Columbia River Project Water Use Plan

Lower Columbia River Fish Management Plan

Lower Columbia River Effects on Wintering Great Blue Heron

Implementation Year 1

Reference: CLBMON-49

Study Period: November, 2013 – February, 2014.

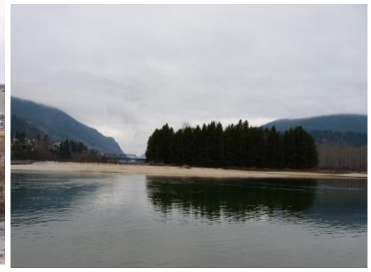
Okanagan Nation Alliance

April 8, 2015

ARROW LAKES RESERVOIR

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






CLBMON-49 Year 1 - 2013/2014

Analysis-Summary Report

FINAL

Prepared for

BC hydro

BC Hydro Generation
Water Licence Requirements
6911 Southpoint Drive
Burnaby, BC

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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 the first year (2013/14) of monitoring surveys for 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, approximately eight kilometers downstream of the Hugh Keenleyside Dam, which impounds the Columbia River to form Arrow Lakes Reservoir.

Though relatively common and widespread, Great Blue Heron are of special concern (blue-listed) in BC owing to human disturbance and habitat loss. During the Columbia River Water Use Planning process of the early 2000s, concern was expressed about the potential impact of winter river flow regulation by the Hugh Keenleyside Dam on herons using the Waldie Island area.

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. This study addresses the response of herons to river flow and elevation during winter and the potential impacts on heron foraging and winter habitat.

The general approach for this study is, by necessity, opportunistic. BC Hydro cannot alter flow rates and river elevations at specific times specifically to provide a controlled, experimental basis for this study. Rather, heron inventories, behavioural, and habitat surveys are completed prior to, during, and after flows related to management of Mountain Whitefish (generally November 1 to February 28), which encompasses varied water elevations and flow rates resulting from known dam operations.

For this first year of study, two main tests were conducted: the first to determine what flow regime and environmental variables, if any, influence the number of herons observed around Waldie Island. The second to determine which shoreline and physicochemical variables best predicted heron presence. The results so far are informative, but not conclusive.

This study was successful in re-evaluating the use of Waldie Island, adjacent areas, and the broader Castlegar region, by over-wintering Great Blue Herons. It shows where roosting herons were present, and provides an estimate of the relatively low number of herons present during the 2013/14 winter. Given that herons were believed to be in decline during the early 2000s, the even lower number of herons detected during this year of surveys highlights a need for continued monitoring.

There is little evidence so far that variation in heron numbers are related to discharge from the Hugh Keenleyside Dam and the resulting river elevations downstream. Considering only the period before and during whitefish flows when heron abundance was highest, there was a significant negative correlation between heron counts and water flow, and a non-significant negative correlation between heron counts and water elevation. Heron numbers appeared to be best predicted by air temperature but due to low sample sizes, the result may only indicate that air temperature was the best fit given the variables, not that it is a good predictor of heron numbers. When heron presence was tested using water physicochemical data, water velocity came out as the best predictive variable. It would appear that none of the measured variables were highly indicative of heron abundance during the winter of 2013/14. However, this result is tenuous because relatively few herons were detected (compared to earlier studies) and water elevations tended to be above average. Additional years of sampling are needed to clarify relationships, if any, between the tested variables and heron abundance.

Many factors likely influence the abundance and distribution of over-wintering herons in the Castlegar area. As no known 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 may certainly impact shoreline utilization or heron abundance, but additional data are required before any linkages can be made. Confounding our ability to detect such linkages are potential changes in breeding success and colony structure elsewhere, lack of ability to manipulate river flows experimentally, and other potential impacts such as eagle and human-caused disturbances. These other factors must be considered, and additional years of data collection are necessary, before any conclusions may be drawn. We propose a restructuring of management questions and an increase to the breadth of the study area to better address the study's objectives.

The status of CLBMON-49 after Year 1 (2013/14) with respect to the management questions is summarized below.

MQ	Able to Address MQ?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
1 – How does the flow regime in the lower Columbia River influence the number of wintering Great Blue Herons that roost on Waldie Island?	Not at this time	Suggestion of interaction between flow regime and roosting herons reported by Machmer (2003), in that heron numbers were highest prior to whitefish flows, and lowest post-whitefish flows.	• Delete management question; otherwise: • Revise question to extend area of interest beyond Waldie Island • Sample herons during more periods of low and high water levels/flows.	• Natural annual population variation • Low use of Waldie Island as a roosting site in 2013/14 • Lack of control sites • Lack of experimental manipulation ability • Variable flow regimes
2 – Are there operational changes that could improve Waldie Island as a roosting location for Great Blue Herons?	Not at this time	N/A	• Revise question by merging with MQ7 under a new MQ. • Revise question to include a broader area than just Waldie Island. • Access Waldie Island interior to search for signs of roosting herons that might otherwise be obscured	• Natural annual population variation • Variable reservoir operations • Lack of use of Waldie Island as a roosting location

MQ	Able to Address MQ?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
3 – Where are the shoreline areas that are used by Great Blue Herons?	Partially	Mapped heron locations showing all shoreline areas where herons detected. Occupied sites similar to those determined by Machmer (2003).	• Sample areas outside of Castlegar to determine where herons are overwintering in the region as a whole. • Continue sampling all areas around Castlegar as in Year 1.	• Natural annual population variation • Difficult to observe at night • Variable dam flows affecting shorelines throughout the day and the year • Human and other disturbances potentially limiting site utilization • Lack of experimentation to assess how varying the flows affects herons at different times through the winter period
4 – How does the flow regime affect the area, distribution, and attributes of shoreline areas?	Partially	Shoreline area for roosting and foraging increases with decreasing water elevation and vice versa. Response not equal among sites.	• Bathymetric data, digital elevation model, or aerial photos of the study area at different water elevations (if any of the above exist) should be assessed in a geographic information system to map the area and extent of shorelines at varying water levels.	• Variable reservoir operations • Uneven site response • Lack of knowledge about which areas are important for foraging
5 – How does the flow regime in the lower Columbia River influence the total number of Great Blue Herons that forage along the shorelines in the vicinity of Waldie Island?	Not at this time	N/A	• Delete management question; otherwise • Add night vision surveys to attempt to observe and document locations and foraging behaviours of nocturnally-foraging herons. • Revise question to include areas beyond Waldie Island, as it is not known where herons predominantly forage	• Natural annual population variation • Unknown foraging locations • Unknown target prey • Nocturnally-foraging herons difficult to observe • Variable dam operations
6 – How does the flow regime in the lower Columbia River influence the distance between Great Blue Herons that are foraging in shoreline areas (i.e., the number of herons foraging/site)?	Not at this time	N/A	• Delete this management question; otherwise • Add night vision surveys to observe and document locations and foraging behaviours of nocturnally-foraging herons.	• Natural annual population variation • Low numbers of herons in study area • Unknown foraging locations • Nocturnally-foraging herons difficult to observe • Variable dam operations

MQ	Able to Address MQ?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
7 – Are there operational changes that could improve the availability of suitable shoreline areas for the Great Blue Herons from Waldie Island?	Partially	Shoreline areas are impacted by changing water elevations. Winter water elevations have been relatively high since 2012.	• Merge this question with the very similar MQ2 under a new MQ • Bathymetric data, digital elevation model, or aerial photos of the study area at different water elevations (if any of the above exist) should be assessed in a geographic information system to map the area and extent of shorelines at varying water levels. • Surveys should aim to capture the periods of highest and lowest water elevations	• Variable dam operations • Uneven site response • Lack of knowledge about which areas are important for foraging
8 – Are there physical works that could improve the availability of shoreline areas for the Great Blue Herons from Waldie Island?	Not at this time	N/A	• Expand MQ to focus on the general area, not just Waldie Island • Surveys should aim to capture the periods of highest and lowest water elevations	• Variable dam operations • Natural annual population variation • Lack of physical works to benefit herons already undertaken from which to inform recommendations

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

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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 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 wintering 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. 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 should provide the necessary information to address management questions relating the response of herons to flow and stage regime from the Hugh Keenleyside Dam during the winter period (November 1 to February 28) 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 report summarizes the findings of Year 1 (2013/14) monitoring surveys for BC Hydro's Monitoring Program CLBMON-49: *Lower Columbia River Effects on Wintering Great Blue Herons.* This project is being delivered collaboratively between the Okanagan Nation Alliance (ONA) and LGL Limited environmental research associates.

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. Results of this monitoring program will help clarify the importance of Waldie Island and surrounding shorelines 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 will 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 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*."

MQ1: How does the flow regime in the lower Columbia River influence the number of wintering Great Blue Herons that roost on Waldie Island?

MQ2: Are there operational changes that could improve Waldie Island as a roosting location for Great Blue Herons?

MQ3: Where are the shoreline areas that are used by Great Blue Herons?

MQ4: How does the flow regime affect the area, distribution, and attributes of shorelines areas?

MQ5: How does the flow regime in the lower Columbia River influence the total number of Great Blue Herons that forage along the shoreline in the vicinity of Waldie Island?

MQ6: How does the flow regime in the lower Columbia River influence the distance between Great Blue Herons that are foraging in shoreline areas (i.e., the number of herons foraging/site)?

MQ7: Are there operational changes that could improve the availability of suitable shoreline areas for the Great Blue Herons from Waldie Island?

MQ8: Are there physical works that could improve the availability of shoreline areas for the Great Blue Herons from Waldie Island

2.1 Management Hypotheses

Answering the management questions (above) requires the testing of specific hypotheses related to the relationships between the variation in the number of Great Blue Herons and water elevations, as outlined in the Terms of Reference (2012). These relationships can be tested (for some management questions) via simple regression and the relationship between the variation in the numbers of Great Blue Herons roosting on Waldie Island, the number of foraging herons, and the variation in the distance between herons foraging along a shoreline will be assessed relative to water elevation (as measured at the Norns Creek gauge). Given the potential importance of factors other than flow regime, we assess the impact of water flows while considering environmental and other variables (see Section 4.7). The hypotheses as outlined in the Terms of Reference (2012) were written as follows:

H_1: More than 60% of the variation in the number of Great Blue Herons that roost on Waldie Island between November 15 and March 1 can be explained by the water elevation measured at the Norns Creek Gauge on the lower Columbia River (*i.e.*, the co-efficient of determination, $r^2 > 0.60$).

H_2: More than 60% of the variation in the number of Great Blue Herons foraging along the shoreline in the vicinity of Waldie Island between November 15 and March 1 can be explained by the water elevation measured at the Norns Creek Gauge on the lower Columbia River (*i.e.*, the co-efficient of determination, $r^2 > 0.60$).

H_3: More than 60% of the variation in the distance between Great Blue Herons that are foraging in a shoreline area (i.e., the number of herons foraging/site) in the vicinity of Waldie Island between November 15 and March 1 can be explained by the water elevation measured at the Norns Creek Gauge on the lower Columbia River (*i.e.*, the co-efficient of determination, $r^2 > 0.60$).

The justification for the use of $r^2 > 60\%$ as a cutoff is unclear. This suggests that "most of the time" the variation in the dependent variables can be explained by water levels. Alternatively, 40% of the time, there is another explanation for the observed effect. If $r^2 > 0.60$, then the variation being tested will be assumed to be associated with water levels. This approach appears to align more with equivalence testing, where in contrast to the traditional casting of the null hypothesis, the null hypothesis becomes that a treatment has a large effect; the alternative is one of practical equivalence (Hoenig and Heisey 2001).

To avoid any confusion regarding the need to test for a specific co-efficient of determination, we have re-written the hypotheses as follows, and in consistence with our proposal:

H_1: The variation in the number of Great Blue Herons that roost on Waldie Island between November 15 and March 1 can be explained by the water elevation measured at the Norns Creek gauge on the lower Columbia River.

H_2: The variation in the number of Great Blue Herons foraging along the shoreline in the vicinity of Waldie Island between November 15 and March 1 can be explained by the water elevation measured at the Norns Creek gauge on the lower Columbia River.

H_3: The variation in the distance between Great Blue Herons that are foraging in a shoreline area (i.e., the number of herons foraging/site) in the vicinity of Waldie Island between November 15 and March 1 can be explained by the water elevation measured at the Norns Creek gauge on the lower Columbia River.

This approach provides the opportunity to report on the co-efficient of determination associated with the data along with an interpretation of those results and whether they are biologically relevant.

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 Columbia Basin is characterized by steep valley side slopes and short tributary streams that flow into Columbia River from all directions. The Columbia River valley floor elevation falls from approximately 800m near Columbia Lake to 420m near Castlegar. 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, and about 10 per cent of the Columbia River drainage area above Mica Dam exceeds this 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 (Figure 3-1). 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) (Figure 3-1). 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.

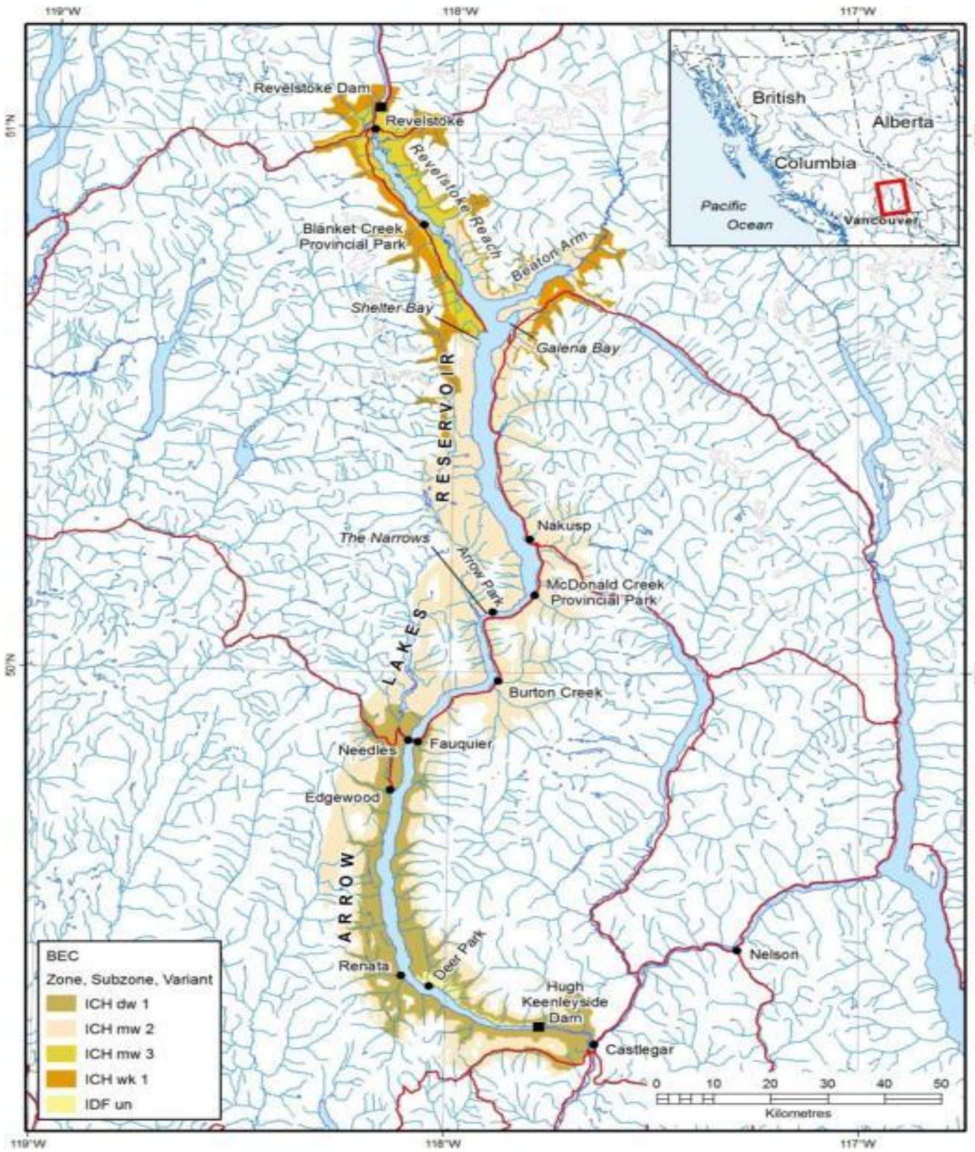

Figure 3-1: Location of Hugh Keenleyside Dam and its relation to Castlegar and the Arrow Lakes Reservoir in British Columbia

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 (BC Hydro 2007). The normal operating range of the reservoir is between El. 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 3-2).

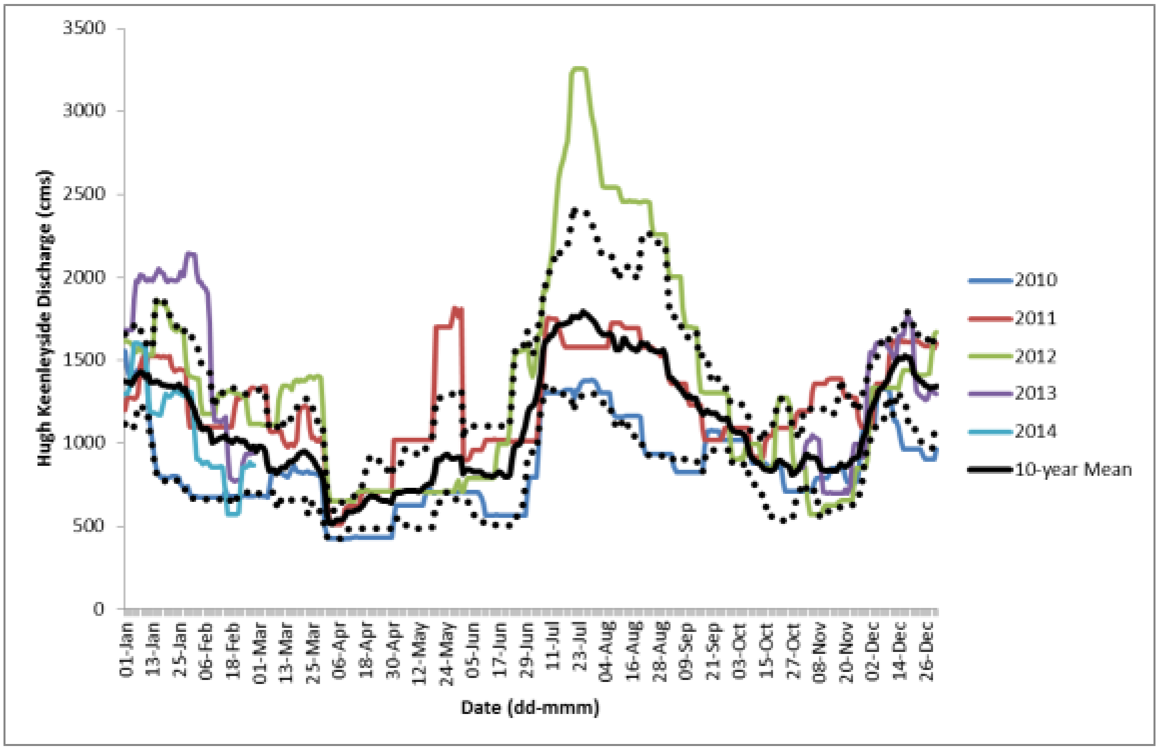

Figure 3-2: Hugh Keenleyside Discharge rates (cubic metres per second) from 2010 to 2014. Dotted lines represent the 10th and 90th percentiles. The 10 year mean is provided to indicate the general timing of high and low flow rates

3.3 Study Location

For CLBMON-49, the area of interest is 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 follows the Columbia and Kootenay Rivers between these locations (Figure 3-3). Within this study area, the focus is on Waldie Island and immediately adjacent locations (e.g., Breakwater Island) (Figure 3-4).

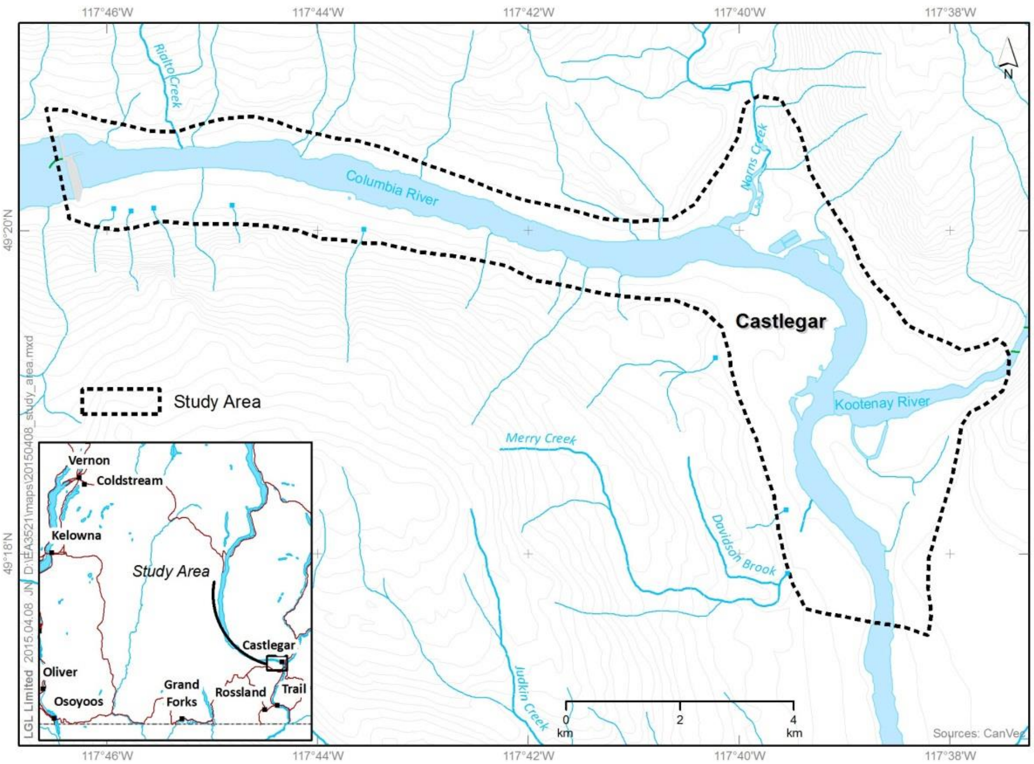

Figure 3-3: The CLBMON-49 study area is bounded by the Hugh Keenleyside Dam in the west, the Brilliant Dam in the east, and the Kinnaird Bridge to the south, and includes all shoreline locations within that area

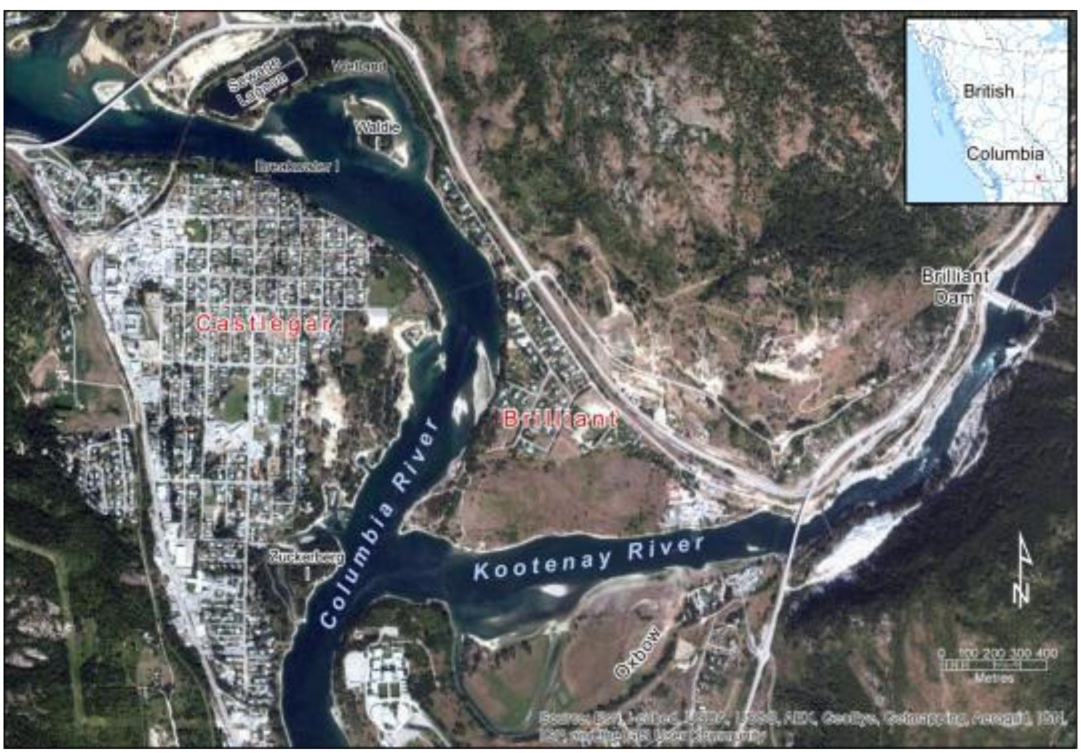

Figure 3-4: Satellite view of area of interest for CLBMON-49. Locations within the main area of interest (Waldie Island, Breakwater Island, etc.) are labelled

Water and shoreline sampling was conducted at 17 locations spanning the study area (Table 3-1). Focal surveys for herons were completed wherever herons were observed. However, several key sites were accessed regularly to scan for herons including Nimby Point (north end of 2nd Ave.), 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. Most other viewing locations were at or near the shoreline sampling locations.

Table 3-1: Sampling locations for shoreline surveys and heron vantage points. Coordinates are shown in UTM coordinates

Area	Name used in Report	Easting	Northing
Shoreline Sampling Location			
Hugh Keenleyside Dam	HLK	444354	5465744
Mill Site (N. Bank)	Mill Site	446540	5465589
Midway	Midway	448868	5464998
Pass Creek	Pass Creek	451556	5464888
Breakwater Island North	Breakwater Island	452043	5464402
Waldie Island West	Waldie West	452285	5464542
Waldie Island North	Waldie North	452535	5464597
Waldie Island East	Waldie East	452736	5464284
4th Ave Lookout	4th Ave	452334	5464093
Pipeline crossing at Twin Rivers Park	Pipeline X	452756	5463803
Twin Rivers Park	Twin Rivers Park	452664	5463453
Zuckerberg Island North	Zuckerberg North	452358	5462913
Zuckerberg Island Centre	Zuckerberg Central	452365	5462703
Brilliant	Bridgeview	452806	5463089
Brilliant	Kootenay Pt	452902	5462783
Confluence Delta	Grassland	453224	5462555
Confluence Delta	Oxbow	452854	5462395
Heron Vantage Points (the above locations plus)			
Nimby Pt	Nimby	452508	5463997
Sewage Lagoons	Sewage Lagoons	451942	5464454
Log Ramp	Log Ramp	450868	5464641

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 cannot 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 inventories, behavioural, and habitat surveys were completed throughout the period of interest (November 1 to February 28), encompassing varying water elevations and flow rates through predictable operationally-mediated changes. Survey sessions could not be scheduled for a specific flow rate or water elevation, given the variability around those measures, but were planned to span the period prior to, during, and after flows related to management of Mountain Whitefish. Water flow/elevation data was then compiled based on data provided by BC Hydro following the sampling period.

4.3 Field Schedule

Field sampling 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). A bi-weekly sampling schedule was implemented to allow for even coverage of the over-wintering period. In 2013/2014 sampling occurred from November 25 to 29, December 10 to 13 and 27 to 30, January 14 to 17, February 3 to 6, and February 24 to 27.

Each survey period was four days in duration; except the November session, which was five days to allow a preliminary reconnaissance of the study area. With six sessions completed, the total number of survey days was 24, as proposed. This is equal to the sampling effort of Machmer (2003), despite a switch from weekly (Machmer) to bi-weekly sampling (this study).

4.4 General Data Collection

The focus of this study is on the herons of Waldie Island and immediate surroundings. As such, this area was inventoried for heron abundance on each field day. However, herons are capable of dispersing throughout the entire study area (and beyond). For a better regional estimate of heron numbers to be obtained, the complete study area was surveyed at least once per field session (i.e., on one or more days per four day sampling period) with no other field tasks being performed until the whole inventory was complete to reduce the potential for birds to move among sites and be double-counted or missed.

In addition to counting herons, behavioural observations and shoreline sampling were conducted. Behavioural observations were done opportunistically wherever herons were encountered to determine the daily activity budgets of herons. Shoreline sampling was done at discrete locations throughout the study area. As it is not possible to perform all survey protocols at all sites on any given day, shoreline sampling was conducted throughout each session until all accessible sites had been surveyed once.

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) could prevent surveys from being completed, these conditions were virtually absent during the sampling sessions.

4.5 Heron Surveys

4.5.1 Abundance, Density and Distribution

Upon arriving at a site, all visible shoreline and surrounding trees were surveyed for heron presence and abundance (RISC 1998a). 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).

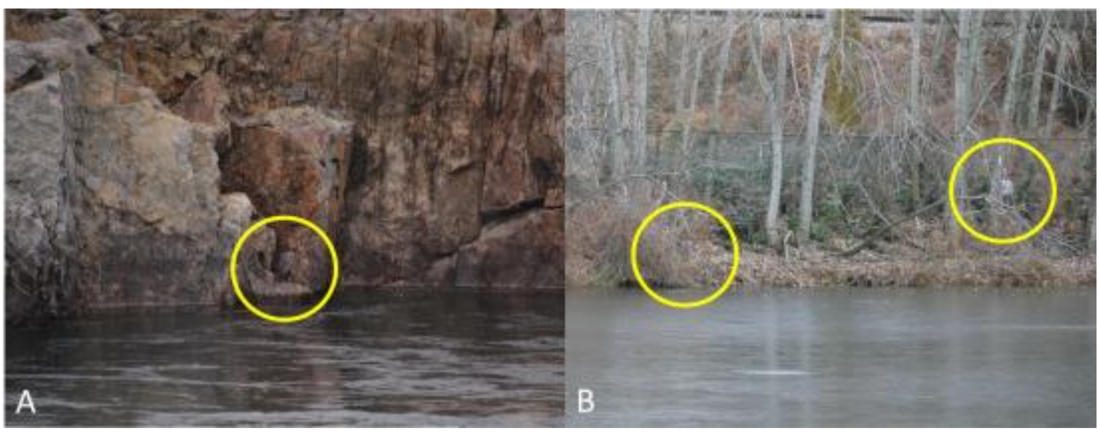

Figure 4-1: Herons are large, conspicuous birds when perched in the open, but can be considerably harder to detect against rocky (A: HLK Dam) or vegetated (B: Sewage Lagoon) backgrounds

For this reason, a more detailed scan using a 20-60x spotting scope was also conducted (RISC 1998a). 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 outerbranch 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.

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.

4.5.2 Focal and Scan Sampling

Abundance, density and distribution data collected with the methods above are supplemented with behavioural observations to help answer the management questions. To determine whether herons are roosting or foraging, and to calculate their daily time activity budgets, focal samples and scan samples were completed on all herons daily.

Focal sampling consists of watching an individual for a fixed period of time and recording its behaviours (Sutherland et al. 2004). We conducted 10 minute focal samples of all Great Blue Herons. The recorder cued the observer to begin the sample and recorded the time in hours, minutes and seconds (hh:mm:ss) format. The observer then dictated all changes in behavior. The scan ended after 10 minutes was up, or the bird was no longer visible. With any and each behavioural change, the recorder noted the time. 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).
- Lost – observer temporarily or permanently loses sight of a heron either because it has become obscured (e.g., due to fog or moving around a corner) or because it has departed the area.
- Other – observer defined category for any behaviours not easily classifiable into one of the above (e.g., stretching [without preening], defecating).

If multiple birds (>3) are present and visible at the same time, a scan sample will be used. A scan sample involves systematically scanning each individual in turn and categorizing its behaviour when first observed (Sutherland et al. 2004). In this case, every individual is scanned in succession, followed by a 15 second pause. This is continued until there are 20 observations per bird. Scan sampling will be a particularly useful method if larger aggregations of birds are present at any one site. In general, at sites where scan sampling is invoked, three individuals will also be selected for focal sampling. This ensures that data can be compared among sites and also allows for a direct comparison of sampling methods. Each individual scanned by either method is also assigned to an age class to help determine if there are any differences in daily activity budgets between adults and immatures. During 2013/14 scan sampling was only conducted on one occasion, when three birds were present, to allow comparison of the methods.

4.6 Shoreline Surveys

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 (Table 3-1, Figure 4-2). 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). These characteristics can characterize benthic macroinvertebrate microhabitat.

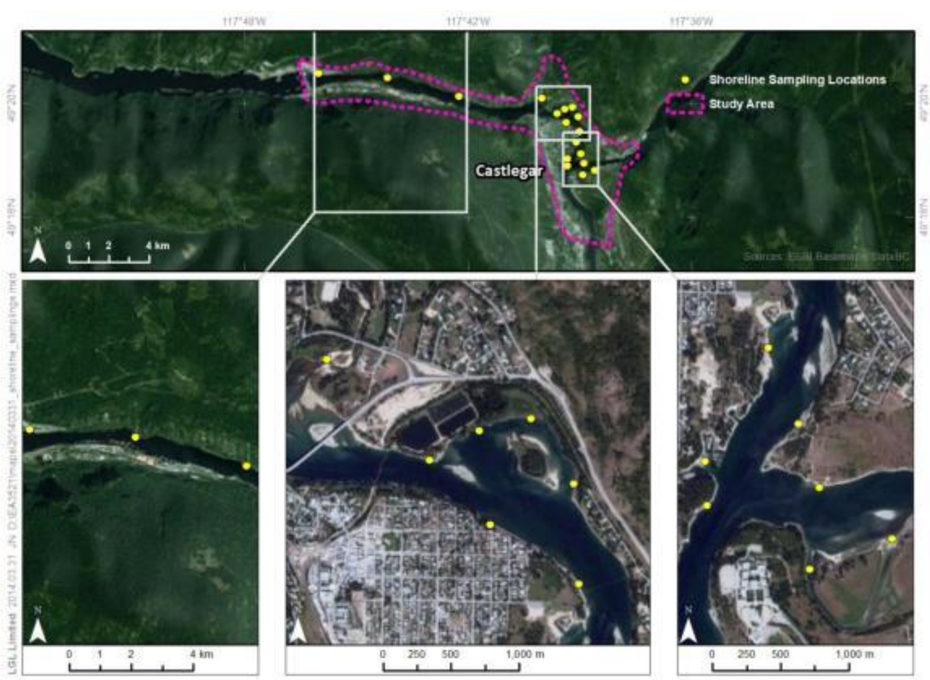

Figure 4-2: Shoreline sampling locations were scattered throughout the study region to capture representative sites both with and without heron activity

Water chemistry data are 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. <http://www.eutechinst.com/>), and a Triton Turbidity Wedge (Triton Environmental Consultants Ltd, Richmond, BC) . The recorded water chemistry variables and their definitions (based on RISC 1998b) included:

- Dissolved Oxygen (mg/L) – the amount of oxygen dissolved in water. The concentration of dissolved oxygen is a function of daily and seasonal factors such as temperature, photosynthetic activity and river discharge. Waterfalls, rapids, and photosynthetic production by aquatic plants are all sources of dissolved oxygen.
- Specific Conductance (µS/cm) – a measurement of the ability of water to conduct an electric current. This value increases with greater ion concentration in the water. Specific conductance is temperature corrected conductivity, and thus allows for direct comparisons among samples where water temperature varies.
- pH – unit-less measurement of hydrogen-ion concentration in the water ranging from acidic to basic.
- Water Temperature (˚C) – the intensity of heat stored in a volume of water.
- Turbidity (NTU) – measurement of suspended particulate matter in a water body which interferes with the passage of a beam of light through the water.

Finally, the dominant substrate class (Table 4-1) and local water velocity (m/s) were measured. Water velocity was measured using a head rod measurement technique (CABIN 2012). This 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 4-1: 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 Data Analysis

As outlined in the Terms of Reference, three management hypotheses have been presented to statistically test the relationship between flow rates and overwintering herons. However, 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. In the case of this study, the inability to alter flow rates experimentally makes it challenging to directly link flow rates to herons, given the influence of potentially confounding factors, such as time or environmental conditions. Due to low sample sizes and the lack of witnessed foraging, alternative analyses have been conducted for the first year of study. Two main tests were conducted: the first to determine what flow regime and environmental variables, if any, influence the number of herons observed around Waldie Island. The second to determine which shoreline and physicochemical variables best predicted heron presence. It is important to note that results from these tests are informative, but not conclusive. Results of all statistical tests were considered significant at $\alpha = 0.10$.

4.7.1 Heron Counts

To compare heron counts prior to, during, and after peak flows for mountain whitefish management, boxplot graphs were used. In boxplot graphs, the boxes represent between 25 per cent and 75 per cent of the ranked data. The horizontal line inside the box is the median. The length of the boxes is their interquartile range (Sokal and Rohlf 1995). A small box indicates that most data are found around the median (small dispersion of the data). The opposite is true for a long box: the data are dispersed and not concentrated around the median. Whiskers are drawn from the top of the box to the largest observation within 1.5 interquartile range of the top, and from the bottom of the box to the smallest observation within 1.5 interquartile range of the bottom of the box.

One goal of the study was to determine whether the variation in the number of roosting herons on Waldie Island could be explained by the water elevation measured at the Norns Creek Gauge on the lower Columbia River. As there were not enough data to investigate that specifically, we instead built a general linearized model (GLM) to assess which selected factors, if any, could predict heron abundance. In addition to water flow and water elevation, additional factors were measured for potential inclusion in the predictive GLM model, including water temperature, air temperature, precipitation, snow height and eagle counts. Because the heron abundances were measured as counts, a Poisson error structure was assumed (Crawley 2007) for the general linearized model (GLM). Before running the regression, variables were tested for collinearity using Pearson's correlations (r) and variance inflation factors (VIF). Variables were considered as not collinear when Pearson's r was below 0.6, VIF values were below 10, and mean VIF scores were not considerably greater than 1 (Chatterjee et al. 2000).. Stepwise techniques were used to remove the remaining variables one at a time. Each time, the Akaike Information Criterion (AIC) of the reduced model was compared to that of the fuller version, until any further removals produced a model with significantly poorer fit than the previous. R^2 approximations were calculated for GLMs as the squared correlation between the predicted and observed values.

4.7.2 Heron Presence

A multiple logistic regression analysis was used to determine if a suite of water physicochemical variables could predict the probability of heron presence. A logistic regression was selected for this test as heron presence has only two levels (present or absent). The regression was initially run with a binomial error structure. However, the residual deviances were large relative to the degrees of freedom (suggesting overdispersion). To estimate an overdispersion parameter, the model was re-run, this time using the 'quasibinomial' error structure (Crawley 2007). On each sampling occasion at each site, water elevation, shoreline area, water temperature, dissolved oxygen, specific conductivity, pH and water velocity were measured, and the presence/absence of herons was recorded. Herons were considered to be present at a site, if individuals or tracks were found within 250 m of the site. Before running the regression, variables were tested for collinearity using Pearson's correlations (r) and variance inflation factors (VIF). Variables were considered as not collinear when Pearson's r was below 0.6, VIF values were below 10, and mean VIF scores were not considerably greater than 1 (Chatterjee et al. 2000). One of each pair of significantly correlated variables was removed from the input. Stepwise techniques were used to remove remaining variables from the model, one variable at a time. Each time, ANOVA was 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.

The probability estimates from the final model were transformed into 'presence predicted' (probability ≥ 0.50) or 'absence predicted' (probability < 0.50) categories. 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.

4.7.3 Other Analyses

Other than the modelling described above, we also performed various regressions, correlations and analyses of variance. Standard statistical techniques (Crawley 2007) were used throughout. All statistical analyses were carried out using R (R Core Team 2013) with plots generated using the 'ggplot2' package (Wickham 2009), and VIFs calculated using the 'car' package (Fox and Weisberg 2011).

5.0 RESULTS

5.1 Heron Abundance, Density and Distribution

During the 2013/14 field season herons were detected on 21 of 24 survey dates. Heron numbers ranged from 0 to 7 individuals (0 to 2 adults and 0 to 5 immatures) on any given day. In general, heron counts were highest in the late December and January sessions, corresponding to the period of peak flow rates (Figure 5-1). Numbers were lowest post-whitefish flows, during the February sampling dates, including the only days when no herons were observed. The majority of heron detections were from the Waldie Island area, including Waldie Island, Breakwater Island, the sewage lagoons, Pass Creek and surrounding foreshore areas, and this was the only area where multiple herons were often sighted. The Waldie Island area was surveyed daily; however, even on days when the entire study area was surveyed, heron numbers were highest around Waldie. Thus, the greater number of herons near Waldie Island is not likely due to the greater survey effort there. When we look at just the Waldie Island area, the suggestion of highest heron numbers during peak flows and lowest post-whitefish flows remains (Figure 5-1). The variation in heron counts among time periods, however, makes it difficult to draw conclusions, and more sampling is required.

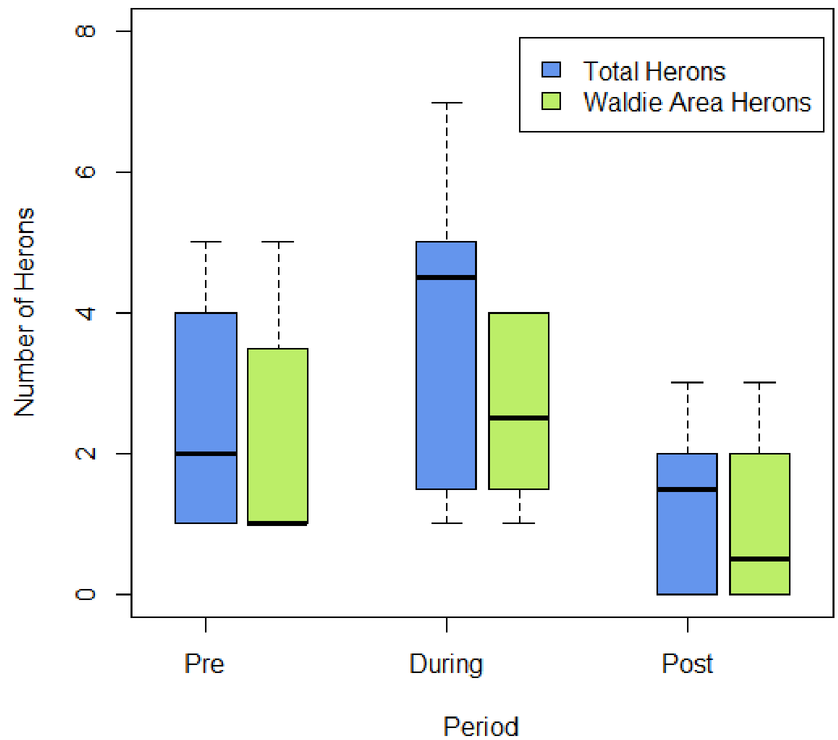

Figure 5-1: Number of herons before, during, and after flows related to the management of mountain whitefish in the study area as a whole (blue boxes), and for the Waldie Island area in particular (green boxes)

Herons were distributed patchily from the Hugh Keenleyside Dam in the west to the Brilliant Dam/Kootenay River area in the east, and south as far as Zuckerberg Island and the Kootenay Oxbow (near the Columbia and Kootenay rivers confluence). Despite the extent of shoreline, herons were only found from about seven general locations (Figure 5-2). The sewage lagoons and Breakwater Island proved to be the most consistent location for herons, though a single bird was often seen at both HLK dam and the Kootenay River near the Brilliant Bridge.

Figure 5-2: Locations where herons were observed on all survey days combined. Dots represent each location where a heron was seen, but do not refer to unique individuals

Typically herons were seen roosting on foreshore areas (especially on Breakwater Island) or the sewage lagoons, though individuals were found roosting in trees at Waldie Island, on the south side of the Columbia River opposite the Sewage Lagoons, and on Zuckerberg Island. Tracks were noted in the soft sediments in the backchannel between Waldie Island and the mainland, on the westside of the large oxbow below Selkirk College, and in the channels on the north side of Zuckerberg Island (Figure 5-3). As most shoreline areas are rocky, it is possible that the distribution of nocturnally-foraging herons is greater than these results suggest.

Figure 5-3: Heron tracks in the soft sediment of back-channels were the only evidence of site use at several locations

5.1.1 Historical Results and Other Data Sources

Previous surveys indicate a variable overwintering heron population, albeit one that appears to have declined. 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, residents of Castlegar provided data on heron numbers from Waldie Island, Breakwater Island, and mainland foreshores from 1995/96, another (unspecified) year during the late 1990s, and January 2013 through to the end of February 2014 (Walter Volovsek and Caroline Halligan pers. comm.). Mr. Volovsek's data show maximum December/January counts of 17 birds in 1995/96, with an average of 12 birds being detected. During December/January counts in an unspecified year sometime in the late 1990s, counts reached up to 26 birds with an average of 15. Notable in these data are the apparent lack of survey declines in numbers as the observation period progresses through January (Figure 5-4).

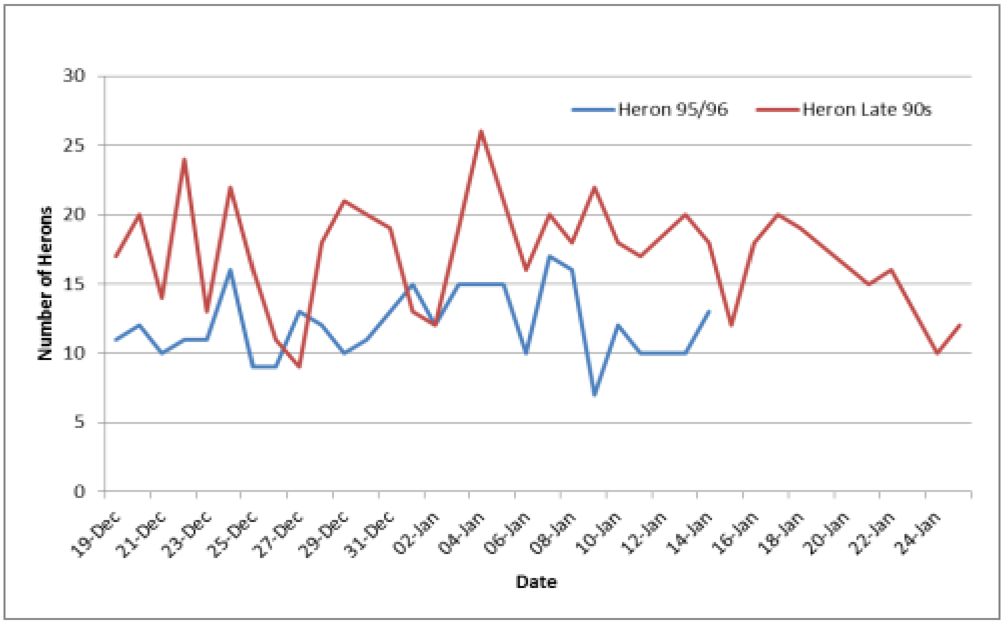

Figure 5-4: Counts of herons from the Waldie Island area during the winter of 1995/96 and another year in the late 1990s. Heron numbers are variable but relatively even throughout the period, in contrast to current results. Data provided by Walter Volovsek

This same observer reported a maximum of only 8 herons during the winter of 2004/05, consistent with a declining trend. However, contrary to that apparent decline he noted a maximum of 35 on Breakwater Island during the winter of 2006/07 (W. Volovsek pers. comm.). Breakwater Island, rather than Waldie Island, appears to be the main roosting location even in years when many herons are present (W. Volovsek pers. comm., Figure 5-5)

Figure 5-5: In years of high heron abundance, individuals (yellow circles) congregate at Breakwater Island to roost during the day. Photo © Walter Volovsek

Near daily counts of herons during 2013 and early 2014 from a house overlooking Waldie Island, Breakwater Island and surrounding shorelines show an annual cycle of heron numbers remaining low through the winter and spring then rising during the late summer and autumn (data courtesy of Caroline and Ian Halligan). Heron numbers peaked in late September, likely corresponding to dispersal of adults and juvenile herons away from breeding colonies (Figure 5-6). Heron numbers then declined to low levels through the period of interest for this current study, matching our survey results.

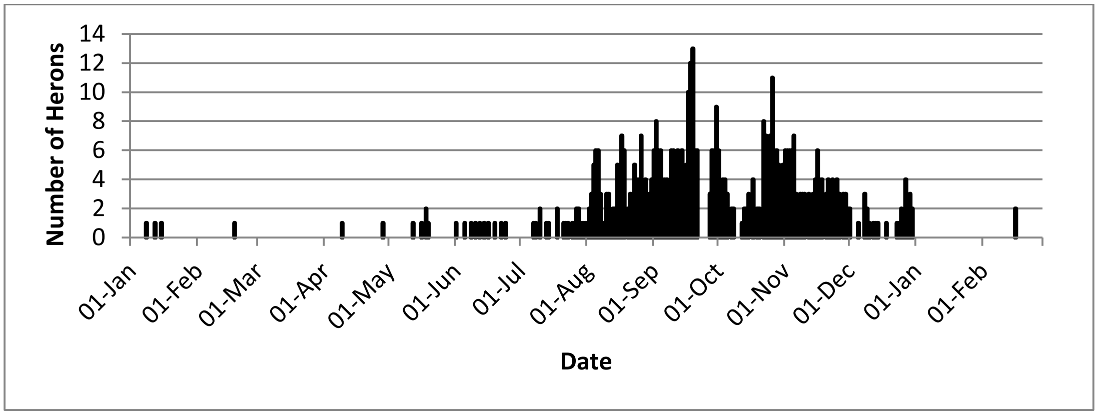

Figure 5-6: Daily maximum heron counts in the Waldie Island area during 2013 and early 2014 from a property overlooking the area. Seasonal fluctuations in numbers correspond to distinct periods of the annual cycle (e.g., breeding, dispersal). Data courtesy of Caroline and Ian Halligan

Several citizen science initiatives have also been undertaken which provide some level of information relative to both the general Castlegar area and to Waldie Island in specific. Two such sources of information are the Christmas Bird Count, administered in Canada through Bird Studies Canada with data housed by the National Audubon Society, and eBird, launched by the Cornell Lab of Ornithology. These citizen science initiatives are carried out 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.

Christmas Bird Count data were accessed for the Castlegar count and are shown in Table 5-1 (http://birds.audubon.org/data-research). Bald Eagles are a known predator of Great Blue Herons, and while eagle impacts on wintering herons is not well documented, their count totals are also included here. The four herons counted on the 2013 Christmas Bird Count, held on January 4, 2014, are consistent with our total of five individuals detected on December 30, 2013. These Christmas Bird Count data provide an indication of how variable heron counts are among years.

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

Count Date	Year	Heron Count	Eagle Count
18-Dec-2005	2005	2	4
23-Dec-2006	2006	16	10
22 Dec 2007	2007	4	10
20-Dec-2008	2008	19	11

Count Date	Year	Heron Count	Eagle Count
3-Jan-2010	2009	7	15
19-Dec-2010	2010	17	14
17-Dec-2011	2011	18	12
15-Dec-2012	2012	10	12
4-Jan-2014	*2013*	*4*	*13*
Median Count		**10**	**12**

While millions of records are accessible through eBird, there are considerably fewer points for any given locality. A query of Great Blue Heron counts between November 1st and March 1st in all years returned 34 records for Waldie Island (www.ebird.ca; accessed March 28, 2014. Almost all of these records (n=25) were submitted by one individual observer from 2010 to present, with the remaining submissions pertaining to records from 1999 to present. While sample sizes are limited, based on these data there is a potential decreasing trend in heron numbers occurring rapidly after the beginning of December (Figure 5-7). The apparent increase in numbers in mid-January is due to a single record of 14 individuals in 1999. While direct comparisons cannot be made, the greater number of herons being reported during the first half of the time period relative to the latter half appears consistent with the observations of this study and others.

All available information, from this study, local citizens, and citizen science data indicate that wintering heron numbers in the Castlegar area are variable. Potentially obscured by this variability is the suggestion of a decline in the number of wintering herons beginning sometime in the early 2000s. It is clear that few herons were detected during the winter of 2013/14. Less clear is how heron numbers varied with respect to water flow; but there is the suggestion of a trend of higher numbers prior to and during whitefish flows relative to post-whitefish flows, consistent with the previous findings by Machmer (2003).

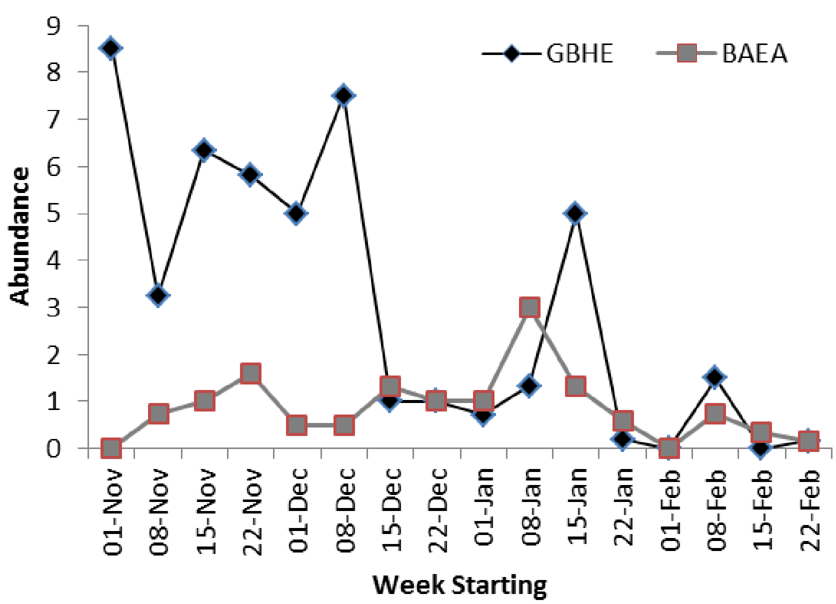

Figure 5-7: Abundance (average number of individuals reported for all submissions) for all eBird submissions from Waldie Island between November 1st and March 1st. Black triangles are data for Great Blue Herons (GBHE) with records

from 1999 to 2014, grey squares are for Bald Eagles (BAEA) with records from 2003 to 2014

5.2 Heron Behaviour

In total, heron focal scans were completed on 60 occasions. However, as the daily heron count was in the single-digits this means that multiple behavioural observations were completed on the same individuals over multiple days, and occasionally on the same day. Representative of the greater number of immature herons, a total of 36 observations were done on immature birds, while 14 were on adults, a further ten were on herons of unknown age. The vast majority of time herons were observed resting (Table 5-2). A total of 59 observations included at least some resting, with 80 percent of birds spending three-quarters or more of their time resting. Herons, when not resting, exhibited a variety of behaviours, though individual herons sometimes spent a large proportion of one scan in some other behaviour. Some individuals spent larger amounts of time preening, being alert, and walking (Table 5-2). Foraging typically ranked lowest or near to lowest on a heron's daily activity budget, with very few foraging behaviours being noted, none of which involved prey capture.

Related to foraging, it was clear that herons remained largely inactive during daylight hours. Observations targeting the dawn and dusk periods (typically just as it was light enough to detect movements) indicated that heron movements were more prevalent during this time period, and birds were occasionally seen entering or departing from roost locations. Typically birds were seen to move short distances, such as between Waldie Island and the riverbank, or between the sewage lagoons and Waldie Island, though occasionally birds were seen flying upstream or downstream out of sight. Other daytime movements could sometimes be linked to disturbance events from human-related sources. However, even such flights were rarely recorded, and more typically no movements were noted at all while daylight permitted observation.

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 other categories.

	Behaviour (Per cent 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

The low number of herons prevented the need for scan sampling this season. On one occasion scan sampling was conducted on three herons immediately following a focal scan. The results are largely similar between the two scan types (not identical as they were not overlapping in time), and support the validity of scan sampling as a technique, in the event that behavioural observations are continued on greater heron numbers in future years.

Table 5-3: Percentage of observations in each behaviour type documented during focal and scan samples on the exact same herons. The scan sample was conducted immediately following the focal sample

	Focal Sample			Scan Sample		
	RE	**PR**	**OTH**	**RE**	**PR**	**OTH**
Heron 1	**100**	**0**	**0**	**95**	**5**	**0**
Heron 2	**100**	**0**	**0**	**100**	**0**	**0**
Heron 3	**82**	**10**	**8**	**85**	**15**	**0**

5.3 Shoreline Sampling

A total of 80 shoreline samples were conducted at 17 locations (Table 3-1, Figure 4-2). The locations were distributed throughout the study region, with a focus on areas around Waldie Island and the Columbia/Kootenay confluence. Shoreline sampling locations were based on areas where heron detections were reported by Machmer (2003), as well as additional sites including areas where no heron detections were known. Samples aimed to be distributed from sites with a variety of adjacent land types and throughout the study region.

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. Almost no macrophyte coverage was detected at any site. Similarly, very low periphyton coverage was detected, with most sites having no or extremely limited periphyton coverage. Only six samples had any periphyton with >1 mm coverage.

Water physicochemistry data were recorded from each site. Three samples at each site were averaged for each site visit, and the sample size, mean, standard deviation, minimum and maximum of these averages are presented below (Table 5-4). In general, values for most parameters are similar among sites, which is logical given that they are all part of the same river system. One notable exception is the specific conductance at Pass Creek, which is considerably lower than all other sites. This measurement was confirmed using two separate meters, and likely reflects the conditions out of Pass Creek rather than the Columbia or Kootenay rivers from where other measurements were taken.

Table 5-4: Water physicochemistry and physical variables measured from shoreline survey locations. If herons were considered to be present at a site if they were detected within 250 m of the sampling location

			pH					DO (mg/L)					Specific Conductance (µS/cm)				
Site	N	Herons Detected?	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
4th Ave	1	Y	1	8.44		8.44	8.44	1	22.69		22.69	22.69	1	128.73		128.73	128.73
Breakwater Island North	5	Y	4	8.37	0.28	7.96	8.58	5	25.66	1.06	23.96	26.73	4	132.50	5.45	127.40	138.50
Bridgeview	7	N	6	8.31	0.16	8.12	8.52	7	25.95	2.49	22.45	30.21	7	134.63	17.69	118.75	170.20
Grassland	5	Y	5	8.54	0.41	8.05	9.05	5	27.50	3.31	23.14	30.59	5	155.01	15.97	131.39	171.33
HLK Dam	1	Y	0					1	26.82		26.82	26.82	1	137.13		137.13	137.13
Kootenay Pt	5	N	4	8.32	0.15	8.16	8.50	5	26.96	2.48	23.08	29.99	5	164.29	5.03	158.40	170.97
Midway	5	N	4	8.28	0.26	7.94	8.49	5	25.76	1.26	23.90	27.29	5	134.80	4.59	128.73	140.43
Mill Site	6	N	5	8.28	0.29	7.95	8.62	6	25.69	2.88	22.26	30.80	6	133.06	4.75	124.53	137.40
Oxbow	4	Y	4	8.32	0.27	7.97	8.63	4	26.83	1.42	24.91	28.00	4	165.97	4.31	160.37	170.67
Pass Creek	1	Y	1	8.26		8.26	8.26	1	28.54		28.54	28.54	1	58.23		58.23	58.23
PipelineX	6	N	5	8.44	0.25	8.20	8.81	6	26.54	2.24	22.60	28.78	6	135.70	5.79	127.50	140.82
Twin Rivers Park	6	N	5	8.29	0.17	8.09	8.55	6	25.75	1.58	22.99	27.55	6	134.17	4.61	128.13	140.17
Waldie East	4	Y	4	8.52	0.47	8.19	9.19	4	24.90	2.31	21.97	27.05	4	130.19	9.22	119.13	138.40
Waldie North	6	Y	6	8.29	0.36	7.90	8.83	6	25.54	1.87	22.72	27.68	6	130.21	5.57	125.06	138.30
Waldie West	6	Y	6	8.23	0.31	7.76	8.58	6	24.64	1.62	22.13	26.85	6	136.86	11.08	122.90	151.57
Zuckerberg Central	6	Y	5	8.17	0.28	7.79	8.42	6	26.03	2.22	22.23	28.60	6	138.45	8.97	126.47	153.72
Zuckerberg North	6	Y	5	8.24	0.23	7.87	8.45	6	25.70	1.59	22.73	27.30	6	142.44	10.57	128.43	154.37

			Elevation (m)					Area (m^2)					Velocity (m/s)				
Site	N	Herons Detected?	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
4th Ave	1	Y	1	420		420	420	1	450.00		450.00	450.00	1	0.38		0.38	0.38
Breakwater Island North	5	Y	4	418	11	402	426	6	1143.20	791.45	140.00	2016.00	4	0.51	0.07	0.43	0.61
Bridgeview	7	N	6	418	4	412	422	8	1669.14	1243.99	715.00	4140.00	7	0.56	0.17	0.30	0.79
Grassland	5	Y	5	419	5	413	425	6	14468.40	10520.54	5616.00	32100.00	4	0.18	0.16	0.00	0.36
HLK Dam	1	Y	1	426		426	426	2	315.00		315.00	315.00	1	0.39		0.39	0.39
Kootenay Pt	5	N	4	420	4	415	423	6	3005.80	1489.99	344.00	4551.00	5	0.25	0.19	0.00	0.46
Midway	5	N	4	423	3	420	426	6	1285.00	844.72	0.00	2431.00	5	0.41	0.08	0.29	0.51
Mill Site	6	N	3	423	2	422	425	6	1013.20	575.93	80.00	1691.00	5	0.49	0.09	0.39	0.58
Oxbow	4	Y	4	415	6	407	419	5	671.25	284.72	265.00	965.00	3	0.22	0.19	0.00	0.36
Pass Creek	1	Y	1	420		420	420	2	4950.00		4950.00	4950.00	1	0.70		0.70	0.70
PipelineX	6	N	5	419	5	411	423	7	1954.00	962.70	960.00	3728.00	6	0.61	0.14	0.48	0.84
Twin Rivers Park	6	N	5	422	5	415	427	7	1431.00	1421.26	0.00	4004.00	6	0.44	0.10	0.30	0.57
Waldie East	4	Y	4	423	6	417	431	5	1459.13	679.11	366.00	2226.00	3	0.37	0.11	0.25	0.48
Waldie North	6	Y	6	419	4	412	424	7	3638.67	2584.61	234.00	8000.00	4	0.31	0.22	0.00	0.51
Waldie West	6	Y	2	415	6	411	419	7	284.17	112.85	75.00	408.00	5	0.30	0.26	0.00	0.57
Zuckerberg Central	6	Y	4	420	5	414	425	7	568.33	394.10	0.00	1080.00	6	0.43	0.17	0.15	0.60
Zuckerberg North	6	Y	5	421	4	416	426	7	2354.67	1663.63	0.00	4633.00	6	0.30	0.18	0.07	0.61

Turbidity as measured with the turbidity wedge indicated that the water was very clear almost everywhere. Only one sample had any visible obscurity at all, and this was at Waldie North where the substrate was fine and lots of waterfowl were foraging and stirring up the mud. Using a sonde to determine precise NTU values, it is clear that the water was very clear (<5 NTU) at the vast majority of sites and sampling sessions (Figure 5-8). With two exceptions (once at Kootenay Pt. and once at the Mill Site), only the Kootenay Oxbow and backwater channels (i.e., between Waldie Island and the north-side mainland) had readings >5 NTU, due to their soft, sandy sediments. The highest reading via the sonde (63 NTU) corresponds to the highest reading via the turbidity wedge.

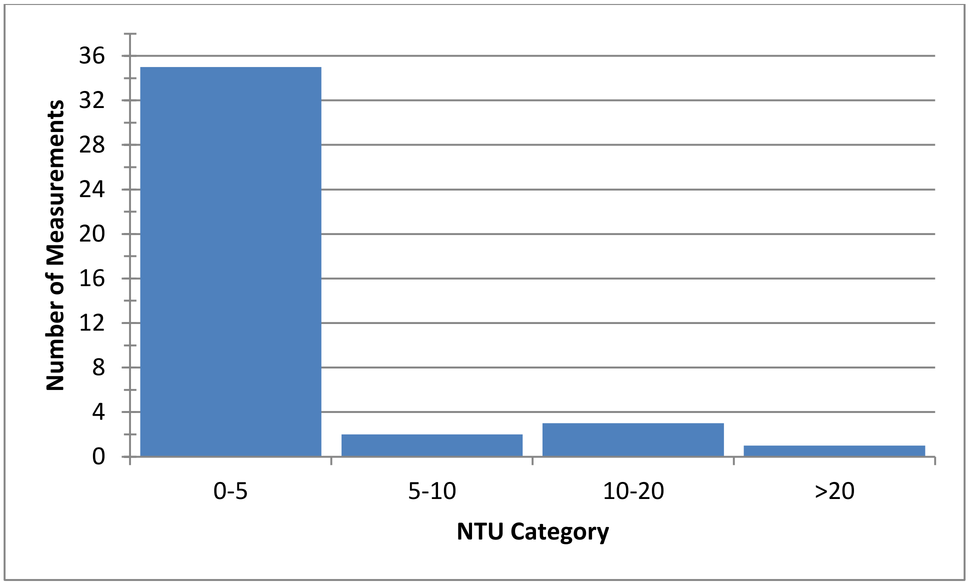

Figure 5-8: Number of measurements within each turbidity bin. Lower NTU values indicate clearer water

5.4 Shoreline Area

Approximate shoreline areas were calculated from estimates of shoreline length and width measured visually with a range finder. In general it was found that there were considerable differences in shoreline area among sampling periods (Table 5-5). However, those differences were not consistent among sites, suggesting that water elevation changes have site-specific impacts on shoreline area. For example, a reduction in water levels could increase the length of available shoreline, the width, or both concomitantly. Shoreline lengths were measured precisely, but not necessarily accurately, as the end points for shoreline length could be difficult to judge in some circumstances. However, the shoreline width is much easier to assess (being the distance from the water's edge to the upper edge of the inundation area). Here again there were site specific differences in response to water's elevation (Table 5-5). However, for both area and width, as water elevation increased relative to the previous sampling session, the size decreased relative to the last sampling session (Figure 5-9).

Table 5-5: Percent change in shoreline area and width between each survey period. Negative values indicate a reduction in size, while positive values indicate an increase in size

Percent Change Among Periods										
	Area					*Width*				
Period	*N*	*Mean*	*SD*	*Min*	*Max*	*N*	*Mean*	*SD*	*Min*	*Max*
Early Dec - Late Nov	9	-25.4	131.0	-95.3	314.5	9	-46.9	38.4	-87.5	20.0
Late Dec - Early Dec	9	218.1	354.0	-88.8	830.2	9	140.7	220.9	0.0	700.0
Mid Jan - Late Dec	12	196.2	217.0	-33.3	575.4	12	121.1	306.2	-20.0	1066.7
Early Feb – Mid Jan	10	101.1	191.9	-67.8	501.8	11	83.3	110.9	-6.7	356.3
Late Feb - Early Feb	12	32.7	50.6	-35.0	109.0	13	4.5	27.4	-47.9	55.6

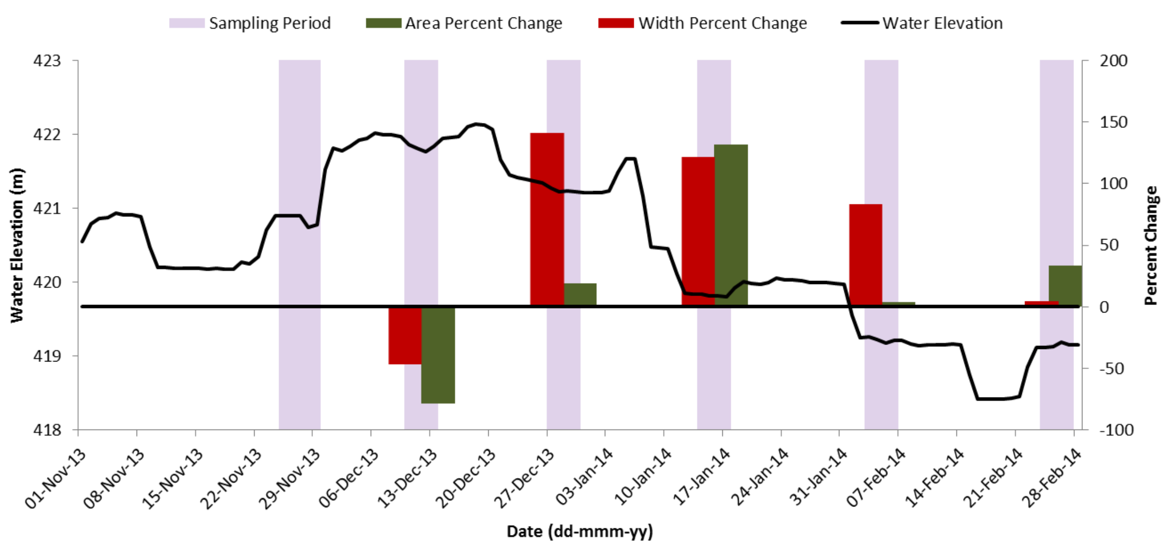

Figure 5-9: Relationship between water elevation and the change in shoreline area or width relative to elevation during the previous sampling period. As water elevation increased between two sampling periods, shoreline area and width decreased, and vice versa. Sampling periods are shown as light purple rectangles. Area and width measurements were conducted concurrently and within the sampling period, but are shifted in the graph relative to each other and the sampling period to ease comparisons

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, 2013 and February 28, 2014 flow rates varied from 569.5 cms to 1,792.6 cms. Flow rates peaked in mid-December in general, though the single greatest flow was on December 4. During the peak whitefish spawning period (December 21 to January 21), flows were between 1,165.3 cms and

1,646.7 cms. This is within the flow rate range for this period reported by Machmer (2003).

Water elevation ranged from 418.4 m to 422.2 m as measured at the Norns Creek gauge (CNN). 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 2013/2014 (n = 1190 days) water elevations exceeded 420.7 m on 87 days (7 per cent) (Figure 5-10). All but three of those dates have occurred since January 2012.

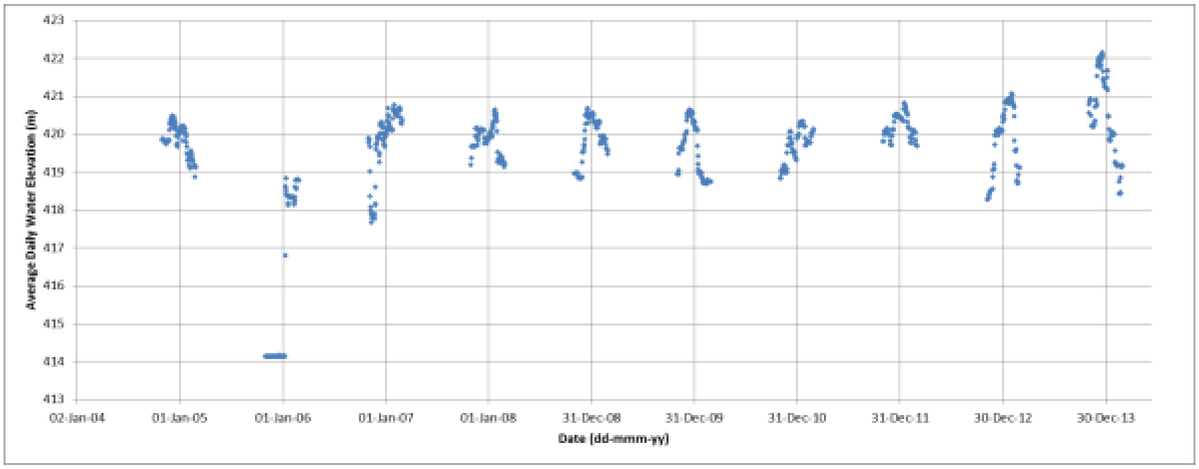

Figure 5-10: Average daily water elevations during the winter heron period (November through February) from 2004/05 to 2013/14. Water elevations were higher during the winter of 2013/14 than in any other winter over the past decade

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 range of water elevation has also been greater during the past two winters than most other years over the past decade. There is a positive relationship between flow rates and water elevation with temporal changes in discharge being closely mirrored by elevation (Figure 5-11).

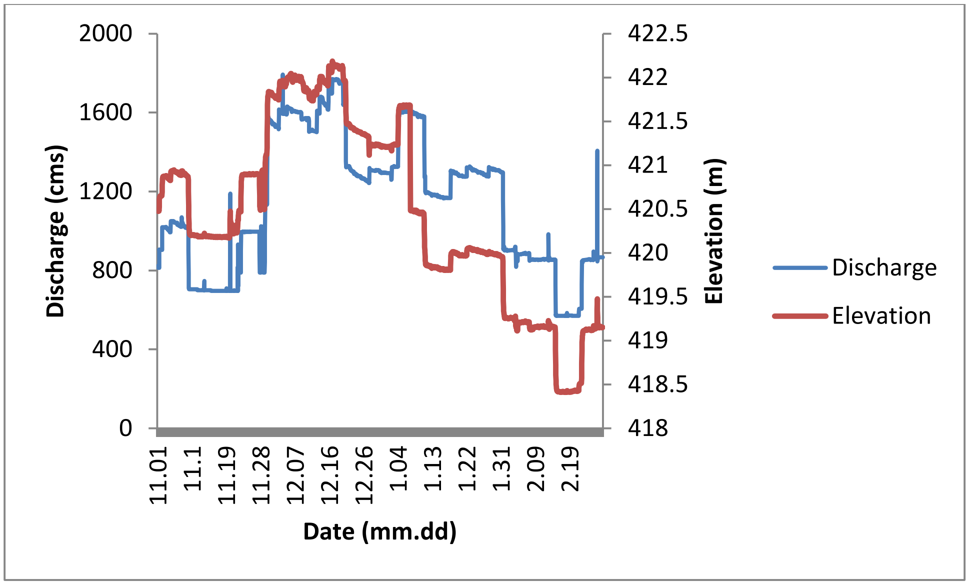

Figure 5-11: Flow rates out of Hugh Keenleyside Dam and water elevations as measured at the Norns Creek gauge. The two measurements are correlated, with changes in flow dictating water elevations

5.6 Management Hypotheses

As outlined in Section 2.1, three revised management hypotheses have been presented to test the relationship between flow rates and overwintering herons. However, 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. In addition, care must be taken not to violate the assumptions of a particular test. In the case of this study, the inability to alter flow rates experimentally makes it challenging to directly link flow rates to herons, given the influence of potentially confounding factors, such as time or environmental conditions. Additional problems are discussed under the relevant management hypotheses below. The three management hypotheses are:

H_1: The variation in the number of Great Blue Herons that roost on Waldie Island between November 15 and March 1 can be explained by the water elevation measured at the Norns Creek Gauge on the lower Columbia River.

Herons were observed roosting on Waldie Island only on two occasions; once in November, and once in February. Furthermore, based on results from this study and the observations of local residents (W. Volovsek pers. comm.), overwintering herons typically do not roost on Waldie Island, preferring Breakwater Island and the sewage lagoons. This hypothesis is not testable as stated, given the results from the 2013/2014 survey year.

H_2: The variation in the number of Great Blue Herons foraging along the shoreline in the vicinity of Waldie Island between November 15 and March 1 can be explained by the water elevation measured at the Norns Creek Gauge on the lower Columbia River.

Herons were rarely observed foraging. Out of 60 behavioural watches, only four herons were observed foraging, and even then did so for a minority of the time. One heron was observed picking in the mud and shallow water near Waldie Island in late November, and appeared to be foraging on invertebrates. This foraging was observed after sunset, and the heron was only watched briefly before it became too dark to observe. Other movements of herons at dawn and dusk, combined with the results of previous studies (Machmer 2003) indicate that herons forage predominantly at night in the study area. Based on these results, it is not possible to test this hypothesis as stated.

H_3: The variation in the distance between Great Blue Herons that are foraging in a shoreline area (i.e., the number of herons foraging/site) in the vicinity of Waldie Island between November 15 and March 1 can be explained by the water elevation measured at the Norns Creek Gauge on the lower Columbia River.

As stated under the second hypothesis, foraging herons could not be observed during this study period. Beyond that, multiple herons in the same area were only occasionally observed. This hypothesis is not testable given this year's results. Given the apparent propensity of herons to forage at night, this hypothesis will likely be difficult to address even with additional years of surveys.

Given the lack of ability to test the stated management hypotheses, alternative analyses were undertaken to test the predictive ability of variables (including flow rate and water elevation) to estimate heron abundance and site use.

5.6.1 Heron Counts

One goal of the study was to determine whether the variation in the number of herons on Waldie Island could be explained by the water elevation measured at the Norns Creek Gauge on the lower Columbia River. When the variables in the generalized linear model were tested for collinearity, some were significantly correlated. Specifically, water elevation (waterelev) was highly correlated with Keenleyside flow (HLKflow) ($r = 0.84$, $df = 22$, $P < 0.0001$) and water temperature (watertemp) ($r = 0.72$, $df = 22$, $P < 0.0001$). Therefore, flow rate and temperature were removed from the model. Once removed, all remaining Variance Inflation Factors (VIFs) were close to 1 (range: 1.13 to 1.69), indicating acceptable levels of collinearity between all retained variables (Bowerman and O'Connell 1990). Thus, the model used to predict heron counts included the following parameters: water elevation, air temperature, precipitation, snow depth and eagle counts. A total of 24 observations were available to fit the model.

Only air temperature was retained as the sole remaining predictive variable in the model, as its removal resulted in a significantly poorer fit ($Dev = 5.8$, $df = 1$, $P = 0.016$). The final predictive model took the form:

$$\widehat{Heron} = e^{\,0.83975 + (0.08974 \times \text{air temperature})}$$

The overall fit of the model was relatively poor (Figure 5-12): the approximate R^2 of the final model was 0.21.

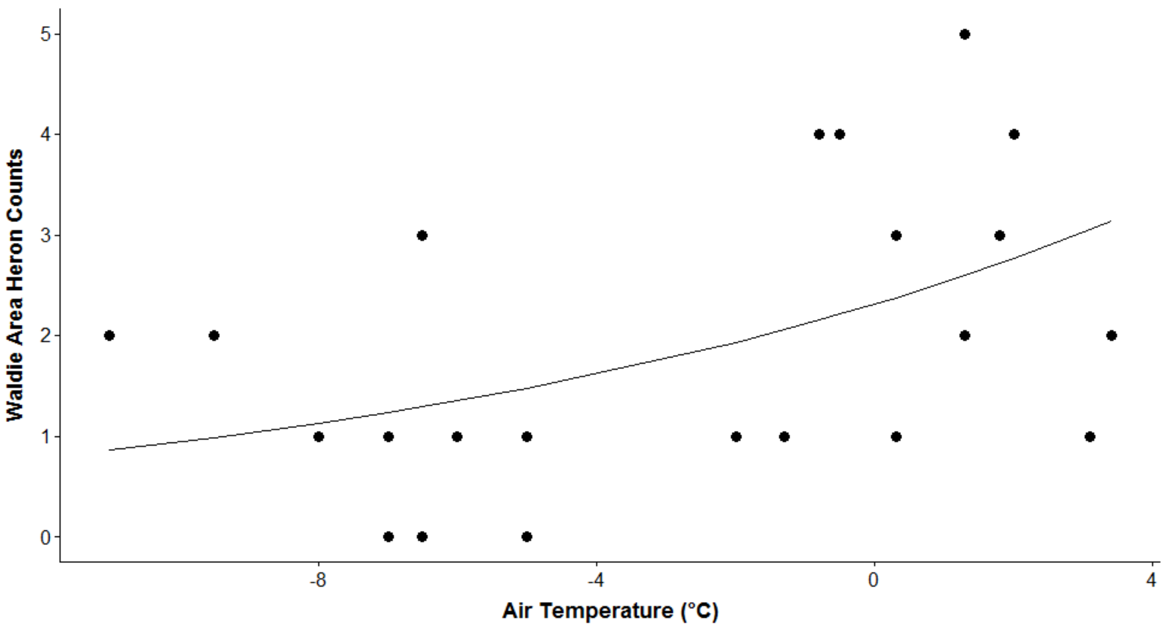

Figure 5-12: Waldie Island heron counts as a function of air temperature. Line of best fit is from a GLM with Poisson-distributed error structure. Approximate R^2 = 0.21.

5.6.2 Heron Presence

A logistic regression was used to assess the significance of water physicochemistry variables on the diurnal presence of herons in the proximity of a given site. Due to missing values for some parameters, 18 of the 80 records were excluded, and only 62 observations were used to fit the regression. Due to a strong correlation between water temperature and dissolved oxygen (r = 0.79, df = 78, $P < 0.0001$), the latter variable was excluded. After, the remaining VIFs ranged from 1.11 to 1.82, indicating acceptable levels of collinearity.

For the logistic regression, variables were removed one at a time until local water velocity was retained as the sole predictive variable in the model. The removal of water velocity resulted in a significantly poorer fit (Dev = 5.7, df = 1, $P = 0.021$). Because missing values for some of the initial parameters resulted in 18 records being excluded, we decided to re-run the reduced model using all available observations. In all, 76 observations were used to re-fit the GLM. The reduced model (Figure 5-13) was correct in predicting heron presence in 66.5 per cent of cases, and took the form:

$$\widehat{Prob.Heron} = \left(1 + e^{-(1.791-(4.073 \times velocity))}\right)^{-1}$$

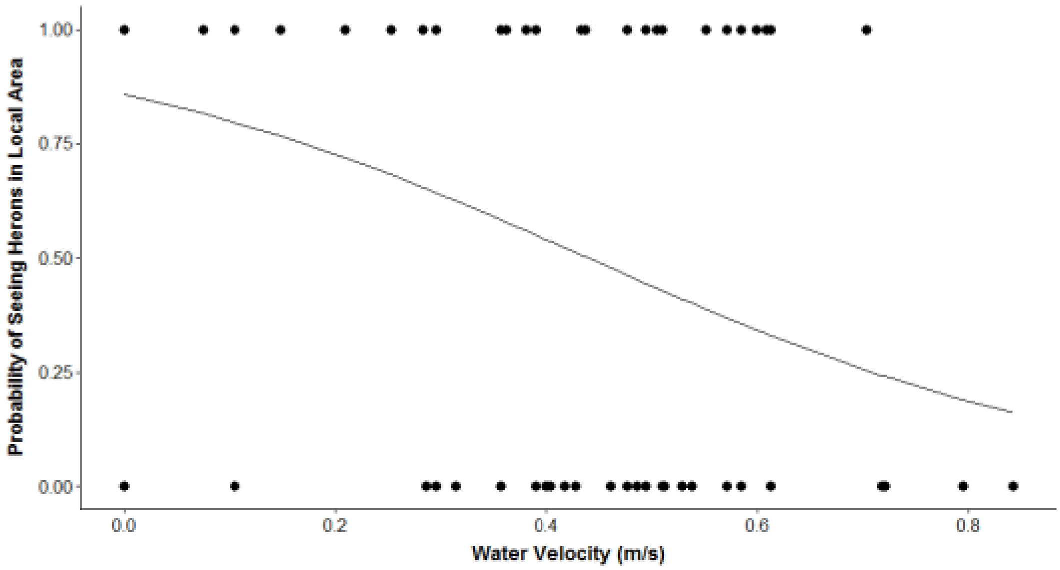

Figure 5-13: The heron presence (1) or absence (0) and the probability of heron presence (line) of within a 250 m buffer area around physicochemical data collection sites, as a function of water velocity

The area under the ROC curve was 0.637, indicating that discrimination level was poor. Nevertheless an ANOVA showed that local water velocity was significantly slower at sites with herons (0.36 m/s) versus those without (0.47 m/s; $F_{1,74}$ = 10.1, P = 0.002; Figure 5-14).

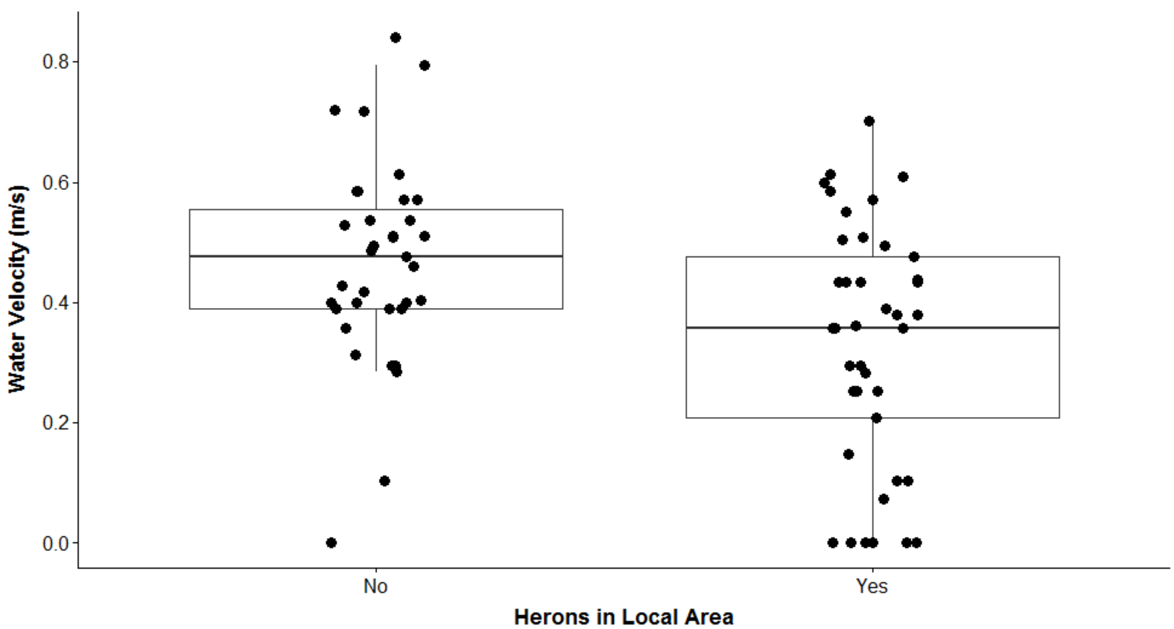

Figure 5-14: Water velocity at sites with and without herons within 250 m. Velocity data are jittered (plotted in a randomized position) along the x-axis to help reduce overlap of point on the graph. Boxes enclose the 25th and 75th percentile values, with central horizontal lines indicating the median value. Vertical 'whiskers' extend to last point that is less than 1.5 × the interquartile range

5.6.3 Other analyses

In 2001/02 and in 2002/03, there was no obvious relationship between Waldie Island heron numbers, flows or water elevations (Machmer 2003). Our data indicated that this was true in 2013 as well. Quasipoisson models relating heron counts to water elevation and those relating heron counts to flow rates were not significantly different from models with no predictive variables (elevation: $F = 1.9$, $df = 1$, $P = 0.18$; flow: $F = 0.01$, $df = 1$, $P = 0.90$).

However, in 2001 to 2003, heron counts tended to be highest prior to whitefish flows (when flows and elevations were also highest) and lower post-whitefish flows. In 2013, median heron counts before, during and after the whitefish flows were 1.0, 2.5, and 0.5 birds. Heron numbers were found to be statistically different among time periods ($F = 2.8$, $df = 2$, $P = 0.082$). A post-hoc test showed that heron counts post-whitefish flows were significantly different (lower) than the period during peak flows ($Z = -2.2$, $P = 0.07$), but no other statistical differences were found among flow periods.

Considering only the period before and during whitefish flows (when heron numbers were highest), there was a significant *positive* correlation between heron numbers, flow rates and water elevations in both 2001/02 and in 2002/03. However, in 2013 the data showed significant *negative* correlation between heron numbers and flow rates only ($r = -0.52$, $df = 14$, $P = 0.036$).

6.0 DISCUSSION AND MANAGEMENT QUESTIONS

This study was partially successful in re-evaluating the use of Waldie Island, adjacent areas, and the broader Castlegar region, by over-wintering Great Blue Herons. It has shown where roosting herons were present, and provided an estimate of the over-wintering heron population during the past year. It also highlights that numbers appear to be even lower than in the early 2000s, when Machmer (2003) noted an apparent decline in heron abundance. Detection of any decline has been hampered by the lack of dedicated, systematic surveys between the winters of 2003 and 2013. However, information from local residents and available citizen science datasets both support the hypothesis of a reduction in local over-wintering heron numbers between the 1990s/early 2000s and now. Those same datasets also indicate highly variable counts, and the extent by which those fluctuations or an apparent decline are dictated by local conditions is unknown.

Regarding the objectives of this study, there is little evidence that variation in heron numbers are related to flows through the Hugh Keenleyside Dam and related water elevations. Considering only the period before and during whitefish flows when heron abundance was highest (as per Machmer 2003), there was a significant negative correlation between heron counts and water flow, and a non-significant negative correlation between heron counts and water elevation. This is the opposite trend reported by Machmer (2003). However, this result is tenuous; sample sizes are low, and in general few herons were detected at any flow period relative to the 2001 to 2003 survey period. The magnitude of change in water elevation has been large during the past couple winters. While the implications of that are currently unknown, it has the potential to influence heron counts. Biologically speaking, it would appear that none of the measured variables were indicative of heron abundance during the winter of 2013/14. More sampling is required to determine if any tested variables are indicative of heron abundance.

Although statistically heron counts appeared to be best predicted by air temperature, the fit of the model was poor and the correlation between heron numbers and air temperature was also low (R^2 = 0.21). The result could be spurious due to the low sample sizes involved, and only indicates that air temperature was the best fit given the variables included, not that it is a good predictor of heron numbers. Additional years of data will help clarify if this relationship is true.

When heron presence was tested using the water physicochemical data collected at each site, local water velocity came out as the best predictive variable. Specifically, sites with lower water velocities were more likely to have herons present nearby. The sighting of heron tracks in most soft-sediment areas (those with lower local water velocities) raises the likelihood that these are important foraging areas. All other physicochemical attributes were similar among sites. More importantly, all were within a tolerable range for supporting potential prey organisms, such as invertebrates and fish. Even the low specific conductance measurement at Pass Creek is unlikely to affect heron presence, as it does not preclude other fauna. However, our lack of foraging data limits inference. No conclusions can be reached based solely on one year of data with low heron numbers and above average water elevations.

The presence and distribution of target prey may also influence the presence and distribution of herons. We do not have fish data concurrent with heron surveys. Machmer (2003) reported that fish densities of all fish species were higher during the night than the day. Such a pattern is consistent with our findings of heron behaviour. That herons appear to be foraging nocturnally would support that fish densities remain highest during the night; though alternatively, it is possible that prey capture is highest at night regardless of density. Machmer (2003) also indicated that fish densities had inconsistent responses to flow period over the two study seasons. During the 2001/02 surveys, fish densities were lower during whitefish flows, relative to pre- or post-flows, while no significant differences were found with flow period in 2002/03. Fish densities and heron numbers were both lower in 2002/03 than in 2001/02, while flow rates and water elevations were higher (Machmer 2003). In addition, fish populations appear to be dynamic, including species composition. For example, the density of both subadult and adult Mountain Whitefish appears to have declined between the 1990s and 2012; adult density was lower in 2010 to 2012 than all other study years (Ford et al. 2013). In contrast, Northern Pike went undetected in fish surveys near Castlegar prior to 2010, but appear to be increasing and have been consistently found since that time (Ford et al. 2013). It is not known if herons have a preference for 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 is not understood. While we cannot address fish specifically for our year 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.

While it is convenient in speech and writing to describe the over-wintering heron "population", the population dynamics of this group of herons is 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. In contrast, eagle populations appeared to increase through the period. 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, no nesting currently is known from the Castlegar area. Herons nested unsuccessfully at Waldie Island in the past, though the last known active nest was in 2001. As no known nesting occurs in the vicinity of Waldie Island, over-wintering 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 over-wintering herons on the Columbia, 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 apparent declines could be attributable to conditions on the wintering grounds, breeding grounds, migration stopovers, or any combinations thereof.

Many factors likely influence the abundance and distribution of herons in the Castlegar area. As reproductive success may alter the population size overall, the availability of foraging habitat may limit their distribution. For example, in the interior in general, frozen wetlands and waterways limit heron foraging habitat, and therefore their range (Gebauer and Moul 2001). 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 Castlegar area have few areas where they are not exposed to disturbances. Eagles are one such source of disturbance. While no eagle attacks of Great Blue Herons were noted in 2013/14, Machmer reported such events on four occasions in 2002/03. Furthermore, she noted disturbance by eagles on 45.8 per cent of all observation dates. Herons were observed to be disturbed by humans, dogs, and a train during the 2013/2014 season. On several occasions birds were flushed from the shoreline by people and dogs walking along the Waldie Island Trail. Humans and dogs (both leashed and unleashed) were encountered at the majority of sampling locations, even when sampling locations were away from paths. At least during the winter of 2013/14, humans and dogs appeared to be the greatest source of disturbance to herons, with no eagle activities conclusively attributed to heron disturbance. Both the sewage lagoons and the islands appear to offer some refuge to herons by limiting direct access by humans, though these areas are not completely isolating to human activities (Figure 6-1). However, the birds in the sewage lagoon were flushed on one occasion as a train passed along the tracks adjacent to the lagoons. Despite these observations, there were other occasions when herons did not seem to react at all to passersby, tug boat activity, or other potential disturbances.

Figure 6-1: Shoreline areas are frequented by humans and dogs, and appear to be the main source of disturbance to herons. Note the fishermen on the shores of the Waldie Island Reserve where access is theoretically prohibited. Photo © Walter Volovsek

While human disturbances may not directly lead to a population decline, repeated disturbances could affect their utilization of specific sites. Immatures outnumbered adults during the 2013/14 period, and it is young birds that also have the highest mortality rates (Vennesland and Butler 2011). Given the increased likelihood of mortality for young birds, any stressor could have implications on their survival. For example, one immature heron was observed resting on the shore near the Waldie West location on the February 4, 2014 and looked unhealthy relative to other herons that had been observed. At one point, a mouse (a typical prey item) walked past the heron, with no reaction from the heron noted. In the same general area on February 25, the scattered remains of a heron were found (Figure 6-1). It is not possible to know the cause of the mortality, or to link any factors to it, but it emphasizes the need to reduce disturbances or other factors that could impact an individual heron's ability to successfully overwinter.

Figure 6-2: These feathers and bits of skin of a Great Blue Heron were found near Waldie Island on February 25, 2104. They represent the only known mortality event of the 2013/14 season, though the cause is unknown

In summary, the dynamics influencing overwintering herons along the Lower Columbia River are likely complex and interconnected. Flow regime may certainly impact shoreline utilization or heron abundance, but additional data are required before any linkages can be made. Confounding our ability to detect such a trend are changes in breeding success and colony structure, lack of flow manipulation ability, and other impacts such as eagle and human-caused disturbances. These other factors must be considered, and additional years of data collection necessary, before any conclusions can be made.

6.1 Management Questions

6.1.1 MQ1: How does the flow regime in the lower Columbia River influence the number of wintering Great Blue Herons that roost on Waldie Island?

Based on the results of the first year of this study, the flow regime does not appear to influence the number of herons roosting in the vicinity of Waldie Island. Herons were observed roosting on Waldie Island only on two occasions; once in November, and once in February. Observations by local residents suggest that herons prefer to roost on Breakwater Island (W. Volovsek pers. comm.). In addition, “there was no obvious relationship between heron numbers and fine scale changes in flows and water elevations at Waldie Island” reported by Machmer (p. 14, 2003). While Machmer did report a trend of highest heron numbers during high flows and elevations and lowest numbers post whitefish flows, that pattern is confounded by potential underlying temporal trends unrelated to flows (e.g., a natural migration/dispersal patterns or mortality-driven population declines over the course of the winter). Additional years of sampling are required to help elucidate the influence, if any, of the flow regime on heron numbers in the Waldie Island area; however, given the low number of herons in general, and near absence of herons roosting on Waldie Island, it is unlikely that this question will be answerable in its current form.

6.1.2 MQ2: Are there operational changes that could improve Waldie Island as a roosting location for Great Blue Herons?

Few herons were observed roosting on Waldie Island, or even in the surrounding area during the winter of 2013/2014. While caution is warranted when interpreting these results, analyses indicated that flow rates and water elevations are not good predictors of heron abundance. Nevertheless, a maximum water elevation of 420.7 m has been recommended to ensure that suitable shoreline area remains, particularly around Breakwater Island which becomes submerged at water elevations of around 422 m (Machmer 2003, revised by BC Hydro 2012). This target was clearly exceeded for a large portion of the 2013/2104 wintering period.

6.1.3 MQ3: Where are the shoreline areas that are used by Great Blue Herons?

Herons were located at roughly seven foreshore locations (Figure 5-2). The area around Breakwater Island was most frequently used, with herons seen on Breakwater Island, and occasionally on shore along the southern bank of the Columbia opposite Breakwater Island. They were also located in shoreline areas on Waldie Island, paralleling the Waldie Island Trail, and on the gravel bars near the Pass Creek delta. Additional sites included the rocks just on the south side of the Arrow Lakes Generating Station, and near the Brilliant Bridge on the Kootenay River. No herons were observed on any shoreline between the Hugh Keenleyside Dam and the Pass Creek area, or along the Columbia River downstream of Waldie Island. Our observations are limited to dusk, dawn, and daylight periods, and it is possible that distributions are different at night.

Machmer (2003) describes the shoreline area opposite Waldie Island, Pass Creek, Tin Cup Rapids area, and the Kootenay River Oxbow as being the most intensively and consistently used areas. This roughly corresponds to the areas we located herons (with the exception of Tin Cup Rapids), even though we found much fewer overwintering herons.

6.1.4 MQ4: How does the flow regime affect the area, distribution, and attributes of shorelines areas?

High flow rates out of Hugh Keenleyside Dam are related to higher water elevations as measured at the CNN (Columbia before Norms) gauge. As water elevations increase, the amount of available shoreline decreases (Figure 5-9). During the 2013/14 winter, the shore area was found to decrease from November to December as water elevations increased. As water levels receded through February, the shore area increased. However, the effect may have different consequences depending on whether birds use a specific shoreline area for roosting or foraging. If herons are foraging along the river, the area of shoreline should not matter as much as the length along the water's edge. At sites with long shorelines paralleling the river, changes in water elevation may not affect foraging opportunities greatly. However, changes in area may limit the amount of roosting habitat available at a given location. Thus, changes will likely be most pronounced at islands, such as Breakwater Island, which experiences concomitant decreases in shoreline area and length as water elevations increase. Similarly, effects are likely also greater at shallow-water sites with low local flow rates, such as near the north end of Zuckerberg Island, and the main channel behind Waldie Island.

6.1.5 MQ5: How does the flow regime in the lower Columbia River influence the total number of Great Blue Herons that forage along the shorelines in the vicinity of Waldie Island?

Herons were rarely observed foraging during the 2013/2014 survey year. Out of 60 behavioural watches, only four herons were observed foraging, and even then did so for a minority of the time. One heron was observed picking in the mud and shallow water near Waldie Island in late November, and appeared to be foraging on invertebrates. This foraging was observed after sunset, and the heron was only watched briefly before it became too dark to observe. The lack of observed foraging combined with movements witnessed at dawn and dusk suggest that herons forage nocturnally. Machmer (2003) reported seeing only two fish captures during 102 observation hours in 2002/03 (including at night). Heron tracks were found in the soft sediments in the backwater channel of Waldie Island, the Kootenay Oxbow, and the north side of Zuckerberg Island. Herons were otherwise rarely or never observed at these locations, indicating that foraging is likely taking place there at night. However, as most other sites have rocky substrates, no evidence of heron activity could be found. Given the lack of daytime foraging by herons, and the lack of knowledge regarding where herons actually forage, it is not possible to address this question at this time.

Determining how many herons forage in the vicinity of Waldie Island would require the implementation of nocturnal foraging observations, using night-vision optics. Such methods were utilized by Machmer (2003), but she noted that snow, rain, fog, and background light conditions from Castlegar all limited night-time visibility. More critically, herons were extremely wary and easily flushed at night. The limitations of night-vision technology require much closer approach distances than with traditional optics during daytime, and it is likely that collecting a few data points on nocturnally-foraging herons would require a great amount of effort. Given that nocturnal survey effort would take away from daytime observation periods, we feel that using night-vision optics to gather nocturnal observations is not currently warranted.

6.1.6 MQ6: How does the flow regime in the lower Columbia River influence the distance between Great Blue Herons that are foraging in shoreline areas (i.e., the number of herons foraging/site)?

As stated under the second management question, foraging herons could not be observed during this study period. Beyond that, multiple herons in the same area were only occasionally observed. While the inter-bird distance was recorded when multiple roosting herons were observed, the spatial aggregation of foraging birds is likely to be unrelated. This hypothesis is not testable given this year's results. Given the apparent propensity of herons to forage at night, and the low sample sizes, this hypothesis will likely be difficult to address even with additional years of survey data.

6.1.7 MQ7: Are there operational changes that could improve the availability of suitable shoreline areas for the Great Blue Herons from Waldie Island?

Previously, Machmer (2003) provided a recommendation to keep water elevations below 421 m (revised to 420.7 m, BC Hydro 2012) during the winter period to ensure adequate roosting habitat remained at Breakwater Island and adjacent shoreline areas. Given the above consideration (see MQ6) to how water elevation may affect shoreline areas for both roosting and foraging Great Blue Herons, and the apparent importance of Breakwater Island as a roosting site, we preliminarily agree with that recommendation. Between 2005 and 2012 water elevations largely remained at or below these levels during the November through February period. During the past two winters (2012/13 and 2013/14) water elevations have consistently exceeded these levels. Consideration should be put into lowering these levels below 420.7 m again in future winters.

6.1.8 MQ8: Are there physical works that could improve the availability of shoreline areas for the Great Blue Herons from Waldie Island

Additional years of data collection are required to answer this question, and no physical works should be conducted based on this one year. However, if Breakwater Island proves to be one of the most important local shoreline roosting locations (as indications point towards) then a potential issue is the lack of shoreline availability at this location if water levels experienced during the past couple winters become routine. One possibility would be to increase the size of Breakwater Island, particularly along the streamside and downstream sides. Such an increase would require both building the island up and out 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.

A weir has been proposed that would span the channel due north of Waldie Island (W. Volovsek pers. comm.). Such an initiative could trap water above the weir, thus forming a marsh during lower water periods. While this wouldn't increase the availability of shoreline area per se, it could increase the amount of potential foraging and/or roosting habitat near to other shoreline areas. Herons were frequently observed roosting beside the sewage lagoons during the winter of 2013/14. These lagoons are superficially marsh-like, so the potential exists for increasing habitat availability generally.

Before any physical works should be implemented, additional data are needed on the influence of water elevation on wintering herons, particularly pertaining to important wintering locations.

6.1.9 Management Questions Summary

Several management questions are addressed by this study (Table 6-1); all will benefit from additional years of study, but some may not be addressable as they are currently stated. We feel that the opportunity exists to introduce additional methods with which to study herons along the Lower Columbia River. Most notably, data on foraging herons is lacking, due to their apparent nocturnal feeding habits in this area. However, changes in heron abundance and distribution may have occurred since the previous study ended in 2003. A revision to the management questions to reduce the focus on Waldie Island proper may be warranted. These topics are discussed further in the summary table, and Recommendations section, below.

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

MQ	Able to Address MQ?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
1 – How does the flow regime in the lower Columbia River influence the number of wintering Great Blue Herons that roost on Waldie Island?	Not at this time	Suggestion of interaction between flow regime and roosting herons reported by Machmer (2003), in that heron numbers were highest prior to whitefish flows, and lowest post-whitefish flows.	• Delete management question; otherwise: • Revise question to extend area of interest beyond Waldie Island • Sample herons during more periods of low and high water levels/flows.	• Natural annual population variation • Low use of Waldie Island as a roosting site in 2013/14 • Lack of control sites • Lack of experimental manipulation ability • Variable flow regimes
2 – Are there operational changes that could improve Waldie Island as a roosting location for Great Blue Herons?	Not at this time	N/A	• Revise question by merging with MQ7 under a new MQ. • Revise question to include a broader area than just Waldie Island. • Access Waldie Island interior to search for signs of roosting herons that might otherwise be obscured	• Natural annual population variation • Variable reservoir operations • Lack of use of Waldie Island as a roosting location
3 – Where are the shoreline areas that are used by Great Blue Herons?	Partially	Mapped heron locations showing all shoreline areas where herons detected. Occupied sites similar to those determined by Machmer (2003).	• Sample areas outside of Castlegar to determine where herons are overwintering in the region as a whole. • Continue sampling all areas around Castlegar as in Year 1.	• Natural annual population variation • Difficult to observe at night • Variable dam flows affecting shorelines throughout the day and the year • Human and other disturbances potentially limiting site utilization • Lack of experimentation to assess how varying the flows affects herons at different times through the winter period
4 – How does the flow regime affect the area, distribution, and attributes of shoreline areas?	Partially	Shoreline area for roosting and foraging increases with decreasing water elevation and vice versa. Response not equal among sites.	• Bathymetric data, digital elevation model, or aerial photos of the study area at different water elevations (if any of the above exist) should be assessed in a geographic information system to map the area and extent of shorelines at varying water levels.	• Variable reservoir operations • Uneven site response • Lack of knowledge about which areas are important for foraging

MQ	Able to Address MQ?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where applicable	
5 – How does the flow regime in the lower Columbia River influence the total number of Great Blue Herons that forage along the shorelines in the vicinity of Waldie Island?	Not at this time	N/A	• Delete management question; otherwise • Add night vision surveys to attempt to observe and document locations and foraging behaviours of nocturnally-foraging herons. • Revise question to include areas beyond Waldie Island, as it is not known where herons predominantly forage	• Natural annual population variation • Unknown foraging locations • Unknown target prey • Nocturnally-foraging herons difficult to observe • Variable dam operations
6 – How does the flow regime in the lower Columbia River influence the distance between Great Blue Herons that are foraging in shoreline areas (i.e., the number of herons foraging/site)?	Not at this time	N/A	• Delete this management question; otherwise • Add night vision surveys to observe and document locations and foraging behaviours of nocturnally-foraging herons.	• Natural annual population variation • Low numbers of herons in study area • Unknown foraging locations • Nocturnally-foraging herons difficult to observe • Variable dam operations
7 – Are there operational changes that could improve the availability of suitable shoreline areas for the Great Blue Herons from Waldie Island?	Partially	Shoreline areas are impacted by changing water elevations. Winter water elevations have been relatively high since 2012.	• Merge this question with the very similar MQ2 under a new MQ • Bathymetric data, digital elevation model, or aerial photos of the study area at different water elevations (if any of the above exist) should be assessed in a geographic information system to map the area and extent of shorelines at varying water levels. • Surveys should aim to capture the periods of highest and lowest water elevations	• Variable dam operations • Uneven site response • Lack of knowledge about which areas are important for foraging
8 – Are there physical works that could improve the availability of shoreline areas for the Great Blue Herons from Waldie Island?	Not at this time	N/A	• Expand MQ to focus on the general area, not just Waldie Island • Surveys should aim to capture the periods of highest and lowest water elevations	• Variable dam operations • Natural annual population variation • Lack of physical works to benefit herons already undertaken from which to inform recommendations

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. During Year 1 it became apparent that current methods were inadequate to address several of the management questions. This was a direct result of conditions outside of the control of LGL or ONA, and largely stemmed from the inability of the project to establish an experimental approach to addressing the effects of flow regime on heron counts. Furthermore, numbers of herons remained low throughout the survey period, greatly limiting the ability to test management questions and hypotheses in the statistical framework outlined in the Terms of Reference (BC Hydro 2012). Even where statistical results may be obtained, any apparent correlation between flow regime and heron counts will be confounded by numerous unmeasured variables (e.g., natural temporal variation over the course of the study period, human disturbances, and/or weather conditions) which may contribute to or exacerbate similar results, leading to spurious conclusions on the effects of the water regime. It is also not known how or if conditions in the Castlegar area are reflective of conditions in the broader Kootenay region.

As a result of these limitations, slight revisions are proposed to the survey methods and management questions. These revisions, however, do not change the objectives of the study nor do they nullify work conducted to the present.

7.1 Sampling Protocol

1. Expand study area to include the broader Kootenay region. We do not know if trends in heron numbers observed in Castlegar are part of a regional pattern. In addition, we cannot assess the suitability of heron habitat in the Castlegar area without knowing what areas they select elsewhere in the region. We recommend that additional sampling include sites outside of the Castlegar area with known historical heron presence.
2. Switch to sampling in November (pre-whitefish flows) and February (post-whitefish flows) to capture conditions in early and late winter. Two trips allows for the same number of field-days (necessary without a budget increase) to be completed while surveying the broader Kootenay region. All sites in Castlegar from the 2103/14 study year will remain surveyed. In addition, daily counts from the Waldie Island area will be requested from resident observers.
3. Behavioural observations were successful in 2013/14, but most birds were found resting. If the study area is expanded, formal focal scans should be dropped in favor of increasing the amount of time for sampling additional sites. The behaviours of all herons observed will still be recorded, but the formalized time period to watch heron behaviour should be relaxed.
4. In addition to the shoreline sampling data collected in Year 1, surveyors should also estimate within the proximity of a sampling site the (1) presence/proportion of open water, (2) the presence of fields, and (3) the snow depth on/near the field.

7.2 Management Questions

Eight management questions (below) were originally developed by BC Hydro 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*." However, over the course of Year 1 of CLBMON-49, it became evident that some revision to the management questions should be considered to better reflect the conditions surrounding overwintering herons. The management questions are presented below, along with our recommendations for how management questions should be presented to better address the intent of CLBMON-49.

MQ1: *How does the flow regime in the lower Columbia River influence the number of wintering Great Blue Herons that roost on Waldie Island?*

Revised MQ1: Delete this management question.

Justification: Determining the effect of flow regime on the number of herons requires an experimental approach, wherein flows can be manipulated at times chosen by the study. Without this, the study cannot confidently answer this question with the current observational approach due to confounding variables. In addition, heron numbers were very low during Year 1 of the study preventing an assessment of the influence of flow regime, and changes in heron numbers in future years may be a consequence of natural population variation or other factors (e.g., disturbance) rather than any effect of flow.

MQ2: *Are there operational changes that could improve Waldie Island as a roosting location for Great Blue Herons?*

Revised MQ2: Merge this question with the very similar MQ7 under a separate, new management question (see MQ"B").

Justification: The specific focus on Waldie Island is unjustified given the current knowledge of roosting locations (micro-sites where herons rest, which may be on the ground or in a tree) for Great Blue Herons. During Year 1, roosting was only noted from Waldie Island proper on a couple occasions. Other shoreline areas, such as Breakwater Island, appear to be selected preferentially for roosting. Thus, focus on Waldie Island should be removed. Furthermore, with so few herons found in Year 1, the new emphasis should be placed on roosting habitat rather than specific roosting locations which may be under-utilized currently. As roosting habitat is often on shorelines, this question broadly overlaps that of MQ7.

MQ3: *Where are the shoreline areas that are used by Great Blue Herons?*

Revised MQ3: No revisions to this question are proposed.

Justification: Both current and proposed methods will continue to address this question as stated.

MQ4: *How does the flow regime affect the area, distribution, and attributes of shoreline areas?*

Revised MQ4: No revisions to this question are proposed.

Justification: Both current and proposed methods will continue to address this question as stated.

MQ5: *How does the flow regime in the lower Columbia River influence the total number of Great Blue Herons that forage along the shorelines in the vicinity of Waldie Island?*

Revised MQ5: Delete this management question.

Justification: See justification for MQ1 regarding the requirement for an experimental approach and sample size issues. In addition, determining how many herons forage in the vicinity of Waldie Island would require dedicated nocturnal surveys as herons appear to forage at night. Such nocturnal surveys would likely require a large amount of effort to gather sufficient data for a valid conclusion to be made.

MQ6: *How does the flow regime in the lower Columbia River influence the distance between Great Blue Herons that are foraging in shoreline areas (i.e., the number of herons foraging/site)?*

Revised MQ6: Delete this management question.

Justification: See justification for MQ1 regarding the requirement for an experimental approach to properly answer this question and sample size issues. Foraging observations would require dedicated nocturnal surveys (see justification for MQ5). There is also no evidence that the number of herons foraging in a given site is related to flows, or that the density of herons relates to habitat suitability. Without specific studies to assess prey availability and the effects of flows on prey that might indirectly influence heron density, the current methods would not answer this question.

MQ7: *Are there operational changes that could improve the availability of suitable shoreline areas for the Great Blue Herons from Waldie Island?*

Revised MQ7: Merge this question with the very similar MQ2 under a separate, new management question (see MQ"B").

Justification: The wording of the original question focuses on herons "from Waldie Island". This is unjustified as herons did not typically roost on Waldie Island during our study period. Nor have herons nested on Waldie Island for many years, if "from" refers to the nesting origin of the overwintering "population". This question can be answered more precisely via methods currently proposed, but also with the previous approach. Regardless, the focus should be broadened to the general area. There is overlap with MQ2 as herons may roost on shoreline areas, and are therefore affected by the availability of suitable shoreline areas.

MQ8: *Are there physical works that could improve the availability of shoreline areas for the Great Blue Herons from Waldie Island?*

Revised MQ8: Are there physical works that could improve the availability of suitable shoreline areas for Great Blue Herons on Waldie Island and in the Castlegar area?

Justification: This question again focuses too specifically on Waldie Island. As herons do not appear to be "from" Waldie Island, the question should instead reflect shoreline availability to herons in the general area. Again, this question can be addressed with both old and newly proposed methods.

MQ"A": *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?*

Newly proposed management question.

Justification: An experimental design cannot be implemented to properly address the management questions we propose deleting (Nos. 1, 5 and 6). Furthermore, the vagaries of research on low group sizes make any meaningful comparisons difficult to infer. Though the focus has been on Waldie Island (original questions), and though we included the greater Castlegar area in our approach (Year 1 report), it is still unknown if habitat there is typical of overwintering habitat utilized by interior herons. By assessing attributes of heron distribution and habitat utilization elsewhere in the region, we can better assess the conditions for roosting and foraging herons in Castlegar and the Waldie Island area. Once that is known, we can infer how flow regime might affect those conditions; which ultimately is what management questions 1, 5 and 6 were trying to address.

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

Newly proposed management question. Merging and re-wording original MQs 2 and 7.

Justification: The original focus of MQs 2 and 7 involved operational changes that could improve roosting habitat and the availability of suitable shoreline areas respectively. Roosting habitat is often on shoreline areas (individuals were more frequently observed roosting on the ground than in trees during Year 1 field studies), so to eliminate redundancy these questions should be merged. A further broadening of the question scope from Waldie Island to the Castlegar area is warranted as suitable and available habitat exists outside of Waldie Island proper that is also affected by water flows. The new wording of this question is sufficient to cover roosting habitat, foraging habitat, the suitability of those habitats relative to shoreline availability, and how they are affected by flows.

In summary, we propose the following new list of Management Questions. Questions can be re-numbered at BC Hydro's discretion.

MQ3: *Where are the shoreline areas that are used by Great Blue Herons?*

MQ4: *How does the flow regime affect the area, distribution, and attributes of shoreline areas?*

MQ8: *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"A": *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"B" *Are there operational changes that could improve habitat availability and suitability for Great Blue Herons on Waldie Island and in the Castlegar area?*

A summary of our proposed changes are as follows:

1. Remove focus on Waldie Island specifically,

2. Remove focus on counts,
3. Shift focus to a habitat-based assessment with count data to support conclusions (where possible),
4. Reduce the number of questions from 8 to 5. Remove original MQ 1, 5, and 6 and add MQ "A". Merge MQ 2 and 7 into a new MQ “B”.
5. MQ 3 and 4 remain as currently written. MQ 8 removed emphasis on Waldie Island and supplemented with the broader Castlegar area.

7.3 Management Hypotheses

Hypotheses were originally presented in the Terms of Reference 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. In Year 1 we performed multiple linear regressions and dropped the focus on specific statistical outcomes, rather addressing the more relevant biological context of the results. Unfortunately, the inability to create a properly controlled, experimental design to this study severely limits any statistical inferences that can be drawn. Few herons were detected, one consequence of studying dynamic ecological systems, further highlighting the inadequacies of a strict hypothesis-driven approach.

As a result of the above limitations, we have proposed removing three management questions (MQs 2, 7 and 8). These management questions were also the ones that the following hypotheses related to:

H_1: The variation in the number of Great Blue Herons that roost on Waldie Island between November 15 and March 1 can be explained by the water elevation measured at the Norns Creek gauge on the lower Columbia River.

H_2: The variation in the number of Great Blue Herons foraging along the shoreline in the vicinity of Waldie Island between November 15 and March 1 can be explained by the water elevation measured at the Norns Creek gauge on the lower Columbia River.

H_3: The variation in the distance between Great Blue Herons that are foraging in a shoreline area (i.e., the number of herons foraging/site) in the vicinity of Waldie Island between November 15 and March 1 can be explained by the water elevation measured at the Norns Creek gauge on the lower Columbia River.

Given the proposal to shift focus away from heron counts we recommend eliminating these hypotheses altogether. Instead we propose to 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.

7.4 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 2013/14, and to a slightly lesser extent in 2012/13. While no definitive link has yet been made between water elevations and heron utilization of the Waldie Island area, given the apparent importance of Breakwater Island as a roosting location, and its susceptibility to inundation at elevations above 422 m, operations should continue to attempt to limit the elevation to the previously recommended level.

7.5 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 daily during the 2013/14 year 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 would likely receive objection from members of the community.
2. 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. This would also benefit the ducks and other wildlife that utilize this zone.
3. 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.
4. Heron disturbances have been noted by members of the community in response to fish surveys and boat traffic near Breakwater Island (W. Volovsek pers. comm.). Care should be taken to minimize fish surveys in this vicinity to the greatest extent possible during the heron over-wintering period.

8.0 ADDITIONAL REPORTING REQUIREMENTS

8.1 Data Deliverables

The following data deliverables have been or will be provided to BC Hydro to fulfill the Terms or Reference associated with CLBMON-49:

1.	Draft technical report	Submitted April 15, 2014
2.	Copies of notes, maps, photos	TBD
3.	Digital appendix (data)	TBD

8.1.1 Data Provided to BC Hydro

An MS Access or MS Excel database containing all 2013 through 2016 data will be provided to BC Hydro with the submission of the final report. This database conforms to the standards established by the B.C. Ministry of Environment for wildlife species inventories.

9.0 REFERENCES

BC Hydro. 2007. Columbia River project water use plan. BC Hydro Generation, Burnaby BC. 41 pp.

BC Hydro. 2012. Columbia River project water use plan. Monitoring program Terms of Reference. CLBMON-49: Lower Columbia River effects on wintering Great Blue Herons. Burnaby, BC. 21 pp.

Bowerman, B. L., and R. T. O'Connell. 1990. Linear Statistical Models. Second Edition. PWS-Kent Publishing.

Butler, R.W., P.E. Whitehead, A.M. Breault, and I.E. Moul. 1995. Colony effects on fledging success of Great Blue Herons (*Ardea herodias*) in British Columbia. Colonial Waterbirds 18:159-165.

Campbell, R.W., N.K. Dawe, I. McTaggart-Cowan, J. Cooper, G. Kaiser, and M.C.E. McNall. 1990. The Birds of British Columbia. Vol. 1. Non-passerines: loons through waterfowl. Royal British Columbia Museum, Victoria, BC.

(CABIN) Canadian Aquatic Biomonitoring Network. 2012. Field Manual: wadeable streams. Environment Canada, Ottawa, ON. 52 pp.

Chatterjee, S., A.S. Hadi and B. Price. 2000. Regression analysis by example, 3rd edition. John Wiley & Sons, Inc., New York

Crawley, M.J. 2007. The R Book. John Wiley & Sons, Inc.

Ford, D., D. Roscoe, J. Thorley, L. Hildebrand, and D. Schmidt. 2013. CLBMON-45 Lower Columbia River Fish Population Indexing Surveys – 2012 Investigations. Report prepared for BC Hydro Generations, Water LIcence Requirements, Castlegar, BC. Golder Report No. 1014920102-R-Rev0: 65 pp. + appendices.

Fox, J. and S. Weisberg. 2011. An R Companion to Applied Regression, Second Edition. Sage Publications.

Gebauer, M.B., and I.E. Moul. 2001. Status of the Great Blue Heron in British Columbia. Wildlife working report No. WR-102. Ministry of Environment, Lands and Parks, Wildlife Branch, Victoria, BC. 66 pp.

Hawkes, V.C. 2005. Distribution of Red-legged Frog (Rana aurora auora) breeding habitat in the Jordan River Watershed, Vancouver Island, British Columbia. LGL Project EA1667. Unpublished report by LGL Limited environmental research associates for BC Hydro Fish and Wildlife Bridge Coastal restoration Program, Burnaby BC. iv + 39 pp. + Appendices.

Hoenig, J.M. and D.M. Heisey. 2001. The abuse of power: the pervasive fallacy of power calculations for data analysis. The American Statistician 55: 1–6.

Machmer, M.M. 2002. Evaluation of fall and winter use of Waldie Island by Great Blue Herons. Unpubl. Report, BC Hydro, Burnaby, B.C. 27pp.

Machmer, M.M. 2003. Evaluation of fall and winter use of Waldie Island by Great Blue Herons: Final Report. Unpublished report. BC Hydro and Power Authority, Burnaby, BC. 21 pp + appendices.

Machmer, M.M. 2005. Great Blue Heron breeding inventory and stewardship in the Columbia Basin. Columbia Basin Fish & Wildlife Compensation Program, Nelson, BC. 24 pp + appendices.

Machmer, M.M. 2006. Great Blue Heron and Bald Eagle inventory and stewardship in the Columbia Basin (2005-2006). Columbia Basin Fish & Wildlife Compensation Program, Nelson, BC. 23 pp + appendices.

Machmer, M.M. 2007. Great Blue Heron and Bald Eagle inventory and stewardship in the Columbia Basin. Columbia Basin Fish & Wildlife Compensation Program, Nelson, BC. 29 pp + appendices.

Machmer, M.M. 2009. Great Blue Heron and Bald Eagle Inventory and Stewardship in the Columbia Basin (2008-2009). 2009. Columbia Basin Fish & Wildlife Compensation Program, Nelson, BC. 23 pp + appendices.

Machmer, M.M., and C. Steeger. 2003. Breeding inventory and habitat assessment of Great Blue Herons in the Columbia River Basin. Columbia Basin Fish & Wildlife Compensation Program, Nelson, BC. 21 pp + appendices.

Machmer, M.M., and C. Steeger. 2004. Great Blue Heron breeding inventory and habitat assessment in the Columbia Basin. Columbia Basin Fish & Wildlife Compensation Program, Nelson, BC. 24 pp + appendices.

MacKenzie, W., and J. Shaw. 2000. Wetland classification and habitats at risk in British Columbia. In: Proceedings of a conference on the biology and management of species and habitats at risk. Volume II, editor L.M. Darling, 537-47. Victoria, B.C.: B.C. Ministry of Environment, Lands, and Parks.

Nilsson, C. and K. Berggren. 2004. Alterations of riparian ecosystems caused by river regulation. BioScience 50:783–792.

R Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/.

(RISC) Resources Inventory Standards Committee. 1998a. Inventory methods for colonial-nesting freshwater birds: Eared Grebe, Red-necked Grebe, Western Grebe, American White Pelican, and Great Blue Heron. Standards for components of British Columbia's biodiversity No. 8. Version 2.0. Province of British Columbia, Resources Inventory Standards Committee, Victoria, B.C.

(RISC) Resources Inventory Standards Committee. 1998b. Guidelines for Interpreting Water Quality Data. Version 1.0. Province of British Columbia, Resources Inventory Standards Committee, Victoria, B.C.

Robin, X., N. Turck, A. Hainard, N. Tiberti, F. Lisacek, J.-C. Sanchez, and M. Müller. 2011. pROC: an open-source package for R and S+ to analyze and compare ROC curves. BMC Bioinformatics, 12:77.

Sokal, R.R. and F.J. Rohlf. 1995. Biometry. Third edition. W.H. Freeman and Company, New York. 850 pp.

Sutherland, W.J., I. Newton, and R.E. Green. 2004. Bird Ecology and Conservation: A Handbook of Techniques. Oxford University Press, Oxford. 386 pp.

Vennesland, R.G. and R.W. Butler. 2004. Factors influencing Great Blue Heron nesting productivity on the Pacific Coast of Canada from 1998 to 1999. Waterbirds 27:289-296.

Vennesland, R.G. and R.W. Butler. 2011. Great Blue Heron (Ardea herodias), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/025.

Wickham, H. 2009. ggplot2: elegant graphics for data analysis. Springer.