Columbia River Project Water Use Plan

Lower Columbia River Fish Management Plan

Lower Columbia River Effects of Whitefish Flows on Great Blue Heron & Winter Use of Waldie by Great Blue Heron

Implementation Year 3

Reference: CLBMON-49

Final Report

Study Period: 2013-2016

Okanagan Nation Alliance, Westbank BC

and

LGL Limited environmental research associates
Sidney, BC

September 30, 2017

ARROW LAKES RESERVOIR

CLBMON-49 Lower Columbia River Effects on Wintering Great Blue Herons




CLBMON-49

Comprehensive Final

Final Report

Prepared for

BC Hydro Generation
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6911 Southpoint Drive
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From left to right: Great Blue Heron (*Ardea herodias*) in tree © Nathan T. Hentze, LGL Limited; Hugh Keenleyside Dam, Waldie Island, and Great Blue Heron track © Jeremy Gatten, LGL Limited

EXECUTIVE SUMMARY

This report summarizes the findings of BC Hydro's Monitoring Program CLBMON-49: *Lower Columbia River Effects on Wintering Great Blue Herons.* Small but variable numbers of Great Blue Heron (*Ardea herodias*) overwinter in the lower Columbia River and often congregate in the area around Waldie Island near Castlegar. Castlegar is about eight kilometers downstream of the Hugh Keenleyside Dam, which impounds the Columbia River to form Arrow Lakes Reservoir.

Concern about the impact of dam operations on herons during winter was triggered by the death of five herons in the vicinity of Waldie Island during January 2000. In the mid-1990s, BC Hydro had initiated a still-active program to stabilize river flows downstream of the dam in winter to minimize impacts on spawning success of Mountain Whitefish (*Prosopium williamsoni*). That program requires variable river flows prior to whitefish spawning, which corresponds with the beginning of the wintering period for Great Blue Heron. Higher flows for Mountain Whitefish during early winter may directly impact the abundance, density, distribution, and habitat use of herons on Waldie Island and the lower Columbia River.

The general approach for this study was, by necessity, opportunistic. BC Hydro could not alter flow rates and river elevations at specific times specifically to provide a controlled, experimental basis for this study. Rather, heron distribution and abundance, along with physicochemical and other habitat and environmental parameters were used to assess the pattern of heron use in the lower Columbia River. For comparative purposes, we expanded the study area during the final two winters to include surveys at a variety of sites throughout the Kootenays during the winter months. Surveys were completed prior to, during, and after flows related to management of Mountain Whitefish (November 1 to February 28) in the Castlegar area, encompassing varied water elevations and flow rates resulting from known dam operations. Surveys were conducted over three winters in Castlegar (from 2013/2014 to 2015/2016), and over two winters (2014/2015 and 2015/2016) in the broader Kootenay region.

In the Kootenay region, herons were observed in Revelstoke, Burton (near Nakusp), Castlegar, Creston, Lumberton (near Cranbrook) and Invermere. Herons were fairly widely distributed in November/December, being detected at all of the above mentioned localities, but during January/February surveys herons were only located in Castlegar, Creston, and Invermere. Typically only one to three herons were present at any locality, except around Waldie Island and Duck Lake where larger congregations occurred in the early winter. Up to 11 herons were observed in November at Waldie Island during standardized surveys, while concentrations of 11 herons were found around Duck Lake in November and January/February surveys (with daily heron counts for Creston sometimes exceeding 20 birds during these periods owing to additional sightings outside of Duck Lake).

Daily counts from the Waldie Island area conducted by a local observer indicate that herons are either not detected or detected in small numbers (typically 1 or 2 individuals) from early January until late July. Peak numbers occurred in September in two of three survey years (and early December in the other year). Heron numbers were relatively high in November, but appeared to decline

throughout December. Differences in heron numbers both within a winter period and between survey years indicate strong inter- and intra-annual variation. Overall herons in Castlegar appeared to arrive and depart Castlegar in relation to life-history attributes (e.g., post-breeding dispersal and migration) and environmental conditions. Herons departed the Castlegar area on average 50 days prior to peak snow accumulations, but also during a period when water elevations were high.

Sites within the Castlegar area were similar to sites elsewhere in the general Kootenay region in regards to physicochemical and other measured habitat variables (e.g., macrophyte coverage, water velocity). Physicochemical and other habitat variables were likewise similar between sites with and without herons. These results suggest that potentially suitable winter heron habitat within the Kootenay region exists outside of areas where herons were observed, excepting where/when water freezes completely over and snow depths exceed some (undetermined) tolerable limit for successful foraging. This is supported by a predictive model of habitat suitability, which indicates that potentially suitable winter heron habitat exists elsewhere in the Kootenay region, even if currently unoccupied. The occupancy of that potentially suitable habitat is also prone to intra- and inter-annual variation, as evidenced by herons present at certain sites in some years but not others (e.g., Burton Creek) or only during early winter (e.g., Revelstoke), related to environmental conditions and other factors. Suitable winter heron habitat exists around Castlegar including locations were herons were not observed by us during these three survey years. However, the amount of potentially available habitat in the Castlegar region is highly variable owing to changing water elevations related to Keenleyside discharge. At higher water elevations, sites with historic heron use, such as Breakwater Island, may lose the majority of their land area, or be completely inundated as water levels rise. Overall, approximately 100 per cent and 86.1 per cent of potential shoreline habitat at Breakwater Island and Waldie Island respectively was inundated between the minimum and maximum water elevations recorded during the November to February period in this study.

Comparing climate data for the region, it is clear that the Rocky Mountain Trench is colder and snowier than other areas of the Kootenays, and herons appear to have relatively low use of that area during the winter. In contrast Castlegar is relatively milder during the winter months with a lower snowpack. These conditions, along with the flows from Hugh Keenleyside Dam, retain open water along the Lower Columbia River throughout the winter. In Creston, even though much water freezes, open water remains around sluice gates used for water management, and in holes in the ice of locations such as Duck Lake. Suggestive of the necessity of open water for foraging, herons were only found in the Rocky Mountain Trench in Invermere where and when open water patches remained within otherwise frozen waterways. Herons were observed foraging from ice holes around Creston (most notably Duck Lake), in contrast to Castlegar where no foraging activity was observed during the day.

Many factors likely influence the abundance and distribution of over-wintering herons in the Castlegar area. As no known, successful nesting occurs in the vicinity, the over-wintering herons must be from other breeding locations and are thus also subject to population influences and habitat conditions elsewhere. The dynamics influencing over-wintering herons along the Lower Columbia River are likely complex and interconnected. Flow regime, while not directly linked to heron numbers, greatly affects the amount of potential shoreline habitat available. Confounding our ability to detect linkages are potential annual changes in breeding success and colony structure elsewhere, lack of ability to manipulate river flows experimentally, changes in environmental conditions, and other potential impacts such as human-caused disturbances.

It is recommended that water elevations should continue to be limited to 420.7 m or lower to retain much of the potentially suitable shoreline habitat along Waldie Island and Breakwater Island. Additional habitat could be created by building up islands/sandbars in the vicinity of the Pass Creek delta or Breakwater Island to buffer against high water periods when these areas traditionally become inundated. Several factors limit the inferences made in this study related to the effects of flow regime on wintering herons in the Castlegar area, and these could in part be addressed by expanding this study to incorporate shallow water fish surveys to determine the distribution of heron prey as well as that prey's response to the effects of flow regime concurrent with heron surveys, and expanding the duration of the study over additional years to better incorporate inter-annual variation in heron numbers and flow regime.

The status of CLBMON-49 after completion of this study with respect to the management questions is summarized below.

MQ	Able to Address MQ?	Supporting results	Sources of Uncertainty
Where are the shoreline areas that are used by Great Blue Herons?	Yes	• Mapped heron locations showing all shoreline areas where herons detected. • Distribution of herons aligns with historical Christmas Bird Count data. • Occupied sites in Castlegar similar in all survey years. • Habitat suitability model showing areas with high suitability for heron presence	• Natural annual population variation • Variable dam flows among years and throughout the day • Human and other disturbances potentially limiting site utilization • Difficult to observe at night • Lack of experimentation to assess how varying the flows affects herons at different times through the winter period • Statistical models had weak support and key parameters for highly suitable winter habitat unknown and unmeasured.
How does the flow regime affect the area, distribution, and attributes of shoreline areas?	Yes	• Shoreline areas increase with decreasing water elevation and vice versa. • Physicochemical parameters do not seem to be affected.	• Variable dam operations and inter-annual variation. • Uneven site response • Unknown how heron prey respond to flow regime in shallow water habitats
Are there physical works that could improve the availability of shoreline areas for Great Blue Herons on Waldie Island and in the Castlegar area?	Yes	• Locations where herons occur and knowledge of how water elevations affects the most commonly utilized roosting areas	• Variable dam operations • Natural annual population variation in numbers and site utilization • Unknown movement patterns of herons • Lack of physical works to benefit herons already undertaken from which to inform recommendations
How does the suitability of winter habitat on Waldie Island and in the Castlegar area compare to habitat used by wintering Great Blue Herons elsewhere in the surrounding region?	Yes	• Physicochemical parameters do not appear to differ • Water remains ice-free through entire winter period in Castlegar, unlike some other areas in Kootenays • Security and foraging opportunities present reliably among years	• Only two years of data for areas outside of Castlegar • Unknown distribution, abundance, or site selection attributes of herons from areas with high winter abundances outside study area (e.g., Okanagan, Idaho). • Unknown foraging opportunity or how fish presence/density varies among sites • Natural annual population variation
Are there operational changes that could improve habitat availability and suitability for Great Blue Herons on Waldie Island and in the Castlegar area?	Partially	• Available potential shoreline habitat mapped out at different water elevations • Heron numbers low in January, overlapping whitefish flow period when water elevations higher	• Unknown how fish or other aquatic organisms utilize recently inundated areas • Inability to experimentally alter flows • Unknown ultimate cause of timing of heron movement patterns

Key Words: heron, Columbia River, habitat use, Hugh Keenleyside, flow regime, Waldie Island

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Sk̓ʷʕas (Great Blue Heron) and the Syilx (Okanagan) People

Syilx people pass their cultural knowledge from one generation to the next through a collection of stories and teachings called Captikwł which represent natural laws and so inform the people's rights and responsibilities to their land, culture, and each other. When people first came to the land, the four Food Chiefs, Skəmixist (Black Bear); Ntytyix (Salmon); Siyaʔ (Saskatoon Berry) and Sp̓iƛ̓əm (Bitterroot) decided at the time that the timixw (all living things) would give of themselves to help the people survive. So, to this day, and for the well-being of all future generations, Syilx people have a sacred responsibility to care for, respect and sustain timixw throughout Syilx territory.

When the CLBMON-49 *Lower Columbia River Effects on Wintering Great Blue Herons* project was first conceived, the idea of capturing and tagging herons to follow their movements was considered. How to safely catch and tag herons was a difficult technical problem. That aspect of the study was eventually abandoned, and this report is the product of the observational approach eventually undertaken. This observational approach also aligned with the cultural perspective of the Okanagan Nation. A perspective that comes from the promise of the Syilx people not to hunt or harass herons; these teachings come from stories of how heron got its long legs...

How Heron Got Its Long Legs
told by Dixon Terbasket

"I have been doing research on the importance of Sk̓ʷʕas (the Great Blue Heron) to the Syilx people. I have heard a story from elder Theresa Terbasket and her father Tommy Michel Terbasket on how the herons got their long legs. This may apply to all the cousins of the heron who now have long legs. The stories told were that a man was attempting to capture one of them in the beginning before heron had long legs.

This man was hunting and saw a bird swimming on a swamp and was looking for a way to catch his dinner. Thinking for a bit he came up with an idea—he would swim under the water, but the bird was very far out there; how would he do it?

Thinking about it and looking around, the man found a reed that was hollow. He would use it to breathe under the water and swim under the bird and grab it by its legs. Well this worked; as he swam under the water breathing through the reed he was able to get under the bird without the bird noticing him. Once below the bird, he grabbed the bird's legs but the bird was bigger than he thought and it took off lifting the man into the air. Not thinking quickly enough, the man did not let go of the bird.

The bird took him high into the sky forcing the man to hang on. He looked down on the Earth and realized that if he let go he would surely die. The bird's legs were starting to stretch but it kept flying higher and higher. The man started to think 'I am going to die soon' as he was getting tired and he was still getting higher. He thought, maybe if I ask the bird to lower me I wouldn't die! The heron's legs were now stretching to the length they are now; the man still thinking of a deal he could make with the bird.

He asked the bird what he wants if he would let him down. The bird thought about it for a while and then said to the man, “If you promise never hunt or harass us I will let you down”.

Once the man agreed, the heron with its new long legs also agreed and lowered the man to a mountaintop, leaving him there to find his own way home. And it is known to this day that we do not harvest or bother herons. How they got their name Sk̓ʷʕas remains unclear to me.

Sk̓ʷʕas are very powerful beings; it is said that they are our ancestors gone before us and we should respect them when we encounter them on the land and not disturb them when they are fishing or standing on shore.

I was told that when the fish are running and the herons are on the shore fishing that we have to wait our turn to fish. They are very sensitive to our presence when we are on the land. As it is said, they are our ancestors and if we interfere, we will have no luck catching fish. There is truth to that—I was in Burton Creek on the Arrow Reservoir fishing and there were 16 herons on the shore. Not knowing, I set my net and started to fish. At first it was okay, but then my net got caught on a log and was torn to pieces; so that confirms the teaching. I had to learn the hard way. So respect the heron on its shore as they are truly amazing birds.”

1.0 INTRODUCTION

Dams regulate the flow regime in the majority of the world's large river systems and the flooding resulting from dam construction and water storage creates a complex disturbance that can modify entire ecosystems (Nilsson and Berggren 2004). Most major rivers in British Columbia have been dammed and such hydroelectric developments have had numerous upstream and downstream impacts on wetland and shoreline ecosystems (Hawkes 2005). These impacts can be broad, interact in complex ways, and are not only restricted to the direct flooding and loss of riparian and wetland habitats upstream of the dam, but extend downstream of the dam through disturbance of the annual flooding regimes (MacKenzie and Shaw 2000). For wetland-dependent organisms, dam operations can impact all life stages. Furthermore, changes to one component to benefit any given species can have unintentional consequences to other organisms within the reservoir system.

Great Blue Herons (*Ardea herodias*) are one of the most common, widespread, and adaptable species of wading bird in North America. While they may occur in a variety of habitats, they are typically associated with water at all seasons (Vennesland and Butler 2011). Many prey items (e.g., small mammals, frogs, birds) may be taken, though fish are primarily chosen. Both interior (*A. herodias herodias*) and coastal (*A. h. fannini*) subspecies are blue-listed in the province, owing to disturbance and habitat loss (Gebauer and Moul 2001). While the coastal subspecies is typically resident, interior populations may migrate or remain as environmental conditions dictate (Campbell et al. 1990, Machmer 2002, Vennesland and Butler 2011). In the lower Columbia River, small but variable numbers of herons overwinter (Machmer 2003). A number of these birds congregate in the area around Waldie Island, near Castlegar, BC (Machmer 2003, W. Volovsek pers. comm.). The increased use of Waldie Island by herons may be highest when foraging conditions are limited at other sites due to water elevations, disturbances, or environmental conditions (Machmer 2003).

Mountain Whitefish (*Prosopium williamsoni*) spawn in the Columbia and Kootenay rivers during the winter, with peak spawning in January. To minimize dewatering of eggs due to reservoir operations, flows are stabilized during the peak spawning period. Achieving stabilization requires a period of high and variable flow releases prior to whitefish spawning, which corresponds with the beginning of the wintering period for Great Blue Herons. During the Columbia River Water Use Planning process (WUP), concerns were expressed about potential impacts of the operations of Hugh Keenleyside Dam on the herons of Waldie Island (BC Hydro 2005). Higher flows from the Lower Arrow Lake Reservoir for Mountain Whitefish during early December may directly impact the abundance, density, distribution, and/or habitat use of herons on Waldie Island and the lower Columbia River. This study stems from the need to address the response of herons to flow and stage regime from this dam during the winter period due to its potential impacts on foraging and winter habitat, and to determine feasible mitigative actions.

Monitoring the aggregation of herons at Waldie Island and the lower Columbia River requires understanding the movements and behaviours of herons in the broader Kootenay region. By understanding herons in the region, we were better able to assess the habitat availability and suitability within the Castlegar area during the winter period (November 1 to February 28). We therefore relate the Hugh Keenleyside Dam flow and stage regime to heron responses in this period due to the potential effects on availability of shallow-water foraging and winter refuge habitats, and provide information on habitat use and feasible mitigative actions.

This report summarizes the findings of three winters of surveys (2013/2014 to 2015/2016) for BC Hydro's Monitoring Program CLBMON-49: *Lower Columbia River Effects on Wintering Great Blue Herons.*

1.1 Key Water Use Decision Affected

The key operating decisions that might be affected by this monitoring program are the following:

1) Should the early winter flow releases from Arrow Lakes Reservoir be altered to mitigate potential impacts of high river elevations on overwintering Great Blue Herons in the vicinity of Waldie Island?
   - The monitoring project will provide information on how the current flow regime in the lower Columbia River affects the foraging ecology and overwinter survival of Great Blue Herons.
   - The monitoring project might suggest changes to the flow regime that would improve the availability of shoreline winter foraging areas for Great Blue Herons.
2) Are there physical-works projects that would enhance or create suitable shallow-water foraging areas for the over-wintering Great Blue Herons?

Water flow from the Hugh Keenleyside Dam must balance the needs of fish and spawning habitat with that of water-dependent terrestrial animals (i.e., Great Blue Herons), power generation and environmental objectives while simultaneously addressing requirements under the Columbia River Treaty, such as increased downstream power generation and flood control benefits. Results of this monitoring program help clarify the relative importance of Waldie Island and surrounding shorelines and shallow water habitat for wintering Great Blue Herons, and provide recommendations on how and if water flow changes can be implemented to minimize or mitigate potential impacts to Great Blue Herons while addressing the aforementioned concerns. Information on the life history requirements of Great Blue Herons in this local context combined with monitoring results also help inform management decisions regarding the design and location of any potential physical works projects within this study area.

2.0 OBJECTIVES AND MANAGEMENT QUESTIONS

Eight management questions (MQs) were originally developed to address the intent of CLBMON-49 as outlined by the Consultative Committee to: (1) address "*whether there was an operational link between the mountain whitefish flows and impacts to herons on Waldie Island*"; (2) *"assess the response of herons to flow and stage regime from the Hugh Keenleyside Dam during the winter period due to its potential effects on availability of shallow-water foraging and winter refuge habitats*"; and (3) "*provide information on habitat use and feasible mitigative actions*." (BC Hydro 2012). However, over the course of Year 1 of CLBMON-49, it became evident that some revision to the management questions was required owing to an inability to experimentally influence water flow rates from the Hugh

Keenleyside Dam, low numbers of overwintering herons, and focus on a small habitat patch. Based on these limitations, the scope of the study was altered, while maintaining the original study intent outlined by the Consultative Committee, and the new approach was approved in a revised Terms of Reference (BC Hydro 2014). This process necessitated revision to the management questions, which are worded as follows:

MQ: Where are the shoreline areas that are used by Great Blue Herons?

MQ: How does the flow regime affect the area, distribution, and attributes of shoreline areas?

MQ: Are there physical works that could improve the availability of shoreline areas for Great Blue Herons on Waldie Island and in the Castlegar area?

MQ: How does the suitability of winter habitat on Waldie Island and in the Castlegar area compare to habitat used by wintering Great Blue Herons elsewhere in the surrounding region?

MQ: Are there operational changes that could improve habitat availability and suitability for Great Blue Herons on Waldie Island and in the Castlegar area?

2.1 Management Hypotheses

Hypotheses were originally presented in the Terms of Reference (BC Hydro 2012) that were designed to test specific relationships between the variation in the number of Great Blue Herons (count data) and water elevations. The original proposal laid out reasons why using a simple linear regression and strict cut-off values for the result was nonsensical in this project. The original management hypotheses were related to management questions that were subsequently dropped. As a result, these management hypotheses were likewise removed (BC Hydro 2014). Instead, we shift the focus of CLBMON-49 to address the quality and availability of wintering habitat in a regional context and how habitat availability is altered in the Castlegar area at different water (flow) regimes.

3.0 STUDY AREA

3.1 Physiography

The Columbia Basin in southeastern British Columbia is bordered by the Rocky, Selkirk, Columbia, and Monashee Mountains. The headwaters of the Columbia River begin at Columbia Lake in the Rocky Mountain Trench and the river flows northwest along the trench for about 250 km before it empties into Kinbasket Reservoir behind Mica Dam (BC Hydro 2007). From Mica Dam, the river continues southward for about 130 km to Revelstoke Dam. The river then flows almost immediately into Arrow Lakes Reservoir behind Hugh Keenleyside Dam. The entire drainage area upstream of Hugh Keenleyside Dam is approximately 36,500 km^2.

The Kootenay River has its headwaters in the Rocky Mountains, just north of Kootenay National Park. From there it flows south through the Rocky Mountain Trench and into Lake Koocanusa, which is impounded by the Libby Dam in Montana. Past the dam it again re-enters British Columbia south of Creston, eventually flowing into Kootenay Lake. From the west arm of Kootenay Lake the river flows west to join the Columbia River in Castlegar. The entire Kootenay Basin encompasses about 46,620 km^2 in both Canada and the U.S.A., and is the second largest tributary of the Columbia River by runoff volume. The Kootenay River flows for about 780 km from the headwaters to its terminus in the Columbia River.

Both the Columbia and Kootenay basins are characterized by steep valley side slopes and short tributary streams that flow into the respective rivers from all directions. The Columbia River valley floor elevation falls from approximately 800m near Columbia Lake to 420m near Castlegar. Over the course of its length, the Kootenay River drops about 1,805 m in elevation, though the majority of that drop occurs between the headwaters and the Rocky Mountain Trench, with the river dropping less than 305 m between Canal Flats and Kootenay Lake. Approximately 40 per cent of the drainage area within the Columbia River Basin is above 2000 m elevation. Permanent snowfields and glaciers predominate in the northern high mountain areas above 2500 m elevation.

3.1.1 Climatology

Precipitation in the basin occurs from the flow of moist low-pressure weather systems that move eastward through the region from the Pacific Ocean. More than two-thirds of the precipitation in the basin falls as winter snow. Snow packs often accumulate above 2000m in elevation through the month of May and continue to contribute runoff long after the snow pack has depleted at lower elevations. Summer snowmelt is reinforced by rain from frontal storm systems and local convective storms. Runoff begins to increase in April or May and usually peaks in June to early July, when approximately 45 per cent of the runoff occurs. The mean annual local inflow from upstream of the Hugh Keenleyside project is 355 m^3/s.

Air temperatures across the basin tend to be more uniform than precipitation. The winter climate is usually cool and wet. The Environment Canada climate normals between 1981 and 2010 show median snow depths of 0 to 7 cm at the Hugh Keenleyside Dam between the months of November and March. The daily maximum temperature for the same time period ranged from 0.5 to 4.8˚ C.

3.2 Arrow Lakes Reservoir

Arrow Lakes Reservoir is an approximately 230 km long section of the Columbia River drainage between Revelstoke and Castlegar, BC. It has a north-south orientation, set in the valley between the Monashee Mountains in the west and Selkirk Mountains in the east.

Two biogeoclimatic zones occur at lower elevations surrounding Arrow Lakes Reservoir: the Interior Cedar Hemlock (ICH) and the Interior Douglas-fir (IDF). The majority is ICH, with IDF restricted to the southernmost portion of the area. The Arrow Lakes Reservoir is situated within the province’s Selkirk Resource District.

Most of the Columbia Basin watershed is forested. Dense forest vegetation thins above 1500 m elevation and tree-line occurs at ~2000 m elevation. The forested lands around Arrow Lakes Reservoir have been and continue to be logged, with recent logging occurring on both the east and west sides of the reservoirs. The area around Castlegar is urbanized with a population of approximately 8,000.

Commercial, industrial, residential and recreational developments all exist along the Columbia River in the vicinity of Castlegar.

The Hugh Keenleyside Dam, located 8 km west of Castlegar, spans the Columbia River and impounds Arrow Lakes Reservoir. Arrow Lakes Reservoir has a licensed storage volume of 7.1 MAF[1] (BC Hydro 2007). The normal operating range of the reservoir is between 418.64 m and 440.1 m ASL. Reservoir elevations are determined by flows through Hugh Keenleyside Dam, which in turn determines the elevation of the Columbia River downstream of the dam. Flow rates vary throughout the year, typically reaching peaks in early winter and mid-summer (Figure 3-1).

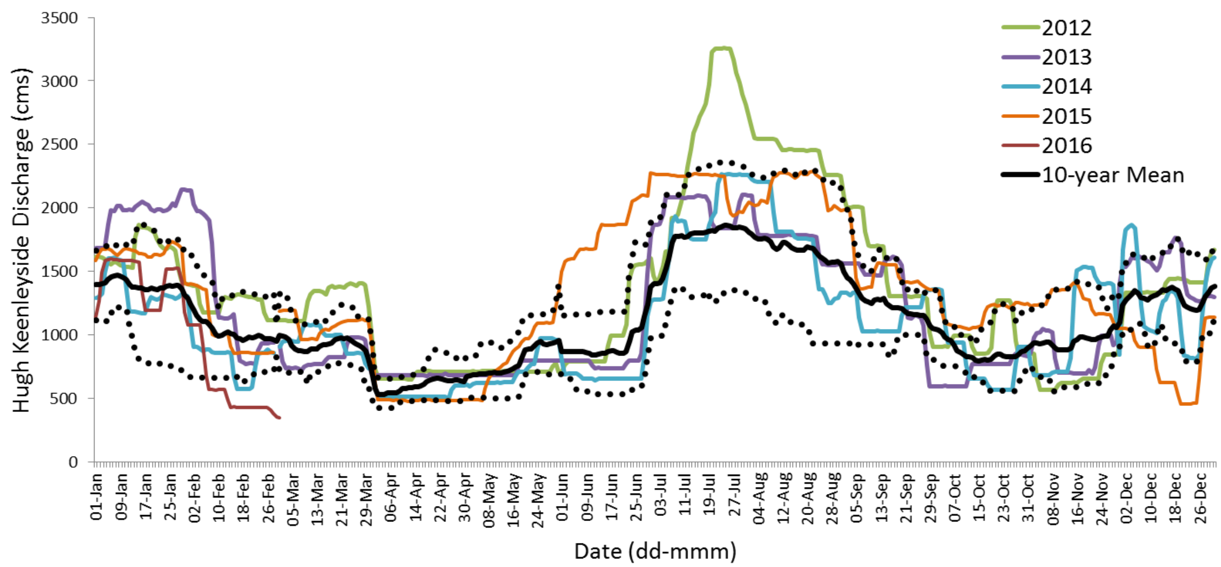

Figure 3-1: Hugh Keenleyside Discharge rates (cubic metres per second) from 2012 to 2016. The 10-year mean (2006 through 2015) is provided to indicate the general timing of high and low flow rates. Dotted lines represent the 10th and 90th percentiles of the mean.

3.3 Study Location

The study area for CLBMON-49 was focused around the Castlegar region, but encompassed a broad area of potential habitat for Great Blue Herons wintering in the Columbia/Kootenay region. The Castlegar study area was roughly bounded by the Hugh Keenleyside Dam in the west, the Brilliant Dam in the east, and the Kinnaird Bridge (Hwy 3) to the south, and followed the Columbia and Kootenay Rivers between these locations (Figure 3-3). Within this local study area, the focus was on Waldie Island and immediately adjacent locations (e.g., Breakwater Island) (Figure 3-3). The Castlegar area was surveyed exclusively during the first

[1] One acre-foot is the volume of one acre of surface area to a depth of one foot. One million acre-feet (MAF) is equivalent to approximately 1.2 trillion litres.

winter of study (2013/2014), with the study area expanded during the following two winters.

The regional study area extended from Revelstoke in the northwest and followed the Arrow Lakes Reservoir south through to Castlegar in the southwest. The study area then extended eastward to include Creston, as far south as the Canada-United States border, Cranbrook, and Fort Steele. From there the study area followed the Kootenay River northwards, encompassing Columbia Lake, before terminating in the Kimberley/Invermere area. This resulted in a roughly horseshoe-shaped study area (Figure 3-2).

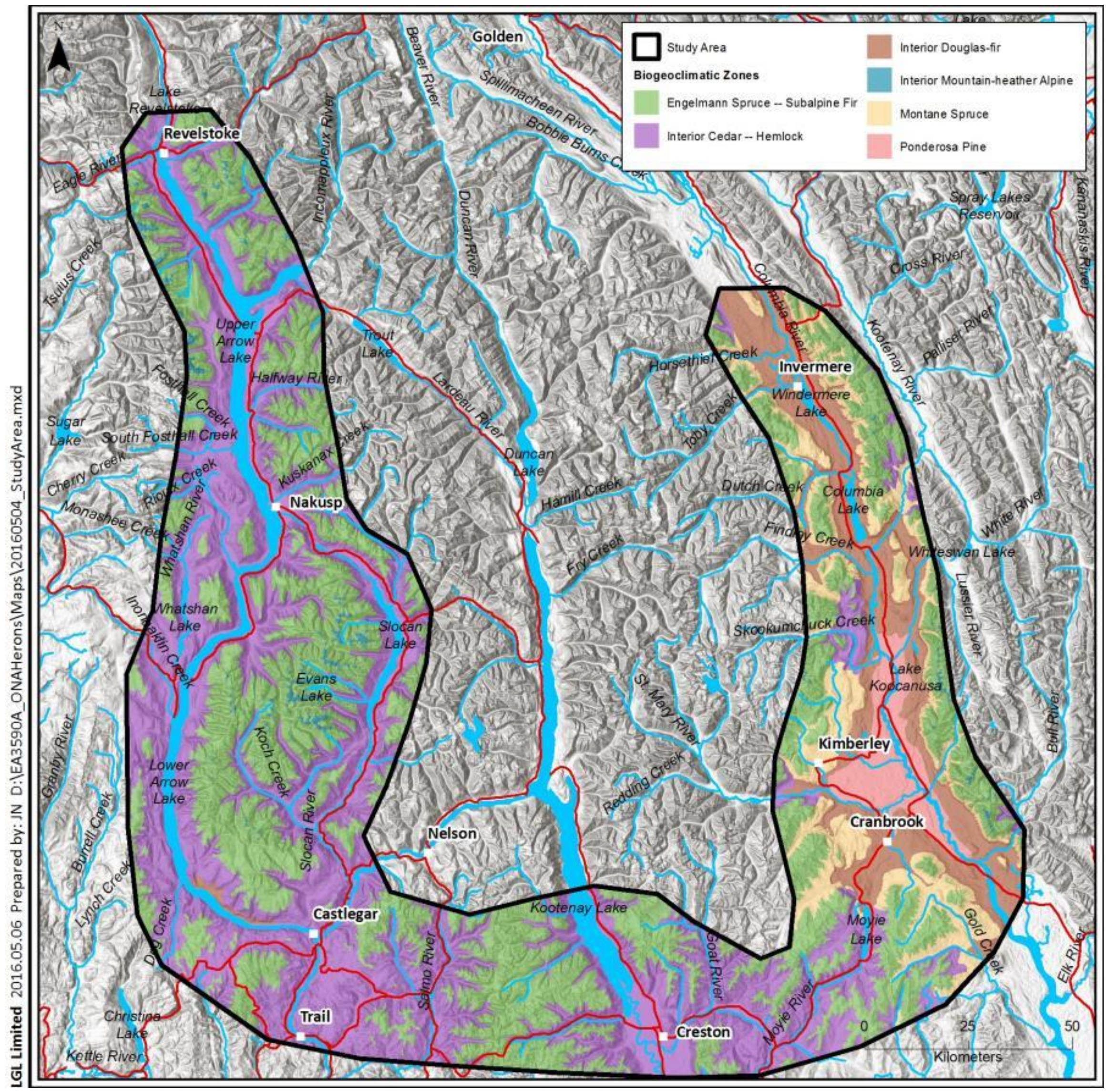

Figure 3-2: Overall Kootenay/Columbia regional study area for heron surveys. The study area essentially followed the Columbia River south from Revelstoke, including the Arrow Lakes Reservoir, as well as the headwaters at Columbia Lake. The Kootenay River was followed from south of Columbia Lake to Cranbrook, and again at Creston and near the confluence with the Columbia in Castlegar

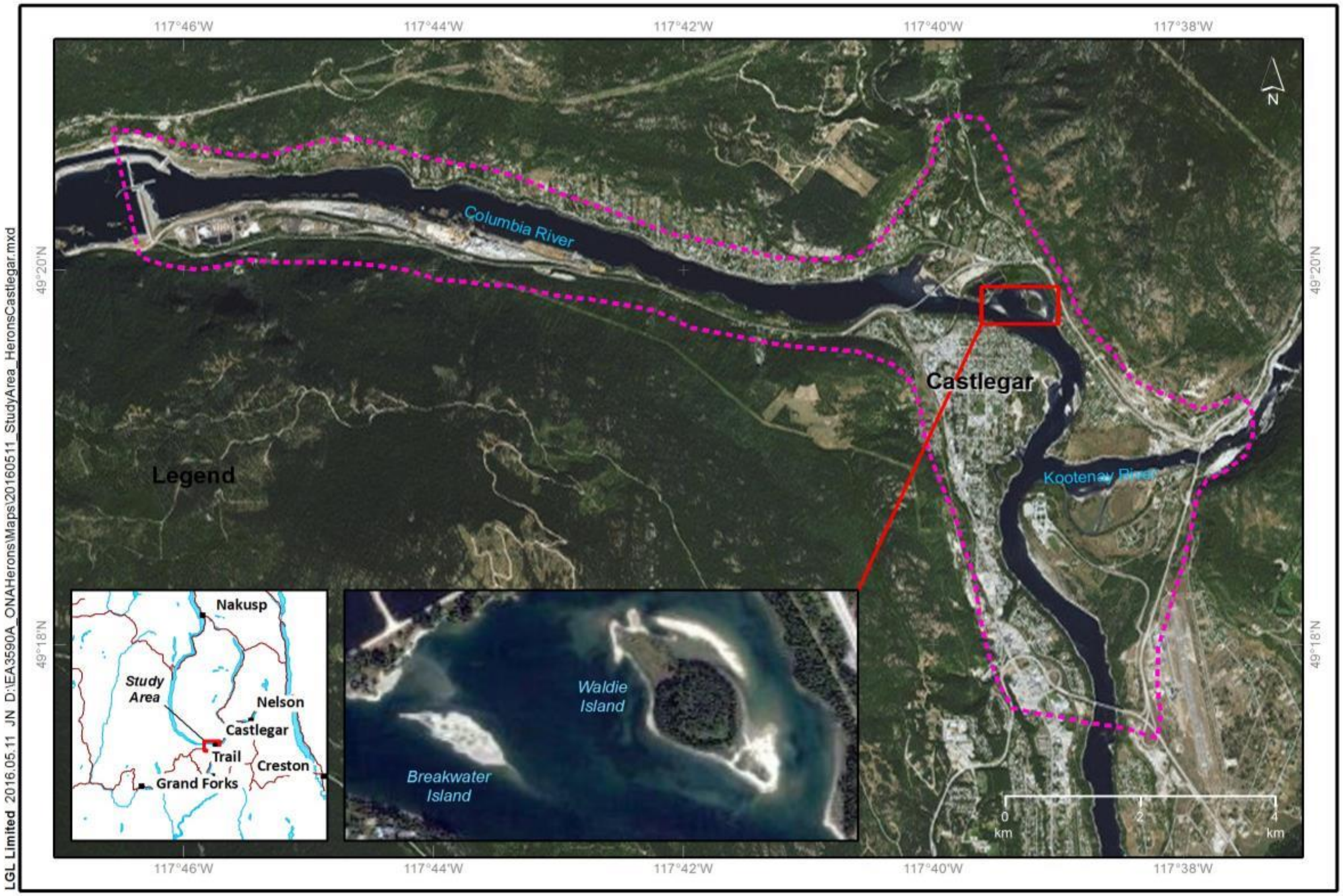

Figure 3-3: The CLBMON-49 core study area (pink dashed line) is bounded by the Hugh Keenleyside Dam in the west, the Brilliant Dam in the east, and the Kinnaird Bridge to the south, and includes all shoreline locations within that area. The Waldie Island area is shown in the inset.

Survey areas outside of Castlegar were chosen in part based on heron locations from existing data sources (i.e., Christmas Bird Count data and eBird). Christmas Bird Count and eBird data sources both have inherent limitations, but these were only used to identify sampling areas. Areas with varying levels of historic heron counts, from relatively high (such as around Castlegar and Creston) to moderate (such as around Nakusp and Invermere) to low (such as Revelstoke and Cranbrook) were selected for sampling. Within each of these broad areas, precise locations for sampling were identified using locations of historic sightings and by using digital maps to determine additional sites that appeared to have (1) a waterbody (e.g., lake or river), and (2) public access. Additional serendipitous sampling was encouraged in the field at sites that looked like suitable winter habitat for herons and as time permitted.

Water and shoreline sampling was conducted at 67 locations spanning the regional study area (Figure 4-2, Appendix A). In addition to these locations, scans for herons were completed at multiple locations where shoreline sampling was not possible. Sampling and observation sites in Castlegar were consistent across all years of study. Most vantage points in the Castlegar area were at the same location as shoreline sampling sites. However, several key vantage sites were accessed solely to scan for herons including Nimby Point (north end of 2nd Ave.), the old log ramp just west of the Pass Creek delta, and the Waldie Island Trail running between the south end of Old Mill Rd. and the west end of Brilliant Rd. which provides visibility into the sewage lagoons (via an installed observation platform), Breakwater Island, Waldie Island, and the surrounding foreshore areas on both sides of the Columbia River.

4.0 STUDY DESIGN AND METHODS

4.1 Study Objectives and Scope

The Water Use Plan Consultative Committee outlined the general objectives to be addressed by CLBMON-49. The objectives of this study are:

1. Address whether there was an operational link between the mountain whitefish flows and impacts to herons on Waldie Island;
2. Assess the response of herons to flow and stage regime from the Hugh Keenleyside Dam during the winter period due to its potential effects on availability of shallow-water foraging and winter refuge habitats; and
3. Provide information on habitat use and feasible mitigative actions.

4.2 Study Approach

The general approach for this program is, by necessity, opportunistic in nature. Given BC Hydro’s operational constraints, an experimental approach could not be taken. That is, BC Hydro cannot alter flow rates/water elevations at specific times specifically to provide a controlled, experimental basis for this study. Rather, heron counts and habitat surveys were completed throughout the period of interest (November 1 to February 28), encompassing varying water elevations and flow rates. Survey sessions could not be scheduled for a specific flow rate or water elevation, given the strong intra- and inter-month and year variability around those measures (see Figure 3-1), but were planned to span the period prior to and after flows related to management of the Mountain Whitefish. Water flow/elevation data were then compiled based on data provided by BC Hydro following the sampling period. As a consequence of this opportunistic study design, regional data on heron numbers and water physicochemical attributes are used to provide a regional context for the fine-scale changes observed along the Lower Columbia River. Together, these local and regional data are used to infer wintering heron habitat suitability in the Castlegar area, especially around Waldie Island.

4.3 Field Schedule

Field sampling incorporating heron counts and shoreline surveys was conducted between November and February to coincide with the heron over-wintering period prior to, during, and after flows related to Mountain Whitefish management, as documented by Machmer (2003). During the first year of surveys, a bi-weekly sampling period was implemented to allow for even coverage throughout the over-wintering period of interest, given financial and other constraints. Each survey period was four days in duration; excepting the initial November session which was five days in order to allow a preliminary reconnaissance of the study area. With six sessions completed, the total number of survey days was 25, as originally targeted. This is equal to the sampling effort of Machmer (2003), despite a switch from weekly (Machmer study) to bi-weekly sampling (this study, year 1). To survey the region as a whole during the following two survey years, two sampling periods were established, each twelve days in duration. With two sessions completed, the total number of comprehensive survey days was 24, equivalent to the effort expended during 2013/2014, despite a broadening of the study area, and a reduction in the total number of survey sessions.

Table 4-1: Survey dates for field sessions during the three winters of surveys.A study design change between the first and subsequent survey years created fewer sampling sessions while maintaining the same overall effort

Survey Year	Sampling Dates						Total Survey Days
	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	
Year 1 (2013/2014)	25-29 Nov	10-13 Dec	27-30 Dec	14-17 Jan	3-6 Feb	24-27 Feb	**25**
Year 2 (2014/2015)	17-28 Nov	10-21 Feb	-	-	-	-	**24**
Year 3 (2015/2016)	23 Nov - 4 Dec	25 Jan - 5 Feb	-	-	-	-	**24**

In addition to the heron and shoreline sampling survey days, near-daily counts of herons were made on the Waldie Island area year-round from 2013 through 2015, with the cooperation of local citizens. These daily observations provide count data with higher resolution than any previous surveys, and span the entire pre-, during, and post-whitefish flow periods. Thus, for example, during the November 1, 2014 to February 1, 2015 survey period, 24 days of heron counts plus shoreline sampling was conducted by LGL and ONA biologists, while heron counts near Waldie Island were completed on 120 days by a local observer.

Daily heron counts thus also encompass migratory or dispersal periods which occurred outside of the winter period surveyed by LGL and ONA staff. In total there were 1,089 days of heron counts conducted between 1 January 2013 and 31 December 2015.

4.4 General Data Collection

The focus of this study is on the herons of Waldie Island and immediate surroundings. However, herons are capable of dispersing throughout the region (and beyond) for reasons that may not be related to flows from the Hugh Keenleyside Dam. For a better regional understanding of heron numbers and distribution to be obtained, broad surveys of the Kootenay region were completed twice during the survey period each winter during the second and third study years, once prior to whitefish flows, and once post-whitefish flows.

In addition to counting herons, shoreline sampling was conducted whenever possible during all survey sessions. Due to the expansion of the study area between the first and second study years, shoreline sampling was conducted for three survey years for most sites around Castlegar, and for two survey years at most sites throughout the Kootenays. Repeated sampling at all sites was intended, but was not possible at all sites during all survey sessions owing to changing conditions (e.g., road conditions, ice extent). Behavioural observations were done opportunistically wherever herons were encountered to determine the instantaneous behaviour of herons.

For both behavioural and shoreline surveys environmental conditions were recorded. These conditions included the air temperature (°C), wind speed (km/h), and relative humidity (per cent) (all measured with a Kestrel® 4000 weather meter [Nielsen-Kellerman, http://www.nkhome.com]), and cloud cover, ceiling height and precipitation assessed visually. Other initial data common to all survey types were the start and end time, site name, date, GPS location and elevation, observer names, and the number and age(s) of any herons and eagles present.

Due to the limited field time each day (due to day length) and each sampling period, surveys were completed from dawn until dusk. Although some weather conditions (e.g., fog, heavy snow) prevented surveys from being completed, these conditions were largely absent during the sampling sessions.

Water elevation was based on measurements from the Norns Creek gauge (CNN). Water flow rate was the sum of Hugh L. Keenleyside Dam (HLK) and the adjacent Arrow Lakes Generating Station (ALH) discharges. Elevation and flow measurements were collated from data provided by BC Hydro and Poisson Consulting Ltd. after each field season ended.

4.5 Heron Surveys

Upon arriving at a site, all visible shoreline and surrounding trees were surveyed for heron presence and abundance (RIC 1998). Initial scans were conducted by naked eye, and with the aid of 8x or 10x binoculars. Herons are large and conspicuous birds when perched in the open; however, they can be considerably less visible when perched in trees or tucked into shoreline rocks or vegetation (Figure 4-1).

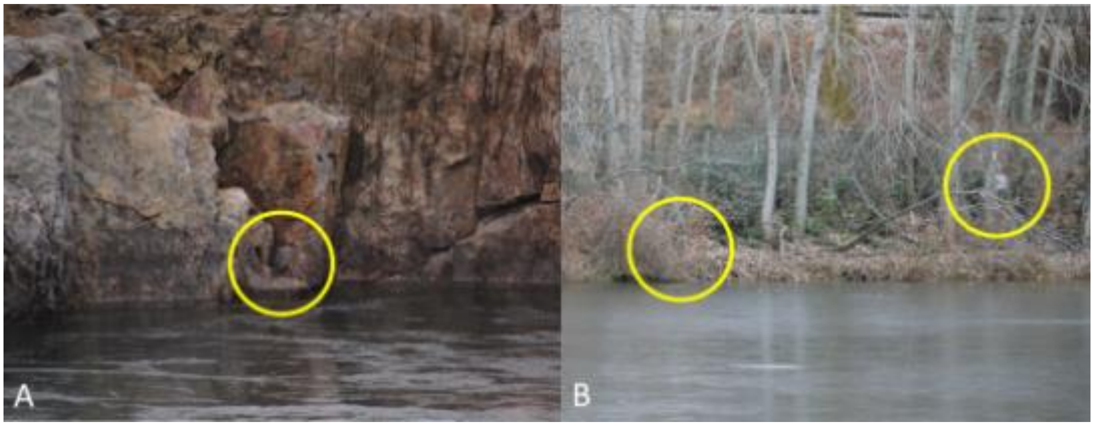

Figure 4-1: Herons are large, conspicuous birds when perched in the open, but can be considerably harder to detect against rocky (A: HLK Dam) or vegetated (B: Castlegar Sewage Lagoon) backgrounds

For this reason, a more detailed scan using a 20-60x spotting scope was also conducted (RIC 1998). The total number of herons present (if any) was recorded. Whenever possible, each individual was assigned to an age class of immature or adult based on plumage characteristics. Next, if more than one heron was present at a site, the distance between individuals was recorded. A range finder was used to accurately measure distance, and a compass bearing recorded, from the georeferenced observation location to the bird(s). The physical location of each bird (e.g., 4 m from shore in river, 10 m high on outer branch of tree, etc.) was also noted. While the observer conducted the initial scan, the recorder documented environmental and count data on standardized data sheets. Data sheets were also developed for recording start and end times, site, and weather details for sites where no herons were recorded, to document survey effort.

When herons were encountered, brief behavioural observations were recorded based on what the individual was doing at the time of observation. Multiple behaviours were recorded if observed, but no formal behavioural observation period was implemented during the second and third survey years. During the first survey year, 10-minute focal scans of all Great Blue Herons observed in Castlegar were conducted. The focal scan consisted of watching each individual heron and recording each behaviour observed as well as the time when a behaviour changed occurred. This was done for the whole 10 minute period or until the heron was no longer visible. These focal scans allowed for daily activity budgets to be estimated for daylight hours. Daily activity budgets could not be calculated for the second and third years, rather the informal behavioural observation period in those years allowed us to maximize the number of separate locations visited in a day while still providing data on heron behaviour in local areas. In all cases, the behavioural categories were defined as:

- Resting – either standing or perched in tree, with or without head tucked into back. Typically with neck retracted, and little to no movement.
- Preening – remaining in place, but actively grooming by rubbing feathers through bill, often with some flapping or stretching to re-arrange feathers.

- Foraging – wading slowly through water or sitting motionless but with neck extended. Obviously focused on ground, water or water's edge.
- Alert – remaining in place, but with neck extended and sometimes appearing somewhat agitated, such as in response to some disturbance. No obvious intent of foraging (i.e., not focused on substrate).
- Walking – moving purposefully along a substrate, but no obvious intent of foraging.
- Flying – flight along a path, for any distance. Often, but not always, preceded by other behaviours (e.g., preening or alert).
- Other – observer defined category for any behaviours not easily classifiable into one of the above (e.g., stretching [without preening], defecating).

Natural or anthropogenic factors influencing wildlife use, such as human or wildlife-induced disturbances, were noted. As Bald Eagles are known predators of Great Blue Herons (Vennesland and Butler 2011), and have the potential to affect heron density and distribution, all eagle observations were also recorded, regardless of their perceived activity.

4.6 Shoreline Surveys

4.6.1 Habitat Availability

Habitat availability was assessed digitally for the area downstream of Hugh Keenleyside Dam at different water elevations. Using a subset of a LiDAR point cloud comprised by ~47 million bathymetric and topographic 3D points, a digital elevation model (DEM) was created. The topographic and bathymetric datasets were collected on October 2012 and November 2011, respectively. Using aerial imagery from October 2012, the study area in the Columbia River was delineated. Based on available imagery and the DEM, the delineated area was selected as the upper shore line from west of Pass Creek to south of the Columbia/Kootenay confluence, and along the Kootenay River as far as Brilliant Dam. The Waldie Island and Breakwater Island areas were independently delineated. Potential shoreline habitat was defined as the area between the level of the water and the high-water mark, and typically included all essentially non-vegetated land between these zones. One exception was Waldie Island, where the forested interior was included in the delineation of "shoreline" owing to its relatively low elevation and frequent roosting usage by herons, the only location in the Castlegar area where herons were regularly observed in trees. Shoreline habitat in our usage is referring to any area meeting the above criteria that may be used by herons for any purpose (e.g., roosting, foraging, etc.). Once the DEM and the area of study were created, different water levels were used to simulate the potential change in habitat availability.

4.6.2 Habitat Suitability

Shoreline characteristics and water physicochemical parameters were recorded to aid in assessing the potential impacts of increasing flow and water elevations on wintering herons. Shoreline surveys were completed throughout the study region at sites both with and without detected herons (Figure 4-2, Appendix A). Shoreline sampling procedures generally followed the Canadian Aquatic

Biomonitoring Network (CABIN) field manual (2012). All data were recorded on standardized datasheets printed on waterproof paper. In addition to recording environmental conditions, surveyors took photographs of each site (upstream, downstream, cross-stream, substrate, and shoreward), as well as the general physical attributes of the shoreline areas including stream habitat type (riffle, rapids, straight run, or pool/back eddy), surrounding vegetation (presence and dominance of vegetation groups: shrubs, deciduous trees, coniferous trees), width of shoreline (from vegetation edge to water's edge), length of shoreline, periphyton and macrophyte coverage, and locations of sources of disturbance (e.g., roads, walking paths) (CABIN 2012).

Macrophyte coverage referred to the quantity of rooted aquatic vegetation that was present within the water or its reach, including submergent, emergent (e.g., bullrushes, reeds), and floating (e.g., duck weed, water lilies) vegetation. Periphyton is a mix of algae, detritus, cyanobacteria and microbes that are attached to submerged surfaces (e.g., rocks) (CABIN 2012). Together, macrophyte and periphyton coverage can characterize benthic macroinvertebrate microhabitat. Macrophyte and periphyton coverage are expected to influence fish presence and abundance by providing cover and macroinvertebrate forage. However, no direct estimates of fish presence or availability are made in this study. It is acknowledged that fish availability is an important component of habitat suitability. However, given current data limitations, this study has an inherent assumption that fish presence is possible at any shoreline site, and that fish abundance did not markedly change across the time period of this study, or in other words, that prey availability is constant among sites and years. See the Discussion (Section 6.0) for additional information regarding fish in the Lower Columbia River.

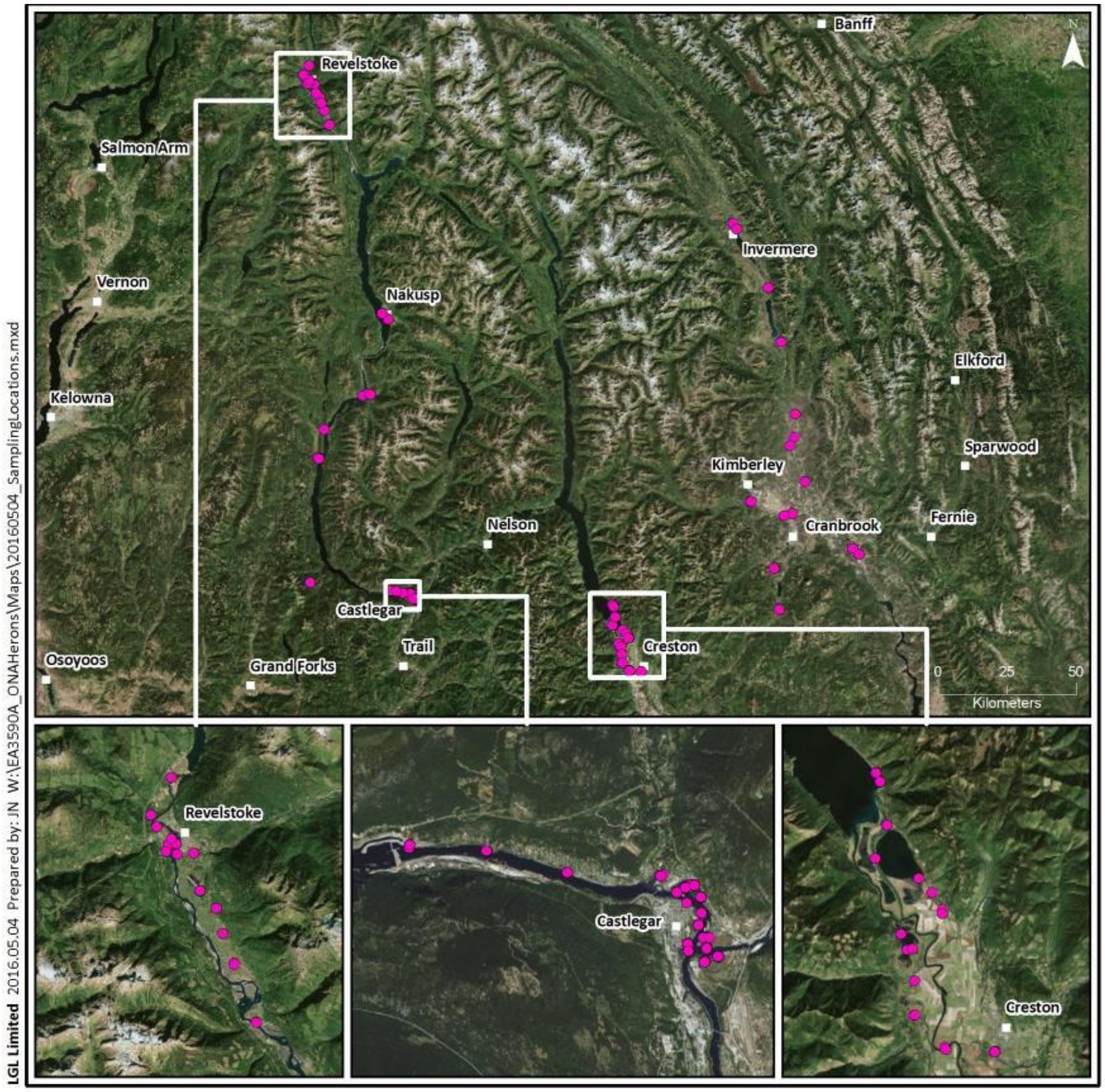

Figure 4-2: Shoreline sampling locations (pink dots) were scattered throughout the study region to sample representative sites both with and without heron activity. Sampling locations around Castlegar (bottom middle) were typically surveyed during all three years of the study, while other locations were surveyed only during the second and third survey years.

Water chemistry data were measured at three locations (separated by approximately 5 to 10 m) at each site to create an average site value. In the water near shore (at a depth of roughly 30 cm), water chemistry data were measured using a YSI Pro2030 instrument, a YSI 6-Series Sonde (YSI Inc., <www.ysi.com>), a pHTestr 30 meter (Eutech Instruments PTE Ltd. <www.eutechinst.com/>), and a Triton Turbidity Wedge (Triton Environmental Consultants Ltd, Richmond, BC) . The recorded water chemistry variables and their definitions (based on RIC 1998b) are described in Table 4-2.

Table 4-2: Physicochemical and environmental variables collected during shoreline sampling at each survey site. These variables are the same as those measured during the 2013/14 field-season. Definitions and justifications for the measured parameters were compiled from the Canadian Aquatic Biomonitoring Network (CABIN 2012) and Guidelines for Interpreting Water Quality Data (RISC 1998b)

Parameter	Definition and Justification
Dissolved Oxygen (mg/L)	Dissolved oxygen (DO) is the amount of oxygen dissolved in water, and is essential for respiratory metabolism of most aquatic organisms. The concentration of DO is a function of daily and seasonal factors such as temperature, photosynthetic activity and river discharge. Higher concentrations of DO are generally considered better for supporting diverse animal communities.
Specific Conductance (µS/cm)	A measurement of the ability of water to conduct an electric current. Conductivity is affected by temperature, and specific conductance is temperature corrected conductivity. Specific conductance values increase with greater ion concentration in the water, and can be used as an alternative measure of dissolved solids. It can be used to indicate potential pollution.
pH	pH is a unit-less measurement of hydrogen-ion concentration in the water, ranging from acidic to basic. Lethal effects on aquatic life occur below pH 4.5 (too acidic) and above pH 9.5 (too basic), and young fish and aquatic insects are especially vulnerable to extreme pH values. Water within a pH range of 6.5 to 9 is optimal for the greatest diversity of aquatic organisms.
Temperature (˚C)	Temperature is the intensity of heat stored in a volume of water. Temperature affects the solubility of compounds which can exacerbate the effects of pollutants. In addition, cold water is more likely to support ice formation which can impact a heron's ability to forage.
Turbidity (NTU)	Turbidity is a measure of the clarity of water due to suspended particulate matter. It is measured in Nephelometric Turbidity Units. More turbid water has greater particulate matter and appears murkier. Water with high turbidity is associated with decreased oxygen levels, decreased photosynthetic activity, disease-causing micro-organisms, reduced growth rates of fish or other aquatic organisms, and cessation of egg and larval development.
Macrophyte and Periphyton coverage	Macrophyte coverage refers to the quantity of rooted aquatic vegetation that was present within the water or its reach, including submergent, emergent, and floating vegetation. Periphyton is a mix of algae, detritus, cyanobacteria and microbes that are attached to submerged surfaces. Together these characterize benthic macroinvertebrate microhabitat.

Parameter	Definition and Justification
Substrate Class	Dominant substrate ranges from organic cover to bedrock. Macrophyte and periphyton coverage will be influenced by the substrate type. Herons are expected to be able to utilize most substrates, but certain preferences may exist.
Water Velocity (m/s)	Water velocity is the measure of the speed of water flowing past a specific point in a given period of time. Water velocity may influence a heron's ability to forage.

Finally, the dominant substrate class (Table 4-3) and local water velocity (m/s) were measured. Water velocity was measured using a Swoffer 2100 current velocity meter (Swoffer Instruments Inc., <www.swoffer.com>) or using a head rod measurement technique (CABIN 2012). This method consisted of placing a meter stick vertically in the stream with the narrow edge in line with the oncoming flow of water and measuring the water level (flowing water depth [D1]). Then, with the wide ruler surface perpendicular to the water flow, the water level was again measured at the upstream side of the ruler and recorded (depth of stagnation [D2]). Velocity was then calculated using the formula:

$$Velocity = \sqrt{\left(2\left((D2 - D1)/100\right)9.81\right)}$$

Table 4-3: Dominant substrate codes and definitions (from CABIN 2012)

Code	*Definition*	*Code*	*Definition*
0	Organic Cover	5	3.2-6.4 cm (large pebble)
1	<0.1 cm (fine sand, silt , clay)	6	6.4-12.8 cm (small cobble)
2	0.1-0.2 cm (coarse sand)	7	12.8-25.6 cm (large cobble)
3	0.2-1.6 cm (gravel)	8	>25.6 cm (boulder)
4	1.6-3.2 cm (small pebble)	9	bedrock

4.7 Climatic Conditions

Local environmental data were downloaded from Environment Canada for the Nov. 1, 2013 to Feb. 28, 2016 period. In total, data from 16 stations were accessed. These stations were selected as they represent locations throughout the entire study region. The stations, as named by Environment Canada, are: Golden A, Revelstoke A, Revelstoke Airport, Nakusp CS, New Denver, Kaslo, Kimberley PCC, Cranbrook Airport, Cranbrook A, Nelson NE, Nelson Rixen Creek, Nelson CS, Castlegar BCHPA Dam, Castlegar A, Warfield, and Creston Campbell.

Historical average temperatures for the entire region were compiled and downscaled by WorldClim using climatic time series data over a 50-year time period (1950-2000) (Hijmans et al. 2005) and the SRTM (USGS 2004) digital elevation model. The WorldClim global dataset is composed of several layers of temperature and other bioclimatic variables in grid format with a spatial resolution of 30 arc-seconds, which is equivalent to one squared kilometre at the equator. These data were visualized in ArcGIS 10.3.

The Environment Canada weather stations provided current (2013-2016) weather data for select local areas where heron surveys were conducted. The WorldClim data provided a regional climate average over a broader region, but is interpolated over the landscape surface where no weather stations were present. Due to the ~1 km^2 resolution of the WorldClim dataset, this model cannot be expected to represent the actual climate within any given pixel or localized area, especially given the considerable topographical variation that can occur within short distances in mountainous terrain. Furthermore, these data are not intended to forecast weather conditions in the future, nor to address changes in climate over the past several decades related to global climate change or other factors. However, these data are useful for providing a continuous dataset of regional conditions.

4.8 Data Analysis

As discussed, the formal testing of management hypotheses was abandoned owing to the inability to alter flow rates experimentally and the low sample size of wintering herons. In order to be valid and biologically meaningful, statistical testing should be based on studies that have a good study design (including controls and replication) and adequate sample sizes. The lack of experimental ability makes it challenging to link flow regime from the Hugh Keenleyside Dam to heron counts in the Castlegar area. Furthermore, the influence of co-varying factors such as time of year or environmental conditions further confounds any observed trends. For this reason we pursued a greater focus on habitat attributes and heron distribution and abundances in the broader Kootenay region. However, to align with the study objectives, we maintain some analyses related to shoreline parameters measured among locations and time periods, and to daily heron counts and water elevation in the Castlegar area. It is important to consider that there were a limited number of sites with herons present, limiting the power of any tests analysing that response. Results of all statistical tests were considered significant at $\alpha=0.10$. All statistical analyses were carried out using R (R Core Team 2016).

4.8.1 Habitat Parameters

Habitat investigations were restricted to the following variables: water temperature, dissolved oxygen, specific conductance, pH, turbidity, dominant substrate, water velocity, air temperature, wind speed, relative humidity, cloud cover, shoreline width, shoreline length, macrophyte score, and periphyton score. All parameters failed the Shapiro-Wilk test for normality ($p< 0.1$), thus non-parametric tests were employed for significance testing.

We investigated habitat differences between surveys conducted early (November-December; pre-whitefish flow) vs. late (January-February; post-whitefish flow) in a given winter. To test these differences we performed paired Wilcoxon Signed-Rank Tests (n=105 sites visited in both pre- and post-periods in a given year). The Wilcoxon Signed Rank Test is the non-parametric analogue of the paired t-test, and it tests whether the median of the distribution of the differences (i.e., the differences between the before and after values of each pair) is significantly different from zero. Because multiple tests were conducted (one for each physicochemical variable), we adjusted the α values by dividing by the number of tests conducted (Bonferroni correction).

To examine habitat differences between sites at Castlegar vs. all other areas, we used Mann–Whitney tests (the non-parametric analogue of the t-test). Data were restricted to sites that were visited both early (Nov/Dec) and late (Jan/Feb) in a given winter, and to data from the 2014-15 and 2015-16 (n=182 sites). Again, Bonferroni adjustments were used to control for the number of variables examined.

Since there was interest in whether physicochemical values changed over time within a site, we initially approached the problem as a series of within-site tests. However, sample-size limited the value of such tests. To utilize the dataset to its best potential, we decided to run a MANOVA, with fifteen dependent variables, and with Site and Year (and interaction) as factors. Data were restricted to sites that were visited both early (Nov/Dec) and late (Jan/Feb) in a given winter, and to data from the 2014-15 and 2015-16 (n=182 sites). Note that since the dependent variables deviated from normality, the *P* values from this test are not exact and should be interpreted with caution.

4.8.2 Regional Heron Presence

A multiple logistic regression was used to determine if a suite of habitat variables could predict the probability of heron presence. Owing to a small sample size of sites with heron presence, only numerical factors were included (i.e., no categorical variables such as ceiling type, and all ordinal parameters were treated as continuous) to retain sufficient degrees of freedom for the analysis. The resulting variables included were: air temperature, water temperature, turbidity, water velocity, dissolved oxygen, specific conductance, pH, wind speed, relative humidity, shoreline width, shoreline length, and the four ordinal variables: dominant substrate size, cloud cover, macrophyte score, and periphyton score. A site was considered to have heron presence if a heron was detected within a 150 m buffer from the sampling location during the same sampling session. The distance of 150 m was chosen without biological significance, but was based on a distance that was reasonable for an individual heron to travel in a relatively short period of time (i.e., 150 m was typically less than the length of Breakwater Island) and also was broad enough to encompass the whole shoreline sampling station while typically not overlapping adjacent sampling stations.

Only data from the last two years of study were used, and only sites that were sampled in both early (Nov-Dec) and late (Jan-Feb) periods of a given year (n=182). Due to missing values for some parameters, 26 records were excluded, leaving 177 observations used to fit the saturated (all variables included) Generalized Linear Model (GLM). All variables were tested for correlations using a Spearman Rank correlation test. The Spearman Rank correlation was chosen (rather than Pearson) since these parameters were found to deviate significantly from normal. No variables were sufficiently correlated to justify their removal from the full GLM ($-0.7 < r < 0.7$). The GLM was run with a binomial error structure. The residual deviances were small relative to the degrees of freedom, thus overdispersion was not suspected. A stepwise procedure was used to remove variables from the full model, one-at-a-time, until the best model was found (by means of Akaike Information Criterion). ANOVA test was subsequently used to compare the reduced model to the fuller version and to the initial (saturated) model, until any further removals produced a significantly poorer fit.

To test the goodness of fit of the final logistic regression equation, we calculated the percent of the observations that would have been correctly categorized by the model. The area under the receiver operator curve (ROC) was also calculated (Robin et al. 2011). The ROC is an index of discrimination ability (range of 0.5 to 1.0 with 0.5 random and 1.0 perfect) provided by the model. ROC values of 0.5-0.6 indicate worthless discrimination, 0.6-0.7 poor, 0.7-0.8 fair, 0.8-0.9 good, and 0.9-1.0 excellent discrimination.

Species distribution models (SDM) combine species presence/absence data with environmental variables to predict their spatial distributions across the landscape. SDMs are used in terrestrial, marine and freshwater environments and with a vast array of wildlife species (Elith and Leathwick 2009). Using the program R (R Core Team 2016) and its package dismo (Hijmans et al. 2016), several suitability models were calculated. The algorithm that produced the model with best accuracy was Random Forest (Liaw and Wiener 2002). This method was derived from the classification and regression trees algorithms (CART) (Breiman et al. 1984), which are widely used in Ecology.

The spatial variables used with this model were: elevation, slope, precipitation in the coldest quarter, mean temperature in the coldest quarter, distance to waterbodies (i.e., major rivers, lakes), and distance to agricultural lands. All variables had a spatial resolution of 1 kilometer, and were continuous over the study area. All variables were converted to raster datasets with an identical geographical extent and spatial resolution. A number of other variables collected during field sampling could not be used in the model owing to their non-continuous structure.

The presence/absence data used to produce the distribution model was randomly divided in training and testing datasets. The training dataset was comprised of 197 presence and 362 absence locations, while the testing dataset had 62 presence and 59 absence locations. After executing the algorithm, the model was evaluated using performance metrics such as the area under the receiver operator curve (auc=0.863). This metric described a good performance of the model in predicting habitat suitability for Great Blue Herons. Suitability was depicted with a yellow-red color palette, with only habitat with a strong probability (>50 per cent) of heron presence being illustrated.

4.8.3 Castlegar Heron Counts

A multiple regression was conducted to determine whether the maximum daily count of herons on Waldie Island could be predicted by Keenleyside flow rate, tailrace elevation data, air temperature, precipitation, and/or snow height in three winter survey periods (2013/14, 2014/15, and 2015/16).

For the GLM, stepwise term deletions were performed manually. Variables were removed from the full model, one-at-a-time, until the best model was found. ANOVA tests were subsequently used to compare each reduced model to the fuller version and to the initial (saturated) model, until any further removals produced a significantly poorer fit. The approximate R^2 for the model was calculated as the squared Pearson correlation coefficient of heron counts by the fitted final model.

5.0 RESULTS

5.1 Heron Abundance, Density and Distribution

Heron observations during the 2014/2015 and 2015/2016 survey years were highly clustered in two main areas: Castlegar and Creston. During the 2015/2016 field season, herons were observed on 18 of 24 survey dates. Heron numbers ranged from 0 to 17 individuals on any given day. In contrast, during the 2014/15 field season herons were detected on 12 of 24 survey dates, but maximum daily counts were higher at ~24 individuals. Overall, herons were more widespread in November than in February (Figure 5-1). November/December surveys located herons in Revelstoke, Burton Creek (south of Nakusp), Castlegar, Creston, Lumberton (just north of Moyie Lake), and Invermere. By January/February, surveys recorded birds only at Castlegar, Creston, and Invermere.

Within Castlegar, numbers of herons differed among years. Daily maximum counts in the area of Waldie Island were 7, 9, and 14 individuals in Years 1, 2 and 3 of the study respectively. The wintering heron population in Castlegar was likely 1-3 individuals more than these counts, owing to consistent detections of individuals in areas outside of Waldie Island, such as at the Hugh Keenleyside Dam and the Kootenay River. During the winters of 2013/2014 and 2015/2016, the majority of heron detections were from Breakwater Island, a gravel bar just upstream of Waldie Island. Contrary to those winters, the majority of heron detections in 2014/2015 were from Waldie Island proper. Other areas with sporadic heron observations included the rip rap below the Hugh Keenleyside Dam, Pass Creek, the Castlegar Sewage Lagoons, Zuckerberg Island, Twin Rivers Park, and the Kootenay River Oxbow near Selkirk College. Some of these sightings likely pertain to birds undertaking movements from the Waldie Island area. Many observations were at sites where herons were consistently found in all three years, and observations were also consistent with the locations of herons during the early 2000s (Machmer 2003). Coordinates for all heron locations are provided in Appendix B.

Typically herons were seen roosting on foreshore areas, though individuals were found roosting in trees along the southern edge of Waldie Island, Zuckerberg Island, the hydro right-of-way near the Kootenay River Oxbow, and Burton Creek. At Duck Lake near Creston, herons were typically concentrated on the frozen surface of the lake itself, or along marsh edges along frozen lakes/creeks. Other herons were observed near water kept open by sluice gates, in ditches adjacent to agricultural fields, or in agricultural fields.

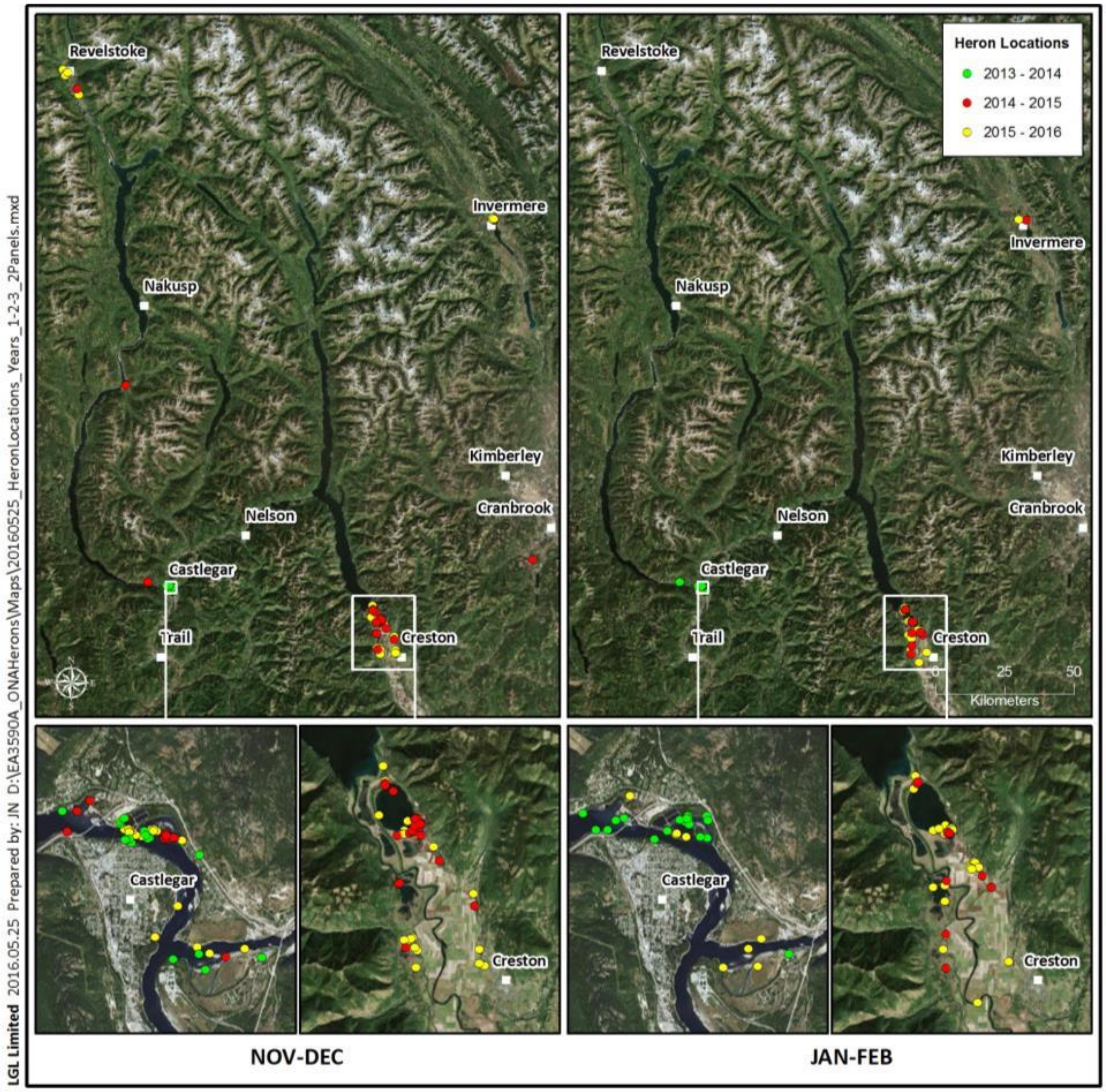

Figure 5-1: Locations (coloured dots) of Great Blue Herons observed during November/December (left panel) and January/February (right panel) during all years of surveys (green dots=2013/2014, red dots=2014/2015, and yellow dots=2015/2016). Note that 2013/2014 surveys were only done in the Castlegar area. Dots represent each location where a heron was seen, but do not necessarily refer to unique individuals. Bottom figures illustrate the distribution of heron sightings in the Castlegar and Creston areas

Around Waldie Island, and during our study period, daily counts show that heron numbers were highest in November through early December, and declined gradually through the pre-whitefish flow period (Figure 5-2). Counts continued to decline during the whitefish flow period from mid to late December through mid-January, and herons were virtually absent from the Waldie Island area from mid-January onwards (Figure 5-2). Heron numbers were highest during the winter of 2015/2016, but daily count data were only available until 31 December, 2015. Surveys by LGL and ONA during late January found only two herons, suggesting that the number of herons declined from late December through late January consistent with the previous winters.

When maximum daily heron counts are considered for the entire year, a distinct annual pattern appears to be emerge. In general herons are absent or occur in low numbers from early January through to late July and August. Then in the late summer heron numbers increase quite rapidly and peak around mid-September. Heron numbers decline through late September and early October before again climbing in late October or early November, when they again gradually decline to early January. This pattern is similar across all years of data, though the exact timing of heron peaks and the actual counts differ between years. During 2015/2016 heron numbers did not rapidly increase in late September as with previous years, but rather in late October/early November with overall daily numbers remaining higher than the previous two winters.

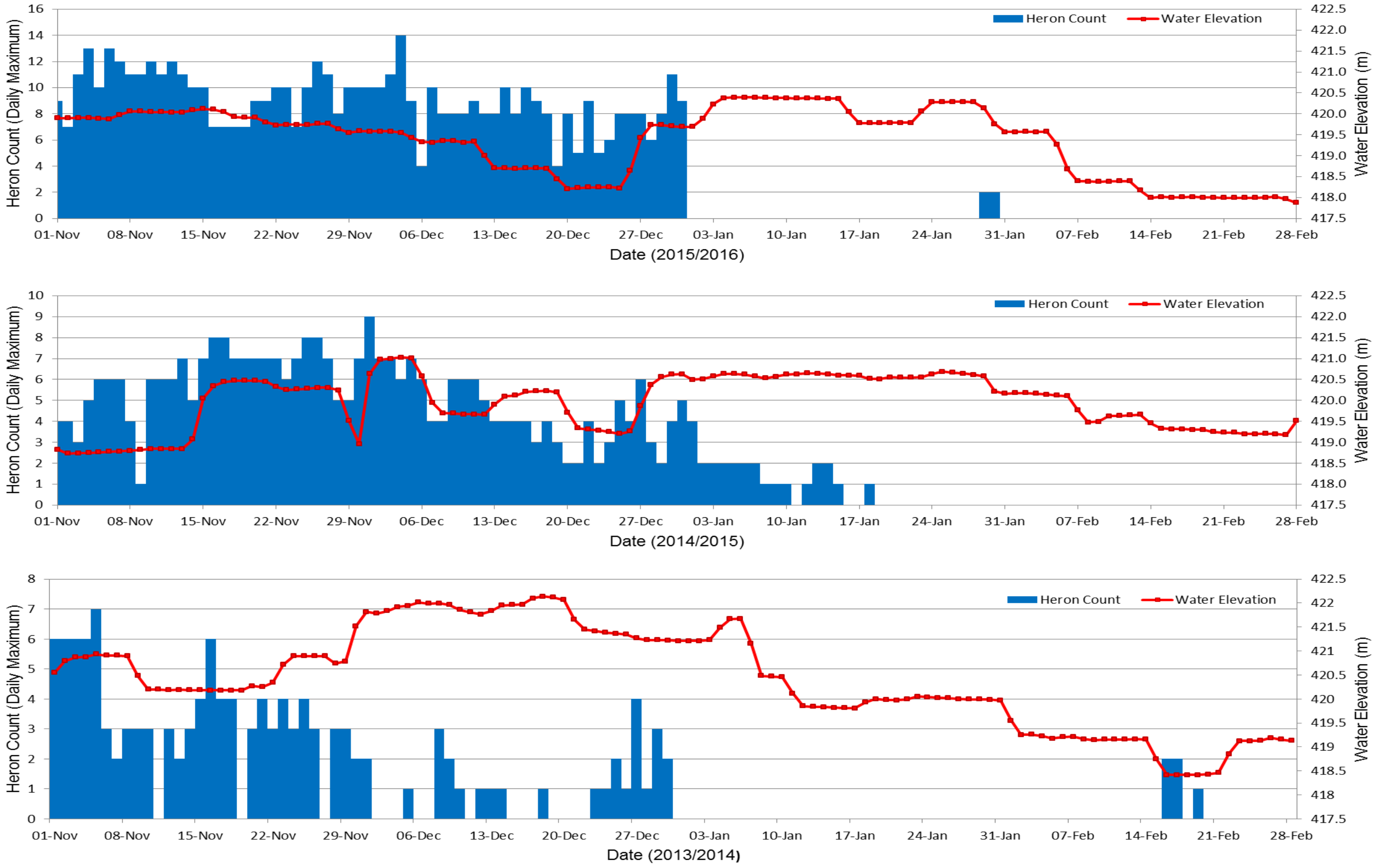

Figure 5-2: Maximum daily heron counts and daily average water elevations for the three survey years from most recent (top panel) to oldest (bottom panel). Note that the left vertical axis differs slightly among graphs. Daily count data provided by Caroline Halligan, and elevation data provided by BC Hydro and Poisson Consulting Ltd. Daily count data stops at December 31, 2015, the two herons observed in late January were detected by ONA biologists during scheduled surveys, and the number of herons between those two periods is unknown.

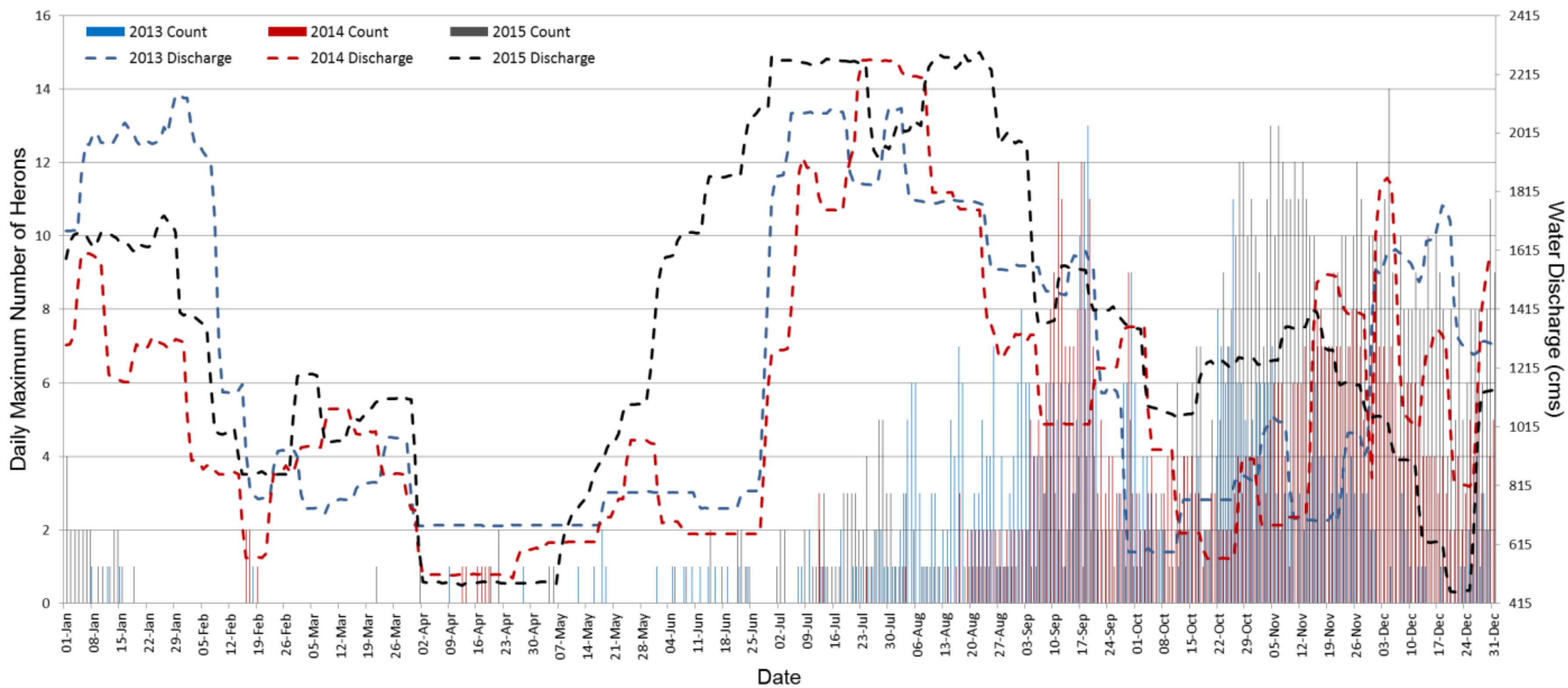

Figure 5-3: Daily maximum heron counts in the Waldie Island area during 2013 (blue bars), 2014 (red bars), and 2015 (black bars), from a property overlooking the area. Seasonal fluctuations in numbers correspond to distinct periods of the annual cycle (e.g., breeding, dispersal). The water flow rate is overlaid for comparison. Count data courtesy of Caroline Halligan

5.1.1 Christmas Bird Count Results

Previous surveys indicate a variable overwintering heron population around Castlegar, albeit one that is currently lower than in the early 2000s. Dedicated surveys following methods comparable to this study found up to 29, 26, and 21 individual herons in the winters of 2000/01, 2001/02 and 2002/03 respectively (Machmer 2003). Dedicated surveys for herons were not completed, to our knowledge, between 2003 and the commencement of this study. However, Christmas Bird Count data present a longer-term (though variable by count) dataset for a variety of areas throughout British Columbia and the northern United States, that can be used to help determine how, or if, heron numbers have changed over time at local levels.

The Christmas Bird Count is a long-term citizen science initiative administered in Canada through Bird Studies Canada with data housed by the National Audubon Society. These counts are conducted on one day a year (between mid-December and early January) by individuals with varying levels of experience and training, are not heron-specific, and may not be properly corrected for effort or environmental conditions. While caveated, these data still provide supplementary information on heron abundance throughout the Kootenay region. In general, the Christmas Bird Count data for the Castlegar area over the past three years has aligned well with counts that we have completed in the area.

Historical Christmas Bird Count data were obtained for 25 counts within the Kootenay region of B.C. and related areas of the northern United States (http://birds.audubon.org/data-research). Bald Eagles are a known predator of Great Blue Herons, and while eagle impacts on wintering herons are not well documented, their count totals are also included here (see Appendices Appendix C-Appendix H).

Heron numbers were consistently higher in Castlegar and Creston than any other Christmas Bird Count conducted in the study region. Christmas Bird Count data from Castlegar and Creston indicate highly variable winter heron counts (Table 5-1). Heron counts were higher in Castlegar than Creston on seven out of the past eleven years, though the highest overall counts were observed in Creston. Christmas Bird Count results from other areas in the Kootenay/Columbia region are typically low, with inter-year variability and no obvious trend in numbers over the past decade. Based solely on these data, there is obvious inter-annual variation, though no strong case could be made for an overall decline in numbers across the entire period. Indeed, combining counts for these two locations shows consistent tallies in the low to high twenties most winters, with the exception of a couple winters with low counts at both locations (Table 5-1). Again based solely on these Christmas Bird Count data, years with higher counts in Castlegar often correspond to years with lower counts in Creston, and vice versa, indicating that conditions that promote heron occurrence at a given place and time may not be applicable to the region as a whole.

Heron numbers on Christmas Bird Counts in adjacent regions of the United States (Montana, Idaho, and Washington) show similar inter-annual variation with no clear long-term trends (Appendices Appendix F-Appendix H). The count for Spokane goes back to 1940, and clearly shows strong inter-annual variation with no obvious long term trend (with the exception of a possible initial population increase during early decades of the count) (Appendix H). Heron numbers are also relatively low overall, although a couple of counts typically record greater numbers of herons than counts in the Kootenays of B.C. These include Spokane (Washington), with counts typically exceeding 20 individuals, and notably Indian Mountain (Idaho) where counts have reached 100 individuals. Counts at Indian Mountain (at the south end of Lake Coeur d'Alene) appear to have maintained high numbers since the early 2000s. Interestingly, the habitat around the Indian Mountain count appears similar to the Creston area, with a mixture of water channels, marshy habitats, and agricultural fields, in addition to a large lake. The north end of Lake Coeur d'Alene does not record particularly high numbers of herons (a maximum of 30, but typically single-digits). However, even at these locations there is strong year to year variability, such as totals from Indian Mountain of 99 and 11 in 2015 and 2016 respectively, and an increase over those same years from 5 to 51 at the Sandpoint (Idaho) count.

Table 5-1: Great Blue Heron and Bald Eagle count results from the Castlegar and Creston Christmas Bird Counts from the 2005 count year to 2015

Count Year	Heron Count			Eagle Count	
	Castlegar	Creston	Combined	Castlegar	Creston
2005	2	23	25	4	14
2006	16	11	27	10	9
2007	4	15	19	10	27
2008	19	4	23	11	21
2009	7	1	8	15	32
2010	17	3	20	14	15
2011	18	9	27	12	25
2012	10	15	25	12	20
2013	4	24	28	13	34
2014	5	3	8	14	21
2015	12	10	22	10	24
Median Count	*10*	*10*	*23*	*12*	*21*

5.2 Heron Behaviour

In total, herons observations were conducted on 60 occasions in 2013/2014, and on 97 and 148 occasions in 2014/2015 and 2015/2016 respectively. This total includes all observations of all herons and all dates, such that this number is higher than the total number of herons owing to multiple encounters of the same individuals on the same or subsequent days or weeks. During the first winter of study, dedicated focal scans were completed over 10-minute periods to determine daily activity budgets. During the second and third winters behaviours were recorded based on the observed behaviour at the time of observation with no pre-specified duration of observation. The most frequently encountered behaviour was resting, in all years and locations (Table 5-2; Table 5-3). Herons in Castlegar in the first year rested overall for 85% of the time during daylight observation periods (Table 5-2). Herons, when not resting, exhibited a variety of behaviours. Birds were typically alert during disturbance events (e.g., dog walkers, trains). Disturbances occasionally escalated to the point that the heron flushed. Herons were noted in flight for at least part of the observation in 44 instances during the second and third winters, with some appearing to be caused by specific disturbances. Foraging was seldom observed during daylight hours. Foraging herons were most often detected from the Creston area, such as around Duck Lake, but foraging was also observed during twilight around Waldie Island.

Table 5-2. Daily activity budgets (represented in percent of time) of Great Blue Herons in the Castlegar area for all herons, adults only, and immatures only. The mean, standard deviation (SD), minimum and maximum values are shown. Behaviour codes are RE: resting, PR: preening, FO: foraging, AL: alert, FL: flying, WA: walking, OTH: any behaviour not classifiable into the previous category

	Behaviour (% of Time)						
	RE	PR	FO	AL	FL	WA	OTH
Overall (n=60)							
$\bar{x}$	84.9	3.1	1.0	5.2	1.4	2.9	1.6
S.D.	23.7	8.7	4.9	12.1	4.6	9.2	4.7
Min.	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max.	100.0	46.7	34.5	64.2	24.7	63.3	24.5
Immature (n=36)							
$\bar{x}$	79.9	3.6	1.4	6.7	2.1	4.0	2.2
S.D.	28.6	10.6	6.2	14.7	5.7	11.6	5.3
Min.	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max.	100.0	46.7	34.5	64.2	24.7	63.3	24.5
Adult (n=14)							
$\bar{x}$	91.0	2.3	0.0	4.3	0.0	1.0	1.4
S.D.	11.0	4.4	0.0	7.2	0.0	2.8	4.8
Min.	71.2	0.0	0.0	0.0	0.0	0.0	0.0
Max.	100.0	11.5	0.0	23.5	0.0	10.2	18.0

Table 5-3: Behaviours of all Great Blue Herons observed during surveys in the Columbia/Kootenay region during the winters of 2014/2015 and 2015/2016. Numbers refer to the number of observations in each age and behaviour category, but do not refer to unique number of individuals which is fewer owing to multiple sampling of individual herons. Behaviour codes are RE: resting, PR: preening, FO: foraging, AL: alert, WA: walking, FL: flying, and Mixed Behaviour indicates that multiple behaviours were shown by one individual during an observation.

Age Class	Behaviour							*Total*
	RE	PR	FO	AL	WA	FL	Mixed Behaviour	
Adult	62	3	9	8	2	3	23	*110*
Immature	56	2	1	5	2	0	20	*86*
Unknown	19	0	3	4	1	9	13	*49*
Total	*137*	*5*	*13*	*17*	*5*	*12*	*56*	*245*

Related to foraging, it was clear from the first year's behaviour results that herons around Castlegar were predominantly foraging at night (Hentze et al. 2015). This was also true of observations made by Machmer (2003). Herons in the Creston area appeared to be using a different strategy. There, herons were standing on the frozen surface of the south end of Duck Lake, often hundreds of metres from shore (Figure 5-4). Although the lake was mostly frozen across, holes in the ice provided foraging opportunity. Herons were observed fishing from these holes, occasionally shifting to alternative ice holes to resume foraging. On one occasion, a heron was observed catching a (unidentified) fish from an ice hole, and other capture attempts were documented that appeared unsuccessful. This ice fishing strategy is regularly observed during the winter from this locality (Marc-André Beaucher pers. comm.).

Figure 5-4: A Great Blue Heron forages above an ice hole on an otherwise frozen-looking Duck Lake near Creston.

These ice holes may remain open in part due River Otter (*Lontra canadensis*) activity. On one occasion at Leach Lake in Creston, six River Otters were observed catching multiple fish (possibly sculpins) from ice holes in the lake. An adult heron flew in from the north and landed on the ice, and proceeded to walk around the otters (Figure 5-5). It is not known whether the heron was attracted to potential fish scraps left by the otters or to the presence of an obviously productive foraging location. This may provide herons with additional foraging opportunities not present to herons wintering in Castlegar. During February 2016, seven herons were observed along a small area of open water along an otherwise frozen stream in Invermere, a situation similar to that in Creston.

Figure 5-5: A Great Blue Heron (rear centre) flew in and approached a group of six River Otters (four visible here in foreground) as they dived in holes in the ice during November 2014. The otters were actively and successfully catching fish (possibly sculpins). River Otter activity may aid in the maintenance of these ice holes which are then utilized by Great Blue Herons for foraging

In general it appears that herons in Castlegar may be less active during daylight hours than those from other regions (Table 5-6). While Castlegar herons spent more time resting and preening and less time foraging or otherwise being active (walking or flying), they also were less likely to be detected being alert.

Table 5-4: Percentage of observations of herons resting (resting: RE, and preening: PR, combined), foraging (FO), active (walking: WA, and flying: FL, combined), and alert (AL) for herons observed in Castlegar and elsehwere in the Columbia/Kootenay region during the winters of 2014/2015 and 2015/2016. Per cents do not add to 100 as mixed behaviours (e.g., resting and active) are excluded.

Location	Behaviour				Total
	RE / PR	FO	WA / FL	AL	
Castlegar	69.6	3.3	2.2	2.2	77.2
Elsewhere	51.0	6.5	9.8	9.8	77.1
Combined	58.0	5.3	6.9	6.9	77.1

5.3 Habitat Availability

As discharge rates from Hugh Keenleyside Dam increase, so does the downstream water elevation. Potentially available shoreline areas are any exposed, essentially non-vegetated areas below the maximum high-water mark that could be used for foraging and/or roosting, and the forested section of Waldie Island that could be used for roosting. The elevation of shoreline areas is critically important in determining whether a given increase in water elevation will flood that habitat. In addition, the location of exposed land and the slope of the shoreline will have an effect on the extent and rapidity by which it floods as waters rise. For example, an increase in water levels could reduce the length of available shoreline, the width, or both concomitantly. For this reason, low-lying islands are particularly susceptible to changes in potentially available habitat with changing water elevations.

Waldie Island and Breakwater Island are two locations that are reliably used by Great Blue Herons during the winter period in the Castlegar area. Herons were frequently encountered on Breakwater Island during the 2013/14 winter, only occasionally being seen on Waldie Island. In 2014/15 this pattern was reversed, with herons frequenting the shores of Waldie Island. In 2015/2016 most herons were found on Breakwater Island, though some individuals were regularly observed roosting in trees on Waldie Island or utilizing the Waldie Island shoreline at dusk. Both of these islands have a large decline in shoreline area as water elevations increase (Appendix I). The lowest water levels during the study were from February 2016 (417.88 m), while the maximum was recorded in December 2013 (422.14 m). This is an elevation difference of 4.26 m. The greatest within-month change in shoreline area overall occurred in November 2014, which experienced a 2.39 m change in water elevation during the pre-whitefish-flow period (Appendix I). The month with the lowest change in water elevation varied from December during Year 1 to January during Year 2 to November during Year 3, with differences of 0.93 m, 0.82 m, and 0.57 m respectively. Despite these overall changes, different sites respond slightly differently owing to site-specific topography. For example, Waldie Island had a 73.4 per cent decrease in shoreline area in November 2014 between minimum and maximum water elevations that month. In December 2014, Waldie Island experienced a 62.1 per cent decrease, for a total shoreline loss between November minimums and December maximums of 78.9 per cent that year (Figure 5-6). Breakwater Island, being shallower, had losses of 80.9 per cent in

November, and 99.8 per cent in December, and a total shoreline loss between minimum and maximum water elevations of 99.9 per cent during that same survey year (Figure 5-6). Overall, water levels rising from 417.88 m (study period minimum) to 422.14 m (study period maximum) in the Castlegar area signify inundation of approximately 72.6 ha (73.5 per cent) of available shoreline and lowland habitat. Breakwater Island is virtually or entirely inundated at water elevations exceeding 421 m.

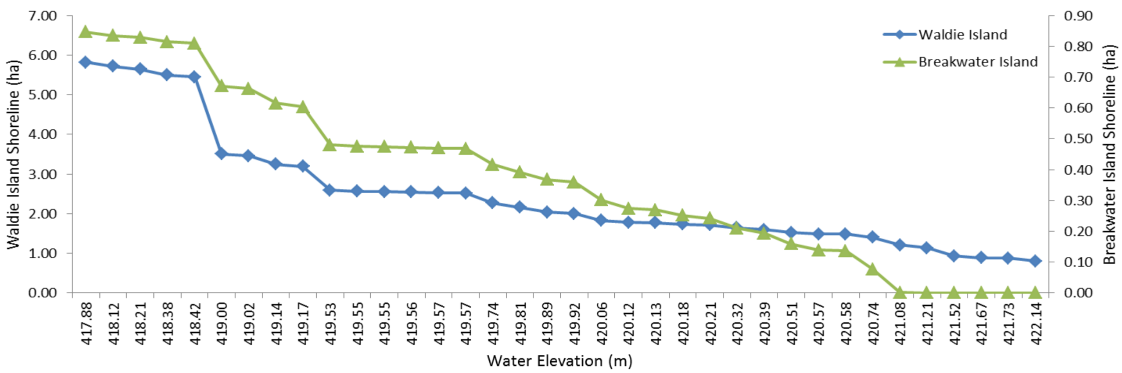

Figure 5-6: The amount of shoreline area (potential heron habitat) in hectares available at the monthly minimum, maximum, and average water elevations for all survey months of all survey years. Note that Waldie Island and Breakwater Island are plotted on different vertical axes.

During the first two winters of study (2013/2014 and 2014/2015), monthly average water elevations increased (and hence shoreline area decreased) between November and December, and then increased over each subsequent month. In the third winter, average water elevations decreased between November and December, increased between December and January, and decreased again between January and February (Figure 5-7). Among years, water elevations were most similar in January, corresponding to the Mountain Whitefish flows. Thus, January was typically a period of relatively stable, high water elevations relative to all years of this study, though the exact pattern of water flows varied by year (Figure 5-7).

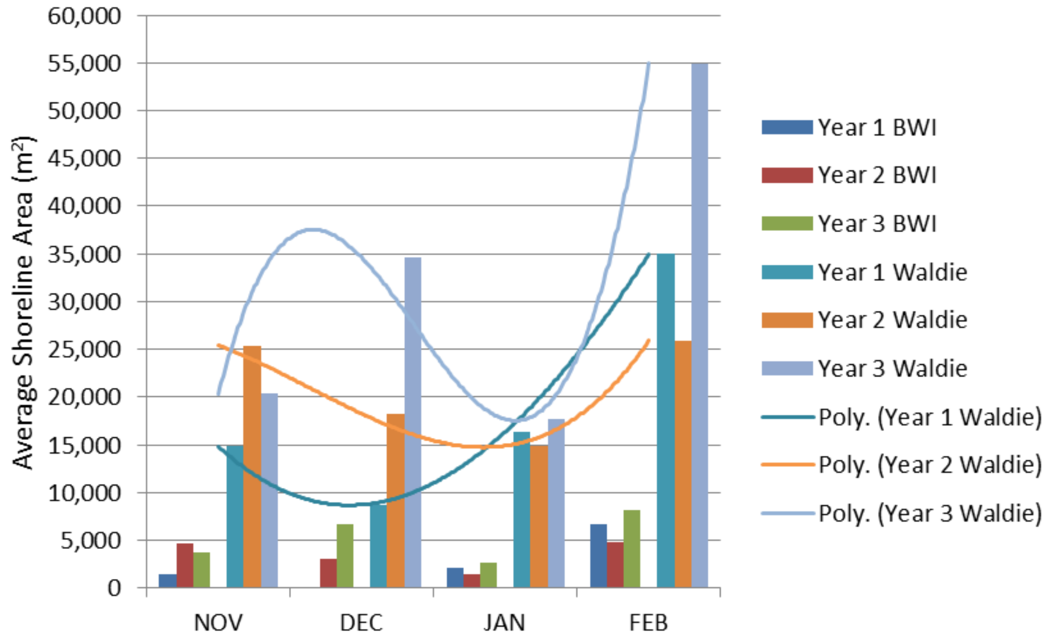

Figure 5-7: Amount of available potential shoreline habitat by month based on average water elevations for each month for the three winters of study. Data are shown for Breakwater Island and Waldie Island. Trendlines (third order polynomial) have been added to illustrate the varying nature of water inundation among years across the winter survey period.

The main areas that are exposed during low water periods that become mostly or wholly submerged at high water elevations include the Pass Creek Delta, Breakwater Island and the extent of land between the island and the foreshore, Waldie Island and the mudflats separating it from the mainland shore, Tin Cup Rapids, the channels and flats north and west of Zuckerberg Island, and the shoreline along the eastern side of the Columbia River downstream of the confluence (Figure 5-8 and Figure 5-9). With the exception of the east side of the Columbia and Tin Cup Rapids, herons have been observed at all these locations during the past two winters of surveys. Other than the forested portion and extreme upper reaches of Waldie Island, the area that retains the most shoreline habitat is the area just east of the Kootenay River oxbow (Figure 5-8). This habitat is mostly grassy, and may not be utilized by herons the same way that alternative shoreline areas would.

Figure 5-8: The available shoreline areas between the river and the high-water mark (orange areas) at the minimum (417.88 m in Feb. 2016, top panel) and maximum (422.14 m in Dec. 2013, bottom panel) water elevations present in the study area between November 1 and February 28 of survey years. Water elevation was measured from the CNN gauge at Norns Creek (source BC Hydro). The bounds of the area for this analysis are outlined in blue

Figure 5-9: The available shoreline areas between the river and high-water mark (orange areas) at the minimum and maximum water elevations present around Waldie Island between Nov. 1 and Feb. 28 of survey years. Top Left=Feb. 2014 (418.42 m), Bottom Left=Dec. 2013 (422.14 m), Top Right=Feb. 2016 (417.88 m), Bottom Right=Jan. 2016 (420.39 m). Water elevation was measured from the CNN gauge at Norns Creek (source BC Hydro). The bounds of the area for this analysis are outlined in blue

5.4 Habitat Suitability

A total of 296 shoreline samples were conducted at 67 locations (Figure 4-2). Whenever possible, the same location was surveyed in the early (November/December) and late (January/February) sampling sessions. Due to access restrictions (e.g., ice cover, construction) during one of the sampling periods, only 105 locations were sampled in both November and February in a given winter. The locations were distributed throughout the study region. In the Castlegar area, sampling sites were the same as during the winter of 2013/14, and were focused on areas around Waldie Island and the Columbia/Kootenay confluence. Elsewhere in the region, sampling sites were the same as in 2014/2015.

Sites were adjacent to a variety of land types and uses including city parks, greenspaces, fields, forests and commercial/industrial. Included in the shoreline surveys were assessments of macrophyte and periphyton coverage as they both contribute to habitat and food sources for invertebrates and fish, which in turn could benefit herons. Little macrophyte coverage was detected at any site.

Similarly, very low periphyton coverage was detected, with most sites having no or extremely limited periphyton coverage.

Water physicochemistry data were recorded from each site. Where multiple samples were taken at a given visit to a site, the values were averaged. The mean and standard deviation of these averages, as well as a discussion, are presented in Table 5-5. In general, values for most parameters were similar among sites.

Table 5-5: Physicochemical and environmental variables collected during shoreline sampling at each survey site. These variables are the same as those measured during the 2013/14 field-season. Definitions and justifications for the measured parameters were compiled from the Canadian Aquatic Biomonitoring Network (CABIN 2012) and Guidelines for Interpreting Water Quality Data (RISC 1998b)

Parameter	Mean ± SD	Typical Limits and Discussion
Dissolved Oxygen (mg/L)	15.33 ± 6.93	Maximum solubility of oxygen is ~15 mg/L at 0˚C. Invertebrates require DO of higher than 4 mg/L, the point below which acute mortality occurs. Only six measured DO values were at or below these minimal levels, all were in Creston (herons were present at 2 of these sites). Two sites had DO values of between 4.6 and 4.8 mg/L (measured only in February 2015 after being frozen over most of the winter). A third site in the channel south of Duck Lake had a very low DO concentration of 0.7 mg/L in Nov. 2014 and 2.9 mg/L in Nov. 2015. In Jan/Feb 2016, Cartier Bay and Leach Lake South had values of 3.6 and 3.9, respectively.
Specific Conductance (µS/cm)	175.57 ± 98.04	Natural waters vary from 50 to 1500 µS/cm with interior streams ranging up to 500 µS/cm. Only two sampling locations had a measured specific conductivity less than 50 µS/cm (39.4-45.6 µS/cm at Pass Creek; 36.7 µS/cm at St. Mary's, below the plant), with four other sites measuring approximately 50 µS/cm. These were often in streams or side channels. Two sites had values greater than 500 µS/cm (556-604.6 µS/cm at South Duck Lake Channel; and 531.5 µS/cm at Side Channel S. of Bridge).
pH	7.77 ± 0.58	Natural fresh waters have a pH ranging from 4.0 to 10.0. Most lakes in BC have pH of 7.0 or greater. Lethal effects of aquatic life occur below pH 4.5 and above pH 9.5, with optimal levels being between pH 6.5 and 9.0. All of our recorded values fell within the range

Parameter	Mean ± SD	Typical Limits and Discussion
		that aquatic life can tolerate, with our measurements ranging from pH 5.3 to 8.9. All of our measurements except for two (5.3 at Bridge Channel in Feb 2015 and 6.2 at Waldie West in Jan 2016) were within the optimal pH level for aquatic organisms.
Temperature (˚C)	3.80 ± 2.20	Temperature naturally varies in a waterbody from 0˚ to 40˚ (hot springs). All of our temperature measurements fall between 0.0 and 8.8˚C. While the temperatures are all ok for supporting aquatic organisms, colder waters may be more prone to freezing, and therefore limit heron foraging potential. Of the 38 average water temperatures <1˚C, 29 were recorded in the early session (Nov-Dec) and 9 in the late session (Jan-Feb). This is attributed not to colder temperatures early in the winter, but rather sites becoming completely frozen over, thus preventing sampling later in the winter.
Turbidity (NTU)	11.72 ± 38.11	Pure distilled water has a turbidity of 0 NTU. High levels of turbidity reduce light penetration and therefore plant growth and can thereby suppress fish productivity, and can limit visibility which may inhibit foraging by visual predators. Drinking water has a turbidity limit of 1 NTU for health, and 5 NTU for aesthetics. The majority of samples (66%) had very clear water, and turbidity levels that were <5 NTU. Fifteen samples had turbidity values >50 NTU, with the most extreme being 392 NTU at the Kuskanook South. In all cases, the high turbidity levels were temporary, as readings from other surveys were not as high. Three sites with > 50 NTU readings had herons present.
Macrophyte and Periphyton coverage	Macrophyte: typically 0-25% coverage Periphyton: typically 0-0.5 mm thick.	Higher macrophyte and periphyton coverage may increase invertebrate habitat which may influence fish presence. Macrophyte coverage varied from 0% to 76-100%, but 91.5% of all sites had macrophyte coverage of either 0% or 1-25%. Periphyton coverage varied from none to lots (>20 mm thick), but most (71.6%) had no or minimal (<0.5 mm thick) coverage.
Substrate Class	Organic cover to	The substrate may be related to stream flow, but prey may be more abundant in certain substrate

Parameter	Mean ± SD	Typical Limits and Discussion
	boulders	types. No single substrate class dominated the dataset.
Water Velocity (m/s)	0.25 ± 0.23	Water velocity varies as a function of stream size and the amount of water moving past. Water velocities were relatively slow in most locations, varying from 0 to 1.3 m/s. Only eight sites had velocities greater than 0.7 m/s on at least one occasion. 47 sites measured zero m/s. Of the 40 sites with herons, 33 had velocity measurements, and of these six had zero velocity.

For the sites in which samples were taken in both November and February, the physicochemical parameters were compared between the time periods to see if any changes occurred. Paired analyses showed that most of the physicochemical parameters had significant differences between the time periods (Table 5-6, Figure 5-10). While statistically significant, the differences were relatively small and overall not of any apparent biological significance. In general, all of the measured values in both time periods were within ranges that should be tolerable to aquatic organisms (Figure 5-10).

Table 5-6. Results of Wilcoxon Signed-Rank tests for paired differences in physicochemical parameters between the the early (November/December) and late (January/February) sampling periods. *P* values are deemed significant (*) or not (ns) only after using the Bonferroni-correction (critical value=0.0067 for 15 tests)

Parameter	Mean Difference (Early - Late)	Wilcoxon statistic (V)	*P* value	
Water Temperature	0.737	3691.0	0.0009	*
DO	-0.861	5556.0	< 0.0001	*
Sp. Conductance	-6.644	5565.0	< 0.0001	*
pH	0.410	5558.0	< 0.0001	*
Turbidity	5.865	3050.0	0.3934	ns
Dom. Substrate Score	-0.165	3130.0	0.2673	ns
Water Velocity	-0.021	3.0	< 0.0001	*
Air Temperature	-1.569	972.0	< 0.0001	*
Wind Speed	1.885	2901.5	0.5792	ns
Relative Humidity	-5.504	5565.0	< 0.0001	*
Cloud Cover	14.071	5250.0	< 0.0001	*
Shoreline Width	-12.986	4025.5	< 0.0001	*
Shoreline Length	-36.963	5565.0	< 0.0001	*
Macrophyte Score	-0.044	31.5	< 0.0001	*
Periphyton Score	0.186	374.0	< 0.0001	*

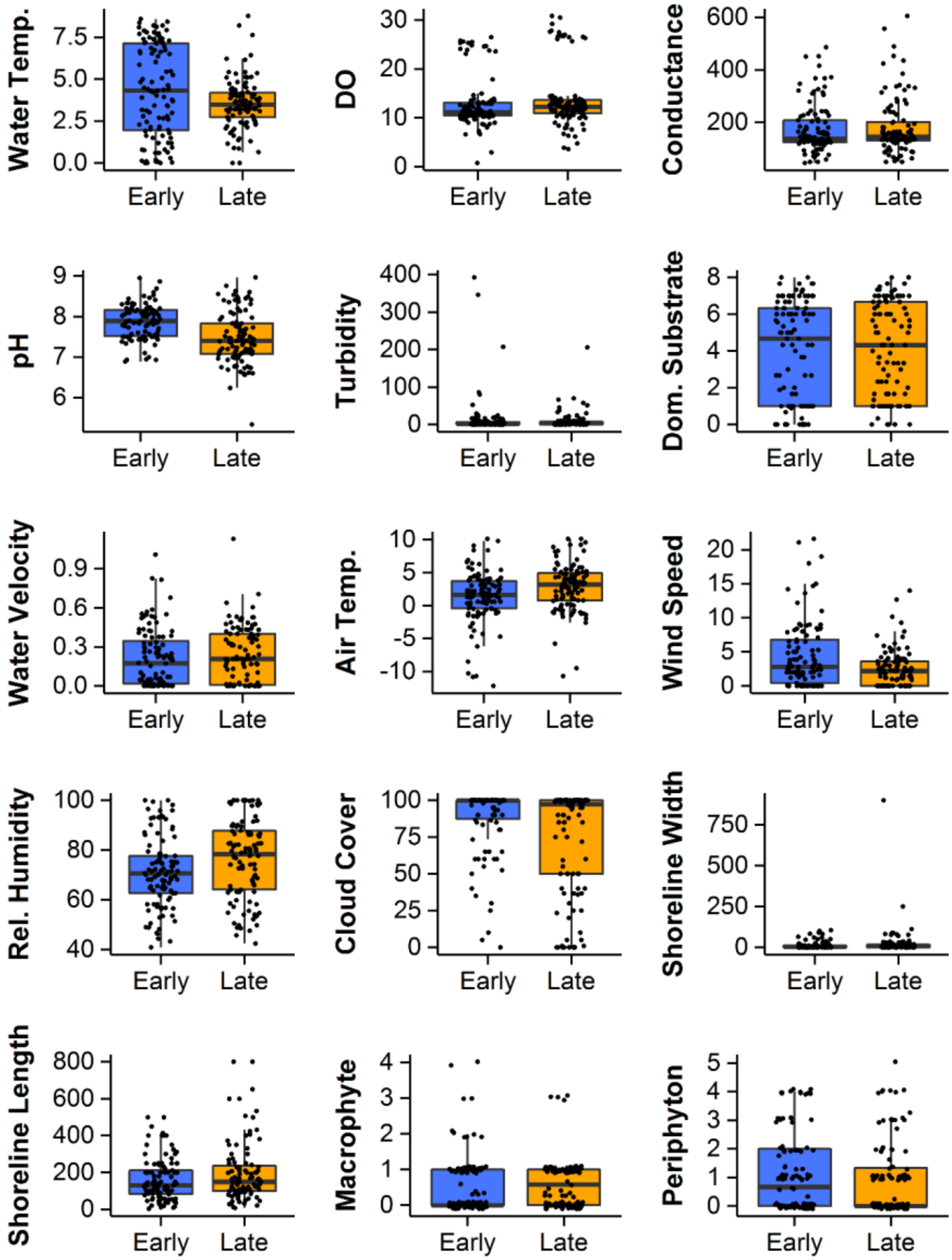

Figure 5-10. **Boxplots (with datapoints overlaid) showing the distribution of average values of each habitat parameter, data restricted to sites surveyed in both early (Nov-Dec) and late (Jan-Feb) periods of a given year (n=105). Data are jittered horizontally to help prevent dots from overwriting each other. Macrophyte and Periphyton data also jittered vertically**

Shoreline parameters were also compared between sites in Castlegar and sites in all other localities surveyed (Figure 5-11). Wind speed and the temperatures of air and water were all significantly higher in Castlegar than in other areas (Table 5-7). Conversely, the specific conductance and turbidity were significantly lower at Castlegar sites than in other areas within the study region. In general, water physicochemical parameters appeared more variable in those other areas (Figure 5-11), perhaps owing to the greater geographic extent of sampling. In general though, no major differences stand out that would indicate that habitat around Castlegar is more suitable based on these measured parameters than at other locations in the region.

Table 5-7. Results of Wilcoxon Tests for differences in physicochemical parameters between the Castlegar sites and those located in other areas. P values are deemed significant (*) or not (ns) only after using the Bonferroni-correction (critical value=0.0067 for 15 tests)

Parameter	Mean Value Castlegar	Mean Value Other	Wilcoxon statistic (V)	*P* value	
Water Temperature	5.8	3.1	6110.0	< 0.0001	*
DO	11.7	11.2	3354.5	0.4668	ns
Sp. Conductance	133.9	210.2	2174.0	< 0.0001	*
pH	7.5	7.6	3021.5	0.0830	ns
Turbidity	3.7	18.6	1790.0	< 0.0001	*
Dom. Substrate Score	4.6	3.6	4436.5	0.0107	ns
Water Velocity	0.2	0.2	2815.5	0.0830	ns
Air Temperature	4.3	1.6	5073.5	< 0.0001	*
Wind Speed	4.8	2.5	4601.0	0.0014	*
Relative Humidity	74.8	75.3	3481.0	0.8726	ns
Cloud Cover	85.0	83.5	3032.5	0.1766	ns
Shoreline Width	12.2	23.6	3969.5	0.0664	ns
Shoreline Length	169.9	196.1	3249.5	0.8046	ns
Macrophyte Score	0.5	0.7	3010.0	0.2516	ns
Periphyton Score	1.0	1.0	3643.0	0.6401	ns

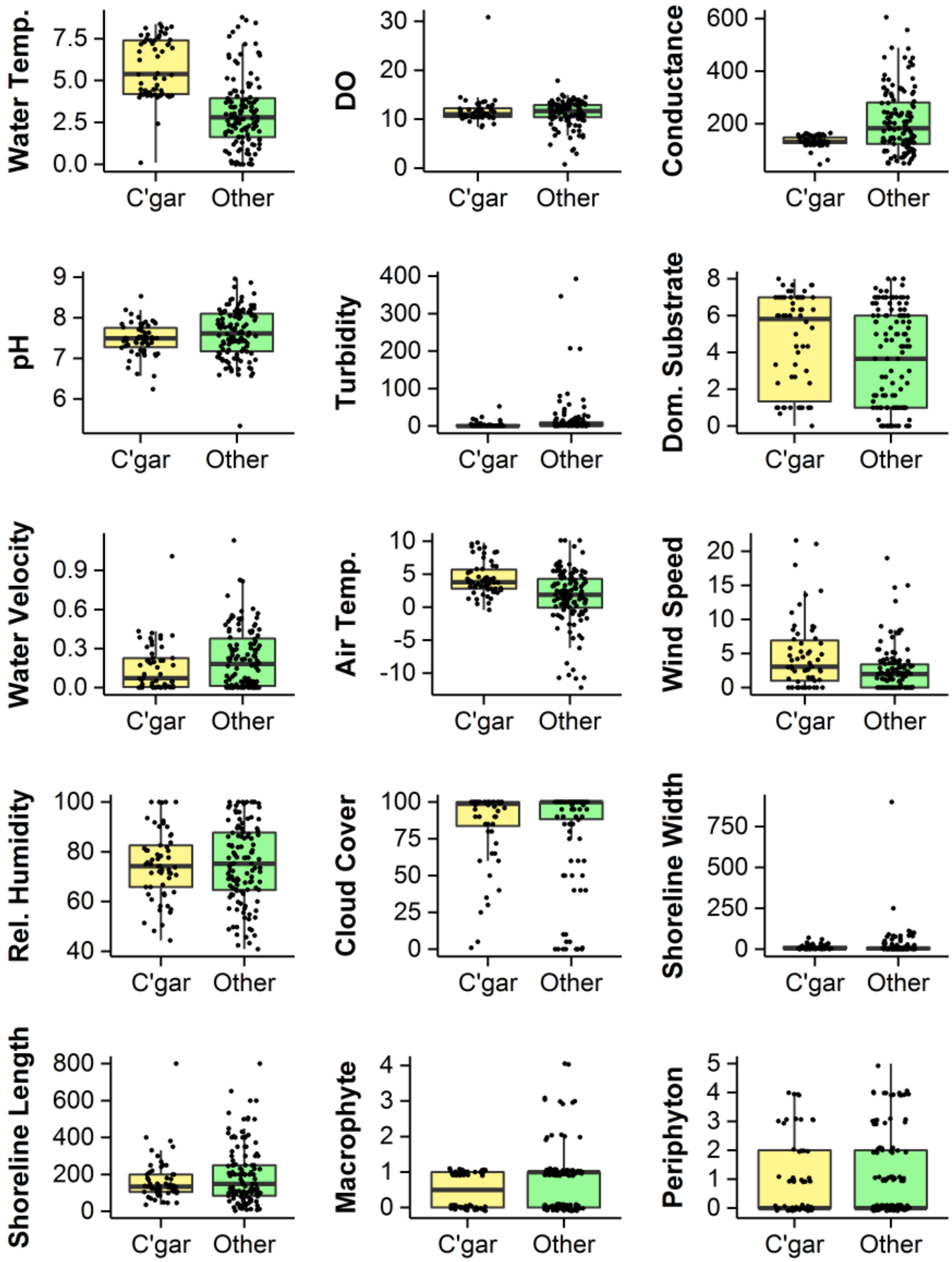

Figure 5-11: **Boxplots (with datapoints overlaid) showing the distribution of average values of each habitat parameter, by location (Castlegar or Other). Data were restricted to sites surveyed in the last two years, and in both early (Nov-Dec) and late (Jan-Feb) periods of a given year (n=182). Other details as in Figure 5-10**

A MANOVA was run to test whether physicochemical values changed over time within sites. The site x year interaction term in the MANOVA was not significant (F=0.89, *P*=0.94), so the analysis was re-run without it. The reduced MANOVA showed highly significant differences among sites (F=1.9, *P*<0.0001) and between years (F=6.2, *P*<0.0001). Investigating individual habitat variables (Figure 5-12), we found strong between-year differences in water temperature, air temperature, relative humidity and shoreline length. Weaker year effects were observed for pH, wind speed, cloud cover, and periphyton (Table 5-8).

Table 5-8. Results of MANOVA testing for differences in physicochemical parameters between years. *P* values were deemed significant (*) if < 0.1, or highly significant (**) if < 0.0067.

Parameter	Mean Value 2014-2015	Mean Value 2015-2016	Approx. F	*P* value	
Water Temperature	4.4	3.6	12.1	0.0008	**
DO	11.9	10.8	1.5	0.2201	ns
Sp. Conductance	172.3	198.6	1.0	0.3254	ns
pH	7.5	7.6	5.1	0.0259	*
Turbidity	13.1	14.5	0.3	0.5795	ns
Dom. Substrate Score	4.1	3.7	2.7	0.1030	ns
Water Velocity	0.2	0.2	2.3	0.1341	ns
Air Temperature	4.2	0.8	30.3	< 0.0001	**
Wind Speed	2.8	3.6	4.4	0.0382	*
Relative Humidity	71.2	78.8	8.0	0.0056	**
Cloud Cover	77.9	89.9	5.9	0.0170	*
Shoreline Width	24.7	15.8	0.9	0.3349	ns
Shoreline Length	226.8	152.4	21.2	< 0.0001	**
Macrophyte Score	0.6	0.7	1.0	0.3177	ns
Periphyton Score	0.9	1.1	3.9	0.0497	*

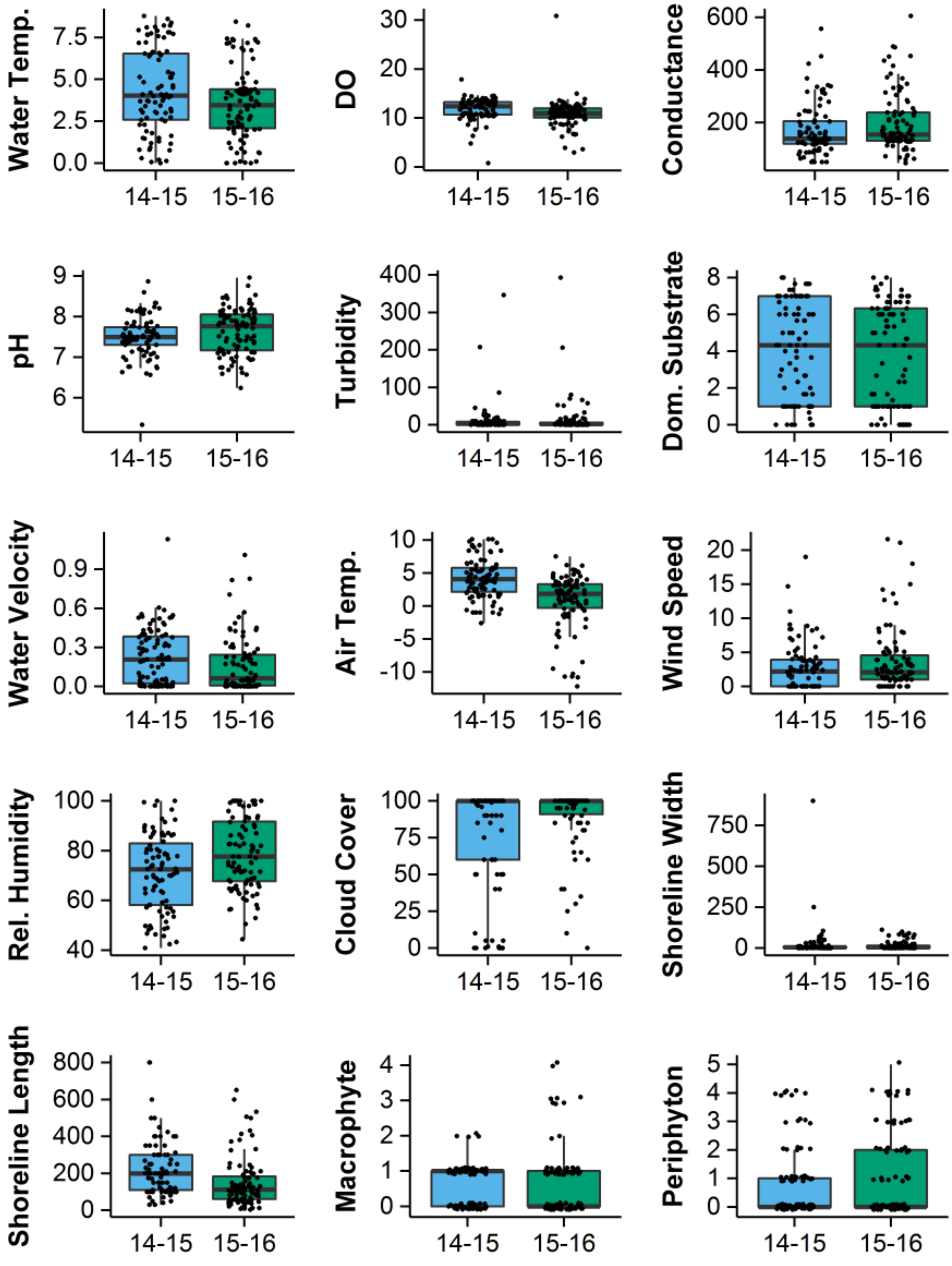

Figure 5-12: Boxplots (with datapoints overlaid) showing the distribution of average values of each habitat parameter, by year. Data were restricted to sites surveyed in the last two years, and in both early (Nov-Dec) and late (Jan-Feb) periods of a given year (n=182). Other details as in Figure 5-10.

Heron habitat suitability was mapped out using those variables that could be converted into a continuous layer. These were elevation, slope, precipitation in coldest quarter of the year, mean temperature in the coldest quarter of the year, distance to waterbodies (i.e., major rivers, lakes), and distance to agricultural lands. The suitability map shows a strong clustering of highly suitable habitat around the Creston area, with additional highly suitable habitat scattered around Lower Arrow Lake, the lower Columbia River, Kootenay Lake, and the lower Kootenay River (Figure 5-13). Based on this model, highly suitable habitat may be limited in the Kootenay region, with the dominant areas being around Creston and to a lesser extent Castlegar (Figure 5-13 and Figure 5-14). Suitable habitat based on the model is lacking in the Rocky Mountain Trench, with the exception of some areas near Invermere.

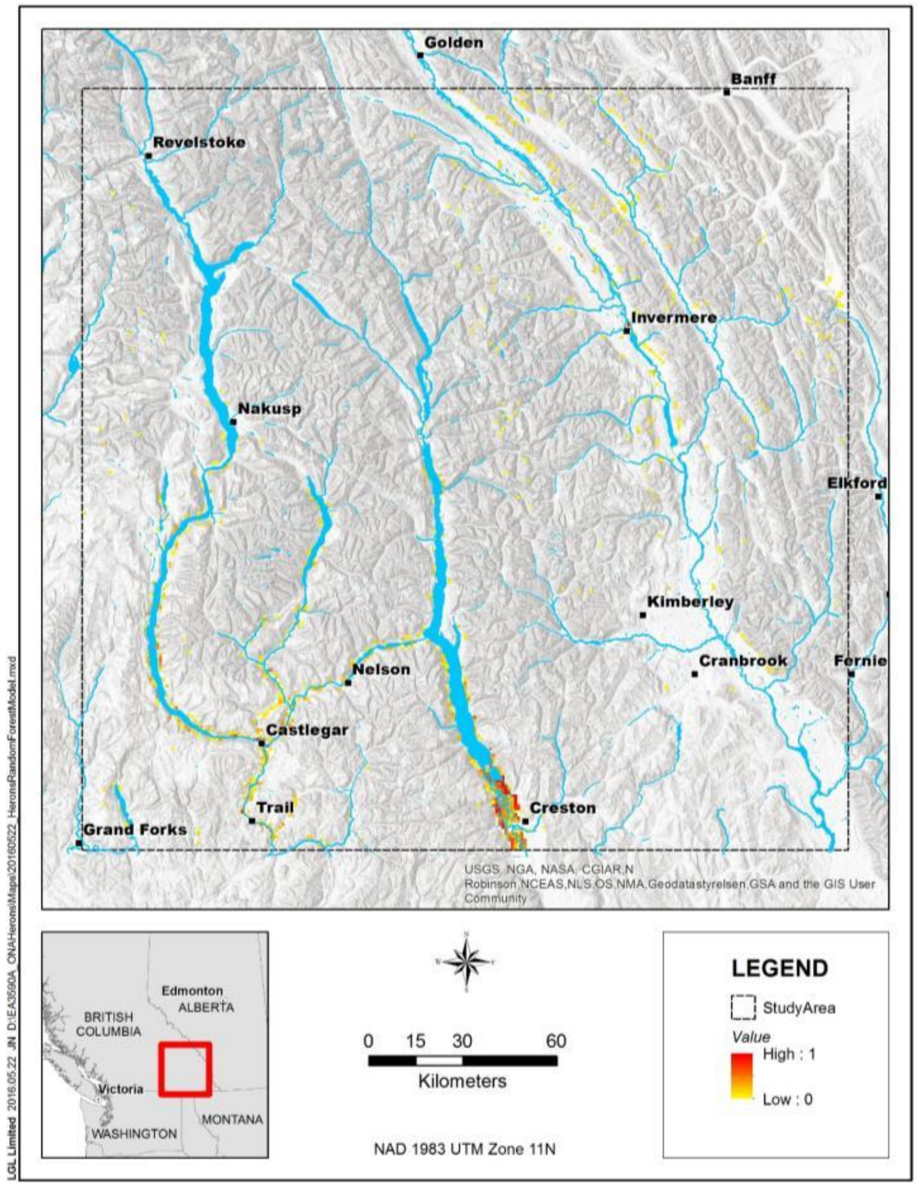

Figure 5-13: Habitat suitability map showing predicted areas of occupance for Great Blue Herons in the Kootenays. Areas with greater than 50 per cent predicted occurrence are coloured, with darker colours (red) corresponding to areas with greatest predicted occurrence.

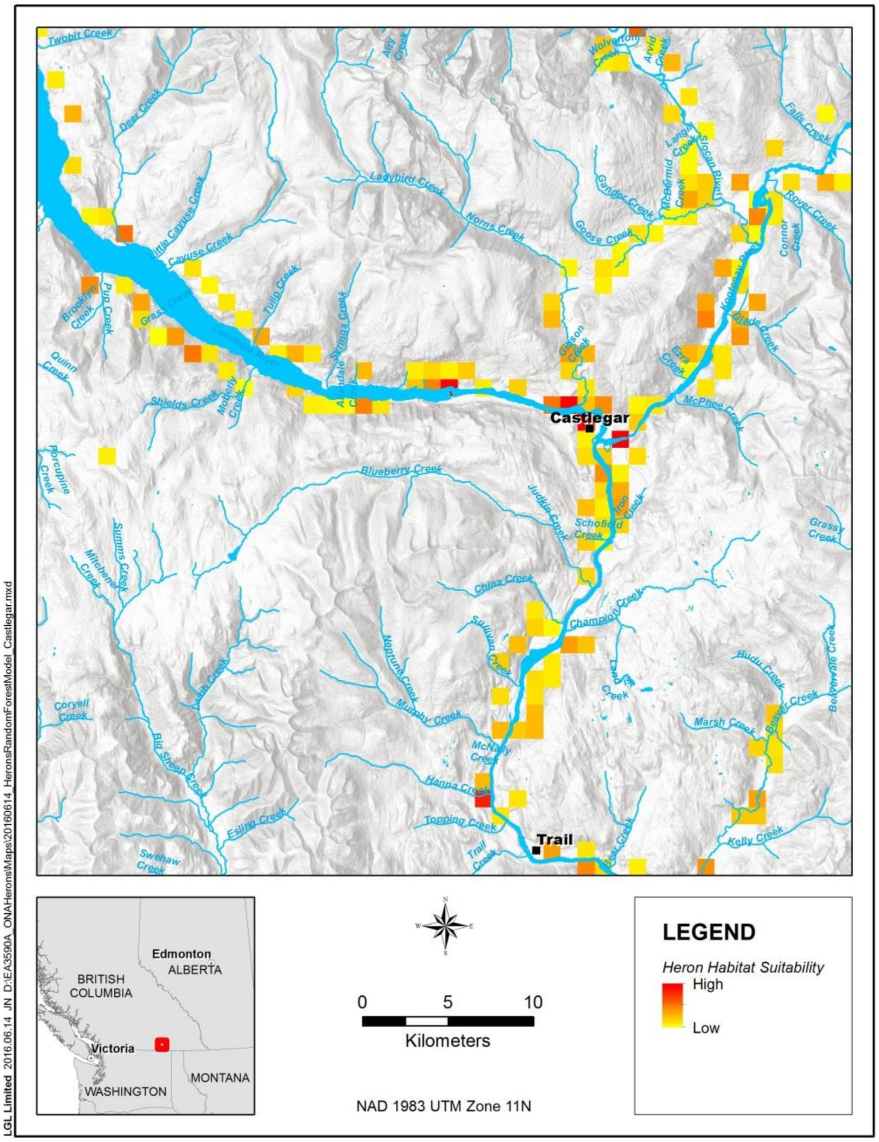

Figure 5-14: Habitat suitability map showing predicted areas of occupance for Great Blue Herons in the Lower Columbia River. Areas with greater than 50 per cent predicted occurrence are coloured, with darker colours (red) corresponding to areas with greatest predicted occurrence. The spatial resolution of the model is 1 km x 1 km.

5.5 Water Flow and Elevation

Flow rates out of Hugh Keenleyside Dam vary depending on inflows, storage, power generation, and Columbia River Treaty requirements. In the period between November 1 and February 28 during all survey years, daily average flow rates varied from 381.3 cms to 1,862.9 cms (Table 5-9). Flow rates were highly variable in pattern among years, but during the winters of 2014/2015 and 2015/2016 there was a period of relatively stable flows throughout January; during the first winter, flows were relatively stable for the second half of January only (Figure 5-15). This stable period coincides with peak whitefish spawning, and corresponds to water elevations of approximately 420.0 m to 420.6 m.

Table 5-9: Maximum, minimum, and average flow rates (HLK + ALH discharge) from Hugh Keenleyside Dam and water elevations as measured at the CNN gauge near Pass Creek over the three survey winters

Flow Regime Variable	Survey Winter		
	2013/2014	2014/2015	2015/2016
Water Elevation (m) - Max	422.14	421.02	420.39
Water Elevation (m) - Min	418.42	418.74	417.88
Water Elevation (m) - Avg	420.44	419.95	419.38
Flow Rate (cms) - Max	1766.87	1862.89	1596.56
Flow Rate (cms) - Min	569.82	682.13	381.30
Flow Rate (cms) - Avg	1139.85	1257.42	1019.64

Water elevation ranged from 417.88 m to 422.14 m as measured at the Norns Creek gauge (CNN) (Table 5-9). Machmer (2003) recommended winter water elevations be kept below 421.0 m to ensure suitable shoreline area remains around Breakwater Island (which becomes submerged at around 422 m). Based on the Norns Creek discharge rating curve this recommendation was amended to 420.7 m (BC Hydro 2012). During the winter of 2001/02 the recommended elevation was not exceeded, but it was exceeded on 16 days during the same time period in 2002/03 (Machmer 2003). In the period of November 1 to February 28 from the winters of 2004/05 to 2012/2013 (n=1,070 days) daily average water elevation exceeded 420.7 m on 41 days (3.8 per cent) (Figure 5-16). All but three of those dates have occurred since January 2012. This water elevation recommendation was exceeded for at least a portion of the day on 54 (45 per cent), 15 (12.5 per cent), and 0 dates during the 2013/2014, 2014/2015, and 2015/2016 winters respectively. Daily average water elevation exceeded the 420.7 m recommendation on 53, 4, and 0 dates over the three survey winters respectively. The recommended water elevation was exceeded for 46 consecutive days between November 23, 2013 and January 7, 2014, peaking in mid-December. In addition, water elevation exceeded 422 m on five dates in December 2013. The recommended water elevation was only exceeded for six consecutive days during the winter of 2014/15, with no dates exceeding 422 m. There is a positive relationship between flow rates and water elevation with temporal changes in discharge being closely mirrored by elevation (Figure 5-15).

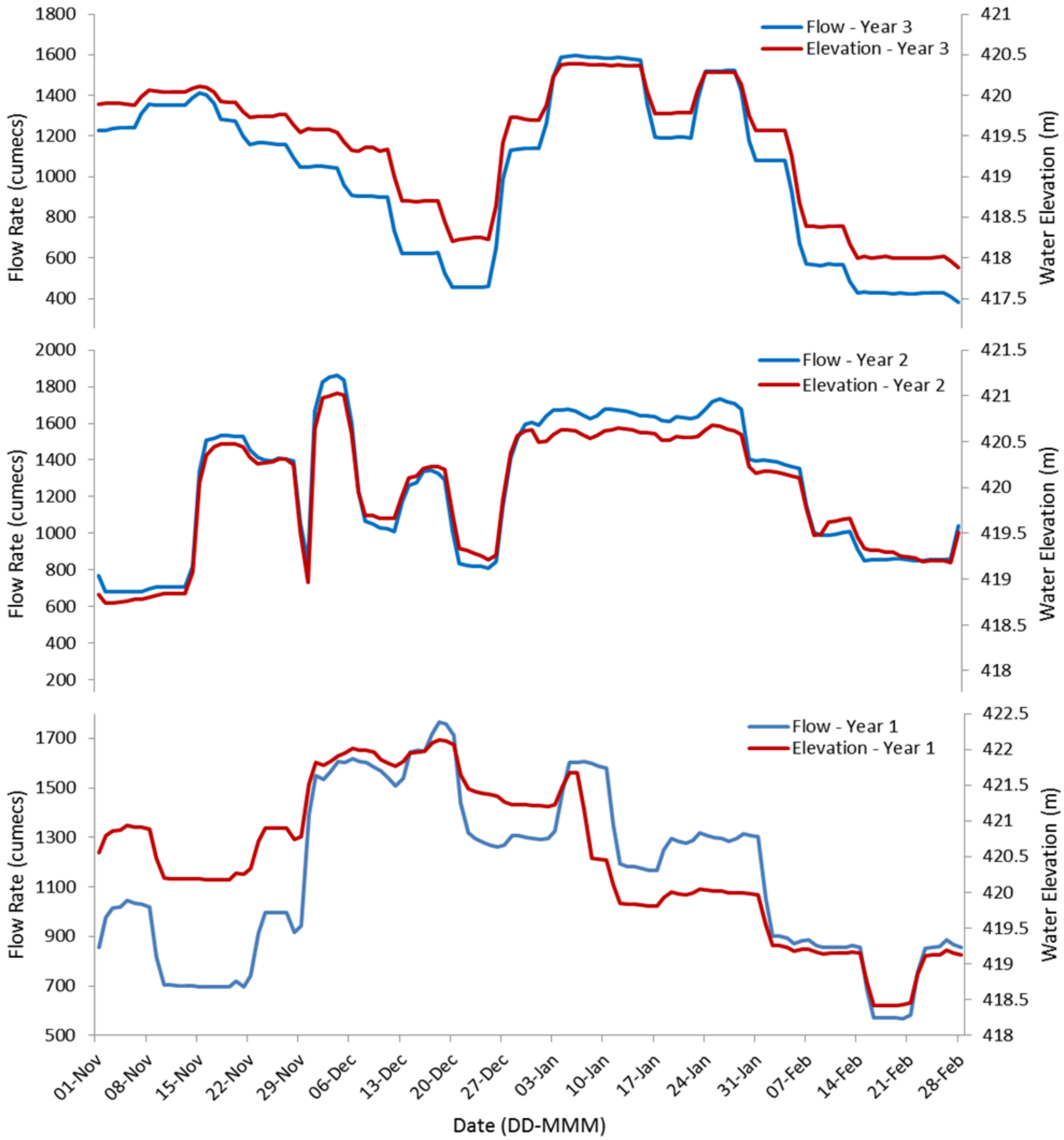

Figure 5-15: Flow rates out of Hugh Keenleyside Dam (HLK + ALH discharge) and water elevations as measured at the Norns Creek gauge. The two measurements are highly correlated, with changes in flow dictating water elevations

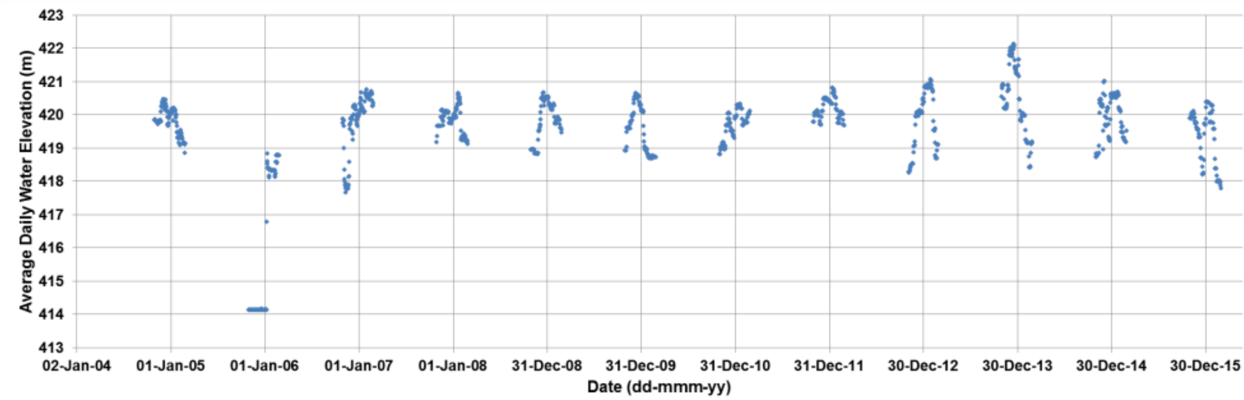

Figure 5-16: Average daily water elevations during the winter heron period (November through February) from 2004/05 to 2015/16. Water elevations were higher during the winter of 2013/14 than in any other winter over the past decade

5.6 Climatic Conditions

Herons were present throughout the Kootenay region, though the distribution of birds differed between November/December and January/February survey periods. Absent effects of dam and reservoir operations, environmental conditions may, in part, explain some of these movements. We compared data from 16 Environment Canada weather stations throughout the Kootenays. There were clear temperature differences among months and locations, with the Rocky Mountain Trench (Golden, Kimberley, and Cranbrook stations) in particular being colder in all months between November and February than other stations (Figure 5-17). The warmest stations overall were Castlegar and Nelson, though most stations in the lower Columbia and Creston/Kootenay Lake regions were similar. Environmental conditions are more similar within a drainage basin than from north to south, although the most northerly sites within each basin (e.g., Golden, Revelstoke) tend to be colder overall. Average monthly temperature was typically highest in November and lowest in December for these weather stations.

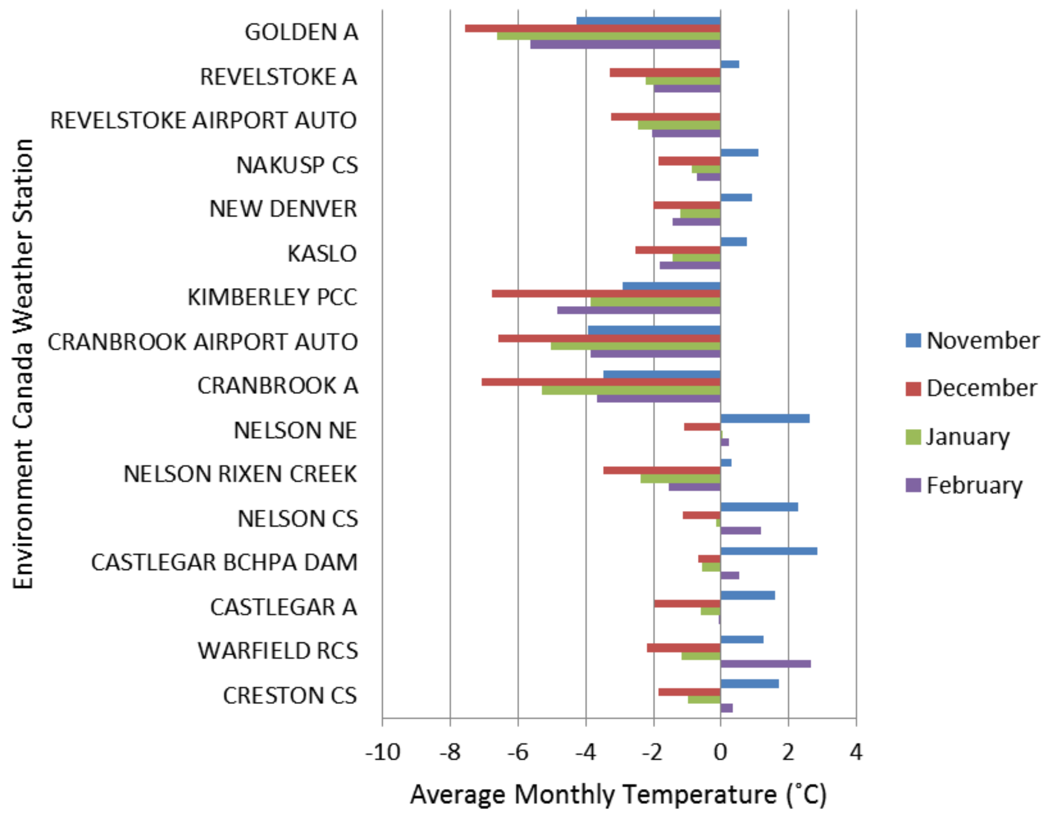

Figure 5-17: Average monthly temperatues in the November through February period at various Environment Canada weather stations throughout the Kootenay region. Data are pooled for all survey years. Stations in the Rocky Mountain Trench are noticeably colder than other stations

Herons are likely excluded from areas with frozen waterbodies and high snow depth that prevent or limit foraging opportunities. The proportion of days within the study period (n=360 days) that have average temperatures below freezing and snow depth >10 cm varies by location (Figure 5-18). The locations with the highest proportion (>50 per cent) of cold days and high snow depth are those within the Rocky Mountain Trench between Golden and Cranbrook, Revelstoke, and Nelson Rixen Creek. During the three survey winters combined, the weather stations with the lowest proportion of days with snow depths greater than 10 cm were in Castlegar, Creston, and Nelson. Note that Creston had a moderately high number of days with freezing temperatures, despite a relatively low proportion of days with less than 10 cm of snow. Unlike temperature, which was chosen based on the point when water freezes and therefore fishing potential becomes limited, the specific snow depth (≥10 cm) was chosen as herons locate prey by sight (Vennesland and Butler 2011) and it was assumed that most mammalian prey would be obscured from sight at this depth as they tunnel underneath the snow. We surmise that sites with colder temperatures and greater snow depths would be less suitable for herons in the winter period owing to reduced foraging potential.

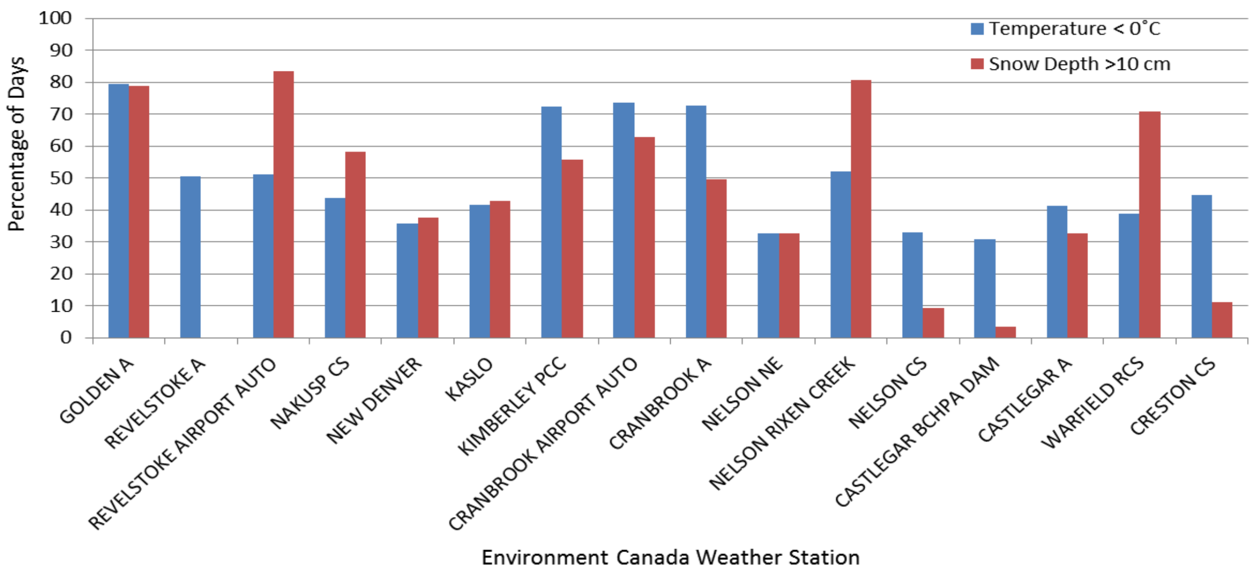

Figure 5-18: The proportion of days with below freezing temperatures (blue bars) and snow depths greater than 10 cm (red bars) at Environment Canada weather stations throughout the Kootenay region. Data from November through February of all survey years are pooled.

The results from the survey years align nicely with the 50-year average (1950-2000) climate normals for the region (Figure 5-19). Differences are apparent among months and regionally across the study area. While December and January stand out as being historically the coldest months for the region, more notable are the temperature differences between the various rivers and lakes. For example, the temperature difference between the Rocky Mountain Trench and the remainder of the Kootenay and Columbia systems is striking (Figure 5-19). The Rocky Mountain Trench appears colder in all months, with average temperatures below freezing across the entire valley. The Columbia system and the lower Kootenay including Kootenay Lake, are similar in temperature within each month. In both of these areas, November is the warmest month, with February showing an increased temperature from December and January.

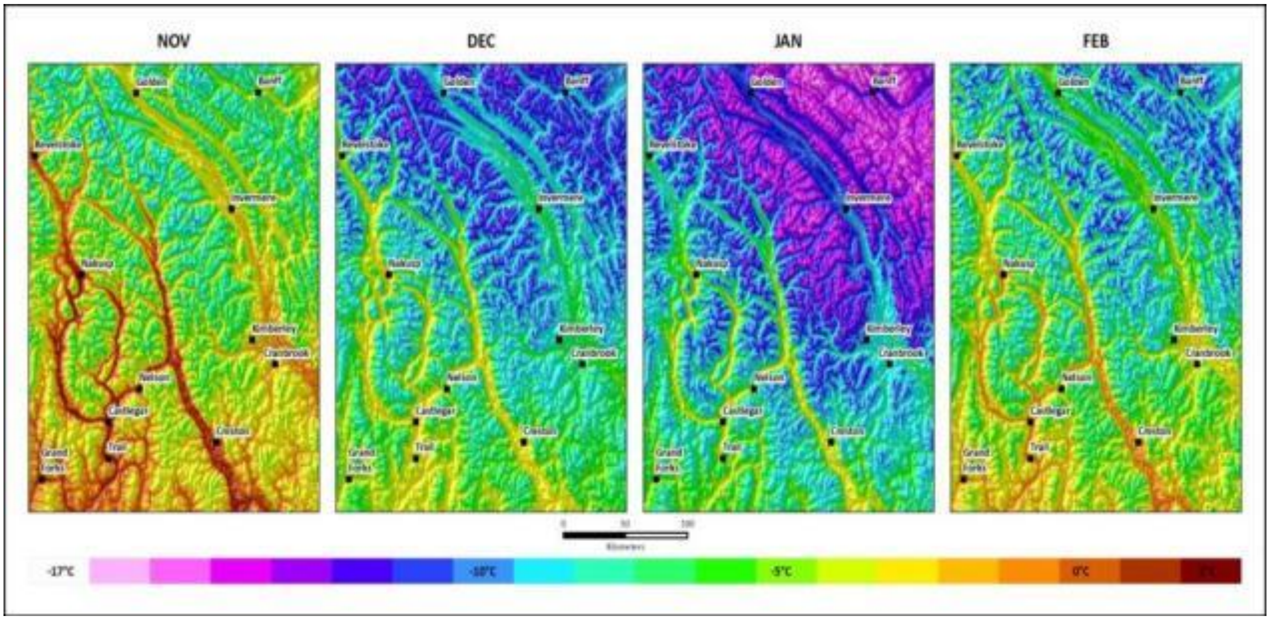

Figure 5-19: Temperature scaling based on the 50-year climate normals (1950-2000) for the Kootenay region. Orange and red colouration indicates temperatures ≥0˚ C. January and December are the coldest months in the heron winter period, but note that the Rocky Mountain Trench (Golden to Cranbrook) remains cooler than adjacent areas of the Kootenay and Columbia systems on any given month

5.7 Regional Heron Presence

A multiple logistic regression was conducted to determine if a suite of habitat variables could predict the probability of heron presence. The initial model was reduced, one parameter at time, each time without significantly affecting the model fit. In the end, there were four habitat parameters whose removal resulted in significant differences in model fit: dissolved oxygen (Dev=6.6, P=0.0097), specific conductance (Dev=4.7, P=0.030), relative humidity (Dev=6.8, P=0.0090), and cloud cover (Dev=5.3, P=0.021). The fit of the final model, which included these four parameters, was not significantly different from that of the full model (Dev=9.2, P=0.60).

When the parameter-set of the model was reduced, it was possible to bring some of the previously excluded data back into the analyses. That is, if any data point is missing from any parameter, then the whole row is left out of the analysis. For example, if two rows in the dataset are missing temperature data and three rows are missing cloud cover data, then five rows of data are excluded, but if after reducing the model it is found that cloud cover is not an important factor and is removed from the model, then we can put those three rows back into the analysis, since they are not missing any of the data that is being included in the reduced model. For runs of the reduced model, only 5 records were excluded, leaving 177 observations for the fit. The final model's parameter-set included an intercept (estimate=4.44, SE=1.98, logit link), and four habitat-related slopes (estimates in logit space: dissolved oxygen: -0.37, SE=0.11; specific conductance: -0.006, SE=0.003; relative humidity: -0.049, SE=0.018; and cloud cover: 0.026, SE=0.012).

Overall, the model was able to correctly predict the presence/absence of herons for 87.6% of cases. The area under the ROC curve was 0.540, indicating a 'worthless' discrimination level. Sites with and without herons did not differ significantly in specific conductance, relative humidity or cloud cover (P>0.05). Although an ANOVA showed that dissolved oxygen in sites where herons were observed (10.0 mg/L, SE=0.46) was significantly lower than for sites where herons were not detected (11.5 mg/L, SE=0.22) (F=6.7, P=0.011), the difference in these absolute values is small and on the same magnitude indicating that this is of no biological significance. Furthermore, there was much overlap in most of the measurements for numeric parameters between sites with and without herons in each sampling period, indicating that these parameters are unlikely to have a biological effect on determining heron presence at the levels measured (Table 5-10).

Table 5-10: Average values for physicochemical parameters ± 1 standard error

Period	Heron Presence	n	Water Temperature	DO	Specific Conductance	pH
Early	Y	17	5.56 ± 0.66	10.15 ± 0.40	179.22 ± 23.20	7.70 ± 0.09
Early	N	74	3.99 ± 0.34	11.24 ± 0.27	183.41 ± 11.46	7.85 ± 0.05
Late	Y	6	3.46 ± 0.52	9.52 ± 1.42	143.12 ± 24.70	7.31 ± 0.21
Late	N	85	3.63 ± 0.18	11.80 ± 0.32	192.34 ± 12.37	7.30 ± 0.06

Period	Heron Presence	Turbidity	Water Velocity	Air Temperature	Wind Speed
Early	Y	10.16 ± 5.63	0.13 ± 0.04	3.18 ± 0.81	4.71 ± 1.17
Early	N	18.90 ± 7.48	0.19 ± 0.03	1.07 ± 0.51	4.42 ± 0.61
Late	Y	19.18 ± 10.83	0.004 ± 0.002	1.98 ± 0.80	3.75 ± 1.97
Late	N	9.77 ± 2.73	0.23 ± 0.02	3.52 ± 0.38	1.86 ± 0.19

Period	Heron Presence	Relative Humidity	Cloud Cover	Shoreline Length	Shoreline Width
Early	Y	66.44 ± 2.51	90.88 ± 4.42	8.92 ± 2.63	129.18 ± 22.49
Early	N	71.63 ± 1.83	87.79 ± 2.88	15.24 ± 3.01	175.58 ± 14.22
Late	Y	78.55 ± 4.70	89.50 ± 4.27	11.17 ± 6.23	273.33 ± 88.36
Late	N	79.78 ± 1.59	78.92 ± 3.83	27.12 ± 11.21	205.62 ± 18.17

5.8 Castlegar Heron Counts

Daily heron counts from the Waldie Island area were conducted by a local observer from 2013 to 2016. The time series of heron counts was smoothed over a 7-day period to remove any missing values. The smoothed time series was decomposed seasonally (i.e., the average count was calculated for each calendar day, averaged over the three years, and deviations from the average were calculated), which revealed an increasing trend over time (Figure 5-20).

The daily heron count data showed consistent heron presence only from July to January. Few to no herons were present during other months. Including the dates with no herons would lead to zero-inflated counts. Zero inflation can cause problems with statistical inference by leading to underestimation of the standard errors of parameters, narrow confidence intervals, and small p-values, thereby biasing estimates of biological effects (Martin et al. 2005; Sileshi 2008). To avoid these issues related to zero inflated models, heron data from 1 February to 30 June of each year were excluded from the generalized linear model (the heron data were modified by setting all values from February to June to "na"). The modified (July to January) and non-modified (full year) smoothed heron time series were compared to the smoothed flow, temperature, precipitation and snow time series (Figure 5-21) using cross-correlation. Flow was used instead of water elevation as there were too many values missing from the elevation time series. Visual inspection of the data suggested that the peaks in heron numbers in the July-January period lined up with the troughs of the flow data from that same period, so these data series were not lagged for subsequent analyses. It also appeared that herons arrived in the area as temperatures started to decline, with the number of herons peaking on average 111 days after temperature peaked at its highest (i.e., cross-correlation analysis showed that the time series were most correlated when the temperature data were lagged by 111 days). Visually, the data also showed that herons departed after snow accumulation began, and the number of herons peaked on average 50 days before snow depth peaked at its maximum (i.e., cross-correlation analysis showed that the time series were most correlated when the heron data were lagged by 50 days). Maximum correlations with the modified (July-January) heron time series were observed when the precipitation time series was lagged by 8 days.

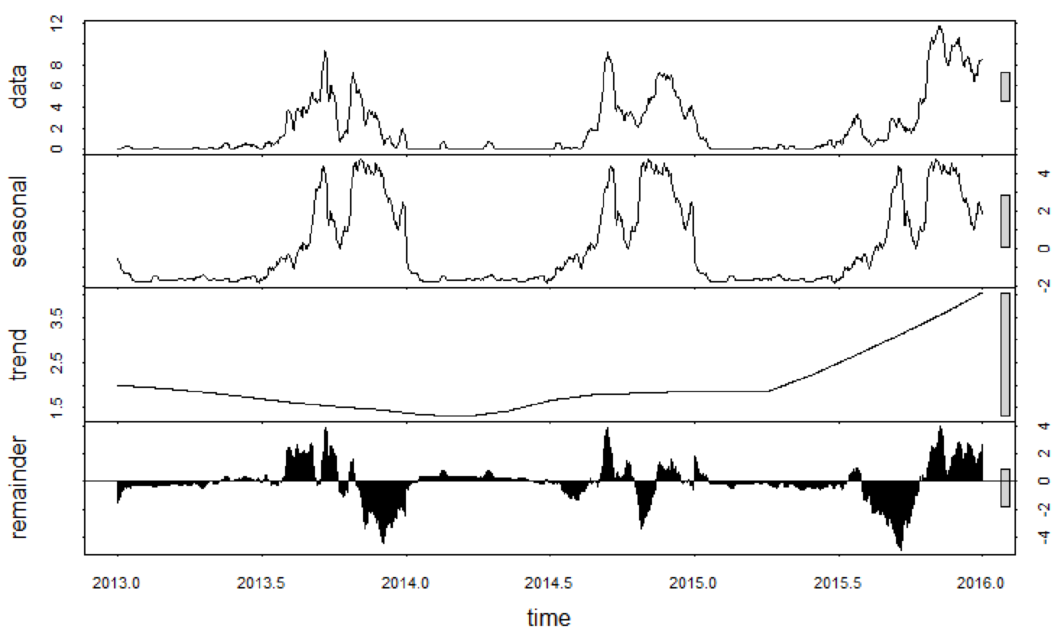

Figure 5-20: Seasonally decomposed heron count time series, showing smoothed data ("data"), average annual pattern ("seasonal"), the temporal trend ("trend"), and residuals ("remainder"). The x-axis represents time of year from January 1, 2013 to January 1, 2016, with 2013.5, for example, being mid-way (i.e., approximately July 1) between the beginning of 2013 and the beginning of 2014.

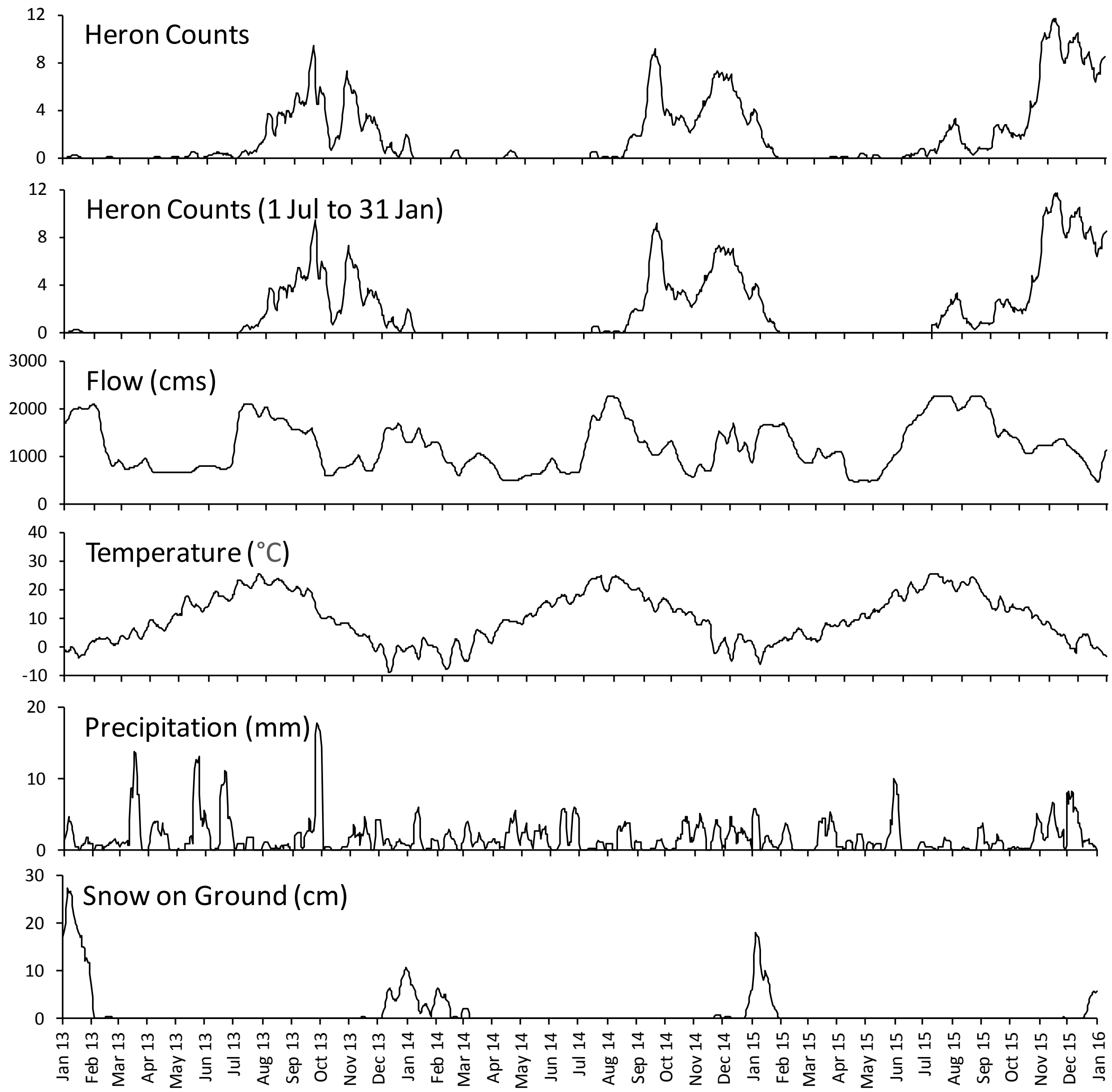

Figure 5-21: Smoothed time series of heron counts (all data), modified heron counts (only 1 July to 31 January), flow, temperature, precipitation and snow cover.

Once the time series lags were determined, we went back to the raw (not smoothed) values, and lagged them accordingly. It should be noted that sample size is lost when data are lagged. Lagging these data left 936 heron observations for which all other variables had corresponding values. Once lagged, we used a generalized linear model to fit heron counts to the predictive variables (flow, temperature, snow accumulation and precipitation). The dataset included 498 data points, once rows with missing values (n=101) and those associated with February to June heron counts (n=337) were excluded. For this modified dataset (1 July to 31 January), flow and temperature were highly correlated (r_s=0.65, *P*<0.0001), thus temperature was dropped from the model.

Initially, the heron counts were modelled using a Poisson error structure, but the residual deviances were large relative to the degrees of freedom (suggesting overdispersion), so the model was re-run, this time using the 'quasipoisson' error structure (Crawley 2007). We attempted to reduce the initial model, one parameter at time, but none could be removed without significantly affecting the model fit (precipitation: Dev=10.4, *P*=0.043; snow: Dev=48.7, *P*<0.0001; flow: Dev=155.6, *P*<0.0001). The final model's parameter-set included an intercept (estimate = 1.92, SE=0.13, log link), and three slopes (estimates in log space: precipitation (estimate=0.013, SE=0.006; more herons at Waldie Island in years with more rain), snow (estimate=0.047, SE=0.010; more herons in years with more snow) and flow (estimate -0.0007, SE=0.0001; fewer herons during higher flows). The final model fit relatively poorly, explaining approximately 14% of the variation in July-January heron counts (R^2=0.147).

We emphasize here that the model fit is poor, and these parameters do not explain most of the variation in heron counts. Certain results may be spurious owing to a limited number of years of sampling (correlations to climatic conditions typically require longer time series owing to variation within the heron counts and within the climate parameters themselves among years). That heron numbers peak after temperature maximums (which occur during the summer) is straightforward, given dispersal and migration from colonies to wintering sites, and that they also peak before snow reaches maximum depths in winter is logical given that snow depths and resulting cold temperatures may put physiological strains on wintering herons. The suggestion that more herons are present around Waldie Island in years with greater precipitation is perhaps a response of herons in the broader region to climatic conditions; that is, in years with greater snow, herons are concentrated to the open waters and relatively milder temperatures around Castlegar, yet overall herons are still departing the area before snow depths peak. Fewer herons during years with higher flows may be related to the associated decrease in habitat availability (see Section 5.8 Habitat Availability).

6.0 DISCUSSION AND MANAGEMENT QUESTIONS

This study presents a regional view of Great Blue Heron abundance and site use. By understanding the locations that herons are using in the broader Kootenay region, we are better able to understand the habitat choices, behaviours, and potentially the abundance of birds that utilize the Waldie Island and Castlegar areas. Surveys in the Castlegar area from November to February confirm that the number of wintering herons is currently lower than those presented by Machmer (2003) in the early 2000s. Numbers increased slightly over the three winters surveyed, but it is not known if this represents a continuing increase towards previous numbers, or simply inter-annual variation. Christmas Bird Count data, while not as rigorous, also suggest strong inter-annual variation in heron counts at any given location throughout the region (including adjacent portions of the United States of America). Cumulative Christmas Bird Count data for Great Blue Herons in the Kootenays show no obvious trends over the past decade. The extent to which fluctuations in heron counts in the Castlegar area are related to local, site conditions versus regional factors remains unknown.

Regarding the objectives of this study, there is little conclusive evidence that variation in heron numbers are related to variation in flows through the Hugh Keenleyside Dam and associated water elevations. There is a strong temporal trend for heron counts to be highest prior to mountain whitefish flows in November, and declining throughout December and into the peak whitefish flow period. In all years of study, herons were essentially absent post-whitefish flows. However, caution is warranted when considering only water flows related to mountain whitefish management. Although heron counts differ among the whitefish flow periods (prior to, during, and post), the time-scale over which these periods correspond may coincide with specific aspects related to Great Blue Heron life history (e.g., post-breeding dispersal, courtship, etc.) or environmental conditions (e.g., decreasing temperature, increasing snow cover, etc.). Indeed, our analysis comparing maximum daily heron counts to water elevation, select environmental conditions, and temporal attributes found essentially no support for the role of water elevation on heron counts overall. While statistically it is difficult to assess the effect of flow rates on heron counts near Waldie Island (owing to inter-annual variation in heron counts, water flows, and the lack of ability to alter flows specifically for this project), water elevations do have a notable effect on the amount of potential shoreline habitat available to herons. At the upper limits of water elevation during the winter period, the majority of potential shoreline habitat is lost, with features such as Breakwater Island (a regularly used feature, although not in 2014/2015) becoming mostly or entirely submerged. While unproven, high water elevations may limit the number of herons that can successfully overwinter (by limiting the amount of potential foraging and/or roosting habitat). Once habitat becomes inundated in the winter, herons may depart the region altogether, no longer responding to local changes in such variables as water elevation. In addition, herons are relatively long-lived (Vennesland and Butler 2011), and if herons use past experience to inform winter site selection, they may chose more stable locations, so long as foraging opportunity and safety occur at alternate sites.

Water elevations were typically highest overall during the month of January, with high elevations being sustained over a relatively long period of time as flows stabilised during the peak whitefish spawning period (Figure 5-2). That heron numbers declined through this period in two of the three winters, and were lowest overall during the winter with highest water elevations, suggests that high water elevations, related to flows from Hugh Keenleyside Dam, limit habitat suitability and the overwintering ability of Great Blue Herons in the Castlegar area. Despite this result, conclusive evidence would require experimentation with water elevations during this time period, in a study design accounting for inter-annual variation in heron numbers as well as intra- and inter-annual variation in the distribution and abundance of prey fish. In addition to the water elevation proper, the duration of an inundation event could potentially affect the distribution or abundance of herons in the region, even though a direct link between water flows (or elevation) and heron counts is lacking.

When heron presence was tested using the water physicochemical data collected at each site, none of the measured parameters appeared to have a strong influence on determining site presence. The low number of sites with herons present limited statistical inference. However, virtually all the parameters were within tolerable levels for supporting aquatic organisms (Table 5-5). This suggests that potential fish prey availability at most ice-free sites should not be limited by physicochemical parameters. Therefore, potential foraging habitat should be widespread throughout the ice-free parts of the study area based on measured parameters. Regarding site presence, it is also possible that herons are utilizing a greater range of sites than we have detected, but are doing so outside our limited observation periods (e.g., at night). For example, some sites during the winter of 2013/14 were known to be used by herons owing solely to tracks visible in the soft, muddy substrate, but no evidence remains of heron presence at sites with rocky substrates

The presence, abundance, and distribution of target prey likely influences the presence and distribution of herons. We do not have fish data concurrent with heron surveys, and the presence and accessibility of fish to herons remains an underlying assumption in this study. Machmer (2003) reported that fish densities of all fish species were higher during the night than the day in upper, nearshore waters in Castlegar. Such a pattern is consistent with our findings of heron behaviour. That herons appear to be foraging nocturnally in Castlegar would support that fish densities are highest during the night; though alternatively, it may indicate that the rate of prey capture is highest at night regardless of density (for example, if fish are less likely to detect a predator at night). Machmer (2003) also indicated that fish densities had inconsistent responses to flow period over the two study seasons. During the 2001/2002 surveys, fish densities were lower during whitefish flows, relative to pre- or post-whitefish flows, while no significant differences were found with flow period in 2002/2003. Fish densities and heron numbers were both lower in 2002/2003 than in 2001/2002, while flow rates and water elevations were higher (Machmer 2003). In addition, fish populations appear to be dynamic, including species composition. For example, the abundance of both subadult and adult Mountain Whitefish appeared to have declined markedly between 2001 and 2015 (Golder Associates et al. 2016). This may be due in part to migration out of the area, and/or increased predation by piscivorous fish such as Walleye and Northern Pike (Golder Associates et al. 2016). Highlighting the dynamic of fish populations in the Lower Columbia River and potentially elsewhere in the study area, Northern Pike went undetected in fish surveys near Castlegar prior to 2010, but were consistently found after that time (Golder Associates et al. 2016). Pike are voracious, apex predators which may be impacting native fish populations. The release of over 140,000 White Sturgeon into the Lower Columbia River may also influence prey fish populations (Golder Associates et al. 2016). The exact distribution and density of Mountain Whitefish, Rainbow Trout, and Walleye differed from each other, and were likely linked to river morphology and habitat conditions, but these and other species (e.g., Redside Shiner, Yellow Perch) were present, though not necessarily evenly, throughout the Castlegar region (Golder Associates et al. 2016). It is not known if herons have a preference for certain fish species in the area. Shifting fish densities and species composition may influence heron use of a site, but the situation is dynamic and the role of fish on heron abundance and distribution, while potentially an important factor, is not understood. While we cannot address fish specifically for our years of study, it is important to note that they are another component of the system that may be influenced by flows as well as being influential to herons as an important food source, thereby impacting the suitability of potential winter habitats.

Herons are plastic in their foraging ability, and in addition to fish they may prey upon a variety of organisms including rodents, reptiles, amphibians, and occasionally even birds (Vennesland and Butler 2011). In Creston, herons behaved differently than in Castlegar, exhibiting a greater amount of active behaviour (e.g., foraging, alert, flying). Birds were witnessed foraging from ice holes on Duck Lake, an apparently common behaviour for wintering birds at this location (Marc-André Beaucher pers. comm.).

While it is convenient in speech and writing to describe the over-wintering heron "population", the population dynamics of this group of herons are also unknown. Wintering herons may be from one or many breeding colonies, each with its own specific set of conditions and potentially limiting factors. Breeding heron inventories were initiated in 2002, with Bald Eagle nest inventories added beginning in 2006 (Machmer 2009). Those inventories found high rates of heron nest failure, rising steadily from 20 per cent in 2002 to ~44 per cent in 2005 and 2006 (Machmer and Steeger 2003; 2004; Machmer 2005; 2006; 2007). Eagle harassment and predation was implicated as a leading factor in nest failures in most cases, and colony abandonment was documented as a result. This was true of the Pass Creek colony closest to the Waldie Island area, where all nests in 2011 (11 nests) and 2012 (2 nests) were abandoned due to Bald Eagle harassment and predation (Machmer unpubl. data). In contrast, eagle populations appeared to increase. Bald Eagles are one of the main predators of Great Blue Herons (Gebauer and Moul 2001, Vennesland and Butler 2011). Increased rates of nest failure and colony abandonment have been directly linked to eagle predation and disturbance (Butler et al. 1995, Vennesland and Butler 2004, Machmer 2009). Despite the presence of herons through the summer months in Castlegar, no nesting currently is known from the area. Herons nested unsuccessfully at Waldie Island in the past, though the last known active nest was in 2001. As no known successful nesting occurs in the vicinity of Waldie Island, overwintering herons must be from one or more other breeding locations. Changing configurations of these heron colonies and lower success rates could have implications on the number of herons overwintering on the Columbia and elsewhere in the Kootenays, especially if high nesting failure rates persist. In other words, the over-wintering heron population cannot be considered separate from the breeding population(s), and changes in numbers annually could be attributable to conditions on the wintering grounds, breeding grounds, migration stopovers, or any combinations thereof.

In addition, it may be incorrect to refer to "overwintering" populations when referring to any specific location. The pattern in occurrence that has revealed itself in Castlegar suggests that herons are largely absent from early to mid-January and remain so for the remainder of the winter and spring. This trend is similar to that found by Machmer (2003) in the early 2000s when more herons were present; in that study, heron numbers declined through January and February, after which time they were largely absent from the study area. It is not known to where the herons that were present in November and December dispersed. Furthermore, even if herons were present in all months, without individual-specific tags (e.g., colour bands, wing tags, telemetry) we cannot be certain that it is the same individuals present all winter. Elsewhere in the region herons appeared to withdraw from many areas, especially northern ones, being more widely distributed in November than in February. Such temporal changes in heron distribution are important to consider when identifying the impacts of variables, such as water elevation, which also vary temporally.

Herons have been shown to be very susceptible to both eagle and human disturbance at their breeding colonies (summarized in Gebauer and Moul 2001; Vennesland and Butler 2011). While considerably less research appears to have been undertaken on disturbance effects on the wintering grounds, wintering herons in the Kootenay region have few areas where they are not exposed to disturbances. Eagles are one such source of disturbance. While no eagle attacks on Great Blue Herons were noted during this study, Machmer (2003) reported such events on four occasions in 2002/2003. Furthermore, she noted disturbance by eagles on 45.8 per cent of all observation dates. Herons were observed to be disturbed by humans, dogs, vehicles and trains every winter of this study. On several occasions birds were flushed from shorelines and/or trees by people and dogs walking close by. Humans and dogs (both leashed and unleashed) were encountered at many sampling locations throughout the Kootenays, even when sampling locations were away from paths. For example, in February 2015 near the Columbia-Kootenay confluence, eight people were fishing, four trucks were present (some of which were running), and one dune buggy was operating. Humans and dogs appeared to be the greatest source of disturbance to herons. In contrast, no eagle activity was conclusively attributed to heron disturbance. Some areas, such as sewage lagoons (only the Castlegar sewage lagoon had heron presence) and islands, may offer refuge to herons by limiting direct access by humans, though these areas are not completely isolating to human activities (e.g., herons in the Castlegar sewage lagoons were flushed by approaching trains on multiple occasions).

While human disturbances may not directly lead to a population decline, repeated disturbances could affect their utilization of specific sites. Contrary to the winters of 2013/2014 and 2015/2016, no herons were observed by us on Breakwater Island in 2014/2015. Rather, herons were present on Waldie Island, from which they were largely absent the first winter, and present in low numbers the third winter. While speculative, this may have been due to extensive construction activity around the sewage lagoons. A slump and leakage at the south-east corner of the sewage lagoon berm triggered extensive work in the area commencing around September 22, 2014 (W. Volovsek pers. comm.). This work activity was ongoing during the November sampling period. This construction could have affected the number of herons that chose to winter in the area, or it may have precluded herons from Breakwater Island (though the construction was not on Breakwater Island itself). Heron numbers declined around the time that construction activities commenced, but a mid-September decline was also apparent in 2013 when no construction occurred.

Figure 6-1: The view looking from the south bank of the Columbia River towards the Castlegar waste water treatment plant prior to (left panel) and during (right panel) construction. Construction activity in the fall of 2014 removed extensive vegetation along the sewage lagoon berm as well as reinforcing the berm with rip-rap (visible in right panel). Note the proximity of Breakwater Island in the foreground to the construction area behind. Such activity may have affected the distribution of herons in the Waldie Island area during the winter of 2014/15. Photos © Walter Volovsek

As disturbances may influence site utilization, so too may climate. In the interior in general, frozen wetlands and waterways limit heron foraging habitat, and therefore their range (Gebauer and Moul 2001). Comparison of historical climate averages as well as climate data over the survey period (November through February 2013 to 2016) shows that there are subregional differences in factors such as temperature and snow cover (Figures Figure 5-17 to Figure 5-19). In particular, the Rocky Mountain Trench is colder and snowier than other areas in the Kootenays. Northern sites, such as Revelstoke, are also colder and snowier than most sites further south. The climate data indicate that November was typically the warmest month at most stations (Figure 5-17), corresponding with when herons were most widely distributed throughout the region. Climate across this time period may interact with life history stages of herons in ways that might help explain temporal changes in heron counts, or may mask effects of water flow rates or elevation. As sites in the north and in the Rocky Mountain Trench become inhospitable to birds by eliminating foraging opportunities, birds likely disperse to other areas. This is exemplified by anecdotal observations, such as in the slough north of Columbia Lake in the Athalmer area, where on November 27, 2014 water was almost entirely frozen over and no herons were observed, but where, according to a local naturalist, only two weeks prior five herons were present when there was significantly more open water, and where herons were found in November/early December 2015 and February 2016 when patchy open water remained. The annual count data for the vicinity of Waldie Island show a spike in heron numbers twice: once in early to mid-September, and again in October or November. This may indicate two separate arrival periods for birds in the Castlegar area. The first a result of post-breeding dispersal and fall migration, and the second a result of deteriorating conditions in other regions forcing birds into remaining suitable habitat. The initial increase in heron numbers in late July and August aligns with the reported dispersal of herons (mostly young) away from breeding colonies (including birds dispersing from colonies in the United States) (Campbell et al. 1990). Counts are likely then augmented by the southward migration of herons, which occurs in September and October

(Campbell et al. 1990). In the interior, the largest numbers of herons are typically found in March, during spring migration when birds begin to arrive at breeding colonies (Campbell et al. 1990, Vennesland and Butler 2011). That numbers do not increase in Castlegar is likely attributable to the fact that no active heronries are present. It is possible that a reduction in heron numbers from January onwards in the Castlegar area represents birds that are departing to return to areas closer to breeding colonies in preparation for pair formation and courtship, but it is such factors that confound the interpretation of effects of water elevation on heron numbers. That herons do not appear to return following that decline in December and January may then best be explained by migration back towards breeding colonies. The complex interaction of life history, climate, and water flow management in the lower Columbia River and elsewhere in the region hampers our ability to detect effects.

In summary, the dynamics influencing overwintering herons along the Lower Columbia River are complex and likely interconnected. Flow regime may certainly impact shoreline utilization or heron abundance, most likely via maintaining low shoreline availability during whitefish flow periods, but additional data over longer time series, and ideally experimental manipulation of flow rates during this period, are required before conclusive linkages can be made. It is clear that increasing elevation restricts the amount of potential shoreline habitat, with effects greatest on small islands such as Breakwater Island. Confounding our ability to detect such a trend are changes in breeding success and colony structure, lack of flow manipulation ability, inter-annual variability in weather, and other impacts such as human-caused disturbances. Despite these limitations we identified multiple locations where herons are present over the course of the winter period, identified habitats most likely to be utilized by herons, and determined that physicochemical variables did not differ in biologically meaningful ways between Castlegar and the surrounding region or between sites with herons present and no herons detected.

6.1 Management Questions

6.1.1 MQ: Where are the shoreline areas that are used by Great Blue Herons?

Herons were located at roughly 40 general locations throughout the region during the entirety of the study (Figure 5-1). The majority were detected around Castlegar (Waldie Island area) and north of Creston (Duck Lake area). Around Castlegar the most frequently used locations were Waldie Island, specifically the southern and western sides, and Breakwater Island. Herons were also seen in the Castlegar sewage lagoons, near Pass Creek and the opposite shoreline, near Tin Cup Rapids, at the Hugh Keenleyside Dam, and along the Kootenay River upstream of the confluence. These foreshore locations align with where herons were seen in the early 2000s (Machmer 2003). Considering only the area around Waldie Island, heron distribution was not the same in all survey years. In 2013/2014, herons were only rarely witnessed on Waldie Island, instead frequenting Breakwater Island during the day. No herons were observed on Breakwater Island in 2014/15, possibly due to ongoing construction along the Waldie Island Trail and sewage lagoons adjacent to the island, and sightings were more frequent on Waldie Island. In 2015/2016 the largest congregations of herons were observed roosting on Breakwater Island, though individual herons were also observed roosting and foraging on Waldie Island. No herons were observed on any shoreline between the Hugh Keenleyside Dam and the Pass Creek area, or along the Columbia River south of Zuckerberg Island.

In Creston, herons were present both at the northern and southern ends of Duck Lake (both on the ice of the lake and along wetland margins), along the channel to the southeast of the lake, and in the wetland complexes around Leach Lake and Corn Creek, as well as in several agricultural fields.

Elsewhere in the region, herons were observed in and around Revelstoke, at Burton Creek south of Nakusp, near Lumberton, and near Invermere. Birds appeared to withdraw from their distribution in January/February compared with November/December, and excepting sightings near Invermere, birds were only found in Castlegar and Creston during the January/February period. As evidenced by the daily heron counts of Waldie Island, numbers also decreased during the January/February period, with many days without detections.

Herons were found in a variety of habitats (e.g., flowing river, frozen lake, agricultural field) and there does not appear to be anything particularly unique about sites that were chosen. There is much overlap in site characteristics and physicochemical attributes between sites where herons were present and sites where herons were not detected. In general, herons were only found where open water remained, with the exception of Duck Lake where herons congregated and foraged from holes in the ice, and where agricultural fields were present. Our observations are limited to dusk, dawn, and daylight periods, and it is possible that distributions are different at night.

A habitat suitability model based on continuous data variables and sites where herons were and were not detected, indicate that the most suitable habitat occurs in the Creston area, with moderate to high suitability habitat spread out around Kootenay Lake and the lower Kootenay River, Castlegar, Lower Arrow Lake (between Needles/Fauquier and the Hugh Keenleyside Dam), and the lower Columbia River. Both the modeling exercise and the field data that it was based upon indicate that heron numbers and distribution are limited in the Kootenay Region during the winter months, with a possible retraction of suitable habitat over the course of the winter. This may be explained by the sustained or increasing effects of winter, such as increased snow depth and cold temperatures over the study period.

6.1.2 MQ: How does the flow regime affect the area, distribution, and attributes of shoreline areas?

High flow rates out of Hugh Keenleyside Dam are related to higher water elevations as measured at the CNN (Columbia below Norns Creek) gauge. As water elevations increase, the amount of available shoreline decreases (Figure 5-6). During the three winters surveyed, vertical water elevations rose between 2.3 m and 3.7 m, varying by year. The minimum water elevation occurred in mid-February, early November and late February in the three survey years (presented chronologically), while the maximum occurred in mid-December, early December and early January. Between these minimum and maximum water elevations in each of the three years, between 63.3 and 67.7 per cent of potential shoreline habitat was lost due to inundation. At Waldie Island and Breakwater Island, the amount of potential shoreline habitat flooded was 72.6 to 85.2 per cent and 77.2 to 100 per cent respectively. Monthly average and minimum water elevations were highest in January in two of the three survey years, making that the month in which shoreline habitat was most limited for the longest period of time, but during the first year of study (2013/2014), shoreline habitat was most limited during December. Similarly, the lowest ultimate amount of potential shoreline habitat occurred in December, for a short period of time, corresponding to the maximum winter water elevation, but only in the first two winters. During the third winter the maximum occurred in January. At sites with long shorelines paralleling the river, changes in water elevation may not affect foraging opportunities greatly, so long as some shoreline habitat remains. Thus, changes were most pronounced at islands, especially small, low elevation ones like Breakwater Island, which experienced concomitant decreases in shoreline area and length as water elevations increased.

At high water elevations, shoreline habitat is limited to a small upstream area in the Pass Creek delta, higher areas of Waldie Island mainly composed of the forested interior of that island, and the large grassy field habitat near the Kootenay River oxbow (Figure 5-8). In comparison, much habitat is available throughout the area during lower water events including channels and backwater areas around Zuckerberg Island and Waldie and Breakwater Islands, as well as sandbars near Pass Creek, and exposed gravel bars near the Tin Cup Rapids (Figure 5-8). The above areas represent approximately 59.8 ha of potential heron foraging and/or roosting habitat that is temporarily lost when water elevations peak.

There does not appear to be much biologically meaningful difference in physicochemical parameters of water samples taken in the different time periods, or between sites with and without herons. This indicates that most of the habitat present could be utilized by herons, so long as security and foraging requirements are met. In addition, there was no distinct difference in physicochemical parameters between sites in Castlegar and those elsewhere in the region. While scouring of vegetation may occur along shoreline areas with changing water elevations, this would not be expected to negatively affect heron presence or distribution. The above suggests that sites in the region may be underutilized owing to low numbers of wintering herons. It does not appear that flow regime impacts the attributes of shoreline sites in ways that influence heron utilization, beyond the impacts to shoreline area. However, those impacts to shoreline area may have an impact on the suitability of sites to herons.

6.1.3 MQ: Are there physical works that could improve the availability of shoreline areas for Great Blue Herons on Waldie Island and in the Castlegar area?

The availability of shoreline in the Castlegar area is strongly dependent on water elevation, which in turn is correlated with flow rates from the Hugh Keenleyside Dam. However, even during periods of low water elevations during the winter months, herons are strongly clustered around Waldie and Breakwater islands. While available shoreline on Waldie Island is reduced with increasing water elevation, the effect is most pronounced on Breakwater Island. The rate of habitat loss is greatest when water elevations increase from about 418 to 419 m, and the majority of shoreline area on this island is lost above about 421 m. One possibility to mitigate this would be to increase the size of Breakwater Island, particularly along the southern and eastern sides. Such an increase would benefit most from building the island up in height to ensure that it does not become inundated during flooding periods. The island should not be extended along any direction that would increase its accessibility from the mainland shoreline. To be most effective, the island should be built up to a minimum of 423 m over at least 50 per cent of its area.

Additional shoreline habitat could also be created at a new location. As the river is used by a variety of users, options for the creation of habitat that does not impede navigation are limited. However, the area around the Pass Creek delta already contains numerous sandbars. One or more of these, especially along the southern edge (closer to the main river) could be built up in height and area to provide an island similar to Breakwater Island that is within close proximity to the Castlegar Sewage Lagoons (where herons have been observed roosting), as well as both Breakwater and Waldie islands (Figure 6-2). This location could also provide a “backup” location for roosting herons in the event that activities around Breakwater Island or Waldie Island create disturbance there (as may have been the case during the 2014/2015 winter when construction along the sewage lagoons and Waldie Trail coincided with reduced heron usage of Breakwater Island).

Figure 6-2: Potential area (red polygon) where physical works could be implemented to enhance existing sandbars to be resistant to inundation by increasing height to 422 m or higher. In this photo Waldie Island is visible to the right of the figure, with Breakwater Island occuring directly south of the Castlegar Sewage Lagoons.

Physical works at these sites would not be expected to increase peak heron counts, as numbers at the current sites are depressed compared with surveys in the early 2000s (see Machmer 2003), suggesting that the current habitats are below carrying capacity. Furthermore, much of Waldie Island (especially the edge of the forested interior) remains accessible to herons during high water elevations, yet herons do not appear to remain in the area, potentially due to the loss of shoreline foraging habitat. However, by providing flood-resistant and/or additional islands, herons may be able to tolerate higher water levels for longer periods of time (providing both roosting and foraging habitat), thereby increasing the January and potentially February heron counts at this site, given the assumption that higher water levels do not significantly decrease the availability of heron prey. To minimize disturbance to birds, any physical works should be done during periods when no or few herons are present. The March to April period typically has both low numbers of herons and low flow rates from Hugh Keenleyside Dam.

6.1.4 MQ: How does the suitability of winter habitat on Waldie Island and in the Castlegar area compare to habitat used by wintering Great Blue Herons elsewhere in the surrounding region?

The only two areas where herons appeared to congregate in any numbers during the November to February period were around Waldie Island in Castlegar and around Duck Lake in Creston. Sightings elsewhere included several birds around Revelstoke, at the mouth of Burton Creek south of Nakusp, along a shallow, slow moving stream near Lumberton, and several sightings of herons in a slough just north of Columbia Lake near Invermere. These birds were in a range of habitats and adjacent land uses, but were all present in open water with the exception of the Duck Lake and Invermere birds. The Duck Lake birds, while on ice, were congregated around open ice holes from which they were able to hunt, and thus open water, while a very small amount, was still present. The same strategy was used by the Invermere birds, which were found near open areas of the river.

In addition to having permanently open water, the Castlegar area and Waldie Island experience great changes in the amount of available shoreline habitat as water elevations fluctuate. While habitat might remain available, foraging habitat may be unsuitable if fish do not quickly move into areas recently flooded, as some evidence suggests (Machmer 2003). Thus, stable habitats may actually be more suitable, even if the area of those habitats is more restricted.

There does not appear to be much difference in physicochemical parameters of water samples taken in the Castlegar area versus the broader Kootenay region. Both air and water temperatures as well as wind speed were higher on average in Castlegar than other locations. Conversely, specific conductance and turbidity were lower in Castlegar. That air and water temperatures are higher and open water habitat is available may be one reason why herons are typically more numerous in Castlegar than other locations in the region (excepting Creston). In general, there is a lower range in values from Castlegar samples than all other locations, but this is expected given that all sites in Castlegar are connected in the same Columbia River system and geographic location, and other sites occur over a greater geographic spread and site type. In general though, no major differences in physicochemical parameters stand out that would indicate that habitat around Castlegar is more suitable based on these measured parameters than at other locations in the region. A habitat suitability modeling exercise resulted in highly suitable habitat occurring around Creston, with smaller patches of suitable habitat throughout Lower Arrow Lake and the Lower Columbia River including Castlegar, as well as from Kootenay Lake downstream to the Columbia/Kootenay confluence. These results suggest that unoccupied suitable habitat exists, and is unoccupied due to lack of availability (e.g., ice cover), influence of an unmeasured variable (e.g., fish density), or simply because the region, which is along the northern extent of the interior wintering Great Blue Heron range, does not support a large enough winter heron population to occupy the remaining sites.

Security and foraging opportunity must be considered under habitat suitability. Foraging opportunity is assumed, but the nocturnal and crepuscular foraging methods around Castlegar may limit habitat suitability compared to Creston where herons presumably forage diurnally and nocturnally. Security does seem to be granted around Waldie Island owing to sites with limited human or dog access and/or good vantages or elevated perching sites (e.g., Waldie Island, Breakwater Island, Castlegar sewage lagoons). Both these considerations may be reflected in the selection of Duck Lake as a wintering site, where foraging is apparently successful through ice holes, and the frozen lake provides a buffer around potential disturbances as well as a good vantage over any potential threats. In comparison, other locations selected by the model as being “suitable” in terms of habitat, may in reality be unoccupied due to the threat of predators, humans, or other disturbances.

The presence of relatively high numbers of Great Blue Herons through to at least January (compared with other surveyed areas in the Kootenays), and statistically higher air and water temperatures and year-round open water are indicative that the Castlegar area is among the most suitable wintering habitat for Great Blue Herons in the region. Specifically, the Waldie Island area has historically and currently supported numbers of herons in the winter period. Most habitat parameters do not differ between Castlegar and other sites, indicating that sites around Waldie Island are not more, or less, suitable than elsewhere in the region based on water chemistry or other measured variables. Instead, suitability is likely reflective of other considerations such as security and foraging opportunity. There is a potential that the effects of duration of inundation events related to fish occupancy may reduce habitat suitability near Waldie Island over the course of the winter period, but this remains untested.

6.1.5 MQ: Are there operational changes that could improve habitat availability and suitability for Great Blue Herons on Waldie Island and in the Castlegar area?

In the early 2000s a higher number of herons were observed in the winter period than have been observed over the course of these surveys. Machmer (2003) recorded high counts of 31, 26, and 21 individuals in her three respective years of study in the early 2000s, compared to peak counts in the vicinity of Waldie Island of 7, 9 and 14 in the three years of this current study. Despite the higher number of herons, Machmer (2003) found no definitive link of flow regime to heron counts during the winter period. While counts are lower now, there is still weak to no evidence for an effect of water elevation on counts. However, there is a clear relationship between the water elevation and the amount of available potential shoreline habitat. Previously a maximum water elevation of 420.7 m has been recommended to ensure that enough shoreline remains, particularly around Breakwater Island which becomes submerged at elevations around 422 m (Machmer 2003, revised by BC Hydro 2012).

A water elevation of 420.7 translates to a loss of approximately 63 per cent of shoreline habitat overall in the Castlegar study area. The losses to Waldie Island and Breakwater Island are approximately 75.5 per cent and 90.7 per cent respectively. Above that elevation, the extent to which increases affect shoreline habitat relates to the topography of the shoreline. For example, increasing water elevations by 0.4 m above the recommended maximum reduces Waldie Island shoreline area by an additional ~3 per cent, but ~9 per cent to Breakwater Island. The rate of shoreline loss decreases as water elevation increases. We thus continue recommending that 420.7 m be kept as an operational maximum whenever possible, but acknowledge that temporary habitat loss occurs even at lower elevation levels. Maximizing shoreline availability requires keeping elevations as low as possible during the winter period. However, given the lack of explanatory power of water elevation on heron counts, there does not appear to be strong justification for maximizing habitat, so long as frequently used sites such as Waldie and Breakwater Islands remain available. During this study, the winter with the highest water elevations had the lowest number of herons, and vice versa, but caution must be applied in interpreting this trend. Long-term data sets, such as some of the Christmas Bird Count results from the northern U.S.A., show highly variable, almost cyclical declines and increases in heron numbers over time (e.g., Spokane, Washington, see Appendix H), and the trend we observed may be spurious.

In all of our survey years heron numbers declined throughout January until few or no herons remained around Waldie Island. However, in viewing the annual trend in heron numbers at Waldie Island, counts actually peak in mid-October to late-November, regardless of whether flows are increasing or decreasing during that time period in a given year. Thus, operational changes may have no impact on this trend, which could be driven by unrelated factors. Operational changes could influence those herons that remain in the area in December and January, but without establishing a proper experiment, with the ability to manipulate flows and control for prey-fish abundance, the results of any changes are hypothetical. If an experiment could be established, lowering the water elevations in January would provide a useful contrast to better determine if water elevations are limiting the number of herons at that time period, or if herons depart regardless for unrelated reasons. This would need to be done over multiple years, and may interfere with the Mountain Whitefish spawning period.

There does not appear to be any difference in habitat suitability with water elevation on variables that we measured. As herons are not relying on shoreline vegetation for any aspect of daily activity, and as shoreline vegetation may actually hinder a heron's ability to detect a predator, the regular cycle of inundation and exposition of shoreline areas would not appear to negatively affect the suitability of that habitat for herons, and may actually benefit them in some situations. However, the flooding process may impact heron prey. It has been reported that recently inundated areas have low fish use (Machmer 2003). Machmer (2003) also comments that during the winter period, the rate of recolonization by fish to recently inundated areas may be slow. As a result, nearshore habitat where herons hunt following inundation events may not be productive foraging grounds. This would suggest that the lower water elevations could be the most suitable for wintering herons, and that higher nearshore habitats, even if available, may not be as suitable. If this is the case, the recommendation would remain to keep water elevations as low as possible given other operational constraints.

6.1.6 Management Questions Summary

Several management questions are addressed by this study (Table 6-1). This study has benefited from a broadening of the study area and investigations of herons elsewhere in the Kootenay region, as the Castlegar area is not a microcosm. Rather, a complex of variables related to climatic conditions and heron breeding success will impact how many herons are present in the Castlegar area during the winter months. Nonetheless, severe limitations arose owing to the inability to manipulate flow rates and establish an experimental study. Rather, an observational study was designed which leaves many unanswered questions as to the ultimate reasons for the observed heron trends. In addition, prey data were not collected, and the inter-annual trends in fish numbers, fish species composition, and effects of flow regime on fish habitat utilization are unknown. Based on the data collected, the Waldie Island area hosts a high number of wintering herons, until at least January, and in the Kootenay region heron numbers were only higher in the Creston area. Furthermore, there is no direct evidence of an impact of flow regime on heron numbers or population trends. Confounding analysis was an inconsistent pattern of flow regime among years, but what is clear is a declining amount of available shoreline habitat with increasing water elevation. The effects of this are most pronounced on smaller and lower land areas, in particular Breakwater Island, which otherwise appears to be an important roosting area for Great Blue Herons in the region. Dam operations should aim to keep water elevations below 420.7 m when possible, as the island is essentially inundated at elevations above 422 m. Breakwater Island could be raised, or additional islands created in the Pass Creek area, to help maintain habitat during periods of high water elevations, but overall heron populations and the temporal trend of heron numbers throughout the winter may be unaffected by such measures.

Table 6-1: Relationships between management questions (MQs), methods and results, and Sources of Uncertainty to CLBMON-49

MQ	Able to Address MQ?	Supporting results	Sources of Uncertainty
Where are the shoreline areas that are used by Great Blue Herons?	Yes	• Mapped heron locations showing all shoreline areas where herons detected. • Distribution of herons aligns with historical Christmas Bird Count data. • Occupied sites in Castlegar similar in all survey years. • Habitat suitability model showing areas with high suitability for heron presence	• Natural annual population variation • Variable dam flows among years and throughout the day • Human and other disturbances potentially limiting site utilization • Difficult to observe at night • Lack of experimentation to assess how varying the flows affects herons at different times through the winter period • Statistical models had weak support and key parameters for highly suitable winter habitat unknown and unmeasured.
How does the flow regime affect the area, distribution, and attributes of shoreline areas?	Yes	• Shoreline areas increase with decreasing water elevation and vice versa. • Physicochemical parameters do not seem to be affected.	• Variable dam operations and inter-annual variation. • Uneven site response • Unknown how heron prey respond to flow regime in shallow water habitats
Are there physical works that could improve the availability of shoreline areas for Great Blue Herons on Waldie Island and in the Castlegar area?	Yes	• Locations where herons occur and knowledge of how water elevations affects the most commonly utilized roosting areas	• Variable dam operations • Natural annual population variation in numbers and site utilization • Unknown movement patterns of herons • Lack of physical works to benefit herons already undertaken from which to inform recommendations
How does the suitability of winter habitat on Waldie Island and in the Castlegar area compare to habitat used by wintering Great Blue Herons elsewhere in the surrounding region?	Yes	• Physicochemical parameters do not appear to differ • Water remains ice-free through entire winter period in Castlegar, unlike some other areas in Kootenays • Security and foraging opportunities present reliably among years	• Only two years of data for areas outside of Castlegar • Unknown distribution, abundance, or site selection attributes of herons from areas with high winter abundances outside study area (e.g., Okanagan, Idaho). • Unknown foraging opportunity or how fish presence/density varies among sites • Natural annual population variation
Are there operational changes that could improve habitat availability and suitability for Great Blue Herons on Waldie Island and in the Castlegar area?	Possibly	• Available potential shoreline habitat mapped out at different water elevations • Heron numbers low in January, overlapping whitefish flow period when water elevations higher	• Unknown how fish or other aquatic organisms utilize recently inundated areas • Inability to experimentally alter flows

7.0 RECOMMENDATIONS

The objectives of CLBMON-49 are to assess the response of herons to flow and stage regime from the Hugh Keenleyside Dam during the winter period due to its potential effects on availability of shallow-water foraging and winter refuge habitats, and to provide information on habitat use and feasible mitigative actions. This study has provided a comprehensive picture of heron abundance, distribution, behaviour, and selection of sites throughout a significant portion of the Kootenay region. Heron numbers remained relatively low throughout the study period (compared to counts in the early 2000s), but especially during January and February. Recommendations are presented below that relate to herons wintering in the Castlegar area. It is the cause of the decline in heron numbers during January (the Mountain Whitefish flow period) that is most ambiguous. Currently a decline in numbers related to high water elevations is circumstantial, but plausible, while other factors such as fish distribution and abundance, climate or life-history factors could also be at play. Additional recommendations are presented below to expand a study to help elucidate the cause of this trend.

7.1 Hugh L. Keenleyside Dam Operations

The previous recommendation (Machmer 2003) of limiting water elevations at or below 420.7 m (based on the Norns Creek ratings curve) was largely met between 2005 and 2012. Water elevations exceeded that recommended limit for an extended period during the winter of 2013/2014, and to a slightly lesser extent in 2012/2013. While there was little evidence for an effect of water flows on heron utilization of the Waldie Island area, given the apparent importance of Breakwater and Waldie islands as roosting locations, and their susceptibility to inundation at elevations above 422 m, operations should continue to attempt to limit the elevation to the previously recommended level. Elevations should be kept as low as possible during the stable whitefish flow period in January.

7.2 Study Design

1. During the three years of this study water elevations and the temporal pattern of the rate of change of shoreline areas due to water elevations differed among years. The numbers of herons also changed over these three years, increasing each year, and the distribution of herons differed slightly during these years as well. Long-term datasets show inter-annual variation in heron counts for a given site. Due to the difficulty in determining relationships between factors in such dynamic systems, any future studies should be conducted over a longer time scale (i.e., 10 years).
2. The daily count data collected over the entire year may help elucidate trends in heron numbers that may be obscured from focusing in on a specific timeframe (i.e., winter). The daily counts collected over this study show that the peak in heron numbers often occurred prior to this project's start date (i.e., Nov. 1), and that the decline in heron numbers from this peak typically began in advance of high water elevations.
3. Heron numbers were very low or zero from early January onwards. Water elevations should be experimentally kept low during and prior to this month in several years to help determine whether high water elevations are causing herons to abandon the area at this time, or whether non-flow related causes are involved.

4. Conduct shallow water fish surveys over the winter period in conjunction with heron observations to determine fish composition and how prey density varies with different water elevations and durations of inundation. Nocturnal fish surveys would be required owing to the apparent nocturnal foraging of herons in the Castlegar area.
5. Expand the study area to include additional sites identified as being highly suitable based on our mapping, as well as survey adjacent regions within the Columbia/Kootenay basins (e.g., Idaho) and/or adjacent regions outside the basin (e.g., Okanagan Valley).
6. The movements of herons within the Columbia/Kootenay region are not well known. The source population for birds that spend all or a portion of the winter period in the region is likewise unknown. Great Blue Herons are capable of migrating thousands of kilometers, and therefore apparent or survey declines could be influenced by factors on the breeding grounds, migratory stop overs, or wintering grounds. A tagging project using GPS transmitters or similar technology would be beneficial in helping to understand heron movements within and potential outside of the region. It is noted that such a project was described in the Terms of Reference, but ultimately omitted from the monitoring project due to concerns of the welfare of captured herons, as well as financial and other logistical challenges (BC Hydro 2012).

7.3 Additional Recommendations

The following recommendations address issues that might influence heron abundance and utilization of sites around Waldie Island, though they are not under BC Hydro’s management authority. They are offered here for completeness and to highlight additional actions that appropriate decision-makers might take to benefit herons irrespective of hydro operations.

Breeding herons are extremely susceptible to disturbances during the breeding season. While disturbance impacts on non-breeding herons are less clear, they are unlikely to be beneficial. Human and dog (both leashed and unleashed) activity was noted near-daily during the past two winters of surveys at almost all shoreline locations, and their presence may limit heron utilization of otherwise suitable sites. Additionally, human-caused disturbances were noted multiple times. As the Waldie Island area appears to be the most significant wintering site for herons in the Castlegar area, consideration should be made to reduce potential disturbances in that area. These include:

1. Implementing and enforcing regulations requiring all dogs to be on leash on the Waldie Island Trail. As even the sound of dogs barking was noted to disturb herons, a complete dog ban would be ideal, but unlikely to be accepted by community members.
2. The current ban on human and dog activity on Waldie Island needs enforcement. Various users throughout the year (e.g., fishermen accessing via boat, and humans and on-leash and off-leash dogs during low water levels) have been noted on the island, depleting its utility as a wildlife reserve.

3. All human and dog activity (including watercraft) in the area between Breakwater Island, Waldie Island, and the mainland shore (the area referred to as Mill Pond), and along the backwater channel, including shorelines, between Waldie Island and the mainland should be banned and enforced. An enforced ban in this area would also benefit other wildlife that utilize this zone.
4. The boardwalk that previously was built along the Waldie Island Trail was destroyed during a high-water event in 2012. The boardwalk should be re-built to discourage trail users from walking on the beach and other shoreline areas, and to prevent further degradation of habitat.

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APPENDICES

Appendix A: Shoreline sampling location coordinates for all sample sites in the Kootenay region during all survey years

Region	Name	Zone	Easting	Northing
Burton	Burton Ck Mouth	11 U	436231	5536947
Burton	Burton Creek	11 U	437061	5536803
Burton	Burton South	11 U	435080	5536590
Castlegar	4th Avenue	11 U	452334	5464093
Castlegar	Breakwater Island North	11 U	452040	5464395
Castlegar	Bridgeview	11 U	452806	5463089
Castlegar	Grassland	11 U	453264	5462533
Castlegar	HLK Dam	11 U	444298	5465767
Castlegar	Kootenay Pt	11 U	452908	5462808
Castlegar	Midway	11 U	448876	5464976
Castlegar	Mill Site	11 U	446540	5465589
Castlegar	Oxbow	11 U	452829	5462386
Castlegar	Pass Creek	11 U	451646	5464924
Castlegar	PipelineX	11 U	452756	5463803
Castlegar	Twin Rivers Park	11 U	452664	5463453
Castlegar	Waldie East	11 U	452738	5464269
Castlegar	Waldie North	11 U	452540	5464629
Castlegar	Waldie West	11 U	452285	5464542
Castlegar	Zuckerberg Central	11 U	452365	5462703
Castlegar	Zuckerberg North	11 U	452345	5462925
Columbia Lake	Canal Flats	11 U	585607	5555724
Columbia Lake	Fairmont	11 U	580910	5575192
Cranbrook	Kootenay River South of Bull River	11 U	613740	5478898
Cranbrook	Norbury Creek	11 U	611379	5481057
Cranbrook	St. Eugene's Mission	11 U	589651	5493545
Cranbrook	St. Mary's - Wycliffe South	11 U	586616	5492837
Creston	Bridge Channel	11 U	525610	5456263
Creston	Corn Creek Pond	11 U	528011	5442731
Creston	Creston Channel Rd	11 U	529557	5450418
Creston	Duck Lake South	11 U	528377	5451636
Creston	Dyke rd ditches	11 U	527906	5439735
Creston	Goat River	11 U	535012	5436626
Creston	Kootenay River South	11 U	530704	5436798
Creston	Kuskanook 87	11 U	524642	5460758
Creston	Kuskanook South	11 U	525044	5459990
Creston	Leach Lake North	11 U	526846	5446801
Creston	Leach Lake South	11 U	527354	5445432
Creston	Mid Channel	11 U	524607	5453367
Creston	South Duck Lake Channel	11 U	530396	5448588
Edgewood	Edgewood South	11 U	418032	5513983
Edgewood	Lower Inonoaklin	11 U	420433	5524119
Invermere	Columbia – North of Invermere	11 U	568179	5598651
Invermere	Windermere Lake North	11 U	569471	5596499
Kimberley	Marysville – St. Mary’s River	11 U	574207	5498100
Kimberley	St. Mary’s – Below treatment plant	11 U	574645	5497946
Lumberton	Lumberton	11 U	583036	5473938
Lumberton	Moyie Lake	11 U	584806	5458955
Nakusp	Nakusp Creek Mouth	11 U	441436	5565932
Nakusp	South Nakusp Creek Mouth	11 U	443509	5563896
Revelstoke	Across from Log Dump	11 U	414430	5648994
Revelstoke	Airport South	11 U	417362	5645560
Revelstoke	Ball Park - West	11 U	415294	5649650

Region	Name	Zone	Easting	Northing
Revelstoke	Big Eddy	11 U	413611	5651114
Revelstoke	Cartier Bay	11 U	419325	5641859
Revelstoke	Illecillewaet Confluence	11 U	415393	5648722
Revelstoke	Illecillewaet River Bridge	11 U	416805	5648823
Revelstoke	Montana Slough	11 U	418774	5644080
Revelstoke	Moose Creek	11 U	414848	5655401
Revelstoke	Revelstoke-9 mile spit	11 U	420328	5639352
Revelstoke	Revi Reach South	11 U	422240	5634194
Revelstoke	Side Channel Across from Town	11 U	414603	5649523
Revelstoke	Side Channel S. of Bridge	11 U	414868	5650105
Revelstoke	Westside Channel	11 U	413095	5652126
Rocky Mountain Trench	Kootenay	11 U	594166	5505248
Rocky Mountain Trench	Skookumchcuk	11 U	590698	5529448
Rocky Mountain Trench	North Wasa Bridge	11 U	590397	5521346
Rocky Mountain Trench	Wasa Bridge	11 U	588724	5518182

Appendix B: UTM coordinates for all heron observations during this study. Locations refer to the actual heron location (not the observer location).

Region	Zone	Easting	Northing	Date
Burton	11 U	436243	5537120	20-Nov-14
Burton	11 U	436160	5536954	20-Nov-14
Burton	11 U	436233	5537014	20-Nov-14
Castlegar	11 U	452285	5464304	28-Nov-13
Castlegar	11 U	452214	5464402	28-Nov-13
Castlegar	11 U	452263	5464294	28-Nov-13
Castlegar	11 U	453062	5462460	11-Dec-13
Castlegar	11 U	452231	5464343	11-Dec-13
Castlegar	11 U	452032	5464233	12-Dec-13
Castlegar	11 U	451069	5464682	13-Dec-13
Castlegar	11 U	453849	5462633	27-Dec-13
Castlegar	11 U	452612	5462612	29-Dec-13
Castlegar	11 U	452004	5464285	29-Dec-13
Castlegar	11 U	451948	5464274	29-Dec-13
Castlegar	11 U	451942	5464274	29-Dec-13
Castlegar	11 U	452972	5462679	30-Dec-13
Castlegar	11 U	452985	5464068	30-Dec-13
Castlegar	11 U	451878	5464498	30-Dec-13
Castlegar	11 U	451888	5464531	30-Dec-13
Castlegar	11 U	451918	5464566	30-Dec-13
Castlegar	11 U	451936	5464584	30-Dec-13
Castlegar	11 U	450916	5464642	16-Jan-14
Castlegar	11 U	444152	5465773	16-Jan-14
Castlegar	11 U	444163	5465801	16-Jan-14
Castlegar	11 U	453782	5462683	16-Jan-14
Castlegar	11 U	451484	5464578	16-Jan-14
Castlegar	11 U	451258	5464413	17-Jan-14
Castlegar	11 U	451371	5464550	17-Jan-14
Castlegar	11 U	451094	5464417	17-Jan-14
Castlegar	11 U	451907	5464283	04-Feb-14
Castlegar	11 U	452334	5464534	04-Feb-14
Castlegar	11 U	452376	5464612	04-Feb-14
Castlegar	11 U	452649	5464301	05-Feb-14
Castlegar	11 U	452552	5464322	05-Feb-14
Castlegar	11 U	452637	5464617	05-Feb-14
Castlegar	11 U	452652	5464544	05-Feb-14
Castlegar	11 U	452386	5464570	05-Feb-14
Castlegar	11 U	452384	5464536	05-Feb-14
Castlegar	11 U	452261	5464555	06-Feb-14
Castlegar	11 U	452393	5464491	06-Feb-14
Castlegar	11 U	452360	5464568	06-Feb-14
Castlegar	11 U	452094	5464400	24-Feb-14
Castlegar	11 U	444173	5465792	24-Feb-14
Castlegar	11 U	444170	5465773	27-Feb-14
Castlegar	11 U	452611	5464315	21-Nov-14
Castlegar	11 U	452613	5464320	21-Nov-14
Castlegar	11 U	452617	5464313	21-Nov-14
Castlegar	11 U	452639	5464304	21-Nov-14
Castlegar	11 U	452588	5464317	21-Nov-14
Castlegar	11 U	452520	5464337	21-Nov-14
Castlegar	11 U	451140	5464395	21-Nov-14
Castlegar	11 U	444160	5465802	21-Nov-14

Region	Zone	Easting	Northing	Date
Castlegar	11 U	452517	5464307	21-Nov-14
Castlegar	11 U	452519	5464322	21-Nov-14
Castlegar	11 U	452519	5464322	21-Nov-14
Castlegar	11 U	452527	5464336	21-Nov-14
Castlegar	11 U	452503	5464360	21-Nov-14
Castlegar	11 U	452505	5464359	21-Nov-14
Castlegar	11 U	452487	5464293	21-Nov-14
Castlegar	11 U	451448	5464825	21-Nov-14
Castlegar	11 U	451270	5464679	21-Nov-14
Castlegar	11 U	452519	5464307	22-Nov-14
Castlegar	11 U	452535	5464306	22-Nov-14
Castlegar	11 U	453347	5462643	22-Nov-14
Castlegar	11 U	452605	5464307	22-Nov-14
Castlegar	11 U	452617	5464313	22-Nov-14
Castlegar	11 U	451949	5464568	22-Nov-14
Castlegar	11 U	452518	5464332	22-Nov-14
Castlegar	11 U	452518	5464332	22-Nov-14
Castlegar	11 U	452518	5464332	22-Nov-14
Castlegar	11 U	452518	5464332	22-Nov-14
Castlegar	11 U	451136	5464395	22-Nov-14
Castlegar	11 U	451136	5464395	22-Nov-14
Castlegar	11 U	451136	5464395	22-Nov-14
Castlegar	11 U	451136	5464395	22-Nov-14
Castlegar	11 U	444015	5465678	22-Nov-14
Castlegar	11 U	444159	5465762	22-Nov-14
Castlegar	11 U	453123	5462689	23-Nov-15
Castlegar	11 U	452950	5462784	23-Nov-15
Castlegar	11 U	452542	5464316	23-Nov-15
Castlegar	11 U	452542	5464316	23-Nov-15
Castlegar	11 U	452736	5464270	24-Nov-15
Castlegar	11 U	452361	5462916	24-Nov-15
Castlegar	11 U	452178	5464323	24-Nov-15
Castlegar	11 U	452178	5464323	24-Nov-15
Castlegar	11 U	452178	5464323	24-Nov-15
Castlegar	11 U	452178	5464323	24-Nov-15
Castlegar	11 U	452089	5464347	24-Nov-15
Castlegar	11 U	452089	5464347	24-Nov-15
Castlegar	11 U	452089	5464347	24-Nov-15
Castlegar	11 U	452307	5464421	24-Nov-15
Castlegar	11 U	451938	5464423	24-Nov-15
Castlegar	11 U	451938	5464423	24-Nov-15
Castlegar	11 U	452680	5463350	24-Nov-15
Castlegar	11 U	453609	5462752	24-Nov-15
Castlegar	11 U	452388	5464404	24-Nov-15
Castlegar	11 U	452388	5464404	24-Nov-15
Castlegar	11 U	452388	5464404	24-Nov-15
Castlegar	11 U	452037	5464406	24-Nov-15
Castlegar	11 U	452037	5464406	24-Nov-15
Castlegar	11 U	452089	5464347	25-Nov-15
Castlegar	11 U	452343	5464422	25-Nov-15
Castlegar	11 U	452017	5464428	25-Nov-15
Castlegar	11 U	452017	5464428	25-Nov-15
Castlegar	11 U	452017	5464428	25-Nov-15
Castlegar	11 U	452017	5464428	25-Nov-15
Castlegar	11 U	452017	5464428	25-Nov-15

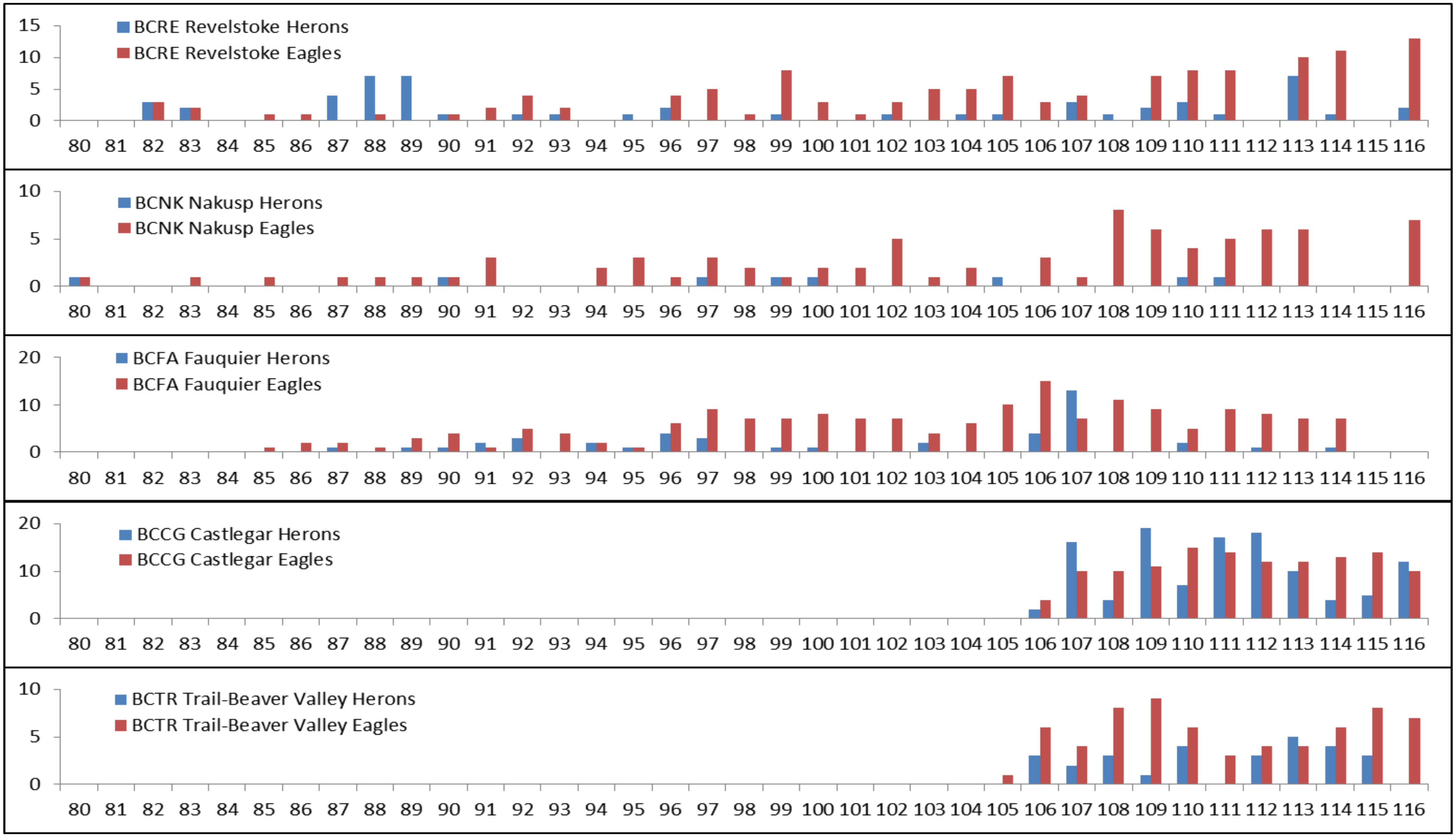
Region	Zone	Easting	Northing	Date
Castlegar	11 U	452017	5464428	25-Nov-15
Castlegar	11 U	452017	5464428	25-Nov-15
Castlegar	11 U	452017	5464428	25-Nov-15
Castlegar	11 U	452017	5464428	25-Nov-15
Castlegar	11 U	452017	5464428	25-Nov-15
Castlegar	11 U	452017	5464428	25-Nov-15
Castlegar	11 U	451989	5464421	25-Nov-15
Castlegar	11 U	451989	5464421	25-Nov-15
Castlegar	11 U	451989	5464421	25-Nov-15
Castlegar	11 U	451989	5464421	25-Nov-15
Castlegar	11 U	451989	5464421	25-Nov-15
Castlegar	11 U	451989	5464421	25-Nov-15
Castlegar	11 U	451989	5464421	25-Nov-15
Castlegar	11 U	451989	5464421	25-Nov-15
Castlegar	11 U	451989	5464421	25-Nov-15
Castlegar	11 U	452337	5464404	05-Dec-15
Castlegar	11 U	451997	5464380	05-Dec-15
Castlegar	11 U	451997	5464380	05-Dec-15
Castlegar	11 U	451997	5464380	05-Dec-15
Castlegar	11 U	451997	5464380	05-Dec-15
Castlegar	11 U	451997	5464380	05-Dec-15
Castlegar	11 U	451997	5464380	05-Dec-15
Castlegar	11 U	451997	5464380	05-Dec-15
Castlegar	11 U	452216	5464355	29-Jan-16
Castlegar	11 U	452219	5464365	29-Jan-16
Castlegar	11 U	451567	5464892	29-Jan-16
Castlegar	11 U	453347	5462512	30-Jan-16
Castlegar	11 U	452871	5462495	30-Jan-16
Castlegar	11 U	453400	5462895	30-Jan-16
Castlegar	11 U	453223	5462752	30-Jan-16
Castlegar	11 U	452351	5464317	30-Jan-16
Creston	11 U	528171	5452813	23-Nov-14
Creston	11 U	527591	5451492	23-Nov-14
Creston	11 U	528584	5452300	23-Nov-14
Creston	11 U	528410	5452530	23-Nov-14
Creston	11 U	528264	5452725	23-Nov-14
Creston	11 U	527999	5451507	23-Nov-14
Creston	11 U	528403	5451980	23-Nov-14
Creston	11 U	525516	5455853	23-Nov-14
Creston	11 U	526132	5455143	23-Nov-14
Creston	11 U	527961	5452002	23-Nov-14
Creston	11 U	528595	5451296	23-Nov-14
Creston	11 U	533217	5445157	23-Nov-14
Creston	11 U	530168	5449105	23-Nov-14
Creston	11 U	526590	5447120	24-Nov-14
Creston	11 U	527278	5441555	24-Nov-14
Creston	11 U	526734	5447145	24-Nov-14
Creston	11 U	525429	5455666	25-Nov-14
Creston	11 U	527799	5451648	25-Nov-14
Creston	11 U	527773	5451658	25-Nov-14
Creston	11 U	528376	5452233	25-Nov-14
Creston	11 U	528617	5452288	25-Nov-14
Creston	11 U	528053	5452141	25-Nov-14
Creston	11 U	527997	5452741	25-Nov-14
Creston	11 U	528049	5452742	25-Nov-14

Region	Zone	Easting	Northing	Date
Creston	11 U	528084	5452741	25-Nov-14
Creston	11 U	528482	5452278	25-Nov-14
Creston	11 U	526525	5451273	25-Nov-14
Creston	11 U	525573	5455891	16-Feb-15
Creston	11 U	525499	5455789	16-Feb-15
Creston	11 U	528318	5451386	17-Feb-15
Creston	11 U	528233	5451429	17-Feb-15
Creston	11 U	528233	5451429	17-Feb-15
Creston	11 U	528233	5451429	17-Feb-15
Creston	11 U	528195	5451465	17-Feb-15
Creston	11 U	528195	5451465	17-Feb-15
Creston	11 U	528195	5451465	17-Feb-15
Creston	11 U	528162	5451516	17-Feb-15
Creston	11 U	528162	5451516	17-Feb-15
Creston	11 U	528162	5451516	17-Feb-15
Creston	11 U	528141	5451583	17-Feb-15
Creston	11 U	528281	5451428	17-Feb-15
Creston	11 U	528279	5451438	17-Feb-15
Creston	11 U	528279	5451438	17-Feb-15
Creston	11 U	528279	5451445	17-Feb-15
Creston	11 U	528279	5451449	17-Feb-15
Creston	11 U	528280	5451466	17-Feb-15
Creston	11 U	528281	5451470	17-Feb-15
Creston	11 U	531881	5446789	17-Feb-15
Creston	11 U	531881	5446789	17-Feb-15
Creston	11 U	531881	5446789	17-Feb-15
Creston	11 U	531142	5447745	17-Feb-15
Creston	11 U	525558	5455928	17-Feb-15
Creston	11 U	528010	5447348	17-Feb-15
Creston	11 U	527994	5442761	18-Feb-15
Creston	11 U	527963	5439818	18-Feb-15
Creston	11 U	529647	5450299	26-Nov-15
Creston	11 U	528517	5452413	26-Nov-15
Creston	11 U	528559	5452353	26-Nov-15
Creston	11 U	528359	5451354	26-Nov-15
Creston	11 U	528359	5451354	26-Nov-15
Creston	11 U	528163	5451444	26-Nov-15
Creston	11 U	528163	5451444	26-Nov-15
Creston	11 U	527886	5451440	26-Nov-15
Creston	11 U	528056	5441569	26-Nov-15
Creston	11 U	533605	5441396	26-Nov-15
Creston	11 U	527114	5451710	26-Nov-15
Creston	11 U	524926	5453060	26-Nov-15
Creston	11 U	525501	5456058	26-Nov-15
Creston	11 U	525307	5457321	26-Nov-15
Creston	11 U	527493	5442177	27-Nov-15
Creston	11 U	527811	5442438	27-Nov-15
Creston	11 U	527671	5442352	27-Nov-15
Creston	11 U	527117	5442217	27-Nov-15
Creston	11 U	528217	5441326	27-Nov-15
Creston	11 U	533610	5440204	27-Nov-15
Creston	11 U	533110	5446250	28-Nov-15
Creston	11 U	534083	5440001	28-Nov-15
Creston	11 U	526845	5451448	28-Nov-15
Creston	11 U	526845	5451448	28-Nov-15

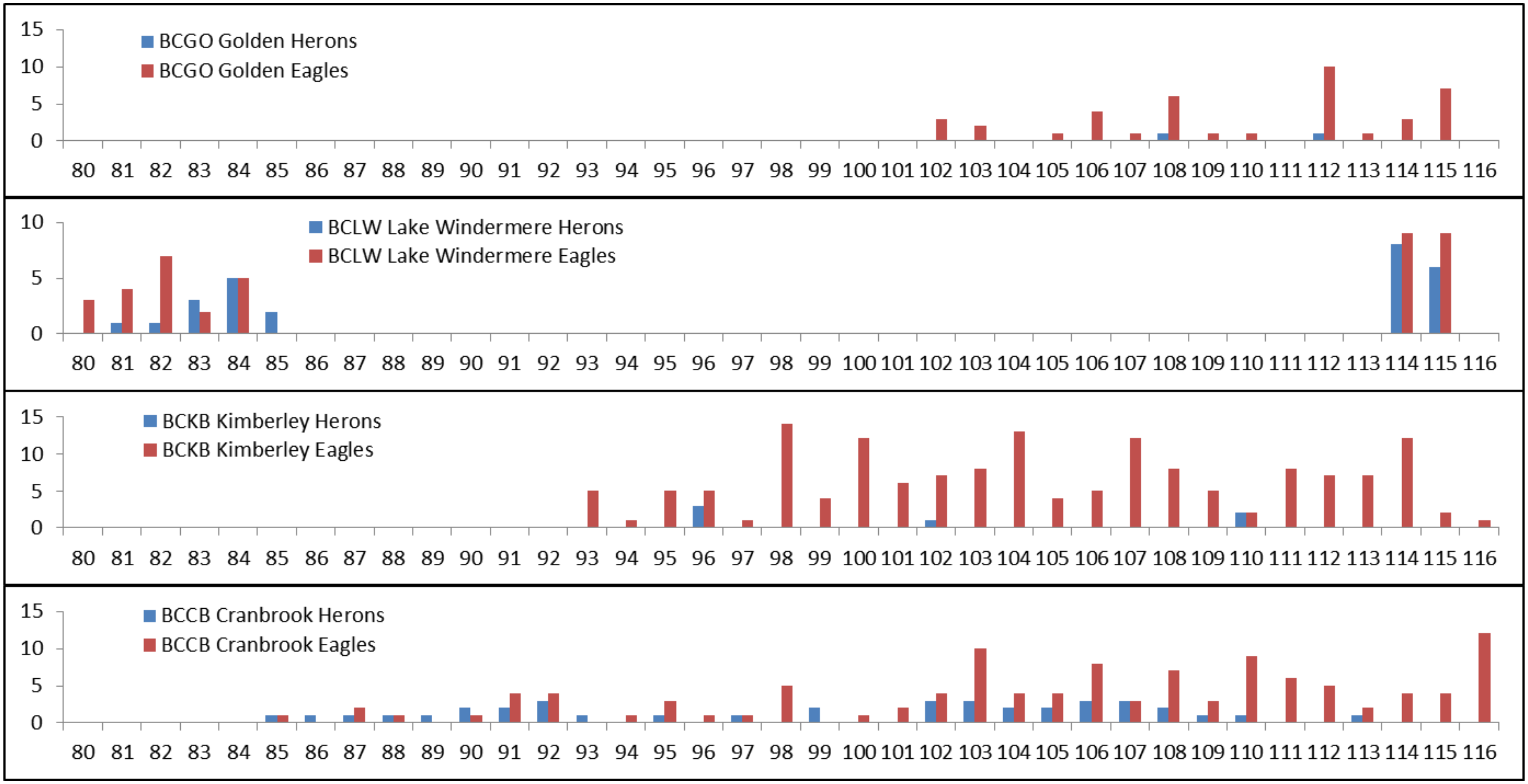
Region	Zone	Easting	Northing	Date
Creston	11 U	526845	5451448	28-Nov-15
Creston	11 U	526845	5451448	28-Nov-15
Creston	11 U	527405	5452558	28-Nov-15
Creston	11 U	527035	5451418	28-Nov-15
Creston	11 U	527075	5451408	28-Nov-15
Creston	11 U	527075	5451408	28-Nov-15
Creston	11 U	528015	5451439	28-Nov-15
Creston	11 U	527970	5451366	28-Nov-15
Creston	11 U	527970	5451366	28-Nov-15
Creston	11 U	527970	5451366	28-Nov-15
Creston	11 U	528121	5439830	28-Nov-15
Creston	11 U	525203	5455349	31-Jan-16
Creston	11 U	525362	5456457	31-Jan-16
Creston	11 U	530166	5448810	31-Jan-16
Creston	11 U	530344	5448883	31-Jan-16
Creston	11 U	530375	5448887	31-Jan-16
Creston	11 U	530388	5449028	31-Jan-16
Creston	11 U	530428	5449047	31-Jan-16
Creston	11 U	530425	5448866	31-Jan-16
Creston	11 U	530546	5448959	31-Jan-16
Creston	11 U	530849	5448508	31-Jan-16
Creston	11 U	530106	5448471	31-Jan-16
Creston	11 U	530131	5448459	31-Jan-16
Creston	11 U	530204	5448389	31-Jan-16
Creston	11 U	531878	5446806	31-Jan-16
Creston	11 U	526858	5451728	31-Jan-16
Creston	11 U	526846	5446801	01-Feb-16
Creston	11 U	527986	5442615	01-Feb-16
Creston	11 U	533406	5440354	01-Feb-16
Creston	11 U	527746	5441434	01-Feb-16
Creston	11 U	527873	5446962	01-Feb-16
Creston	11 U	527901	5445563	01-Feb-16
Creston	11 U	530704	5436798	02-Feb-16
Creston	11 U	527948	5452183	02-Feb-16
Creston	11 U	528334	5451887	02-Feb-16
Creston	11 U	528369	5451911	02-Feb-16
Creston	11 U	528454	5451838	02-Feb-16
Creston	11 U	528529	5451914	02-Feb-16
Creston	11 U	528506	5451946	02-Feb-16
Creston	11 U	528483	5451934	02-Feb-16
Creston	11 U	528495	5451950	02-Feb-16
Creston	11 U	528565	5451798	02-Feb-16
Creston	11 U	527878	5451429	02-Feb-16
Creston	11 U	528052	5451537	02-Feb-16
Creston	11 U	527372	5451876	02-Feb-16
Invermere	11 U	569342	5596681	20-Feb-15
Invermere	11 U	569452	5596595	30-Nov-15
Invermere	11 U	569006	5596772	30-Nov-15
Invermere	11 U	569079	5596902	30-Nov-15
Invermere	11 U	568642	5596952	30-Nov-15
Invermere	11 U	568771	5597498	30-Nov-15
Invermere	11 U	569221	5597140	30-Nov-15
Invermere	11 U	569197	5596606	01-Dec-15
Invermere	11 U	569119	5596696	01-Dec-15
Invermere	11 U	568771	5597101	01-Dec-15

Region	Zone	Easting	Northing	Date
Invermere	11 U	568901	5597259	01-Dec-15
Invermere	11 U	568901	5597259	01-Dec-15
Invermere	11 U	568901	5597259	01-Dec-15
Invermere	11 U	569108	5596908	04-Feb-16
Invermere	11 U	569034	5596953	04-Feb-16
Invermere	11 U	569035	5596960	04-Feb-16
Invermere	11 U	569039	5596981	04-Feb-16
Invermere	11 U	568874	5597307	04-Feb-16
Invermere	11 U	568888	5597327	04-Feb-16
Invermere	11 U	569018	5596837	05-Feb-16
Invermere	11 U	569018	5596837	05-Feb-16
Invermere	11 U	569018	5596837	05-Feb-16
Invermere	11 U	569018	5596837	05-Feb-16
Invermere	11 U	569018	5596837	05-Feb-16
Invermere	11 U	569018	5596837	05-Feb-16
Invermere	11 U	569018	5596837	05-Feb-16
Lumberton	11 U	583094	5473876	27-Nov-14
Revelstoke	11 U	418753	5644080	18-Nov-14
Revelstoke	11 U	413591	5651109	02-Dec-15
Revelstoke	11 U	414603	5649523	02-Dec-15
Revelstoke	11 U	414430	5648994	02-Dec-15
Revelstoke	11 U	415369	5649930	02-Dec-15

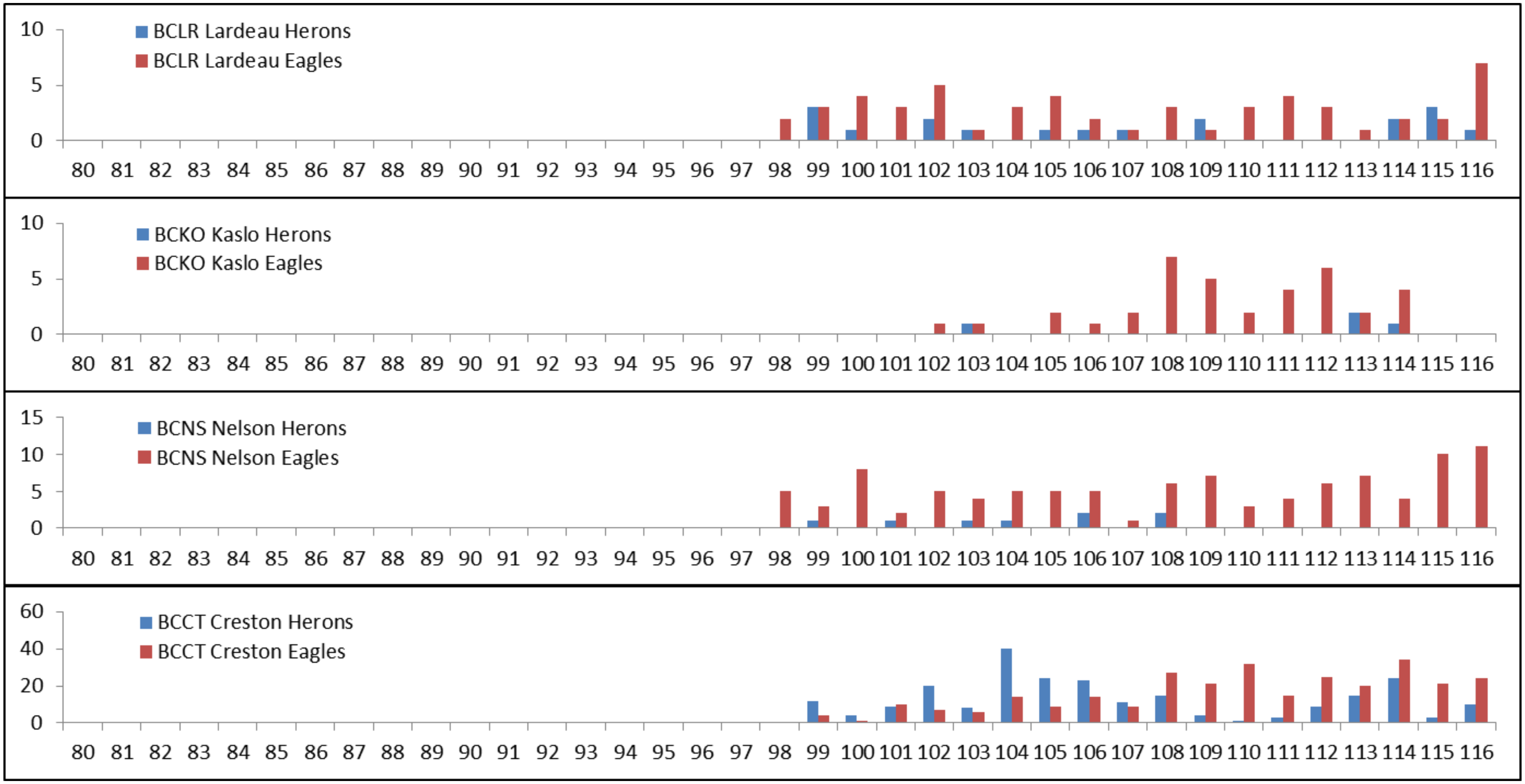
Appendix C: Christmas Bird Count results for counts along the Columbia River between Revelstoke and Trail. Note that the vertical axis values differ between graphs. The vertical axis refers to the number of herons (blue bars) and Bald Eagles (red bars). The horizontal axis gives the count year as indicated by the National Audubon Society. Count year "80" refers to the 1979-1980 count, while count year "116" refers to the 2015-2016 count



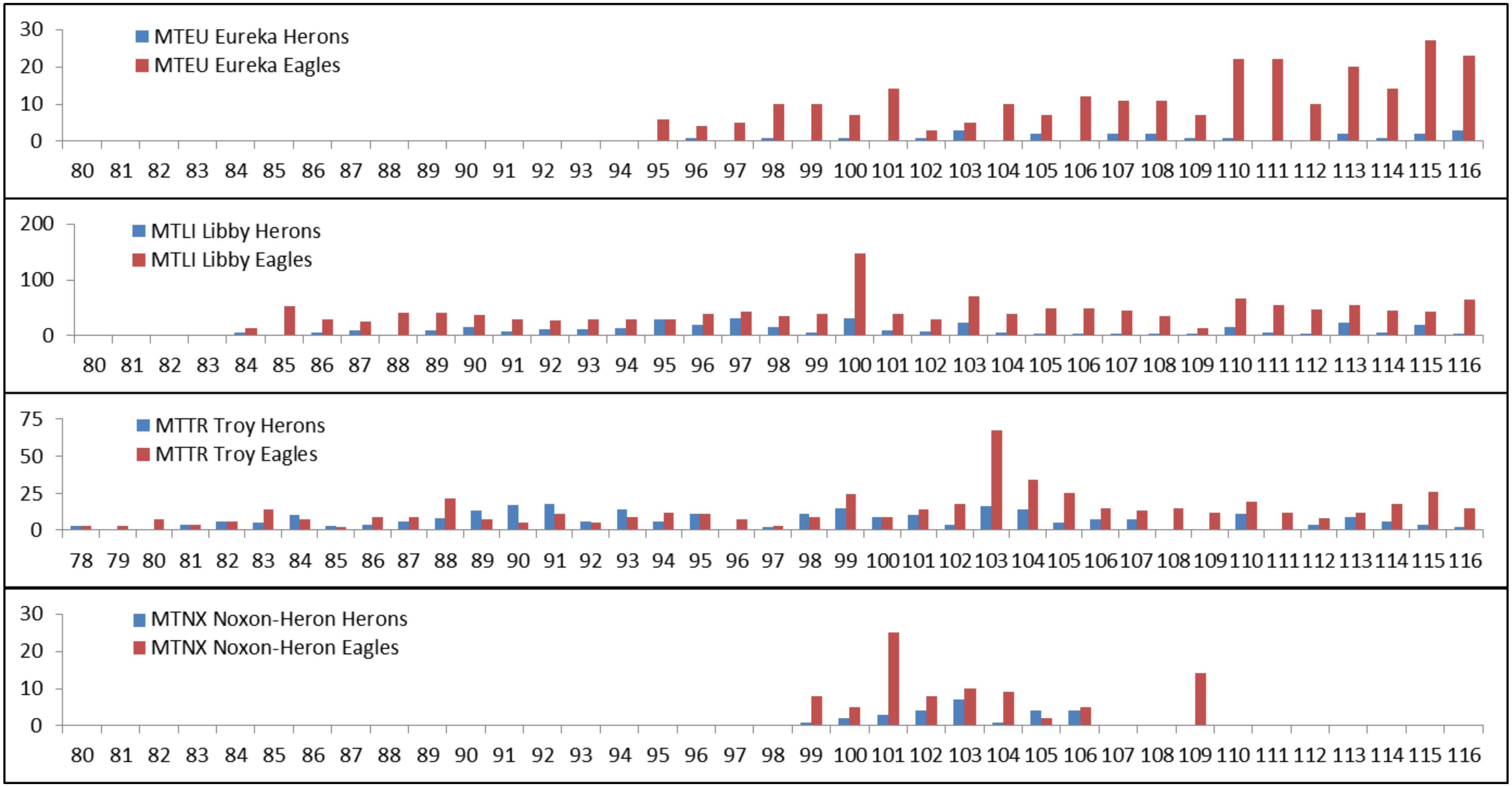
Appendix D: Christmas Bird Count results for counts along the Rocky Mountain Trench from Golden to Cranbrook. Note that the vertical axis values differ between graphs. The vertical axis refers to the number of herons (blue bars) and Bald Eagles (red bars). The horizontal axis gives the count year as indicated by the National Audubon Society. Count year "80" refers to the 1979-1980 count, while count year "116" refers to the 2015-2016 count



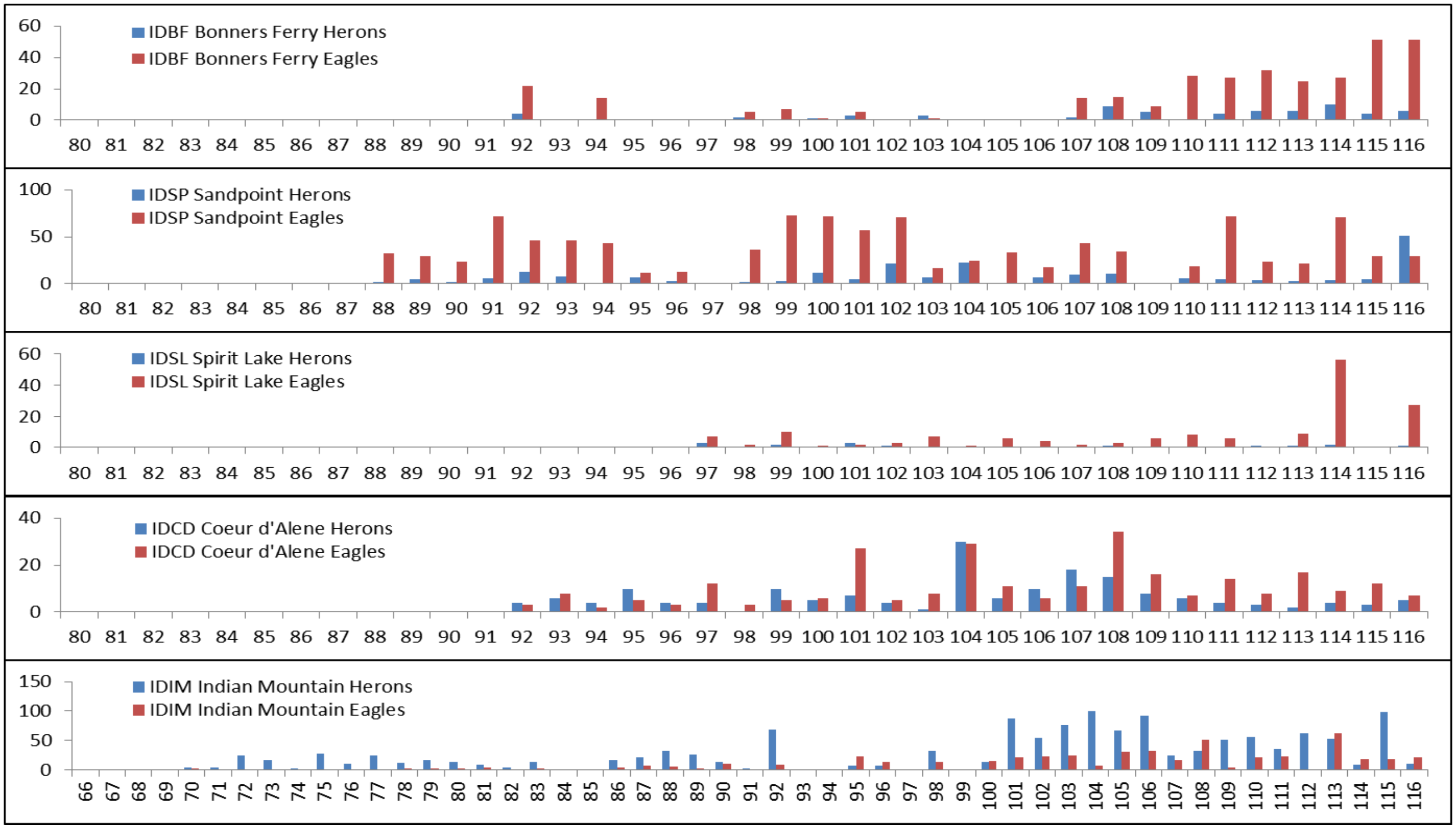
Appendix E: Christmas Bird Count results for the Kootenay Lake and Creston region. Note that the vertical axis values differ between graphs. The vertical axis refers to the number of herons (blue bars) and Bald Eagles (red bars). The horizontal axis gives the count year as indicated by the National Audubon Society. Count year "80" refers to the 1979-1980 count, while count year "116" refers to the 2015-2016 count



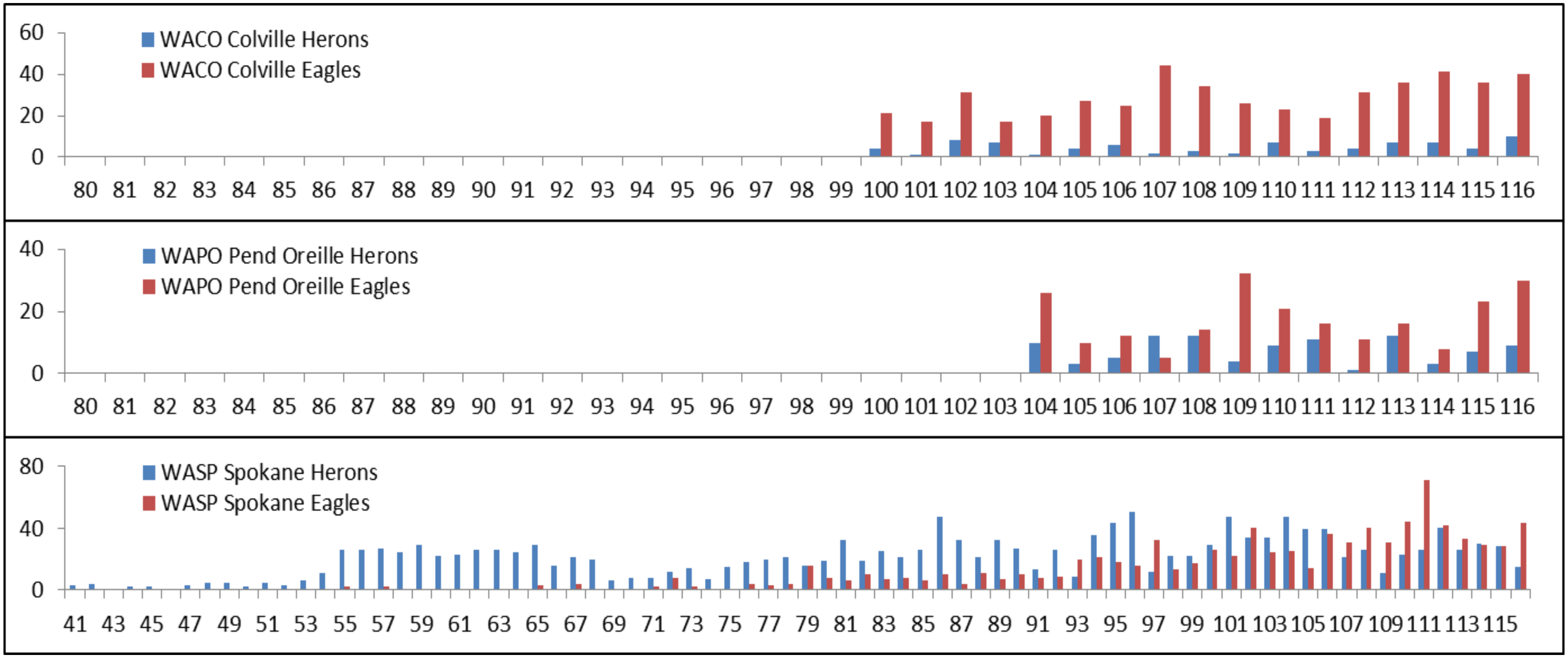
Appendix F: Christmas Bird Count results for northwest Montana. The Eureka, Libby, and Troy count circles all include portions of the Kootenay River. Note that the vertical axis values differ between graphs. The vertical axis refers to the number of herons (blue bars) and Bald Eagles (red bars). The horizontal axis gives the count year as indicated by the National Audubon Society. Count year "80" refers to the 1979-1980 count, while count year "116" refers to the 2015-2016 count



Appendix G: Christmas Bird Count results for northern Idaho. Most of these count circles are near large lakes. The Sandspit and Spirit Lake counts are near Lake Pend Oreille, and the Coeur d'Alene and Indian Mountain counts are near Lake Coeur d'Alene. Heron counts are higher at Indian Mountain than any other count circle considered, but have been especially high since approximately 2000 (count 101). Note that the vertical axis values differ between graphs. The vertical axis refers to the number of herons (blue bars) and Bald Eagles (red bars). The horizontal axis gives the count year as indicated by the National Audubon Society. Count year "80" refers to the 1979-1980 count, while count year "116" refers to the 2015-2016 count



Appendix H: Christmas Bird Count results for north-eastern Washington. The Spokane count has an extended dataset going back to 1940. Heron numbers are relatively high here, show interannual variation, but no overall population trend is obvious. Note that the vertical axis values differ between graphs. The vertical axis refers to the number of herons (blue bars) and Bald Eagles (red bars). The horizontal axis gives the count year as indicated by the National Audubon Society. Count year "80" refers to the 1979-1980 count, while count year "116" refers to the 2015-2016 count



Appendix I: Amount of available shoreline area for the Castlegar region in general, Breakwater Island, Waldie Island, and the grand total. Values are presented for the monthly minimum, maximum, and average water elevations for the November to February survey period for each of the three survye winters. Values underneath the month category indicate the water elevations that correspond to the resulting calculated areas

	Available Shoreline (m^2) (Nov 2013 - Feb 2014)												
SITE	TOTAL AREA	NOV AVG	NOV MAX	NOV MIN	DEC AVG	DEC MAX	DEC MIN	JAN AVG	JAN MAX	JAN MIN	FEB AVG	FEB MAX	FEB MIN
		420.58	421.52	420.18	421.73	422.14	421.21	420.32	421.67	419.81	419.00	419.55	418.42
Castlegar	2,266,967	329,171	274,616	368,919	265,429	253852	290,005	352,325	267,697	425,047	601,295	483,731	747,451
Breakwater Island	8,541	1,369	1	2,509	0	0	5	2,102	0	3,911	6,710	4,756	8,100
Waldie Island	59,472	14,851	9,311	17,322	8,726	8076	11,389	16,376	8,824	21,562	34,995	25,621	54,530
Total	2,334,980	345,390	283,928	388,750	274,155	261928	301,399	370,803	276,520	450,520	643,000	514,108	810,082

	Available Shoreline (m^2) (Nov 2014 - Feb 2015)												
SITE	TOTAL AREA	NOV AVG	NOV MAX	NOV MIN	DEC AVG	DEC MAX	DEC MIN	JAN AVG	JAN MAX	JAN MIN	FEB AVG	FEB MAX	FEB MIN
		419.56	420.51	418.12	420.06	421.08	419.17	420.57	420.74	419.92	419.53	420.21	419.14
Castlegar	2,266,967	481,129	334,284	840,930	384,390	296,554	563,144	329,502	317,221	405,977	487,171	365,153	569,601
Breakwater Island	8,541	4,720	1,593	8,343	3,015	10	6,035	1,393	773	3,593	4,803	2,418	6,156
Waldie Island	59,472	25,419	15,226	57,166	18,249	12,070	31,884	14,890	13,997	20,032	25,891	17,122	32,500
Total	2,334,980	511,268	351,102	906,439	405,655	308,634	601,063	345,785	331,990	429,601	517,865	384,693	608,257

	Available Shoreline (m^2) (Nov 2015 - Feb 2016)												
SITE	TOTAL AREA	NOV AVG	NOV MAX	NOV MIN	DEC AVG	DEC MAX	DEC MIN	JAN AVG	JAN MAX	JAN MIN	FEB AVG	FEB MAX	FEB MIN
		419.89	420.12	419.55	419.02	419.74	418.21	420.13	420.39	419.57	418.38	419.57	417.88
Castlegar	2,266,967	409,526	376,020	482,275	595,113	437330.5	801,234	374,474	344,395	478,506	754,817	477,231	920,753
Breakwater Island	8,541	3,673	2,742	4,745	6,628	4164.5	8,287	2,687	1,930	4,697	8,146	4,680	8,470
Waldie Island	59,472	20,378	17,759	25,573	34,595	22714	56,463	17,668	15,952	25,286	54,914	25,191	58,221
Total	2,334,980	433,577	396,521	512,593	636,336	464,209	865,984	394,829	362,277	508,489	817,876	507,101	987,443