Variation in Harlequin Duck Distribution and Productivity: The Roles of Habitat, Competition, and Nutrient Acquisition

A Final Report to the
BC Hydro Bridge-Coastal Fish and Wildlife Restoration Program (BCRP)

for Fiscal Year 2003-04
(Year 1 of a 3-year project)

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

This project, led by Simon Fraser University's Centre for Wildlife Ecology, is designed to address, on a regional scale, the factors that influence harlequin duck distribution and productivity in the southern Coast Mountains. This research project supports the Bridge Coastal Fish and Wildlife Restoration Program mandate of habitat restoration by filling the information gaps that currently inhibit informed management. This work provides the scientific background necessary to understand how variation in habitat (including that related to hydroelectric operations and other human activity) affects harlequin ducks, and prescribe concrete mitigation or restoration activities that would improve harlequin duck productivity. A primary objective of the research is to develop models describing the relationship between harlequin duck distribution and habitat attributes (for example, stream gradient, width, substrate, vegetation, prey availability, fish presence, etc) at a regional scale. Once completed, this model will have predictive value for evaluating effects of development and restoration on harlequin ducks breeding on streams in the Coast Mountains. In addition to the broad-scale description of patterns in harlequin duck distribution and productivity, we are addressing 2 specific mechanisms that we consider critically important for understanding how breeding habitat (and changes to that habitat) influence harlequin duck productivity. These mechanisms address the premise that availability of invertebrate prey may have an important influence on harlequin duck habitat selection and productivity. The specific questions that we are addressing are: (1) does foraging on breeding streams constitute an important part of the energy and nutrients required for clutch formation? And (2) does fish abundance influence the availability of harlequin duck invertebrate prey (through either effects on invertebrate abundance or behavior)? Answers to these questions will provide insight into links between food, tropic interactions, and subsequent harlequin duck productivity.

This document reports on the progress for the first year of this three-year project. We describe the research approach and provide summaries of data collected to date. In brief, the project is progressing successfully, with a clear data collection process in place that has resulted in data quality and quantity that will be more than adequate for subsequent analysis and inference for harlequin duck habitat restoration and conservation.

INTRODUCTION

Harlequin ducks (*Histrionicus histrionicus*) are of conservation concern across the continent, as they are thought to be particularly sensitive to habitat degradation (Robertson and Goudie 1999, Smith et al. 1999). Like other sea ducks, harlequin ducks spend the nonbreeding portion of their annual cycle in nearshore coastal environments. Harlequin duck breeding habitat, however, is unusual, as they nest and raise broods along fast-flowing rivers and streams in mountainous terrain. Changes to the attributes of these breeding streams could affect harlequin duck productivity and, subsequently, population dynamics. We initiated this project to determine the attributes of breeding streams that correspond to harlequin duck density and productivity and, further, to explore the mechanisms by which variation in habitat affects the ducks. In turn, this information will lead to clear advice for conserving harlequin ducks, through recommendations for habitat restoration or mitigation and for placement of projects that could affect ducks.

There is evidence suggesting that constraints on harlequin duck populations are exerted on the breeding streams. A long-term program examining harlequin duck demography in the Strait of Georgia (led by the Canadian Wildlife Service and the Centre for Wildlife Ecology, SFU) concluded that recruitment was not compensating for annual adult mortality, and that productivity was likely too low to sustain populations (Smith et al. 2001, Rodway et al. 2003, Robertson and Goudie 1999). However, there have been only a small number of studies that have attempted to link harlequin duck distributions or productivity to habitat features (Bruner 1997, Rodway 1998, Wright et al. 2000, Hill and Wright 2000, Freeman and Goudie 2001). This project was intended to build upon these studies by considering habitat – duck relations on a regional scale and, also, by considering specific mechanisms by which habitat variation could affect productivity.

Hydroelectric development in the Bridge-Coastal region resulted in loss of harlequin duck habitat, through flooding of streams, and changes to harlequin duck habitat as a result of riparian vegetation and benthic invertebrate changes downstream from hydroelectric operations. Effective restoration of harlequin duck habitat requires a clear understanding of the habitat attributes that are positively related to harlequin duck abundance and productivity. We view this study as the first, important step in habitat restoration, that is, filling the information gaps that currently inhibit informed management. This work was designed to (1) describe, on a regional scale, the relationship between habitat attributes and harlequin duck distribution, abundance, and productivity, and (2) explore the mechanisms that explain observed variation. We think that this approach is critical for understanding both whether changes in habitat related to hydroelectric development affect harlequin ducks and how habitat change affects ducks.

To understand the relationship between habitat and harlequin duck distribution and productivity, we conducted surveys on each of the study streams. On each of the stream sections, we also documented a suite of habitat attributes. From these data, we will create a model that describes variation in harlequin duck densities based on habitat attributes. Similar approaches have been applied to the question of harlequin duck breeding distribution (e.g., Bruner 1997, Rodway 1998, Wright et al. 2000), including on breeding streams in British Columbia (Hill and Wright 2000, Freeman and Goudie 2001). However, most of these were conducted on a single watershed; as described above, we intend to create a region-wide, broadly applicable model that will be useful for drawing inference across a range of watersheds and habitat types.

In addition to the broad-scale description of patterns in harlequin duck distribution and productivity, we are addressing 2 specific mechanisms that we consider critically important for understanding how breeding habitat (and changes to that habitat) influence harlequin duck productivity. These mechanisms address the premise that availability of invertebrate prey may have an important influence on harlequin duck habitat selection and productivity. This premise is well-supported in the literature. For example, Gardarsson and Einarsson (1994) described close correlation between varying food supply and waterfowl populations. For harlequin ducks specifically, Bengston and Ulfstrand (1971) indicated effects of food availability on breeding propensity, and Rodway (1998) suggested that harlequin ducks were food-limited on breeding streams. The specific questions that we are addressing are: (1) does fish abundance influence the availability of harlequin duck invertebrate prey (through either effects on invertebrate abundance or behavior)? and (2) does foraging on breeding streams constitute an important part of the energy and nutrients required for clutch formation? Answers to these questions will provide insight into links between food, tropic interactions, and subsequent harlequin duck productivity.

Do fish affect suitability of stream habitats for breeding harlequin ducks? The roles of competition and indirect effects. Under a variety of ecological conditions, fish predation has been documented to have strong impacts on macroinvertebrate communities (Thorp 1986). Further, numerous studies have suggested that ducks and fish may compete for invertebrate resources (e.g., Eriksson 1979, Hunter et al. 1986, Giles et al. 1990). Also, high fish densities have been correlated with low waterfowl use of lake habitats (Giles 1994), although this has not been addressed for stream-breeding harlequin ducks.

This aspect of the proposed work examines the trophic interactions among fish, invertebrates, and harlequin ducks. Fish and invertebrate abundance will be considered as habitat attributes that may influence harlequin duck distribution and productivity. Also, we are documenting how fish abundance influences benthic invertebrates, either through direct consumption or through behavioral responses of invertebrates to fish abundance. In turn, this will lead to conclusions regarding how effects of hydroelectric development on fish may have indirect effects on harlequin ducks. Also, we will be able to infer how another anthropogenic habitat change, broad-scale fish introductions, may have contributed to harlequin duck population declines. Finally, we will determine how fish management could be modified as a method of harlequin duck habitat restoration.

This part of the study is using detailed observations of fish, invertebrate, and harlequin duck distributions to determine distributional relationships. Also, we are using experimental approaches to determine effects of fish and ducks, separately and additively, on benthic invertebrate abundance and behavior.

Is food on breeding streams an important source of nutrients and energy for clutch formation by harlequin ducks? Egg synthesis in birds involves production of yolk, albumen, and eggshell, which are derived from lipid, protein, and mineral macronutrients (Carey 1996). Energetic and nutritional costs of egg formation by waterfowl are high relative to most other birds (King 1973). Waterfowl clutches are comprised of numerous, large, energy-dense eggs and daily costs of egg synthesis can exceed 200% of the female's basal metabolic rate (Alisauskas and Ankney 1992). Waterfowl employ an array of strategies to meet high clutch formation costs, including storing and using endogenous nutrient reserves away from breeding areas, relying on food sources at breeding areas, or a combination of these approaches. There are a number of factors that influence the best strategy for acquiring egg nutrients, including the ability of hens to carry reserves during migration, food abundance and quality on nonbreeding and breeding areas, and other behavioral and physiological constraints. These issues have never been addressed for harlequin ducks. In this part of the project, we are documenting the relative contribution of breeding stream foods for meeting the nutritional and energetic demands of clutch formation. In turn, this will lend important insight into how, and at what life stages, breeding stream quality is important for harlequin duck productivity. Further, we will use this information to predict how changes in stream quality (related to hydroelectric development, fish introduction, or other anthropogenic influences) would result in changes to harlequin duck population health. Once we determine the importance of stream nutrients for egg formation, we can make conclusions about the efficacy of restoration activities designed to increase spring food.

This report summarizes the approach and findings from the first year of this three-year study. The project will continue with another season of field work in 2004, with a year of data analysis and write-up to follow, to fully explore the questions described above and provide concrete recommendations for restoration activities.

STUDY AREA

Because this project was designed to address, on a regional scale, the factors that influence harlequin duck distribution and productivity, the work has occurred within several of the watersheds that fall under the BCRP, including the Bridge, Seton, and Cheakamus Rivers. We also included several watersheds within the Bridge-Coastal Region that are not specifically listed under the BCRP, to allow contrast with streams that have not had hydroelectric development. These included Cayoosh Creek (which drains into the Seton River), the Yalakom River (which joins with the Bridge River), Rutherford Creek, Ryan River, and Birkenhead River. These represent a variety of habitat types and duck densities and allow broad inference.

METHODS

Duck Surveys and Habitat Attributes

The first part of the project, linking harlequin duck distribution and productivity data with habitat information, required duck surveys and detailed measurement of habitat attributes, as described below.

Pair Surveys:

On each of 7 streams (Bridge, Seton, Cheakamus, Yalakom, Cayoosh, Birkenhead, and Rutherford), sections roughly 5 km in length were selected based on access and contribution towards representation across a range of harlequin duck densities and habitat attributes (Table 1). Each of these were surveyed once during the pair arrival and laying period (30 April to 23 May) prior to freshet. Surveys were conducted following standard harlequin duck survey protocol outlined in the Provincial Resource Inventory Committee Standards. In brief, each survey team consisted of at least 2 observers, who hiked upstream adjacent to the stream channel and continuously scanned for birds with the aid of binoculars. Where thick riparian vegetation prohibited continuous viewing of the stream, observers attempted to access the stream every 50 to 100 m and scanned up- and down stream. Each observation was given a unique code, HD-“Creek”-“Year Number”-“Observation Number”. HD indicates that it was a harlequin duck observation, as opposed to a habitat station (see below). The creek was indicated by a 2-letter code, which is simply the first 2 letters of the stream name (see Table 1).

The year number is 1 for the first year (2003) of surveys and 2 for the second. For example, the first duck observation in 2003 on Cayoosh Creek was HD-CA-1-01. At each observation we recorded: the number of individuals, sex of each, band code if banded, and behaviour. Behaviour was described first as "in water" or "hauled out". Dominant behaviour was then described as: "feeding" or "other", which included any other behaviour such as resting, preening, courting, or alert/evasive. Exact locations of each bird location were mapped and GPSed. For all GPS applications, NAD 83 projection was used.

Brood Surveys:

Brood surveys followed the same protocol as pair surveys. Brood observations were coded as BR- "Creek"-"Year Number"-"Observation Number". Observations of single females without ducklings were coded as SF- "Creek"-"Year Number"-"Observation Number". At each observation, the number of hens, the number of ducklings, and the age class of ducklings (Class Ia, Ib, Ic, IIa, IIb, and III) were recorded. Age class designations followed those of Gollop and Marshall (1954), in which: Ia = totally down covered, Ib = down-covered but color fading, Ic = body elongating, IIa = first feathers on sides and tail, IIb = > half of body covered with feathers, IIc = small amount of down on back, and III = fully feathered but incapable of flight. Behavior was described in the same manner as for pair surveys. Exact locations of each bird location will be mapped and GPSed.

Habitat Measurements:

During pair surveys, we measured "time-sensitive" habitat attributes, that is, habitat features that change over time and hence measurement could not be deferred until later in the season. These were measured at systematically located points along each stretch of creek, starting with a randomly selected first point and then at every 500 m thereafter. These points were measured as linear distances from the start point or the last habitat station, using a GPS; we did not attempt to measure the 500 m as a stream distance, given logistical and technological constraints. Also, habitat attributes were measured at the location of each duck sighting. Habitat sites were given unique codes that parallel the structure of the duck observation codes; for random habitat sites, codes will start with SH (for "stream habitat"), then have the creek code, survey number, and observation number. For example, the third random habitat station on Cayoosh Creek during the first year of surveys was given the code SH-CA-1-03. Habitat measures at duck sites were given the duck observation code. Each habitat site consisted of a 20 m section of stream (10 m upstream and 10 m downstream of the habitat sampling point or the exact duck location). The time-sensitive habitat attributes that were measured during the pair survey season include: stream width, flow rate, water depth, water temperature, pH, substrate, slope, number of in-stream boulders, and invertebrate abundance. Also, the presence of gravel bars, islands, and nearby tributaries was noted in the comments section. Each of the sites for habitat measurements was GPSed and flagged to facilitate measurement of remaining (vegetation) habitat features later in the summer.

The habitat sampling methods that we used are described below; note that time sensitive attributes are indicated by an asterisk.

Invertebrate Abundance* – We sampled aquatic invertebrates from surface rocks at every other systematic habitat site, beginning at the second site, using a 5-rock technique. We started at the downstream end of the habitat site and worked upstream, to avoid disturbing insects before they have been sampled. Each sample consisted of gathering 5 fist-sized cobbles. An aquatic D-net was positioned downstream of each rock as it was picked up and the invertebrates on the surface of the cobble were removed into the net using a brush. Rock volume (+/- 25 mL) was estimated by water displacement in a graduated cylinder – each rock was measured individually and water volume was recorded both before and after the rock is submerged to facilitate later calculations. Invertebrates were extricated from the net and put into plastic sample containers with water. A total of 3 sampling sites per habitat site (at 10 m downstream of the station, at the station point, and at 10 m upstream) were completed, for a total of 15 rocks. Invertebrate samples were transferred into carefully labeled vials and preserved in a solution of 70% ethanol at the end of the day.

On a subset of streams with easy access and a homogenous stretch of habitat (Cayoosh, Yalakom, and Seton), we intensively sampled invertebrates to quantify sampling error associated with the 5-rock method. At each stream, 15 consecutive 5-rock samples were taken at 10 m intervals along a 150 m stretch of homogenous habitat. Label intensive sampling vials as IS-“Creek”-“Year Number”-“Sample Number”.

Flow type* **-** We estimated the areal proportion of the 20 m habitat sampling section that fell into the flow type categories to the nearest 5%. Flow types that were present but less than 5% were indicated by “trace” on the data sheet. Categories for flow type included: pool, which is still or nearly still water in a broadened area of the stream; glide, when the water is flowing, even quickly, but there is no surface turbulence; riffle, areas where whitewater occurs, through either flow over rocks or high volume passage through constrained areas; and cascade, which occurs in areas with > 4% gradient where water is rushing and tumbling through the channel.

Substrate size and composition* – We visually estimated areal percentage of each substrate type (bedrock, boulder, cobble, gravel, and sand) in 20 m stream sections centered at each random and duck site. Proportion of each substrate type was estimated to the nearest 5%.

Number of exposed boulders* - Number of exposed boulders, i.e., rocks that were not being topped with water at any time, were counted in the 20 m stream section centered on each random and duck site. Boulders were a minimum of 1 m apart to constitute a unique exposed boulder to avoid including clusters of closely situated rocks as separate boulders.

Stream width* – We visually estimated the wetted stream width to the nearest meter. We took 3 measures: 1 at the exact station point and 1 each at 10 m up- and downstream.

Stream depth* – We visually estimated the “maximum” and “mean” depth at each random and duck site to the nearest 1/10 of a meter. This was done as a transect across the stream at the station point and at the 10m points above and below the station.

Flow rate* **-** We measured stream velocity by timing the movement of a stick through a 10m section of stream, done 3 times to generate an average.

Temperature* **-** Temperature was measured once in each survey reach using a digital instream thermometer.

pH – pH was measured once in each survey reach using a digital instream pH meter.

Slope – This was measured with a clinometer from one end of the 20 m stream section to the other.

Vegetation Sampling - Vegetation was described for the 20 m habitat sampling segment. Measurements were taken for the stream bank opposite of the observers. We measured the maximum horizontal distance that overhanging vegetation extended over the stream bed. We defined overhanging vegetation as vegetation within 1.5 m above the stream surface that extended over the stream bed. We also estimated the mean overhand, as the mean horizontal distance that overhanging vegetation extended over the stream bed. We also recorded the linear extent of overhang, which was the length, to the nearest 0.5 m, of the shoreline (within the 20 m sampling section) that had overhanging vegetation. We measured woody debris in a manner similar to overhanging vegetation, with woody debris defined as logs and sticks that are partially in the water and break the water surface. We recorded the maximum horizontal distance that woody debris extended into the stream bed. We also estimated the mean horizontal distance that woody debris extended into the stream bed. Also, we recorded the length, to the nearest 0.5 m, of the shoreline that had woody debris. Finally, we measured vegetation cover, which incorporated both height and density attributes. At 3 different heights above the lower extent of vegetation, we described the linear distance, to the nearest 0.5 m, that is open, with open defined as allowing visibility beyond a plane extending vertically from the edge of the river channel. This was estimated for the band from 0 to 1 m above the point where vegetation first occurs (or the stream bed if no vegetation at all is present, such as on talus slopes), for the 1-5 m band, and for the 5-10 m band. Large boulders and steep banks that fell into the vertical plane were included in the cover estimate.

Duck Capture, Sampling, and Telemetry

To address the questions pertaining to nutrient acquisition and allocation to clutch formation by harlequin ducks, we needed to capture, handle, radio-mark and release females. We captured harlequin ducks on breeding streams from arrival through the egg-laying period, using an established and effective method of mist-netting. We used an 18m mist net with a mesh size of 127mm. On easily crossable stream sections, we set the net across the stream using two 3m conduit poles that were guyed out with cord. In areas where the stream was not crossable, we threw a rope from one side to the other where another crew member pulled the net across. Nets were set up above water and were usually upstream of targeted birds. Crew members herded the birds toward the net while others waited by the net and communicated with the herders by radio. Captured ducks were immediately removed from the net and placed in cloth bags until processing.

Mass was determined by placing each bird, restrained in a Velcro strap, on a digital scale and recording to the nearest 0.5 gram. All ducks were fitted with a USFWS stainless steel band on the right leg and a coded, colour tarsus band on the left leg. Morphometric measurements included exposed culmen length and diagonal tarsal length to the nearest 0.01mm, as well as wing chord (flattened and straightened), wing stub, and the length of the ninth primary to the nearest mm. Sex was determined by plumage characteristics and age class was estimated by the depth of the Bursa of Fabricius where bursas ≤ 3mm are after third year (ATY), bursas 4-10mm are third year (TY), and bursas >10mm are second year (SY) (Mather and Esler 1999).

We used newly-established, non-lethal methods for determining reproductive status of females. Concentrations of two main plasma yolk precursors, vitellogenin (VTG) and very low-density lipoprotein (VLDL) have been shown to vary predictably in relation to reproductive status (Vanderkist et al. 2000, Challenger et al. 2001). Therefore, we collected blood samples for subsequent yolk precursor analysis. A 2 ml blood sample was taken from the jugular vein of each female using a heparinized 5ml syringe with a 21-gauge needle. The blood was transfered into a labeled, sodium heparinized vial by removing the needle and slowly emptying the syringe, which prevented lysing of the red blood cells. Samples were stored in a cooler with an ice pack until we returned home at the end of the day. Then the plasma was separated from the red blood cells using a centrifuge and Hamilton syringe (rinsed with distilled water between samples). The plasma was stored in vials and frozen.

We also used stable isotope analysis of harlequin duck eggs to determine the relative contributions of resources from marine areas (where harlequin ducks winter) and breeding streams, following methods described by Hobson et al. (2000). To do this, we radio-marked captured females and follow radio signals to the nest. We also collected a subcutaneous lipid biopsy from the abdomen to determine isotope signatures of fat depots. Feathers on the belly were parted using isopropyl alcohol. The site was prepped with Betadine solution. Using forceps, the skin was lifted and a small (< 10 mm) incision in the skin was made with surgical scissors. A quantity of approximately 100mg of lipid in the region of the incision was removed with forceps. Any bleeding was stemmed with direct pressure with sterile gauze and the incision site was sealed with vet grade adhesive (VetBond). Each lipid sample was stored in a labeled snap-top vial and frozen. In order to make stable isotope comparisons, prey items were collected from both marine and freshwater habitats. These items were stored and frozen in vials until analysis.

Each female older than second year (>SY) had a radio transmitter attached on its back using a subcutaneous anchor. The transmitters, made by Holohil Systems Ltd, were the 6 gram RI-2B model with a mortality switch and a lifespan from 3 to 9 months. Prior to capture, the transmitter frequency and mortality switch were tested, and then immediately before attachment, the magnet was be removed. The transmitter was attached in the small depression between the scapulae, dorsal to the approximate junction of the cervical and thoracic vertebrae. The feathers were parted using isopropyl alcohol and the site was prepped with Betadine solution. The transmitter anchor was also cleaned with Betadine solution. The skin was pinched and lifted at the attachment site, and a sterile 18-gauge hypodermic needle was used to puncture the skin, without contacting the underlying muscle, nerves or blood vessels. The needle was removed and the anchor of the transmitter inserted into the hole made by the needle, and manipulated until the anchor was situated with the head of the arrow pointing forward and resting flat on the bird's back. Vetbond was used around the insertion site and to glue the top and bottom of the transmitter to the bird's feathers.

Radio-tagged birds were monitored weekly until August and we recorded hen survival, brood survival, number of ducklings, nesting success, hatch date, and movements.

Once the radio-tagged females began incubating, birds were tracked to their nests using handheld receivers and a three-element Yagi antenna and one egg was collected from each nest found. The horizontal and vertical distance from the water’s edge, the number of eggs and a site description were recorded. Egg buoyancy (sink, neutral, float) and floatation angle (horizontal, acute, obtuse, or vertical) were measured to determine the age of the egg. Also, candling of the eggs was conducted following the methods of Weller (1956). Egg floats and candling were used to estimate the hatch date. Each egg was boiled for easy separation and then frozen.

Fish, Duck, and Invertebrate Interactions

This part of the project was not implemented fully during the first year of the project, as the focus of the field work during year one was on the other project objectives. Also, the invertebrate sampling required methods development and testing.

This question will be addressed in part by comparing the broad distribution patterns of fish, invertebrates, and ducks across the different study streams. Some of these data (duck and invertebrate abundance) are generated by the survey and habitat protocol described above. Fish information will be gleaned from existing sources or from direct sampling in subsequent years.

Intensive invertebrate sampling and controlled experiments will be conducted during the second field season, and will be described in the year 2 final report.

RESULTS

Data Results

The results described in this section summarize the data collected during the first year of this three-year project. Full analysis will occur once all data from both years have been collected, entered, and checked for errors.

Duck Surveys and Habitat Attributes

We successfully completed surveys for harlequin ducks on 5 km stretches on each of the 7 study streams, which included (near Lillooet) the Bridge River, Seton River, Cayoosh Creek, and Yalakom River and (near Pemberton) the Cheakamus, Birkenhead, and Ryan Rivers. Associated with each survey were a set of habitat measurements, described in the methods section above.

Data for pair and brood surveys are summarized in Tables 2 and 3, respectively. We were successful in detecting a wide range of harlequin ducks densities during pair surveys (Table 2), which should lead to a powerful analysis of causes of that variation. We detected no broods during the brood survey period on our study reaches (Table 3). This season was not very good for harlequin duck productivity, a finding that was corroborated by the monitoring of radio-marked females.

Habitat data are summarized in Table 4. As with duck densities, habitat attributes varied considerably between and within study reaches. This should provide appropriate resolution for considering relationships between duck numbers and habitat features.

Duck Capture, Sampling, and Telemetry

Another important data collection task involved the capture, sampling, radio-marking, and monitoring of female harlequin ducks, in support of the objective addressing nutrient acquisition for clutch formation. We successfully captured and radio-marked 15 adult female harlequin ducks (Table 5) – the most ever radioed in a single breeding study. From each female, we took a blood sample for measuring serum yolk precursor levels, an indicator of their breeding status. We also took a small lipid biopsy from each, for stable isotope analysis to determine whether they build reserves on marine wintering areas or on freshwater breeding streams. Finally, we attached a small radio transmitter to each. Radioed hens were monitored weekly following marking. Nine were confirmed on nests, and a single egg was collected from each of the nests for stable isotope analysis. Also, for the nest on the Bridge River (Table 6), we collected the complete clutch after it was flooded by rain and abandoned. This will give us the opportunity to examine within-clutch variation in stable isotope signatures, to determine whether contribution of marine nutrients to eggs varies from the first through last eggs laid.

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<u>Performance Measures</u>

Because this is not a direct restoration activity, but rather a project that fills information gaps to help prescribe restoration, the performance measures described in the BCRP performance measures table (in terms of square meters of habitat restored) are not directly applicable. However, the results from this work will be useful for Impact Mitigation, Habitat Conservation, Maintenance or Restoration of Habitat, and Habitat Development categories for harlequin ducks. All of these require an understanding of the habitat features that enhance suitability for harlequin ducks and, also, would benefit from information linking variation in habitat with harlequin duck productivity. Of the habitats listed in the performance measures table, the following would be affected by application of our work: Instream Habitat (both main stem and tributaries), Riparian, Reservoir Shoreline Complex, and Riverine.

DISCUSSION

The goals for the first year of this three-year project were met with great success. We developed a plan for data collection that will answer the questions described in the proposal and executed the plan successfully. We are confident that the next 2 years of the project will proceed as successfully and that, by the end of the work, we will have results that lead to clear recommendations for restoration and conservation of harlequin duck populations on BCRP streams and beyond.

Along with the field data collection summarized above, there are other aspects of data generation that have been conducted. Laboratory analysis of yolk precursor concentrations in plasma of captured female harlequin ducks has been completed, and the preliminary results indicate that this method will be an extremely useful tool for determining reproductive status of individuals. Stable isotope analysis has been arranged and initiated with Dr. Keith Hobson of the Canadian Wildlife Service and University of Saskatchewan. Dr. Hobson is a leading expert in this field, and his collaboration will be a great benefit to the project. Invertebrate processing for the first field season has been completed, which required identification, sorting, drying, and weighing the large numbers of invertebrate samples. Also, we have conducted an evaluation of our 5-rock invertebrate sampling method, which will direct sampling protocol for subsequent invertebrate data collection.

We have engaged in a number of community interactions in relation to this project, as part of our Communications Plan. First, we have contacted all of the individuals and organizations that provided letters of support for the proposal, to let them know that the project was proceeding and to offer an opportunity for exchange of information. We also formally participated in several meetings. Dan Esler and Jeanine Bond attended a meeting arranged by the Lillooet Watershed Council on 14 April 2002 in Pemberton; the meeting was called to discuss Independent Power Producers and was heavily attended. Dan described the harlequin duck project and how the results would be relevant for risk assessment, mitigation, and restoration associated with IPPs. Also, on 15 April 2002, Dan and Jeanine met with the Lillooet Tribal Council in Lillooet to describe the project and discuss opportunities for collaboration and employment with the Cayoosh Creek Band. Also, Ron Ydenberg presented an invited presentation on harlequin duck breeding ecology at a BCRP luncheon on 10 April 2002. We also have described preliminary results from the project. We presented a seminar on 2 March 2003 at the Canadian Wildlife Service office in Delta, describing the project and elaborating on how the data would be useful in a management and restoration context. We also presented this information to the Lillooet Naturalists Association and the Lillooet Tribal Council on 15 April 2004. All of these presentations have explicitly noted the financial support of the BCRP and have displayed the BCRP logo (see Appendix B).

Another highlight of this project has been the participation of local members of the Lillooet Tribal Council, Cayoosh Creek Band, and Bridge River Band. We have received a great deal of interest in the work, as well as a strong interest in the employment opportunities associated with the project. We have hired several technicians locally and they have all proven to be enthusiastic and reliable help, which has contributed greatly to the success of the project.

RECOMMENDATIONS

Ecological research is, by necessity, a long-term endeavor. This project is no exception, and is designed to generate specific recommendations only after 2 years of intensive data collection and another of data analysis and interpretation. Thus, it would be premature to provide recommendations for harlequin duck restoration at this point in time. However, based on the data collected in year 1, we are confident that the project will result in clear recommendations for management of streams for the benefit of harlequin ducks.

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Table 1. Location of selected stream stretches.

Coast Mountain Harlequin Duck Study Project Reaches

Stream	Reach length (km)	Start desc.	Start GPS	Start alt(m)	End desc	End GPS	End alt(m)	Map
Seton R	4.22	Fraser R confluence	50 40 54.4 121 55 36.4	700	Seton Dam	50 40 10.2 121 58 38.6	225	92i/12
Bridge R	5.00	Yalakom R confluence	50 51' 48.4" 122 10 21.2	440	d/s of Yankee CK	50 49' 58.0" 122 11 53.6	475	92j/16
Yalakom R	5.28	Buck Ck	50 52 57.0 122 12 07.0	535	FSR Bridge	50 54 46.0 122 14 20.6	685	92j/16
Cayoosh Ck	5.24	trib. d/s of Downton Ck	50 36 13.6 122 06 11.2	655	u/s of Downton Ck	50 33 49.4 122 05 35.8	715	92j/9
Birkenhead R	5.25	Owl Ck	50 20 58.6 122 43 41.8	275	u/s of bailey bridge	50 23 03.2 122 42 25.0	335	92j/7
Ryan R	5.07	tributary confluence	50 27 06.8 123 05 19.0	685		50 27 37.0 123 08 40.0	715	92j/6
Cheakamus R-lower	5.27	highway pullout	49 56 14.4 123 10 01.6	300	highway bridge	49 58 33.8 123 08 39.0	360	92g/14

Harlequin Duck Densities – Spring

STREAM	NO. OF DUCKS	NO. OF PAIRS	REACH DISTANCE	DUCKS /KM	PAIRS /KM
CAYOOSH CREEK	6	3	5.24	1.15	0.57
YALAKOM RIVER	5	2	5.28	0.95	0.38
BRIDGE RIVER	0	0	5.00	0.00	0.00
SETON RIVER	8	3	4.22	1.90	0.71
BIRKENHEAD RIVER	2	1	5.25	0.38	0.19
CHEAKAMUS RIVER	10	2	5.27	1.90	0.38
RYAN RIVER	15	5	5.27	2.85	0.95

Table 2. Densities of harlequin ducks during pair surveys on study streams in the Coast Mountains.

Harlequin Duck Densities – Brood

STREAM	NO. OF DUCKS	NO. OF BROODS	REACH DISTANCE	DUCKS/KM	BROODS/KM
BIRKENHEAD RIVER	0	0	5.25	0	0
CAYOOSH CREEK	1	0	5.24	0.19	0
CHEAKAMUS RIVER	4	0	5.27	0.76	0
YALAKOM RIVER	0	0	5.28	0	0
RYAN RIVER	0	0	5.27	0	0
BRIDGE RIVER	1	0	5.00	0.20	0
SETON RIVER	0	0	4.22	0	0

Table 3. Densities of harlequin ducks during brood surveys on Coast Mountain study streams.

Harlequin Duck Capture Summary

STREAM	FEMALES	MALES	RADIOS ATTACHED
CAYOOSH CREEK	6	9	6
YALAKOM RIVER	1	1	1
BRIDGE RIVER	3	2	3
RYAN RIVER	2	3	2
RUTHERFORD RIVER	3	6	3
SETON RIVER	0	0	0
BIRKENHEAD RIVER	0	0	0
CHEAKAMUS RIVER	0	0	0
TOTAL	15	21	15

Table 5. Numbers of harlequin ducks captured and radioed during spring 2003 in the Coast Mountains. All radios were deployed on females.

Harlequin Duck Nest Summary

Nest	# of eggs	incubation initiation	Nest site	Nest fate	Number of Ducklings: Class 1A	Class 1C	Class 2B
Cayoosh Creek 1	5	May-24	cliff ledge	depredated	0		
Cayoosh Creek 2	5	May-27	island	successful	3	3	1
Bridge River	7	May-25	boulder in river	flooded by rain	0		
Yalakom River	5	May-19	island	flooded by river	0		
Rutherford River 1	5	May-26	island	successful	1	1	1
Rutherford River 2	6	Jun-15	root wad	successful	2	1	unk
Ryan River	7	Jun-02	island	unknown	0		
Ryan River Tributary	5	May-26	island	successful	unk		
Seton Lake	5	May-25	cliff ledge	successful	2	0	0

Table 6. Data for nests of radio-marked female harlequin ducks in the Coast Mountains.

Appendix A. Financial Report

Appendix B. Confirmation of BCRP Recognition

During all presentations of the project we have displayed the BCRP logo on the opening slide of our PowerPoint presentations (see attached) and explicitly noted that BCRP provides a portion of project funding.