Nesting habitat and diet studies of sandhill cranes (*Grus canadensis*) from the central and north coast of British Columbia

by

Krista Roessingh
BSc., University of Victoria, 2005
MSc., Pondicherry University, 2007

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of the Requirements for the Degree of

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in the Department of Geography

Supervisory Committee

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Dr. Dan Smith, (Department of Geography)
Co-Supervisor

Dr. Dennis Jelinski, (Department of Geography)
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Abstract

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The purpose of this study was to document the occurrence, habitat, and diet of sandhill cranes that breed in coastal British Columbia, a population believed to belong to the subspecies *rowani*. Specific objectives were to: 1) locate cranes and their nests in selected coastal areas of the central and north coasts (51°38'N, 128°05'W - 54°00'N, 130°37'W) and foster observer expertise in conducting aerial crane surveys; 2) describe sandhill crane nest habitat using a range of stand- and site-level characteristics; and, 3) identify diet content of breeding cranes from faecal samples. Helicopter surveys were conducted within 1.5 km of the coastline during May 2007 and 2008. Twenty nest sites were visited in 2008 to collect data on nest habitat characteristics. Satellite imagery was used to measure stand-level and landscape features for 29 nests. Faecal samples were collected at 6 nest and roost sites. During the 2008 survey, 104 cranes and 19 nests were counted over a 430 km^2 area (average survey effort = 2.0 km^2/min.). Crane nests were located in bog habitat, while cranes frequented bogs, shorelines, and marshes. Nests were in bog pools under 0.5 ha in size with the exception of one that occured in a 1.2 ha beaver-dammed pond (median = 0.10 ha, inter-quartile range (IQR) = 0.037 – 0.17 ha, *n* = 29), and had median water depth of 56 cm around nest islets (IQR = 49 – 77 cm, *n* = 21). Bog pools were in forest or woodland bog openings with median distance from the pool edge to the nearest treeline of 46 m (IQR – 24 – 160 m, *n* = 25) and median forest buffer width of 150 m (IQR = 93 – 260 m, *n* = 25). Forested habitat may serve as a corridor for cranes with pre-fledged young connecting bog nest and roost sites with shoreline foraging areas. Median distance from nest to shoreline was 400 m (IQR = 200 – 500 m, *n* = 28). Food items characteristic of faecal samples (*n* = 138) included mussel (*Mytilus edulis*), periwinkle (*Littorina littorea*) and limpet shells, insects, sedge (*Carex* spp.) and crowberry (*Empetrum nigrum*), plant remains, and crab remains. Changes in the probability of observing periwinkle and limpet in samples were observed between sites, while the frequency of occurrence of insects differed between time periods and that of sedge, crowberry, and mussels differed between time periods and sites. Sandhill cranes were sparsely distributed on inner and outer coastal islands with bog nesting habitat and sheltered intertidal foraging habitat.

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Acknowledgments

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Many thanks are owed to my committee members for their patience, frankness, and encouragement: to Briony Penn for getting the Crane Project off the ground and to Dan Smith for seeing me through. I am forever grateful for the ongoing support and patience of my family and friends.

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Dedication

This work is dedicated to unbounded wildness and wonder, and to the cautious, curious, and clever cranes whose cacophonous calls can be heard across islands and channels.

Photo: Krista Roessingh, May 2009.

Chapter 1: General Introduction

Sandhill cranes (*Grus canadensis*) are large wading birds in the family Gruidae that may live over 30 years in the wild (Figure 1). They are perennially monogamous, usually laying a single brood per year from which only one chick generally survives (Tacha et al. 1992). Sandhill cranes are among the oldest living birds, and have shown a high degree of natal philopatry (Walkinshaw 1949, Littlefield and Ivey 1995). They are opportunistic omnivores that feed on a wide variety of plants and animals, including grains and seeds, insects and other invertebrates, and small vertebrates (Tacha et al. 1992). They breed across North America, in northeastern Siberia, and in Cuba (Tacha et al. 1992).

Three subspecies of sandhill crane occur in British Columbia (B.C.): Lesser (*Grus canadensis canadensis*), Greater (*G.c. tabida*), and Canadian (*G.c. rowani*), the latter being of uncertain taxonomic status (Cooper 1996). Breeding distributions, population sizes, and migratory pathways within B.C. are poorly known for all subspecies (Cooper 1996). Cranes breeding on the B.C. coast are part of the Pacific Flyway Population (PFP) and may belong to *G.c. rowani* (Cooper 1996). Cranes belonging to this subspecies are thought to breed along the coast of Oregon, Washington, and B.C., as well as in scattered locations in the boreal forest from northern Alberta to northern Ontario, and possibly inland in northern B.C. (Littlefield and Ivey 2002). Some members of the coastal population winter in California's Central Valley with sandhill cranes of other subspecies migrating from the interior of B.C. and Alaska, while others winter in the Lower Columbia River region west of the Cascades in Oregon and Washington (Ivey et al. 2005).

In 1990 it was estimated that 3,500 cranes of all three subspecies migrated and potentially bred along the B.C. coast and southeast Alaska (Campbell et al. 1990). This estimate may have included up to 2,000 *G.c. canadensis* migrating to Alaska, and up to 1,500 *G.c. rowani* nesting along the B.C. coast. In the fall of 2002, 4,273 birds were counted on staging grounds on the Lower Columbia River, and may have represented the nesting population of coastal B.C. and southeast Alaska (Ivey et al. 2005). Ivey et al. (2005) recommended that coastal breeding *G.c. rowani* be managed as a separate population, due to differences in morphology and breeding distribution from *G.c. canadensis* and *G.c. tabida* in the PFP.

All subspecies were blue-listed (considered vulnerable) by the B.C. Conservation Data Centre (CDC) from 1998 to 2008, with the exception of the red-listed Georgia Depression population that reside in the lower mainland (B.C. CDC 2009). This designation was due to the paucity of information regarding their population status and lack of protection for their habitat throughout the province (Cooper 1996). The sandhill crane provincial species status ranking was changed to S4B (apparently secure) in January 2009 (B.C. CDC 2009).

Figure 1. Sandhill crane pair feeding in intertidal rockweed (*Fucus* spp.) on Cypress Island, near Bella Bella, B.C., 30 May 2007. Photo: Ingmar Lee.

There is a lack of information regarding location of breeding sites for this species, particularly in more remote and inaccessible areas along B.C.'s mid- and north coast regions. This largely intact region is under increasing pressure from an array of ecological threats, including industrial logging, oil and gas extraction, overfishing, aquaculture, mining, sport hunting, recreation activities, marine traffic and climate change (Paquet et al. 2004). Information regarding species abundance, nesting habitat, productivity, sensitivity to disturbance, diet, and distribution of foraging resources is required to inform more efficient management of the sandhill crane throughout its range in the province. Research needs identified in the “Status report on the sandhill crane in British Columbia” (Cooper 1996) and the Identified Wildlife Management Strategy (IWMS) for the sandhill crane (B.C. MWLAP 2004) include the determination of the impact of logging on breeding cranes in the Chilcotin-Cariboo-Coast region, and also of an appropriate forest buffer width to isolate nesting cranes from logging.

Prior to the present study there were no recent nest records for the central and north coasts of B.C., although there were scattered records from Haida Gwaii (Hearne and Hamel 2003, Preston and Campbell 2007) and northern Vancouver Island (Cooper 2006), and older records of sightings from the north and central coast (Campbell et al. 1990). The coastal islands and adjacent mainland coast, between the northeast of Vancouver Island and Alaska were identified as potential habitat for sandhill cranes, based on ecosystem classification and current knowledge of habitat preferences (B.C. MWLAP 2004).

Study Area

The study area (51°38’N, 128°05’W - 54°00’N, 130°37’W) is within the Hecate Lowlands Ecosection (HEL) of the Coastal Gap Ecoregion area. The following first nations hold traditional territory within this area: Heiltsuk, Kitasoo/Xaixais, Gitga'at, and Gitxaala First Nations, Port Simpson and Metlakatla bands of the Tsimshian First Nation.

The HEL is a narrow band of island archipelago and lowlands stretching 500 km (NW-SE) along the central and north coast of B.C., with rough, low topography, convoluted shorelines, and productive estuaries (Province of British Columbia 1996). The HEL is in the Coastal Western Hemlock zone, very wet hypermaritime subzone (CWHvh2) (Meidinger and Pojar 1991). The dominant vegetation of the hypermaritime coast is a mosaic of open, shrubby, and woodland bog types, also referred to as the blanket mire complex. This complex features vegetation that is distinct from muskeg or bog vegetation in interior and boreal regions (MacKenzie and Moran 2004). Poor drainage, infrequent disturbance, and a scarcity of glacial till are the main factors associated with the development of the blanket mire complex. Soils are developed from weathered bedrock, organic material, or colluvium. Bogs are highly acidic and offer low nutrient availability to vegetation (Banner et al. 2005). Many coastal islands feature productive forests on sloping terrain interspersed with less productive forests and wetlands on more level terrain (Banner et al. 2005). Other wetland types include fens, marshes, lakes, and estuarine marshes.

Average daily temperature at Boat Bluff, within the study area (52° 38.400'N; 128°31.200'W, elevation 11 m asl) from 1971-2000 ranged from 3.1°C (SD = 1.9°C) in January to 15.1°C (SD = 0.9°C) in August. Average monthly precipitation ranged from 166.7 mm in July to 689.2 mm in November. The driest and warmest months were June, July, and August. Average annual precipitation was 5028.9 mm, with snowfall making up 120.1 mm of the total (Environment Canada 2008).

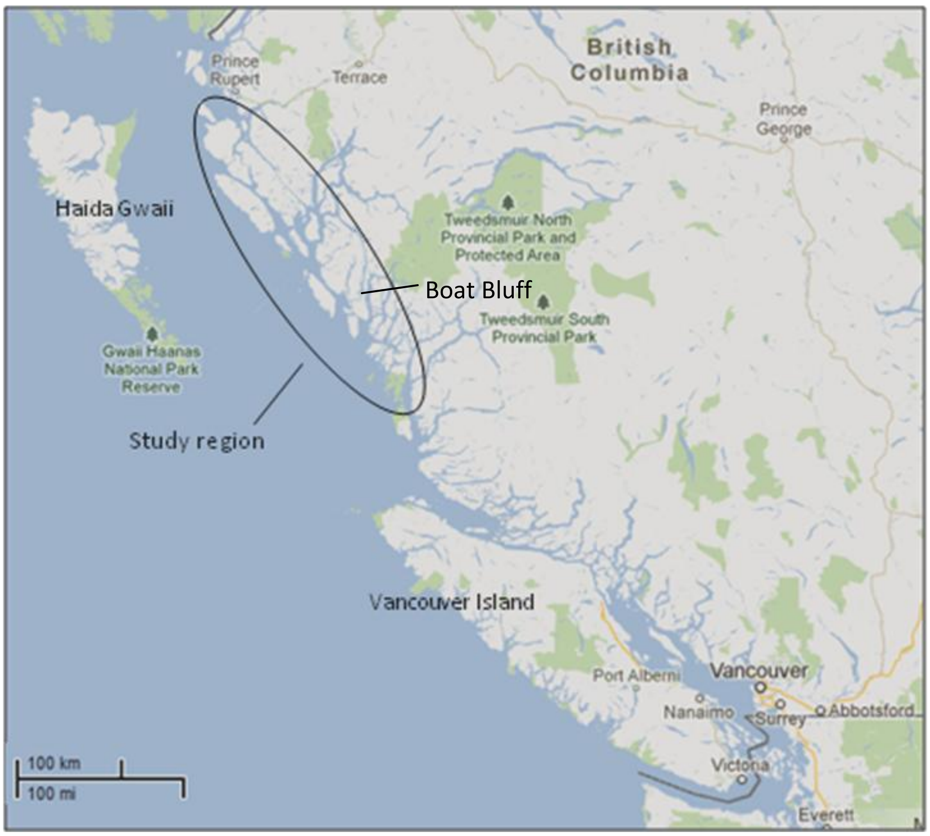

Figure 2. Map of western B.C. showing the study region. Base map from Google Maps (Google 2012).

Project background

A pilot study to establish the scope of a research project on sandhill cranes on the islands of the central coast was initiated in May 2006 by Dr. Briony Penn, with assistance from members of the Heiltsuk Nation. Observations and sightings suggested a pattern of habitat use by breeding pairs including: upland bogs used for nesting and roosting, estuaries and beaches used for daytime foraging, and old-growth fringe forest used for escape cover and sheltered access to nest areas from the shoreline (B. Penn, Raincoast Conservation Foundation, and J. Housty, Qqs Projects Society, unpublished report). Foraging of intertidal marine resources had not been recorded for sandhill cranes elsewhere.

Research goals and objectives

My research goals were to locate and describe sandhill crane nest habitat on the central and north coast of B.C., and to identify diet content of a sample of breeding cranes in the Bella Bella area using faecal analysis.

Specific objectives were to:

1) locate cranes and their nests in selected coastal areas between Hakai Pass, south of Bella Bella, and Prince Rupert;
2) describe sandhill crane nest habitat using a range of stand- and site-level characteristics including vegetation, site position with regard to important landscape features, nest pool size and depth, and nest construction, based on data collected in the field and analysis of satellite imagery;
3) collect faecal samples and identify diet content and differences in the diet of breeding cranes in the Bella Bella area over early-, mid-, and late-season periods in 2008.

The scope of this study includes nesting habitat at sites located while surveying the central coast islands between the Spider group at the south end of Hunter Island (51°50’N, 128°15’W) and the north end of Aristazabal Island (52°45’N, 129°17’W), as well as portions of Banks, Porcher, and McCauley islands on the north coast (Figure 3). The analysis was not intended as a predictive model of habitat selection, but rather to characterize crane nesting habitat more generally.

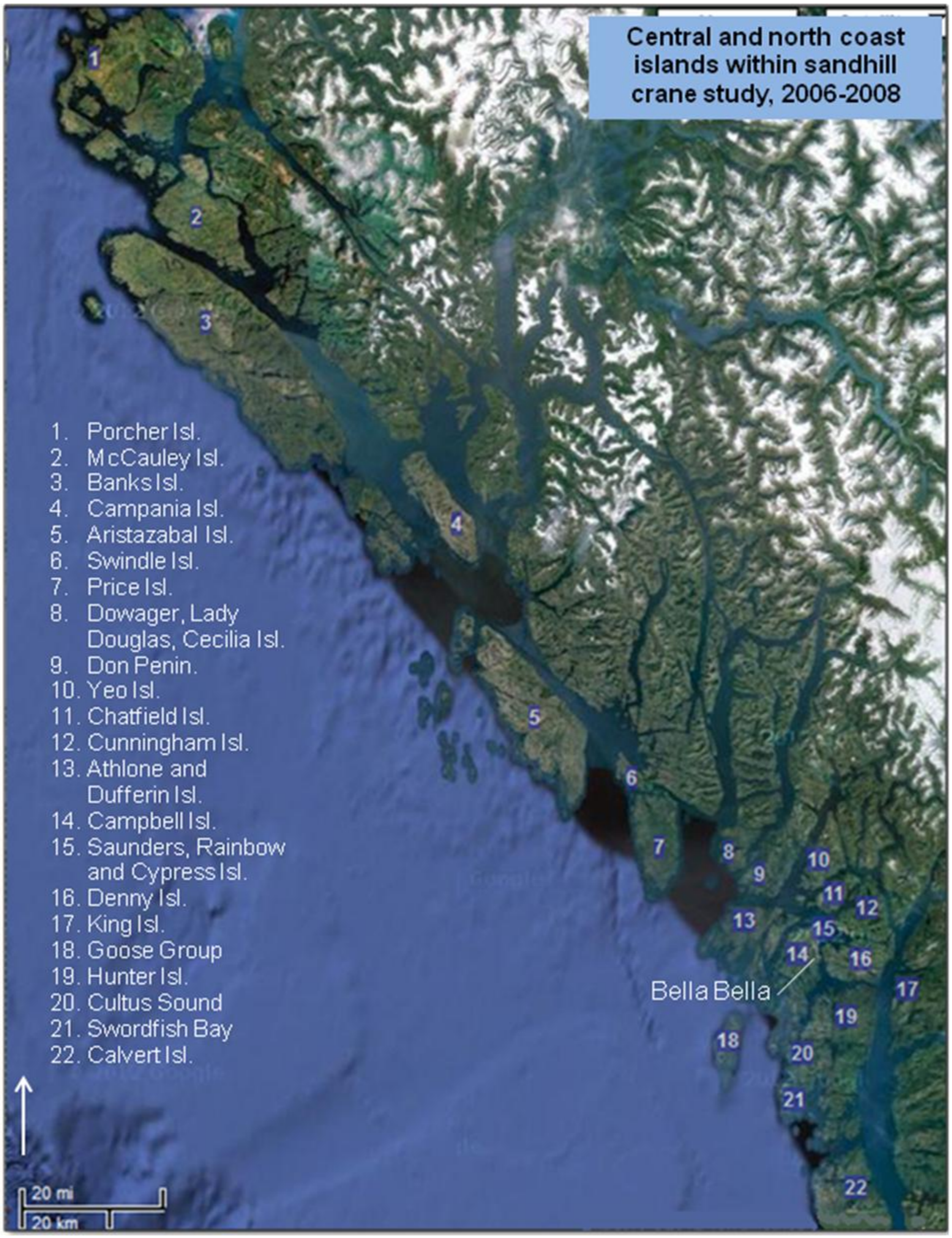

Figure 3. Map of central and north coast islands within sandhill crane study area, 2006-2008. Base map imagery: Terrametrics 2012. Map data: Google 2012.

Chapter 2: Literature Review

The following review provides an introduction to sandhill crane distribution, breeding habitat, and foraging ecology within the context of the coastal population. “The Status of the Sandhill Crane in British Columbia” by J. Cooper (1996) provides a comprehensive review of the literature and reports relating to all of British Columbia’s (B.C.) crane populations.

Distribution

There are 3 migratory subspecies of sandhill cranes (*G.c. canadensis*, *rowani*, and *tabida*), as well as three non-migratory subspecies (*G.c. pulla*, *pratensis,* and *nesiotes*). Migratory subspecies currently reside in 5 major populations across North America, while non-migratory subspecies reside in three smaller populations **(**Figure 3). There is some controversy over whether *G.c. rowani* should be designated as a separate subspecies, as recent genetic studies (Glenn et al. 2002, Petersen et al. 2003) and past morphometric studies (Tacha et al. 1985) differentiated only *G.c. tabida* and *G.c. canadensis*. These studies did not include cranes from the Pacific Flyway or from B.C., whereas studies of chick development (Baldwin 1976) and morphology (Johnson et al. 2005) that included cranes from coastal Alaska indicated that *G.c. rowani* were probably a separate subspecies. In addition, populations of *G.c. rowani* differ in migrational timing and pathways (Ivey et al. 2005, Petrula and Rothe 2005) and breeding distribution (Johnson et al. 2005) from *G.c. tabida* and *G.c. canadensis*. Most *G.c. canadensis* breed in the North American subarctic and arctic regions; *G.c. rowani* in parkland and boreal ecoregions of Alaska and Canada; and *G.c. tabida* in several regions of southernmost Canada and the United States (Johnson et al. 2005).

The species as a whole came close to extinction in the early 20th century due to hunting and loss of wetland habitat, but has recovered in most of its former range since the implementation of the Migratory Bird Treaty Act in 1918 (Walkinshaw 1973). Populations in the northern boreal forest and arctic were thought to have stabilized in the 1980s, while populations in eastern temperate regions of the U.S. and Canada were still expanding rapidly in the 1990s (Meine and Archibald 1996).

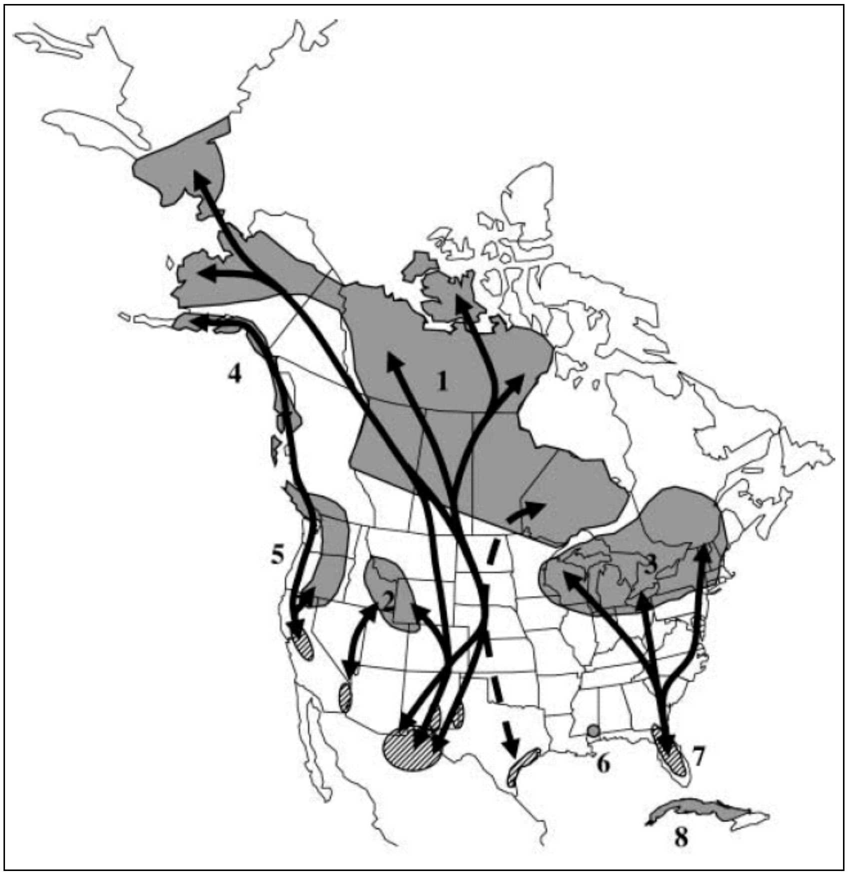

Figure 4. Migration and range map for the sandhill crane. Breeding (grey) and overwintering (hashed) ranges, as well as migratory paths are shown. Refer to Table 1 for the figure key. (Reprinted with permission from Jones et al. 2005).

Table 1. Subspecies, breeding and wintering locations for North American sandhill crane populations (reprinted with permission from Jones et al. 2005).

Population	Subspecies	Breeding location	Wintering location
1. Midcontinental population	*G.c. canadensis, G.c. rowani, G.c. tabida*	Eastern Siberia, Alaska, central Canada from the Canadian Rockies to Hudson Bay, and Minnesota	Texas Plains, New Mexico, Arizona, Mexico, and Gulf Coast of Texas
2. Rocky Mountain population	*G.c. tabida*	Colorado, Idaho, Montana, Utah, and Wyoming	New Mexico, Arizona, and Mexico
3. Eastern Flyway population	*G.c. tabida*	Great Lakes Region of the USA and southeastern Canada	Southern Georgia, and central Florida
4. Pacific Flyway population	*G.c. canadensis, G.c. rowani*	Coastal regions of southern Alaska and northern British Columbia	Central Valley of California
5. Central Valley population	*G.c. tabida*	British Columbia, Washington, Oregon, Nevada, and California	Central Valley of California
6. Mississippi Sandhill population	*G.c. pulla*	Mississippi Sandhill Crane National Wildlife Refuge	Nonmigratory
7. Florida Sandhill population	*G.c. pratensis*	South-central Georgia and central Florida	Nonmigratory
8. Cuban Sandhill population	*G.c. nesiotes*	Mainland Cuba and the Isla de la Juventud	Nonmigratory

In B.C. known breeding areas include much of the Central Interior, Haida Gwaii, the central mainland coast, Mara Meadows near Enderby, the East Kootenay Trench, Fort Nelson Lowland, the Fraser Lowland (Campbell et al. 1990), and northern Vancouver Island (Cooper 2006). *G.c. tabida* are thought to breed throughout most of the Interior. *G.c.* c*anadensis* occur in large numbers during migration to breeding grounds in Alaska, and may also breed in northeastern B.C. (Cooper 1996). *G.c. rowani* are thought to breed on the B.C. coast (Cooper 1996) and possibly in the central Interior and northeast of the province (Littlefield and Thompson 1979). Nesting cranes were likely extirpated from central Vancouver Island and parts of the lower mainland due to loss of habitat and disturbance during the 1930s and 1940s (Cooper 1996). Staging and wintering habitat in northwestern U.S. for this population has been significantly altered and diminished, and remains threatened due to increasing development pressure (Littlefield and Ivey 1999, 2002).

Breeding habitat

The three migratory subspecies breed in broadly differing regions and wetland types. *G.c. tabida* typically breed in bogs, fens, sedge meadows, cattail marshes, riparian areas, flooded meadows, beaver ponds, and other wetland types. *G.c. canadensis* breed mainly on the arctic lowland coasts, river deltas, and tundra, utilizing bogs, shallow lakes, riparian marshes, and seasonal ponds. *G.c. rowani*, the subspecies thought to occur on the central and north coast of B.C., nest in shallow muskeg and boreal wetlands including open and forested bogs (Walkinshaw 1973, Drewien and Bizeau 1974, Johnsgard 1983).

Throughout most of the species' range, nest sites are characterized by the presence of standing water with emergent aquatic vegetation (Tacha et al. 1992). Known breeding habitats in B.C. include isolated bogs, fens, other wetland types and meadows from near sea level to 1,220 m asl (Campbell et al. 1990). A habitat suitability index developed for *G.c. tabida* described the primary components of its breeding habitat as the nest site, roosting area, foraging sites, and some degree of isolation from human activities (Armbruster 1987).

G.c. tabida are known to exhibit strong fidelity to their breeding territory (Walkinshaw 1949, Drewien 1973), and strong natal philopatry (Walkinshaw 1949, Littlefield 1968, Drewien 1973, Littlefield and Ivey 1995, Nesbitt et al. 2002). Local movements, the period of occupancy on defended territory (Drewien 1973), and nest density (Armbruster 1987) are affected by food availability. For example, in large productive wetlands at Grays Lake in Idaho, sandhill crane territories and home ranges of non-flying chicks averaged 17 ha, and nesting pair density was 2 pairs/km^2 (Drewien 1973, Armbruster 1987). At the other extreme, bog nesting cranes in the Upper Peninsula of Michigan foraged in forest openings within a 3 km radius of the nest site (Taylor 1976). Marsh nesting cranes in the Lower Peninsula had average territories of 53 ha (Walkinshaw 1973). *G.c. canadensis* in arctic Canada nest in muskeg areas, and on grass-covered sand dunes (Walkinshaw 1973). Wet marshes of the heath-marsh mosaic tundra and sedge-grass meadows were used for nesting on the Yukon-Kuskokwim Delta, with nest densities ranging from 0.54 to 0.74 nests/km^2 (Boise 1977).

Breeding populations are limited by the availability of undisturbed wetland habitat, water level fluctuations, and predation (Safina 1993)**.** Nest success may vary between years due to nest initiation date, weather, water depth, changes in habitat, and predation. Typical predators in the continental US include coyote (*Canis latrans*), racoon (*Procyon lotor*), and Common raven (*Corvus corax*) (Littlefield and Ivey 2002, Ivey 2007). Several studies of nesting cranes have shown positive correlations between nest success, greater water depth, and vegetation height at the nest (Littlefield and Paullin 1990, Urbanek and Bookhout 1992, Littlefield 2001), while others have found water depth, but not concealment (associated with vegetation height), to influence nest success (Austin et al. 2007, Ivey 2007).

Studies of breeding habitat selection for sandhill cranes have shown that potential predictor variables include vegetation communities (composition and structure), water depth at the nest, prey availability, land use, topography, and climate (Baker et al. 1995, Littlefield 1995, Maxson and Riggs 1996). Water depth, or proximity to water, which provides security from predators, may determine nest site selection more than vegetation type or wetland size (Armbruster 1987).

In a multi-scale study of crane breeding habitat selection based on vegetation cover types at Seney National Wildlife Refuge in Michigan, Baker et al. (1995) found that cranes selected nest sites in or near seasonally flooded emergent (non-woody) wetlands but avoided forested uplands. There was no habitat selection at distances beyond 200 m from a nest, other than avoidance of unsuitable habitat (forest or open water). Maxson and Riggs (1996) studied nest habitat selection and nest success in northwestern Minnesota using 15 habitat characteristics. The authors found that nest sites had higher sedge stem density and concealment than randomly selected sites, and nests in water >9.7 cm deep were 3.7 times less likely to suffer predation than those in shallower water. Littlefield (1995) also found that nest site selection was linked to nest success in a long-term study at Malheur National Wildlife Refuge, Oregon. In the Malheur study, egg predators varied with concealment: compared with well-concealed nests, ravens destroyed more poorly-concealed nests, coyotes took more poorly- and fairly-concealed nests, and raccoons did not differentiate.

Foraging ecology

Sandhill cranes primarily forage on land, feeding on items visible from the soil surface, but also from the sub-surface which they probe with their bills (Walkinshaw 1949, 1973). As omnivorous food generalists, they feed on waste grains, insects and other invertebrates, and small vertebrates (Johnsgard 1983). Wild flightless chicks feed principally on insects and other protein-yielding foods during their early stages of high growth. By the start of migration young colts have been observed to share the same diet as adults (Johnsgard 1983).

In B.C., foraging and roosting habitat is known to include margins of lakes, marshes, swamps, bogs, ponds, meadows, estuarine marshes, and intertidal areas as well as dry uplands (Campbell et al. 1990). Sandhill cranes have used coastal habitat in the wet coastal tundra on the western shore of Hudson Bay, and on the Aransas National Wildlife Refuge (ANWR) on the Texas Gulf Coast (Harvey et al. 1968, Tacha et al. 1986). Sandhill cranes at ANWR roosted in a tidally-influenced lake (Tacha et al. 1986), but foraged in upland croplands and some natural habitats (Hunt and Slack 1989). Wolfberry fruit (*Lycium caroliniamum*, high in ascorbic acid), acorns from Southern live oak (*Quercus virginiana*, high in iron, calcium, and essential amino acids) (USDA 1978), and insects were the most important foods by volume and frequency in fecal samples collected over two winters (1983-1984). Eight foods were identified in total (Hunt and Slack 1989).

Most studies of sandhill crane diets have taken place during wintering or staging periods, rather than during the breeding season (i.e. Iverson et al. 1985, Reinecke and Krapu 1986, Tacha et al. 1986, Hunt and Slack 1989, Sparling and Krapu 1994). These studies employed time-budget analysis (Sparling and Krapu 1994), collection and examination of crane specimens (Iverson et al. 1982, Tacha et al. 1986, Ballard and Thompson 2000), estimates of grain removal by cranes (Iverson et al. 1985), as well as faecal analysis (Hunt and Slack 1989). Faecal analysis has been used in studies of whooping cranes as a non-invasive method to accurately describe diet content (i.e. Hunt and Slack 1989, Westwood and Chavez-Ramirez 2005).

The diet of sandhill cranes during summer varies among populations and locations. Diets of *G.c. tabida* at Grays Lake, Idaho, contained 73% plant material and

27% insects and earthworms, including timothy corms (*Phleum pratense*), short-horned grasshoppers, and fly larvae (Mullins and Bizeau 1978). *G.c. canadensis* nesting on Banks Island, Nunavut, inhabited sand dunes and dry tundra next to lakes, ponds, and rivers. Cranes and their young were observed feeding on fish remains, lemmings, lichens and old-growth vegetation, and scraps of snow geese (*Chen caerulescens*) and squirrels at the entrance of a fox den. In August they were observed feeding on large numbers of crowberries (*Empetrum nigrum*), bilberry (*Vaccinium uliginosum*), and mountain cranberry (*Vaccinium vitis-idaea*) (Reed 1988). Near Hudson Bay, summering cranes were reported eating the eggs of snow goose (Harvey et al. 1968). Released Florida sandhill cranes fed on plant material and insects ($\bar{x}$ = 80.9% and 19.1% of faecal sample volume, respectively), including subsurface bulbs, roots, grass tubers, and pine seeds. They also fed opportunistically on small mammals, crustaceans, and amphibians (Rucker 1992). Marsh nesting cranes were reported to eat a wide variety of foods, including snails, crayfish, birds, frogs, snakes, toads, insects, roots, and browsed vegetation (Walkinshaw 1973).

Conservation

Sandhill crane populations are limited by low annual recruitment rates and habitat availability throughout their range (Tacha et al. 1992). Factors that limit cranes in other regions and may affect populations in B.C. include predation of young birds, habitat loss, hunting mortalities, accidental collisions with power lines, and human disturbance (Littlefield 1995, Cooper 1996, Pacific Flyway Council 1997). Winter and staging habitat of sandhill cranes that summer in coastal B.C. and southeast Alaska has been impacted by wetland conversion to agriculture and other land use changes, and continues to be threatened by various forms of development. Privately-owned crane habitat in the Lower Columbia River region is under significant threat of loss to incompatible agricultural uses such as tree nurseries and berries, and to hard development (Littlefield and Ivey 2002). This region is the only major staging area between northern breeding grounds and wintering areas in California (Ivey et al. 2005). Crane wintering habitat in the Central Valley of California has been lost to urban expansion and crops such as orchards and vineyards (Littlefield and Ivey 1999).

Sandhill cranes, their nests and eggs are protected in Canada and the United States under the federal Migratory Birds Convention Act of 1994 and in B.C. under the British Columbia Wildlife Act of 1996. All subspecies were provincially ranked as vulnerable (S3S4) in B.C. until January 2009 (B.C. CDC 2009). Cooper (1996) recommended that sandhill cranes should be listed as vulnerable in B.C. because of incertitude regarding their population status, the small (though unknown) overall numbers of breeding pairs for each population, the threat of logging in the habitat of the core population of *G.c. tabida* in the Chilcotin-Cariboo, and the general scarcity of protected crane habitat in the province. In 2009, the provincial ranking changed to apparently secure (S4) although the number of occurrences recorded by B.C.'s CDC is still low (35, with 1-12 occurrences appropriately protected [B.C. CDC 2012]) and there is still no population-level data available. Breeding Bird Surveys showed a significant rise in sandhill crane numbers in B.C. from 1970-2009 (24%; 23 routes; $P < 0.05$) although the rate of rise was 0.3 % per annum from 1999-2009 (Canadian Widlife Service 2008). Analysis of breeding bird surveys across North America showed an increase of 5% per year ($P = 0.00$) from 1980-2007 (Sauer et al. 2008).

The B.C. Ministry of Environment established an Identified Wildlife Management Strategy (IWMS) for sandhill cranes, under the requirements of the Province's *Forest and Range Practices Act*, which provided management guidelines with respect to forest and range activities that may negatively affect the species and critical crane habitat (B.C. MWLAP 2004). Under the IWMS, Wildlife Habitat Areas (WHAs) could be established to protect critical habitat for listed species from logging and range activities. As the province has removed sandhill cranes from the category of Species at Risk, the IWMS no longer applies.

Chapter 3: Sandhill cranes of coastal British Columbia: Results of aerial surveys and preliminary observations of habitat use

Introduction

Three subspecies of sandhill crane occur in British Columbia (B.C.): Lesser (*Grus canadensis canadensis*), Canadian (*G.c. rowani*), and Greater (*G.c. tabida*). Breeding distributions, population sizes, and migration pathways are poorly known for all subspecies in the province (Cooper 1996). Cranes summering on the B.C. and central Alaskan coasts are thought to belong to *G.c. rowani*, which generally breed in parkland and boreal parkland ecoregions of Canada and Alaska (Herter 1982, Pogson and Lindstedt 1991, Cooper 1996, Ivey et al. 2005, Johnson et al. 2005).

All subspecies were blue-listed (considered vulnerable) in B.C. by the B.C. Conservation Data Centre (B.C. CDC) from 1998 to 2009, with the exception of the red-listed Georgia Depression population residing in the lower mainland (B.C. CDC 2009). This designation was due mainly to the paucity of information regarding their population status and lack of protection for their habitat throughout the province (Cooper 1996).

In 1990 it was estimated that 3,500 sandhill cranes migrate and potentially breed along the B.C. coast (Campbell et al. 1990). They form part of the Pacific Flyway Population of sandhill cranes, which numbers approximately 25,000 birds. The majority of this population is made up of *G.c. canadensis* that summer in southern Alaska and winter in the Central Valley of California (Tacha et al. 1992). Cranes marked with platform transmitter terminals (PTTs) (reported as *G.c. rowani* from morphometric measurements) that summered on the B.C. and southern Alaskan coasts in 2002 used staging grounds in the Lower Columbia River region west of the Cascades in Oregon and Washington in spring and fall of that year. One marked crane continued on to winter in California's Central Valley with sandhill cranes of other subspecies from interior B.C. and Alaska (Ivey et al. 2005). Ivey et al. (2005) recommended that coastal breeding *G.c. rowani* be managed as a separate population, due to differences in morphology and breeding distribution from *G.c. canadensis* and *G.c. tabida*. Up to 4,273 birds counted in the fall of 2002 on staging grounds on the Lower Columbia River may have represented the breeding population of coastal B.C. and southeast Alaska at that time (Littlefield and Ivey 2002, Ivey et al. 2005).

The coastal islands and adjacent mainland coast between the northeast of Vancouver Island and Alaska have been identified as potential habitat for sandhill cranes, based on ecosystem classification and current knowledge of habitat preferences (B.C. MWLAP 2004). Prior to this study there were no recent nest records for the central and north coasts of B.C., although there were scattered records from Haida Gwaii, an archipelago separated from the central and north mainland coasts by a wide strait, and from northern Vancouver Island (Hearne and Hamel 2003, Cooper 2006, B.C. CDC 2009).

At the time of this study, the central and north coast regions were the focus of extensive planning under the Central Coast and North Coast Land and Resource Management Plans and other regional planning efforts. There remains a need for information on the distribution and habitat requirements of sandhill cranes, in order for these to be considered in management planning for both protected and unprotected areas.

A pilot study to establish the scope of a research project on sandhill cranes on the central coast was initiated in May 2006. The purpose of the pilot study was to determine the feasibility and research goals of a multi-year study, and consisted of gathering local knowledge, conducting boat and helicopter surveys, and observations from blinds (B. Penn, Raincoast Conservation Foundation, and J. Housty, Qqs Projects Society, unpublished report).

Helicopter surveys were repeated in May of 2007 and 2008, with new survey areas covered on the north coast in 2008. Sighting locations on the central coast were checked by boat or on foot to confirm suspected use sites in both years. The objectives of these surveys were to locate cranes and their nests, to observe habitat use in their summer range, and to foster observer expertise in the coastal environment (Roessingh and Penn 2010).

Methods

Study area

Refer to Chapter 1. A general map of survey areas for all years is shown in Figure 5.

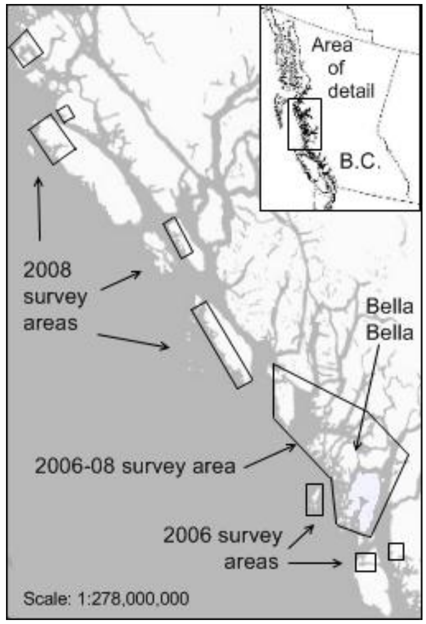

Figure 5. Overview of sandhill crane helicopter survey areas (outlined) on B.C.'s north and central coast. Base map: Mapsof.net, 2009.

Surveys

Interviews were conducted with residents of Bella Bella and neighbouring Denny Island over a 3-day period in May 2006 to identify possible crane locales on the central coast. These locales were marked on laminated 1:50,000 NTS topographic maps, which were used to record helicopter survey areas in lieu of aerial photos. Most aerial photography for the north and central coasts was at a 1:60,000 scale and dated from the early 1980s or earlier, and there is no land cover mapping available for this area.

Helicopter surveys were used to locate sandhill cranes and their nests between 13 and 18 May 2006. Initially, searchers travelled to reported crane locales and surveyed shorelines and estuaries. If cranes were spotted, the helicopter landed and the upland bog and forest were surveyed on foot for evidence of cranes. Sites where cranes were located in 2006 were rechecked from 14 to 17 May 2007, and shorelines and upland bogs located within 0.5-1.5 km of the shore in other areas of the outer central coast were surveyed. As only 2 nests were seen from the air, sightings within a 25 km radius of Bella Bella were visited by boat and on foot to check for evidence of nests, roost sites and foraging areas following the nesting period in 2007. Locations of cranes, tracks, and droppings were recorded with a handheld Global Positioning System (GPS), and vegetation and other site characteristics were noted. Crane behaviour and habitat were documented using video, still photography and written notes.

Crane locales identified on the outer central coast in previous years were rechecked by helicopter from 15 to 21 May 2008. The survey area was expanded to include locales with habitat associations observed during previous surveys and new reports of crane sightings from locals and mariners. New areas included the west coast of Price Island, portions of the west coast of Campania and Aristazabal islands (mainly around bays and inlets), Kingkown Inlet and lagoons on the north end of Banks Island, McCauley Island in the region where a platform transmitter terminal (PTT) marked crane summered in 2002 (G. Ivey, personal communication 2008), and the southwest corner of Porcher Island (Figures 8-10). Satellite imagery (SPOT 5 and GoogleEarth), shoreline typing maps (shoreline type units from the B.C. Ministry of Energy and Mines and estuaries from Pacific Estuary Conservation Program 2004) and topographic maps were examined to locate estuaries with bog pools nearby. More time was spent surveying upland wetlands than shorelines compared with previous surveys as the principle objective was to locate nests and roost sites. In 2008, weekly visits on foot to 4 nests with 2 eggs each were made in the Bella Bella area during May and early June to ascertain approximate hatching dates.

An R-44 helicopter was used for surveys in all years. Flights were based out of Shearwater on Denny Island for central coast surveys and out of Prince Rupert for north coast surveys. Reconnaissance surveys were flown at 100-200 m asl elevation, whereas shoreline and bog surveys were flown at 35-50 m at speeds between 55-65 km/hr. Searchers flew along shorelines at approximately 100 m elevation, descended to 50 m at estuaries and inlets, and circled over nearby upland wetlands. Circling at low altutitude over known sites allowed close to full coverage, a technique used in other aerial surveys to locate nesting cranes (Johns 2011).

Surveys were carried out at mid to low tide levels, and between 0900 hours and 1730 hours to avoid low solar angles that reduced visibility. Cranes were observed in situ or when flushed. When a crane was sighted during 2007 and 2008 surveys, the helicopter would circle once to check for a nest (if necessary), record the location using the helicopter's GPS, and then leave the area. Video and still photographs of habitat were taken. Three or 4 people were present in the helicopter at all times during surveys to improve detection and to assist with recording and navigation. Permissions were obtained from all of the First Nations councils on whose territories we planned to visit prior to commencing surveys in all years.

Analysis

The area of low altitude surveys for each year was calculated using polygon measure tools in ArcGIS (higher altitude transects were not included since cranes were not sighted). Average survey effort for each year was estimated by dividing the total time by the total low altitude survey area. Numbers of nests, sightings, and cranes were tabulated according to bog, marsh, or shoreline habitat type for each year. The average number of cranes sighted per square kilometre was calculated for each year's surveys. The average density of nests sighted was calculated only for 2008, since low nest sighting numbers in previous years were due to observer inexperience. Nest and crane densities based on sightings are not estimates of actual densities because methods for estimating visibility bias were not employed.

Results

The total number of cranes sighted in each year of helicopter surveys was 18, 56, and 104, respectively. The number of nests found was 0, 3, and 19 (Appendix B). The total low altitude survey effort in 2006 was 180 km^2 over 12 hours (4.0 min/km^2), 260 km^2 over 10.5 hours (2.4 min/km^2) in 2007, and 430 km^2 over 13.5 hours (2.0 min/km^2) in 2008. The observed (not adjusted for error) density of cranes and nests over the survey area in 2008 was 0.24 $cranes/km^2$ and 0.044 $nests/km^2$. In 2007, 9 of the 13 bog sightings of cranes recorded during aerial surveys were surveyed on foot from June to August, after the nesting period. Cranes were also tracked by foot from beach, bog or forest sightings on 10 islands in the vicinity of Bella Bella. In total 15 (vacated) nests were located and cranes were found on 45 occasions during foot or boat searches (Figure 6; Appendix C). Of these sightings, 21 were on rocky shores, 13 were on pebble beaches, 5 were in bogs, 4 were in estuaries, and 2 were on mud beaches. Rocky shores and pebble beaches featured abundant cover of rockweeds (*Fucus* spp.) in the intertidal zone, and typically a band of sedge (*Carex* spp.) along the supratidal zone. Cranes were observed feeding on mussels (*Mytilus edulis*) and periwinkle snails (*Littorina littorea*) in the intertidal zone. Estuary foraging habitat was salt marsh with abundant sedges and Pacific silverweed (*Potentilla anserina pacifica*), and mudflats merging with rockweed-covered rocky shores or pebble beaches.

Maps of crane and nest sightings from 2008 helicopter surveys are shown in Figures 7-9. Sightings during 2008 surveys were of single cranes on a nest or in bog habitat in 35 of all 65 sightings, while one third of all cranes sighted were in pairs but not at a nest. Groupings of more than 2 cranes occurred only at 3 locations (all on shorelines), and accounted for 22 out of the total 104 cranes sighted.

Bogs where cranes or evidence of crane use (droppings, feathers, and tracks) were found on foot had pools under 1 ha in size, 0.25-1.25 m deep with 0.15-0.75 m of mud and decomposing plant material under the water surface, and islets of moss where nests and roosts were located. Two nests were found on islets in beaver-made lakes over 1 ha in area. Nests were made of a single layer or layers of twigs laid on a moss surface with the exception of 2 nests that were several layers deep.

Nine of the nest sites active in 2007 were rechecked in May 2008. Only 2 of these were active in 2008. However, 3 nests were found within the same wetland complex (within 300 m) as the 2007 sites, and one nest was 1 km away from a 2007 nest site.

Of the 4 nests that were monitored for hatched eggs, 3 were vacant in the last week of May and one nest was vacant in the second week of June leaving one egg behind. Eggshell fragments were found in all nests and chicks were later seen near to all 4 sites.

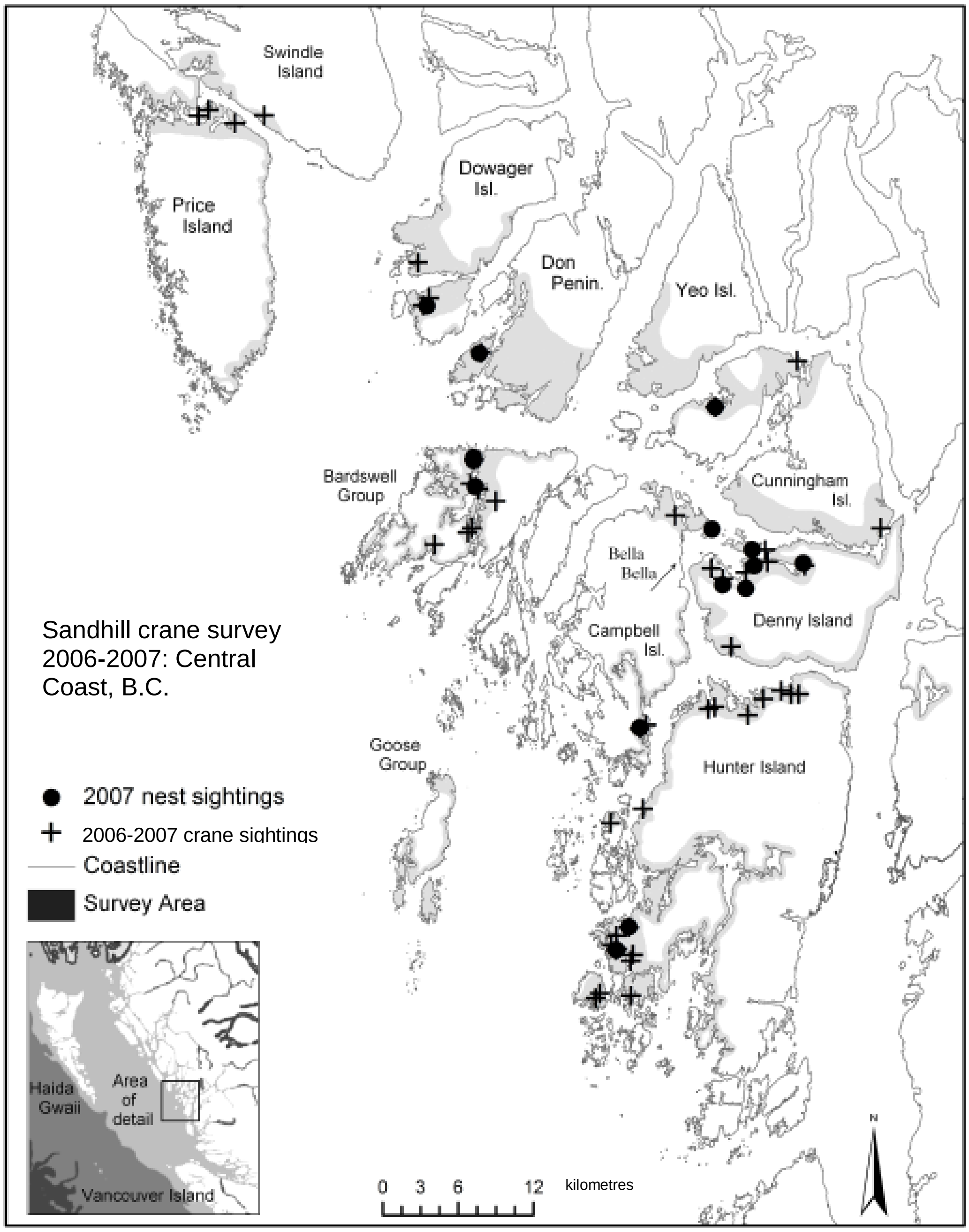

Figure 6. Map of 2006-2007 sightings of sandhill cranes and their nests from helicopter surveys on the B.C. central coast, including nests that were found during foot searches in 2007. Crane sightings do not include cranes that were seen on nests.

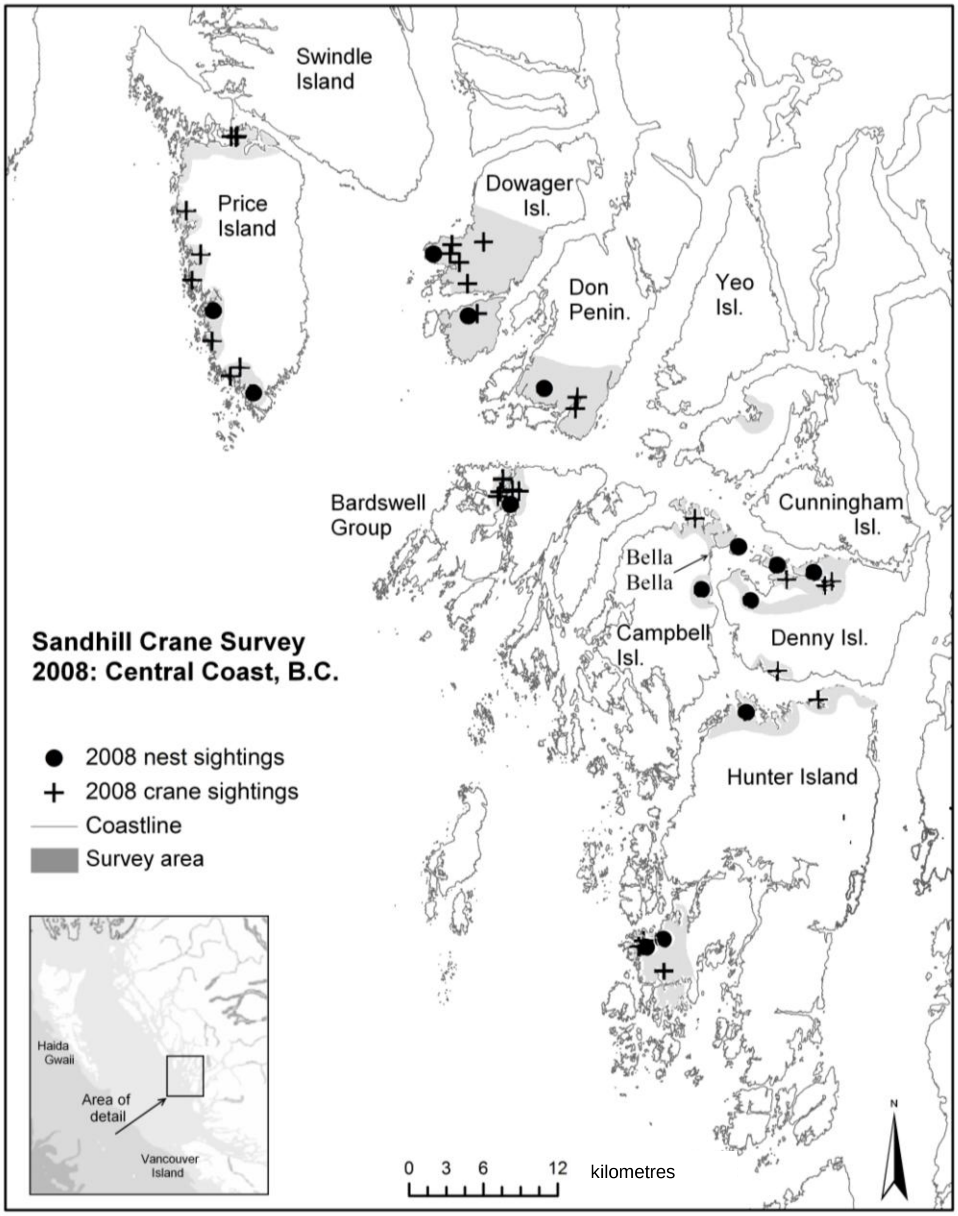

Figure 7. Map of 2008 sightings of sandhill cranes and their nests from helicopter surveys on the B.C. central coast. Crane sightings do not include cranes that were seen on nests.

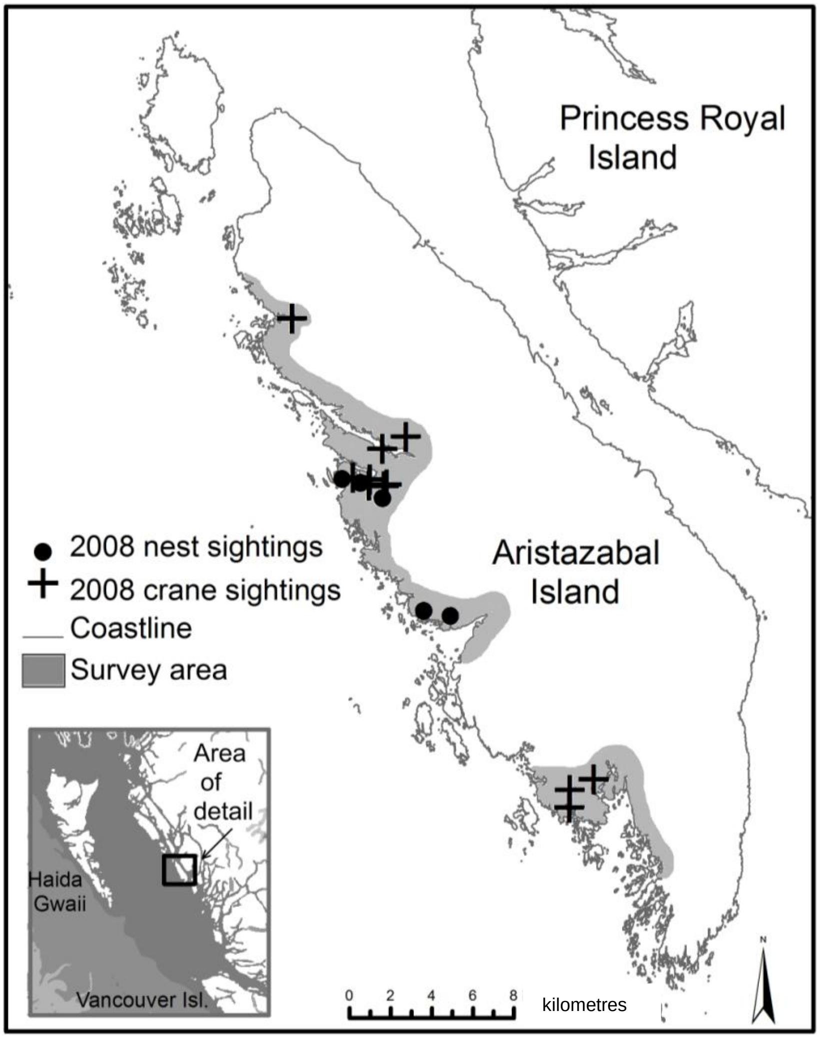

Figure 8. Map of 2008 sightings of sandhill cranes and their nests from helicopter survey of Aristazabal Island on the B.C. north coast. Crane sightings do not include cranes that were sighted on nests.

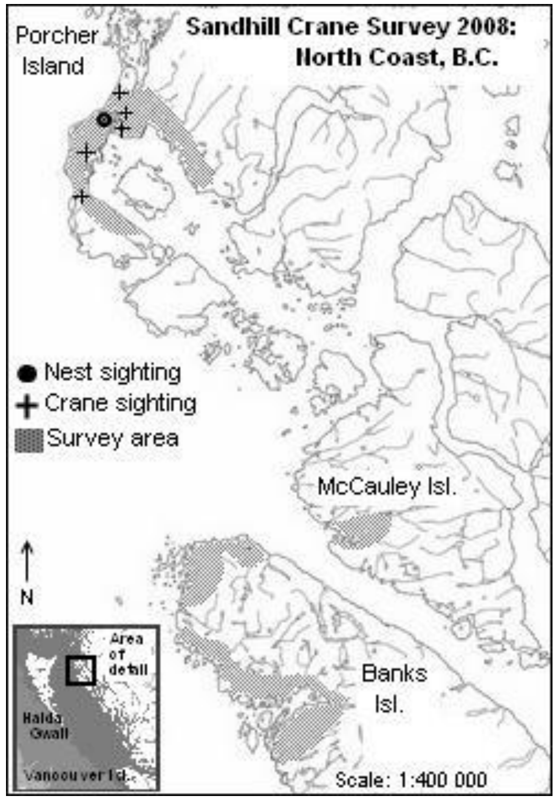

Figure 9. Map of 2008 sightings of sandhill cranes and their nests from helicopter surveys of north coast islands near Prince Rupert, B.C. Crane sightings do not include cranes that were seen on nests.

Discussion

Helicopter surveys

The rise in the ratio of crane and nest sightings to survey effort during helicopter surveys each year reflected improved observer expertise. Observer familiarity with the geography of the study area, visual recognition of different habitat types, and ability to pick out the well-camouflaged cranes increased over time. The 3 months spent tracking cranes on foot and by boat in 2007, as well as sighting location data gathered from local people and mariners contributed to improved detection during surveys. Each year more sightings were reported as public awareness of the research grew. Aerial surveys conducted mid-way through the breeding season were useful due to the large geographic area divided by many waterways, no prior knowledge of breeding areas, and a need to acquire data on breeding status. Helicopter surveys are the most efficient technique for surveying nesting sandhill cranes, mainly because of the ability to move more slowly and at lower altitude over wetlands than is possible with fixed wing aircraft (i.e. Cooper 1996, Hoffman 1983). Hoffman (1983) prefered the use of helicopters to fixed wing aircraft for sandhill crane surveys in Michigan swamps because cranes generally flushed or remained visible with the approach of a low-flying helicopter but did not flush under airplanes at the higher altitude and rate of speed necessary for safe flight. In our surveys, cranes often flushed, stood at full height or crouched low over their nests, or fled on foot to shelter under trees if they were at the shoreline. Nesting cranes that flushed generally went only as far as the edge of the nesting bog pool and remained visible. Sighting cranes that did not take wing or move quickly on foot was more difficult. Cranes were not sighted in forested habitat, possibly due to poor detectability under forest cover. Detection in all habitats was more difficult in windy conditions, when movement in the vegetation obscured movement of the cranes and the helicopter was less stable, and with any amount of precipitation beyond sprinkling rain.

Water and ground-based surveys, concentrated on sighting information gathered from boaters and local people, are reasonable alternatives to aerial surveys on the central coast, which are fuel-intensive, expensive, and noisy. Almost all of these sighting data are for shoreline locations, but examination of satellite imagery gives an indication of potential upland breeding and roosting wetlands to survey. Presence/absence surveys could be conducted in discrete study areas upland from shoreline crane sighting locations. It was necessary to carefully check every islet in bog pools, as incubating cranes can be very difficult to detect unless flushed, and when approached on foot they may not flush until the observer is within 3 m or less. Ground surveys are more time intensive, require boat access, and are biased towards areas where people tend to anchor or cruise close to shore. Another drawback is that only relatively small areas can be covered during the nesting period, and early or late-nesting birds may be missed if the area can be visited only once during the nesting period. However, ground searches allow for observation of cranes and their habitat at close range and the potential for point-count and triangulation methods to improve detection.

There are several methods available for conducting future aerial surveys to obtain adjusted counts, depending on survey objectives, such as estimating relative abundance in different habitat zones or density throughout a defined study area based on a sampling frame. On the coast, the sampling frame could consist of a random selection of islands with a minimum area of bog habitat, over which coastal contour transects within 1.5 km of the coastline, inland transects oriented perpendicular to the coast, and total counts on a sample of small islands are flown.

The survey method that is likely most appropriate to obtaining a reliable estimate given the complexity of the coastal study area, vegetation cover, and low density of cranes is double sampling, where a subsample of transects is surveyed intensively to obtain a correction factor for incomplete aerial surveys. Double sampling in this situation may employ fixed-wing aircraft transects over study strata with helicopter transects over sub-strata, or fixed-wing aircraft or helicopter transects over study strata with ground transects over sub-strata. The assumptions of double sampling methods are: 1) survey transects represent a random sample and subsample, 2) all individuals are counted within the subsample transects or units, 3) there is a linear relationship between incomplete and complete counts. Also, subsamples must be surveyed within the same time frame as main samples, but spaced long enough apart to avoid double-counting of flushed birds (Thompson 2002). Variance is determined by replicated surveys of subsample transects, and this should be evaluated as a measure of survey adequacy in different habitat types as well as for overall count numbers (Smith 1995).

A double observer method can be used for both aerial and ground survey components (Canadian Wildlife Service & US Fish and Wildlife Service 1987). Two observers record observations independently in order to maximize the transect width (100 m on each side) and to reduce bias caused by different observers. Detection rates for the 2 observers are combined with the number of birds detected to obtain an adjusted count. The assumptions are that observer counts are independent and that there is equal probability of each observer recording a sighting.

There are problems with both of the above methods in the case of species that occur in low numbers or that have low detection probabilities, such as cranes breeding on the coast. For example, minimum counts are needed in order to achieve a visibility correction factor based on double sampling (Smith 1995). Distance sampling methods (Burnham et al. 1980, Buckland et al. 1993) offer another way to obtain direct estimates of density based on models of variation in detectability, but may be too difficult to undertake by helicopter and impractical to conduct on foot in the case of cranes because of the assumption that birds are detected prior to evasive movement (although models that factor in responsive movements have been developed [Palka and Hammond 2001]), and the requirement of measuring distance from the observer/platform to the bird. On the ground, crane calls can be heard from several kilometres away, and cranes may hide quietly even when the observer is very close. Another option is to conduct replicate aerial surveys over short time periods, using the mean count between surveys to estimate relative abundance (Nixon and Majiski 1991), but this method does not give a correction factor.

With any of the above methods, factors that affect detectability such as observer experience and environmental variables such as tide level, weather, and solar angle should be standardized as much as possible. Timing, flight speed and height should also be standard for relative abundance surveys. Ideally, pilot studies could be conducted to assess the efficacy of the method, associated cost, and appropriate sample size needed to obtain minimum counts in different habitats or sample area types (see Bart and Earnst 2002). Classified landcover maps created from recent aerial photographs under the B.C. Ministry of Forests Vegetation Resources Inventory program, soon to be available, could be used with future survey data to study spatial patterns in crane and nest distribution, including habitat associations and selection.

Sandhill crane habitat and density

Crane locales were generally consistent in areas where surveys were repeated from 2007 to 2008. Cranes, nests or both were sighted in both years in or around Higgins Pass, between Price and Swindle Islands, Gale Pass, which runs between Athlone and Dufferin Islands of the Bardswell Group, and the north side of Denny and Hunter Islands. These areas have in common relatively sheltered shorelines and large lagoon or estuary systems with upland bog. The southwest end of Dowager Island, Lady Douglas Island, and the Cultus Sound area at the southwestern end of Hunter Island were also consistent for crane sightings, and feature small sheltered inlets with upland bog. The east side of Price Island is predominantly exposed, steep rocky shoreline. No cranes were sighted there in 2007, however in 2008 cranes and nests were sighted on the west side of Price

Island, which has highly convoluted shorelines with several large sheltered lagoons and extensive upland bog. The west side of Aristazabal Island and the surveyed portion of Porcher Island, where the number of crane sightings was high, have similar features (Figure 10). More cranes were spotted in bog habitat than on shorelines in 2008 relative to 2007. This is likely because in 2008, more time was spent searching bog habitat than shorelines in order to locate nests, which were eligible for habitat protection under existing provincial legislation. Sightings of cranes at nests were mostly of single birds (13 out of 15 sightings), while single birds spotted in the bog but not at a nest accounted for one fifth (22 of 104) of all cranes sighted. It is uncertain whether these singles were part

Figure 10. Lagoon and estuary sytems on the west coast of Aristazabal Island, showing forested shoreline and upland bog complex, 18 May 2008. Photo: Briony Penn.

of a nesting pair, or possibly yearling cranes recently expulsed from their parents' breeding territory. Out of the 45 cranes spotted on shorelines, many were in groups of up to 10 birds (22 cranes total), 18 were in pairs, and only 5 were alone. Larger groups were likely made up of nonbreeding cranes, including juvenile and widowed birds (G. Ivey, International Crane Foundation, pers. comm. 2008). Among *G.c. tabida* from the Rocky Mountain Population, nonbreeders comprised 31-39% of the total population (Drewien 1973). Pairs may have included juvenile cranes that mated but did not nest successfully.

Young sandhill cranes may mate several times before successfully breeding at 3-7 years of age (Tacha et al. 1992). Single cranes spotted on shorelines may have been associated with single cranes seen at nests.

Cranes were observed with pre-fledged young foraging at the shoreline repeatedly at 4 locations around Bella Bella in 2008. When approached by boat from a distance, they either retreated to the forest edge, often walking into the forest, or one crane became aggressive while the other retreated with the chicks. These groups would have needed to use the forest to go between nesting or roosting bog pools and shoreline foraging habitat. Cooper (1996) found that cranes with young in the Chilcotin-Caribou region retreated under forest cover when approached by aircraft during aerial surveys. In Haida Gwaii, cranes with young have been found deep in mature coniferous forest and cranes have been found nesting in logging slash near a mountaintop (Campbell et al. 1990, Hearne and Hamel 2003). *G.c. tabida* with young in Michigan left their bog nesting sites to forage in coniferous forests (Taylor 1976). Cooper (1996) speculated that forest use may be associated with thermal cover or foraging needs. In this case forest use may be necessary for cranes and their young to connect shoreline foraging habitat with their bog nesting and roosting habitat. Although sandhill cranes in other regions use bog wetlands for nesting, no other population is known to forage on marine resources or nest in estuarine habitat. Cranes have been observed nesting in estuarine tidal meadows in Haida Gwaii (Hearne and Hamel 2003).

The occurrence of cranes in intertidal habitats near to bog nest and roost sites indicates that either breeding crane territories include intertidal foraging areas and the forest between nesting pools and the shoreline, or that breeding cranes forage outside of defended territories because food availability in bog nesting habitat is low. Foraging in areas removed from defended territories is not uncommon among other sandhill crane populations (Armbruster 1987). Food availability is known to affect local movements of breeding cranes, the period of occupancy on defended territory (Drewien 1973), as well as nest density (Armbruster 1987).

Measurements of nest density are partially dependent on detectability during surveys, area coverage, and on other non-habitat related variables that may not be comparable between studies (Armbruster 1987). Nesting pair density calculated from several studies by Hoffmann (1983) in terms of total area used ranged from 0.02-2 pairs/km^2. In this study, observed density of 0.044 nests/km^2 (uncorrected) was comparable to 0.02 (1976) and 0.03 (1977) pairs/km^2 in southern Wisconsin marshes (Bennett 1978) and 0.05 nests/km^2 in open and lightly forested sheet bog habitat on the north end of Vancouver Island (Cooper 2006). Cooper (2006) found 16 cranes and 4 nests during aerial surveys of Knob Hill and Shushartie Mountain on northwestern Vancouver Island, and suggested the total population for Vancouver Island to be in the range of a few dozen pairs. Most estimates of nesting pair density or nest density are much higher, as with nesting pair density of 0.30 pairs/km^2 in marshlands at Malheur Wildlife Refuge in Oregon (Littlefield 1976a), nest density ranging from 0.54-0.74 nests/km^2 in wet marshes on the Yukon-Kuskokwim Delta (Boise 1977) and nesting pair density of 2.00 pairs/km^2 in highly productive marshlands at Grays Lake, Idaho (Drewien 1973).

Greater sandhill cranes, like many species of birds, are known to exhibit strong breeding territory fidelity (Walkinshaw 1949, Drewien 1973), and strong natal philopatry (Walkinshaw 1949, Littlefield 1968, Drewien 1973, Littlefield and Ivey 1995, Nesbitt et al. 2002). Among *G.c. tabida*, individuals are known to return to the same nesting territories and wintering sites consistently, unless habitat conditions become unsuitable (Tacha et al. 1992, Drewien et al. 1999). Within our small sample of 9 nest sites checked in both 2007 and 2008, 3 of the 2008 sites were likely within breeding territories used the previous year (within 300 m and in the same wetland complex), in addition to 2 nests that were reoccupied. Similarly, sandhill cranes nesting in wetlands in the Chilcotin-Cariboo and B.C.'s Central Interior appeared to return to the same network of wetlands rather than to specific wetlands (Cooper 1996). Familiarity with a breeding territory is thought to be beneficial due to improved foraging efficiency, predator avoidance, and mate retention, while reducing conflicts with neighbours (Hinde 1956, Greenwood and Harvey 1982)**.** Variation in levels of breeding site and territory fidelity within philopatric bird species may include breeding territory quality, age and sex of individuals (Bollinger and Gavin 1989, Payne and Payne 1993), and prior successful breeding attempts (Haas 1998, Hoover 2003).

Management Implications

Under the requirements of B.C.'s Forest and Range Practices Act (Province of British Columbia 2002), the Ministry of Environment established an Identified Wildlife Management Strategy (IWMS) for the sandhill crane, which provided management guidelines with respect to forest and range activities that could negatively affect the species, and allowed for the protection of critical breeding habitat (B.C. MWLAP 2004). Twenty-one nest sites and 9 roost sites identified in this study were proposed for Wildlife Habitat Area (WHA) designation under the IWMS, with support from the Ecosystems Branch of the Ministry of Environment. The rest of the nest sites are located within conservancy areas or in the Hakai Recreation Area. Conservancy area designation may not provide adequate protection for sandhill cranes and their habitat as some industrial activities, such as wind farms and hydroelectric projects, have been permitted within specific conservancies. As a significant proportion of potential sandhill crane habitat on the central and north coast is within conservancy areas, guidelines should be established to protect sandhill crane breeding, roosting and foraging habitat within these areas.

Eleven sites were approved for WHA status in January 2010 but the remainder of the site proposals were abandoned because the provincial status of sandhill cranes was down-graded to 'apparently secure', rendering the IWMS obsolete. Forest and range activities in WHAs are restricted, but it is unknown whether the size and design of WHAs provide adequate protection from logging for nesting cranes. The IWMS allowed approximately 20 ha of operable area (harvestable timber) to be set aside for each WHA. The scrub forest adjacent to most wetland nest and roost sites is currently classed as inoperable for logging, but operability thresholds may alter as market demand increases for old-growth red and yellow cedar (Banner et al. 2005). While laying out the WHA proposals, at least 50 ha of land (including operable and inoperable areas) were needed to provide a forested buffer around breeding wetlands, and to encompass the forest between breeding wetlands and shoreline foraging areas. The primary information need identified in the IWMS was the tolerance of cranes to logging adjacent their breeding habitat (B.C. MWLAP 2004). Cranes were not found in areas with active or recent logging.

Sandhill cranes in the study area were extremely wary of humans when approached on foot or by boat (including kayaks). Their reaction was to flush or retreat from the shoreline into the forest at distances of 100 m or more from an observer, except when pre-fledged young were present, in which case they became aggressive. It is recommended that guidelines for approaching cranes be developed and publicized locally to prevent unnecessary disturbance from human observers.

An apparent increase in the numbers and ecoprovinces in which they were found led to a change in the species' designated status to 'apparently secure' in January 2009 (B.C. CDC 2009). The status designation is for all subspecies and populations and does not take into account possible differences in population levels and trends, which are still unknown numbers in B.C. The majority of known sandhill crane breeding habitat remains unprotected.

Cranes summering in Alaska are vulnerable to sport and subsistence hunting. Sandhill cranes (all subspecies) remain on the endangered species list in Washington State (Washington Department of Fish and Wildlife 2012), while *G.c. tabida* are listed as threatened in California (State of California Natural Resouces Agency 2011). Staging and wintering habitats of the coastal-breeding population, in the Lower Columbia River region and in the Central Valley of California respectively, have been impacted by wetland conversion to agriculture and other land use changes, and continue to be threatened by various forms of development (Littlefield and Ivey 2002). The array of threats to this population in its breeding, staging and wintering areas lead Ivey et al. (2002) to conclude that it merits elevated conservation efforts and separate management from interior-nesting *G.c. tabida*. The apparently sparse distribution of sandhill cranes on the central and north coast of B.C. gives further support to these recommendations. It is also recommended that public education efforts and the gathering of sighting data from the public continue. "Citizen Science" data collection methods are worthwhile given the size and complexity of the coastal archipelago. Boat-based and ground surveys are economical options, but these can only cover a limited geographic area during nesting or fledging periods. Future aerial surveys may be used to devise more accurate estimates of crane and nest density in different habitat types.

Chapter 4: Breeding habitat and diet of coastal sandhill cranes in British Columbia

Introduction

Sandhill cranes use a variety of wetland and vegetation types for nesting (Armbruster 1987). Nest sites are characterized by the presence of standing water with emergent aquatic vegetation (Tacha et al. 1992). In British Columbia (B.C.), known breeding areas of the three migratory subspecies of sandhill crane include much of the Central Interior, Haida Gwaii, the central mainland coast, Mara Meadows near Enderby, the East Kootenay Trench, Fort Nelson Lowland, the Fraser Lowland (Campbell et al. 1990), and northern Vancouver Island (Cooper 2006). Recorded breeding habitats in B.C. include isolated bogs, fens, other wetland types, and meadows from near sea level to 1,220 m asl (Campbell et al. 1990). The three migratory subspecies breed in broadly differing regions and wetland types. *G.c. tabida* typically breed in bogs, fens, sedge meadows, cattail marshes, riparian areas, flooded meadows, beaver ponds, and other wetland types in southern Canada and northern US. *G.c. canadensis* breed mainly on the arctic lowland coasts, river deltas, and tundra, utilizing bogs, shallow lakes, riparian marshes, and seasonal ponds. *G.c. rowani* nest in shallow muskeg and boreal wetlands including open and forested bogs (Walkinshaw 1973, Drewien and Bizeau 1974, Johnsgard 1983).

The principal components of *G.c. tabida*'s breeding territory are the nest site, roosting area, feeding area, and some measure of isolation from human disturbance (Armbruster 1987). Potential predictor variables of breeding habitat selection include the composition and structure of vegetation communities, water depth at the nest, prey availability, land use, topography, and climate (Baker et al. 1995, Littlefield 1995, Maxson and Riggs 1996). Water depth or proximity to water, which provides security from predators, may determine nest site selection more than vegetation type or wetland size (Armbruster 1987). Water depth, predation pressure, weather, and habitat condition can also influence nest success (Littlefield and Ivey 2002).

G.c. tabida are known to exhibit strong fidelity to their breeding territory (Walkinshaw 1949, Drewien 1973), and strong natal philopatry (Walkinshaw 1949, Littlefield 1968, Drewien 1973, Littlefield and Ivey 1995, Nesbitt et al. 2002). Local movements, the period of occupancy on defended territory (Drewien 1973), and nest density (Armbruster 1987) are affected by food availability.

Limiting agents in species abundance, such as predation or prey availability (Huston 1994), and habitat variables, such as vegetation structure and productivity (Lack 1933), may act as simultaneous constraints to bird habitat selection (Cody 1981). Resource selection occurs in a hierarchical fashion, from the species' geographic range, to the home range of an individual animal, to use of broad habitats within the home range, to the selection of specific elements within the general habitat (Johnson 1980). Spatial heterogeneity and vegetation structure determine patterns of habitat occupancy by animals at coarser scales (Wiens 1969) while plant species composition may play a more significant role at finer scales (Rotenberry and Wiens 1998).

Sandhill cranes are opportunistic omnivores that feed on a variety of plants and animals, including grains and seeds, insects and other invertebrates, and small vertebrates (Tacha et al. 1992). They are food generalists, adapting to local sources of vegetable foods in abundance (Johnsgard 1983). They forage primarily on land, feeding on items visible from the soil surface and sub-surface, which they dig with their bills (Walkinshaw 1949, 1973). Individual food items include roots, berries, snails, snakes, earthworms, mice, greens, and occasionally eggs and young birds (Harvey et al. 1968, Littlefield 1976b, Reynolds 1985). In spring, when nutrient requirements in egg-laying females are high, insects, earthworms, and other macroinvertebrates form an important part of the diet (Reinecke and Krapu 1986, Davis and Vohs 1993). Young sandhill crane chicks raised in captivity required a low protein (24%) and low sulfur amino acid level diet to avoid high growth rates, which were associated with leg and wing abnormalities (Serafin 1982). By the start of migration young birds have been observed to share the same diet as adults (Johnsgard 1983).

Research on foraging patterns and diet content is essential to understanding local habitat needs, and the potential impact of factors that influence habitat productivity (Litvaitis et al. 1994). For example, Darimont et al. (2004) looked at patterns in prey remains identified from faeces of wolf (*Canis lupus*) collected throughout B.C.'s central and north coastal archipelago to understand how fragmented landscapes might influence predator-prey dynamics. Analysis of collected faecal samples is a non-intrusive, non-destructive, but indirect method of studying habitat use. One limitation of faecal analysis is that of differential digestion, whereby the proportion of certain prey items in the diet is either under- or overestimated according to the particular item's relative digestibility. For example some very small items, such as tiny spiders, may be under-represented (Ralph et al. 1985). However, controlled feeding tests on gallinaceous birds suggest that identifiable remains of almost all foods can be found in droppings (Jensen and Korschgen 1947).

The sandhill crane was identified as a species of management concern in B.C. until 2009, because of a lack of protected breeding habitat and gaps in knowledge related to the potential impacts of logging. Breeding sites for the species, particularly in more remote and inaccessible areas along B.C.'s mid- and north coast, are poorly known. More information regarding species abundance, nesting habitat, productivity, sensitivity to disturbance and distribution of foraging resources (including information on diet) was required to inform more efficient management of this species throughout its range in the province. Research needs identified in the "Status report on the sandhill crane in British Columbia" (Cooper 1996) and the Identified Wildlife Management Strategy (IWMS) for the sandhill crane (B.C. MWLAP 2004) include the determination of the impact of logging on breeding cranes on the coast and in the Chilcotin-Cariboo region, and of an appropriate forest buffer width to isolate nesting cranes from logging.

My objectives were: 1) to describe sandhill crane nest habitat using a range of characteristics including vegetation, site position with regard to important landscape features, forested buffer width, nest pool size and depth, and nest construction; and, 2) to identify diet content and differences in the diet of breeding cranes in the Bella Bella area over early, mid-, and late season periods in 2008.

Methods

Study area

Refer to Chapter 1 and Figure 11. Scat collection locations sites were between 190 m and 880 m of the coastline. Sites 1 and 4 were separated from steep rocky shorelines by closed canopy western redcedar – western hemlock (*Thuja plicata-Tsuga heterophylla*) stands on steep slopes, and site 5 was inland from Shearwater Marina, an active commercial and industrial complex. Site 1 consisted of a small bog pool surrounded by forest, while all other sites were within an open bog/bog woodland complex. Sites 2, 3 and 6 were close to gently sloping pebble or rocky bays separated from bog nesting sites by redcedar – western hemlock forest on gentle to moderate slopes.

Sampling: Nest habitat

During June to September 2008, twenty nest sites were visted to gather data on habitat characteristics (Figure 11). Both active and older nest sites were sampled as they represented individual, though possibly non-independent cases of nest site selection. At each nest site, 20 m transects were laid in cardinal directions from the edges of the nest pool. Tree (>10 m) and tall shrub (2-10 m) percent cover were estimated along each transect using visual cover estimates (Luttmerding et al. 1990). Canopy height was estimated by measuring the height of representative trees or tall shrubs along each transect with a clinometer. Percent cover of lower vegetation layers was measured in 1x1 m^2 plots along each transect, and for the whole of each nest islet using a modified Daubenmire cover class scheme (Daubenmire 1959). Slope was measured with a clinometer along these transects.

Nest pool size was measured with a GPS. ArcMap (Version 9.3, ESRI 2008) or Google Earth was used to measure nest pool size for 9 additional sites that were not visited on the ground. Percent open water and emergent vegetation cover were estimated visually. Measurements of islet size, distance from the nest islet to the nearest pool edge and to the nearest islet, water depth around the nest, nest size and height above water were taken. Nest concealment was measured using a Robel pole (Robel et al. 1970) at the nest, to measure the height of visual obstructions from the edges of the nest pool in cardinal directions.

The horizontal distance from the nest pool to the nearest shoreline, estuary, marsh or lake was measured with measure tools in ArcMap using SPOT 5 pan-enhanced satellite imagery at a 1:5,000 scale, or using Google Earth imagery where resolution was higher. Forest buffer width, defined here as the width of treed area in cardinal directions from the nest pool, was also measured with satellite imagery and averaged for each site.

Tree cover was visually differentiated by tone, texture, and colour from water, open bog, and low shrub cover.

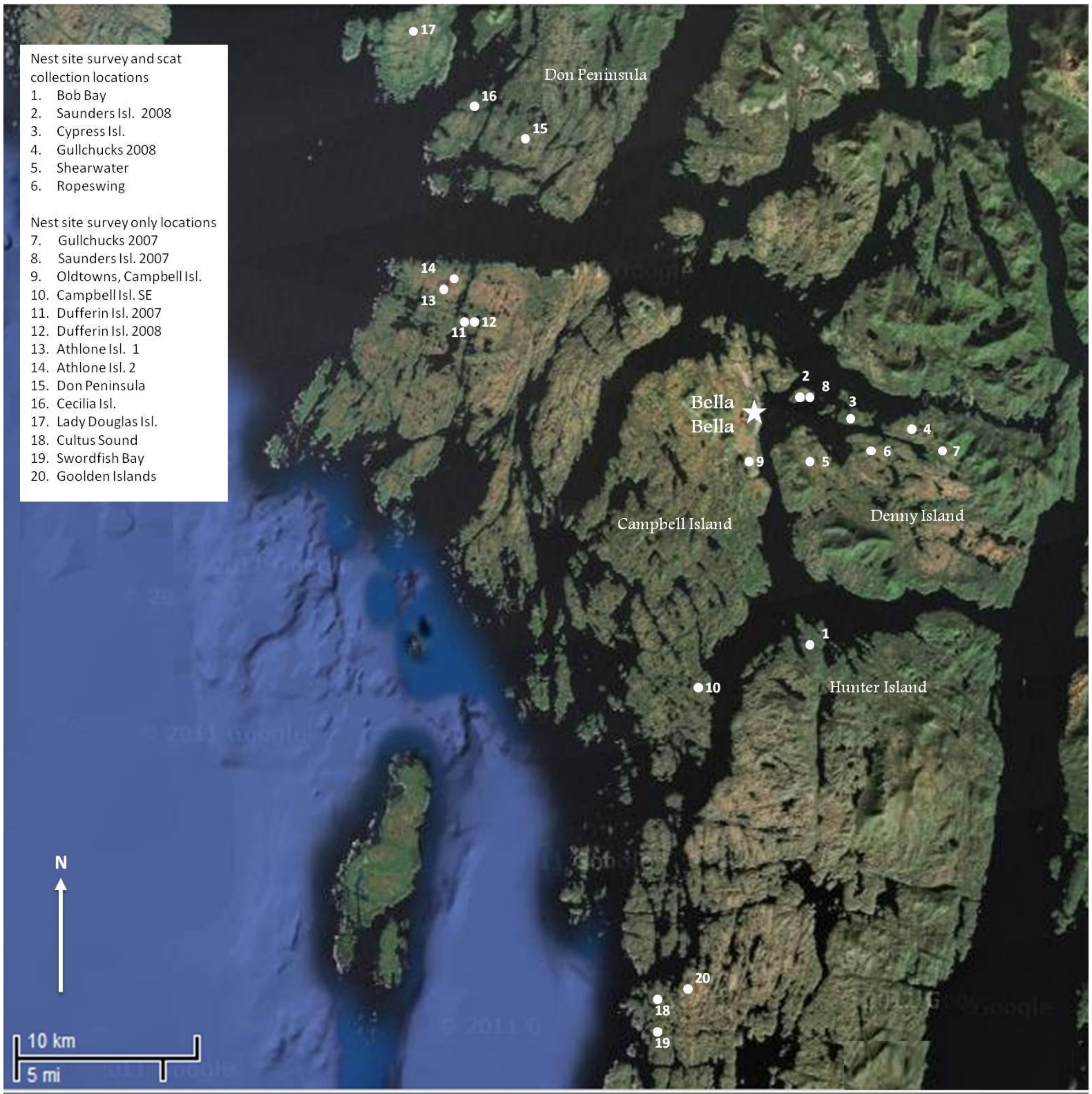

Figure 11. Sandhill crane nest sites where nest habitat and diet data were collected in 2008, Central coast, B.C. Base map imagery: Terrametrics, 2011. Map data: Google, 2011. Years adjacent to site names refer to the year in which the nest was active if 2 nests were located close together in consecutive years.

Measurement error for distances involving treelines was estimated as either 10 m or 20 m, depending on the resolution of the imagery used. Four sites where the error was thought to exceed 20 m because of poor resolution or interpretability of the imagery (due to shadows or terrain) were not included. Measurement error for estuary, lake and wetland distances was approximately 10 m. Cumulative measurement error for mean distance from nest pool to treeline and from treeline to the next break in treeline (forest buffer width) was 94 m, and 47 m for other distances measured in metres. Distance from the nest pool to human habitation, logging, and the closest road were measured in Google Earth to the nearest kilometre.

Sampling: Diet

Visits to 4 active nest sites (sites 1-4) and one marsh roost site (site 6) were made at average intervals of 2 weeks from 23 May to 29 Aug 2008, however no scats were found at site 4 after June 21. An additional nest site (site 5) was sampled 3 times before shifting to a nearby (500 m away) fen roosting and foraging site for the remainder of the season. Fresh, intact fecal samples were collected within 100 m of nest and roost sites and were frozen until analysis. Some foods may pass through cranes slowly compared with the speed of their movements through different habitats, so the content of fecal samples is not necessarily associated with the habitat where they were collected (Hunt and Slack 1989).

Subsamples of 0.5-1.5 g were randomly selected from thawed samples and dissected under a microscope. Food items were measured by percent volume, either by separating and measuring individual contents or by estimation to the nearest 5%. Reference materials collected in the study area were used to help identify food items.

Droppings from chicks or young colts could be differentiated from adult droppings by size, but droppings for older colts could not. Therefore, sample data from droppings of all young and adults were pooled for analysis. Scat samples were sorted into 3 time periods corresponding with crane foraging behaviour as follows: 23 May to 14 June (foraging close to the nest area during nesting and immediately after hatching), 21 June to 7 July (foraging with pre-fledged chicks), and 22 July to 29 August (foraging with fledging young). Percent volume of each food item was summed and divided by the number of samples to obtain means. Frequency was determined by dividing the number of times a food item occurred during a time period or at a site by the total number of samples for that time period or site (Westwood and Chavez-Ramirez 2005). Absolute differences between different food items in samples could not be compared directly because of potential differences in their digestibility (Hunt and Slack 1989, Westwood and Chavez-Ramirez 2005).

Analysis

Nest habitat

Vegetation plot data were simplified by averaging values for all plots at each of the 20 sites, and removing species that occurred ≤ 3 times among all plots (20 spp. out of 107). Species that occurred in tree, tall shrub, and herb layers were treated as separate species during analyses in order to characterize vegetation structure as well as composition. Sites were grouped based on vegetation data with hierarchical agglomerative polythetic cluster analysis using a Euclidean distance measure and Ward's linkage method. Indicator species analysis was then used to describe the differences between groups in terms of both the faithfulness of occurrence of species and the concentration of abundance of species in each group, following Dufrêne and Legendre (1997). Indicator values were determined by combining the proportional abundance of a particular species in a particular group relative to the abundance of that species in all groups, and the proportional frequency of each species in each group. The resulting indicator value for each species in each group was then evaluated for statistical significance using a Monte Carlo randomization (PC-ORD version 5.33; McCune and Mefford 2006).

Diet study

Chi-square tests of homogeneity were used to identify significant differences (adjusted for ties, $P<0.05$) in frequency of occurrence of foods across time periods and sites. Generalized linear regression models (GLM, binomial logistic form) were developed to determine whether time period, site, or interaction of time and site were important predictors of the probability of occurrence of foods that showed significant differences in both time period and site. Significant differences in the GLMs were determined using the appropriate analysis of deviance test for binomially distributed data. I compared models using the Akaike Information Criteria with small sample (2^{nd} order) bias adjustment (AIC_c) (Burnham and Anderson 2002). To rank and compare models, I calculated AIC_c differences ($\Delta AIC_{c,i}$) and then Akaike weights (w_i), which sum to one, to assess the relative likelihood adjusted for the number of parameters in the model (Burnham and Anderson 2002). A larger $\Delta AIC_{c,i}$ results in smaller w_i and thus Model *i* is less likely to be the best model. The model with the greatest w_i was selected as the best approximating model. Kruskal-Wallis (K-W) tests were used to look for significant differences in percent volume of food items between time periods and sites (R, version 2.13.0; The R Foundation for Statistical Computing 2011).

Results

Nest habitat

Over 100 plant species were identified in vegetation plots at 20 nest sites. Among these, 5 species or genera had >5% mean cover at all sites (Table 2). I chose to prune the cluster dendrogram at 4 groups with 43% information remaining (Figure 12), as this arrangement simplified the results while losing little information in the form of significant indicator species or average *P*-value for all indicator species (Table 3).

Tree canopy cover was mostly absent in plots around nest sites; only site 1 had mean vegetation height over 10 m; 50% of nest sites visited[1] (*n* total = 18) had shrub vegetation cover between 3 and 5 m tall (Figure 13a).

Table 2. Species or genera occurring at all sample sites with >5% mean percent cover among sites, in vegetation plots sampled at 20 sandhill crane nest sites in 2008 on the central coast of B.C.

Common name	Latin name	Mean cover (%)	SD (%)
Sweet gale	*Myrica gale*	17	9.2
Small red and Magellan's peat moss	*Sphagnum capillifolium* and *S. magellanicum*	5.9	4.7
Reindeer mosses	*Cladina* spp.	22	9.1
Crowberry	*Empetrum nigrum*	7.0	4.5
Yellow cedar (shrub layer)	*Chamaecyparis nootkatensis*	8.4	5.1

[1] Some measurements were not taken at every site due to access limitations; therefore I have noted the relevant sample sizes throughout.

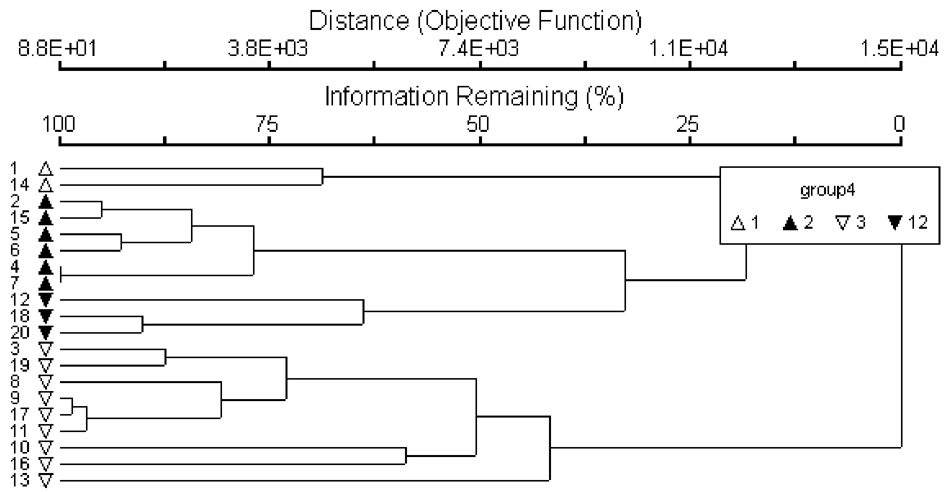

Figure 12. Hierarchical cluster analysis of 20 sandhill crane nest sites on the central coast of B.C., based on mean species cover for each site from vegetation plots sampled in 2008. Site numbers are on the left axis. Group numbers refer to cluster groups as described by indicator species composition in Table 3.

Table 3. Results of indicator species analysis on clustering of vegetation data collected at 20 sandhill crane nest sites on the central coast of B.C. in 2008, showing indicator species with *P*-values ≤0.05 for 4 groups. Indicator values are expressed as the percentage of perfect indication of group membership.

Group number	Site numbers	Indicator species	Indicator value (%)	*P*-value
1	1	Tree layer:		
	14	*Chamaecyparis nootkatensis*	92.5	0.007
		Tsuga heterophylla	92.6	0.006
		Pinus contorta	85.5	0.012
		Shrub layer:		
		Gaultheria shallon	57.3	0.035
2	2, 4, 5, 6,	Shrub layer:		
	7, 15	*Juniperus communis*	44.3	0.021
		Pinus contorta	50.6	0.026
		Bryoid layer:		
		Cladina spp.	37.0	0.021
3	3, 8, 9,	Herb layer:		
	10, 11,	*Triantha glutinosa*	49.2	0.019
	13, 16,	Bryoid layer:		
	17, 19	*Sphagnum austinii*	49.0	0.001
		Racomitrium lanuginosum	41.5	0.050
12	12, 18,	Shrub layer:		
	20	*Chamaecyparis nootkatensis*	42.2	0.029
		Bryoid layer:		
		Sphagnum capillifolium and *S. magellanicum*	54.1	0.006

Tree and tall shrub canopy layers contained yellow cedar, western redcedar, shore pine (*Pinus contorta*), western hemlock, and western yew (*Taxus brevifolia*) in low percent cover classes; maximum canopy cover among sites (n = 19) was 35% while the median was 16% (Figure 13b). Nest sites were in small forest openings; the median distance from the nest pool edge to the closest forest edge (tree line) was 46 m (n = 25 sites), and only 10% of 100 measurements fell between 300 m and 850 m, the maximum distance (Figure 13c). Most nests were within a small basin (15 of 20 sites) rather than facing any particular aspect. Median slope around 20 nest pools was 2.4˚ (IQR = 1.3-6.3˚) and the maximum slope was 16˚. Mean slope for each site was not significantly correlated with mean canopy cover (R = 0.174, P = 0.477) or height (R = 0.223, P = 0.374).

Twenty-three of 29 nests occurred in pools under 0.2 ha in size (Figure 13d). Two nests were in beaver-dammed ponds, the largest being 1.2 ha in size. Water depth measurements around nest islets ranged from 10-150 cm; median depth among sites was 56 cm (IQR = 49-77 cm, n = 21) (Figure 13f). Islets are hummocks of *Sphagnum* mosses and lichens that remain in a decaying bog where the surrounding peat moss has decomposed and filled in with surface water. Larger islets support shrubby vegetation in addition to the variety of mosses, lichens, and herbaceous plants commonly found on smaller islets.

There was no significant correlation between pool water depth and pool size (R = -0.110, P = 0.674, n = 21). Most pools had turbid water below 25 cm depth (median visible depth = 18 cm, IQR = 12-26 cm). Emergent vegetation cover in nest pools (Figure 13e) was mainly composed of buckbean (*Menyanthes trifoliata*), sedges (*Carex* spp., predominantly slough sedge, *C. obnupta*), cottongrasses (*Eriophorum* spp.), rushes, and yellow water lily (*Nuphar lutea*).

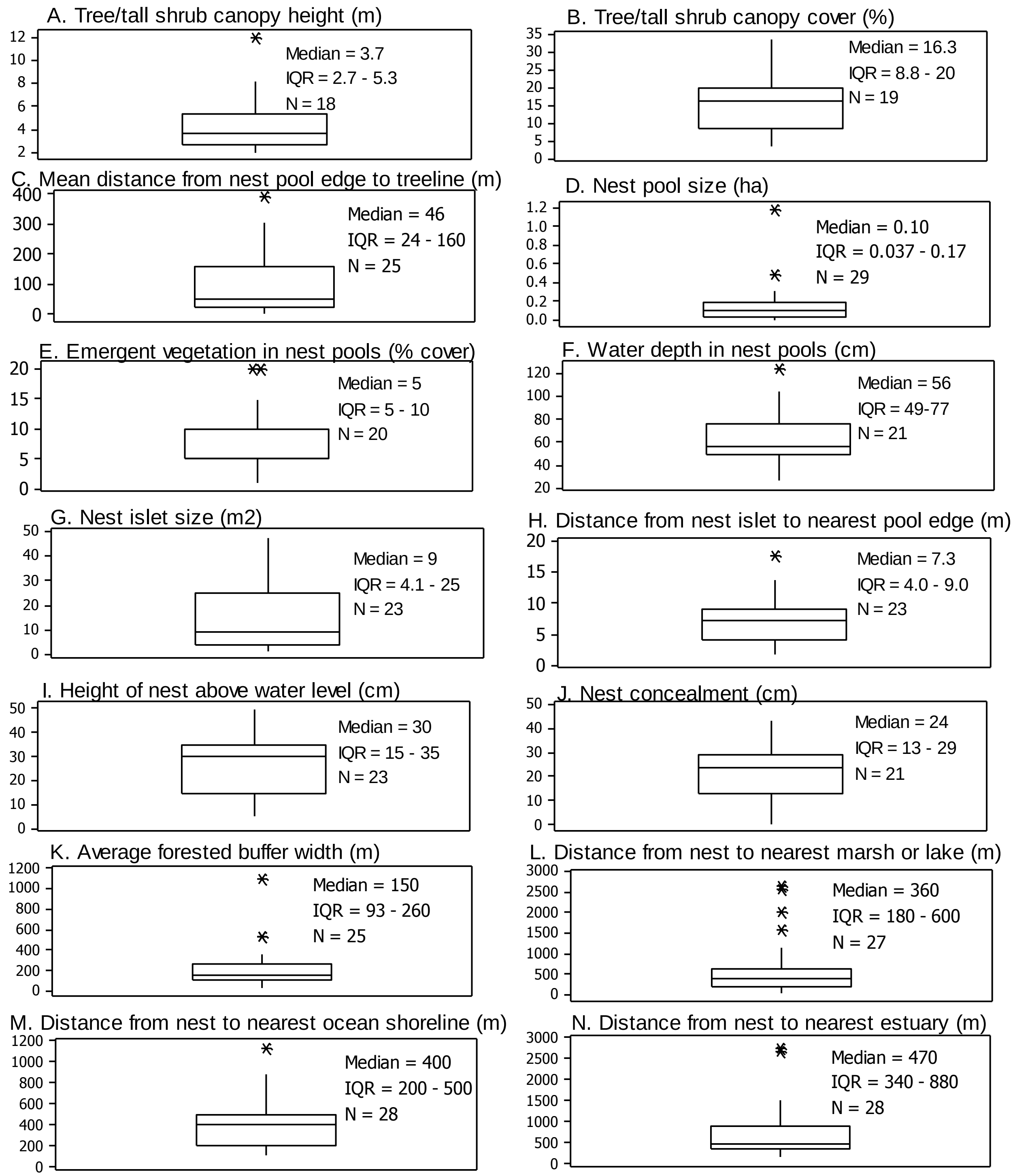

Figure 13. Boxplots of selected sandhill crane nest habitat variable medians for nests on the central and north coast of B.C. sampled in 2008.

Half of sampled nest pools (N = 20) had 10 or fewer islets while 30% had 10-20 islets. The site with the greatest number of islets had 65 islets in a 0.32 ha pool. Nest islet size was variable but nest islets under 6 m^2 occured most frequently (32% of sampled sites, Figure 13g). All but one of 21 sampled nest islets were within 1-6 m of the nearest islet while the remainder was 10 m away. Nest islets that were farther from the pool edge were within sites that had higher mean tree or tall shrub height ($R = 0.48$, $P = 0.044$, $n = 20$) and canopy cover ($R = 0.46$, $P = 0.048$, $n = 20$).

Nests were constructed on the moss surface of islets at varying heights above water (median = 30 cm, IQR = 15-35 cm, $n = 23$; Figure 13i). Materials used in nest construction were available from nest islets or from the vegetation around the pool (Table 3). Nests often consisted of one or 2 layers of material laid down on the mossy surface of islets (nest height: median = 2 cm, IQR = 1-2 cm, $n = 23$), however one nest, composed of cedar twigs, was 7 cm high, and another composed of sweet gale twigs (*Myrica gale*) was 10 cm high (Figures 17 and 19). Nest height and height above water were not significantly correlated ($R = -0.150$, $P = 0.494$, $n = 23$). Nest length (median = 45 cm, IQR = 40-55 cm, $n = 23$) and width (median = 35 cm, IQR = 30-45 cm, $n = 23$) ranged from 20-60 cm. Nest concealment as seen from the pool edge varied considerably (Figure 13j), but the highest frequency class was 0-5 cm (26% of measurements). Nests in larger pools tended to be better concealed ($R = 0.47$, $P = 0.035$, $n = 20$), while nests in pools with a greater number of islets tended to be less well-concealed ($R = -0.449$, $P = 0.047$, $n = 20$). There was no correlation between pool size or concealment and the amount of open water, emergent vegetation cover, or distance from the nest to the pool edge.

Table 4. Nest construction materials of sandhill crane nests sampled on the central coast of B.C. in 2008.

Nest construction material	Number of nests (n=23)
Sweet gale twigs	10
Cedar twigs	5
Moss depression	2
Crowberry twigs	1
2cm strips of cedar bark with sweet gale twigs	1
Grasses over moss	1
Sphagnum plants and sedges	1
Cedar and sweet gale twigs	1
Sweet gale twigs and sedges	1

At the stand level, the forest buffer width (the distance from the forest edge to the next forest opening, whether open bog or waterbody), measured in cardinal directions around the nest pool (Figure 13k) was significantly correlated with tree and tall shrub canopy height in plots around nest pools ($R = 0.663$, $P = 0.004$, $n = 20$). The largest measurement (2,160 m) occurred at a site that also had the lowest mean distance from nest pool edge to treeline ($\bar{x} = 1$ m, SD = 0 m). This site (site 1, Bob Bay) was located at the north end of Hunter Island, where the topography consists of steep-sided, thickly-forested knolls and larger hills rising behind a series of coves and inlets with estuaries at their head. Boggy openings were few and isolated, but pairs and groups of cranes were frequently seen in the estuaries and other bog openings contained large amounts of crane scat and feathers.

The nearest water bodies to nests other than bog pools or ocean were lakes (73%), marshes (19%), or tidal lakes (2%) ($n = 27$). Nests were located within 500 m of the seashore at most sites (21/28 sites; Figure 13m); however this result may be biased by the fact that our helicopter surveys were mainly within 1.5 km of the coastline. Four sites, located on small (Lady Douglas Island) to large (Aristazabal Island) islands, were 800-900 m from shore, and one site, located on the Don Peninsula (part of the mainland coast) was 1130 m from shore. Distances from the nest to the nearest estuary were farther than distance to shore (Figure 13n). The largest distances (2740 m and 2660 m) were from nests from consecutive years located on a small island with no estuaries, meaning that much of the distance was over the ocean.

No nest sites were located near to active logging sites. Two nests were within 0.5 km of a road. The nest closest to a road (0.36 km from the road running between the McLoughlan Bay ferry terminal and Bella Bella) had suffered from predation of its 2 eggs, probably by birds, when we discovered it in 2008, whereas the nest next nearest to a road (0.50 km from the airport road on Denny Island) was successful in both 2007 and 2008.

Figure 14. Site 14 (Athlone 2), vegetation group 1, 24 July 2008. The nest is at the edge of the islet in the rear left, under the fallen tree. *Sphagnum rubellum* is visible on the islet in the foreground. Photo: Krista Roessingh.

Figure 15. Site 7 (Gullchucks 2007), vegetation group 2, 7 August 2008. A small pool with shore pine, juniper and *Cladina* dominant, with bog woodland in the distance. The nest was on the islet in the centre-right of the photo. Photo: Krista Roessingh.

Figure 16. Site 17 (Lady Douglas Island), vegetation group 3, 15 September 2008. Note raised hummocks of *Sphagnum austinii*, *S. papillosum*, and *S. rubellum* at pool edge, and white *Cladina* lichens in foreground. The nest, made of strips of bark and twigs, is visible in the centre foreground. Photo: Krista Roessingh.

Figure 17. Site 18 (Cultus Sound), vegetation group 4, 9 July 2008, showing cedar twig nest, tufted clubrush, and mounded *Sphagnum* islets in the background. Photo: Krista Roessingh.

Figure 18. Site 2 (Saunders 2008), vegetation group 2, 14 May 2009. This was the smallest nest islet in the sample. Islets were mainly composed of hoary rock moss and *Sphagnum austinii*. Photo: Krista Roessingh.

Figure 19. Site 5 (Shearwater), 27 May 2007. This nest occurred in a beaver-dammed pond containing vegetation characteristic of fens – mainly sweet gale and Sitka sedge (*Carex obnupta*). The nest was 5 cm above the water level and was the tallest nest (10 cm) of those sampled. The pond was surrounded by bog woodland vegetation. Photo: Ingmar Lee.

Diet

Among all samples (n = 138), the constituent occurring at the highest frequency was grit (43%), followed by mussel shells (*Mytilus edulis,* 41%), periwinkle (*Littorina littorea*) and limpet shells (41%; these items could not be identified separately), insects (30%), sedge (*Carex* spp.) and crowberry (*Empetrum nigrum*) (28% each), plant remains (21%), crab remains (10%), and trace amounts (<5%) of moss leaves, small seeds, and vertebrate remains (Figures 20 and 21). By volumetric content for all samples, sedge was the largest component ($\bar{x}$ = 27%, SD = 44%), followed by mussel shells ($\bar{x}$ = 21%, SD = 34%), crowberry ($\bar{x}$ = 19%, SD = 37%), periwinkle and limpet shells ($\bar{x}$ = 14%, SD = 26%), plant remains ($\bar{x}$ = 8%, SD = 23%), grit ($\bar{x}$ = 6%, SD = 10%), and trace amounts ($\bar{x}$ <2%) of crab shells, insect remains, small seeds, moss, and vertebrate remains.

The occurrence of diet components periwinkle/limpet and mussel was best modeled including an interaction term for site and time, and I interpreted this as there being no consistent trend across time or across sites. The occurrence of sedge and crowberry differed across sites, but those sites with lower occurrence were consistent across all time periods. The occurrence of insects in the diet was consistent across sites, but varied by time period (Table 5). Significant differences in percent volume across site and time periods were tested using non-parametric Kruskal-Wallis tests (Table 6).

There were significant differences in both the frequency of occurrence and percent volume of periwinkle and limpet in scat samples between sites but not time periods. Periwinkle and limpet were lowest at sites 4 and 6 (6% and 24% occurrence, respectively; Figures 22 and 23). Significant differences in frequency and percent volume of mussels were observed between sites and time periods. Mussels occurred more often in samples from sites 2, 3 and 5 ($\bar{x}$ = 54%, SD = 5.1%), and less often at sites 1, 4, and 6 ($\bar{x}$ = 16%, SD = 9.0%) (Figures 22 and 24), while frequency and content were much higher in the early-season period ($\bar{x}$ = 41%, SD = 41%) than in mid- ($\bar{x}$ = 16%, SD = 27%) and late-season ($\bar{x}$ = 16%, SD = 31%) (Figure 25).

Sedge and crowberry had significant differences in frequency over time periods and sites. The best model describing the probability of finding sedge in crane scats indicated that both time and site were important factors but the interaction effect was not. The probability of observing sedge in scat samples was highest in mid-summer and lowest in the late-season time period (Figure 26). Among sites, there was no sedge in samples collected at site 2, while samples collected from site 4 had greater frequency and percent volume of sedge than other sites (Figures 20 and 22). Differences in mean percent volume of sedge content for site (Figure 22) and time (Figure 25) were significant and followed this pattern as well.

Table 5. Significance of logistic regression models constructed for testing the effect of site and time on the presence of each diet component. Fitted models included two one-way main effect models, and one model with a two-way interaction term between site and time period. I compared all models to a null model with no covariates. The best model for each diet component was the model with the highest amount of variability and the fewest regression parameters, identified by the largest AICc model weight, on a comparative 0-1 scale.

Diet Component	Site	Time	Site x Time	AICc weight
periwinkle/limpet	0.004	0.568	<0.001	0.94
mussel	<0.001	0.017	<0.001	0.99
sedge	<0.001	<0.001		0.94
crowberry	<0.001	<0.001		0.99
insects		<0.001		0.61

Table 6. Results of non-parametric Kruskal-Wallist tests on differences in percent volume of diet components across site and time periods.

Diet component	Site (df = 5)		Time (df = 2)	
	H	*P*	*H*	*P*
periwinkle/limpet	14.31	0.014	0.06	0.97
mussel	19.77	0.001	8.48	0.014
crowberry	31.87	0.000	50.29	0.000
sedge	46.68	0.000	23.17	0.000

For crowberry, both site and time period were highly significant covariates, and the best model had no interaction between these factors. The probability of observing crowberry in scat samples was zero in the early period, and increased in the mid and late-season periods for all sites. Among sites, frequencies were lower at sites 3 and 4 (8% and 0% respectively), however no samples were collected at site 4 in the late-season period when crowberries were abundant (Figure 27). Percent volume of crowberry in samples showed significant differences over sites, with lowest percent volume at sites 3 ($\bar{x}$ =

0.32%, SD = 1.6%) and 4 ($\bar{x}$ = 0%) (Figure 22), and over time period, with highest mean value in the late-season period ($\bar{x}$ = 48%, SD = 45%) (Figure 25).

Insects were very low in percent volume overall ($\bar{x}$ = 0.70%, SD = 2.6%), but occurred at varying frequencies ($\bar{x}$ = 30%, SD = 18%). In the logistic regression models, the effect of time period was highly significant, while site and the interaction effect were also significant factors. The model with the lowest AIC_c value was a simple model with only the effect of time period (w_i = 0.607). The probability of occurrence decreased in the mid-season period and was much higher in the late-season period (Figure 28).

Correlations between diet components and habitat measurements suggest that crowberry became more important the farther scats were collected from an estuary, while sedge became less important (Table 7). Likewise, the larger the distance from nest pool to treeline, the more important the sedge component of the diet while the contribution of mussels decreased. There was no relationship between the percent cover of crowberry or sedge with the frequency of occurrence or percent volume of these items in faecal samples collected at nest and roost sites (Figure 29).

Table 7. Correlations (Pearson's r; df = 136, $P<0.05$) between landscape-level habitat variables (means for sites 1-6) and percent volume of diet components in sandhill crane scat samples for each site (N = 138) collected in the Bella Bella area in 2008.

Habitat component	Diet item	*R*	*P*
Distance from nest pool edge to nearest treeline	sedge	0.183	0.0313
	mussel	-0.168	0.0485
Distance from nest to nearest estuary	sedge	-0.391	<0.001
	crowberry	0.340	<0.001

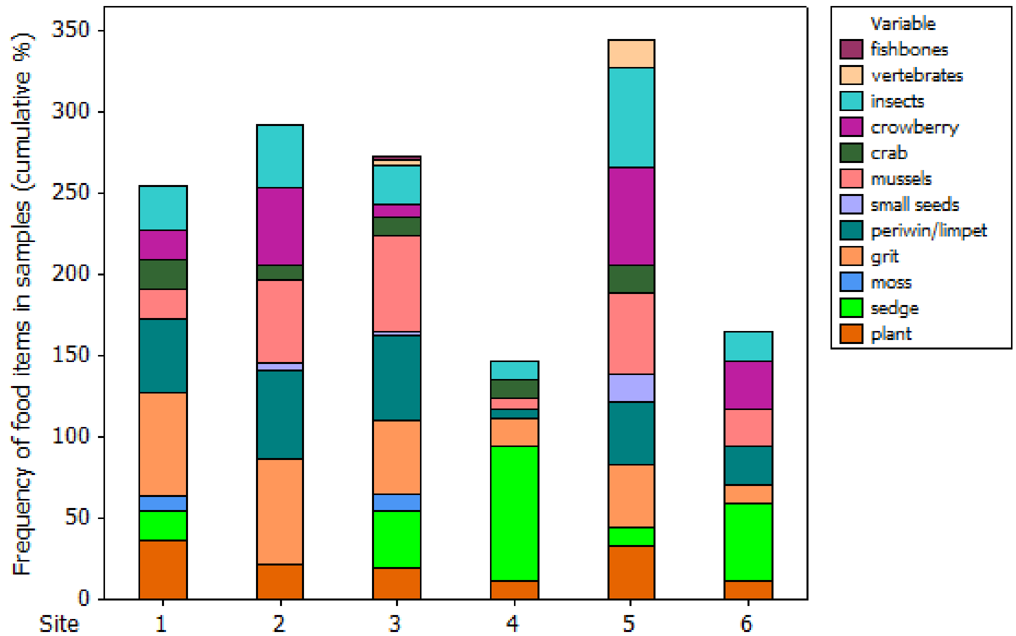

Figure 20. Frequency of all food items by site for food item remains identified in sandhill crane faecal samples (n = 138) collected near Bella Bella, B.C., in 2008.

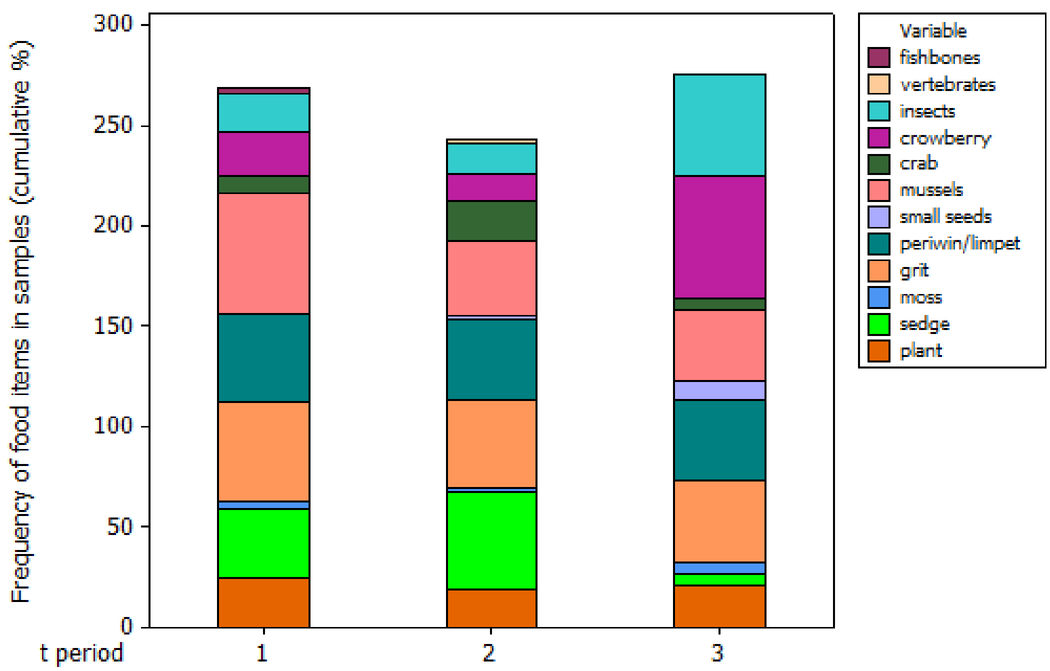

Figure 21. Frequency of all food items by time period for food item remains identified in sandhill crane faecal samples (n = 138) collected near Bella Bella, B.C., in 2008.

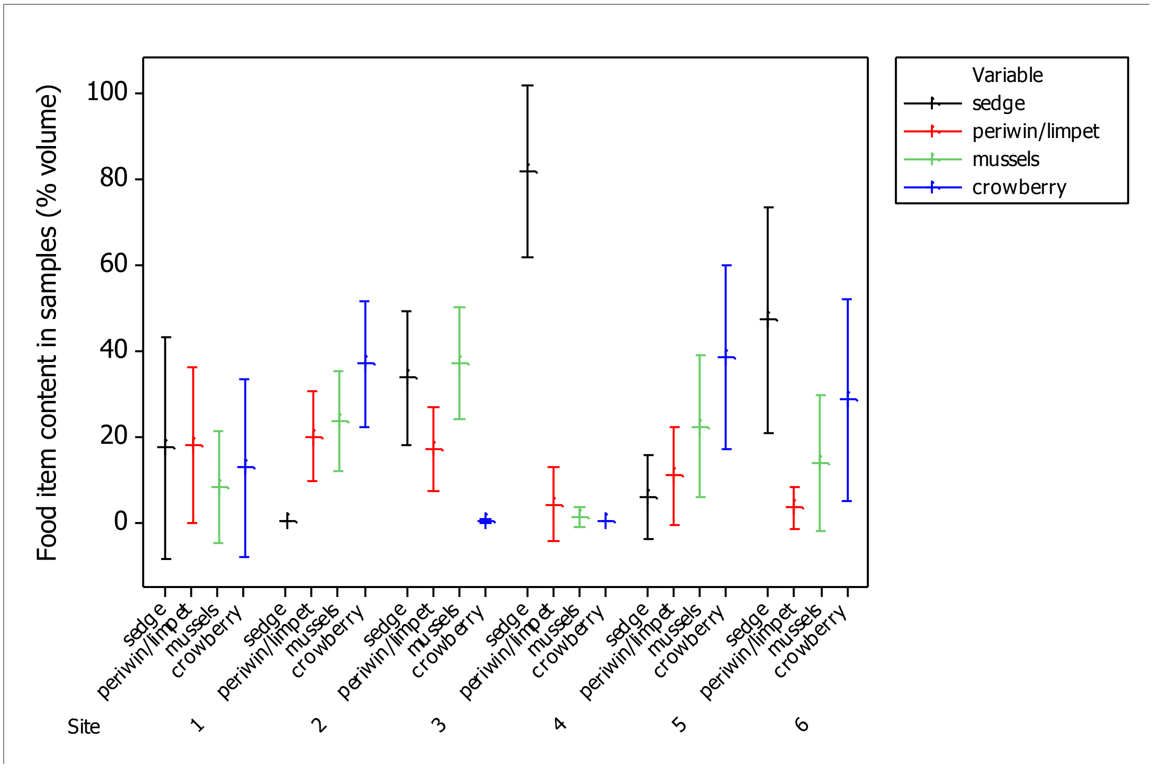

Figure 22. Food item content (mean percent volume with 95% confidence interval) by site for food item remains identified in sandhill crane faecal samples (*n* = 138) collected near Bella Bella, B.C., in 2008.

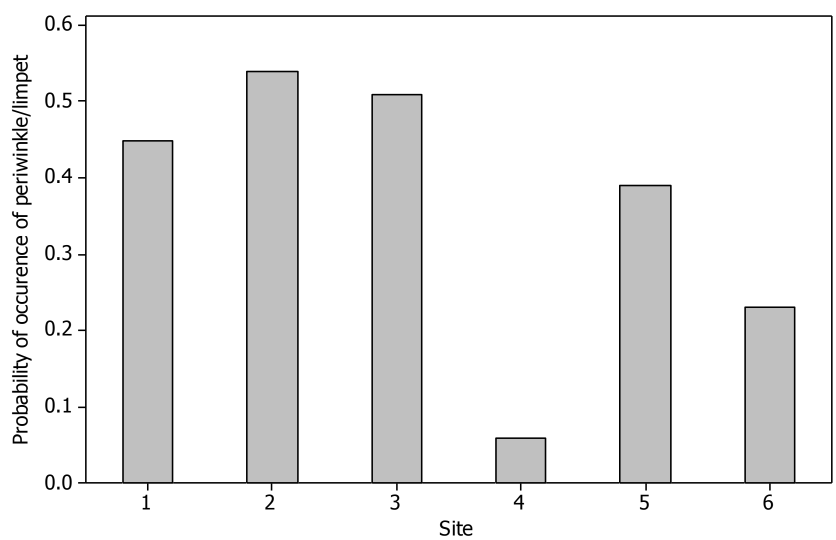

Figure 23. Probability of occurrence of periwinkle and limpet by site for food item remains identified in sandhill crane faecal samples (*n* = 138) collected near Bella Bella, B.C., in 2008.

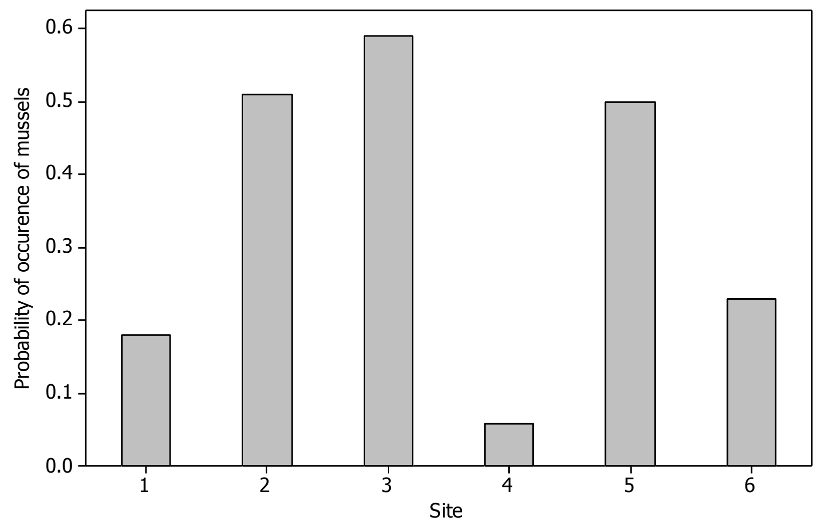

Figure 24. Probability of occurrence of mussels by site for food item remains identified in sandhill crane faecal samples (*n* = 138) collected near Bella Bella, B.C., in 2008.

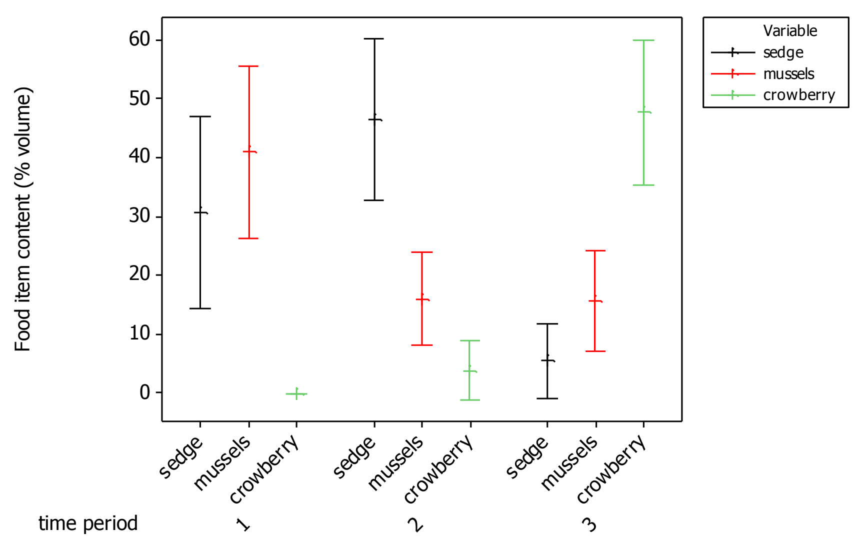

Figure 25. Content (% volume; mean and 95% confidence interval) of sedge, mussels, and crowberry by time period (1 = early, 2 = mid, and 3 = late-season) for food item remains identified in sandhill crane faecal samples (*n* = 138) collected near Bella Bella, B.C., in 2008.

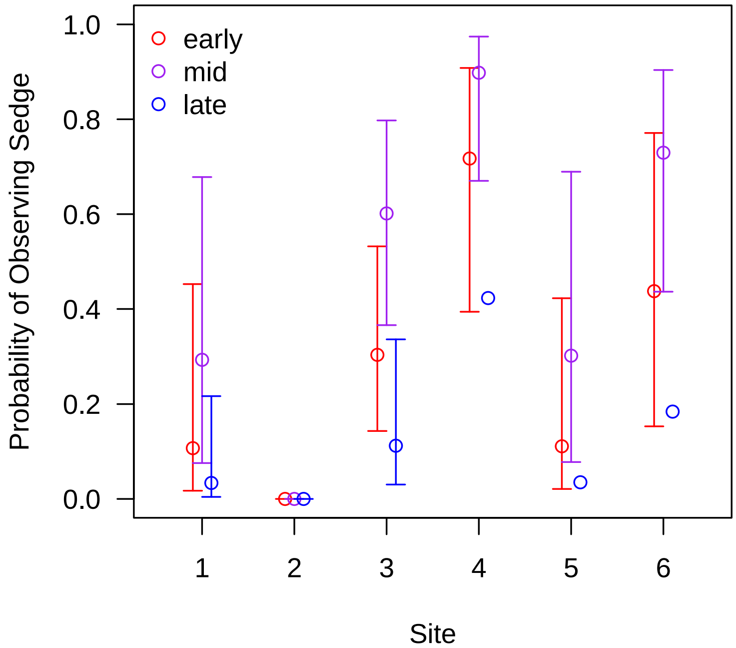

Figure 26. Probability of observing sedge by time period and site, based on a logistic regression model with no interaction effect for food item remains identified in sandhill crane faecal samples (n = 138) collected near Bella Bella, B.C., in 2008.

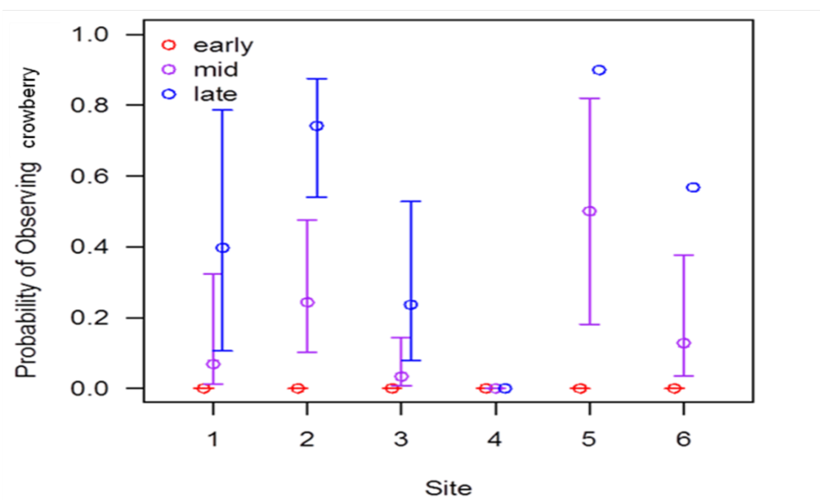

Figure 27. Probability of observing crowberry by time period and site, based on a logistic regression model with no interaction effect for food item remains identified in sandhill crane faecal samples (n = 138) collected near Bella Bella, B.C., in 2008.

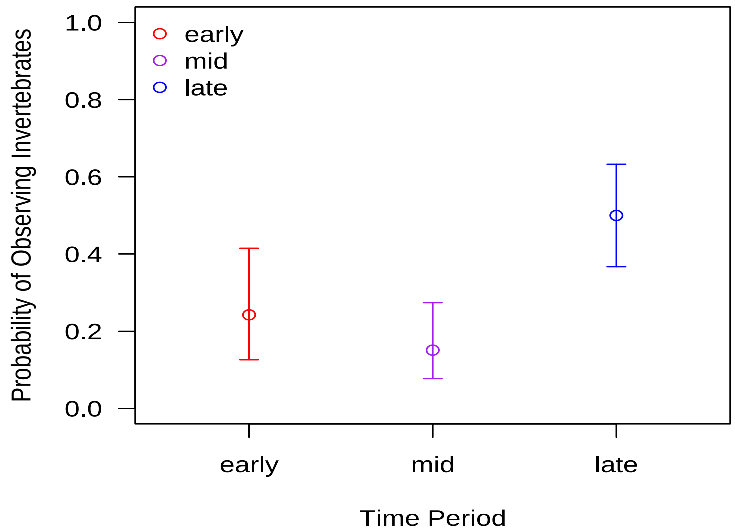

Figure 28. Probability of observing insects by time period, based on logistic regression model ‘time period’ for food item remains identified in sandhill crane faecal samples (n = 138) collected near Bella Bella, B.C., in 2008**.**

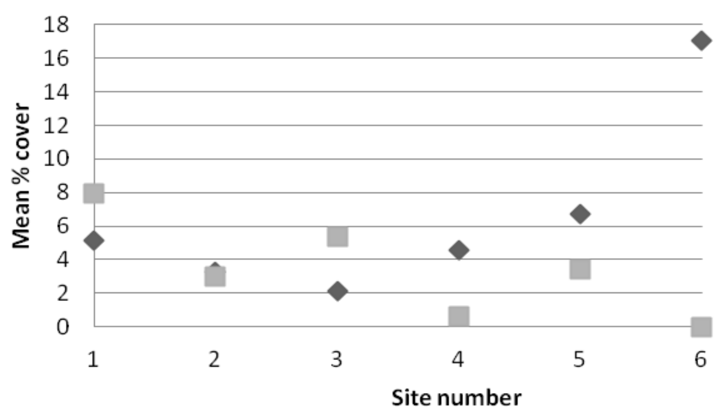

Figure 29. Mean % cover of sedges (squares) and crowberry (diamonds) at faecal collection sites for food item remains identified in sandhill crane faecal samples (*n* = 138) collected near Bella Bella, B.C., in 2008.

Figure 30. Sandhill crane parents and colt foraging in rockweed near the Saunders Island nest site, central coast B.C., 23 August 2008. Photo: Krista Roessingh.

Discussion

Nest habitat

All sites fit within the bog wetland site class described in Wetlands of British Columbia (MacKenzie and Moran 2004). Bogs are wet or very wet sites, with the soil surface tier dominated by fibric or mesic sedge or moss peat, pH lower than 5.5, stagnant or sluggish water flow, very poor to poor nutrient regimes, and an abundance of *Sphagnum* mosses, conifers and ericaceous shrubs. They generally develop in basins where peat has accumulated to the extent that its surface is above the water table. Sandhill crane nest sites in this study fell largely within the common juniper – tufted clubrush – hoary rock moss (*Juniper communis - Trichophorum cespitosum - Racomitrium lanuginosum*) bog site unit (Wb52), based on composite vegetation data (MacKenzie and Moran 2004). This site unit is representative of bogs where peat is no longer accumulating, and is characteristic for its shallow pools created by peat degradation, as well as the prevalence of hoary rock moss and ground lichens. However, high microtopographical variation and edges between bog and bog woodland were ubiquitous among sample sites. Vegetation characteristic of the shore pine – crowberry – tough peat-moss (*Pinus contorta* var. *contorta – Empetrum nigrum-Sphagnum austinii*) (Wb51) and particularly shore pine – yellow cedar – tufted clubrush (*Pinus contorta – Chamaecyparis nootkatensis – Trichophorum cespitosum*) (Wb53) bog site units was common. Site unit Wb51 represents raised bogs on level terrain or depressions, with mounds of *Sphagnum austinii* and scattered low shrubs. This site type has the poorest soil nutrient regime and the most acidic soils among the three, which enable the active growth of *Sphagnum* mosses and other bog vegetation. Site unit Wb53 (bog woodland) occurs on sloping terrain or along drainageways, rarely has standing water, and has a sparse canopy of stunted yellow cedar and shore pine. Sites 1 and 14 (vegetation group 1) had typical bog woodland vegetation surrounding nest pools, thus tree layer species had high indicator values compared with other groups.

Site series described by Banner et al. (1993) that occurred within 20 m of nest pool edges included bog woodland (CWHvh2/12), open bog (CWHvh2/32), drier forest (CWHvh2/03), and scrub forest (CWHvh2/02). Subcommunities of the open bog site series included vegetation typical of hummocks, dry mounds, pools and depressions (Asada et al. 2003).

Sandhill crane nesting habitat in coastal B.C. may be better compared with that of cranes nesting in muskegs of northern Canada and Alaska, but detailed data are lacking for these regions. Nesting habitat described in studies of sandhill cranes in California and Oregon includes open, shallow-flooded meadows in northeastern California (Littlefield 1995) to dense, coarse emergents (mainly burreed and hardstem bulrush, *Scirpus acutus*) at Malheur National Wildlife Refuge in Oregon (Littlefield 2001). In B.C.'s central interior, 15 nest sites were found in sedge-dominated wetlands surrounded by forests, while others occurred in heavily vegetated bulrush marshes encircled by rangelands (Cooper 1996). In Haida Gwaii, sandhill cranes have been found nesting in brackish estuaries (Hearne and Hamel 2003). It is remarkable that we did not find nests in marsh or fen habitat, as these wetland types occur within the survey area. Moss islets in bogs may substitute for coarse emergent and marsh vegetation often used for nesting in other wetland types, as they provide close proximity to fresh water, seclusion, and natural nest platforms.

Nest pools were small in comparison with the requirements for breeding wetland size described in the IWMS (>1 ha) (B.C. MWLAP 2004). Pool size was comparable to beaver ponds (0.04-0.08 ha) where nests were reported from the Rocky Mountain population of *G.c. tabida* (Drewien 1973) and forest bogs (0.20 ha) used by Eastern Flyway population *G.c. tabida* in Michigan (Taylor 1976).

Water depth is important for nesting and roosting cranes because standing water provides nocturnal security from terrestrial predators, and predation is the most common cause of nest failure (Armbruster 1987, Stone 2009). For example, in a study of nest habitat selection and nest success in northwestern Minnesota, nests in water deeper than 9.7 cm were 3.7 times less likely to suffer predation than those in shallower water (Maxson and Riggs 1996). Water depth was greater on average (median = 56 cm, IQR = 49-77 cm, n = 21) in central coast sphagnum bog sites than that reported in several studies of marsh-nesting cranes, where depths averaged 25 cm or less (Walkinshaw 1973, Robinson and Robinson 1976, Littlefield 2001), but there are some exceptions. Records for three floating nests found in B.C. indicate water depths at the nest site ranging from 15 cm to 1.5 m (Campbell et al. 1990). Nests located in hardstem bulrush at Sycan Marsh, Oregon, were in 40-60 cm ($\bar{x}$ = 50 cm) of water (Littlefield and Ivey 2002).

Cranes in the study area built their nests on moss islets rather than building up a platform out of vegetation in water. Raised hummocks (islets) in bog pools accounted for much of the measured nest height above water, as the height of the nest itself was negligible. Moss islets are likely to provide protection from flooding, which is a significant cause of nest failure in marsh-nesting cranes (Ivey 2007). All but one nest pool had 2 or more islets, which showed evidence of roosting and other activities in addition to nesting. Feathers and scat were found on islets adjacent to nest islets at all locations, and subsequent video monitoring at two nest sites showed mates of nesting cranes roosting, preening, and performing sentry duty on adjacent islets, as well as chicks traversing islets to get to the pool edge (Pacific Wild 2009-2010). Distance of nest islets from the nest pool edge may be important for protection from terrestrial predators, but the range of distances in this study does not indicate an optimum distance.

Nests of *G.c. tabida* generally consist of large piles of residual emergent vegetation of a variety of types, including sedge, reed canarygrass, and rush (Littlefield and Ryder 1968, Drewien 1973, Walkinshaw 1973). Limited use of muskrat (*Ondatra zibethica*) lodges, dikes, and islands in deeper marshes has been reported (Drewien 1973, Walkinshaw 1973). Nest records for B.C. indicate a range of nesting materials including grasses, bulrushes, sedges, leaves, hardhack branches, and *Sphagnum*, and construction varying from a few branches on dry ground to a large floating bulrush platform (Campbell et al. 1990). Nesting materials used in nests in this study came mainly from the dominant shrub vegetation, although residual herbaceous plants such as sedge, rush, and grasses were available.

Concealment from view from the pool edge, either by vegetation or other islets, was highly variable at study nests (median = 24 cm, IQR = 13–29 cm, n = 21). Other research has shown that cranes select nest sites with higher sedge stem density and concealment than randomly selected sites (Maxson and Riggs 1996), and that egg predators vary with levels of concealment (Littlefield 1995). In the latter study, nests were placed in marsh vegetation with a mean height of 37.3 cm (n = 727, Littlefield 1995). In comparison, emergent vegetation cover in bog nest pools was generally low (median = 5%, IQR = 5-10%) and sparse, and did not contribute to nest concealment.

Sites with lower (<100 m) mean distance from the treeline closest to the nest to the next forest opening (forest buffer width) were located on flatter outer coastal islands, where mosaics of open bog and pools, bog woodland, scrub forest, and small lakes are typical. Sites with greater forest buffer widths occurred on inner islands, which are more topographically complex and support more productive forests. No nests were found in close proximity to active logging, but sites close to roads (<0.5km) had forest buffer widths of 170 m and 290 m between the nest and the road. Forest buffers may provide seclusion for nesting wetlands and escape cover for cranes with young (B.C. MWLAP 2004) as well as for moulting cranes. The small basins where most nests were located also provide seclusion due to topography.

On average, nests were located closer to the shoreline than to the nearest lake or marsh but farther from the nearest estuary. The prevalence of intertidal mollusks in crane diets suggests that proximity to the shoreline may be more important than proximity to freshwater habitats. If shoreline foraging areas are considered part of the breeding territory, the distance from nest to foraging area was relatively large (median = 400 m, IQR = 200–500 m, n = 28). At Malheur National Wildlife Refuge in Oregon, a highly productive marsh, the distance to the nearest feeding meadow averaged 40 m (n = 515, range 0-345 m) (Littlefield 2001). However, nesting cranes may forage outside of defended territories when food availability is low. Cranes nesting at Grays Lake, Idaho, foraged within their nesting territories until their young fledged during years when food was plentiful, but fed outside their territories during bad food years (Drewien 1973, Armbruster 1987). Bog nesting cranes in the Upper Peninsula of Michigan foraged in forest openings within a 3 km radius of the nest site (Taylor 1976). *G.c. tabida* in Colorado (Bieniasz 1979) and in southeastern Wisconsin (Bennett 1978) also moved away from nests to forage in uplands when colts were only days old. On the Yukon-Kuskokwim delta, *G.c. canadensis* nested on the tundra but brought their broods to saline marshes after they hatched (Gracz et al. 2008).

Diet

Data from this research show a reliance on mollusks foraged from the intertidal zone throughout the breeding season, as well sedges, crowberries, and other plants. These food items signify the use of different foraging habitats by breeding sandhill cranes: mollusks from intertidal areas, sedges from upper beach, bogs, fens or marshes, and crowberries from bog woodlands.

Intertidal marine life has not been reported in records of sandhill crane diet from other coastal locations. At Aransas National Widlife Refuge (ANWR) on the Texas Gulf Coast, wintering cranes roosted in a tidally-influenced lake (Tacha et al. 1986), but foraged in upland croplands and some natural habitats (Hunt and Slack 1989). Wolfberry fruit (*Lycium caroliniamum*, high in ascorbic acid), acorns (from *Quercus virginiana*, high in iron, calcium, and essential amino acids), and insects were the most important foods in samples collected in the winter of 1983 and 1984 (Hunt and Slack 1989). *G.c. canadensis* nesting on Banks Island, Nunavut, inhabited sand dunes and dry tundra next to lakes, ponds, and rivers. Cranes and their young were observed feeding on fish remains, lemmings, lichens and old-growth vegetation, and scraps of snow geese and squirrels at the entrance of a fox den. In August they were observed feeding on large numbers of crowberries, bilberry (*Vaccinium uliginosum*), and mountain cranberry (*Vaccinium vitis-idaea*) (Reed 1988). Near Hudson Bay, summering cranes were reported eating the eggs of blue goose (*Chen caerulescens*) (Harvey et al. 1968). Whooping cranes (*Grus americana*) feed on mollusks and crustaceans in their breeding grounds, and use brackish bays, estuaries, marshes, and tidal flats on their wintering grounds at ANWR (Johnsgard 1983).

In the coastal rainforest, marine-derived nutrient subsidies may compensate for restricted prey availability on small or isolated islands for some typically terrestrial predators, as demonstrated by analyses of gray wolf faeces collected in B.C.'s central and north coast archipelago (Darimont et al. 2004). Small mollusks, which occur on the surface of rockweed (*Fucus* spp.) on rock and pebble beaches, may be more readily available and more profitable as a protein and calcium source than small vertebrates and invertebrates commonly eaten by marsh-nesting cranes (Walkinshaw 1973). Mussels are high in protein, and contain fats, vitamins, minerals, and several essential amino acids (USDA 2008). Periwinkles are likely higher in protein than mussels but are lower in fats and vitamins (USDA 2008). Consumption of mollusks may also be for the purpose of obtaining grit, which may be needed to break down items such as berry seeds and crab (Westwood and Chavez-Ramirez 2005). Mollusk shells may be an important source of calcium to egg-laying females as it is an essential nutrient for birds, particularly for egg-laying females and growing young (St. Louis and Breebaart 1991). Scats containing mollusk shells were collected in bog nesting or roosting habitat throughout the breeding season at most sites. In order to access intertidal mollusks, cranes with unfledged young must either walk through forest from the upland bog nest and roosting areas, or else leave the young behind. Cranes and their young, from very small chicks to fledglings, were observed foraging on the beach at several locations near to nest sites in the Bella Bella area in 2008.

Wild flightless chicks have been observed feeding primarily on insects and other protein-yielding animal foods during their early stages of high growth (Lewis et al. 1977, Johnsgard 1983). By the start of migration young colts have generally been observed to share the same diet as adults (Johnsgard 1983). However, frequency of insects occurring in samples was lower in the mid-season and higher in the late-season period. Site 5 had the highest frequency of insect remains overall, and 90% of samples from site 5 had insect remains in the late-season period, but these occurred in trace amounts. Insect remains occurred at trace volumes in all but 5 samples, thus they were not an important food source for breeding cranes and their young in this area.

Differences in diet content over the breeding season were anticipated from observations of crane habitat use and seasonal changes in abundance and quality of food sources. Significant differences among sites were less expected, given that sites were within a 7 km radius, and all sites were within 900 m of the shore, however these differences are less reliable due to small sample sizes drawn from some sites during some time periods. Sites 4 and 6 had fewer food items, and both had lower periwinkle and limpet as well as lower mussel frequency (however, scats were not found at site 4 during the late collection period). These sites differed from other sites in that site 4 was located in a bog upland separated from a rocky shore by a steep forested slope, and site 6 was a marsh roost site rather than a nest site. Cranes with chicks were seen on beaches near to site 6 but not site 4. Site 4 was also the site with the highest sedge in volume and frequency; it was located closer to a small lake (200 m) than to shore (400 m). Sedge remains were absent at site 2, which was located on a small island with no marsh, fen, or estuary habitat, although sedges do occur in the high intertidal zone along some sections of shoreline. Sites 1 and 5 had comparable probability of observing sedge based on sample frequency, although site 1 was surrounded by forest with no marsh or fen nearby and site 5 included samples collected at a marsh roosting site. Further research with more collection sites and a greater sample size is needed to explore associations between diet and habitat differences as they relate to availability of food items in breeding and foraging areas.

Increased frequency of sedge remains in the mid-season period at all sites except site 2 may be related to plant phenology; sedges were at their peak growth in late June. Likewise, crowberries were abundant and ripe in the late-season period, when the probability of observing them in scat samples was highest at all sampled sites. Similar frequency but reduced percent volume of mussel remains in mid and late-season periods may indicate an inverse relationship with sedge (mid-season) and crowberry (late-season) consumption. Shifts in diet composition may be related to changes in energy needs, or to phenological changes in prey causing differences in availability, palatability, and profitability (Smith and Remington 1996). The greatest change in dietary overlap between months in a study of whooping cranes wintering on the Texas coast occured with the end of the fruiting stage of wolfberry fruit (*Lycium carolinianum*), an important component of their diet when available (Westwood and Chavez-Ramirez 2005).

Management Implications

The nest sites described together as a sample of coastal sandhill crane breeding habitat in this research indicate the importance of small bog pools in bog woodland openings under 50 m in radius, with *Sphagnum* islets to provide nest platforms. Concealment from emergent vegetation or islet vegetation varied considerably. The ideal forest buffer width between nest sites and human disturbance could not be determined. Cranes nested successfully within 0.5 km a shipyard and sawmill, however industrial activity at this location has been ongoing since the 1940s. The blanket mire complex in which nests were located is currently classed as inoperable for logging. Other industrial developments that have been proposed in crane breeding habitat on the central and north coast, such as wind farms and gravel pits, may have negative effects on cranes.

Proximity to the shoreline may be important for breeding crane nest habitat selection because of foraging requirements. Differences in diet composition between nest and roost sites may be related to landscape position and terrain, for example, cranes with pre-fledged chicks may access intertidal foraging areas more easily versus marshes or lakes. Changes in diet over the breeding season are probably related to the phenology of sedges, berries, and intertidal gastropods. Further studies of habitat selection could employ GIS analysis based on new map layers for the study region currently being developed under the B.C. Ministry of Forest’s Vegetation Resources Inventory program. A larger study of seasonal diet composition, including nest sites at varying distance from the coastline, could be linked with habitat selection modelling to better understand the relationship between the foraging and nesting habitat requirements of coastal breeding cranes.

Chapter 5: Conclusion

This is the first study to focus on the sandhill cranes of the central and north coast of B.C., and describes the range of nesting habitat features and diet composition among a sample of breeding cranes. The following is a brief summary of the research results with regards to the objectives presented in the introduction, together with my recommendations for further research and management.

Surveys

Cranes were located consistently in areas with sheltered shorelines (such as inlets and lagoons) and upland bog, including the area in and around Higgins Pass, between Price and Swindle Islands, Gale Pass, which runs between Athlone and Dufferin Islands of the Bardswell Group, the north side of Denny and Hunter Islands, the Cultus Sound area at the southwestern end of Hunter Island, the southwest end of Dowager Island, Lady Douglas Island, the west side of Price and Aristazabal Islands, and lowland parts of Porcher Island.

The number of cranes sighted during helicopter surveys rose from 18 over an area of 180 km^2 to 104 cranes over 430 km^2 from 2006 to 2008, while the number of nests sighted rose from 0 to 19 and average survey effort decreased by half. Crane nests were located only in bog habitat, while cranes frequented bogs, shorelines, and rarely, marshes. The observed density of nest sites in the 2008 survey (0.044/km^2; uncorrected for detectability) was similar to that observed by Cooper (2006) in sheet bogs on northern Vancouver Island. Aerial surveys allowed coverage of a large geographic area during mid-May, when both early- and late-nesting birds were most likely to be incubating eggs. Sighting cranes that did not flush and those in forested habitat was difficult. Data collection on sightings from mariners and others in the study area combined with examination of satellite imagery were useful methods for identifying potential crane habitat.

Crane habitat and use

Cranes and nests were sighted where sheltered islands, lagoons, or inlets and upland bog occur together. These habitats occur on the extreme outer coastal islands as well as on the inner islands and some coastal mainland areas. Frequent sightings of cranes in intertidal habitats near to bog nest and roost sites may indicate that breeding crane territories include intertidal foraging areas and the forest between these areas and bog nesting pools. Another possibility is that bog nesting habitat does not have adequate food resources, and thus breeding cranes must forage outside of defended territories.

Nest site vegetation

All 20 nests that were sampled on the ground were in ombotrophic peatlands. None were found in fen or marsh wetlands. Following the site unit classification scheme for wetlands of B.C. by MacKenzie and Moran (2004), these sites shared vegetation characteristic of open bog with pools created by decaying peat (*Juniper communis - Trichophorum cespitosum - Racomitrium lanuginosum*; site unit Wb52), bog woodland (*Pinus contorta – Chamaecyparis nootkatensis – Trichophorum cespitosum*; Wb53), raised, actively-growing bogs (*Pinus contorta* var. *contorta – Empetrum nigrum-Sphagnum austinii*; site unit Wb51), as well as a smaller component of fen vegetation, with most sites having less than 25% total tree and shrub cover. Among all 20 sites, the most common and abundant species were *Myrica gale*, *Sphagnum capillifolium* and *S. magellanicum*, *Cladina* spp., *Empetrum nigrum*, and *Chamaecyparis nootkatensis*.

Nesting pools

Bog pools where nests were found were mostly under 0.2 ha (23 of 29 nests) in size but ranged up to 1.2 ha, with scant emergent vegetation cover and turbid water below 25 cm depth. Water depth in bog nest pools was variable; the median depth among sites was 56 cm (IQR = 49–77 cm, n = 21). The majority were located in small forest openings, with distance from nest pool edge to treeline under 50 m (median = 46 m, IQR = 24–160 m, n = 25), in small, gently sloped basins that may provide topographical isolation from human activity and potential predators. Nests were all constructed on islets of *Sphagnum* mosses and other vegetation in bog pools, at varying height above water (median = 30 cm, IQR = 15–35 cm, n = 23). Bog pools had more than one islet in all but one case, and islets adjacent to nest islets showed evidence of roosting and preening. Nests were not consistently concealed from view from the pool edge, either by vegetation or by other islets.

Stand and landscape - level characteristics

The median forest buffer width (width of forested area adjacent to nest pool openings), measured with satellite imagery, was 150 m (IQR = 90–260 m, *n* = 25). Forested habitat may serve as a corridor for cranes with pre-fledged young for travelling between bog nest and roost sites and shoreline foraging areas, and may provide cover for cranes in moult. On average, nests were located closer to the shoreline (median = 400 m, IQR = 200–500 m, *n* = 28) than to the nearest lake or marsh but farther from the nearest estuary. The prevalence of intertidal mollusks in crane diets suggests that proximity to the shoreline may be more important than proximity to freshwater habitats.

I did not find nests close to active industrial logging activity. Two nests were located within 0.5 km of roads outside the communities of Bella Bella and Shearwater (Denny Island); one had suffered predation of its eggs while the other was successful in both 2007 and 2008. These sites had forest buffer widths of 290 m and 170 m, respectively, between the nest and the road.

Diet

Food items characteristic of faecal samples collected at 6 nest and roost sites from May to August 2008 included mussel, periwinkle and limpet, insects, sedge, crowberry, plants (not identified individually), and crab. These items were available in different habitats used by sandhill cranes, including intertidal zones, upper beach sedge meadows, bogs, fens and marshes, and bog woodlands. Mollusks were present in samples throughout the season. Small mollusks, which occur on the surface of rockweed (*Fucus* spp.) on rock and pebble beaches, may be more readily available and therefore more profitable as a protein and calcium source than small vertebrates and invertebrates commonly eaten by marsh-nesting cranes. Insect remains occurred frequently but at trace volumes. Fluctuations in diet content generally followed seasonal availability. Percent volume and frequency of mussel content was much higher in early (23 May - 14 June) and mid-season (21 June – 7 July) sampling periods than in the late-season (22 July – 29 August) period. The probability of observing sedge in scat samples was highest in mid-summer and lowest in the late-season time period. The probability of observing crowberry in scat samples was zero in the early period, and increased in the mid- and late-season periods for all sites. There were significant differences between diet components found in scats among collection sites, but a larger study would be needed to relate these to factors such as the distance from crane nest sites to shorelines or the foraging quality of bog nesting habitat.

Recommendations for further study

Repeat surveys are needed to evaluate crane and nest density as well as levels of nest or wetland philopatry in this population. Survey methods that allow for the calculation of a visibility correction factor or other error measure to adjust for incomplete counts should be selected based on the resources available at the time of surveys. Double sampling and double observer methods within selected study areas are recommended for aerial surveys.

A larger study of crane diets with more collection sites to investigate associations between diet content and habitat assemblages used by coastal breeding cranes would be valuable. Foraging habitat quality likely plays a significant role in nest habitat selection as well as nest density. The diet of coastal-nesting cranes may vary considerably depending on the proximity of nest sites to coastlines. Habitat selection modelling, based on comparison of used and available sites, could be done with GIS analysis of measurable features from aerial and satellite imagery and with new classified imagery from the B.C. Ministry of Forests Vegetation Resources Inventory program.

A phylogenetic study is needed to determine the correct subspecies designation of coastal cranes, as well as the degree of relationship or isolation of the coastal population to interior and southern populations.

Recommendations for management

It is recommended that efforts to raise awareness about cranes and to gather sighting information should be continued in coastal communities. Data-sharing with B.C.'s Breeding Bird Atlas, the Conservation Data Centre, the B.C. Marine Conservation Atlas, the International Crane Foundation and other bodies remains important although cranes are no longer listed as a vulnerable species in the province. Communications with managers in the southern parts of the coastal population's range regarding population status and threats should also be continued. In addition, some effort should be directed towards raising awareness about the sensitivity of cranes to human observers and boats in order to limit disturbance.

Guidelines should be established to protect sandhill crane breeding, roosting and foraging habitat within conservancy areas from potential developments such as wind farms, hydroelectric projects and recreation sites. A forest buffer around breeding wetlands and the forest between breeding wetlands and coastal foraging areas where nests are located close to the shoreline should be set aside for each nest site. Proponents of developments such as wind farms should be aware that cranes in this area may shift nest sites from year to year. Protecting nest sites that are active at a given point in time may not provide adequate breeding habitat for cranes. Ideally, wetland complexes where cranes and nests are found, complete with forest buffers and access to shoreline foraging habitat, should be left undisturbed. Cranes are likely to be affected by pollution in intertidal foraging areas, therefore they should be included in impact assessments of potential pollution events such as marine oil spills and leaks as well as radiation leaks. It is recommended that B.C.'s coastal population be afforded protection of critical habitat as previously under the IWMS at a minimum, due to its small (but unknown) size and sparse distribution, and the extent of threats to habitat throughout its range.

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Appendix A
Summary of helicopter survey results

Results of helicopter surveys for sandhill cranes on the central and north coast of B.C., 2006-2008.

	2006			2007				2008			
	B	S	T	B	S	M	T	B	S	M	T
Nests			0	3			3	19			19
Eggs			0				6				34
No. of cranes	13	5	18	16	39	1	56	57	45	2	104
Total sightings	5	2	7	15	18	1	34	46	17	2	65
Ave. no. cranes/hr			1.5				5.3				7.7
Ave. no. cranes/km^2			0.10				0.20				0.240
Ave. no. nests/km^2											0.044

Note: B=bog, S=shoreline, M=marsh, T=total

Appendix B
Survey data

Survey data: 2007 sightings	note: all UTMs are in NAD 83 Zone 9					
Location	**x**	**y**	**Date**	**Time**	**Number**	**Observer and platform**
Whiskey Cove	561154	5778805	13-May	13:00	1 + 1	Krista/kayak
Whiskey Cove	561154	5778805	13-Jun	12:00	10 flying	
Whiskey Cove	561154	5778805	13-Jun	14:00	2	
Whiskey Slough	561463	5778463	27-May	6:30	1	
Whiskey Slough	561463	5778463	21-May	11:00	one	Krista/foot
Whiskey Slough	561463	5778463	19-Sep		~40 circling	Ian
Whiskey Slough	561463	5778463	06-Oct		6 flying over	Ian
Campbell Island, Ardmillan Bay	560038	5782211	17-May		one	
Campbell Island, Ormidale	558532	5783000	04-Jun	11:38	1	
Cannery beach	562012	5778247	17-May	15:00	one	Ingmar and Desmond on foot
Cannery beach	562012	5778247	22-May		1	
Cannery	562012	5778247	08-Aug	9:30	2 flying over towards airport bogs	
NW Denny Island	128 06.5	52 09.01	14-May		One on bog	heli
Denny Island, Kajustis Lagoon	128 02.553	52 09.258	14-May		One crane from lagoon	heli
Denny Island, Kajustis Lagoon	565289	5778752	01-Jun		2	Krista/kayak
Denny Island, Gullchucks			14-May	16:22	One crane up the estuary behind the cabin	heli
Denny Island, Gullchucks	567889	5777984	02-Jun	19:40	2 by fish trap	SV Habitat
Denny Island, Gullchucks			05-Jul		6	Kyle
Denny Island, Gullchucks			06-Jul		6	Kyle
Denny Island, Gullchucks			06-Jul		6	Kyle
Denny Island, Gullchucks	567784	5777485	29-Aug	19:00	11 behind berry island	Ingmar/kayak
Denny Island, Gullchucks bog	127 59.980	52 09.074	14-May	16:23	Pair from bog	heli
Denny Island, Gullchucks bog	568342	5778348	06-Aug		2 + calls	SV Habitat
Denny Island, Gullchucks N entrance	565420	5779029	19-May	11:30	single	Ingmar/kayak
Denny Island, Gullchucks, just past po	565977	5778632	22-May		1	SV Habitat
Denny Island, ropeswing beach	564654	5778761	19-May	12:00	single	Ingmar/kayak
Denny Island, ropeswing beach - from bog behind			24-Jul		2 flying	Ingmar/kayak
Denny Island, Klik Bay	563418	5778499	19-May	7:00	single on E pt. of bay	
Denny Island, Klik Bay			15-May	8:30	Calls heard from SW hotel	
Denny Island, Klik Bay	563823	5778053	01-Jun	6:00	1 at long beach	
Denny Island, Klik Bay	563397	5777374	01-Jun		3 at JM's	
Denny Island, Canal Bight	128 05.195	52 05.649	15-May		One crane on estuary, went up into forest	heli
Denny Island, field station	560733	5779098	25-May	17:00	8	
Denny Island, field station			28-May	am	5	
Denny Island, field station			13-Jun	12:10	5 landing	
Denny Island, field station			25-Jul	6:30	2, calling to cranes on Cunningham	Klaus
Denny Island, burial island across fror	560196	5779297	23-Jul	am	2	Klaus
Denny behind Croil Lake	561452	5777473	13-Jun	6:00	2 flew flushed	
Denny near Airport			23-Jul		2	Chris D.
Denny near Airport			05-Aug	16:00	2+2	Ingmar flushed, lots of tracks around
Denny near Airport	563747	5776498	19-Aug	15:00		heard calls from nearby
Cypress isthmus	563743	5780184	12-Aug	7:00	2	I/kayak
Cypress isthmus	563600	5780346	25-Aug	am	6	Krista
Cypress NW	563292	5780120	19-May	pm	2+ Tipsy on separate beaches	Ingmar/kayak
Cypress N	564138	5780061	04-Jun	13:30	10	I/K boat

Survey data: 2007 sightings	note: all UTMs are in NAD 83 Zone 9					
Location	**x**	**y**	**Date**	**Time**	**Number**	**Observer and platform**
Cypress Bay	563441	5779958	20-May	11-16:0(	5 including Tipsy	all/kayak
Cypress Bay	563624	5780306	02-Jun		8+2	K/I kayak
Cypress bog	564202	5779692	19-Jun	15:00	heard one call	K
Cypress E beach	564759	5779729	09-Jul	11:00	2+chick	I/kayak
Kynumpts	558068	5783001	17-May	afternoo	2 on beach	Ingmar/kayak
Kynumpts	128 08.614	52 11.724	28-May	15:30	1	I/K boat
Kynumpts, behind float plane dock	557986	5782982	20-Aug	am	1	Krista/ craniac
Kynumpts	558395	5783648	31-Aug	noon	3+2+colt	Krista/ craniac
Morris Bay, Campbell Island			20-Aug		3 on beach	SV Sans Souci
Calver Point	565302	5779572	19-May		1	Ingmar/kayak
Calver Point	128 02.718	52 09.766	16-May		2 cranes, one went into woods	Ingmar/heli
Rainbow Island	563523	5780416	04-Jun	13:20	1	SV Habitat
Saunders Island nest/beach	561047	5781263	14-May	7:30	1 + nest with 2 eggs	Krista and Briony
Saunders Island beach	561047	561047	24-May		beach	Krista
Saunders Island nest			29-May		still nesting	Krista
Saunders Island nest			04-Jun		shells	Krista
Saunders Island beach	561047	561047	07-Aug	9:00	2+chick	Ingmar/kayak
Saunders Island beach	561047	561047	17-Aug	10:00	2+chick	Jess B/Ingmar.
Saunders Island beach	561047	561047	12-Aug	7:30	2+chick	Krista/kayak
Saunders Island bog			07-Aug	16:00	2+chick	Ingmar
Cunningham Island, Beale's lagoon			16-May		15	Ingmar/heli
Cunningham Island, Beale's lagoon	569546	5782095	01-Jun		6	Krista
Cunningham Island, Beale's lagoon	569546	5782095	23-Jul		1	Ingmar/kayak
Cunningham Island, near marker	571986	5779764	14-Jun	14:00	3 flying	SV Habitat
Cunningham Island, near marker	571986	5779764	11-Jul		6	Ian
Lady Douglas Island, Clam Passage	128 26.108	52 20.764	14-May	11:00?	1 from bog	heli
Athlone Island, Gale Passage	128 23.325	52 12.762	14-May		One on estuary	heli
Athlone Island, Gale Passage	128 22.770	52 12.521	14-May		One flushed from bog	heli
Athlone Island, Waskesiu Passage	128 25.894	52 10.153	14-May		2 on estuary	heli
Athlone Island, Gale Passage S.	128 23.261	52 10.840	14-May	14:13	one on estuary	heli
Athlone Island, Gale Passage S.	128 23.59	52 10.613	14-May		one on bog - nest site	heli
Athlone Island, Gale dogleg	539447	5782168	07-Jun	7:00	1	SV Habitat
Athlone Island, Gale N of rapids	541701	5784808	09-Jun	8:00	3	SV Habitat
Athlone Island, Gale N of rapids	542474	5787331	09-Jun	8:10	1+	SV Habitat
Athlone Island, Gale N of rapids	542853	5786933	09-Jun	8:10	1	SV Habitat
Hunter Island, Fanny Cove	128 04.100	52 02.701	15-May	10:24	8 cranes on rich grassy estuary	heli
Hunter Island, one W before Fancy Co	128 01.728	52 03.734	15-May		One crane, circled away to East	heli
Hunter Island, Fancy Cove	128 02.453	52 03.544	15-May	10:38	One crane on estuary	heli
Hunter Island, Fancy Cove	128 00.508	52 03.565	16-May		2 cranes	Ingmar heli
Hunter Island, Fancy Cove	128 01.060	52 03.570	16-May		One crane	Ingmar heli
Hunter Island, Bob Bay	128 06.388	52 03.057	15-May	10:47	2 cranes in gorge landed in lake at	heli
Hunter Island, Bob Bay	561394	5766932	18-Jul-07	10:20	2	SV Habitat
Hunter Island, Serpent Point	569125	5769786	20-Jun-07		2	boat
Dufferin Island, camp spot	542801	5783167	05-Jun-07	pm	8	SV Habitat
Dufferin Island, near clam camp	542313	5784227	06-Jun-07	15:00	10	K/foot
Dufferin Island, near clam camp	542011	5783965	07-Jun-07	13:00	8	K/foot
Campbell Island, SE	128 11.624	52 02.170	15-May		One flushed from bog	heli
Hunter Island, Spitfire Channel	128 12.437	51 52.177	15-May		One crane flushed	heli

Survey data: 2007 sightings	note: all UTMs are in NAD 83 Zone 9					
Location	**x**	**y**	**Date**	**Time**	**Number**	**Observer and platform**
Spider Island	128 15.995	51 50.681	15-May	13:50	6 cranes flushed from trail, later seen on beach at	heli
Spider Island	128 14.932	51 50.600		14:26	6	heli
Hunter Island, Swordfish Bay	128 13.376	51 52.698	15-May	14:35	One crane, nest with 2 eggs	heli
Hunter Island, Swordfish Bay	128 13.806	51 52.873	15-May		One crane on nearby estuary	heli
Hunter island, Cultus Sound	128 13.401	51 53.269	15-May		One crane, nest with 2 eggs	heli
N McNaughton	128 13.760	51 58.117	15-May	14:52	One flushed from bog	heli
Hunter across from Latta	128 11.474	51 58.715	15-May		2 cranes on estuary/beach	heli
Cecilia Island, Bend Point	128 22.514	52 18.384	16-May	9:55	2 cranes on estuary	heli
Dowager Island, SW	128 26.884	52 22.295	16-May		One on estuary	heli
Swindle Island, Higgins Passg	128 37.676	52 28.635	16-May	10:42	One on estuary, E side	heli
Swindle Island, Higgins Lagoon	128 39.750	52 28.313	16-May		One crane defending trail on S side of estuary	heli
Swindle Island, Higgins Lagoon	128 41.578	52 28.892	16-May	11:04	One crane, went into forest	heli
Swindle Island, Higgins Lagoon	128 42.313	52 28.636	16-May		2 cranes coming out of bog	heli
Swindle Island, Higgins Lagoon	128 41.416	52 29.060	16-May		2 cranes foraging along beach	from landing spot
Cockle Bay, Lady Douglas Island	541602	5799397	21-Aug-07	7:00	2 + 2 cranes foraging	Ing/Kris
Cockle Bay, Lady Douglas Island	541741	5799487	22-Aug-07	5:30	2 + 2 cranes foraging	Ing/Kris

2007 nests				
Date recorded	**Location**	**x**	**y**	**Number of cranes seen**
17/06/2007	Behind Shearwater, Denny Island	561880	5776780	1
26/07/2007	Near Kajustis lagoon, Denny Island	564408	5778312	2
19/08/2007	Near airport, Denny Island	563747	5776498	0
06/08/2007	Gullchucks, Denny Island	568326	5778518	2
19/06/2007	Cypress Island	564238	5779597	2
30/07/2007	Campbell Island SE	555306	5765424	2
14/05/2007	Saunders Island	561040	5781219	2
15/05/2007	Swordfish Bay, Hunter Island	553418	5747706	1
15/05/2007	Cultus Sound, Hunter Island	554419	5749528	1
09/08/2007	Athlone Island, NE	541992	5786714	1
09/08/2007	Athlone Island, NE	541993	5786952	0
23/08/2007	Cecilia Island	542467	5795259	2
23/08/2007	Gale Passage, Dufferin Island	542126	5784621	0

2008 nests with eggs - located during helicopter surveys				
location	**date**	**y**	**x**	**number of cranes**
S Hunter	May 15	51.88717	-128.2228	1 crane 2 eggs
Denny	May 15	52.15785	-128.020733	1 crane, 2 eggs
Denny behind Shearw	May 15	52.13807	-128.095833	crane on last year's nest SW
Cypress	May 15	52.16354	-128.0635	1 crane lying down on nest Cypress
Saunders	May 15	52.17685	-128.108017	2 birds, 2 eggs
Campbell	May 15	52.14647	-128.153517	nest with shells
Don Peninsula	May 16	52.29362	-128.337	10:40-10:41 nest with eggs
Price	May 16	52.29178	-128.681533	crane on islet 2 eggs
Price	May 16	52.35168	-128.728833	crane on islet 2 eggs, standing
Dowager	May 17	52.39187	-128.46685	crane and 2 eggs and 2 geese (Evelyn's nest)
Porcher	May 18	53.94115	-130.696017	nearby; flushed crane from nest; 1-2 eggs
Hunter	May 19	52.05702	-128.10245	crane and 2 eggs!
Aristazabel	May 20	52.66550	-129.226667	1 crane 2 eggs
Aristazabel	May 20	52.66380	-129.213467	2 cranes and 1 egg
Aristazabel	May 20	52.65722	-129.197817	nest with 2 eggs, crane stayed close
Aristazabel	May 20	52.60812	-129.168083	1 crane, nest with 2 eggs, little bit to West
Aristazabel	May 20	52.60588	-129.14895	crane with 2 eggs just a little northwest of coords
Gale	May 21	52.20970	-128.378117	One egg
Lady Douglas	May 21	52.34690	-128.4265	2 eggs and a crane

2008 non-nest sightings from helicopter surveys				
location	yy	xx	date	number of cranes
S Hunter	51 53.299	128 13.891	May 15	2 on estuary
S Hunter	51 53.543	128 13.565	May 15	another crane
Denny	52 09.074	127 59.98	May 15	1 crane Gullchucks marsh near last year's nest site
Denny	52 08.894	128 00.472	May 15	3 cranes at Gullchucks
Denny	52 09.183	128 03.177	May 15	1 at ropeswing guarding nest? Lying down
Campbell, Ormidale	52 11.891	128 09.610	May 15	1 or 2 cranes? Roost? Nest? Small islet it was on...
Cunningham	52 11.053	127 58.985	May 15	10 at Beale's Lagoon
Don Peninsula	52 17.234	128 17.867	May 16	10:29-10:30 crane sighting
Don Peninsula	52 16.734	128 18.012	May 16	location at 10:33, sighting at 10:34
Price	52 17.982	128 41.093	May 16	old nest, pile of bleached sticks on islet in bog
Price	52 18.637	128 41.824	May 16	2 cranes flew, not sure of nest, one islet in series of streams
Price	52 18.266	128 42.519	May 16	1 crane flush from pool right near estuary
Price	52 19.800	128 43.823	May 16	2 cranes flew out over water
Price	52 23.565	128 44.601	May 16	old nest
Price	52 25.466	128 45.615	May 16	one crane fly from the bog
Price	52 28.655	128 42.035	May 16	one crane flushed from bog
Price	52 28.679	128 42.383	May 16	one crane in last year's spot
Price	52 28.716	128 41.961	May 16	one crane flew from bog
Price	52 22.446	128 45.216	May 16	crane on estuary, lots of geese, near landing spot
Price	52 22.614	128 45.061	May 16	stopping point at 4:30, saw crane tracks and some old feathers in bog to the northeast
Dowager	52 22.216	128 25.611	May 17	one crane flew, from edge of creek in bog
Dowager	52 23.149	128 26.177	May 17	2 cranes flew from edge of the bog
Dowager	52 23.529	128 26.819	May 17	2 cranes flying around fennish area
Dowager	52 23.917	128 26.684	May 17	2 cranes flying from just a bit nw of that, from edge of bog, didn't see nest
Dowager	52 24.021	128 24.436	May 17	one crane, marshy sedgy area
Porcher	53 55.055	130 41.443	May 18	estuary where we saw 2 cranes fly by Linda's sighting
Porcher	53 55.356	130 42.231	May 18	small crane flushed from bog
Porcher	53 56.824	130 40.309	May 18	9 cranes on estuary
Porcher	53 53.895	130 42.313	May 18	flushed crane on edge of bog, another crane little bit west
Porcher	53 56.320	130 39.480	May 18	2 cranes on estuary
Porcher	53 57.954	130 39.812	May 18	flushed pair on nest? Couldn't see nest
Hunter	52 03.936	128 01.041	May 19	2 cranes on estuary
S Denny	52 05.210	128 03.901	May 19	flushed one crane from bog
Aristazabel	52 44.132	129 15.791	May 20	one crane on est. at Borrowman Bay
Aristazabel	52 40.724	129 11.891	May 20	flushed 2 just up from estuary, coords. a few 100ms east from where they were
Aristazabel	52 39.788	129 11.689	May 20	1 crane flushed from bog
Aristazabel	52 41.042	129 10.865	May 20	flushed 1 from little narrow long bog off of Kettle Inlet, came off of edge of the bog
Aristazabel	52 39.747	129 11.819	May 20	1 crane flushed from bog
Aristazabel	52 39.972	129 13.155	May 20	1 crane flushed, fish traps and hulk nearby
Aristazabel	52 39.922	129 12.425	May 20	1 crane on estuary, close to nest with 2 eggs
Aristazabel	52 39.767	129 12.447	May 20	2 more cranes flying from further up same estuary as fish traps
Aristazabel	52 36.613	129 10.574	May 20	flushed 1 crane from little wetland
Aristazabel	52 31.803	129 03.799	May 20	2 cranes in bog
Aristazabel	52 31.345	129 03.814	May 20	crane on estuary just behind us
Aristazabel	52 32.084	129 02.759	May 20	flushed crane from edge of bog
Athlone	52 13.150	128 23.405	May 21	2 cranes on estuary
Athlone	52 12.946	128 23.587	May 21	2 cranes just before entrance to rapids, 2nd to last estuary on W side
Gale	52 13.705	128 23.207	May 21	crane from edge of bog
Gale	52 13.680	128 23.224	May 21	crane from streamy bog, close to last year's nest site

2008 non-nest sightings from helicopter surveys				
location	**yy**	**xx**	**date**	**number of cranes**
Gale	52 13.221	128 22.531	May 21	one crane flushed from little wetland
Gale	52 13.172	128 22.083	May 21	one crane flushed
Lady Douglas	52 20.906	128 24.938	May 21	2 cranes flushed

Appendix C
Nest site data

Nest site data												
Site	Bob Bay		Goolden Islands	Swordfish	Cultus Sound nest 1		Ropeswing	Shearwate	SE Campb	Cypress		Gullchucks
Site number	1		20	19	18		6	5	10	3		4
Date	Jul-03		Jul-08	Jul-08	Jul-09		Jun-17	Jul-01	Jun-25	Jul-02		Aug. 8
Recorder(s)	Krista, Sarah, Jaimie		Krista, Jaimie, Sarah	Krista, Ingr	Krista, Ingmar, Jaimie		Krista, Ingr	Krista, Sar	Krista, Ingr	Krista, Sarah, Jaimie,		Krista, Jai
Weather	overcast, warm, rained e		cloudy, wet, has been a lot of rai		rainy		overcast a	overcast a	overcast, l	sunny		overcast/s
Nest location	52.05702, -128.10245		51.89310, -128.2030	51.8783, -	51.8875, -128.223116		52.151549	52.13807,	52.036166	52.16354, -128.06350		52.15785,
Slope (deg)												
N	6		6	6	10		15	3	0	0		2
E	8		3	5	10		10	0	5	-2		2
S	0		0	0	5		-5	3	0	2		6
W	2		-1	15	0		5	5	0	6		10
Slope average	4		2	6.5	6.25		6.25	2.75	1.25	1.5		5
Aspect	basin		270		330		basin	basin	basin	90		basin
			W		NW							
Average aspect	basin											
Pool size (ha)	0.1707			0.11923			0.1045		0.17514	0.08487		0.0469
Open water within pool (%)	80		95	70	70		90	70	80	70		95
Emergent vegetation (%)	20		5	20	2		5	15	10	5		5
Species	15bogbean2.5carex2.5lily		lily/bogbean	10sloughs	bogbean/lily/rush/sedg		nl cottongr	5bogbean5	5bogbean/	bogbean/smallrush		red rush, s
Frequencies	Bogbean		Carex spp		Juncus spp		red-flowered rush		lily			
Number of islets in the pool	9		7	15	40		6	1	10	15		2
Bog substrate material	mud		muck, firm silt bottom	mucky	muck, uneven depth		muck	muck	muck	muck, loose cobble		shale and
	13 nests with straight muck bottom											
	6 nests with muck over firmer substrate (silt, cobble, shale)											
	1 nest with sand over rotten wood bottom											
water depth measurement date (if different)	Jun-10							Jun-14	Jun-13	Jun-02		Jun-09
Water depth around the nest (cm)	NEST A	NEST B			NEST A	NEST B				NEST A	NEST B	
N	50		60	25	100	120	60	55	100	105		35
E	55		60	55	80	110	50	60	85	124		45
S	60		60	60	55	10	25	75	110	150		35
W	85		50	50	70	70	60	35	125	120		35
water depth mean/site	62.5		57.5	47.5	76.25	77.5	48.75	56.25	105	124.75		37.5

Nest site data												
Site	Bob Bay		Goolden Islands	Swordfish	Cultus Sound nest 1		Ropeswing	Shearwate	SE Campb	Cypress		Gullchucks
Site number	1		20	19	18		6	5	10	3		4
Clear water depth around the nest												
N	0		25	5	25	35	15	25	30	55		10
E	20		30	10	25	30	20	50	20	38		15
S	20		30	10	20	40	15	50	15	50		10
W	0		15	15	40	35	0	15	15	45		10
clear water depth mean/site	10		25	10	27.5	35	12.5	35	20	47		11.25
Concealment												
N	30		70	35	40	0	50	30	10	25		0
E	20		10	15	0	15	40	50	45	23		15
S	20		55	0	20	25	10	30	55	30		10
W	80		40	35	0	5	20	45	0	0		0
concealment plot mean	37.5		43.75	21.25	15	11.25	30	38.75	27.5	19.5		6.25
Nest islet length (m)	2.1	2.1	8.8	9.2	6.8	5.2	1.5	6.5	5.5	3	3.6	2.3
Nest islet width	2.1	1.8	3.5	5.2	2.5	1.5	2.5	3.7	5.2	2.8	2.5	0.7
Nest islet area (Lxw, m2)	4.41	3.78	30.8	47.84	17	7.8	3.75	24.05	28.6	8.4	9	1.61
D nest islet-nearest edge (m)	12.1	17.7	6.8	8	8	8	4.6	8.6	6.4	7.3	2.5	6.2
D nest islet - nearest islet	3.3	3	3.5	3	1.3	1			5.5	2.5	2.3	5
D nest islet to nearest tree/tall shrub outside pool	14.5	19	6.8	14	12	13	4.7	9	7.5	2.7	2.5	7.5
Presence of tree sp on islet	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y
Tree sp on islet (presence/absence)	y=18	n=4										
Side of nest tree is on	S	N	E,SW	W,S,N	N,S	N	W	W,E	W		SE,SW	S
species	pine			pine			pine	pine	cypress		pine	pine

Nest site data												
Site	Bob Bay		Goolden Islands	Swordfish	Cultus Sound nest 1		Ropeswing	Shearwate	SE Campb	Cypress		Gullchucks
Site number	1		20	19	18		6	5	10	3		4
Height of nest above water (cm)	40	45	25	35	30	20	50	5	20	50	35	15
Nest dimensions (length)	30	40	40	65	60	40	40	45	30	55	60	30
width	27	30	40	50	50	35	30	25	30	45	30	30
height	2	5	0	2	7	2	2	10	1	1	1	2
Nest construction material	cedar and sweet ga	sg tw	moss depression	sweet gale	cedar twig	cedar twigs	sweet gale	sweet gale	sweet gale	crowberry,	cedar twigs	sweet gal
	1	2	3	4	5	5	4	4	4	6	5	4
Tree/tall shrub canopy height												
N	14		5		13		5	5		0		2
E	13		4.5		4		9	7		5		1
S	10		5		0		8	2		0		2.5
W	11		4.5		11		6	3		5		2.5
tree/tall shrub height site mean	12		4.75		7		7	4.25		2.5		2
Average percent canopy cover around nest pool												
N	25		15		30		40	20	10	0		0
E	15		10		10		20	30	5	30		0
S	20		20		0		5	5		0		5
W	20		20		20		15	30	30	10		20
% canopy cover around nest pool mean	20		16.25		15		20	21.25	15	10		6.25
How many sides with (min. 10%) tree cover?	4		0		2		0	0	0	0		0
How many sides with (min. 10%) tall shrub cover?	0		4		1		3	3	2	2		1

Nest site data											
Site	Gullchucks	Oldtowns	Saunders 2008	Saunders 2007	Athlone 2	Athlone 1	Dufferin 2007	Dufferin 2008	Lady Douglas	Cecilia	Don Penin. 1
Site number	7	9	2	8	14	13	11	12	17	16	15
Date	Aug. 7	Aug. 9	Aug. 11	Jul-14	Jul-24	Jul-24	Jul-25		Sept. 14	Aug. 15	Aug. 14
Recorder(s)	Krista, Ingr	Krista, Jaim	Krista, Jaimie	Krista and Sara	Krista, Ingr	Krista, Ingr	Krista, Ingmar	Krista, Ingmar	Krista, Ingmar, I	Krista, Natalie	Krista, Natalie, Ingr
Weather	Hot and su	cloudy, warr	overcast/sunny,	sunny hot, NW	breeze	sunny, war	wind backing to	cloudy, wet, buggy	Foggy, light bre	Sunny, warm, no	Hot, nice breeze
Nest location	52.15293 -	52.14647, -	52°10'37.05"N 1	52.1780646111	52.231384	52.229244	52.2104176729	52.209761, -128.378	52.34668 -128.4	52.3060274576	52.29362, -128.337
Slope (deg)											
N	3	12	-1	-10	5	0	3	9	-1	0	0
E	4	20	-1	8	18	0	5	0	0	0	30
S	-2	12	10	5	5	0	5	0	3	-1	-2
W	3	20	0	2	5	2	3	-2	0	0	2
Slope average	2	16	2	1.25	8.25	0.5	4	1.75	0.5	-0.25	7.5
Aspect	basin	basin	basin	basin	basin	basin	basin	basin	320	0	basin
									NW	N	
Average aspect											
Pool size (ha)	0.10152	0.14687	0.31734	0.03393	0.48789	0.00174	0.23127	0.07202	0.06343	0.10361	0.02948
Open water within pool (%)	85	80	60	50	75	75	40	80	80	80	90
Emergent vegetation (%)	15	1	5	5	5	5	5	10	2	5	5
Species	sedge	narrow sedg	bogbean, sedge	bogbean/nlcott	sedges	bogbean>s	bogbean/rush/r	bogbean/rush	sedge, nl cotton	bogbean	rush, slough sedge
Frequencies											
Number of islets in the pool	3	11	65	20	5	2	33	11	7	10	8
Bog substrate material	muck over	muck	cobble, muck	muck	muck	mucky	muck over sha	sand and rotten woo	mucky	mucky	mucky
water depth measurement date (if different)	Jun-09										
Water depth around the nest (cm)											
N	45	55	45	50	30	35	70	15	80	120	55
E	55	40	40	50	70	55	60	30	40	100	105
S	45	50	35	45	50	75	55	30	40	90	120
W	50	60	40	55	45	60	70	30	35	100	75
water depth mean/site	48.75	51.25	40	50	48.75	56.25	63.75	26.25	48.75	102.5	88.75

Nest site data											
Site	Gullchucks	Oldtowns	Saunders 2008	Saunders 2007	Athlone 2	Athlone 1	Dufferin 2007	Dufferin 2008	Lady Douglas	Cecilia	Don Penin. 1
Site number	7	9	2	8	14	13	11	12	17	16	15
Clear water depth around the nest											
N	15	10	15	20	15	10	10	10	5	10	20
E	20	25	10	15	30	55	15	10	7	5	15
S	15	25	15	15	30	75	20	10	20	10	20
W	15	20	20	20	10	60	10	20	10	15	20
clear water depth mean/site	16.25	20	15	17.5	21.25	50	13.75	12.5	10.5	10	18.75
Concealment											
N	15	15	0	0	30	30	50	10	0	45	0
E	30	10	0	0	45	30	15	60	30	0	0
S	30	55	0	5	30	35	25	10	50	0	0
W	20	20	0	20	10	1.2	30	20	20	35	0
concealment plot mean	23.75	25	0	6.25	28.75	24.05	30	25	25	20	0
Nest islet length (m)	5.2	2.1	1.4	3.3	7	4.4	13	8.6	3.5	2.5	2.3
Nest islet width	4.8	1.8	1	2.7	5.5	2.8	2.5	2.8	3	2	1.8
Nest islet area (Lxw, m2)	24.96	3.78	1.4	8.91	38.5	12.32	32.5	24.08	10.5	5	4.14
D nest islet-nearest edge (m)	9	9	7.4	3.3	13.7	3	12	5.1	2.2	1.7	4
D nest islet - nearest islet	3	5	1.2	1.7	3	2	2	1.2	2.5	4	10
D nest islet to nearest tree/tall shrub outside pool	15	9	12	4.8	13.7	20	16	7.4	10	4	12
Presence of tree sp on islet	y	Y	N	N	Y	Y		Y	Y	Y	N
Tree sp on islet (presence/absence)											
Side of nest tree is on	E	SE			E	NE		N, E	W	S and N	
species								small rc	pine		

Nest site data											
Site	Gullchucks	Oldtowns	Saunders 2008	Saunders 2007	Athlone 2	Athlone 1	Dufferin 2007	Dufferin 2008	Lady Douglas	Cecilia	Don Penin. 1
Site number	7	9	2	8	14	13	11	12	17	16	15
Height of nest above water (cm)	30	30	30	10	15	35	45	15	25	20	5
Nest dimensions (length)	45	35	45	55	40	45	55	55	40	20	60
width	30	35	40	40	30	45	40	50	40	20	60
height	1	1	0	2	1	2	3	2	2	0.5	2
Nest construction material	sweet gale	cedar twigs	nothing: built on	sg twigs	sg twigs	sg twigs	sweet gale twig	cedar twigs	strips of cedar c	grasses on hoar	dead fluffy sphagnu
	4	5	3	4	4	4	4	5	7	8	9
Tree/tall shrub canopy height											
N	2	4	3.5	3.5	3.5	2	2	5	5	4	3
E	3	3.5	2	2	11	0	3.5	3	4	4	2
S	2.5	3	4	0.5	7.5	3	4	3	5	5	5.5
W	3	4	3	5	11	4	5	4	4	3.5	3.2
tree/tall shrub height site mean	2.625	3.625	3.125	2.75	8.25	2.25	3.625	3.75	4.5	4.125	3.425
Average percent canopy cover around nest pool											
N	20	10	20	20	5	5	10	10	5	20	45
E	5	5	0	5	50	0	10	10	5	15	0
S	20	20	5	0	10	5	20	5	5	50	15
W	20	5	5	40	70	5	40	10	1	15	10
% canopy cover around nest pool mean	16.25	10	7.5	16.25	33.75	3.75	20	8.75	4	25	17.5
How many sides with (min. 10%) tree cover?	0	0	0	0	2	0	0	0	0	0	0
How many sides with (min. 10%) tall shrub cover?	3	2	1	2	1	0	4	3	0	4	3

Nest site means											
Site	Site number	Slope (deg)	Aspect (deg)	Pool size (ha)	Open water within pool (%)	Emergent vegetation (%)	Number of islets in the pool	water depth mean/site (cm)	clear water depth mean/site (cm)	concealment plot mean (cm)	Nest islet length (m)
Bob Bay	1	4	basin	0.171	80	20	9	63	10	38	2.1
Bob Bay b	1										2.1
Saunders 2008	2	2	basin	0.317	60	5	65	40	15	0	1.4
Cypress	3	1.5	90	0.085	70	5	15	125	47	20	3.0
Cypress b	3										3.6
Gullchucks 2008	4	5	basin	0.047	95	5	2	38	11	6	2.3
Shearwater	5	2.75	basin	0.225	70	15	1	56	35	39	6.5
Ropeswing	6	6.25	basin	0.105	90	5	6	49	13	30	1.5
Gullchucks 2007	7	2	basin	0.102	85	15	3	49	16	24	5.2
Saunders 2007	8	1.25	basin	0.034	50	5	20	50	18	6	3.3
Oldtowns	9	16	basin	0.147	80	1	11	51	20	25	2.1
SE Campbell	10	1.25	basin	0.175	80	10	10	105	20	28	5.5
Dufferin 2007	11	4	basin	0.231	40	5	33	64	14	30	13.0
Dufferin 2008	12	1.75	basin	0.072	80	10	11	26	13	25	8.6
Athlone 1	13	0.5	basin	0.002	75	5	2	56	50	24	4.4
Athlone 2	14	8.25	basin	0.488	75	5	5	49	21	29	7.0
Don Penin. 1	15	7.5	basin	0.029	90	5	8	89	19	0	2.3
Cecilia	16	-0.25	0	0.104	80	5	10	103	10	20	2.5
Lady Douglas	17	0.5	320	0.063	80	2	7	49	11	25	3.5
Cultus Sound nest 1	18	6.25	330		70	2	40	76	28	15	6.8
Cultus b	18							78	35	11	5.2
Swordfish	19	6.5		0.119	70	20	15	48	10	21	9.2
Goolden Islands	20	2	270	1.189	95	5	7	58	25	44	8.8

Nest site means											
Site	Nest islet width (m)	Nest islet area (m2)	D nest islet-nearest edge (m)	D nest islet - nearest islet (m)	D nest islet to nearest tree/tall shrub outside pool (m)	Height of nest above water (cm)	Nest dimension s (length cm)	width (cm)	height (cm)	tree/tall shrub height plot mean (m)	% canopy cover around nest pool mean
Bob Bay	2.1	4.41	12.1	3.3	14.5	40	30	27	2	12.0	20
Bob Bay b	1.8	3.78	17.7	3.0	19.0	45	40	30	5		
Saunders 2008	1	1.4	7.4	1.2	12.0	30	45	40	0	3.1	8
Cypress	2.8	8.4	7.3	2.5	2.7	50	55	45	1	2.5	10
Cypress b	2.5	9	2.5	2.3	2.5	35	60	30	1		
Gullchucks 2008	0.7	1.61	6.2	5.0	7.5	15	30	30	2	2.0	6
Shearwater	3.7	24.05	8.6		9.0	5	45	25	10	4.3	21
Ropeswing	3	3.75	4.6		4.7	50	40	30	2	7.0	20
Gullchucks 2007	4.8	24.96	9.0	3.0	15.0	30	45	30	1	2.6	16
Saunders 2007	2.7	8.91	3.3	1.7	4.8	10	55	40	2	2.8	16
Oldtowns	1.8	3.78	9.0	5.0	9.0	30	35	35	1	3.6	10
SE Campbell	5.2	28.6	6.4	5.5	7.5	20	30	30	1		15
Dufferin 2007	2.5	32.5	12.0	2.0	16.0	45	55	40	3	3.6	20
Dufferin 2008	2.8	24.08	5.1	1.2	7.4	15	55	50	2	3.8	9
Athlone 1	2.8	12.32	3.0	2.0	20.0	35	45	45	2	2.3	4
Athlone 2	5.5	38.5	13.7	3.0	13.7	15	40	30	1	8.3	34
Don Penin. 1	1.8	4.14	4.0	10.0	12.0	5	60	60	2	3.4	18
Cecilia	2	5	1.7	4.0	4.0	20	20	20	0.5	4.1	25
Lady Douglas	3	10.5	2.2	2.5	10.0	25	40	40	2	4.5	4
Cultus Sound nest 1	2.5	17	8.0	1.3	12.0	30	60	50	7	7.0	15
Cultus b	1.5	7.8	8.0	1.0	13.0	20	40	35	2		
Swordfish	5.2	47.84	8.0	3.0	14.0	35	65	50	2		
Goolden Islands	3.5	30.8	6.8	3.5	6.8	25	40	40	0	4.8	16

Appendix D
Landscape level data

Landscape level data								
Site	Accuracy (m)	Pool size (ha)	Distance from nest pool edge to treeline (m)	N	E	S	W	Mean d from nest pool edge to treeline (m)
Bob Bay	10	0.171		1	1	1	1	1
Goolden	5	1.189		0	0	27	0	6.75
Swordfish	5	0.119		20	17	12	5	13.5
Cultus Sound nest 1	5	0.188		5	45	114	13	44.25
Ropeswing	10	0.105		2	5	0	10	4.25
Shearwater	10	0.225		0	1	1	1	0.75
SE Campbell	5	0.175		20	29	21	18	22
Cypress	10	0.085		20	2	59	20	25.25
Gull 08	10	0.047		380	207	245	380	303
Gull 07	10	0.102						
Oldtowns	10	0.147		3	567	2	3	143.75
Saun 08	10	0.317		3	350	294	30	169.25
Saun 07	10	0.034		2	60	23	15	25
Athlone 2	5	0.488		180	0	820	0	250
Athlone 1	5	0.002		13	75	25	15	32
Dufferin 2007	5	0.231		100	5	23	57	46.25
Dufferin 2008	5	0.072		48	25	70	25	42
Lady Douglas	10	0.063		550	760	80	165	388.75
Cecilia	5	0.104		40	50	25	150	66.25
Don Penin. 1	10	0.029		40	250	0	125	103.75
Dowager	10	0.080		105	310	50	50	128.75
Price 1	10	0.030						
Price 2	10	0.020						
Porcher	10	0.210						
Aristazabel 1	10	0.030		0	0	150	90	60
Aristazabel 2	10	0.040		40	40	10	45	33.75
Aristazabel 3	10	0.020		30	190	22	50	73
Aristazabel 4	10	0.184		40	105	220	495	215
Aristazabel 5	10	0.060		520	0	290	125	233.75

Landscape level data										
Site	Distance from treeline to next open patch (m)	N	E	S	W	Mean d from treeline to next break in treeline (m)	HD distance from nest to nearest shoreline (m)	HD from nest to nearest estuary (m)	HD from nest to nearest marsh or lake (m)	marsh or lake?
Bob Bay		1145	700	2160	390	1098.75	390	560	60	lake
Goolden		130	75	60	27	73	360	380		pool is a sr
Swordfish		76	60	10	50	49	480	480	214	lake
Cultus Sound nest 1		360	50	330	1380	530	200	200	100	lake
Ropeswing		106	25	17	40	47	470	470	60	marsh
Shearwater		30	233	92	170	131.25	878	1361	360	marsh
SE Campbell		317	20	86	103	131.5	612	620	136	marsh
Cypress		38	101	135	886	290	197	440	596	marsh
Gull 08		210	61	240	580	272.75	405	895	205	lake
Gull 07							440	440	220	lake
Oldtowns		60	289	20	88	114.25	840	1128	175	lake
Saun 08		185	184	175	320	216	190	2736	2561	small lake
Saun 07		90	197	40	686	253.25	100	2661	2659	
Athlone 2		480	70	100	40	172.5	400	435	15	lake
Athlone 1		16	15	23	40	23.5	337	337	313	lake
Dufferin 2007		133	40	27	80	70	180	250	680	tidal lake
Dufferin 2008		380	36	50	100	141.5	165	166	370	tidal lake
Lady Douglas		35	125	125	180	116.25	850	1500	335	marsh
Cecilia		240	130	250	160	195	180	200	2000	lake
Don Penin. 1		1136	60	40	160	349	1130	1130	390	lake
Dowager		780	460	550	310	525	200	200	1562	sm. Lake
Price 1							465	465	445	lake
Price 2							150	150	530	lake
Porcher										
Aristazabel 1		25	250	230	25	132.5	220	700	1120	lake
Aristazabel 2		165	225	40	170	150	345	345	530	lake
Aristazabel 3		50	65	75	60	62.5	830	830	480	lake
Aristazabel 4		43	80	415	138	169	420	420	190	lake
Aristazabel 5		60	55	320	160	148.75	500	500	100	lake

Landscape level data					
Site	HD from nest to human habitation (km)	HD from nest to nearest logging (km)	logging location?	Logging active?	HD from nest to nearest road (m)
Bob Bay	1.4	12.2	by coastgu	n	9
Goolden	>25	>25			>25
Swordfish	>25	>25			>25
Cultus Sound nest 1	>25	>25			>25
Ropeswing	1.4	4.8	by coastgu	n	1.3
Shearwater	0.85	2.6	by coastgu	n	0.5
SE Campbell	7.3	13	behind BB	n	11.6
Cypress	2.2	1.8	grave islan	y	2.4
Gull 08	3.8	5.2	grave islan	y	3.2
Gull 07	4.9	6.3	grave islan	y	3.8
Oldtowns	0.87	2	behind BB	n	0.36
Saun 08	0.71	0.65	grave islan	y	0.71
Saun 07	0.85	0.79	grave islan	y	0.85
Athlone 2	16	2.1	n athlone	n	9.7
Athlone 1	16	2.2	n athlone	n	9.7
Dufferin 2007	15.3	3.4	N end of At	n	9.2
Dufferin 2008	15	3.3	N end of At	n	8.9
Lady Douglas	>25	2.6	to old loggi	n	>25
Cecilia	21.9	2.3	to old loggi	n	>25
Don Penin. 1	18.3	5.4	to old loggi	n	9.8
Dowager	21.6	5.9	to Dowage	n	14.1
Price 1	>25	22	Kitasoo Hil	n	22
Price 2	29	14		n	14
Porcher					
Aristazabel 1	>25	>25			>25
Aristazabel 2	>25	>25			>25
Aristazabel 3	>25	>25			>25
Aristazabel 4	>25	>25			>25
Aristazabel 5	>25	>25			>25

Appendix E
Vegetation data

Vegetation plot data - mean percent cover per site with rare species removed										
Site #	1	2	3	4	5	6	7	8	9	10
Species	Bob Bay	Saunders I	Cypress Isl	Gullchucks	Shearwate	Ropeswing	Gullchucks	Saunders I	Oldtowns,	Campbell I
yctree	15	0	0	0	0	0	0	0	0	2.5
rctree	0	0	0	0	0	0	0	0	0	0
pinetree	8.75	0	0	0	0	0	0	0	0	1.25
mhtree	4.25	0	0	0	0	0	0	0	0	0
yewtree	1.25	0	0	0	0	0	0	0	0	0
pineshru	0	13.75	1.25	6.75	11.75	3.75	8.75	6.25	3	0
ycshrub	0	6.25	3	0.5	2.5	7.75	0	7.5	3.25	0
rcshrub	0	2.5	2.5	0	5.5	2.5	3.75	3.75	1.25	0
mhshrub	0	0	3.75	0	1	0	0	0	3	0
bogblueb	0	0	0	1.692308	0.153846	0.416667	0.384615	2.307692	0	0.166667
bogcranb	2.615385	0.230769	0.846154	6.692308	1.153846	0.833333	0.615385	0.923077	0.153846	0.583333
boglaure	1.076923	2.769231	0.692308	0.846154	1.230769	2.916667	1.153846	3.769231	0.615385	1.666667
bogrosem	0.384615	1.769231	0.384615	0.384615	0	0.833333	0.846154	1.230769	1.076923	0.166667
brackenf	0	2.384615	3.076923	0.769231	0.923077	9.166667	0.538462	7.307692	8.230769	6.166667
burnetbi	0	0.769231	0	2.692308	0	0	3.076923	1.923077	0	0
burnetsm	1	3.384615	0.846154	1.615385	0.923077	1.25	1.846154	1.384615	2.615385	3.5
crowberr	5.153846	3.307692	2.153846	4.538462	6.692308	17.08333	4.769231	6.923077	9.538462	7
cypress	2.692308	6.538462	9.615385	5	2.692308	2.916667	4.384615	13.46154	0.384615	9.666667
deerfern	1.153846	0.769231	1.153846	0	2.076923	2.916667	0.923077	0.461538	4.692308	0.333333
dwfblueb	0.384615	0.076923	0	0.538462	1.153846	0	0.230769	0.076923	0.384615	0.166667
falseaza	1.076923	0	1.230769	0	0.153846	2.916667	0.076923	0.153846	0.076923	0.166667
hemlock	0	0	0.076923	0	0	0.833333	0	0.923077	0	0
juniper	0	8.769231	1.923077	18.38462	6.692308	7.083333	18.15385	5	9.230769	8.333333
labrtea	7.923077	4.076923	7.153846	1.076923	5.076923	5.416667	2.076923	5.846154	3.230769	3.416667
pine	0.769231	5	0.846154	4.384615	2	2.083333	8.153846	1.923077	6.384615	1
redcedar	5.769231	6.923077	17	0.769231	2.692308	0	3.846154	0	14.23077	0
redhuckl	1	0	0.384615	0	0.384615	0.416667	0	0.384615	0.076923	0.416667
salal	9	0	1.230769	0.076923	3.307692	4.583333	0.307692	0.846154	0.846154	1.333333
sweetgal	19.61538	12.30769	10.84615	18.84615	11.53846	5.416667	19.23077	16.15385	8.076923	21.25
twinflow	1.692308	0.846154	2.230769	0.076923	0.153846	0.583333	0	1.230769	0.846154	0.75
asphodel	0.153846	1.230769	1.538462	0.307692	0.384615	1.666667	0.846154	1.769231	0.461538	1.25
biggentia	0	0	0	0.076923	0	0.166667	0.076923	0.076923	0	0
boggenti	0.692308	0	0.076923	0	0	0	0.153846	0.076923	0	0.166667
bogbean	0.384615	0.384615	1.153846	0	0	0	0	0	0	0
cloudber	0	0.076923	0.153846	0	0	0	0	0.769231	0.769231	0.666667
deercabb	0	0	0.769231	0	0.769231	0	1.153846	3.846154	3.846154	0
dogwood	2.230769	0	0.538462	0	0.461538	0.166667	0	1.538462	1.461538	0.666667
falselil	1.307692	0	0	0	0.076923	0	0	0	0.153846	0.166667
femleaf	0.384615	0	0.923077	0	0.153846	0	0	0.153846	0.230769	0
oleafsun	0.076923	0.076923	0.076923	0.076923	0	0	0	0.153846	0.076923	0
rleafsun	2.076923	1.923077	0.923077	0.769231	0.923077	1.25	0.384615	3.923077	0.923077	1.25
starflow	0.384615	0.538462	0.153846	0.923077	0.076923	0	0.615385	1	0.153846	1.333333
3lfgoldt	0.384615	1.230769	0.153846	0	0.076923	0.416667	0.076923	0.615385	0.615385	0.5
bluesedg	1.923077	1.846154	1.615385	0.615385	2.076923	0	1.538462	1.307692	0.769231	1.166667
fewflows	0	0	0.384615	0	0.384615	0	0	0.846154	0	0
greensed	0.153846	0.384615	0.076923	0	0.153846	0	0	0	0.538462	0
sloughse	5.461538	0.769231	2	0	1.153846	0	0	0.153846	0	0.75
unknsedg	0.384615	0	1.692308	0	0	0	0.153846	0	0	0.583333
feagrasm	0.153846	0	0.307692	0.076923	0	0	0	0.538462	0	0

Vegetation plot data - mean percent cover per site with rare species removed										
Site #	1	2	3	4	5	6	7	8	9	10
Species	Bob Bay	Saunders I	Cypress Isl	Gullchucks	Shearwate	Ropeswing	Gullchucks	Saunders I	Oldtowns,	Campbell I
chamisso	0	0	0	0	0	0	0	0	0	0
feagrasb	0	0.538462	0	0	0	0	1.153846	0	0.076923	0
narlfcott	0	10.92308	2.461538	1.461538	8.846154	0.833333	7.461538	5.153846	2.769231	2
tuftclub	0.153846	1.923077	0.153846	5.384615	1.923077	2.083333	8.461538	5.769231	1.538462	2.25
unkngras	1.538462	0.153846	0	0.615385	0.153846	1.25	1.153846	0	0.153846	0.416667
whbeakru	0	2.076923	0	1.923077	0	0	0.384615	0.769231	1.384615	0
brostesp	13.46154	0	13.38462	0.769231	4.230769	0.833333	0.769231	17.30769	0.153846	0
sphfatbr	5.769231	23.07692	19.92308	8.846154	5.769231	12.41667	9.230769	39.15385	35.23077	6.666667
Sphangus	0	0	0	0	0	0	0	0.769231	0	0
sphred	5.153846	2.615385	0.384615	1.153846	0.769231	4.166667	3.230769	9.230769	4.538462	1.25
Sphmendo	0	2.846154	0	0	3.846154	0	1.153846	0	0	3
Sphconto	20	0	0.769231	0	0	0	0	4.615385	0	0
bigredst	9.230769	0	2.307692	0.076923	10.76923	0	0	1.153846	0.769231	0
blackfis	0	0	0	0.384615	0.384615	0	1.538462	0	0	0
cladina	6.769231	35.69231	17.76923	33.76923	26.53846	32.08333	32.69231	16.69231	19	20.83333
coscisso	4.615385	0	0	0	0	0	0	0	0	0
deerclad	0	8.769231	0	0.384615	0	0	0.384615	0.384615	0.384615	0
Dicranum	1.538462	0.384615	1.230769	0	0.769231	0	0	1.923077	0.384615	0
hardscal	0	0	0	0.076923	0	0	0	0	0	0
hoaryroc	0	14.15385	7.307692	11.15385	15.38462	13.33333	10	12.69231	15.38462	37
lankymos	0.846154	0	0	0	1.923077	2.083333	1.923077	0	0	0
lipstick	0.384615	0	0.153846	0	0	2.083333	0	0	0	0
myliaano	1.538462	0	0	0	0.384615	0	0	0	0	0
oregonbe	0	0	0	0	0	0	0	0	0	0
polystric	0	0	0	0	0.384615	0	0	0	0	0
purplewo	0	0	0	0.538462	0	0	0	0	0.769231	0.083333
ribbedbo	0	0.307692	0	0	0.384615	0.166667	0.384615	2.461538	1.153846	0.083333
runningc	0.307692	0	0.461538	0	0.076923	0.416667	0	0	0	0.75
stepmoss	6.692308	0	6.538462	0.153846	5.769231	6.25	0	2.076923	0	0
unknmoss	1	0	2.692308	0.384615	1.692308	0	0	0.384615	0.384615	0
stiffclu	0	0	0	0	0	0	0	0	0	0
pineclub	0	0	0	0.538462	0	0.833333	0	0.384615	0.461538	0
firclubm	0	0	0	1.538462	0	0	0.769231	0.076923	0.076923	0.166667
minersoi	0	0	0	2.692308	0	0	7.692308	0	0	0
indianhe	0.769231	0	0	0	0	0	0	0	0	0.416667
muck	0	2.692308	0	0	0	0	0	0	0	0
copperbu	0	0	0	0	0	0	0.769231	0	0.384615	0
buttwort	0.384615	0	0.076923	0	0.153846	0	0	0	0.384615	0

Vegetation										
Site #	11	12	13	14	15	16	17	18	19	20
Species	Dufferin Isl	Dufferin Isl	Athlone Isl.	Athlone Isl.	Don Penins	Cecilia Isl.	Lady Doug	Cultus Sou	Swordfish I	Goolden Is
yctree	0	0	0	12.5	0	0	0	2.5	0	0
rctree	0	0	0	2.5	0	0	0	5	0	0
pinetree	0	0	0	12.5	0	0	0	5	0	0
mhtree	0	0	0	6.25	0	0	0	1.25	0	0
yewtree	0	0	0	0	0	0	0	0	0	0
pineshru	6.75	1.5	2.25	1.25	6.25	10	0.5	2.5	0	9
ycshrub	8	2.75	1	1.25	3.75	10	2.25	0	0	5
rcshrub	5	1.5	0.25	0	2.5	6.25	2.5	0	0	1.75
mhshrub	0	0	0	0	3.75	3.75	0	0	0	2.25
bogblueb	0	0	0	0	0	0.923077	0	0	0.153846	0.769231
bogcranb	0.384615	3.076923	0.5	0.615385	2.846154	0.076923	0.230769	1.538462	0.923077	0.923077
boglaure	1.923077	2.769231	1.916667	0.230769	1.076923	1.692308	0.076923	2.692308	0.923077	1.769231
bogrosem	0.769231	0.615385	2.166667	1.230769	0.846154	1.461538	1.692308	0.230769	0.923077	0
brackenf	0.923077	2.692308	0	1.538462	2.384615	0.153846	3.461538	0	0	1.923077
burnetbi	0.461538	0.846154	0.833333	0	0.461538	0	1.846154	0.769231	0	1.076923
burnetsm	3	3.846154	4.916667	2.846154	0.692308	1.461538	1.384615	0.692308	1	1.384615
crowberr	11.92308	17.38462	3.083333	2.153846	4.846154	3.615385	4.307692	5.692308	8	11.69231
cypress	8.615385	7.692308	11.25	3.846154	11.53846	14.92308	5.769231	20.15385	14.76923	12.84615
deerfern	0.384615	0	0.833333	4.615385	2.076923	0.769231	0	2.769231	2.076923	1.153846
dwfblueb	1.384615	0.153846	0	0.307692	0.153846	1.076923	0	0.076923	0	0.692308
falseaza	0.384615	1.923077	1	2.076923	0	0.923077	0	0.153846	1.076923	0.846154
hemlock	0.384615	3.846154	0.416667	0.076923	1.307692	1.923077	0.769231	1.923077	0.384615	0
juniper	10.38462	4.230769	15.41667	2.923077	7.307692	12.30769	10.23077	4.538462	5.615385	2.461538
labrtea	4.923077	4.615385	6.416667	5.307692	3.461538	3.692308	7.076923	3.076923	3.384615	7.384615
pine	1.538462	6.615385	8.916667	4.461538	6.461538	9.076923	5.461538	9	5.461538	4.230769
redcedar	12.61538	5.769231	2.916667	8.461538	1.538462	3.461538	15.30769	0	9.615385	10.38462
redhuckl	0.153846	0	0	4	2.769231	4.230769	0	0.153846	0	0
salal	0.769231	3.153846	0	6.692308	3.153846	1.230769	0.076923	0.923077	1.461538	5.153846
sweetgal	17.61538	37.69231	41.66667	20.76923	13.84615	7.692308	13.92308	19.38462	7	17.23077
twinflow	0.538462	0.307692	0.666667	0.307692	0.384615	0.769231	0.461538	1	1	2.461538
asphodel	2.692308	1.076923	2.916667	0.230769	0.153846	0.538462	2.461538	0.615385	0.769231	0.384615
biggentia	0.153846	0	0	0	0	0	0.076923	0	0	0.153846
boggenti	0	0.076923	0	0	0	0.076923	0	0.615385	0.307692	0.384615
bogbean	0.153846	0	1.416667	0.769231	0	0.153846	0	0	0	0
cloudber	1.769231	2.153846	1	0	0	0.076923	3.384615	0	0	0
deercabb	3.461538	0	0	0.769231	0	0	0	0.384615	0	0
dogwood	1.461538	0.846154	0	3.153846	0.769231	1.538462	1.923077	2	1.384615	2.769231
falselil	0	0	0	0	0	0	0	0.846154	0.076923	2
fernleaf	0	0	0	0	0.384615	0	0	0.538462	1.307692	0.307692
oleafsun	0	0.538462	0.5	0	0.307692	0	0.153846	0	0.153846	0
rleafsun	1.461538	1.923077	3.666667	2.692308	1.076923	0.923077	0.923077	4.461538	1.384615	1.230769
starflow	0.846154	0.384615	1.416667	0.307692	0.461538	0.230769	0.846154	0.153846	1.461538	0.615385
3lfgoldt	0.230769	0.153846	1	0	0.307692	0.538462	1.307692	0.538462	0.230769	1.076923
bluesedg	1.923077	1.923077	4.75	1.076923	0.307692	0.538462	0	8.615385	0.769231	0.538462
fewflows	0.384615	0	0	0	0.076923	0	0	0	0.538462	0.384615
greensed	0.384615	0.153846	0.416667	0.538462	0	0.769231	0	0	0	0.153846
sloughse	0	2.076923	8.333333	3.461538	0.769231	1.769231	0	0.307692	0.384615	3.615385
unknsedg	0	0	0	0	0	0	0	1.923077	0.923077	0
feagrasm	0.153846	0.076923	0.333333	0.461538	0	0.153846	0	0	0	0

Vegetation										
Site #	11	12	13	14	15	16	17	18	19	20
Species	Dufferin Isl	Dufferin Isl	Athlone Isl.	Athlone Isl.	Don Penins	Cecilia Isl.	Lady Doug	Cultus Sou	Swordfish	Goolden Is
chamisso	0	0	0.416667	0.769231	0	0	0	0.076923	1.307692	1.538462
feagrasb	0	0	0.833333	0.769231	0.461538	0	0	0	0	0
narlfcott	5.384615	1.538462	11.25	5	6.692308	4.538462	13	3.692308	2.615385	1.538462
tuftclub	3.461538	1.153846	10	4.230769	5	2.846154	5.461538	5.923077	4.923077	3.846154
unkngras	1.461538	0	0.583333	0.076923	1.923077	0.153846	0	0.076923	0	0.384615
whbeakru	1.153846	1.923077	7.916667	10	6.923077	2.692308	1.076923	0.230769	0	0
brostesp	0	0.769231	7.083333	0	0	0	6.538462	7	1.923077	1.923077
sphfatbr	32.92308	7.692308	30.83333	23.07692	18.46154	31	39	0	24.61538	0
Sphangus	0	0	0.833333	0	1.538462	0	0	0	0	0
sphred	6.923077	13.84615	4.166667	5.769231	5.538462	4.923077	4.461538	14.76923	6.538462	17.69231
Sphmendo	0.769231	0.384615	1.25	1.923077	1.538462	1.538462	0	0.384615	0	0.076923
Sphconto	0	0	0	0	0	0	0	3.076923	8.461538	0.923077
bigredst	0.769231	0	0	4.230769	0	0	0	1.692308	0.923077	6.307692
blackfis	0	0	0	0	1.538462	0.384615	0	0.230769	0	0
cladina	26.53846	37.30769	16.33333	10.38462	22.46154	7.461538	17.53846	13.69231	18.61538	25.38462
coscisso	3.076923	0	0	0	0	0	0	3.538462	2.307692	1.923077
deerclad	0.846154	1.923077	0	0.384615	0.307692	1.153846	0.538462	1.307692	0	1.230769
Dicranum	1.307692	0	0.583333	0.153846	0.538462	0	0	0	0.923077	0.384615
hardscal	0	0	0.166667	1.153846	0	0	0	0	0	0
hoaryroc	13.84615	8.846154	7.5	3.846154	12.38462	32.61538	18.76923	10	22.30769	15.69231
lankymos	0.769231	0	0	6.153846	2.461538	1.153846	0.153846	0	0	3.461538
lipstick	0.153846	0	0	0	0	0	0	0	0	0
myliaano	0.153846	0	0	0	0.384615	0.769231	0	2.307692	1.538462	3.461538
oregonbe	0.384615	0	0.416667	0.769231	0.769231	0	0	0	0	0
polystric	0	0	2.916667	0	0	0.384615	0	0.769231	0	0
purplewo	0.384615	0	0	0	0.769231	0.769231	0	0.076923	0	0.384615
ribbedbo	1	0.153846	0.416667	0	0	0.153846	1.384615	0	0.153846	0.538462
runningc	0	0	0	0.769231	0	0	0	1.307692	0.076923	0.461538
stepmoss	0	3.846154	0	4.230769	0.769231	0	0	0.923077	0.769231	1.923077
unknmoss	0	0	0	0	0	0	0	2	0.384615	0.769231
stiffclu	0	0	1.166667	0.769231	0	0.384615	0.461538	0.461538	0	0.538462
pineclub	0.384615	0	0	0	0	0	0.076923	0	0	0
firclubm	0	0	0	0	0	0	0	0	0	0
minersoi	3.846154	0	0	0	0	0	0	0	3.846154	0
indianhe	0	0	0	0	0.769231	0	0	0.769231	0	1.153846
muck	1.923077	0	4.166667	0	1.923077	0.769231	0	0	0	0
copperbu	0	0	0	0	0.153846	0	0	0	0	0
buttwort	0	0	0	0	0	0	0	0	0.153846	0

Appendix F
Diet data

Diet data - raw percent volume																			
Sample #	Site	Date	Time period	Total vol (mL)	plant	sedge	berry husks	moss leaves	fishb ones	grit	periwin /limpet	bugs	berry seeds	sm seeds	mussels	crab	red mit es	verts	crow seeds + husks
112	3	25/05/2008	1	1.1	55	0	0	30	0	0	15	0		0	0	0	0	0	0
118	3	23/05/2008	1	1	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
119	3	23/05/2008	1	0.7	5	0	0	0	0	1	20	1	0	0	73	0	0	0	0
133	3	23/05/2008	1	0.9	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
111	4	25/05/2008	1	0.9	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
113	4	25/05/2008	1	1	0	0	0	0	0	10	69	0	0	0	20	1	0	0	0
120	5	24/05/2008	1	1.2	0	20	0	0	0	0	0	0	0	0	80	0	0	0	0
114	6	25/05/2008	1	0.6	0	0	0	0	0	0	0	1	0	0	99	0	0	0	0
115	6	25/05/2008	1	1.3	0	0	0	0	0	10	10	0	0	0	80	0	0	0	0
4	1	10-Jun	1	2.5	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	2	04/06/2008	1	1.4	0	0	0	0	0	50	20	0	0	0	30	0	0	0	0
77	2	04/06/2008	1	1.5	0	0	0	0	0	10	50	0	0	0	40	0	0	0	0
78	2	04/06/2008	1	0.9	0	0	0	0	0	5	5	0	0	0	85	5	0	0	0
79	2	04/06/2008	1	1.4	0	0	0	0	0	40	55	0	0	0	5	0	0	0	0
121	3	06/06/2008	1	1.1	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
122	3	06/06/2008	1	0.9	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
123	3	06/06/2008	1	0.5	0	0	0	0	0	10	0	1	0	0	89	0	0	0	0
124	3	06/06/2008	1	0.4	1	0	0	0	0	30	0	0	0	0	69	0	0	0	0
125	3	06/06/2008	1	1.1	0	0	0	0	10	0	0	1	0	0	89	0	0	0	0
126	3	06/06/2008	1	0.9	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
127	3	06/06/2008	1	0.9	0	0	0	0	0	10	1	1	0	0	88	0	0	0	0
128	3	06/06/2008	1	0.7	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
129	3	06/06/2008	1	0.6	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
130	3	06/06/2008	1	1	0	0	0	0	0	10	5	1	0	0	84	0	0	0	0
131	3	06/06/2008	1	1.2	0	0	0	0	0	10	1	0	0	0	89	0	0	0	0
1	4	10-Jun	1	9	0	99	0	0	0	0	0	0	0	0	0	0	1	0	0
2	4	10-Jun	1	3.2	0	95	0	0	0	5	0	0	0	0	0	0	0	0	0
3	4	10-Jun	1	3.5	40	0	0	0	0	0	0	0	0	0	0	59	1	0	0
5	4	10-Jun	1	3.2	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80	4	03/06/2008	1	1.1	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
74	5	07/06/2008	1	1.1	10	0	0	0	0	10	20	0	0	0	60	0	0	0	0
76	5	07/06/2008	1	1.1	10	0	0	0	0	5	5	0	0	0	80	0	0	0	0
146	5	14/06/2008	1	0.7	0	0	0	0	0	1	5	0	0	0	94	0	0	0	0
81	1	24/06/2008	2	0.9	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
82	1	24/06/2008	2	0.9	0	90	0	0	0	10	0	0	0	0	0	0	0	0	0
83	1	24/06/2008	2	1.5	0	0	0	0	0	40	0	0	0	0	0	55	0	0	0
84	1	24/06/2008	2	1.3	0	0	0	5	0	49	45	1	0	0	0	0	0	0	0
85	1	24/06/2008	2	1.5	80	0	0	0	0	0	0	0	0	0	0	20	0	0	0
87	2	23/06/2008	2	0.4	95	0	0	0	0	0	5	0	0	0	0	0	0	0	0
89	2	23/06/2008	2	0.9	2	0	0	0	0	44	34	0	1	0	20	0	0	0	0
90	2	23/06/2008	2	1.2	80	0	0	0	0	20	0	0	0	0	0	0	0	0	0
91	3	24/06/2008	2	1.5	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0

Diet data - raw percent volume																				
Sample #	Site	Date	Time period	Total vol (mL)	plant	sedge	berry husks	moss leaves	fishb ones	grit	periwin /limpet	bugs	berry seeds	sm seeds	mussels	crab	red mit es	verts	crow seeds + husks
92	3	24/06/2008	2	1.1	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
93	3	24/06/2008	2	1.5	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
94	3	24/06/2008	2	1.8	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
95	3	24/06/2008	2	2.5	84	0	0	0	0	5	5	1	0	0	5	0	0	0	0
96	3	24/06/2008	2	1.3	0	0	0	0	0	15	5	0	0	0	80	0	0	0	0
97	3	24/06/2008	2	1.1	0	0	0	0	0	10	20	0	0	0	69	1	0	0	0
98	3	24/06/2008	2	2.5	0	80	0	0	0	20	0	0	0	0	0	0	0	0	0
99	3	24/06/2008	2	2	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
100	3	24/06/2008	2	1.4	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
101	4	21/06/2008	2	1.1	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
102	4	21/06/2008	2	1	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
103	4	21/06/2008	2	1.6	0	95	0	0	0	5	0	0	0	0	0	0	0	0	0
104	4	21/06/2008	2	0.8	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
105	4	21/06/2008	2	0.9	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
106	4	21/06/2008	2	1	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
107	4	21/06/2008	2	0.7	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
108	4	21/06/2008	2	0.5	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
109	4	21/06/2008	2	0.9	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
110	4	21/06/2008	2	1.1	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
73	5	22/06/2008	2	1.6	0	0	0	0	0	10	15	1	0	0	15	59	0	0	0
132	6	23/06/2008	2	0.5	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
134	6	23/06/2008	2	0.6	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
135	6	23/06/2008	2	1	0	0	0	0	0	10	40	0	0	0	50	0	0	0	0
136	6	23/06/2008	2	0.8	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
137	6	23/06/2008	2	0.7	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
138	6	23/06/2008	2	0.9	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
139	6	23/06/2008	2	1.1	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
86	1	03/07/2008	2	1.5	0	0	0	0	0	20	20	0	0	0	60	0	0	0	0
52	2	07/07/2008	2	2	0	0	0	0	0	10	0	0	0	0	90	0	0	0	0
53	2	07/07/2008	2	1.9	0	0	0	0	0	0	95	0	0	0	5	0	0	0	0
54	2	07/07/2008	2	1.9	0	0	0	0	0	0	84	0	0	0	15	1	0	0	0
56	2	07/07/2008	2	1.6	0	0	0	0	0	0	79	0	1	0	20	0	0	0	1
57	2	07/07/2008	2	2.5	0	0	63	0	0	5	1	1	30	0	0	0	0	0	93
59	2	07/07/2008	2	1.1	10	0	0	0	0	10	68	1	0	0	10	1	0	0	0
60	2	07/07/2008	2	1.4	0	0	0	0	0	5	0	0	0	0	95	0	0	0	0
61	2	07/07/2008	2	1.3	1	0	0	0	0	10	5	0	0	0	84	0	0	0	0
62	2	07/07/2008	2	1	5	0	0	0	0	30	0	1	0	0	64	0	0	0	0
63	2	07/07/2008	2	2	0	0	0	0	0	10	10	0	0	0	80	0	0	0	0
51	3	02/07/2008	2	1	0	0	0	0	0	0	30	0	10	10	50	0	0	0	10
71	3	03/07/2008	2	2	0	0	0	0	0	25	54	0	1	0	20	0	0	0	1
55	5	06/07/2008	2	1	0	0	0	0	0	0	75	0	0	0	10	15	0	0	0
58	5	06/07/2008	2	1.5	15	0	0	0	0	5	68	0	1	0	10	1	0	0	1

Diet data - raw percent volume																			
Sample #	Site	Date	Time period	Total vol (mL)	plant	sedge	berry husks	moss leaves	fishbones	grit	periwin /limpet	bugs	berry seeds	sm seeds	mussels	crab	red mites	verts	crow seeds + husks
64	5	06/07/2008	2	1.5	75	0	0	0	0	10	5	5	5	0	0	0	0	5	5
117	6	07/07/2008	2	1.2	0	0	15	0	0	0	0	5	80	0	0	0	0	0	95
14	2	23/07/2008	3	1.5	0	0	0	0	0	5	94	0	0	0	1	0	0	0	0
17	2	23/07/2008	3	1.6	0	0	99	0	0	0	0	0	1	0	0	0	0	0	100
18	2	23/07/2008	3	1.6	0	0	69	0	0	20	0	1	10	0	0	0	0	0	79
19	2	23/07/2008	3	1.5	0	0	0	0	0	15	80	0	0	0	5	0	0	0	0
20	2	23/07/2008	3	0.5	0	0	79	0	0	0	0	20	1	0	0	0	0	0	80
21	2	23/07/2008	3	1.6	0	0	79	0	0	0	0	1	20	0	0	0	0	0	99
22	2	23/07/2008	3	0.9	0	0	89	0	0	0	0	1	10	0	0	0	0	0	99
23	2	23/07/2008	3	0.7	0	0	39	0	0	15	15	1	30	0	0	0	0	0	69
15	3	22/07/2008	3	1.5	0	0	0	0	0	0	99	0	0	0	1	0	0	0	0
16	3	22/07/2008	3	1.5	0	0	0	0	0	1	99	0	0	0	0	0	0	0	0
24	3	22/07/2008	3	1.3	0	0	0	0	0	10	45	0	0	0	45	0	0	0	0
26	3	22/07/2008	3	1.4	0	0	0	0	0	5	5	0	0	0	90	0	0	0	0
27	3	22/07/2008	3	1	0	0	0	10	0	0	79	1	0	0	10	0	0	0	0
28	3	22/07/2008	3	1.4	0	0	0	20	0	0	80	0	0	0	0	0	0	0	0
29	3	22/07/2008	3	1.2	5	0	0	0	0	0	45	1	0	0	44	5	0	0	0
30	3	22/07/2008	3	1.1	5	0	0	0	0	0	0	0	0	0	95	0	0	0	0
25	5	22/07/2008	3	1.4	0	0	89	0	0	0	0	1	10	0	0	0	0	0	99
31	5	22/07/2008	3	1.5	0	0	25	0	0	0	0	1	69	0	5	0	0	0	94
32	5	22/07/2008	3	1.7	0	84	0	0	0	0	0	1	15	0	0	0	0	0	15
140	6	22/07/2008	3	1.9	1	0	49	0	0	0	5	0	40	0	5	0	0	0	89
141	6	22/07/2008	3	1.5	0	0	50	0	0	0	0	0	50	0	0	0	0	0	100
142	6	22/07/2008	3	1	0	0	60	0	0	0	0	0	40	0	0	0	0	0	100
6	1	02/08/2008	3	0.4	20	0	0	0	0	39	1	1	39	0	0	0	0	0	39
7	1	02/08/2008	3	2.5	0	0	79	0	0	0	0	1	20	0	0	0	0	0	99
8	1	02/08/2008	3	2	20	0	0	0	0	10	70	0	0	0	0	0	0	0	0
9	2	04/08/2008	3	2	0	0	0	0	0	0	5	0	0	0	95	0	0	0	0
10	2	04/08/2008	3	3.3	0	0	84	0	0	0	5	1	10	0	0	0	0	0	94
11	2	04/08/2008	3	1.9	0	0	95	0	0	0	0	1	4	0	0	0	0	0	99
12	2	04/08/2008	3	2.2	0	0	90	0	0	5	0	0	5	0	0	0	0	0	95
13	2	04/08/2008	3	1.5	0	0	98	0	0	0	0	1	1	0	0	0	0	0	99
38	5	06/08/2008	3	1.5	30	0	39	0	0	0	0	1	30	0	0	0	0	0	69
45	5	11/08/2008	3	0.8	49	0	0	0	0	5	0	1	0	0	45	0	0	0	0
48	5	06/08/2008	3	1.7	0	0	30	0	0	0	0	1	49	20	0	0	0	0	79
49	5	06/08/2008	3	1	0	0	70	0	0	0	0	0	10	20	0	0	0	0	80
50	5	06/08/2008	3	1	0	0	30	0	0	0	0	1	69	0	0	0	0	0	99
36	1	22/08/2008	3	1.3	0	0	0	0	0	10	60	0	0	0	30	0	0	0	0
33	2	19/08/2008	3	1.2	80	0	0	0	0	0	0	10	10	0	0	0	0	0	10
34	2	19/08/2008	3	0.8	50	0	0	0	0	5	25	0	20	0	0	0	0	0	20
35	2	19/08/2008	3	1.5	0	0	20	0	0	5	5	0	70	0	0	0	0	0	90
37	2	19/08/2008	3	1	0	0	84	0	0	10	0	1	5	0	0	0	0	0	89

Diet data - raw percent volume																			
Sample #	Site	Date	Time period	Total vol (mL)	plant	sedge	berry husks	moss leaves	fishb ones	grit	periwin /limpet	bugs	berry seeds	sm seeds	mussels	crab	red mit es	verts	crow seeds + husks
42	2	19/08/2008	3	1.5	0	0	73	0	0	5	0	1	20	1	0	0	0	0	93
46	2	19/08/2008	3	1.4	0	0	0	0	0	5	0	0	0	0	95	0	0	0	0
47	2	19/08/2008	3	1.4	0	0	40	0	0	5	0	0	15	15	25	0	0	0	55
40	3	21/08/2008	3	0.8	0	0	0	20	0	5	35	0	0	0	39	1	0	0	0
43	3	19/08/2008	3	0.7	0	0	0	0	0	5	1	0	1	0	88	5	0	0	1
44	3	19/08/2008	3	0.6	1	0	0	0	0	5	0	1	0	0	93	0	0	0	0
39	5	29/08/2008	3	1.5	0	0	74	0	0	0	0	1	25	0	0	0	0	0	99
41	5	21/08/2008	3	2	0	0	49	0	0	0	0	1	1	49	0	0	0	0	50
116	6	28/08/2008	3	1.5	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
143	6	20/08/2008	3	1.1	80	0	0	0	0	0	0	20	0	0	0	0	0	0	0
144	6	20/08/2008	3	0.6	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
145	6	20/08/2008	3	0.7	0	0	30	0	0	0	1	0	69	0	0	0	0	0	99

Diet data - frequency of diet items by site and time period													
Frequency by site													
Site	N	plant	sedge	moss leave	grit	periwin/lim	sm seeds	mussels	crab	crow seeds	insects	vertebrates	fishbones
1	11	0.3636	0.1818	0.0909	0.6364	0.4545	0.0000	0.1818	0.1818	0.1818	0.2727	0.0000	0
2	37	0.2162	0.0000	0.0000	0.6486	0.5405	0.0541	0.5135	0.0811	0.4865	0.3784	0.0000	0
3	38	0.1892	0.3514	0.1081	0.4595	0.5135	0.0270	0.5946	0.1081	0.0811	0.2432	0.0270	0.026316
4	17	0.1176	0.8235	0.0000	0.1765	0.0588	0.0000	0.0588	0.1176	0.0000	0.1176	0.0000	0
5	18	0.3333	0.1111	0.0000	0.3889	0.3889	0.1667	0.5000	0.1667	0.6111	0.6111	0.1667	0
6	17	0.1176	0.4706	0.0000	0.1176	0.2353	0.0000	0.2353	0.0000	0.2941	0.1765	0.0000	0
Frequency by time period													
With time periods collapsed to early, mid and late (1,2,3)													
t period	N	plant	sedge	moss	grit	peri/limpet	insects	mussels	crowberry	small seed	crab	vertebrates	fishbones
1	32	0.25	0.34	0.03	0.50	0.44	0.19	0.59	0.22	0.00	0.09	0.00	0.03
2	53	0.19	0.49	0.02	0.43	0.40	0.15	0.38	0.13	0.02	0.20	0.02	0.00
3	52	0.21	0.06	0.06	0.40	0.40	0.50	0.35	0.62	0.10	0.06	0.00	0.00