Lady's Thumb–Lamb's Quarter	Imperfectly to moderately well drained; the lowest vegetated elevations
MA	Marsh Cudweed–Annual Hairgrass	Imperfectly to moderately well drained; common in the Bush Arm area
MC	Mixed Conifer	Well drained, above CT along forest edge
RC	Reed Canarygrass	Imperfectly to moderately well drained; similar elevation to CO community
RD	Common Reed	*Phragmites australis*
SH	Swamp Horsetail	Poorly drained, wetland association
TP	Toad Rush–Pond Water-starwort	Imperfectly drained, above LL, wet sites
WB	Wool-grass–Pennsylvania Buttercup	Poorly drained, wetland association
WD	Wood Debris	Thick layers of wood debris, no vegetation
WS	Willow–Sedge wetland	Very poorly drained, wetland association

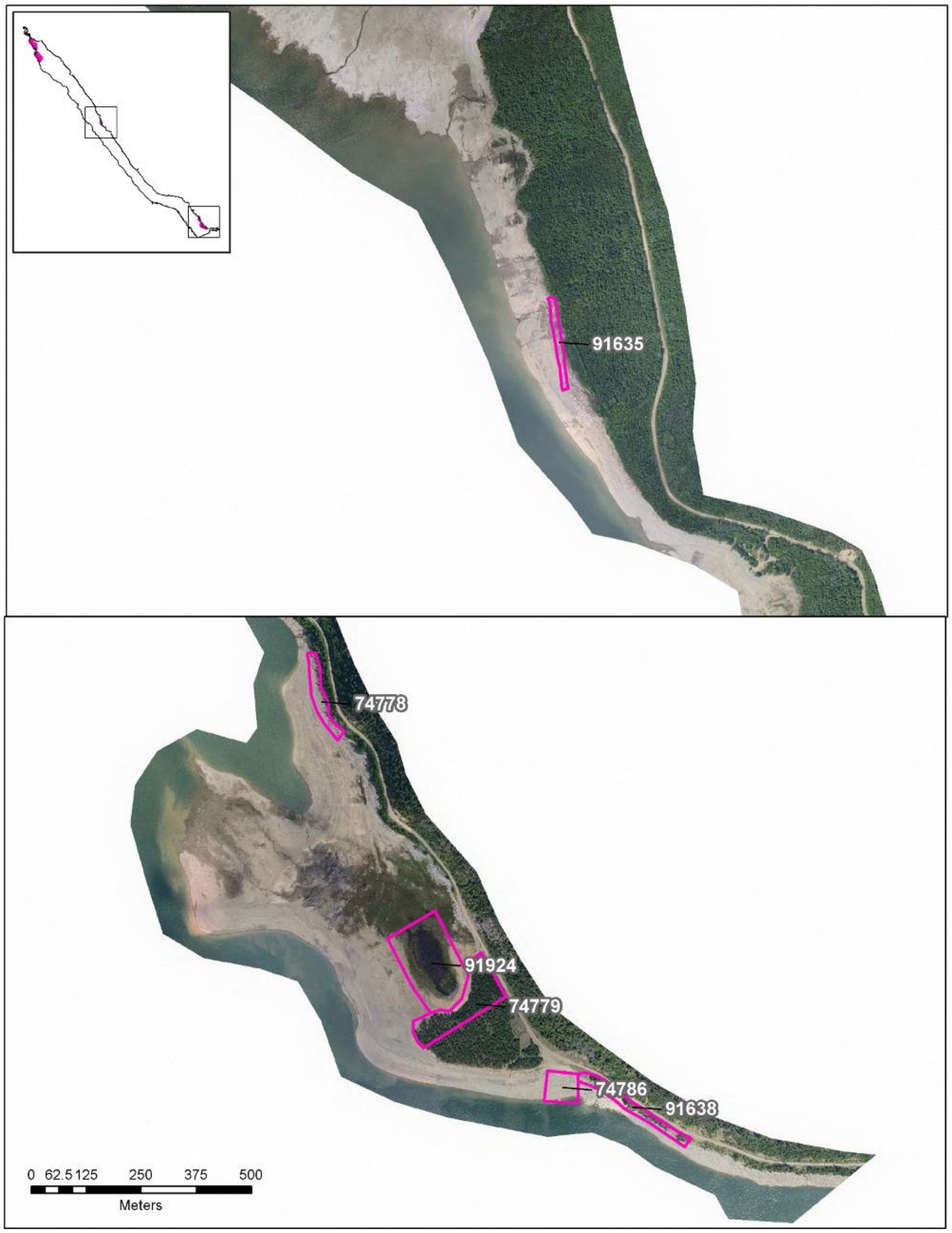
Vegetation communities within the Revelstoke Reach drawdown zone

Code	Category	Description
RF	Riparian forest	Riparian forest with cottonwoods and shrubs, with variable conifer component
UC	Upland conifer	Conifer-dominated upland forest
UM	Upland mixed	Upland forests typically containing high amounts of birch and white pine
EG	Equisetum grassland	Horsetail-dominated grassland
MG	Mixed grassland	Grasslands with variable mixture of graminoids
PG	Sparse grassland	Grasslands with sparse/low graminoid cover
RC	Reed canarygrass	Grasslands dominated by well-developed reed canarygrass cover
SG	Sedge grassland	Sedge-dominated grassland
SH	Shrub savannah	Shrub-savannah
SR	Riparian shrub	Riparian shrub
BE	Steep bedrock	Bluffy steep banks comprised of bedrock slabs or cliffs. Variable vegetation and coarse woody debris
RB	Rocky bank	Steep banks comprised of boulders, talus, and loose rocks. Variable vegetation and coarse woody debris
SB	Sand bank	Sand banks - usually failing. Variable vegetation and coarse woody debris
TH	Thalweg	Columbia River channel
CR	Coarse rocks	Coarse rocks, cobbles, boulders, etc.
GR	Gravel	Gravel, pebbles, etc.
SA	Sand	Sand
SI	Silt	Silt
UR	Urban	Residential, industrial, etc.
BF	Floating bog	Floating peat bog that provides island habitat
BR	Bulrush	Pond habitat with large stands or patches of bulrush
BS	Submerged buoyant bog	Peat bog that rises with water but becomes flooded
CK	Creek	Gravel/rocky creek channel or estuary
CT	Cattail	Cattail-dominated wetland
CW	Shrub wetland complex	Transitional, containing a mixture of wetland components, often with shrubs
LD	Low elevation draw	Muddy/clay depression or channel
PO	Pond	Open water pond habitat with variable amounts of submergent vegetation
SW	Swamp	High in the drawdown zone. Beaver ponds, skunk cabbage, alders, etc.
WM	Wet meadow	Sedge, grass, seasonally flooded area with depressions
WS	Water Sedge	Sedge-dominated marsh or fen

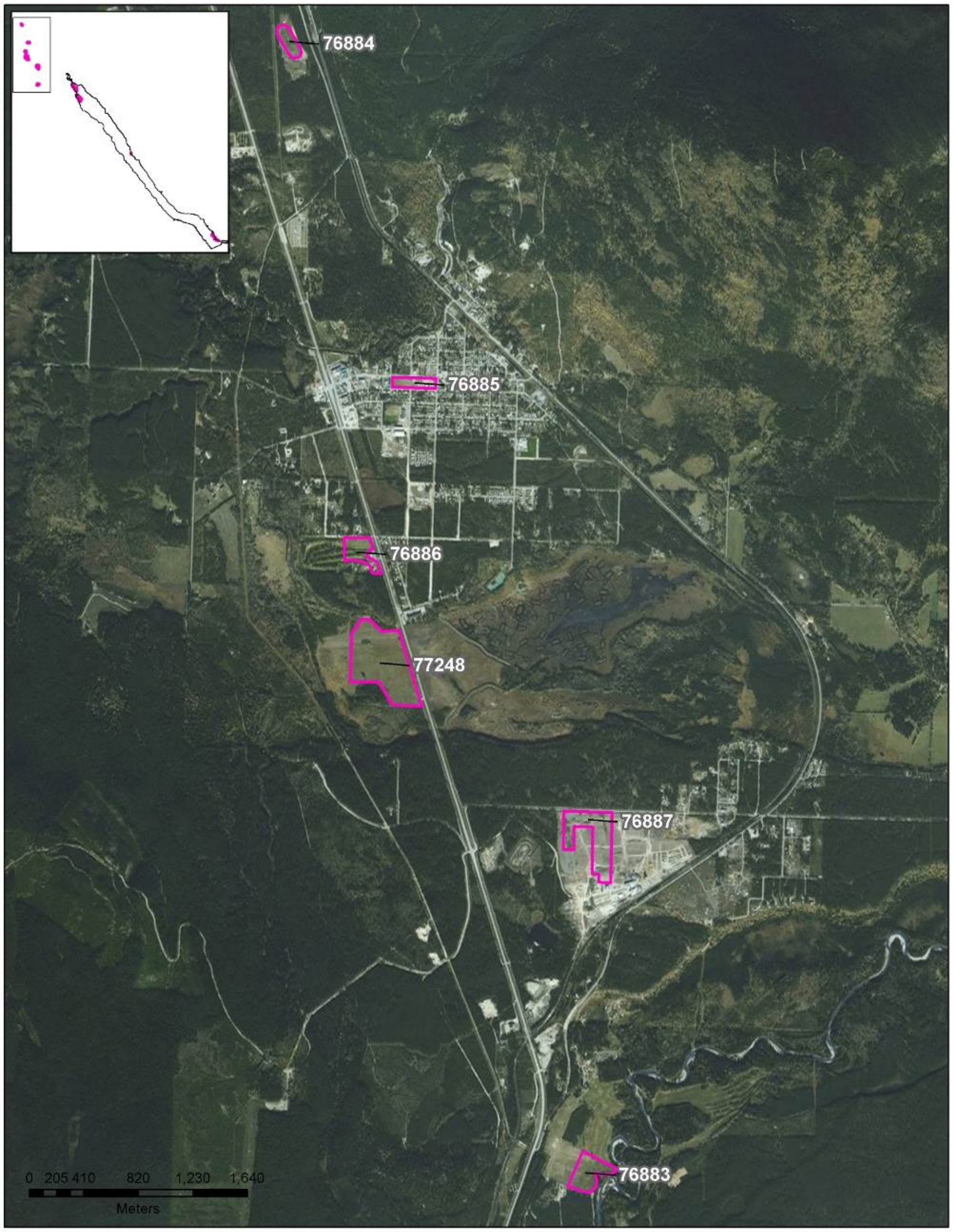
Appendix 6-3: Locations of study sites at Canoe Reach



Northern Canoe Reach

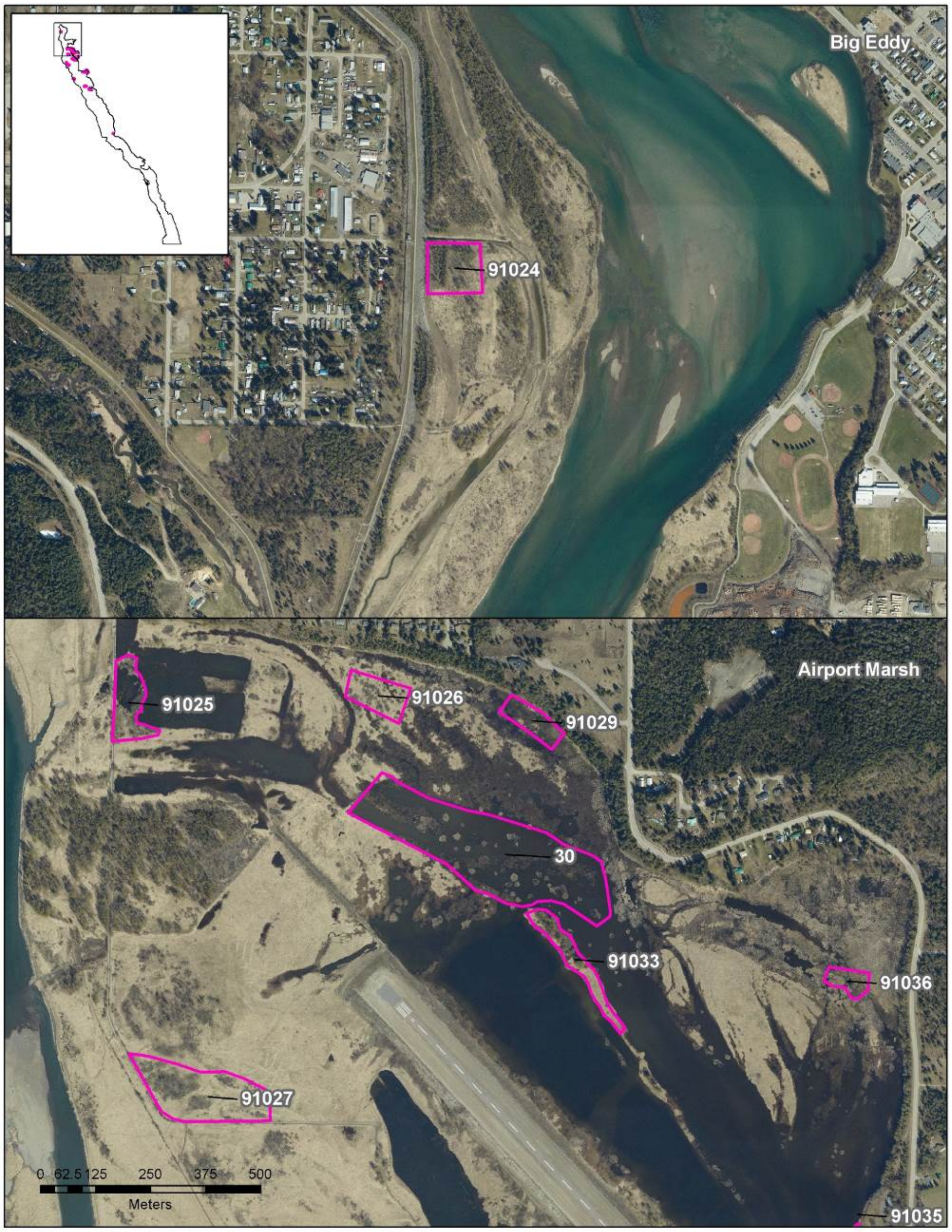


Southern Canoe Reach

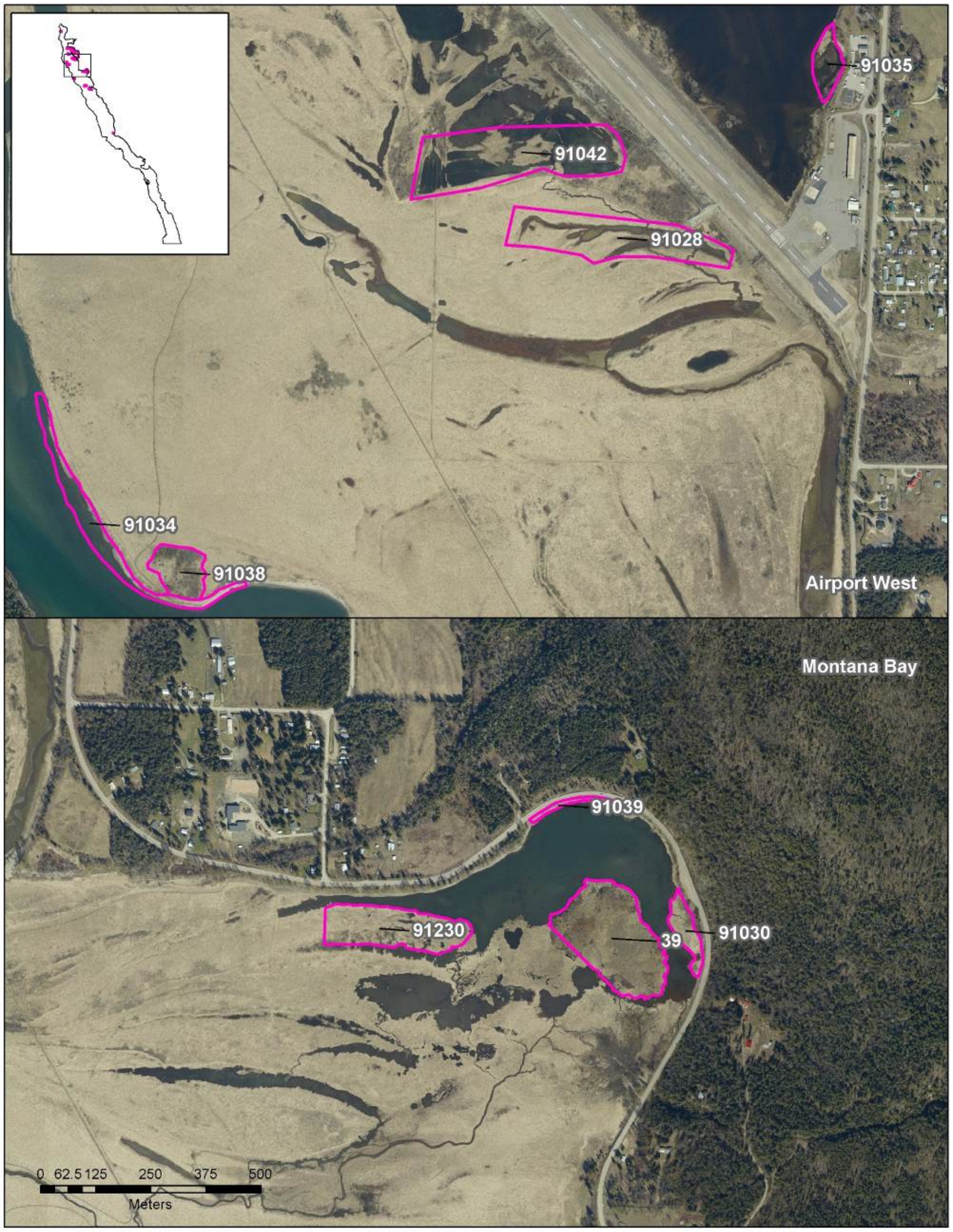


Focal species monitoring sites above the drawdown zone (SAVS)

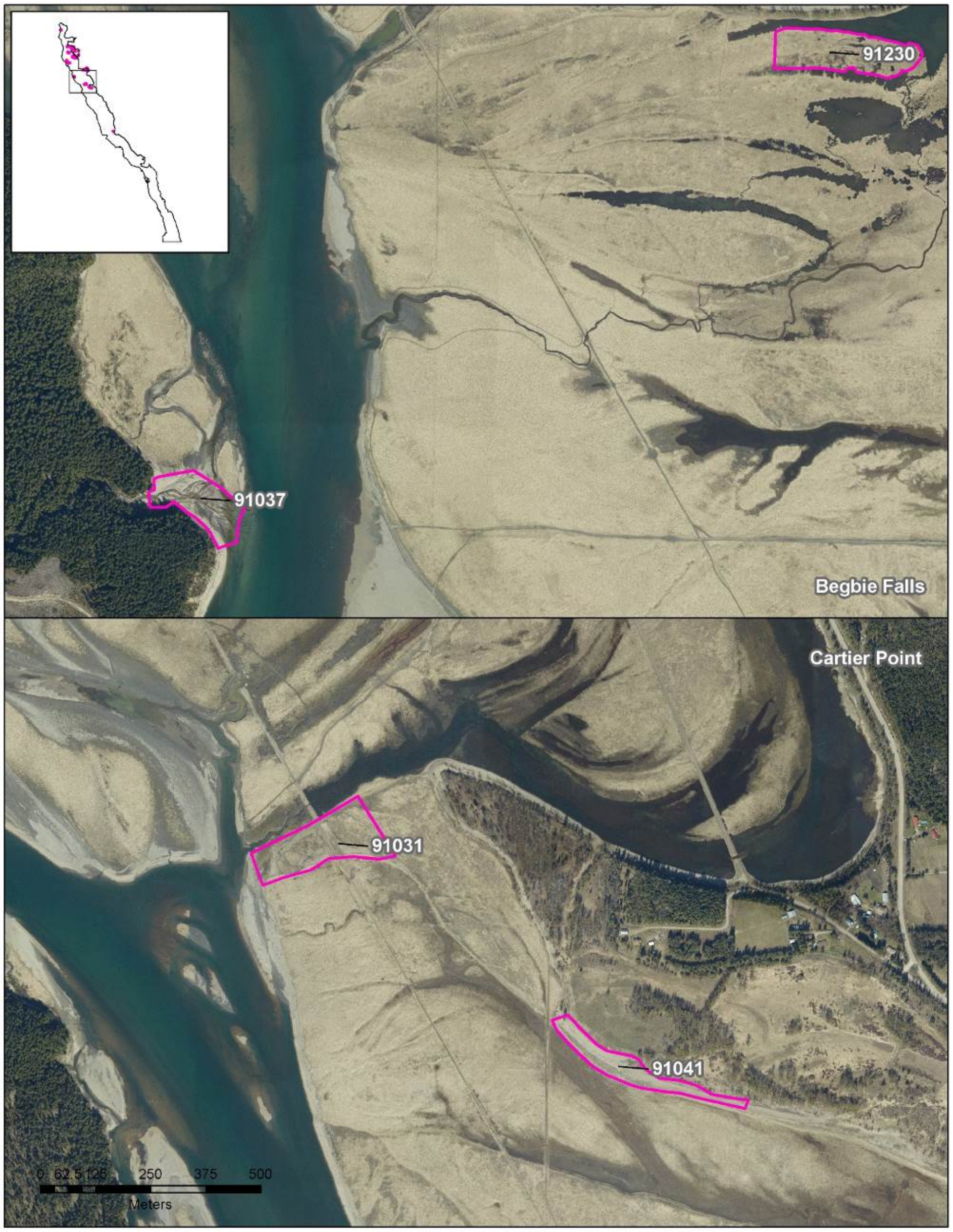
Appendix 6-4: Locations of study sites at Revelstoke Reach



Northern Revelstoke Reach - Near Town (top); Airport Marsh (bottom)



Northern Revelstoke Reach. Airport West (top); Montana Slough (bottom).



Revelstoke Reach. Begbie Falls (top); Cartier Bay (bottom).

Revelstoke Reach. 12 Mile.

Appendix 6-5: Nest mortalities due to reservoir operations (e.g., flooding) in 2015 in each study area (RR = Revelstoke Reach, CR = Canoe Reach)

Area	Nest ID	Nest Position	Species	Elevation (m asl)	Nest Height (m)
CR	95237	Ground	Savannah Sparrow	751.6	0
CR	94450	Ground	Spotted Sandpiper	748.2	0.1
CR	93416	Ground	Savannah Sparrow	747	0

Appendix 6-6: Validation of Bayesian nest survival model

In 2015, considerable effort was made to explore Bayesian analysis of nest daily survival rates (DSR). DSR has been the standard metric used to express the probability of nest survival ever since Mayfield showed how reporting raw nest outcome observations leads to a positively biased estimation of nesting success, simply because datasets usually include a subset of all nesting attempts, with nests that fail shortly after initiation being underrepresented (Mayfield 1961). Estimation of DSR has a long history of varied approaches from simple hand calculation (Mayfield 1961), to a variety of frequentist approaches using variations of a Generalized Linear Model (Shaffer 2004). Several of the approaches have been criticized (Shaffer 2004), and fitting mixed effects models is sufficiently challenging using the frequentist approach. A Bayesian approach to modeling offers a high degree of flexibility (Kéry 2010, Kéry and Schaub 2012, Zuur et al. 2012) and Bayesian nest DSR models, including mixed effects, have been coded, presented, and applied recently (Royle and Dorazio 2008, Schmidt et al. 2010, Brown and Collopy 2012, Converse et al. 2013). A worked example of a Bayesian nest DSR model (Royle and Dorazio 2008) was adopted for our purposes. We wrote code to import data from the CLBMON-36 database, and format appropriately for these models; this involved extracting scalar values about the dataset, vectors of data about the nests, and matrices of data about the nests' states over time. The models were written in WinBUGS language (Lunn et al. 2000), and fit using Markov Chain Monte Carlo simulations with the Gibbs sampling protocol in WinBUGS. Once the Bayesian models were de-bugged, they worked well with our data.

To verify and validate the model we adapted (Royle and Dorazio 2008), we analyzed simulated observation data, taken from simulated nest survival data generated with known DSR. We simulated 100 nests with 30 day incubation periods. Nests were allowed to be initiated anytime during a 30 day period (a uniform distribution was used); hence the nesting season was 60 days long. Nest survival was simulated by applying daily repeated Bernoulli trails in R, using a fixed probability (DSR). Nest observations were simulated to occur with uneven intervals ranging from approximately every 1 to 5 days using normally distributed random intervals (typically every 3 days). We assumed perfect detection of active nests. To demonstrate the validity of the method, we simulated 10 datasets, each built using the DSR values that increased progressively by incremental steps of 0.01 over the biologically-relevant range of 0.90 through 0.99. Each dataset was analyzed using the appropriate null model, and the DSR estimate recorded. DSR modeling showed strong validity in estimating the true DSR value from the simulated nest observations, with a strong relationship between true and observed DSR within 10 data points ($F_{1,8}$ = 427, R2 = 0.98, intercept = -0.09, slope = 1.10, $p < 0.0001$; Figure 6-1).

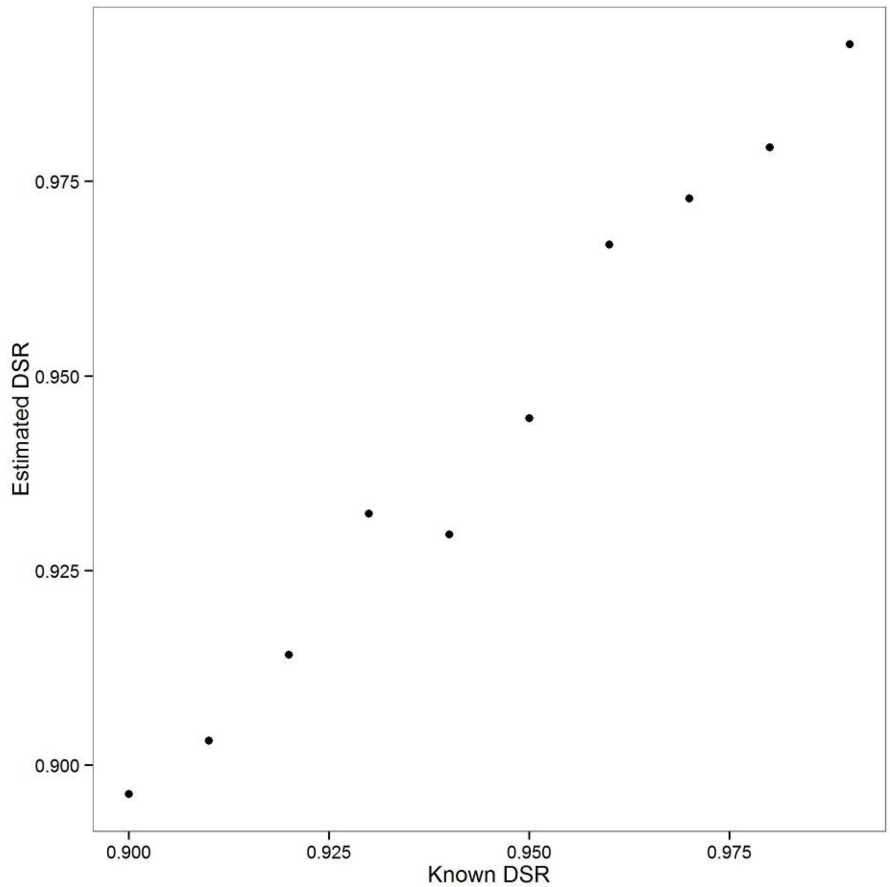


Figure 6-1: **Analysis results from a Bayesian model of DSR estimated from simulated nest observation data where the DSR value was known**

Appendix 6-7: Detailed methods and results from the Bayesian duck nest survival analysis

In 2015 we applied a Bayesian nest survival model to the available duck data to estimate the effects of nesting location on DSR. Below are the specifics of this modelling method and results.

All models used the same Monte Carlo Markov Chain settings (Kéry 2010): 100,000 iterations with burn in of 10,000 (90,000 draws saved from the posterior distribution); three chains were used, with a thinning rate of 3. Chain convergence was examined graphically and assessed using the Gelman-Rubin statistic (Rhat) which is greater than 1.1 when the chains do not mix satisfactorily (Kéry 2010). DIC statistics were used for model selection; like AIC, low DIC values indicate simpler more powerful models.

In the first suite of models, all parameter estimates were positive except for DEM in models 8 and 9 (Table 6-1); as such, BF was always modeled to improve nest DSR. In models 3, 4 and 8 the intercept parameter failed to converge (Table 6-1). DIC ranked model 6 (DSR = BF + r(SPP)) and the null model as the best models, but the DIC spread (Δ DIC values) was not large among any of the models. According to the null model (model 1), DSR was estimated at 0.920. Model 6 estimated DSR to be 0.903 unless the nest was positioned in BF habitat, when DSR improved to 0.936.

In the second suite of models which excluded BF nests, the effect of DEM was weak and negative in two of the three models that estimated this term (Table 6-2). DIC values differed little among the models, suggesting that little was gained by including DEM in a model. Excluding model 3 for which the intercept failed to converge, DIC ranked the null model as the best model (Table 6-2), which estimated a DSR value of 0.908.

Table 6-1: Daily Survival Rate (DSR) models for dabbling 59 duck nests located in the ALR drawdown zone; 36 nests were located on floating bog (BF) habitat, and therefore protected from reservoir operations and likely subjected to different predation pressure. The fixed effect of elevation in the drawdown zone (DEM) was estimated, while assigning BF nests were positioned at full pool (440.1 m asl). The effect of BF was examined as a fixed effect. Year (YR) and species (SPP) effects were modelled as random effects

	Model	DIC[1]	Parameter	Estimate	Rhat[2]
1	DSR = FIXED	442.6	intercept	2.443	1.0
2	DSR = DEM	445.6	intercept	2.445	1.0
			beta.dem	0.095	1.0
3	DSR = DEM + r(SPP)	446.3	intercept	2.713	1.7
			beta.dem	0.123	1.0
			sd.spp	1.923	1.0
4	DSR = DEM + r(YR)	445.5	intercept	2.354	1.2
			beta.dem	0.133	1.0
			sd.yr	0.329	1.0
5	DSR = BF	443.7	intercept	2.287	1.0
			beta.bf	0.400	1.0
6	DSR = BF + r(SPP)	442.4	intercept	2.238	1.1
			beta.bf	0.453	1.0
			sd.spp	1.071	1.0
7	DSR = BF + r(YR)	443.4	intercept	2.252	1.0
			beta.bf	0.433	1.0
			sd.yr	0.150	1.0
8	DSR = DEM + BF + r(SPP)	444.6	intercept	2.442	1.5
			beta.bf	0.516	1.0
			beta.dem	-0.056	1.0
			sd.spp	1.700	1.1
9	DSR = DEM + BF + r(YR)	445.1	intercept	2.270	1.0
			beta.bf	0.467	1.0
			beta.dem	-0.028	1.0
			sd.spp	0.175	1.0

1. DIC is similar to AIC, with lower values representing optimal models
2. Rhat is the Gelman-Rubens statistic of MCMC chain mixing; values > 1.1 signify chains that did not converge

Table 6-2: Daily Survival Rate (DSR) models for dabbling 59 duck nests located in the ALR drawdown zone; nests located on floating bog (BF) habitat were omitted as these nests may interfere with estimating the effect of nest elevation (DEM). Year (YR) and species (SPP) effects were modelled as random effects

	Model	DIC[1]	Parameter	Estimate	Rhat[2]
1	DSR = FIXED	252.4	intercept	2.287	1.0
2	DSR = DEM	253.4	intercept	2.294	1.0
			beta.dem	-0.064	1.0
3	DSR = DEM + r(SPP)	251.8	intercept	2.282	1.4
			beta.dem	0.012	1.0
			sd.spp	1.737	1.0
4	DSR = DEM + r(YR)	252.5	intercept	2.257	1.0
			beta.dem	-0.005	1.0
			sd.yr	0.639	1.0

1. DIC is similar to AIC, with lower values representing optimal models
2. Rhat is the Gelman-Rubens statistic of MCMC chain mixing; values > 1.1 signify chains that did not converge