Columbia River Project Water Use Plan

Arrow Lakes Reservoir Operations Management Plan

Arrow Lakes Reservoir Shorebird and Waterbird Monitoring Program

Year 10

Study Period: March, 2017 – November, 2017

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

May 31, 2018

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

Year 10, 2017

Prepared for

BC Hydro
Water Licence Requirements
Burnaby, British Columbia

Prepared by

Ryan Gill & John M. Cooper
Cooper Beauchesne and Associates Ltd.
Head Office
1250 Winchester Road
Qualicum Beach, BC V9K 1W9
Tel: 250 954-1822
Contact: John Cooper
jcooper@cooperbeauchesne.com

January 30, 2018

syilx Okanagan Nation Alliance

Suggested Citation:

Gill, R., J.M. Cooper, and S. Beauchesne. 2018. CLBMON-40: Arrow Lakes Reservoir Shorebird and Waterbird Monitoring Program. Annual Report – Year 10, 2018. Unpublished report for BC Hydro Generation, Water Licence Requirements, Burnaby, BC. 41 pp. + Apps.

Cover photo: The Airport marsh of the Arrow Lakes Reservoir, in October 2017 (R. Gill photo).

EXECUTIVE SUMMARY

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

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

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

Waterfowl were monitored annually in spring and/or fall at two scales. Aerial surveys were used to monitor the distribution of waterfowl over the entire study area. Weekly land-based surveys focussed on individual wetlands, and monitored temporal changes to abundance, details of species composition, and mapped distributions within the wetlands. The productivity of four wetland raptor species (Bald Eagle, Osprey, Short-eared Owl, and Northern Harrier), and of waterbirds with precocial young (loons, grebes, waterfowl) was monitored using nest monitoring and/or brood count surveys. Additionally, in 2017 revisions to the habitat mapping were made through ground-truthing, as well as compiling vegetation species list for each habitat category.

Wetlands retained ice well into April in 2017, longer than in most previous years during the study. With wetlands frozen during the peak of migration, it is likely migrating waterfowl passed over habitat in the Revelstoke Reach, or used open water habitat not monitored during spring migration. Cool temperatures and precipitation characterized spring and early summer, bolstering the input to the Arrow Lakes reservoir. The hydrograph rose sharply through May and June, peaking below full pool, but maintaining a high level for a longer period than in previous years. The aggressive filling likely suppressed waterfowl productivity in 2017, with much of the drawdown zone habitat inundated by mid-June – peak breeding season. As in previous years, five species of waterfowl were seen with broods: Canada Goose, Mallard, American Wigeon, Wood Duck and Common Merganser. Short-eared Owl and Northern Harrier were not known to breed in 2017, and observations were lower than in previous years.

Bald Eagle and Osprey productivity was low in 2017, with only two Bald Eagle nests, and one Osprey nest producing young. A severe windstorm in late July had catastrophic effects on many Osprey nests, and, as in 2014, accounted for nest failures.

Fall monitoring of waterfowl migration occurred between September and the end of October in 2017. Migration appeared to peak prior to the beginning of surveys which may have been a reflection of the widespread forest fires across the Fraser plateau. Only one aerial waterfowl survey was conducted in the fall of 2017, timed to capture migration at its predicted maximum.

In 2017, ground-truthing of the habitat map was pursued with limited results. Persistent high water, and limited access due to road closures made accessing a wide array of polygons difficult. Polygons which were ground-truthed showed a 67% accuracy rate for the desktop mapping exercise. Vegetation species composition was also compiled for each habitat category, and is included in an appendix to this report.

Year 10 marks the final year of study for CLBMON-40, and as such limited multi-year analysis was conducted in this report. Comprehensive reporting will occur in the 10 year synthesis. No further recommendations are made in this report.

KEYWORDS

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

ACKNOWLEDGEMENTS

Many people have contributed greatly to the completion of Year 10 of the CLBMON-40 project. BC Hydro Water Licence Requirements sponsored the project. We thank Trish Joyce (BC Hydro), Harry van Oort (BC Hydro) and Susan Pinkus (BC Hydro) for their management and support for this project.

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

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

Ryan Gill picked up the reins on analysis and reporting from Harry van Oort, who led this project for the past 9 years. Without Harry laying the groundwork this last year would have been far more challenging. Additionally, Ryan Gill provided GIS mapping for this report and conducted the mapping revision.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

1 INTRODUCTION

The Columbia River is one of the most modified rivers systems in North America (Nilsson et al. 2005); its flow is regulated by multiple hydroelectric dams and water storage reservoirs. Water storage reservoirs positioned in succession along the main stem of the Columbia River in British Columbia include the Kinbasket Reservoir (Mica Dam, 1973), Lake Revelstoke (Revelstoke Dam, 1984) and Arrow Lakes Reservoir (Hugh Keenleyside Dam, 1968). Following the completion of these projects, few areas of natural riparian habitats and wetlands remained[1]. The footprint areas of these reservoirs have removed or altered much of the valley-bottom habitat, and their drawdown zones are typically comprised of steep shorelines (Enns et al. 2007, Utzig and Schmidt 2011). In the upper elevations of the drawdown zones, the growth of riparian and wetland vegetation is possible, but such habitats are uncommon (Enns et al. 2012, M.T. Miller et al. 2015).

At the north end of the Arrow Lakes Reservoir (ALR), Revelstoke Reach (Figure 1-1) provides a relatively high concentration of productive wetland habitat, including a reservoir-altered bog, an extensive and diverse cattail/bulrush marsh, and several ponds. The rarity of such habitats[1] in the landscape makes Revelstoke Reach an area of great regional importance for wetland wildlife (Tremblay 1993, Jarvis and Woods 2001, CBA 2013, CBA 2013a, CBA 2013b). In addition to these natural, and modified habitats, extensive revegetation efforts have been undertaken in the Upper Arrow Lakes beginning with reed canarygrass for erosion control, and continuing today with sedge plugs and shrub staking (Moody 2005, Keefer and Moody 2010, Kellner and Bird 2017)

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

Through this consultative process, the operation of ALR was identified as having a potential impact to the availability and quality of habitat in Revelstoke Reach for waterbirds (e.g., loons, grebes, waterfowl, raptors, and shorebirds). Prior to this study, how reservoir operations influence waterbird use of the ALR drawdown zone had not previously been studied in detail, and the relationship between reservoir operations and habitat quality was poorly understood. In general, habitat quality for waterbirds can vary greatly as a direct function of a reservoir's water elevations. Vegetation cover and foraging substrates may be exposed or submerged, and fluctuating water depth may affect foraging resource quality and distribution of waterbirds (Rundle and Fredrickson 1981, Parsons 2002, Baschuk, Koper, Wrubleski, and Goldsborough 2012). Although there are few studies available, some reservoir operations have been shown to change the annual cycle of vegetation growth and affect migrant/winter waterfowl populations (e.g. Guan et al. 2014); changes to reservoir operations can positively affect the quality of food resources available to waterfowl (e.g., (Guan et al. 2016)).

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[1] It has been estimated that 7,700 ha of wetland habitat have been impounded in the Canadian portion of the Columbia basin (Utzig and Schmidt 2011). The wetlands in Revelstoke Reach are the only significant wetland habitats between Valemount and Castlegar, an approximate linear distance of 400 km of valley bottom that was impounded in this region. An additional 100 km of valley-bottom habitat was flooded between Mica and Donald along Columbia Reach of Kinbasket Reservoir.

While the synthesis of the long-term dataset will occur after the tenth and final year of this project, we have greatly increased our understanding of the impacts of reservoir operations on waterbirds over the last nine years, as documented in the annual reports. Years 1-5 saw a steady cohesion of methods and an evolution of some of the MQ's and hypotheses. The Year 5 summary report set the stage for many of the analyses to be completed in Year 10, and Years 6-10 have bolstered the already rigorous dataset. From annual analysis and reporting we have gained a better understanding of the impacts of reservoir operations, some of which are:

- The importance of low elevation wetlands as stopovers for migratory waterfowl, despite these wetlands only functioning effectively when they are not inundated;
- Osprey productivity appears to be influenced by (among other factors) higher reservoir levels, which may affect their ability to provision for their young;
- Shorebird migration patterns are unpredictable at a local scale, varying in diversity and abundance annually.
- Despite a smaller than desirable dataset, reservoir operations have been shown to have a strong biological effect on Short-eared Owl productivity, likely through the effect on vole populations. While this warrants further study to bolster the statistical results, we are able to answer the MQ's for this species.

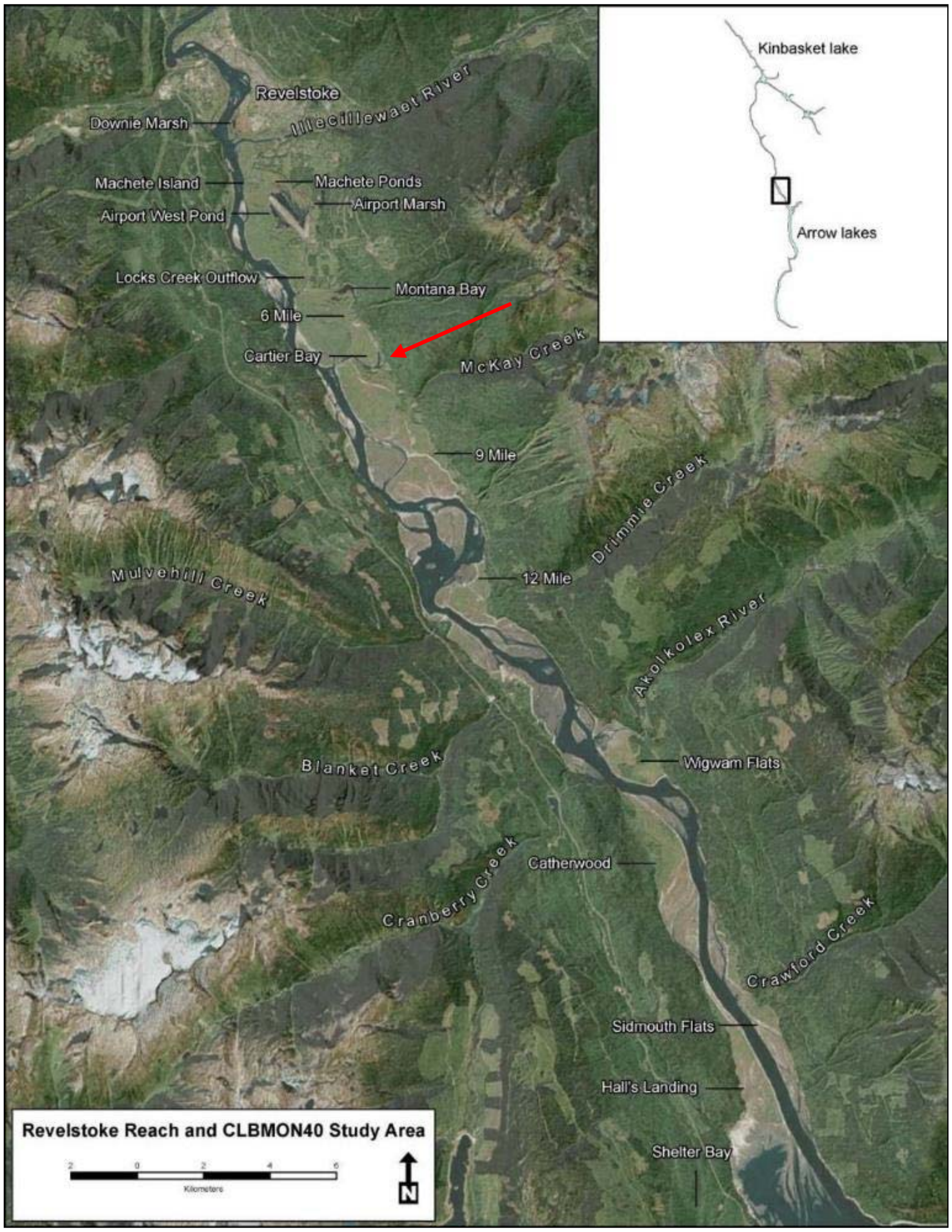

Figure 1-1: **Overview map of Revelstoke Reach, with geographic features labelled. Note that this image shows the reservoir at very low levels; at full pool conditions, most of the valley bottom in this map becomes flooded. The red arrow points to Gawiuk Point where a Short-eared Owl nested in 2016.**

1.1 Scope and objectives

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

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

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

1.2 Management questions

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

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

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

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

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

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

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

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

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

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

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

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

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

1.3 Management hypotheses

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

This report includes results from the spring, summer and fall of Year 10 (2017).

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

1.4 Study area

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

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

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

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

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

1.5 Arrow Lakes Reservoir operations

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

2 METHODS

A brief description of the methods used for CLBMON-40 is described below. Comprehensive methods are provided in an annual protocol report written primarily for field technicians (Gill et al. 2017).

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

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

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[4] In 2017 shorebird surveys were removed from the program, and these efforts were replaced with ground-truthing the habitat mapping. Data collected over the previous nine years is deemed sufficient to address the MQ's relating to shorebird use of the reservoir.

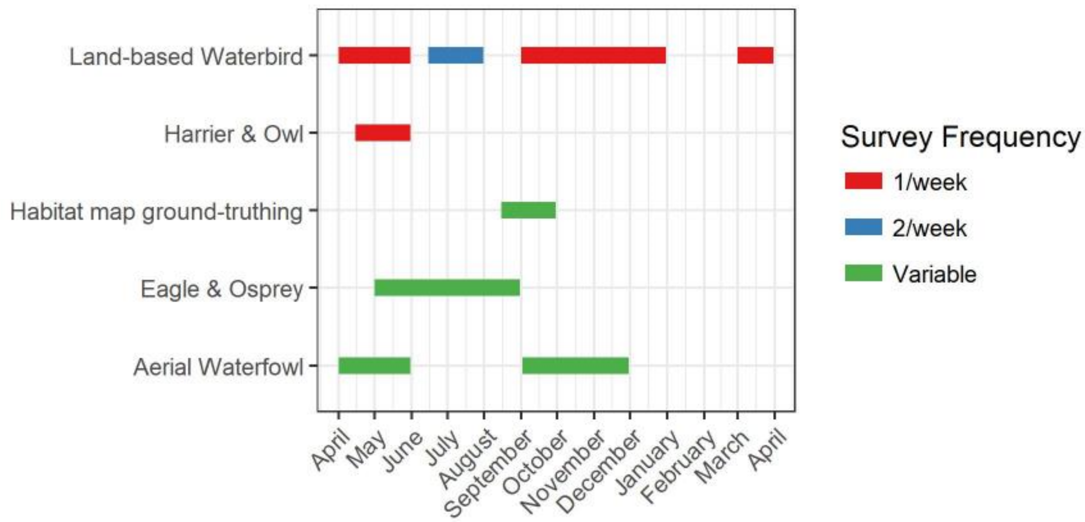

Figure 2-1: **Overview of how the CLBMON-40 monitoring surveys are scheduled. In 2017 the effort previously dedicated to shorebird surveys was used to ground-truth the habitat mapping of the Revelstoke reach.**

2.1 Land-based waterbird surveys

Land-based surveys monitor seasonal and spatial usage of waterbirds within the most important wetlands (Figure 2-2).[5] Weekly land-based waterbird surveys began on April 7 and continued until the end of May. Fall surveys began on September 9 and were conducted until October 31st in 2017. In previous years, weekly surveys also took place in November through March but very few observations were made during these winter months, so this practice was discontinued. Waterfowl are the primary monitoring target for these surveys, but all waterbirds are monitored.

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

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

2.2 Aerial waterfowl surveys

Helicopter-based aerial waterfowl surveys occurred opportunistically to capture data when migration intensity was high, and to build a database of distributions over a range of reservoir elevations (weather conditions permitting). All aerial surveys covered the entire study area. All observations of waterfowl were assigned to one of 129 habitat polygons. Aerial waterfowl surveys followed the methods outlined by the Resource Inventory Standards Committee (Resource Inventory Committee 1999). Two personnel were required for these surveys: one observer and one recorder. A Eurocopter Astar B2 helicopter was used. The observer was seated next to the pilot and navigated with the aid of an iPad loaded with Avenza PDF and custom maps showing the survey polygons. The observer made a complete count of waterfowl within the polygons. Waterfowl were identified to species when possible but were not sexed.

Over the course of CLBMON-40 study, gaps in the aerial waterfowl dataset have become fewer, and less significant; as in 2015, aerial surveys were only conducted when opportunities allowed data gaps to be filled (e.g., at reservoir elevations not previously observed). In 2017 only one aerial survey was conducted at what was predicted as peak migration in the fall. This data point serves only as an annual reference point. Intensive surveys in 2017 were deemed unnecessary as we have sufficient data from previous years.

2.3 Shorebird surveys

Shorebird surveys were not conducted in 2017 as the data from the previous nine years are deemed sufficient to answer management questions related to habitat use by shorebirds. The effort originally intended for shorebird surveys was put toward refining the habitat mapping with ground-truthing and species lists for habitat types. However, shorebird observations made during other surveys were recorded.

2.4 Habitat Map Ground-truthing and polygon vegetation composition

Ground-truthing of the habitat map initiated in 2012 was continued in 2017. Plots were stratified for their ease of access (those occurring north of 12 mile) and habitat category. A sub-selection of randomly chosen plots was visited to compare vegetation on the ground with the habitat category assigned during the desktop mapping. In the field, the surveyor was supplied with a GPS with the polygon ID and the mapped boundaries, but was blind to the original designation of the polygon. A list of habitat categories and their descriptions were also supplied to ensure consistency (Appendix 7-6).

A list of characteristic vegetation species was compiled for each mapped habitat category. Habitat characteristics for each mapped polygon were collected during ground-truthing. Additionally, for those mapped polygons for which we did not have sufficient ground-truthing data, we used vegetation composition data collected during the spring component of CLBMON-39 (CBA 2013b). In this instance, plots sampled for CLBMON-39 were only used if they fell completely within a mapped habitat category.

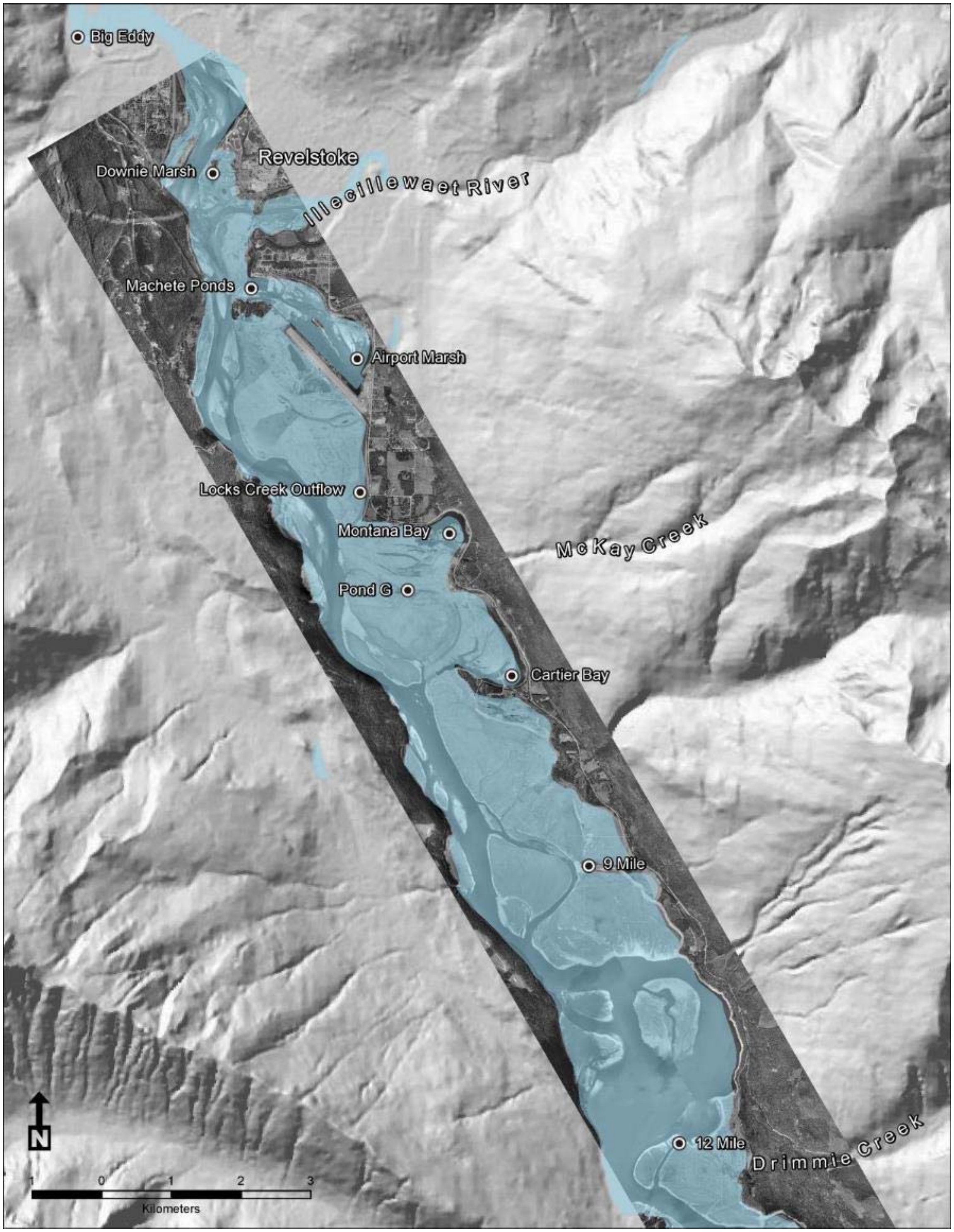

Figure 2-2: Locations of wetlands in Revelstoke Reach where land-based waterbird surveys and brood surveys were conducted are represented by points. Some of these wetlands were monitored by multiple fixed-observation stations.

2.5 Productivity monitoring of waterfowl

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

2.6 Productivity monitoring of Bald Eagle and Osprey

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

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

Nest monitoring for Bald Eagle and Osprey began on May 17 and occurred as helicopter and observers were available. Efforts were made to monitor nests during nesting stages when failure was more likely (early stages, notable weather events) and nearer the end of the nesting period to confirm fate of each nest. A total of five nest monitoring surveys were completed in 2017; these surveys were conducted every two weeks during June and though July. The final survey occurred on August 14.

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

2.7 Productivity monitoring of Short-eared Owl and Northern Harrier

Short-eared Owl and Northern Harrier may occasionally nest in the drawdown zone of Revelstoke Reach (Jarvis 2006; CBA 2013, 2017). We attempted to monitor productivity of these species by surveying the entire suitable part of the study area (i.e., all grasslands north of Drimmie Creek) divided into five monitoring regions. Each region was surveyed at least twice during the breeding season, where we spent a minimum of 30 minutes scanning for both species during each visit. Nesting activity of these species was unlikely to go unnoticed given other types of field work (bird nest searching and monitoring under CLBMON 36) occurring in the areas.

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

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

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

2.8 Analytical methods and multi-year analyses

All statistics, graphing and data manipulation were performed with R (R Core Team 2014). As this is the final year of the project, only one update to the multi-year analysis was completed. The Short-eared Owl analysis from 2016 was continued in 2017.

2.8.1 Short-eared Owl productivity

CBA has monitored Short-eared Owl nesting status under CLBMON-40 since 2008 (10 years). Additionally, there were two years prior to this project when the species was known to nest: 2001 and 2002. As such, there were 12 years for which we knew whether or not the species was nesting in the study area. In addition to examining nesting performance and the potential for the reservoir to flood nests, we wished to see what local conditions might affect nesting decisions. For each year of known nesting status, we compiled data on four possible predictor variables:

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

Each of these four inputs relate to the vole population in the drawdown zone and likely response of owls to these population changes. Short-eared Owl abundance is known to closely follow *microtine* populations (Lockie 1955, Village 1987); we therefore used factors affecting voles as predictors of the likelihood of owl presence in the spring.

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

2.9 Permits

No specific permits were required or obtained for this study.

3 RESULTS

3.1 Annual results

3.1.1 Water levels in Arrow Lakes Reservoir

The ALR reservoir operations were shifted slightly to the left of the normal hydrograph in 2017, but overall followed a historically average trend (Figure 3-1). Reservoir elevation rose sharply in March this year, counter to the historic trend of the hygrograph at this time, when the reservoir would normally be drafting. Reservoir elevations reached a minor peak in mid-March at 429.6 m asl before subsiding again to meet the upper quartile. From April through June, the reservoir rose more sharply than in most previous years, and sustained a higher level for longer. In late September, the reservoir began filling briefly before stabilizing at 435 m asl. The maximum elevation of 439.38 asl was reached on July 30.

3.1.2 Weather

Weather in 2017 was cooler and wetter than normal in the spring, followed by an unusually hot and dry summer and fall (Figure 3-2). Snow was mostly melted by the second week of April, while ice persisted until April 20th on all wetlands, later than most previous years (Figure 3-4). Precipitation in the spring was higher than normal, but at the beginning of July a long period of dry weather prevailed until the end of October (Figure 3-3).

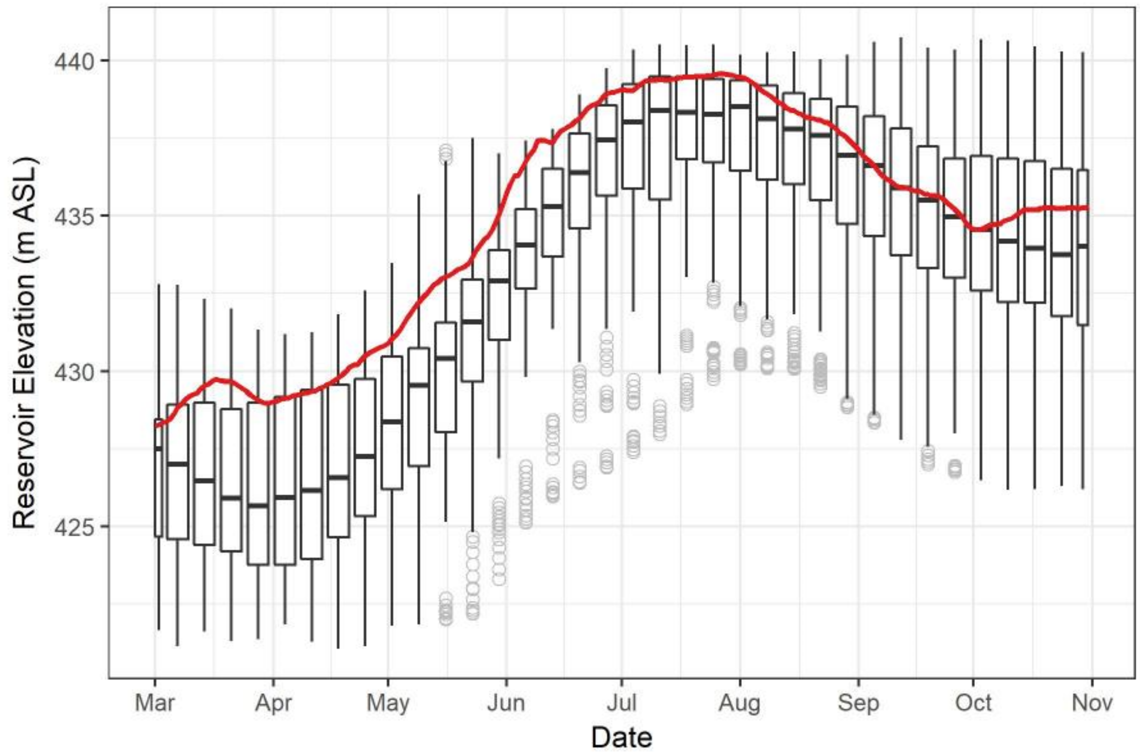

Figure 3-1: **Elevation of the Arrow Lakes Reservoir from March 1 to September 30, 2017 is plotted in red; the historical range of values is plotted in weekly intervals as boxplots.**

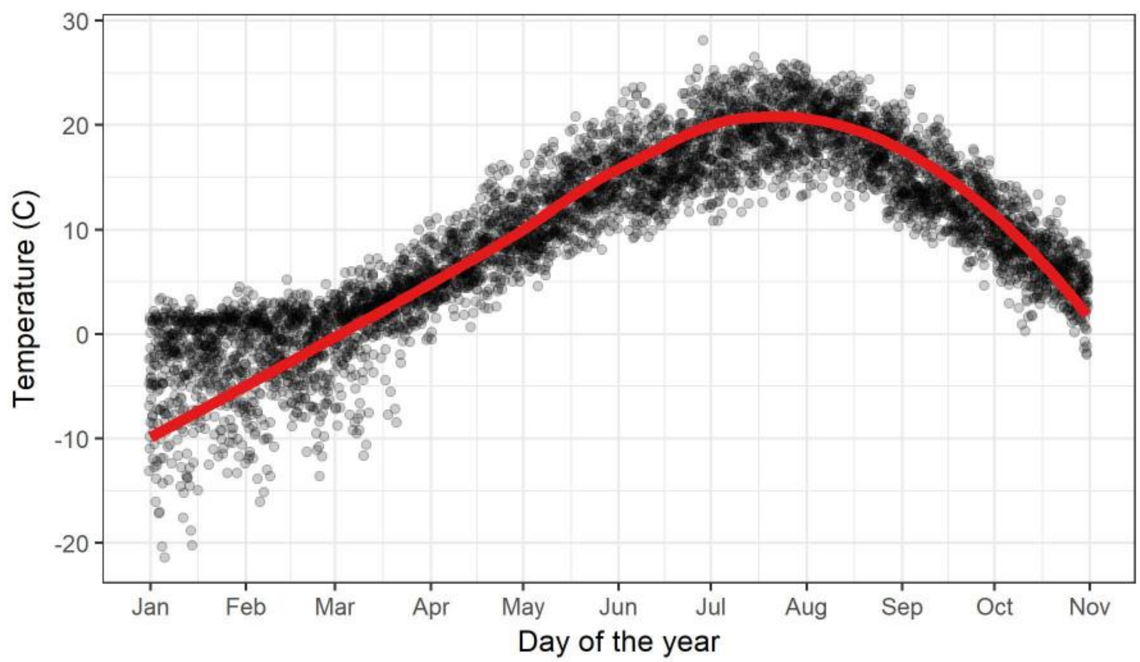

Figure 3-2: **Mean daily temperatures observed during the study. The 2017 data are illustrated by the red line.**

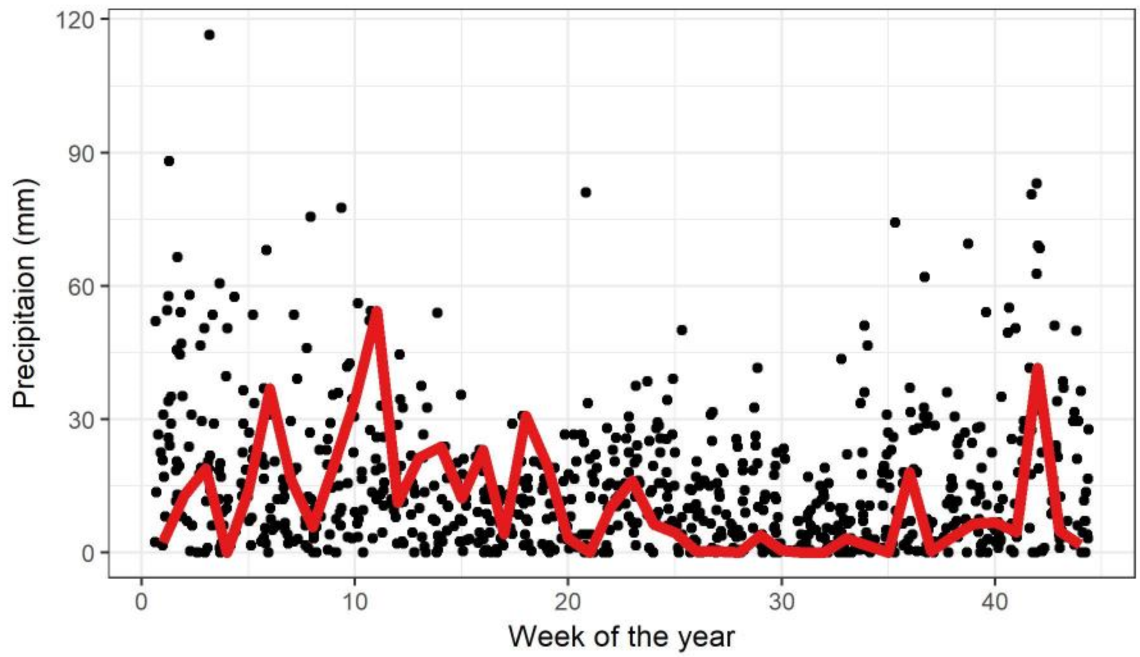

Figure 3-3: **Weekly precipitation observed during the study. Values recorded in 2017 are represented by the red line.**

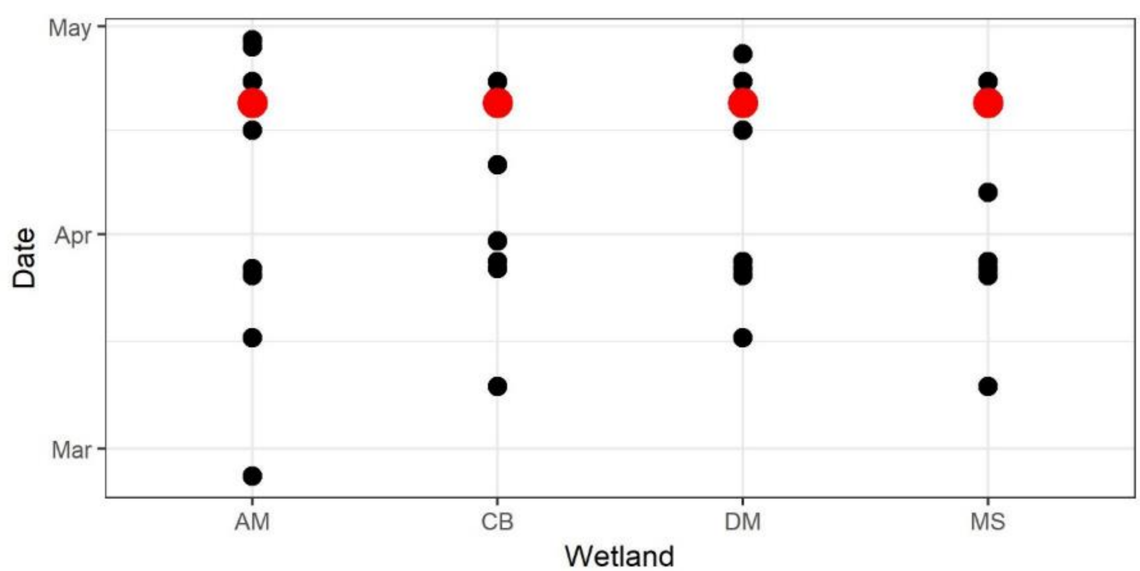

Figure 3-4: **Comparison of dates when the Airport Marsh (AM), Cartier Bay (CB), Downie Marsh (DM) and Montana Slough (MS) were first observed to be ice free during land-based waterbird surveys (2009 to present). Ice-free dates from 2017 are graphed as red points.**

3.1.3 Survey effort

In this report, we summarize work accomplished from March through October 2017 but data from other months and years may be included for illustrative purposes.

Nine land-based waterfowl surveys took place during the spring migration period (approximately March 31st – May 30th). During the brood rearing period, 12 surveys were conducted (June 15th – July 31st). During the fall migration period (September 1st – October 31st), 8 surveys were completed by the end of October.

We have abundant data for aerial waterfowl surveys, and in recent years the focus has been to fill data gaps with regards to surveys at different reservoir elevations. Only one aerial waterfowl survey was conducted in the fall, timed to occur roughly when peak migration was occurring.

Five surveys were conducted for monitoring Bald Eagle and Osprey productivity on May 17th, June 7th, June 30th, July 28th and August 14th. The earliest survey for Bald Eagles and Osprey was delayed in 2017 due to poor weather. Subsequent surveys were also limited by availability of personnel and weather. Surveys for Short-eared Owl and Northern Harrier nesting took place in the spring between April 21st and May 30th, on ten days.

Efforts historically put toward shorebird surveys were used in ground-truthing the habitat mapping initiated in 2012. In addition, this year we focused on compiling a plant species list for each of the habitat categories. Three days were dedicated to these surveys.

3.1.4 Spring and fall waterfowl migration

Ice on the main wetlands persisted until late April in 2017, so these habitats were not available to migrating waterfowl until after the inter-annual average peak spring migration had passed. Figure -3-5 illustrates the late start to our surveys, and where the initiation of our surveys fell during migration. Migration of dabbling ducks in the spring had a very slight peak, but was well below previous years. Migration of diving ducks showed a short, sharp peak within the normal range of previous migrations while Canada Goose migration was tailing off when spring surveys began. The Canada Goose migration appeared to be dropping steeply when we began surveys, suggesting a slightly higher than average spring peak. Fall migration was similar in intensity to previous years, but the peak appears to have occurred earlier in the season prior to fall surveys beginning. Diving ducks were less numerous in 2017, showing two very low peaks in September and October (Figure 3-6).

Species composition during 2017 was similar to previous years in the spring, with American Wigeon, Mallard and Canada Goose being the most commonly detected species. Fall migration saw American Coot arrive in large numbers to be the third most common species after Canada Goose and American Wigeon. A table of species detected during spring and fall migrations can be found in Appendix 7-2.

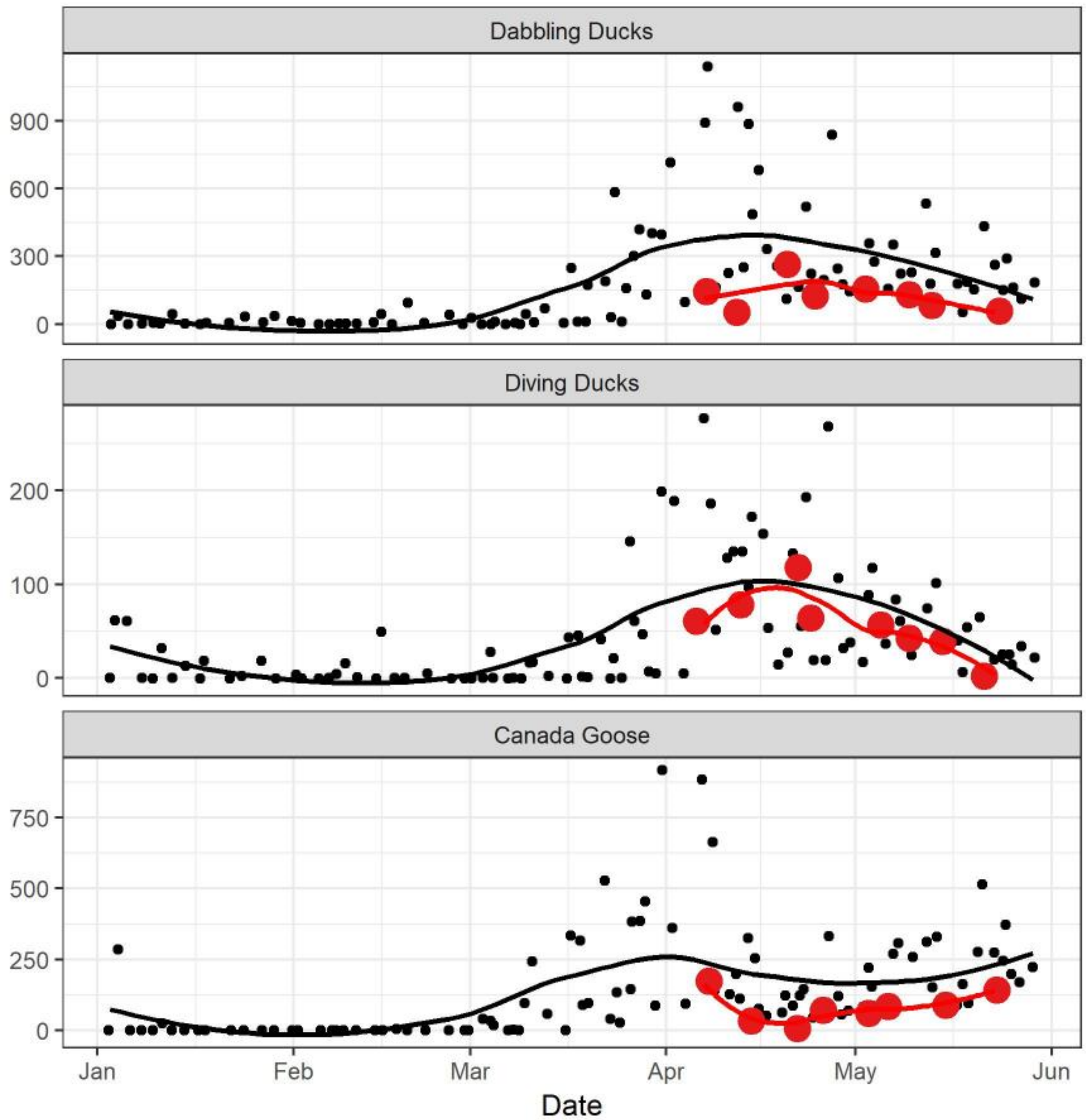

Figure -3-5: Spring 2017 waterfowl counts recorded at the wetlands monitored under the land-based waterbird survey (Downie Marsh, Airport Marsh, Locks Creek Outflow, Montana Slough, and Cartier Bay). Raw data points are plotted, with counts from the current year in red. A Loess smoother is fit to all data (black), and for the current year data (red) for illustrative purposes.

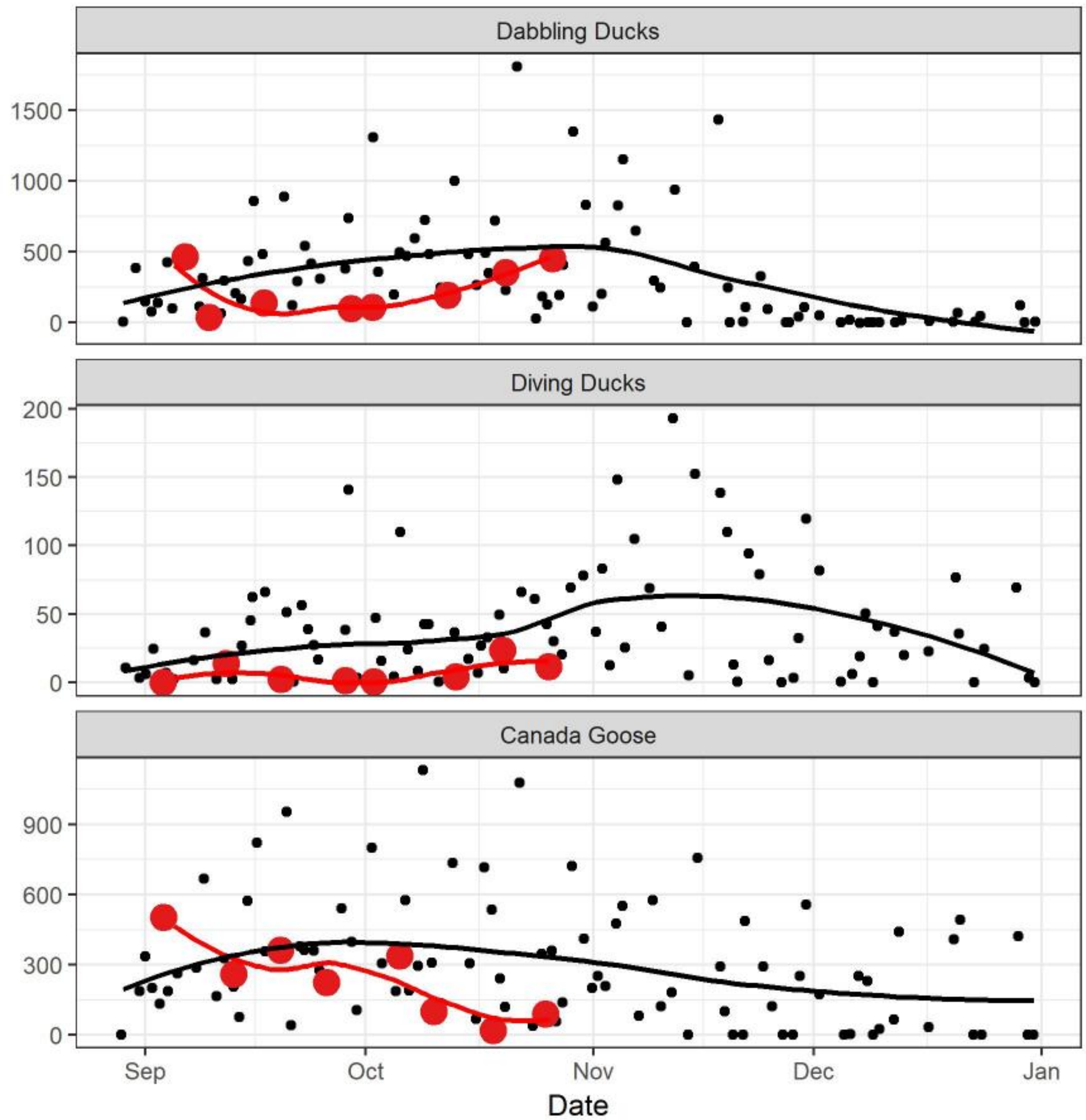

Figure 3-6: **Fall 2017 waterfowl counts recorded at the wetlands monitored under the land-based waterbird survey (Downie Marsh, Airport Marsh, Locks Creek Outflow, Montana Slough, and Cartier Bay). Raw data points are plotted, with counts from the current year in red. A Loess smoother is fit to all data (black), and for the current year data (red) for illustrative purposes.**

3.1.5 Waterfowl productivity

Five species were observed with broods: Canada Goose, Mallard, American Wigeon, Wood Duck and Common Merganser. Canada Goose broods were the most frequently observed, with broods detected on 10 surveys, and a maximum of 17 broods detected on one survey. Canada Goose were detected in all wetlands. Mallard and Wood Duck broods were detected on three surveys each. Two Wood Duck broods were detected on one survey indicating a minimum of two broods for this species. Mallard broods were also detected more than once in one wetland, as well as at wetlands distant from one another, suggesting at least three broods of this species. A single Common Merganser brood was detected three times in the same wetland and only one American Wigeon brood was detected on one survey.

Broods were recorded at Downie Marsh, Airport Marsh, Airport West pond, Locks Creek, Montana Bay and Cartier Bay.

3.1.6 Raptor productivity

3.1.6.1 Short-eared Owl

Short-eared Owls were only observed twice in May 2017. The first observation was made on May 10, a bird of unknown sex. Three weeks later, on May 30, two birds were seen foraging together. Subsequent visits to this area under CLBMON-36 revealed no new observations of birds. Because of the lack of detections, no focused nest searches were conducted in 2017.

3.1.6.2 Northern Harrier

Northern Harriers were detected throughout May of this year, however, only females were observed. The first bird was observed on May 4, and observations were made on each subsequent survey until the end of May. However, there was no evidence of breeding, or focused use. All observations were of foraging. Subsequent visits under CLBMON-36 did not indicate breeding was occurring.

3.1.6.3 Osprey

Of the nine Osprey nests monitored in 2017, only one was known to be successful. By the end of June, four nests had failed, and at the end of July four more had failed. Notably, at the end of July a violent windstorm passed through Revelstoke with sustained winds of 69 km/h and gusts to 96 km/h. A survey was completed just after this storm with many nests sustaining damage or losing contents (Figure 3-7). Several nests had adults attending empty nests, with one adult attending the remnants of a destroyed nest. As a matter of interest, several of the other inactive nests were checked on this survey to determine how nests fared. Of these inactive nests, five had been destroyed since they were first checked in May (Appendix 7-3).

Figure 3-7: Destroyed Osprey nest tree (center right) from violent July windstorm. This nest (nest 6) was a dependable and productive Osprey nest, fledging seven young over the past 10 years.

Only two Osprey nests remained active after July, one of which was never observed to have nestlings, but had adults attending at each visit. The other nest was noted to have large nestlings at the end of July; however, this nest was not visited again as it was the only remaining nest and was outside our core study area, in Beaton Arm.

3.1.6.4 Bald Eagle

No new Bald Eagle nests were found in 2017. Only five Bald Eagle nests were active and monitored in 2017, three of which failed early in the season, between the first two surveys (May 17 and June 7). One of these failed nests was found to be breaking down on the first visit when an adult was seen attending. The nest was marked as destroyed on the subsequent visit (but prior to the windstorm) when no birds and no useable nest structure remained (Appendix 7-3). A maximum total of three Bald Eagle juveniles fledged from two nests in 2017.

3.2 Habitat Mapping Ground-truthing and Species List

In 2015 we ground-truthed 78 polygons using stratified random sampling. Each of the mapped categories had three polygons selected for ground-truthing. In 2017, we built on this previous ground-truthing by sampling 18 new polygons, fewer than we had planned for. High water levels and restricted access limited our ability to examine all the sites we had planned for. Restricted vehicle access through the northern part of the study area limited our ability to move easily between sites, and reservoir levels made navigating the drawdown zone difficult. Consequently, most of the sites visited were closer to the edge of the reservoir or limited to areas where road access was not restricted.

Of the 18 polygons examined, 12 were assigned the same category in the field as they were mapped, for an accuracy of 67% (**Error! Reference source not found.**). Of the polygons assigned different values in the field, two were of habitat found along edges of the reservoir.

Combining results from 2015 (54 of 78 polygons accurately mapped), our overall mapping accuracy is 69%.

Table 3-1: Results of polygon ground-truthing. Of the polygons visited, six were classified differently on the ground from how they were mapped.

mapped category	ground-truthed category	result
UF	UF	same
UF	UF	same
MG	MG	same
SH	SH	same
RF	BE	different
RF	RF	same
SR	SH	different
SH	SH	same
SG	RC	different
SH	SH	same
MG	UF	different
PG	SG	different
RC	RC	same
PG	PG	same
SH	SH	same
SH	PG	different
MG	MG	same
MG	MG	same

A general vegetation species list for each mapped habitat category has also been compiled (Appendix 7-6). Plant species comprising the dominant vegetation for each category have been identified over the course of the project. However, this vegetation list isn't an exhaustive inventory of each species found in a mapped habitat category but captures the general vegetative and structural characteristics of the plot, with dominant species listed.

The detail of vegetation composition reflects the scale at which we elected to map habitat. This was not a vegetation inventory map, rather a broader view of the landscape from a largely structural perspective.

3.3 Multi-year analysis

3.3.1 Short-eared Owls in the ALR drawdown zone

In 2017 we recorded only two detections of Short-eared Owls using drawdown zone habitat in the spring. Neither of these detections indicated breeding was occurring, and the birds disappeared in early June.

The additional year of data had little effect on the results of the previous analysis, with the same model of maximum elevation of the reservoir in the previous year being the most predictive of owl nesting. The relationship between reservoir elevation and nesting probability is weakened slightly (slope = -0.76 in 2017, compared to -1.14 in 2016), but the P value is slightly stronger with the additional year ($P_{2016} = 0.16$, $P_{2017} = 0.14$) (Table 3-2).

There were 12 years where we knew if Short-eared Owls nested or not (2001, 2002, and 2008 through 2017). As with the previous year's analyses, nesting status was not significantly predicted by any of the predictor variables.

Table 3-2: Four univariate models to predict probability of Short-eared Owls nesting in the Arrow Lakes Reservoir. The first three related to winter conditions prior to spring migration (Snow = snowfall accumulation, MinTemp = lowest temperature recorded, AveTemp = average daily temperature), and MALR is maximum reservoir elevation during the previous year. All four variables could potentially affect the vole population and therefore modulate habitat attractiveness. AIC scores select MALR, which has the most dramatic effect size indicating a strong influence of reservoir operations on the probability of nesting.

Predictor	Slope	*P*	AICc	ΔAICc
Snow	-0.01	0.11	17.26	1.44
MinTemp	0.14	0.41	19.86	4.04
AveTemp	0.56	0.39	19.86	4.03
MALR	-0.76	0.14	15.82	0.00

4 DISCUSSION

4.1 Year 10

In the spring of 2017, snow and ice persisted later than in previous years, with wetland thaw not occurring until the third week in April. Cooler weather allowed snow cover to persist, and delayed green-up of vegetation. These conditions during spring migration may explain the diminished numbers of waterfowl recorded during migration. It is possible that with the frozen wetlands, waterfowl either passed over habitat in the Revelstoke Reach, or were selecting non-wetland, open water areas for resting. These open water channel habitats are not as influenced by reservoir operations, and they are of limited value to waterbirds during migration, as such, we do not monitor them on land-based surveys.

Reservoir levels in 2017 followed a familiar pattern, if slightly above average for any particular point during the spring inundation. Filling began early but settled into a historic pattern beginning in early April. While full pool was not achieved in 2017, a very high level was sustained for a longer period, with the reservoir being above 439m asl for 38 days. Habitat inundation happened at a similar rate to 2016, with rapid inundation of grasslands beginning in mid-May. Unlike 2016, however, in 2017 the water continued rising rapidly to inundate the shrub habitats within the drawdown zone by early June. This rapid inundation of habitat during the breeding season is reflected by the few ground-nesting waterfowl broods detected in 2017 (we assume most nests were flooded before eggs hatched).

Short-eared Owl and Northern Harrier observations in May were sparse, with only two observations made of owls during the breeding season. These few observations contradict the results of the univariate analysis conducted last year. Because Short-eared Owl presence is highly correlated with vole populations, and because there was a long period of low water beginning in the late summer of 2016, allowing voles to repopulate the drawdown zone, we anticipated a higher likelihood of owls breeding in 2017. In fact, we saw the opposite to be true, no owls were detected to be breeding in 2017. However, the second most suitable model (snow as a predictor of nesting) has a weak negative effect on the probability of nesting, and the winter of 2016/2017 had a higher cumulative snowfall than the two previous winters, and 37% more snow than in two of the winters previous to a known nesting year. While the observations of 2017 do not corroborate the analysis, we feel that in spite of few data, there is a biological effect of weather and reservoir conditions on predicting Short-eared Owl nesting which warrants continued investigation.

Bald Eagle and Osprey productivity was low in 2017, with a mid-summer windstorm supplanting any other weather or reservoir effects. Sustained winds destroyed many active and inactive nests in 2017 and thus we chose to not update the multi-year analysis with the data from Year 10.

During the fall migration Canada Geese and dabbling ducks were noted to have an early peak – evidently in mid-August, as Figure 3-6 illustrates - prior to fall surveys beginning. While the cause of this early peak is not known, it coincides with record numbers caught at the CLBMON-39 migratory bird banding station (Cooper Beauchesne and Associates Ltd (CBA) In prep.). While these two migratory events may not be related, it is possible that there was a common ecological driver behind them. Large fires burned across the Fraser plateau in 2017 during the breeding and fall migration seasons, and as the Tatlayoko Bird Observatory noted, fewer birds were caught there during migration than in any previous year (Cameron 2017). It is possible birds using habitats in these fire-affected regions underwent an early migration, and followed different migratory routes. A comparison of

4.2 Multi-year progress and new analysis

In anticipation of the comprehensive report, we are limiting our multi-year reporting for 2017. With the exception of discussing the Osprey productivity in 2017 in the context of what we have learned in previous years, and the addition of the final year to the Short-eared Owl analysis we have focussed efforts towards analysis in the comprehensive report.

4.3 Conclusions

This, the final year of CLBMON-40, shed little new light on conclusions drawn over the past 10 years. As would hope to be expected, data collected in 2017 contributed only incrementally to the knowledge gained over the past 10 years. While there are still unknowns with regards to how reservoir operations impact waterbirds, much of the knowledge gained over the course of this project has informed us sufficiently to make recommendations for operations beneficial to breeding and migratory waterbirds.

As this is the annual technical report, preceding the comprehensive 10-year review, we make no detailed conclusions, nor provide recommendations. A detailed summary of all components of this project will be provided in the final report.

5 ADDITIONAL REPORTING REQUIREMENTS

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

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7 APPENDICES

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

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

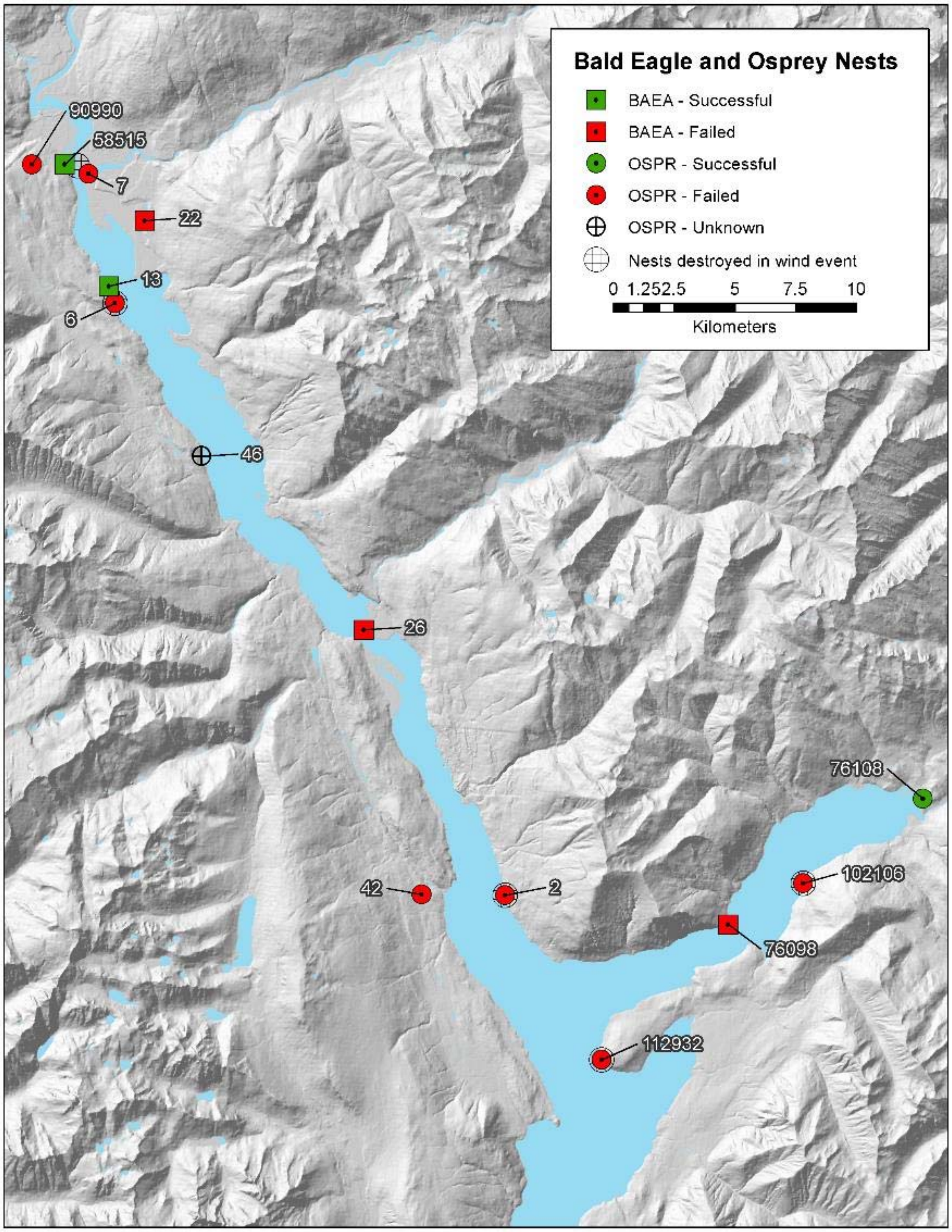
Objective 2	Management Questions	Management Hypotheses	Year 9 Status Summary Points
Inform BC Hydro on how reservoir operations affect waterbirds by monitoring their abundance, species richness, distribution, productivity, and patterns of habitat use over time.	2) What implication does the year-to-year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

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

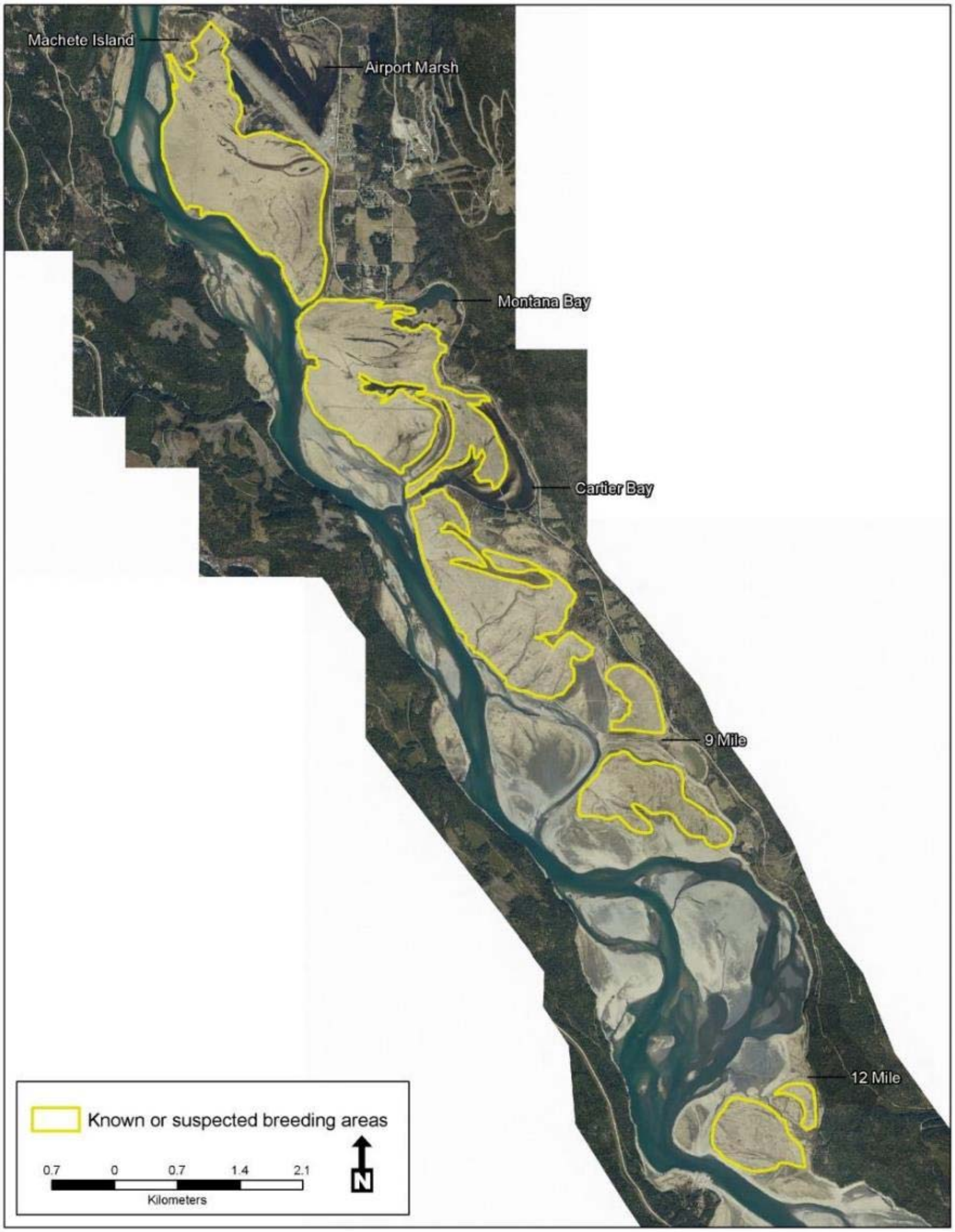
Appendix 7-2: Total numbers of waterbirds (adults and young) observed during land-based waterbird surveys in 2017

Common Name	Scientific Name	Spring	Brood	Fall
American Coot	*Fulica americana*	179	0	1442
American White Pelican	*Pelecanus erythrorhynchos*	2	0	0
American Wigeon	*Anas americana*	755	32	2100
Barrow's Goldeneye	*Bucephala islandica*	14	2	0
Blue-winged Teal	*Anas discors*	16	1	9
Bufflehead	*Bucephala albeola*	104	1	18
Canada Goose	*Branta canadensis*	732	770	2179
Canvasback	*Aythya valisineria*	5	0	0
Cinnamon Teal	*Anas cyanoptera*	12	1	0
Common Goldeneye	*Bucephala clangula*	21	1	1
Common Loon	*Gavia immer*	2	4	7
Common Merganser	*Mergus merganser*	285	43	22
Eurasian Wigeon	*Anas penelope*	2	0	0
Gadwall	*Anas strepera*	7	0	8
Goldeneye Sp	*Bucephala sp*	15	0	4
Green-winged Teal	*Anas crecca*	109	0	121
Hooded Merganser	*Lophodytes cucullatus*	42	0	25
Lesser Scaup	*Aythya affinis*	29	0	0
Mallard	*Anas platyrhynchos*	686	68	957
Northern Pintail	*Anas acuta*	18	0	25
Northern Shoveler	*Anas clypeata*	49	0	84
Pacific Loon	*Gavia pacifica*	0	0	3
Pied-billed Grebe	*Podilymbus podiceps*	7	2	25
Red-necked Grebe	*Podiceps grisegena*	6	0	4
Redhead	*Aythya americana*	1	0	0
Ring-necked Duck	*Aythya collaris*	247	2	86
Ruddy Duck	*Oxyura jamaicensis*	1	0	1
Scaup Sp	*Aythya sp*	14	0	4
Snow Goose	*Chen caerulescens*	1	0	5
Surf Scoter	*Melanitta perspicillata*	0	0	1
Trumpeter Swan	*Cygnus buccinator*	10	0	0
Unidentified Duck	*Anatinae (gen, sp)*	8	1	170
Unidentified Swan	*Cygnus sp*	21	0	0
Unidentified Teal	*Anas sp*	0	0	1
Western Grebe	*Aechmophorus occidentalis*	0	0	9
Wood Duck	*Aix sponsa*	9	29	123

Appendix 7-3: **Map of Bald Eagle and Osprey nests monitored in 2017. Nests destroyed during the windstorm in late July have a second, underlying symbol as indicated in the legend.**



Appendix 7-4: Map of Short-eared Owl habitat based on the author's professional opinion. These polygons were analyzed to describe habitat elevation distribution and habitat classification.



Appendix 7-5: Habitat classifications and their descriptions.

Strata	Category	Category Name	Description
Channel	TH	Channel	The Columbia River channel and gravel bars
Forest	RF	Riparian	Riparian forest with cottonwoods and shrubs, with variable conifer component.
Forest	UF	Upland forest	These habitats generally exist above the high water mark.
Grassland	EG	Equisetum grassland	Grasslands with a high amount of scouring rush
Grassland	MG	Mixed grassland	This is the default grassland category
Grassland	RC	Reed canarygrass	Grasslands dominated by thick reed canarygrass
Grassland	SG	Sedge grassland	Grasslands with a high sedge content
Grassland	PG	Sparse grassland	Grasslands with relatively sparse cover; often low elevation, just above unvegetated habitat
Shrub	SR	Riparian shrub	These habitats are found along creeks, and near the mouths of creeks on aluvial fans
Shrub	SH	Shrub savannah	Shrub-savannah with low shrubs of variable density.
Steep bank	SB	Sand bank	Steep sand banks; usually eroding, with variable amounts of vegetation
Unvegetated	CR	Coarse rocks	Loose rocks with low amounts of grass or shrub or tree cover
Unvegetated	GR	Gravel	Gravel habitat with low amounts of grass or shrub or tree cover
Unvegetated	RB	Rocky bank	Steep bank of loose rocks or talus with variable amounts of vegetation
Unvegetated	SA	Sand	Sand habitat with low amounts of grass or shrub or tree cover
Unvegetated	SI	Silt	Unvegetated low elevation habitat comprised of silt and other fine deposits
Unvegetated	BE	Steep bedrock	Steep bank of bedrock, with variable amounts of vegetation
Urban	UR	Urban	Residential or industrial areas including pavement
Wetland	BR	Bullrush	Marsh area with abundant patches of bulrush
Wetland	CT	Cattail	Marsh area with abundant cattail growth
Wetland	CK	Creek	Gravel/rocky creek channel or estuary
Wetland	BF	Floating bog	Floating peat bog that provides dry floating islands of habitat
Wetland	LD	Low elevation draw	Muddy/clay depression or channel with variable amount of sedge and or grass
Wetland	PO	Pond	Marsh or Pond with variable amount of submergent vegetation
Wetland	BS	Submerged buoyant bog	Peat bog that rises with water, but is still slightly submerged when flooded
Wetland	SW	Swamp	Rich complex swamp habitat with shrubs, beaver dams, and skunk cabbage

Wetland	WS	Water sedge	Marsh area with abundant sedge growth
Wetland	WM	Wet meadow	sedge, grass, seasonally flooded area with depressions

Appendix 7-6: Plant species list for each of the vegetated, mapped habitat categories.

Category	Dominant Species
RF	*Populus balsamifera, Pinus monticola, Thuja plicata, Picea glauca, Cornus stolonifera, Salix sp., Rosa woodsii, Lonicera involucrata, Rubus parviflorus, Spiraea douglasii*, forbs (many exotics), graminoids
UF	*Populus balsamifera, Populus tremuloides, Thuja plicata, Pseudotsuga menziesii, Pinus monticola, Pinus contorta, Paxistima myrsinites, Mahonia sp., Rubus sp., Galium sp., Lathyrus sp.,* mosses, lichens
EG	*Equisetum sp., Calamagrostis canadensis, Phalaris arundinacea, Carex sp.*
MG	*Calamagrostis canadensis, Phalaris arundinacea, Carex sp.*
RC	*Phalaris arundinacea*
SG	*Carex aperta, Carex aquatilis*
PG	*Phalaris arundinacea*
SR	*Salix sp.*, graminoids
SH	*Salix sp, Calamagrostis canadensis, Phalaris arundinacea, Carex sp.*
BE	mosses (predominantly rock)
BR	*Schoenoplectus tabernaemontani*
CT	*Typha latifolia*
BF	*Spiraea douglasii, Alnus sp., Pinus monticola, Betula papyrifera, Sorbus scopulina, Phalaris arundinacea, Carex sp., graminoids, Equisetum sp., Schoenoplectus tabernaemontani, sphagnum, Eriophorum sp., Betula occidentalis, Kalmia microphylla*
LD	*Phalaris arundinacea, Carex sp*., graminoids, forbs, *Equisetum sp.*
PO	*Potamogeton natans, Eleocharis palustris, Juncus balticus, Nuphar polysepala, Comarum palustre, Persicaria amphibia, Myriophyllum spicatum*
BS	sphagnum, graminoids, *Eriophorum sp., Kalmia microphylla*
SW	*Carex sp., reeds, rushes, Alnus sp., Salix sp., Cornus stolonifera, Lysichiton americanus, Spiraea douglasii, Typha latifolia,* emergent vegetation
WS	*Carex sp.*, graminoids
WM	Phalaris arundinacea, Carex aperta, Carex aquatilis, Carex lenticularis