Columbia River Project Water Use Plan

Arrow Lakes Reservoir Operations Management Plan

Arrow Lakes Reservoir Shorebird and Waterbird Monitoring Program

Implementation Year 7

Reference: CLBMON-40

Study Period: 2014

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 7, 2014

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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EXECUTIVE SUMMARY

Impoundments along the Columbia River have greatly reduced the number and quality of wetlands in the region. Several remnant wetlands with regional ecological importance remain in Revelstoke Reach of the Arrow Lakes Reservoir (ALR). It is unclear how the operation of ALR affects the availability and quality of these wetlands for wildlife. Habitat quality for waterbirds and shorebirds varies greatly as a direct function of the reservoir's water elevations because vegetation cover and foraging substrates may be exposed or submerged, and because water depth affects foraging opportunities. How reservoir operations affect waterbird and shorebird use of the drawdown zone had not been studied in detail, and the relationship between reservoir operations and habitat quality is poorly understood.

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

The CLBMON-40 project monitors stopover use of the Revelstoke Reach wetlands during spring and fall migration, the importance of these wetlands for breeding waterbirds, and how these ecological services are impacted by reservoir operations. This report summarizes progress in Year 7 of the ten year study. Annual effort and results, and multi-year progress are briefly summarized. We also present new analyses of the data.

Waterbird monitoring occurred in spring and fall at two scales. Aerial surveys were used to monitor the distribution of waterbirds over the entire study area. Weekly land-based surveys focussed on individual wetlands, and monitored temporal changes to abundance, details of waterbird 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.

In 2014, the ALR filled relatively early during the spring draw, peaking ~1 m below the full pool elevation of 440.1 m in early July. Spring temperatures were relatively cold, and the wetlands opened late causing the spring migration of waterfowl to be a comparatively ephemeral event. During the summer months, weather conditions were warm, and there was low precipitation and few storms relative to previous years. Five species of waterfowl were observed with broods: Pied-billed Grebe, Canada Goose, Common Merganser, Mallard, and American Wigeon. One Northern Harrier nest was located not far from the Revelstoke Airport at 437.7 m ASL. This nest was > 2 m below the full pool elevation and would surely have failed by submersion had it not failed early in the nesting period. The harriers did not re-nest. Short-eared Owl nesting was not detected in the study area in 2014.

In 2014, we expanded the study area for monitoring Bald Eagle and Osprey nests in the ALR in order to enhance sample size. There were five active Bald Eagle nests in 2014, and three of these were successful. Four out of ten active Osprey nests were also successful. There was a relatively strong shorebird fall migration observed in the study

area in 2014, with 15 shorebird species observed. An extended land-based shorebird survey season afforded improvements to the modelling of the migration of Long-billed/Short-billed Dowitchers. The fall waterfowl migration peaked rather late in the fall, ending in mid-November when the wetlands froze.

Also in 2014, analyses were updated to model the timing of waterfowl migrations, and the impact that reservoir operations have on waterfowl use of the main wetlands: Airport Marsh, Montana Slough, and Cartier Bay. After controlling for seasonal effects, the analyses showed a strong impact of water depth on the number of waterfowl using the Cartier Bay wetland, but no measureable effects at Montana Slough or Airport Marsh – both wetlands being positioned higher in the drawdown zone.

As the project enters the final years of study, analysis of the multi-year data will be emphasized. It is recommended that the Terms of Reference be reviewed for this project.

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.

ACKNOWLEDGEMENTS

Many people have contributed greatly to the completion of Year 7 of the CLBMON-40 project. BC Hydro Water Licence Requirements sponsored the project. We thank Jason Watson (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 Alexis Friesen of the ONA contributed to field studies. Al Peatt managed the ONA's involvement and provided a technical review of this report.

Devon Anderson, Corey Bird, Russell Cannings, Stacey Carnochan, Catherine Craig, Jason Fidorra, Alexis Friesen, Ryan Gill, Michal Pavlik, Harry van Oort, and Bruce Weaver conducted field studies on waterbirds, shorebirds and raptors. Ryan Gill and Harry van Oort conducted aerial waterfowl surveys. Ryan Gill provided GIS mapping and analysis. Suzanne Beauchesne provided overall supervision and monitoring of crews. John Cooper acted as Project Manager.

We would like to thank Rod Watt at Canadian Helicopters for providing exceptionally safe and consistent piloting of his aircraft, and personnel at BC Hydro Aircraft Operations for helping to assure that our flying was performed in safe flying conditions.

Analysis and report writing was done by Harry van Oort. Comments provided by Al Peatt greatly improved this report.

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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 primary course 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 in the landscape makes Revelstoke Reach an area of great regional importance for wetland wildlife (Tremblay 1993, Jarvis and Woods 2001, CBA 2013a).

The operation of ALR is thought to affect the availability and quality of habitat in Revelstoke Reach for waterbirds and shorebirds. Habitat quality for waterbirds and shorebirds 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 and shorebirds (Rundle and Fredrickson 1981, Parsons 2002). How reservoir operations affect waterbird and shorebird use of the drawdown zone has not previously been studied in detail, and the relationship between reservoir operations and habitat quality is poorly understood.

During the Columbia River Water Use Planning process, a number of potential impacts from reservoir operations on shorebirds and 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 and shorebirds in Revelstoke Reach.

[1] Between Castlegar and Valemount, an approximate linear distance of 400 km of valley bottom was impounded, and natural habitats (including riparian and wetland) were flooded. Additionally, between Mica and Donald along Columbia Reach of Kinbasket Reservoir, an approximate linear distance of 100 km of valley-bottom habitat was flooded.

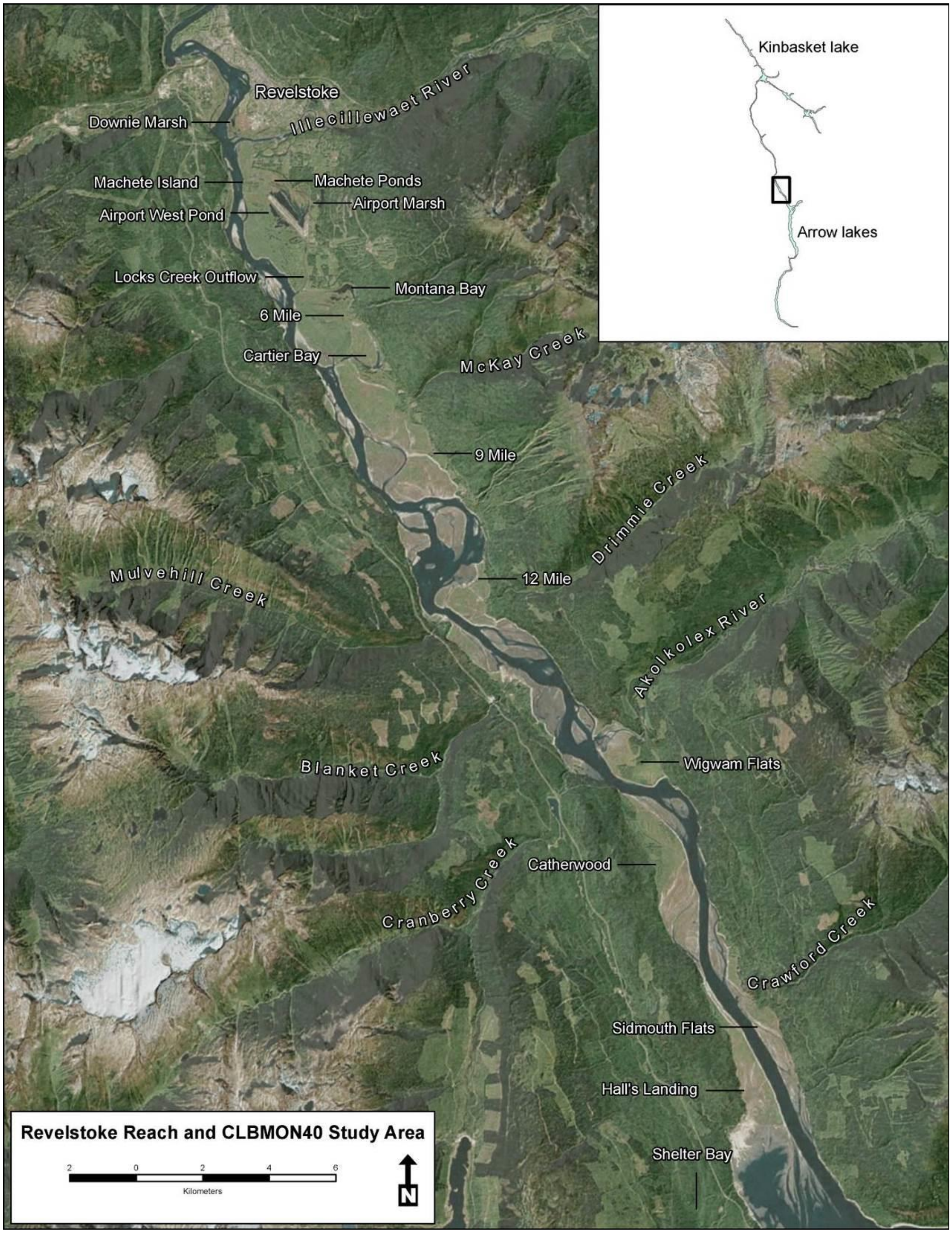

Figure 1-1: Overview map of Revelstoke Reach, with geographic features labelled

1.1 Scope and objectives

CLBMON-40 will determine if and how reservoir operations affect waterbird populations, and if the effects are negative, how to mitigate those effects. The specific objectives of the 10-year project are to: [2]

1) determine the abundance, distribution, and habitat use of waterbirds and migratory shorebirds and the productivity of waterbirds in Revelstoke Reach;

2) examine how variation in flow and reservoir water elevations influence seasonal and yearly abundance, distribution, and habitat use of waterbirds and migratory shorebirds and the productivity of waterbirds in Revelstoke Reach;

3) inform how physical works and revegetation can be designed to mitigate adverse impacts to waterbirds and shorebirds resulting from reservoir operations, and

4) assess the effectiveness of physical works and revegetation at enhancing habitat for waterbirds and shorebirds.

For the purposes of this study, we defined the term "productivity" as (an index of) the average reproductive output (the number of offspring produced) of a population.

1.2 Management questions

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

1. What are the:

   I. seasonal and annual variations the abundance and spatial distribution of waterbirds in Revelstoke Reach; and

   II. variations in the abundance and spatial distribution of shorebirds during fall migration in Revelstoke Reach?

2. What impacts do year-to-year and within-year reservoir operations have on resident and migratory waterbirds and migratory shorebird populations?

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

4. What is the annual variation in the productivity of waterbirds in Revelstoke Reach and does productivity vary spatially (e.g. are there areas of higher waterbird productivity or brood counts)?

5. Which species of shorebirds and waterbirds are most likely to be affected 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 the productivity of waterbirds in Revelstoke Reach between years?

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[2] The wording of the management objectives, questions and hypotheses stated in the BC Hydro terms of reference for CLBMON-40 are presented verbatim.

8. Can minor adjustments be made to reservoir operations to minimize the impact on migrating waterbirds and shorebirds or on waterbird productivity?

9. Can physical works be designed to mitigate any adverse impacts on migrating waterbirds and shorebirds or on waterbird productivity resulting from reservoir operations?

10. Does revegetating the drawdown zone affect the availability and use of habitat and its use by shorebirds or waterbirds in Revelstoke Reach?

11. Do wildlife physical works projects implemented during the course of this monitoring program affect waterbird and shorebird abundance, and/or diversity, or waterbird productivity?

As part of BC Hydro's Water Licence Requirements, BC Hydro is required to adequately address these 11 questions over a 10-year study period.

1.3 Management hypotheses

From these management questions, several management hypotheses were outlined by BC Hydro for testing by the CLBMON-40 research:

H_1: The annual and seasonal variation in water levels resulting from reservoir operations, the implementation of soft constraints, and the potential impact from Rev 5, ("reservoir operations"), do not result in a reduction of waterbird or shorebird use in Revelstoke Reach.

H_{1A} Reservoir operations do not result in decreased species diversity in waterbirds or migratory shorebirds in Revelstoke Reach.

H_{1B} Reservoir operations do not result in a decrease in the abundance of waterbirds or migratory shorebirds in Revelstoke Reach.

H_{1C} Reservoir operations do not result in changes in waterbird or shorebird distribution in Revelstoke Reach.

H_{1D} Reservoir operations do not result in a decrease in the productivity of waterbirds in Revelstoke Reach.

H_{1E} Reservoir operations do not result in a decrease in shorebird foraging habitat in the drawdown zone.

If changes in species diversity, abundance, distribution or productivity are detected over time, the following hypotheses will be tested to determine whether these changes can be attributed to changes in habitat quality or availability as a result of reservoir operations, or to revegetation efforts or physical works projects implemented during the course of this monitoring program.

H_2: Annual variation in reservoir water levels, reservoir operations, the implementation of soft constraints, and the potential impact from Rev 5, do not result in a reduction or degradation of waterbird or shorebird habitats.

H_3: Revegetation and wildlife physical works do not increase the utilization of habitats by birds in Revelstoke Reach.

H_{3A}: Revegetation and wildlife physical works do not increase the species diversity or abundance of shorebird or waterbirds in Revelstoke Reach.

H_{3B}: Revegetation and wildlife physical works do not increase the productivity of waterbirds in Revelstoke Reach.

H_{3D}: Revegetation and wildlife physical works do not increase the amount of shorebird or waterbird habitat in Revelstoke Reach.

The monitoring program designed to address these objectives/questions/hypotheses—CLBMON-40—was initiated in 2008. The research program spans 10 years in order to determine the effect of reservoir operations (water level management) on the abundance, distribution and productivity of waterbirds and shorebirds and to assess and inform physical works. Several approaches are being used; 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 7 (2014).

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 most of its precipitation in the form of snowfall delivered by Pacific frontal systems during 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 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 these flats 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*) and black cottonwood (*Populus balsamifera*). Prior to the completion of the Hugh Keenleyside Dam near Castlegar, Revelstoke Reach was developed as farmland, and it 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 of less significance. 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 levels are 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 420 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

The methods used are described below; additional information is available in a detailed protocol report written primarily for field technicians (CBA 2014a).

CLBMON-40 involved six surveys in 2014 (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 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).

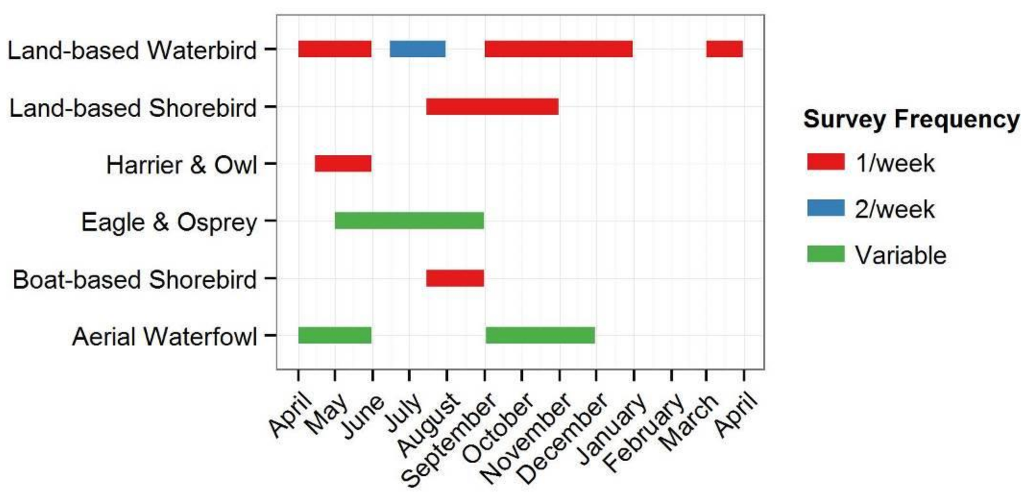

Figure 2-1: Overview of how the six CLBMON-40 monitoring surveys are scheduled. Data from the two types of shorebird surveys can be married as one data set during weeks when both surveys take place

2.1 Land-based waterbird surveys

Land-based surveys monitor seasonal and spatial usage of waterbirds within the most important wetlands (Figure 2-2).[3] Weekly land-based waterbird surveys were 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.

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, resting, preening) 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 Bell 206B 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.

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 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 earlier peak part of the monitoring season – which coincides with the peak migration of

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[3] “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.

most species. Land-accessed areas were surveyed over an extended time period, with the late-season surveys focussed on Dowitcher 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.

In addition to monitoring the sites mentioned above, random locations were monitored during boat-based surveys to assess if any particular recognized habitat classifications had particular importance to shorebird. These sites were chosen using GIS based on available mapped habitat types and the reservoir water elevation at time of survey.

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

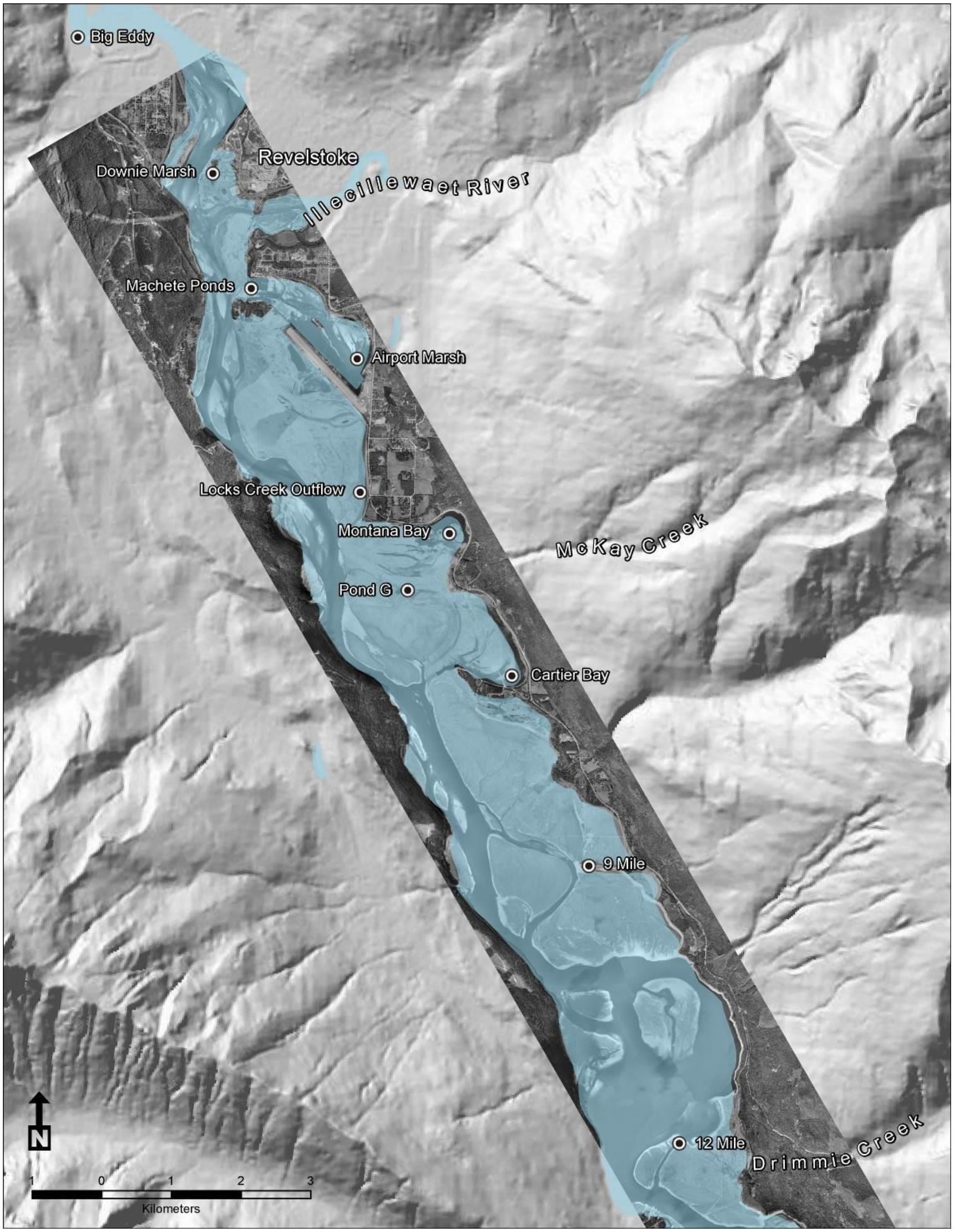

Figure 2-2: Locations of wetlands in Revelstoke Reach where land-based waterbird surveys and brood surveys were conducted are represented by points. Some of these wetlands were monitored by multiple fixed-observation stations

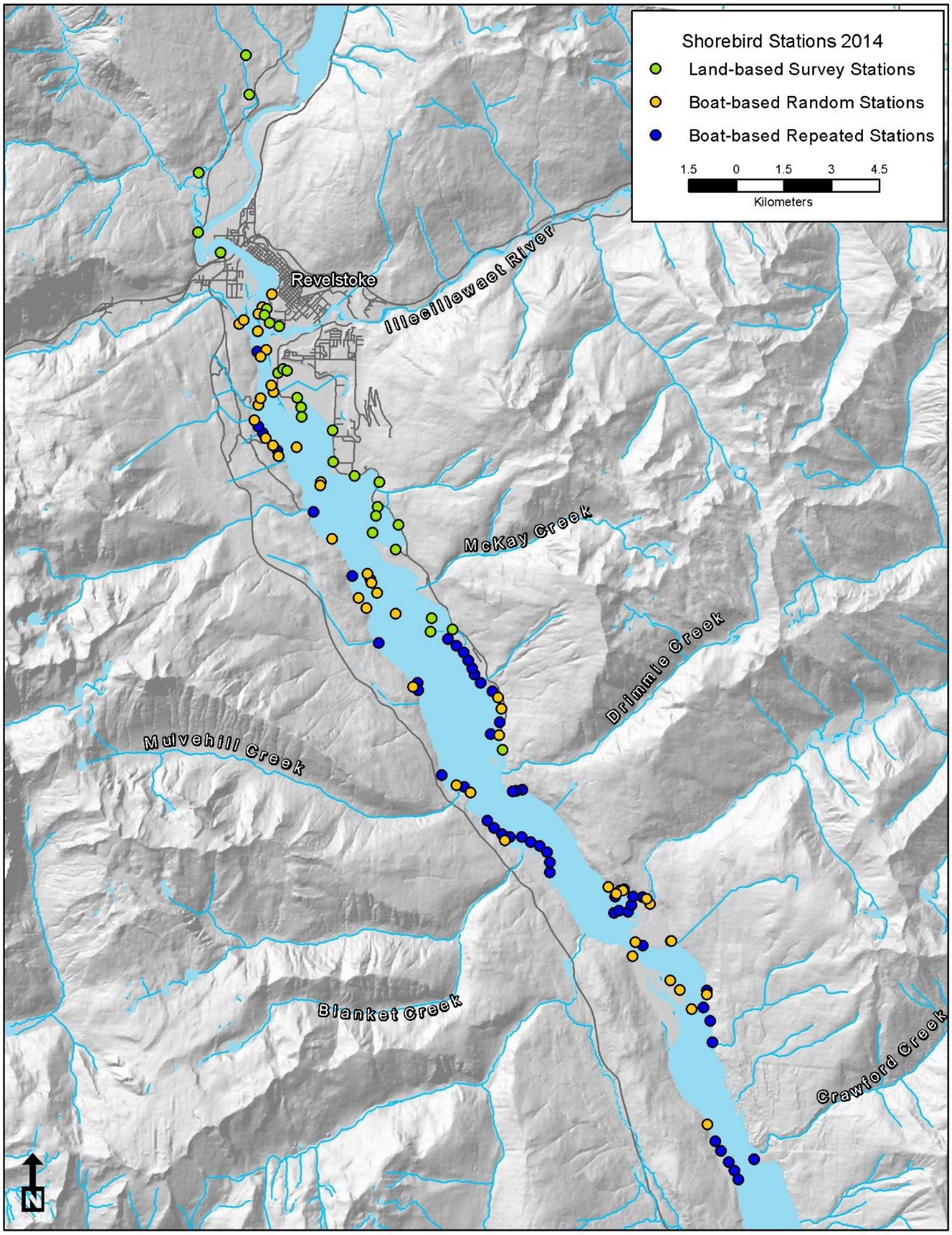

Figure 2-3: Locations of shorebird observation stations in Revelstoke Reach. Only random stations monitored in 2014 are shown. All other stations have been monitored for multiple years

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.

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. A Bell 206B (Jet Ranger) helicopter was used to assist with nest checks and nest searches (2 – 3 flights per year). In 2014, we checked known Bald Eagle nests in mid- to late-April during an aerial waterfowl survey, as Bald Eagle begin nesting relatively early. One nest search was conducted per year (mid-May) while checking known/existing nests. The helicopter was also used to check active nests in mid-June. In mid-July until fledging, nests were checked while conducting boat-based shorebird surveys (once per week) or by ground access.

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.

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 2003, CBA 2011). 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 either species during each visit. Nesting activity of these species was unlikely to go unnoticed given other types of field work 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 Pilot field video surveillance on Osprey nests

In 2014 we conducted a pilot study to assess the idea of using video surveillance to determine if reservoir operations impact food delivery rates to nestlings. Footage was gathered at two nests. The data are being retrieved over the 2014/15 winter, and will not be available for reporting until a later date.

2.8 Analytical methods

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

For the multi-year analysis, the data were often influenced by non-linear relationships, so we relied heavily on General Additive Models (GAM). The GAM's were applied to count data containing many low counts (near zero) so consideration was given to the type of distribution used to model the stochastic component of the data. We began by specifying a quasi-Poisson family in our model of count data. Like the Poisson distribution, these models assume that there is a relationship between variance and the estimate of central tendency, but, unlike standard Poisson models this relationship could be adjusted. Overdispersion of count data was assessed by calculating the sum of squared Pearson residuals and dividing this number by the residual degrees of freedom; this overdispersion parameter (Φ) will equal one if the data fit the model well, but will be greater than one if overdispersed (Zuur et al. 2012). Quasi-Poisson models can be used when overdispersion is low or moderate ($\Phi < 20$, Zuur et al. 2009). If highly overdispersed ($\Phi > 20$), negative binomial distributions were specified to improve fit, and we re-assessed for overdispersion using the same method. GAM's were fit using the mgcv package (Wood 2011).

A two-tailed alpha, set at 0.05, was used for all tests.

2.9 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 elevation was relatively high in early May (~ 429 m ASL), and during the spring draw compared with historic water elevations (Figure 3-1). The maximum elevation was ~ 1 m below full pool (maximum elevation = 439.1 m ASL on July 4). Following, the reservoir levels receded rapidly over the remainder of the summer (Figure 3-1).

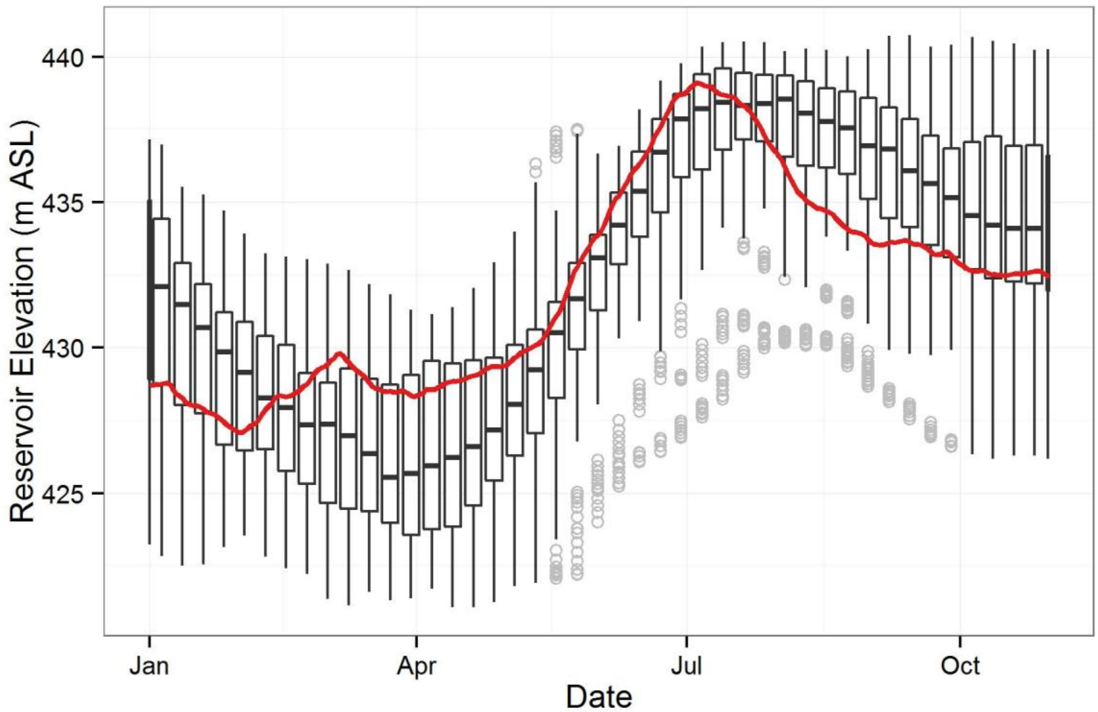

Figure 3-1: Elevation of the Arrow Lakes Reservoir from April 1 to October 31, 2014 is plotted in red; the historical range of values is plotted in weekly intervals as boxplots

3.1.2 Weather

Following a relatively cold, late winter (Figure 3-2) characterized by several large precipitation events (Figure 3-3), a deep snowpack persisted in spring. The result was a comparatively late thaw of the wetlands (Figure 3-4). May was moderately wet compared with previous years. Summer was dry and seasonably warm. Fairly normal weather was observed in the fall.

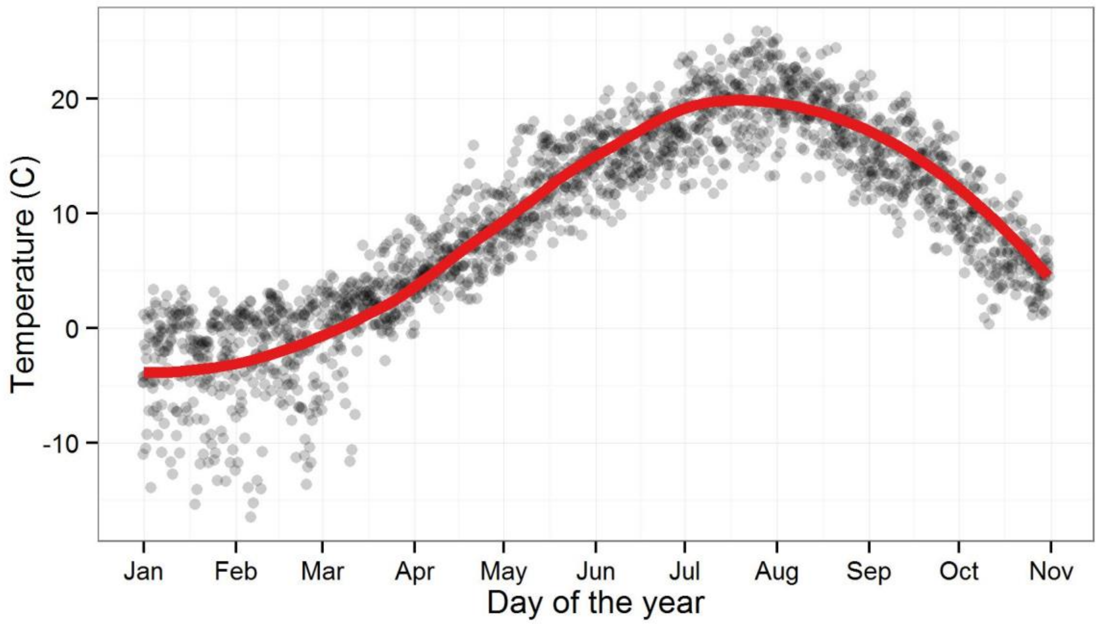

Figure 3-2: **Mean daily temperatures observed during the course of the study. The current year data is illustrated by the red line**

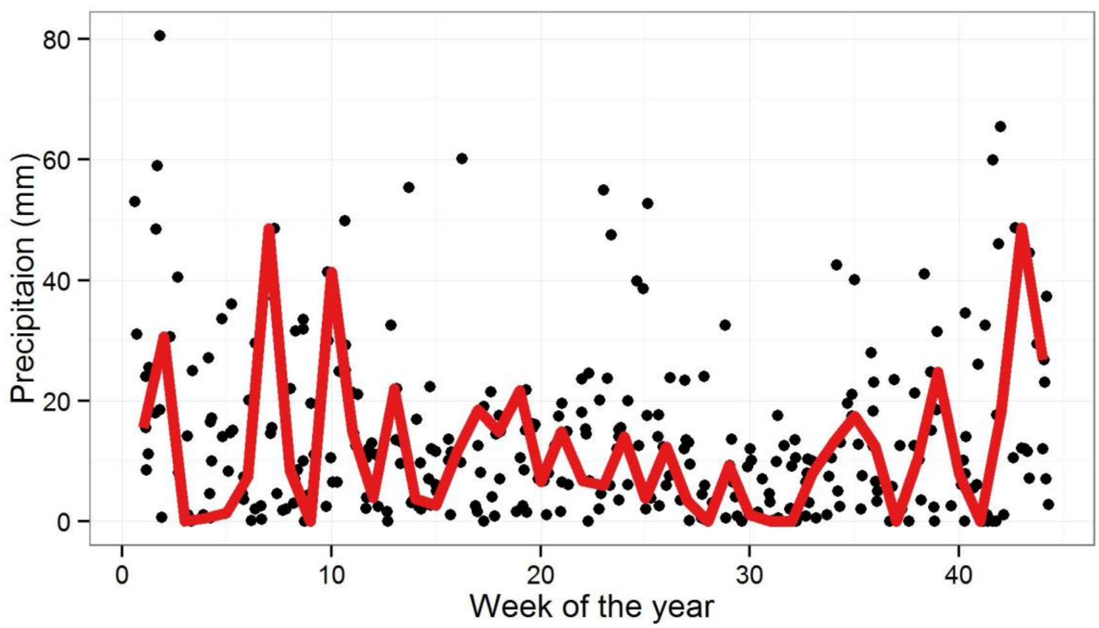

Figure 3-3: **Weekly precipitation observed during the course of the study. Values recorded in the current year are represented by the red line**

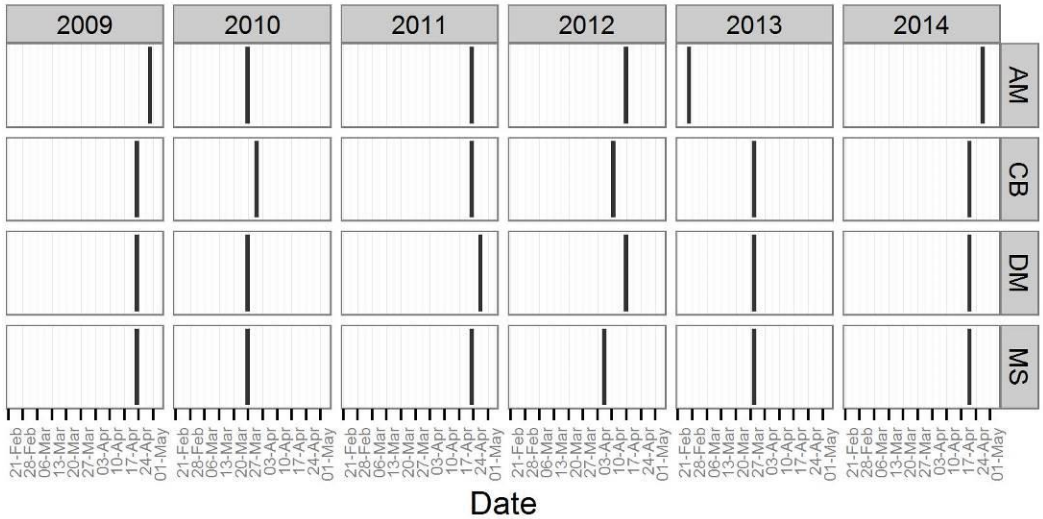

Figure 3-4: **Comparison of dates when the Airport Marsh (AM), Cartier Bay (CB), Downie Marsh (DM) and Montana Slough (MS) were first observed to be ice free during land-based waterbird surveys (2009 to present)**

3.1.3 Survey effort

In this report, we summarize work accomplished from March through December, 2014 but data from other months and years may be included for illustrative purposes.

Five aerial waterfowl surveys were conducted (one in spring; four in fall).

Ten individual surveys were conducted for monitoring Bald Eagle and Osprey nesting. The first survey was done on April 15 using a helicopter to check status of known Bald Eagle nests. A second survey (May 20) was done with a helicopter to search for new nests and to check all known nests. The third survey (June 19) was a helicopter survey to check all active nests. All other nest checks were done during boat-based shorebird surveys, or were land-based.

Seven days of survey work for Short-eared Owl and Northern Harrier nesting took place in spring. These days were often split into multiple surveys (e.g., one in the morning and one in the evening) for a total of 15 separate surveys.

Six boat-based shorebird surveys were completed. Eighteen land-based shorebird surveys were completed during the fall migration.

Nine land-based waterbird surveys took place during the spring migration period. During the brood rearing period, 12 surveys were made. During the fall migration period, thirteen surveys were completed, ending when the wetlands froze and snowpack limited waterfowl access to terrestrial forage.

3.1.4 Waterfowl migration

The spring migration initiated relatively late this year (Figure 3-5). The dabbling duck migration was ephemeral, with only one survey capturing the peak level of migration (Figure 3-5). Canada Goose counts were relatively low during the spring migration compared with some of the larger counts made in previous years (Figure 3-5).

The fall migration peaked relatively late in the fall (Figure 3-6). For most waterfowl, the migration ended with a high pressure system in mid-November that froze the wetlands. Canada Goose counts also diminished shortly thereafter when snowfall covered much of their grassland forage.

A table of species observed during land-based waterbird surveys can be found in Appendix 7-2.

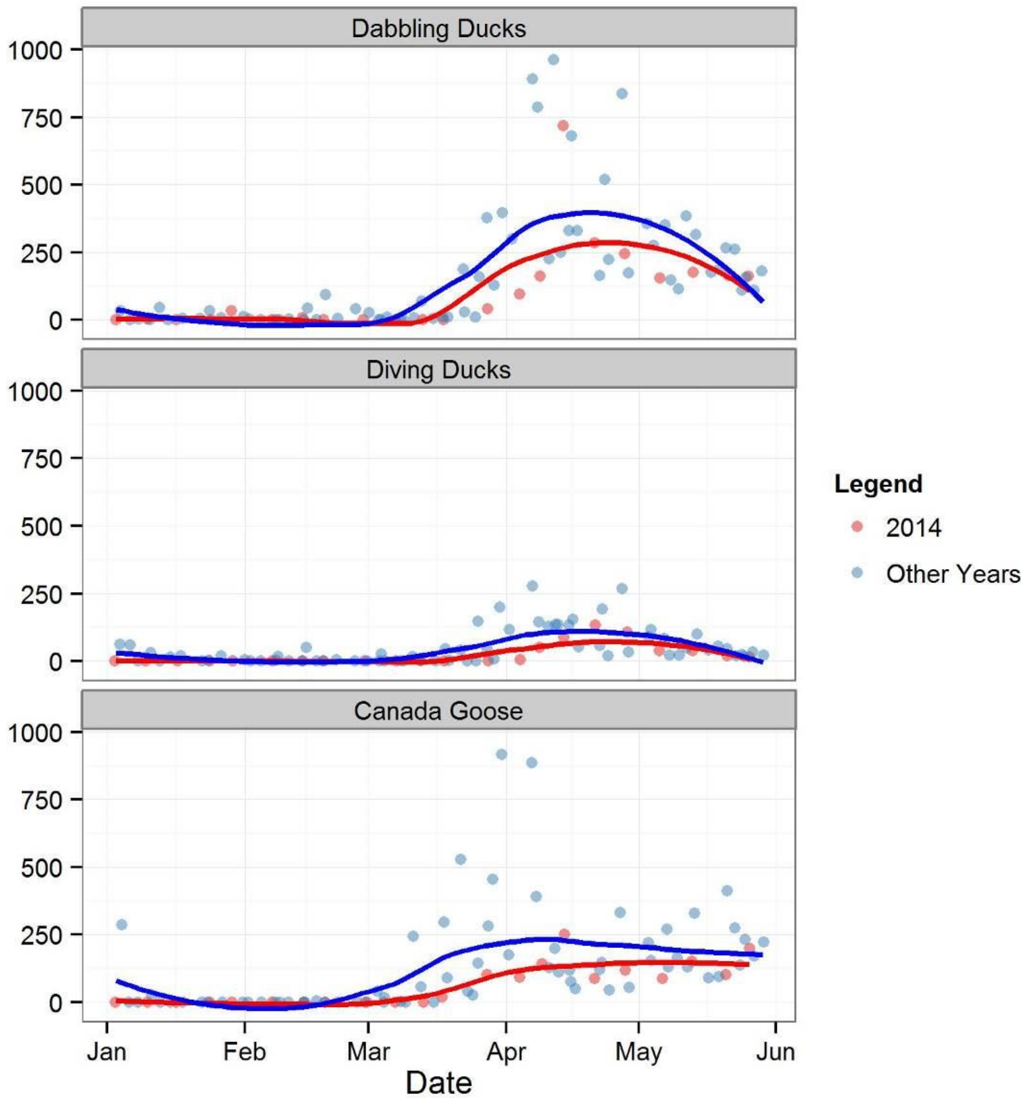

Figure 3-5: Spring waterfowl counts recorded at the core wetlands (Downie Marsh, Airport Marsh, Locks Creek Outflow, Montana Slough, and Cartier Bay). A Loess smoother is fit to all data (blue), and for the current year data (red) for illustrative purposes

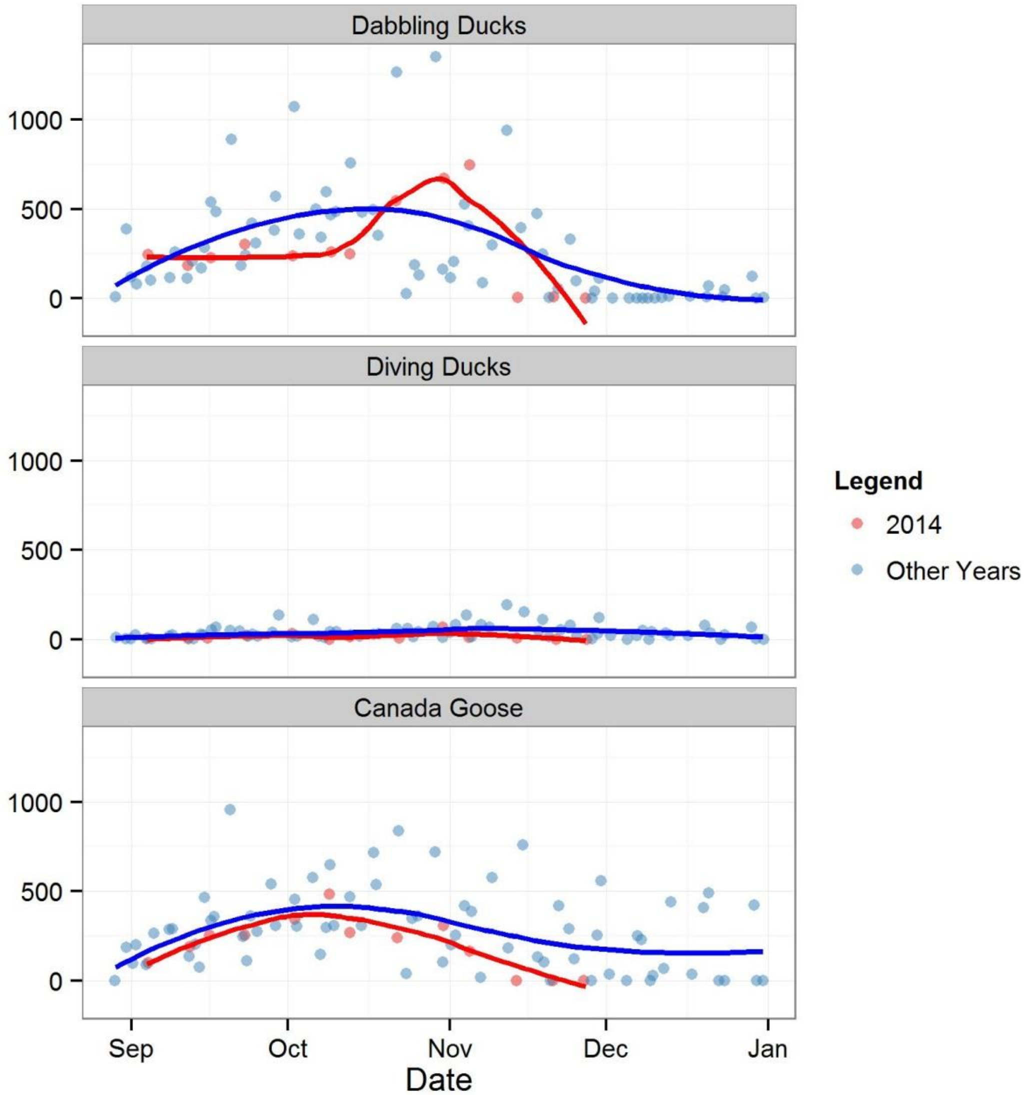

Figure 3-6: **Fall waterfowl counts recorded at the core wetlands (Downie Marsh, Airport Marsh, Locks Creek Outflow, Montana Slough, and Cartier Bay). A Loess smoother is fit to all data (blue), and for the current year data (red) for illustrative purposes**

3.1.5 Waterfowl productivity

Five species were observed with broods: Pied-billed Grebe, Canada Goose, Common Merganser, Mallard, and American Wigeon. Canada Goose broods were the most commonly observed; these were recorded at Cartier Bay, Montana Slough, the Airport Marsh, and at Locks Creek Outflow. A Common Merganser brood was consistently observed in the Cartier Bay area. One Mallard brood observation was made at Locks Creek Outflow. Three American Wigeon broods were observed at Machete Ponds.

3.1.6 Raptor productivity

One Northern Harrier nest was located in the drawdown zone (Figure 3-7). A single egg was laid, but the nest failed during the laying period. There were no indications that the pair re-nested. The nest was located in a horsetail patch at 437.7 m ASL; therefore had it persisted longer, it would have ultimately failed due to reservoir flooding.

Short-eared Owl nesting was not detected in the study area this year. This species was observed during spring migration but not later than April 24.

Five known and previously monitored nests of Bald Eagle or Osprey nests were missing (i.e. destroyed over winter), and eight previously unknown nest structures were located during the nest search this year. One of the new Osprey nests, which was likely built as a replacement of a nearby nest that was lost in the winter, was subsequently destroyed during a strong wind storm in the breeding season (Figure 3-8), making a total of six destroyed nests by the end of the breeding season (Figure 3-9). Three out of five active Bald Eagle nests were successful in 2014. Four of ten active Osprey nests were successful (Appendix 7-3).

Figure 3-7: Northern Harrier nest located at 437.7 m asl, approximately 2.3 m below the full pool elevation with one freshly laid egg (May 26, 2015). The nest failed immediately. The nest site flooded on June 23, 2015, which would have been near the end of the incubation period

Figure 3-8: **Video monitoring of an Osprey nest captured the nest's demise. In this frame, the Osprey can be seen taking flight when its nest is dislodged during a strong summer wind storm. This nest was built in spring, following the over winter destruction of its previous nest that was situated on a different transmission line structure nearby. The photo was captured by video surveillance work conducted as a pilot study under CLMBON-40. The pilot work will be reported in a future report when initial data are available.**

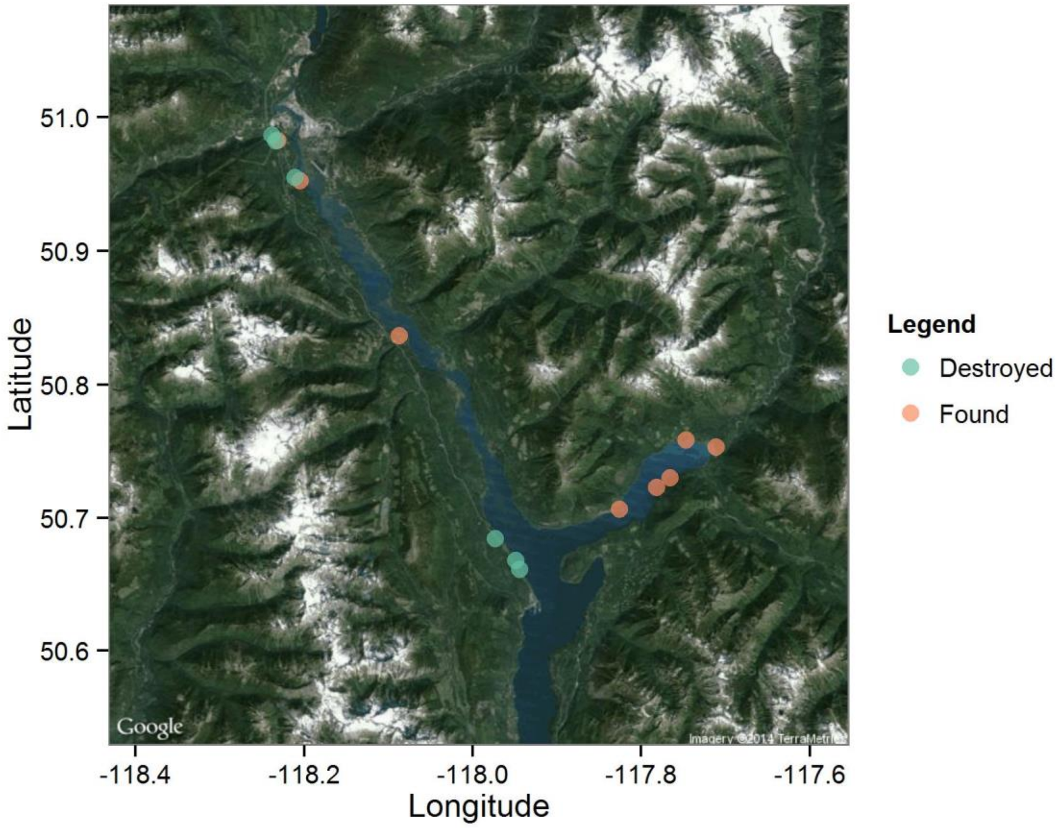

Figure 3-9: **Newly found (2014) and missing nests of Bald Eagle and Osprey. Note that the Beaton Arm section was added this year to increase sample size**

3.2 Shorebird fall migration

Shorebirds were relatively abundant during the fall migration, with 15 species observed. Our complete surveys (weeks with both boat and land-based surveys) began after the migration had started, but captured the primary migration period (Figure 3-10). An exceptionally high count of 64 Spotted Sandpipers was made on one survey (Figure 3-10). Considering land-based surveys only, it was evident that the Dowitcher migration was relatively well pronounced this year (Figure 3-11). By extending the monitoring period for land-based surveys, we are now able to monitor the conclusion of the Dowitcher migration (Figure 3-11). A summary of shorebird species detections are provided in Appendix 7-4.

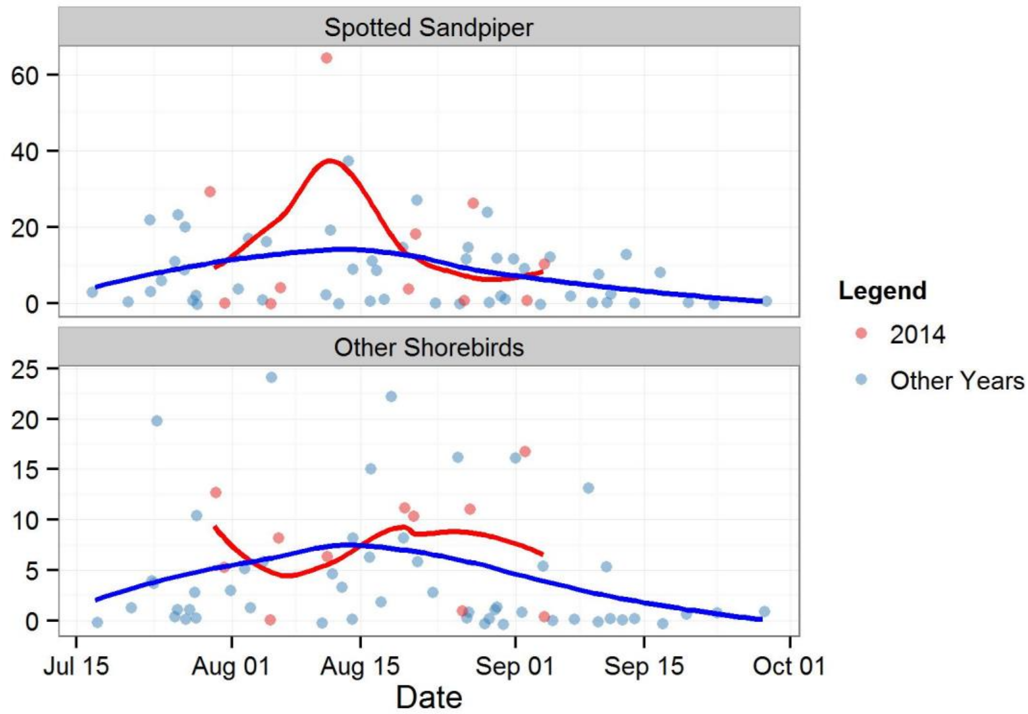

Figure 3-10: **Fall shorebird counts recorded in weeks when both land-based and boat-based surveys were conducted. A Loess smoother is fit to all data (blue), and for the current year data (red) for illustrative purposes**

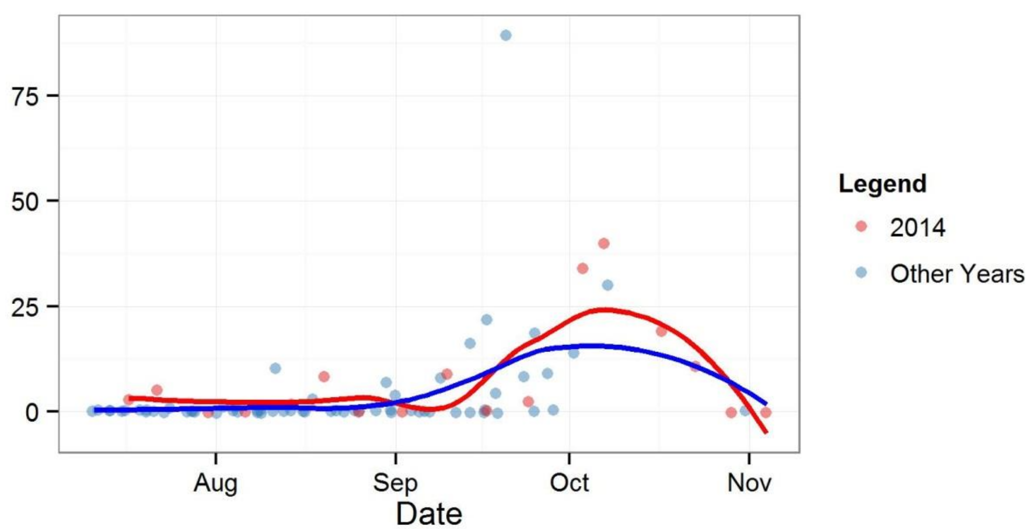

Figure 3-11: **Fall shorebird counts of Dowitcher recorded in land-based surveys. A Loess smoother is fit to all data (blue), and for the current year data (red) for illustrative purposes**

3.3 Multi-year analysis

3.3.1 The effect of seasonality on duck counts

The seasonal influence of migration was modelled using a quadratic smoothing spline with negative binomial error distribution. The model fit was not overdispersed (Φ = 0.86), and the model captured a strong effect of ordinal date on duck counts ($P < 0.001$, $R^2 = 0.53$, Figure 3-12). Daily estimates were saved to provide a seasonal index for controlling migration intensity in other models.

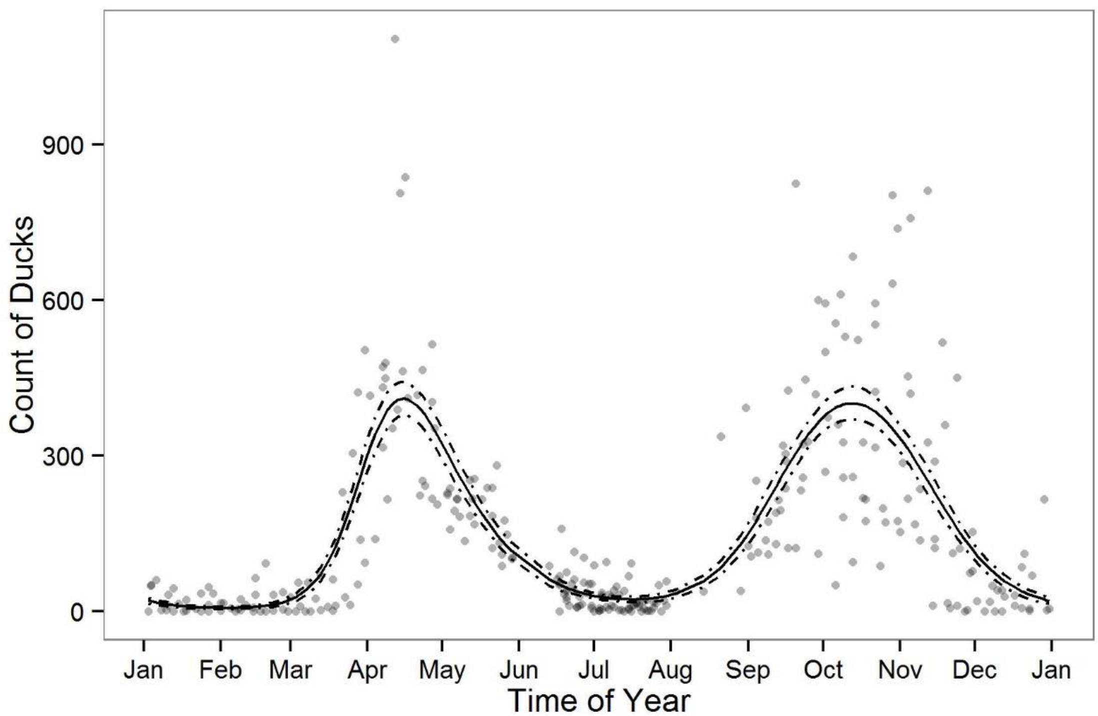

Figure 3-12: **Negative binomial cyclical GAM modelling seasonal abundance of dabbling and diving ducks from the land-based waterbird survey data (2008-2014). Raw data (points), the model estimate (solid line) and the model standard error (dashed line) are plotted**

3.3.2 The effect of reservoir operations on duck counts during the fall

Duck abundance and distribution may be impacted during the fall migration (September through November) when reservoir operations inundate some wetland habitats. The Airport Marsh is positioned at a sufficiently high elevation (> 438 m asl) that it was rarely impacted in 2014; at a lower elevation (~ 436 m asl), Montana Slough had intermediate inundation impacts; Cartier Bay (< 434 m asl) was commonly inundated (Figure 3-13).

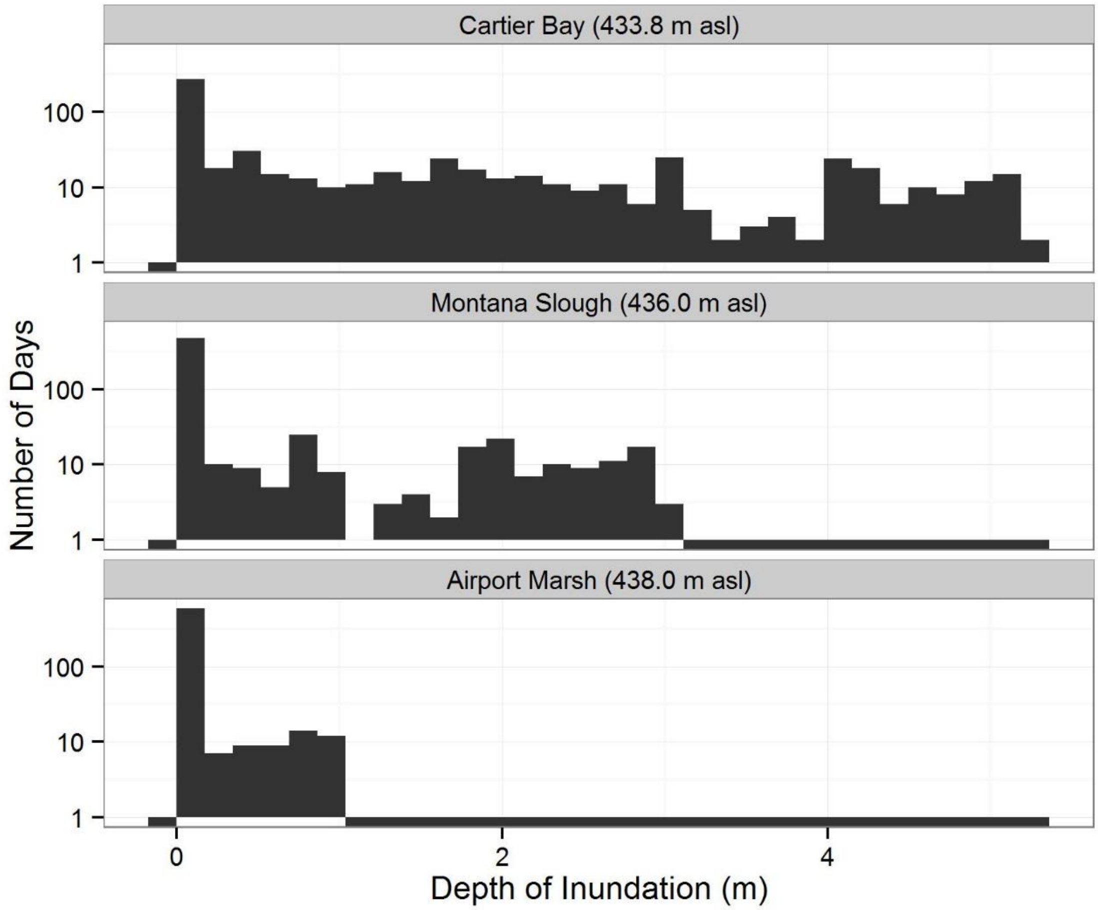

Figure 3-13: Histograms showing the cumulative number of days during the fall (September through November) that the ALR water surface elevations were greater than the resting elevations of three major wetlands in Revelstoke Reach (2008 through 2014). Note log scale.

Controlling for seasonal abundance (migration intensity) using the seasonal function developed above, duck abundance was modelled as a function of water depth separately for dabbling and diving ducks at each of three wetlands: Cartier Bay, Montana Slough, and the Airport Marsh. In all cases, the random errors were modelled using the negative binomial distribution to avoid overdispersion issues. The only significant impact of reservoir operations on duck abundance in 2014 was detected for dabbling ducks at Cartier Bay ($P < 0.001$; Figure 3-14); all other models failed to link water depth in 2014 to duck abundance.

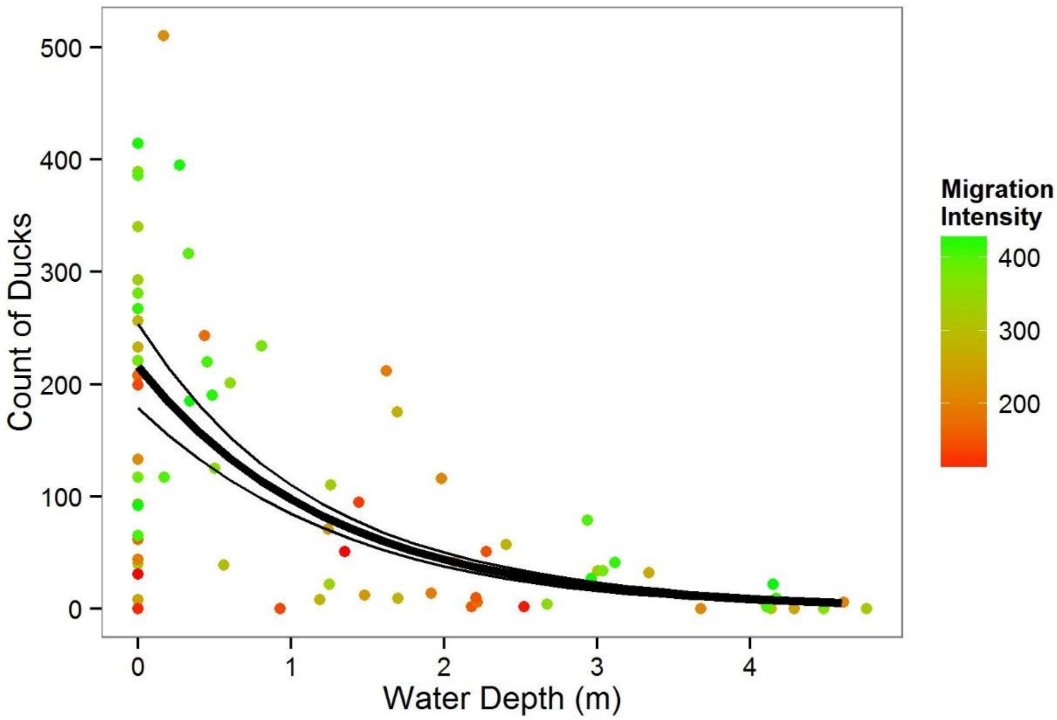

Figure 3-14: **Negative binomial model of how depth of reservoir inundation influenced dabbling duck counts at Cartier Bay, after controlling for migration intensity (a temporal effect)**

4 DISCUSSION

4.1 Year 7

The 2014 season started out with a relative late spring thaw, leading to late spring migration of waterfowl, with only one week where high abundance was observed.

Short-eared Owls migrated through the area, but did not settle down to breed. One pair of Northern Harrier attempted to breed, but the nest failed prior to being inundated. This was the first known nesting attempt for this species during the study (2008-2014). Earlier evidence of nesting by Northern Harrier in the Revelstoke Reach drawdown zone was noted in 2002 when it was presumed that the nest failed due to reservoir operations (Jarvis 2003). The 2014 nest was positioned at 437.7 m asl in the low-lying drawdown shrub savannah habitat, allowing no chance that the nest could have been successful under typical reservoir operations. The egg was laid in late May, which is relatively late compared to sites elsewhere in North America (Macwhirter and Bildstein 1996); even if the nest were initiated earlier, inundation of the nesting area would likely cause 100% loss of productivity. The shrub savannah habitat of Revelstoke Reach will typically be unproductive for this species due to reservoir operations. Whether the habitat can be technically called an ecological trap is a question of semantics. Northern Harrier show very low preference for nesting in the area, suggesting that it is not a trap; yet when they do nest in the drawdown zone, the nests probability of success is very low due to an ecological trap type of factor – reservoir inundation. The same arguments can be applied to nesting by Short-eared Owl.

A relatively small number of waterfowl broods were observed in 2014, but included a Common Merganser seen at Cartier Bay. It is unlikely that this brood hatched from a CLBWORKS-30 nest box (Kellner 2013). Examination of these nest boxes during the 2014/15 winter indicated that four of these boxes were used in 2014; however, these nests were from smaller birds based on egg morphology – likely Wood Duck (Kellner 2015). Wood Duck broods were not observed in 2014, but this is not surprising. Wood Duck rear their broods in areas with high amounts of visual cover and are therefore often not seen during brood surveys.

Bald Eagle and Osprey productivity in Revelstoke Reach was comparatively low in 2014. Causes of nest failure for Bald Eagle and Osprey remain largely unexplained. In 2014, pilot video footage was collected for monitoring food delivery rates at Osprey nests. This work is still in progress, but the footage did capture the demise of one nest, destroyed during a storm. To increase sample size for this project, additional Bald Eagle and Osprey nests were searched for, found, and monitored in 2014 by expanding the study area to include Beaton Arm.

The fall shorebird migration was relatively well-pronounced in 2014, beginning early, in mid-July. The Spotted Sandpiper and Dowitcher migrations were also prominent in 2014.

The fall waterfowl migration peaked relatively late, but ended relatively early when cool high pressure weather froze the wetlands in mid-November, followed shortly thereafter by considerable snowfall.

4.2 Multi-year progress and data gaps

In most cases, CLBMON-40 analyses require complex models that control for seasonal processes (e.g., migration intensity) and/or are analyses where each year of monitoring contributes one data point (e.g., where the analysis examines the effects of annual differences in reservoir operations as a predictor, or productivity as a response). With the completion of seven years of monitoring analyses, we can begin to examine annual effects and seasonal patterns. These will increasingly be the focus of future analyses in Years 8 to 10.

Previously, we identified a lack of data regarding the concluding period of the Dowitcher migration (CBA 2013). The Dowitcher population is one of the most reliably abundant shorebird species to make use of the study area each fall, but previous attempts to model the timing of the Dowitcher migration were inaccurate due to the truncation of monitoring during peak migration intensity. This led to models predicting ever increasing numbers during the fall (CBA 2013). In 2014, we extended the monitoring and gathered additional Dowitcher counts until the species had vacated the study area. As a result, with just one year of extended monitoring, the ability to accurately model Dowitcher migrations is greatly improved. With the addition of future monitoring data, we should be able to model the timing of the Dowitcher migration with satisfactory results.

A remaining limitation of CLBMON-40 is the ability to link reservoir operations to the productivity of Bald Eagles and Ospreys. The primary issue is a low sample size. One solution to this would be to extend the study area. This was done with minimal additional cost in Year 7, by including Beaton Arm. Extending the study to include nest monitoring elsewhere on the ALR would potentially provide benefit, but it is possible that the impact of ALR operations differ among regions given differences in water clarity and bathymetry, both of which may affect foraging behaviour. See the Section 4.3 of the Year 6 report for a full discussion of the potential factors that could be influencing Osprey productivity among years (CBA 2014b).

Despite small sample sizes, in 2013 we provided some evidence that ALR operations may be having a negative impact on Osprey nesting success (CBA 2014b). The leading theory is that the ability of adults to catch fish (and thus provision young) is contingent on reservoir elevation (CBA 2014b). In 2014, we conducted a pilot study to test the practicality and effectiveness of monitoring Osprey nests using video surveillance in order to quantify food delivery rates. Data were collected at two nests. Initial feedback suggests that the method may be useful, but might be limited by the number of nests that can be monitored and by relatively high maintenance effort (e.g., battery management). Data retrieval during the 2014/2015 winter will determine how many hours of footage could be gained per battery charge. Direct observation may be more practical and flexible. Methods and results for this component will be presented in a future report.

4.3 New analysis (2014)

In this report we continued with analyses of how reservoir inundation affects waterfowl abundance at wetlands in Revelstoke Reach. These analyses were first attempted for the Interim Report (CBA 2013) and refined for Cartier Bay ducks as part of the CLBWORKS-30 assessment of WPW14/15 (Hawkes et al. 2014). Here, we used updated data, repeated the Hawkes et al (2014) analysis separately for diving ducks and dabbling ducks, and in addition to running the analysis for the Cartier Bay data, we also considered Montana Slough and the Airport Marsh (six models).

In this report, our results suggest that the only major impact to ducks occurred at Cartier Bay, where dabbling ducks were highly sensitive to changing water depth. This is not surprising, given that Cartier Bay is more influenced by reservoir operations, being situated lower in the drawdown zone, and is also one of the most heavily used wetlands by dabbling ducks; Cartier Bay is an ideal site to document this effect. Dabbling ducks are numerically the most dominant guild of waterfowl that use Cartier Bay, so it is not surprising that the effect was only well pronounced in this group. Ecologically, one would also expect that dabbling ducks are more sensitive to water depth, based on the assumption that diving ducks may have a more variable range of water depths under which they can forage.

Montana Bay/Slough was inundated to a lesser (moderate) extent compared with Cartier Bay, but the models found no significant impact of reservoir inundation on the duck counts. While the reservoir flooding is less severe than what is observed at Cartier Bay, it is still substantial. The extensive pond complex where a large percentage of ducks are observed at Montana Slough are subject to considerable impoundment effects. However, there is considerable high elevation edge habitat (primarily shrubs) and the floating bog island habitat in Montana Slough; as such, considerable apparently suitable habitats remain during inundation. This and the fact that the wetland is used less by ducks, compared with Cartier Bay, likely contributed to the results.

The Airport Marsh is positioned sufficiently high in the drawdown zone that it is rarely inundated during fall. Even when inundated, large parts of the wetland are positioned above 438 m as the wetland extends above the full pool elevation (see Figure 1-3). Consequently, it is not surprising that the Airport Marsh showed no significant impact from reservoir operations.

These analyses are part of an ongoing effort to answer the question of how reservoir operations influence the abundance and distribution of waterbirds (Management Question 6), and to address how reservoir operations can be, or if they should be modified to minimize the impact of reservoir operations on migrant waterbirds (Management Question 8). Additional analyses are required; final analyses will be written as a stand-alone report.

4.4 Recommendations

We continue to suggest that the land-based shorebird surveys should continue into November each year to document the conclusion of the migration. We also maintain that boat-based shorebird surveys should operate during the peak of the regular shorebird migration (mid-July if possible, through August).

A review of the CLBMON-40 TOR is recommended.

4.5 Conclusions

No conclusions are made at this time.

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 after Year 7 (see CBA 2013a for details on many of the Summary Points)

<table>
<tr><th>Objective 1</th><th>Management Questions (MQ)</th><th>Management Hypotheses</th><th>Year 7 Status Summary Points</th></tr>
<tr><td rowspan="3">Determine the abundance, distribution, and habitat use of waterbirds and migratory shorebirds and the productivity of waterbirds in Revelstoke Reach</td><td>1) What are the:
I. seasonal and annual variations the abundance and spatial distribution of waterbirds in Revelstoke Reach; and
II. variations in the abundance and spatial distribution of shorebirds during fall migration in Revelstoke Reach?</td><td>N/A</td><td>• The seasonal aspects of this MQ have been addressed, but estimates of annual variation are limited to seven data points
• See Interim report (CBA 2013) for additional detail</td></tr>
<tr><td>3) Which habitats within the drawdown zone in Revelstoke Reach are utilized by shorebirds and waterbirds and what are their characteristics (e.g. foraging substrate, vegetation, elevation, and distance to the waters edge)?</td><td>N/A</td><td>• This Management Question was not fully addressed in this document
• Key sites were 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, but analyses await results from CLBMON-11B-4</td></tr>
<tr><td>4) What is the annual variation in the productivity of waterbirds in Revelstoke Reach and does productivity vary spatially (e.g. are there areas of higher waterbird productivity or brood counts)?</td><td>N/A</td><td>• Graphical analysis indicated that there was considerable variability in the number of broods among years
• Although not discussed in this report, observations suggest that Canada Geese, the most abundant brood-rearing species, congregate away from the brood survey area in the Catherwood site where flooded grass is available in high water conditions
• Downie and Airport Marsh appeared to be consistently one of the most important brood rearing sites for other brood-rearing waterfowl
• From 2009 through 2013 there were between 3 and 7 Bald Eagle nests, and between 0 and 7 Osprey nests that were successful each year
• There was a maximum number of 7 active Bald Eagle nests and 12 active Osprey nests counted in Revelstoke Reach each year
• There was evidence that as many as 3 Short-eared Owl nests were active in 2010. Only one Short-eared Owl nest was located, and this nest site was flooded during the nestling period. In all other years no Short-eared Owl nesting activity was observed
• One Northern Harrier nesting attempt took place in 7 years. This nest was positioned with very high exposure to being flooded.</td></tr>
</table>

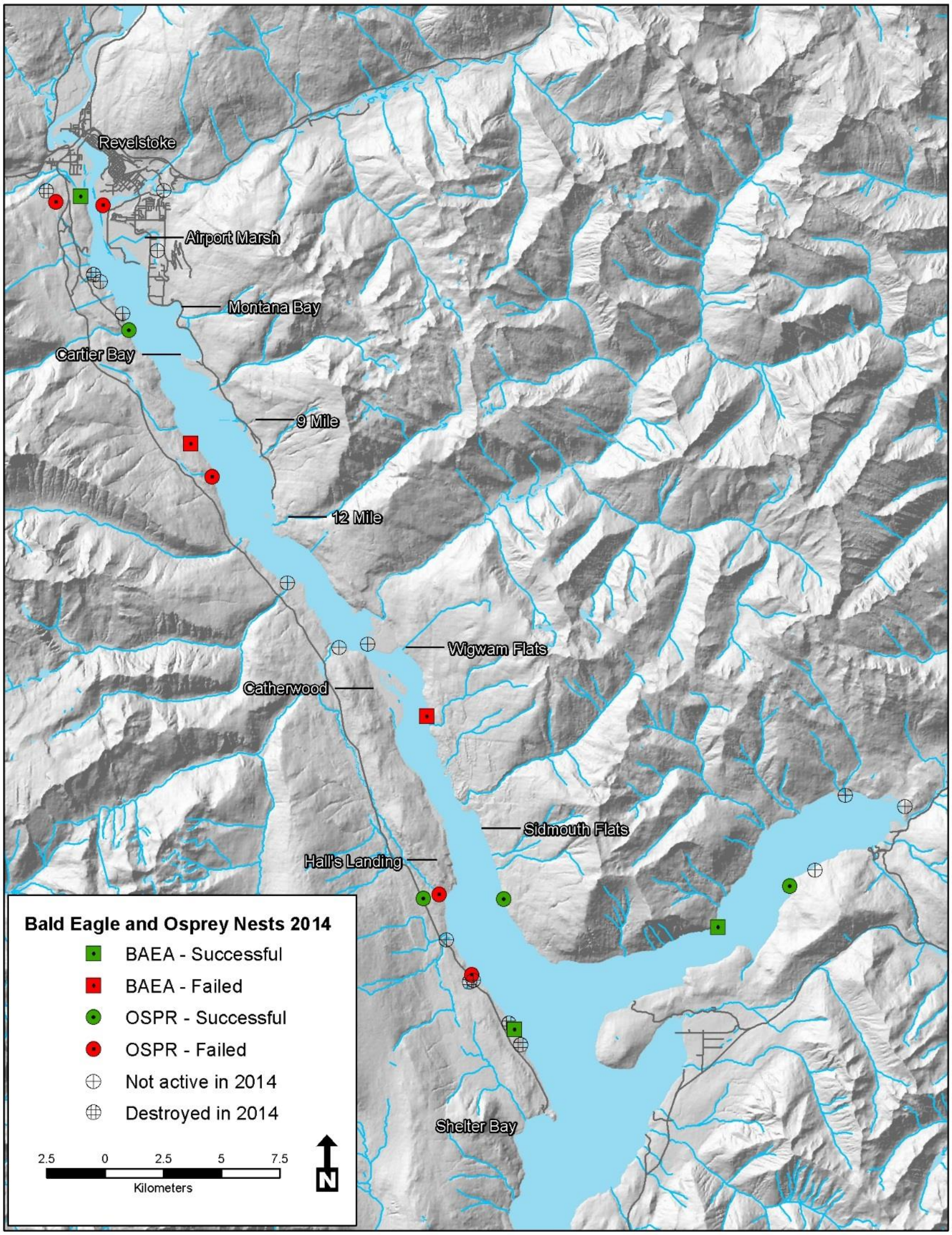
Objective 2	Management Questions	Management Hypotheses	Year 7 Status Summary Points
Examine how variation in flow and reservoir water elevations influence seasonal and yearly abundance, distribution, and habitat use of waterbirds and migratory shorebirds and the productivity of waterbirds in Revelstoke Reach	2) What impacts do year-to-year and within-year reservoir operations have on resident and migratory waterbirds and migratory shorebird populations?	N/A	• This MQ cannot be addressed empirically with this study, except where good productivity data is available, but linking reservoir operations to productivity also remains a challenge. • Results indicate that productivity is likely impacted by reservoir operations for some waterfowl species • Results indicate that habitat availability is likely impacted for migrating shorebirds and waterfowl, but it would be challenging to estimate impacts these effects have on populations • There was weak evidence that reservoir operations could potentially be linked to Osprey productivity, but this needs to be explored in great detail, and the analysis requires additional data.
	5) Which species of shorebirds and waterbirds are most likely to be affected by reservoir operations?	N/A	• This MQ is not phrased well, and no data were explored specifically for this MQ in this document • Taken literally, the obvious answer to this question is that all species of shorebirds and waterbirds that utilize the drawdown zone are equally likely to be affected by reservoir operations to some degree, because reservoir operations have and continue to define habitat in the drawdown zone. Complete lists of species that utilize the drawdown zone have been presented in annual technical reports, but were not repeated here. • Which species are most affected? The most important impact of reservoir operations to waterbirds is likely the impacts to productivity of some waterfowl species (e.g., Mallard, Teal spp., American Wigeon), some shorebird species (Spotted Sandpiper and Killdeer), Northern Harriers and Short-eared Owls. It can be argued that these species are 'most affected by reservoir operations' if this is what is meant • The data now indicate potential that Ospreys may be sensitive to 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?	H1: The annual and seasonal variation in water levels resulting from reservoir operations, the implementation of soft constraints, and the potential impact from Rev 5, (“reservoir operations”), do not result in a reduction of waterbird or shorebird use in Revelstoke Reach. H1A Reservoir operations do not result in decreased species diversity in waterbirds or migratory shorebirds in Revelstoke Reach. H1B Reservoir operations do not result in a decrease in the abundance of waterbirds or migratory shorebirds in Revelstoke Reach. H1C Reservoir operations do not result in changes in waterbird or shorebird distribution in Revelstoke Reach.	• This MQ has been explored statistically and graphically • H1 is a poorly constructed null hypothesis and should be re-written, or ignored. The other hypotheses are also poorly worded. • 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 • There was no obvious indication that waterfowl abundance was influenced by reservoir elevations • The diversity of shorebirds appeared to be uninfluenced by reservoir elevations, but the data are still very limited. • 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 the productivity of waterbirds in Revelstoke Reach between years?	H1D Reservoir operations do not result in a decrease in the productivity of waterbirds in Revelstoke Reach.	• Variability in brood counts was explored graphically, separately for species that were exposed to and not exposed to nest flooding • For exposed species, total brood counts generally appeared to steadily increase during the summer in the year with minimal nest flooding threat • In years of intermediate nest flooding potential, brood counts increased late in the year • In years of extreme nest flooding potential, brood counts did not increase during the year • Other patterns were evident for non-exposed species. • The complexity indicates that more data are warranted before statistical tests should be applied (n = 5 years), although the relationships are strong and tight enough to allow statistical significance with the existing data. • The data now indicate potential that Ospreys may be highly sensitive to reservoir operations. • Short-eared Owls and Northern Harriers, when nesting are highly exposed to being impacted by reservoir operations.

Objectives 3-5	Management Questions	Management Hypotheses	Year 7 Status Summary Points
Examine how variation in flow and reservoir water elevations influence seasonal and yearly abundance, distribution, and habitat use of waterbirds and migratory shorebirds and the productivity of waterbirds in Revelstoke Reach	8) Can minor adjustments be made to reservoir operations to minimize the impact on migrating waterbirds and shorebirds or on waterbird productivity?	H1E Reservoir operations do not result in a decrease in shorebird foraging habitat in the drawdown zone. H2: Annual variation in reservoir water levels, reservoir operations, the implementation of soft constraints, and the potential impact from Rev 5, do not result in a reduction or degradation of waterbird or shorebird habitats.	• Currently, this MQ can only be addressed by examining patterns of usage and distribution • Due to time constraints, there was no formal analysis specifically to address this MQ, although results presented for MQ-6 have high relevance • Graphical examination of waterbird and shorebird abundance indicated that some high use sites are negatively impacted by increasing water elevations. This result was also mirrored by models indicating probability of usage at wetland sites by waterfowl decreasing with water depth (see aerial waterfowl analysis (see Fig. 9). • Formal models relating usage at specific sites to depth of inundation will allow this question to be addressed fully. • Current results suggest that there are well-used sites that are selected even at relatively high water elevations (e.g., Wigwam flats for shorebirds and Airport Marsh for waterfowl); as such, there may be less need to make fine adjustments unless the reservoir is near full pool. If true this simplifies the problem considerably. • Our data cannot easily assess the relative quality of habitat. It is possible that crowding at certain sites at high elevations indicate high usage at a poor site which is the only remaining option available to the birds. Currently we do not have a means for assessing this possibility. One option is that foraging rates are assessed at these wetlands to compare how habitat quality is impacted by reservoir elevation.
Inform how physical works and revegetation can be designed to mitigate adverse impacts to waterbirds and shorebirds resulting from reservoir operations	9) Can physical works be designed to mitigate any adverse impacts on migrating waterbirds and shorebirds or on 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. • Currently a WPW projects is being considered at Cartier Bay. Our results show that Cartier Bay is adversely affected by reservoir operations, but this WPW can only provide minor mitigation. We do not recommend this project proceed given that it is unpredictable how habitat quality of this, the single most important site for migrant waterfowl will be impacted (low benefit vs. high risk).
Assess the effectiveness of physical works and revegetation at enhancing habitat for waterbirds and shorebirds	10) Does revegetating the drawdown zone affect the availability and use of habitat and its use by shorebirds or waterbirds in Revelstoke Reach?	H3: Revegetation and wildlife physical works do not increase the utilization of habitats by birds in Revelstoke Reach. H3A: Revegetation and wildlife physical works do not increase the species diversity or abundance of shorebird or waterbirds in Revelstoke Reach. H3B: Revegetation and wildlife physical works do not increase the productivity of waterbirds in Revelstoke Reach. H3D: Revegetation and wildlife physical works do not increase the amount of shorebird or waterbird habitat in Revelstoke Reach.	• Assessing impacts of planting terrestrial vegetation for waterfowl and shorebirds is challenging, and of questionable value. • It is possible that terrestrial revegetation could create nesting habitat for waterfowl, but this is not something being monitored by CLBMON-40 • The only obviously successful revegetation treatments were cottonwood stakes, which were planted at high elevations and are also challenging to monitor during high water levels.
	11) Do wildlife physical works projects implemented during the course of this monitoring program affect waterbird and shorebird abundance, and/or diversity, or waterbird productivity?		• WPW6A is the only project completed to date. • WPW6A prevents erosion caused naturally by spring snow melt, and does not mitigate adverse impacts of reservoir operations. • WPW6A protects Airport Marsh, which is a very important site for waterbirds. • If WPW6A is successful in preventing erosion, it will have been effective (CLBMON-40 does not monitor erosion rates).

Appendix 7-2: Total numbers of waterbirds observed during land-based waterbird surveys in 2014

Common Name	Scientific Name	Spring	Brood Survey	Fall
American Coot	*Fulica americana*	78	0	216
American Wigeon	*Anas americana*	1297	54	2345
Barrow's Goldeneye	*Bucephala islandica*	10	0	0
Blue-winged Teal	*Anas discors*	23	2	13
Bufflehead	*Bucephala albeola*	131	1	84
Cackling Goose	*Branta hutchinsii*	0	0	4
Canada Goose	*Branta canadensis*	1457	834	3537
Canvasback	*Aythya valisineria*	0	0	2
Cinnamon Teal	*Anas cyanoptera*	19	0	0
Common Goldeneye	*Bucephala clangula*	20	0	70
Common Loon	*Gavia immer*	8	16	6
Common Merganser	*Mergus merganser*	128	44	27
Eurasian Wigeon	*Anas penelope*	6	0	0
Gadwall	*Anas strepera*	4	0	2
Goldeneye sp	*Bucephala sp*	11	1	3
Greater Scaup	*Aythya marila*	11	1	0
Green-winged Teal	*Anas crecca*	262	0	294
Hooded Merganser	*Lophodytes cucullatus*	11	1	158
Lesser Scaup	*Aythya affinis*	11	0	1
Mallard	*Anas platyrhynchos*	1247	92	1743
Northern Pintail	*Anas acuta*	36	0	60
Northern Shoveler	*Anas clypeata*	10	0	17
Pied-billed Grebe	*Podilymbus podiceps*	7	12	111
Red-necked Grebe	*Podiceps grisegena*	4	0	5
Redhead	*Aythya americana*	3	0	7
Ring-necked Duck	*Aythya collaris*	219	3	43
Ruddy Duck	*Oxyura jamaicensis*	3	0	2
Scaup sp	*Aythya sp*	25	0	2
Snow Goose	*Chen caerulescens*	4	0	1
Trumpeter Swan	*Cygnus buccinator*	1	0	1
Unidentified Duck	Anatinae (gen, sp)	197	15	114
Unidentified Swan	*Cygnus sp*	1	0	0
Unidentified Teal	*Anas sp*	0	0	643
Western Grebe	*Aechmophorus occidentalis*	0	1	11
Wood Duck	*Aix sponsa*	13	0	28

Appendix 7-3: Map of Bald Eagle and Osprey nests monitored in 2014


Revelstoke
Airport Marsh
Montana Bay
Cartier Bay
9 Mile
12 Mile
Wigwam Flats
Catherwood
Sidmouth Flats
Hall's Landing
Shelter Bay
Bald Eagle and Osprey Nests 2014
BAEA - Successful
BAEA - Failed
OSPR - Successful
OSPR - Failed
Not active in 2014
Destroyed in 2014
2.5 0 2.5 5 7.5
Kilometers
N

Appendix 7-4: Total numbers of shorebirds observed during land-based and boat-based shorebird surveys in 2014

Common Name	Scientific Name	Number
Semipalmated Plover	*Charadrius semipalmatus*	1
Killdeer	*Charadrius vociferus*	58
Spotted Sandpiper	*Actitis macularius*	179
Solitary Sandpiper	*Tringa solitaria*	15
Greater Yellowlegs	*Tringa melanoleuca*	21
Lesser Yellowlegs	*Tringa flavipes*	5
Unidentified Yellowlegs	*Tringa melanoleuca/flavipes*	1
Sanderling	*Calidris alba*	5
Semipalmated Sandpiper	*Calidris pusilla*	4
Western Sandpiper	*Calidris mauri*	11
Least Sandpiper	*Calidris minutilla*	2
Baird's Sandpiper	*Calidris bairdii*	7
Pectoral Sandpiper	*Calidris melanotos*	10
Unidentified *Calidris*	*Calidris sp.*	10
Unidentified Dowitcher	*Limnodromus sp.*	5
Long-billed Dowitcher	*Limnodromus scolopaceus*	128
Unidentified Shorebird		3
Wilson's Snipe	*Gallinago delicata*	22
Red-necked Phalarope	*Phalaropus lobatus*	2