Columbia River Project Water Use Plan

Arrow Reservoir Operations Management Plan

Reference: CLBMON-40

Arrow Lakes Reservoir Shorebird and Waterbird Monitoring Program: Year 9

Study Period: 2016

Cooper Beauchesne and Associates Ltd.
Head Office
1250 Winchester Road
Qualicum Beach, BC

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CLBMON-40: Arrow Lakes Reservoir Shorebird and Waterbird Monitoring Program

Year 9, 2016

Prepared for

BC Hydro

Water Licence Requirements

Burnaby, British Columbia

Prepared by

Harry van Oort & John M. Cooper

Cooper Beauchesne and Associates Ltd.

Head Office

1250 Winchester Road

Qualicum Beach, BC V9K 1W9

Tel: 250 954-1822

Contact: John Cooper

jcooper@cooperbeauchesne.com

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Cover photo: Low water in the Arrow Lakes Reservoir in 2016 reveals cable ferry landing at 12 Mile.

EXECUTIVE SUMMARY

The regulation of the Canadian portion of the Columbia Basin has impacted or destroyed an estimated 7,700 ha of wetland habitat via the impoundments behind dams. The remaining wetlands provide vital ecological functions for fish, wildlife, water retention, and other environmental factors. Several remnant wetlands that continue to provide particularly important ecological functions within the Columbia Basin are found in the drawdown zone of the Arrow Lakes Reservoir (ALR), near its north end (Revelstoke Reach). It is unclear how the operation of ALR affects the availability and quality of these wetlands for wildlife that depend on them. Waterbird habitat quality in the ALR likely depends on the reservoir's surface elevation because vegetation cover and foraging substrates may be exposed or submerged, and because water depth affects foraging opportunities for most waterbird species.

During the Columbia River Water Use Planning process in the early 2000's, it was evident that the impacts of reservoir operations on waterbird use of the drawdown zone was unclear, and that the relationship between reservoir operations and habitat quality was poorly understood. A number of potential impacts from reservoir operations on waterbirds in Revelstoke Reach were identified as key wildlife management concerns by the Consultative Committee. As a result, a Water Licence Requirements study (CLBMON-40) was developed to improve understanding of how reservoir operations affect waterbirds in Revelstoke Reach.

The CLBMON-40 project monitors stopover use of the Revelstoke Reach wetlands during spring and fall waterfowl migration, the importance of these wetlands for breeding waterbirds, and how ecological functions are impacted by reservoir operations. This report summarizes progress in Year 9 of the 10-year study. Annual effort and results are briefly summarized in addition to some analyses of the multi-year dataset.

Waterfowl were monitored annually in spring and/or fall at two scales. Aerial surveys were used to monitor the distribution of waterfowl over the entire study area. Weekly land-based surveys focussed on individual wetlands, and monitored temporal changes to abundance, details of species composition, and mapped distributions within the wetlands. Shorebird distribution and abundance was also monitored during the fall migration. Shorebird surveys monitored a selection of suitable foraging sites via land-based and boat-based approaches, depending on site accessibility. The productivity of four wetland raptor species (Bald Eagle, Osprey, Short-eared Owl, and Northern Harrier), and of waterbirds with precocial young (loons, grebes, waterfowl) was monitored using nest monitoring and/or brood count surveys.

In 2016, the wetlands thawed early relative to previous years. The ALR spring storage operation was also early, with increasing water surface elevation being several meters higher than historic norms, especially in May. However, the storage operation also ended almost a month early compared with previous years, resulting in a low annual maximum elevation (437.2 m asl) despite being above average for that time of year (June 12).

With spring being early, and warmer than normal, the migration of waterfowl was observed to be a brief event, with waterfowl moving through the study area primarily in late March. The summer was cool and wet prior to August, which may have made nesting and brood rearing more challenging for some species. Five species of waterfowl were observed with broods in 2016: Canada Goose, Mallard, American Wigeon, Wood Duck and Pied-billed Grebe. One pair of Northern Harriers, and two pairs of Short-eared Owl nested in 2016. All three of the initial nests of these two species failed due to reservoir flooding, and all re-nested at slightly higher elevations, which were safe from

flooding given the low maximum reservoir elevation. In the second nesting attempts, the harriers were successful, but the two Short-eared Owl nests failed, presumably due to predation. There were seven active Bald Eagle nests monitored which were all successful, with at least four nests fledging two young each. Two out of nine active Osprey nests were successful; the causes of nest failures was unclear. Four of the seven nest failures occurred in early June; the other three failures occurred later in the summer (late July/early August).

In 2016, we observed a notable number of shorebirds in the Revelstoke Reach drawdown zone during their fall migration. Most notably, we observed many Pectoral Sandpiper using our study sites, far exceeding previous counts observed for this species in previous years. The unusually low water levels allowed CBA to monitor shorebird activity at Cartier Bay, which was commonly selected by several shorebird species. A relatively large number of waterfowl also made use of the Revelstoke Reach wetlands during the fall migration, which lasted until early December when the wetlands froze.

In this report, we summarized multi-year data on Short-eared Owl nesting activities. We show that their nesting and foraging habitat is likely to be inundated during the nesting season, and reflect that because of this, and in regards to the available empirical data on nest performance, the drawdown zone likely functions as an ecological trap, with the population representing a population 'sink'. As such, management actions that can make the drawdown zone less attractive, or less hazardous for nests, should be considered. A model indicated a strong negative relationship between the annual maximum water level, and the probability of nesting in the following year. This suggests that minor changes to reservoir operations could potentially reduce the risks associated with Short-eared Owls nesting in the drawdown zone: assure that the habitat is flooded fully each year, and they might be less likely to nest there the next year. Our discussion largely focusses on addressing all the Management Questions with regards to Short-eared Owl productivity.

In 2017, Year 10 – the final planned year for the CLBMON-40, we suggest that the project resources need to be carefully allocated to allow time for analysis and additional reporting. Some changes to field program are suggested.

KEYWORDS

BC Hydro, Water Licence Requirements, Arrow Lakes Reservoir, Revelstoke Reach, reservoir operations, waterbirds, waterfowl, shorebirds, Short-eared Owl, Northern Harrier, Osprey, Bald Eagle, wetlands, productivity, migration, water management, brood count, impoundment.

ACKNOWLEDGEMENTS

Many people have contributed greatly to the completion of Year 9 of the CLBMON-40 project. BC Hydro Water Licence Requirements sponsored the project. We thank Trish Joyce (BC Hydro) and Susan Pinkus (BC Hydro) for their management and support for this project.

CBA collaborates with the Okanagan Nation Alliance (ONA) for delivery of CLBMON-40, with ONA biologists and technicians providing field and technical support, and insight into the perspectives and protocols of the Syilx (Okanagan) people. Bruce Weaver of the Okanagan Indian Band and Kayla Williams of the ONA contributed to field studies. Al Peatt managed the ONA's involvement and provided a technical review of this report.

At the heart of this project is the data collection; we thank everyone who was involved with this task for their willingness, good attitudes and expertise. Devon Anderson, Corey Bird, Catherine Craig, Ryan Gill, Harry van Oort, Bruce Weaver, and Kayla Williams conducted field studies on waterbirds, shorebirds and raptors. Ryan Gill and Harry van Oort conducted aerial surveys. We would like to thank Selkirk Mountain Helicopters for providing exceptionally safe and consistent piloting on aerial surveys, and personnel at BC Hydro Aircraft Operations for helping to assure that our flying was performed in safe flying conditions. Harry van Oort and John Cooper co-managed this project. Suzanne Beauchesne provided logistical coordination to assure that the resources and staffing were in place.

Analysis and report writing was primarily the work of Harry van Oort. Additionally, Ryan Gill provided GIS mapping for this report and conducted the mapping revision; Catherine Craig conducted the Osprey productivity analysis. Al Peatt improved this report by providing helpful review, edit, and critique.

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1 INTRODUCTION

The Columbia River is one of the most modified rivers 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 (Mica Dam, 1973), Lake Revelstoke (Revelstoke Dam, 1984) and Arrow Lakes Reservoir (Hugh Keenleyside Dam, 1968). Following the completion of these projects, few areas of natural riparian habitats and wetlands remained[1]. 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). In the upper elevations of the drawdown zones, the growth of riparian and wetland vegetation is possible, but such habitats are currently uncommon (Enns et al. 2007, Hawkes et al. 2007).

At the north end of the Arrow Lakes Reservoir (ALR), Revelstoke Reach (Figure 1-1) provides a relatively high concentration of productive wetland habitat, including a reservoir-altered bog, an extensive and diverse cattail/bulrush marsh, and several ponds. The rarity of such habitats[1] in the landscape makes Revelstoke Reach an area of great regional importance for wetland wildlife (Tremblay 1993, Jarvis and Woods 2001, CBA 2013a).

During the Columbia River Water Use Planning process, a number of potential impacts from reservoir operations on waterbirds in Revelstoke Reach were identified as key wildlife management concerns by the Consultative Committee (BC Hydro 2005). As a result, this Water Licence Requirements study (CLBMON-40) was developed to improve understanding of how reservoir operations affect waterbirds in Revelstoke Reach.

Through this consultative process, the operation of ALR was identified as having a potential impact to the availability and quality of habitat in Revelstoke Reach for waterbirds (e.g., loons, grebes, waterfowl, raptors, and shorebirds). Prior to this study, how reservoir operations influence waterbird use of the drawdown zone had not previously been studied in detail, and the relationship between reservoir operations and habitat quality was poorly understood. Habitat quality for waterbirds varies greatly as a direct function of the reservoir's water elevations because vegetation cover and foraging substrates may be exposed or submerged, and fluctuating water depth affects foraging opportunities for waterbirds (Rundle and Fredrickson 1981, Parsons 2002).

While the synthesis of the long-term dataset will occur in the tenth and final year of this project, we have greatly increased our understanding of the impacts of reservoir operations on waterbirds over the last nine years, as documented in the annual reports. Years 1-5 saw a steady cohesion of methods and an evolution of some of the MQ's and hypotheses. The Year 5 report set the stage for many of the analyses to be completed in Year 10, and Years 6-9 have bolstered the already rigorous dataset. We now understand the importance of low elevation wetlands as stopovers for migratory waterfowl, despite

[1] It has been estimated that 7,700 ha of wetland habitat have been impounded in the Canadian portion of the Columbia basin (Utzig and Schmidt 2011). The wetlands in Revelstoke Reach 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 Kinbasket Reservoir.

these wetlands only functioning effectively when they are not inundated; that Osprey productivity is influenced by (among other factors) higher reservoir levels, which may be affect their ability to provision for their young; and shorebird migration patterns are unpredictable at a local scale, varying in diversity and abundance annually. Finally, in this report we answer the MQ's of CLBMON-40 for Short-eared Owl. In spite of a small dataset, reservoir operations have been shown to have a strong biological effect on Short-eared Owl productivity, likely through the effect on vole populations. While this warrants further study to bolster the statistical results, we are able to answer the MQ's for this species.

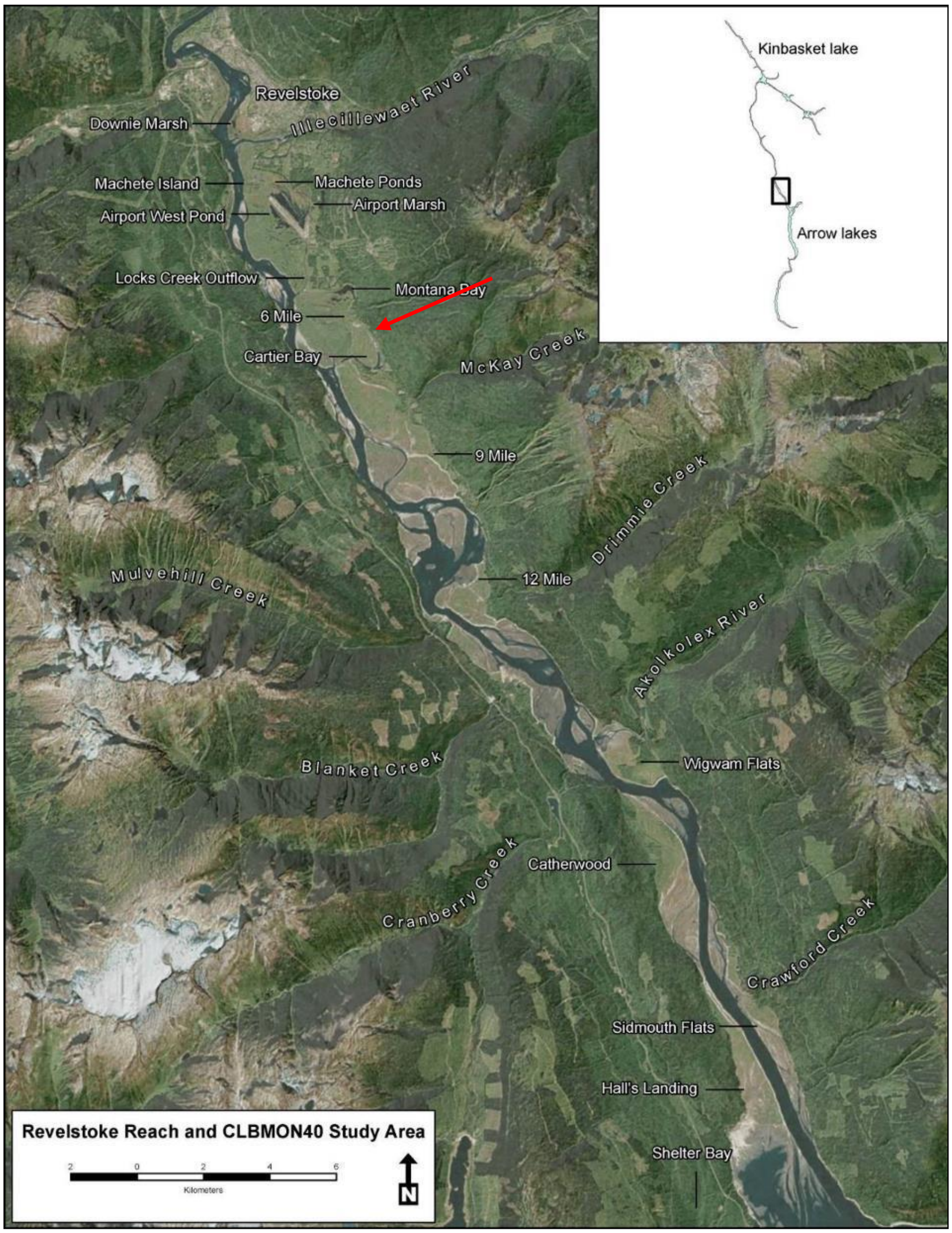

Figure 1-1: Overview map of Revelstoke Reach, with geographic features labelled. Note that this image shows the reservoir at very low levels; at full pool conditions, most of the valley bottom in this map becomes flooded. The red arrow points to Gawiuk Point where Short-eared Owl nested in 2016

1.1 Scope and objectives

CLBMON-40 will determine if and how reservoir operations affect waterbirds, and if the effects are negative, seek ways to mitigate those effects if necessary. The specific objectives of the 10-year project are to:

- Determine the extent of use of Revelstoke Reach by waterbirds by determining their abundance, species richness, distribution, productivity, and patterns of habitat use.
- Inform BC Hydro on how reservoir operations affect waterbirds by monitoring their abundance, species richness, distribution, productivity, and patterns of habitat use over time.
- Determine whether minor adjustments can be made to reservoir operations to minimize the impact on waterbirds or whether mitigation strategies are required to reduce the risks to these populations from reservoir operations.
- Provide the data necessary to inform how physical works projects may enhance waterbird habitat in Revelstoke Reach.
- Provide the data necessary to evaluate whether physical works projects or revegetation initiatives enhance waterbird habitat in Revelstoke Reach.

1.2 Management questions

To meet the above objectives, 11 management questions (research questions) were composed[2]:

1) What is the seasonal and annual variation in the abundance and spatial distribution of waterbirds within Revelstoke Reach during migration?

2) What implication does the year-to-year or within-year operations of Arrow Lakes Reservoir have on resident and migratory shorebird and waterbird populations?

3) Which habitats and wetland features within the drawdown zone in Revelstoke Reach are utilized by waterbirds and what are their characteristics (e.g., foraging substrate, vegetation, elevation and distance to waters edge)?

4) What is the annual variation in summer productivity (reproduction) of waterbirds in Revelstoke Reach and do indices of waterbird productivity vary spatially (e.g., are there areas of higher waterbird productivity)?

5) Which waterbird species have the greatest exposure to being highly impacted by reservoir operations?

6) Do reservoir operations (e.g., daily and maximum monthly water levels) influence the distribution and abundance of waterbirds and shorebirds in Revelstoke Reach?

7) To what extent do water levels in Arrow Lakes Reservoir influence indices of waterbird productivity in Revelstoke Reach?

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[2] These were revised in 2015 to improve clarity.

8) Can minor adjustments be made to reservoir operations to minimize the impact on migrating waterbirds or on indices of waterbird productivity?

9) Can physical works be designed to mitigate any adverse impacts on migrating waterbirds or on indices of waterbird productivity resulting from reservoir operations?

10) Does revegetating the drawdown zone affect the availability and use of habitat for waterbirds in Revelstoke Reach?

11) Do physical works projects implemented during the course of this monitoring program increase waterbird abundance, or species richness, or indices of waterbird productivity?

1.3 Management hypotheses

From the above management questions, several management hypotheses were outlined by BC Hydro for testing by the CLBMON-40 research[3]:

H1A: Reservoir operations do not result in decreased species richness in waterbirds utilizing the drawdown zone.

H1B: Reservoir operations do not result in a decrease in the abundance of waterbirds utilizing the drawdown zone.

H1C: Changes in the distribution of waterbird distribution in Revelstoke Reach are not attributable to reservoir operations.

H1D: Reservoir operations do not result in a decrease in indices of productivity of waterbirds utilizing the drawdown zone.

H2A: Annual variation in reservoir water levels or reservoir operations do not result in a reduction or degradation of waterbird habitats.

H2B: The implementation of soft constraints does not result in a reduction or degradation of waterbird habitats.

H2C: Rev 5 does not result in a reduction or degradation of waterbird habitat.

H3A: Revegetation does not result in an increase in the species richness or abundance of waterbirds utilizing the drawdown zone.

H3B: Wildlife physical works do not result in an increase in the species richness or abundance of waterbirds utilizing the drawdown zone.

H3C: Revegetation does not increase indices of productivity of waterbirds utilizing the drawdown zone.

H3D: Wildlife physical works do not increase indices of productivity of waterbirds utilizing the drawdown zone.

H3E: Revegetation does not increase the amount of waterbird habitat in the drawdown zone.

H3F: Wildlife physical works do not increase the amount of waterbird habitat in the drawdown zone.

[3] These were modified in 2015 to enhance clarity.

The monitoring program designed to address these objectives/questions/hypotheses—CLBMON-40—was initiated in 2008. The research program was designed, using several approaches, to determine the effect of reservoir operations (water level management) on the abundance, distribution, and productivity of waterbirds and to assess and inform physical works wildlife habitat enhancement projects. Progress to date and an account of outstanding issues are reviewed in Appendix 7-1. Multi-year analyses of the 5 Year datasets were presented in the recent interim report (CBA 2013a).

This report includes results from the spring, summer and fall of Year 8 (2015).

1.4 Study area

Revelstoke Reach extends north of Shelter Bay/Beaton Arm, to the Revelstoke town site, and is bounded by the Monashee and Selkirk Mountains to the west and east respectively (Figure 1-2). This area lies within the “interior wet belt” of British Columbia (ICHmw2 and ICHmw3) and receives much precipitation as snowfall delivered by Pacific frontal systems in winter (Meidinger and Pojar 1991).

The Columbia River flows south along Revelstoke Reach from the Revelstoke Dam towards the Arrow Lakes Reservoir. Most parts of Revelstoke Reach are impounded by the reservoir when the pool elevation is maximized, which occurs during the summer in most years (Figure 1-1, Figure 1-2). When water levels are sufficiently low (e.g., in winter and spring), Revelstoke Reach consists largely of a level floodplain vegetated primarily by reed canarygrass (*Phalaris arundinacea*) and sedges (*Carex* spp.). The subtle topography of the valley floodplain was shaped by the erosion and deposition of material from the Columbia River, and contains oxbow features, back channels, gravel shoals and sand banks. Historically, this area was naturally forested by western redcedar (*Thuja plicata*), Engelmann spruce (*Picea engelmannii*), white pine (*Pinus monticola*) and black cottonwood (*Populus balsamifera*). Prior to the completion of the Hugh Keenleyside Dam near Castlegar, Revelstoke Reach was cleared for farming and contained the Arrowhead branch of the Canadian Pacific Railway. The old roads and rail grades influence the hydrology of the study area in some locations.

Permanent wetlands are primarily situated at the northern end of Revelstoke Reach. They include several natural and human-made ponds, a large cattail marsh near the Revelstoke Airport (Airport Marsh, Figure 1-3) and a bog wetland in Montana Bay. Cartier Bay contains an oxbow lake. These three wetlands are situated at different elevations (between 433 and 438 m ASL). There are many small flooded depressions scattered throughout the study area. The Revelstoke Reach floodplain gradually decreases in elevation towards the southern end of the reach; therefore, the south end is flooded for longer periods and is more sparsely vegetated than the northern end. Extensive tracts of non-vegetated habitat (sand or silt) are present at low water levels (Korman 2002).

Figure 1-2: Revelstoke Reach in spring. Drawdown wetland habitat is visible near the Revelstoke Airport (left). With the exception of the airstrip, the drawdown zone is well defined in this photo as the habitat between the coniferous forests on either side of the valley

Figure 1-3: The Airport Marsh is comprised of extensive tracts of cattail and sedge and many bulrush "islands". It is flooded by about 90 cm of reservoir water in this photo

1.5 Arrow Lakes Reservoir operations

The Arrow Lakes Generating Station adjacent to the Hugh Keenleyside Dam is a relatively small component of the Columbia generation system; the ALR is operated primarily by BC Hydro for downstream flood control and power generation in the US. Reservoir surface elevation is influenced by precipitation and spring climate (rain, snow, and freshet), and controlled by discharge from the Mica and Revelstoke Dams upstream, and by outflow from the Hugh Keenleyside Dam and Arrow Lakes Generating Station. The reservoir is licensed to operate between elevations of 418.6 m and 440.1 m. With approval from the Comptroller of Water Rights, the maximum allowable level is 440.75 m. Since 1968, the typical operation of Arrow Lakes Reservoir has involved storing water during the spring freshet and drafting the reservoir in fall and winter. Consequently, the reservoir elevation cycles annually, with high water levels in summer and low water levels in late winter/early spring.

2 METHODS

A brief description of the methods used for CLBMON-40 is described below. Comprehensive methods are provided in an annual protocol report written primarily for field technicians (CBA 2015).

CLBMON-40 is characterized by six types of waterbird surveys that occur annually at various times of the year (Figure 2-1):

1. land-based waterbird surveys in spring, during the brood rearing season, and in fall;
2. aerial waterfowl surveys in spring and/or fall;
3. land-based shorebird surveys during the fall migration;
4. boat-based shorebird surveys during the fall migration;
5. productivity monitoring of Bald Eagles and Ospreys (nest monitoring); and
6. productivity monitoring of Short-eared Owls and Northern Harriers (nest monitoring).

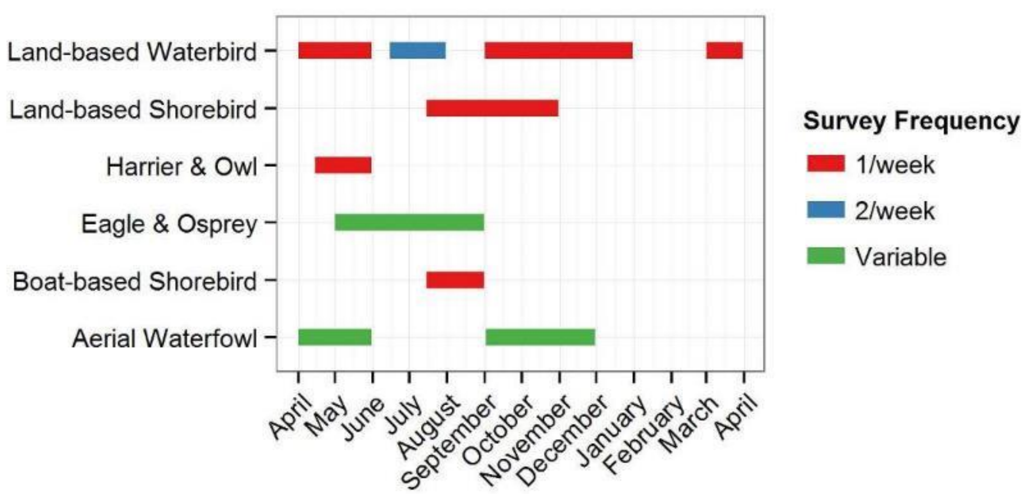

Figure 2-1: **Overview of how the six CLBMON-40 monitoring surveys are scheduled. Data from the two types of shorebird surveys can be combined as one data set during weeks when both surveys take place**

2.1 Land-based waterbird surveys

Land-based surveys monitor seasonal and spatial usage of waterbirds within the most important wetlands (Figure 2-2).[4] Weekly land-based waterbird surveys are typically conducted for eight weeks in the spring (April and May) and resumed in September until the wetlands freeze, usually in November. In previous years, weekly surveys also took place in November through March but very few observations were made during these winter months, so this practice was discontinued. However, in the warmer spring of 2016, the surveys commenced in late March to capture the period of ice break up. Waterfowl are the primary monitoring target for these surveys, but all waterbirds are monitored.

Observations were made from fixed observation stations. During each survey, the group size, species, and location of all waterbirds visible from each station were recorded and mapped on field maps as points or polygons. The activity of the waterbirds (e.g., foraging, roosting, preening, etc.) and the type of habitat they were using was also noted. A minimum of five minutes was allocated to scan for waterfowl, but the amount of time spent at each station varied considerably due to the high variability in the time required to identify and count waterbirds and map their locations. Upon completion of the field survey, the maps were digitized and the data were entered into the database.

2.2 Aerial waterfowl surveys

Helicopter-based aerial waterfowl surveys occurred opportunistically to capture data when migration intensity was high, and to build a database of distributions over a range of reservoir elevations (weather conditions permitting). All aerial surveys covered the entire study area. All observations of waterfowl were assigned to one of 129 habitat polygons. Aerial waterfowl surveys followed the methods outlined by the Resource Inventory Standards Committee (Resource Inventory Committee 1999). Two personnel were required for these surveys: one observer and one recorder. A Eurocopter Astar B2 helicopter was used. The observer was seated next to the pilot, and navigated with the aid of a global positioning system (GPS; model Garmin Map76CSx) and laptop computer for real-time tracking and navigation using DNRGarmin extension for ArcView 3.3. The observer made a complete count of waterfowl within the polygons. Waterfowl were identified to species when possible but were not sexed.

Over the course of CLBMON-40 study, gaps in the aerial waterfowl dataset have become fewer, and less significant; as in 2015, aerial surveys were only conducted when opportunities allowed data gaps to be filled (e.g., at reservoir elevations not previously observed). The flying budget was prioritized for Osprey monitoring in 2016.

2.3 Shorebird surveys

Shorebird surveys were conducted during the fall migration period (July 15 to October 31). Shorebird observations were recorded and mapped as points or polygons. Surveys occurred once per week, and always monitored the same sites. The sites were chosen

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[4] "Important wetlands" are those used by a large percentage of waterbirds on a regular basis, and those that may be modified by physical works. Accessibility sometimes limited the opportunity for land-based surveys, so some or parts of some important wetlands could not be monitored in this survey. Aerial surveys (see below) were used to collect habitat selection data across the entire study area.

based on their suitability for shorebirds. We attempted to monitor all sites with high suitability, but also included many sites of moderate or marginal importance. Many sites could be accessed by land or kayak, depending on reservoir elevation. Other sites required powerboat access. Sites accessed by powerboat were surveyed over six weeks during the peak migration period. Land-accessed areas were surveyed over an extended time period, with the late-season surveys focussed on Dowitcher use of drawdown zone habitats.

All surveys involved two biologists. Power boat-based surveys also included a boat operator. The larger survey sites required multiple observation stations. Locations of survey stations were not entirely fixed: they changed somewhat in relation to the shoreline, which moved according to reservoir levels. Our goal was to make a complete census of the numbers of shorebirds present in the surveyed habitats on each survey occasion. This can be challenging in a reservoir system where habitats and shorelines keep moving or disappear altogether. When boats or kayaks were used, a spotting scope was not effective, so we also included a slow transect between survey stations to ensure all visible birds were detected.

At each station, two surveyors scanned all appropriate habitats in order to make a complete count of shorebirds. The species, number of birds, behaviour and habitat being used were recorded for each group of shorebirds detected. Locations were recorded on field maps and were digitized during data entry. All shorebirds observed were identified to species whenever possible.

Shorebirds observations were also recorded during other CLBMON-40 surveys.

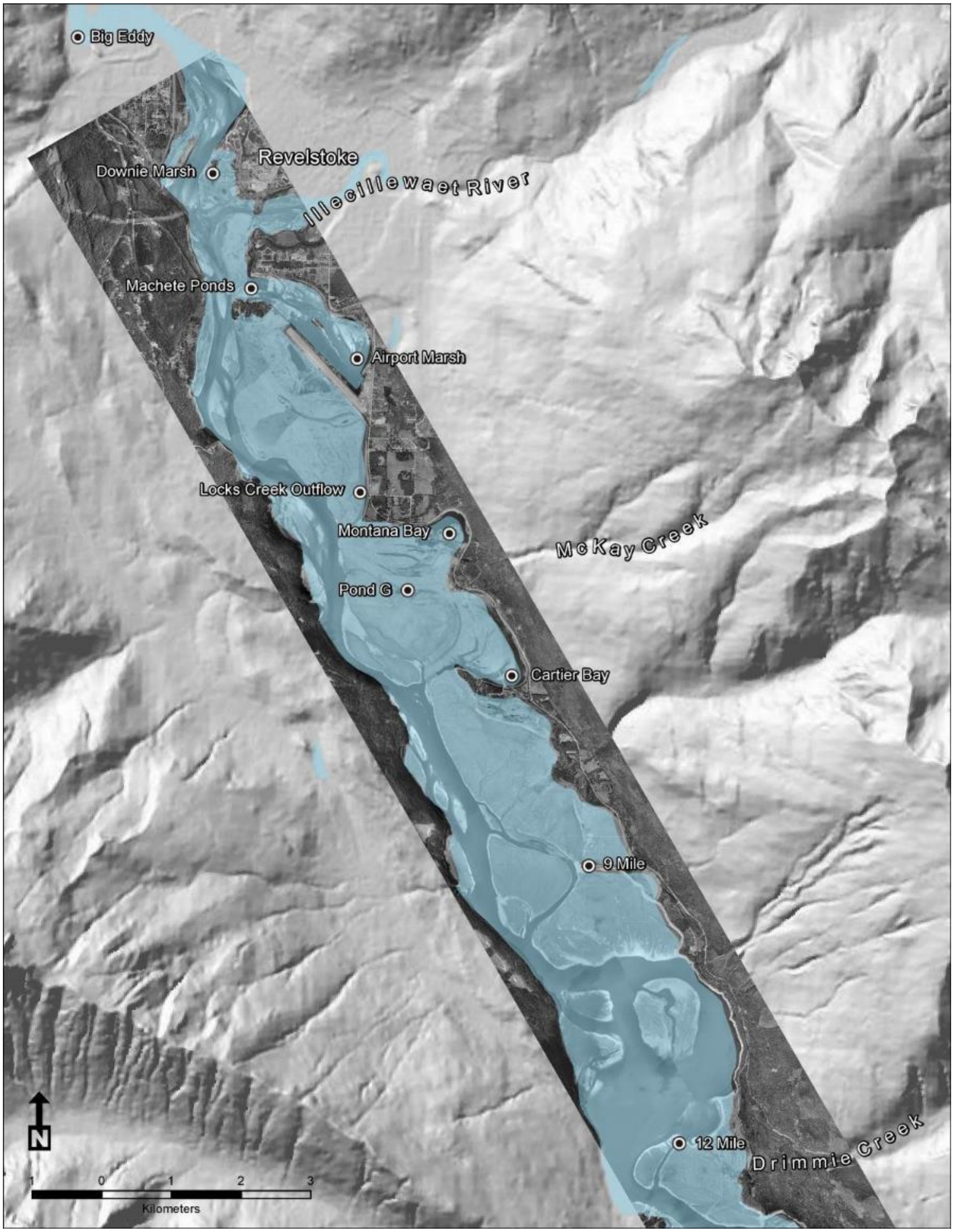

Figure 2-2: Locations of wetlands in Revelstoke Reach where land-based waterbird surveys and brood surveys were conducted are represented by points. Some of these wetlands were monitored by multiple fixed-observation stations

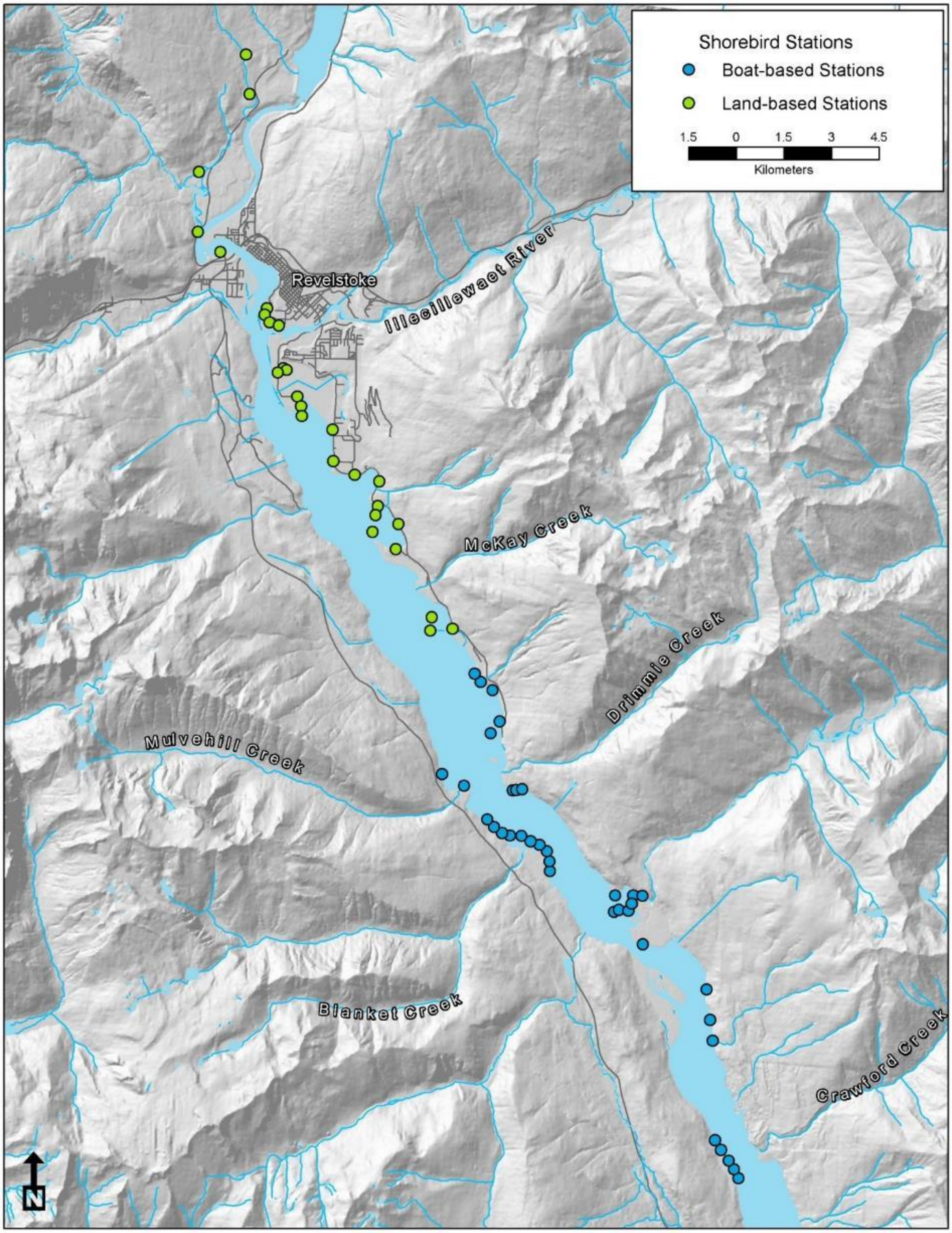

Figure 2-3: Locations of shorebird observation stations in Revelstoke Reach

2.4 Productivity monitoring of waterfowl

Waterfowl brood count surveys, a component of the land-based waterbird surveys, were conducted during a six-week period from June 15 to July 30. The brood monitoring period began after earliest brood emergence (primarily Canada Goose and occasional Mallard) but surviving broods of these species were still easily counted. The brood monitoring season extended late enough to monitor late brood emergences from re-nesting birds. Surveys were conducted twice per week. The methods and locations used for the waterfowl brood count surveys were identical to those for the land-based waterbird surveys (Section 2.1), but for the brood count surveys, the number of broods, and the size and age of broods was also recorded (Gollop and Marshall 1954). Waterfowl 'young' that were a similar size as their parents were classified as 'juveniles'. Multiple broods of Canada Goose young were often grouped together, which made individual broods impossible to count; therefore, the total number of young and attending adults were counted. The number of broods was estimated based on the number of adults attending these groups (e.g., 18 young attended by 6 adults = 3 broods). We did not attempt to count the number of broods of Canada Goose young classified as juveniles because they are more challenging to age at distance, and tend to socialize in very larger groups, making brood counts unreliable.

2.5 Productivity monitoring of Bald Eagle and Osprey

Monitoring the productivity of Bald Eagles and Ospreys involved locating their nests, and monitoring the nests to determine nesting activity and outcome of each nesting attempt (nest success and the number of young fledged). Nests were considered successful if at least one young fledged or grew to full size.

A Eurocopter Astar B2 helicopter was used to assist with nest checks and nest searches. Many nests were first identified and mapped in earlier years (2008 until the present year), but searches for new nests were conducted annually. Both species re-use nests in consecutive years. In 2016, we conducted a search for new nests and checked known Bald Eagle nests on April 28. Prior to nest search surveys, the coordinates of known nest sites were compiled and uploaded into a hand-held GPS (model Garmin Map76CSx). Two observers, positioned on the same side of the helicopter (slope side), conducted the surveys. The survey area included the shoreline and slopes above the entire Revelstoke Reach study area. Previously known nests were checked, and searches for new nest sites were conducted using a meandering transect over appropriate habitats situated immediately above the reservoir. When new nests were located, the coordinates and other details were recorded on a nest observation form. Nest monitoring was conducted throughout the breeding season until active nests failed or nestlings fledged.

Nest monitoring for Bald Eagle and Osprey began on June 16. A total of 10 nest monitoring surveys were completed in 2016; these surveys were conducted approximately one per week during late June and though July. The final survey occurred on August 18.

On all nest monitoring occasions, observers recorded the location of the adults, as well as the nesting behaviour (i.e., incubating or brooding), and number of eggs, nestlings and fledglings. One or more of these data were used to determine if the nest was active.

2.6 Productivity monitoring of Short-eared Owl and Northern Harrier

Short-eared Owl and Northern Harrier may occasionally nest in the drawdown zone of Revelstoke Reach (Jarvis 2006). We attempted to monitor productivity of these species by surveying the entire suitable part of the study area (i.e., all grasslands north of Drimmie Creek) divided into five monitoring regions. Each region was surveyed at least twice during the breeding season, where we spent a minimum of 30 minutes scanning for both species during each visit. Nesting activity of these species was unlikely to go unnoticed given other types of field work (bird nest searching and monitoring under CLBMON 36) occurring in the areas.

If owls or harriers were observed in a region, we continued monitoring for a minimum of one hour for signs of nesting activity, and later made additional area visits to assess breeding activity. Additional monitoring effort was concentrated in the area south of Machete Island where Short-eared Owl and Northern Harrier are known to nest and have been repeatedly observed each year. In this area, we spent a minimum of one hour at sunrise and/or at sunset twice per week monitoring for owl and harrier nesting activity.

Both Short-eared Owl and Northern Harrier nest on the ground (Macwhirter and Bildstein 1996, Wiggins et al. 2006) and locating nests of either species is challenging. If nesting of either of these species was suspected, systematic grid search searches would be initiated in the most likely area. If located, nest monitoring was conducted on a weekly schedule, taking care to minimize disturbance to the birds.

Surveys were performed by two observers (at dawn and dusk) once per week from mid-April until the end of May.

2.7 Analytical methods and multi-year analyses

All statistics, graphing and data manipulation were performed with R (R Core Team 2014).

2.7.1 Osprey productivity

CLBMON-40 is concerned with the impacts that reservoir operations have on waterbirds, including the reproductive success of certain raptors such as the Osprey. We previously identified that annual variation in Osprey nest success was correlated with variation in reservoir operations and June rainfall (CBA 2015). In this report, we provide an analysis that is further updated with the 2016 data. We fit fixed slope linear and/or exponential functions [y ~ log(x)] to assess possible predictors of nesting success in addition to considering, relationships. Model fit, strength and significance was assessed by plotting residuals versus fitted values and comparing the regression lines, adjusted R^2 values, P-values, and AICc.

2.7.2 Short-eared Owl productivity

We examined the frequency of inundation of nesting habitat (mean nest elevation) during the past ALR operations.

Nest records were summarized to determine measure of nesting success. Initiation dates of owl nests were calculated from hatch dates assuming an incubation period of 25 days (Wiggins et al. 2006) or from direct observation of laying sequence. We calculated the daily survival rate (DSR) from the nest observation data (5 nests) using a basic null model in the Bayesian framework (Royle and Dorazio 2008)[5]. We did not attempt to

[5] The model was fit using the R2winBUGS package (Lunn et al. 2000, Sturtz et al. 2005, Kéry 2010). The one parameter in the model was estimated with three chains, each of 10 000 Monty

predict variability in DSR (e.g., among years, over time, or as a function of nest age) due to the low number of nests in our data.

CBA monitored Short-eared Owl nesting status under CLBMON-40 since 2008 (9 years). Additionally, there were two years prior to this project when the species was known to nest: 2001 and 2002. As such, there were 11 years for which we knew whether the species was nesting. In addition to examining nesting performance and the potential for the reservoir to flood nests, we wished to see what local conditions might affect nesting decisions. For each year of known nesting status, we compiled data on four possible predictor variables:

1. Maximum ALR Elevation (MALR). The annual maximum reservoir elevation recorded during the previous year.
2. Minimum Winter Temperature (MinTemp). The minimum temperature recorded during the previous winter (November through March) at the Revelstoke airport weather station.
3. Average Daily Winter Temperature (AveTemp). The average daily temperature recorded during the previous winter (November through March) at the Revelstoke airport weather station.
4. Snowfall (Snow). Snow accumulation during the previous winter, recorded by the city of Revelstoke.

A correlation matrix was used to assess correlations among nesting predictors. We then applied uni-variate logistic regression models to test individual predictors of nesting. Data were too sparse to consider fitting multi-variate regressions.

2.8 Permits

No specific permits were required or obtained for this study.

3 RESULTS

3.1 Annual results

3.1.1 Water levels in Arrow Lakes Reservoir

The ALR water elevations were higher than usual during the rising limb of the hydrograph in spring, but because the spring storage phase of the reservoir ended early (June 12), an unusually low annual maximum pool elevation was reached in 2016 (437.2 m asl). Low water levels continued and reservoir elevations were atypically low through the fall (Figure 3-1).

3.1.2 Weather

Spring was unusually warm in 2016 (Figure 3-2) followed by a relatively cool summer with steady precipitation (Figure 3-3). Due to the warm spring, the snow and ice diminished quickly in spring causing a comparatively early thaw of the wetlands (Figure 3-4).

Carlo iterations, but we removed the first 1000 iterations as the chain convergence “burn-in” which was checked graphically and found to be adequate (Kéry 2010).

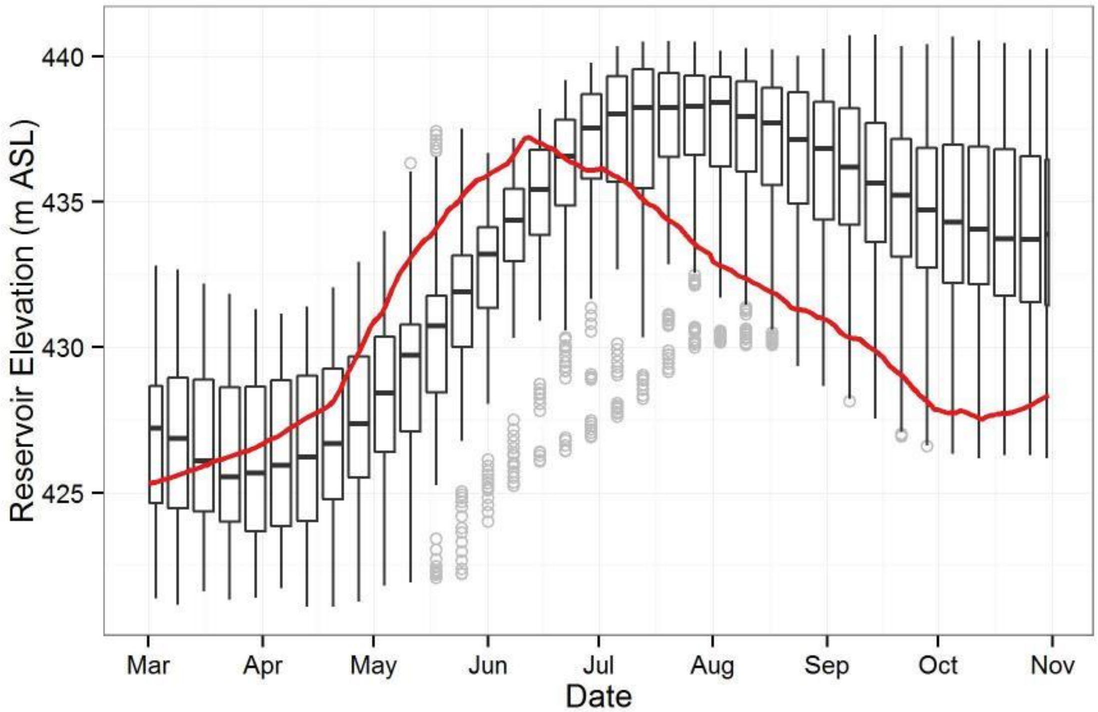

Figure 3-1: **Elevation of the Arrow Lakes Reservoir from March 1 to October 31, 2016 is plotted in red; the historical range of values is plotted in weekly intervals as boxplots**

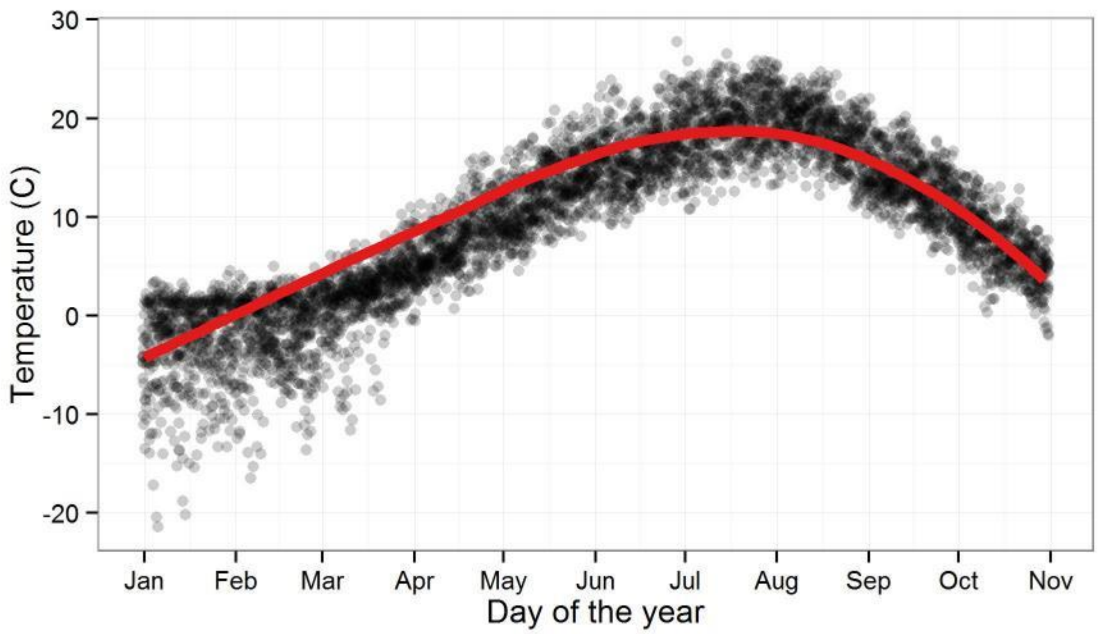

Figure 3-2: **Mean daily temperatures observed during the study. The 2016 data are illustrated by the red line**

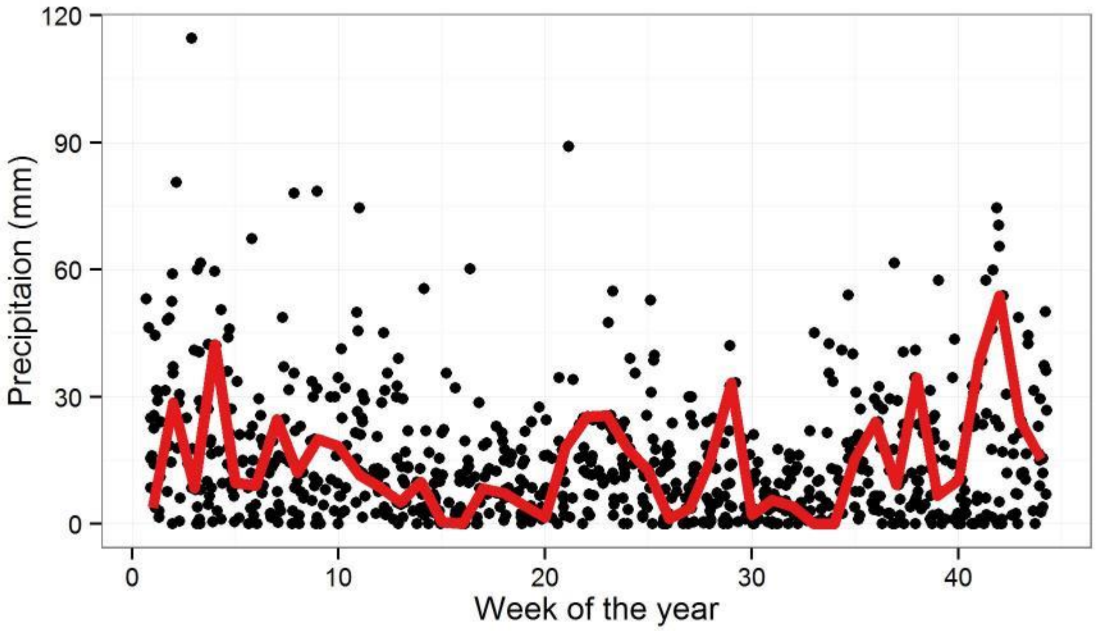

Figure 3-3: **Weekly precipitation observed during the study. Values recorded in 2016 are represented by the red line**

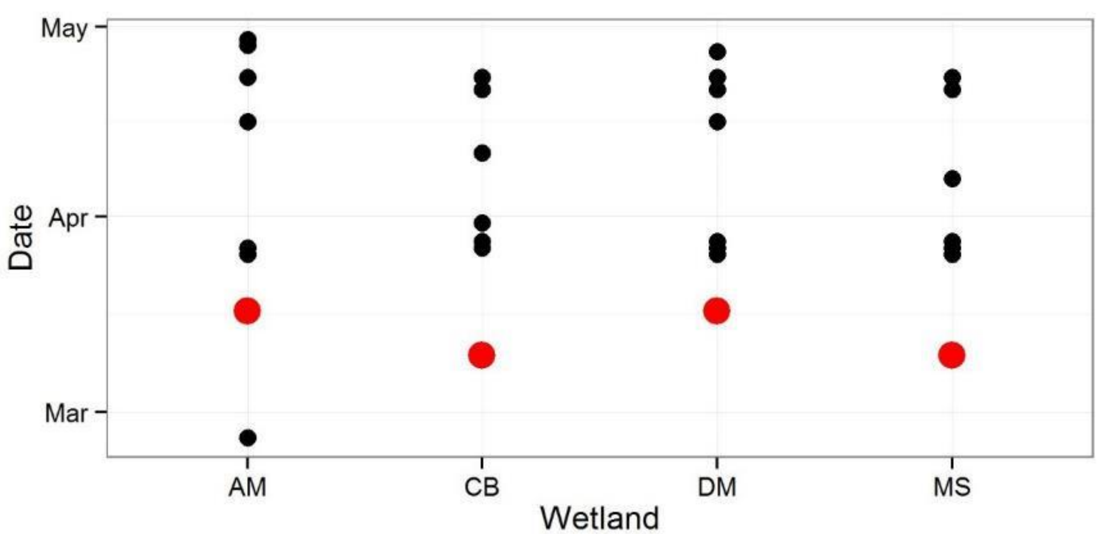

Figure 3-4: **Comparison of dates when the Airport Marsh (AM), Cartier Bay (CB), Downie Marsh (DM) and Montana Slough (MS) were first observed to be ice free during land-based waterbird surveys (2009 to present). Ice-free dates from 2016 are graphed as red points**

3.1.3 Survey effort

In this report, we summarize work accomplished from March through October, 2016 but data from other months and years may be included for illustrative purposes.

Thirteen land-based waterbird surveys took place during the spring migration period. During the brood rearing period, 13 surveys were made. During the fall migration period, 15 surveys were completed by freeze-over in early December.

Two aerial waterfowl surveys were conducted in the fall (2016-10-03, 2016-11-18) during low reservoir elevations.

Seven surveys were conducted for monitoring Bald Eagle and Osprey productivity. Surveys for Short-eared Owl and Northern Harrier nesting took place in spring on 13 days.

Four boat-based shorebird surveys were completed, and 16 land-based shorebird surveys were completed during the fall migration prior to October 31. Low reservoir elevations limited the number of boat surveys in 2016 (Figure 3-5).

Figure 3-5: Low water levels in late summer 2016, as seen here at the Akolkolex River mouth (Wigwam), limited boating access and our ability to survey for shorebirds.

3.1.4 Waterfowl migration

With early spring melt, the migrant waterfowl passed through the study area relatively early and quickly (Figure 3-6). In the fall, the migration was well pronounced (Figure 3-7) with Mallard, American Wigeon and American Coot being the most numerous species using the various wetlands in Revelstoke Reach prior to winter freeze up; a table of species observed during land-based waterbird surveys can be found in Appendix 7-2.

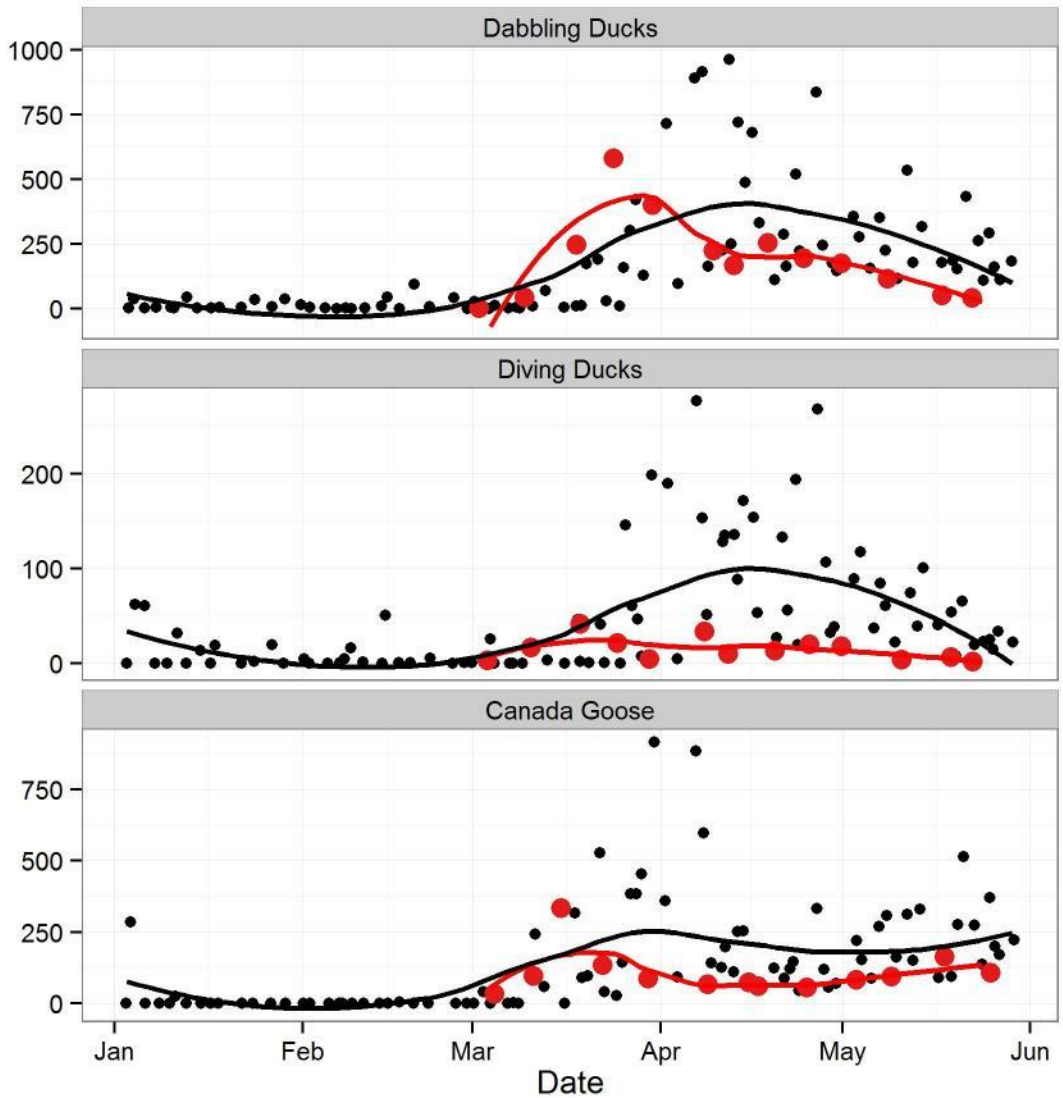

Figure 3-6: Spring 2016 waterfowl counts recorded at the wetlands monitored under the land-based waterbird survey (Downie Marsh, Airport Marsh, Locks Creek Outflow, Montana Slough, and Cartier Bay). Raw data points are plotted, with counts from the current year in red. A Loess smoother is fit to all data (black), and for the current year data (red) for illustrative purposes.

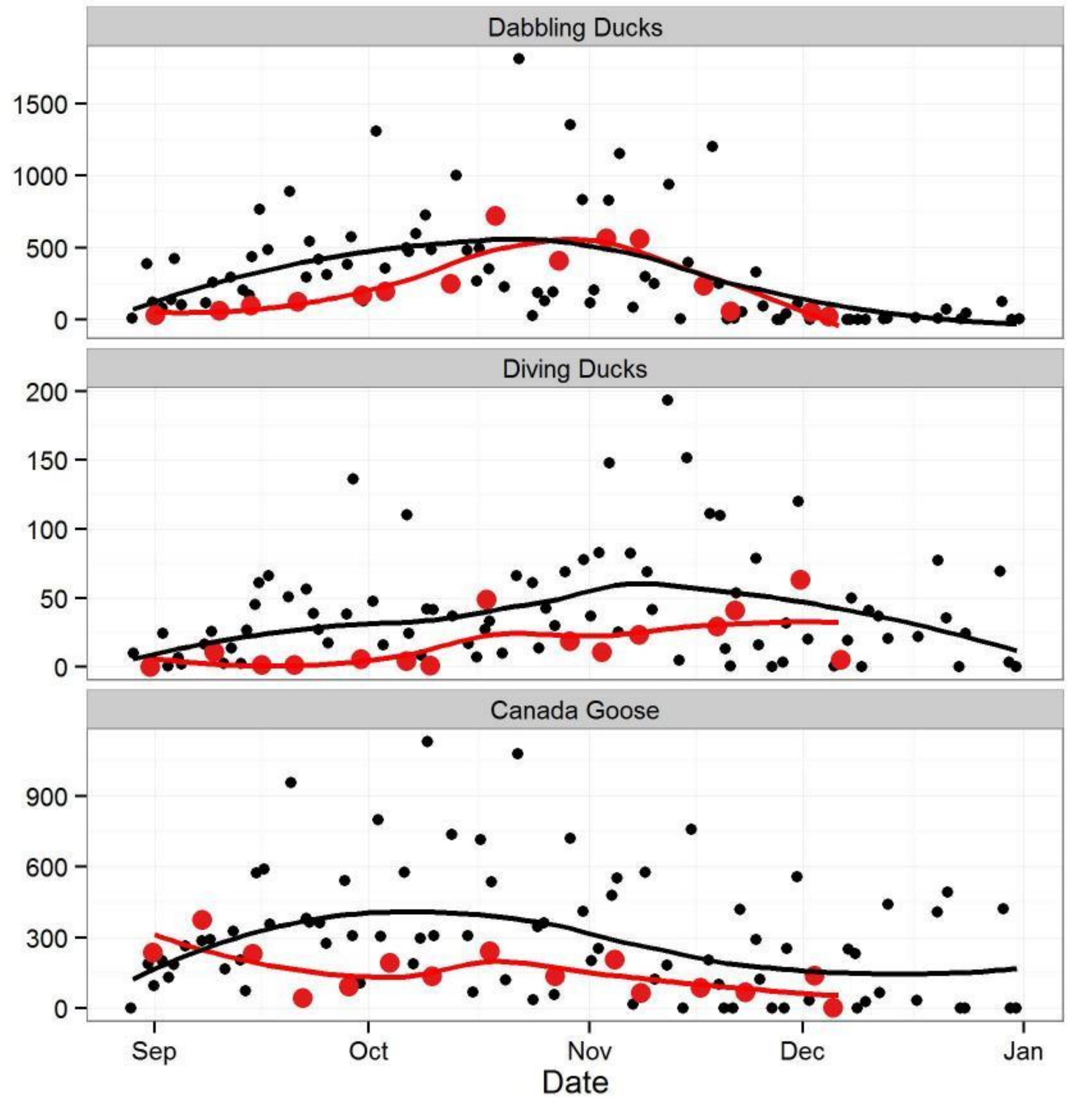

Figure 3-7: **Fall 2016 waterfowl counts recorded at the wetlands monitored under the land-based waterbird survey (Downie Marsh, Airport Marsh, Locks Creek Outflow, Montana Slough, and Cartier Bay). Raw data points are plotted, with counts from the current year in red. A Loess smoother is fit to all data (black), and for the current year data (red) for illustrative purposes**

3.1.5 Waterfowl productivity

Five species were observed with broods: Canada Goose, Mallard, American Wigeon, Wood Duck and Pied-billed Grebe. American Wigeon and Canada Goose broods were the most frequently observed. No more than one American Wigeon Brood was observed on any given survey day, but locations varied among surveys. As many as 15 Canada Goose broods were counted within a survey. Mallard broods were only observed on two occasions. Broods were recorded at Downie Marsh, the Machete Ponds, Airport Marsh, Airport West pond, Locks Creek, Montana Bay and Cartier Bay. The Wood Duck brood was observed at Montana Bay, and the Pied-billed Grebe brood was seen at Airport Marsh.

3.1.6 Raptor productivity

3.1.6.1 Short-eared Owl

Short-eared Owls were first observed on May 5, but were not observed again until May 24. Observations of this species became frequent at the end of the month and nesting was suspected. Under the companion WLR study on nesting birds, CLBMON-36, Short-eared Owls were monitored for nesting and the first nest was located at Machete South grasslands on June 9 (elevation = 436.1 m asl). This nest was, 341 m to the south of the 2010 nest site. A second nest with an incomplete clutch (laying stage) was found on the same day at a different site (Gawiuk Point; Figure 1-1) just north of Montana Slough (elevation = 436.3 m asl). Both nests were flooded by the reservoir over the following two days. Water levels peaked shortly after flooding these nests, and habitat was available to the owls during the remainder of the breeding season.

On June 30 another Short-eared Owl nest was found at higher elevation (437.3 m asl) in the Gawiuk Point area (laying stage). Finally, on July 7 one more nest was located at 12 Mile (elevation = 436.8 m asl). We suspect that there were just two nesting pairs of owls in 2016: the pair at Gawiuk Point, and a pair that moved to the 12 Mile territory following nest flooding at the Machete South territory. The two late nests failed, presumably due to predation.

3.1.6.2 Northern Harrier

One Northern Harrier pair nested in 2016. The initial nest was found on 30 May in the Gawiuk Point area (435.4 m asl). The nest was promptly flooded in early June. The pair then established another nest at a higher elevation which was found on 30 June (436.6 m asl; Figure 3-8). This second nest was successful (three fledged young).

3.1.6.3 Osprey

Two previously monitored Osprey nests were destroyed over winter, and three new Osprey nests were located during the nest search (Figure 3-9). Two of nine active Osprey nests were successful (Appendix 7-3). Four Osprey nests had failed by the first week of June, one failed in late July, and two others had failed by August 11. It was unclear what caused nest failures. One additional (non-active) nest had Osprey activity throughout the summer (perched adults), but these birds were never observed incubating.

3.1.6.4 Bald Eagle

We found two new Bald Eagle nests in 2016 (Figure 3-9). Seven active Bald Eagle nests were monitored, and all were successful with at least four nests fledging two young each (Appendix 7-3).

Figure 3-8: Clutch of three Northern Harrier eggs at Gawiuk Point in 2016. This nest replaced one that had flooded in early June at a lower elevation

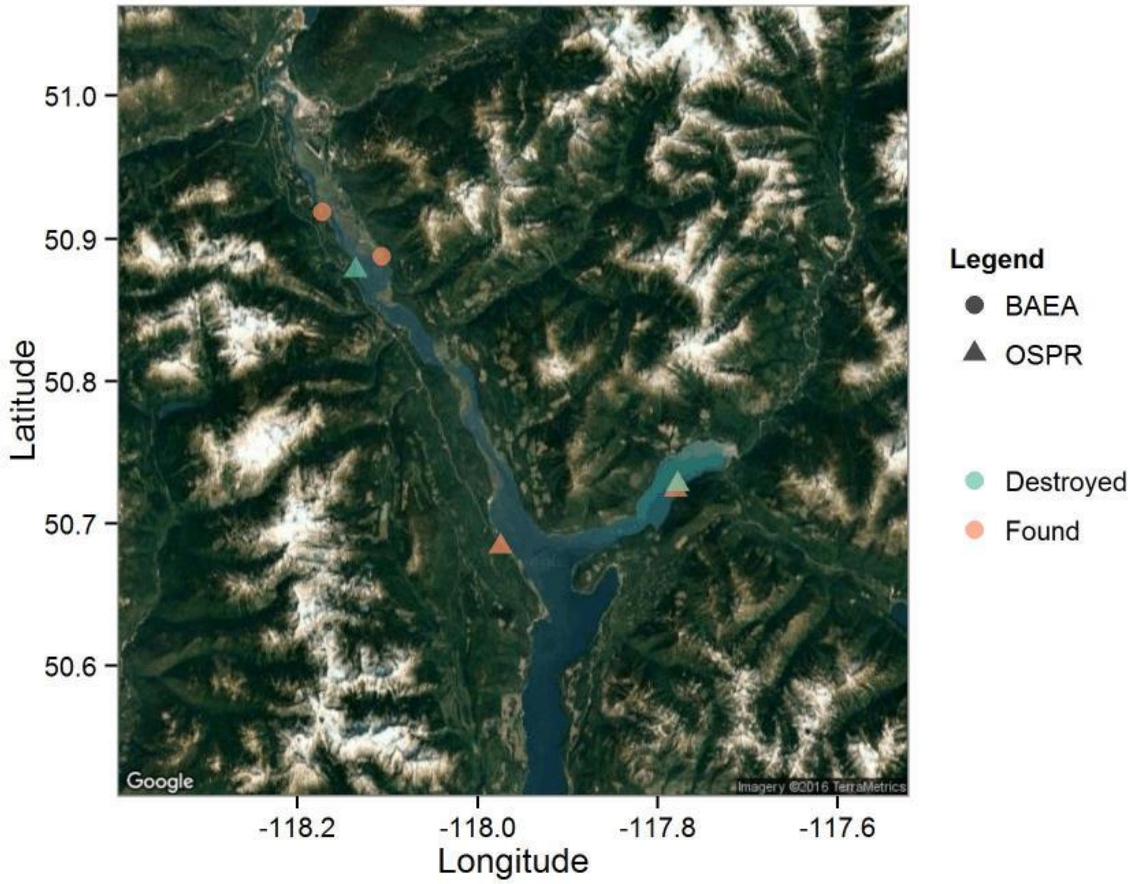

Figure 3-9: **Locations of Bald Eagle and Osprey nests that were either destroyed during the 2015/16 winter, or found during the 2016 summer**

3.2 Shorebird fall migration

Shorebirds were relatively abundant during the fall migration, and 11 species were observed. A summary of shorebird species detections is provided in Appendix 7-4. In 2016, we observed a relatively large number of Killdeer, Greater Yellowlegs, and Lesser Yellowlegs. Spotted Sandpipers were also numerous, but less so than in previous years. Our comprehensive surveys (weeks with both boat and land-based surveys) captured the primary migration period, which was consistent with the temporal pattern observed in previous years (Figure 3-10). Within the more numerous land-based surveys, we observed higher than normal shorebird counts (Figure 3-11), and the Dowitcher migration was consistent with previous years (Figure 3-12).

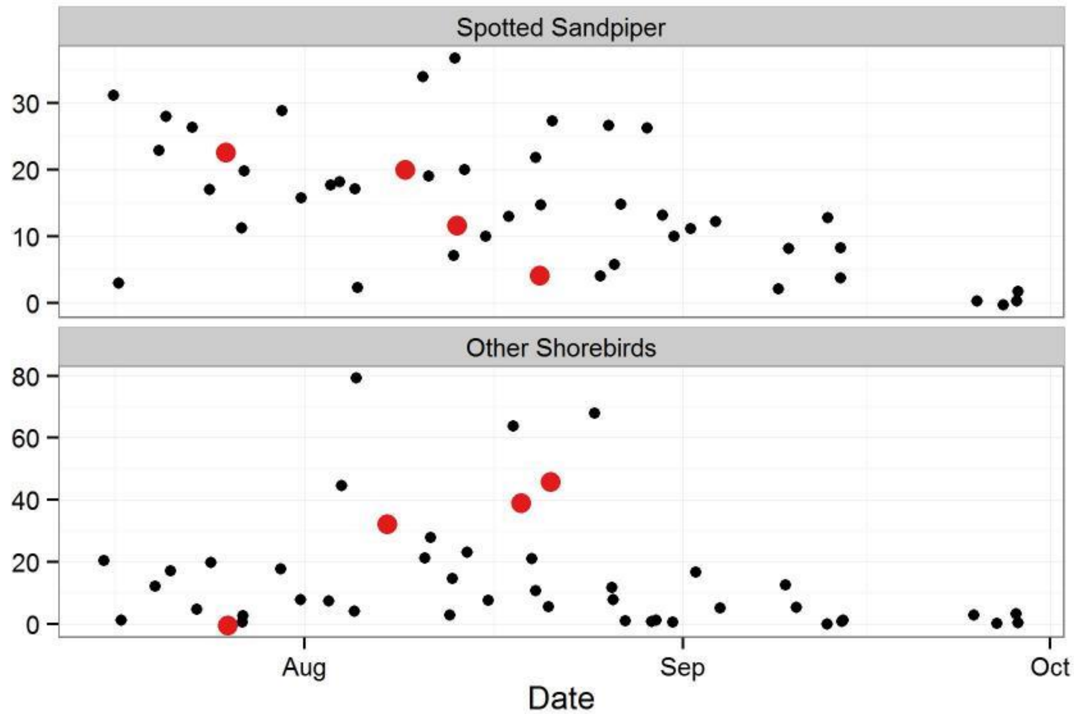

Figure 3-10: Fall 2016 shorebird counts recorded in weeks when both land-based and boat-based surveys were conducted. Data points from the current year are represented by enlarged red points

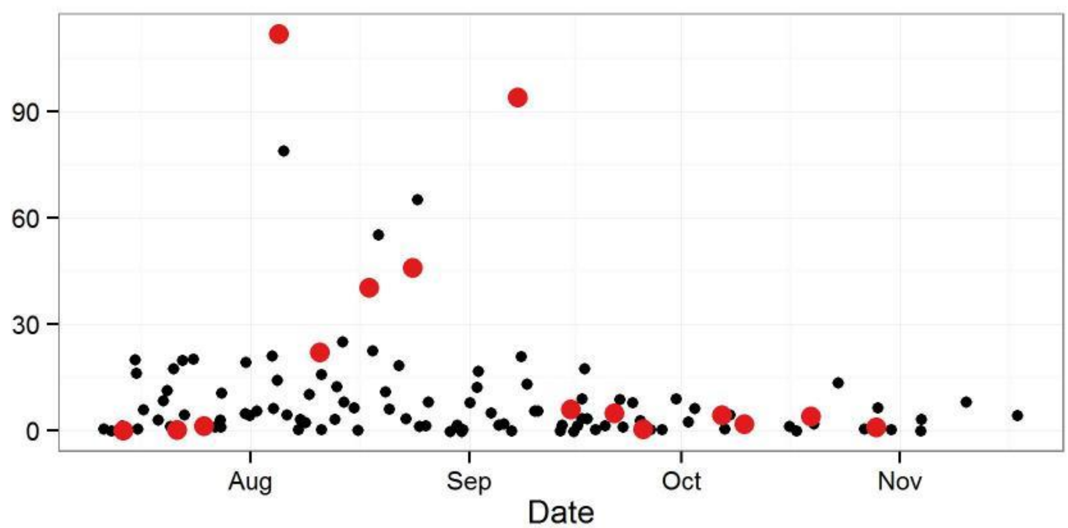

Figure 3-11: Fall 2016 shorebird counts recorded during land-based surveys. Plotted counts do not include Dowitchers or Spotted Sandpipers. Data points from the current year are represented by enlarged red points

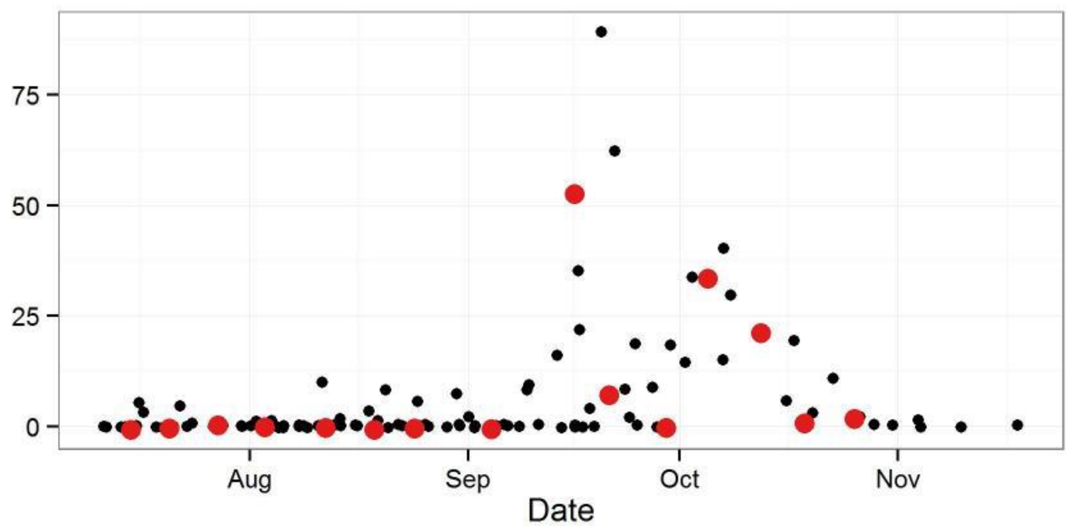

Figure 3-12: **Fall 2016 shorebird counts of Dowitcher recorded in land-based surveys. Data points from the current year are represented by enlarged red points**

3.3 Multi-year analysis

3.3.1 Habitat selection within wetlands

3.3.2 Osprey productivity

With the addition of one more year of monitoring Osprey, the negative relationship between productivity and June rainfall remained significant (Linear Model: adj. R^2 = 0.56, Slope = -0.008, P = 0.02, AICc = 11.8), but the significance of the negative relationship with maximum reservoir elevation was lost (Linear Model: adj. R^2 = 0.27, Slope = -0.15, P = 0.02, AICc = 15.9; Figure 3-13). The former model was improved when the log of the predictor was modeled (adj. R^2 = 0.65, Slope = -0.64, P = 0.01, AICc = 10.0; Figure 3-14).

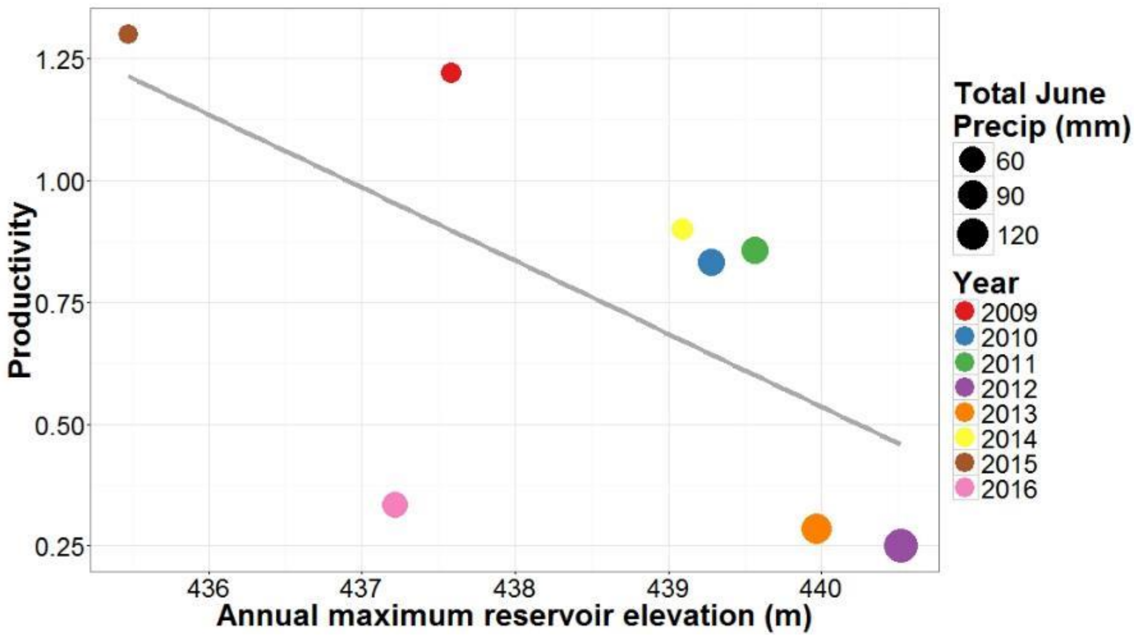

Figure 3-13: **Annual estimates of Osprey productivity in Revelstoke Reach (average number of fledged young per nest) plotted against the maximum elevation of the Arrow Lakes Reservoir**

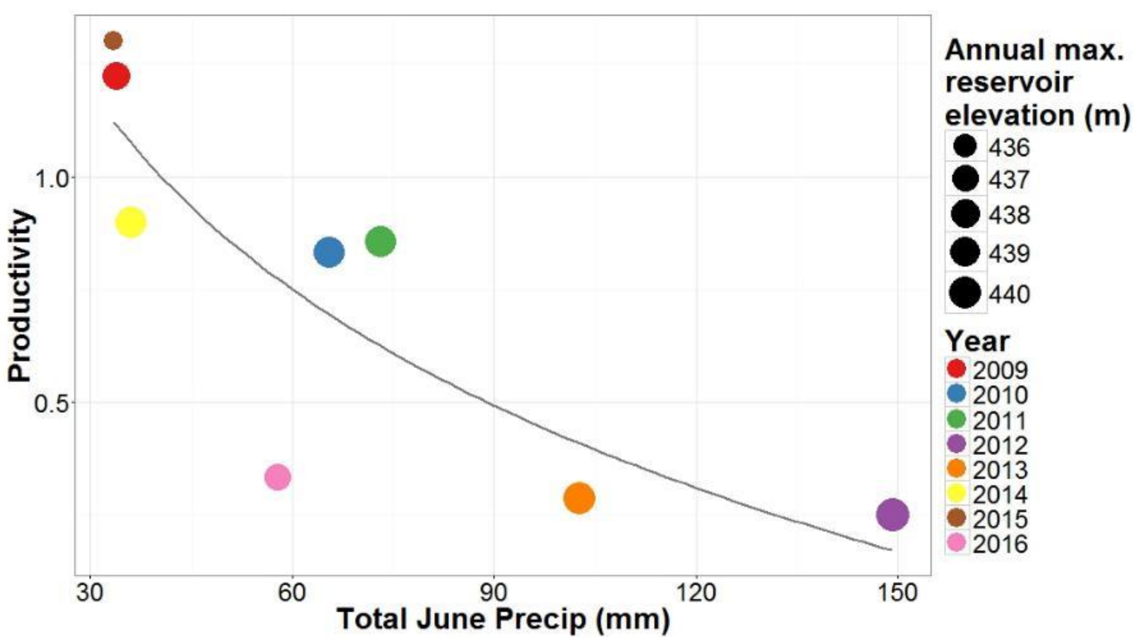

Figure 3-14: **Annual estimates of Osprey productivity Revelstoke Reach (average number of fledged young per nest) plotted against the cumulative rainfall in June.**

3.3.3 Short-eared Owls in the ALR drawdown zone

From 2008 through 2016, 94 observations were made of Short-eared Owl; 60 during dedicated surveys, 17 observations at active nest sites, and another 17 incidental observations during other field work. Together, these 94 observations took place on 53 different days, and in six different months (April, May, June, July, October, November). There were two years when Short-eared Owls were not observed (2008 and 2009). The observations mostly took place in spring (Figure 3-15). From our observations, we delineated polygons which we considered to be suitable Short-eared Owl habitat (Appendix 7-5).

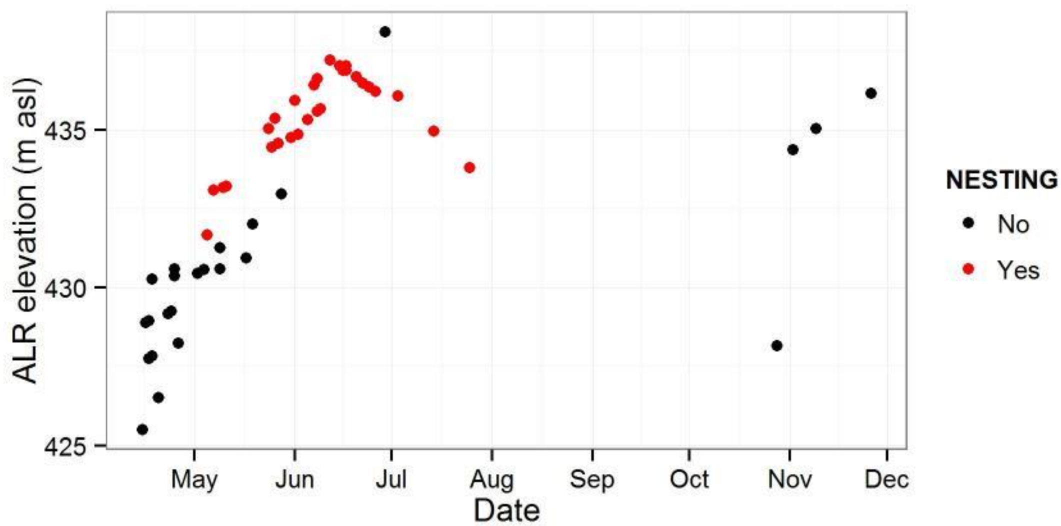

Figure 3-15: Reservoir elevations on dates when Short-eared Owl have been observed in the Arrow Lakes Reservoir drawdown zone in the Revelstoke Reach region.

Our analysis of the mapped owl habitat (Appendix 7-5) showed that 95% of the Short-eared Owl foraging habitat was positioned between 433.7 and 437.7 m asl, or approximately 2.4 to 6.4 below the full pool elevation (440.1 ma asl). Their foraging habitat was dominated by mixed grassland habitat (Table 3-1) which is the most abundant grassland habitat in the area. This type of habitat is dominated by reed canarygrass (*Phalaris arundinacea*), but also includes bluejoint reedgrass (*Calamagrostis canadensis*), Canada bluegrass (*Poa compressa*), redtop (*Agrostis gigantea*), quickgrass (*Elymus repens*), and annual bluegrass (*P. annua*) as well as sedges (e.g., *Carex lenticularis, C. aperta*).

Survey work conducted for CLMBON-40 resulted in five Short-eared Owl nest records, and an additional two suspected nesting attempts (Table 3-2). Including additional historic records (Boulanger et al. 2002, Jarvis 2003), confirmed nest sites were in the grasslands south of Machete Island (3 nests), at Gawiuk Point (2 nests), and at 12 Mile (1 nest). All monitored nests were positioned on the ground at sites with 0% shrub cover and 0% canopy cover, and the nest site ground elevations ranged from 436.1 to 437.3 m asl (mean = 436.6 m asl). Nesting habitat was dominated by reed-canary grass. The surrounding habitat was generally devoid of shrub growth except at 12 Mile where there was a low density of willow (Figure 3-16). In that case, the closest shrub was > 25 m away from the nest site.

Table 3-1: Breakdown of habitat mapping in area identified as the primary habitats used by Short-eared Owl from 2008 through 2016 in the Revelstoke Reach drawdown zone

Code	Habitat Type	Description	Area (ha)	%
EG	Equisetum	dominated by Equisetum spp.	50.78	5.5
LD	Low draw	low elevation draw, often wet, or sparsely vegetated	21.60	2.4
MG	Mixed grassland	medium height grassland	558.52	60.9
PG	Sparse grassland	sparsely vegetated grassland	9.29	1.0
RC	Reed-canary grass	dominated by Reed Canary grass, often vigorous growth	101.55	11.1
SG	Sedge grassland	moist substrate, sedge dominated	100.45	11.0
SH	Shrub	shrub dominated, can be sparse	56.58	6.2
SR	Riparian shrub	dense shrub habitat	0.01	0.0
WM	Wet meadow	wet meadow, often with standing water	18.16	2.0

Table 3-2: Available data on Short-eared Owl nests in Revelstoke Reach. Nest records in 2001 and 2002 were not associated with CLMBON-40. One nest in 2002 and two nests in 2010 were not found, but were suspected based on the presence of pairs of owls repeatedly observed. The outcomes of these nests are assumed to have flooded given their nesting behaviour and the operations of the reservoir in these years.

Year	Nest Found	Elevation (m asl)	Clutch Size	Date Initiated	Outcome
2001[a]	YES	Coordinates undocumented	Not documented	Unknown	Unknown (not flooded)
2002[b]	NO	Unknown	Unknown	Unknown	Flooded (assumed)
2010	NO	Unknown	Unknown	Unknown	Flooded (assumed)
2010	NO	Unknown	Unknown	Unknown	Flooded (assumed)
2010	YES	436.8	6	25/04/2016	Flooded (nestlings, 22 June)
2016	YES	436.1	5	01/06/2016	Flooded (eggs, 11 June)
2016	YES	436.3	1	08/06/2016	Flooded (egg, 10 June)
2016	YES	437.3[c]	4	12/06/2016	Predated (nestlings, 29 July)
2016	YES	436.8[c]	5	13/06/2016	Predated (nestlings, 6 July)

a) See Boulanger 2002
b) See Jarvis 2003
c) These nests were likely second attempts following nest flooding. Only elevated nest habitat was available given reservoir levels.

Figure 3-16: A Short-eared Owl flushed from its nest in shrub savannah habitat at 12 Mile. All other known nests have been in grasslands that were essentially devoid of shrub growth. We suspect this higher elevation site represents a secondary habitat used for re-nesting following nest flooding at a lower elevation.

Three of five monitored nests successfully hatched, but none successfully fledging young. More than half of the observed nest failures were caused by nest flooding; predation likely caused the other two failures (Table 3-2). From the five nests that we monitored, the daily survival rate was estimated at 0.94 ± 0.027, resulting in nest success estimate of ~ 9.4 % over a 40-day nesting period.

Across all years of reservoir operation, the mean nest elevation became flooded in 79% of the years; on average, this occurred on July 2. A model showing the probability of flooded nest habitat based on historic operations is shown in Figure 3-17, and another showing mean water depth indicates that they typically initiated nests when water levels were rapidly approaching their nest elevations with flooding likely within less than a month following nest initiation (Figure 3-18).

There were 11 years where we knew if Short-eared Owls nested or not (2001, 2002, and 2008 through 2016). Nesting status was not significantly predicted by any of the predictor variables. There was a trend for the owls to nest following winters with low snowfall and following years of low water storage; the latter effect had the greatest strength (slope = -1.14), and was selected as the best model (Table 3-3; Figure 3-19).

Table 3-3: **Four univariate models to predict probability of Short-eared Owls nesting in the Arrow Lakes Reservoir. The first three related to winter conditions prior to spring migration (Snow = snowfall accumulation, MinTemp = lowest temperature recorded, AveTemp = average daily temperature), and MALR is maximum reservoir elevation during the previous year. All four variables could potentially affect the vole population and therefore modulate habitat attractiveness. AIC scores select MALR, which has the most dramatic effect size indicating a strong influence of reservoir operations on the probability of nesting.**

Predictor	Slope	*P*	AICc	ΔAICc
Snow	-0.01	0.11	16.4	2.4
MinTemp	0.31	0.32	18.7	4.7
AveTemp	0.49	0.43	19.3	5.2
MALR	-1.14	0.16	14.0	0

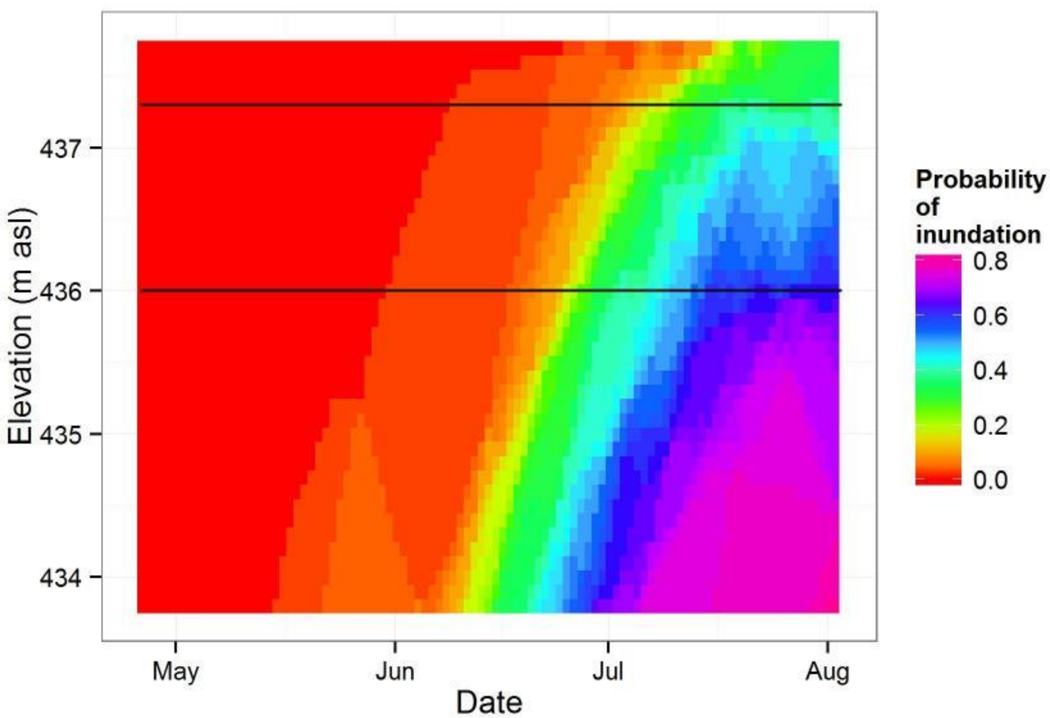

Figure 3-17: **A model of probability of inundation based on historic reservoir operations. The total graph area spans the estimated elevation of foraging habitat (y axis) and the estimated nesting season (x axis), acknowledging normal variation in nest initiation times (earliest egg was late April). We estimate that more than two months are required before it is safe to flood nesting habitat. All flooding will diminish foraging options. The two black lines bound the elevation band that Short-eared Owls were using for nesting**

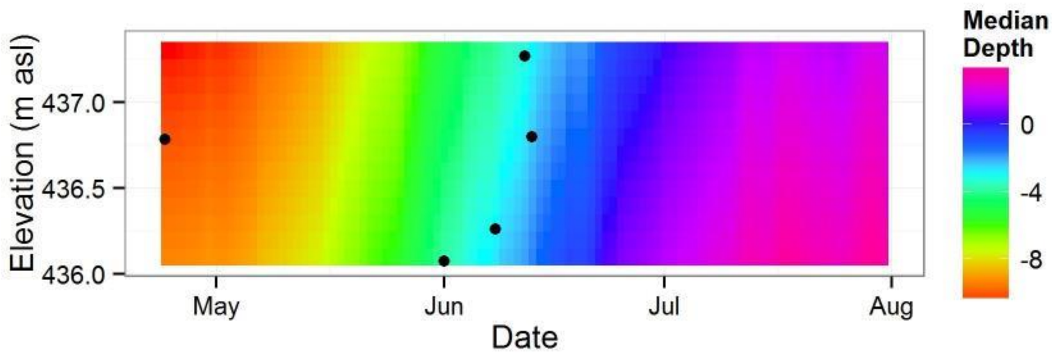

Figure 3-18: **The median depth that the ALR reservoir has had since operation during the nesting period, and at elevations where nesting occurs. Negative values represent reservoir levels below habitat elevations (in meters); positive values indicate flooded habitat. Five nests located during CLBMON-40 monitoring are represented as black points plotted by the nest elevation, and the estimated date when the first egg was laid. Likely more than two months of non-flooded habitat after nest initiation is required to allow successful reproduction**

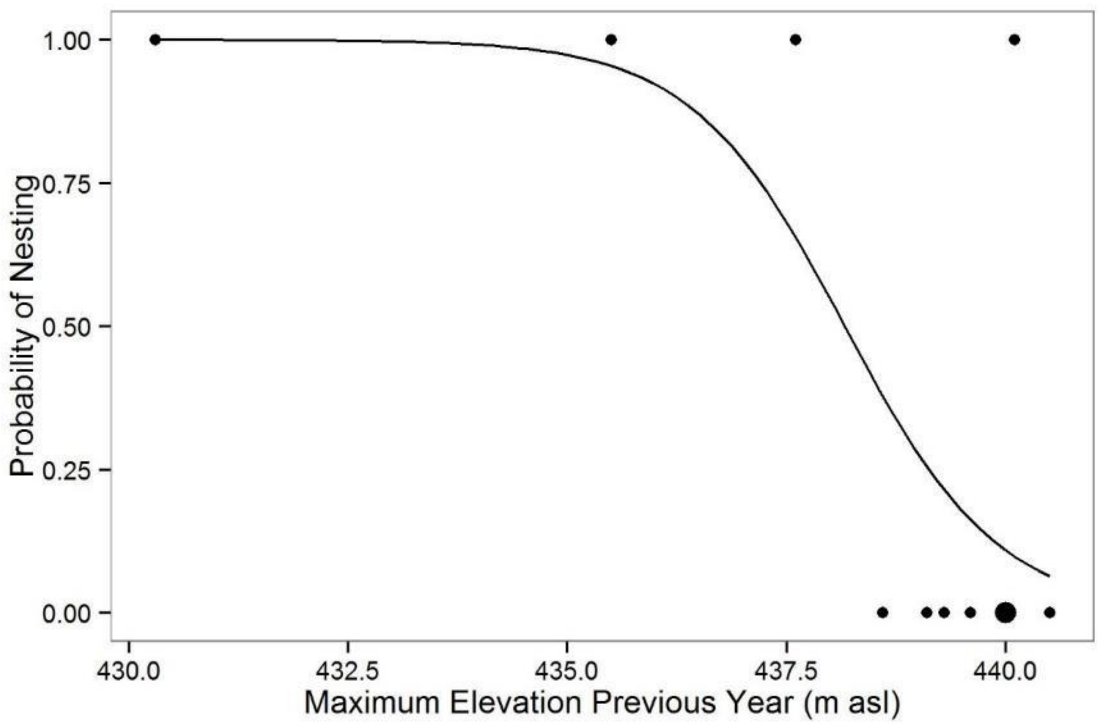

Figure 3-19: **The non-significant, but strong potential effect of reservoir operations on Short-eared Owl nesting decisions. Maximum reservoir elevations from the previous year is plotted for each year that owl nesting status was known (n = 11 years). The large point represents two overlapping data points. Years with nesting owls are plotted at the top of the y axis, and years when owls did not nest are plotted at the bottom of the plot. The probability curve represents the best (albeit non-significant) predictive model (MALR)**

4 DISCUSSION

4.1 Year 9

Following another low snowpack winter, the 2016 spring thaw came early. Accordingly, the spring waterfowl migrated past the study area relatively quickly. May was unusually warm, and Short-eared Owl observations were infrequent during the spring migration. At a relatively late date, the species was more frequently observed and began to show signs of initiating nests, for only the second time since the beginning of this study.

The Arrow Lakes Reservoir was drawn to a low maximum elevation for the second year in a row, making grasslands exposed and largely available as habitat during the summer; nonetheless, a portion of the grasslands was temporarily flooded, resulting in the flooding of nests for some ground nesting species including two Short-eared Owl nests and one Northern Harrier nest. It seems these birds all re-nested, but only the Northern Harrier was successful in fledging young. This was the first successful nest recorded for this species in the study area. Monitoring under CLBMON-36 located a number of nesting waterfowl, but brood survey results under CLBMON-40 showed relatively low brood numbers, especially considering the low potential for nest flooding in 2016. Another surprise, given previous trends, was the low success of Osprey, which have historically done well in low water years (CBA 2016).

Shorebirds were relatively numerous during the fall. Most notably, Pectoral Sandpipers utilized the shorelines in the Arrow Lakes Reservoir drawdown zone in numbers far exceeding what has been observed previously during this study. Other species that were commonly observed included both Greater and Lesser Yellowlegs and Killdeer. Spotted Sandpipers were present in less abundance compared with previous years.

During the fall migration, waterfowl utilized our study site in relatively large numbers from September through November.

4.2 Multi-year progress and data gaps

a) In this report, we present a new analysis on how reservoir operations impact productivity of Short-eared Owls. Our findings indicated that the drawdown zone likely functions as an ecological trap when owls are attracted to nest there, and that the attractiveness of the nesting habitat is possibly modulated directly by reservoir operations. This is discussed in greater detail below.
b) We are currently analyzing an integrated dataset to examine how waterfowl use varies in relation to habitat attributes. The dataset includes data characterizing habitat variability within wetlands collected under the CLBMON-11B4 study (Miller and Hawkes 2014). We anticipate reporting on this analysis in Year 10.
c) Currently, there remain several other key analyses that need to be conducted in Year 10, but aside from gathering the final year data, we foresee no major data gaps and look forward to satisfactory conclusion of the CLBMON-40 study in Year 10.
d) We recommend that a focus in the final year should be to qualify the previous habitat mapping by a second round of ground truthing in addition to compiling vegetation species lists for each habitat classification. We see little need to continue with shorebird sampling in 2017, as the existing data are sufficient for the level of analysis

that is required (describing the timing of their fall migration, species diversity, and habitat distribution).

4.3 New analyses – The case of the Short-eared Owl

There are many waterbird species considered under the umbrella of CLBMON-40 including waterfowl, diving birds, gulls, Osprey, Bald Eagle, Northern Harrier and Short-eared Owl. The latter is unique among the study species because it is a species listed under the Species At Risk Act (SARA).

Short-eared Owl populations are generally declining across their Holarctic range, and it is recognized as a species of 'Special Concern' by the federal government of Canada in the SARA (Wiggins 2008, Booms et al. 2014). Canadian populations declined by 27% over 10 years (Wiggins 2008, Booms et al. 2014). Conservation and recovery options are extremely limited for this species, partially because the species is nomadic, with low fidelity to nesting grounds. Because Short-eared Owl populations are declining, there is particular interest in how this species is impacted by reservoir operations.

Short-eared Owl's primary prey – voles and lemmings (e.g., *Microtus* spp.), naturally fluctuate in abundance, making the suitability of nesting grounds variable over time (Elton 1924, Krebs and Myers 1974, Turchin and Ostfeld 1997). As a result of fluctuating prey abundance, Short-eared Owl are opportunistic breeders, and their nesting density is strongly reflective of local prey abundance (Phelan and Robertson 1978, Village 1987, Korpimaki and Norrdahl 1991, Poulin et al. 2001, Keyes 2011). This nesting behaviour is adaptive in natural ecosystems, but an ecological trap (Schlaepfer et al. 2002, Robertson and Hutto 2006) might occur if voles are abundant in habitats where nest failure is likely.

In this report, we examined available data on Short-eared Owl nesting in the Arrow Lakes Reservoir. Because the species is declining, SARA-listed, and known to nest in the drawdown zone, it is perhaps the single most important species to focus CLBMON-40 analyses on. Below, we discuss the current analysis and result in relation to the most relevant Management Questions.

4.3.1 Objective 1: Determine the extent of use of Revelstoke Reach by waterbirds by determining their abundance, species richness, distribution, productivity, and patterns of habitat use.

For Short-eared Owl, this objective was relatively easy to address. The primary region of habitat use was mapped based on a large experience base of owl observations (Appendix 7-5). We applied digital elevation models and habitat mapping to characterize the elevation and habitat classifications of their habitat. Nest records allowed nesting elevations and habitat cover to be described (see Section 3.3.3), and the vegetation mapping was used to describe their foraging habitat (Table 3-1). Note the temporal habitat use includes seasonal and inter-annual variation.

4.3.1.1 MQ-1: What is the seasonal and annual variation in the abundance and spatial distribution of waterbirds within Revelstoke Reach during migration?

For Short-eared Owl, seasonal abundance can be characterized as low level migratory abundance in most (7 of 9) years (e.g., March through May, and October through November), with occasional moderate densities of nesting birds in some breeding seasons (June through August). Our data indicated that spring is a more common time for the species to use the drawdown zone; we observed only two years of nesting in nine years of monitoring. Altogether there were four years of known nesting when records from previous studies were included (Boulanger et al. 2002, Jarvis 2003). For more detail on annual variation in abundance see section 4.3.2 below.

Our analysis showed that 95% of the Short-eared Owl foraging habitat was positioned between 433.7 and 437.7 m asl, or approximately 2.4 to 6.4 below the full pool elevation (440.1 ma asl). While this only included sites that we observed Short-eared Owl activity, the habitat is a product of reservoir operations, and there may be other potential Short-eared Owl habitat areas in the ALR at similar elevations (e.g., Halls Landing, Catherwood or elsewhere in the ALR; see Figure 1-1).

For Short-eared Owl, we consider MQ-1 to be fully addressed, but acknowledge that additional nesting data will enhance knowledge of annual variation and spatial distribution.

4.3.1.2 MQ-3: Which habitats and wetland features within the drawdown zone in Revelstoke Reach are utilized by waterbirds and what are their characteristics (e.g., foraging substrate, vegetation, elevation and distance to waters edge)?

Short-eared Owl select open habitats including prairie, pasture, coastal grasslands, heath, moorlands, marshes, bogs, shrub-steppe, tundra, grassy dunes, and agricultural areas (Campbell et al. 1990, Wiggins et al. 2006); CLBMON-40 can build on this list by including reservoir drawdown zones. What these habitats have in common is an open habitat with low shrub, minimal tree cover, and the strong presence of their prey – the microtine voles or lemmings. Similar habitats are used for both foraging and nesting. In Revelstoke Reach, we observed foraging in grassland habitats including Mixed Grassland, pure Reed Canarygrass and Sedge Grassland. Our analysis showed that 95% of the Short-eared Owl foraging habitat was positioned between 433.7 and 437.7 m asl, or approximately 2.4 to 6.4 below the full pool elevation (440.1 ma asl). As always with this species, these habitats only constituted suitable habitat when prey were sufficiently abundant; see section 4.3.2 below for more detail. Data were not available on their distance to waters edge, but during field observations, there was no indication that they were attracted to water, or trying to avoid the water's edge.

For Short-eared Owl, we consider MQ-3 to be fully addressed given the sparse nest records, and large biological effect seen in our small sample size. One further year of monitoring (Year 10), may improve the model, but we feel confident that the existing data can answer MQ-3. Additional monitoring at other grasslands are not practical due to difficult access, but would enhance knowledge of their habitat distribution in the ALR.

4.3.1.3 MQ-4: What is the annual variation in summer productivity (reproduction) of waterbirds in Revelstoke Reach and do indices of waterbird productivity vary spatially (e.g., are there areas of higher waterbird productivity)?

The available data on nest success suggests that Short-eared Owl productivity is very poor. The nesting population in our study area was estimated to be as large as three nesting pairs in 2010, and two nesting pairs in 2016; previously, there was no indication that more than one nesting pair was present (Boulanger et al. 2002, Jarvis 2003). None of the five nests observed were successful. Prior to our study, the scant details indicate that the 2001 nest may have been successful (Boulanger et al. 2002, Jarvis 2003, 2006), but, although not found, the breeding pair observed in 2002 surely failed as the water levels flooded habitat (Jarvis 2003). Based on data from the five nests we monitored, we estimated a daily nest survival probability of 0.94 ± 0.027, resulting in nest "success" estimate of ~ 9.4 % over a 40-day nesting period. In general, we conclude that productivity is low due to sporadic nesting and poor nesting success.

Additional data would be highly beneficial. For Short-eared Owl, we consider MQ-4 to be partially addressed, and advise that additional monitoring (minimum 5 years) would be beneficial.

4.3.2 Objective 2: Inform BC Hydro on how reservoir operations affect waterbirds by monitoring their abundance, species richness, distribution, productivity, and patterns of habitat use over time.

This objective has high relevance to the conservation of Short-eared Owl, and we address the Management Questions to the extent possible given the available data below.

4.3.2.1 MQ-2: What implication does the year-to-year or within-year operations of Arrow Lakes Reservoir have on resident and migratory shorebird and waterbird populations?

To the best of our knowledge, across a very large region (Kinbasket Lake Reservoir, Lake Revelstoke, Arrow Lakes Reservoir and surrounding ranges), breeding Short-eared Owl have only been recorded in the drawdown zone at Revelstoke Reach. As such, any implications of reservoir operations have regional significance.

As noted above, our empirical results indicate a very low productivity. None of the five Short-eared Owl nests we monitored were successful, and our nest survival analysis indicated that <10% of nests would survive 40 days. Our observations indicated that 60% to 75% of nest failures were caused by the reservoir flooding nests. Finally, examination of nesting elevations and ALR operations suggest that nesting habitat elevations were flooded in 79% of the years, typically in the first week of July, when nestlings are typically incapable of flying and/or dependent on their parents for food. It should be noted that flooding of their habitat would have extreme consequences for the ability of adults Short-eared Owls to provide food to their young.

It is hard to give a numerical answer to directly answer MQ-2, but we have generated many different numerical measures of productivity, which is a central pillar of population resiliency. Whether we approach productivity from simple nest monitoring observations, statistically derived nest performance measures, or through simple analysis of past reservoir operations, we arrive at the same conclusions: (1) Short-eared Owl productivity is very low; (2) the probability of Short-eared Owl nest success is minimal; and (3) the operations of the Arrow Lakes Reservoir plays a major role in limiting nest success.

It is beyond the scope of this project to examine other measures of population impacts and we therefore suggest that MQ-2 has been adequately addressed for the Short-eared Owl.

4.3.2.2 MQ-5: Which waterbird species have the greatest exposure to being highly impacted by reservoir operations?

Because productivity is such an important measure of population resiliency, and because species that nest on the ground in low elevation habitats are highly susceptible to nest flooding, several waterbirds are highly exposed to negative impacts of reservoir operations including Common Loon, American Avocet, Wilson’s Snipe, Wilson’s Phalarope, Spotted Sandpiper, Killdeer, Mallard, American Wigeon, Green-winged Teal, Blue-winged Teal, Cinnamon Teal, Northern Shoveler, Northern Harrier, and Short-eared

Owl. Most of these species, including Short-eared Owl have been observed to experience nest flooding. A more thorough review will be conducted in the final report.

4.3.2.3 MQ-6: Do reservoir operations (e.g., daily and maximum monthly water levels) influence the distribution and abundance of waterbirds and shorebirds in Revelstoke Reach?

There were two Short-eared Owl nests that were established following nest flooding at lower elevations, these presumed replacement nests were positioned at higher elevations than the other three nests previously recorded. With only five recorded nest coordinates, there was insufficient information to test differences in nest elevations with sufficient statistical power.

Short-eared Owl often forage and nest in wet meadows and other moist open habitats, but they cannot forage or nest in habitats inundated by the reservoir. Undoubtedly, the approaching water line will concentrate prey, making a temporary adjustment to their foraging tactics and their distribution. When water has entirely submerged their habitat, the owls leave the area, as supported by our observations. Consequently, both the distribution and abundance of Short-eared Owl is affected by current water levels in Revelstoke Reach; but the impact also influences future abundance.

The most interesting outcome from the CLBMON-40 study of Short-eared Owl is strong support for the idea that reservoir operations controls future habitat suitability, and thereby influences the distribution and abundance of Short-eared Owls in the following year. This finding is particularly important given the conclusions from MQ-2, that the ALR is negatively impacting this SARA-listed species. More monitoring is required (we estimate minimum 5 years) before the results will reach statistical significance, but the effect size was large, which has more biological meaning than the statistical significance. In this regard, we feel that the merit of MQ-6 is greater than was probably originally anticipated with respect to Short-eared Owl, and we suggest that the MQ is only partially answered for this species (strong support, but statistical non-significance: more data required).

4.3.2.4 MQ-7: To what extent do water levels in Arrow Lakes Reservoir influence indices of waterbird productivity in Revelstoke Reach?

For Short-eared Owl, this ALR has a high influence on productivity. As noted above, our observations indicated nest success is very low and that the majority of nest failures were caused by the reservoir flooding their nests. Examination of nesting elevations and ALR operations suggested that nesting elevations were flooded in 79% of the years.

For Short-eared Owl, this MQ is adequately addressed, although additional monitoring would be beneficial to increase sample size (precision).

4.3.3 Objective 3: Determine whether minor adjustments can be made to reservoir operations to minimize the impact on waterbirds or whether mitigation strategies are required to reduce the risks to these populations from reservoir operations.

This objective, and MQ-8, are likely of greatest direct relevance to the over-arching goals of the Water Use Plan; yet they are also among the most challenging to address quantitatively. In the case of the Short-eared Owl, however, MQ-8 is a question that can be addressed due to the unique ecology of this species and how their foraging and reproductive ecology is affected by reservoir operations. By applying well documented biology and utilizing the available data, we believe that there is a strong case that MQ-8 can be answered. If statistical significance and larger data set are of interest, a follow up study can be considered after CLBMON-40 has concluded.

4.3.3.1 MQ-8: Can minor adjustments be made to reservoir operations to minimize the impact on migrating waterbirds or on indices of waterbird productivity?

We consider ‘minor adjustments’ to entail slight changes to the hydrograph that can be accommodated while meeting other WUP commitments and operational constraints. The task here is to derive guiding principles to fine tune water use decisions to enhance ecological values for wildlife. We recognise that the potential magnitude of possible adjustments will be situation-specific, depending on factors such as forecasted storage regimes, current water levels, current ecological, recreational and functional constraints, and on the time of year. We therefore suggest that operational guidelines we suggest can only be applied in certain years, and that the margin of ecological improvement will vary as well.

Below we consider three potential options to manage risks to Short-eared Owls: (1) by enhancing habitat suitability during their migration; (2) by disarming the ecological trap mechanism (preventing nest flooding); and (3) reducing attractiveness of the habitat (i.e., removing the vole ‘bait’ from the ecological trap). The potential to remove nesting habitat availability by advancing habitat flooding prior to nesting (e.g., filling to > 437 m asl in April) would always constitute a major change to reservoir operations, and is not considered here. Note that the three potential management levers below involve opposing water use planning guidance.

<u>Migration</u>

For the highly transient Short-eared Owl, the exposed grasslands in Revelstoke Reach offer potentially valuable foraging habitat during their spring and fall migration. However, these habitats likely have reduced value in the fall because the vole population in the grasslands is often in initial stages of repopulation following inundation; not surprisingly, we typically see less usage during the fall compared with the spring (Figure 3-15). Attempting to improve vole abundance may be possible with some minor changes to operations in some situations; however, we do not recommend managing for migration (e.g., enhancing vole populations) because it can conflict with management for breeding (see below) which is a more important management lever.

<u>Nest Flooding</u>

During the breeding period, nest flooding is an issue for many waterbirds including Short-eared Owl. In most years, releasing water from the ALR (or reducing input from Mica) to keep water levels low, and prevent nest flooding, would constitute a major adjustment (Figure 4-1). However, a minor adjustment may be possible in some years; we provide the following guideline:

> **Operation Guideline 1. Maintain the ALR surface elevation below 437.0 prior to August 15 to prevent flooding Short-eared Owl nests. This may constitute a minor (feasible) adjustment to operations in years when it appears that the maximum pool elevation of the ALR might be ~ 437.5 ± 0.5 (e.g., as in 2016).**

Note that the 437.0 m asl benchmark was based on water levels observed in 2016 by the data logger (maximum elevation = 437.22 m asl at the FQR data logger), which inundated the earliest (and lowest elevation) nests.

Despite considerable variability in maximum pool elevations over time, the conditions when this guideline can be implemented via minor adjustments have been few. In the past, the ALR has reached a high pool elevation between 437.0 and 438.0 in just two years (4%; 2009, 2016). Additionally, it is highly likely that when **Operation Guideline 1** can be applied, Short-eared Owl might not be nesting (i.e., if the previous year was filled to capacity; 2016 was probably the first such occasion). Hence, we consider this guideline to have very low potential to reduce the ecological costs of normal operations to the Short-eared Owl.

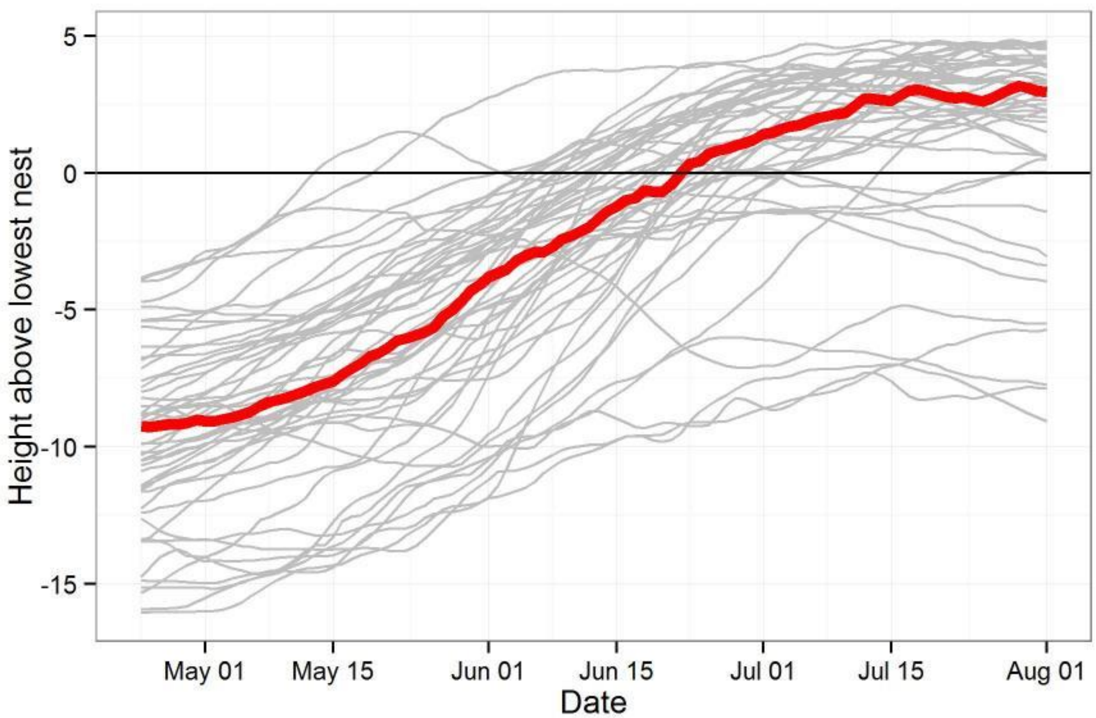

Figure 4-1: **A graphic showing annual (grey) and median (red) ALR elevation relative to the elevation of the lowest Short-eared Owl nest over the span of the nesting season. Lines above the zero (horizontal black) represent flooded nesting habitat. The median line shows that in most years, the reservoir needs to be lowered by ~ 3 m to avoid flooding nestlings. We do not consider adjustments to avoid flooding nests as 'minor adjustments'**

Vole Management

We concluded that the drawdown zone is simply not a good place for Short-eared Owls to nest, and here we propose to use a minor adjustment to prevent them nesting in the ALR drawdown zone (to the extent practical). We believe that the potential for nest success is sufficiently low that Short-eared Owl would be more productive if they nested outside of the ALR in natural habitats. Our data indicates that the drawdown zone acts as an ecological trap, and as a population sink. We therefore conclude that discouraging Short-eared Owls from nesting would be positive for their conservation.

The reservoir normally fills above the upper elevation of the Short-eared Owl nesting habitat during the breeding season, which must incur a very large impact on the vole population in these grasslands. Our results indicate that this normal operation of the ALR does indeed create non-attractive habitat for Short-eared Owls as they passed through but did not breed in most years of the study. Short-eared Owls occasionally chose to nest following a year of unusually low water storage when the vole population was presumably allowed to grow to a density attractive to the owls (see Figure 3-17). This is an important finding because it underscores potential to manipulate ecological risks to Short-eared Owls via potentially minor adjustment to reservoir operations.

We propose the following guideline:

Operation Guideline 2. Fill the ALR to above 437.7 m asl each year.

Operation Guideline 2 would be a relatively easy WUP goal to achieve in most years, with adjustments required infrequently, more often of low magnitude (Table 4-1). Normally (77% of the time in the past; Table 4-1) no adjustment to reservoir operations would be required given historic operations of the ALR: since 1969, the water was sufficiently high (> 437.7 m asl) to cover all of the Short-eared Owl/vole habitat in all but 11 years. In the 11 years where some habitat was left exposed above the reservoir (maximum elevation < 437.7 m asl), the adjustment required would have been relatively minor (50 cm or less) on two occasions (18 %; Table 4-1).

Operation Guideline 2 needs to be qualified with further data. It could be that the functionality of vole eradication requires filling the ALR to levels higher than 437.7 m asl. With only one more year left for CLBMON-40, the relationship between reservoir operation and owl nesting will not be validated statistically. We recommend that monitoring, at even a very basic level of determining whether or not Short-eared Owls nest, can be used to validate the relationship between site selection and vole abundance. We also note that studying the relationship between reservoir operations and vole abundance will be informative for managing impacts to Short-eared Owls. Finally, in regards to the elevation of habitat (437.7 m asl) referenced, this benchmark was estimated based on mapped elevations of habitat, and is therefore potentially erroneous due to DEM errors. It would be valuable to re-assess with a more accurate DEM.

Which guideline?

In Table 4-1 we contrast potential to make operational adjustments for **Operation Guidelines 1 and 2** using historic reservoir operations as a representation of 'normal'. From this table it is clear that **Operation Guideline 2** has higher feasibility, with adjustments required in fewer years, and when needed, the adjustments were more likely to be minor (i.e., in 18% vs 2.6% of the years). In years when the ALR water levels must stay low and vole populations increase, there may be other ways to reduce habitat attractiveness that can be explored (not considered here). It would likely be productive to make further exploration towards an operation guidance and alternate tools to minimize impacts, but we believe that the Short-eared Owl case has been thoroughly explored to the extent required for CLBMON-40.

Table 4-1: Table comparing two opposing operational guidelines to reduce Short-eared Owl nest mortalities using historic ALR operations as a model of normal operations. Historically, Guideline 2 was met more frequently, and when adjustments were required (n_1 = 39 years; n_2 = 11 years), they were more often less than 50 cm. The median adjustment size was similar, but the maximum adjustment size was greater for Guideline 2.**

Guideline	Goal	Rule*	% years met historically	% adjust. < 50 cm	Med. adjust	Max. adjust
1	To not inundate nesting habitat	< 437.0	18.8 %	2.6 %	2.95	3.85
2	To inundate vole habitat	> 437.7	77.1 %	18.0 %	2.62	6.79

* applies during nesting season only for Guideline 1.

** 50 cm is an example value to represent minor adjustments; it is recognized that adustments to reservoir elevations will depend on operating constraints

4.3.4 Objective 4: Provide the data necessary to inform how physical works projects may enhance waterbird habitat in Revelstoke Reach.

We do not see opportunities to enhance Short-eared Owl habitat using physical works.

4.3.4.1 MQ-9: Can physical works be designed to mitigate any adverse impacts on migrating waterbirds or on indices of waterbird productivity resulting from reservoir operations?

If BC Hydro were to prioritize among waterbirds for allocating resources towards mitigating negative impacts, we encourage a focus on the Short-eared Owl. This species has undergone large declines (27% in 10 years) in Canada, and is in decline globally. Creating a Short-eared Owl captive breeding and release program would be one option that could be supported by BC Hydro. It would be educational, relevant to operational impacts and ecologically valuable (if effective). Similar programs have been very successful with other raptor species. It is questionable if rescue of eggs and or nestlings prior to flooding can mitigate nest flooding impacts, but should continue to be explored (see CBA 2011). Outsider of building a captive breeding center, we see no potential for WPW projects to mitigate adverse impacts of reservoir operations on Short-eared Owl.

4.3.5 Objective 5: Provide the data necessary to evaluate whether physical works projects or revegetation initiatives enhance waterbird habitat in Revelstoke Reach.

For Short-eared Owl, their abundance and scale of habitat use is not conducive for providing data to address Objective 5. Below we address the Management Questions largely based on principles of their ecology, as learned from CLBMON-40 monitoring.

4.3.5.1 MQ-10: Does revegetating the drawdown zone affect the availability and use of habitat for waterbirds in Revelstoke Reach?

Prior to WLR projects, the grasslands in our study area were created as a dust control measure; the establishment of grasslands in the drawdown zone may have eventually happened naturally, but there is little doubt that the planting programs in the 1990’s were instrumental in making the Short-eared Owl habitat we see today. In this respect, we reflect that revegetating the drawdown zone has indeed affected the availability and use of habitat by Short-eared Owls. But this was not helpful for the species as we discussed earlier.

The only clear successes in the recent (WLR) revegetation program in the Revelstoke Reach area have been the staking of cottonwoods in small areas between Cartier Bay and 9 Mile, and at 12 Mile island; but successes in the revegetation efforts were accompanied by many failed efforts. The implications of the mixed revegetation results can be assessed in different ways. From one point of view, the failure to successfully plant trees can be viewed as a success for maintaining potential Short-eared Owl habitat because they select open grassland habitat. From another point of view, given that Short-eared Owls should be discouraged from nesting in the Revelstoke Reach drawdown zone, we can view the revegetation successes as a step towards reducing suitability of grassland habitat for Short-eared Owls. However, the reality is that the revegetation program has made no difference because (1) it is minimal relative to the availability of their habitat; and (2) because the majority of the Short-eared Owl habitat (433.7 and 437.7 m asl) is below the minimum elevations that were targeted for revegetation program – generally above 438 ma asl.

Regarding Short-eared Owls, no additional effort is warranted to address MQ-10.

4.3.5.2 MQ-11: Do physical works projects implemented during the course of this monitoring program increase waterbird abundance, or species richness, or indices of waterbird productivity?

There have been two physical works projects undertaken during the course of this monitoring program: WPW6A and WPW15. In both cases, the habitats that were protected by the physical works projects were ponded wetlands and are not important components of Short-eared Owl habitat. As noted above, Short-eared Owl detections are likely governed by reservoir operations and snowpack which affect vole abundance. But the data are too sparse even to statistically support these relatively strong effects; there is no reasonable option to examine their abundance as a function of these physical works projects, and we must rely on professional opinion. This is particularly true because the owls do not use these habitats, and are far-ranging.

Regarding Short-eared Owls, no additional effort is warranted to address MQ-11.

4.4 Recommendations

1. Field sampling should be used to validate habitat map and to create species lists for habitat classifications. Improving the habitat mapping will enhance our ability to address MQ-3, asking which habitats are utilized by waterbirds.
2. Continued monitoring of Short-eared Owl nesting could allow more effective analysis of whether and how reservoir operations impact nesting decisions.
3. Study of how vole populations are impacted by reservoir operations could allow more precise operating guidelines to be defined for vole management in the ALR drawdown zone.

4.5 Conclusions

The ALR drawdown zone constitutes an (infrequently used) ecological trap and population sink for Short-eared Owls during the year following very low summer maximum reservoir elevations.

There are some options available to BCH to reduce negative impacts to Short-eared Owl using minor changes to reservoir operations, but validity of these approaches requires further research.

This year we chose to present comprehensive results for the Short-eared Owl after the relatively larger number of nests that we found last year. Further conclusions regarding the other focal species will be reported at the end of the 10-year study within the final comprehensive report for CLBMON 40.

5 ADDITIONAL REPORTING REQUIREMENTS

No federal or provincial reporting for permits is required for this study.

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7 APPENDICES

Appendix 7-1: The CLBMON-40 Objectives, Management Questions (MQ) and Management Hypotheses, and a review of the results. This table includes results reported in this report, as well as previous annual reports.

Objective 1	Management Questions (MQ)	Management Hypotheses	Year 9 Status Summary Points
Determine the extent of use of Revelstoke Reach by waterbirds by determining their abundance, species richness, distribution, productivity, and patterns of habitat use.	1) What is the seasonal and annual variation in the abundance and spatial distribution of waterbirds within Revelstoke Reach during migration?	N/A	• The seasonal aspects of this MQ have been addressed, but estimates of annual variation are limited by the number of years of study; 10 years of data should be sufficient. • Among-wetland spatial analysis is completed. Within-wetland spatial analysis is planned. Study area-wide spatial analysis of aerial data is planned. • See Interim report (CBA 2013) for additional detail
	3) Which habitats and wetland features within the drawdown zone in Revelstoke Reach are utilized by waterbirds and what are their characteristics (e.g., foraging substrate, vegetation, elevation and distance to waters' edge)?	N/A	• Habitat features have been identified for waterfowl and shorebirds • Raster maps of waterfowl usage within sites were created for the primary wetlands monitored by the land-based waterfowl surveys • Correlations between waterfowl usage and habitat characteristics within sites are planned. • Elevational profile of Short-eared Owl (and Northern Harrier) habitat was estimated from the DEM in 2016. • An improved DEM would be an asset
	4) What is the annual variation in summer productivity (reproduction) of waterbirds in Revelstoke Reach and do indices of waterbird productivity vary spatially (e.g., are there areas of higher waterbird productivity)?	N/A	• There was considerable variability in the number of broods observed among years • Canada Goose broods often congregate away from the brood survey area in the flooded grasslands at the south end of the study area • Downie and Airport Marsh appeared to be consistently important brood rearing sites for other brood-rearing waterfowl • From 2009 through 2016 there were between 3 and 7 Bald Eagle nests, and between 0 and 7 Osprey nests that were successful each year • An annual maximum of 7 active Bald Eagle nests and 12 active Osprey nests have been observed in Revelstoke Reach; usually fewer. • There was evidence that as many as 3 Short-eared Owl nests were active in 2010 and 2 nesting pairs initiated two nests each in 2016. In all other years, no Short-eared Owl nesting activity was observed. • The leading cause of nest failure for SEOW was flooding. Predation likely ended all other nesting attempts we monitored. • Northern Harrier nesting attempts took place in 2 of 9 years. 1 of 3 was successful.

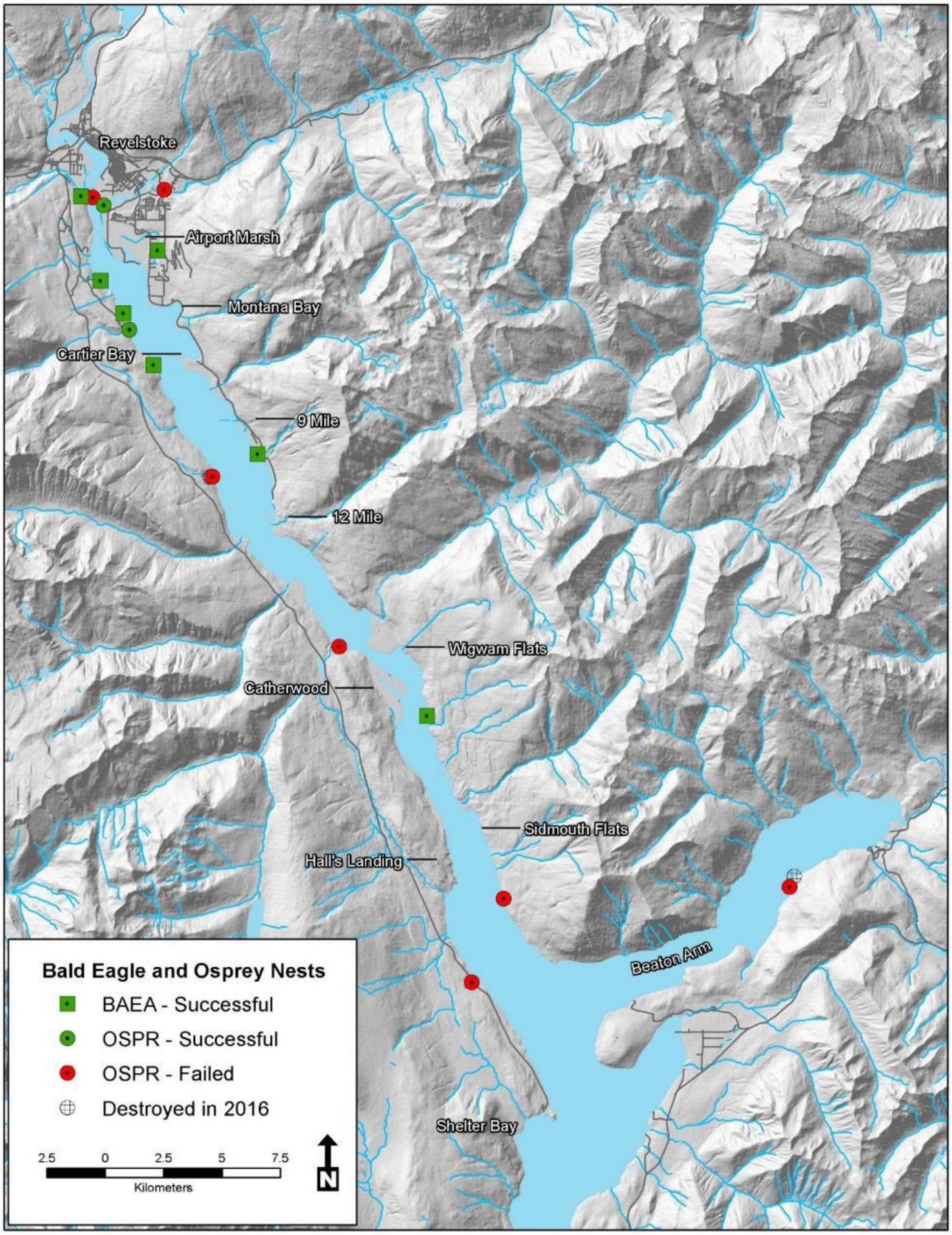
Objective 2	Management Questions	Management Hypotheses	Year 9 Status Summary Points
Inform BC Hydro on how reservoir operations affect waterbirds by monitoring their abundance, species richness, distribution, productivity, and patterns of habitat use over time.	2) What implication does the year-to-year or within-year operations of Arrow Lakes Reservoir have on resident and migratory shorebird and waterbird populations?	N/A	• This MQ has been removed from CLBMON-40 as it cannot be adequately addressed by the study.
	5) Which waterbird species have the greatest exposure to being highly impacted by reservoir operations?	N/A	• The most important impact of reservoir operations to waterbirds is likely the impacts to productivity of ground-nesting waterbirds via nest flooding (e.g., Mallard, Teal spp., American Wigeon, Spotted Sandpiper, Killdeer, Northern Harrier and Short-eared Owl). • The data indicate potential that Osprey productivity might be sensitive to reservoir operations for other (unknown) reasons. • Waterbirds appear to be able to find alternative stop-over and staging habitats within the drawdown zone during the migration, when wetlands are impounded, and some key wetlands are usually not-flooded during migrations. As such, we infer that impacts to migrants are relatively minor.
	6) Do reservoir operations (e.g., daily and maximum monthly water levels) influence the distribution and abundance of waterbirds and shorebirds in Revelstoke Reach?	H1A: Reservoir operations do not result in decreased species richness in waterbirds utilizing the drawdown zone. H1B: Reservoir operations do not result in a decrease in the abundance of waterbirds utilizing the drawdown zone. H1C: Changes in the distribution of waterbird distribution in Revelstoke Reach are not attributable to reservoir operations.	• This MQ has been explored statistically and graphically • Using water depth as a measure of reservoir operations, and probability of detecting waterfowl as an index of their distributions, we showed that distributions can be highly influenced by reservoir operations • To date there has been no obvious indication that waterfowl abundance was influenced by reservoir elevations; more analyses are planned. • The diversity of shorebirds appeared to be uninfluenced by reservoir elevations in the interim analysis. Analysis to be repeated in year 10. • The diversity of waterfowl appeared to be influenced by reservoir elevations early in the fall migration with greater diversity being recorded in years when reservoir elevations were higher. • The latter trend was driven by diving species that moved into wetlands when inundated. • We suggest that diversity is more informative when measured within foraging guilds. Otherwise, high diversity could simply reflect a re-distribution of some species (e.g., diving birds), and reflect compromised foraging for other species.
	7) To what extent do water levels in Arrow Lakes Reservoir influence indices of waterbird productivity in Revelstoke Reach?	H1D: Reservoir operations do not result in a decrease in indices of productivity of waterbirds utilizing the drawdown zone.	• Brood counts are influenced by reservoir operations. Nest flooding is known to be an important source of mortality for dabbling ducks, but not for Canada Goose. • Short-eared Owl and Northern Harrier, are highly exposed to being impacted by reservoir operations via nest flooding. • Osprey productivity is correlated with reservoir operations, but causation has not been confirmed.

Objectives 3-5	Management Questions	Management Hypotheses	Year 9 Status Summary Points
Determine whether minor adjustments can be made to reservoir operations to minimize the impact on waterbirds or whether mitigation strategies are required to reduce the risks to these populations from reservoir operations.	8) Can minor adjustments be made to reservoir operations to minimize the impact on migrating waterbirds or on indices of waterbird productivity?	H2A: Annual variation in reservoir water levels or reservoir operations do not result in a reduction or degradation of waterbird habitats.	• 2012 surcharge resulted in loss of floating bog habitat, cattail habitat, and erosion of reservoir banks • Analysis concludes that wetlands are avoided when inundated by reservoir.
		H2B: The implementation of soft constraints does not result in a reduction or degradation of waterbird habitats.	• Soft constraint to match 1984 to 1999 reservoir operations (above 434 m asl) during spring and summer was not observed/implemented. • Soft constraint unlikely to affect waterbird habitat
		H2C: Rev 5 does not result in a reduction or degradation of waterbird habitat.	• No change to habitat has been observed anecdotally. • In general, Rev 5 effects are predicted to be pronounced when the reservoir is low; the wetlands will not be impacted under these conditions.
			• Minor adjustments could be used to keep certain wetlands in optimal state (not inundated) for migrating waterbirds. • It is likely that adjustments required to minimize impacts to productivity will not be classified as 'minor'. Waterbirds nest over a wide range of elevations.
Provide the data necessary to inform how physical works projects may enhance waterbird habitat in Revelstoke Reach.	9) Can physical works be designed to mitigate any adverse impacts on migrating waterbirds or on indices of waterbird productivity resulting from reservoir operations?	N/A	• It is likely that construction of wetlands for waterfowl and wetlands for shorebirds positioned near or above the full pool elevation can be pursued, and that these would have a high probability of success. • Possible sites for waterfowl and/or shorebird habitat enhancements can be found at Airport Marsh, 12 Mile, McKay Creek and Catherwood. • Airport Marsh project proposed to enhance productivity
Provide the data necessary to evaluate whether physical works projects or revegetation initiatives enhance waterbird habitat in Revelstoke Reach.	10) Does revegetating the drawdown zone affect the availability and use of habitat for waterbirds in Revelstoke Reach?	H3A: Revegetation does not result in an increase in the species richness or abundance of waterbirds utilizing the drawdown zone.	• All revegetation treatments were terrestrial, so did not apply for waterbird habitat (see H3C for terrestrial nesting result).
		H3C: Revegetation does not increase indices of productivity of waterbirds utilizing the drawdown zone.	• Waterfowl nests were not located in revegetation treatment areas. Monitoring continues.
		H3E: Revegetation does not increase the amount of waterbird habitat in the drawdown zone.	• All revegetation treatments were terrestrial, so did not apply for waterbird habitat (see H3C for terrestrial nesting result).
	11) Do physical works projects implemented during the course of this monitoring program increase waterbird abundance, or species richness, or indices of waterbird productivity?	H3B: Wildlife physical works do not result in an increase in the species richness or abundance of waterbirds utilizing the drawdown zone.	• WPW6A and WPW15 are completed. • Neither WPW projects increase amount of waterbird habitat in the drawdown zone, or affect productivity. • Both WPW projects prevent erosion and do not mitigate adverse impacts of reservoir operations. • Both WPW projects protect highly important habitats for waterbirds • If WPW6A is successful in preventing erosion, it will have been effective (CLBMON-40 does not monitor erosion rates).
		H3D: Wildlife physical works do not increase indices of productivity of waterbirds utilizing the drawdown zone.	
		H3F: Wildlife physical works do not increase the amount of waterbird habitat in the drawdown zone.	

Appendix 7-2: Total numbers of waterbirds (adults and young) observed during land-based waterbird surveys in 2016

Common Name	Scientific Name	Spring	Brood Survey	Fall
American Coot	*Fulica americana*	1	0	1459
American Wigeon	*Anas americana*	710	254	1499
Barrow's Goldeneye	*Bucephala islandica*	4	0	0
Blue-winged Teal	*Anas discors*	27	3	5
Bufflehead	*Bucephala albeola*	32	0	40
Canada Goose	*Branta canadensis*	895	2134	1972
Canvasback	*Aythya valisineria*	0	0	6
Cinnamon Teal	*Anas cyanoptera*	27	3	0
Common Goldeneye	*Bucephala clangula*	2	0	1
Common Loon	*Gavia immer*	2	4	1
Common Merganser	*Mergus merganser*	62	5	58
Eurasian Wigeon	*Anas penelope*	2	0	0
Gadwall	*Anas strepera*	3	3	23
Goldeneye Sp	*Bucephala sp*	1	2	0
Greater Scaup	*Aythya marila*	3	0	1
Greater White-fronted Goose	*Anser albifrons*	0	6	0
Green-winged Teal	*Anas crecca*	227	7	950
Hooded Merganser	*Lophodytes cucullatus*	14	3	84
Lesser Scaup	*Aythya affinis*	1	0	0
Mallard	*Anas platyrhynchos*	686	112	1088
Northern Pintail	*Anas acuta*	33	0	77
Northern Shoveler	*Anas clypeata*	85	10	6
Pied-billed Grebe	*Podilymbus podiceps*	3	22	34
Red-necked Grebe	*Podiceps grisegena*	0	0	10
Redhead	*Aythya americana*	0	0	2
Ring-necked Duck	*Aythya collaris*	82	10	21
Ruddy Duck	*Oxyura jamaicensis*	0	0	4
Scaup Sp	*Aythya sp*	4	0	18
Trumpeter Swan	*Cygnus buccinator*	1	0	0
Tundra Swan	*Cygnus columbianus*	0	0	0
Unidentified Duck		32	16	673
Unidentified Grebe		0	0	1
Unidentified Swan	*Cygnus sp*	1	0	0
Unidentified Teal	*Anas sp*	0	2	324
Western Grebe	*Aechmophorus occidentalis*	0	0	3
Wood Duck	*Aix sponsa*	40	23	15

Appendix 7-3: Map of Bald Eagle and Osprey nests monitored in 2016



Appendix 7-4: Total numbers of shorebirds observed during land-based and boat-based shorebird surveys in 2016

Common Name	Scientific Name	Number
Semipalmated Plover	*Charadrius semipalmatus*	4
Killdeer	*Charadrius vociferus*	55
Spotted Sandpiper	*Actitis macularius*	104
Solitary Sandpiper	*Tringa solitaria*	12
Greater Yellowlegs	*Tringa melanoleuca*	31
Lesser Yellowlegs	*Tringa flavipes*	12
Great Knot	*Calidris tenuirostris*	1
Semipalmated Sandpiper	*Calidris pusilla*	28
Western Sandpiper	*Calidris mauri*	1
Least Sandpiper	*Calidris minutilla*	49
Baird's Sandpiper	*Calidris bairdii*	3
Pectoral Sandpiper	*Calidris melanotos*	28
Stilt Sandpiper	*Calidris himantopus*	1
Unidentified Calidris Sandpiper	*Calidris sp.*	2
Unidentified Dowitcher	*Limnodromus sp.*	1
Long-billed Dowitcher	*Limnodromus scolopaceus*	11
Unidentified Shorebird		9
Wilson's Snipe	*Gallinago delicata*	24
Red-necked Phalarope	*Phalaropus lobatus*	3

Appendix 7-5: Map of Short-eared Owl habitat based on observer professional opinion. These polygons were analyzed to describe habitat elevation distribution and habitat classification.