Columbia River Project Water Use Plan

KINBASKET AND ARROW LAKES RESERVOIRS

Reference: CLBMON-40

Arrow Lakes Reservoir Shorebird and Waterbird Monitoring Program: Year 8

Study Period: 2015

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

March 31, 2016

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

Year 8, 2015

Prepared for

BC Hydro

Water Licence Requirements

Burnaby, British Columbia

Prepared by

Harry van Oort, Catherine Craig, Ryan Gill & 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

March 31, 2016

Okanagan Nation Alliance

Suggested Citation:

van Oort, H., C. Craig, R. Gill, J.M. Cooper, and S. Beauchesne. 2016. CLBMON-40: Arrow Lakes Reservoir Shorebird and Waterbird Monitoring Program. Annual Report – Year 8, 2015. Unpublished report for BC Hydro Generation, Water Licence Requirements, Burnaby, BC. 41 pp. + Apps.

Cover photo: Habitat map of Airport Marsh.

EXECUTIVE SUMMARY

The impoundments of the Canadian portion of the Columbia Basin have been estimated to have impacted or destroyed 7,700 ha of wetland habitat. The remaining wetlands provide vital ecological functions for fish, wildlife, water retention, and other environmental factors. Several remnant wetlands with regional ecological importance within the Columbia Basin remain in Revelstoke Reach, the northern arm of Arrow Lakes Reservoir (ALR). These wetlands are positioned within the reservoir drawdown zone, but 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 had not been studied in detail, 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, this 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 migration, the importance of these wetlands for breeding waterbirds, and how ecological functions are impacted by reservoir operations. This report summarizes progress in Year 8 of the 10 year study. Annual effort and results are briefly summarized in addition to some analyses of the multi-year dataset.

Waterfowl monitoring occurred in spring and 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 brood count surveys.

The wetlands thawed relatively early in 2015. The ALR filled aggressively during the early part of the spring draw, but reached the annual maximum elevation unusually early in the year (June 16). Given the early peaking date, the high pool elevation, at 435.5 m asl, was the lowest yet observed during the course of the study. During the relatively warm spring, the migration of waterfowl was observed to be an ephemeral event, with waterfowl moving through the study area primarily in early April. During the early summer, weather conditions were warm and very dry; the late summer was cooler with moderate regular precipitation. Five species of waterfowl were observed with broods in 2015: Canada Goose, Common Merganser, Mallard, American Wigeon, and Wood Duck. No Northern Harriers or Short-eared Owls nested in 2015. There were five active Bald Eagle nests in 2015, and three of these were successful. Seven out of ten active Osprey nests were also successful.

In a year with unusually low fall reservoir elevations, there was an unusually large shorebird presence during the fall migration in 2015, with 16 shorebird species observed, many in relatively large numbers. The majority of the observed shorebirds were using wetlands monitored using the land-based survey; very few shorebirds were observed during the boat-based survey. The fall waterfowl migration was light with relatively few birds, but some larger counts of ducks were observed the week before freeze up.

In 2015, we focussed on improving spatial/habitat aspects of CLBMON-40. Specifically, we gained access to recent high resolution colour aerial imagery taken when the reservoir was at low levels, and with this greatly improved imagery, we conducted a major revision to the habitat map. Polygon delineation and classification constituted the major revision task. The habitat classification scheme was also modified slightly, to improve clarity and consistency. We also examined the precision of waterbird counts and the precision and accuracy of waterbird mapping. A repeatability test showed that counts of waterbirds were highly repeatable, with an Interclass Correlation Coefficient lying between 0.981 to 0.995. Mapping of waterbird locations was not very precise, but reasonably accurate. Independently mapped polygons showed low levels of overlap, but captured the same information regarding habitat usage by waterfowl.

Several new multi-year analyses were performed in 2015. A mixed effects Poisson model showed that in spring, when wetlands were not inundated by reservoir flooding, more ducks use Cartier Bay, compared with the Airport Marsh, and that relatively few ducks use Locks Creek Outflow and Montana Slough. Another new analysis used a quasi-Poisson regression to determine that duck productivity was significantly reduced in years with high maximum pool elevations. Similarly, linear regressions showed that Osprey productivity diminished in years of high maximum pool elevations, and in years with high precipitation. We continue to suspect that impacts to foraging efficiency or nestling provisioning might mediate these relationships. The use of video cameras to examine if reservoir operations impacts nestling provisioning rates was determined to be unfeasible. Current and future approaches to examining how reservoir operations influence Osprey productivity include expanding datasets with existing data from elsewhere in the ALR, and possibly at other water bodies (e.g., as a control), and investing higher monitoring effort to improve the quality of data being collected by CLBMON-40. This approach may allow us to better disentangle the effects of rainfall versus reservoir operations.

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 8 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 Karle Zelmer 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 Karle Zelmer 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.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

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).

The operation of ALR is thought to affect the availability and quality of habitat in Revelstoke Reach for waterbirds (e.g., loons, grebes, waterfowl, raptors, and shorebirds). 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). How reservoir operations affect waterbird 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 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.

---

[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.

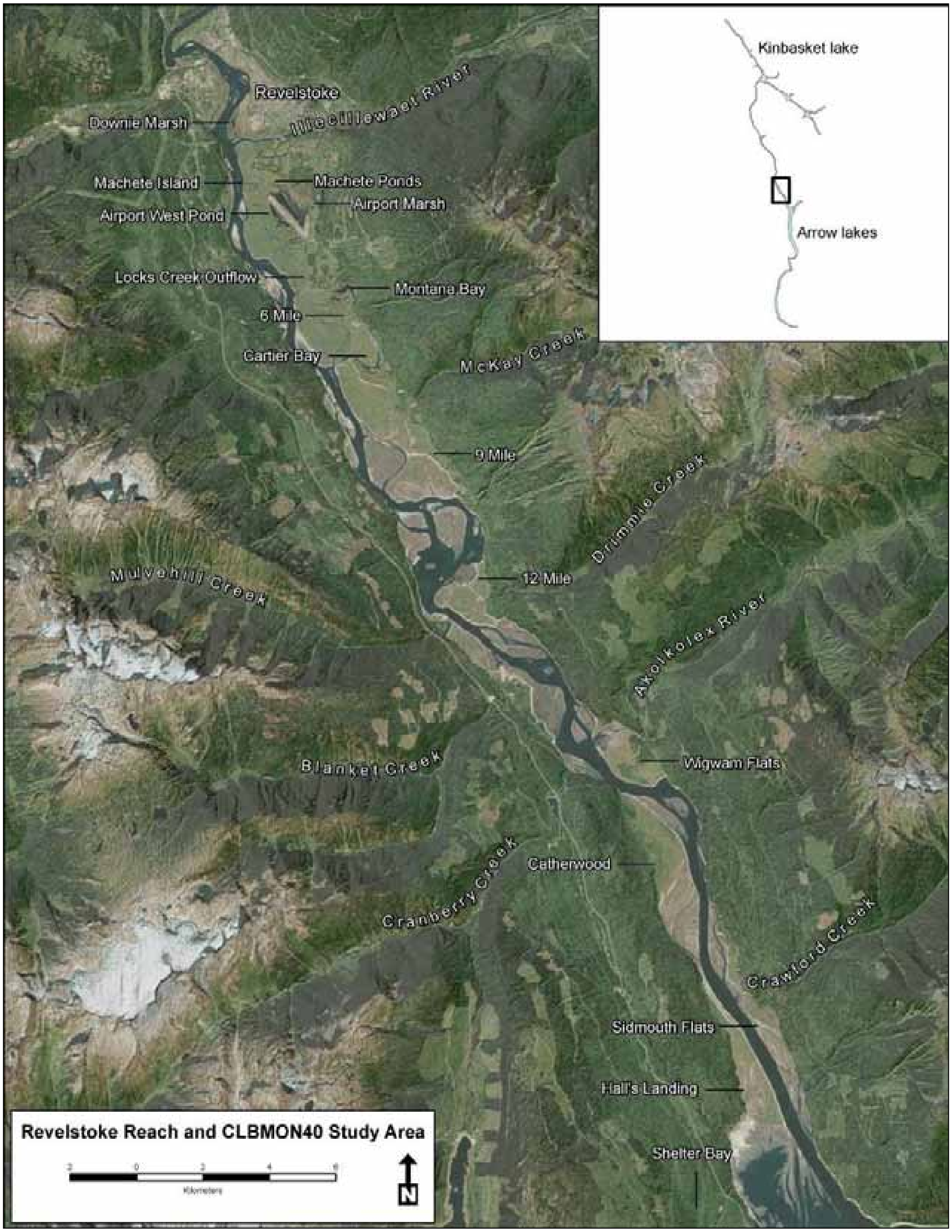


Figure 1-1: **Overview map of Revelstoke Reach, with geographic features labelled. Note that this image shows the reservoir at very low levels; at full pool conditions, most of the valley bottom in this map becomes flooded**

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?

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?

---

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

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.

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

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

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 methods used for CLBMON 40 are 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).

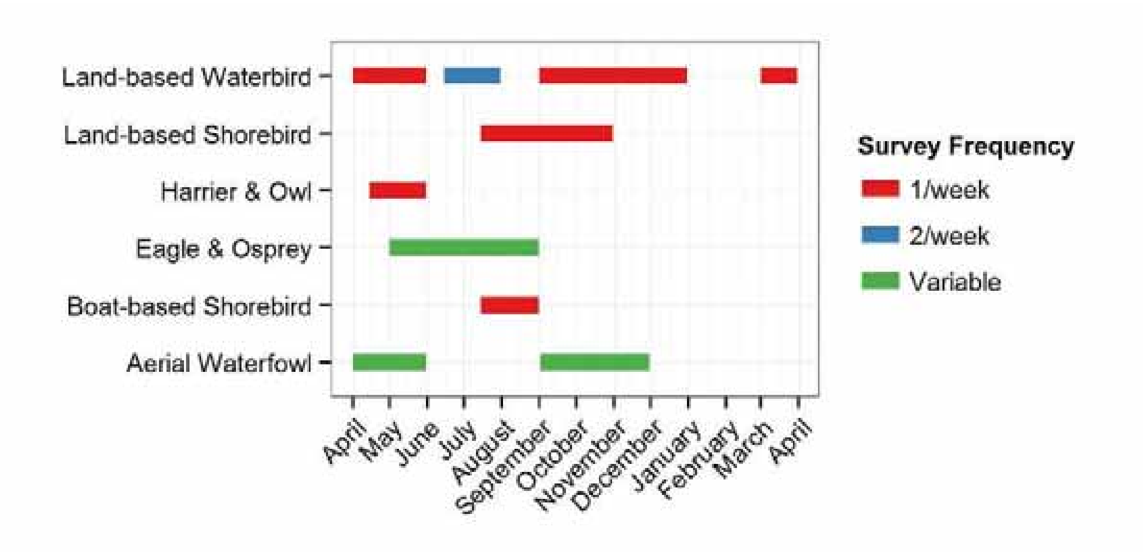


Figure 2-1: **Overview of how the six CLBMON-40 monitoring surveys are scheduled. Data from the two types of shorebird surveys can be combined as one data set during weeks when both surveys take place**

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 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. In the spring of 2015, 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.

---

[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.

2.1.1 Doubled observations

In 2015, we took steps to assess the precision of counting waterfowl and the precision of mapping their locations during the fall migration. Observations (counts and mapping of waterfowl) were performed simultaneously by two independent observers. These data were collected without sharing information to assure independence of the observations. The waterfowl counts were entered separately into an excel spreadsheet. Mapping was stored in a dedicated directory for GIS analysis.

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; 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 2015.

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 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.

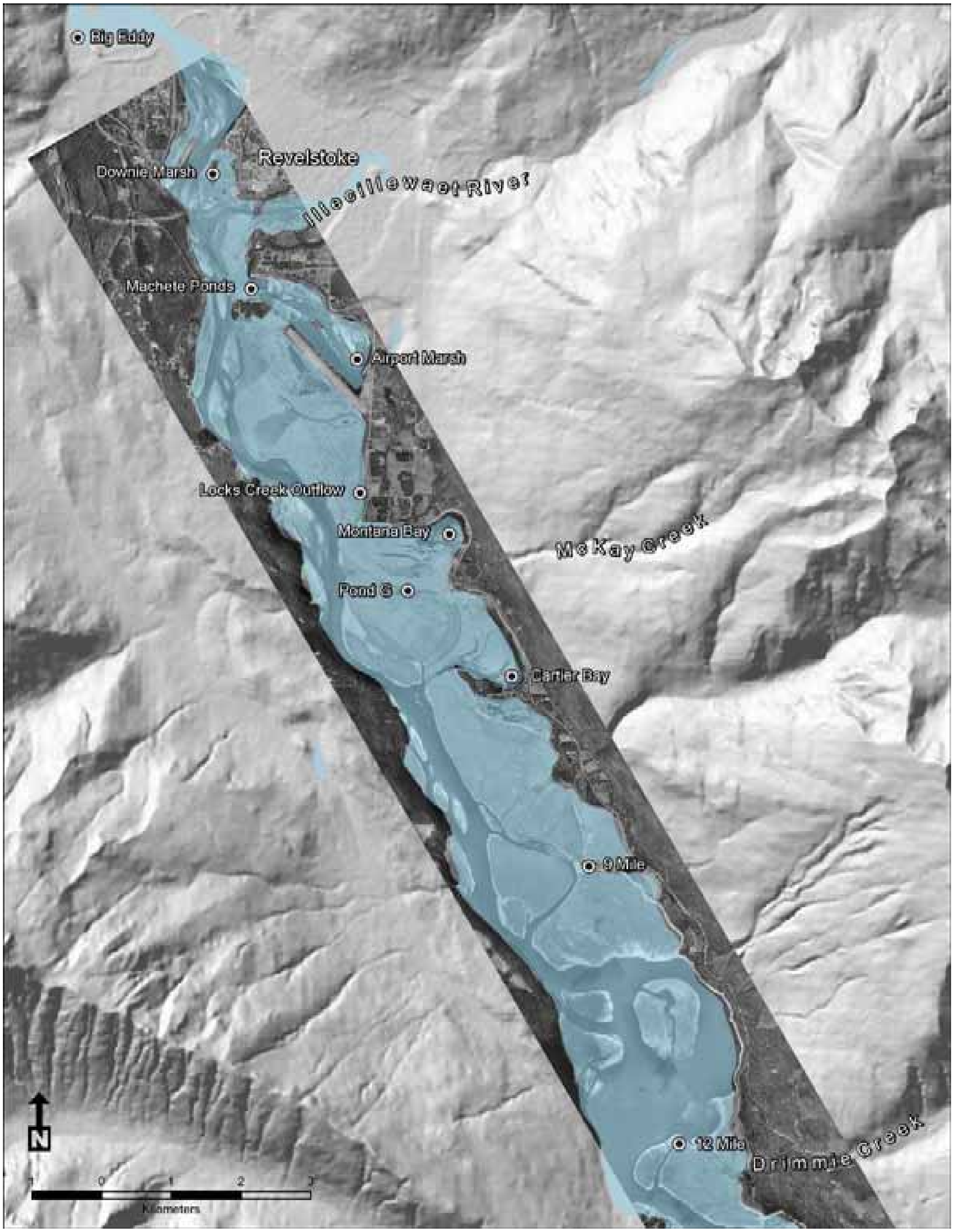


Figure 2-2: Locations of wetlands in Revelstoke Reach where land-based waterbird surveys and brood surveys were conducted are represented by points. Some of these wetlands were monitored by multiple fixed-observation stations

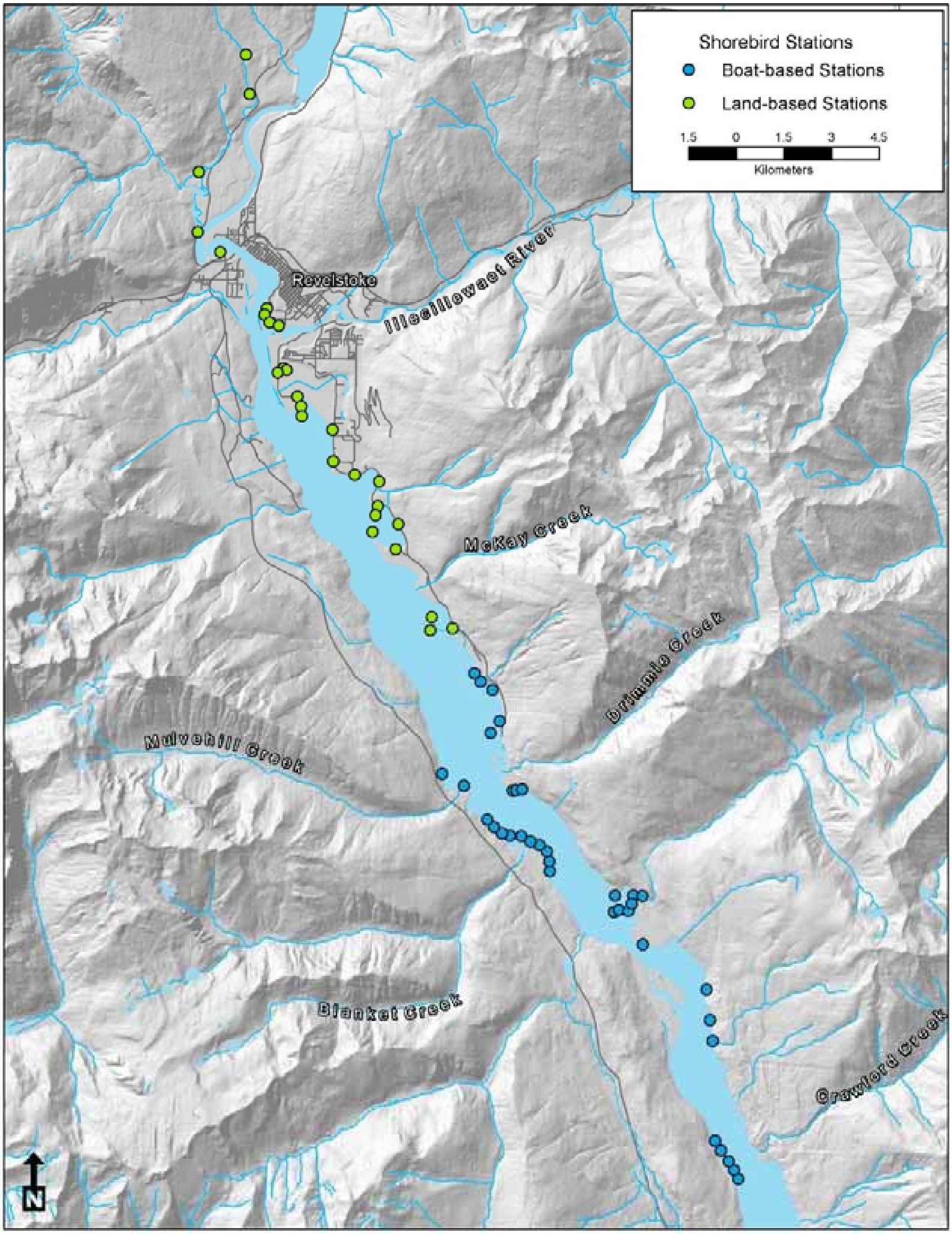


Figure 2-3: **Locations of shorebird observation stations in Revelstoke Reach**

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 2015, 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. In 2015 we increased the frequency of helicopter checks for nest monitoring purposes in order in improve the data quality. A total of 10 nest monitoring surveys were completed in 2015; 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 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 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 Habitat Mapping

Under CLBMON-40, we previously produced a habitat map of Revelstoke Reach (CBA 2012). Two sets of photos were available to digitize habitat for the original map version, depending on the region of the study area, each at different resolutions, and one in black and white. In 2014, we conducted a systematic ground truthing of the original map layer. We used a stratified random sampling protocol to select 78 polygons, three from each of the 27 habitat classes. In the field, the observer was blind to the map classification, and was required to classify the polygon, and examine the quality of the linework; 70% of the field classifications matched the map classifications. From this exercise, we gained knowledge on how classifications could be improved, and realized that the linework could be improved.

In 2015, we acquired a new complete coverage of high resolution colour imagery and we conducted comprehensive revisions to the habitat map of Revelstoke Reach. The new imagery provided a consistent and high-resolution background, facilitating accurate adjustments to polygon typing and linework. The new imagery was shot in April 2015, when reservoir elevations were sufficiently low (426 m asl) to map most parts of the reservoir drawdown zone, including all vegetated habitats.

The revision was conducted by one individual (Ryan Gill), and included additional field assessments in areas/habitats identified as problematic to classify and/or map.

2.8 Analytical methods

All statistics, graphing and data manipulation were performed with R (R Core Team 2014). One of the key analyses we conducted this year was to produce repeatability statistics on our count and mapping observations made during the land-based waterbird surveys. This is outlined next, followed by sections outlining the methods used in the long-term data set analyses.

2.8.1 Repeatability

In sections 3.3.1 and 3.3.2 we calculate repeatability statistics (Intraclass Correlation Coefficient; ‘r’) using the ‘ICCest()’ function from the ICC package for R (Wolak et al. 2012). This parametric statistic assesses how repeatable measurements are (in this case - counts) by contrasting ‘observer measurement variability’ against ‘among observation variability’ (Lessells and Boag 1987); the statistic ‘r’ ranges from 0 (measurements are not repeatable) to 1.0 (measurements are perfectly repeatable). In the case of studying how repeatable our counts were between observers, an r score of 1.0 would mean that we always counted exactly the same number of birds, and a value close to 1 (e.g., 0.95) means that observer count errors occur, but are small relative to the biological effects. If the repeatability r scored 0, it would mean that the observer errors are as large as the true biological effects.

We used a different approach to assess consistency of habitat-use mapping. If field observers were highly consistent and accurate when mapping waterfowl locations, the polygons that were drawn by two observers, each independently mapping the location of the same group of waterfowl, should show a high degree of overlap, and capture the same type of habitat being used. When mapping locations in wetland features such as a pond, there is a degree of error to be expected. It is unlikely that observers would map polygons identically, but there is an expectation that the drawn polygons are at least in the correct type of habitat. In this report, we report the number of times that two independent observers drew polygons that overlapped, and the degree of habitat-use mapping (polygon area) that was mapped by both observers in comparison to the mapping that was only captured by one observer. To assess if errors in polygon mapping were very serious, we examined how conclusions about habitat types within the paired use-polygons (derived from the CBA vegetation community map) differed as a function of inter-observer mapping inconsistencies. Specifically, we report the number of times that one observer captured a habitat type that was not captured by the other, and the magnitude of this inconsistency (was it a large area mapped and classified differently by one of the observers?). In some other cases, both observers may have both captured the same two or more habitat types; in these cases, we examine how commonly the two polygons showed the same habitat type as being the dominant type. Together these results give an impression of mapping accuracy and the ramifications of mapping error.

2.8.2 Wetland usage by dabbling ducks

To address the question of how habitats are selected by migrating waterfowl (MQ-1), we considered three scales: throughout the study area, among wetlands, and within wetlands. In section 3.4.1, we examine differences in duck abundance at the second scale. Previously, it was shown that a large majority of waterfowl detections occurred in the wetlands monitored by the land-based survey (CBA 2013b), but only an informal pilot comparison was made regarding how waterfowl were distributed among these wetland features. The analysis focused on the spring migration (surveys in March through May) because this migration is relatively unaffected by reservoir levels at this time of year, thereby allowing us to compare usage without having to control for reservoir impacts statistically.

Over-dispersion (where the errors are distributed more widely than a model predicts) is a common and expected issue in ecological count data (Zuur et al. 2009, 2012, Kéry 2010) as we have seen in our analyses of waterfowl abundance previously (CBA 2013a, 2015). Quasi-Poisson models can be used to account for low to moderate levels of over-dispersion, but in previous analyses, this method was inadequate, and we found negative binomial distributions to be the best option (Zuur et al. 2009, Kéry 2010, CBA 2015). In the current analysis, comparing counts of dabbling ducks among the four wetlands, it was also necessary to control for the hierarchical effect of survey occasion because counts at wetlands were performed on the same day/survey occasion. This is important, because even after controlling for migration intensity (a seasonal effect regarding the progression through the migration), counts could be low on some days and high on others for any number of reasons. For example, survey occasion effects could be influenced by early ice break up (Hawkes et al. 2014), or because detection was poor on some days (e.g., poor lighting), or because weather was influencing the duck behaviour. These survey occasion effects are of little interest, but contribute to potentially important variability in duck counts, common to all wetlands surveyed on a given day. Furthermore, by including an observation occasion random effect, the lack of independence of observations made on the same day is structured appropriately (i.e., we avoid treating every count at every wetland as an independent data point; Royle and Dorazio 2008, Zuur et al. 2009, Kéry and Schaub 2012). The sheer number of survey occasions means that fixed effects are inappropriate to control for this variability; a mixed effects model is required.

To fit a mixed effects model, we used the 'glmer()' function from the lme4 package for R (Bates et al. 2011). This Generalized Linear Mixed-effects Model (GLMM) was fit with effects parameterization. The deterministic part of the model included migration intensity as a covariate, survey occasion as a random intercept effect, and wetland as a fixed effect of interest. Unfortunately, negative binomial distributions and quasi- models were not possible in the lme4 package; but by specifying the Poisson distribution, our models would be over-dispersed. To solve this problem, we specified an observation-level random effect to account for the extra-Poisson variation. This type of model allows for additional random variation among observations to be incorporated on the log scale, prior to modeling count variation with a Poisson distribution (Elston et al. 2001, Zuur et al. 2012, Harrison 2014). The inclusion of the observation-level random effect solved the over-dispersion problem but made minimal difference to the fitted estimates; the inclusion of this additional random error effect increased uncertainty around parameter estimates as expected (parameter uncertainty is artificially diminished if important random effects are not controlled for).

2.8.3 Impacts of reservoir operations on dabbling duck counts

In section 3.4.2 we provide an updated model examining variability in brood counts among years in relation to reservoir operations. Previous examination of the data showed that seasonal effect altered the relationship that could be seen between brood counts and reservoir operations: a low brood count was observed in years when ALR had aggressive filling, but only later in the brood rearing season (CBA 2013a). In 2015 we re-analyzed the effect of reservoir operations on brood counts, making use of the previous findings to guide our approach. This analysis included 8 years of data, which is a considerable improvement over the sample size analyzed previously (5 years).

The approach used was to calculate the average count of broods observed in the late part of the brood monitoring period (week 25 to 31 in the year) when brood counts are maximal. This generated eight data points (average brood counts) which were analyzed against the maximum reservoir elevation observed each year. A quasi-Poisson distribution was used to model random scatter around the regression function.

2.8.4 Impacts of reservoir operations on 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. In 2014, we identified that annual variation in Osprey nest success was correlated with variation in reservoir operations; specifically, we found that aggressive filling of the Arrow Lakes Reservoir was negatively associated with the proportion of nests observed to be successful (CBA 2014). This preliminary analysis did not consider other potential confounding annual effects (e.g., weather). In 2014, with one additional data point, we re-analyzed the data, and also considered how weather conditions influenced Osprey productivity. Craig et al (2015) determined that Osprey productivity (mean annual number of fledglings produced per active nest) was negatively correlated with both the maximum annual reservoir water surface elevation, and with the total amount of rainfall observed during the month of June. These updated results were presented at the Regulated Rivers Conference hosted by the Columbia Mountains Institute of Applied Ecology[5] (Craig et al. 2015).

In this report, we provide an analysis that is further updated with the 2015 results, and improved upon by considering alternate relationship functions. We also examined some additional Osprey nest data from the ALR region (Davidson 2011). We fit linear models to assess possible predictors of nesting success, considering first and second degree polynomials and exponential, y ~ log(x), relationships. Model fit, strength and significance was assessed by plotting residuals versus fitted values and comparing the regression lines, adjusted r^2 values, and p-values. We separately analyzed data from ALR Osprey nests near Nakusp (Davidson 2011) to see if the results would be similar to ours.

2.8.4.1 Video surveillance of Osprey provisioning

Osprey productivity is considered food-limited, with brood reduction being a common outcome when provisioning rates are constrained (Poole 1982). There are many potential reasons why reservoir elevation could alter foraging efficiency of Osprey, and it was suggested that this mechanism could lead to the among-year relationships discussed above (CBA 2014). Recognizing the importance of the relationship detected in 2013 to the concerns and objectives of CLBMON-40, that is, the need to understand how reservoir operations impact waterbirds (including breeding Osprey), we ran a pilot study to assess the potential of exploring how reservoir operations influence provisioning rates of Osprey.

In 2014, we initiated a pilot study to assess the feasibility of quantifying variation in foraging rates using video methods (Cox et al. 2012). The primary goal of the pilot study was to assess the most powerful way to gather provisioning data using video surveillance, and whether the logistical challenges could be overcome. One aspect that we were interested in was determining if measurement error could be reduced by measuring nest provisioning rates at a particular time of day when their provisioning behaviours are maximized. For example, if the nestlings receive more meals in the morning, monitoring in the morning would produce a more powerful dataset, compared with monitoring that took place over a longer time span, or at other times of the day. Additionally, by focussing on a shorter window of time each day, we would optimize the field work, reducing the frequency of trips for battery maintenance, and the time require to extract data from the footage.

High resolution 5-50 mm varifocal security camera capable of 32x digital zoom were used to record high resolution video images of Osprey and their nests. Video was recorded using a Seorim AKR-100 mini digital video recorder which recorded video in H.264 format onto a 32 GB SD card. The unit was powered by a single (55 amp-hour) sealed lead acid 12 volt battery which rested on the ground beneath the video recording equipment. The camera and video recorder were housed in a customized box and positioned onto a tree

[5] Conference proceedings available at cmiae.org

that would provide the optimal angle for capturing images of the nest and the approach flight paths of the adult Osprey. Camera settings were adjusted by attaching a small test monitor to the camera and digital video recorder while in the field. Video was viewed with Micro-D Player version 4.0.

Two nests (81083 and 6) were monitored by video during the 2014 nesting season. Monitoring at nest 81083 took place from July 9 until July 23, at which time the nest was destroyed during a wind storm. During this time, video monitoring was successful over three full days and seven partial days (90.8 hours total). Monitoring at nest 6 took place from August 1 until August 18, capturing the final stages of nestling period, including fledging. During this time, video monitoring was successful over seven full days and eight partial days (172.4 hours total).

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

Compared with historic reservoir operations, the ALR water elevation was normal during the rising limb of the hydrograph in spring. However, spring storage phase of the reservoir was truncated early (June 16), causing an unusually low annual maximum pool elevation to be reached (435.5 m asl); the reservoir elevations were atypically low in the fall (Figure 3-1).

3.1.2 Weather

Following a relatively warm winter (Figure 3-2) characterized by relatively low precipitation (Figure 3-3), the snow and ice diminished quickly in spring. The result was a comparatively early thaw of the wetlands (Figure 3-4). Spring and early summer were relatively warm with low precipitation, followed by more normal weather in late summer and fall.

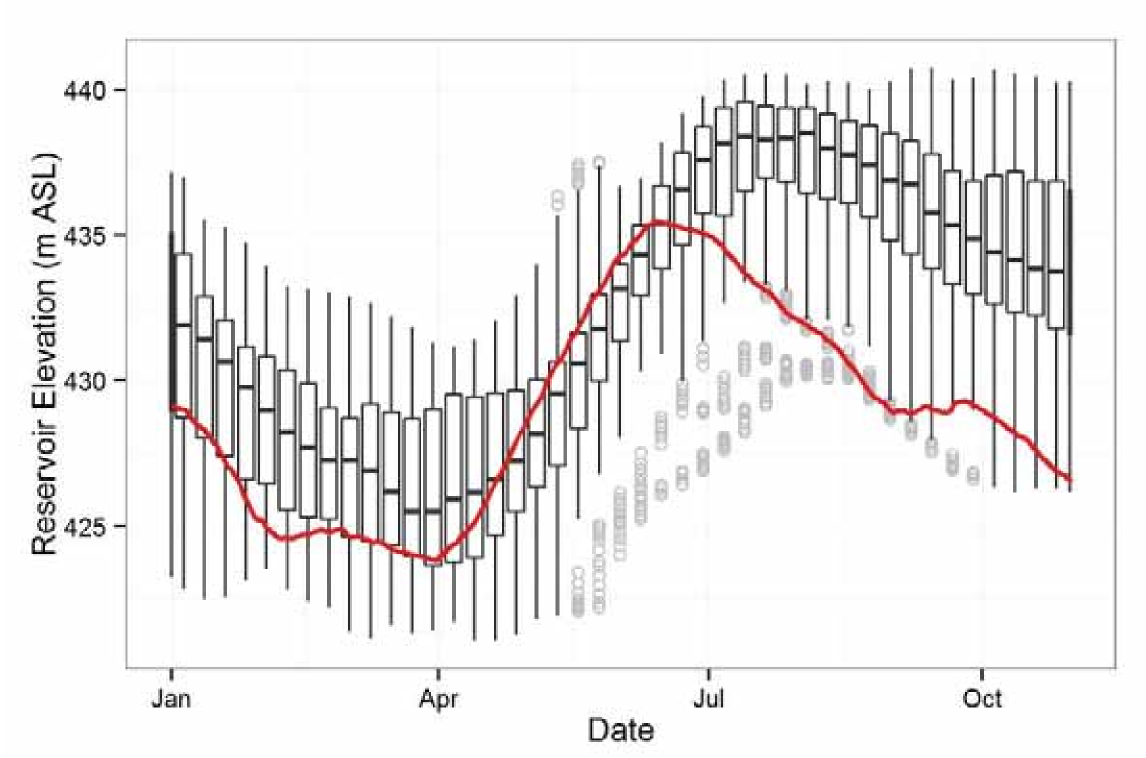


Figure 3-1: **Elevation of the Arrow Lakes Reservoir from April 1 to October 31, 2015 is plotted in red; the historical range of values is plotted in weekly intervals as boxplots**

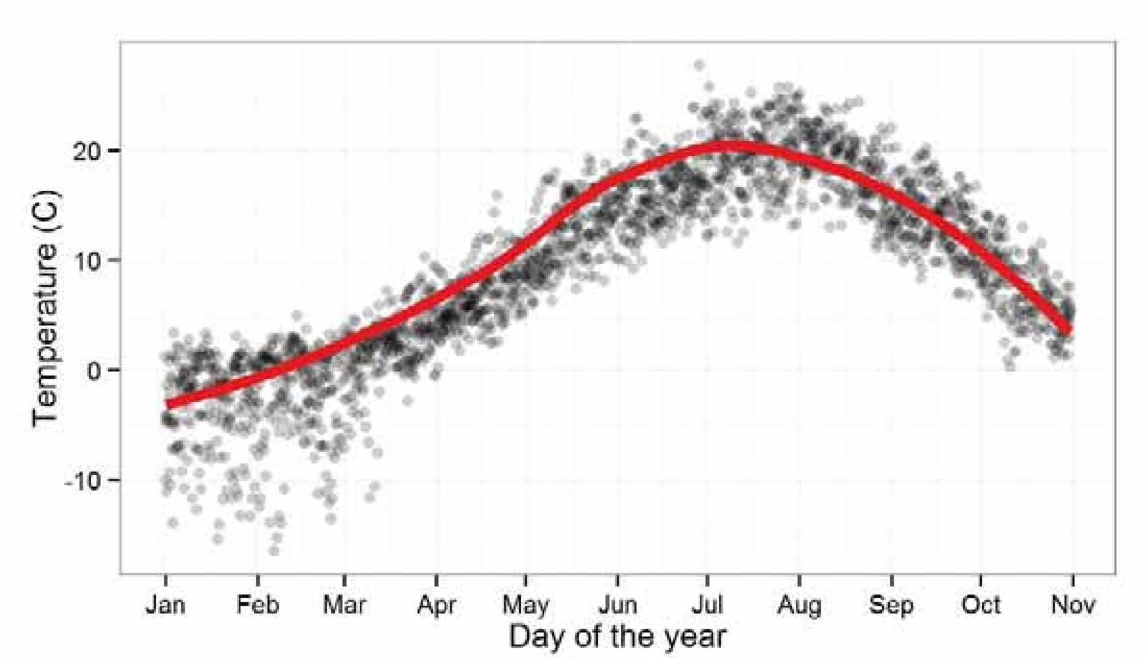


Figure 3-2: **Mean daily temperatures observed during the course of the study. The current year data is illustrated by the red line**

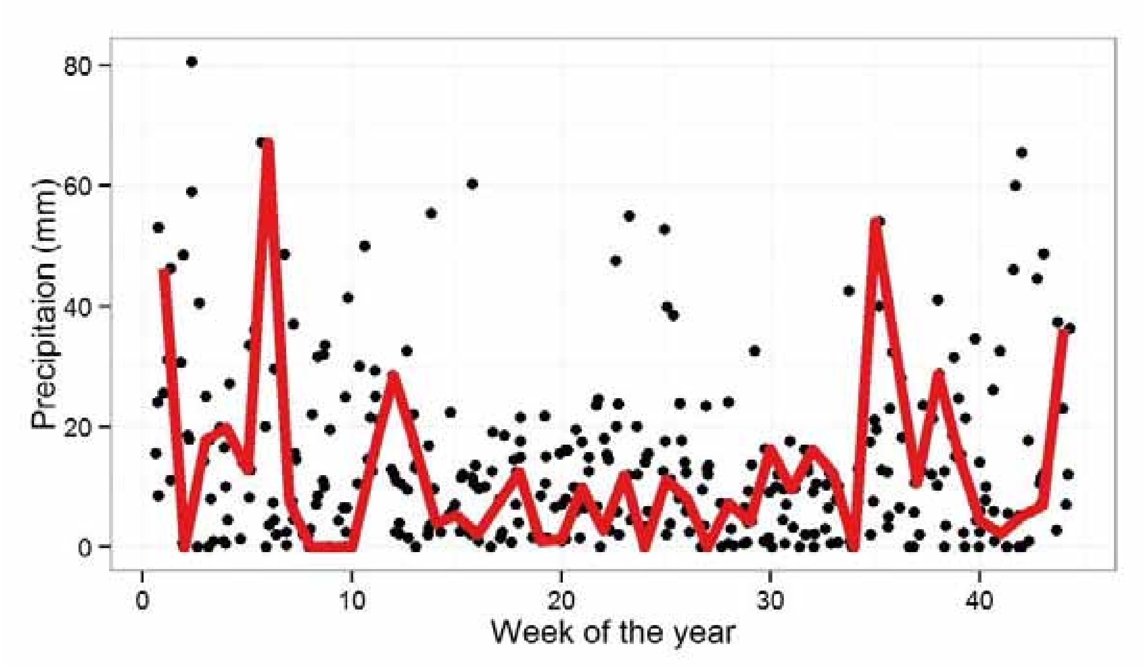


Figure 3-3: **Weekly precipitation observed during the course of the study. Values recorded in the current year are represented by the red line**

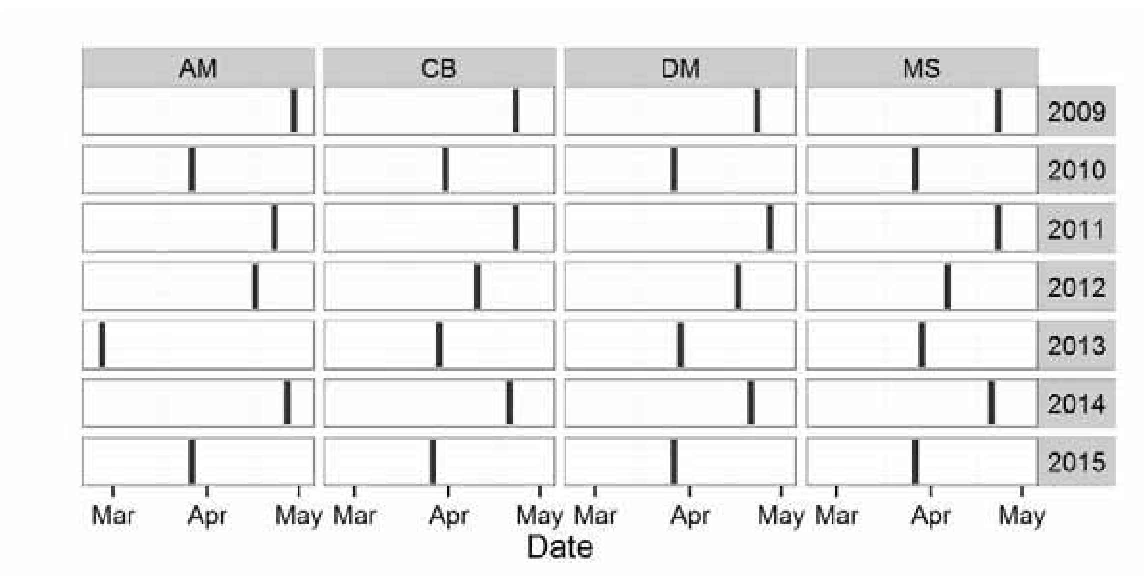


Figure 3-4: **Comparison of dates when the Airport Marsh (AM), Cartier Bay (CB), Downie Marsh (DM) and Montana Slough (MS) were first observed to be ice free during land-based waterbird surveys (2009 to present)**

3.1.3 Survey effort

In this report, we summarize work accomplished from March through November, 2015 but data from other months and years may be included for illustrative purposes.

Eleven 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, 12 surveys were completed by freeze over in late November.

One aerial waterfowl survey was conducted in the fall (2015-09-23) during low reservoir elevations for which we did not have previous data during the fall season (~ 428 m asl).

Ten individual surveys (aerial) were conducted for monitoring Bald Eagle and Osprey productivity.

Twelve 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 17 separate surveys.

Seven boat-based shorebird surveys were completed, and 16 land-based shorebird surveys were completed during the fall migration prior to October 31.

3.1.4 Waterfowl migration

The spring migration initiated relatively early this year (Figure 3-5). The dabbling duck migration was less intense this year compared with previous years (Figure 3-5). Diving duck counts and Canada Goose counts were also a little lower than what was observed in previous years during the spring migration (Figure 3-5). The migration was also a relatively small event in the fall compared with previous years, with waterfowl counts only increasing notably, just prior to freeze over in late November (Figure 3-6). A table of species observed during land-based waterbird surveys can be found in Appendix 7-2.

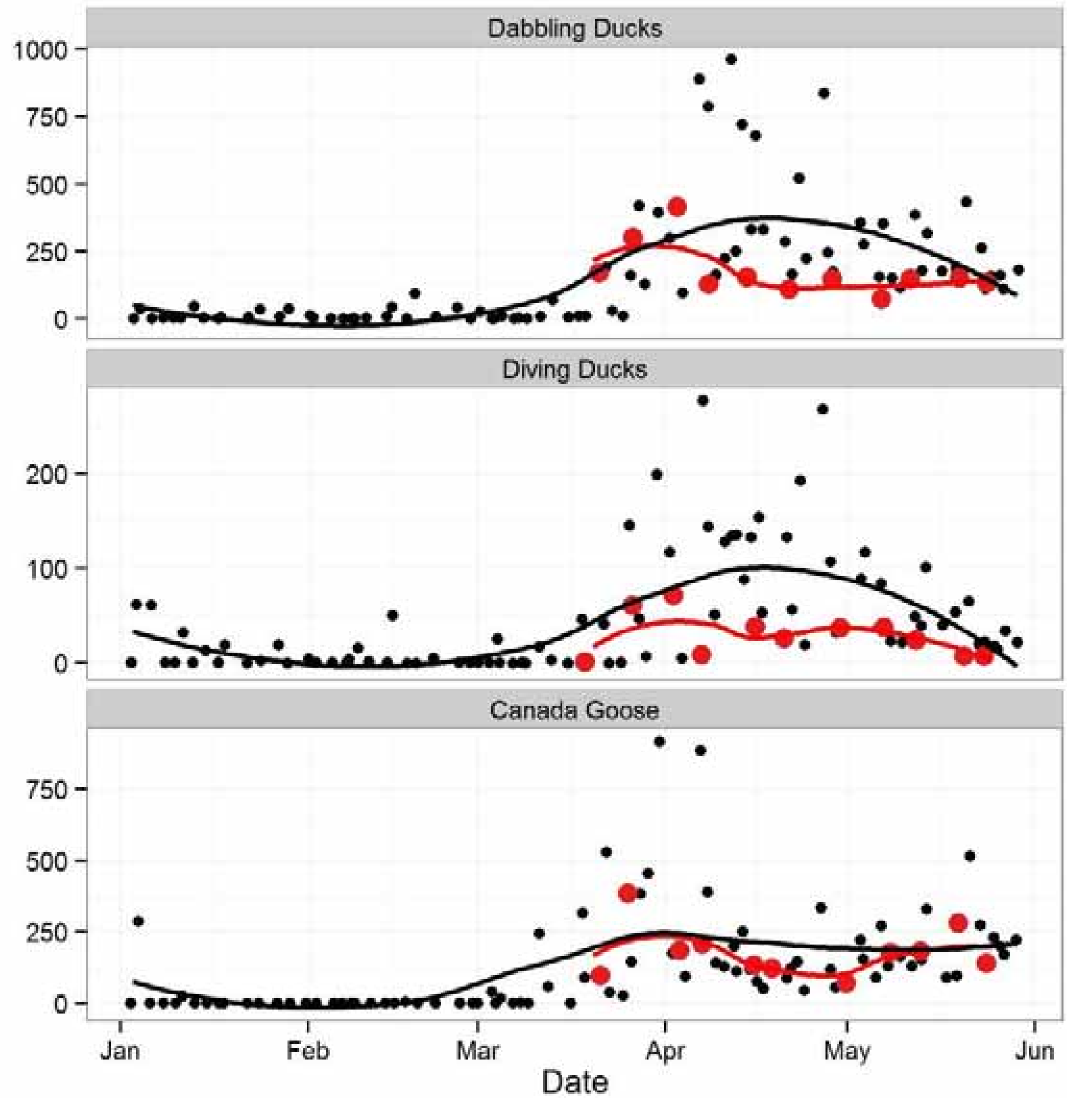


Figure 3-5: **Spring waterfowl counts recorded at the wetlands monitored under the land-based waterbird survey (Downie Marsh, Airport Marsh, Locks Creek Outflow, Montana Slough, and Cartier Bay). Raw data points are plotted, with counts from the current year in red. A Loess smoother is fit to all data (black), and for the current year data (red) for illustrative purposes**

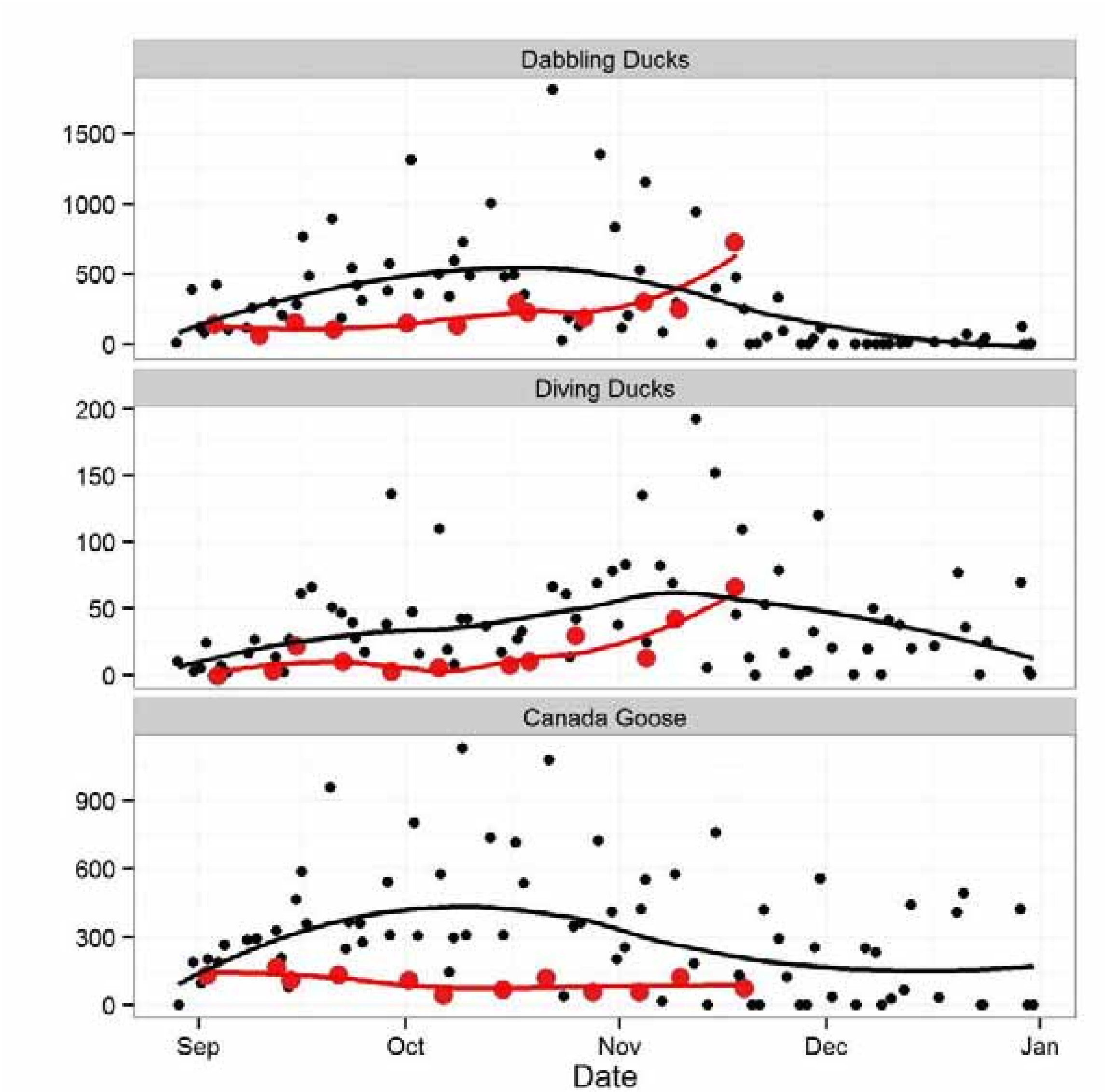


Figure 3-6: Fall waterfowl counts recorded at the wetlands monitored under the land-based waterbird survey (Downie Marsh, Airport Marsh, Locks Creek Outflow, Montana Slough, and Cartier Bay). Raw data points are plotted, with counts from the current year in red. A Loess smoother is fit to all data (black),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

3.1.5 Waterfowl productivity

Five species were observed with broods: Canada Goose, Common Merganser, Mallard, American Wigeon, and Wood Duck. American Wigeon broods were the most commonly observed; these were regularly recorded at the Airport Marsh, Airport West pond, Cartier Bay, and Downie Marsh. The next most commonly observed species with broods were Mallard and Wood Duck. Only two Canada Goose broods and one Common Merganser brood were observed.

3.1.6 Raptor productivity

Short-eared Owls were observed on three days in the typically preferred grasslands near the airport, and south of Machete Island. On one occasion (2015-04-15) three birds were observed; on the other three occasions, only one owl was counted. We concluded that these birds were non-breeding transients.

There was a prolonged and obvious presence of Northern Harriers in 2015, which were commonly observed in similar locations to where they had bred previously, and where the owls are often seen. The activity gave our field observers a strong impression that they were nesting, but if nesting was initiated, the attempt did not last long. By May 7, we confirmed that the birds were not incubating, and monitoring did not continue past that date. For the remainder of the spring, there was no anecdotal evidence of nesting observed during other field work activity in the area.

One previously monitored Osprey nest was destroyed over winter, and two new Osprey nests were located during the nest search (Figure 3-7). Seven of ten active Osprey nests were successful (Appendix 7-3); two of these nests appeared to be successful in raising three fledglings, and two other nests raised two fledglings. As such, Osprey productivity was high in 2015. Three out of five active Bald Eagle nests were successful in 2015.

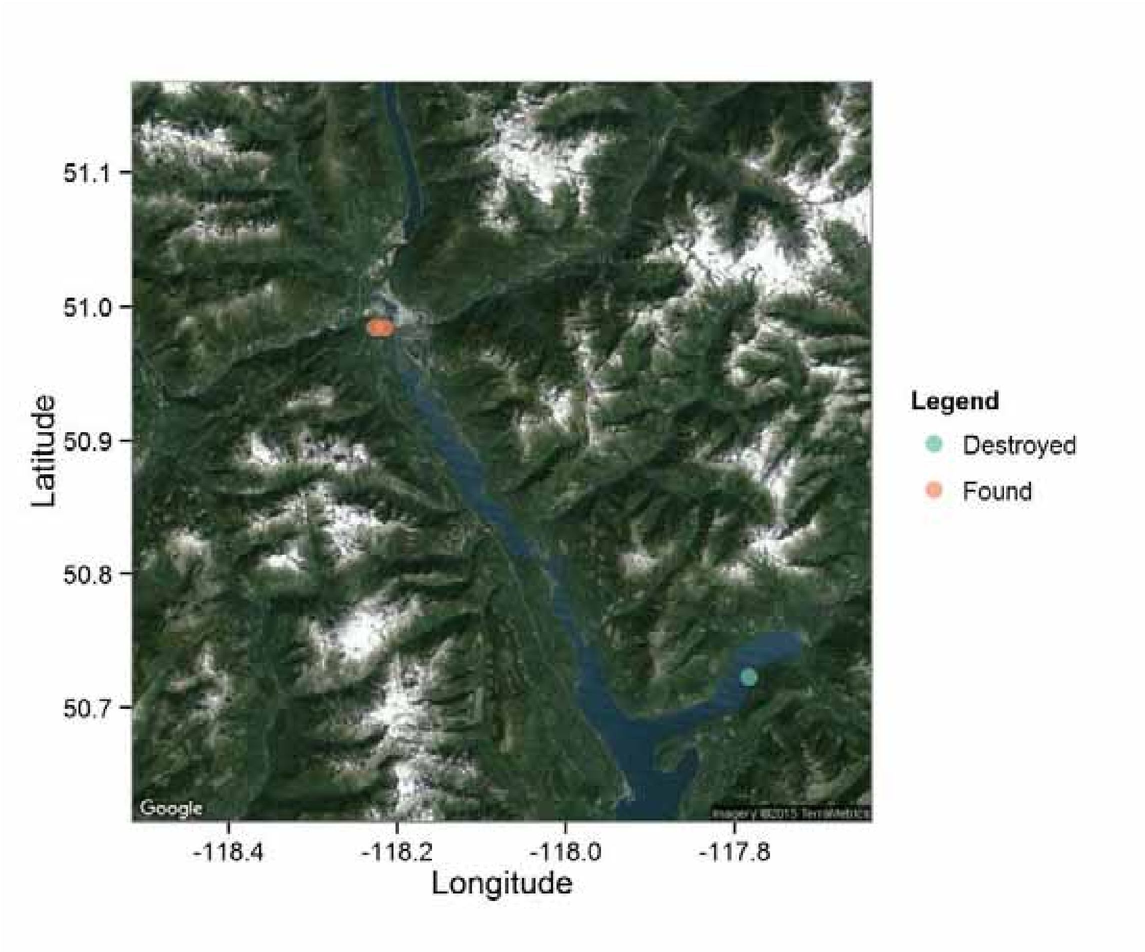


Figure 3-7: Locations of destroyed and new Osprey nests

3.2 Shorebird fall migration

Shorebirds were relatively abundant during the fall migration, with 16 species observed. A summary of shorebird species detections are provided in Appendix 7-4. In 2015, we observed a larger number of Killdeer, Spotted Sandpipers, Greater Yellowlegs, Lesser Yellowlegs, Semipalmated Sandpipers, Least Sandpipers, Pectoral Sandpipers and Wilson's Snipe during the fall migration, compared with previous years. Our comprehensive surveys (weeks with both boat and land-based surveys) captured the primary migration period, which was similar to the temporal pattern observed in previous years (Figure 3-8). Considering land-based surveys only, another well pronounced Dowitcher migration was observed this year (Figure 3-9); this migration concluded during the month of October (Figure 3-9). Most shorebird observations were made during the land-based survey, with very few species/detections, other than Spotted Sandpipers, during the boat-based surveys.

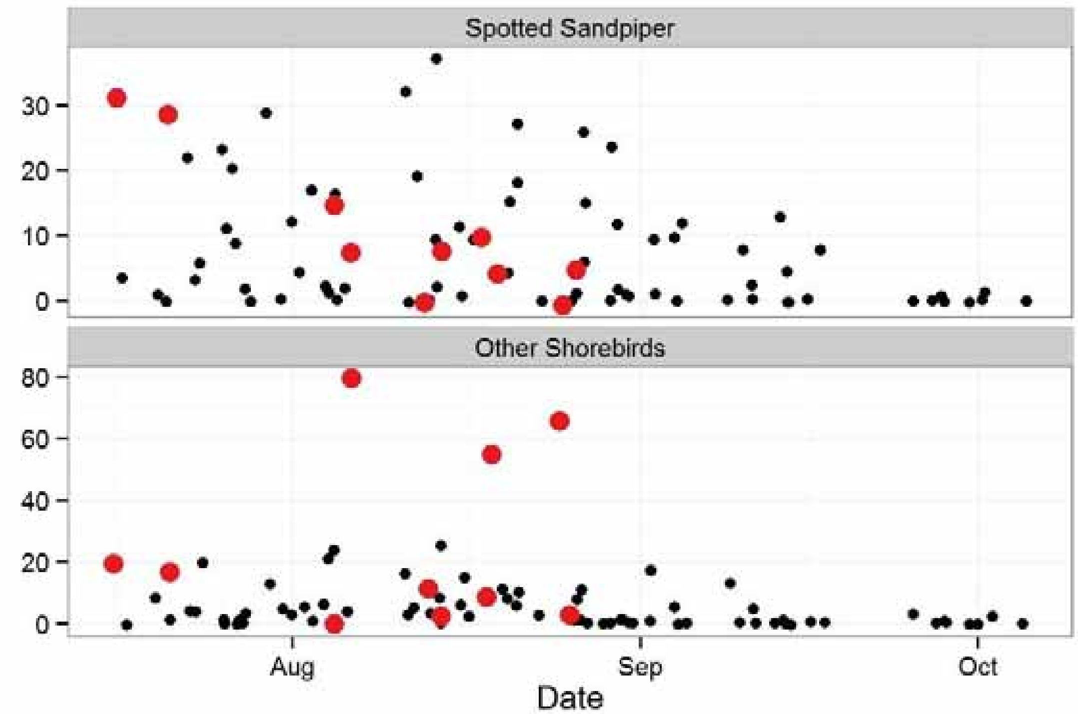


Figure 3-8: **Fall shorebird counts recorded in weeks when both land-based and boat-based surveys were conducted. Data points from the current year are represented by enlarged red points**

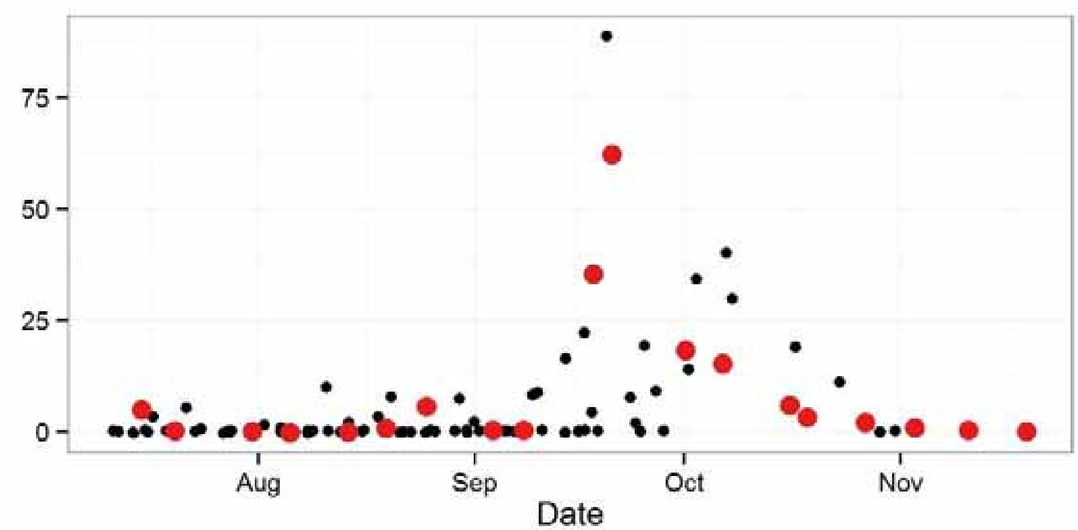


Figure 3-9: **Fall shorebird counts of Dowitcher recorded in land-based surveys. Data points from the current year are represented by enlarged red points**

3.3 Habitat map revisions

Linework improvements constituted the bulk of the revisions. Higher resolution images improved our ability to identify transitions between habitat types, particularly in areas along the perimeter of the reservoir. Re-typing of polygons was also a large part of the effort, with 11% of the non-forested polygons seeing a change in their habitat category. Many of the polygons with typing changes were in areas which were originally delineated using the black and white images. The colour imagery allowed us to better differentiate areas of sparse vegetation (PG), from silt (SI) and sand (SA); as well as differentiate between other grassland types (SG, MG).

The most significant change in mapping was the decision to remove the ‘upland coniferous’ (UC) and ‘upland mixed’ (UM) categories and merge them into one new forested category called ‘upland forest’ (UF). This leaves two forested cover types: ‘riparian forest’ (RF) – which is defined as forested cover type with a polygon mean elevation less than 440.1m ASL (full pool), and ‘upland forest’ (UF) which is forested cover with a polygon mean elevation greater than 440.1m ASL. The mapping was also clipped just above full pool (440.5m ASL) to focus on drawdown zone habitats only.

An example of the revised map is provided in Figure 3-10.

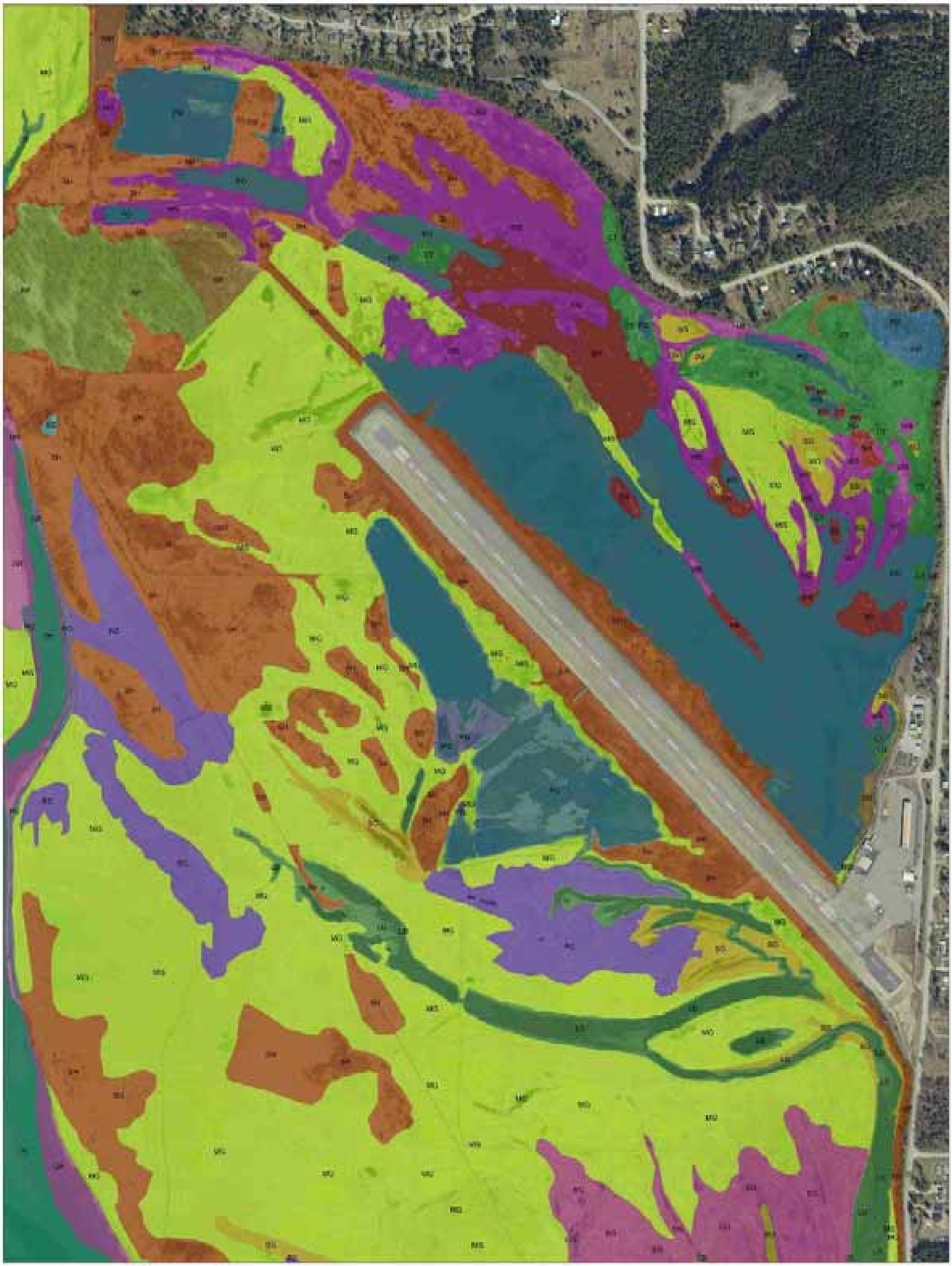


Figure 3-10: **Example of the revised Revelstoke Reach habitat map showing vegetation communities in the Airport Marsh region**

3.3.1 Waterfowl count precision

In the fall of 2015, we conducted blind double observer counts on 39 occasions. These count comparisons showed a very strong correlation between counts made by each observer, relative to the biological effect size: the repeatability (or Intraclass Correlation Coefficient) r was calculated at 0.99, with a 95% confidence interval of 0.981 to 0.995.

3.3.2 Habitat use mapping precision

Between 20 May and 4 November, double observer mapping of waterbird locations was performed on 74 occasions (74 groups of waterbirds). When asked to draw a polygon where a group of waterfowl was observed, there was high congruence in the habitats that were mapped independently by two observers, but low congruence in the exact location of the polygons. For example, the polygons drawn by observers overlapped in only 32 cases (43.2 %), and only 28 % of the summed area mapped as used by waterfowl was mapped by both observers. However, when we examined the habitats that were mapped as used by waterfowl, observers were highly consistent, despite their mapping being misaligned. There were 25 cases where one observer mapped usage of a habitat type that was not mapped by the other observer (33.8 %); however, these tended to be marginal ‘slivers’ of habitat mapped at polygon edges, and accounted for only 3.7% of the sum of the use-mapping. There were seven cases where two habitat types were mapped within polygons; in all but two of these cases, both observers’ data indicated the same dominant habitat type within the polygon. As such, differences in habitat results derived from mapping were relatively small.

3.4 Multi-year analysis

3.4.1 Which wetlands are most used during the spring waterfowl migration?

The Poisson GLMM indicated that dabbling ducks were more numerous at Cartier Bay ($P < 0.001$), and less numerous at both Montana Slough ($P < 0.01$) and Locks Creek ($P = 0.002$), compared with the Airport Marsh (Figure 3-11).

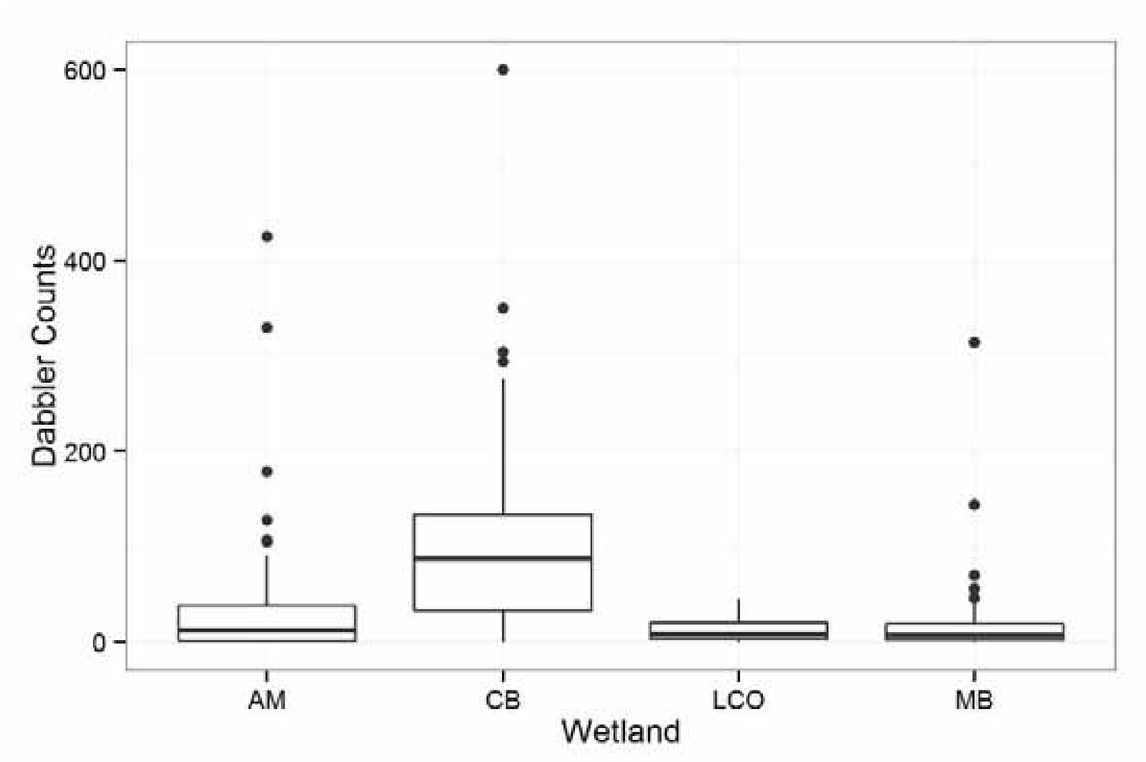


Figure 3-11: Dabbler counts during the spring migration at Airport Marsh (AM), Cartier Bay (CB), Locks Creek Outflow (LCO) and Montana Bay (MB) from 2008 through 2014. Relative to Airport Marsh, the counts were modelled to be lower at LCO and MB and higher at CB

3.4.2 Do reservoir operations limit duck productivity?

The quasi-Poisson regression showed a strong negative relationship between maximum reservoir pool each year, and the average number of duck broods observed per survey during the late part of the brood rearing season ($P = 0.02$, McFadden's $r^2 = 0.58$).

3.4.3 Reservoir operations and the productivity of Ospreys

With a dry June in 2015, a low reservoir maximum pool elevation, and high Osprey productivity, the addition of the 2015 data points strengthened the negative relationship between annual maximum reservoir elevation Osprey productivity seen in the 2014 data (Craig et al. 2015). While the negative correlation of reservoir operations with Osprey productivity is increasingly conclusive, more data will be beneficial to further strengthen the conclusion, and to understand the manner of the correlation. To the latter end, preliminary modeling in 2015 showed that the relationship between Osprey productivity and maximum annual reservoir elevation was best described by a second-degree polynomial (adjusted $r^2 = 0.82$, $p = 0.003$) where the effect was increasingly evident in years with higher maximum elevations; there was less correlation among years with lower maximum elevations (Figure 3-12). A first-degree polynomial (straight line function) and an exponential model both fit well for the correlation between productivity and total amount of June rainfall, but we chose the straight line for simplicity (adjusted $r^2 = 0.88$, $p = 0.006$, Figure 3-13). In other words the effect of June rainfall was steady, with every increase in rainfall diminishing Osprey productivity.

Whether rainfall or reservoir operations were directly involved as a causal agent is still far from being known. One potential way to examine this is to see if similar rainfall effects are seen in other study areas; if so, it could be argued that rainfall is a ubiquitous constraint on Osprey productivity, and that the effect of reservoir operations is simply spurious correlation associated with rainfall. To further investigate the potential effects of maximum annual reservoir elevation and weather on Osprey productivity in the Columbia River basin, we looked for correlations between these variables and the productivity of nests monitored near Nakusp (Davidson 2011) between 1994 and 2010. We found no relationships between the annual productivity of these nests and either weather variables (including total amount of June rainfall) or annual maximum reservoir elevation.

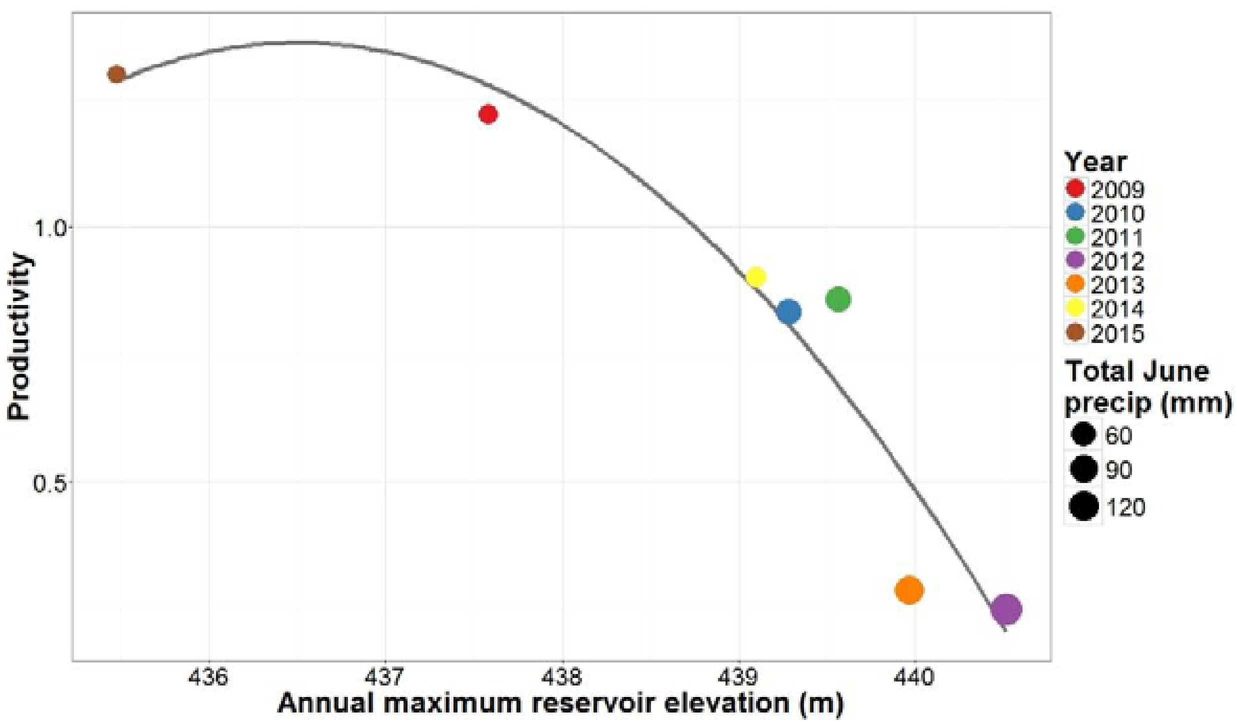


Figure 3-12: **Annual productivity of Osprey's nesting in Revelstoke Reach is plotted as a function of the annual high pool elevation of the Arrow Lakes Reservoir. The amount of rainfall in June is expressed by the size of the points plotted. Year is themed by colour. Productivity is measured as the average number of young fledged per nest**

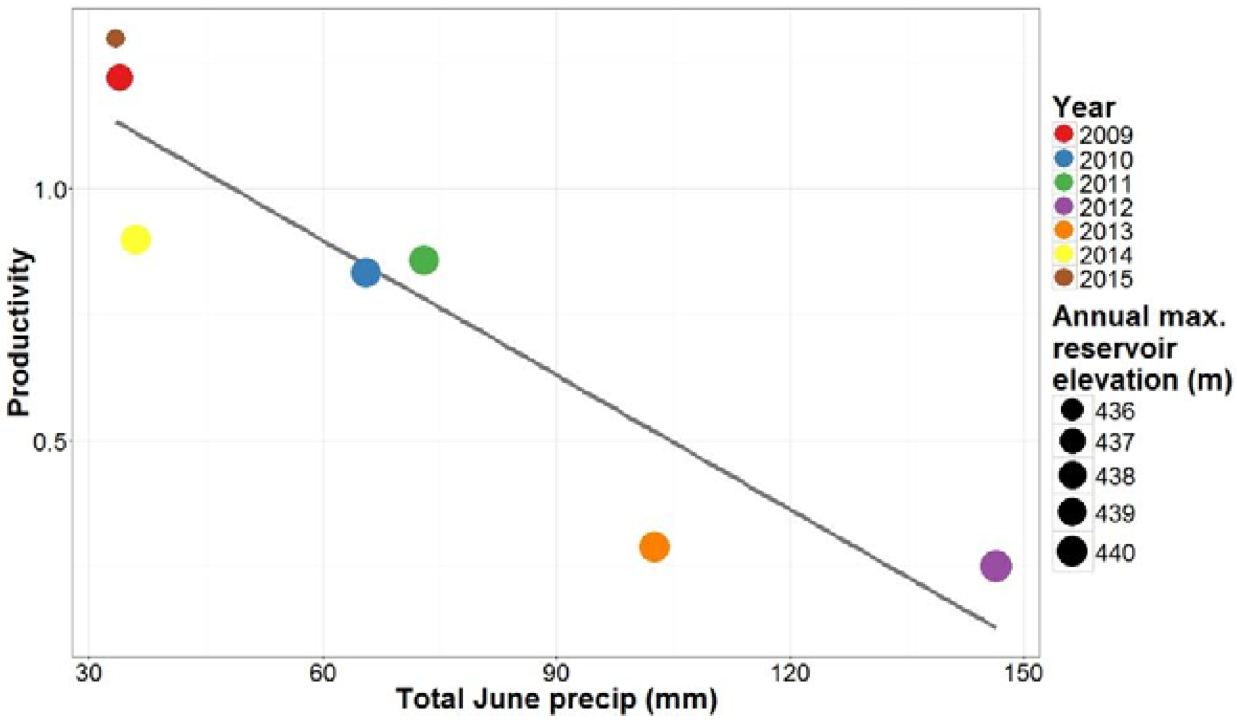


Figure 3-13: **Annual productivity of Osprey's nesting in Revelstoke Reach is plotted as a function of the total rainfall in June. The annual maximum pool elevation for the ALR is expressed by the size of the points plotted. Year is themed by colour. Productivity is measured as the average number of young fledged per nest**

3.4.4 Video surveillance of Osprey provisioning

We respectively recorded 331 and 1284 flying events in the recordings at nest 81083 and 6, including all arrivals, departures, and flybys. At nest 81083, we recorded 0.430 prey deliveries per hour; on fully monitored days, we recorded an average of 7.3 ± 3.51 prey deliveries per day (n = 3, range = 4 to 11 deliveries per day). Higher prey deliveries were recorded later in the year at nest 6, with an average of 1.142 deliveries per hour, or 19 ± 13.29 prey deliveries per day (n = 7, range = 3 to 40 deliveries per day).

We found little evidence of an optimal time of day for monitoring prey delivery rates. During the day, rates of food delivery were highly variable, within and between nests (Figure 3-14). Climatic conditions such as temperature and wind speed may have contributed to variability in feeding rates. We found indications that feeding rates increased under warmer temperatures (Figure 3-15) but warmer temperatures occurred in early August, when demands for food may have been greatest, prior to fledging (Figure 3-16). There was also a suggestion that provisioning rates decreased on days with winds > 20 km/h, but there were few data points to assess this relationship well. These aspects cannot be controlled by experimental design, but could potentially be controlled statistically.

Prey delivery rates showed no correlation with flows from the Revelstoke Dam. During the course of the season, reservoir elevations decreased. This change did not correlate with provisioning rates.

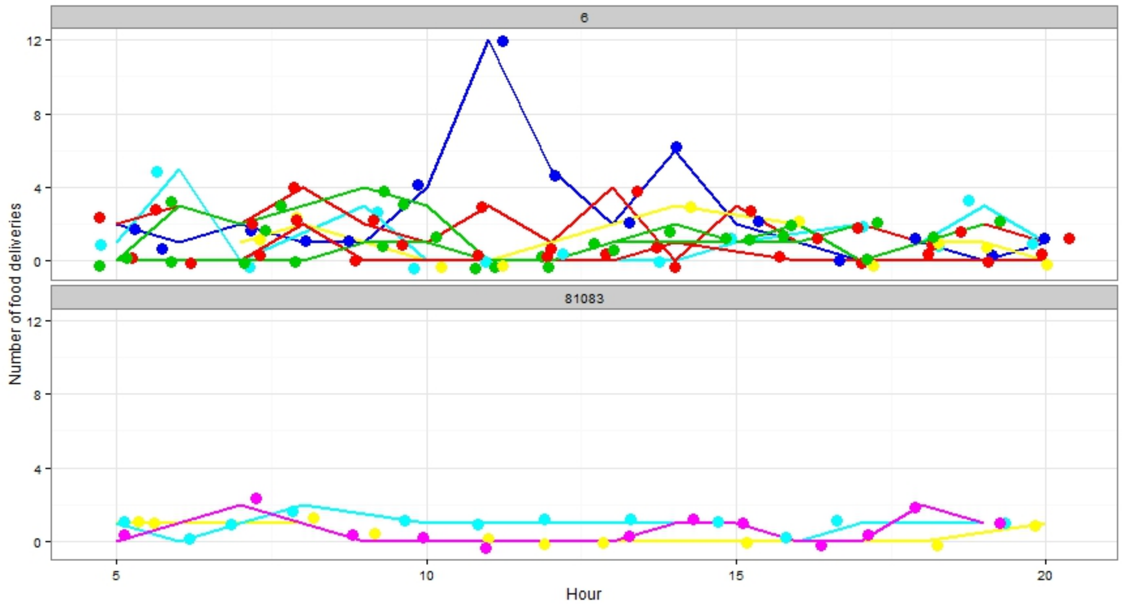


Figure 3-14: **The number of food deliveries at two nests during the diurnal period. The upper panel (nest 6) portrays provisioning rates later in the year, when three nestlings were being fed. The lower panel shows data from earlier in the year, when an unknown number of nestlings were still very young**

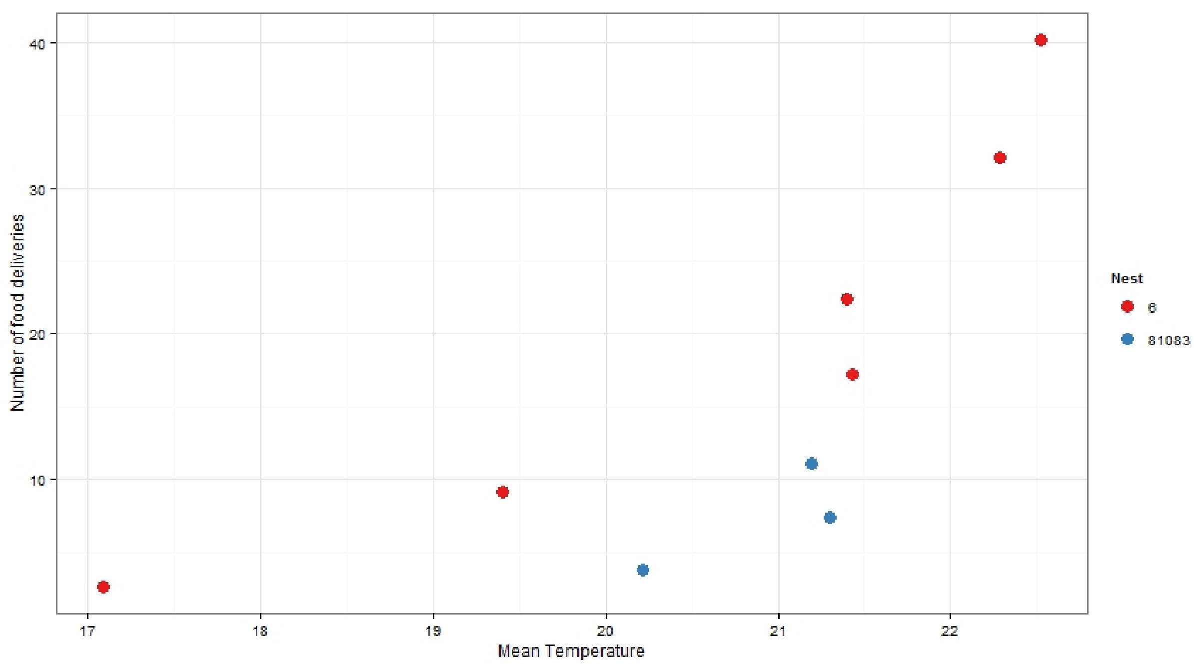


Figure 3-15: **The number of food deliveries per day at two Osprey nests plotted as a function of daily mean temperature.**

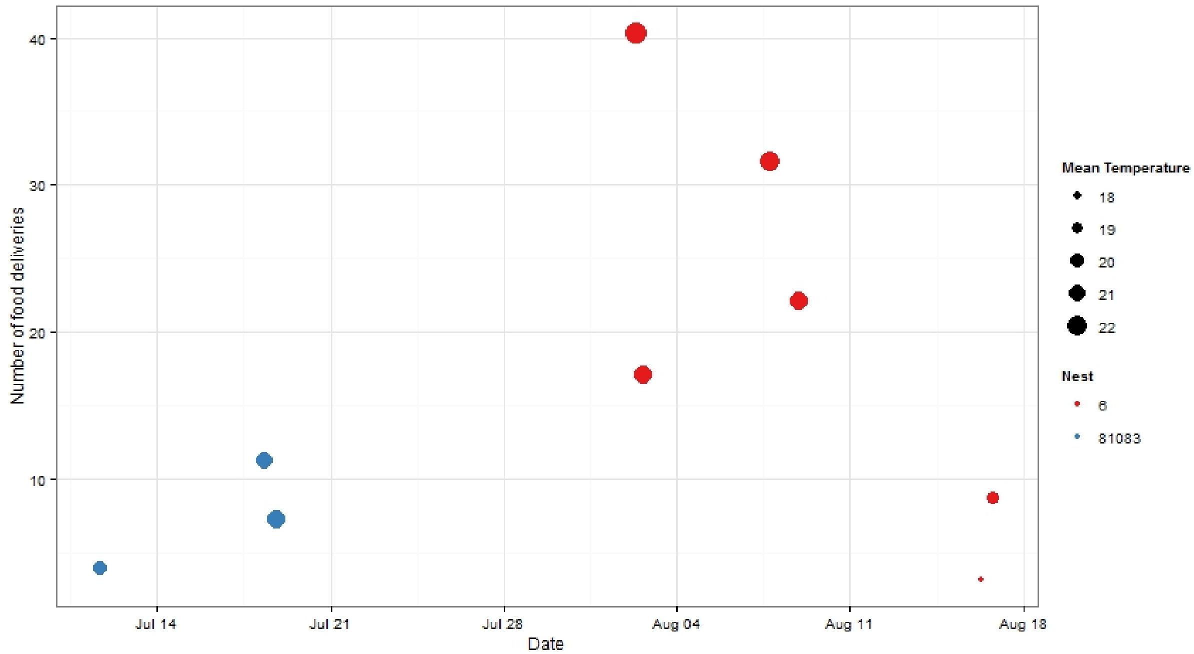


Figure 3-16: **The number of food deliveries per day are plotted as a function of time of year.**

4 DISCUSSION

4.1 Year 8

Following a low-snowpack winter, the 2015 spring thaw came early, but the ice free wetlands were used by a relatively low number of waterfowl compared with previous spring migrations. Both Short-eared Owls and Northern Harrier migrated through the area, but neither species nested. The latter species showed signs of attempting to nest, but no serious nesting activities were observed, and relatively intensive monitoring allowed us to conclude that they were not nesting by late May. No evidence of nesting was seen thereafter.

Reservoir water levels remained unusually low in 2015, producing conditions never observed previously during the course of this study. The low water levels appeared to be beneficial for waterbird productivity. We observed maximal numbers of waterfowl broods, and Osprey productivity was above average. We did however observe very few Canada Goose broods in 2015. Canada Goose is typically been the most abundant brood-rearing waterfowl species each year. We believe that with very low water levels, the geese vacated the wetlands and arid grasslands in the study area shortly after hatching to forage in flooded grasses further south. We suspect that the high number of American Wigeon broods was a result of low nest flooding. The low water levels may also have contributed to us detecting unusually large numbers of shorebirds in the northern part of the study area, and a low usage of the southern parts that we access via the boat-based shorebird survey.

Like the spring migration, waterfowl had a low attendance at the Revelstoke Reach wetlands during the fall migration of 2015. It is possible that the relatively weak migration in spring was due to the early thaw, which allowed waterfowl to move north ahead of schedule. We have no hypothesis to explain why there were not more waterfowl during the fall migration.

4.2 Multi-year progress and data gaps

In recent years, we have recognized increasing evidence that reservoir operations may limit Osprey productivity. In 2015, we addressed two data gaps. First, we completed the analysis of video footage of two Osprey nests recorded in 2014. This pilot study was created to examine how food provisioning to nestlings is impacted by reservoir elevation. Having the pilot study completed, and the quality of data examined, we concluded that that the methods used in the pilot study would be insufficient to address the data gap. The effort required to gain the footage and retrieve the data was exceptionally large, there were very few nest sites for which these data could be recorded, and the quality of the data (i.e., our ability to count food delivery with certainty) was relatively low. As such, we do not recommend pursuing this data gap further.

The second data gap that we addressed in 2015 was the low precision of Osprey nest monitoring in previous years. In 2014, our analysis highlighted that the relationship between reservoir operations and Osprey nesting success could potentially be a spurious correlation with precipitation levels (Craig et al. 2015). We greatly improved our monitoring quality in 2015 by conducting more frequent aerial surveys. This allowed us to more conclusively examine the nest contents and more accurately determine the timing of nest failures, which may shed some light on whether productivity is more strongly affected by precipitation levels in June or the maximum elevation of the reservoir (typically peaks in July).

A final remaining data gap was recently addressed; in the fall of 2015 we obtained detailed habitat data to characterize habitat variability within wetlands, collected under the CLBMON-11B-4 study by LGL Ltd. (Miller and Hawkes 2014). We plan to integrate the CLBMON-11B-4 habitat data with our waterfowl mapping in Year 9.

4.3 New analyses

4.3.1 MQ-1 and 3: How are waterfowl distributed among habitats and sites?

In this report we outlined a new model to compare dabbling duck counts among four key wetlands in Revelstoke Reach. We used a mixed effects model to control for survey occasion (grouping counts made on the same day) while controlling for seasonal abundance during the spring migration, to examine how spring counts differed among Airport Marsh, Cartier Bay, Locks Creek Outflow, and Montana Bay. Previous analyses have shown that these four wetlands are collectively the most important habitats in Revelstoke Reach for waterfowl – particularly dabbling ducks (CBA 2013a). Within these wetlands, our new mixed effects model confirmed that Cartier Bay is the most important of all habitats in Revelstoke Reach, followed by Airport Marsh; Locks Creek Outflow and Montana Bay have relatively low importance during spring when reservoir elevations are not directly influencing habitat quality. Management Question 1, which asks how waterfowl are distributed, is now better addressed at the scale of wetlands. Two other scales should also be re-examined.

At the scale of the study site, future analyses should attempt to improve models presented previously regarding how aerial waterfowl counts vary among all parts of Revelstoke

Reach. We plan to use GIS-derived habitat descriptors to see if more constructive models can be used to examine usage among non-wetland polygons – particularly, grassland habitats. As always, it is important to remember that habitat distribution data is more complete when reservoir elevations effects are modelled: this is particularly true for grassland habitats that have low intrinsic value for waterbirds until they become inundated.

Addressing MQ-3, and of relevance to MQ-1, future analyses should also examine how waterfowl are distributed within wetlands with a detailed examination of habitat selection (water depth, submergent vegetation species cover, etc.). We will be examining waterfowl habitat-use using the CLBMON-11B-4 dataset in conjunction with our habitat-use mapping in Year 9.

4.3.2 MQ-3: Habitat mapping and habitat use

In 2015, we increased attention to the quality of our habitat data. Specifically, we made revisions to the habitat map that was produced previously (CBA 2012), and examined observer mapping errors. Together this effort will allow us to better quantify habitat use, and evaluate the variability in perceived habitat use that arises as a result of observer error. These are discussed below.

Future revisions to the habitat mapping should be focussed on field sampling to validate the polygon typing. Using TEM protocols, a level 5 field assessment is recommended, whereby 10-15% of the polygons are randomly selected and ground truthed (BC Ministry of Environment, Resources Inventory Committee 1998). In addition to the field sampling, a list of each habitat category's vegetation community should be compiled to further validate the polygon typing as well as to quantify each category's characteristics. Improving the habitat mapping will enhance our ability to address MQ-3, asking which habitats are utilized by waterbirds.

4.3.3 MQ-4, MQ-7 and H1D: Are brood counts associated with reservoir operations?

In this report we provided an updated analysis that confirmed a negative relationship between reservoir operations (annual maximum ALR elevation) and average brood counts observed late in the brood rearing season. With eight years of data, this is more convincing than what was examined in the Year 5 Interim report (CBA 2013a). As this is correlative in nature, it is possible that other factors are the true causation; for example, it could be that weather is predictive of both reservoir operations and duck productivity. It is also possible that broods are simply harder to count when reservoir elevations are higher; for example, if brood rearing habitats are selected in regions that are not monitored, or if brood rearing switches from wetlands to flooded shrubs.

Analyses are underway to cross-examine how duck nest survival is related to reservoir operations. This analysis should be ready to present in the Year 9 report, and validate whether there is alternate information that supports the reservoir-causation hypothesis. In particular, information on spatial positioning of nests in relation to reservoir elevations, and occurrences of nest submersions will provide unequivocal support for this scenario.

4.3.4 MQ-7: Productivity of Osprey in Revelstoke Reach

Correlation of Osprey productivity and reservoir operations was first detected after the 2013 field season; specifically, our results indicated that the proportion of successful nests declined in years with more aggressive filling of the Arrow Lakes Reservoir (CBA 2014). With one additional year of data (2014), the relationship was confirmed and strengthened a year later; however, we also found an additional negative correlation with June rainfall

(Craig et al. 2015). Either correlation could potentially reflect true causation. Both are mirrored in other studies from the Columbia River basin (reviewed below), and both potential predictor variables (reservoir operations and precipitation) are clearly inter-related. Both relationships were confirmed and strengthened with the addition of this year's (2015) data. As such, the last two years of additional data support and strengthen the original grounds for focusing on Osprey productivity under the WLR objectives (CBA 2014).

Previous work in the Columbia Basin has shown that both rain-fall and reservoir operations may influence Osprey productivity, but the evidence is mixed across studies. For example, closely resembling our results, Van Deale and Van Deale (1982) found that Osprey productivity at the Cascade Reservoir, Idaho, decreased in years when the reservoir pool was drawn to a higher elevation. That study indicated low productivity in high water years was mediated through low foraging success that occurred at high water levels. In contrast with our Revelstoke results and those in the Van Deale study, we found no evidence that the productivity of the Nakusp Osprey population was influenced by reservoir operations (this report). In another study, consistent with our results, Osprey brood size was negatively correlated with June rainfall in the Pend Oreille River area of northern Idaho (Johnson et al. 2008). In contrast, Arndt et al. (2006) found that Osprey productivity was positively correlated with summer precipitation during 10 years of nest monitoring in the West Kootenay. In this report, our analysis of Osprey nesting data from Nakusp (taken from Davidson 2011) found no support for correlation with any weather variables (temperature, precipitation).

Pooling all sources of information provides inconsistent results, and while the mechanism of nest failure remains elusive, we wish to note several key points at this time. First, despite the mixed results among studies, the strength of the CLBMON-40 results continues to increase over time. Due to the direct relevance to CLBMON-40 objectives, the correlation between reservoir operations and Osprey productivity should remain a focal subject in the remaining two years of study.

Second, variability among studies and study sites is not unexpected. Geographically, it is likely that local populations of Osprey forage for different species of fish, use different foraging habitats, and potentially have different foraging tactics; these different foraging ecologies may have differential impacts from reservoir operations. In Revelstoke Reach, Osprey forage in moving water (the Columbia River) or in separate wetlands when water levels are low. When the drawdown zone is submerged by the ALR, these available foraging habitats change dramatically with the river and wetland features and grasslands being submerged by the reservoir (dispersed/redistributed prey, change in water depth etc). The drawdown zone is very different near Nakusp, providing lake foraging only, and the metamorphoses of habitat caused by reservoir operations is far less extreme. It is possible that reservoir operations affect Revelstoke Reach Osprey more than Nakusp Osprey. We find it improbable that direct impacts of rainfall to Osprey productivity (i.e., nestling mortality caused by exposure to elements), would vary considerably among study sites; however, the effect of rainfall on productivity could also vary regionally, if mediated through impacts to foraging efficiency (Grubb 1977). Rainfall can influence water turbidity, temperature, flows, and depth – all of which could potentially influence the foraging efficiency of Osprey – but the changes to foraging conditions caused by rainfall likely varies among watersheds, and would be influenced by river regulation.

Finally, it should be noted that there is potential to partially de-couple the collinear effects of rainfall and reservoir operations via strength of the relationships, and by gathering more detailed nest monitoring data. Continued monitoring will eventually show greater support for one correlation versus the other. Operations that fill the ALR to high pool levels in dry years are possible, and would be invaluable for our understanding. There is also value in expanding the dataset to include a broader geographic (and temporal) scope, including additional (more recent) data from Nakusp, southern ALR, and elsewhere in the Columbia Basin (e.g., Kootenay Lake). Better knowledge of when nests fail and of brood sizes (and reduction if possible) will provide a much higher support from the data when considering why nests are failing in high pool years.

4.3.4.1 Can we measure foraging efficiency?

Due to the suspected role of foraging in Osprey productivity (CBA 2014), the first action we took towards clarifying the impact of reservoir operations on Osprey ecology was to determine if we could directly monitor foraging efficiency (prey delivery to nestlings) in our study area. In 2014, we conducted a pilot study to assess nest monitoring by video as a tool. One of the primary considerations in designing the pilot study was to determine to what degree sampling should occur *within* versus *among* nests. Prey delivery rates at individual nests are likely influenced by many factors. Weather is a factor that likely affects foraging success to some degree for all birds nesting within a given year. Brood size and parental quality will influence provisioning rates of individual nesting attempts. Nest location likely influenced provisioning rates because individual nests have different proximities to human disturbance, and to foraging habitats, which themselves differ in quality. In theory, the impact of reservoir operations would differ among nests, owing to the difference in the nature and elevation of the foraging areas near nest sites. In short, we recognized a high potential for inter-nest variability, indicating that a repeated annual monitoring of individual nests (repeated measures) designs would be necessary to make inferences about the impact of reservoir operations on nest provisioning rates. With this in mind, we should note that we do not have multiple year foraging data available to us.

In 2014, we discovered that it was challenging to find suitable locations to mount the video equipment where viewing of the nest site was possible. Many shoreline nest sites are remote, entailing considerable approach times, and the forested nature of the shorelines prevented any viewing of most nests. We were only able to find two nests that allowed our video monitoring to proceed, and one of these nests was destroyed during the field season.

Exacerbating the study was a very large effort required to (1) maintain the monitoring equipment in working order, and (2) to extract data from the video footage. We found the video equipment to be fairly challenging to set up with respect to optimizing battery life, focus the lens, and optimize the video resolution (pixel count and frame rate). The batteries required replacement approximately every two days, and there was always risk that the equipment may have failed to operate properly. After the field data were collected, two months of work were required to extract data from the videos.

The operational logistical constraints and effort alone were grounds for us to discontinue this study approach. Further convincing us of this conclusion was the fact that we found relatively high variability in provisioning rates within and across nests; the latter likely largely driven by nest stage and differences in brood size. More importantly, we found no evidence of an optimal time of day for monitoring. Had we found that a majority of provisioning to young occurred during part of the day (e.g., first three hours after sunrise), we could have greatly reduced the effort required by scheduling the video camera to run for shorter periods of time, thereby reducing the battery maintenance effort.

Finally, it could be that there are too many factors at play to be able to tease out the role played by reservoir operations. This is likely a certainty given the logistical constraints noted above, and the low sample size expected. In this study area, we do not think it is feasible to measure provisioning rates well enough to be effective.

4.3.4.2 Next Steps

We have begun two other approaches to parsing influences of June rainfall and reservoir operations. The first is more frequent aerial nest monitoring, which will provide us with more detailed information on nest contents (e.g. timing of laying, clutch size, brood reduction) and the timing and possible causation of nest failures. Secondly, we hope to be able to examine more results from existing nest monitoring data from elsewhere in the region and from other years. We are aware of several previous, and potentially ongoing, Osprey productivity datasets including data from further down the Arrow Lakes (Davidson 2011), near Creston (Steeger et al. 1992), and near Nelson (Steeger et al. 1992, Machmer 1998, Arndt et al. 2006). By examining data from areas with different weather histories, from different years, and that are uninfluenced by the operations of Arrow Lakes, we may be able to better assess the degree to which rain versus reservoir operations influence the productivity of Ospreys.

4.4 Recommendations

1. We continue to suggest that the land-based shorebird surveys should continue into November each year to document the conclusion of the Dowitcher migration.
2. We maintain that boat-based shorebird surveys should operate during the peak of the regular shorebird migration (starting no later than mid-July if possible, through August).
3. In 2015, we reallocated flying resources from aerial waterfowl surveys towards Osprey nest monitoring, having recognized that the former study had already established a fairly complete dataset. The modification to the work plan greatly increased the quality of the Osprey data in 2015, because we were able to visually inspect nest contents from above more frequently. By conducting more regular monitoring during the breeding season, we were better able to document nesting progress during the field season, and better establish the timing and potential causes of nest failures. We recommend that aerial survey work continues to focus on Osprey monitoring, with less frequent aerial waterfowl surveys, which target conditions that have not previously been documented (e.g. regarding reservoir elevations). Additional monitoring of other Arrow Lakes Osprey populations should be considered for 2016 and 2017.
4. Given (1) the very high effort/cost required, (2) the highly restricted opportunities to monitor Osprey nests, and (3) inherent variable nature of the data, we concluded prior to the 2015 field season that the video monitoring approach was not feasible for our purposes.

4.5 Conclusions

Conclusions 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.

6 LITERATURE CITED

Arndt, J., E. Moore, L. Prosser, and R. Wege. 2006. Ten years of monitoring nesting Ospreys (*Pandion halliaetus*) in the west Kootenay region of British Columbia. Wildlife Afield 3:125–133 pp.

Bates, D., M. Maechler, and B. Bolker. 2011. lme4: Linear mixed-effects models using S4 classes. R package version 0.999375-42, Retrieved April 29, 2013, from http://CRAN.R-project.org/package=lme4.

BC Hydro. 2005. Consultative Committee report: Columbia River Water Use Plan, Volumes 1 & 2, BC Hydro, Burnaby, BC.

BC Ministry of Environment, Resources Inventory Committee. 1998. Standard for Terrestrial Ecosystem Mapping in British Columbia, Victoria, BC.

Cooper Beauchesne and Associates Ltd (CBA). 2011. CLBMON 40: Arrow Lakes Reservoir shorebird and waterbird monitoring program: monitoring protocols, Year 3, BC Hydro Water Licence Requirements, Castlegar, B.C.

Cooper Beauchesne and Associates Ltd (CBA). 2012. CLBMON 40: Arrow Lakes Reservoir shorebird and waterbird monitoring program, Year 4, 2011. Supplemental winter report, BC Hydro Water Licence Requirements, Castlegar, BC.

Cooper Beauchesne and Associates Ltd (CBA). 2013a. CLBMON-40: Arrow Lakes Reservoir shorebird and waterbird monitoring program. 5 Year Interim Review Report: 2008-2012, BC Hydro Water Licence Requirements, Burnaby, BC.

Cooper Beauchesne and Associates Ltd (CBA). 2013b. CLBMON-36: Kinbasket and Arrow Lakes Reservoirs: Nest Mortality of Migratory Birds Due to Reservoir Operations. 5 Year Interim Review Report: 2008-2012, BC Hydro Water Licence Requirements, Burnaby, BC.

Cooper Beauchesne and Associates Ltd (CBA). 2014. CLBMON-40: Arrow Lakes Reservoir shorebird and waterbird monitoring program: monitoring protocols, Year 7, BC Hydro Water Licence Requirements, Castlegar, B.C.

Cooper Beauchesne and Associates Ltd (CBA). 2015. CLBMON-40: Arrow Lakes Reservoir shorebird and waterbird monitoring program: monitoring protocols, Year 8, BC Hydro Water Licence Requirements, Castlegar, B.C.

Cox, W. A., M. S. Pruett, T. J. Benson, S. J. Chiavacci, and R. Frank III. 2012. Development of camera technology for monitoring nests. Chapter 15:185–210 pp.

Craig, C., H. van Oort, R. Gill, C. Bird, and J. M. Cooper. 2015. Osprey productivity and nest provisioning in Revelstoke Reach. Proceedings from the Regulated Rivers: Environment, Ecology and Management Conference, Columbia Mountains Institute of Applied Ecology, Castlegar, BC. Retrieved November 17, 2015, from http://cmiae.org/resources/cmi-conference-summaries/.

Davidson, G. 2011. Birds of the Nakusp, New Denver, and Burton region of Southeastern British Columbia, 1975 to 2010 – Part 1: Nonpasserines (Introduction and waterfowl through woodpeckers). Wildlife Afield 8:3–103 pp.

Elston, D., R. Moss, T. Boulinier, C. Arrowsmith, and X. Lambin. 2001. Analysis of aggregation, a worked example: numbers of ticks on red grouse chicks. Parasitology 122:563–569 pp.

Enns, K. A., R. Durand, P. Gibeau, and B Enns. 2007. Arrow Lakes Reservoir inventory of vegetation resources (2007) – addendum to 2007 final report. Report by Delphinium Holdings Inc. for BC Hydro, BC.

Gollop, J. B., and W. H. Marshall. 1954. A guide for aging duck broods in the field. Mississippi Flyway Council Technical Section. Northern Prairie Wildlife Research Center Online., Retrieved from http://www.npwrc.usgs.gov/resource/birds/ageduck/index.htm (Version 14NOV97). [accessed October 13, 2008].

Grubb, T. 1977. Weather-dependent foraging in Ospreys. Auk 94:146–149 pp.

Harrison, X. 2014. Using observation-level random effects to model overdispersion in count data in ecology and evolution. PeerJ 2:e616 pp.

Hawkes, V. C., C. Houwers, J. D. Fenneman, and J. E. Muir. 2007. Monitoring program No. CLBMON-10 Kinbasket Reservoir inventory of vegetation resources, BC Hydro Water Licence Requirements, Castlegar, BC.

Hawkes, V. C., H. van Oort, M. Miller, C. Wood, and A. Peatt. 2014. CLBWORKS-30 Ecological Impact Assessment - Wildlife Physical Works Project 14 & 15A, BC Hydro, Water Licence Requirements, Burnaby, BC.

Jarvis, J. 2003. Preliminary evaluation of the impact of reservoir operations on nesting birds in the Revelstoke Reach, Upper Arrow Lakes Reservoir, Revelstoke, British Columbia, Canada, BC Hydro, Burnaby, B.C.

Jarvis, J., and J. G. Woods. 2001. Waterbirds of the Revelstoke Reach wetlands Upper Arrow Reservoir, Revelstoke, British Columbia, Canada, BC Hydro, Burnaby, B.C.

Johnson, D., W. Melquist, and T. Fleming. 2008. Rainstorm effects on Osprey brood survival. Journal of Raptor Research 42:51–53 pp.

Kéry, M. 2010. Introduction to WinBUGS for ecologists: Bayesian approach to regression, ANOVA, mixed models and related analyses, Academic Press.

Kéry, M., and M. Schaub. 2012. Bayesian population analysis using WinBUGS: a hierarchical perspective, Academic Press.

Korman, J. 2002. Simulating the response of aquatic and riparian productivity to reservoir operations: description of the vegetation and littoral components of BC Hydro's integrated response model (IRM), BC Hydro Water Licence Requirements, Castlegar, B.C.

Lessells, C., and P. T. Boag. 1987. Unrepeatable repeatabilities: a common mistake. The Auk:116–121 pp.

Machmer, M. 1998. Causes and consequences of sibling aggression in nestling ospreys (*Pandion haleaetus*), Simon Fraser University, Burnaby, BC.

Macwhirter, R. B., and K. L. Bildstein. 1996. Northern Harrier (*Circus cyaneus*), The Birds of North America online (A. Poole Ed.), Cornell Lab of Ornithology, Ithica, NY. Retrieved from http://bna.birds.cornell.edu/bna/species/210 [accessed November 2, 2012].

Meidinger, D., and J. Pojar. 1991. Ecosystems of British Columbia, BC Ministry of Forests, Victoria, B.C.

Miller, M., and V. C. Hawkes. 2014. CLBMON-11B4 Monitoring wetland and riparian habitat in Revelstoke Reach in response to wildlife physical works. Annual report - 2013. LGL Report EA3413., BC Hydro Water Licence Requirements, Castlegar, BC.

Nilsson, C., C. A. Reidy, M. Dynesius, and C. Ravenga. 2005. Fragmentation and flow regulation of the world's large river systems. Science 308:405–408 pp.

Parsons, K. C. 2002. Integrated management of waterbird habitats at impounded wetlands in Delaware Bay, U.S.A. Waterbirds 25:24–41 pp.

Poole, A. 1982. Brood reduction in temperate and sub-tropical ospreys. Oecologia 53:111–119 pp.

R Core Team. 2014. R: a language and environment for statistical computing, R Foundation for Statistical Computing, Vienna, Austria. Retrieved from http://www.R-project.org.

Resource Inventory Committee. 1999. Inventory methods for waterfowl and allied species: loons, grebes, swans, geese, ducks,American coot, sandhill crane., Standards for components of British Columbia's biodiversity, Ministry of Environment, Lands and Parks, Victoria, BC.

Royle, J. A., and R. M. Dorazio. 2008. Hierarchical modeling and inference in ecology: the analysis of data from populations, metapopulations and communities, Academic Press.

Rundle, W. D., and L. H. Fredrickson. 1981. Managing seasonally flooded impoundments for migrant rails and shorebirds. Wildlife Society Bulletin 9:80–87 pp.

Steeger, C., H. Esselink, and R. Ydenberg. 1992. Comparative feeding ecology and reproductive performance of Ospreys in different habitats in southeastern British Columbia. Canadian Journal of Zoology 70:470–475 pp.

Tremblay, E. M. 1993. Use of the Upper Arrow Lakes Reservoir at Revelstoke, BC by waterfowl and other waterbirds. British Columbia Birds. British Columbia Birds 3:3–12 pp.

Utzig, G., and D. Schmidt. 2011. Dam footprint impact summary; BC Hydro dams in the Columbia Basin, Fish and Wildlife Compensation Program, Columbia Basin, Nelson, B.C.

Van Deale, L., and H. Van Deale. 1982. Factors affecting the productivity of Ospreys nesting in west-central Idaho. Condor 84:292–299 pp.

Wiggins, D. A., D. W. Holt, and S. M. Leasure. 2006. Short-eared owl (*Asio flammeus*), The Birds of North America online (A. Poole Ed.), Cornell Lab of Ornithology, Ithica, NY. Retrieved from http://bna.birds.cornell.edu/bna/species/062 [accessed November 2, 2012].

Wolak, M. E., D. J. Fairbairn, and Y. R. Paulsen. 2012. Guidelines for estimating repeatability. Methods in Ecology and Evolution 3:129–137 pp.

Zuur, A. F., E. N. Ieno, N. Walker, A. A. Saveliev, and G. M. Smith. 2009. Mixed effects models and extensions in ecology with R, Springer, New York.

Zuur, A. F., A. Saveliev, and E. N. Ieno. 2012. Zero inflated models and generalized linear mixed models with R, Highland Statistics Ltd, Newborgh, UK.

7 APPENDICES

Appendix 7-1: The CLBMON-40 Objectives, Management Questions (MQ) and Management Hypotheses, and a review of the results (see CBA 2013a for details on many of the Summary Points)

Objective 1	Management Questions (MQ)	Management Hypotheses	Year 8 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.
	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 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 2015 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. 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 8 years. This nest was positioned with very high exposure to being flooded.

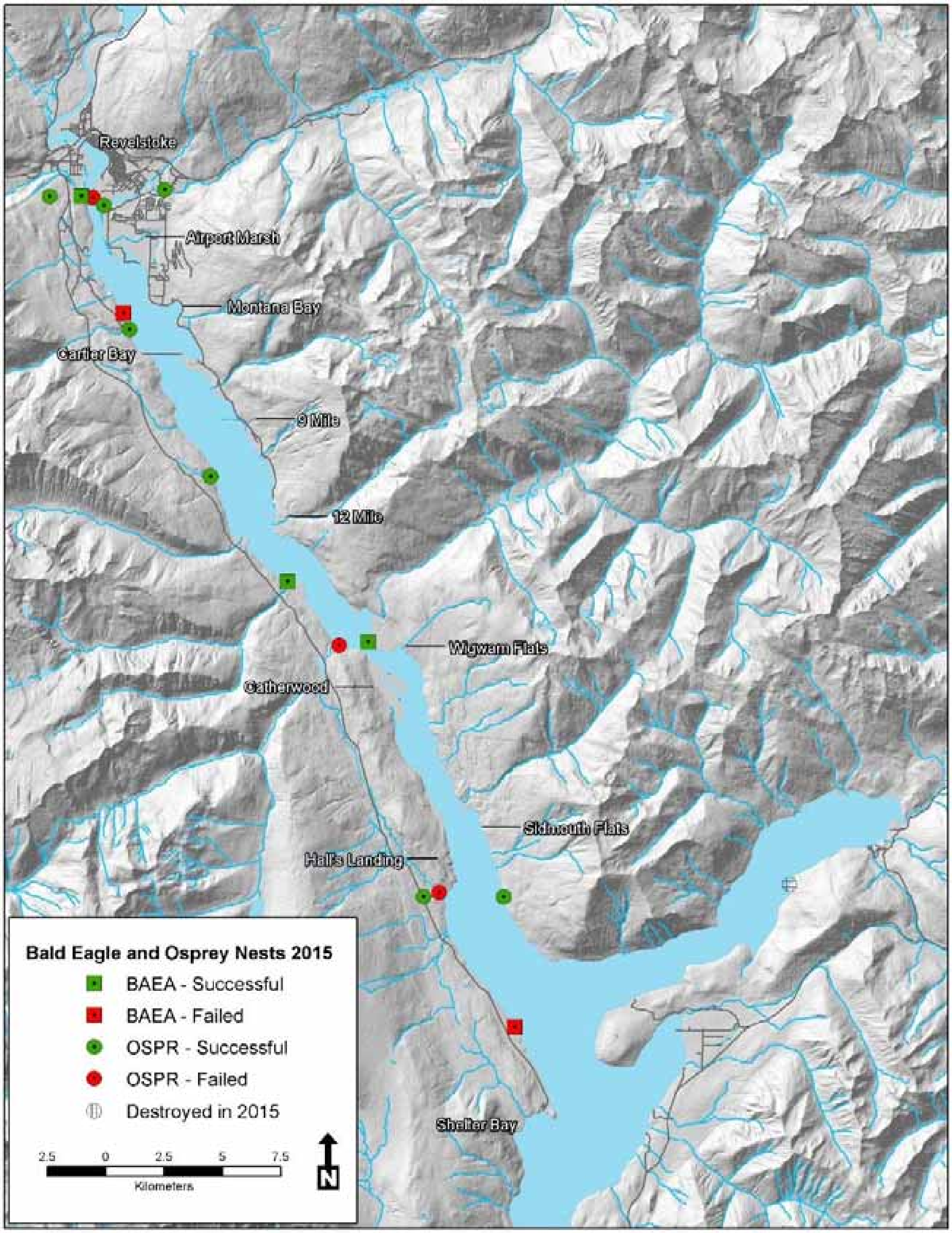
Objective 2	Management Questions	Management Hypotheses	Year 8 Status Summary Points
Inform BC Hydro on how reservoir operations affect waterbirds by monitoring their abundance, species richness, distribution, productivity, and patterns of habitat use over time.	2) What implication does the year-to-year 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 Owls). • 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 Owls and Northern Harriers, when nesting are highly exposed to being impacted by reservoir operations. • Osprey productivity is correlated with reservoir operations, but causation has not been confirmed.

Objectives 3-5	Management Questions	Management Hypotheses	Year 8 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.
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 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).
		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 observed during land-based waterbird surveys in 2015

Common Name	Scientific Name	Spring	Brood Survey	Fall
American Coot	*Fulica americana*	131	0	118
American Wigeon	*Anas americana*	1287	456	1483
Barrow's Goldeneye	*Bucephala islandica*	61	0	0
Blue-winged Teal	*Anas discors*	21	12	15
Bufflehead	*Bucephala albeola*	71	0	0
Canada Goose	*Branta canadensis*	1613	1166	1118
Canvasback	*Aythya valisineria*	2	0	1
Cinnamon Teal	*Anas cyanoptera*	31	1	0
Common Goldeneye	*Bucephala clangula*	8	0	0
Common Loon	*Gavia immer*	1	1	2
Common Merganser	*Mergus merganser*	153	6	89
Eurasian Green-winged Teal	*Anas c. crecca*	0	0	0
Eurasian Wigeon	*Anas penelope*	1	0	3
Gadwall	*Anas strepera*	29	1	0
Goldeneye Sp	*Bucephala sp*	19	0	0
Green-winged Teal	*Anas crecca*	383	9	251
Hooded Merganser	*Lophodytes cucullatus*	1	5	121
Horned Grebe	*Podiceps auritus*	0	0	2
Lesser Scaup	*Aythya affinis*	5	0	0
Mallard	*Anas platyrhynchos*	798	459	630
Northern Pintail	*Anas acuta*	94	3	65
Northern Shoveler	*Anas clypeata*	17	0	60
Pied-billed Grebe	*Podilymbus podiceps*	16	59	110
Red-necked Grebe	*Podiceps grisegena*	0	1	8
Redhead	*Aythya americana*	0	0	1
Ring-necked Duck	*Aythya collaris*	389	8	21
Ruddy Duck	*Oxyura jamaicensis*	3	0	1
Scaup Sp	*Aythya sp*	28	0	7
Trumpeter Swan	*Cygnus buccinator*	5	0	2
Unidentified Duck		151	11	121
Unidentified Swan	*Cygnus sp*	7	0	0
Unidentified Teal	*Anas sp*	1	0	368
Western Grebe	*Aechmophorus occidentalis*	0	0	2
Wood Duck	*Aix sponsa*	18	152	4

Appendix 7-3: Map of Bald Eagle and Osprey nests monitored in 2015



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 2015
BAEA - Successful
BAEA - Failed
OSPR - Successful
OSPR - Failed
Destroyed in 2015
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 2015

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