Columbia River Project Water Use Plan

KINBASKET AND ARROW LAKES RESERVOIRS

Reference: CLBMON-36

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

Study Period: 10 Year Final Report, 2008-2017

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FINAL – May 2020

FINAL REPORT

CLBMON-36: Nest Mortality of Migratory Birds Due to Reservoir Operations

Photo Credit: Catherine Craig

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Bush Arm drawdown zone, Kinbasket Reservoir, 2017. Photo © Catherine Craig.

EXECUTIVE SUMMARY

In 2008, BC Hydro initiated CLBMON-36, a 10-year program designed to determine the effects of reservoir operations (water level management) on the breeding success of birds nesting in the drawdown zones of Kinbasket Reservoir (KIN) and Arrow Lakes Reservoir (ALR). Additionally, the program aimed 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). The monitoring program evolved over the 10 years of study (**Appendix A**) and this report addresses the current seven Management Questions and provides recommendations related to the objectives of the study.

Field studies were conducted at Revelstoke Reach of ALR (2008 to 2017) and at Canoe Reach (2008 to 2015) and Bush Arm (2009 to 2012 and 2016 to 2017) of KIN. Over this time, a strong knowledge was acquired of the bird communities in each vegetation community, the distribution and timing of nesting activities, and of nest and juvenile survivorship. A model of nest density by elevation and time of year was developed for mapped regions of both reservoirs.

Sixty-five species were found nesting in the ALR drawdown zone and twenty-nine species were found nesting in the KIN drawdown zone. Species richness and nest abundance was higher at ALR due to its more complex and diverse vegetation. Nests were concentrated at higher elevations at both reservoirs, where vegetation was most established. Nest density varied with habitat, with the highest densities in shrub and wetland habitats. Airport Marsh in the ALR drawdown zone contained regionally rare habitats with higher nest densities and species not found elsewhere. An examination of nest phenology showed a more pronounced peak in nesting activity for KIN and a longer nesting season at ALR.

The greatest causes of nest failure in both reservoirs were predation and abandonment; however, nest success was also influenced by reservoir operations. There were 209 monitored nests of 38 species flooded from 2008 to 2017 (4.2% of monitored nests at KIN, 7.5% of monitored nests at ALR). There were some ground or low shrub nesting species for which flooding caused the most nest failures, with some species having as many as 31% of their nests flooded. Generally, nest flooding was a larger issue at ALR than at KIN, due to the differences in reservoir operations.

The risk of nest flooding depended on nest phenology, nest elevation, and water levels as demonstrated by the nest flooding model. Nests initiated earlier in the season and at higher elevations were less likely to experience flooding. There was annual variation in reservoir operations and some years when very few nests were flooded at any elevation. For some species (e.g., Yellow Warbler), nest failures due to flooding were compensated for to some degree by reduced predation of remaining nests, thus flooding of habitat did not always impact overall nest productivity.

Juvenile survival of Yellow Warbler was influenced by reservoir operations. Warblers fledging from nests above flooded habitat were less likely to survive to 21 days than those from nests in unflooded habitat. It is likely that some other shrub-nesting species would experience the same effects. However, there was relatively low impact to juvenile Savannah Sparrow (a ground-nesting species) from reservoir operations and their survival was more strongly related to temporal variables (e.g., bird age).

A species with the status of Special Concern on Schedule 1 of the *Species at Risk Act* (SARA), Short-eared Owl, nested in the ALR drawdown zone in 2010 and 2016. Owls nested on the ground at relatively low elevation and all nests were flooded in both years.

For both reservoirs, filling later (as shown by the nest model) would reduce the potential for nest flooding and increase avian productivity; this is particularly true at ALR. Lowering the maximum elevation would also provide an initial benefit to nesting bird productivity; however, this change in operations may also promote vegetation growth lower in the drawdown zone. If this vegetation response occurred, it could cause birds to nest lower in the drawdown zone, and eventually nest flooding may revert to status quo levels. Alternatively, the reservoirs could be filled to a higher elevation prior to the breeding season, making habitat that will be flooded later unavailable for nesting from the outset.

Enhancing habitat in the KIN drawdown zone could improve avian productivity as the flooding of higher elevation habitats does not typically coincide with the prime bird breeding season. At ALR, vegetation should only be enhanced at the highest elevations and to ensure that nests are high enough above ground level to avoid flooding. Key and rare habitats such as Airport Marsh could be stabilized and protected from inundation to reduce nest losses and increase breeding bird productivity.

Table 1.1 Summary of Key Monitoring Results for each Management Question

Management Question	Summary of Key Monitoring Results
MQ-A. Which bird species breed in the drawdown zones and how are they distributed among the drawdown zone habitat classes?	• 65 species nested at ALR; 29 species nested at KIN. • Nest density was greatest in shrub/tree and wetland habitats. • Airport Marsh at ALR contained regionally rare habitats and bird species not found elsewhere.
MQ-B. What are the seasonal patterns of habitat use by birds nesting in the drawdown zones?	• ALR has a longer nesting season compared to KIN due to the greater diversity of habitats and thus bird species nesting. • Nest timing in KIN was more similar among vegetation communities as many of them were dominated by one species, Savannah Sparrow. • Nesting activity occurred earlier in wetlands than other habitats.
MQ-C. Do reservoir operations affect nest survival?	• 209 nests of 38 species flooded from 2008 to 2017 (4.2% of nests at KIN, 7.5% of nests at ALR). • For some shrub-nesting species, such as Yellow Warbler, nest flooding was compensated for by reduced predation on remaining nests, thus reservoir operations did not affect overall productivity. • All nests of the federally-listed Short-eared Owl (Special Concern under SARA) were flooded.
MQ-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)?	• Predation was the most common cause of nest failure in both reservoirs; abandonment was the second most common. • For some ground- and low-elevation nesting species, flooding caused the most nest failures. • Nest flooding was more common at ALR than at KIN. • Nests initiated earlier in the season and at higher elevations were less likely to be flooded.
MQ-G. Do reservoir operations affect juvenile survival when water levels inundate post-fledging habitat?	• Yellow Warbler juvenile survival was reduced by 21% in flooded versus unflooded habitats. • Savannah Sparrow juvenile survival was most strongly correlated with temporal factors.
MQ-H. How can the operations of the Kinbasket and Arrow Reservoirs be optimized to reduce nest submersions and/or improve avian productivity?	• Filling later may reduce the potential for nest flooding and increase avian productivity, particularly at ALR. • Early filling prior to breeding season would prevent birds from nesting in habitats that would later be flooded.

MQ-K. Can drawdown zone habitats be managed to improve nest survival and/or site productivity? If so, how?	• Stabilizing the water level in key habitats (e.g., wetlands such as Airport Marsh) and protecting them from inundation. • Improve habitat at upper KIN drawdown zone, where flooding is unlikely. • Establish floating islands to provide “unfloodable” nesting habitat within the reservoir drawdown zones.

KEYWORDS

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

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Cooper Beauchesne and Associates Ltd. (CBA) conducted the field studies and managed the project from 2008 through 2017.

CBA collaborated with the Okanagan Nation Alliance (ONA) for the delivery of CLBMON-36 from 2013 to 2017. ONA biologists and technicians provided field and technical support, and insight into the perspectives and protocols of the Syilx (Okanagan) people. Raven Douglas, Mike Dunn, Alexis Friesen, Autumn Solomon, Kayla Williams, and Karle Zelmer of the ONA and Bruce Weaver of the Okanagan Indian Band contributed to field studies. Al Peatt and Dave DeRosa managed the ONA's collaboration.

Over the 10-year program, the field studies were planned and coordinated by Harry van Oort, Ryan Gill, and Catherine Craig. Fieldwork was conducted by many CBA field staff: Devon Anderson, Rudy Badia, Nicole Basaraba, Corey Bird, Pierre-Paul Bitton, James Bradley, Russell Cannings, Stacey Carnochan, Allan Carson, Dominic Cormier, Kevan Cowcill, Catherine Craig, Leonard Edwards, Jason Fidorra, Ryan Gill, Jennifer Greenwood, Nathan Hentze, Chris Joseph, Felicia Juelfs, Laura Kennedy, Peter LeCouffe, Paul Levesque, Jotvir Mann, Jeannine Randall, Michal Pavlik, Lucie Parker, Vicky Prigmore, Jennifer Sheppard, Emily Smith, Vicky Smith, Paul Smylie, Tim Sneider, Brad Stewart, Harry van Oort, and Emily Williams. Suzanne Beauchesne provided overall supervision of field crews. John Cooper acted as Project Manager.

Catherine Craig compiled this report and conducted all new analyses, building on work completed by Harry van Oort during the first nine years of study. Ryan Gill provided GIS mapping, database management, and a technical review of this report.

CBA worked closely with Simon Fraser University for 10 years on some aspects of this study. Dr. David Green of Simon Fraser University provided scientific guidance to CBA and coordinated the Yellow Warbler research, which was conducted by Amber Benoit, Graham Dixon-MacCallum, Kate Gibson, Celia Grande, Matthew Hepp, Terry Jones, Rianne Mariash, Michaela Martin, Michal Pavlik, Matt Pennell, Annette Potvin, Christine Rock, Kyle Tonneson, and Lena Ware. All methods used in this study were approved by the Simon Fraser University Animal Care Committee.

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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Definition
ALR	Arrow Lakes Reservoir
BA	Bush Arm
CR	Canoe Reach
DEM	Digital Elevation Model
KIN	Kinbasket Reservoir
RR	Revelstoke Reach
SARA	*Species at Risk Act*

LIST OF SYMBOLS AND UNITS OF MEASURE

Symbol / Unit of Measure	Definition
ha	hectare
km	kilometre
m	metre

1.0 INTRODUCTION

The Columbia River is one of the most modified river systems in North America (Nilsson et al. 2005); its flow is regulated by multiple hydroelectric dams and water storage reservoirs. Water storage reservoirs positioned in succession along the main stem of the Columbia River in British Columbia include the Kinbasket Reservoir (KIN) (Mica Dam, 1973), Lake Revelstoke (Revelstoke Dam, 1984) and Arrow Lakes Reservoir (ALR) (Hugh Keenleyside Dam, 1968).

Following the completion of these projects, few areas of natural riparian habitats and wetlands remained. It has been estimated that 7,700 ha (hectares) of wetland habitat have been impounded in the Canadian portion of the Columbia basin (Utzig and Schmidt 2011). The wetlands in Revelstoke Reach (RR) are the only significant wetland habitats between Valemount and Castlegar, an approximate linear distance of 400 km of valley bottom that was impounded in this region. An additional 100 km of valley-bottom habitat was flooded between Mica and Donald along Columbia Reach of KIN. The footprint areas of these reservoirs have removed or altered much of the valley-bottom habitat, and their drawdown zones are typically comprised of steep shorelines (Enns et al. 2007, Utzig and Schmidt 2011). 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 the BC portion of the basin (Utzig and Schmidt 2011).

In the upper elevations of the drawdown zones, the growth of riparian and wetland vegetation is possible, but such habitats are uncommon (Enns et al. 2012, Miller et al. 2015). 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 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 at KIN, also contain several vegetated areas suitable as nesting habitat (CBA 2010, 2011, 2013). Because these remnant breeding habitats are in reservoir drawdown zones, the operation of KIN and ALR (through rising water levels in late spring/early summer) may have impacts on the productivity of resident bird populations (CBA 2013). Due to potential flooding of nesting habitats and nests during the breeding season (Wolf 1955, Espie et al. 1998, Anteau et al. 2012), it is possible that some nesting habitats within the reservoirs act as ecological traps (Schlaepfer et al. 2002, Robertson and Hutto 2006, Anteau et al. 2012, CBA 2013), or that some drawdown zone populations act as population sinks (Pulliam 1988).

During the Columbia River Water Use Planning process (BC Hydro 2007), nest mortality caused by reservoir operations was identified as an important issue that had not been previously assessed. The primary concern was that the operations of KIN and ALR 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 identified in 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, BC Hydro initiated CLBMON-36, a 10-year (2008 to 2017) program designed to determine the effects of reservoir operations (water level management) on breeding 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). The field monitoring program was initiated in 2008, and methods and Terms of Reference were modified as needed over the 10 years of study (**Appendix A**).

1.1 Objectives

The objectives of CLBMON-36 were:

- 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.

This report summarizes the results of the 10-year study and addresses each of the seven Management Questions (MQs) in their own section of the report. New analyses are described in the **Appendices**. These analyses, previously reported analyses, and other studies are referenced throughout each section to address the MQs. Changes were made to the MQs in 2015 and this report only includes MQs from the 2015 Terms of Reference (BC Hydro 2015).

2.0 STUDY AREAS AND RESERVOIR OPERATIONS

Field studies were conducted at Canoe Reach (CR) and Bush Arm (BA) at KIN, and Revelstoke Reach (RR) at ALR (**Figure 2.1**). Both reservoirs are surrounded by steep slopes, mountainous terrain, and managed coniferous forests. KIN is the uppermost reservoir along the Columbia River and impounds a 216 km section of the Columbia and Canoe Rivers.

CR is the northern arm of KIN and the study area is approximately 50 km long (**Figure 2.1**). It is primarily comprised of unvegetated shorelines, but also includes grass and sedge habitats near seepage sites and remnant peatlands to the north.

BA is at the southern end of KIN where the Bush River flows west into the Columbia from the Rocky Mountains (**Figure 2.1**). The study area is about 24 km long and extends Bush River to Bear Island. Much of the area is comprised of unvegetated silt and old tree stumps, but it is also rocky in places, sporadically vegetated at upper elevations, and contains some small wetlands.

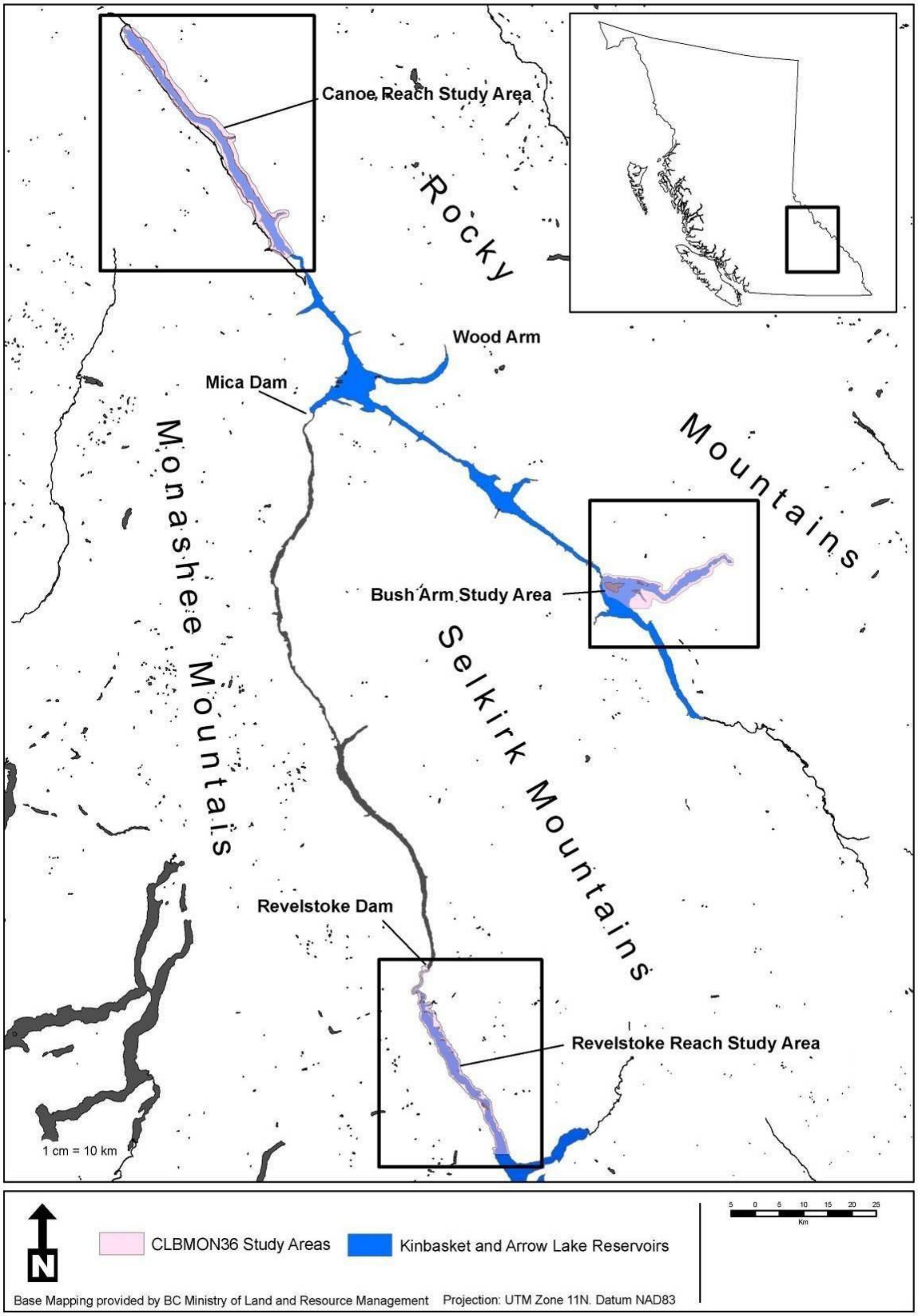

Figure 2.1 Location of the CLBMON-36 study areas

RR is the most northerly section of ALR and extends south for about 42 km (**Figure 2.1**). The lowest elevations of the drawdown zone are comprised of unvegetated silt and old trees stumps, but vegetation becomes more complex at higher elevations, transitioning from grasses and sedges to willows (*Salix spp.*) and cottonwoods (*Populus trichocarpa*).

2.1 Kinbasket Reservoir Operations

KIN is licensed to operate between 707.41 m and 754.38 m elevation (BC Hydro 2007). Being positioned near the head of the Columbia River and having a huge capacity for storage, the KIN water level traditionally reaches its annual maximum later in the year compared to the ALR (**Figure 2.2**, **Figure 2.3**). From 2008 to 2017, KIN had a representative range of operations, reaching elevations both below and above average (**Figure 2.2**).

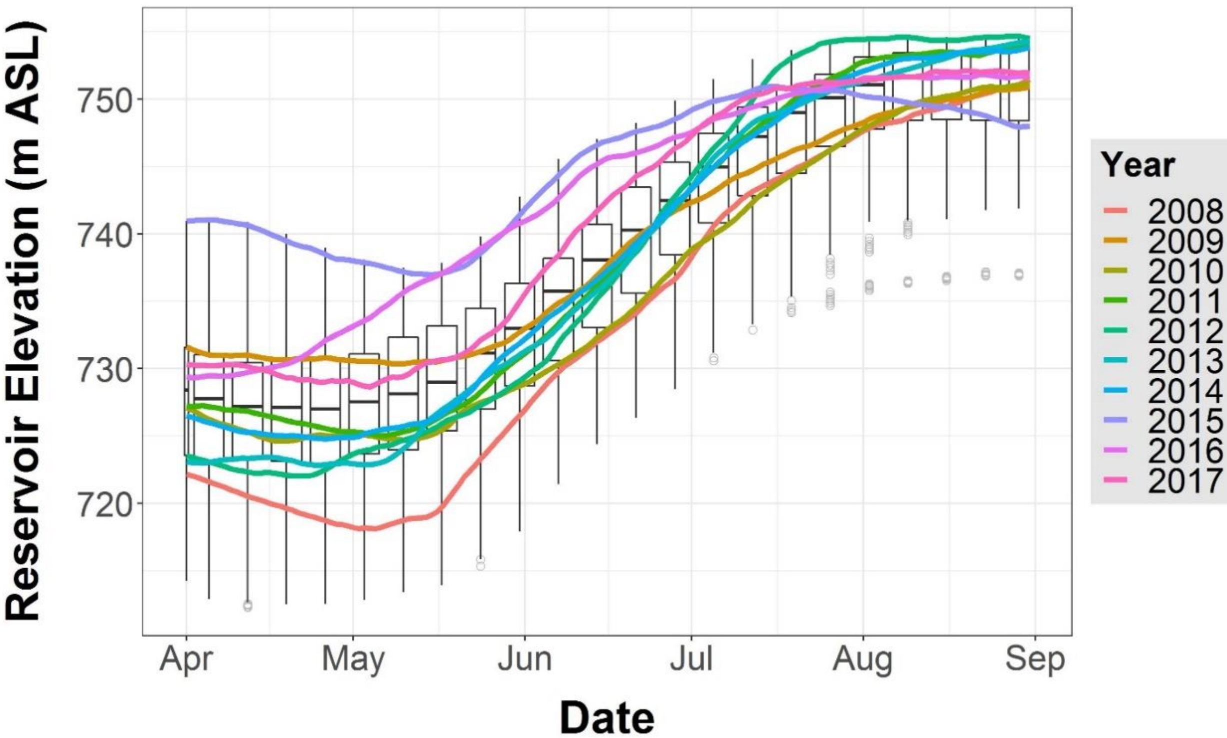

Figure 2.2 Reservoir elevations of Kinbasket Reservoir from 2008 to 2017. Box plots show historical average.

2.2 Arrow Lakes Reservoir Operations

ALR is licensed to operate between 418.6 m and 440.1 m elevation (BC Hydro 2007). From 2008 to 2017, ALR had higher than average water levels throughout the peak bird breeding season (June) in most years (**Figure 2.3**), although there was variation in the height and timing of the peak elevation. The higher water levels may have prevented birds from nesting in lower elevation habitats, which could have affected the amount of nest flooding observed at these elevations. In 2015 and 2016, the water levels peaked low and early, and in 2012, the reservoir reached an abnormally high level in July and remained high through the rest of the bird breeding season.

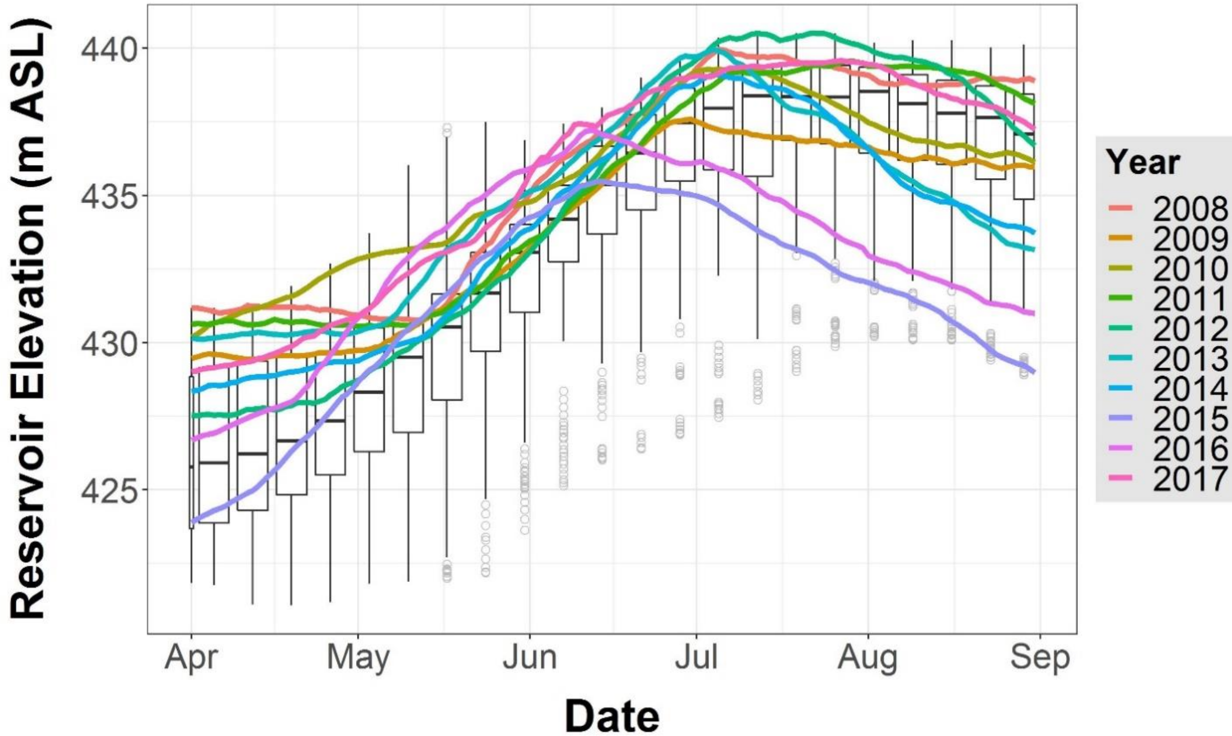

Figure 2.3 Reservoir elevations of Arrow Lakes Reservoir from 2008 to 2017. Box plots show historical average.

3.0 METHODS

3.1 Overview

Detailed descriptions of study design, site selection, field protocols, and data management are outlined in the CLBMON-36 protocol report (CBA 2016) and the annual reports (e.g., CBA 2015).

Briefly, CLBMON-36 methods involved 1) monitoring nest productivity for all species found nesting within the drawdown zone, and 2) studying juvenile survivorship or detailed nesting biology for focal species.

The nest productivity monitoring was conducted through 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. Habitat categories for both reservoirs are described in **Appendix B**. At KIN, the drawdown zone habitats were classified by the vegetation communities identified in CLBMON-10 (Hawkes et al. 2010). In RR, the drawdown zone habitats were classified by vegetation communities identified by a habitat map developed by Cooper Beauchesne and Associates (CBA 2012). Biogeographical monitoring involved selecting new study plots annually from representative patches of each habitat class in all three study areas. Within each study plot, field technicians attempted to find and monitor all bird nests.

In addition to community-level monitoring, focal species were selected to allow for better examination of factors influencing the survivorship of nests and fledged juveniles. Field efforts attempted to generate larger sample sizes of nests of focal species for statistical purposes rather than finding every nest at a given site. Key breeding habitats were monitored for focal species each year. Focal species included Savannah Sparrow (*Passerculus sandwichensis*), 'Traill's' Flycatcher (either of the closely related Willow or Alder Flycatchers, *Empidonax traillii* and *Empidonax alnorum*, respectively), Yellow Warbler (*Setophaga petechia*), and Cedar Waxwing (*Bombycilla cedrorum*) (see timeline in **Appendix A**). To monitor post-fledging juvenile survival, radio-telemetry research was conducted on Savannah Sparrow in BA and CR, and Yellow Warbler in RR. Simon Fraser University (SFU) researchers intensively monitored Yellow Warbler at three permanent plots in Revelstoke Reach throughout the study and those nests are included in the project data sets.

Detailed methods for novel analyses are individually described within the Appendices. All raw data were entered into a custom online database or Excel spreadsheets. All data processing, statistical analysis, and visualization was performed using R (R Core Team 2019) and all figures were created with the R package ggplot2 (Wickam 2019). An p-value limit of 0.05 was used for determining statistical significance. All analyses performed for this report used the data sets described below.

3.2 Data Sets

3.2.1 Reservoir Elevations

3.2.1.1 Reservoir Water Level

Reservoir water elevation data were provided by BC Hydro and included the daily average surface elevation of both ALR and KIN from April 1, 1968 to September 30, 2017. The ALR elevations were primarily from the monitoring station at Fauquier (station number 08NE102) and the KIN elevations were primarily from below Garrett Creek (08NB017). This data set was used to plot the reservoir operations graphs in **Section 2.0**, plus provided water level values for dates of nest and juvenile observations.

3.2.1.2 Digital Elevation Model

Digital elevation model (DEM) data were provided by BC Hydro with 5 m horizontal resolution. These data were used to estimate the ground-level elevation of the reservoir as well as nest elevations (DEM + nest height above ground). These data were found to be inconsistently inaccurate, sometimes varying up to ~80 cm from the actual elevation.

3.2.2 Nests

The Nests data set was exported from the CLBMON-36 online database but nests for which no nest outcome (e.g., Successful, Failed) was entered were excluded. It included information about all nests (n = 3437) found from 2008 to 2017 both within and outside of the drawdown zone (one row of data per nest). 794 nests were located at KIN and 2643 were located at ALR. At KIN, 500 nests were at CR and 294 were at BA.

A further breakdown of sample sizes by location and for each focal species is provided in **Table 3.1** and **Table 3.2**. In the tables, "on-plot" refers to nests on community-level nest monitoring plots, "SFU plot" refers to nests on SFU Yellow Warbler monitoring plots, and "off plot" refers to nests located outside of either type of monitoring plot (including nests outside of the drawdown zone). Further details on the variables contained within this data set are in **Appendix D**. These data were used to answer MQs A, B, C, and D.

Table 3.1 Sample Sizes in Nests Data Set for Focal Species

Species	Location	All Study Areas	Kinbasket Reservoir		Arrow Lakes Reservoir
			Bush Arm	Canoe Reach	Revelstoke Reach
Cedar Waxwing	On-plot	364	48	6	310
	Off plot	45	0	23	22
	SFU plot	52	0	0	52
	Within drawdown zone	396	47	3	346
	Outside of drawdown zone	65	1	26	38
Savannah Sparrow	On-plot	377	75	205	22
	Off plot	120	7	60	53
	SFU plot	-	-	-	-
	Within drawdown zone	320	82	200	38
	Outside of drawdown zone	102	0	65	37
Traill's Flycatcher*	On-plot	171	12	4	155
	Off plot	9	0	3	6
	SFU plot	7	-	-	7
	Within drawdown zone	179	12	4	163
	Outside of drawdown zone	8	0	3	5
Yellow Warbler	On-plot	104	9	1	94
	Off plot	3	0	0	3
	SFU plot	487	-	-	487
	Within drawdown zone	577	9	0	568
	Outside of drawdown zone	17	0	1	16

*Includes both willow and alder flycatcher (closely related species)

Table 3.2 Sample Sizes in Nests Data Set by Location

	Location	All Study Areas	Kinbasket Reservoir		Arrow Lakes Reservoir
			Bush Arm	Canoe Reach	Revelstoke Reach
Type of nest plot	On-plot	2266	273	339	1654
	Off plot	562	21	161	380
	SFU plot	609	-	-	609
Position relative to drawdown zone	Within drawdown zone	3080	292	331	2457
	Outside of drawdown zone	357	2	169	186

3.2.3 Nest Observations

The Nest Observations data set (n = 17539 observations) included all field observations associated with each of the nests in the Nests data set. An observation was entered for every visit to a nest to document information relevant to nesting progress, such as clutch size, brood size, nestling age, and nest stage (building, egg-laying, incubation, nestlings, fledged, failed).

These data were primarily used for nest survival analyses to answer MQ-C. Additional details on the Nest Observations data set, and nest survival analyses methods are provided in **Appendix H**.

3.2.4 Radio-telemetry

Two data sets were produced from monitoring the juvenile survival of Savannah Sparrow and Yellow Warbler using radio-telemetry. The Yellow Warbler Juvenile Telemetry data set contained records for 39 tagged juveniles, and the Savannah Sparrow Juvenile Telemetry data set contained records for 102 tagged juveniles. After a juvenile was tagged, an observation was recorded daily, resulting in 188 observations of tagged Yellow Warbler juveniles, and 920 observations of tagged Savannah Sparrow juveniles.

Samples sizes for these data sets are summarized briefly below (**Table 3.3**, **Table 3.4**) and further details are provided in Hepp et al. (2018) and **Appendix J**.

Table 3.3 Sample Sizes of Tagged Young by Location

Species	Location	All Study Areas	Kinbasket Reservoir		Arrow Lakes Reservoir
			Bush Arm	Canoe Reach	Revelstoke Reach
Yellow Warbler	Within drawdown zone	39	-	-	39
Savannah Sparrow	Within drawdown zone	58	22	36	0
	Outside of drawdown zone	24	0	17	7

Table 3.4 Sample Sizes in Telemetry Data Sets Subsets

Species	Location	Nests Tagged	Young Tagged	Tagged Young - Fledged	Tagged Young - Known Outcome
Yellow Warbler	Within drawdown zone	38	39	26	-
Savannah Sparrow	Within drawdown zone	70	76	58	71
	Outside of drawdown zone	26	26	24	23

4.0 MANAGEMENT QUESTIONS

4.1 MQ-A: Which bird species breed in the drawdown zones and how are they distributed among drawdown zone habitat classes?

Over the 10 years of the study, 65 species were recorded nesting in the ALR drawdown zone and 29 species were recorded nesting in the KIN drawdown zone for a total of 66 species (**Figure 4.1**, **Appendix D**). The only species observed nesting at KIN that was not found nesting at ALR was Vesper Sparrow (*Pooecetes gramineus*). At ALR, there were 37 species nesting that were not observed nesting at KIN. The number of new species detected each year decreased dramatically in later years of the study in both drawdown zones (**Figure 4.1**), suggesting that most species commonly nesting in the study areas have been detected.

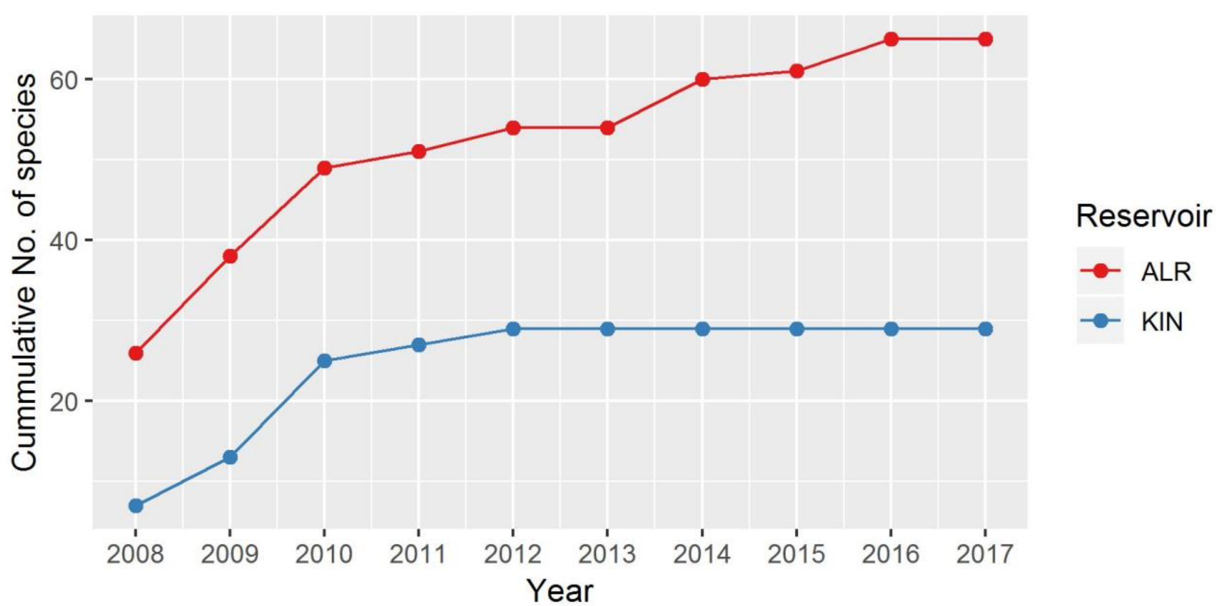

Figure 4.1 Cumulative count of species detected nesting in the drawdown zones of Kinbasket Reservoir (KIN) and Arrow Lakes Reservoir (ALR).

Nests at both reservoirs were concentrated at higher elevations within each drawdown zone, where more shrubs and trees were present (**Figure 4.2**). The abundance of nests above ground level at ALR reflects the more complex habitats found in this reservoir (**Figure 4.2**).

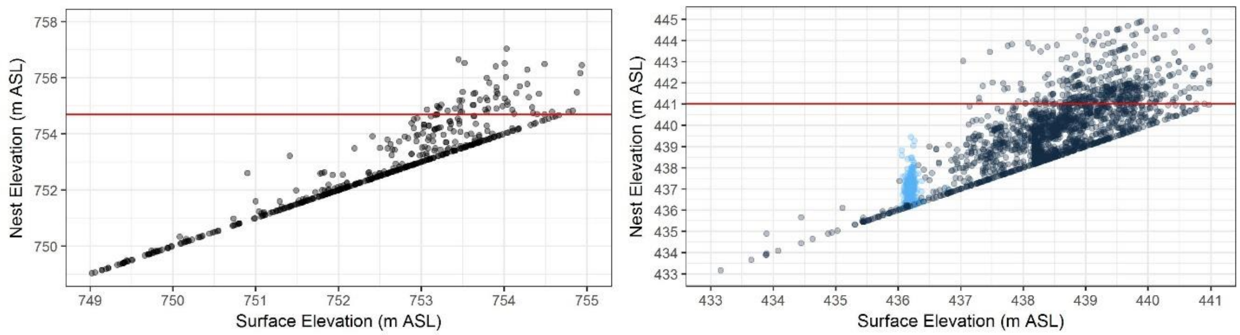

Figure 4.2 The elevation of nests in the drawdown zones of KIN (left) and ALR (right). Blue points are located on floating habitat in Montana Bay at ALR. The red line represents historic maximum water elevation.

There was a positive relationship in both reservoirs between the mean elevation of a vegetation community and its nest density (nests/ha) (**Figure 4.3**, **Figure 4.4**, **Appendix E**). This relationship is unsurprising given the greater vegetation complexity (i.e., more shrubs and trees) at higher reservoir elevations. At ALR in particular, the most nest-dense habitats make up a small percentage of the drawdown zone (**Figure 4.4**), suggesting much of the nesting activity is concentrated within a relatively small area. A similar relationship was also present for species richness, although the evidence was not as strong (**Appendix E**). The details of the bird species found in the most species rich and nest dense habitats are described for each reservoir below (see **Appendix E** for additional information).

4.1.1 Kinbasket Reservoir

At KIN, 18 of the 19 vegetation communities defined by CLBMON-10 (Hawkes et al. 2010, **Appendix B**) were monitored for nesting birds, but the monitoring effort in each vegetation community was scaled according to habitat availability (**Appendix C**).

The most common of the 29 species nesting (>15 nests) were Savannah Sparrow, Spotted Sandpiper (*Actitis macularius*), Cedar Waxwing, Lincoln's Sparrow (*Melospiza Lincolnii*), Killdeer (*Charadrius vociferus*), Chipping Sparrow (*Spizella passerina*), and Clay-colored Sparrow (*Spizella pallida*) (**Appendix D**). Generally, the most common species were found in a range of vegetation communities (**Appendix E**). For five uncommon bird species, only one nest was found in one vegetation community (**Appendix E**).

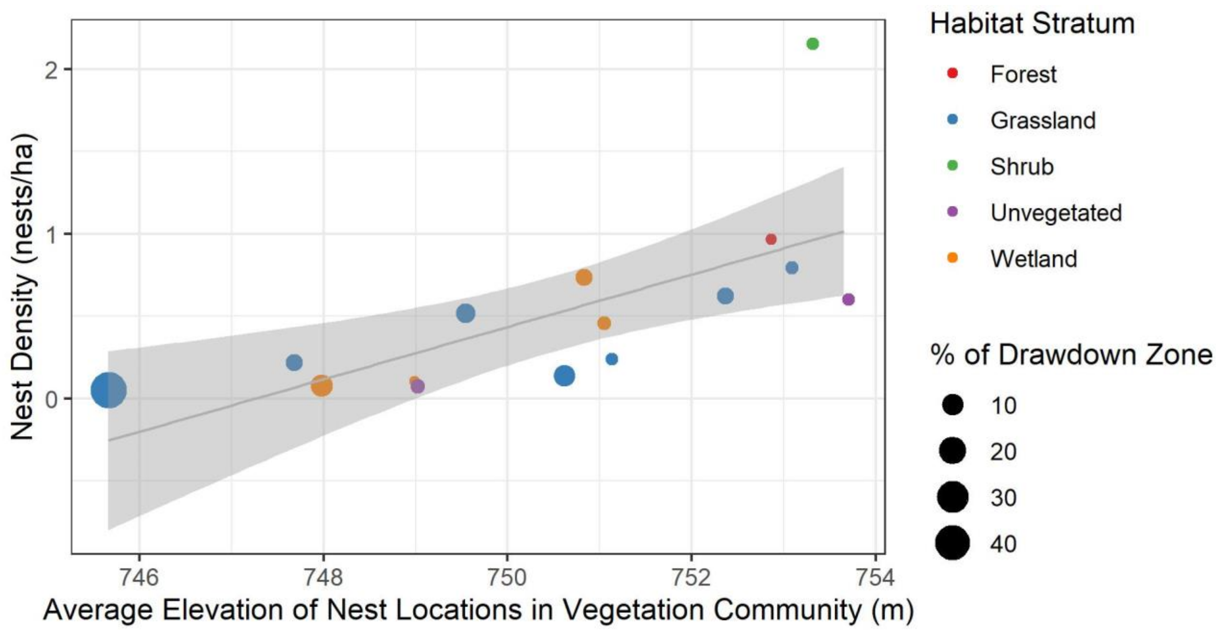

Figure 4.3 **The nest density of each vegetation community (15 communities colour-coded by more general habitat strata) in the KIN drawdown zone of plotted against the average elevation of nests in the vegetation community. For more information, see Appendix E.**

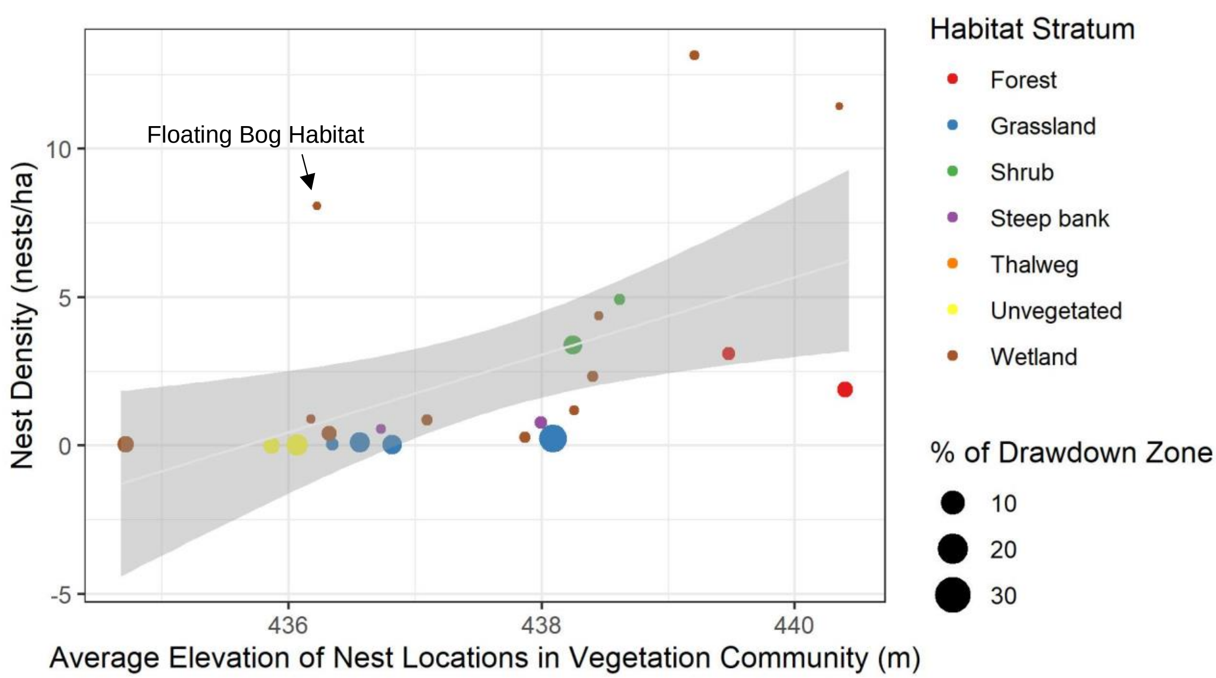

Figure 4.4 **The nest densities of vegetation communities (22 communities colour-coded by habitat strata) in the ALR drawdown zone plotted against the average elevation of the vegetation community. One community floats, as noted on the figure, so its elevation changes with the water level. For more information, see Appendix E.**

Savannah Sparrow was the most abundant breeding species, nesting in 12 of the 18 monitored vegetation communities (**Appendix E**), which collectively make up almost 41% of the mapped parts of the KIN drawdown zone (**Appendix C**) at elevations ranging from 746.8 m to 753.9 m. Most of the nests were in five vegetation communities: wool-grass-Pennsylvania buttercup (78), clover-oxeye daisy (47), swamp horsetail (46), willow-sedge wetland (34), and Kellogg's sedge (32) (**Appendix E**). Due to the dominance of this species at KIN, it has a large influence over the monitoring results presented throughout this report.

Spotted Sandpiper nested in eight grassland and wetland vegetation communities, but the majority of nests were in Kellogg's sedge (18), clover-oxeye daisy (15), wool-grass-Pennsylvania buttercup (12), and common horsetail (7) (**Appendix E**). Nests were at elevations ranging from 743.8 m to 753.9 m.

Killdeer nested in eight vegetation communities, included grasslands, wetlands, and unvegetated habitats, and nests were spread more evenly among them (**Appendix E**). They were the only species to nest in the wood debris vegetation community, an unvegetated habitat (which likely did have a bit of vegetation where the nest was located). Nests were at elevations ranging from 741.03 m to 753.7 m.

Mountain Bluebird (*Sialia currucoides*) was unique for nesting primarily at BA (n = 14). This species used many different wetland and grassland habitats (**Appendix E**) where there was adequate nesting habitat (e.g., stumps with cavities). The sparse distribution of suitable stumps may have been a limiting factor for this species. It nested at drawdown zone elevations ranging from 739.3 m to 752.7 m (nest cavity elevations were 740.4 m to 753 m) which were the lowest of any species.

Vesper Sparrow nested at CR only (n = 5), where nests were found in clover-oxeye daisy and swamp horsetail vegetation communities (**Appendix E**) at a high position in the drawdown zone (752 m to 754.6 m elevation). It may be that there is limited habitat available for this species as it typically prefers drier grassland habitats with perches (e.g., shrubs) and nested within a narrow elevation range. The low numbers of breeding records may also be related to KIN being at the far northeast edge of the species' breeding range.

Willow-sedge wetland habitat was particularly important for songbird nesting at KIN. This habitat had the greatest density of nests (2.15 nests/ha) and highest species richness (14), despite making up only 1.16% of the mapped part of the drawdown zone (**Appendix E**, **Appendix C**). One of the most common nesting species, Clay-colored Sparrow placed 94% (14/15) of its nests in this habitat (**Appendix E**). The majority of Cedar Waxwing (77%), Willow Flycatcher (92%), and Lincoln's Sparrow nests were also in this habitat and it was also the only habitat where Yellow Warbler, Song Sparrow (*Melospiza melodia*), Swainson's Thrush (*Catharus ustulatus*), and Least Flycatcher (*Empidonax minimus*) nested (**Appendix E**). The unique nesting community here is attributed to it being the only habitat with shrubs commonly present and its diverse vegetation (Hawkes et al. 2010). Nests within this habitat were at elevations ranging from 743.4 m to 754.7 m.

Two other habitats with high species richness were clover-oxeye daisy (0.62 nests/ha, 85 nests, 12 nesting species) and wool-grass Pennsylvania buttercup (0.74 nests/ha, 107 nests, 11 species), which are grassland and wetland habitats, respectively (**Appendix E**). Nest density in both of those habitats was lower than in the cottonwood-trifolium (forest, 0.92 nests/ha, 10 nests, 4 species) and bluejoint reedgrass (grassland, 0.79 nests/ha, 12 nests, 3 species) habitats (**Appendix E**). As expected, these communities were used by common nesting species at KIN, Savannah Sparrow or Spotted Sandpiper, with the exception of cottonwood-trifolium.

Nesting opportunities are limited in the KIN drawdown zone due to low complexity in the vegetation communities, which leads to lower species richness and abundance. It was not surprising then, that most of the species in this nesting community were detected during the very first few years of the study (**Figure 4.1**), and that the majority were ground-nesting species.

4.1.2 Revelstoke Reach

At ALR, 26 of the 29 mapped vegetation communities were monitored and monitoring effort in each vegetation community was scaled according to habitat availability (**Appendix C**).

The most common species nesting on community-level monitoring plots (~50% of nests, ≥70 nests per species) were Cedar Waxwing, Willow Flycatcher, Song Sparrow, Yellow Warbler, Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*), and Common Yellowthroat (*Geothlypis trichas*) (**Appendix D**). Generally, the most abundant nesting species were those with a broad criterion for suitable nesting habitat (**Appendix E**). For 13 species, only one nest was found on nest monitoring plots (**Appendix E**). Nests from four additional species were found within the drawdown zone but outside of nest monitoring plots (Swainson’s Thrush, Hermit Thrush (*Catharus guttatus*), Black-headed Grosbeak (*Pheucticus melanocephalus*), and Osprey (*Pandion haliaetus*).

The habitat with the greatest species richness was shrub savannah (37 species). This diverse habitat hosted ground-, shrub-, tree-, and cavity-nesting birds, although it was dominated by Cedar Waxwing (157 nests) and Willow Flycatcher (50 nests) (**Appendix E**). The shrub savannah vegetation community covers 5% of drawdown zone in Revelstoke Reach (**Appendix C**) and nests were at elevations from 436.0 m to 440.5 m.

Riparian forest was also very species-rich (29 species), with Cedar Waxwing (35 nests), American Redstart (*Setophaga ruticilla*, 32 nests), and Veery (*Catharus fuscescens*, 21 nests) being the most common species (**Appendix E**). Nests were located at elevations ranging from 438.0 m to 441.0 m and riparian forest covered 0.4% of the drawdown zone in Revelstoke Reach (**Appendix C**).

The third-most species rich habitat was the floating bog in Montana Bay. This habitat covered only 0.04% of the Revelstoke Reach drawdown zone (**Appendix C**), but it was also the third-most nest-dense habitat with 9.08 nests/ha (**Appendix E**). The nesting community here included shrub-, wetland-, and ground-nesting species as the vegetation at the bog was diverse. The most common nesting species were Song Sparrow (60 nests), Willow Flycatcher (49 nests), Cedar Waxwing (47 nests), and Wilson’s Snipe (*Gallinago delicata,* 38 nests) (**Appendix E**). The majority of Song Sparrow (55%) and Wilson’s Snipe nests (66%) on nest monitoring plots were found in this habitat. It also hosted the most Common Yellowthroat nests (28) of any vegetation community and the only American Goldfinch (*Spinus tristis*) nest found during the study (**Appendix E, Table 11.4**).

The most nest-dense habitats were two wetland habitats: shrub wetland complex (13.16 nests/ha) and swamp (11.44 nests/ha) (**Appendix E**). Nesters at shrub-wetland complex included a mix of wetland species (e.g., Red-winged Blackbird (*Agelaius phoeniceus*), Virginia Rail (*Rallus limicola*), Sora (*Porzana carolina*)) and shrub-nesting species (e.g., Cedar Waxwing, Yellow Warbler, Willow Flycatcher)

(**Appendix E**). Shrub-wetland complex made up 0.19% of the drawdown zone (**Appendix C**). The swamp vegetation community hosted mainly shrub-nesting species (e.g., Song Sparrow, Cedar Waxwing, Yellow Warbler) and was where the only nest of Northern Waterthrush (*Parkesia noveboracensis*) was found (**Appendix E**). Swamp makes up only 0.02% of the Revelstoke Reach drawdown zone (**Appendix C**) and nesting occurred from 440.0 m to 441.0 m elevation.

The marsh habitats of bulrush and cattail contained the bulk of nests for marsh-nesting species such as Yellow-headed Blackbird, Red-winged Blackbird, Marsh Wren (*Cistothorus palustris*), and Pied-billed Grebe (*Podilymbus podiceps*) (**Appendix E**). Nests in these habitats were at reservoir elevations ranging from 438.2 m to 439.6 m. Bulrush made up 0.2% of the drawdown zone and cattail made up 0.07% of the drawdown zone at Revelstoke Reach (**Appendix C**).

Two provincially Blue-listed species, Short-eared Owl and American Avocet (*Recurvirostra americana*), were detected nesting at ALR (**Appendix E**). Short-eared Owl is also designated as a species of Special Concern under SARA (ECCC 2018). Short-eared Owl nests were found in 2010 and 2016 in two vegetation communities: shrub savannah and mixed grassland. All nests failed and several were flooded by reservoir operations. One brood of Short-eared Owl was rescued and taken to a wildlife rehabilitation facility (CBA 2011). American Avocet nested once in pond habitat in 2009 and the nest was flooded by the reservoir.

An additional at-risk species likely nested within the drawdown zone, but its nest was not located. A Yellow-breasted Chat (*Icteria virens*) pair was captured with a recently fledged juvenile at the CLBMON-39 Machete Island banding station in 2017, suggesting that they likely bred close by (CBA 2018). A male had been observed singing there in previous years but is not suspected to have bred prior to 2017. Due to proximity, it is likely that these individuals came from the SARA-listed (Endangered) Southern Mountain population (ECCC 2016) in British Columbia, rather than the ‘not at risk’ Prairie population of the Yellow-breasted Chat subspecies *Icteria virens auricollis*.

The broad range of habitats at ALR makes it a much more productive drawdown zone than KIN, with some unique habitats (marsh and floating bog) that were particularly nest-dense. The wetland habitats in Airport Marsh are also regionally rare, providing the only location in this section of the Columbia Valley where many marsh-nesting species can breed. As noted above, these productive habitats make up a relatively small area of the total drawdown zone, with a large proportion of the drawdown zone made up of habitats less suitable for nesting (e.g., sand, gravel, sedge grassland). Conservation of the most nest-dense habitats (shrub wetland complex, swamp, floating bog, marsh) and species-rich habitats (shrub savannah, riparian forest) would assure that biodiversity of drawdown zone populations are maintained.

At ALR, due to the complexity of habitats available, there may be additional species nesting within the drawdown zone that were not detected during the study (CBA 2018), but it is not expected that there are any major knowledge gaps. The study has greatly expanded on the knowledge previously presented for the area in general by Campbell et al. (1997, 2001), and specifically for ALR by Boulanger et al. (2002) and Jarvis (2006).

4.1.3 Effects, Challenges, Opportunities

The breeding bird communities in each reservoir were well-documented and MQ-A has been addressed using a comprehensive data set. Any remaining knowledge gaps regarding breeding species diversity in either reservoir are minor and there would be diminishing returns to further study.

4.2 MQ-B: What are the seasonal patterns of habitat use by birds nesting in the drawdown zones?

Nesting phenology curves show a more pronounced peak of nesting at KIN and a longer nesting season at ALR (**Figure 4.5**). ALR's more complex vegetation communities support a wider range of species (**Section 4.1**) and thus more early- and late-season nesting birds than KIN. It should also be noted that nest searching and monitoring occurred both earlier and later in the season at ALR; however, the temporal inputs to these curves are based on calculated nesting periods, not dates of field observations, so reservoir-bias is expected to be minimal.

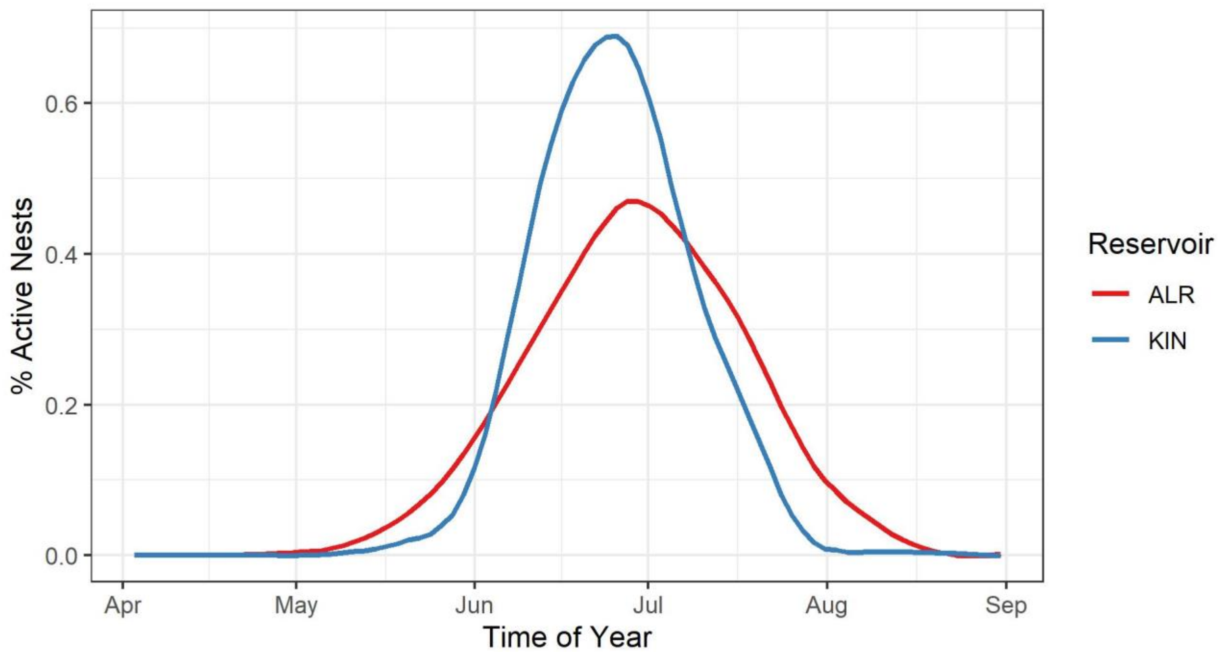

Figure 4.5 Nest phenology of breeding birds at Kinbasket Reservoir and Arrow Lakes Reservoir drawdown zones. For more information, see Appendix F.

Within each reservoir, there were differences in the timing of nesting among habitat strata (**Figure 4.6**, **Figure 4.7**), as well as the vegetation communities within each stratum (**Figure 4.8**, **Figure 4.10**, **Appendix F**).

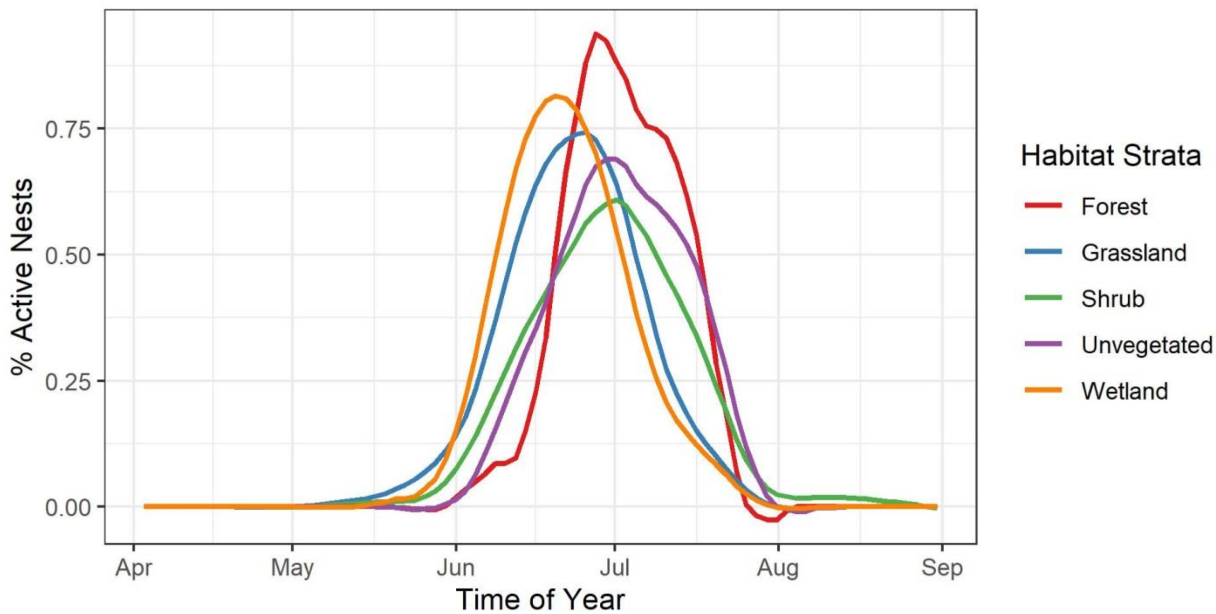

Figure 4.6 **Nest phenology by habitat strata at Kinbasket Reservoir. For more information, see Appendix F.**

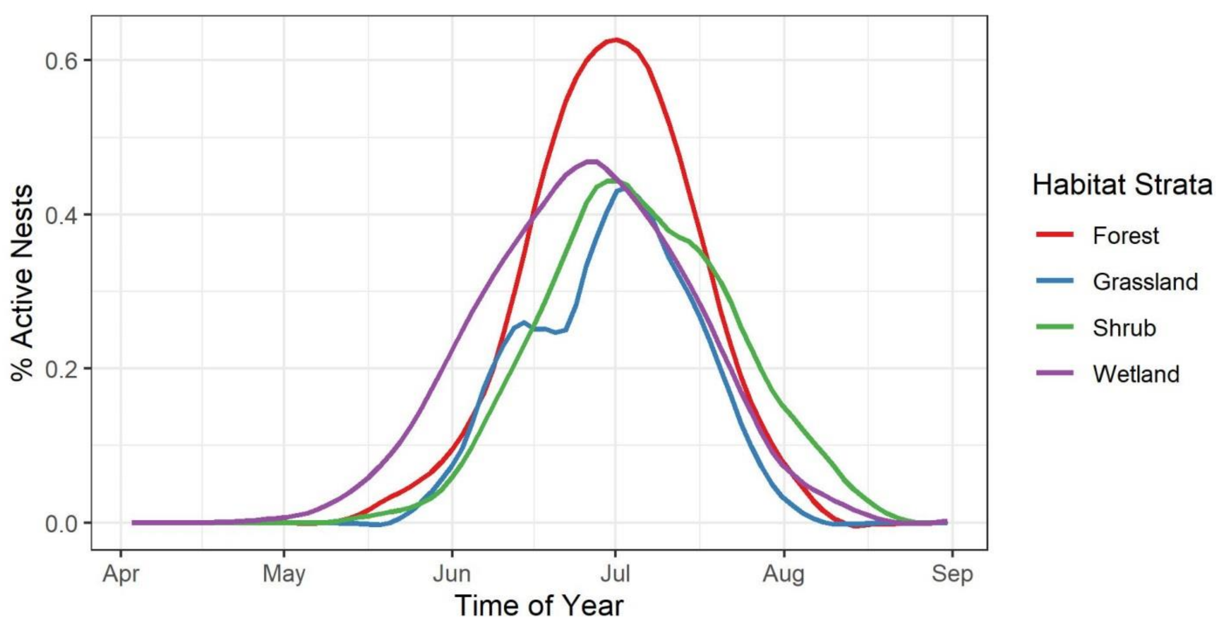

Figure 4.7 **Nest phenology by habitat strata at Arrow Lakes Reservoir. For more information, see Appendix F.**

Wetland vegetation communities in both reservoirs had earlier nesting activity compared to those in other habitat strata, although at KIN the timing was quite similar to that in grasslands (**Figure 4.6**). At ALR, wetland habitats with the earliest peaks in nest-timing included the nest-rich vegetation communities of bulrush, shrub wetland complex, water sedge, and cattail (**Appendix F**, **Figure 12.9**). Some of the early-nesting bird species found on the community-level nest monitoring plots in these vegetation communities were Song Sparrow, Red-winged Blackbird, Pied-billed Grebe, Marsh Wren, Virginia Rail, Sora, and Canada Goose (*Branta canadensis*) (**Figure 12.10**). At KIN, nests in wetland habitats were primarily in the wool-grass-Pennsylvania buttercup and swamp horsetails vegetation communities and the main nesting species in these habitats was Savannah Sparrow (**Appendix E**).

An examination of the nest phenology of Savannah Sparrow shows very little difference in its nest phenology among habitats (**Figure 4.9**), which accounts for the similarity between wetland and grassland nest-timing at KIN, as Savannah Sparrow was the primary nester in both habitat strata (**Section 4.1.1**, **Appendix E**). Savannah Sparrow is also a primary user of grassland habitats at ALR, however the nest phenology curve there shows a longer nesting period than at KIN (**Figure 4.7**), representing the broader diversity of species nesting in grassland habitats at ALR (**Appendix E**).

Of the most nest-dense vegetation communities at ALR, cattail and water sedge have a distinctly earlier nesting period (**Figure 4.10**) due to early-nesting species such as Song Sparrow and Red-winged Blackbird (**Table 11.4**, **Figure 12.10**). Shrub wetland complex is unique in having an early pulse in nesting activity, followed by a peak later in the season. This indicates the diversity of species (both shrub and wetland associated) that nest in this habitat (**Table 11.4**).

Of the most nest-dense communities at KIN, bluejoint reedgrass and wool-grass-Pennsylvania-buttercup had the earliest peak in nesting activity (**Figure 4.8**). However, nest phenology at KIN was more similar among the nest-dense vegetation communities than at ALR, likely due to the Savannah Sparrow being the most common nesting species across many of the communities (**Figure 4.8**, **Table 11.3**). The later nest timing in willow-sedge wetland is attributable to the presence of species such as Cedar Waxwing and Willow Flycatcher (**Table 11.3**, **Figure 12.10**).

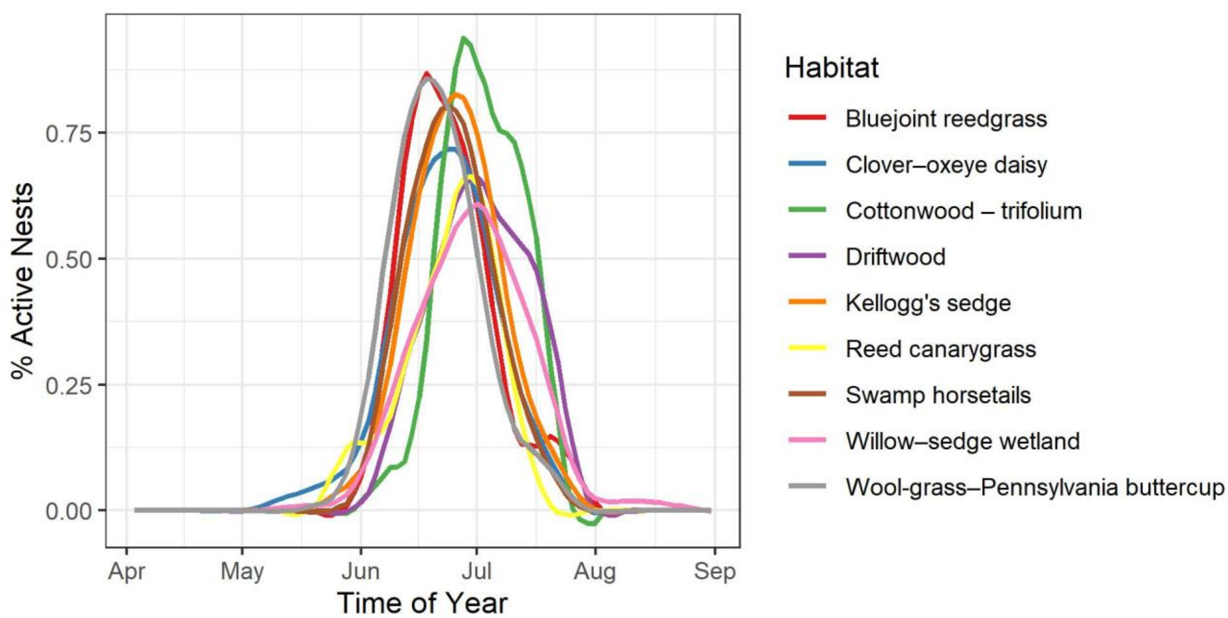

Figure 4.8 Nest phenology for the most nest-dense vegetation communities in the KIN drawdown zone. For more information, see Appendix F.

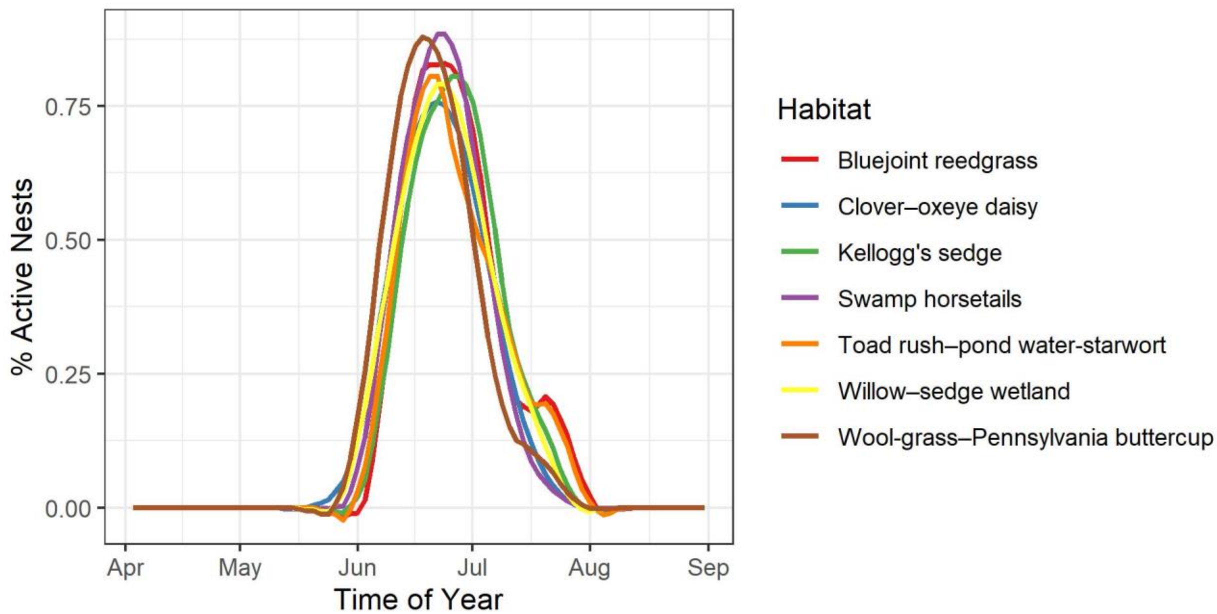

Figure 4.9 Nest phenology of Savannah Sparrow among vegetation communities in the KIN drawdown zone. For more information, see Appendix F.

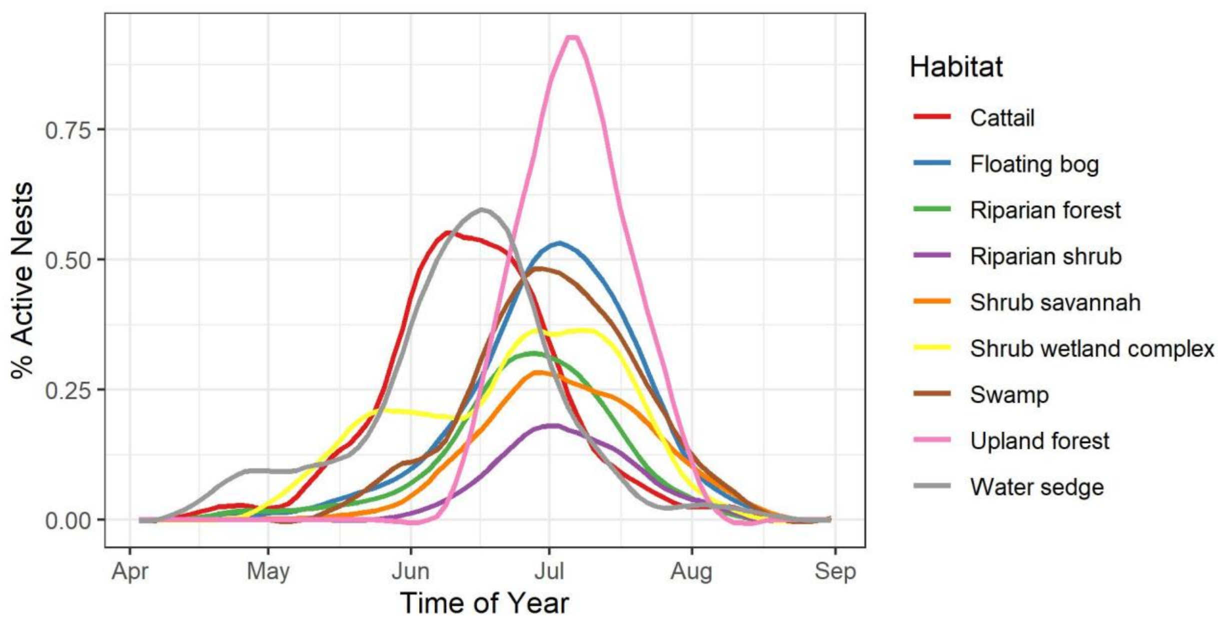

Figure 4.10 Nest phenology for the most nest-dense vegetation communities in the ALR drawdown zone. For more information, see Appendix F.

Nesting phenology also differs among species (**Figure 12.10**). Early-nesting species included Canada Goose, Song Sparrow, Red-winged Blackbird, American Robin (*Turdus migratorius*), Mountain Bluebird, Marsh Wren, Short-eared Owl, Killdeer, Sora, and Virginia Rail. Late-nesters included Cedar Waxwing, Willow Flycatcher, and Gray Catbird (*Dumetella carolinensis*).

4.2.1 Effects, Challenges, Opportunities

As noted above, early- or late-nesting species may be slightly under-represented due to lower field effort at the fringes of the breeding seasons. Information on nest phenology is also limited for species that are uncommon in the drawdown zones (e.g., those that have very few nest records). However, overall, there was an abundance of data available to address this MQ.

One challenge with examining nesting phenology of birds within reservoirs is that the operation (i.e., water levels) of the reservoirs affects the phenology among habitats. Thus, any further analysis should also consider reservoir operations and habitat availability.

This study focused on species breeding within the drawdown zones; however, knowledge of how birds use the habitat could be further enhanced by studying species that use the drawdown zone for other purposes, such as foraging, without nesting directly within it (e.g., Great Blue Heron).

4.3 MQ-C: Do reservoir operations affect nest survival?

There is sufficient evidence of nest failure due to flooding to assume that nest survival must be affected by reservoir operations to some degree. Measuring the significance, size, and direction of this effect is not straightforward, and depends on the reservoir, species, and distribution of suitable habitats, as these factors all influence species-specific exposure to this impact. MQ-C is addressed here by reviewing empirical evidence of nest flooding and through statistical analyses that measure the effects of variables related to the exposure of nests to reservoir operations.

Reservoir operations were responsible for the failure of nests in all years of study: 209 active nests of 37 species were observed to have failed due to flooding over the 10 years of study (**Appendix H**, **Figure 14.1**). At KIN, 26 nests (4.2%) were flooded, affecting 8 species. At ALR, 183 nests (7.5%) were flooded, affecting 34 species. At KIN, nest inundation was observed in every year except 2008, 2009, and 2014; at ALR, nest inundation was observed in every year except 2015 (**Figure 14.1**).

There were annual differences in the elevations of nests that were flooded over the course of the project (**Figure 13.1**). For example, in years with lower maximum reservoir elevation (2009, 2015, 2016), nest flooding was only observed at lower elevation nests.

In 2012, a nest model was developed which allowed the prediction of the nest flooding potential of reservoir operations (CBA 2013). The model can be used to predict the number of active nests in the mapped portions of the drawdown zones, based on nest densities for each vegetation community, on every day of the nesting season calculated for each 50 cm elevation band. Note that these models are based on mapped regions of the drawdown zone, which is complete at RR, but incomplete at KIN; disproportionate mapping coverage at low elevations in KIN influences the model's summation of nesting densities across elevations.

The model was found to have a strong correlation between predicted and observed values in both KIN and ALR (CBA 2013). The graphical view of these models (**Figure 4.11**) shows that at ALR the elevation of the reservoir is more likely to interact with active nests compared with KIN. These models are important results as they can be used to contrast the nest flooding impact of actual and hypothetical reservoir hydrographs.

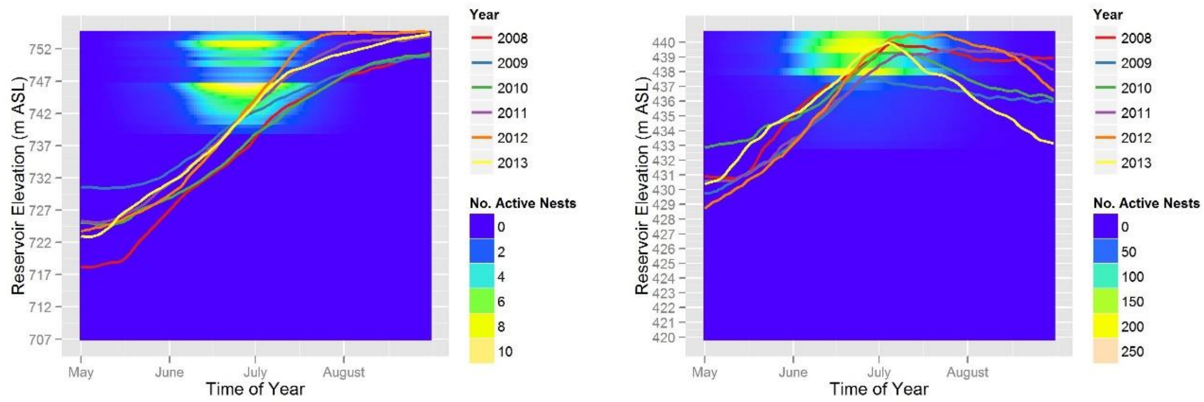

Figure 4.11 Graphical view of the nest models for Kinbasket Reservoir (left) and Arrow Lakes Reservoir (right) with the reservoir elevations for the first six years of the study plotted on top.

The direct observation of nest flooding, and the interaction that is predicted by the aforementioned nest models, both illustrate the potential for reservoir operations to affect nest survival; however, demonstrating an impact by reservoir operations to overall nest survival is not straight-forward and interpretation needs to be made with care. Observations of nest flooding do not necessarily indicate lower nest survival because overall nest survival for a given species can be affected by many other factors, such as predator abundance and food. Such factors may also be influenced negatively or positively by reservoir operations and these trends may differ depending on the nest elevation, nest habitat, or behaviour of a given species.

Ground-nesting birds face assured nest failure when the reservoir inundates nesting habitat. The timing of flooding at ALR (**Figure 4.11**) puts at risk the nests of ground-nesting species that nest in low elevation habitats in the drawdown zone (e.g., Spotted Sandpiper, Savannah Sparrow, Western Meadowlark (*Sturnella neglecta*), Short-eared Owl).

Spotted Sandpiper was one of the ground-nesting species that had nests flooded by both reservoirs. Nesting at higher elevations led to an increase in nest survival at ALR, but not at KIN (**Appendix H**). This difference may be related to the timing of when each reservoir's water level reaches Spotted Sandpiper habitat, as day of the year (ordinal date) was the factor with the greatest influence on nest survival at KIN (**Appendix H**).

For Savannah Sparrow, the variable with the greatest effect on nest survival was day of the year; nests active later in the breeding season had decreased survival rates (**Appendix H**). There was no evidence of a difference in nest survival between nests above and within the drawdown zone or due to nest elevation (**Appendix H**). The difference between these results versus those of Spotted Sandpiper is likely related to the lower minimum nest elevation of Spotted Sandpiper (0.56 m lower in ALR).

Short-eared Owl and Northern Harrier (*Circus hudsonius*) nested at ALR infrequently, but nests were situated low in the drawdown zone and inundation by the reservoir caused the failure of all Short-eared Owl and one of three Northern Harrier nests (Gill and Craig 2020).

For shrub- and tree-nesting species, whether habitat flooding impacts nest survival is more complicated because these nests can remain active even after water has flooded the habitat below them. The extent to which reservoir operations affects nest survival for these species varies depending on the nest height above the ground. Species nesting in shrubs commonly suffer from nest flooding in the ALR, but this impact is compensated for to some degree by reduced predation on higher nests positioned over water, resulting in no net effect of reservoir operations on nest survival (e.g., Yellow Warbler, van Oort et al. 2015). However, nest survival is only one component of productivity, and does not account for impacts to juvenile survival (see **Section 4.5**). Hepp et al. (2018) found that juveniles that fledged from nests in flooded territories were significantly less likely to survive to 21 days old than those fledged from nests in unflooded habitat.

There was some evidence that nest survival was greater for Cedar Waxwing, a late-season shrub-nesting species, when nesting outside of a drawdown zone compared nesting within a drawdown zone (**Appendix H**). When data for the reservoirs were modelled separately, support for this difference was strongest at KIN (**Appendix H**). These results corroborated preliminary results reported in the 5 Year Interim Review (CBA 2013). There was no evidence for a difference in survival between nests at KIN versus those at ALR (**Appendix H**).

For Cedar Waxwing nests within the drawdown zone, nest elevation was not found to be related to nest survival (**Appendix H**). Cedar Waxwing nest at relatively high elevations within the drawdown zone and very few of their nests are flooded. Thus, the cause of increased survival outside the drawdown zone is more likely related to lower pressure from predators or differences in habitat quality. However, within the drawdown zone, reservoir operations affect these factors and therefore could affect Cedar Waxwing indirectly.

The above discussion primarily concerns species nesting at ALR. Nests in shrubs or trees rarely flooded at KIN, thus nest flooding would have little impact on the nest survival of shrub- and tree- nesting species in that reservoir (**Appendix G**, **Figure 13.1**).

Populations of some species may be limited by reservoir operations and could potentially increase if nest flooding was not an issue. Given the timing of reservoir operations this is more likely an issue at ALR than KIN. Short-eared Owl for example, nested infrequently and faced nest inundation when it chose to do so. Without reservoir inundation affecting its nest success (and likely its prey community; Gill and Craig 2020), it is possible that this species would be able to nest within the drawdown zone on an annual basis.

Savannah Sparrow is another species for which breeding habitat at ALR (and thus potential productivity in the region) may be limited by reservoir operations. It is regularly detected in lower elevation grasslands at ALR prior to the annual spring flooding of these habitats. Being pushed out of these habitats may cause delays in nesting, reducing the opportunity to have multiple clutches, and also relegate it to lower quality habitat.

4.3.1 Effects, Challenges, Opportunities

Further information on how reservoir operations affect the predator community and consequently nest predation rates would be valuable to understanding the reservoirs' ecology and avian nest survival. As would information on reservoir impacts on the prey base of nesting birds (e.g., the voles that Short-eared Owls feed on or insects consumed by songbirds). These topics were not included in the Terms of

Reference for this study, but are both likely to be influenced by reservoir operations and have an influence on nest survival.

Additional research could also be done as to how reservoir operations affect the nesting of Savannah Sparrow at ALR. Adults arriving in the spring could be tagged and tracked using radio-telemetry to map their movements as the water level rises, and determine whether this displacement causes a delay in nest initiation.

A challenge to predicting the flooding of habitat and nests in RR was the inaccuracy of the DEM. It varied by 80 cm over or under the actual elevation at some locations, meaning that some nest elevations (DEM + nest height above ground) are inaccurate. Acquiring more accurate elevational data for RR (e.g., LIDAR data) could greatly improve the accuracy of predictions related to nest flooding.

4.4 MQ-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)?

The causes of nest failure within and above each drawdown zone are shown in the nest outcome table below (**Table 4.1**). The percentages of each type of failure were lower at KIN due to the much higher rate of nest success there, but the relative distribution of these causes within each reservoir were similar. The most common cause of nest failure in both drawdown zones was predation, as is typical for nest monitoring studies (Martin 1992), followed by abandonment and reservoir operations.

Table 4.1 Nest Outcomes Within Each Reservoir Drawdown Zone (% of Total Nests Within Reservoir)

Nest Outcome	ALR	KIN
Abandoned	9.0	6.9
Only Brown-headed Cowbird fledged	0.6	-
Failed by other means	0.9	1.3
Failed by unknown means	3.9	1.5
Predation	31.8	21.4
Reservoir operations (nest flooding)	7.7	4.1
Successful	39.3	53.0
Unknown	6.6	11.7

Note: Includes 2491 nests for ALR and 699 nests for KIN

At ALR, the species with the greatest proportion of nests observed to be flooded (in declining order) included Wilson's Snipe, Spotted Sandpiper, Common Yellowthroat, American Wigeon (*Mareca americana*), Savannah Sparrow, Clay-colored Sparrow, Chipping Sparrow, Yellow-headed Blackbird, Red-winged Blackbird, Virginia Rail, and Willow Flycatcher. At KIN, the species that experienced the most flooding were Spotted Sandpiper, Willow Flycatcher, and Mountain Bluebird; however, the percentages of nests affected were much lower than for the most heavily impacted species at ALR.

Spotted Sandpiper was the only species at KIN for which reservoir operations caused more nest failure than predation (**Appendix I**). At ALR, this was true for Common Yellowthroat, Red-winged Blackbird, Spotted Sandpiper, Virginia Rail, and Yellow-headed Blackbird. These are all ground or low shrub/wetland nesting species with nest elevations ranging between 438 m and 439 m at ALR.

Causes of nest failure also differed among habitat classes, although the primary cause across all habitat classes was predation (**Appendix I**). At ALR, a greater percentage of nests in the lower elevation unvegetated and grassland habitat strata were impacted by reservoir operations than other habitat classes (**Appendix I**). However, in years with higher maximum reservoir levels (e.g., 2012), the proportion of nests failing due to reservoir operations was much greater in higher elevation habitats (e.g., shrubs and wetlands).

The causes of nest failure, as alluded to above, also varied with elevation at ALR. The proportion of monitored nests flooded was greater for species with lower average nest elevations (**Figure 4.12**). Differences in flooding rates among species that nest at similar elevations are likely due to nest timing. Species that begin nesting earlier have a greater chance of fledging young prior to reservoir levels reaching their nest elevation, as can be seen in the nest model (**Figure 4.11**).

This relationship did not exist for species nesting at KIN, likely due to the timing of reservoir operations relative to peak nesting activity.

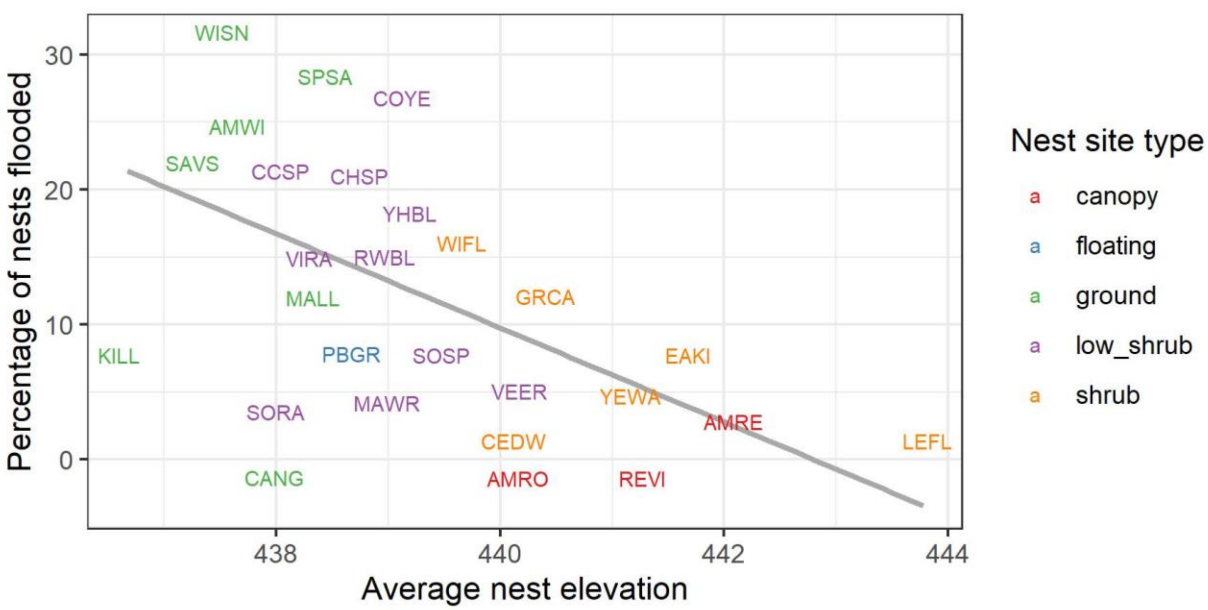

Figure 4.12 Percentages of nests flooded for species with >10 nests monitored at ALR drawdown zone from 2008 to 2017 plotted against average nest elevation. Nests located in the floating bog habitat are excluded. Species labels are adjusted to avoid overlap. Four letter codes for bird species can be found in Appendix D.

CLBMON-36 has provided robust information for addressing questions as to fates of birds nesting within the drawdown zone. Whether a nest within the drawdown zone is successful depends on the nest elevation, nest timing, and when and how high the reservoir water level increases in a given year. As described for MQ-A, nesting community is greatly influenced by elevation and vegetation community, which are inter-related. The nest model shown for MQ-C (**Section 4.3**) provides the best summary of these impacts. In general, birds that nest lower in the drawdown zone, earlier, and on the ground are more likely to be affected by reservoir operations. However, as was noted above, for at least some shrub-nesting species, habitat flooding does not necessarily impact overall nest survival.

4.4.1 Effects, Challenges, Opportunities

As was mentioned in **Section 4.3.1**, further research to determine the main nest predators and how they are affected by reservoir operations (and, in turn, impact nest survival) would be valuable.

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

Addressing this MQ required intensive research methods, and previous research on this topic is sparse. Two study species were monitored: the shrub-nesting Yellow Warbler at ALR and the ground-nesting Savannah Sparrow at KIN. Yellow Warbler is often able to fledge young after the reservoir inundates their nesting habitat (van Oort et al. 2015), but it is unclear if this riparian species is adapted to fledging over water (e.g., via delayed fledging). Savannah Sparrow juveniles have the ability to walk or fly away from water as it inundates their natal nesting area; the impact of reservoir operations for this species will not only depend on their ability to avoid water, but also on the frequency of such interactions. Due to the timing of the KIN operations, Savannah Sparrow have a low chance of experiencing such interactions, but a proportion of late-season nests are likely exposed to this hazard. The research conducted for CLBMON-36 confirmed that reservoir operations inundating post-fledging habitat did cause mortality for both species, and did affect juvenile survival, but the impact differed between the two focal species.

For Yellow Warbler, 26 tagged young successfully fledged: 15 from flooded territories, and 11 from unflooded territories (Hepp et al. 2018). There were 16 juvenile mortalities observed, and all post-fledging mortalities occurred within four days of the juveniles leaving the nest. Ten juveniles drowned during this period. A Cox's proportional hazards model (Cox 1972) fit to these data indicated that Yellow Warbler juveniles that fledged from nests in flooded territories were significantly less likely to survive to 21 days old than those fledged from nests in unflooded habitat, despite there being no difference in nestling condition at banding (Hepp et al. 2018). In the long-term population monitoring data set on 438 colour-banded Yellow Warbler nestlings (SFU had additional years of data to augment CLBMON-36) there was a non-significant tendency for higher juvenile recruitment nests in dry habitat (Hepp et al. 2018).

For Savannah Sparrow, only data from birds tagged at KIN were analyzed. 74 of the tagged nestlings fledged and 39 (53%) survived the post-fledging monitoring period. All post-fledging mortalities occurred within nine days after leaving the nest and three juveniles drowned in reservoir water (not including one that drowned in a natural puddle). The greatest cause of post-fledging mortality was predation.

Survival modelling for Savannah Sparrow juveniles suggested that bird age at time of observation typically had a greater impact on post-fledging survival than nest location or reservoir elevation variables (**Appendix J**). The age of the bird at the time of observation was the top-ranked model for nearly all data subsets examined and the relationship was positive, indicating that juvenile survival rate increased as the age of the juvenile increased (**Appendix J**). This would be expected because the mobility of a juvenile increases as it ages, allowing it to more easily escape predators (or rising water).

Although only a few Savannah Sparrow juveniles drowned in the reservoir, it is possible that rising water levels could impact the movement of predators and which could in turn impact the survival of juvenile Savannah Sparrow. However, there was no evidence of a difference in juvenile survival between birds tagged above and below the reservoir in CR (**Table 16.4**). Overall, results suggest that habitat inundation is of much greater concern for Yellow Warbler juveniles than Savannah Sparrow juveniles.

The greater number of Yellow Warbler juveniles impacted by the reservoir operations compared to Savannah Sparrow juveniles is likely related to both the timing of the rise of ALR into their breeding habitat and the location of their nests. Yellow Warbler nest in shrubs and trees at elevations such that they can continue nesting and fledging young after the habitat below the nest is flooded. This means that some young fledge over water, which made it possible to compare juvenile survival between flooded and unflooded habitats (described above, Hepp et al. 2018).

For Yellow Warbler, reservoir operations did not impact overall nest survival (van Oort et al. 2015), thus the decrease in juvenile survival when water floods their nesting habitat is potentially the greater concern for this species. It is likely that a decrease in juvenile survival would also occur for other shrub-nesting songbirds when reservoir operations flood their habitat during the nesting season (e.g., Willow Flycatcher, Cedar Waxwing, Chipping Sparrow, Eastern Kingbird (*Tyrannus tyrannus*), Gray Catbird). This is of greater concern at ALR than KIN, since ALR's shrub habitats are inundated much earlier in the nesting season.

4.5.1 Effects, Challenges, Opportunities

Tagging juveniles in the nest and tracking them daily is more invasive than the other research techniques used during CLBMON-36. It was worthwhile and the results are useful for understanding how reservoir operations affect nesting birds in both reservoirs. However, additional work is likely unnecessary.

For Yellow Warbler, a large effect size was found with a relatively small sample size.

For Savannah Sparrow, any effect of reservoir operations on juvenile survival would likely be small and hard to detect. Savannah Sparrow nest on the ground, meaning that once the reservoir reaches that elevation, the nests fail, so most of the time juveniles are only fledging from nests in unflooded habitat. The distance of these successful nests from the reservoir water varies greatly and the situation where the reservoir shoreline is in proximity to recently fledged juvenile Savannah Sparrow may not be that common, especially early in the breeding season. Indeed, many of the tagged Savannah Sparrow were not close to the reservoir when they fledged, thus did not have much of an opportunity to be directly affected by it. Reservoir operations at KIN during the study had only a small impact on Savannah Sparrow juveniles. Given that some birds were found drowned, there is the possibility of a greater impact if water levels were to increase earlier in the season, but the primary impact would likely be on nest survival rather than juvenile survival.

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

The results for MQ-A (**Section 4.1**) demonstrate a pattern of nesting that is probably typical of many water storage reservoirs with deep, partially-vegetated drawdown zones (i.e., reservoirs that have large seasonal fluctuations in water depth): nesting within the reservoir drawdown zone is concentrated at higher elevations where the vegetation is more complex, and nesting species diversity and nest density decreases with the decreasing vegetation complexity at lower elevations. Additionally, some of the highest nest densities and species richness are within vegetation communities that cover relatively small areas (e.g., unique habitat features). Protecting these most productive habitats from inundation during the nesting season would reduce nest submersions and improve the overall avian productivity of the drawdown zone.

For both KIN and ALR, filling later or to a lower maximum elevation reduces the potential for nest flooding, and is likely to increase avian productivity in a given year – especially for ground-nesting species (see **Section 4.3**, Espie et al. 1998, Anteau et al. 2012). Nest flooding is a bigger issue at ALR compared with KIN primarily because of the difference in timing between the reservoirs' hydrographs. ALR reaches its maximum annual elevation during the nesting season, whereas KIN reaches its maximum after the nesting season (**Figure 2.2**, **Figure 2.3**). During this study, ALR has been filling earlier than in the past (**Figure 2.3**), increasing the likelihood of nest flooding impacts. Any ability to delay ALR operations would make a significant difference to decreasing these impacts.

Particularly for ALR, avoiding the flooding of biodiversity hotspots, such as the Airport Marsh, during prime nesting season would greatly increase productivity for birds nesting in emergent vegetation (e.g., rails, grebes; CBA 2015). There are few possible nesting locations for these species elsewhere in either reservoir. A relatively large ecological benefit could be achieved by a relatively small change to reservoir operations because a high diversity and high density of birds nest at upper elevations of the drawdown zone (**Section 4.1**), and because these elevations are inundated for the least amount of time.

Species that nest at lower elevations in the ALR drawdown zone, which are typically ground-nesting birds (e.g., Savannah Sparrow, Short-eared Owl, Northern Harrier), experience nest-flooding impacts earlier than species that nest at higher elevations, and have high rates of nest flooding. Delaying the flooding of low elevation habitats (<436 m), or flooding these habitats prior to the breeding season to make them unavailable for nesting, would both require a major operational change (Gill and Craig 2020). However, smaller adjustments would still provide a benefit to ground-nesting species (Gill and Craig 2020).

Additionally, for Short-eared Owl and Northern Harrier, which are specialized small mammal (i.e., vole) predators, there is likely a relationship between reservoir operations and the abundance of their prey. These species only nest in meadow habitat when vole abundance is suitable (Wiggins et al. 2006), thus it may be possible to adjust reservoir operations to regulate their food supply (to prevent nesting in the first place), in lieu of adjusting operations to not flood nests. This would entail filling the reservoir at some point each year to keep the vole population at a low level. Short-eared Owl is SARA-listed (Special Concern) so impacts to this species are of particular interest.

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

4.7.1 Enhancement of Drawdown Zone Habitat

4.7.1.1 Previous Enhancement

Cottonwood stakes were planted in several locations within the ALR drawdown zone (Keefer and Moody 2010) and these treatment areas were monitored for nesting birds. The stakes had varying levels of survival success, but nests of Clay-colored Sparrow, Chipping Sparrow, and Eastern Kingbird were found in stakes that successfully established (CBA 2013, **Appendix K**). Songbirds (American Robin, Chipping Sparrow, and Willow Flycatcher) have also been found nesting in cottonwood stakes in other regions of ALR (Wood et al. 2018), demonstrating the potential for these stakes to provide nesting habitat. Wood et al. (2018) also reported observations of cottonwood stakes providing habitat to recently fledged birds thought to have been from nests in other locations.

The stakes within RR of ALR are still relatively young and may be used by other species as they grow taller. Young cottonwoods may potentially provide foraging opportunities prior to becoming suitable for nesting, while older cottonwoods provide a habitat that is rare within the drawdown zone. During the study, a total of 23 species were found nesting in cottonwood trees at ALR (**Appendix K**).

4.7.1.2 Future Enhancement

If possible, enhancing habitat in the KIN drawdown zone will improve avian productivity because the existing habitat is not suitable for nesting by most species, and because flooding of higher elevation habitats does not typically coincide with the nesting season. Habitat enhancements should focus on higher elevations (e.g., above 747 m) and include both increasing vegetation density and diversity – especially for shrubs, riparian, and wetland species, in addition to nest boxes. Nest boxes located above the maximum reservoir level could be a cost-effective wildlife physical works project (CBA 2011, BC Hydro 2013), providing nesting substrates for species such as Mountain Bluebird and cavity-nesting ducks.

At ALR, vegetation should only be enhanced at the highest elevations (e.g., above 439 m) to minimize the risk of attracting birds to habitat at risk of flooding.

4.7.2 Water Level Stability in Airport Marsh

Installing flood control features to prevent the flooding of Airport Marsh and protect species nesting in emergent vegetation was discussed in a previous annual report (CBA 2015). Protecting the marsh would benefit a high density of nests, a high diversity of species, and regionally rare species and habitats. Assuming that the habitat configuration of the drawdown zone has remained unchanged, it was calculated that if the marsh had been protected from inundation, between 5-26% of nests in RR would have been protected from nest flooding each year since 1985 (CBA 2015). Multiple species nesting in the Airport Marsh have nest flooding as the primary mortality mechanism (see **Appendix I**), thus protecting the marsh would increase the productivity of these species.

Additionally, there were other years (2010 and 2013) where water levels in the marsh were unusually low for unknown reasons and species like Yellow-headed Blackbird did not nest. Thus, understanding how the hydrology of the area operates and stabilizing it may also be beneficial during years when the reservoir does not directly impact the marsh.

4.7.3 Construct Floating Habitat Islands

An additional suggestion is to construct floating islands within the drawdown zone to provide additional nesting habitat that could not be flooded (CBA 2013). Floating islands have proven effective for Common Loon on Whatshan Reservoir, a BC Hydro reservoir, but there has been no use of a platform installed at Montana Slough at ALR (Kellner 2017). Few species would be able to use islands of the small size constructed for Common Loon, as their size is insufficient to meet nesting habitat requirements for most birds. Islands could possibly be targeted for species that can tolerate nesting in denser groups (e.g., Cedar Waxwings), but otherwise would have to be quite large (like the natural floating bog island in Montana Bay). Larger islands have been successfully created in other regions for colonial nesting species such as Caspian Tern (Moore and Austing 2009, Floyd 2011) and Dalmatian Pelican (Rojo 2015).

5.0 REVELSTOKE UNIT 5

Revelstoke Unit 5 began operation in 2010, thus was operating during most of the CLBMON-36 study period. Water fluctuations and flow velocities were expected to be similar to previous conditions (Unit 4), except in the area between the Revelstoke Dam and the Revelstoke Golf Course (BC Hydro 2005). The majority of bird breeding habitat is downstream of this location, thus is unlikely to be affected.

For Unit 5 to have an effect on breeding birds, there would have to be changes to elevation of the reservoir throughout the breeding bird season or to the velocity of flows such that breeding birds or their habitat would be impacted. Given the lack of expected change to fluctuations in water level near breeding bird habitat, it is not expected that the installation of Unit 5 would have had impacts on nesting productivity or juvenile survival. If larger fluctuations did occur, they would be most likely to impact ground-nesting species, as is the case with any fluctuation in reservoir level.

Increased flows could cause erosion to breeding bird habitat, but as noted above, these effects were not expected to be noticeable downstream of the Revelstoke Golf Course. A recent environmental inspection record indicates that there was no erosion or sedimentation attributable to Unit 5 and that erosion rates are comparable or lower than pre-Unit 5 erosion rates (EAO 2017).

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7.0 APPENDIX A – PROJECT TIMELINE

Table 7.1 Timeline of CLBMON-36 Activities

Year	Project Activities
2008	• First year of study. Field reconnaissance, sites selection, and initial development of monitoring plan. • Sampling occurred in Canoe Reach (CR) of KIN, and in Revelstoke Reach (RR) of ALR. • As suggested by the Terms of Reference, the monitoring sites were chosen as long-term plots to be sampled throughout the full breeding season each year. • As suggested by the Terms of Reference, monitoring of juvenile survival was attempted using colour banding of nestlings, and mist nets. • Three focal species were studied: Yellow Warbler, Willow Flycatcher, and Savannah Sparrow.
2009	• Inability to monitor enough representative plots recognized. Scope of monitoring increased in RR. • Cedar Waxwing was added as an additional focal species.
2010	• Sampling began in Bush Arm (BA), a second KIN study area. • Sampling design now altered to allow new sites to be monitored annually.
2011	• Telemetry was chosen as method for studying juvenile survivorship • Traill's Flycatcher (Willow Flycatcher and Alder Flycatcher) were accepted as a focal species to expand options at KIN (where Willow Flycatcher were uncommon and replaced by Alder Flycatcher). These are two very closely related species.
2012	• Telemetry approach initiated for studying juvenile survivorship of Yellow Warbler and Savannah Sparrow in RR. • Torrential rains truncated the field season in BA by washing out the FSR access road and flooding plots.
2013	• Sampling was discontinued in BA due to the previous year's logistical issues. • Telemetry monitoring of juvenile survivorship of Savannah Sparrow began in CR. • Wildlife Physical Works Project 6A was completed this fall near Machete Ponds.
2014	• The Terms of Reference were revised, and the objectives, management questions (MQs), and hypotheses were refined, addressing several outstanding issues that were highlighted in previous reports (e.g., CBA 2013) and improving clarity. Two MQs (E and F) were removed because they could not 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. • An analysis of nest survival for two shrub-nesting species (Yellow Warbler and Willow Flycatcher) was published in a peer-reviewed journal (van Oort et al. 2015). • An effort was made to find and monitor Canada Goose nests throughout Revelstoke Reach.
2015	• An analysis of dabbling duck nest survival at ALR found duck survival to be low overall, but higher on the floating bog in Montana Bay than in the rest of the drawdown zone. • An analysis of Yellow Warbler juvenile survival data found that fledging over flooded habitat reduced survival (Hepp et al. 2018).
2016	• Sampling occurred again in BA, targeting under sampled vegetation communities and including study of juvenile survival of Savannah Sparrow using radio-telemetry. • All sampling in CR was discontinued as all vegetation communities had been sufficiently sampled.
2017	• Sampling in BA focused primarily on Savannah Sparrow, including juvenile survivorship using telemetry. • Above drawdown zone Cedar Waxwing nests were targeted in RR to increase the sample size for that focal species.

8.0 APPENDIX B – VEGETATION COMMUNITIES

Table 8.1 Vegetation Communities at Kinbasket Reservoir Drawdown Zone as Mapped by CLBMON-10 (Hawkes et al. 2010)

Vegetation Community	Abbreviation	Description
Bluejoint reedgrass	BR	Above CH, often above KS
Buckbean–slender sedge	BS	Very poorly drained, wetland association
Common horsetail	CH	Well drained, above LL or lower elevation on sandy, well-drained soil
Clover–oxeye daisy	CO	Well drained, typical just below shrub line and above KS
Cottonwood – trifolium	CT	Imperfectly to well drained, above CO, below MC and LH
Driftwood	DR	Long, linear bands of driftwood, very little vegetation
Forest	FO	Any forested community
Kellogg's sedge	KS	Imperfectly to moderately well drained, above CH
Lodgepole pine–annual hawksbeard	LH	Well drained, above CT along forest edge, very dry site
Lady's thumb–lamb's quarter	LL	Imperfectly to moderately well drained; the lowest vegetated elevations
Marsh cudweed–annual hairgrass	MA	Imperfectly to moderately well drained; common in the Bush Arm area
Mixed conifer	MC	Well drained, above CT along forest edge
Reed canarygrass	RC	Imperfectly to moderately well drained; similar elevation to CO community
Common reed	RD	*Phragmites australis*
Swamp horsetail	SH	Poorly drained, wetland association
Toad rush–pond water-starwort	TP	Imperfectly drained, above LL, wet sites
Wool-grass–Pennsylvania buttercup	WB	Poorly drained, wetland association
Wood debris	WD	Thick layers of wood debris, no vegetation
Willow–sedge wetland	WS	Very poorly drained, wetland association

Table 8.2 Vegetation Communities in Revelstoke Reach, Arrow Lakes Reservoir

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

9.0 APPENDIX C – HABITAT MONITORING

9.1 Introduction

The purpose of this analysis was to calculate the amount of area of each drawdown zone vegetation community monitored.

9.2 Methods

Since some areas of drawdown zone were monitored in multiple years, both the total "Monitored Area" and an "Effective Total" (sum of all areas for all years) were calculated. The total mapped area of each vegetation community was divided by the total mapped area of the drawdown zone to calculate the percentage of the drawdown zone composed of each vegetation community.

9.3 Results

At KIN, 18 of the 19 drawdown zone vegetation communities defined by CLBMON-10 (**Table 8.1**) were monitored for nesting birds. Mixed conifer did not cover a sufficient area for monitoring (**Table 9.1**). Nest searching and monitoring occurred for over 10 ha of 14 vegetation communities, over 5 ha of 1 vegetation community, and less than 5 ha of the remaining 3 monitored communities. Total nest mortality monitoring effort covered 628 ha of the mapped area and the monitoring effort in each vegetation community was scaled according to habitat availability (**Table 9.1**).

At ALR, 26 of the 29 mapped vegetation communities (**Table 8.2**) were monitored (**Table 9.2**). Steep bedrock (BE), coarse rocks (CR), and urban (UR) were not monitored; these habitats were typically comprised of only small areas above the drawdown zone. Nest searching and monitoring occurred for over 10 ha of 11 vegetation communities, over 5 ha of 9 vegetation communities, and less than 5 ha of 7 vegetation communities. The total nest mortality monitoring effort covered 596 ha of the mapped area (**Table 9.2**).

Table 9.1 Mapped Habitat Available and Monitored at Kinbasket Reservoir from 2008 to 2017

Vegetation Community	Total Area[1]	Percentage of Drawdown Zone	Monitored Area[2]	Effective Total[3]
Bluejoint reedgrass	41.56	1.40	15.25	15.25
Buckbean–slender sedge	12.01	0.40	14.41	20.46
Common horsetail	287.64	9.67	70.42	85.08
Clover–oxeye daisy	136.45	4.59	61.17	136.12
Cottonwood – trifolium	20.27	0.68	6.59	10.35
Driftwood	36.90	1.24	20.55	28.16
Forest	159.58	5.37	2.44	2.64
Kellogg's sedge	210.68	7.08	51.97	104.20
Lodgepole pine–annual hawksbeard	0.52	0.02	0.50	0.50
Lady's thumb–lamb's quarter	1299.73	43.71	54.91	102.20
Marsh cudweed–annual hairgrass	140.30	4.72	20.05	23.22
Mixed conifer	0.18	0.01	0.00	0.00
Reed canarygrass	31.47	1.06	28.81	45.37
Common reed	0.63	0.02	0.59	1.18
Swamp horsetail	52.39	1.76	53.75	132.39
Toad rush–pond water-starwort	310.03	10.43	110.79	120.44
Wool-grass–Pennsylvania buttercup	128.87	4.33	68.29	144.79
Wood debris	69.99	2.35	27.65	27.65
Willow–sedge wetland	34.47	1.16	20.46	66.00
Total	**2973.67**	**100**	**628.6**	**1066**

[1] 'Total Area' is the sum of mapping for each vegetation community within the reservoir.
[2] 'Monitored Area' is the sum of mapping for each vegetation community within the reservoir.
[3] Some sites were monitored more than one time. 'Effective Area' includes areas monitored repeatedly.

Table 9.2 Mapped Habitat Available and Monitored in Revelstoke Reach from 2008 to 2017

Vegetation Community	Total Area[1]	% of Drawdown Zone	Monitored Area[2]	Effective Total[3]
Steep bedrock	5.75	0.09	0	0
Floating bog	2.55	0.04	2.55	42.35
Bulrush	12.74	0.20	6.96	107.43
Submerged buoyant bog	4.24	0.07	4.26	39.48
Creek	25.13	0.39	6.85	6.85
Coarse rocks	0.10	0	0	0
Cattail	4.29	0.07	3.53	13.49
Shrub wetland complex	12.22	0.19	7.52	7.52
Equisetum grassland	56.57	0.88	17.94	17.94
Gravel	193.52	3	5.39	5.42
Low elevation draw	189.05	2.93	43.69	63.63
Mixed grassland	1019.30	15.79	92.83	147.16
Sparse grassland	372.36	5.77	44.97	47.20
Pond	127.53	1.98	45.7	89.30
Rocky bank	57.57	0.89	5.71	7.57
Reed canarygrass	109.91	1.70	38.78	50.87
Riparian forest	77.08	1.19	32.27	60.42
Sand	474.09	7.35	27.84	27.91
Sand bank	10.45	0.16	2.54	3.42
Sedge grassland	364.08	5.64	72.75	93.81
Shrub savannah	323.51	5.01	91.70	124.37
Silt	710.07	11	10.34	10.34
Riparian shrub	25.76	0.4	8.75	13.37
Swamp	1.19	0.02	2.36	2.36
Thalweg	2068.64	32.05	1.35	1.35
Upland forest	152.87	2.37	6.19	12.15
Urban	1.24	0.02	0	0
Wet meadow	25.78	0.4	8.41	13.56
Water sedge	25.97	0.4	5.72	35.57
Total	**6453.56**	**100**	**596.9**	**1044.84**

[1] 'Total Area' is the sum of mapping for each vegetation community within the reservoir.
[2] 'Monitored Area' is the sum of mapping for each vegetation community within the reservoir.
[3] Some sites were monitored more than one time. 'Effective Area' includes areas monitored repeatedly.

10.0 APPENDIX D – NEST RECORDS SUMMARY

10.1 Introduction

The purpose of this section is to describe the Nests data set in more detail and compile the numbers of nests for each species recorded within each drawdown zone.

10.2 Methods

The Nests data set is briefly described and sample sizes are presented in **Section 3.2.2** of the report. This data set was exported from the CLBMON-36 online database using a query that excluded nests for which no outcome was entered. The following information was available for each nest: year, date of first observation, site ID, site name, nest ID, whether nest contents were monitored, species code, species common name, species scientific name, number for taxonomic sorting, nest height, UTM coordinates, nest substrate (e.g., willow), whether the nest was found (occasionally nests may have been entered in the database because biologists suspected one was present due to bird behaviour), reservoir (ALR or KIN), study area (CR, BA, or RR), nest outcome (e.g., Successful), number of young fledged, fledge error (how accurate the estimate of number of young fledged was), DEM (reservoir ground-level elevation at the nests UTM location), veg code (which of the mapped vegetation communities the nest was in, if possible), date of first egg (this information was calculated after each season for nests with sufficient data, and added to the database annually), maximum possible clutch size (based on largest number noted in nest observation data).

Additional columns were added prior to generating any results, including: whether a nest was within or outside of the drawdown zone (1/0), annual maximum reservoir elevation, nest site type (e.g., ground, shrub, cavity), whether a nest was on the island in Montana Bay or not (1/0), average nest height for that species, nest elevation (the sum of DEM and nest height), height of nest above reservoir full pool (maximum) elevation, and whether the nest was at a SFU Yellow Warbler monitoring site (1/0).

Changes were also made to some variables, including simplifying values for nest substrate to be more consistent, changing subspecies values to their full species (e.g., Oregon Junco to Dark-eyed Junco), updating four-letter species codes (e.g., YWAR to YEWA for Yellow Warbler), and updating scientific names for some species (e.g., wood warblers).

Using the Nests data set, the number of nests found for each species in each reservoir drawdown zone was summarized. Nest numbers for any location within the drawdown zone as well as those located on community-level nest monitoring plots were compiled separately. Whether a nest is within the drawdown zones is defined by historical maximum water elevation and was determined for each nest record using the DEM: nests elevated in vegetation above the maximum historic reservoir elevation are included as nests in the drawdown zone.

10.3 Results

At ALR, at total of 2457 nests of 65 species were found within the drawdown zone, including 1599 nests of 61 species on community-level nest monitoring plots. At KIN, 623 nests of 29 species were found within the drawdown zone, including 580 nests of 28 species on community-level nest monitoring plots.

Table 10.1 Nest Records from Revelstoke Reach of Arrow Lakes Reservoir and Kinbasket Reservoir Drawdown Zones from 2008 to 2017

Common Name	Scientific Name	Species Code	ALR		KIN	
			Any location	Nest plots	Any location	Nest plots
Common Loon	*Gavia immer*	COLO	6	5		
Pied-billed Grebe	*Podilymbus podiceps*	PBGR	31	27		
Canada Goose	*Branta canadensis*	CANG	134	22	1	
American Wigeon	*Mareca americana*	AMWI	41	36		
Mallard	*Anas platyrhynchos*	MALL	69	44	2	2
Blue-winged Teal	*Spatula discors*	BWTE	3	3		
Cinnamon Teal	*Spatula cyanoptera*	CITE	3	3		
Unidentified Teal	*Spatula spp.*	UNTE	4	4		
Northern Shoveler	*Spatula clypeata*	NSHO	1	1		
Green-winged Teal	*Anas crecca*	GWTE	9	7	2	2
Ring-necked Duck	*Aythya collaris*	RNDU	1	1		
Unidentified Duck	*Anatinae (gen, sp)*	UNDU	5	5		
Osprey	*Pandion haliaetus*	OSPR	1			
Northern Harrier	*Circus hudsonius*	NOHA	3	2		
Ruffed Grouse	*Bonasa umbellus*	RUGR	1	1		
Virginia Rail	*Rallus limicola*	VIRA	47	32		
Sora	*Porzana carolina*	SORA	45	34		
Killdeer	*Charadrius vociferus*	KILL	33	11	27	20
American Avocet	*Recurvirostra americana*	AMAV	1	1		
Spotted Sandpiper	*Actitis macularius*	SPSA	37	13	86	61
Wilson's Snipe	*Gallinago delicata*	WISN	61	58	13	13
Wilson's Phalarope	*Phalaropus tricolor*	WIPH	2	2		
Long-eared Owl	*Asio otus*	LEOW	4	2		
Short-eared Owl	*Asio flammeus*	SEOW	6	5		
Rufous Hummingbird	*Selasphorus rufus*	RUHU	1	1		
Downy Woodpecker	*Picoides pubescens*	DOWO	1	1		
Northern Flicker	*Colaptes auratus*	NOFL	5	5	3	3
Western Wood-Pewee	*Contopus sordidulus*	WEWP	8	8		
Alder Flycatcher	*Empidonax alnorum*	ALFL	2	2	2	2
Traill's Flycatcher	*Empidonax alnorum/traillii*	TRFL	8	8		
Willow Flycatcher	*Empidonax traillii*	WIFL	153	142	14	14
Least Flycatcher	*Empidonax minimus*	LEFL	15	14	1	1
Dusky Flycatcher	*Empidonax oberholseri*	DUFL	5	5	4	4

Common Name	Scientific Name	Species Code	ALR		KIN	
			Any location	Nest plots	Any location	Nest plots
Eastern Kingbird	*Tyrannus tyrannus*	EAKI	15	14		
Unidentified Flycatcher	*Tyrannidae (gen, sp)*	UNFL	9	6	1	1
Warbling Vireo	*Vireo gilvus*	WAVI	8	8		
Red-eyed Vireo	*Vireo olivaceus*	REVI	19	17		
American Crow	*Corvus brachyrhynchos*	AMCR	4	4		
Tree Swallow	*Tachycineta bicolor*	TRES	1	1	2	2
Black-capped Chickadee	*Poecile atricapillus*	BCCH	5	5	1	1
Marsh Wren	*Cistothorus palustris*	MAWR	36	36		
Mountain Bluebird	*Sialia currucoides*	MOBL	1	1	14	12
Veery	*Catharus fuscescens*	VEER	31	31		
Swainson's Thrush	*Catharus ustulatus*	SWTH	2		3	3
Hermit Thrush	*Catharus guttatus*	HETH	1			
American Robin	*Turdus migratorius*	AMRO	44	31	10	10
Gray Catbird	*Dumetella carolinensis*	GRCA	75	62		
Cedar Waxwing	*Bombycilla cedrorum*	CEDW	346	293	50	50
Tennessee Warbler	*Oreothlypis peregrina*	TEWA	2	1		
Yellow Warbler	*Setophaga petechia*	YEWA	568	90	9	9
Yellow-rumped Warbler	*Setophaga coronata*	YRWA	1	1	1	1
American Redstart	*Setophaga ruticilla*	AMRE	69	60	1	1
Northern Waterthrush	*Parkesia noveboracensis*	NOWA	1	1		
MacGillivray's Warbler	*Geothlypis tolmiei*	MGWA	8	8	1	1
Common Yellowthroat	*Geothlypis trichas*	COYE	80	77	5	5
Unidentified Warbler	*Parulidae (gen, sp)*	UNWA	1	1		
Chipping Sparrow	*Spizella passerina*	CHSP	39	30	19	19
Clay-colored Sparrow	*Spizella pallida*	CCSP	17	16	18	18
Vesper Sparrow	*Pooecetes gramineus*	VESP			5	5
Savannah Sparrow	*Passerculus sandwichensis*	SAVS	38	22	282	275
Song Sparrow	*Melospiza melodia*	SOSP	112	110	8	8
Lincoln's Sparrow	*Melospiza lincolnii*	LISP	14	12	37	36
Dark-eyed Junco	*Junco hyemalis*	DEJU	1	1	1	1
Black-headed Grosbeak	*Pheucticus melanocephalus*	BHGR	3			
Lazuli Bunting	*Passerina amoena*	LAZB	4	3		
Red-winged Blackbird	*Agelaius phoeniceus*	RWBL	62	60		
Western Meadowlark	*Sturnella neglecta*	WEME	6	4		
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	YHBL	80	80		

Common Name	Scientific Name	Species Code	ALR		KIN	
			Any location	Nest plots	Any location	Nest plots
Bullock's Oriole	*Icterus bullockii*	BUOR	2	2		
American Goldfinch	*Spinus tristis*	AMGO	1	1		
Unidentified Bird	*Aves (gen, sp)*	UNBI	4	4		
Unidentified Songbird	*Aves (gen, sp)*	UNSO	1	1		
Total Nest Numbers			**2457**	**1599**	**623**	**580**

11.0 APPENDIX E – SPECIES-HABITAT ASSOCIATIONS

11.1 Introduction

To address MQ-A, relationships between nesting species and habitats were explored. This was approached through tabular data summaries and modeling and visualizing summary data to examine overall trends within the reservoirs.

11.2 Methods

Using the Nests data set (see **Section 3.2.2** and **Section 10.2**), the number of nests found for each bird species in each reservoir drawdown zone vegetation community was summarized. These summaries included nests located within the drawdown zones for which the bird species and vegetation community were known (n = 555 for KIN, n = 2457 for ALR). Nests both in and outside of community-level monitoring plots are included.

Using the Nests data set, species richness, Shannon Diversity Index, and Shannon Evenness Index were calculated for each vegetation community using the vegan R package (Oksanen et al. 2019) (**Table 11.5**, **Table 11.6**). Only nest records within the drawdown zones and on community-level nest monitoring sites, and for which the bird species and vegetation community were known, were included.

Nest density was estimated for each vegetation community by dividing the total number of nests recorded in community by the total effective area monitored for community (also see **Appendix C**).

Linear models were fit to explore the relationships between species richness, nest density, and the elevation of vegetation communities in each drawdown zone.

11.3 Results and Discussion

11.3.1 Kinbasket Reservoir

The summary of nest numbers by habitat for KIN shows that the greatest number of nests were in the willow-sedge wetland, wool-grass-Pennsylvania buttercup, clover-oxeye daisy, swamp horsetail, and Kellogg's sedge vegetation communities (**Table 11.3**).

Savannah sparrow was by far the most numerous bird species, with 265 nests in 12 different vegetation communities. It was typically the most common species in any habitat it nested in, except for willow-sedge wetland, which had a much more diverse bird community owing to its more complex vegetation (**Table 11.3**).

Forest habitat was not extensively monitored because it is rarely inundated by the reservoir. However, the only nest for Dusky Flycatcher was found in the cottonwood-trifolium vegetation community, along with a few other shrub and tree-nesting species more common in willow-sedge wetland.

Further results and discussion of species of interest (Savannah Sparrow, Spotted Sandpiper, Killdeer, Mountain Bluebird, and Vesper Sparrow) and the bird diversity of certain species-rich vegetation communities (willow-sedge wetland) are provided in the main body of the report (**Section 4.1**).

There was a statistically significant relationship between the mean elevation of vegetation communities and their nest densities (**Table 4.3**), and to a lesser extent, between the mean elevation and species richness (**Table 11.1**, **Figure 11.1**). These relationships are due to the greater availability of more complex and diverse vegetation at higher elevations with the drawdown zone.

Table 11.1 Summary of Linear Model Results for Vegetation Communities at Kinbasket Reservoir

Dependent Variable	Independent Variable	Estimate	Standard Error	p-value	Adjusted R-squared
Nest density (nests/ha)	Mean elevation (m)	0.159	0.047	< 0.01	0.428
Species richness	Mean elevation (m)	0.942	0.397	0.034	0.249

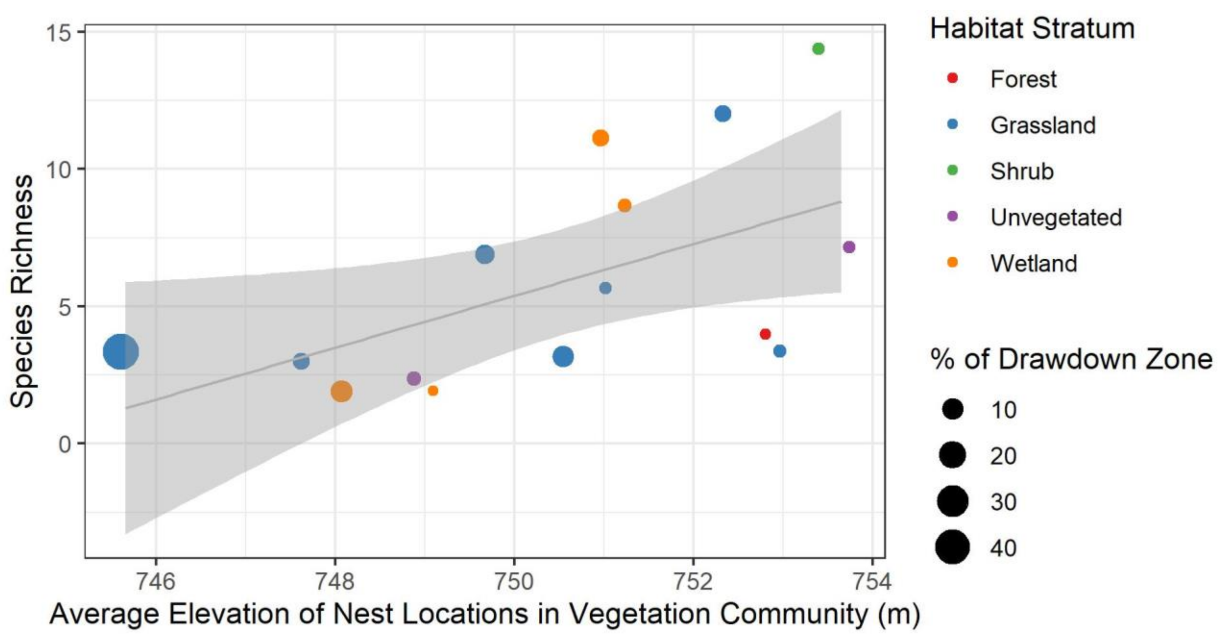

Figure 11.1 The species richness of vegetation communities in the Kinbasket Reservoir drawdown zone plotted against the average elevation of the vegetation community.

11.3.2 Arrow Lakes Reservoir

The summary of nest numbers by habitat for ALR shows that the greatest number of nests were in shrub savannah, floating bog, riparian forest, riparian shrub, bulrush, water sedge, and shrub wetland complex (**Table 11.4**).

Results and discussion of species of interest and the bird diversity within vegetation communities are found in the main body of the report (**Section 4.1**).

There was a statistically significant relationship between the mean elevation of vegetation communities and their nest densities (**Section 4.1**, **Table 4.4**), and a near significant relationship between the mean elevation and species richness (**Table 11.2**, **Figure 11.2**).

These relationships are due to the increased availability of more complex and diverse vegetation at higher elevations with the drawdown zone. Also notable is the high nest density in vegetation communities that take up smaller area of the drawdown zone (**Figure 4.4**). This suggests that increasing or maintaining the abundance of nesting birds within the drawdown zone could be done largely by focussing on relatively small areas.

Table 11.2 Summary of Linear Model Results for Vegetation Communities at Arrow Lakes Reservoir

Dependent Variable	Independent Variable	Estimate	Standard Error	p-value	Adjusted R-squared
Nest density (nests/ha)	Mean elevation (m)	1.308	0.461	0.010	0.243
Species richness	Mean elevation (m)	2.357	1.327	0.090	0.089

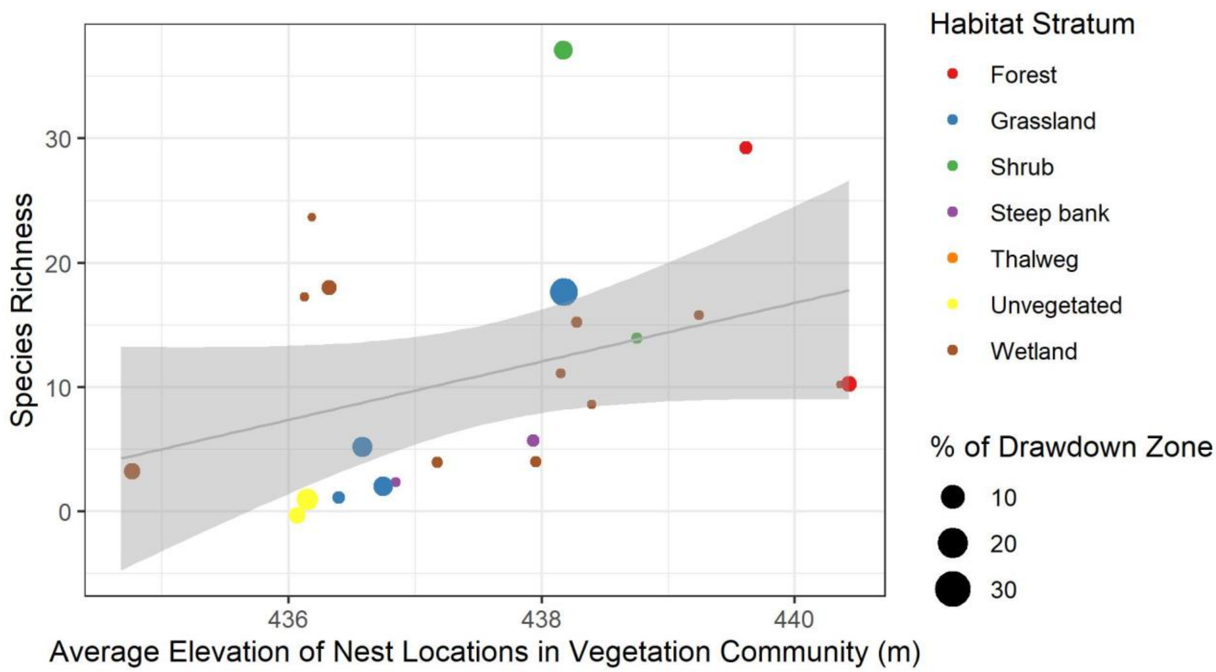

Figure 11.2 The species richness of vegetation communities at Arrow Lakes Reservoir drawdown zone plotted against the average elevation of the vegetation community.

Table 11.3 Numbers of Nests of Each Species in Each Habitat at Kinbasket Reservoir from 2008 to 2017

Common Name	Habitat Code*														
	BR	BS	CH	CO	CT	DR	KS	LL	MA	RC	SH	TP	WB	WD	WS	Total
Canada Goose												1				**1**
Alder Flycatcher						1										**1**
Least Flycatcher															1	**1**
Dusky Flycatcher					1											**1**
Black-capped Chickadee				1												**1**
Swainson's Thrush															1	**1**
Dark-eyed Junco										1						**1**
Mallard							1						1			**2**
Green-winged Teal													1		1	**2**
Tree Swallow				1									1			**2**
Vesper Sparrow				1							1					**2**
Northern Flicker			1	1							1					**3**
Common Yellowthroat													2		2	**4**
Song Sparrow															7	**7**
Yellow Warbler															8	**8**
American Robin				1	2						1		1		5	**10**
Wilson's Snipe		1					1				5		3		3	**13**
Willow Flycatcher						1									12	**13**
Mountain Bluebird				4			1	2	2	1			4			**14**
Clay-colored Sparrow							1								15	**16**
Chipping Sparrow	1			4	4	2				1	1		2		3	**18**
Killdeer			4	3			5	4			2	4	1	1		**24**
Lincoln's Sparrow	3			8		5				2	2		3		14	**37**
Cedar Waxwing				2	3	4					2				37	**48**

Common Name	Habitat Code*															
	BR	BS	CH	CO	CT	DR	KS	LL	MA	RC	SH	TP	WB	WD	WS	Total
Spotted Sandpiper		1	7	15		1	18	1	1	2			14			**60**
Savannah Sparrow	8	1		47		3	32		4	5	46	6	78	1	34	**265**
Total	**12**	**3**	**12**	**88**	**10**	**17**	**59**	**7**	**7**	**12**	**61**	**11**	**111**	**2**	**143**	

*Habitat codes are provided in **Table 8.1**, **Appendix B**

Table 11.4 Numbers of Nests of Each Species in Each Habitat at Arrow Lakes Reservoir from 2008 to 2017

Species Code**	Habitat Code*																							
	BF	BR	BS	CK	CT	CW	EG	GR	LD	MG	PG	PO	RB	RF	SA	SB	SG	SH	SR	SW	UF	UR	WM	WS	Total
COLO			2									3												1	6
PBGR		11			7	1						4						3						5	31
CANG	3	18	2		14	8			1	16		22		11			2						12	25	134
AMWI	11		1				1			4		1						20	2					1	41
MALL	20	1	2		4	2				4		3	1	12			2	14	2		1			1	69
BWTE	1									1								1							3
CITE			2															1							3
NSHO			1																						1
GWTE	5		1															3							9
RNDU			1																						1
OSPR																		1							1
NOHA										2								1							3
RUGR																					1				1
VIRA	3	5	1		3	8				2		1												24	47
SORA	2	6	4		1	5				1		2						2						22	45
KILL		1		5				1	4		8	2	1		1	1		9							33
AMAV												1													1

Species Code**	Habitat Code*																								
	BF	BR	BS	CK	CT	CW	EG	GR	LD	MG	PG	PO	RB	RF	SA	SB	SG	SH	SR	SW	UF	UR	WM	WS	Total
SPSA				1				2			1		1	2	3			25	1		1				37
WISN	38		9			1				1		1						8	1				1	1	61
WIPH												2													2
LEOW														2				1	1						4
SEOW										2								4							6
RUHU														1											1
DOWO														1											1
NOFL														4							1				5
WEWP														8											8
ALFL	2																								2
TRFL	3		1			1												3							8
WIFL	49	1	1			9				2		2	1	6				60	4	4	6			8	153
LEFL														14				1							15
DUFL														3				1	1						5
EAKI	4	1												1				7		1				1	15
WAVI													1	4				3							8
REVI														11				2	4		2				19
AMCR														3				1							4
TRES																		1							1
BCCH														4						1					5
MAWR		21			9							1												5	36
MOBL																		1							1
VEER						1								21				3	4	1	1				31
SWTH																		2							2
HETH														1											1
AMRO	1								2		1			16			1	20	2		1				44

Species Code**	Habitat Code*																							
	BF	BR	BS	CK	CT	CW	EG	GR	LD	MG	PG	PO	RB	RF	SA	SB	SG	SH	SR	SW	UF	UR	WM	WS	Total
GRCA	23			1		2				1	1			7				22	15	1	2				75
CEDW	47		2	3		14				3		1	1	38				177	44	7	3	1	2	3	346
TEWA														1					1						2
YEWA	26		1	19		11				4		5		111	1			205	177	5			1	2	568
YRWA														1											1
AMRE				2										35				4	23		5				69
NOWA																				1					1
MGWA														6				2							8
COYE	28	1			7	9				2		1	1	1				12		2			1	15	80
CHSP	3										1							34	1						39
CCSP	2																	15							17
SAVS	4						1			12		2						19							38
SOSP	60		3		5	21				1		3	1	2				8	3	4				1	112
LISP	3		2							1				2				6							14
DEJU																1									1
BHGR														2					1						3
LAZB									1					1				2							4
RWBL	3	19			9	13				1		4												13	62
WEME										2								4							6
YHBL		55			23	1																		1	80
BUOR														2											2
AMGO	1																								1
Total	**342**	**140**	**36**	**31**	**82**	**107**	**2**	**3**	**8**	**62**	**12**	**61**	**8**	**334**	**5**	**2**	**5**	**708**	**287**	**27**	**24**	**1**	**17**	**129**	

*Habitat codes are provided in **Table 8.2**, **Appendix B**
Species codes are provided in **Table 10.1, **Appendix D**

Table 11.5 Bird Species Diversity and Nest Density for Vegetation Communities at Kinbasket Reservoir

Vegetation Community	Species Richness	Shannon Entropy (diversity index)	Shannon Evenness	No. Nests	Nest Density (nests/ha)
Forest	0	0	0	0	0
Lodgepole pine–annual hawksbeard	0	0	0	0	0
Mixed conifer	0	0	0	0	0
Common reed	0	0	0	0	0
Lady's thumb–lamb's quarter	3	0.95	0.86	5	0.05
Wood debris	2	0.69	1.00	2	0.07
Toad rush–pond water-starwort	2	0.67	0.98	10	0.08
Buckbean–slender sedge	2	0.69	1.00	2	0.10
Common horsetail	3	0.89	0.81	12	0.14
Marsh cudweed–annual hairgrass	3	0.95	0.86	5	0.22
Reed canarygrass	6	1.64	0.86	11	0.24
Swamp horsetails	9	1.02	0.31	61	0.46
Kellogg's sedge	7	1.11	0.43	54	0.52
Driftwood	7	1.76	0.83	17	0.60
Clover–oxeye daisy	12	1.57	0.40	85	0.62
Wool-grass–Pennsylvania buttercup	11	1.13	0.28	107	0.74
Bluejoint reedgrass	3	0.82	0.76	12	0.79
Cottonwood–trifolium	4	1.28	0.90	10	0.97
Willow–sedge wetland	14	2.12	0.60	142	2.15

Table 11.6 Bird Species Diversity and Nest Density for Vegetation Communities at Arrow Lakes Reservoir

Vegetation Community	Species Richness	Shannon Entropy (diversity index)	Shannon Evenness	No. Nests	Nest Density (nests/ha)
Steep bedrock	0	0	0	0	0
Coarse rocks	0	0	0	0	0
Gravel	0	0	0	0	0
Reed canarygrass	0	0	0	0	0
Silt	0	0	0	0	0
Thalweg	0	0	0	0	0
Urban	0	0	0	0	0
Sedge grassland	2	0.64	0.94	3	0.03
Sand	1	0	1.00	1	0.04
Equisetum grassland	1	0	1.00	1	0.06
Low elevation draw	3	1.04	0.94	4	0.06
Sparse grassland	5	1.61	1.00	5	0.11
Mixed grassland	18	2.72	0.84	36	0.24
Wet meadow	4	1.39	1.00	4	0.29
Pond	18	2.75	0.87	37	0.41
Sand bank	2	0.69	1.00	2	0.58
Rocky bank	6	1.79	1.00	6	0.79
Creek	4	1.24	0.87	6	0.88
Submerged buoyant bog	17	2.54	0.75	35	0.89
Bulrush	11	1.73	0.51	129	1.20
Upland forest	10	2.05	0.78	23	1.89
Water sedge	15	2.29	0.66	83	2.33
Riparian forest	29	2.75	0.54	187	3.10
Shrub savannah	37	2.51	0.33	423	3.40
Cattail	9	1.78	0.66	59	4.37
Riparian shrub	14	2.07	0.57	66	4.94
Floating bog	24	2.52	0.52	342	8.08
Swamp	10	2.03	0.76	27	11.44
Shrub wetland complex	16	2.34	0.65	99	13.16

12.0 APPENDIX F – NEST PHENOLOGY

12.1 Introduction

This appendix quantifies the seasonality of nesting in and among vegetation communities of the reservoirs.

12.2 Methods

The timing of nesting activity within the KIN and ALR drawdown zones was examined using the Nests data set. Most of these analyses only included nests from the community-level nest monitoring plots within the drawdown zones. Phenology curves were plotted by reservoir, study area, vegetation communities, habitat strata, and species to explore the seasonal patterns of habitat use within the drawdown zones (MQ-B).

Determining nesting phenology required knowledge of when nests were initiated. Nest initiation dates (the date when the first egg was laid in a nest) were estimated using one of two methods. Method 1 involved back-calculating dates from observations of nests during the laying or nestling stages using published average clutch size, incubation period, and nestling periods for guidance (Rodewald 2019). For nests observed only during the incubation stage, the date of first egg was calculated by subtracting the span of days over which the nest was known to be active (incubating) from the species' incubation period to estimate the maximum possible amount of time left in the incubation period. This number was then divided by two (rounding up if it was an odd number), added to the sum of the monitoring period and the clutch size, and one day was subtracted. For some nests, there was too little information to calculate the nest initiation date and these nests were excluded from the analysis.

The last observation at a nest was used to determine the end of the nesting period. Using the nest initiation dates and last observation dates, a data set was generated indicating the status of each nest (active/inactive, 1/0) on each day of the nesting season (April 3 to August 31, based on CLBMON-36 nest data). For a given subset of data (e.g., Kinbasket Reservoir drawdown zone), the percentage of nests that were active on each day was determined by summing the number of nests active on that day and dividing that value by the total number of nests in the data set. These values were then plotted using a loess smoother (span = 0.2) within the geom_smooth function in the R package ggplot2 (Wickham 2016). Note that the smoother sometimes caused the line showing "% of Active Nests" to dip below zero, but there were not actually negative values for the y-axis.

12.3 Results and Discussion

Excluding nests without nest initiation date information resulted in a data set of 2048 nests. For most of the nest phenology curves, only nests within the drawdown zone and from community-level nest monitoring sites were included, which reduced the data set to 1271 nests.

As discussed in the main body of the report (**Section 4.2**), nesting phenology curves show a more pronounced peak of nesting at KIN and a longer nesting season at ALR (**Figure 4.5**). Within each reservoir, there were differences in the timing of nesting among habitat strata (**Figure 4.6**, **Figure 4.7**), as well as vegetation communities (**Figure 4.8**, **Figure 4.10**).

Wetland vegetation communities in both reservoirs had earlier nesting activity compared to those in other habitat strata, although at KIN the timing was quite similar to that in grasslands (**Figure 4.6**, **Figure 4.7**). Further details and a discussion of Savannah Sparrow nest phenology at KIN are discussed in the main body of the report (**Section 4.2**).

There were no nests found in the unvegetated habitat stratum on community-level nest monitoring plots at ALR, so that habitat stratum was not plotted on **Figure 4.7**. Species found nesting in the unvegetated habitat stratum away from community-level plots were Killdeer and Spotted Sandpiper (**Table 11.4**, habitat codes GR and SA), which typically initiate nesting in May and June, respectively (**Figure 12.10**). At ALR, water levels rise earlier in the season and flood these habitats, in contrast to KIN, where nesting in unvegetated habitats peaked in late June and July (**Figure 4.6**). However, species nesting in the habitats (driftwood and wood debris) at KIN included shrub-nesters such as Cedar Waxwing and Chipping Sparrow (**Table 11.3**) suggesting that they were not completely devoid of vegetation.

Of the most nest-dense vegetation communities at ALR, cattail and water sedge have a distinctly earlier nesting period (**Figure 4.10**) due to early-nesting species such as Song Sparrow and Red-winged Blackbird (**Table 11.4**, **Figure 12.10**). Shrub wetland complex is unique in having a bump in nesting activity early on, followed by a later peak. This indicates the diversity of species (both shrub and wetland associated) that nest in this habitat (**Table 11.4**). Upland forest has a uniquely concentrated nesting period, which could be due to the lower sample size (n = 23), lower nesting density relative to the other vegetation communities, or smaller relative area of this habitat that was surveyed (**Table 9.2** and **Table 11.6**).

Of the most nest-dense communities at KIN, bluejoint reedgrass and wool-grass-Pennsylvania-buttercup had the earliest peak in nesting activity (**Figure 4.8**). Nesting phenology at KIN was more similar among the nest-dense vegetation communities than at ALR, likely due to the Savannah Sparrow being the most common nesting species across many of the communities (**Table 11.3**, **Figure 4.8**). The later nest timing in willow-sedge wetland is attributable to the presence of species such as Cedar Waxwing and Willow Flycatcher (**Table 11.3**, **Figure 12.10**).

Nest timing also differs among species (**Figure 12.10**). Early-nesting species included Canada Goose, Song Sparrow, Red-winged Blackbird, American Robin, Mountain Bluebird, Marsh Wren, Short-eared Owl, Killdeer, Sora, and Virginia Rail. Later-nesters included Cedar Waxwing, Willow Flycatcher, and Gray Catbird.

Samples sizes for nest records on community-level nest monitoring sites with nest timing information available for each reservoir are given in **Table 12.1** and **Table 12.2**. Figures showing the variation in nest phenology among vegetation communities in each habitat stratum are presented below the tables. Vegetation communities with low sample sizes are shown on the figures, however, the nest phenology in these habitats remains uncertain due to the lack of information available. The low elevation draw, creek, and wet meadow vegetation communities were eliminated from the ALR wetland figure due to the low sample sizes and to provide a less cluttered figure.

Table 12.1 Number of Nests with Nest Phenology Data Located on Community-Level Nest Monitoring Plots for each Vegetation Community at Kinbasket Reservoir

Habitat Stratum	Vegetation Community	Number of Nests
Forest	Cottonwood – trifolium	9
Grassland	Bluejoint reedgrass	7
	Clover–oxeye daisy	58
	Common horsetail	2
	Kellogg's sedge	38
	Lady's thumb–lamb's quarter	1
	Marsh cudweed–annual hairgrass	3
	Reed canarygrass	7
Shrub	Willow–sedge wetland	100
Unvegetated	Driftwood	12
	Wood debris	1
Wetland	Buckbean–slender sedge	1
	Swamp horsetails	44
	Toad rush–pond water-starwort	7
	Wool-grass–Pennsylvania buttercup	75

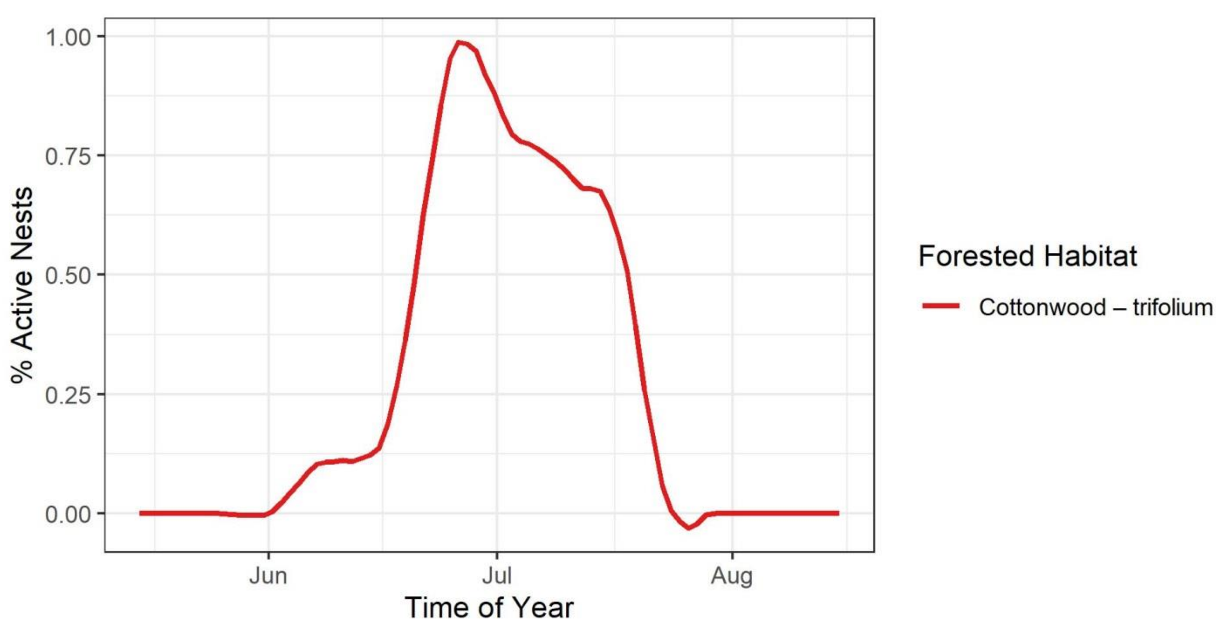

Figure 12.1 Nest phenology for forest habitat at Kinbasket Reservoir

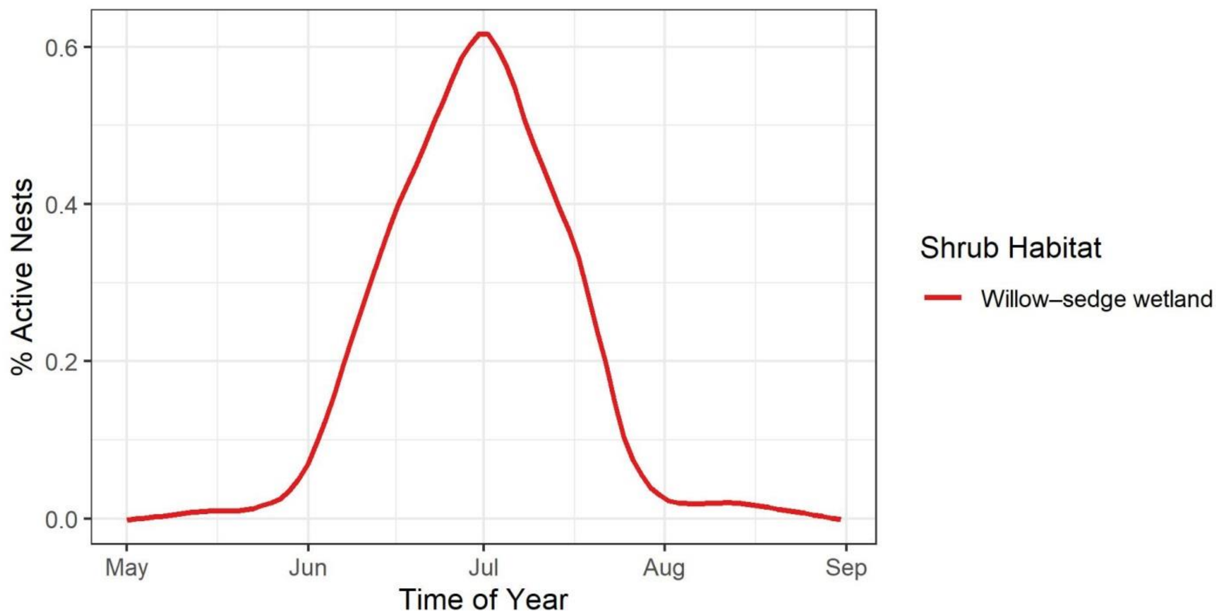

Figure 12.2 Nest phenology for shrub habitat at Kinbasket Reservoir

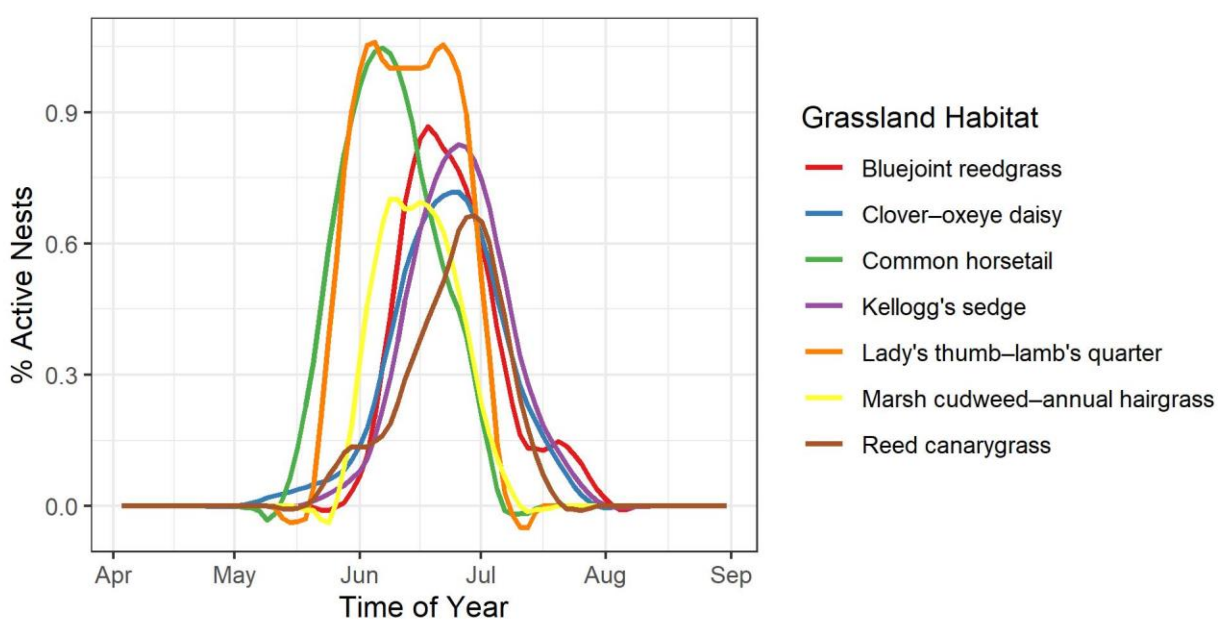

Figure 12.3 Nest phenology for grassland habitat at Kinbasket Reservoir

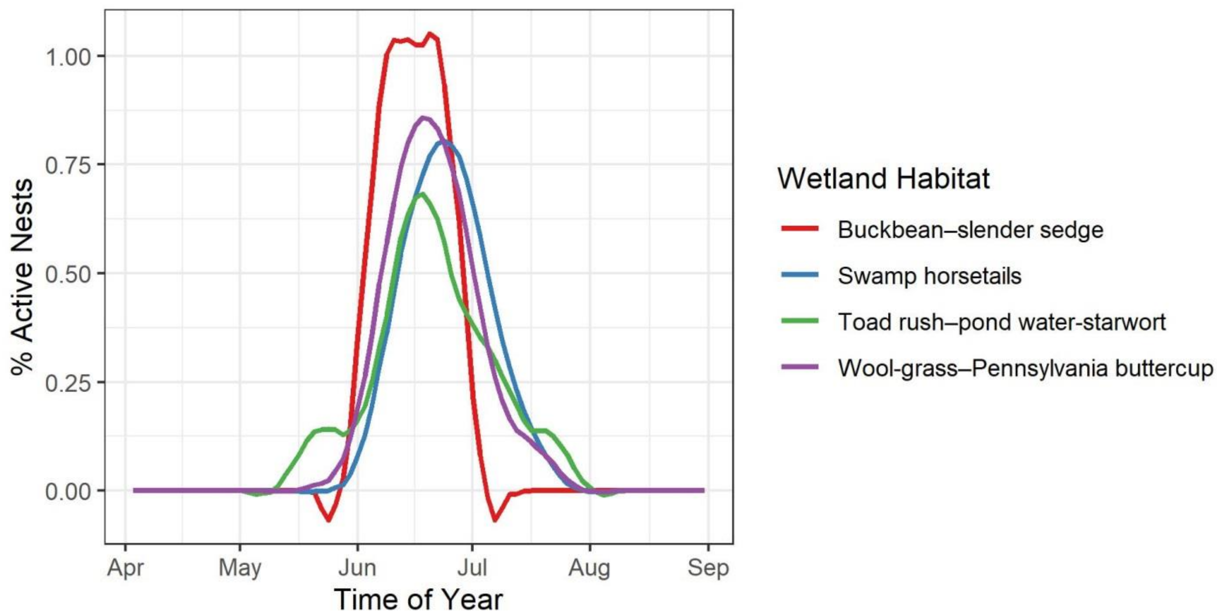

Figure 12.4 Nest phenology for wetland habitat at Kinbasket Reservoir

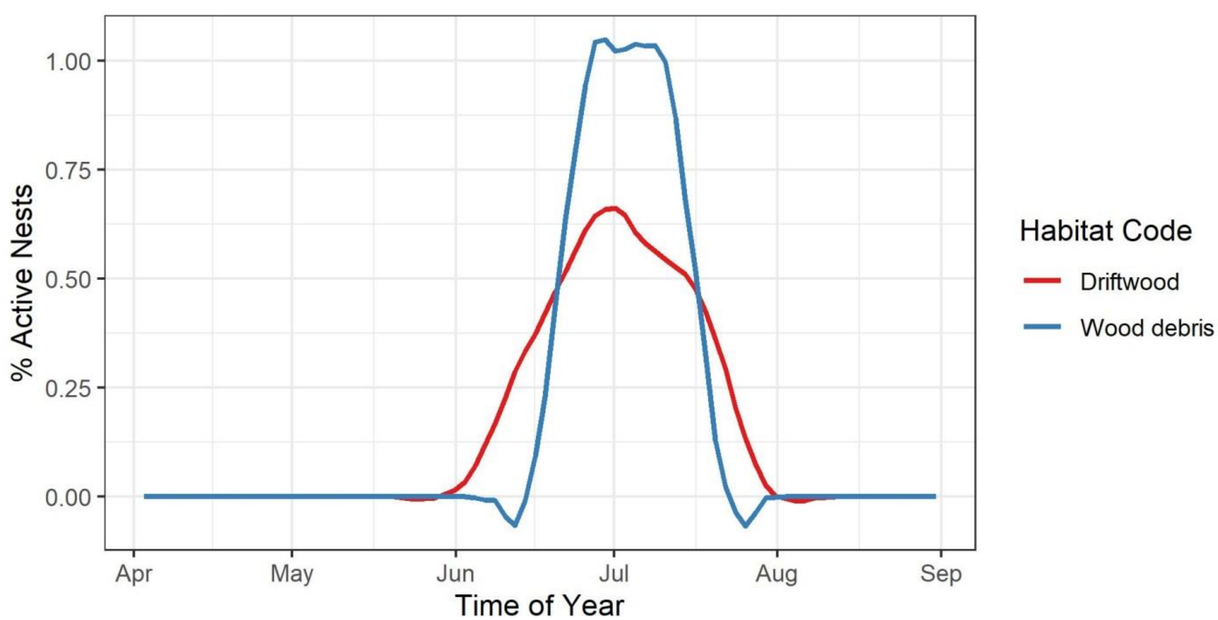

Figure 12.5 Nest phenology for unvegetated habitat at Kinbasket Reservoir

Table 12.2 Number of Nests with Nest Phenology Data Located on Community-Level Nest Monitoring Plots for each Vegetation Community at Arrow Lakes Reservoir Drawdown Zone

Habitat Stratum	Vegetation Community	Number of Nests
Forest	Riparian forest	87
	Upland forest	14
Grassland	Mixed grassland	22
	Sedge grassland	3
	Sparse grassland	2
Shrub	Riparian shrub	39
	Shrub savannah	224
Steep bank	Rocky bank	4
	Sand bank	1
Wetland	Bulrush	75
	Cattail	31
	Creek	1
	Floating bog	213
	Low elevation draw	1
	Pond	14
	Shrub wetland complex	57
	Submerged buoyant bog	18
	Swamp	24
	Water sedge	45
	Wet meadow	2

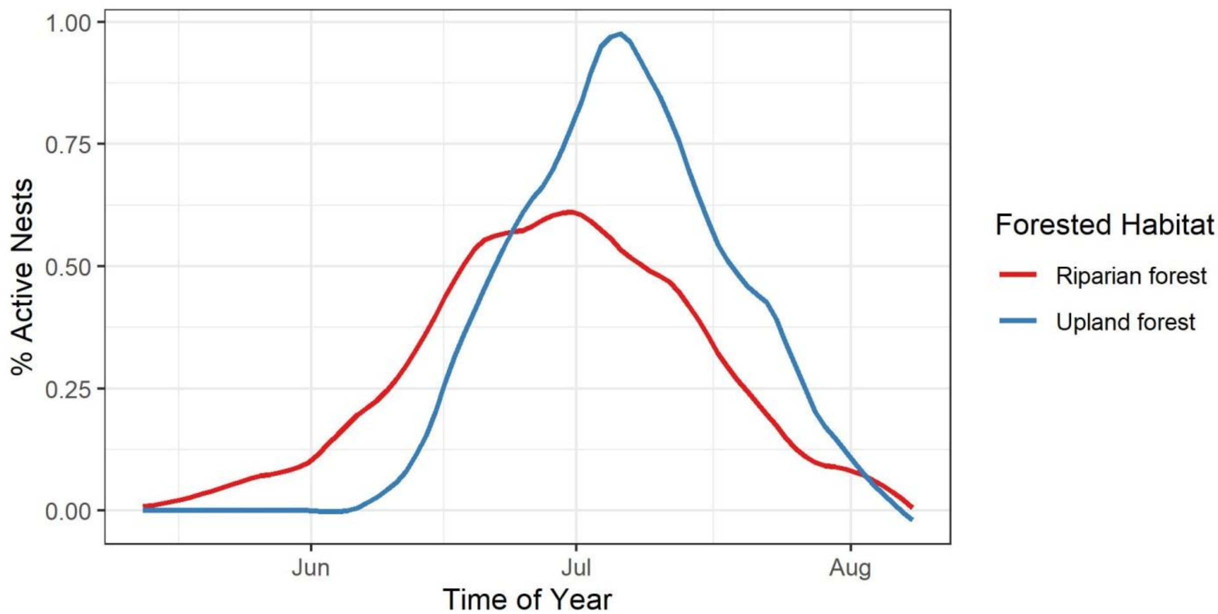

Figure 12.6 Nest phenology for forest habitat in Revelstoke Reach of Arrow Lakes Reservoir

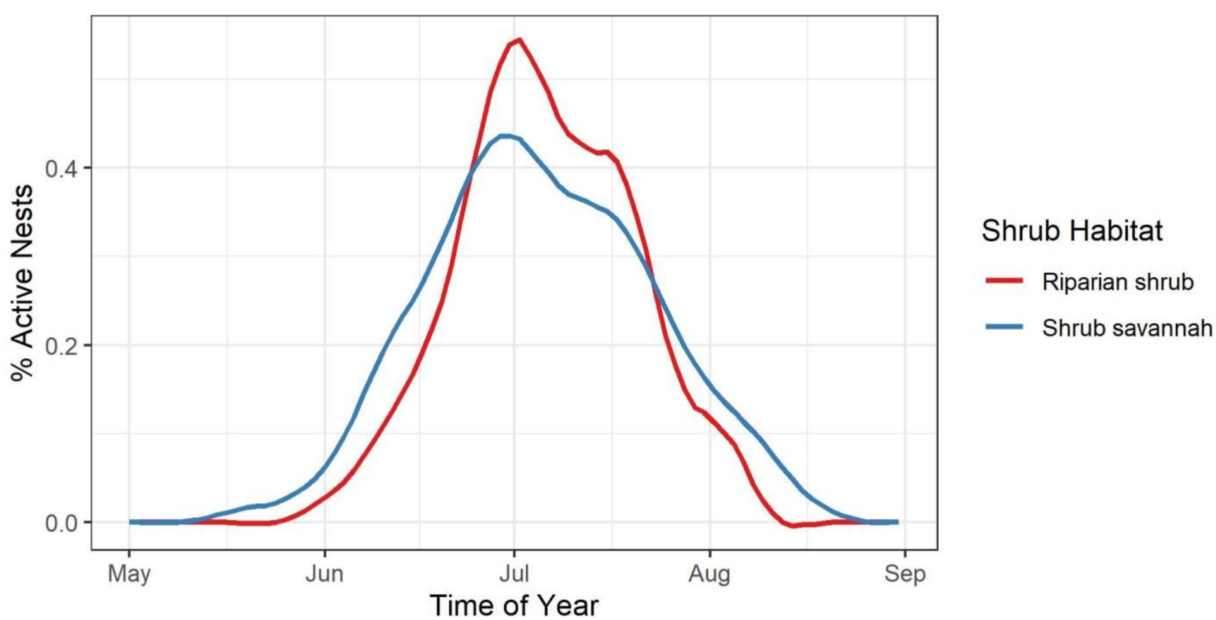

Figure 12.7 Nest phenology for shrub habitat in Revelstoke Reach of Arrow Lakes Reservoir

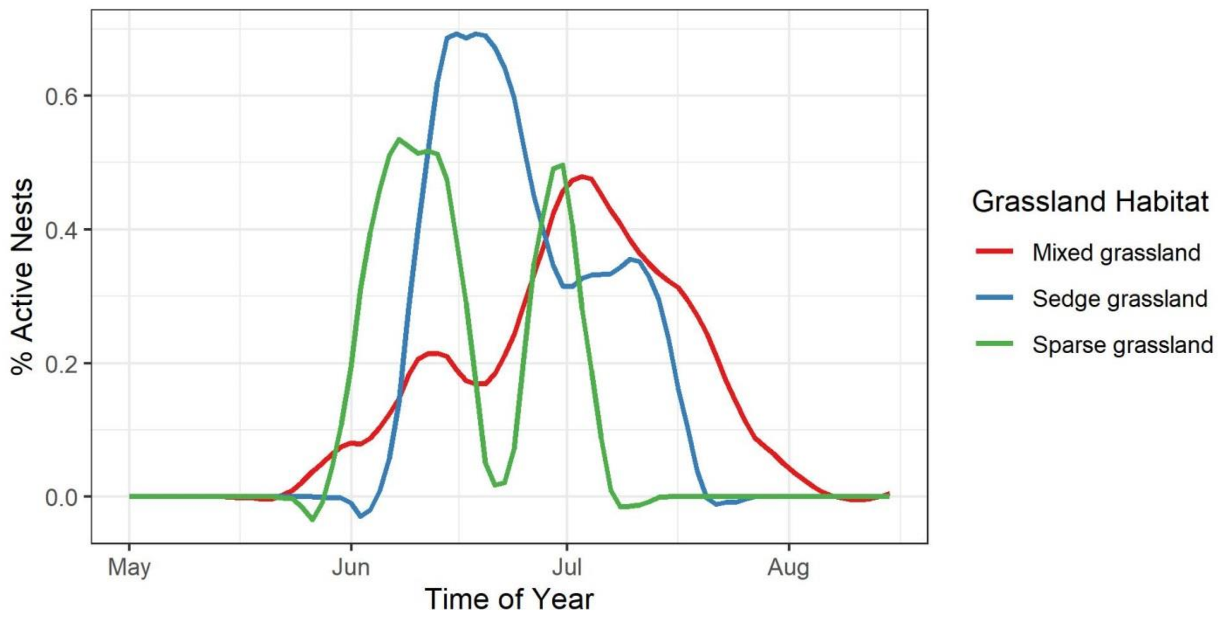

Figure 12.8 Nest phenology for grassland habitat in Revelstoke Reach of Arrow Lakes Reservoir

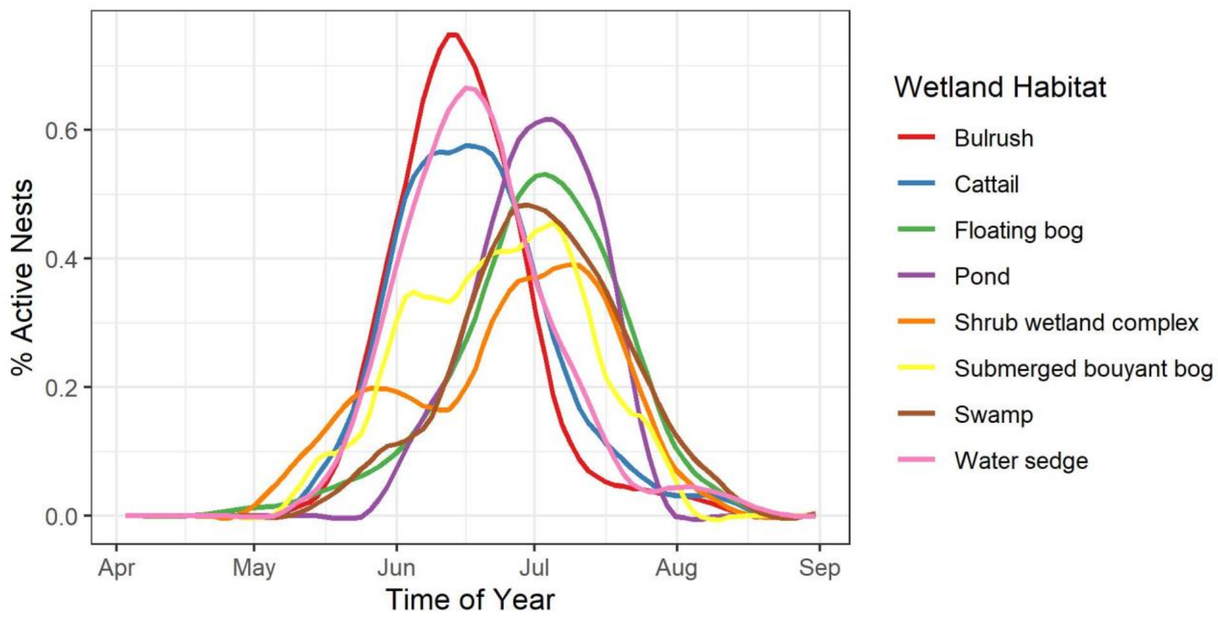

Figure 12.9 Nest phenology for wetland habitat in Revelstoke Reach of Arrow Lakes Reservoir

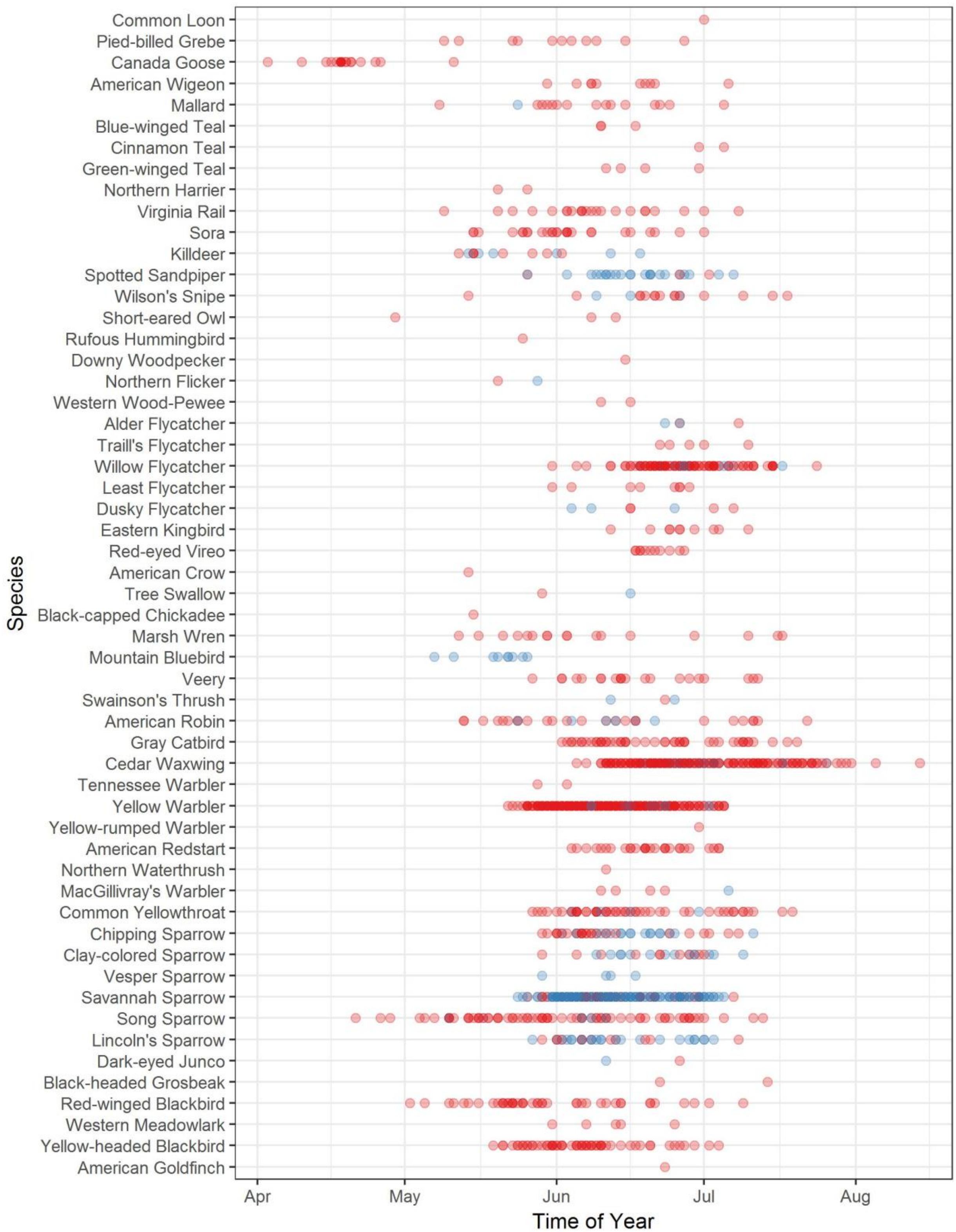

Figure 12.10 First egg dates for species nesting at Kinbasket Reservoir (blue) and Revelstoke Reach of Arrow Lakes Reservoir (red)

13.0 APPENDIX G – NEST FLOODING

13.1 Introduction

This appendix examines and summarizes data related to nest flooding.

13.2 Methods

Using the Nests data set, the numbers of nests of each species flooded within each drawdown zone were compiled. The summary results were grouped by nesting location (e.g., ground, shrub) and included nests both on and off of community-level nest monitoring plots.

To visually explore the elevations of nests flooded throughout the study, a figure was plotted showing the elevations of nests that flooded for each year of the study. The points were colour-coded by nest location (e.g., ground, shrub).

13.3 Results and Discussion

The majority of nest flooding was observed at ALR and nests that flooded were primarily of species that nested on the ground or low to the ground (in shrubs or emergent vegetation) (**Table 13.1**).

There were visually apparent annual differences in the elevations of nests that were flooded over the course of the project (**Figure 13.1**) which correspond with the annual fluctuations in reservoir water level (**Figure 2.2**, **Figure 2.3**). For example, years with lower maximum reservoir elevation (2009, 2015, 2016) only had nest flooding occur at lower elevation nests.

Table 13.1 Nests Observed Flooded at Kinbasket Reservoir and Arrow Lakes Reservoir Drawdown Zones from 2008 to 2017

Nesting Locations	Common Name	ALR	KIN
Ground	Common Loon	2	
	American Wigeon	7	
	Mallard	10	
	Blue-winged Teal	1	
	Green-winged Teal	3	
	Northern Harrier	1	
	Killdeer	4	1
	American Avocet	1	
	Spotted Sandpiper	11	8
	Wilson's Snipe	5	
	Wilson's Phalarope	1	
	Long-eared Owl	1	
	Short-eared Owl	3	
	Savannah Sparrow	7	12
	Lincoln's Sparrow		1

Nesting Locations	Common Name	ALR	KIN
Low shrub or emergent vegetation	Pied-billed Grebe	2	
	Virginia Rail	7	
	Sora	2	
	Marsh Wren	1	
	Veery	2	
	MacGillivray's Warbler	1	
	Common Yellowthroat	16	1
	Chipping Sparrow	7	
	Clay-colored Sparrow	3	
	Song Sparrow	4	
	Red-winged Blackbird	9	
	Yellow-headed Blackbird	15	
Shrub	Traill's Flycatcher	2	
	Willow Flycatcher	15	1
	Dusky Flycatcher	1	
	Eastern Kingbird	1	
	Unidentified Flycatcher	2	
	Gray Catbird	8	
	Cedar Waxwing	7	
	Yellow Warbler	20	
Forest	American Robin		1
	American Redstart	1	
Cavity	Mountain Bluebird		1

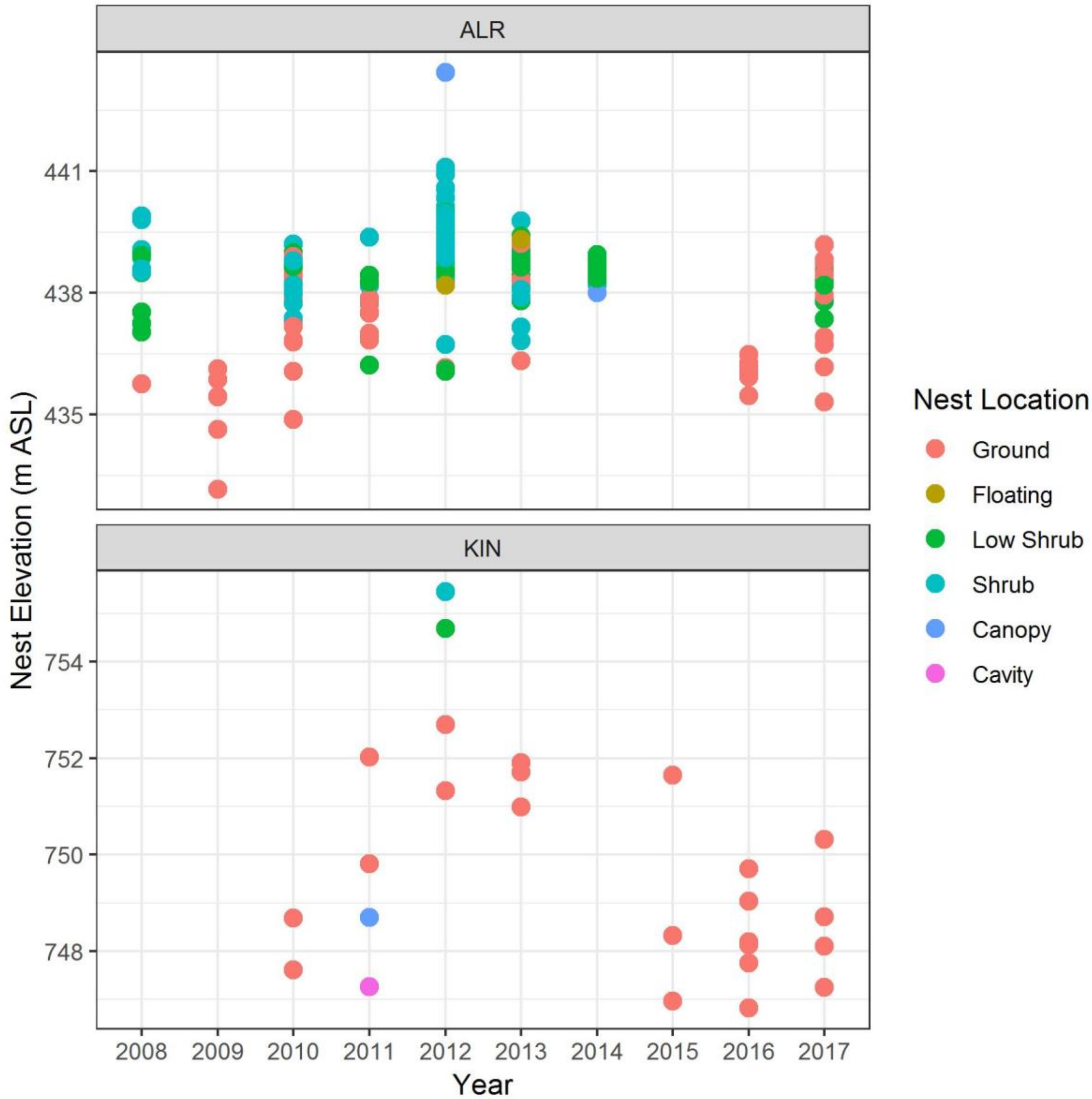

Figure 13.1 **Nest elevations of flooded nests at ALR (upper) and KIN (lower) for each year of the study**

14.0 APPENDIX H – NEST SURVIVAL

14.1 Introduction

Understanding the factors affecting nest survival of birds is one of the primary objectives of CLBMON-36. This appendix provides details of the analysis of nest survival for focal and other representative species.

14.2 Methods

Data for the analysis of nest survival of individual species were extracted from the Nest Observations data set (described in **Section 3.2.3**), which included the following data for every nest visit: nest ID, survey ID, nest observation ID, observer, time of observation, nest stage, whether nest contents were monitored, whether the nest needed another monitoring visit, number of eggs, age of eggs, number of young, age of young, number of dead young, number of cowbird eggs, number of cowbird young, location of adults, height of nest above water, depth of water under/at nest location, and additional comments.

Variables added to the data set included ordinal date (day of the year) and the reservoir elevation on the date of observation. Exposure time (the number of days since the last observation) was calculated by subtracting the date of the previous visit from the date of each observation.

Nest survival for Cedar Waxwing (a shrub-nesting species) and Savannah Sparrow (a ground-nesting species) were analyzed because they were focal species for CLBMON-36. The nest survival of Spotted Sandpiper (another ground nesting species) was analyzed because it is a low-elevation nesting species within the drawdown zone, nests in habitats with less complex vegetation (compared to other focal species), and was one of the most common species detected nesting at KIN. Nest survival analyses for the other CLBMON-36 focal species, Yellow Warbler and Willow Flycatcher (both shrub-nesting), was completed previously (van Oort et al. 2015).

Nests on the floating bog in Montana Bay were excluded from the examination of nest survival in relation to reservoir elevation because the bog elevation changes with the reservoir water level.

Multiple variables were examined as predictors of nest survival (**Table 14.1**). These were considered for the full data set as well as location-based subsets of the data (e.g., all nests in the Revelstoke area, only nests within the RR drawdown zone, only nests above the KIN drawdown zone, etc.). Some variables were excluded when modeling certain data sets. For example, vegetation community was not included when a data set included nests above the drawdown zone since the habitat above the drawdown zone was not mapped. Additionally, the location-based variables included in each model set depended on which data set was being used.

Each variable was included in a univariate model. The full list of variables and models examined for each data set are given in the model-ranking tables below (**Section 14.3**).

Table 14.1 Descriptions of Possible Variables for Nest Survival Models

Variable	Variable Type	Description
ord date	Numeric	Ordinal date (day of the year). For example, January 1 would be 1, January 2 would be 2, etc.
nest age	Numeric	Age of the nest, beginning when eggs are laid.
year	Categorical	Year, included all years from 2008 to 2017.
nest elevation	Numeric	Elevation of the nest in metres (dem + height of the nest above the ground).
DEM	Numeric	Digital elevation model – the ground elevation at the nest location in metres above sea level.
reservoir elevation	Numeric	Water level of the reservoir in metres above sea level.
ddz	Categorical	Whether a nest was within or outside of the drawdown zone. Either 1 (within) or 0 (outside of).
reservoir	Categorical	Which reservoir the nest was in, either ALR or KIN.
study area	Categorical	Revelstoke Reach, Bush Arm, or Canoe Reach.
vegetation community	Categorical	Vegetation community, possible values for KIN and ALR are in **Table 8.1** and **Table 8.2**, respectively, in **Appendix B**.
habitat stratum	Categorical	Broad habitat categories, values included: unvegetated, grassland, wetland, shrub, forest.

Logistic exposure models were fit to determine which variables were most related to nest survival (Schaffer 2004, Bolker 2019, Schwarz 2019). An information-theoretic approach was used to evaluate support for the models and they were ranked using Akaike's Information Criterion adjusted for small sample size, AIC_c (Burnham and Anderson 2002, Burnham et al. 2011). Model ranking was completed with the MuMIn package in R (Barton 2018).

14.3 Results and Discussion

At KIN, nest inundation was observed in every year except 2008, 2009, and 2014; at ALR, nest inundation was observed in every year except 2015 (**Figure 14.1**).

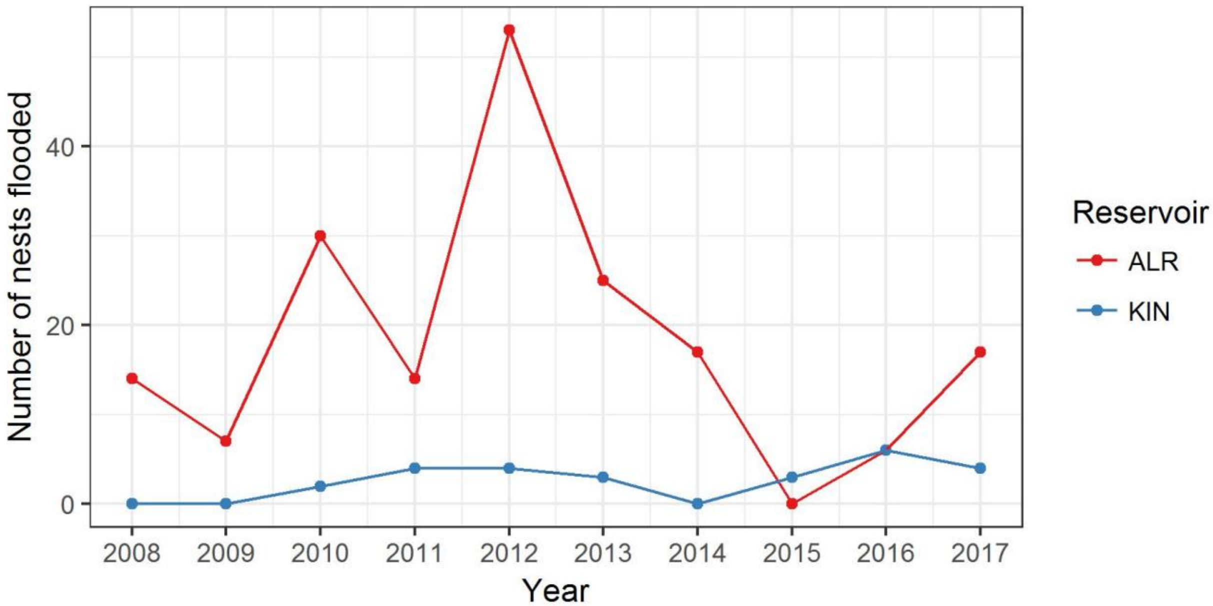

Figure 14.1 Annual number of observations of nest flooding at Kinbasket Reservoir (KIN) and Arrow Lakes Reservoir (ALR) from 2008 to 2017.

14.3.1 Cedar Waxwing

Below are model ranking tables for the data sets used to explore Cedar Waxwing nest survival. Commentary on the results is provided in the 'Comments' column of the tables.

Table 14.2 Model Ranking for Cedar Waxwing Nest Survival Models - All Nests (n = 322)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
ddz	NA	1233.58	0.00	0.51	Nests in a ddz had a decreased survival rate (estimate -0.52, SE = 0.20, p = 0.01). Nests within Canoe Reach had an increased rate survival rate relative to nests in Revelstoke Reach and Bush Arm.
sa	NA	1234.39	0.81	0.34	
year	NA	1237.63	4.05	0.07	
null model	NA	1238.66	5.08	0.04	
res	NA	1239.28	5.70	0.03	
ord date	0	1240.54	6.96	0.02	

Table 14.3 Model Ranking for Cedar Waxwing Nest Survival Models – All Drawdown Zones (n = 275)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
null model	NA	1073.05	0.00	0.40	The null model was the top ranked model, suggesting little support for any of the variables included in other models.
res	NA	1073.98	0.93	0.25	
ord date	0	1074.81	1.76	0.16	
sa	NA	1074.91	1.86	0.16	
year	NA	1078.21	5.16	0.03	

Table 14.4 Model Ranking for Cedar Waxwing Nest Survival Models - Arrow Lakes Reservoir, (both in and above Drawdown Zone, n = 287)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
ddz	NA	1108.57	0.00	0.41	The top model (ddz) shared support with the null model and ord date, suggesting that it didn't explain much more of the variation in nest survival compared to those lesser ranked models (Estimate -0.35, SE = 0.25, p-value = 0.15).
null model	NA	1108.76	0.19	0.37	
ord date	NA	1110.55	1.98	0.15	
year	0	1111.99	3.42	0.07	

Table 14.5 Model Ranking for Cedar Waxwing Nest Survival Models - Arrow Lakes Reservoir Drawdown Zone (n = 257)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
strata	NA	1006.05	0.00	0.72	Habitat stratum was the top-ranked model and only model ranked above the null model for nests within the ALR drawdown zone. A nest located in a wetland had an increased nest survival rate relative to forest habitats.
null model	NA	1009.60	3.56	0.12	
dem	+	1011.36	5.31	0.05	
ord date	0	1011.41	5.36	0.05	
nest elev	0	1011.61	5.56	0.04	
year	NA	1014.80	8.75	0.01	

Table 14.6 Model Ranking for Cedar Waxwing Nest Survival Models - Kinbasket Reservoir (n = 35)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
sa	NA	125.70	0.00	0.42	Three models were within ~2 AICc of the top model. That, and the distribution of Akaike weights also suggests some support for all these variables. Results suggested that a nest at CR had a higher survival rate than one in BA (Estimate = 1.09, SE = 0.43, p-value = 0.01) and that a nest within a ddz had a lower survival rate (Estimate = -0.92, SE = 0.43, p-value = 0.03).
year	NA	125.95	0.25	0.37	
ddz	NA	127.71	2.01	0.15	
null model	NA	130.54	4.84	0.04	
ord date	-	132.28	6.59	0.02	

Table 14.7 Model Ranking for Cedar Waxwing Nest Survival Models - Kinbasket Reservoir Drawdown Zone (n = 19)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
null model	NA	70.71	0.00	0.37	The null model was the top ranked model, suggesting little support for any of the variables included in other models.
nest elev	NA	71.39	0.69	0.26	
ord date	-	72.57	1.87	0.15	
dem	NA	72.76	2.06	0.13	
year	NA	73.51	2.81	0.09	

14.3.2 Savannah Sparrow

Below are model ranking tables for the data sets used to explore Savannah Sparrow nest survival. Commentary on the results is provided in the 'Comments' column of the tables. Note that the majority of nests were in CR, so the data sets including all nests are heavily influenced by that data.

Overall, results indicated that the variable with the greatest effect on Savannah Sparrow nest survival was ordinal date. This was primarily driven by the large data set from CR, which likely would have swamped any other effects that might have influenced nest survival in BA or RR for data sets that included multiple study areas. Results for data sets including data for just those study areas was inconclusive.

Notably, there was no evidence that whether a nest was located in a drawdown zone or nest elevation affected nest survival.

Table 14.8 Model Rankings for Savannah Sparrow Nest Survival Models – All Data (n = 342)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
ord date	-	683.81	0.00	1	Clear support for ordinal date explaining the differences in nest survival. Nesting later in the season decreased the survival rate of a nest (Estimate = -0.05, SE = 0.01, p-value = <0.01). Note, because this data set included nests in all locations, a nest elevation model was not included in the model set. Also, notably, there was no support for a difference in survival rate among nests located in or outside of the ddz.
sa	NA	714.69	30.88	0	
year	NA	717.09	33.28	0	
res	NA	728.81	45.00	0	
null model	NA	732.61	48.80	0	
ddz	NA	733.32	49.50	0	

Table 14.9 Model Rankings for Savannah Sparrow Nest Survival Models – Kinbasket and Arrow Lakes Drawdown Zones (n = 254)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
ord date	-	527.99	0.00	1	Clear support for ordinal date explaining the differences in nest survival. Nesting later in the season decreased the survival rate of a nest (Estimate = -0.06, SE = 0.01, p-value = <0.01). Note, because this data set included nests in both KIN and ALR, a nest elevation model was not included in the model set.
sa	NA	547.32	19.33	0	
year	NA	548.98	20.99	0	
res	NA	558.73	30.73	0	
null model	NA	560.12	32.13	0	

Table 14.10 Model Rankings for Savannah Sparrow Nest Survival Models – Kinbasket Reservoir (at CR and BA, both in and outside of drawdown zone, n = 282)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
ord date	-	540.23	0.00	1	Clear support for ordinal date explaining the differences in nest survival. Nesting later in the season decreased the survival rate of a nest (Estimate = -0.06, SE = 0.01, p-value = <0.01). Note, because this data set included nests above and below the ddz, a nest elevation model was not included in the model set. The study area model, though explaining much less variation than the ordinal date model, suggests that nest survival is higher in CR than BA (Estimate = 1.03, SE = 0.24, p-value = <0.01).
year	NA	566.40	26.17	0	
sa	NA	567.03	26.80	0	
ddz	NA	579.53	39.30	0	
null model	NA	581.15	40.92	0	

Table 14.11 Model Rankings for Savannah Sparrow Nest Survival Models - Canoe Reach (both in and outside of drawdown zone, n = 223)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
ord date	-	380.42	0.00	1	Ordinal date was the top-ranked model (Estimate = -0.06, SE = 0.01, p-value = <0.01). There was no support for whether a nest was in the drawdown zone influencing nest survival.
year	NA	413.79	33.36	0	
null model	NA	417.32	36.90	0	
ddz	NA	418.42	37.99	0	

Table 14.12 Model Rankings for Savannah Sparrow Nest Survival Models – Kinbasket Reservoir Drawdown Zone (both CR and BA, n = 227)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
ord date	-	452.90	0.00	1	Ordinal date was the top-ranked model (Estimate = -0.06, SE = 0.01, p-value = <0.01). There was no support for nest elevation influencing nest survival. The study area model, though explaining much less variation than the ordinal date model, suggested that nest survival is higher in CR than BA (Estimate = 0.96, SE = 0.25, p-value = <0.01).
sa	NA	473.00	20.11	0	
year	NA	474.12	21.22	0	
null model	NA	484.41	31.51	0	
nest elev	+	486.10	33.20	0	

Table 14.13 Model Rankings for Savannah Sparrow Nest Survival Models - Canoe Reach Drawdown Zone (n = 168)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
ord date	-	294.37	0.00	1	Ordinal date was the top-ranked model (Estimate = -0.07, SE = 0.01, p-value = <0.01). There was no support for nest elevation influencing nest survival.
year	NA	321.57	27.20	0	
null model	NA	323.29	28.92	0	
nest elev	NA	324.67	30.30	0	

Table 14.14 Model Rankings for Savannah Sparrow Nest Survival Models - Bush Arm Drawdown Zone (n = 59)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
ord date	-	148.18	0.00	0.53	Results for BA show limited support for any of the variables explaining nest survival, as the null model shared support with the nest elev and ordinal date models. Those models were within ~2 ΔAICc of each other. For ordinal date, the relationship (negative) was the same as other data sets, but it was less definitive (Estimate = -0.03, SE = 0.02, p-value = 0.052).
null model	NA	149.72	1.54	0.25	
nest elev	NA	150.38	2.20	0.18	
year	NA	152.93	4.75	0.05	

Table 14.15 Model Rankings for Savannah Sparrow Nest Survival Models – Revelstoke Reach (both in and outside of drawdown zone, n = 60)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
ord date	-	145.08	0.00	0.64	Results for RR show some support for ordinal date explaining nest survival, but the null model also had some support so there is some uncertainty there. The relationship (negative) was the same as other data sets, but it was less definitive (Estimate = -0.03, SE = 0.01, p-value = 0.02).
null model	NA	147.68	2.61	0.17	
year	NA	148.67	3.59	0.11	
ddz	NA	149.37	4.29	0.08	

Table 14.16 Model Rankings for Savannah Sparrow Nest Survival Models – Revelstoke Reach Drawdown Zone (n = 27)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
year	NA	66.38	0.00	0.97	Year was the model with the most support, however the distribution of nests among years was uneven, so this could represent a strong year effect or, perhaps, be more related to that habitats/plots sampled in years with greater samples sizes.
null model	NA	74.38	8.00	0.02	
ord date	-	76.12	9.74	0.01	
nest elev	-	76.53	10.15	0.01	
strata	NA	77.73	11.36	0.00	

14.3.3 Spotted Sandpiper

Below are model ranking tables for the data sets used to examine Spotted Sandpiper nest survival. Explanation of the modelling results is provided in the 'Comments' column of the tables. Only nests within the reservoir drawdown zones were included as there were very few nests above the drawdown zones.

Overall, results indicated that nest survival was higher in CR and lowest in RR. Within CR, nests active earlier in the season had a higher survival rate. At RR, nests at higher elevations had a higher survival rate. Results for BA showed little support for any of the included models.

Table 14.17 Model Ranking for Spotted Sandpiper Nest Survival Models - Kinbasket and Arrow Lakes Drawdown Zones (n = 106)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
sa	NA	252.15	0	0.66	Study area was the model with the most support, with some support for reservoir and year. As different sites were surveyed in different years, the support for year is likely also a reflection that there were differences in nest survival among sites/reservoirs. CR had increased nest survival and RR had decreased nest survival relative to BA.
res	NA	254.44	2.29	0.21	
year	NA	255.77	3.63	0.11	
null model	NA	260.57	8.42	0.01	
ord date	-	261.52	9.38	0.01	

Table 14.18 Model Ranking for Spotted Sandpiper Nest Survival Models - Arrow Lakes Reservoir Drawdown Zone (n = 30)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
nest elev	+	76.47	0	0.91	In Revelstoke Reach at ALR, nest elevation and dem had the strongest support and indicated that nest survival rate was higher at higher nest elevations. (Estimate = 0.61, SE = 0.20, p = <0.01).
ord date	+	82.42	5.95	0.05	
null model	NA	83.09	6.62	0.03	
strata	NA	86.53	10.06	0.01	
year	NA	89.17	12.70	0.00	

Table 14.19 Model Ranking for Spotted Sandpiper Nest Survival Models - Kinbasket Reservoir Drawdown Zone (both CR and BA, n = 76)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
ord date	-	164.62	0	0.86	In KIN ddz, ordinal date was the variable that best explained nest survival. The effect was negative (Estimate = -0.05, SE = 0.02, p = <0.01) in contrast to ALR (**Table 14.18**). The model for study area indicated that nests in CR had an increased survival rate compared to BA (Estimate = 0.89, SE = 0.42, p = 0.03).
sa	NA	169.09	4.47	0.09	
null model	NA	171.39	6.77	0.03	
year	NA	173.33	8.72	0.01	
nest elev	-	173.41	8.79	0.01	

Table 14.20 Model Ranking for Spotted Sandpiper Nest Survival Models – Canoe Reach Drawdown Zone (n = 50)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
ord date	-	90.64	0	0.97	Similar to the results for all KIN nests, nest survival rate decreased later in the season (as ordinal date increased). (Estimate = -0.097, SE = 0.03, p = <0.01).
year	NA	98.84	8.2	0.02	
null model	NA	100.1	9.46	0.01	
nest elev	-	101.8	11.16	0.00	

Table 14.21 Model Ranking for Spotted Sandpiper Nest Survival Models – Bush Arm Drawdown Zone (n = 26)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i	Comments
nest elev	+	67.97	0	0.49	Results for BA show little support for any of the variables explaining nest survival, as the null model shared support with the nest elev and ordinal date models. Those models were within 2 ΔAICc of each other.
null model	NA	69.02	1.05	0.29	
ord date	-	69.62	1.64	0.21	
year	NA	75.2	7.23	0.01	

14.4 Management Hypotheses

There are two management hypotheses associated with MQ-C.

- 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.

The rejection of these hypotheses will undoubtedly depend on which species, reservoir, and habitats the nests are from. For example, H1 was rejected for Spotted Sandpipers in the ALR drawdown zone (**Table 14.18**), but this may not be the case for other species or this species in a different location.

H1A was tested by comparing nest survivorship for Cedar Waxwing (a shrub-nesting species) and Savannah Sparrow (a ground-nesting species) for nests above and below the drawdown zone. Results differed by species. For Cedar Waxwing, there was some evidence that nests above the drawdown zone had a greater nest survival than those within the drawdown zone, but there was little evidence to support this difference in nest survival for Savannah Sparrow. See **Section 4.3** for more discussion, and the results above for details on the statistical results (**Section 14.3**).

15.0 APPENDIX I – CAUSES OF NEST FAILURE

15.1 Introduction

This appendix presents the methods and results for the causes of nest failure (MQ-D).

15.2 Methods

The causes of nest failure for species and habitat was examined using the Nests data set. For each species, the percentage of nests with each nest outcome was calculated for each species with greater than 10 nests. The causes of nest failure were summarized by bird species (includes the most common species) and habitat.

The percentages of nests flooded were then examined in relation to nest elevation and linear models were fit to the data.

15.3 Results and Discussion

The summaries of nest failure by bird species and habitat are provided in **Table 15.1**, **Table 15.2**, **Table 15.3**, and **Table 15.4** . A plot of linear model results for percentage of nests flooded and average nest elevation at ALR is included in **Section 4.4** (**Figure 4.12**) and it shows that the proportion of monitored nests that were flooded was greater for species nesting at lower elevations. This model for ALR was statistically significant ($p = 0.001$), but this relationship was not statistically significant for species nesting at KIN.

Table 15.1 Percentage of Each Nest Outcome for Nests of the Common Species at Arrow Lakes Reservoir*

Nest Outcome	AMRE	AMRO	AMWI	CANG	CCSP	CEDW	CHSP	COYE	EAKI	GRCA	KILL	LEFL	MALL	MAWR
Abandoned	9	5	7	1		16	3	13	18	6	3	7	13	3
BCHO* fledge only	1							2				7		
Failed by other means		2				1		2			3			
Failed by unknown means	9	2				9		6		2				
Predated	32	47	39	24	40	46	58	13	18	40	30	33	29	14
Reservoir Operations	1		25		20	2	19	28	9	13	9		13	6
Successful	26	26	18	66	40	21	14	30	36	27	33	33	27	44
Unknown	22	19	11	9		5	6	6	18	12	21	20	18	33

Nest Outcome	PBGR	REVI	RWBL	SAVS	SORA	SOSP	SPSA	VEER	VIRA	WIFL	WISN	YEWA	YHBL
Abandoned	13	16	16		10		5	3	5	7		9	9
BCHO* fledge only												1	
Failed by other means			2		2			3		1		1	1
Failed by unknown means	3		2			6	3		2	10		4	4
Predated	13	26	9	24	5	36	5	39	14	25	25	39	10
Reservoir Operations	6		16	21	5	6	30	6	16	15	31	3	19
Successful	58	32	38	50	71	40	49	35	56	33	25	39	55
Unknown	6	26	16	6	7	11	8	13	7	9	19	5	2

*Species codes are listed in **Table 10.1**.

Table 15.2 Percentage of Each Nest Outcome for Nests of the Common Species at Kinbasket Reservoir*

Nest Outcome	CCSP	CEDW	CHSP	KILL	LISP	MOBL	SAVS	SPSA	WIFL	WISN
Abandoned		14	11	7	8	14	4	8	21	8
Failed by other means				4	3		2	1		
Failed by unknown means	6	2		7	3		1	1		
Predated	33	24	42	11	24	14	19	5	29	54
Reservoir Operations				4	3	7	4	9	7	
Successful	56	4	42	56	51	50	65	65	7	23
Unknown	6	56	5	11	8	14	5	10	36	15

*Species codes are listed in **Table 10.1**

Table 15.3 Percentage of Each Nest Outcome for Nests in Each Habitat Stratum at Arrow Lakes Reservoir Drawdown Zone

Nest Outcome	Forest	Grassland	Shrub	Steep bank	Unvegetated	Urban	Wetland
Abandoned	9	4	9		12		9
BHCO* fledge only	1		0				1
Failed by other means	1		1				1
Failed by unknown means	5		5				3
Predated	33	33	39	30	38		22
Reservoir Operations	1	19	8	10	38		8
Successful	34	35	30	40	12		49
Unknown	16	10	7	20		100	8
TOTAL	**363**	**81**	**1007**	**10**	**8**	**1**	**987**

*Species codes are listed in **Table 10.1**

Table 15.4 Percentage of Each Nest Outcome for Nests in Each Habitat Stratum at Kinbasket Reservoir Drawdown Zone

Nest Outcome	Forest	Grassland	Shrub	Unvegetated	Wetland
Abandoned	10	8	8	21	5
Failed by other means		1	1		3
Failed by unknown means		2	2		1
Predated	10	17	31	16	19
Reservoir Operations		4	1	5	7
Successful	30	57	36	42	59
Unknown	50	11	22	16	6

15.4 Management Hypotheses

There are two hypotheses associated with MQ-D:

- 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

For H1C, insight comes from the analysis of the nest survival of three species: the shrub- or tree-nesting Cedar Waxwing and the ground-nesting Savannah Sparrow and Spotted Sandpiper (**Section 14.0**). For both Cedar Waxwing and Savannah Sparrow, nest survival did not differ across elevations within the drawdown zone of either reservoir. For Spotted Sandpiper, nesting at higher elevations led to an increase in nest survival at ALR, but not at KIN, despite Spotted Sandpiper at KIN also experiencing many nest failures due to reservoir operations. For more details on these analyses, see **Appendix H**.

H1D was found to be false. As shown in **Figure 4.12**, there are differences in the proportions of nests flooded across elevations in the drawdown zone.

16.0 APPENDIX J – JUVENILE SURVIVAL

16.1 Introduction

This appendix examines the juvenile survival of songbirds at KIN and ALR, providing additional background and details of the analysis described in **Section 4.5 MQ-G.** The focal species for this aspect of CLBMON-36 were Yellow Warbler (ALR) and Savannah Sparrow (KIN – individuals were tagged in both reservoirs but only KIN had sufficient sample size for analysis).

16.2 Methods

The Yellow Warbler and Savannah Sparrow Juvenile Telemetry data sets and their samples sizes are described in **Section 3.2.4.** There were three smaller data sets from which information was drawn for the analysis of juvenile survival.

The *deployment* data set included one record for all juveniles tagged and included the following information: bird ID, a code composed of the study site (e.g., CR) and the year of deployment, the date the transmitter was made, the min/max/best radio frequencies, type of transmitter battery, mass of transmitter, pulse of transmitter, rate of transmitter pulse, expected life of transmitter, date of deployment, CWS band number, time of deployment, species, bird age at deployment, number of siblings, nest ID, nest UTM coordinates, antenna length, and any additional comments.

The *observations* data set is composed of the daily observations for tagged juveniles. It included the following information: bird ID, observation number, signal strength, observer, date, time, basic weather (cloud cover, temperature, precipitation, wind, wind direction), UTM coordinates, precision of location, status of transmitter (e.g., in use, expired), alive (1/0), dead (1/0), whether the bird was visually observed, distance from juvenile to nest, height of bird over ground, substrate bird is in/on, substrate height, whether cover (overhead vegetation) is partially or entirely covering bird, four vegetation measurements using a Robel pole (Robel et al. 1970), percentages of the most common vegetation cover around the nest, whether adults were also observed, whether adults were alarm calling, whether adults were seen carrying food, whether the juvenile still seemed dependent on the adults, how many siblings were observed, whether the juvenile was moving or still, distance of the juvenile's furthest flight, whether the juvenile was begging, depth of water by juvenile, percent of the vegetation plot (10 m) that was flooded, whether reservoir water was present in the 10-m plot, and whether ground water was present in the 10-m plot.

The *termination* data set has one record for each tagged bird and includes the following information: bird ID, final status of transmitter (e.g., recovered, expired), whether the bird died, whether body parts were seen, cause of death, type of predator (if bird was predated), whether bird fledged nest, whether reservoir flooded area of juvenile, the date of flooding, and the final outcome of the bird (e.g., survived, drowned, etc.).

Further methods regarding the analysis of Yellow Warbler juvenile survival are provided in Hepp et al. 2018. The methods described below pertain only to the analysis juvenile survival of Savannah Sparrow.

Information from the deployment and termination data sets was added to the observations data set prior to analysis. Additionally, the following variables were added for each observation record: day of the year, days since deployment, fledge date, ordinal fledge date, days since fledging, bird age, exposure period (days since last observation), reservoir elevation, reservoir elevation on fledge date, difference in elevation between nest and reservoir on fledge date, difference in reservoir elevation between fledge date and observation date, and the mass and tarsus length of the juvenile when it was tagged.

Nest survival models included temporal, location-based, reservoir elevation-related, and nestling-related variables (**Table 16.1**). Some variables were excluded when modeling certain subsets of the data. For example, whether a juvenile was in the drawdown zone was not included when examining only the data from BA, where all tagged young were within the drawdown zone. The full list of variables and models examined for each data set, along with the sample size of the data set are given in the model-ranking tables below (**Section 16.3**). Each variable was included in a univariate model.

Table 16.1 Descriptions of Variables Used in Savannah Sparrow Juvenile Survival Models

Variable	Variable Type	Hypothesis Type	Description
ord date	Numeric	Temporal	Ordinal date (day of the year). For example, January 1 would be 1, January 2 would be 2, etc.
age deploy	Numeric	Temporal	Age of the bird at the time of transmitter attachment.
age obs	Numeric	Temporal	Age of the bird at the time of observation.
date fledge ord	Numeric	Temporal	Ordinal date (day of the year) that the juvenile left the nest.
year	Categorical	Temporal	Year, from 2013 to 2017.
res elev	Numeric	Reservoir	Water level of the reservoir in metres above sea level on the day of observation.
kin diff	Numeric	Reservoir	The difference between the reservoir elevation at the time of the observation and the time of fledging. I.e., has the reservoir level changed since the juvenile fledged?
ddz	Categorical	Reservoir/Location	Whether a nest was within or outside of the drawdown zone. Either 1 (within) or 0 (outside of).
study area	Categorical	Location	Revelstoke Reach, Bush Arm, or Canoe Reach.
site name	Categorical	Location	Nest monitoring plot ID.
BA site	Categorical	Location	Causeway or Bear Island plot, for BA data subset only.

Logistic exposure models were fit to determine which variables were most related to nest survival (Schaffer 2004, Bolker 2019, Schwarz 2019). An information-theoretic approach was used to evaluate support for the models and they were ranked using Akaike's Information Criterion adjusted for small sample size, AIC_c (Burnham and Anderson 2002, Burnham et al. 2011). Model ranking was completed with the MuMIn package (Barton 2018).

16.3 Results and Discussion

The full results for Yellow Warbler juvenile survival are provided in Hepp et al. 2018, from which the key points are discussed in **Section 4.5**. Only details on the Savannah Sparrow juvenile survival results (also discussed in **Section 4.5**) are described below.

From 2013 to 2017, 94 juvenile sparrows were tagged at KIN, 63 at CR (44 within the drawdown zone and 19 outside of the drawdown zone), and 31 at BA (all within the drawdown zone).

Not all the juveniles tagged in the nest fledged: 2 drowned when their nests were flooded, 12 were killed by predators in the nest, and 1 was found dead near the nest but cause of death was uncertain. One juvenile also lost its transmitter after fledging (assumption made since transmitter and harness were found intact near nest) and another was not detected around the nest, but there was no evidence of nest predation so its fate is unknown.

Three tagged juveniles were also believed to have been killed by their parents after tagging and one was stepped on during tracking. The juveniles believe to have been killed by their parents were found dead outside the nest when biologists returned the day after tagging, but all the other nestlings in their nest were unharmed. Very little published information was found on the reaction of adult birds to tagged nestlings, so it is unknown how common this behaviour is. Unfortunately, despite best efforts to minimize effects, this research was invasive and there were negative impacts to the birds studied.

A total of 74 juveniles were tracked after fledging and 39 of them survived the monitoring period. Of the mortalities, 20 were confirmed dead due to predation, 4 drowned (3 in reservoir water, 1 in natural puddle), 1 died of exposure, 1 was suspected to have died due to parasite overload (blowflies), 1 was stepped on, 3 died of unknown causes, and 5 had unknown fates. Many predators could not be identified, but five deaths were attributed to snakes and two to mammals.

Results of survival modelling suggested that temporal variables, such as age obs (bird age at time of observation), had a greater impact on post-fledging survival than nest location or reservoir elevation variables (**Table 16.2**, **Table 16.3**, **Table 16.4**, **Table 16.5**, **Table 16.6)**. The univariate model for age obs had the highest Akaike w_i in the model rankings for all juveniles tagged at KIN, all juveniles tagged within the drawdown zone, all juveniles tagged in CR, and all juveniles tagged in BA. Note that the assemblage of variables included in these model sets varied. For all those data sets the effect was positive: survival increased with an increase in the age of the bird.

For juveniles nesting above the drawdown zone in CR (sites were around the town of Valemount), the null model was one of the top-ranked models, indicating no support for any of the other models (**Table 16.5**).

Additional discussion of these results and the results for Yellow Warbler is found in the main body of this report (**Section 4.5**).

Table 16.2 Model Ranking for Savannah Sparrow Juvenile Survival Models – All Data (n = 74)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i
age obs	+	227.98	0	0.99
date fledge ord	-	241.14	13.16	< 0.01
ddz	+	245.41	17.43	< 0.01
null model	NA	245.59	17.61	< 0.01
age deploy	-	246.49	18.51	< 0.01
ord date	-	247.15	19.17	< 0.01
study area	NA	247.41	19.43	< 0.01
year	NA	247.78	19.80	< 0.01

Table 16.3 Model Ranking for Savannah Sparrow Juvenile Survival Models - Canoe Reach and Bush Arm Drawdown Zones (n = 53)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i
age obs	+	185.93	0	0.99
kin diff	+	196.07	10.14	< 0.01
date fledge ord	-	203.13	17.20	< 0.01
null model	NA	205.79	19.86	< 0.01
age deploy	-	206.86	20.92	< 0.01
res elev	+	207.32	21.39	< 0.01
ord date	+	207.81	21.87	< 0.01
study area	NA	207.81	21.87	< 0.01
year	NA	210.32	24.39	< 0.01

Table 16.4 Model Ranking for Savannah Sparrow Juvenile Survival Models - Canoe Reach (within and outside of drawdown zones, n = 57)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i
age obs	+	175.06	0	0.669
date fledge ord	-	178.06	3.00	0.149
age deploy	-	178.22	3.16	0.138
year	NA	182.66	7.60	0.015
null model	NA	183.31	8.26	0.011
ddz	NA	183.33	8.28	0.011
ord date	-	184.04	8.99	0.007

Table 16.5 Model Ranking for Savannah Sparrow Juvenile Survival Models - Above Drawdown Zone at Canoe Reach (n = 17)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i
date fledge ord	-	39.63	0	0.24
null model	NA	39.64	0.01	0.24
ord date	-	40.01	0.38	0.20
year	NA	41.29	1.67	0.10
age obs	+	41.47	1.85	0.09
age deploy	+	41.57	1.95	0.09
site name	NA	42.81	3.18	0.05

Table 16.6 Model Ranking for Savannah Sparrow Juvenile Survival Models - Bush Arm (within drawdown zone, n = 21)

Model	Direction of Effect	AICc	ΔAICc	Akaike w_i
age obs	+	54.22	0	0.92
kin diff	+	61.00	6.79	0.03
age deploy	+	61.03	6.81	0.03
null model	NA	64.11	9.89	< 0.01
year	NA	65.16	10.94	< 0.01
ord date	+	65.74	11.53	< 0.01
date fledge ord	-	65.87	11.65	< 0.01
res elev	+	65.87	11.66	< 0.01
BA site	NA	66.15	11.93	< 0.01
site name	NA	67.34	13.13	< 0.01

16.3.1 Management Hypotheses

There were two management hypotheses associated with this MQ:

- 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.

H2 was found to be false; inundation of post-fledging habitat did influence juvenile survival for Yellow Warbler, as outlined above.

H2A was found to be true for Savannah Sparrow; there was no evidence for a difference in survival for juveniles fledging from nests located above the drawdown zone versus those fledging within the drawdown zone.

17.0 APPENDIX K – NESTING AT REVEGTATION SITES

17.1 Introduction

This appendix summarizes the nests found at cottonwood stake plantings and other nests found in cottonwoods at ALR.

17.2 Methods

Using the Nests data set, the following information was summarized for species nesting in cottonwood stake plantings: site, year, nest outcome, and number of young fledged.

Using the Nests data set, the following information was summarized for species nesting in cottonwood trees within the drawdown zone: number of nests and average nest elevation.

17.3 Results and Discussion

Only three nests of three species were found nesting in cottonwood stakes at the revegetation sites, two at 9 Mile and one at 12 Mile (**Table 17.1**). Two of the nests successfully fledged young and one was predated (**Table 17.1**).

Table 17.1 Nests Found at Cottonwood Stake Revegetation Project Sites

Species	Revegetation Site	Year	Nest Outcome	Number of Young Fledged
Clay-colored Sparrow	12 Mile	2016	Successful	≥ 2
Chipping Sparrow	9 Mile	2014	Successful	≤ 4
Eastern Kingbird	9 Mile	2016	Predated	0

As noted in **Section 4.7.1.1**, the stakes planted at sites at ALR did not successfully establish in most areas. Additionally, there has been limited time for the surviving stakes to grow and greater use for nesting is expected in the future.

Within the ALR drawdown zone, 133 nests of 23 bird species were found in cottonwood trees (**Table 17.2**), providing insight into which species may nest in cottonwood stakes after the stakes have time to mature.

Table 17.2 Nests Found in Cottonwood Trees within the ALR Drawdown Zone

Species	Number of Nests in Cottonwood	Average Nest Elevation (m)
American Crow	1	464.77
American Redstart	29	441.87
American Robin	18	495.79
Black-capped Chickadee	4	519.67
Black-headed Grosbeak	1	441.29
Bullock's Oriole	2	465.34
Cedar Waxwing	19	458.49
Chipping Sparrow	4	596.89
Dusky Flycatcher	1	438.74
Eastern Kingbird	2	442.43
Gray Catbird	1	439.67
Hermit Thrush	1	441.32
Lazuli Bunting	1	441.41
Least Flycatcher	3	446.74
Northern Flicker	2	450.68
Red-eyed Vireo	1	442.16
Swainson's Thrush	1	438.94
Traill's Flycatcher	1	439.77
Warbling Vireo	2	446.95
Western Wood-Pewee	8	448.28
Willow Flycatcher	3	544.59
Yellow-rumped Warbler	1	453.07
Yellow Warbler	27	445.15