Columbia River Project Water Use Plan

Arrow Reservoir Operations Management Plan

Arrow Waterbird and Shorebird Monitoring

Implementation Year 6

Reference: CLBMON-40

Arrow Lakes Reservoir Shorebird and Waterbird Monitoring Program

Study Period: 2013

Cooper Beauchesne and Associates Ltd.
Head Office
Box 646, 1799 Swayne Road
Errington, BC

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CLBMON 40: Arrow Lakes Reservoir Shorebird and Waterbird Monitoring Program

Year 6, 2013

Harry van Oort, Corey Bird, & John M. Cooper

Cooper Beauchesne and Associates Ltd.

Head Office

Box 646, 1799 Swayne Road

Errington, BC V0R 1V0

Tel: 250 954-1822

Contact: John Cooper

jcooper@cooperbeauchesne.com

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Cover photo: Photo taken of Downie Marsh at high water taken during an aerial waterbird survey Photo: Harry van Oort, 2013.

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EXCUTIVE SUMMARY

Impoundments along the Columbia River have greatly reduced wetland availability for waterbirds and shorebirds. Several remnant wetlands remain in Revelstoke Reach, Arrow Lakes Reservoir, but these are regularly impounded by reservoir operations. The CLBMON 40 waterbird and shorebird monitoring program aims to document how reservoir operations affect waterbirds and shorebirds using the Revelstoke Reach wetlands. This report summarizes data recorded in 2013 (Year 6 of the 10-year study). Quantitative analyses of the data from Year 1-5 were conducted and reported in the 5 year interim review report. Here, in addition to summarizing data gathered in 2013, we also re-analyzed and summarized the full 6-year dataset on the productivity of waterfowl, Bald Eagles, and Ospreys.

Waterfowl

During spring migration, 5,629 waterfowl (25 species) were counted during eight land-based surveys: Canada Goose (*Branta canadensis*), American Wigeon (*Anas americana*) and Mallard (*Anas platyrhynchos*) were the most common species. Most waterfowl were observed at Cartier Bay (39%), followed by Airport Marsh (17%) and Downie Marsh (12%). The spring migration peaked in late March as suggested via the land-based surveys. Three aerial surveys were completed in spring; Mallard was the leading species recorded during spring aerial surveys (≤ 399), followed by Canada Goose (≤ 388), American Wigeon (≤ 310), and Ring-necked Duck (*Aythya collaris;* ≤ 146).

During fall migration, 5,794 waterfowl (19 species) were counted during eight land-based surveys: Canada Goose, American Wigeon and Mallard were the most common species. Most waterfowl were observed at Cartier Bay (43%), followed by Airport Marsh (14%) and 9-mile (13%). Six aerial surveys were completed in the fall; Canada Goose was the leading species recorded during fall aerial surveys (≤ 1,280), followed by American Wigeon (≤ 544), and Mallard (≤ 160). The fall migration peaked in the first week of October (2,168 waterfowl observed via aerial survey).

Shorebirds

Reservoir elevations decreased quickly and were quite low throughout most of the fall migration, but despite the high availability of exposed potential habitat, few shorebirds were detected (186 individuals from 7 species). Spotted Sandpiper (*Actitis macularius*) was the most abundant species (74%), followed by Semipalmated Sandpiper (*Calidris pusilla*; 6%). The fall shorebird migration appeared to peak in late July through mid-August, although this pattern was inconsistent among survey types as the land-based surveys suggested a small peak in mid-July, but relatively few birds thereafter. The greatest numbers of shorebirds were recorded at Wigwam Flats (2 species, 31 individuals) and Blanket Creek (1 species, 26 individuals) however; the greatest diversity of shorebirds was recorded at the Locks Creek Outflow (3 species, 10 individuals).

Productivity

During six weeks of semi-weekly brood surveys, 30 waterfowl broods were observed (409 young). Most broods were detected in Airport Marsh (37%), Montana Bay (17%), and Cartier Bay (17%). Canada Goose was the most common brood-bearing species (73%), followed by Mallard (13%), Common Merganser (*Mergus merganser;* 10%), and American Wigeon (3%). One out of seven monitored Osprey (*Pandion haliaetus*) pairs had successful nests in 2013. Five nesting Bald Eagle (*Haliaeetus leucocephalus*) pairs

were monitored in 2013, and 3 were successful (3 young fledged in total). No Short-eared Owl (*Asio flammeus*) or Northern Harrier (*Circus cyaneus*) nests were detected, and these species were not commonly seen after the late spring migration period.

In many CLBMON 40 analyses, each year functions as the fundamental sample unit. A re-analysis of the brood count data showed that the addition of one year's data (2013) strengthened the relationships reported previously in the 5 year comprehensive report. Waterfowl that were vulnerable to nest flooding (most ground-nesting species) showed strong relationships between annual brood count data and the annual predicted severity of nest flooding, but this relationship strengthened as data were compared later in the brood rearing season. There was only a very weak suggestion that the reservoir elevation on the day of each brood count survey was related to the brood count of vulnerable species on those occasions. For species that are not vulnerable to nest flooding (primarily Canada Goose), there was also a strong relationship between annual brood counts and predicted annual severity of nest flooding, but this relationship was strong early and weakened later in the brood rearing season. Additionally, unlike the vulnerable species, there was a strong relationship between the reservoir elevation on the day of a survey and the Canada Goose brood count observed on each occasion. We argue that these results indicate that vulnerable species are highly impacted by reservoir operations in terms of productivity, but that the Canada Goose relationships indicate that they simply move away to new brood-rearing habitats as reservoir elevations increase.

With the addition of recent data, an overview of the Bald Eagle and Osprey data (from 2009 through 2013) indicated a larger variability in nesting success of Ospreys compared with what was previously observed. The variability in the data is consistent with the hypothesis that Osprey nesting success is influenced by reservoir operations. Additional data will be required to adequately support this case. Relationships between reservoir operations and productivity bring to question the mechanism, given that they do not suffer from nest flooding. We hypothesize that an influence of reservoir elevations on foraging efficiency is the most likely mechanism to cause an impact to productivity. We recommend that monitoring prey delivery rates would greatly improve the quality of this part of the research.

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.

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

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

The report was written by Harry van Oort, Corey Bird and John Cooper.

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1 INTRODUCTION

The Columbia River is one of the most modified rivers systems in North America (Nilsson et al. 2005), and its flow is controlled by many hydroelectric dams and water storage reservoirs. A relatively large proportion of the water in the Columbia River basin originates from winter snowpack in south-eastern British Columbia and is discharged into the river during the spring freshet. The flow of water out of British Columbia is controlled by dams, with water stored for controlled release throughout the year (BC Hydro 2007). Decisions to store or release water are made in accordance with international agreements between Canada and the United States under the Columbia River Treaty and through Non-treaty Storage Agreements, but they can be modified to a degree via Water Use Planning (BC Hydro 2007).

Water storage reservoirs along the primary course of the Columbia River in British Columbia include the Kinbasket Reservoir (Mica Dam, 1973), Lake Revelstoke (Revelstoke Dam, 1984) and Arrow Lakes Reservoir (Hugh Keenleyside Dam, 1968). These three reservoirs are positioned serially along the river, and there are few intervening sections where natural riparian habitats and wetlands remain[1]. The footprint areas of these reservoirs have removed 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 uncommon (Enns et al. 2007, Hawkes et al. 2007).

The northern reach of the Arrow Lakes Reservoir, known as Revelstoke Reach (Figure 1-1), provides a relatively high concentration of productive wetland habitat. Within the upper portion of Revelstoke Reach, there is a variety of wetlands, including a reservoir-altered bog, an extensive and diverse cattail/bulrush marsh, and several ponds. The rarity of such habitats in the landscape makes Revelstoke Reach an area of great regional importance for wetland wildlife throughout the year (Tremblay 1993, Jarvis and Woods 2001, CBA 2013a).

The operation of Arrow Lakes Reservoir is thought to affect the availability and quality of habitat in Revelstoke Reach for waterbirds and shorebirds. The vegetation communities in the drawdown zone are governed by water storage regimes because plant species differ in their tolerance to varying periods of inundation (Korman 2002). Habitat quality for waterbirds and shorebirds varies greatly as a direct function of the reservoir's water elevations because vegetation cover and foraging substrates may be exposed or submerged, and the modulation of water column depth affects foraging opportunities (Rundle and Fredrickson 1981, Parsons 2002). How reservoir operations affect waterbird use of the drawdown zone had not been studied in detail, and the relationship between reservoir operations and habitat quality is poorly understood.

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

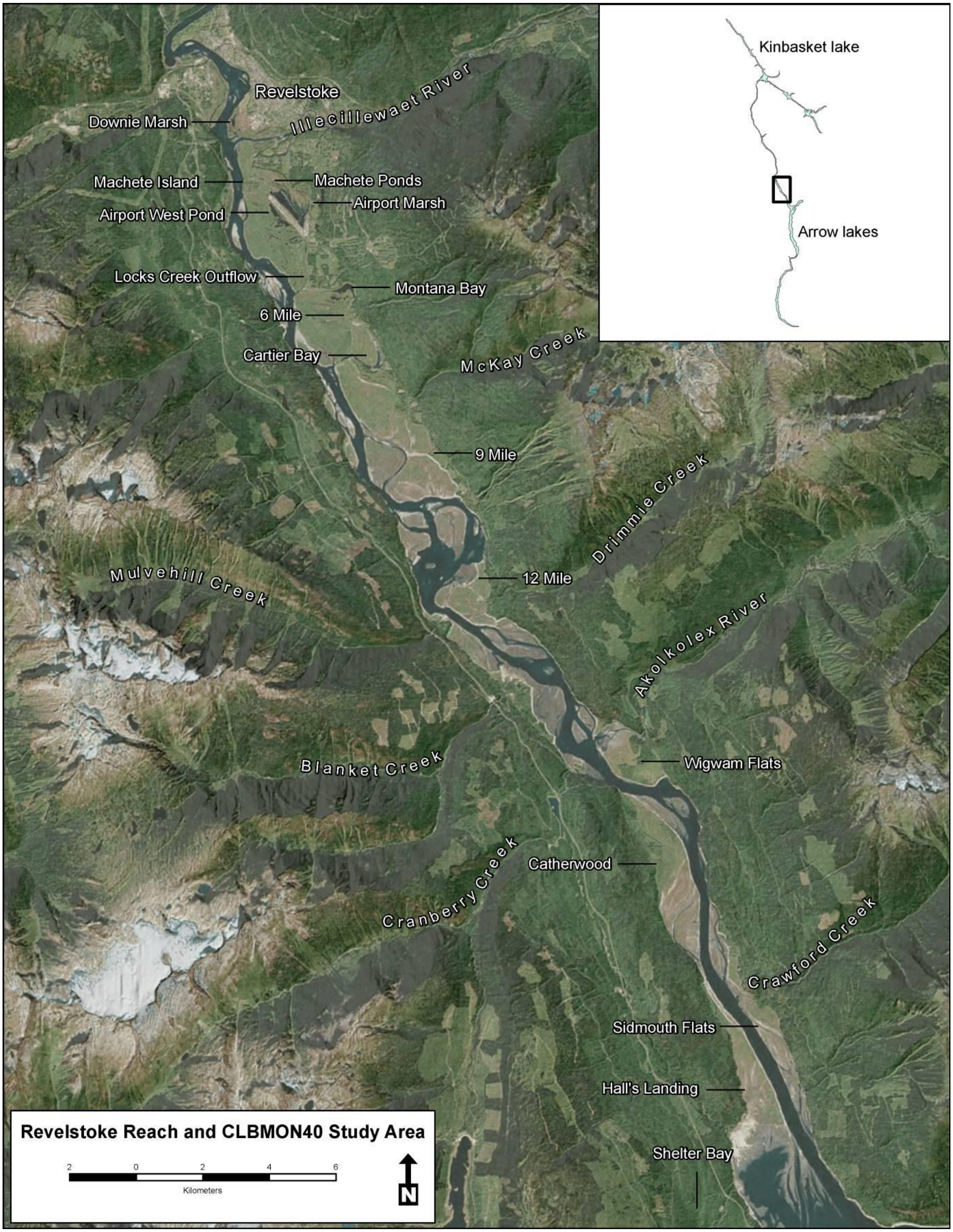

Figure 1-1: Overview map of Revelstoke Reach, with geographic features labelled

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

For the CLBMON 40 monitoring program, the following groups of birds are defined:

- “Waterbird” is a species from any of the following families: Gaviiformes (loons), Podicipediformes (grebes), Phalacrocoracidae (cormorants), Anseriformes (swans, geese, ducks), Rallidae (rails and coots) and Laridae (gulls and terns). In addition, four species of raptors that depend on aquatic, marshy or grassland habitats of the drawdown zone were defined as waterbirds for the purpose of this study: Bald Eagle (*Haliaeetus leucocephalus*), Osprey (*Pandion haliaetus*), Northern Harrier (*Circus cyaneus*) and Short-eared Owl (*Asio flammeus*). Herons were not included as waterbirds because they were to be monitored under a separate Water Licence Requirements study.
- “Waterfowl” is used to identify the subset of waterbirds that forage by swimming in the water (loons, grebes, cormorants, swans, ducks, geese and coots).
- “Shorebirds” are members of the families Charadriidae (plovers), Scolopacidae (sandpipers) and Recurvirostridae (stilts and avocets).

1.1 Scope and Objectives

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

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

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

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

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

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

1.2 Management Questions

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

1. What are the:

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

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

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

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

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

5. Which species of shorebirds and waterbirds are most likely to be affected by reservoir operations?

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

7. To what extent do water levels in Arrow Lakes Reservoir influence the productivity of waterbirds in Revelstoke Reach between years?

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

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

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

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

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

1.3 Management Hypotheses

From these management questions, several management hypotheses were outlined by BC Hydro for testing by the CLBMON 40 research[2]:

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

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

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

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

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

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

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

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

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

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

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

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

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

The monitoring program designed to address these questions/hypotheses—CLBMON 40—was initiated in 2008. Several approaches are being used to answer these management objectives, questions and hypotheses. The research program will span 10 years in order to determine the effect of reservoir operations (water level management) on the abundance, distribution and productivity of waterbirds and shorebirds and to assess and inform physical works. The Management Objectives, Questions and Hypotheses listed above, the progress made in addressing these, and an account of the outstanding issues, are reviewed in Appendix 6-1. Multi-year analyses of the 5 Year datasets were presented in the interim report (CBA 2013a).

This report includes results from the spring, summer and fall of Year 6 (2013). Winter data for Year 6 are not included here. The Year 6 winter waterbird data will be summarized in a separate report.

1.4 Study Area

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

Revelstoke Reach contains the Columbia River as it flows south from the Revelstoke Dam towards the Arrow Lakes Reservoir, and is impounded by the reservoir during the summer, in most years (Figure 1-1, Figure 1-2). When water levels are sufficiently low (winter), Revelstoke Reach consists largely of a floodplain (flats) that is vegetated primarily by reed canarygrass (*Phalaris arundinacea*) and sedges (*Carex* spp.). The subtle topography of the flats was shaped by the erosion and deposition of material from the Columbia River, and contains oxbow lakes, old back channels and sand bars. Historically, this area was naturally forested by western redcedar (*Thuja plicata*), Engelmann spruce (*Picea engelmannii*) and black cottonwood (*Populus balsamifera*). Prior to the completion of the Hugh Keenleyside Dam near Castlegar, Revelstoke Reach was used as farmland, and it contained the Arrowhead branch of the Canadian Pacific Railway. The old roads and rail grades influence the hydrology of the study area in some locations.

The permanent wetlands in Revelstoke Reach are primarily situated at the northern end of this reach. They include several natural and human-made ponds, a large cattail marsh near the Revelstoke Airport (The 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 (Korman 2002); therefore, the south end is flooded for longer periods and is more sparsely vegetated than is 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, and the Arrow Lakes Reservoir is operated primarily by BC Hydro for downstream flood control and power generation in the US. Reservoir levels are controlled by precipitation (snow and rain), discharge from the Mica and Revelstoke Dams, and outflow from Hugh Keenleyside Dam and the Arrow Lakes Generating Station. The reservoir is licensed to operate between elevations of 420 m and 440.1 m. With approval from the Comptroller of Water Rights, the maximum allowable level is 440.75 m. Since 1968, the typical operation of Arrow Lakes Reservoir has involved storing water during the spring freshet and drafting the reservoir in fall and winter; thus, the reservoir elevation cycles annually, with high water levels in summer and low water levels in late winter/early spring (Figure 1-4).

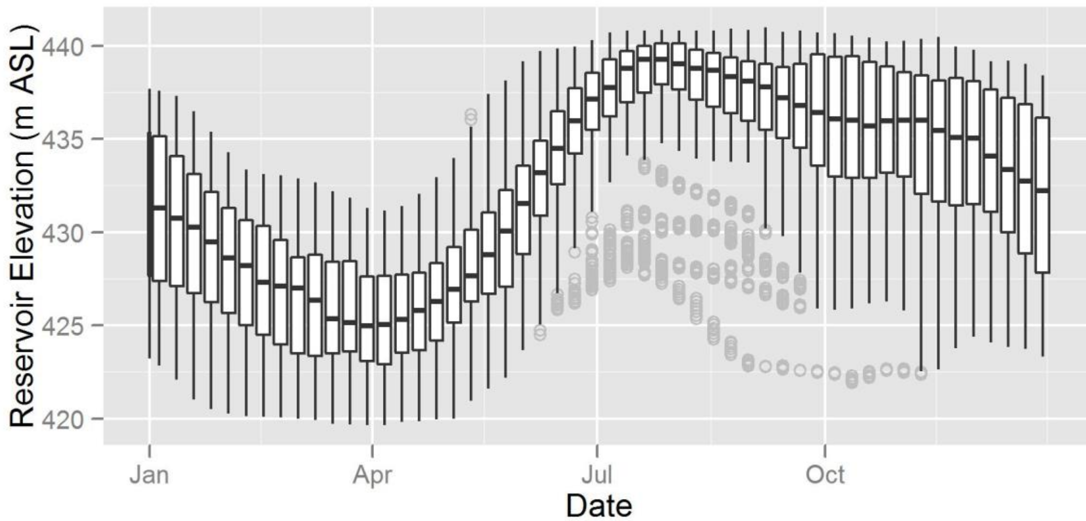

Figure 1-4: **Boxplot graph of historical weekly water elevations for Arrow Lakes Reservoir (1968 through October 2012)**

2 METHODS

The methods used for the various surveys and analyses are described briefly below. For more detailed information, refer to the monitoring protocol report (CBA 2014a).

In 2013, CLBMON 40 included six types of surveys:

1. land-based waterbird surveys in spring, fall and winter
2. aerial waterfowl surveys in spring and fall
3. shorebird surveys during the fall migration
4. productivity monitoring of waterfowl
5. productivity monitoring of Bald Eagles and Ospreys
6. productivity monitoring of Short-eared Owls and Northern Harriers

2.1 Land-based Waterbird Surveys

Land-based surveys were used to monitor seasonal and spatial patterns of usage by waterbirds within the most important wetlands.[3] Weekly land-based waterbird surveys were conducted for eight weeks in the spring (April and May) and eight weeks in the fall (September and October). Observations were made from fixed observation stations (CBA 2014a) and were used to quantify waterbird usage of nine wetlands (Figure 2-1).

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[3] "Important wetlands" are those used by a large number of waterbirds on a regular basis, and those that will be modified by physical works. Aerial surveys (see below) were used to provide unbiased habitat selection data across the entire study area.

During these surveys, we recorded all waterbirds at all accessible wetlands that are particularly suitable for waterfowl. We report raw numbers of all waterbirds recorded annually, but in some cases, we focus on waterfowl in order to remove variation caused by species that are less dependent on these wetlands (e.g., raptors and gulls).

Monitoring has been conducted at seven of the monitored sites since 2008: Downie Marsh, Airport Marsh, Cartier Bay, Locks Creek Outflow, Montana Bay, 9 Mile and 12 Mile (Figure 2-1). We have also monitored several supplementary observation stations, which have been added to the program since 2008. Station 12 at Square Pond was included in 2009 in order to monitor one of the Machete Ponds, which are associated with Wildlife Physical Works 6A (WPW6A). This station can be monitored only when water levels are low. In the fall of 2013 the Machete Ponds were not monitored on 2 occasions because the access road was closed due to construction involved with the WPW6A project. Station 29, which allowed for improved monitoring of WPW14 and 15A, was added in 2009. In 2010 we added Station 30A to monitor an isolated pond near 6 Mile (Pond G) which was regularly used by waterfowl.

During each survey, the group size, species and location of all waterbirds visible from each station were recorded. The locations of groups of birds were mapped on field maps as points or polygons. The activity of the waterbirds (e.g., foraging, resting, preening) and the type of habitat they were using was also noted (CBA 2014a). A minimum of 5 minutes was used to scan for waterfowl, but the amount of time spent at a station varied considerably due to the high variability in the time required to identify and count waterbirds and map their locations(CBA 2014a). Upon completion of the field survey, the maps were digitized and the data were entered into the database.

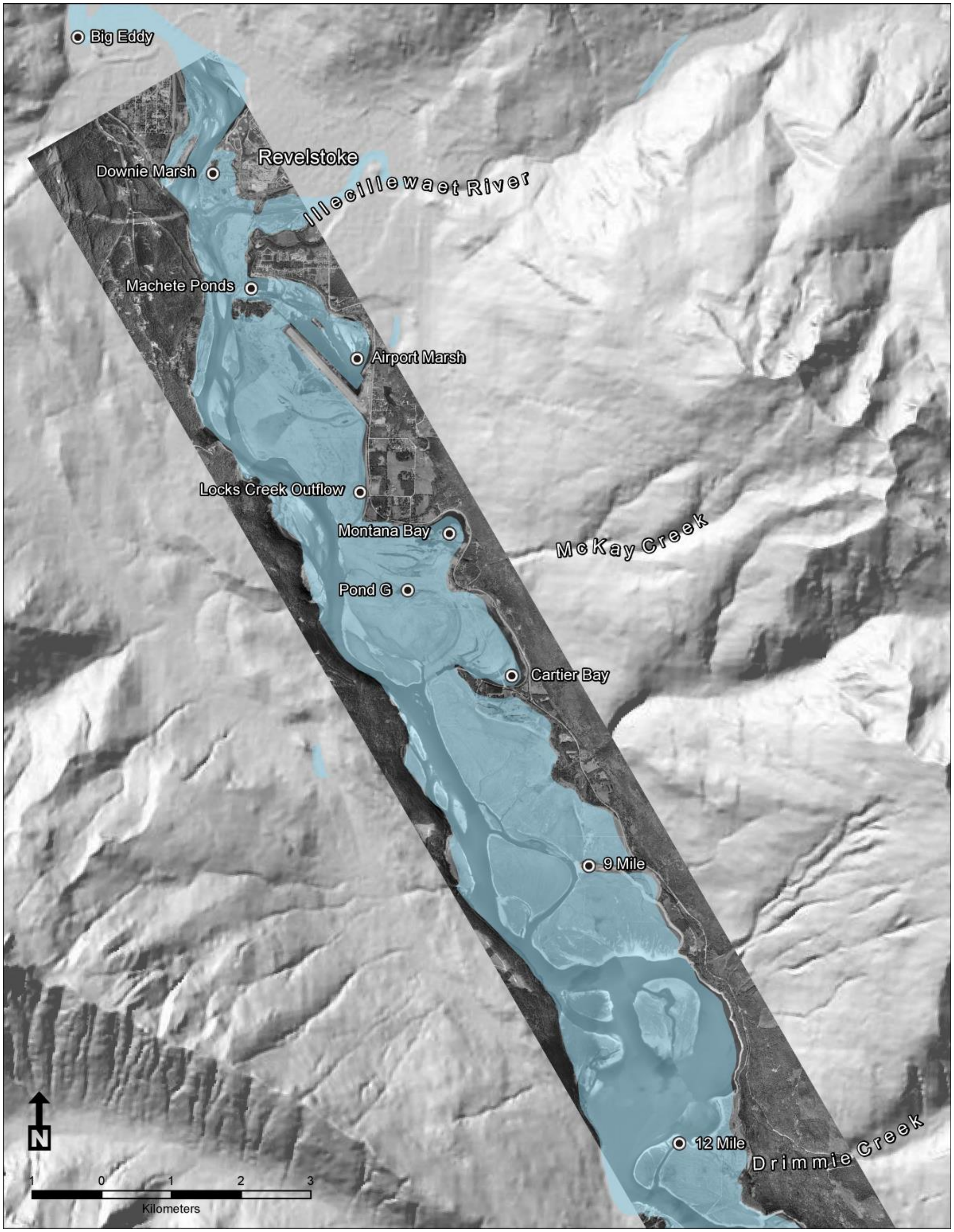

Figure 2-1: Locations of wetlands in Revelstoke Reach where land-based waterbird surveys and brood surveys were conducted are represented by points. Some of these wetlands were monitored by multiple observation stations

2.2 Aerial Waterfowl Surveys

Helicopter-based aerial waterfowl surveys began in 2009. Aerial surveys occurred opportunistically to capture data at peak migrations, and when reservoir water elevations were at a level that is not well represented in the database. All aerial surveys covered the entire study area. All observations of waterfowl were assigned to one of 129 habitat polygons (Table 2-1), which are mapped in the CLBMON 40 protocol report (CBA 2014a)

Aerial waterfowl surveys followed the methods outlined by the Resource Inventory Standards Committee (Resource Inventory Committee 1999). Two personnel were required for these surveys: one observer and one recorder. A Bell 206B helicopter was used for all aerial waterfowl surveys in 2013. The observer was seated next to the pilot, and used a global positioning system (GPS; model Garmin Map76CSx) and laptop computer for real-time tracking and navigation using DNR-Garmin software. The observer made a complete count of waterfowl within the polygons. Waterfowl were identified to species when possible but were not sexed.

Table 2-1: Number of Revelstoke Reach aerial survey polygons in each habitat category

Elevation (m ASL)	Grass	Dense Shrub/Forest	Unvegetated	River Channel	Wetland	Total
431	3		6	31		40
432	3		6	5		14
433	5	2	4	1	1	13
434	11		1	2		14
435	8		1	1	3	13
436	8	2	1	1	1	13
437	7	1				8
438	3				4	7
439	1	4				5
441	1					1
443	1					1
Total	51	9	19	41	9	129

2.3 Shorebird Surveys

Shorebird surveys were conducted during the fall migration period (July 15 to October 5). In 2013 we monitored 37 sites for shorebird activity (Figure 2-2); 13 sites were accessed either by land or kayak depending on reservoir elevations, and other sites were always accessed by boat. Four of the land-accessed sites were control sites located above the drawdown zone; the remaining sites were located within the reservoir drawdown zone. As of 2013, boat-based surveys were conducted on a weekly schedule (as opposed to the biweekly surveys done between 2009 and 2012) to better capture the most active part of the migration season.

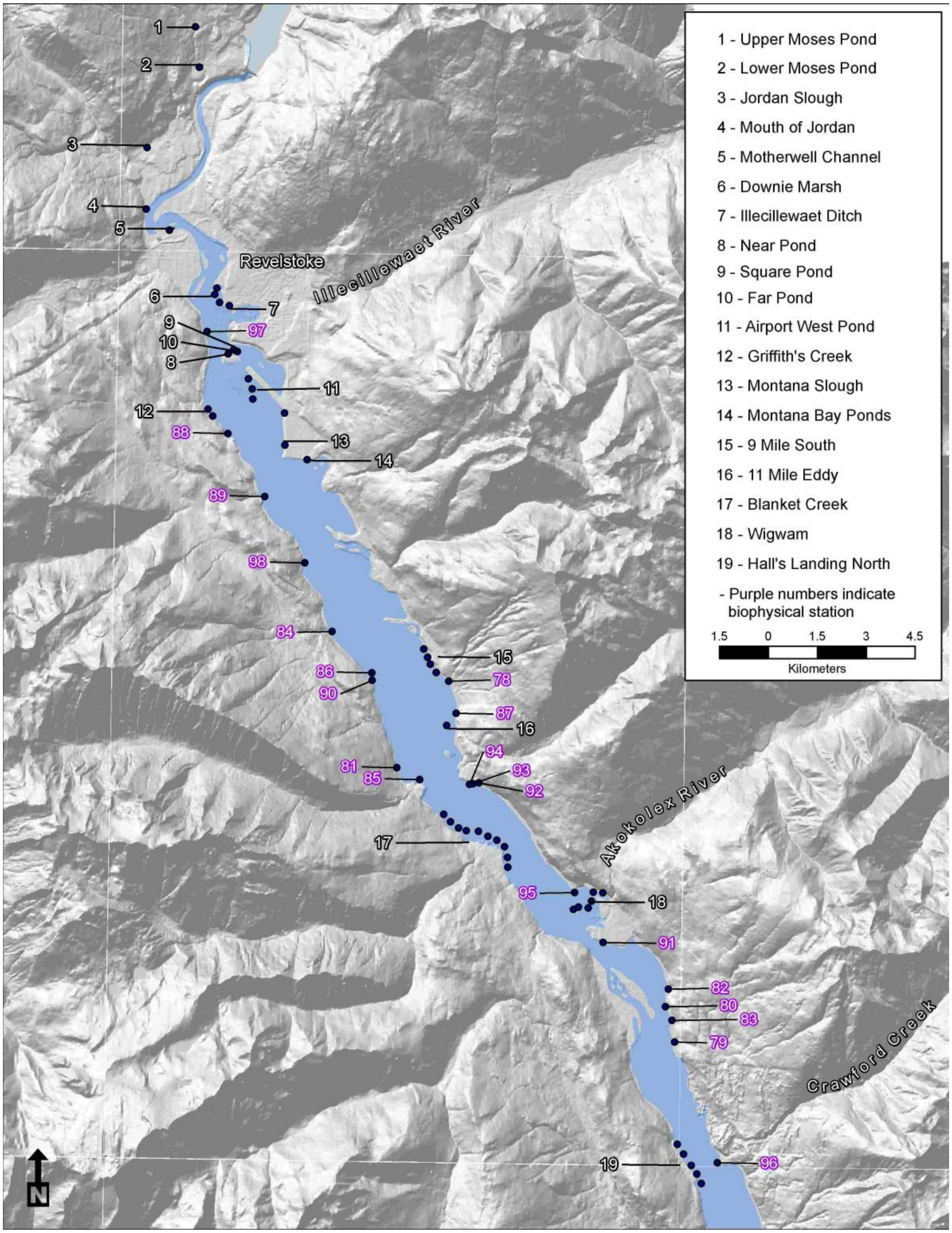

Figure 2-2: **Locations of shorebird surveys in Revelstoke Reach. Black points show approximate locations of observation stations. Purple indicates survey stations added in 2011 to increase the diversity of habitat types sampled**

Two land-accessed sites within the reservoir were influenced more by river flow and discharge from Revelstoke Dam than by reservoir elevations—these were positioned north of the Trans-Canada Highway along the edge of the Columbia River. Originally 19 sites were chosen for their potential to be used by shorebirds (black labels in Figure 2-2). The remaining 18 sites (21 stations) were added in 2011 to sample a larger range of habitat types during our boat-based surveys. These sites were chosen to systematically sample from the habitat types available, as mapped by the CLBMON 11B-1 biophysical mapping (Hawkes et al. 2011, CBA 2014a)

All surveys involved two biologists. Boat-based surveys also included a boat operator. Observations were made from semi-fixed survey stations. The larger wetlands 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 disappearing altogether. When boats or kayaks were used, a spotting scope was not effective, so we included a slow transect between survey stations to ensure we were not missing shorebirds.

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; however, some closely related species could not always be reliably separated in the field. These included the following:

- Both Long-billed and Short-billed Dowitchers occur in the study area. In non-breeding plumage they cannot be reliably identified to species in the field; therefore, dowitchers were often recorded as “dowitcher sp.”.
- Both Greater and Lesser Yellowlegs occur in the study area, but they could not always be reliably separated; therefore, they were sometimes identified as “yellowlegs sp.”.
- Distinguishing Western, Least and Semipalmated Sandpipers can be challenging; therefore, these species were sometimes classified to genus (*Calidris* sp.). See the protocol report for more detail on the methods (CBA 2014a)

Habitat conditions were qualitatively described at each site on every survey occasion by estimating the percentage of the site’s shorelines comprised of each habitat category (e.g., sand, vegetation, mud, cobbles) as seen from the observation stations (CBA 2013a).

2.4 Productivity Monitoring of Waterfowl

Waterfowl brood surveys were conducted during a six-week period from June 15 to July 30. This brood monitoring period misses very early brood emergence (primarily Canada Geese; also Mallard), but these early broods are still very young when the survey season begins, and can be counted at that time. The brood monitoring season extended relatively late in order to monitor late brood emergences from re-nesting birds. Surveys were conducted twice per week for a total of 13 surveys. The methods and locations used for the waterfowl brood surveys were identical to those for the land-based waterbird surveys (Section 2.1), but the size, age and number 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 these counts (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 deductions of brood counts unreliable.

2.5 Productivity Monitoring of Bald Eagles and Ospreys

Monitoring the productivity of Bald Eagles and Ospreys involved locating their nests, and monitoring the nests to determine nesting activity and the outcome of each nesting attempt (nest success and the number of young fledged). Nests were considered successful if at least one young fledged. Productivity was determined by numbers of young fledged per occupied nest.

Many Osprey and Bald Eagle nests along Revelstoke Reach were first identified and mapped in earlier years (2008 until the present year), but searches for new nests were conducted annually. Both Ospreys and Bald Eagles re-use old nests in consecutive years, but they may also alternate between nests from year to year. One aerial survey was conducted on May 30, 2013 using a Bell 206B helicopter, and involved checks of previously located nests and approximately 1.5 hours of nest searching.

Prior to surveying, the coordinates of known nest sites were compiled and uploaded into a hand-held GPS (model Garmin Map76CSx). Two observers, positioned on either side of the helicopter, 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 were terminated (failed or fledged). Where possible, nests were observed from land; others were monitored while conducting boat-based shorebird surveys.

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. All observations were recorded on a standardized nest observation form (CBA 2014a).

2.6 Productivity Monitoring of Short-eared Owls and Northern Harriers

Short-eared Owls and Northern Harriers 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 study area (i.e. all grasslands north of Drimmie Creek) from five monitoring sites (Figure 2-3). Each site was surveyed at least twice during the breeding season, where we spent a minimum of 30 minutes scanning for Short-eared Owls and Northern Harriers during each visit.

If owls or harriers were observed in an area, we continued monitoring for a minimum of one hour for signs of nesting activity, and made additional area visits to assess breeding activity in these areas. Additional monitoring effort was concentrated in the area south of Machete Island where Short-eared Owls and Northern Harriers have been repeatedly observed each year and are known to nest. 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.

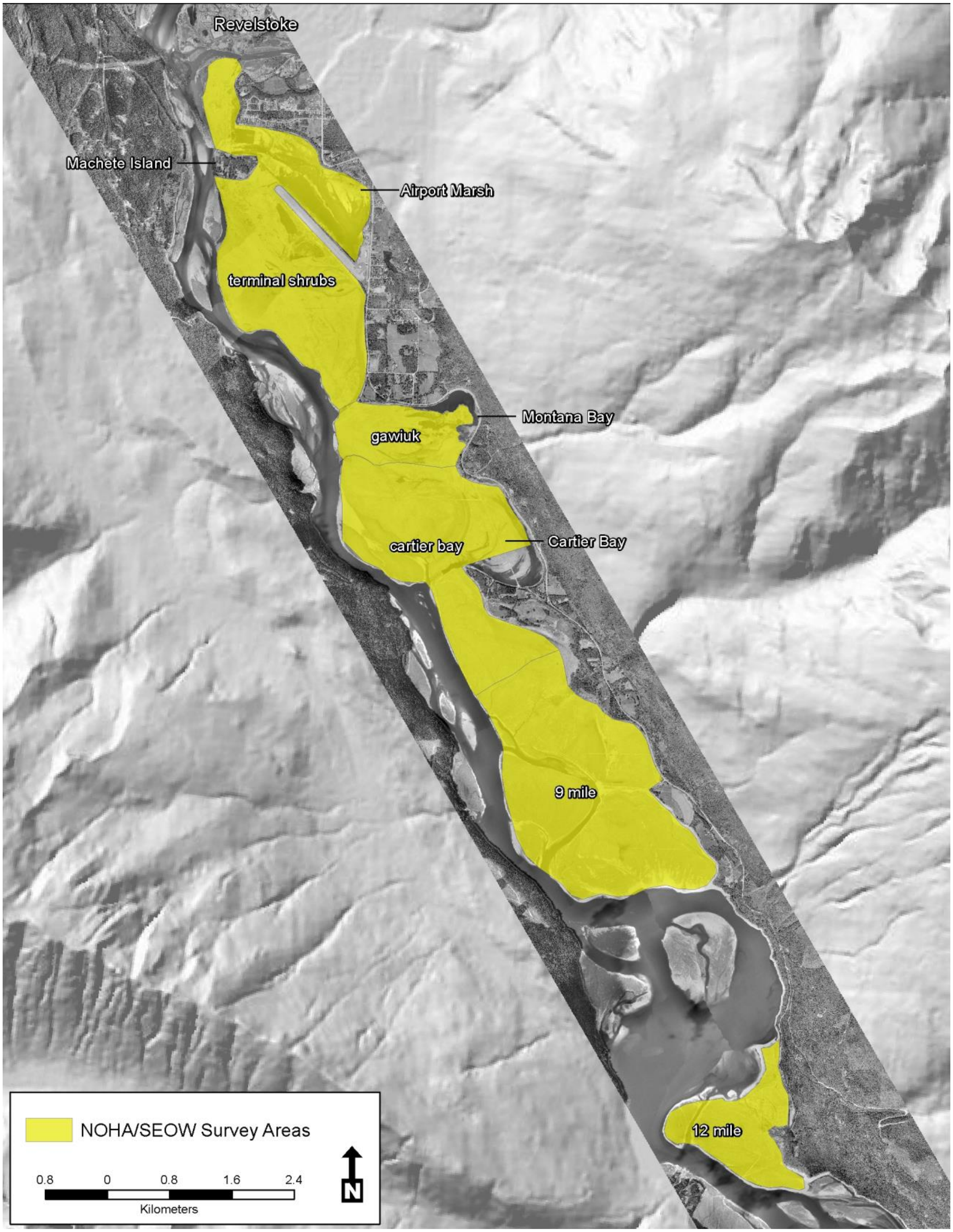

Figure 2-3: **Five areas monitored for Short-eared Owls and Northern Harriers. Non-nesting activity has been observed in all of these areas, but all known nesting and most activity occurred in the Terminal Shrubs area**

Both species 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, nest searches would be initiated and the survey effort would be confined to a relatively small geographic area by employing a systematic grid search. If located, nest monitoring was conducted on a weekly schedule, taking care to minimize disturbance to these birds.

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

2.7 Monitoring Wildlife Physical Works and Revegetation

As part of the sample site selection, we included sites where Wildlife Physical Works (WPW) have been proposed. In 2013, we monitored three proposed WPW projects. Effectiveness monitoring of WPW6A (Golder Associates 2009a, 2009b) focused entirely on the habitat being protected by WPW6A (Machete Ponds and Airport Marsh), not on the actual work site. We monitored this WPW project by aerial and land-based waterbird surveys, brood surveys and shorebird surveys.

WPW14 and 15A (Golder Associates 2009a, 2009b) are related projects planned at Cartier Bay. For these projects, we used the same sampling approach as those for WPW6A, except that no shorebird surveys were conducted because the site is typically flooded by the reservoir during the survey period, which leaves very little habitat.

Several Revegetation Physical Works (RPW) treatments were completed within the study area during fall 2009 and 2013 and spring 2010 and 2011. These terrestrial treatments have very little relevance to waterbirds, with the exception of their nesting habitat. Nest searching plots within treated areas were monitored by CLBMON 36 and will provide data on the effectiveness of RPW treatments for waterbirds. These sites were also monitored during the aerial surveys.

2.8 Analytical Methods

This report provides a summary of progress made in field data collection in 2013. The majority of the results closely follow the outline used in previous annual reports, where only one year of data are considered. Aerial survey results were summarized by calculating the average number of waterfowl within habitat polygons. Average reproductive success for Bald Eagles and Ospreys was calculated as the total number of young produced, divided by the total number of nesting attempts.

In addition to summarizing annual datasets, we also examined the multi-year datasets in two cases. First, we presented multiple years of Bald Eagle and Osprey nesting success data, which had not been presented previously. As part of this analyses we used the nest flooding impact model (see below) as an index of how aggressively the reservoir filled each year, where 0 represents seasonally low elevations/slow filling, and 1 represents seasonally high water levels during the spring draw.

Second, we assessed how waterfowl brood counts were modulated by reservoir operations each year. In this latter analysis, we update analyses presented in the interim report (CBA 2013a), where the CLBMON-36 nest flooding model (CBA 2013c) was used to index the severity of nest flooding impacts (ranging from 0, indicating a historically low impact, to 1 indicating the maximum historical impact), which was modelled as a predictor of brood counts for species that are safe from nest flooding, versus those that are vulnerable to nest flooding (CBA 2013c). See CBA 2013c for additional information on the nest flooding model.

Statistical computing was performed using R software (R Development Core Team 2006). Data are primarily summarized in tables generated using standard data manipulation functions in R. All graphing was done using the ggplot2 package (Wickham 2009). Boxplots were used to display historical daily reservoir elevations within one week bins. Over-plotting (where data points overlap) was dealt with primarily by plotting the data as transparent points (i.e., by altering the “alpha level”). A transparency level of 1/4 indicates that a minimum of four points over-plotted is required to make the point appear 100% opaque. We indicate the transparency levels in the figure captions. If transparency was insufficient to deal with extreme over-plotting, we used the "geom_jitter" function (Wickham 2009), where the exact coordinates of data points on the graph are randomly moved slightly in both axes; the default jitter-settings were used in this report.

We made use of General Linear Models to indicate basic direction of trends observed in some multi-year analyses. These analyses were exploratory as the data sets are still small (6 years). To accomplish these, we used the "lm()" function in R.

3 RESULTS

3.1 Water Levels in Arrow Lakes Reservoir

Reservoir water levels were relatively high relative during the spring filling period and peaked at 439.97 m on July 4 (Figure 3-1). Reservoir water elevations declined relatively quickly through July and were low relative to historical operations through August and September. The reservoir water elevation remained low but changed little through October.

3.2 Other Annual Conditions

Following a winter with a unusually stable (mild) temperatures, and steady rates of precipitation resulting in a normal valley bottom and high elevation snowpack, the 2013 spring field season was somewhat cool and damp but not atypical. This pattern of cool weather and intermittent precipitation continued through the early part of spring until early summer when dry, warm temperatures began; a moderately hot and dry (but normal) period lasted throughout July and August. Some precipitation returned in September but October was unseasonably warm and dry with almost no precipitation.

3.3 Land-based Waterbird Surveys

During the spring and fall land-based waterbird surveys, 11,423 waterfowl from 27 species were observed (Figure 3-2; Appendix 6-2). Canada Goose (*Branta canadensis*) was the most abundant species, followed by American Wigeon (*Anas americana*), Mallard (*Anas platyrhynchos*), Green-winged Teal (*Anas crecca*), Ring-necked Duck (*Aythya collaris*) and American Coot (*Fulica americana*; Figure 3-2).

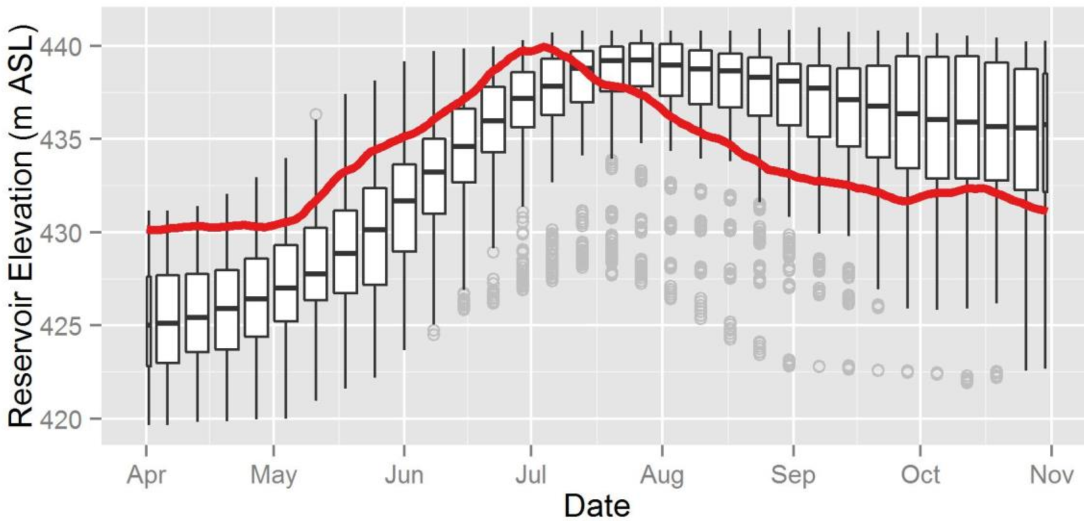

Figure 3-1: **Elevation of the Arrow Lakes Reservoir from April 1 to October 31, 2013 is plotted in red; the historical range of values is plotted in weekly intervals as boxplots**

3.3.1 Spring Migration

During the spring land-based waterbird surveys, 5,629 waterbirds (25 species) were counted (Appendix 6-2), including 1,947 Canada Goose (35%), 1,052 American Wigeon (19%), 900 Mallard (16%), 306 Ring-necked Duck (5%) and 254 American Coot (5%). The spring migration peaked in the third week of March following ice breakup (Figure 3-3), with the initial peak migration counts being dominated by large numbers of Canada Goose.

Waterfowl were not evenly distributed among wetlands (Table 3-1). During spring migration, most waterfowl were recorded at Cartier Bay (39%), followed by Airport Marsh (17%), and Downie Marsh (12%). Among the stations with limited access across the year, we observed 608 waterfowl at station 12, and 659 waterfowl at station 29.

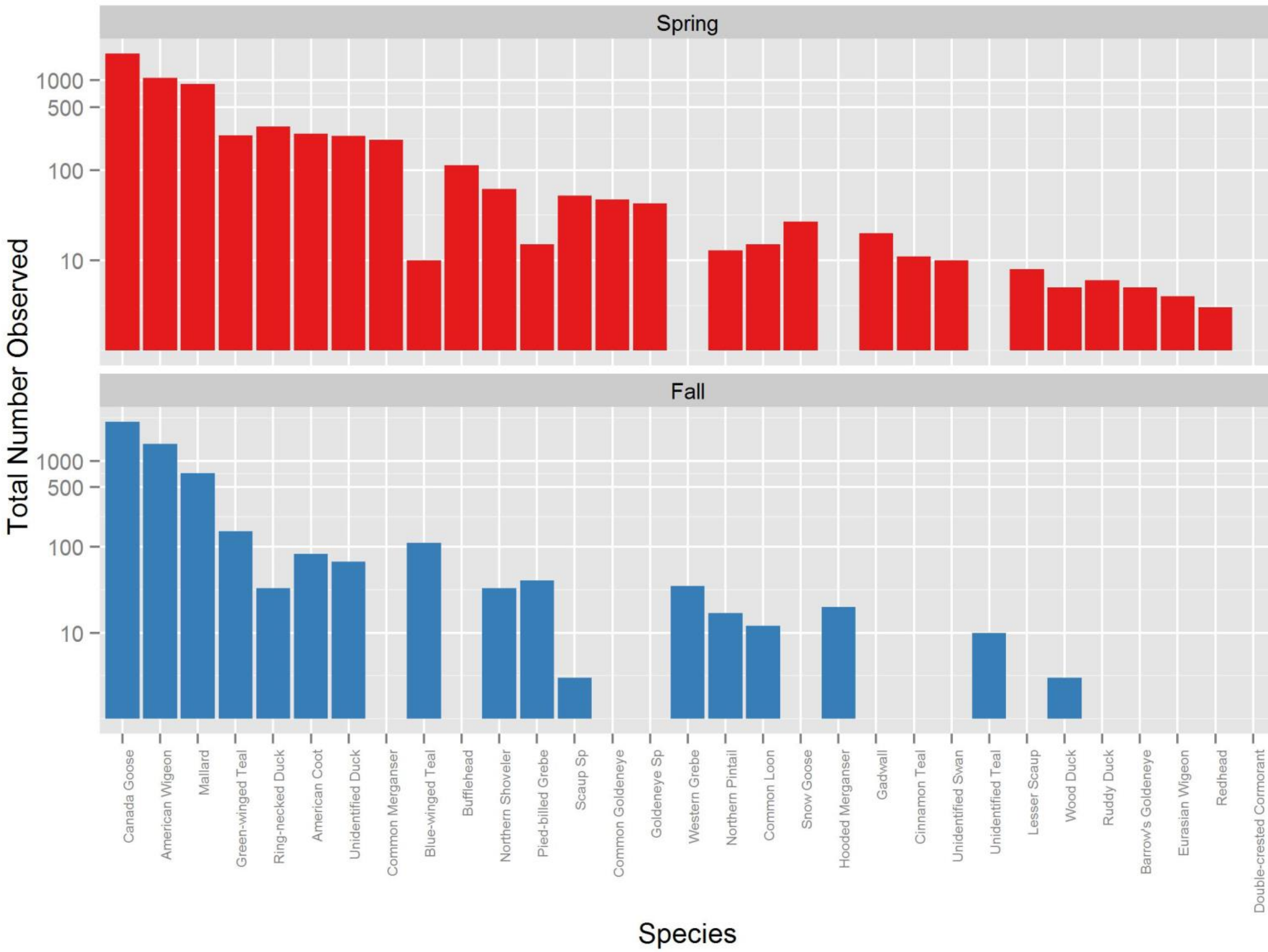

Figure 3-2: **Total number of detections of waterfowl species in the 2013 land-based waterbird surveys (y-axis has a logarithmic scale). If only one individual of a species was detected, it is listed but not plotted (due to scaling in the y-axis)**

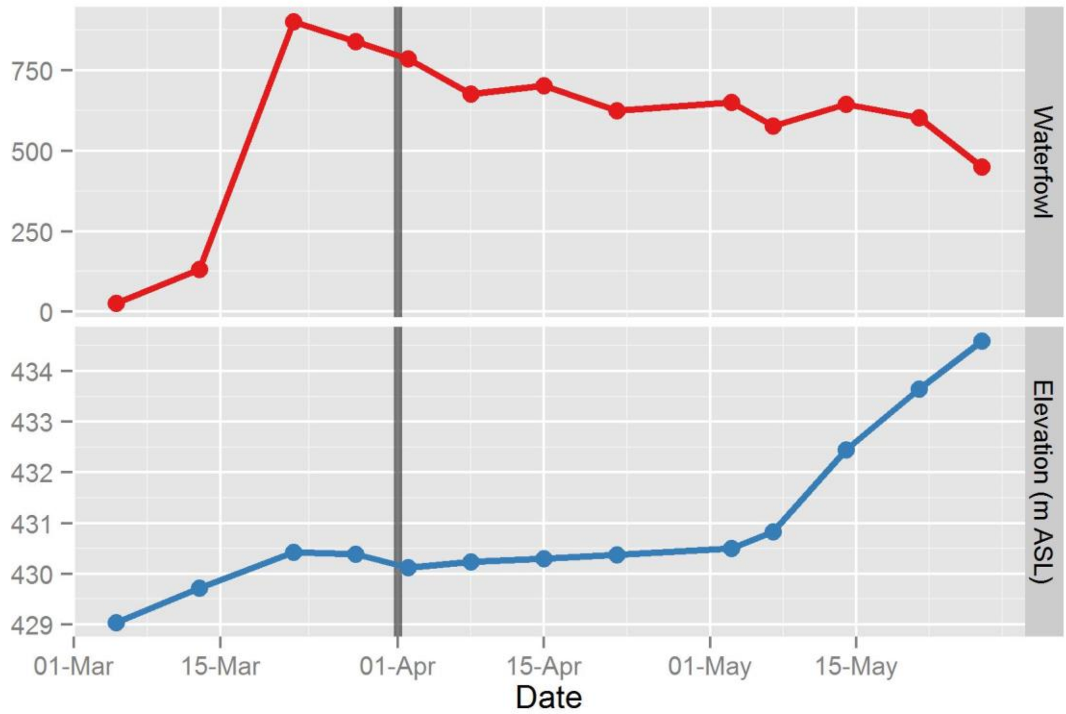

Figure 3-3: **Land-based waterbird survey results for 2013. The total number of waterfowl is plotted for each observation occasion, starting in late winter and extending through the spring observation period. The elevation of the Arrow Lakes Reservoir is plotted for reference. The vertical line marks the beginning of the spring sampling period**

Table 3-1: **Total number of waterfowl recorded at the wetlands from stations with year-round access in 2013**

Wetland Area	Fall	Spring
11 Mile Eddy	17	66
9 Mile	606	164
Airport Marsh	614	744
Big Eddy	0	10
Cartier Bay	1951	1672
Downie Marsh	333	535
Locks Creek Outflow	534	361
Montana Bay	238	397
Pond G	197	366
Total	4490	4315

3.3.2 Fall Migration

During the fall land-based waterbird surveys, 5,794 waterbirds (19 species) were counted (Appendix 6-2), including 2,864 Canada Geese (49%), 1,585 American Wigeon (27%), 719 Mallards (12%), and 153 Green-winged Teal (*Anas crecca*; 3%). The peak migration occurred during the first week of October (Figure 3-4).

During fall migration, most waterfowl were recorded at Cartier Bay (43%), followed by Airport Marsh (14%) and 9-Mile (13%; Table 3-1). At the stations with limited access across the year, 836 waterfowl were recorded at observation station 29, 330 waterfowl were recorded at station 11a, and 201 waterfowl were recorded at station 12 (Machete Ponds).

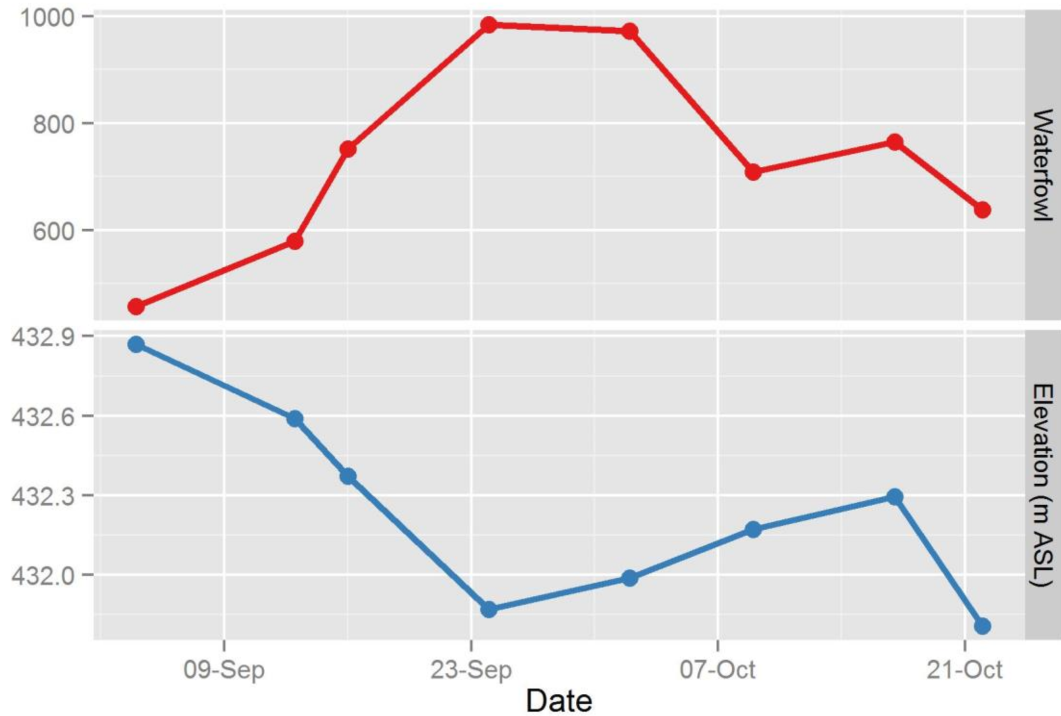

Figure 3-4: Total number of waterfowl observed in fall from eight land-based survey occasions. The elevation of the Arrow Lakes Reservoir is plotted for reference

3.4 Aerial Waterfowl Surveys

3.4.1 Spring Migration

Three aerial waterfowl surveys were conducted in the spring with the largest number of waterfowl recorded during the last survey (i.e., 1,708 waterfowl on April 3, 2013). A total of 3,796 waterfowl were counted during these surveys, and 13 species were identified (Appendix 6-3). Canada Goose was the most numerous species (28.6% of all detections, ≤ 388 per survey), followed by American Wigeon (9.6%, ≤ 310), and Common Merganser (6.4%, ≤ 92; Appendix 6-3).

3.4.2 Fall Migration

Six aerial waterfowl surveys were conducted in the fall, and in agreement with the land-based results (Figure 3-4), the data suggest that the migration intensified in the middle of the fall migration monitoring period (Figure 3-5). A total of 10,156 waterfowl were counted during these surveys, and 11 species were identified (Appendix 6-3). Canada Goose was the most common species recorded (56.8% of all detections, ≤ 1,280 per survey), followed by American Wigeon (10.9%, ≤ 544), and Mallard (6.7%, ≤ 160; Appendix 6-3). A large proportion of waterfowl (19.7%) could not be identified to species from the air.

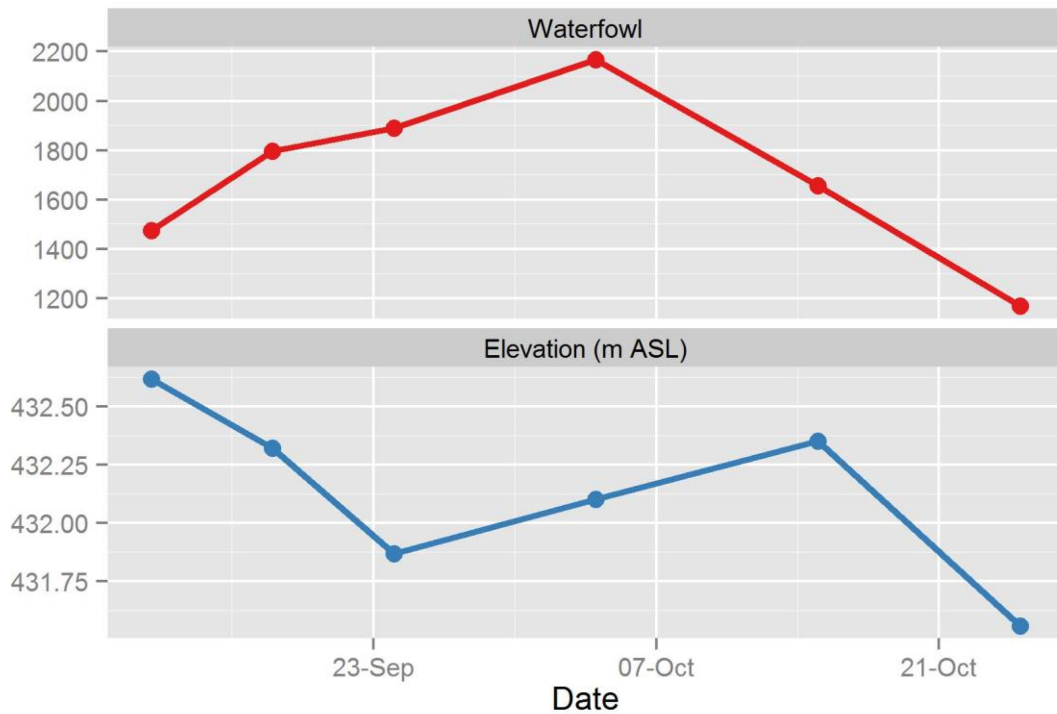

Figure 3-5: Total number of waterfowl recorded during the fall aerial waterfowl surveys. Reservoir elevations are plotted for reference

3.5 Shorebird Surveys

During shorebird surveys in 2013, 186 individuals and 7 species were observed (Table 3-2, Appendix 6-4). Spotted Sandpiper (*Actitis macularius*) was the most abundant species (74%), followed by Semipalmated Sandpiper (*Calidris pusilla; 6%*), Killdeer (*Charadrius vociferous; 5%*) and Lesser Yellowlegs (*Tringa flavipes; 5%*). Most shorebird species were recorded prior to September (Appendix 6-4, Figure 3-6). More shorebird species (species richness = 7) were recorded during the land-based shorebird surveys than during the boat-based surveys (species richness = 3; Appendix 6-4), but the number of shorebirds observed on boat-based surveys was consistently greater than that seen on the land-based surveys (Figure 3-6).

Shorebirds were observed in a wide variety of shoreline habitat types, but most species appeared to avoid cobble or bedrock habitats (Table 3-3). Solitary Sandpipers (*Tringa solitaria*), Lesser Yellowlegs (*Tringa flavipes*), and Least Sandpipers (*Calidris minutilla*) were commonly observed using unvegetated substrates, whereas Greater Yellowlegs *(Tringa melanoleuca)* and to a lesser extent Spotted Sandpipers (*Actitis macularius*) were commonly observed in vegetated substrates.

Table 3-2: Shorebird species detected during land- and boat-based surveys in 2013

Common Name	Species Name	Total Number of Detections
Killdeer	*Charadrius vociferus*	9
Spotted Sandpiper	*Actitis macularius*	138
Solitary Sandpiper	*Tringa solitaria*	7
Greater Yellowlegs	*Tringa melanoleuca*	7
Lesser Yellowlegs	*Tringa flavipes*	9
Semipalmated Sandpiper	*Calidris pusilla*	12
Least Sandpiper	*Calidris minutilla*	4
Total		186

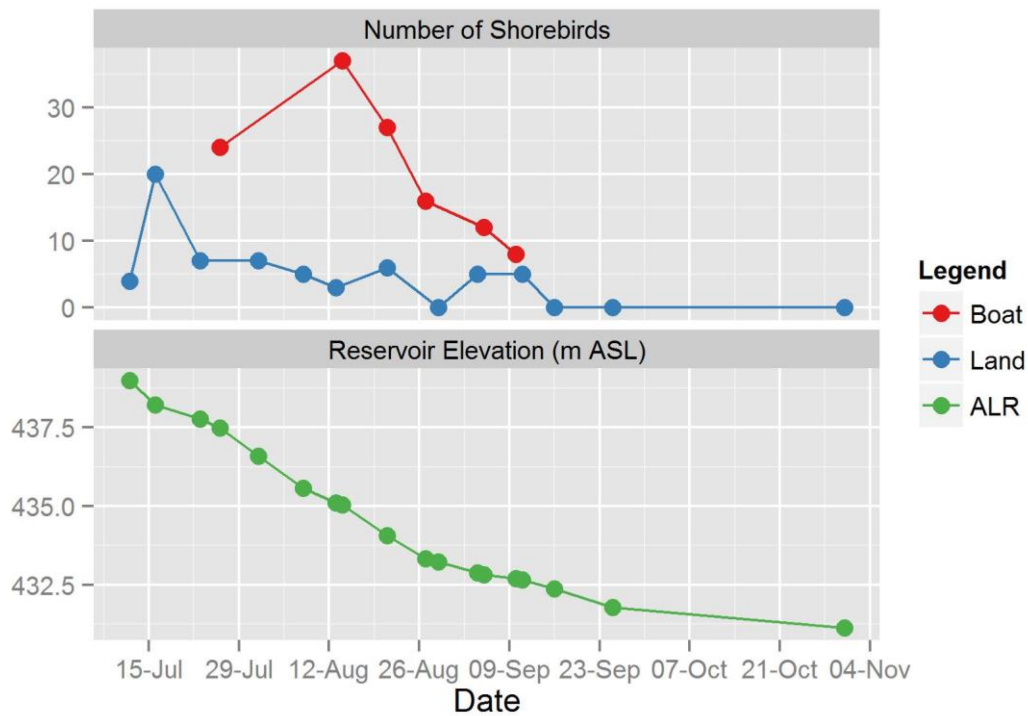

Figure 3-6: Numbers of shorebirds detected during boat-based shorebird surveys and land-based shorebird surveys in 2013. Reservoir elevations (ALR) are plotted for reference

Table 3-3: Percentage of shorebird species detections in each habitat category. Each bird observation could be assigned to more than one category

Common Name	Mud	Sand	Gravel	Cobble	Bedrock	Grass	Flooded Veg
Killdeer	11.1	0.0	22.2	0.0	0.0	0.0	0.0
Spotted Sandpiper	17.4	22.5	20.3	8.0	0.7	8.0	0.7
Solitary Sandpiper	14.3	0.0	0.0	0.0	0.0	0.0	0.0
Greater Yellowlegs	14.3	0.0	0.0	0.0	0.0	42.9	0.0
Lesser Yellowlegs	33.3	0.0	0.0	0.0	0.0	0.0	11.1
Semipalmated Sandpiper	0.0	8.3	0.0	0.0	0.0	0.0	0.0
Least Sandpiper	25.0	0.0	0.0	0.0	0.0	0.0	0.0

3.5.1 Site Usage

Shorebird abundance varied among sites (Appendix 6-5). In 2013, most shorebird detections were recorded at the Airport West Pond, where 37 individuals were observed. At the boat-accessed site Wigwam Flats, 31 individuals were detected; three other sites had between 10 and 26 detections. These numbers are not directly comparable, however, due to differences in survey effort in land- and boat-based sampling. Adjusting for effort by considering only data collected in weeks when both surveys were conducted showed that Wigwam Flats, Blanket Creek, and 9 Mile South were used the most by shorebirds (31, 26, and 17 detections for each site respectively).

3.6 Waterfowl Productivity Monitoring

Reservoir elevations increased during the brood survey period but began to quickly decrease in early July; few waterfowl were observed during periods of high water in late June and early July (Figure 3-7). The number of young observed remained low throughout July (Figure 3-7). In total, 30 brood observations were made (Table 3-4). Canada Goose was the most commonly detected species with broods (73% of all broods), followed by Mallard (13%), Common Merganser (*Mergus merganser*; 10%), and American Wigeon (3%; Table 3-4). The age class data showed that observed young were older as the season progressed (Table 3-5).

Most of the 30 broods detected were found in Airport Marsh (*n* = 11, 37%) Montana Bay (*n* = 5, 17%), Cartier Bay (*n* = 5, 17%), and 9-Mile (*n = 4, 13%*). Another two broods (7%) were detected at Locks Creek Outflow, and one brood (each 3%) detected at 11-Mile, Downie Marsh, and Machete Ponds. Excluding the Canada Goose broods, 8 broods were detected (Table 3-4); two of these broods were detected at Airport Marsh (7%) and 2 were detected at 9-Mile (7%).

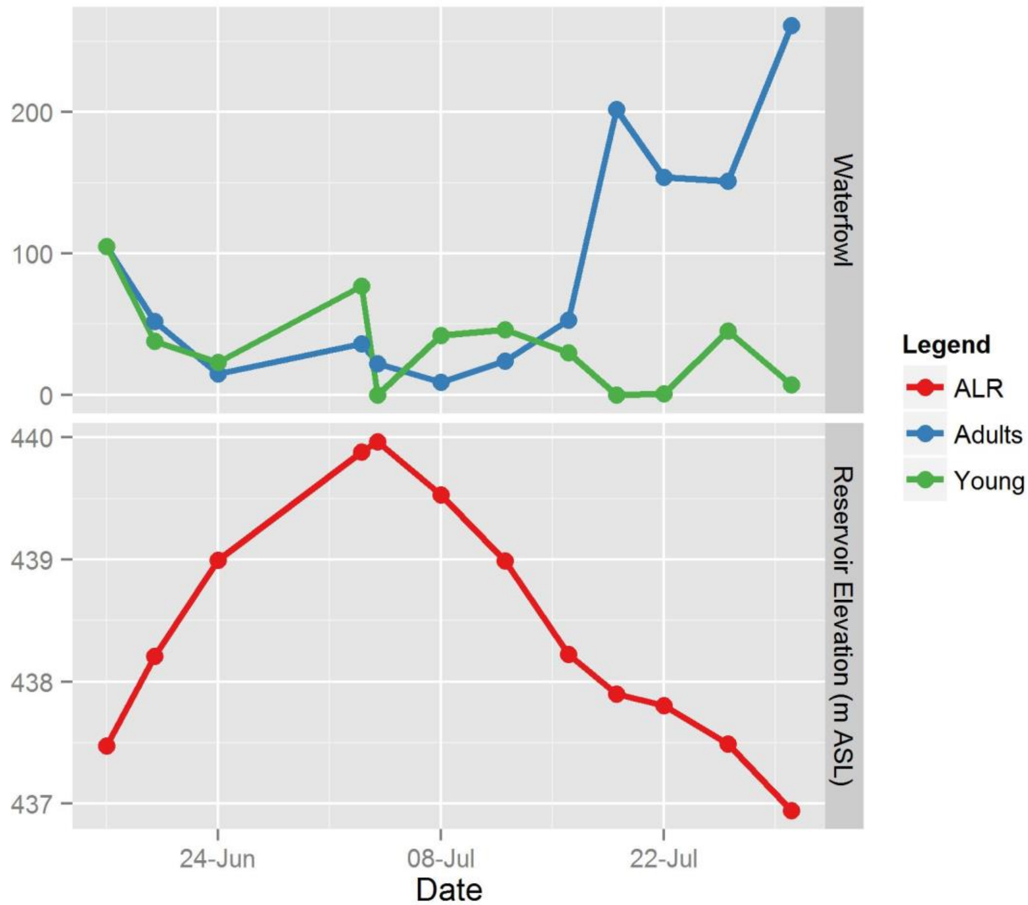

Figure 3-7: Number of waterfowl adults and young observed during surveys in 2013. Reservoir elevation (ALR) is plotted for reference

Table 3-4: Number of waterfowl broods, young and adults recorded during brood surveys in Revelstoke Reach in 2013. Note that the number of young includes juveniles, which were not counted as 'broods'

Common Name	Scientific Name	No. Adult	No. Young	No. Broods
Common Loon	*Gavia immer*	23	0	0
Pied-billed Grebe	*Podilymbus podiceps*	18	0	0
Canada Goose	*Branta canadensis*	836	379	22
Wood Duck	*Aix sponsa*	5	0	0
American Wigeon	*Anas americana*	31	1	1
Mallard	*Anas platyrhynchos*	68	19	4
Cinnamon Teal	*Anas cyanoptera*	1	0	0
Ring-necked Duck	*Aythya collaris*	5	0	0
Bufflehead	*Bucephala albeola*	5	0	0
Hooded Merganser	*Lophodytes cucullatus*	1	0	0
Common Merganser	*Mergus merganser*	12	10	3
Unidentified Duck	*Anatinae* (gen, sp)	3	0	0
Total		1008	409	30

Table 3-5: Number of waterfowl broods observed each week during surveys in 2013, categorized by age class

Age	17/06/2013	20/06/2013	24/06/2013	03/07/2013	04/07/2013	08/07/2013	12/07/2013	16/07/2013	19/07/2013	22/07/2013	26/07/2013	30/07/2013	Total
1c	0	0	0	0	0	0	0	0	0	1	0	0	1
2a	0	0	3	0	0	1	0	0	0	0	0	0	4
2b	5	0	0	0	0	0	1	0	0	0	0	0	6
2c	7	0	0	0	0	0	7	0	0	0	0	0	14

3.7 Bald Eagle and Osprey Productivity Monitoring

In 2013, we monitored 27 nest sites (Figure 3-8). We located two new Bald Eagle nests in 2013, and there were eight previously documented nest structures destroyed prior to the 2013 surveys (tree failure, nest dislodgement etc.).

We observed five nests to be occupied by Bald Eagles. Large nestlings were observed in all five nests (Table 3-6). Three of the five nests were confirmed as successful, with one fledgling produced in each of these nests (an average of 0.6 fledglings per nest). Nesting success could not be easily determined at the remaining two nests. One nest failed due to nest destruction. The other nest was challenging to observe preventing clear conclusions from being made (Table 3-6).

We confirmed seven nesting attempts made by Ospreys (Table 3-6). Only one of these nests was observed to be successful. This nest was observed to contain two nestlings (mid-to-late August). We suspect that both fledglings died because one large fledgling-aged Osprey was found dead below the nest at the time it was expected to fledge, and no live fledglings were observed in the area. We considered this nest as "successful" because young were raised to the fledging stage, being observed in August (a normal benchmark of nesting success).

3.8 Multi-year (2009 - 2013) Bald Eagle and Osprey Productivity Monitoring

Since 2009, we monitored 25 Bald Eagle and 42 Osprey nesting attempts. Over this time period, there was a fairly constant number of nesting attempts observed each year for both species. 2010 had high nesting densities for both species, but there was no obvious trend in nesting attempts observed over time (Figure 3-9).

Bald Eagle nesting success was fairly constant over time (Figure 3-9), and was observed to range from 60% (2013) to 100% (2010 and 2012), averaging 80% among years.

Nest success rate for Osprey declined from 2009 (the first year with complete monitoring; 78%) through 2013 (14%; Figure 3-9). When the nesting success rates observed among all years (including 2008 where data were less complete) were compared with a metric of how aggressively the reservoir filled each year (modelled potential for nest flooding), there was a significant negative relationship between how aggressively the reservoir filled, and the Osprey nesting success rate (Slope = -0.82, adjusted R^2 = 0.72, $F_{1,4}$ = 14.3, P = 0.019).

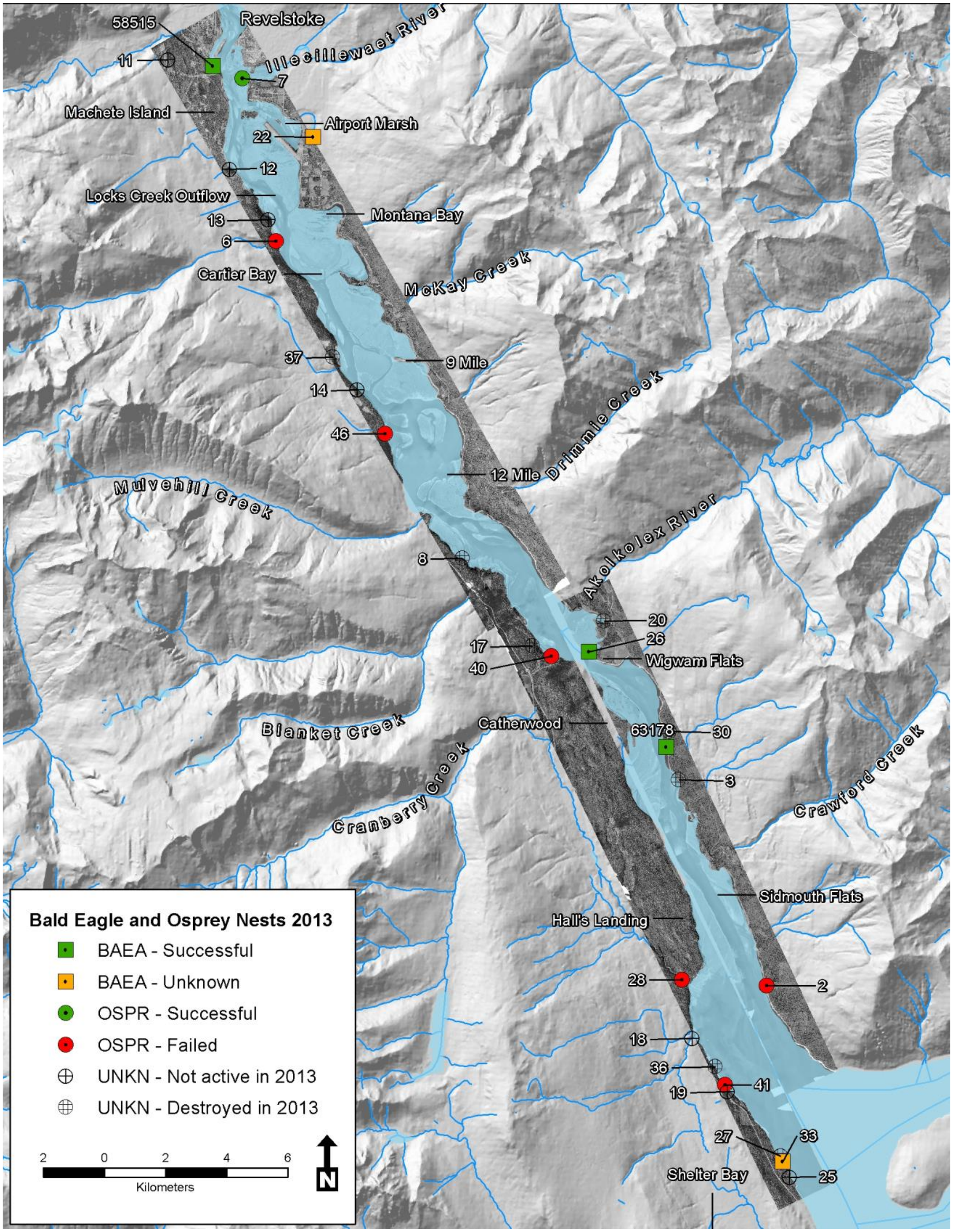

Figure 3-8: **Locations of Bald Eagle (BAEA) and Osprey (OSPR) nests in Revelstoke Reach in 2013. Inactive nests and nests destroyed since the previous year are noted**

Table 3-6: **Productivity results from Bald Eagle (BAEA) and Osprey (OSPR) nest monitoring in 2013. In addition to the data shown, there were 7 inactive nests and an additional 7 nests destroyed between**

Species	Nest ID	Nestlings	Incubation Observed	Nestlings Confirmed	Large Nestling Observed	Fledglings Observed	Outcome
BAEA	22	1	☒	☑	☑	☒	Unknown[1]
	26	1	☒	☑	☑	☑	Fledged
	33	1	☒	☑	☑	☒	Unknown[2]
	58515	1	☒	☑	☑	☑	Fledged
	63178	1	☑	☑	☑	☑	Fledged
OSPR	2	0	☑	☒	☒	☒	Failed
	6	0	☑	☒	☒	☒	Failed
	7	2	☑	☑	☑	☒	Fledged [3]
	28	0	☑	☒	☒	☒	Failed
	40	0	☑	☒	☒	☒	Failed
	41	0	☑	☒	☒	☒	Failed
	46	0	☑	☒	☒	☒	Failed

[1] A large nestling was observed in this nest but fledging was not observed – this nest is difficult to monitor from the ground

[2] This nest likely failed. A large nestling was last observed on July 10 however the nest appears to have been destroyed as it was not seen beyond this date. No BAEA were seen in this area after July 10. Aerial survey in 2014 will confirm that the nest structure is destroyed.

[3] We observed 2 large nestlings in late August however shortly after this a dead nestling was found below nest in the grass. No living fledged young were observed.

3.9 Short-eared Owl and Northern Harrier Productivity Monitoring

No Short-eared Owl nests were located in 2013. A single Short-eared Owl was observed consistently from the third week of April to early May in the area south of Machete Island (Table 3-7). However, there were no observations after May 9 (prior to the reservoir flooding their habitat), thus suggesting that no nesting attempts were made during 2013.

No Northern Harrier nests were located in 2013. Harriers were observed primarily in mid-late April through to mid May (Table 3-7), but there was no indication of pairs attempting to nest.

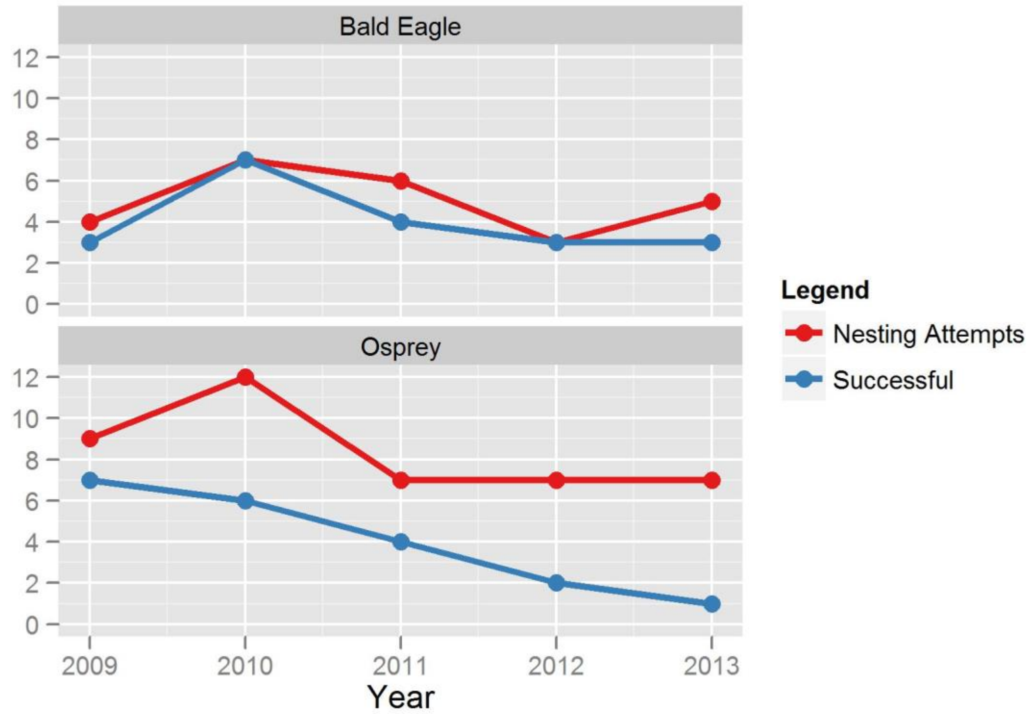

Figure 3-9: **Nesting data for Bald Eagle and Osprey from 2009 through 2013. The incomplete 2008 data are omitted**

Table 3-7: **Number of Short-eared Owl and Northern Harrier detections recorded during surveys conducted in 2013**

Date	Northern Harrier	Short-eared Owl
2013-04-10	0	0
2013-04-11	0	0
2013-04-18	0	1
2013-04-19	2	0
2013-04-25	2	1
2013-05-02	3	1
2013-05-09	0	2
2013-05-15	3	0
2013-05-22	0	0
2013-05-27	0	0

3.10 Multi-year analysis of brood survey data

Paradoxically, the relationship between annual sum of brood detections and the nest-flooding potential 'impact' estimated for annual reservoir operations was much greater for species that were not exposed to nest flooding impacts ('safe.species'; Figure 3-10). For both exposed species and safe species, the relationship was significant (linear regressions, R^2 = 0.84, P = 0.006, and R^2 = 0.73, P = 0.02 respectively). Modelled together using with an interaction term (R^2 = 0.86), both main effects ('species exposure' and 'impact') were significant (P = 0.001, P = 0.04 respectively), and there was a significant interaction between impact and species exposure (P = 0.01).

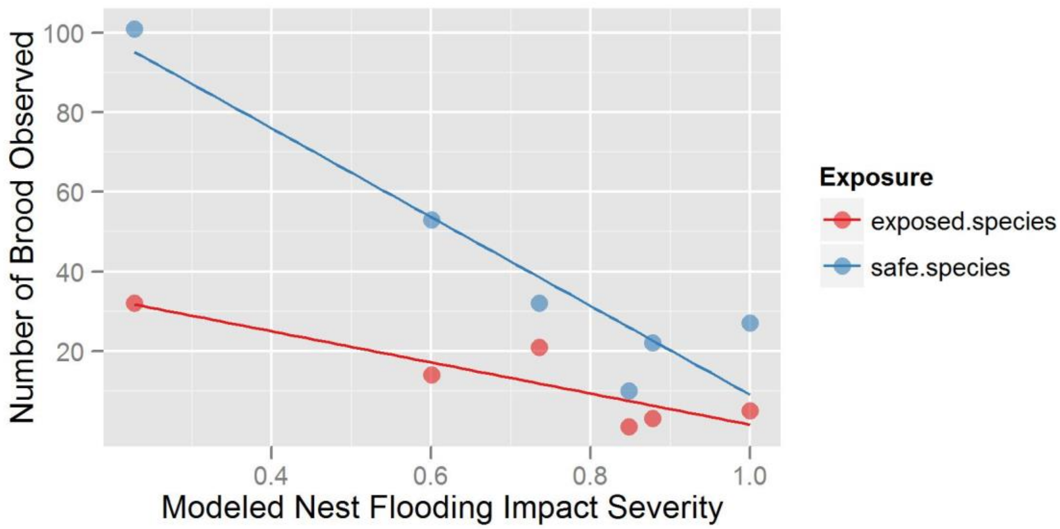

Figure 3-10: **Relationships between the total number of broods counted annually compared with the severity of nest flooding predicted for each year's reservoir operation. Safe species are those that either nest early (e.g., Canada Geese) or nest above the drawdown zone in cavities (e.g., Common Mergansers) and are therefore not impacted by nest flooding. A negative relationship is expected for species exposed to nest flooding impacts (e.g., Mallard, American Wigeon)**

The relationship between brood counts and reservoir operations (impact) clearly changed over the season, and this seasonal effect differed for both types of waterfowl. In general, there was a negative relationship between the brood counts of safe species (Canada Goose) and impact observed in all months, but the relationship became progressively less well pronounced over time (Figure 3-11). In most years, the number of broods diminished over time from week 25 through week 29; this was particularly true for all years except 2009 (impact < 0.4), when the reservoir operation had the lowest potential to flood nests (Figure 3-11). In 2009, the number of broods initially diminished, and then increased.

In contrast, species exposed to nest flooding showed an increase in brood counts over time from week 25 through week 29 (Figure 3-12). Additionally, the strength of relationship between nest flooding impact and brood counts was enhanced over time; in week 25 there was absolutely no relationship between these two variables, but by week 29 there is a very strong relationship.

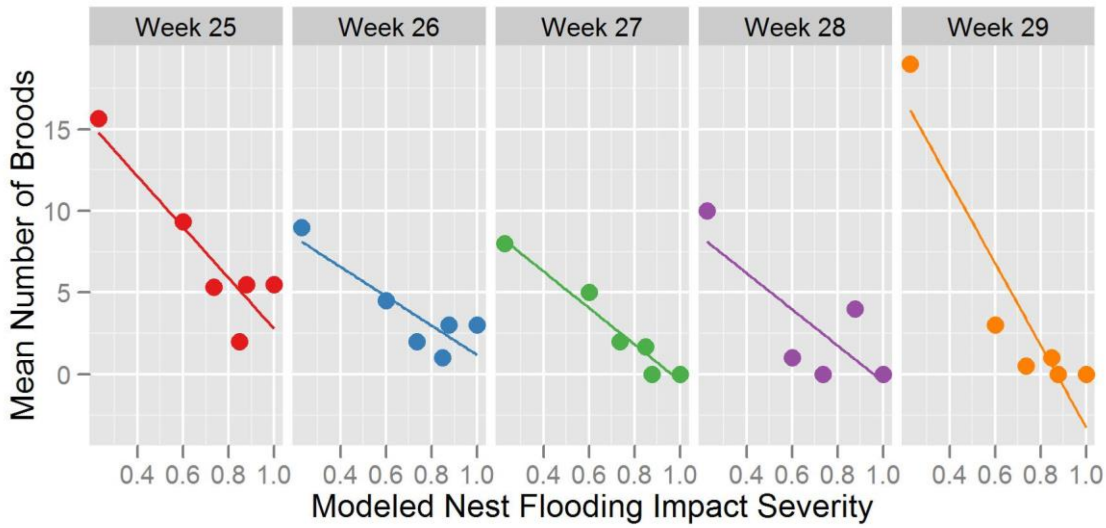

Figure 3-11: **The relationship between modelled nest flooding impact and brood counts for species that are not impacted by nest flooding (e.g., Canada Goose).**

The relationship between daily reservoir water elevation and the number of broods observed on a sampling occasion was considerably stronger in the data considering species that were safe from nest flooding, compared with those that were exposed to nest flooding threats (Figure 3-13).

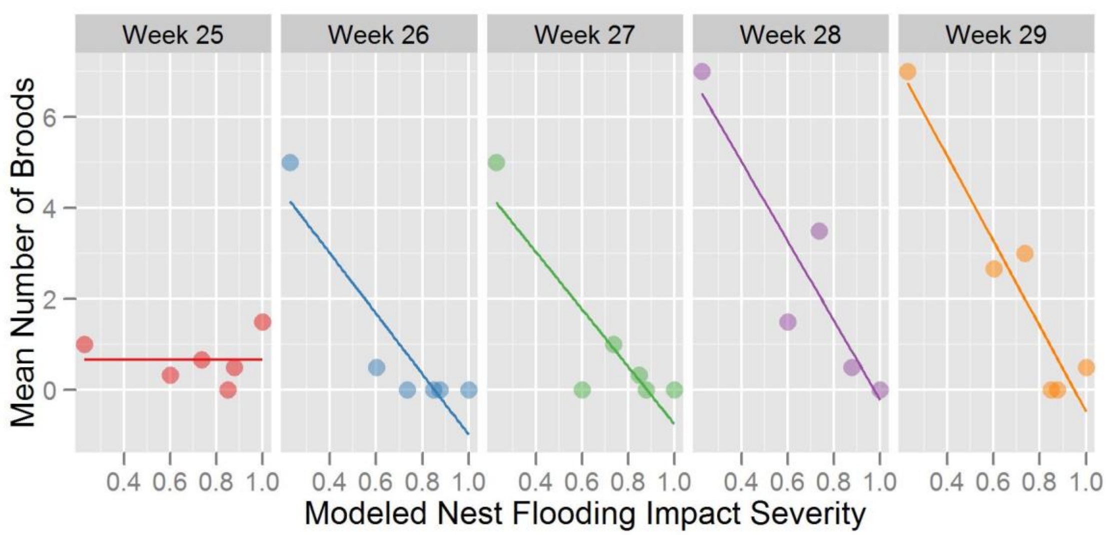

Figure 3-12: **The relationship between modelled nest flooding impact and brood counts for species that are exposed to nest flooding impacts (e.g., Mallard, American Wigeon)**

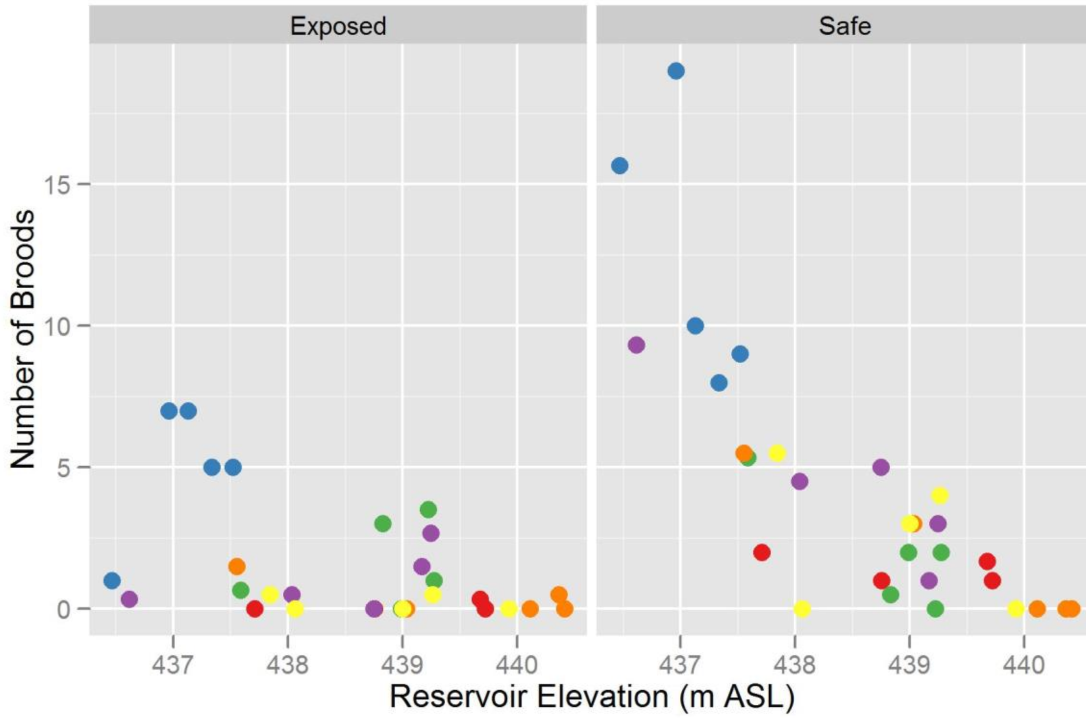

Figure 3-13: **Relationships between reservoir elevations observed on a sampling occasion and the number of broods observed for species exposed to nest flooding impacts (left) and those that were safe (right). Years are distinguished by colour (2008 = red, 2009 = blue, 2010 = green, 2011 = purple, 2012 = orange, 2013 = yellow)**

4 DISCUSSION

CLBMON 40 is a 10-year monitoring program designed to assess the impacts of the operations of Arrow Lakes Reservoir on waterbirds and shorebirds that use Revelstoke Reach Reservoir. This study monitors distributions and abundance of waterbirds and shorebirds to determine habitat use, monitors productivity of waterbirds, and will provide guidelines for habitat management and water use planning. This report summarizes Year 6 of the CLBMON 40 project, following a comprehensive interim report and multi-year analysis of 5 years of data (2008 to 2012; CBA 2013a). Beyond reviewing the 2013 results, two multi-year analyses were revised in this report.

4.1 Highlights of Year 6

Year 6 was the first year following the first multi-year analysis. As a result of the multi-year analysis we made an adjustment to the boat-based survey so that it occurred on a weekly schedule during the first half of the shorebird migration monitoring season, rather than the previous bi-weekly schedule, so that all 6 surveys took place during the core migration, rather than throughout the extended time period. Otherwise, the field sampling in 2013 was similar to previous years.

As with previous years (CBA 2013a), Cartier Bay and Airport Marsh were once again the most numerically important wetlands for migrating waterfowl, and the Airport West Pond and Wigwam Flats near the Akolkolex River provided the largest abundance of shorebirds.

In 2013 the migration was pushed back in time by a relatively late ice break up, but there was an apparent disparity in the timing of peak spring migration seen between land-based and aerial surveys of waterbirds. The peak migration observed by the land-based survey was driven almost entirely by Canada Goose counts; 609 geese were counted on March 22, and the count had diminished to only 214 on April 2. This pattern was not seen in the aerial survey. The aerial surveys must have failed to detect a considerable proportion of geese in the early surveys; geese are difficult to detect in spring when they are situated on the dead grasses in which they are highly camouflaged, prior to green-up. The peak migration detected by the aerial survey more closely approximates the migration of dabbling ducks observed to peak a bit later by both survey methods, and the disparity would be greatly reduced after the Canada Geese data have been removed.

Reservoir elevations were relatively low during the shorebird surveys exposing an abundance of potentially suitable low elevation non-vegetated shoreline habitat; however, we detected relatively few shorebirds in 2013, possibly indicating that these low elevation non-vegetated shoreline habitats were not rich in food. This year had the second lowest year for shorebirds, and the lowest diversity of species to date. Interestingly, we recorded the greatest abundance of Spotted Sandpipers to date (138 in 2013 compared with 134, 68, 81 and 67 in 2012, 2011, 2010 and 2009, respectively) as they made up 74% of all shorebirds observed (66% of which were birds observed during boat-based surveys).

The reservoir came up fast and was relatively high in 2013, and productivity was low for waterfowl and Osprey, both discussed in greater detail below.

4.2 Waterfowl Productivity

Waterfowl productivity was low in 2013. This is consistent with the hypothesis that ground-nesting duck productivity is limited by reservoir operations due to nest failure and reduced availability of nesting habitat. This year, water levels were relatively high at the beginning of the monitoring season. They then rose quickly, peaked at almost full-pool levels, and then receded relatively quickly (after the nesting period). Examination of the age class of waterfowl young over the monitoring season suggested that only an early single cohort of young was produced, and that there were very few successful late nests (e.g., re-nesting) despite the quick recession of ALR reservoir elevation, which did not occur early enough to be taken advantage of. If nest flooding is a large issue for nesting waterfowl, we should be able to find evidence of this by examining all brood survey results among years.

A brief analysis of brood survey results was presented in the Year 5 Interim report (CBA 2013a). In this report, we updated the Year 5 analysis with Year 6 data, and presented additional information to explore the data further. We defined two groups of waterfowl that breed in our area; the first group included species that were 'vulnerable' to having their nests flooded by rising reservoir water elevations. This group of waterfowl were the ground nesting species, and were primarily composed of Mallard and American Wigeon. The second group were those that had very low vulnerability to nest flooding; these 'safe species' nest in tree cavities, or nest very early in the year at high elevations well before expected full pool elevations are approached. The latter case is most relevant because the early nesting Canada Goose was by far the most abundant of the safe species. For this report, we retained these groupings, defined in the Year 5 analysis. We note in the future, it may make more sense to examine Canada Goose data separately, as this species overwhelmingly outnumbers other “safe” species.

We began by examining an obvious basic relationship: we expect to find a relationship between the reservoir operations and brood counts if nest flooding is an issue. Specifically, we predicted that a metric encapsulating how severe the nest flooding potential is in a given year, should be negatively correlated with the brood counts made in that year. We used a nest flooding model developed by the CLBMON-36 nest mortality study (CBA 2014b), to quantify annual potential for nest flooding. Intuitively, one might expect that this relationship is well-defined for vulnerable species, if it exists, and poorly defined for safe species. As expected, there was strong evidence of a negative relationship between reservoir impact and brood counts; however, this relationship was more pronounced in the brood counts of safe species, compared with brood counts of vulnerable species. Initially, this seems counter-intuitive, and raises two questions:

- Why is there a very strong relationship between reservoir operations and brood counts of safe species?
- Why is the relationship between reservoir operations and brood counts relatively weak for the vulnerable species?

We are confident in answering the first question: the strong negative relationship with safe species occurs because the brood-rearing habitat suitability is related to reservoir operations for Canada Goose, and adults and young move away from the monitored sites when water levels are high.

The answer to the second question is that it is likely an incorrect statement; there was in fact, a very strong relationship between reservoir operations and brood counts of vulnerable species, but this was masked when brood counts were pooled within years; it was not until we partitioned data among weeks (e.g., examining data from each week separately), that the among-year relationship became strong. The details of these conclusions follow.

At full pool elevations, when no geese were detected by brood counts and grass was unavailable in the northern part of the study area, we have repeatedly observed large groups (hundreds) of adult and juvenile Canada Goose at the south end of Revelstoke Reach, where large areas of flooded grass were accessible (anecdotally, during aerial surveys of eagle and Osprey nests). In 2009, the reservoir did not approach full pool conditions, and Canada Goose broods were raised in the northern flooded grass habitat (at the brood survey area) that was abundant throughout the brood-rearing season. The movement of Canada Goose broods away from the brood survey area at high water levels, alone, explains why there was such a strong relationship between reservoir operations and brood counts of safe species (in years of high reservoir levels - the brood rearing occurred outside of the brood survey area). This explanation places more emphasis on the real-time reservoir elevations at the time when brood counts were made and, indeed, we found a very strong relationship between Canada Goose numbers and the daily reservoir elevations recorded on the day of brood count surveys, which is something that was not observed as apparent for the vulnerable species. The time frame over which they vacate the northern monitored area was likely linked to how high the reservoir elevations were. In years when the reservoir is low and fills late, they were found in the survey area over an extended period of time. But in years when reservoirs elevations were high and filled early, they were briefly seen early in the season, before they moved away from the survey area to more suitable habitats in southern parts of

Revelstoke Reach. In most years, the reservoir normally created unsuitable local habitats before the end of the brood survey season, and we normally observed no Canada Goose broods late in the year (they were all further south). As such, it is an important distinction that the among-year variability in Canada Goose brood counts primarily occurred early in the year, prior to full pool conditions. It follows, that if brood counts are largely influenced by the migration of broods away from the study area as water levels rise, we should expect (1) a strong relationship between reservoir elevations and brood counts, (2) diminishing brood counts over the season, (3) stronger relationships between reservoir operations and brood counts earlier in the season, and (4) evidence of broods congregating outside of the monitoring area. Our results, and anecdotal observations support these predictions, but the opposite was observed with the vulnerable species.

In our study area, the waterfowl species that were vulnerable to nest flooding were primarily the Mallard, American Wigeon, and teal (mainly Green-winged Teal) species. When the data for each year were summed, there was a significant, but not particularly strong relationship (gentle slope) between the nest flooding impact of reservoir operations and brood counts (Figure 3-10). Unlike the safe species (Canada Goose), the brood counts from vulnerable species tended to increase during the breeding season and, unlike the safe species, the relationship was most well-pronounced later in the field season. In fact, when the relationship between reservoir operations and brood counts were examined separately within weeks of the year, it is evident that our brood survey is initiated just prior to the brood rearing season (or very near the start), so there are almost no broods were observed in the first week of surveys. This is why the relationship was not particularly strong in the initial analysis where brood counts were pooled. When the late season data were examined separately, the expected relationship between reservoir nest flooding impact and brood counts was strongly-defined for these vulnerable species. Unlike the Canada Goose data, there was very weak evidence of a relationship between the reservoir elevations and the brood counts when compared among survey occasions. We have never observed duck broods congregating away from the monitoring area, although we cannot rule out that they become more difficult to detect at high water levels, for example, if they favour flooded shrub habitat that might obscure detections and/or be further from the viewing areas. However, there is an overall reduction of vegetative cover at high water levels, and so we do not believe this is a large source of error.

There is a subtlety of the vulnerable species data when parsed by week of the year that is not immediately apparent but deserves to be highlighted and discussed. Consider that we can categorize nesting histories for vulnerable waterfowl into three groups: (1) those that had successful nests on their first try of the season and are potentially observed rearing broods throughout the survey period; (2) those that had nest failures, but were able to re-nest successfully, to emerge with broods late in the season; and (3) those that were altogether unsuccessful, and were never observed with broods. In the absence of nest flooding there should be a mix of all three groups, and we expect to observe a steady accumulation of broods throughout the nesting season, of mixed age-classes. Initial variation is explained by the natural variability in nest initiation dates within and among species which leads to a range in dates for brood emergence for group 1 above. Furthermore, nest predation is a constant daily threat to the survivorship of nests, so we expect that nests can fail, and be replaced at any stage of the nesting cycle prior to the end of their laying season, leading to a continued emergence of new broods over an extended period of time (group 2). In short, we may normally expect a mix of group 1 and 2 and therefore a steady increase in brood counts throughout the year as initial nests hatch, and then as replacement nests, staggered over time, also hatch and contribute broods. However, when reservoirs flood the nests, we may see different patterns, driven by a reduction of group 1, and in severe nest flooding years, a reduction in group 2 as well. It is possible that a large proportion of initial nests are destroyed by reservoir operations virtually eliminating group 1 or at least a significant proportion of these birds, forcing many or most ducks to re-nest at higher elevations (if habitat is still available). If re-nesting were possible, there would be a delayed onset of brood emergence. In that case, we may see a 'hockey stick' graph, where the brood counts are minimal for a period of time, and begin to increase late in the year because group 1 is missing, and we now only see group 2 broods. If the reservoir continues to rise such that all other nesting attempts fail (all habitat is eventually flooded during the nesting period), there will be no brood emergence at all (group 3 only). Accordingly, in the low impact year (2009, impact < 0.5) we indeed observed the steady increase in brood counts over time. In moderate impact years (2010, 2011, impact between 0.5 and 0.8), we observed evidence of the hockey stick pattern; and in the most severe years (2008, 2012, 2013, impact > 0.8), there were almost no broods counted at all (see Figure 3-12). Future work will help us find support for these ideas, as the sample size is only as large as the numbers of years of monitoring. These patterns were identified in the 5 Year Interim Review report (CBA 2013a) and reinforced by the addition of the 2013 data.

4.3 Bald Eagle and Osprey Productivity

In 2013, moderate numbers of active/occupied nests were observed for both Bald Eagle and Osprey, similar to previous years. Bald Eagle productivity appeared relatively normal in 2013. There were two nests that may have failed. One was difficult to monitor, and we think the other nest was destroyed prior to fledging (an aerial survey in 2014 will confirm this). The former of these unknown nests, near Williamson Lake, has been regularly occupied each year, but growth of vegetation in the foreground of the viewing area has made it very challenging to monitor.

There was near-complete failure of Osprey nests in 2013. Most nests failed early or mid-way through the nesting season, and nestlings were only observed at one nest, where nestlings were observed late in the season (mid-August), but may have ultimately resulted in zero productivity as at least one juvenile died for unknown reasons near fledging time[4]. We have no evidence of what caused the nest failures, and the extreme variability in nesting success over time. We hypothesize below.

Weather may affect nesting success. Storms may destroy nest trees, or dislodge nests, and cool wet conditions increase energetic needs of young (Newton 1979), while rainfall can impede Osprey foraging success (Grubb 1977). Given that foraging success is correlated with productivity (Van Deale and Van Deale 1982, Eriksson 1986), it is not surprising that the number of rainstorms was negatively correlated with brood size in a large dataset gathered in northern Idaho (Johnson et al. 2008). But we do not think weather was likely to provide a satisfactory explanation of the unprecedented rate of nest failures in 2013, because the weather conditions in Revelstoke were normal in 2013, with few storms, little wind, and with normal temperatures and levels of precipitation. Weather did likely cause some nest failures during our study, but we suggest that this source of nest failure is unlikely to be a source of variability in nesting success that could account for a declining trend in nest success over time, or explain the very low nest success rate

[4] We were unable to examine the dead young to perform a necropsy - it was something we learned about later in the year.

in 2013. Nonetheless, when 10 years of data are available, weather metrics should be compared with nesting performance.

Historically, Osprey populations have been heavily impacted by contamination (DDT, lead, mercury, polychlorinated biphenyls (PCB's), etc.). Moreover, there is evidence that PCB contamination is elevated in Osprey eggs collected within the Columbia system, apparently as a consequence of hydroelectric power generation (Elliott et al. 2000), and the Aroclor 1260 PCB cogener was particularly common in yolk sacks of Osprey chicks collected from the Canadian side of the Columbia (Elliott et al. 2001)[5]. At this time, we do not suspect that a toxicological explanation for poor nesting success is 2013 is likely. We are unaware of any events that might have caused among year variation in toxicity levels. Furthermore, PCP contamination is not known to have highly dramatic effects on Osprey productivity; for example, Osprey were recorded to have 59% and 76% nesting success rates near Nelson, BC (Steeger et al. 1992), where the PCB levels were known to be high (Elliott et al. 2000, 2001).

A more promising hypothesis is that nesting success was influenced by variability of foraging conditions among years, with foraging efficiency being low recently. The ability of adults to provision their young is known to be a major limiting factor for raptors (Newton 1979) including Ospreys (Van Deale and Van Deale 1982, Eriksson 1986). Foraging efficiency could be impacted by (1) variability in prey abundance, and/or (2) variability in the capturability of the prey; both factors could have played a role in 2013 and 2012 - the years where we observed the lowest nesting success - as explained below.

In support of (1) above, a decline of salmonid prey was indicated by very low kokanee returns to Hill Creek and the Hill Creek spawning channels in 2012 and 2013 (Cooper 2013; BC Government - Forest, Lands and Natural Resource Operations *unpublished data*); anecdotally, this was corroborated by reports from several fishermen, who had poor angling success in 2013 (H. van Oort *personal communications*). While Osprey do not forage entirely on salmonids, these prey are known to be more important for Osprey, compared with Bald Eagles (Jackman et al. 2007) and are known to form a major part of their diet during the breeding season in other reservoirs (Van Deale and Van Deale 1982, Steeger et al. 1992). As such, it is possible that a major component of the Osprey prey base was simply in low abundance in these years, causing low foraging efficiency, with detrimental impacts to nestling survival (Van Deale and Van Deale 1982, Eriksson 1986). For analyses in the future, it would be ideal if fish return data are examined as a potential explanatory variable.

Regarding (2) above, it is also possible that foraging conditions were impacted by the operations of the Arrow Lakes Reservoir - a theory that is central to CLMBON-40. Reservoir operations may influence hunting success of piscivorous raptors via impacts to the turbidity of the water (Grubb 1995, Hunt et al. 2002), hydrology (Hunt et al. 1992, 2002), and the water depth (Van Deale and Van Deale 1982, Watson et al. 1991, Elliott et al. 2005), among other potential factors (e.g., water temperature gradients). In the Cascade Reservoir in Idaho, Van Deale and Van Deale (1982) indicated that reservoir elevations were the most likely cause of inter-annual variation in productivity, where they reported low brood size and low foraging efficiency when the reservoir water levels were high. The Arrow Lakes Reservoir had the lowest summer levels and the greatest Osprey

[5] Note that Canadian Columbia toxicology sampling took place downstream of the Arrow Lakes Reservoir, at Kootenay Lake and along the lower Kootenay River

productivity in 2009, and the highest reservoir levels and the least Osprey productivity in 2012 and 2013, and we found a significant negative relationship between nesting success rates calculated annually, and a metric representing how aggressively the reservoir filled each year. As such, our data are consistent with other studies that suggest a potential impact of water level management on Osprey productivity. Despite the significance of the result reported here, we suggest that additional years of data should be collected to improve sample size. We also suggest that the influence of reservoir operations should be explored in a more detailed way, by examining various metrics of the operations - an analysis that is premature at this time.

One may question why the piscivorous Bald Eagle did not show similar indications of variable nesting success over time; after all, it has been suggested elsewhere that Bald Eagle foraging success is greater in shallow waters (Watson et al. 1991, Elliott et al. 2005, Jackman et al. 2007). There are several reasons why this difference may arise. First, Bald Eagles nest earlier and may therefore experience less exposure to deep water foraging conditions. Second, Bald Eagles have a much more diverse prey base compared with Osprey, feeding on carrion, birds, and mammals in addition to fish; additionally they can obtain fish by pirating Ospreys and Great Blue Herons. It has been suggested that Bald Eagles may switch foraging strategies when fishing conditions are poor (Grubb 1995); for example, they may capitalize on the abundance of Canada Goose broods when reservoir levels rise.

Regarding the low productivity of Ospreys in 2013, we should also consider the possibility that the 2013 results were simply the next data point in a time series indicating continual decline, and that the water levels in 2013 were not a great factor. Indeed, our data suggest that Osprey productivity has steadily declined during the last five years (2008, excluded, had poor data because no aerial surveys were made), indicating that there could be a persistent long-term factor, rather than annual stochasticity. This would be supported, if productivity does not re-bound in the future. However, we have no explanation for this long term decline, and given the low sample size in this time series, it is possible that the perceived decline in productivity is mere co-incidence. Additional years of data, and comparisons with other regional datasets, if possible, will allow us to examine this possibility.

We have previously suggested that the Osprey and Bald Eagle monitoring program is highly limited because of the low sample sizes, and the low sensitivity of the response variable (i.e., nesting success; CBA 2012a, 2013). The recent results provide greater optimism for rigorous statistical analysis because they greatly expand the observed variability in productivity which was previously seen to be quite low; in other words, we may not require a large dataset to draw conclusions because the biological effect size is large. This turn of events increases the perceived value of this component study because it suggests that there may be a considerably important conservation issue to be identified, and because it forecasts increased potential for the study to be successful. As such, we should consider, again, ways to improve this component of CLBMON-40. We make recommendations to this effect below.

4.4 Recommendations

Following the first analysis of multiple years of data (CBA 2013a), and the results presented in this report, we recognize two components of CLBMON-40 that can be improved (shorebird migration monitoring and Bald Eagle and Osprey productivity monitoring), and we also suggest that resources are re-allocated to address these improvements.

First, we have previously identified that the land-based shorebird monitoring season should be extended through October to capture the end of the Dowitcher migration (CBA 2013a). This would entail four more surveys per year.

Second, we suggest that Osprey provisioning rates to nestlings should be monitored. We have demonstrated a fairly strong albeit early piece of evidence that reservoir operations are impacting Osprey nesting success; however, we can only hypothesize about the mechanism under the current study scope. The leading hypothesis is that nesting success is impacted through the reservoir operations influence on their ability to provision their young. Monitoring of provisioning rates can readily be compared with reservoir elevations using within-year comparisons, because reservoir elevations change dramatically during the nesting season. Currently, we suggest that video monitoring may be best accomplished using a programmable camera that is positioned from the ground from a position where the flights to and from the nest can be observed, and prey deliveries counted, rather than installing nest cameras that monitor what goes on within the nest. This will avoid unnecessary disturbance of the nests and avoid the potentially problematic issue of climbing nest trees at the time of installation. We recommend that these options are investigated, and a pilot project is initiated on one or two nests if possible, in 2014. Following, the sampling can be expanded if the approach is feasible, and adequate data can be collected to study this effect in a relatively short period of time.

Both of these recommended changes may require monitoring resources (field effort), which we suggest should be accounted-for without the need to secure additional funds; rather, we suggest that field effort is reallocated. We recommend that we reduce effort in the winter land-based waterfowl monitoring (in January and February), as this is a period for which we now have considerable data indicating very low waterfowl numbers and very low potential for impacts by reservoir operations.

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6 APPENDICES

Appendix 6-1: The CLBMON-40 Objectives, Management Questions (MQ) and Management Hypotheses, and a review of the results after Year 6 (see CBA 2013a for details on many of the Summary Points)

Objective 1	Management Questions (MQ)	Management Hypotheses	Year 6 Status Summary Points
Determine the abundance, distribution, and habitat use of waterbirds and migratory shorebirds and the productivity of waterbirds in Revelstoke Reach	1) What are the: I. seasonal and annual variations the abundance and spatial distribution of waterbirds in Revelstoke Reach; and II. variations in the abundance and spatial distribution of shorebirds during fall migration in Revelstoke Reach?	N/A	• The seasonal aspects of this MQ have been addressed, but estimates of annual variation are limited to five data points • The average abundance of waterfowl during the fall migration differed among years • A General Additive Model (GAM) with a negative binomial distribution was applied to land-based waterfowl survey data to model seasonal variation in abundance; this provided a relatively good model of seasonal abundance, indicating two well pronounced migrational peaks • Spatial distribution was determined at two scales for waterbirds; Cartier Bay, Airport Marsh and several other wetlands accounted for very high proportions of the waterfowl detected during complete aerial surveys. Raster maps were used to identify spatial hotspots within the high use wetlands. • Shorebird migrations were examined separately for Dowitcher sp., Spotted Sandpipers and 'Other Shorebirds' • Negative binomial GAM's fit the data relatively well in all cases. One model indicated that Dowitcher migrations occurred late in the monitoring season, whereas the model for Spotted Sandpipers indicated a declining abundance throughout the monitoring season. Other Shorebirds had a distinct migration climax in early August. After controlling for seasonal abundance, year effects were detected for Spotted Sandpipers and Other Shorebirds, but not for Dowitchers • Most shorebirds were detected at a relatively small number of sites; six sites were important for all species, two were important for Spotted Sandpipers only.
	3) Which habitats within the drawdown zone in Revelstoke Reach are utilized by shorebirds and waterbirds and what are their characteristics (e.g. foraging substrate, vegetation, elevation, and distance to the waters edge)?	N/A	• This Management Question was not fully addressed in this document • Key sites were identified for waterfowl and shorebirds • Raster maps of waterfowl usage within sites were created for the primary wetlands monitored by the land-based waterfowl surveys • Correlations between waterfowl usage and habitat characteristics within sites are planned, but analyses await results from CLBMON-11B-4 • Habitat data for shorebirds was not presented in this document.
	4) What is the annual variation in the productivity of waterbirds in Revelstoke Reach and does productivity vary spatially (e.g. are there areas of higher waterbird productivity or brood counts)?	N/A	• Graphical analysis indicated that there was considerable variability in the number of broods among years • Although not discussed in this report, observations suggest that Canada Geese, the most abundant brood-rearing species, congregate away from the brood survey area in the Catherwood site where flooded grass is available in high water conditions • Downie and Airport Marsh appeared to be consistently one of the most important brood rearing sites for other brood-rearing waterfowl • From 2009 through 2013 there were between 3 and 7 Bald Eagle nests, and between 0 and 7 Osprey nests that were successful each year • There was a maximum number of 7 active Bald Eagle nests and 12 active Osprey nests counted in Revelstoke Reach each year • There was evidence that as many as 3 Short-eared Owl nests were active in 2010. Only one Short-eared Owl nest was located, and this nest site was flooded during the nestling period. In all other years no Short-eared Owl nesting activity was observed • No Northern Harrier nesting activity was observed

Objective 2	Management Questions	Management Hypotheses	Year 6 Status Summary Points
Examine how variation in flow and reservoir water elevations influence seasonal and yearly abundance, distribution, and habitat use of waterbirds and migratory shorebirds and the productivity of waterbirds in Revelstoke Reach	2) What impacts do year-to-year and within-year reservoir operations have on resident and migratory waterbirds and migratory shorebird populations?	N/A	• No data were explored specifically for this MQ • Results indicate that productivity is likely impacted by reservoir operations for some waterfowl species • Results indicate that habitat availability is likely impacted for migrating shorebirds and waterfowl, but it would be challenging to estimate impacts these effects have on populations
	5) Which species of shorebirds and waterbirds are most likely to be affected by reservoir operations?	N/A	• This MQ is not phrased well, and no data were explored specifically for this MQ in this document • Taken literally, the obvious answer to this question is that all species of shorebirds and waterbirds that utilize the drawdown zone are equally likely to be affected by reservoir operations to some degree, because reservoir operations have and continue to define habitat in the drawdown zone. Complete lists of species that utilize the drawdown zone have been presented in annual technical reports, but were not repeated here. • Which species are most affected? The most important impact of reservoir operations to waterbirds is likely the impacts to productivity of some waterfowl species (e.g., Mallard, Teal spp., American Wigeon), some shorebird species (Spotted Sandpiper and Killdeer), and Short-eared Owls. It can be argued that these species are 'most affected by reservoir operations' if this is what is meant • The data now indicate potential that Ospreys may be highly sensitive to reservoir operations.
	6) Do reservoir operations (e.g. daily and maximum monthly water levels) influence the distribution and abundance of waterbirds and shorebirds in Revelstoke Reach?	H1: The annual and seasonal variation in water levels resulting from reservoir operations, the implementation of soft constraints, and the potential impact from Rev 5, ("reservoir operations"), do not result in a reduction of waterbird or shorebird use in Revelstoke Reach. H1A Reservoir operations do not result in decreased species diversity in waterbirds or migratory shorebirds in Revelstoke Reach. H1B Reservoir operations do not result in a decrease in the abundance of waterbirds or migratory shorebirds in Revelstoke Reach. H1C Reservoir operations do not result in changes in waterbird or shorebird distribution in Revelstoke Reach.	• This MQ was explored statistically and graphically • H1 is a poorly constructed null hypothesis and should be re-written, or ignored. The other hypotheses are also poorly worded. • Using water depth as a measure of reservoir operations, and probability of detecting waterfowl as an index of their distributions, we showed that distributions can be highly influenced by reservoir operations • There was no obvious indication that waterfowl abundance was influenced by reservoir elevations • The diversity of shorebirds appeared to be uninfluenced by reservoir elevations, but the data are still very limited. • The diversity of waterfowl appeared to be influenced by reservoir elevations early in the fall migration with greater diversity being measure in years when reservoir elevations were higher. • The latter trend was driven by diving species that moved into wetlands when inundated. • We suggest that diversity is more informative when measured within foraging guilds. Otherwise, high diversity could simply reflect a re-distribution of some species (e.g., diving birds), and reflect compromised foraging for other species.
	7) To what extent do water levels in Arrow Lakes Reservoir influence the productivity of waterbirds in Revelstoke Reach between years?	H1D Reservoir operations do not result in a decrease in the productivity of waterbirds in Revelstoke Reach.	• Variability in brood counts was explored graphically, separately for species that were exposed to and not exposed to nest flooding • For exposed species, total brood counts generally appeared to steadily increase during the summer in the year with minimal nest flooding threat • In years of intermediate nest flooding potential, brood counts increased late in the year • In years of extreme nest flooding potential, brood counts did not increase during the year • Other patterns were evident for non-exposed species. • The complexity indicates that more data are warranted before statistical tests should be applied (n = 5 years), although the relationships are strong and tight enough to allow statistical significance with the existing data. • The data now indicate potential that Ospreys may be highly sensitive to reservoir operations. • Shore-eared Owls, when nesting are highly exposed to being impacted by reservoir operations.

Objectives 3-5	Management Questions	Management Hypotheses	Year 6 Status Summary Points
Examine how variation in flow and reservoir water elevations influence seasonal and yearly abundance, distribution, and habitat use of waterbirds and migratory shorebirds and the productivity of waterbirds in Revelstoke Reach	8) Can minor adjustments be made to reservoir operations to minimize the impact on migrating waterbirds and shorebirds or on waterbird productivity?	H1E Reservoir operations do not result in a decrease in shorebird foraging habitat in the drawdown zone. H2: Annual variation in reservoir water levels, reservoir operations, the implementation of soft constraints, and the potential impact from Rev 5, do not result in a reduction or degradation of waterbird or shorebird habitats.	• Currently, this MQ can only be addressed by examining patterns of usage and distribution • Due to time constraints, there was no formal analysis specifically to address this MQ, although results presented for MQ-6 have high relevance • Graphical examination of waterbird and shorebird abundance indicated that some high use sites are negatively impacted by increasing water elevations. This result was also mirrored by models indicating probability of usage at wetland sites by waterfowl decreasing with water depth (see aerial waterfowl analysis (see Fig. 9). • Formal models relating usage at specific sites to depth of inundation will allow this question to be addressed fully. • Current results suggest that there are well-used sites that are selected even at relatively high water elevations (e.g., Wigwam flats for shorebirds and Airport Marsh for waterfowl); as such, there may be less need to make fine adjustments unless the reservoir is near full pool. If true this simplifies the problem considerably. • Our data cannot easily assess the relative quality of habitat. It is possible that crowding at certain sites at high elevations indicate high usage at a poor site which is the only remaining option available to the birds. Currently we do not have a means for assessing this possibility. One option is that foraging rates are assessed at these wetlands to assess how habitat quality is impacted by reservoir elevation.
Inform how physical works and revegetation can be designed to mitigate adverse impacts to waterbirds and shorebirds resulting from reservoir operations	9) Can physical works be designed to mitigate any adverse impacts on migrating waterbirds and shorebirds or on waterbird productivity resulting from reservoir operations?	N/A	• It is likely that construction of wetlands for waterfowl and wetlands for shorebirds positioned near or above the full pool elevation can be pursued, and that these would have a high probability of success. • Possible sites for waterfowl and/or shorebird habitat enhancements can be found at 12 Mile, McKay Creek and Catherwood. • Currently a WPW projects is being considered at Cartier Bay. Our results show that Cartier Bay is adversely affected by reservoir operations, but this WPW can only provide minor mitigation. We do not recommend this project proceed given that it is unpredictable how habitat quality of this, the single most important site for migrant waterfowl (low benefit vs. high risk).
Assess the effectiveness of physical works and revegetation at enhancing habitat for waterbirds and shorebirds	10) Does revegetating the drawdown zone affect the availability and use of habitat and its use by shorebirds or waterbirds in Revelstoke Reach?	H3: Revegetation and wildlife physical works do not increase the utilization of habitats by birds in Revelstoke Reach. H3A: Revegetation and wildlife physical works do not increase the species diversity or abundance of shorebird or waterbirds in Revelstoke Reach. H3B: Revegetation and wildlife physical works do not increase the productivity of waterbirds in Revelstoke Reach. H3D: Revegetation and wildlife physical works do not increase the amount of shorebird or waterbird habitat in Revelstoke Reach.	• Assessing impacts of planting terrestrial vegetation for waterfowl and shorebirds is challenging, and of questionable value. • It is possible that terrestrial revegetation could create nesting habitat for waterfowl, but this is not something being monitored by CLBMON-40 • The only obviously successful revegetation treatments were cottonwood stakes, which were planted at high elevations and are also challenging to monitor during high water levels.
	11) Do wildlife physical works projects implemented during the course of this monitoring program affect waterbird and shorebird abundance, and/or diversity, or waterbird productivity?		• WPW6A is the only project completed to date. • WPW6A prevents erosion caused naturally by spring snow melt, and does not mitigate adverse impacts of reservoir operations. • WPW6A protects Airport Marsh, which is a very important site for waterbirds. • If WPW6A is successful in preventing erosion, it will have been effective (CLBMON 40 does not monitor erosion rates).

Appendix 6-2: Total numbers of waterbirds observed during land-based waterbird surveys during the spring, summer (brood counts) and fall monitoring periods

Spring migration

Common Name	Scientific Name	Total
Common Loon	*Gavia immer*	15
Pied-billed Grebe	*Podilymbus podiceps*	15
Unidentified Swan	*Cygnus sp*	10
Snow Goose	*Chen caerulescens*	27
Canada Goose	*Branta canadensis*	1947
Wood Duck	*Aix sponsa*	5
Gadwall	*Anas strepera*	20
Eurasian Wigeon	*Anas penelope*	4
American Wigeon	*Anas americana*	1052
Mallard	*Anas platyrhynchos*	900
Blue-winged Teal	*Anas discors*	10
Cinnamon Teal	*Anas cyanoptera*	11
Northern Shoveler	*Anas clypeata*	62
Northern Pintail	*Anas acuta*	13
Green-winged Teal	*Anas crecca*	243
Redhead	*Aythya americana*	3
Ring-necked Duck	*Aythya collaris*	306
Lesser Scaup	*Aythya affinis*	8
Scaup Sp	*Aythya sp*	52
Bufflehead	*Bucephala albeola*	113
Common Goldeneye	*Bucephala clangula*	47
Barrow's Goldeneye	*Bucephala islandica*	5
Goldeneye Sp	*Bucephala sp*	43
Hooded Merganser	*Lophodytes cucullatus*	1
Common Merganser	*Mergus merganser*	218
Ruddy Duck	*Oxyura jamaicensis*	6
Unidentified Duck	*Anatinae (gen, sp)*	239
American Coot	*Fulica americana*	254
Total		5629

Brood surveys (adults only)

Common Name	Scientific Name	Total
Common Loon	*Gavia immer*	23
Pied-billed Grebe	*Podilymbus podiceps*	18
Canada Goose	*Branta canadensis*	836
Wood Duck	*Aix sponsa*	5
American Wigeon	*Anas americana*	31
Mallard	*Anas platyrhynchos*	68
Cinnamon Teal	*Anas cyanoptera*	1
Ring-necked Duck	*Aythya collaris*	5
Bufflehead	*Bucephala albeola*	5
Hooded Merganser	*Lophodytes cucullatus*	1
Common Merganser	*Mergus merganser*	12
Unidentified Duck	Anatinae (gen, sp)	3
Total		1008

Fall migration

Common Name	Scientific Name	Total
Common Loon	*Gavia immer*	12
Pied-billed Grebe	*Podilymbus podiceps*	41
Western Grebe	*Aechmophorus occidentalis*	35
Double-crested Cormorant	*Phalacrocorax auritus*	1
Unidentified Swan	*Cygnus sp*	1
Canada Goose	*Branta canadensis*	2864
Wood Duck	*Aix sponsa*	3
American Wigeon	*Anas americana*	1585
Mallard	*Anas platyrhynchos*	719
Blue-winged Teal	*Anas discors*	112
Northern Shoveler	*Anas clypeata*	33
Northern Pintail	*Anas acuta*	17
Green-winged Teal	*Anas crecca*	153
Unidentified Teal	*Anas sp*	10
Ring-necked Duck	*Aythya collaris*	33
Scaup Sp	*Aythya sp*	3
Bufflehead	*Bucephala albeola*	1
Hooded Merganser	*Lophodytes cucullatus*	20
Ruddy Duck	*Oxyura jamaicensis*	1
Unidentified Duck	Anatinae (gen, sp)	67
American Coot	*Fulica americana*	83
Total		5794

Appendix 6-3: Total numbers of waterbirds observed during aerial waterfowl surveys during the spring and fall monitoring periods

Spring migration

Common Name	Scientific Name	2013-03-19	2013-03-27	2013-04-03
Unidentified Grebe	Podicepedidae (gen, sp)	0	3	2
Unidentified Swan	*Cygnus sp*	18	32	6
Canada Goose	*Branta canadensis*	383	388	317
American Wigeon	*Anas americana*	32	22	310
Mallard	*Anas platyrhynchos*	242	311	399
Unidentified Teal	*Anas sp*	0	0	25
Northern Pintail	*Anas acuta*	0	9	10
Green-winged Teal	*Anas crecca*	0	17	96
Unidentified Teal	*Anas sp*	10	0	0
Redhead	*Aythya americana*	0	0	1
Ring-necked Duck	*Aythya collaris*	7	1	146
Scaup Sp	*Aythya sp*	0	0	12
Bufflehead	*Bucephala albeola*	6	46	45
Common Goldeneye	*Bucephala clangula*	4	0	0
Goldeneye Sp	*Bucephala sp*	36	40	6
Hooded Merganser	*Lophodytes cucullatus*	0	1	0
Common Merganser	*Mergus merganser*	89	62	92
Unidentified Duck	Anatinae (gen, sp)	12	316	238
American Coot	*Fulica americana*	0	1	3
Total		839	1249	1708

Fall migration

Common Name	Scientific Name	2013-09-12	2013-09-18	2013-09-24	2013-10-04	2013-10-15	2013-10-25
Common Loon	*Gavia immer*	0	2	2	2	1	11
Western Grebe	*Aechmophorus occidentalis*	0	0	0	0	0	2
Unidentified Grebe	Podicepedidae (gen, sp)	0	20	0	0	0	0
Unidentified Swan	*Cygnus sp*	0	0	1	0	0	0
Snow Goose	*Chen caerulescens*	0	0	0	1	0	0
Canada Goose	*Branta canadensis*	1096	809	1039	1280	987	558
American Wigeon	*Anas americana*	0	5	26	544	274	259
Mallard	*Anas platyrhynchos*	88	138	52	106	160	139
Blue-winged Teal	*Anas discors*	0	0	10	0	4	0
Unidentified Teal	*Anas sp*	0	25	0	58	0	37
Northern Pintail	*Anas acuta*	0	0	0	0	2	0
Unidentified Teal	*Anas sp*	10	0	31	0	25	0
Ring-necked Duck	*Aythya collaris*	0	0	5	0	0	4
Bufflehead	*Bucephala albeola*	0	0	0	0	0	8
Goldeneye Sp	*Bucephala sp*	0	0	0	0	0	2
Hooded Merganser	*Lophodytes cucullatus*	12	5	16	22	29	15
Common Merganser	*Mergus merganser*	1	42	9	28	20	22
Unidentified Duck	Anatinae (gen, sp)	257	679	685	126	146	111
American Coot	*Fulica americana*	12	72	15	1	8	0
Total		1476	1797	1891	2168	1656	1168

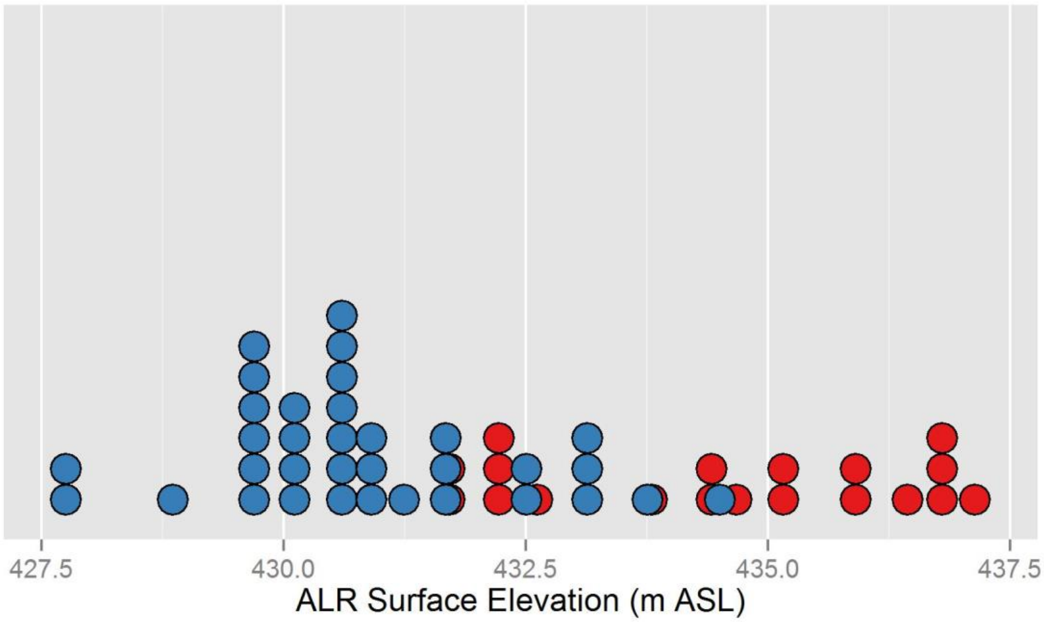
Appendix 6-4: Total numbers of shorebirds recorded during the fall migration in Revelstoke Reach, from mid-July until the end of September

Common Name	Scientific Name	Survey Type	12/07/2013	16/07/2013	23/07/2013	26/07/2013	01/08/2013	08/08/2013	13/08/2013	14/08/2013	21/08/2013	27/08/2013	29/08/2013	04/09/2013	05/09/2013	10/09/2013	11/09/2013	16/09/2013	25/09/2013	31/10/2013
Killdeer	*Charadrius vociferus*	lbsb		5	4															
Spotted Sandpiper	*Actitis macularius*		4	4	3		3	2												
Solitary Sandpiper	*Tringa solitaria*						1		3		2			1						
Greater Yellowlegs	*Tringa melanoleuca*							3						4						
Lesser Yellowlegs	*Tringa flavipes*			1			2										5			
Semipalmated Sandpiper	*Calidris pusilla*			10			1													
Least Sandpiper	*Calidris minutilla*										4									
Spotted Sandpiper	*Actitis macularius*	bbsb				23				37	27	15			12	8				
Lesser Yellowlegs	*Tringa flavipes*											1								
Semipalmated Sandpiper	*Calidris pusilla*					1														
Total			4	20	7	24	7	5	3	37	33	16	0	5	12	8	5	0	0	0

Appendix 6-5: Variability in the number and diversity of shorebirds recorded at each shorebird site during weeks when both boat and land-based sampling was conducted

In Drawdown Zone?	Type of Survey	Site	Total Number Detected	No. Species	No. of Observation Stations
No	Land-based	SB01	4	1	1
		SB02	1	1	1
		SB03	0	0	1
Yes	Land-based	SB04	0	0	1
		SB05	0	0	1
		SB06	4	1	3
		SB07	0	0	1
		SB08	0	0	1
		SB09	0	0	1
		SB10	0	0	1
		SB11	7	2	3
		SB13	10	3	2
		SB14	0	0	1
Yes	Boat-based	SB12	6	1	2
		SB15	17	1	3
		SB16	0	0	1
		SB17	26	1	10
		SB18	31	2	6
		SB19	8	2	5
		SB20	0	0	1
		SB21	0	0	1
		SB22	0	0	1
		SB23	2	1	1
		SB24	2	1	1
		SB25	0	0	1
		SB26	4	1	1
		SB27	0	0	1
		SB28	2	1	1
		SB29	3	1	1
		SB30	3	1	1
		SB31	8	1	1
		SB32	0	0	1
		SB33	1	1	1
		SB34	6	1	1
		SB35	0	0	1
		SB36	5	1	3
		SB37	0	0	2

Appendix 6-6: A display of the aerial waterbird surveys completed to date and the corresponding ALR reservoir elevation. Spring surveys are shown in blue whereas fall surveys are shown in red


427.5
430.0
432.5
435.0
437.5
ALR Surface Elevation (m ASL)