COSEWIC
Assessment and Update Status Report

on the

Great Blue Heron
Ardea herodias fannini

fannini subspecies

in Canada

SPECIAL CONCERN
2008

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

COSEWIC. 2008. COSEWIC assessment and update status report on the Great Blue Heron *fannini* subspecies *Ardea herodias fannini* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 39 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Previous reports:

Butler, W. R. 1997. COSEWIC status report on the Pacific Great Blue Heron *Ardea herodias fannini* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. ii + 9 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Production note:
COSEWIC would like to acknowledge Ross Vennesland and Rob Butler for writing the update status report on the Great Blue Heron *fannini* subspecies, in Canada, prepared with funding provided by the B.C. Ministry of Environment, Parks Canada Agency and Environment Canada. This report was overseen and edited by Dr. Marty Leonard, Co-chair COSEWIC Birds Specialist Subcommittee, with input from members of COSEWIC.

For additional copies contact:

COSEWIC Secretariat
c/o Canadian Wildlife Service
Environment Canada
Ottawa, ON
K1A 0H3

Tel.: 819-953-3215
Fax: 819-994-3684
E-mail: COSEWIC/COSEPAC@ec.gc.ca
http://www.cosewic.gc.ca

Également disponible en français sous le titre Évaluation et Rapport de situation du COSEPAC sur le grand héron de la sous-espèce *fannini* (*Ardea herodias fannini*) au Canada – Mise à jour.

Cover illustration:
Great Blue Heron — Photo by John F. Bargman.

Catalogue No. CW69-14/543-2008E-PDF
ISBN 978-0-662-48821-7

Recycled paper

COSEWIC
Assessment Summary

Assessment Summary – April 2008

Common name
Great Blue Heron *fannini* subspecies

Scientific name
Ardea herodias fannini

Status
Special concern

Reason for designation
In Canada, this subspecies is distributed along the coast of British Columbia with a relatively small population that is concentrated at a few breeding colonies in southern British Columbia. There is evidence of declines in productivity and it is unclear whether the population is stable or declining. Threats from eagle predation, habitat loss and human disturbance are ongoing, particularly in the southern part of the range where concentrations of birds are highest.

Occurrence
British Columbia

Status history
Designated Special Concern in April 1997 and April 2008. Last assessment based on an update report.

COSEWIC
Executive Summary

Great Blue Heron
Ardea herodias fannini

fannini subspecies

Species information

The Great Blue Heron, *Ardea herodias*, is the largest wading bird in North America, standing over 1 m in height. On the coast of British Columbia the subspecies, *Ardea herodias fannini*, referred to as the Pacific Great Blue Heron in this report, resides year round. This subspecies is non-migratory and isolated in part by high mountain ranges to the east and a slightly earlier breeding season, compared to more continental herons. The Pacific Great Blue Heron is darker plumaged, smaller in size and has a smaller clutch size than continental herons.

Distribution

The Great Blue Heron breeds across most of North America south of Alaska, and on the Galapagos Islands. The non-breeding distribution is south of freezing areas in the north, to as far south as Panama. The distribution of the Pacific Great Blue Heron is confined to the Pacific Coast from Prince William Sound, Alaska south to Puget Sound, Washington, where it resides year-round.

Habitat

The Pacific Great Blue Heron forages along the seacoast, in fresh and saltwater marshes, along rivers and in grasslands. Smaller numbers of herons forage in kelp forests, from wharves and at anthropogenic waterbodies (e.g., ornamental ponds and fish farms). Most herons nest in woodlands near large eelgrass (*Zostera marina*) meadows, along rivers, and in estuarine and freshwater marshes. Nesting colony locations are dynamic, especially in areas of high disturbance. Some colonies are used for many years, but most colonies and especially those with fewer than 25 nests, are relocated every few years. In autumn, juvenile herons occupy grasslands on the Fraser River delta and southern Vancouver Island, and adults occupy estuarine marshes, riverine marshes and grasslands.

The size of Great Blue Heron populations is correlated with the area of foraging habitat available locally, and consequently the largest concentrations of Pacific Great Blue Herons occur around the Fraser River delta where extensive mudflats and eelgrass beds provide abundant foraging locations. Local declines in foraging habitat likely have been greatest in south-coastal British Columbia because most of the province's human population is located in this area. Further, the magnitude of use of some foraging locations currently may be limited by the amount of suitable nesting habitat that remains undeveloped.

Suitable tall trees as nesting habitat near foraging areas have declined in some parts of British Columbia over the past century due to increases in the size of human populations and industry. Especially hard hit is south-coastal British Columbia and especially the lower Fraser Valley, where the human population is large and still growing. In this region, nesting habitat might be limiting the size of the heron population. Habitat destruction in south-coastal British Columbia has resulted in the abandonment of at least 21 colonies (from 1972 to 1985 and from 1998 to 1999).

Biology

In springtime, most herons gather in colonies where they court, nest, and raise young. The principal diet is small fish during the breeding season augmented with small mammals in winter. Typically four eggs are laid and less than two chicks on average reach the fledgling stage and leave the nest to become juveniles. Fewer than 25% of juveniles survive their first winter, after which survival increases to about 75% per year for adults. Nests are generally in trees and are made using large sticks.

Population sizes and trends

Population size has been difficult to estimate for the Pacific Great Blue Heron because colonies are not stable and are difficult to track in a standardized fashion. The best available estimates suggest that the Pacific Great Blue Heron population size in Canada is 4000-5000 nesting adults. The global population of the Pacific Great Blue Heron is likely between 9,500 and 11,000 nesting adults.

Christmas Bird Count data show population declines over the past three generations, while Coastal Waterbird Surveys show increases over a recent five-year period. Colony surveys suggest that productivity has declined significantly since the 1970s.

Limiting factors and threats

Declines and other issues with productivity and population size are thought to primarily be due to Bald Eagle predation, human disturbance and destruction of nesting and foraging habitat. The projected doubling in the human population in the next 30 years in the core of the range threatens to exacerbate the human disturbance problem and habitat loss. In addition, the influence of predators may be reducing habitat quality by causing herons to move to new, and ever more limited, sites.

Special significance of the species

The Pacific Great Blue Heron has high public appeal as a symbol of wetland conservation and environmental quality.

Existing protection or other status designations

All Great Blue Herons are protected from hunting and molestation by the *Migratory Birds Convention Act*, Migratory Bird Regulations and the British Columbia *Wildlife Act*. Both subspecies of Great Blue Heron inhabiting British Columbia are at present on the provincial 'Blue List' compiled by the British Columbia Ministry of Environment. The Pacific Great Blue Heron was listed in 1997 as Special Concern by COSEWIC.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2008)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as “Vulnerable” from 1990 to 1999, or “Rare” prior to 1990.

** Formerly described as “Not In Any Category”, or “No Designation Required.”

*** Formerly described as “Indeterminate” from 1994 to 1999 or “ISIBD” (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

Update
COSEWIC Status Report

on the

Great Blue Heron
Ardea herodias fannini

fannini subspecies

in Canada

2008

TABLE OF CONTENTS

List of figures

List of tables

SPECIES INFORMATION

Name and classification

The Great Blue Heron, *Ardea herodias*, belongs to the Class Aves, Order Ciconiiformes and Family Ardeidae. It is a distinctive heron species found in wetlands across southern Canada and is the largest wading bird in North America (standing over 1 m in height).

Five subspecies currently are recognized (Payne 1979; Butler 1992), two of which occur in British Columbia. The subspecies *Ardea herodias herodias* occupies all of southern Canada east of the coastal mountain ranges of British Columbia, while the subspecies *Ardea herodias fannini* occupies the whole British Columbia coast west of the mountain ranges (Figure 1).

Morphological description

The Great Blue Heron measures about 60 cm in height (with neck relaxed), 97 to 137 cm in length, and 2.1 to 2.5 kg in mass (Butler 1992; 1997). The wings are long and rounded, the bill is long, and the tail is short (Butler 1992; 1997). Great Blue Herons fly with deep, slow wing beats and with their necks folded in an S-shape. Plumage is mostly a blue-grey colour and adults have a white crown (Butler 1992; 1997).

The Pacific Great Blue Heron differs from the continental form (*A. h. herodias*) in morphology and breeding behaviour/physiology (Butler 1997). In terms of morphology, the Pacific Great Blue Heron is smaller in size and darker in plumage than *A. h. herodias*.

Genetic description

Genetic characterization of Great Blue Herons in North America has not been conducted.

Designatable units

The American Ornithologists' Union (A.O.U.) recognizes one coastal subspecies of Great Blue Heron in British Columbia referred to in this report as the Pacific Great Blue Heron (*A. h. fannini*).

A recent comparison of heron taxonomy showed that specimens on the Queen Charlotte Islands, the north coast and southeast Alaska had shorter tarsii and darker plumage than specimens on the south coast (Dickerman 2004). South coast herons were intermediate in size between the north coast and specimens from California (Dickerman 2004). From these data, Dickerman (2004) recommended that the *fannini* subspecies designation be restricted to the Queen Charlotte Islands and adjacent north coast of British Columbia in Canada and Alaska, and that south coast herons be considered an intermediate form with California herons. This recommendation has not been considered by the A.O.U. and stands in contrast to the currently accepted designations based on work by Payne (1979), which also was based solely on morphology. Genetic evidence would assist in clarifying the degree of separation of subspecies and geographical boundaries.

This report considers one designatable unit, which is the single coastal subspecies of Great Blue Heron, as per currently accepted A.O.U. taxonomy.

DISTRIBUTION

Global range

The Great Blue Heron breeds from south coastal Alaska, coastal and southern British Columbia, northern Alberta, central Manitoba, southern Ontario and Quebec, New Brunswick, Prince Edward Island and Nova Scotia, south throughout the USA and coastal Mexico, and on the Galapagos Islands (Butler 1992). The winter distribution is south of the frozen regions in the north to as far south as Panama.

The distribution of the Pacific Great Blue Heron, which is the subject of this report, is confined to the coast from Prince William Sound, Alaska south to Puget Sound, Washington (Figure 1).

Canadian range

In Canada, the Pacific Great Blue Heron resides year-round on the north and south coasts of British Columbia and associated islands (e.g., Vancouver Island and the Queen Charlotte Islands; Figure 2), including the Coastal Western Hemlock and Coastal Douglas Fir Biogeoclimatic Zones within 10 km of the coast or large river systems (see *Habitat* section for discussion). Most nesting colonies are located in the Strait of Georgia, the core of the subspecies' range, and the only area where long-term data on nesting habitat are available (Figure 3). The area of occupancy is approximately 188,000 km^2 and includes all terrestrial areas within the Coastal Douglas Fir and Coastal Western Hemlock biogeoclimatic zones that are less than 10 km from either the coastline or a major river system. The extent of occurrence is approximately 244,000 km^2 and is based on a polygon with a minimum number of sides around the entire Canadian range. Approximately 59% of the global extent of occurrence occurs in Canada (approximately 128,000 km^2 in Alaska and 43,000 km^2 in Washington State).

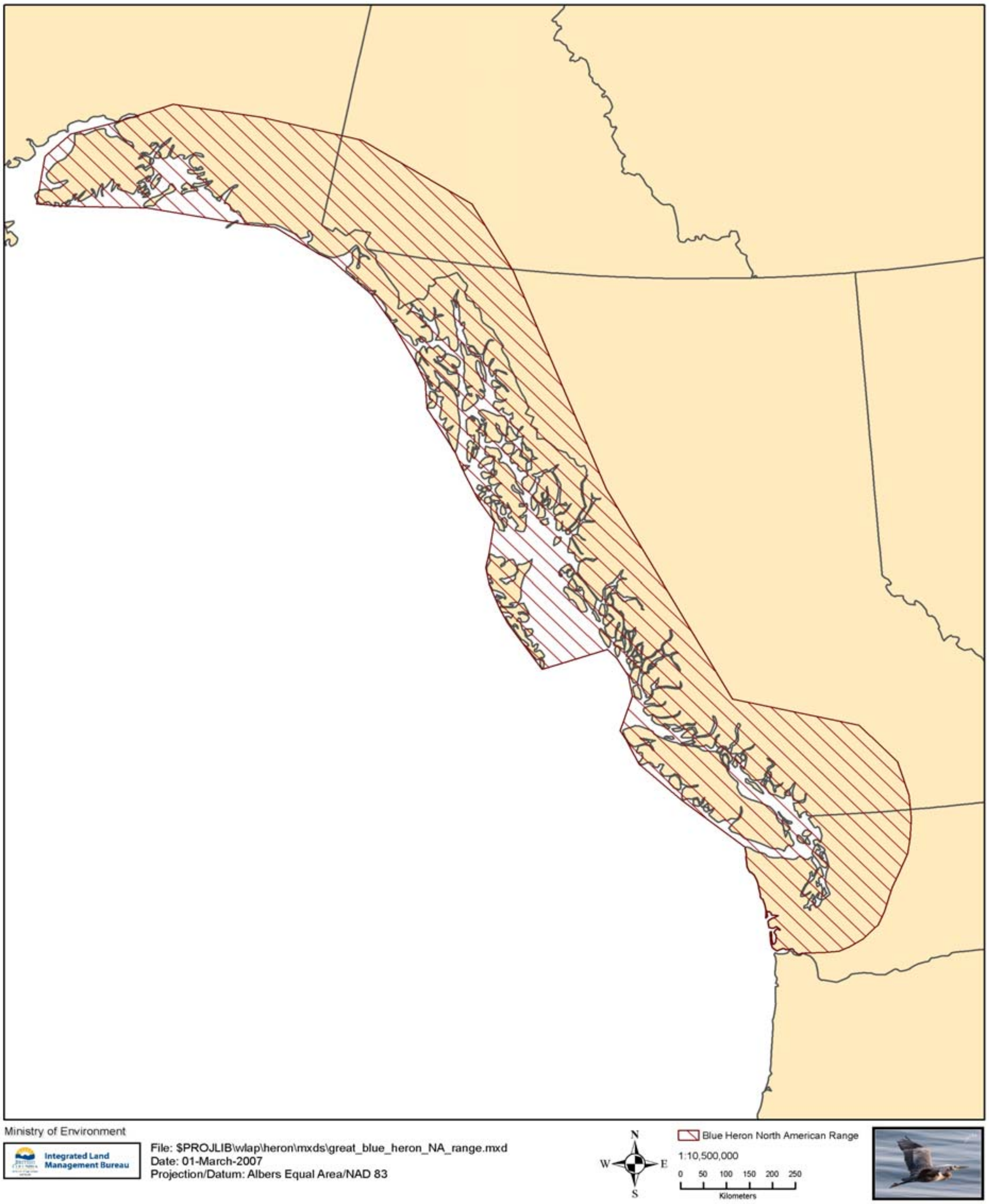

Figure 1. Global range of the Pacific Great Blue Heron, *Ardea herodias fannini* (B.C. Conservation Data Centre 2007).

Figure 2. Canadian range of the Pacific Great Blue Heron showing potential area of occupancy (shaded area). Potential area of occupancy is defined as terrestrial areas within the Coastal Douglas Fir and Coastal Western Hemlock biogeoclimatic zones that are less than 10 km from a potential foraging area. Potential foraging areas are defined as the entire coastline and major river systems (B.C. Conservation Data Centre 2007).

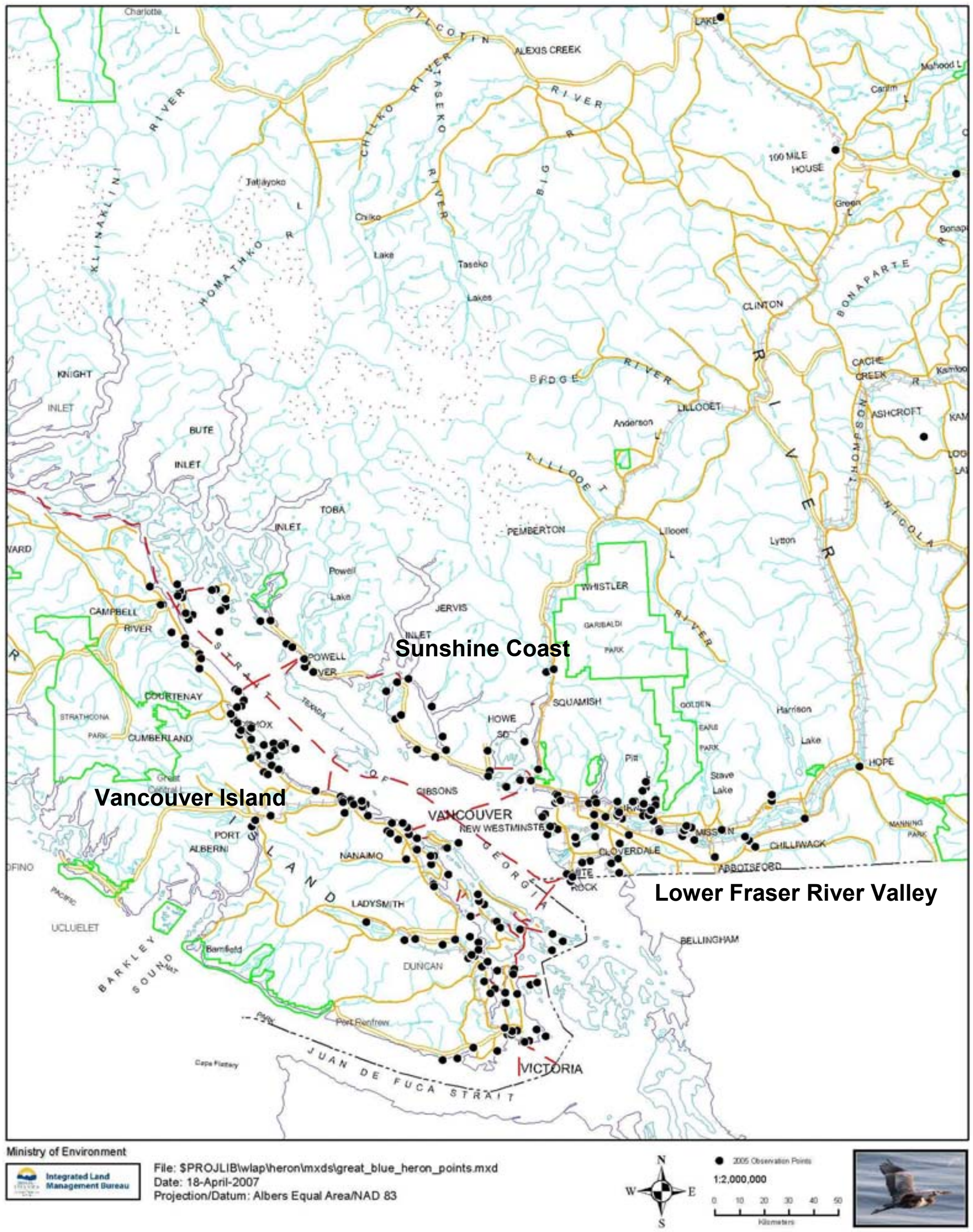

Figure 3. Documented nesting colony locations for the Pacific Great Blue Heron on the south coast and Vancouver Island of British Columbia from 1920 to 2005. Some nesting locations have been identified on other areas of the coast (e.g., Queen Charlotte Islands), but they are few and not based on significant inventory. The three primary regions of south-coastal British Columbia mentioned in the report (Vancouver Island, Sunshine Coast and lower Fraser Valley) are shown on this map (B.C. Conservation Data Centre 2007).

HABITAT

The habitat of the Pacific Great Blue Heron is described by Butler (1995; 1997) and Gebauer and Moul (2001). This subspecies forages along the seacoast, in fresh and saltwater marshes, along rivers and in grasslands. Smaller numbers of herons forage in kelp forests, from wharves and at anthropogenic waterbodies (e.g. ornamental ponds and fish farms). Most herons nest in woodlands near large eelgrass (*Zostera marina*) meadows, along rivers, and in estuarine and freshwater marshes. In autumn, juvenile herons occupy grasslands on the Fraser River delta, and adults occupy estuarine marshes, riverine marshes and grasslands. All known foraging and nesting occurrences are within the Coastal Western Hemlock and Coastal Douglas Fir Biogeoclimatic Zones.

Habitat requirements

Foraging habitat

Breeding Pacific Great Blue Herons require accessible prey within about 10 km of a nesting location (Butler 1995). Important foraging habitats for Pacific Great Blue Herons include aquatic areas such as tidal mudflats, riverbanks, lakeshores and wetlands (Butler 1992; 1997; Gebauer and Moul 2001). During winter on the coast, when aquatic prey are less abundant due to a reduced duration of daytime low tides, fallow agricultural fields become important foraging areas for adult and juvenile herons (Butler 1995; 1997). Inland fields are considered an important foraging habitat for both adults and juveniles in the lower Fraser Valley and on southern Vancouver Island (Gebauer and Moul 2001). The number of herons that use non-aquatic foraging habitats is not known, but large numbers of herons reside in south-coastal areas (Gebauer and Moul 2001), so it is likely that these areas are an important foraging habitat for a significant number of herons. Some foraging habitat is not used by herons each year, suggesting that population growth might not be limited by available foraging habitat.

Nesting habitat

Pacific Great Blue Herons are mostly arboreal nesters and colonies are typically situated in forests near to (usually <10 km from) suitable foraging areas (Butler 1991; 1992; 1995; 1997). Nesting usually occurs at sites that are relatively free from disturbance by human activities, but sometimes occurs in developed areas. Large colonies require more suitable forest than small colonies. Colonies are located in both urban and rural areas, using relatively contiguous forest, fragmented forest and solitary trees (Butler 1997; Vennesland 2000).

Pacific Great Blue Heron colony locations are dynamic, especially in areas of high disturbance (Butler 1992; Vennesland 2000). Some colonies are used for many years (e.g., Shoal Island, Pacific Spirit Park and Point Roberts; all >25 years), but most colonies, especially those with fewer than 25 nests, are relocated every few years (Gebauer and Moul 2001). A site will be re-used by individual herons that failed in their first nesting attempt if other herons are present and if there is sufficient time to complete a nesting cycle (Vennesland 2000). If an entire colony abandons and there is sufficient time to complete a nesting cycle, herons will occasionally return as a group to the same or different colony site in the same year (Vennesland 2000). Herons will sometimes return to a site after one or more years of no use (Moul *et al.* 2001; Chatwin *et al.* 2006).

Habitat trends

Foraging habitat

Suitable foraging habitat likely is declining in British Columbia (Gebauer and Moul 2001), though quantitative information on habitat trends is not available. The size of Great Blue Heron populations has been correlated with the area of foraging habitat available locally (Gibbs and Kinkel 1997), and consequently the largest concentrations of Pacific Great Blue Herons occur around the large estuaries of south-coastal British Columbia, primarily the Fraser River delta where extensive mudflats and eelgrass beds provide abundant foraging locations (Butler 1995; Eissinger 1996). These habitat sites also are highly threatened because most of the province's human population is located near these areas (Butler 1997; Gebauer and Moul 2001). For example, the magnitude of use of some foraging locations (e.g., Boundary Bay) may currently be limited by the amount of suitable nesting habitat that remains undeveloped (B. Smith, unpubl. data; see discussion of nesting habitat below).

Although native eelgrass beds are declining globally, some small and localized habitat gains have been seen on Roberts Bank on the southern Fraser River delta due to jetty construction for a ferry terminal and shipping port (Butler 1997). Outside the Georgia Basin, Pacific Great Blue Herons are scarce but widespread along the coast and feed from kelp beds, wharves and floating objects, and wade in shallow water. There is no loss of suitable habitat for these herons and some might benefit from installations of wharves and fish farms where they can access fish in deep water. At a coast-wide level, however, these potential habitat gains likely are insignificant and probably are overshadowed by habitat loss due to development on different sites, especially in the lower Fraser Valley.

Nesting habitat

Suitable tall trees as nesting habitat for Pacific Great Blue Herons near foraging areas have declined in some parts of British Columbia over the past century due to increases in the size of human populations and industry (Butler 1997, Gebauer and Moul 2001). Especially hard hit is the lower Fraser Valley (Moore 1990, Butler 1997), where the human population is projected to grow from about 2.5 million in 1990 to about 4 million in 2020 (Georgia Basin Ecosystem Initiative 2002). Habitat destruction in south coastal British Columbia has resulted in the abandonment of at least 21 colonies (measured from 1972 to 1985 and from 1998 to 1999; Forbes *et al.* 1985b; Gebauer 1995; Vennesland 2000; Vennesland 2006). Smith *et al.* (unpubl. data) used spatial analysis of the landscape around Boundary Bay to examine the availability of nesting habitat within 15 km of known important foraging locations (the distance at which the energetic cost of flight was 90% of foraging intake that could be provisioned to young). Results showed that nesting habitat is severely limited in this area. Although the foraging habitat in this location can theoretically sustain a large heron population, available nest sites likely limit the population. Perhaps demonstrating this, herons in at least three locations in this area are nesting in untraditional habitats (e.g., farm field hedgerows).

Furthermore, the quality of Pacific Great Blue Heron nesting habitat might be declining as a result of increased disturbance by humans and eagles. Although some herons are persisting in urban settings, others seem reluctant to venture close to humans. Furthermore, Vennesland and Butler (2004) reported that heron nesting productivity was negatively correlated with the level of human activity near colonies. The primary mechanism for this relationship was eagle predation of heron nests, with direct human disturbance as a secondary mechanism. Thus, the impact of eagle predation may be higher as urbanization increases. This may be compounded by the fact that eagle populations in the Strait of Georgia are thought to benefit from humans through, for example, gull populations being enhanced by human refuse (Vermeer *et al.* 1989).

Outside the Georgia Basin, Pacific Great Blue Herons are scattered in small groups and as individuals that nest in the forest. Few nests have been found and all were within a few kilometres of foraging sites. There is no shortage of trees for herons in these areas, so nesting habitat appears to be readily available and has not significantly declined. However, more work is required to locate heron nests in these remote regions as data are limited.

Habitat protection/ownership

Section 34 of the British Columbia *Wildlife Act* (1982; updated 1999) protects heron nests (and consequently also nest trees), but does not provide for buffer areas. The British Columbia *Forest and Range Practices Act* (2004) has guidelines to protect heron colonies (i.e., through the *Identified Wildlife Management Strategy)* on Crown Land, including provision of buffer areas (Vennesland 2004). However, no reserves have been established under this legislation, so currently it affords no protection. No other habitat outside of parks, Wildlife Management Areas (through the British Columbia *Wildlife Act*) or National Wildlife Areas (through the *Canada Wildlife Act*) receives legal protection.

On private land, the British Columbia government advises land users how to best protect wildlife with largely non-legal documents such as the Environmental Best Management Practices for Urban and Rural Land Development in British Columbia (or ‘Develop with Care’) series produced by the Ministry of Environment (MOE 2007). However, there is little legislation to force action on recommendations in these mostly advisory documents. Municipalities have considerable control over the land base within their jurisdiction with the capability of zoning land for different uses and identifying

Development Permit Areas, among other regulatory powers. However, due to the high economic cost of wildlife conservation to landowners, implementation of conservation actions is limited and variable across jurisdictions.

Foraging habitat for Pacific Great Blue Herons includes land and waters under federal jurisdiction (e.g., tidal areas, rivers, national parks, National Wildlife Areas, etc.) and provincial jurisdiction (e.g., private lands, municipal lands, provincial parks, Wildlife Management Areas, etc.). It is not known what proportion of foraging areas are under formal protection, but some notable sites that are protected and support large numbers of foraging herons include Boundary Bay, Sturgeon Bank, Pitt Addington Marsh, Coquitlam River and Parksville-Qualicum Beach Wildlife Management Areas (provincial), and Alaksen, Qualicum and Wigeon Valley National Wildlife Areas (federal). However, regardless of their protective status, many of these sites are under threat from oil spills or other catastrophic events (e.g., Sturgeon Bank and Boundary Bay from nearby ferry and freighter traffic).

Currently active Pacific Great Blue Heron nesting colonies are located in protected and non-protected lands under the control of federal, provincial, regional and municipal governments and on private land. Table 1 lists current nesting locations on protected lands. These seven sites account for 14% of known active locations (n = 49 sites active in 2005), and afford some level of protection to the nesting sites of 37% of the documented nesting pairs in 2005 (n = 1943 nesting pairs). Nevertheless, it should be noted that heron colonies are dynamic in nature and frequently re-locate (Butler 1997; Vennesland 2000). Both Stanley Park and Deer Lake Park are at recently colonized locations, and McFadden has declined from a maximum of 138 active nests in 2000 to two in 2005 (Table 1). In addition, four of the protected sites in Table 1 (Beacon Hill, Salal Park, Stanley Park and Deer Lake Park) are located in municipal parks with high levels of human disturbance. High levels of human disturbance have been correlated with reduced nesting productivity (Vennesland and Butler 2004), so habitat quality at these locations may be low. The other three sites are either fenced or have controlled access, measures thought important to long-term site viability (Carlson and McLean 1996). Of the further 39 sites used by herons for nesting in 2005 that are not protected, four were on Indian Reserves (8%) and 35 (71%) were located on unprotected land under provincial jurisdiction (mostly private ownership). In 2006, three nests were located in Gwaii Haanas National Park (Queen Charlotte Islands). No nests are known within Pacific Rim National Park or Gulf Islands National Park, though they likely do nest there (e.g., a few pairs have been found nesting near Bamfield next to Pacific Rim National Park and large numbers of herons nested on Sidney Island in what is now the Gulf Islands National Park from 1974 to 1990).

Table 1. Pacific Great Blue Heron colonies active in 2005 that have protection in place. Included is general geographic location and number of active heron nests in 2005 (B.C. Conservation Data Centre 2007).

Col_ID	Col_Name	Location	Colony size (no. active nests)	Protective Status
H101-001	Beacon Hill	Victoria	103	Municipal Park
H101-005	McFadden Creek	Saltspring Island	2	Local conservation lands
H101-038	Salal Park	N. Saanich	11	Municipal Park
H204-009	CFB Chilliwack	Chilliwack	203	Municipal Conservation Area
H208-002	Stanley Park	Vancouver	176	Municipal Park leased from the Department of National Defence
H208-005	Mary Hill	Port Coquitlam	222	Provincial Wildlife Management Area
H208-044	Deer Lake Park	Burnaby	4	Municipal Park

BIOLOGY

Life cycle and reproduction

In springtime, most Pacific Great Blue Herons gather in colonies where they court, nest, and raise young. During the nesting season the principal diet is small fish, while during the winter this primarily piscivorous diet is augmented with small mammals.

In south-coastal British Columbia, Pacific Great Blue Heron nesting is initiated between February and April (Butler 1992; Butler 1997; Vennesland 2000; Vennesland and Butler 2004). The initiation period is defined as the period of courtship before eggs are laid, and can last for over two months at some colonies (Butler 1997; Vennesland 2000). At one closely watched colony, males arrived at the colony site and established nest sites followed about a week later by the arrival of females (Butler 1991). Nest repair and/or building can take from as little as several days to about two months (Butler 1991, Vennesland 2000). Monogamous pairs are established for the season (Simpson 1984), and eggs are laid at about two-day intervals (Vermeer 1969; Pratt 1970; R. Butler, pers. obs.). Clutch size reported from Great Blue Heron colonies across North America ranges from one to eight eggs, with three to five being typical (Ehrlich *et al.* 1988; Campbell *et al.* 1990). Clutch size increases with latitude and the Pacific Great Blue Heron lays smaller clutches than expected for this latitude (mean clutch size is about 4 eggs compared to about 4.7 at other sites at this latitude; Butler 1997). Incubation begins soon after the first egg is laid and results in asynchronous hatching (Butler 1992). Hatching occurs after about 27 days of incubation (Butler 1992), though the incubation period in a colony can last for much more than a month as pairs often re-nest after predation or other disturbance events (Vennesland 2000). The chick rearing period lasts about 60 days (Krebs 1974; Simpson 1984).

Herons require about 95 days to complete a nesting cycle, but regularly take much longer than this if re-nesting or other delays occur. Herons can potentially breed more than once if their first attempt fails early.

In south-coastal British Columbia, the number of fledglings raised in a nest varies from 0 to 4 (Butler 1992; 1997; Vennesland 2000). Historically, the nesting productivity of herons in studies across North America has ranged from 1.3 to 2.7 fledglings per active nesting attempt, and from 2.0 to 3.0 fledglings per successful nesting attempt (reviewed by Butler 1997; see also Pratt 1970 and Vos *et al.* 1985). Fewer than 25% of juveniles survive to their second year after which survival increases to about 75% per year for adults (Butler 1997).

Nesting colony characteristics

Pacific Great Blue Herons in British Columbia are normally arboreal nesters and nest solitarily and in colonies (Butler 1992; 1997; Vennesland 2000). Nests are large stick platforms, usually 20 m to 30 m above ground (Butler 1997), but some have nested as low as 2 m in shrubs (Vennesland 2000). For south-coastal British Columbia in 1999, Vennesland and Butler (2004) reported a 'colony' size range of 1 to 400 active nests, with a mean of 62 active nests (SD = 94, n = 31) and a median of 26 nests. The most common tree species used for nesting are Red Alder (*Alnus rubra*), Black Cottonwood (*Populus balsamifera*), Bigleaf Maple (*Acer macrophyllum*), Sitka Spruce (*Picea sitchensis*) and Douglas Fir (*Pseudotsuga menziesii*) (Gebauer and Moul 2001). See Gebauer and Moul (2001) for a full list of tree species used.

Predation

In British Columbia, the Bald Eagle (*Haliaeetus leucocephalus*) is the primary predator of Pacific Great Blue Herons (Butler 1997; Gebauer and Moul 2001; Vennesland and Butler 2004). Bald Eagles prey on heron eggs, nestlings, juveniles and adults (Simpson and Kelsall 1978; Forbes *et al.* 1985b; Forbes 1987; Forbes 1989; Simpson *et al.* 1987; Norman *et al.* 1989; Butler *et al.* 1995; Butler 1997; Gebauer and Moul 2001; Vennesland and Butler 2004), and have been responsible for reduced nesting productivity at many colonies (Norman *et al.* 1989; Gebauer and Moul 2001; Vennesland and Butler 2004). Repeated eagle predation is the suspected cause of many colony abandonments (Forbes *et al.* 1985b; Simpson *et al.* 1987; Butler 1991; Butler 1997; Gebauer and Moul 2001; Vennesland and Butler 2004). The effects of Bald Eagles are covered in more detail in the *Limiting Factors and Threats* section.

Other birds of prey also have been observed preying on Pacific Great Blue Heron nest contents, including Red-tailed Hawks (*Buteo jamaicensis*) on both eggs and nestlings (Simpson 1984, Simpson and Kelsall 1978, Forbes *et al.* 1985b, Norman *et al.* 1989, Butler 1997, Vennesland and Butler 2004) and Northwestern Crows (*Corvus caurinus*) and Common Ravens (*Corvus corax*) on eggs (Butler 1989; Moul 1992). Raccoons prey on nesting herons, but in British Columbia disturbance from non-human mammals is rare (Butler 1997).

Physiology

Specific research on physiological requirements or tolerances of Great Blue Herons from a conservation perspective has been rare. Monitoring of contaminants in eggshells and fetal tissues of Pacific Great Blue Herons has been ongoing since about 1977 (Elliott *et al.* 1989; Elliott *et al.* 1996; Elliott *et al.* 2001; Harris *et al.* 2003). Currently, contaminants (e.g., organochlorine pesticides, polychlorinated biphenyls, dioxins, furans) are not seen as a significant conservation issue for this subspecies as concentrations have generally been in decline over recent years (Elliott *et al.* 1989; Elliott *et al.* 2001; Harris *et al.* 2003). Recently, however, attention has been paid to chemicals that have not previously been tracked. Concentrations of one class of chemicals in particular (polybrominated diphenyl ethers; PBDEs) has been found to be increasing exponentially in heron tissues and may be close to toxicologically significant levels (Elliott *et al.* 2005). The implications of this finding currently are not fully understood, but the situation is seen as a potential emerging threat in urban areas (Elliott *et al.* 2005). There are similar concerns over another emerging class of industrial pollutants, the perfluoro chemicals (PFCs). Environment Canada is currently in the process of investigating spatial and temporal trends of those chemicals, including in herons from the Georgia Basin (J. Elliott, pers. comm.).

Dispersal/migration/movements

The Pacific Great Blue Heron is non-migratory. Banded individuals are known to disperse between habitats in the Strait of Georgia and a few individuals have been found dead in the interior of British Columbia and in coastal Washington and northern Oregon (Butler 1997). Most individuals on the Fraser River delta and other south-coastal areas forage along beaches from March to October and along beaches and grasslands in winter (Butler 1995; 1997). Juvenile herons forage along beaches until about October and reside largely in grasslands in winter (Butler 1995; 1997). When not nesting, herons on the coast of British Columbia roost alone or in loose flocks of over 100 individuals on the ground, in trees, and on man-made objects near feeding grounds during the day (Butler 1992). Some roosts are used repeatedly (Butler 1992). At night, herons sleep in trees with dense foliage during high tide and forage on beaches at low tide (Butler 1992). Limited research has been conducted on annual movements between colonies. Simpson *et al.* (1987) concluded that considerable movement might occur (40% of nesting herons did not return to breed in the second year of the study). Movements between regions are largely unknown but assumed to occur, as birds have been seen by both authors flying across the Strait of Georgia. Colonies will suddenly grow when new arrivals settle, presumably from an abandoned nearby colony (R. Vennesland, unpubl. data).

Interspecific interactions

Interactions of Pacific Great Blue Herons with their predators are described previously in the *Predation* section. Prey includes a wide array of animals including fish, insects, mammals, amphibians, and crustaceans (Butler 1992; 1995; 1997). Fish are a mainstay food item during the nesting season, demonstrated by summer congregations of more than 600 herons feeding together in eelgrass meadows near Tsawwassen on the Fraser River delta (R. Vennesland, unpubl. data). In winter, small mammals in agricultural areas are also important, especially for juvenile survival (Butler 1991; 1995; 1997; Gutsell 1995). Little information is available on diseases, although some have been documented in Great Blue Herons (but not Pacific Great Blue Herons), including *Giardia* and *Eustrongylides* nematodes (Butler 1992).

Adaptability

Some Pacific Great Blue Herons can tolerate human activities near their nests, but many are sensitive to the presence of humans (reviewed by Vennesland 2000; Gebauer and Moul 2001). Human activity near colonies of herons compounds the threat posed by eagle predation to this subspecies (Vennesland 2000, Vennesland and Butler 2004). Butler et al (1995), Carlson and McLean (1996) and Vennesland and Butler (2004) showed that the number of fledglings raised in Great Blue Heron colonies with frequent disturbances was significantly lower than at colonies with no disturbance. When disturbed, herons leave nests unguarded, especially early in the nesting season when humans enter colonies on foot or when loud noises occur nearby (Vennesland 2000). Corvids take eggs when the opportunity arises (Butler 1989; Moul 1992).

POPULATION SIZES AND TRENDS

Search effort

Surveys of the Pacific Great Blue Heron have concentrated on nesting colonies. Many published and unpublished papers have been produced based on these surveys (e.g., Norman *et al.* 1989; Butler *et al.* 1995; Butler 1997; Vennesland 2000; Vennesland and Butler 2004).

Search effort at Pacific Great Blue Heron nesting colonies on the coast of British Columbia has a long and variable history. The database held by the British Columbia Conservation Data Centre (http://www.env.gov.bc.ca/cdc/) has records of nesting colonies going back to 1920. Nesting sites have been documented from across the range of the Pacific Great Blue Heron, though surveys have concentrated on the core of the range (the Strait of Georgia). Survey effort prior to 1970 was minimal (the CDC database holds 77 colony-level observations over 50 years). From 1970 to the mid-

1980s survey effort was increased with the implementation of specific research projects targeted at this species (182 colony level observations from 1970 to 1986). However, data collection over this period (e.g., Forbes *et al.* 1985a) concentrated on successful nests and commonly ignored failed nesting attempts (an important source of variation in nesting productivity; Butler *et al.* 1995; Vennesland 2000; Gebauer and Moul 2001). Some database entries include measures of productivity from successful and failed attempts, but sample sizes are small. Survey effort increased again after 1986 (882 colony-level observations from 1987 to 2005), with annual surveys following consistent methodology covering most of the Georgia Basin in most years during this period (2005 is the last year with data entered as of October 2007). However, due to a generally increasing search effort through this period, absolute population trends based on counts of herons at nesting colonies are difficult to ascertain.

Volunteer-based surveys have also been conducted for many years on the coast of British Columbia, including the wintertime Christmas Bird Count (CBC), wintertime Coastal Waterbird Survey (CWS) and summertime Breeding Bird Survey (BBS). Some caution must, however, be exercised when interpreting trend data from CBC surveys. This caution relates to increased participation in Christmas Bird Counts and the detectability of Great Blue Herons. Specifically, the number of volunteers participating in Christmas Bird Counts has increased significantly over the past 20 years in the lower mainland of British Columbia (D. Fraser pers. comm.), but because herons are easily sighted, this increasing effort does not necessarily result in an increase in the number of birds detected. Given that the trend is calculated as “the number of birds per party hour”, there will be a negative bias introduced as the number of party hours increases without a corresponding increase in the likelihood of detecting additional herons. Thus, declines may partially be a function of an increasing number of observers.

Coastal Waterbird Surveys should be considered to have the most robust data for several primary reasons: participants are relatively well trained, survey locations are geo-referenced and visited multiple times per year and results have been analyzed through well-designed statistical procedures (Badzinski *et al.* 2005). However, results from CWS have been analyzed for only one, five-year period (1999/2000 to 2003/04), which limits their utility compared to CBC and BBS data for which longer data sets are available.

Abundance

Population size is difficult to estimate for the Pacific Great Blue Heron because colonies are not stable and are difficult to track in a standardized fashion, and most coastal areas, especially outside the Strait of Georgia, have not been systematically surveyed (Butler 1997; Vennesland 2000; Gebauer and Moul 2001).

The weakest information on the Pacific Great Blue Heron is from outside the Strait of Georgia, where few projects have been undertaken. A colony of 9 pairs found near Tahsis in 1989 was the first colony reported from the west coast of Vancouver Island. Since then, 1-3 heron nests were located near Bamfield on the west coast of Vancouver

Island and at Rose Harbour, and Ramsay and Murchison Islands in the Queen Charlotte Islands (P. Clarkson & B. Johnston, pers. comm.). Campbell *et al.* (1990) reported small numbers of herons nesting near Prince Rupert. Nevertheless, herons are seen, usually alone, along much of the coastline feeding from floating kelp, on wharves and in shallows, although the numbers are low. Since 1990, much of the coast has been visited during the nesting season by one of us (RWB). Individual adults were sparsely distributed and no concentrations were located. An extensive search by Parks Canada contractors located a few individuals and three nests in Gwaii Haanas National Park Reserve in 2006 (P. Dyment, pers. comm.). This project searched for herons along 1180 km of shoreline on Graham Island and the north end of Moresby Island and resulted in the observation of 19 adults and 6 immature herons. If all 19 adults represented nesting pairs and one of each pair was on a nest, then the number of adults would be 38 and the total number of herons would be 44. At a similar density over the entire 4660 km of coastline in the islands would result in about 174 herons. Engelstoft and Sopuck (2005) surveyed 500 km of shoreline in Gwaii Haanas during the nesting season and counted 8 herons. If those also represented half of the mated pairs, then there might have been 16 herons present (0.032 herons/km). The densities of both surveys are similar (0.037 vs 0.032). We do not have any estimates for other parts of the coast but our observations along much of the central and north coast indicate a low density. The approximately 25,000 km of shoreline outside the Strait of Georgia might support about 875 herons, at a similar density to the Queen Charlotte Islands, but there is no way to know the accuracy of this estimate. Given that not all areas may be suitable, it is likely a liberal estimate. No nests have been located in Pacific Rim National Park Reserve, though a maximum of 6 birds were observed in Grice Bay during surveys in the summer of 2007, some of which were flying inland between foraging bouts suggesting they were nesting nearby (Vennesland, unpubl. data). Although herons are scarce there during the nesting season, up to 100 birds use mudflats near Tofino in August and September after the nesting season (P. Clarkson, pers. comm.).

The most recent published estimate of population size for the Pacific Great Blue Heron in British Columbia is about 3600 nesting adults, of which 3300 were thought to occur in the Strait of Georgia and 300 elsewhere on the coast (Gebauer and Moul 2001, based on data in Butler 1997). Based on 2005 data for the Georgia Basin (1833 active nests estimated in 46 colonies), recent work on the Queen Charlotte Islands (c. 200 herons, P Dyment, pers. comm.), and our estimate of 900 herons outside the Strait of Georgia on the mainland coast, we believe a better estimate of population size to be about 4000-5000 nesting adults in Canada.

Censuses of Pacific Great Blue Herons in neighbouring Washington State have not been as thorough as in British Columbia, but recent attempts to find herons there estimate the population at about 5500 nesting adults (Eissinger 2007). No information is available from Alaska, though populations are likely small as on British Columbia’s north coast. In total, the global population of Pacific Great Blue Heron is likely between 9,500 and 11,000 nesting adults.

Fluctuations and trends

The trend in Pacific Great Blue Heron populations has been assessed in this report from surveys at nesting colonies (B.C. Conservation Data Centre 2007), Christmas Bird Counts (CBC), Coastal Waterbird Surveys (CWS), Breeding Bird Surveys (BBS) and population modelling. Results are variable, with some measures showing declines (nesting productivity from colony surveys, CBC, and demographic modelling), others apparent stability (nest counts from colony surveys, BBS) and one an increase (CWS), though see further for discussion.

Colony surveys – trends from colony size information

Counts of pairs at colonies give a distorted view of trends because survey effort has been variable through time (generally increasing), and herons move between colonies and regions within and between years (Simpson *et al.* 1987). However, if many colonies are included, the overall trend in numbers might capture inter-colony movement and reflect local changes in abundance. The method here is to sum the annual increases and decreases at colonies (e.g., ∑ *[Colony X Year 2 – Colony X Year 1; Colony Y Year 2 – Colony Y Year 1; etc]* across all colonies).

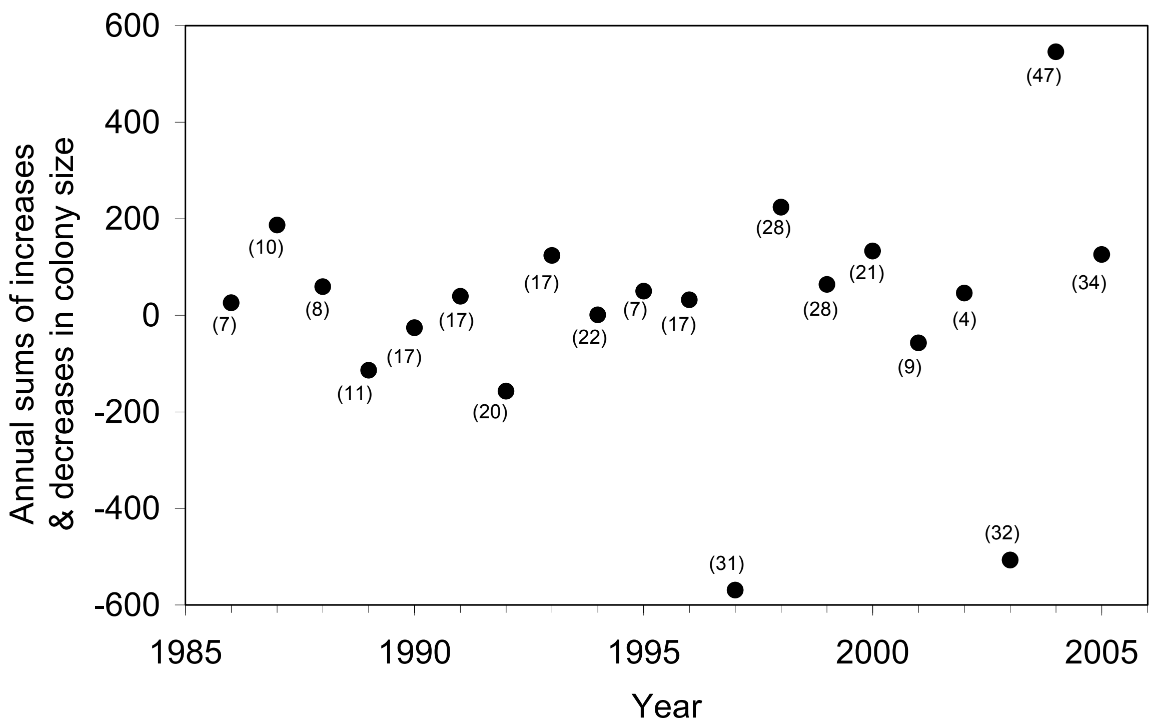

Figure 4. Annual sums of increases and decreases in the number of nesting pairs at Pacific Great Blue Heron colonies in south-coastal British Columbia from 1986 to 2005. Annual colony sample sizes are provided in brackets (B.C. Conservation Data Centre 2007).

Sums of increases and decreases in the number of nesting pairs at colonies from 1986 to 2005 showed that the number of nesting pairs leaving and entering colonies from year to year appears to have remained relatively stable over the period 1986 to 2005 (Figure 4). A bias of this method is that it draws samples only from colonies that have multiple observations in consecutive years. Thus, this method gives a snapshot of a relatively small sample of regularly visited and stable colonies and may not illustrate exact trends in colony occupation. Nevertheless, drastic changes in the nesting population would be evident through this analysis.

The large negative sum in 1997 (-569) occurred mostly because of large declines at the two largest colonies in the Strait of Georgia (Point Roberts and Pacific Spirit Park). Both colonies recovered in numbers in subsequent years, although Pacific Spirit Park was abandoned completely in 2004. Point Roberts was abandoned completely in 2003 and a new location was colonized in 2004 – this event is illustrated in Figure 4 by the large negative value in 2003 and the large positive value in 2004 when these birds colonized the new location.

Colony surveys – trends in nesting success and productivity

As previously outlined, a particular challenge with this dataset is that survey effort has increased markedly through time. Thus, it should be noted that some analyses are anecdotal in nature and the time periods included vary.

Nesting success (the proportion of nesting pairs that successfully raise at least one fledgling) for herons on the coast of British Columbia currently is much lower than in the past. Forbes *et al.* (1985a) estimated that about 92% of nesting pairs were successful during the period 1977 to 1981 and a literature review by Forbes *et al.* (1985a) at the time showed a continent-wide success rate of 80%. Vennesland (2000) estimated that less than half of all nesting attempts were successful in 1998 to 1999 and this trend has been documented in future years as well (Vennesland 2003; McClaren 2005; Chatwin *et al.* 2006).

Mean nesting productivity (fledglings per active nesting attempt) on the coast of British Columbia in recent years has been the lowest of any studies in North America or British Columbia (Vennesland and Butler 2004). In 1971-1986, mean nesting productivity was 1.7 fledglings per active nesting attempt and 2.55 fledglings per successful nesting attempt (R. Vennesland, unpubl. data.). These values are roughly typical for North America at that time (Vennesland 2000). Reported productivity values for south-coastal British Columbia over recent years are 0.82 fledglings per active nesting attempt, and 1.98 fledglings per successful nesting attempt in 1999 (Vennesland and Butler 2004), 0.82 fledglings per active nesting attempt and 1.84 fledglings per successful nesting attempt in 2002 (Vennesland 2003), and 1.3 fledglings per active nesting attempt and 1.7 fledglings per successful nesting attempt in 2004 (McClaren 2005). Nesting productivity has therefore reduced to nearly half of historic levels (Figure 5).

Figure 5 presents a summary of trends in nesting productivity per active nesting attempt from 1971 to 2005. Before 1987, most studies ignored nesting failure and only documented the number of fledglings from successful nesting attempts. As many studies in recent years have shown, nesting failure has an important influence on overall nesting productivity (e.g., Butler *et al.* 1995; Vennesland and Butler 2004). Due to this oversight, few observations before 1987 are available for analysis. Consequently, our analysis here groups colony-level observations into three time periods: 1971 to 1986 (relatively low annual effort – 19 observations total), 1987 to 1995 (increased annual effort – 125 observations total), and 1997 to 2005 (maximum annual effort – 251 observations total). One year (1996) was not included because no data on productivity were collected. The data show that nesting productivity has declined significantly across the three time periods (Figure 5).

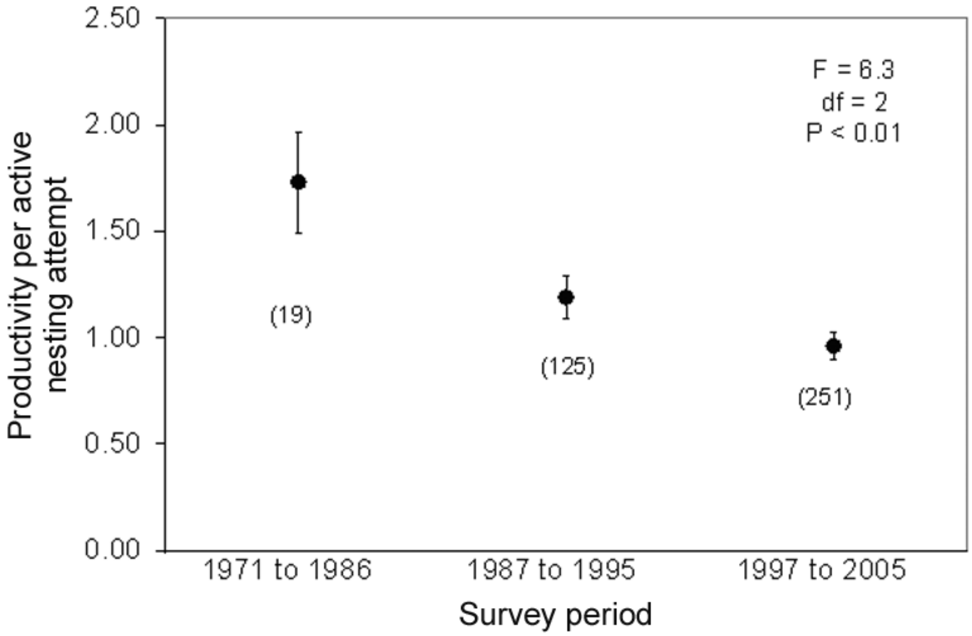

Figure 5. Mean productivity for all active nesting attempts for Pacific Great Blue Heron colonies in south-coastal British Columbia from 1971 to 2005. Productivity per active nesting attempt is the mean number of fledglings produced in all active nesting attempts. Sample sizes of colony-level observations in each period are shown in brackets. No observations were available in 1996. Error bars represent one standard error of the mean (B.C. Conservation Data Centre 2007).

Figure 6 presents a summary of trends in nesting productivity per successful nesting attempt from 1977 to 2005. As this dataset has been collected more consistently than productivity per active nesting attempt, an analysis was possible with annual colony-level observations. However, for clarity data are grouped into years. The analysis uses a poisson generalized linear model (Agresti 2002), adjusting for overdispersion, a likely consequence of having some colonies repeatedly measured over time (Agresti 1996). Nesting productivity per successful nesting attempt declined significantly over this period (Figure 6).

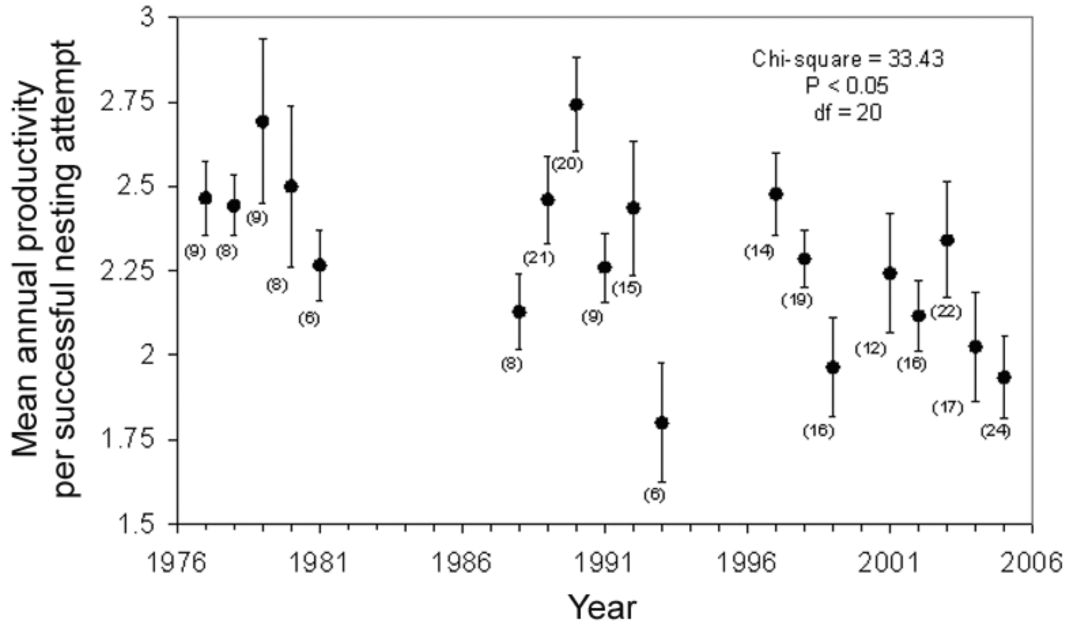

Figure 6. Mean annual nesting productivity for all successful nesting attempts at Pacific Great Blue Heron colonies in south-coastal British Columbia from 1977 to 2005. Productivity per successful nesting attempt is the mean number of fledglings produced in all nests that fledged one or more young. Data from 1982-1987, 1994-1996 and 2000 were excluded due to samples sizes under n = 5. The annual number of colonies analyzed is provided in brackets. Error bars represent one standard error of the mean (B.C. Conservation Data Centre 2007).

Colony surveys – trends in the effects of colony size

A 1999 study showed that nesting productivity per active nesting attempt increased significantly with colony size, presumably due to higher rates of nest failure at small colonies, but that productivity per successful nesting attempt did not relate to colony size (Vennesland and Butler 2004). Here we look at the effect of colony size on productivity over time. Data were grouped into colony size categories and the analyses were conducted on colony-level observations using a logistic generalized linear model (Agresti 2002), adjusting for overdispersion, a likely consequence of having some colonies repeatedly measured over time (Agresti 1996).

From 1987 to 2001, productivity per active nesting attempt increased significantly with colony size (Figure 7), and from 1977 to 2005, productivity per successful nesting attempt decreased significantly with colony size (Figure 8). Herons in large colonies therefore were more successful in their nesting attempts over all (due to lower levels of nest failure). However, when excluding nesting failure (i.e., successful nests) herons in large colonies raised fewer offspring per nesting attempt than herons in smaller colonies.

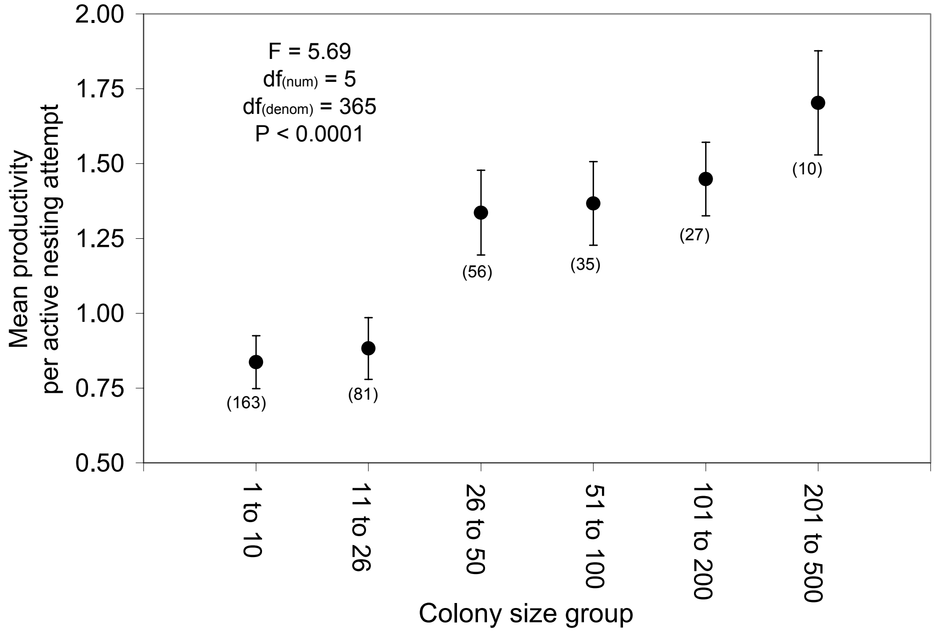

Figure 7. Mean productivity per active nesting attempt for colony size categories of Pacific Great Blue Herons in south-coastal British Columbia from 1987 to 2001. Productivity per active nesting attempt is the mean number of fledglings produced in all initiated nesting attempts. Data from 1994 and 1995 were excluded due to samples sizes under n = 5. Error bars represent one standard error of the mean (B.C. Conservation Data Centre 2007).

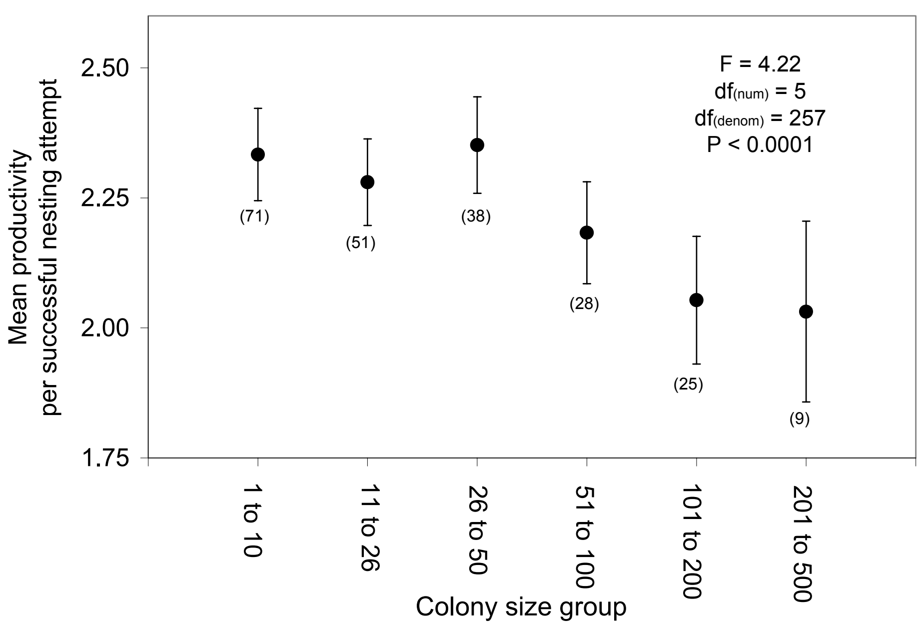

Figure 8. Mean productivity per successful nesting attempt for colony size categories of Pacific Great Blue Herons in south-coastal British Columbia from 1977 to 2001. Productivity per successful nesting attempt is the mean number of fledglings produced in all nests that fledged one or more young. Data from 1982-1987, 1994-1996 and 2000 were excluded due to samples sizes under n = 5. Error bars represent one standard error of the mean (B.C. Conservation Data Centre 2007).

The relatively high productivity per active nesting attempt at larger colonies (Figure 7) implies that nest failure is relatively unimportant at these colonies (Vennesland and Butler 2004). However, previous studies have identified high levels of nest failure on the coast of British Columbia as an important reason for low levels of nesting productivity (Gebauer and Moul 2001; Vennesland and Butler 2004). More importantly, the data show that the loss of young from successful nesting attempts is another reason for low levels of productivity observed in the Strait of Georgia (as per the significant decline in Figure 6). This is particularly a concern for larger colonies that have lower productivity per successful nesting attempt than at smaller colonies (Figure 8).

Furthermore, most nesting pairs breed in large colonies, which are localized in a small part of the subspecies' range (the lower Strait of Georgia). In 2005, 68% of 1833 nesting pairs (n = 46 colonies) were concentrated at six colonies of more than 100 nesting pairs each. Four of these six colonies were located in the lower Fraser Valley, with the other two on southern Vancouver Island and the southern Gulf Islands.

Butler and Vennesland (2000) hypothesized that herons may leave large colonies due to increased disturbance and further disperse in their nesting as they try and find sites relatively free from eagle and human disturbances. However, the opposite pattern has been recently documented in Washington State. Eissinger *et al.* (2007) showed that the proportion of nesting pairs in small colonies is declining while the number in large colonies is increasing, perhaps to dilute predation risk. If this pattern also occurs in Canada and if productivity continues to decline, herons may either suffer high levels of nest failure at small colonies or low numbers of fledglings at large colonies.

<u>Colony surveys – effective range size</u>

Although Pacific Great Blue Heron productivity has declined significantly (by both active nesting attempts and successful nesting attempts) since the 1970s, colony occupancy appears to be generally stable (Figure 4). Some population retraction and severe nesting productivity issues have been observed along the margins of the Strait of Georgia. The number of herons observed nesting on the Sunshine Coast dropped from 97 in 1978 (Forbes *et al.* 1985b) to 4 in 2004 (the last year there are records for that area). About 90 pairs of herons nested in Pender Harbour and 6 small colonies were located along the Sunshine Coast in the 1970s (Simpson 1984). A few colonies were still present there in the 1990s (Butler 1997), but recently a few herons have been observed breeding there (Vennesland 2000). Furthermore, recent surveys on north-eastern Vancouver Island also are troubling. Chatwin *et al.* (2006) report that all colonies north of Nanoose Bay failed to raise any young in 2005. The significance of the population retraction on the Sunshine Coast and the absence of productivity on northern Vancouver Island in 2005 to the overall Pacific Great Blue Heron population is not known.

Although the Pacific Great Blue Heron occurs across the coast, the majority of herons nest in the southern Strait of Georgia and northern Puget Sound where the largest human and significant Bald Eagle threats occur, and this is the only area of the coast where significant successful reproduction occurs.

Trends from volunteer-based population surveys

Christmas Bird Counts

Gebauer and Moul (2001) reported that CBC surveys showed populations to be either declining modestly (Lower Fraser Valley) or sharply (Sunshine Coast). We conducted an analysis of CBC data using data from all coastal count circles (i.e., locations specific to Pacific Great Blue Herons). We limited this analysis to the past three generations to provide relevance to COSEWIC listing criteria. To determine generation time (defined here as the average age of breeding individuals), a population matrix model (as per Caswell 2001) was computed (M. Drever, unpubl. data) assuming survival rates through three life stages (first winter survival rate of 0.273, second year survival rate of 0.5 and annual adult survival rate of 0.727; Butler 1995), an annual nesting productivity of 1.12 fledglings per active nesting attempt (R. Vennesland, unpubl. data for 1986 to 2005) and a maximum life span in the wild of 24 years (Butler 1992). The resulting average age for a breeding Pacific Great Blue Heron in British Columbia was 5.6 years. Given this average age, we have looked at CBC survey data over two periods: from 1991/92 to 2006/07 (assuming a 5-year generation time) and from 1988/89 to 2006/07 (assuming a 6-year generation time).

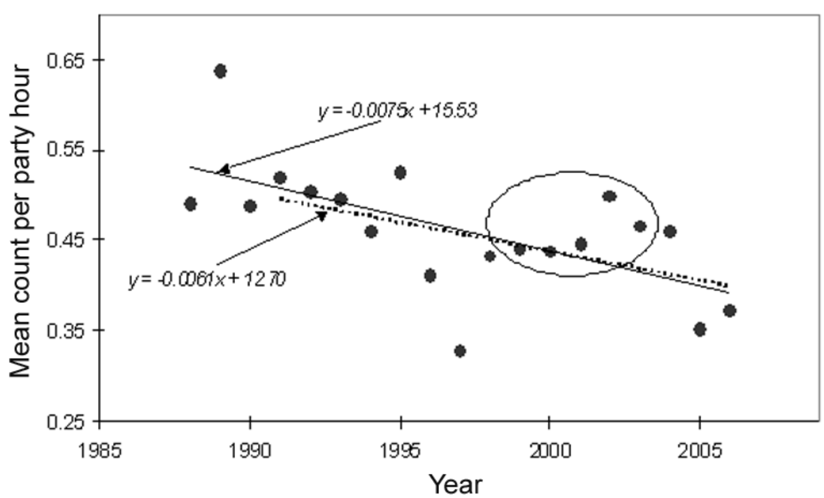

Figure 9. Christmas Bird Count (CBC) data analysis for three generations of the Pacific Great Blue Heron in Canada. Data are shown from the 1988/1989 winter (1988 on figure) to the 2006/2007 winter (2006 on figure). Generation time for the species is calculated at 5.6 years, so trend lines are shown for both 5 years (16-year period – dashed line) and 6 years (19-year period – solid line). Equations are provided for trend lines. The circled data points correspond to the years of CBC data that the Coastal Waterbird Survey analysis (Badzinski *et al.* 2005) also covers.

Since 1991/92, the relationship between the mean number of herons observed per party hour and year shows a significant 19% decline ($t = -2.18$; $P < 0.05$; $n = 16$; $r^2 = 0.20$). Since 1988/89, the relationship between the mean number of herons observed per party hour and year shows a significant 26% decline ($t = -3.18$; $P < 0.01$; $n = 19$; $r^2 = 0.34$). As mentioned earlier, these results should be treated with some caution because of the increase in search effort over time with this highly detectable bird (see Search Effort section).

Using CBC data from across south-coastal British Columbia (assuming a 5-year generation time – a conservative estimate given our result of a 5.6-year average age for breeding adults), we found the lower Fraser Valley showed a nearly significant increase in mean herons observed per party hour ($t = 1.98$; $P = 0.07$; $n = 16$; $r^2 = 0.16$), Vancouver Island showed a significant decline in mean herons observed per party hour ($t = -2.36$; $P < 0.05$; $n = 16$; $r^2 = 0.23$) and the Sunshine Coast showed a significant decline in mean herons observed per party hour ($t = -4.08$; $P < 0.01$; $n = 16$; $r^2 = 0.51$). These results are consistent with other survey data (see previous) and our demographic analyses (see further) that the lower Fraser Valley is the only region of British Columbia that has effective reproduction and that a range contraction may be occurring in northern parts of the Strait of Georgia.

Coastal Waterbird Survey

CWS data show a significant increase in Pacific Great Blue Herons in winter on the coast of British Columbia from 1999/2000 to 2003/04 (6.9% increase per winter; $P < 0.05$; Badzinski *et al.* 2005). The CWS generally has a more robust survey methodology than both CBC and BBS. Both CWS and CBC are conducted during winter, so the results of these surveys as reported here present an apparent contradiction. However, the increasing CWS trend is from a five-year period, as opposed to the much longer period analyzed for CBC data. The period of the CWS analysis corresponds to a period of increased observations in CBC data (though not a significant increase; $t = 1.69$; $P = 0.19$; $n = 5$; $r^2 = 0.32$; Figure 9). This suggests that the time period in the CWS analysis may be too small to accurately reflect long-term trends.

Breeding Bird Survey

BBS data indicated a significant decline in herons on the British Columbia Coast of 5.7% from 1966 to 1994 (Downes and Collins 1996). However, closer inspection of the BBS data apparently has revealed that one census route was driving the analysis down, and when it was removed the downward population trend was no longer significant (B. Smith, unpubl. data).

Summary of trends in nesting productivity and population status

Counts from colony surveys show relatively stable levels of colony occupancy, but these surveys are of limited use for determining population status. Measures of nesting productivity show significant declines, with the number of fledglings per active nest falling by nearly half since the 1970s. Declines in productivity per successful nest may disproportionately affect large colonies in a localized area (about 5000 km^2 in extent) where most of the breeding for the subspecies occurs. Range contraction may be occurring in one region (the Sunshine Coast), and another region (northern Vancouver Island) has shown an absence of productivity in at least one year.

Christmas Bird Count data show a significant 19-26% decline over three generations, Coastal Waterbird Survey data show a significant increase, but these surveys cover only a five-year period, and Breeding Bird Survey data show stable trends.

Trends from demographic analyses

The demographic model for Pacific Great Blue Herons assumes a first winter survival rate of 0.273, second-year survival at 0.5 and a subsequent survival of 0.727 (Butler 1995). We started with 1000 nesting females and mean annual nesting success sampled from colonies on Vancouver Island and the lower Fraser Valley between 1988 and 2003. Nesting productivity was significantly higher in the lower Fraser Valley than on Vancouver Island (Figure 10; $F = 15.3$, $df = 1$, $P < 0.01$), as has been previously reported (Vennesland 2000; Vennesland 2003; McClaren 2005, Chatwin *et al.* 2006).

To maintain the population requires herons to successfully raise fledglings in about 63% of all attempts. On Vancouver Island, the mean nesting success never reached this minimum threshold, whereas colonies in the lower Fraser Valley exceeded this threshold on five of the seven years with available data. In this analysis, the lower Fraser Valley is a source of recruits for Vancouver Island. Using the same analysis, the lower Fraser Valley produces about 66 young for every 1000 females whereas Vancouver Island colonies have a shortfall of 230 young for every 1000 females. Together with our analysis of CBC data (see previous), these preliminary results suggest that over the past three generations the lower Fraser Valley has not been able to compensate for the shortfall in production of juveniles on Vancouver Island (only the lower Fraser Valley has positive population indices).

With the lower Fraser Valley as the source of recruits, this increases the importance of maintaining productivity in this relatively small area (the lower Fraser Valley area is only about 5000 km^2 in extent). It also suggests that the vulnerability of the Pacific Great Blue Heron is greatest where the highest human population resides – in the lower Fraser Valley. Although the range of the Pacific Great Blue Heron is relatively large, its effective range size may be limited to a small and heavily populated region of the province (i.e., the lower Fraser Valley).

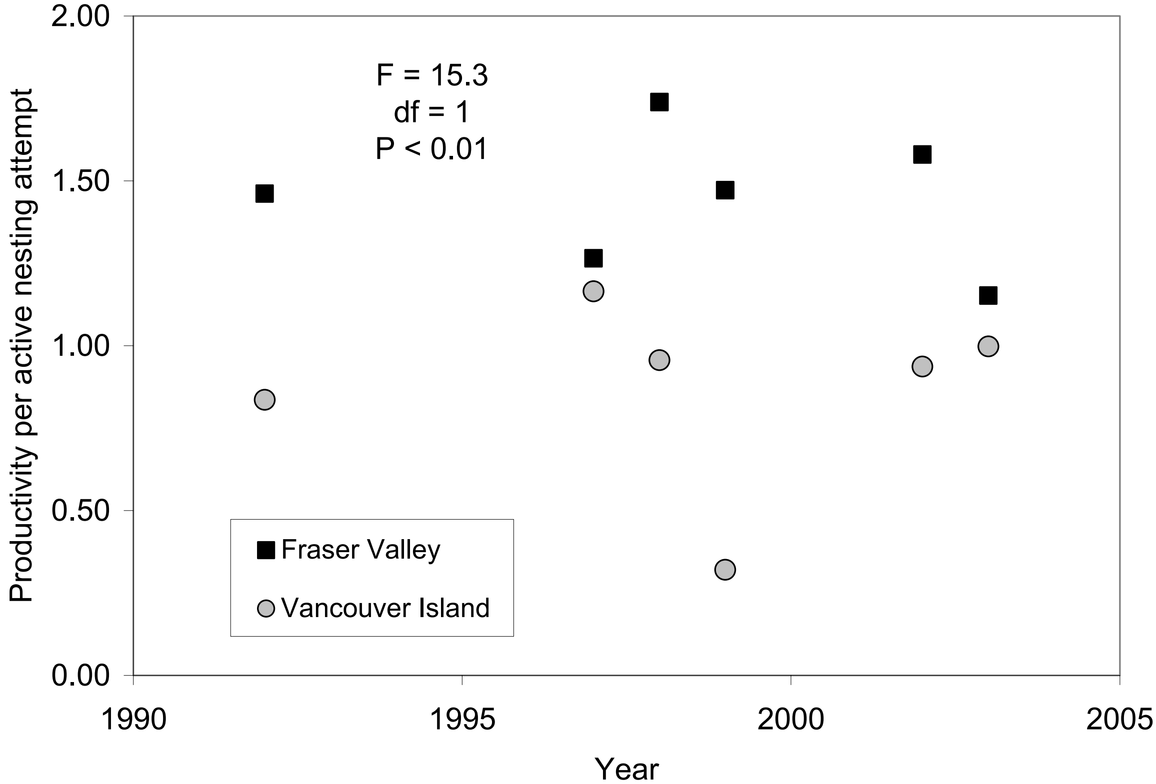

Figure 10. Mean productivity per active nesting attempt for Pacific Great Blue Herons in south-coastal British Columbia from 1992 to 2003 comparing Vancouver Island to the lower Fraser Valley on the mainland (including years from 1987 that have at least 5 colony level observations for each region in each year). Productivity per active nesting attempt is the mean number of fledglings produced in all initiated nesting attempts (B.C. Conservation Data Centre 2007).

Rescue effect

Rescue effect from the south (i.e., from Washington State) is theoretically high due to the contiguous nature of Puget Sound and Georgia Strait, and the roughly equally sized heron populations between the regions. However, threats to heron populations and habitat in the U.S. are similar to those in Canada, perhaps with even higher threats and impacts due to the larger, more established human populations there (Georgia Basin Ecosystem Initiative 2002).

Detailed colony surveys for nesting productivity or population trends are not available from Washington State. However, CBC data from count circles close to the Canada/U.S. border (those within about 100 km of the Strait of Georgia or Juan de Fuca Strait) show a significant population decline of 34% ($t = -3.02$; $P < 0.01$; $n = 16$; $r^2 = 0.35$) over the last 15 years or three generations (assuming a five-year generation time). Therefore, Pacific Great Blue Heron populations near to Canada in Washington State appear to have a higher rate of decline than Canada and so are likely to provide limited rescue.

Rescue effect from the north is likely low due to the small populations of herons that occur there. In addition, productivity of northern areas is unknown.

LIMITING FACTORS AND THREATS

The major factors currently limiting the persistence of heron populations are nesting failure and reduced nesting productivity arising from eagle predation, human disturbance and habitat declines from development (Norman *et al.* 1989; Butler *et al.* 1995; Gebauer and Moul 2001; Vennesland and Butler 2004).

Human disturbance

Moore (1990) showed that for every increase of 1000 people in the population of the Lower Fraser Valley, 89 hectares of rural land was converted to urban uses. On Vancouver Island, human population growth has been only slightly lower than near Vancouver. The human population around the Strait of Georgia is projected to increase by more than 50% from 1990 to 2020 (from about 2.5 million to about 4 million; Georgia Basin Ecosystem Initiative 2002). Under present conditions, we can expect increased human disturbance at heron colonies and reduced habitat availability/quality (Gebauer and Moul 2001).

Human activity disturbs nesting Great Blue Herons (Werschkul *et al.* 1976; Simpson and Kelsall 1978; Vos *et al.* 1985), and has been linked to reduced nesting productivity (Forbes *et al.* 1985b; Gebauer and Moul 2001; Vennesland and Butler 2004; Vennesland 2000; reviewed by Parnell *et al.* 1988). Carlson and McLean (1996) found that the distance of heron colonies from human activity and the width or efficacy of the buffer zone around colonies were positively related to nesting productivity (buffer zones included vegetation, water and fencing). Watts and Bradshaw (1994) reported herons nesting further from human development than would be expected by chance, and Parker (1980) observed that colony size increased with distance from roads.

Several studies have linked the abandonments of colonies to human activity, including housing and industrial development, highway construction, logging, vehicle traffic, and repeated human intrusions (Bjorklund 1975; Mark 1976; Werschkul *et al.* 1976; Simpson and Kelsall 1978; Kelsall and Simpson 1979; Forbes *et al.* 1985b; Leonard 1985; Vennesland and Butler 2004; Eissinger 2007; see also reviews by Parnell *et al.* 1988; Hockin *et al.* 1992; Rodgers and Smith 1995; Nisbet 2000; Vennesland 2000).

Vennesland (2000) found that humans were likely involved in 4 of 14 abandonments from 1998 to 1999, but the effect of humans also could not be separated from the effect of eagles. A possible explanation for the interaction between these factors is that forest fragmentation caused by humans is allowing easier access to sites by predators such as eagles (Vennesland and Butler 2004). Forbes *et al.* (1985b) concluded that 17 of 27 colony abandonments occurred due to human activity near the colony site, including tree cutting, flooding, vehicle use and researcher activity. Simpson (1984) documented construction work that resulted in adult herons leaving nests and ended with a large loss of nestlings to eagles. Simpson and Kelsall (1978) found that housing construction near to a colony in Sechelt in 1978 resulted in the abandonment of about 73% of nests.

Some colonies of Great Blue Herons in British Columbia have become acclimatized to routine human activities. Herons nesting in Stanley Park in Vancouver and Beacon Hill Park in Victoria seem habituated to the frequent human pedestrians and vehicles directly below their nests (Butler 1997; Vennesland 2000). However, colonies in more rural settings may respond to disturbances at a great distance. At a sensitive colony on Vancouver Island (Quamichan Lake, Duncan), adult herons flushed from their nests when a researcher approached within 200 m before eggs had been laid, 100 m after eggs had been laid, and 10 m after chicks were present (Butler 1991). Although no noticeable response is observed by herons at some urban sites, productivity at these locations is negatively correlated with the local level of human activity (Vennesland 2000; Vennesland and Butler 2004).

Bald Eagle predation

Bald Eagles are the primary predator of Pacific Great Blue Herons (Butler 1997; Gebauer and Moul 2001; Vennesland and Butler 2004) and represent a significant limiting factor for heron populations. Predation and associated disturbance results in significantly higher nest and colony abandonment (Butler *et al.* 1995, Vennesland and Butler 2004).

The influence of eagle attacks generally has been described in the context of recovering raptor populations after many populations were decimated by human pollution such as DDT (Bednarz *et al.* 1990; Kjellen and Roos 2000; Butler and Vennesland 2000; Elliott and Harris 2001). This recovery has been ongoing for several decades. The number of nesting eagles increased 30% in the Gulf Islands (Vermeer *et al.* 1989), and 34% in the Puget Sound (McAllister *et al.* 1986) from the mid-1970s to the mid-1980s. Eagle populations on the south coast have increased since the mid-1980s (Elliott and Harris 2001) and the rate of attacks on nesting Pacific Great Blue Herons has more than doubled over this time period (Vennesland and Butler 2004). Eagle nesting productivity from 1992 to 1995 was higher in the Strait of Georgia than on the west coast of Vancouver Island or in Johnstone Strait, and was producing a ‘considerable’ surplus of juveniles (Elliott *et al.* 1998). The reasons for this increase are unclear, but were probably due to increasing prey populations (e.g., gull populations enhanced by human refuse), declining contaminant levels in prey (Vermeer *et al.* 1989;

Elliott *et al.* 1998), and possibly reduced persecution (Vennesland 2000). It is also possible that reduced fish populations have caused eagles to search out alternative sources of food (Vennesland 2000). It is unclear how current eagle populations compare with historical numbers, or how eagle populations compared to heron populations prior to the influence of Europeans. Given the magnitude of increase over the past few decades, it is unlikely that they are significantly below historical levels.

In addition to predation, Bald Eagles might be negatively affecting habitat use by Pacific Great Blue Herons (Butler and Vennesland 2000; Vennesland and Butler 2004). For example, soon after a landowner felled trees that exposed a colony on Vancouver Island in 2005, eagles began to enter the colony at which time the herons abandoned the site (Vennesland 2006). Eagle attacks on nesting herons have escalated in recent years (Vennesland and Butler 2004) and this increased level of predation stimulated many herons to search for new nesting habitat. Interestingly, some herons also are nesting near eagle nests where they might be afforded a reduced level of disturbance from other predators (Koonz 1980; Butler 1995; Vennesland 2000).

SPECIAL SIGNIFICANCE OF THE SPECIES

The Pacific Great Blue Heron is non-migratory and confined to the northeast coast of the Pacific Ocean. It is a symbol of wetland conservation and environmental quality.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

In British Columbia, the Great Blue Heron, its nests and eggs are protected year-round from persecution (Section 34) by the British Columbia *Wildlife Act* (1982; updated 1999). Herons also are protected from hunting through Article 11:3 of the *Migratory Birds Convention Act* (1994) and Sections 5(4) and 6(a) of the *Migratory Birds Regulations* (Butler and Baudin 2000). A few scare/kill permits were provided up to 1998 to reduce heron depredation of hatchery fish stocks, but these have since been revoked (R. Butler, pers. obs.).

Both the *fannini* and the *herodias* subspecies of Great Blue Heron have been designated as ‘Blue list’ species by the British Columbia Ministry of Environment. “Blue-listed” species are considered to be vulnerable and “at risk”, but not yet endangered or threatened. The *fannini* subspecies of Great Blue Heron was listed in 1997 as Special Concern by the Committee on the Status of Endangered Wildlife in Canada.

TECHNICAL SUMMARY

Ardea herodias fannini
Great Blue Heron *fannini* subspecies — Grand Héron de la sous-espèce *fannini*
Range of Occurrence in Canada: British Columbia

Extent and Area Information

• *Extent of occurrence (EO)(km²)* From GIS analysis – minimum polygon around entire Canadian range	244,000 km²
• *Specify trend in EO*	Unknown, possibly declining on peripheries of range
• *Are there extreme fluctuations in EO?*	No
• *Area of occupancy (AO) (km²)* From GIS analysis – see Figure 2	188,000 km²
• *Specify trend in AO*	Unknown, possibly declining on peripheries of range (outside of lower Fraser Valley)
• *Are there extreme fluctuations in AO?*	No
• *Number of known or inferred current locations*	49 nesting locations (2005)
• *Specify trend in #*	Unknown
• *Are there extreme fluctuations in number of locations?*	Not likely
• *Specify trend in area, extent or quality of habitat*	Declining

Population Information

• *Generation time (average age of parents in the population)*	Estimated at 5.6 years
• *Number of mature individuals*	Est. 4000-5000
• *Total population trend:*	Variable - declines based on Christmas Bird Count data over three generations (below), increasing based on Coastal Waterbird Surveys over recent five-year period.
• *% decline over the last 10 years or 3 generations.* • *based on Christmas Bird Count (CBC) data with a 5 (lower number) or 6 (higher)-year generation time*	19-26% (CBC), but increasing based on Coastal Waterbird Surveys
• *Are there extreme fluctuations in number of mature individuals?*	Not likely
• *Is the total population severely fragmented?*	For breeding locations – Range wide, No; In Lower Fraser Valley, Yes
• *Specify trend in number of populations*	Unknown
• *Are there extreme fluctuations in number of populations?*	No
• List populations with number of mature individuals in each:	Unknown

Threats (actual or imminent threats to populations or habitats)

Primary threats are from Bald Eagle predation, human disturbance and habitat destruction. Human influences are especially acute in the lower Fraser Valley (the centre of the subspecies' range).

Rescue Effect (immigration from an outside source)

• *Status of outside population(s)?* USA (Washington State):	declining
• *Is immigration known or possible?*	Yes
• *Would immigrants be adapted to survive in Canada?*	Yes
• *Is there sufficient habitat for immigrants in Canada?*	Unknown, habitat is declining near U.S. border (lower Fraser Valley)
• *Is rescue from outside populations likely?*	Unknown, but may be limited because declining in the U.S.

Quantitative Analysis

n/a

Current Status

COSEWIC: Special Concern (1997 and 2008)

Status and Reasons for Designation

Status: Special Concern	**Alpha-numeric code:** Not applicable
Reasons for Designation: In Canada, this subspecies is distributed along the coast of British Columbia with a relatively small population that is concentrated at a few breeding colonies in southern British Columbia. There is evidence of declines in productivity and it is unclear whether the population is stable or declining. Threats from eagle predation, habitat loss and human disturbance are ongoing, particularly in the southern part of the range where concentrations of birds are highest.	

Applicability of Criteria

Criterion A (Declining Total Population): Not applicable. Does not meet criterion.
Criterion B (Small Distribution, and Decline or Fluctuation): Not applicable. Does not meet criterion.
Criterion C (Small Total Population Size and Decline): May meet Threatened C1 if Christmas Bird Count trends are used to predict future declines.
Criterion D (Very Small Population or Restricted Distribution): Not applicable. Does not meet criterion.
Criterion E (Quantitative Analysis): None.

ACKNOWLEDGEMENTS AND AUTHORITIES CONSULTED

Gary Dick and Colin Copland provided information on the legislation to protect herons and Mike Dunn provided information on the protection of the heron colony at CFB Chilliwack and, along with Robert Elner, commented on the manuscript. John Elliot at Canadian Wildlife Service and Kym Welstead at British Columbia Ministry of Environment provided information on contaminant monitoring. Barry Smith submitted information from a publication that is in preparation. Information on occurrences was provided by Trudy Chatwin, Peter Clarkson, Peter Dyment, Ann Eissinger, Barb Johnston, Pippa Shepherd and Berry Wijdeven. Kym Welstead, Jamie Kenyon, Iain Jones and Dalyce Epp assisted with data management. Statistical assistance was obtained from Carl Schwartz and Marie Loughin at Simon Fraser University. Mark Drever at the University of British Columbia provided assistance with demographic modelling. Bird Studies Canada, supported by the Canadian Wildlife Service, supplied Coastal Waterbird Survey data. Special thanks go to all the volunteers that collect Christmas Bird Count, Breeding Bird Survey and Coastal Waterbird Survey data. Maps were produced and GIS analyses were conducted by James Sanders of the British Columbia Ministry of Agriculture and Lands. Fred Sharpe provided wisdom on Washington State geography to assist with determining CBC count circles of relevance to Pacific Great Blue Herons. Stephanie Hazlitt provided wisdom on interpreting Coastal Waterbird Survey data.

Personal communications

Clarkson, Peter. Assistant Chief Park Warden, Parks Canada Agency, Ucluelet, B.C.
Dyment, Peter. Tlell Sustainability Institute, Tlell.
Elliott, John. Research Scientist, Canadian Wildlife Service, Environment Canada, Delta, B.C.
Johnston, Barb. Ecosystem Scientist, Parks Canada Agency, Waterton Lakes, B.C.
Smith, Barry. Research Scientist, Canadian Wildlife Service, Environment Canada, Delta, B.C.

INFORMATION SOURCES

Agresti, A. 1996. An introduction to Categorical Data Analysis. John Wiley & Sons, New York, NY.
Agresti, A. 2002. Categorical Data Analysis, 2nd edition. John Wiley & Sons, Hoboken, NJ.
American Ornithologists' Union. 1983. Check-list of North American birds. Allen Press, Kansas.
Badzinski, S.S., R.J. Cannings, T. Smith and J. Komaromi. 2005. British Columbia Coastal Waterbird Survey - An Evaluation of Survey Power and Species Trends after Five Years of Monitoring. Report produced for the British Columbia Ministry of Water, Land, and Air Protection & Environment Canada.

Bednarz, J.C., D. Klem Jr., L.J. Goodrich and S.E. Senner. 1990. Migration counts of raptors at Hawk Mountain, Pennsylvania, as indicators of population trends, 1934-1986. Auk 107: 96-109.

B.C. Conservation Data Centre. 2007. Historical database of Great Blue Heron nesting colonies. http://www.env.gov.bc.ca/cdc/.

Bjorklund, R. G. 1975. On the Death of a Midwestern Heronry. The Wilson Bulletin 87:284-287.

Butler, R.W. 1989. Breeding ecology and population trends of the Great Blue Heron (*Ardea herodias fannini*) in the Strait of Georgia. Pages 112-117 in K. Vermeer and R.W. Butler, eds. The ecology and status of marine and shoreline birds in the Strait of Georgia, British Columbia. Spec. Publ., Can. Wildl. Serv., Ottawa, ON. 186pp.

Butler, R. W. 1991. Habitat selection and time of breeding in the Great Blue Heron (*Ardea herodias*). Ph.D. dissertation, University of British Columbia.

Butler, R.W. 1992. Great Blue Heron. In: The birds of North America, No. 25. (A. Poole, P. Stettenheim and F. Gill, eds.) Acad. Natur. Sci., Amer. Orntihol. Union.

Butler, R.W. 1995. The patient predator: foraging and population ecology of the Great Blue Heron in British Columbia. Can. Wildl. Serv. Occas. Pap. No. 86, Ottawa.

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

Butler, R.W. 1997. The coastal retainer: natural history and ecology of the Great Blue Heron on the coast of British Columbia. Univ. Brit. Col. Press, Vancouver, B.C.

Butler, R.W. and P. Baudin. 2000. Status and Conservation Stewardship of the Pacific Great Blue Heron in Canada. In 'Proceedings of a Conference on the Biology and Management of Species and Habitats at Risk,' ed. L.M. Darling (247-249). Wildlife Branch, Ministry of Environment, Lands and Parks and University College of the Cariboo. February 1999, Kamloops, B.C.

Butler R.W. and R.G. Vennesland 2000. Integrating climate change and predation risk with wading bird conservation research in North America. Waterbirds 23(3): 535-540.

Campbell, R.W., N.K. Dawe, I. McTaggart-Cowan, J.M. Cooper, G.W. Kaiser and M.C.E. McNall. 1990. The birds of British Columbia, Volume 1. Introduction, Loons through Waterfowl. Royal B.C. Mus. And Environ. Can., Can. Wildl. Serv.

Carlson, B.A. and E.B. McLean. 1996. Buffer zone and disturbance types as predictors of fledging success in Great Blue Herons, *Ardea* *herodias*. Colonial Waterbirds 19:124-127.

Caswell, H. 2001. Matrix Population Models: Construction, Analysis, and Interpretation. Second edition. Sinauer Associates, Sunderland MA.

Chatwin, T., S. Bonar and M. Kissinger. 2006. Pacific Great Blue Heron population and monitoring Vancouver Island and the Gulf Islands 2005. Unpublished report to the B.C. Ministry of Environment, Nanaimo.

Dickerman, R. W. 2004. Characteristics and distribution of *Ardea herodias fannini* with comments on the effect of washing on the holotype. Northwestern Naturalist 85: 130-133.

Downes, C.M. and B.T. Collins. 1996. The Canadian Breeding Bird Survey, 1966-1994. Can. Wildl. Serv. Progr. Notes No. 214, Ottawa.

Ehrlich, P.R., D.S. Dobkin, and D. Wheye. 1988. The birder's handbook: a field guide to the natural history of North American Birds. Simon and Schuster Inc., Toronto, ON. 875 pp.
Eissinger, A. 1996. Great Blue Herons of the Salish Sea: A model plan for the conservation and stewardship of coastal herons colonies. Report prepared for Trillium Corporation, ARCO Products, and Washington Department of Fish and Wildlife, Olympia, WA.
Eissinger, A. 2007. Great Blue Herons in Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-06. Published by Seattle District, U.S. Corps of Engineers, Seattle, Washington.
Elliott, J.E. and M.L. Harris. 2001. An ecotoxicological assessment of chlorinated hydrocarbon effects on Bald Eagle populations. Reviews in Toxicology 4: 1-60.
Elliott, J.E., R.W. Butler, R.J. Nostrom and P.E. Whitehead. 1989. Environmental contaminants and reproductive success of Great Blue Heron (*Ardea herodias*) in British Columbia, 1986-87. Environ. Pollut. 59:91-114.
Elliott, J.E., P.E. Whitehead, P.A. Martin, G.D. Bellward and R.J. Norstrom. 1996. Persistent pulp mill pollutants in wildlife. Pp. 297-314 in M.R. Servos, K.R. Munkittrick, J.H. Carey and G.J. Van der Kraak (eds.). Environmental fate and effects of pulp and paper mill effluents. St. Lucie Press, Delray Beach, Florida.
Elliott, J. E., I. E. Moul and K. M. Cheng. 1998. Variable reproductive success of Bald Eagles on the British Columbia Coast. Journal of Wildlife Management 62:518-529.
Elliott, J.E., M.L. Harris, L.K. Wilson, P.E. Whitehead and R.J. Norstrom. 2001. Monitoring Temporal and Spatial Trends in Polychlorinated Dibenzo-p-dioxins (PCDDs) and Dibenzofurans (PCDFs) in Eggs of Great Blue Heron (*Ardea herodias*) on the Coast of British Columbia, Canada, 1983–1998. Ambio 30:416-428.
Elliott, J.E., L.K. Wilson and B. Wakeford. 2005. Polybrominated Diphenyl Ether
Trends in Eggs of Marine and Freshwater Birds from British Columbia, Canada, 1979-2002. Environmental Science and Technology 39:5584-5591.
Engelstoft, C. and L. Sopuck. 2005. Great Blue Heron surveys during the breeding period in Gwaii Haanas National Park Reserve/Haida Heritage Site, 2004. Unpublished report prepared for Parks Canada Agency, Gwaii Haanas Field Unit, Queen Charlotte, B.C.
Forbes, L. S. 1987. Predation on adult Great Blue Herons: is it important? Colonial Waterbirds 10:120-122.
Forbes, L. S. 1989. Coloniality in herons: Lack's predation hypothesis reconsidered. Colonial Waterbirds 12:24-29.
Forbes, L. S., K. Simpson, J. P. Kelsall and D. R. Flook. 1985a. Reproductive success of Great Blue Herons in British Columbia. Canadian Journal of Zoology 63:1110-1113.
Forbes, L. S., K. Simpson, J. P. Kelsall and D. R. Flook. 1985b. Great Blue Heron colonies in British Columbia. Unpublished Report, Canadian Wildlife Service, Delta.
Gebauer, M. 1995. Status and productivity of Great Blue Heron (*Ardea herodias*) colonies in the lower Fraser River valley in 1992, 1993 and 1994. Unpublished Report to the B.C. Ministry of Environment, Lands and Parks, Surrey, B.C.

Gebauer, M. B. and I. E. Moul. 2001. Status of the Great Blue Heron in British Columbia. Wildlife Working Report No. 102, British Columbia Ministry of the Environment, Lands and Parks, Wildlife Branch, Victoria.

Georgia Basin Ecosystem Initiative. 2002. Georgia Basin – Puget Sound ecosystem indicators report. ISBN 0-662-31312-7. Accessed in February 2007 at http://www.env.gov.bc.ca/spd/gbpsei/.

Gibbs, J. P. and L. K. Kinkel. 1997. Determinants of the size and location of Great Blue Heron colonies. Colonial Waterbirds 20:1-7.

Gutsell, R. 1995. Age-related foraging behaviour and habitat use in Great Blue Herons. Master of Science thesis. Simon Fraser University, B.C.

Harris M.L., J.E. Elliott, R.W. Butler and L.K. Wilson. 2003. Reproductive success and chlorinated hydrocarbon contamination of resident great blue herons (*Ardea herodias*) from coastal British Columbia, Canada, 1977 to 2000. Environmental Pollution 121: 207–227.

Hockin, D., M. Ounsted, M. Gorman, D. Hill, V. Keller and M. A. Barker. 1992. Examination of the Effects of Disturbance on Birds with Reference to its Importance in Ecological Assessments. Journal of Environmental Management 36:253-286.

Kelsall, J.P., and K. Simpson. 1979. A three-year study of the Great Blue Heron in southwestern British Columbia. Proc. Colonial Waterbird Group 3:69-74.

Kjellen, N. and G. Roos. 2000. Population trends in Swedish raptors demonstrated by migration counts at Falsterbo, Sweden 1942-1997. Bird Study 47: 195-211.

Koonz, W. H. 1980. Bald Eagle nest in a Manitoba heron colony. Blue Jay 38:49.

Krebs, J. R. 1974. Colonial nesting and social feeding as strategies for exploiting food resources in the Great Blue Heron *(Ardea herodias)*. Behaviour 51:99-131.

Leonard, W. 1985. Inventory of Great Blue Heron Nest Colonies in Southern and Western Puget Sound. Unpublished Report. Washington Department of Wildlife, Olympia, Washington, USA.

Mark, D. M. 1976. An Inventory of Great Blue Heron (*Ardea herodias*) Nesting Colonies in British Columbia. Northwest Science 50:32-41.

McAllister, K. R., T. E. Owens, L. Leschner and E. Cummins. 1986. Distribution and productivity of nesting Bald Eagles in Washington. Murrelet 67:45-50.

McClaren, E. L. 2005. Pacific Great Blue Heron population inventory and monitoring Strait of Georgia, British Columbia 2004. Unpublished report to the B.C. Ministry of Environment, Nanaimo.

Moore, K. 1990. Urbanization in the Lower Fraser Valley, 1980-1987. Canadian Wildlife Service Technical Report No. 120. Delta, BC: Canadian Wildlife Service.

Moul, I.E. 1992. The breeding success of herons, eagles and cormorants nesting near the waters surrounding Vancouver Island, 1992. Unpubl. Rep. Can. Wildl. Serv., Pacific and Yukon Reg. 137pp.

Moul, I. E., R. G. Vennesland, M. L. Harris and R. W. Butler. 2001. Standardizing and interpreting nesting records for Great Blue Herons in British Columbia. Canadian Wildlife Service Progress Note No. 217, Canadian Wildlife Service, Ottawa. <http://www.cws-scf.ec.gc.ca/publications/> (1 April 2002).

Nisbet, I. C. T. 2000. Disturbance, habituation, and management of waterbird colonies. Waterbirds 23:312-332.

Norman, D.M., A.M. Breault and I.E. Moul. 1989. Bald Eagle incursions and predation at Great Blue Heron colonies. Colonial Waterbirds 12:143-230.
Parker, J. 1980. Great Blue Herons in Northwestern Montana: Nesting Habitat Use and the Effects of Human Disturbance. M.Sc. thesis, University of Montana.
Parnell, J. F., D. G. Ainley, H. Blokpoel, B. Cain, T. W. Custer, J. L. Dusi, S. Kress, J. A. Kushlan, W. E. Southern, L. E. Stenzel and B. C. Thompson. 1988. Colonial Waterbird Management in North America. Colonial Waterbirds 11:129-345.
Payne, R.B. 1979. Ardeidae, pp. 193-244 in Checklist of birds of the world. (E. Mayr and G.W. Cottrell, eds.) Mus. Comp. Zool., Cambridge, MA.
Pratt, H. M. 1970. Breeding Biology of Great Blue Herons and Common Egrets in central California. Condor 72:407-416.
Rodgers, J., J.A. and H. T. Smith. 1995. Set-back distances to protect nesting bird colonies from human disturbance. Conservation Biology 9:89-99.
Simpson, K. 1984. Factors affecting reproduction in Great Blue Herons (*Ardea herodias*). M.Sc. thesis, University of British Columbia.
Simpson, K. and J. P. Kelsall. 1978. Capture and banding of adult Great Blue Herons at Pender Harbour, British Columbia. Proceedings of the Colonial Waterbird Group 1978:71-78.
Simpson, K., J. N. M. Smith and J. P. Kelsall. 1987. Correlates and consequences of coloniality in Great Blue Herons. Canadian Journal of Zoology 65:572-577.
Vennesland R.G. 2000. The effects of disturbance from humans and predators on the breeding decisions and productivity of the Great Blue Heron in south-coastal British Columbia. Master of Science thesis, Simon Fraser University, B.C.
Vennesland R.G. 2003. Coastal Great Blue Heron inventory and monitoring project – 2002 breeding season report and historical analysis. Unpublished report to the British Columbia Ministry of Water, Land and Air Protection (now Ministry of Environment), Nanaimo and Surrey, B.C.
Vennesland, R.G. 2004. Great Blue Heron Species Account. Identified Wildlife Management Strategy guidelines, Volume 2, B.C. Ministry of Environment, Victoria, B.C.
Vennesland R.G. 2006. Impact of human and Bald Eagle disturbance at a Great Blue Heron colony near Mud Bay on Vancouver Island. Unpublished report prepared for the B.C. Ministry of Environment, Surrey, B.C.
Vennesland, R.G. and R.W. Butler. 2004. Factors influencing Great Blue Heron nesting productivity on the Pacific coast of Canada from 1998 to 1999. Waterbirds 27(3): 289-296.
Vermeer, K. 1969. Great Blue Heron colonies in Alberta. Canadian Field-Naturalist 83:237-242.
Vermeer, K., K.H. Morgan, R.W. Butler and G.E.J. Smith. 1989. Population, nesting habitat and food of Bald Eagles in the Gulf Islands, In: K. Vermeer and R.W. Butler (eds.). The status and ecology of marine and shoreline birds in the Strait of Georgia, British Columbia. Can. Wildl. Serv. Spec. Publ. Ottawa. Pp. 123-131.
Vos, D. K., R. A. Ryder and W. D. Graul. 1985. Response of Breeding Great Blue Herons to Human Disturbance in Northcentral Colorado. Colonial Waterbirds 8:13-22.

Watts, B. D. and D. S. Bradshaw. 1994. The Influence of Human Disturbance on the Location of Great Blue Heron Colonies in the Lower Chesapeake Bay. Colonial Waterbirds 17:184-186.

Werschkul, D. F., E. McMahon and M. Leitschuh. 1976. Some Effects of Human Activities on the Great Blue Heron in Oregon. The Wilson Bulletin 88:660-662.

BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Ross Vennesland studied biology and physical geography at Simon Fraser University for his undergraduate education, completing his B.Sc. degree in 1996. He went on to complete his M.Sc. degree in biology at Simon Fraser University in 2000, studying the behavioural ecology and conservation biology of the Great Blue Heron. During and after his schooling, Ross worked as a private consultant for federal and provincial governments, academic institutions and other organizations, concentrating primarily on ornithological work. From 2002 to 2006, he worked as the Senior Ecosystems Biologist for Species at Risk for the Lower Mainland Region of the British Columbia Ministry of Environment. In that capacity, he worked with a diverse array of organisms including birds, fish, plants, small mammals, amphibians and invertebrates and chaired several recovery teams and the South Coast Conservation Program (www.sccp.ca), a landscape-level conservation program for the region. He is now the Species at Risk Recovery Specialist for Parks Canada at the Western and Northern Service Centre in Vancouver.

Rob Butler received a Bachelor of Science and Master of Science degree at Simon Fraser University and a Doctor of Philosophy in Zoology from the University of British Columbia. He is a Senior Research Scientist with Environment Canada's Canadian Wildlife Service and Adjunct Professor of Biological Sciences at Simon Fraser University in British Columbia. His research specialties are avian migration, ecology and conservation. Dr. Butler is considered a world authority on the Great Blue Heron from his doctoral research, scientific publications and his authoritative book *The Great Blue Heron* (Univ. of B.C. Press, 1997). Dr. Butler is a scientific advisor to the IUCN Heron Specialist Group, Western Hemisphere Shorebird Reserve Network and the Important Bird Areas. He is past President of the *Waterbird Society*, Chair and founding member of the Heron Working Group, and President of the Pacific Wildlife Foundation. He has won numerous awards for his research work on bird migration and conservation in Canada and abroad and he is a Fellow of the American Ornithologists' Union.

COLLECTIONS EXAMINED

No collections were examined for this report.