Environment Canada Environnement Canada

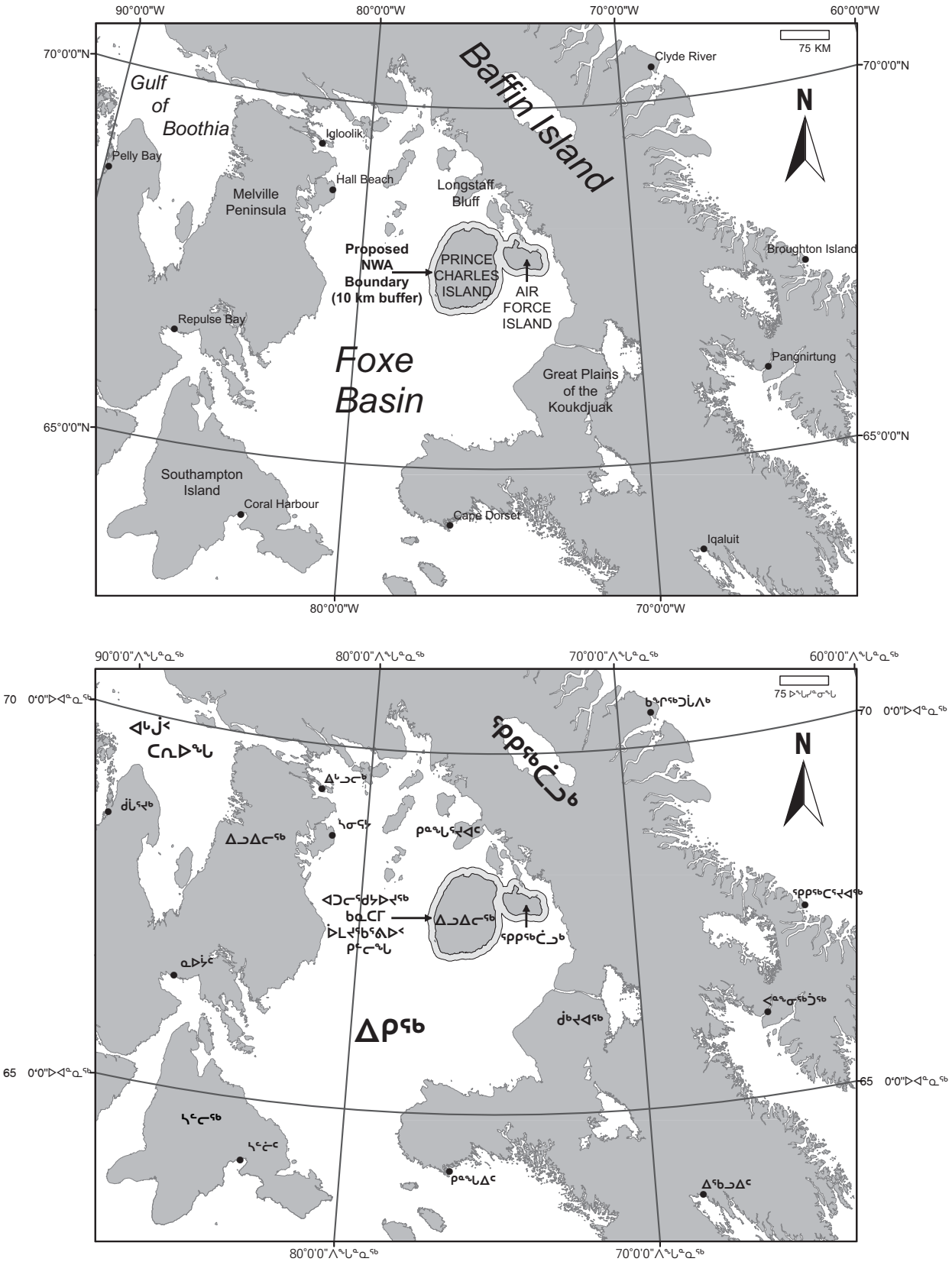
The Birds of Prince Charles Island and Air Force Island, Foxe Basin, Nunavut

Victoria H. Johnston
Stephen T. Pepper

Occasional Paper
Number 117
Canadian Wildlife Service

Canada

Proposed National Wildlife Area for Prince Charles Island and Air Force Island in Foxe Basin, Nunavut



Victoria H. Johnston[1]
Stephen T. Pepper[1]

The Birds of Prince Charles Island and Air Force Island, Foxe Basin, Nunavut

Occasional Paper
Number 117
Canadian Wildlife Service
August 2009

Également disponible en français sous le titre
Les oiseaux des îles Prince-Charles et Air Force, dans le bassin Foxe, au Nunavut
Service canadien de la faune, Publication hors série n° 117

[1] Canadian Wildlife Service
Environment Canada
P.O. Box 2310
Yellowknife, NT
X1A 2P7

Cover photos (left to right)
Red Phalarope, Prince Charles Island, ©V. Johnston, CWS
Sabine's Gull Nest, Air Force Island, ©V. Johnston, CWS
East Coast, Prince Charles Island, ©V. Johnston, CWS

Online in HTML and PDF at www.cws-scf.ec.gc.ca

Catalogue No. CW69-1/117E-PDF
ISBN 978-1-100-12557-2

Library and Archives Canada Cataloguing in Publication

Johnston, Victoria Helen, 1962-
The birds of Prince Charles Island and Air Force Island, Foxe Basin, Nunavut [electronic resource] / Victoria H. Johnston and Stephen T. Pepper.

(Canadian Wildlife Service occasional paper ; 117)
Electronic monograph in PDF format.
Issued also in French under title: Les oiseaux des îles Prince-Charles et Air Force, dans le bassin Foxe, au Nunavut.
Includes abstract in Inuktitut.
"This report is Polar Continental Shelf Project contribution number 03402".
Includes bibliographical references:
ISBN 978-1-100-12557-2
Cat. no.: CW69-1/117E-PDF

1. Bird populations--Nunavut--Foxe Bassin. 2. Birds--Breeding --Nunavut--Foxe Bassin. 3. Birds--Habitat--Nunavut--Foxe Bassin. 4. Birds --Nunavut--Foxe Bassin--Geographical distribution. 5. Birds--Conservation --Nunavut--Foxe Bassin. 6. Bird surveys--Nunavut--Foxe Bassin. I. Pepper, Stephen T II. Canada. Environment Canada III. Canadian Wildlife Service IV. Title. V. Series: Occasional paper (Canadian Wildlife Service : Online) no. 117

QL685.5 N8 J65 2007 598.09719'5 C2009-980112-4

This report is dedicated to the memory of Philip Apak Robinson.

His love of the North and its creatures will always be an inspiration.

ᑕᵒᓇ ᐅᓂᖅᑲᖅ ᑐᓂᔪᐅᔨᖅ ᐃᖃᐅᒪᓗᑐᒍ ᐱᓕᕆ ᐊᑦᕿᒃ ᖃᐱᖓᓱᵒ.

ᐃᓄᐃᑦ ᓄᓇᖏᓐᓂ ᓇᑦᑕᓂᓂᖅᖏᓂᕆᑦᑎᓄᓇ ᐅᒪᔨᖏᓐᓂᑦᓗ ᑕᐃᒪᖏᓕ

ᐱᒻᒪᕆᐅᖏᓐᓇᓂᐊᕐᓵᖅ.

©V. Johnston, CWS

This report is Polar Continental Shelf Project contribution number 03402.

Abstract

We studied the populations of birds breeding on Prince Charles Island and Air Force Island, Foxe Basin, Nunavut, to determine whether the islands should be protected as a National Wildlife Area. In 1996 and 1997, we classified the habitats found on the islands and we determined the numbers and breeding status of birds on 85 survey plots on the islands. Shorebird species diversity and densities were compared to results from published studies carried out elsewhere in the Arctic and to results of shorebird surveys carried out on Prince Charles Island 8 years previously. We also did aerial surveys on both islands to look for waterfowl and Sabine's Gulls *Xema sabini*, and we compared those results with information collected from aerial surveys 12 years previously.

We observed 42 species of birds on the islands and confirmed that 25 of the 42 species were nesting on the islands. Red Phalaropes *Phalaropus fulicarius,* White-rumped Sandpipers *Calidris fuscicollis,* and Ruddy Turnstone *Arenaria interpres morinella* were the most common of the 12 shorebird species recorded. Other breeders were American Golden-Plover *Pluvialis dominica,* Black-bellied Plover *Pluvialis squatarola,* Dunlin *Calidris alpina hudsonia*, and Semipalmated Sandpiper *Calidris pusilla.* Pectoral Sandpipers *Calidris melanotos*, Baird's Sandpipers *Calidris bairdii*, and Semipalmated Plovers *Charadrius semipalmatus* probably breed but we did not confirm this. Red Knot *Calidris canutus rufa* and Purple Sandpipers *Calidris maritima maritima* were observed but, because no breeding behaviour was observed, we assumed that they were migrants.

On Prince Charles Island the best shorebird habitat—wet vegetated graminoid (sedge/grass) tundra—is distributed in a thick band around the outside of the island. The interior of the island is mostly dry and barren. Air Force Island is nearly completely wet vegetated graminoid tundra. Shorebirds were not distributed equally among habitat types. White-rumped Sandpipers and Red Phalaropes seemed to choose from among the various wet habitat types, and they preferred sedge marsh to other wet habitat types.

Prince Charles Island and Air Force Island are major breeding sites for shorebirds. The islands together contain an estimated 272 470 pairs of shorebirds and an estimated 626 045 individuals. The population estimates for eight bird species are greater than 1% of the current North American population estimate. With the Great Plains of the Koukdjuak (West Baffin Island), Prince Charles Island and Air Force Island are the most important known breeding sites for Red Phalaropes and White-rumped Sandpipers in the entire Canadian Arctic.

The numbers and distribution of both shorebird and other bird species have changed over time. The populations of three shorebird species clearly changed on Prince Charles Island between 1989 and 1997: Dunlin increased, and Red Phalaropes and White-rumped Sandpipers both decreased. Between 1984 and 1997, the population size and the extent of the distribution of Lesser Snow Geese *Chen caerulescens caerulescens* increased on Air Force Island, and the population size and the extent of the distribution of Atlantic Brant *Branta bernicla hrota* decreased. Sabine's Gull decreased over the same period of time on Prince Charles Island.

Prince Charles Island and Air Force Island are extremely important to Black-bellied Plovers, American Golden-Plovers, Ruddy Turnstones ssp. *morinella*, White-rumped Sandpipers, Dunlin ssp. *hudsonia*, Red Phalaropes, Purple Sandpipers *Calidris maritima maritima*, Red Knot ssp. *rufa*, Sabine's Gull, Atlantic Brant, and Long-tailed Jaegers *Stercorarius longicaudus*. The islands meet the criteria to be designated a National Wildlife Area, and we recommend that they be protected under the *Canada Wildlife Act* regulations for National Wildlife Areas. The proposed boundaries are marked on the map on the inside front cover.

ᓇᐃᓈᕐᓯᒪᔪᑦ ᐅᓂᒃᑳᑦ

ᖃᐅᔨᓴᓚᐅᕐᕿᑎᒍ ᑎᖕᒥᐊᑦ ᓄᓕᐅᕐᑐᑦ ᓴᓪᓕᕐᒥ ᓴᓪᓕᒃᑲᓂᕐᒥᒧ, ᓯᑯᓯᕚᕐᒥᐅᓪᓗ ᐃᒪᖓᓂ, ᓄᓇᕗᒻᒥ, ᓇᓗᓇᐃᖅᓯᓂᐊᕿᑦᑕ ᕿᑭᖅᑕᐃᑦ ᓴᐳᔾᔭᐅᒪᑭᐊᖃᖕᒪᖖᒋᑕ ᑲᓇᑕᒥ ᐆᒪᔪᖃᕐᕙᐅᓗᑎᒃ 1996-ᒥ 1997-ᒥᓗ, ᖃᐅᔨᓴᓚᐅᕐᑕᕗᑦ ᓇᔪᒐᕆᔭᐅᕙᒃᑐᑦ ᖃᓄᐃᑦᑑᒪᖖᒋᑕᓗ ᖃᐅᔨᓚᐅᕐᑕᕗᑦ ᕿᕐᕿᖅᑖᒃ ᓇᓗᓇᐃᖅᓯᑦᓗᑕᓗ ᖃᓯᐅᓂᖕᒋᓐᓂᒃ ᓄᓚᐅᖕᓂᖕᒋᑦᓗ ᖃᓄᐃᒻᒪᖖᒋᑕ ᑎᖕᒥᐊᑦ 85-ᖑᔪᓂ ᖃᐅᔨᓴᕐᕚᐅᔪᓂ ᕿᑭᖅᑖᖕᓂ.

ᓯᖅᓵᑉᐸᒃᑐᑦ ᑎᖕᒥᐊᑦ ᐊᔾᔨᖖᒋᓐᓂᖕᒋᑦ ᐅᓄᖅᑎᒋᓂᖕᒋᑦᓗ ᖃᐅᔨᓴᖅᑕᐅᓚᐅᖅᑐᑦ ᐊᔾᔨᓐᓂᕐᑲᖕᒪᖖᒋᑕ ᓴᖅᑭᑎᑕᐅᓚᐅᖅᑐᓄᑦ ᖃᐅᔨᓴᖅᑕᐅᓚᐅᖅᑐᓂ ᑲᒪᒋᔭᐅᓚᐅᕐᑐᓂᒃ ᐊᓯᐊᓂ ᐅᑭᐅᖅᑕᖅᑐᕐᒥ ᖃᐅᔾᔭᐅᓚᐅᖅᑐᓄᑦᓗ ᑎᖕᒥᐊᑦ ᓯᖅᓵᑉᐸᒃᑐᑦ ᖃᐅᔨᓴᖅᑕᐅᕌᓂᓚᐅᖅᑐᓂ ᓴᓪᓕᕐᒥ ᐊᕐᕌᒍᐃᑦ 8 ᑭᖑᓂᑦᑎᓐᓂ. ᑎᖕᒥᓃᒃᑯᑦ ᓇᔪᖅᑕᐅᔪᓂᒃ ᕿᓂᓚᐅᕐᒥᔪᒍᑦ ᑕᒪᒃᑮᖕᓂᒃ ᕿᑭᖅᑖᖕᓂ ᐃᒫᓃᓱᖑᔪᓂᒃ ᑎᒻᒥᐊᓂᒃ ᐃᕿᒡᒐᕆᐊᕐᔪᖕᓂᓪᓗ, ᐊᔾᔨᖕᓂᕐᑲᖕᒪᖖᒋᑕ ᖃᐅᔨᓴᓚᐅᖅᑰᑕ ᓄᐊᑕᐅᓚᐅᕐᑐᓂᒃ ᑎᖕᒥᓃᒃᑯᑦ ᖃᐅᔨᓴᕈᑎᒥᖕᓂᒃ ᐅᑭᐅ 12 ᓈᓯᒪᓕᕐᑐᑦ.

ᐊᔾᔨᖖᒋᑦᑑᑎᓂᒃ 42-ᓂᒃ ᑎᖕᒥᐊᕐᓂᒃ ᓇᐅᑦᑎᖅᓱᓚᐅᖅᑐᒍᑦ ᕿᕐᕿᖅᑖᖕᓂ ᐊᖕᒋᕈᓐᓇᖅᑲᑕᓗ 25ᖑᔪᑦ ᑎᓪᒥᐊ ᐱᑭᐅᕐᑲᓇᐊᖕᒋᑕ ᕿᕐᕿᕐᑕᒥ 42ᖑᒐᓚᐅᖕᒪᑕ ᑎᓪᒥᐊᑦ ᐊᔾᔨᖕᒋᑦᑐᑦ. 42ᓃᖕᒫᕐᑐᑦ ᑎᓪᒥᐊᑦ 25-ᖑᔪᑦ ᐊᔾᔨᖖᒋᑦᑑᑎᑦ ᐃᕙᓚᐅᕐᑐᑦ ᕿᑭᖅᑖᖕᓂ. ᓴᐅᕋᐃᑦ, ᓯᓐᓴᓇᐊᕐᔪᑦ ᖃᐅᓪᓗᕐᓂᓖᖅ, ᑕᓪᓕᕙᐃᓪᓗ (ᑐᕝᕕᑎᑎᖅᑭᐅᖅ) ᐊᓚᒃᑲᐅᒪᓖᖑᒐᐅᕐᑐᑦ 12-ᖑᔪᓂᑦ ᑎᖕᒥᐊᓂᒃ ᓯᖅᓵᑉᐸᒃᑐᓂᑦ ᑎᑎᕋᐅᓯᓇᔭᐅᓚᐅᖅᑐᓂᑦ.

ᐊᓯᖕᒋᑦ ᓄᓚᐅᓰᑦ ᐅᑯᐊᖑᓪᓗᑎᒃ: ᕿᕐᓚᐊᔪᐃᑦ, ᑑᓪᓚᓘᕐᔪᐃᑦ, ᑐᐊᖦᓚᔪᐃᑦ, ᐊᒻᒪ ᓯᓐᓴᓇᐊᑦ. ᓯᓐᓴᓇᐊᑦ, ᓚᕙᓚᕙᓖᑦ (ᑐᐃᑐᐃᖅ), ᐊᒻᒪ ᕿᑦᓕᕐᑯᓪᓚᐊᕐᔪᐃᓪᓗ ᓄᓚᐅᕐᑲᑦᑕᖅᑐᒃᓴᐅᒐᓗᐊᕆᓪᓗᑎᒃ ᑕᒪᓐᓇ ᓱᓕᔪᖅᓯᐊᕆᔪᓐᓇᓚᐅᙱᓐᓇᑦᑎᒍᑦ. ᓯᓐᓴᕆᐊᑦ ᓯᓐᓴᕆᐊᓱᓪᔪᐃᓪᓗ ᑕᑯᓐᓇᖅᑕᐅᓪᓗᑎᒃ ᖃᐅᔨᓴᖅᑕᐅᓚᐅᕐᒪᑕ ᑭᓯᐊᓂᓕ ᓄᓚᐅᕋᓱᑦᑎᓪᓗᒋ ᖃᐅᔨᓴᐅᓚᐅᖕᒋᒻᒪᑕ, ᑐᓛᒋᐅᕐᓯᒪᓱᕆᓕᓚᐅᕐᑕᕗᑦ ᑕᐃᑯᖓ.

ᓴᓪᓖᑦ ᐱᐅᓛᖑᕗᖅ ᑎᖕᒥᐊᓄᑦ ᓯᖅᓵᕐᑉᐸᒃᑐᓄᑦ ᓇᔪᖓᕆᓂᑦ—ᐃᒪᖅᓲᓪᓗᓂ (ᐃᕙᒃ/ᐃᕙᖓᖅ) ᓄᓇᖓ—ᕿᑭᖅᑕᐅᑉ ᓯᓚᑖᓗᒃᑖᖓ ᐃᒪᖅᓲᓂᖅᑫᐊᖅᑯᓂ. ᕿᑭᖅᑕᐅᑉ ᐃᓗᐃᓪᓕᖓ ᐸᓂᕐᓂᖅᓴᐅᓪᓗᓂ ᑭᓱᕐᑲᓗᐊᙱᕐᑯᓂ. ᒪᓴᑐᐃᓐᓇᑲᓴᓪᓚᓇᐅᓪᓗᓂ ᐃᓘᓐᓇᓂ ᐱᕈᒃᑐᕐᑲᐅᕐᑐᓂ ᓄᓇᖓ. ᓴᓪᓕᒃᑲᓐᓂᖅ ᐃᓱᖅᓲᐃᓐᓇᐸᓗᒃᑐᖅ. ᑎᖕᒥᐊᑦ ᓯᖅᓵᑉᐸᒃᑐᑦ ᓇᓃᓐᓂᖕᒋᑕ ᐊᔾᔨᓂᕐᑲᖅᐸᓚᐅᙱᑦᑐᑦ ᓇᔪᖓᕙᒃᑕᖕᒋᓐᓂ. ᓯᓐᓴᓇᐊᕐᔪᑦ ᖃᐅᓪᓗᕐᓂᓖᑦ ᓴᐅᕋᐃᓪᓗ ᓂᕈᐊᖅᑯᓚᐃᕙᓚᐅᖅᐳᑦ ᐊᔾᔨᖖᒋᑦᑐᑎᓂᒃ ᐃᒪᖅᓯᕐᓂᒃ, ᐃᒪᖅᓯᕐᒥ ᐃᕙᕐᖃᖅᑑᑦᑐᒪᓂᖅᓴᐅᕗᒃᑲᐅᑎᒃ ᐊᓯᖕᒋᓐᓂᑦ ᐃᒪᖅᓯᕐᓂᑦ.

ᓴᓪᓖᑦ ᓴᓪᓕᒃᑲᓐᓂᕐᒧ ᐊᖕᒋᔫᒪᓇᓪᒥᒃ ᓄᓚᐅᕐᕙᐅᓗᐊᖑᐊᕐᑲᑦᑕᓂᕐᓴᐅᔪᑦ ᓯᓐᓴᖕᒥᐅᑕᐅᔪᓄᑦ. ᕿᑭᖅᑖᒃ ᑕᒪᒃᑭᑦ ᐃᒪᐃᓚᖕᖓᓱᓇᔭᐅᔪᑦ ᑎᖕᒥᐊᕐᑲᕐᑐᓇᔭᐅᔪᖅ 272 470 ᓄᓚᐊᔮᓇᑦ ᑎᓪᒥᐊᑦ ᐃᒫᓃᓱᑦ ᐊᒻᒪᓗ 626 045 ᓄᓚᐊᔮᕐᑲᖕᒋᑦᑐᑦ. ᑎᓪᒥᐊᖑᕐᑲᑎᖑᓐᓃᖕᒫᕐᑐᑦ ᐃᒪᐃᓚᖕᖓᓱᓇᔭᐅᔪᑦ 8ᖑᐸᑕ ᑎᓪᒥᐊᑦ ᐊᖕᒋᓂᖅᓴᐅᕗᑦ 1ᐳᓴᓐᑎᒥᒃ ᑎᓪᒥᐊᖑᕐᑲᑎᖑᓐᓃᖕᒫᕐᑐᓂᒃ ᑲᓇᑕᒥ ᒥᐊᓕᖓᖕᓂᓪᓗ ᑎᓪᒥᐊᖑᕐᑲᑎᖑᑦᑐᓇᔭᐅᔪᓂᒃ. ᐊᖕᒋᔫᒪᓇᐅᓂᖕᖓᓄᑦ ᓄᓇᑐᐃᓐᓇᖅ ᑰᔪᐊᕐᒥ (ᐅᐊᓐᓈᓂ ᕿᑭᖅᑖᔫᑉ), ᓴᓪᓖᖅ ᓴᓪᓕᒃᑲᓐᓂᕐᒧ ᐱᓪᓚᐅᓖᖑᕗᖅ ᓄᓚᐅᕙᒋᔭᐅᓪᓗᓂ ᓴᐅᕋᕐᓄᑦ ᓯᓐᓴᓇᐊᕐᔪᖕᓄᓪᓗ ᖃᐅᓪᓗᕐᓂᓕᖕᓄᑦ ᑲᓇᑕᐅᑉ ᐅᑭᐅᖅᑕᖅᑐᓖᖕᒐᓂ.

ᑕᒪᒃᑮᒃ ᑎᖕᒥᐊᑦ ᐊᔾᔨᖖᒋᑦᑑᒃ ᖃᐅᔨᓴᕐᓂᖕᒋᑦ ᓇᓃᕐᑲᑦᑕᕐᓂᓇᔭᖕᒋᓪᓗ ᐊᓯᔾᔨᕐᓂᑰᕗᖅ.

ᓴᓪᓕᕐᒥ ᐊᑯᓐᓂᖓᓂ 1989 ᐊᒻᒪ 1997 ᖃᐅᓯᐅᓂᖕᒋᑦ ᐱᖓᓱᑦ ᑎᖕᒥᐊᑦ ᐊᔾᔨᖖᒋᑦᑑᑎᑦ ᓯᖅᓵᑉᐸᒃᑐᑦ ᓇᓗᓇᙱᕐᔪᓂ ᐊᓯᔾᔨᕐᓯᒪᔪᖅ: ᑐᐊᖦᓚᔪᐃᑦ ᐅᓄᕐᓂᖅᓴᐅᓕᖅᑐᑎᒃ, ᐊᒻᒪ ᓴᐅᕋᐃᑦ ᓯᓐᓴᓇᐊᕐᔪᐃᓪᓗ ᖃᐅᓪᓗᕐᓂᓖᑦ ᑕᒪᒃᑭᒃ ᐅᓄᙱᓐᓂᖅᓴᐅᓕᖅᑐᑎᒃ. ᐊᑯᓐᓂᖓᓂ 1984 ᐊᒻᒪ 1997, ᑲᖑᐃᑦ ᖃᐅᓯᐅᓂᖕᒋᑦ ᐊᒥᓃᓂᖅᓴᐅᓕᓚᐅᖅᐳᑦ ᓇᓃᕐᑲᑦᑕᕐᓂᖕᒋᑦᓗ ᐊᖕᒋᒡᓕᓪᓗᓂ ᓴᓪᓕᒃᑲᓐᓂᕐᒥ, ᓂᕐᓕᖕᓇᐃᓪᓗ ᖃᓯᓐᓇᕈᕐᐹᓪᓕᖅᓱᑎᒃ ᓇᓃᕐᑲᑦᑕᕐᓂᖕᒋᓪᓗ ᒥᒃᓵᓪᓗᓂ. ᐃᕿᒡᒋᕙᐊᕐᔪᐃᑦ ᖃᓯᐅᓂᖕᒋᑦ ᐊᒥᓃᙱᓐᓂᖅᓴᐅᕆᓪᓗᑎᒃ ᓇᓃᕐᑲᑦᑕᕐᓂᖕᒋᓪᓗ ᒥᒃᓵᓪᓗᓂᓗ ᑕᐃᓴᓱᒪᓂᑦᑕᐃᓐᓇᖅ ᓴᓪᓕᕐᒥ.

ᓴᓪᓖᑦ ᓴᓪᓕᒃᑲᓐᓂᕐᒧ ᐱᓪᓚᐅᔩᒃ ᑑᓪᓚᓘᕐᔪᖕᓄᑦ, ᕿᕐᓚᐊᔪᕐᓄᑦ, ᑕᓪᓕᕙᕐᓄᑦ, ᓯᓐᓴᓇᐊᕐᔪᓄᑦ ᖃᐅᓪᓗᕐᓂᖅᖃᖅᑐᓄᑦ, ᑐᐊᖦᓚᔪᕐᓄᑦ, ᓴᐅᕋᕐᓄᑦ, ᓯᓐᓴᓇᐊᕐᔪᖕᓄᑦ, ᓯᓐᓴᓇᐊᕐᓄᑦ, ᐃᖅᑭᖦᓚᕆᐊᕐᔪᖕᓄᑦ, ᓂᕐᓕᖕᓇᕐᓄᑦ, ᐃᓱᙵᕐᓗᖕᓄᓪᓗ ᕿᑭᖅᑖᒃ ᑎᑭᐅᑎᕗᒃ ᑎᑭᐅᑎᔭᐅᔭᓇᐊᓕᖕᓂᒃ ᑎᒃᑯᐊᖅᑕᐅᔭᓇᐊᒃᓴᖅ ᑲᓇᑕᒥ ᐆᒪᔪᖃᕐᕙᐅᓪᓗᓂ ᓴᐳᒥᔭᐅᕙᐅᓂᕐᒧᑦ, ᓴᐳᒻᒥᕐᑯᔭᐅᓪᓗᑎᒍᓪᓗ ᐊᑖᒍᑦ *ᑲᓇᑕᒥ ᐆᒪᔪᓕᕆᓂᕐᒧᑦ ᐱᕐᑯᔭᖕᖓᑕ* ᐊᑐᐊᖓᖕᒋᑎᒍᑦ ᑲᓇᑕᒥ ᐆᒪᔪᖃᕐᕙᐅᔪᓄᑦ ᓴᐳᒥᔭᐅᔪᓄᑦ.

ᐊᑐᓕᕐᑯᔭᐅᔪᑦ ᑭᓪᓕᖕᒋᑦ ᓄᓇᙳᐊᕐᒥ ᒪᒃᐱᖓᐅᑉ ᖃᖓᑕ ᐃᓗᐊᓂ.

Acknowledgements

We enjoyed the company and appreciated the good nature and efforts of students Elijah Kuppaq, Luttie Nattuk, and Philip Robinson. Jean-Louis Martin graciously permitted us to use some of his unpublished data from Prince Charles Island. Steve A. Smith and crew also contributed their efforts to data collection for this report. A big thank-you to Polar Continental Shelf Project for its logistical support and to the pilots of Kenn Borek Air and Huisson Aviation for keeping us safe in the air. John MacDonald, formerly of the Igloolik Research Centre, hosted us in 1996 and helped us research the human history of the islands, and he contributed weather data from his Igloolik weather station.

The Hall Beach Hunters and Trappers Organization and the Igloolik Hunters and Trappers Organization provided endorsement for our permit applications in both years of the project. This project was carried out under the auspices of WL001528 Government of the Northwest Territories Wildlife Research Permit issued to Victoria Johnston.

Contents

List of figures

List of tables

1. Introduction

The islands of the Foxe Basin, Nunavut, are recognized as a key migratory bird habitat site (Alexander et al. 1991; Latour et al. 2008). North Spicer Island, Prince Charles Island, and Air Force Island were originally accorded key habitat site status on the basis of large populations of waterfowl. Since their original designation, Prince Charles Island and Air Force Island have also been found to have large populations of shorebirds.

Since the late 1950s, migratory birds and their habitats in the area that is now Nunavut have been protected through a growing network of Migratory Bird Sanctuaries established under the *Migratory Birds Convention Act, 1994* and National Wildlife Areas established under the *Canada Wildlife Act*. The bulk of these conservation areas (9 of 13) were created in the 1950s and 1960s to protect nesting and staging areas of Ross's Geese *Chen rossii* and Snow Geese *Chen caerulescens*. The remaining four were established to protect seabird colonies. Two of three new National Wildlife Areas that will be established in Nunavut in the near future (Akpait and Qaqulluit) will also protect seabird colonies and the other (Niginganiq) will protect bowhead whale habitat. No Migratory Bird Sanctuaries or National Wildlife Areas have yet been designated in Nunavut or the Northwest Territories for the protection of shorebird nesting or staging habitat, although most species of North American shorebirds breed in the Arctic (Godfrey 1986). While some of the larger bird sanctuaries provide *de facto* protection for wetlands, none were created expressly to conserve all components of wetland ecosystems. These two elements (shorebird nesting/staging habitat and wetlands) represent significant gaps in the conservation area network in the Northwest Territories and Nunavut (Canadian Wildlife Service 1993; Canadian Wildlife Service 2006). An analysis of key migratory bird habitat sites carried out in 1992 concluded that Prince Charles Island and Air Force Island should be a priority for designation as a National Wildlife Area (Canadian Wildlife Service 1993). However, because the islands' status as a key site was based on limited field studies, the analysis also called for further field assessment before any National Wildlife Area proposal was developed.

The main objective of this study was to assess the suitability of the islands for National Wildlife Area status. With the exception of Morrison's (1997) shorebird survey carried out in 1989, virtually no ground-based bird studies had been completed on the islands prior to this one. This study furnished up-to-date information for shorebirds, waterfowl, and Sabine's Gull *Xema sabini*. Specifically, we investigated the following:

- distribution and abundance of breeding birds on the islands, by habitat type and by geographic location;
- distribution and density of shorebirds, waterfowl, and Sabine's Gulls, including a comparison of the results with the results from surveys 8 and 13 years previous; and
- breeding shorebird abundance and species richness on the islands and other sites across the Arctic.

2. Study area

Prince Charles Island (9945 km^2) and Air Force Island (1612 km^2) [67°30′N, 76º00′W] are located in Foxe Basin, Nunavut (Fig. 1). They are the largest and southernmost of a group of islands in northwestern Foxe Basin. Prince Charles Island is the largest uninhabited island south of the Canadian Arctic Archipelago (Johnston 2005).

The most striking feature of the islands' physiography is their flatness. The islands are relatively young landforms, which have been undergoing isostatic uplift since the disappearance of the Pleistocene ice sheets (Gaston et al. 1986). The island coastlines have emerged from the sea in only the last 2000 years, and raised beach features are very common on the west side of Prince Charles Island. Both islands are bounded by wide intertidal flats and low-lying salt marshes backed by large expanses of marshy tundra. On Air Force Island, marshy tundra of various forms extends across the island. Prince Charles Island includes an interior zone of unvegetated broken shale and a number of large lakes. As uplift continues, the barren centre of the island will expand outward and new areas of wetland will form (Andrews 1974). The islands are morphologically similar to the Great Plains of the Koukdjuak on the west coast of Baffin Island.

Climate on the islands is greatly influenced by the waters of Foxe Basin. The basin is relatively shallow, and the ice pack remains in motion throughout the winter (Stirling and Cleator 1981). Along most of the islands' coasts, shorefast ice persists until July, and Foxe Basin as a whole is not usually navigable until late August or September (Markham 1986). However, along the northern side of Prince Charles Island, a polynya forms around January, and a persistent lead opens southeast of the island in March. This lead opens to a polynya southeast of Prince Charles Island and south of Air Force Island (Stirling and Cleator 1981). Ice in Foxe Basin keeps coastal areas significantly cooler than inland sites (Maxwell 1986). Snowmelt occurs in the last half of June. Temperatures are above freezing on most days in the latter part of June, July, and the first half of August.

The islands were apparently little used by Inuit historically or in recent times. Neither island has a specific name in Inuktitut (Crowe 1969; J. MacDonald, pers. comm.). Oral history and land use studies show that the islands were lightly used in the past by people from Igloolik and Hall Beach hunting for barren-ground caribou *Rangifer tarandus groenlandicus*, but not now (Riewe 1992; J. MacDonald, pers. comm.). No lands owned by Inuit on the islands were selected as part of the Nunavut Land Claims Agreement (Riewe 1992).

The islands were first charted on maps in 1948 after they were sighted from the air by Royal Canadian Air Force personnel (Anonymous 1948). Since then, the islands have been visited infrequently, and only a few biological studies were undertaken there before the present study. Vascular plant collections were made on the northern and southern tips of Prince Charles Island and on the Fee Peninsula of Air Force Island (Baldwin 1953). Fifty-four species of plants were identified in comparison with 73 species on the Great Plains of the Koukdjuak, Baffin Island (Kerbes 1969), and 64 at Igloolik Island, northern Foxe Basin (Lewis and Belyea, unpubl. manuscript[1]). The known flora is very similar to that of the Great Plains of the Koukdjuak.

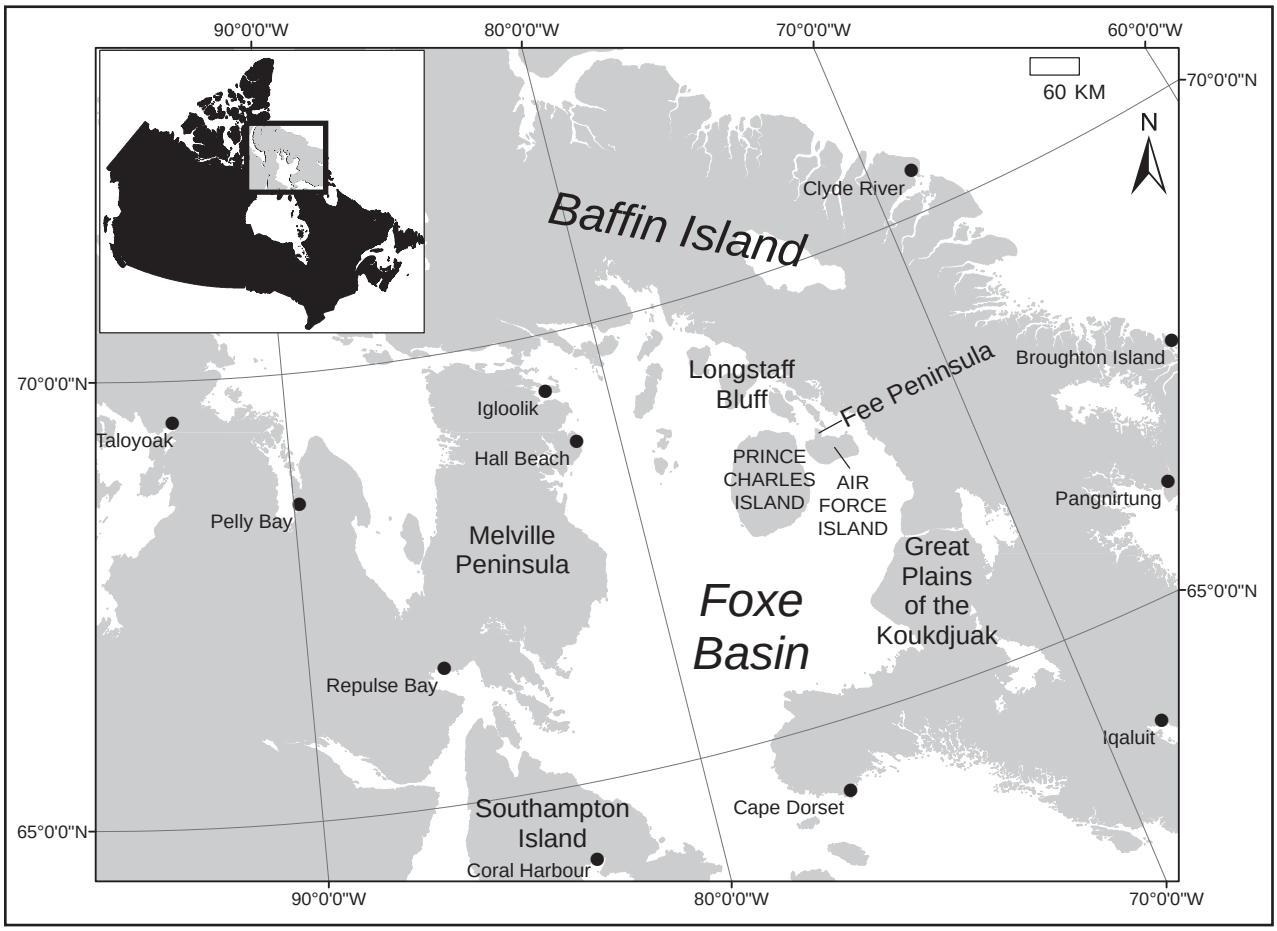
Notes on presence/absence and breeding status of birds were recorded by Ellis and Evans (1960) during the cruise made by Baldwin (1953) at the same locations where Baldwin collected plants. Aerial surveys for waterfowl and other large birds were undertaken in 1979 (Reed et al. 1980) and again in 1984 (Gaston et al. 1986). The surveys showed that both islands hosted high densities of the Atlantic subspecies of Brant *Branta bernicla hrota* and Sabine's Gulls (Gaston et al. 1986). In 1989, a habitat classification for Prince Charles Island was developed from satellite imagery and ground control points (Morrison 1997). The classification was developed to aid in the estimation of the populations of shorebird species across the island. The classification divided the island into three major terrestrial habitat types: graminoid, tundra, and barren. Graminoid habitats, which include wetlands dominated by grass, sedge, or moss and saltmarshes, account for nearly half of the area. The island contains some of the most extensive tracts of productive wetlands in Nunavut. Sparsely vegetated and unvegetated habitats cover approximately 40% of the total land area. Dwarf shrub tundra is uncommon and covers only 10% of the island. An interesting feature of Prince Charles Island is the series of beach ridge complexes (alternating beach ridge and wetland areas) that run the length of the west coast. Ground surveys and extrapolations from habitat-based densities highlighted the importance of Prince Charles Island, particularly the wetlands and beach ridge complexes, to breeding shorebirds (Morrison 1997).

[1] Lewis, M.; Belyea, D. [no date]. The vegetation of Igloolik Island. unpubl. manuscript. Dept. of Biology, York University, Toronto, Ont.

Prince Charles Island is a significant winter denning area for polar bears *Ursus maritimus*. Snow and earth dens are found on eskers throughout the island, with a concentration in the southwest. In late summer and in autumn, polar bears retreat to the island to await the formation of landfast ice in Foxe Basin. In any given year, between 200 and 350 bears probably use the island (M. Taylor, pers. comm.).

Barren-ground caribou live on the islands, and their numbers appear to fluctuate from year to year as they move to and from adjacent islands, including Baffin Island (Riewe 1992). Arctic foxes *Alopex lagopus* are quite numerous, particularly in and immediately after years of lemming cycle peaks (Martin 1998). Both collared lemmings *Dicrostonyx torquatus* and brown lemmings *Lemmus sibiricus* are present. Over the two years of the study, only 12 barren-ground caribou and one Arctic hare *Lepus arcticus* were seen, and there was one observation of Arctic wolf *Canis lupus arctos* scat. No other terrestrial mammals have been recorded recently from the islands.

Figure 1
Regional setting of Prince Charles Island and Air Force Island



3. Methods

3.1 Weather

We wanted to examine weather patterns over the entire breeding season in 1996 and 1997, and in 1989, the year of Morrison's study, but we did not have this information for portions of the breeding season when we were not present on the island. We compared graphs of mean, minimum, and maximum daily temperatures during the field survey period for weather stations at our base camps on Prince Charles Island with data from Igloolik and Hall Beach (approximately 210 km to the northwest on Melville Peninsula) and from Longstaff Bluff (110 km to the north on Baffin Island). We concluded that temperature patterns from the Longstaff Bluff station most closely matched those of the Prince Charles Island data. We therefore used data for Longstaff Bluff for further weather comparisons.

3.2 Survey design

We conducted ground surveys on Prince Charles Island in 1996 and 1997 and on Air Force Island in 1997. The emphasis during the ground surveys was on shorebirds, although all species were recorded. Most surveys in 1996 and all surveys in 1997 were conducted in sample plots. Some transect surveys were also conducted in 1996.

We conducted aerial helicopter surveys for larger bird species in 1996 on Prince Charles Island and in 1997 on Air Force Island. We particularly wanted to get population data for waterfowl and Sabine's Gulls.

Dates and locations of data collected are presented in Appendix 1.

3.2.1 Plot sampling

Sample plots were systematically covered by a pair of observers, who moved through the plot in straight-line transects. This hybrid method combines the advantages of line transects and plot searches (Edwards et al. 1981; Bibby et al. 1993). This method permitted us to sample a considerable area yet maintain a higher detectability for secretive species. It is also easier to sample homogeneous areas of a single habitat type in a plot configuration than it is in long line transects.

We employed a stratified random design (strata = Graminoid/Moss Lowlands, Dry Vegetated Tundra, and Unvegetated/Barren Tundra, in a ratio of 6:3:1) to place sample plots throughout the study area (Fig. 2). Plot locations were stratified by suitability of habitat type (i.e., more plots placed in wetlands and esker complexes). Over two years, we surveyed a total of 85 plots (34 plots in 1996 and 51 plots in 1997) 400 × 400 m each (for a total of 1360 ha). The 51 plots in 1997 were made up of 13 of the 34 plots from 1996 and 38 new plots. We re-surveyed the 13 plots in order to get a sense of between-year variations in bird distribution and abundance at the scale of individual plots.

In both 1996 and 1997, we placed a numbered, flagged bamboo stake or a flagged stone cairn at one corner of each plot so it could be relocated at a later date. Coordinates of all plot corners were recorded by GPS. Together with sketch maps and descriptions, these coordinates were later used to superimpose plot outlines on Morrison's original classified maps and our modified classification of the islands. Pairs of observers surveyed each 400 × 400 m plot by walking along parallel lines 25 m apart. We chose 25 m because previous studies showed that inter-observer distances of 50 m fail to detect some incubating shorebirds (Gratto-Trevor 1994; V. Johnston, unpubl. data). Observers paused every 50 m to check their headings with compasses, to scan the area around them, to listen for birds, and to update their sketch maps. All species observations were recorded. Birds seen outside the plot or flying overhead were recorded for inclusion in the Northwest Territories/Nunavut Bird Checklist Survey database.

3.2.1.1 Shorebird counts within plots

We determined the breeding status of individual shorebirds on the basis of their behaviour, numbers seen together, and the breeding system of that particular species. For bi-parental incubating species (Ruddy Turnstone *Arenaria interpres* (Nettleship 2000), Baird's Sandpiper *Calidris bairdii* (Moskoff and Montgomerie 2002), Semipalmated Plover *Charadrius semipalmatus* (Nol and Blanken 1999), Black-bellied Plover *Pluvialis squatarola* (Paulson 1995), American Golden-Plover *Pluvialis dominica* (Johnson and Conners 1996), Dunlin *Calidris alpina* (Warnock and Gill 1996), Semipalmated Sandpiper *Calidris pusilla* (Gratto-Trevor 1992), and Purple Sandpiper *Calidris maritima* (Payne and Pierce 2002)), two birds that remained in close proximity or one bird displaying on its own counted as one breeding pair. For uni-parental species (White-rumped Sandpiper *Calidris fuscicollis* (Parmelee 1992), Pectoral Sandpiper *Calidris melanotos* (Holmes and Pitelka 1998), and Red Phalarope *Phalaropus fulicarius* (Tracy et al. 2002)), a lone displaying adult counted as one indicated breeding pair. "Display" included distraction displays, alarm calls, territorial displays, and skulking. Any bird not displaying

Figure 2
Plot and transect locations on Prince Charles Island and Air Force Island, 1996 and 1997 (remotely-sensed habitat classification developed by Morrison (1997)). a. Morrison's original 17-class classification. b. Our grouping of 17 classes into 4 (3 terrestrial, 1 water), including the coastal mudflats (see section 3.3 for details). The colour scheme in part a has been modified from the one used in Morrison (1997), and our plot and camp locations have been added.

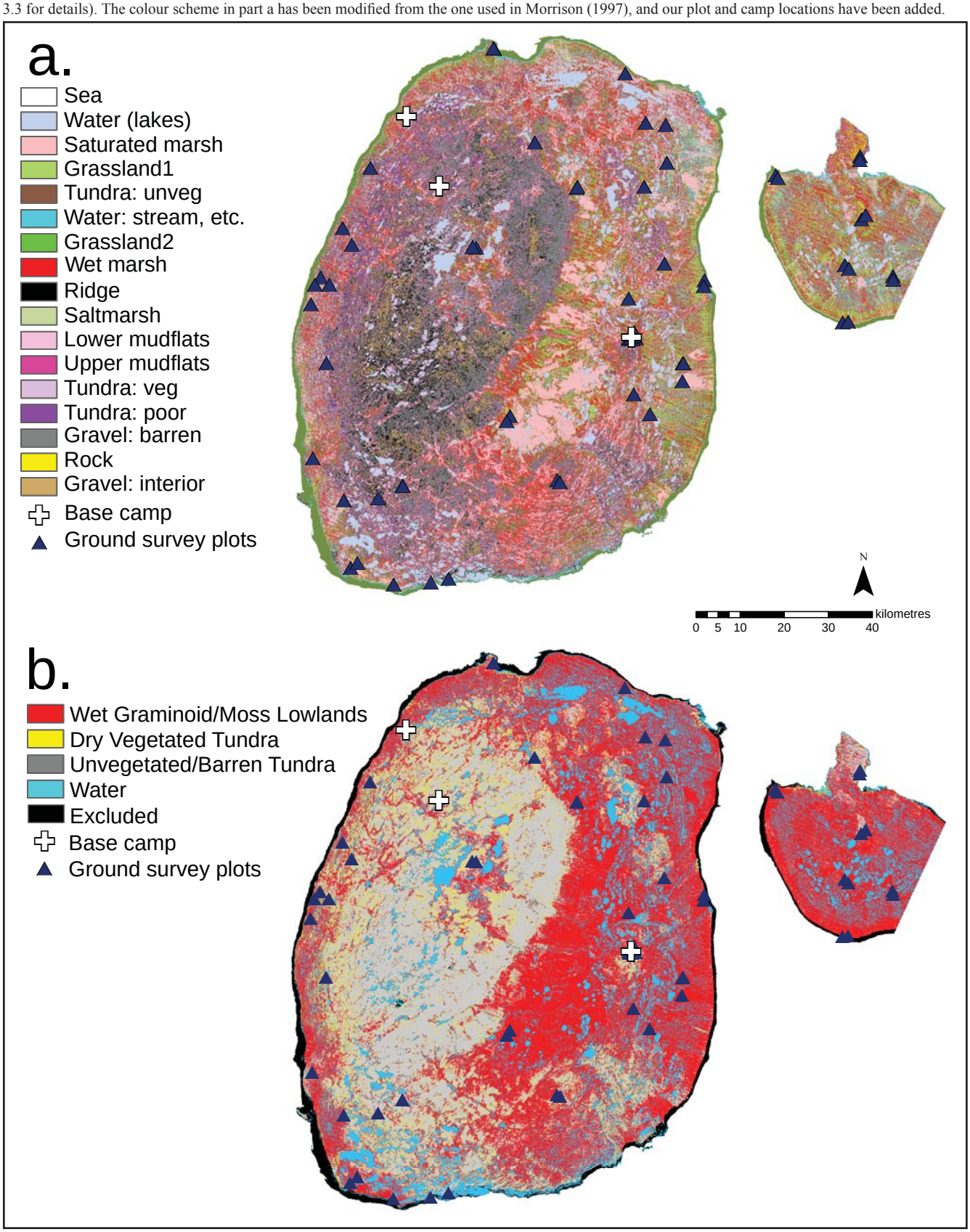


Figure 2a adapted from Figure 2 on page 60 of "The use of remote sensing to evaluate shorebird habitats and populations on Prince Charles Island, Foxe Basin, Canada" by R.I.G. Morrison, *Arctic* 50 (1997). Reproduced with permission of the Arctic Institute of North America.

or not observed as part of a pair was counted as an individual. The "individual" bird category does not include birds already recorded as pairs.

This method of classifying breeding status will result in a conservative estimate of breeding activity, because some breeding birds will likely not exhibit the behaviours described above. Conservative estimates were appropriate for our objectives of 1) calculating a minimum estimate of breeding pairs of each species in the study area and 2) comparing breeding activity between 1996 and 1997.

Numbers of both individual birds and indicated breeding pairs were used to calculate density indices. For non-shorebird species, we recorded only total numbers of birds in ground survey plots. Breeding information was collected for selected species during aerial surveys (see section 3.2.3).

3.2.2 Transect surveys

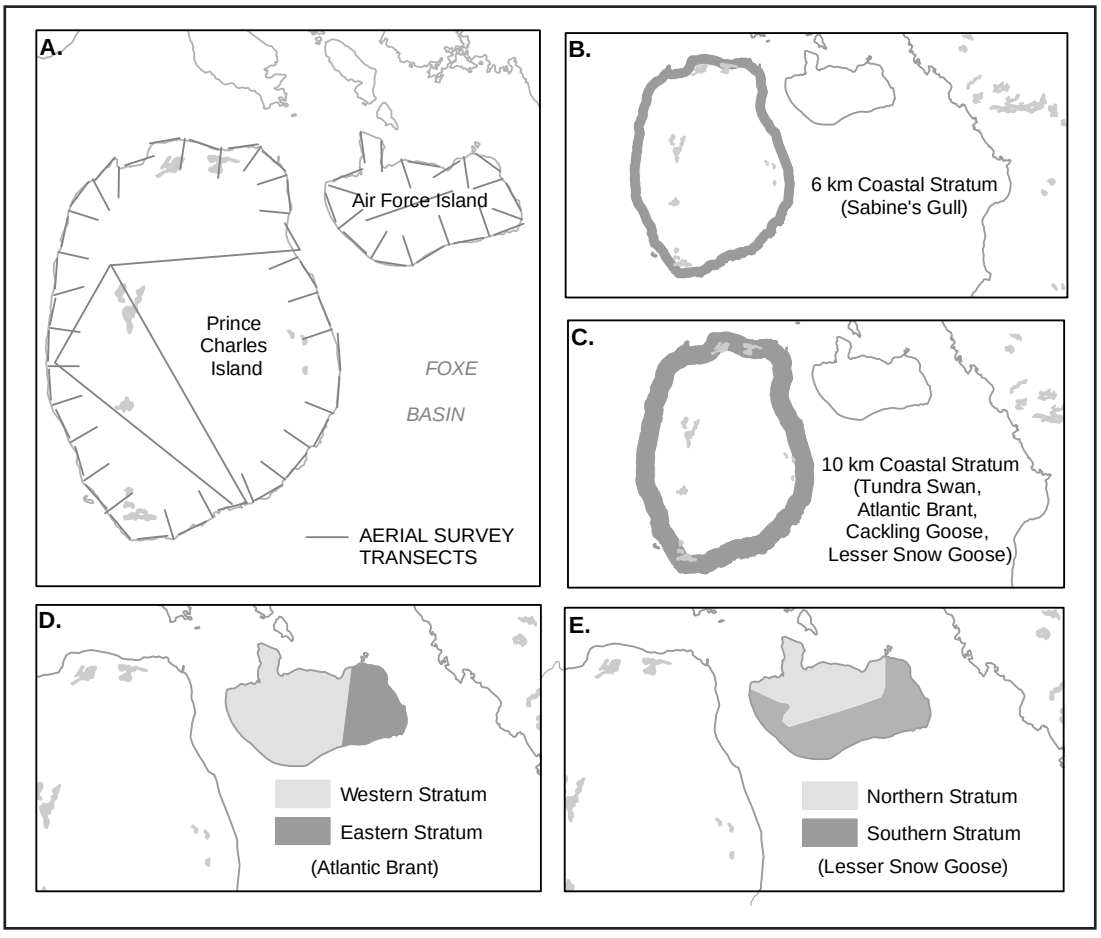
In 1996, there was not enough snow-free ground to allow plots to be surveyed until near the end of June. Prior to that date we conducted transect surveys on Prince Charles Island wherever there was enough bare ground to do so (mostly on beach ridges on the northwest coast). Transects were surveyed by two observers walking 25 m apart for a total transect width of 50 m. Transect length varied according to the amount of bare ground present. Forty-four transects (total area of 248 ha) were surveyed.

3.2.3 Aerial surveys

We conducted helicopter surveys for larger bird species on Prince Charles Island on 3, 4, and 6 July 1996 and on Air Force Island on 5 July 1997. Transects were laid out on each island so that the coast was nearly completely surveyed, a zone from 0 to 10 km inland from the coast was surveyed at a lesser intensity, and the island interior was lightly surveyed (Fig. 3A). The islands were stratified in various ways for density and population calculations, depending on the distribution of the species (Figures 3B to 3E). Transects were 10 km in length, except for interior transects, which were of variable length (Fig. 3A). All transects were subdivided into 2-km segments to permit easy stratification of the data in analyses. Surveys were flown at a height of approximately 45 m above the ground at a speed of 80–90 km/h. The transect width was 200 m on either side of the aircraft for a total transect width of 400 m.

Two observers (one in the front and the other in the rear behind the pilot) counted all of the birds that they observed and recorded the time of the observation. The pilot called out each 2-km segment, which was also recorded. To avoid double-counting, special note was made of birds that were moving from one observer's line of sight toward the other observer. Only birds within an observer's transect zone (200 m) were counted by that observer. Pairs of birds and single birds were recorded for Tundra Swan *Cygnus*

Figure 3
Aerial survey transects and strata for Prince Charles Island (surveyed 3, 4, and 6 July 1996) and for Air Force Island (surveyed 5 July 1997)



columbianus, Cackling Goose *Branta hutchinsii*, Atlantic Brant, and King Eider *Somateria spectabilis*. For all other species, only individuals were recorded.

3.3 Habitat sampling and classification

We used Morrison's (1997) habitat classification of Prince Charles Island and Air Force Island (Fig. 2a). This classification was based on a July 1985 satellite image and on subsequent ground-truthing conducted in July 1989. As Morrison had developed the classification as a tool for remote sensing of shorebird habitats, it was well suited to our purposes.

The eastern 30% of Air Force Island was not covered by Morrison (1997). To classify habitat in this area, we extrapolated proportionately from Morrison's (1997) classification to obtain types and amounts of habitat there. Overflights of the island in 1996 confirmed that the composition of the habitat in this part of the island was similar to the habitat in the portion covered by the satellite image. The only exception was the unique outcrop habitat that comprises the Fee Peninsula on the northwestern tip of Air Force Island. This habitat type was not extrapolated to the portion of the island outside the satellite image.

Morrison's classification provided us with *a priori* knowledge of the islands' habitat composition. We stratified the area according to Morrison's classification prior to selecting plot locations.

We sampled habitat and collected botanical specimens during the bird surveys. Sixty-three species of vascular plants were identified from Prince Charles Island and Air Force Island (Appendix 2). One person recorded habitat variables at the beginning of each survey plot or transect and thereafter when there was a marked change in one of the variables. Habitat types were identified on the basis of dominant vegetation type (species), surficial expression, vegetation cover (%), and amount of ground moisture (Table 1); habitat types are listed in Table 2. Each observer drew a sketch map defining the location of habitat types in a plot and the location and behaviour of birds that were observed. The location and extent of lakes, streams, and ponds were also drawn. Each evening, observers consolidated their data to produce a single map of the plot and a list of birds observed in each habitat type.

We surveyed and classified a total of 1360 ha of the islands' combined area of 1 155 754 ha (0.1%) in 1996 and 1997. We developed a classification of 12 habitat types based on ground survey data and compared this classification to Morrison's (1997) classification. In most cases, the habitat we observed corresponded well with types distinguished in Morrison's classification (Table 2). There were three major differences. We did not distinguish between two types of moss-dominated wetlands described in Morrison (1997), we sampled a Dry graminoid tundra type that is not noted in Morrison's (1997) classification, and areas that we classed as Saltmarsh often appeared as tidal flats on the 1989 classified image. We eliminated the mudflats habitat type from further consideration as it was not a habitat type that was actually available for nesting (i.e., it was more or less inundated by seawater).

We grouped the 11 remaining types into three land classes (Wet Graminoid/Moss Lowlands, Dry Vegetated Tundra, and Unvegetated/Barren Tundra) and two water classes (permanent Ponds/Lakes and ephemeral water (Standing Water)) (Table 3; Fig. 2b). These classes correspond to the major groupings of terrestrial habitat in Morrison's (1997) satellite classification.

Table 1
Habitat variables recorded on Prince Charles Island from 24 June to 14 July 1996 and 26 June to 15 July 1997 and on Air Force Island from 1 to 9 July 1997

Habitat Variable	Description
Location	Latitude and longitude, determined by GPS
Weather	Estimates of temperature, cloud cover, wind speed, and amount and type of precipitation
General aspect	Overall description of surrounding area, including prominent landmarks, e.g., "Low flat area with intermittent large ponds and many recently dried up runoff ponds"
Surficial expression	Categories: hummocky, tussocky, polygons, low and flat, raised, beach ridge, rock outcrop, esker, interrupted, other (describe)
Substrate	Categories: clay, sand, gravel, bedrock, mineral soil, peat, other (describe)
Substrate moisture	Categories: standing water, saturated, moist, dry
Percentage of vegetative cover	Estimates of total vegetative cover on the ground, to the nearest 5%
Percentage covered by water	Estimates of the coverage of the plot by water bodies (flooded terrestrial vegetation is not included in this estimate)
Dominant species	Plant species that make up >20% of vegetative cover, with an estimate of their percentage coverage to the nearest 5%
Other species present	Species present but not dominant

Total area of the habitat classes within plots differed between the satellite classification carried out by Morrison (1997) and our ground classification. The differences were mainly in the amounts of standing water, of dry vegetated habitat (Dry Vegetated Tundra), and of unvegetated habitat (Unvegetated/Barren Tundra) that were calculated (Table 3). The discrepancy in total amount of vegetated and unvegetated habitats may have resulted because Morrison defined and measured the amount of vegetation coverage differently. Morrison's (1997) totals for Dry Vegetated Tundra and Unvegetated/Barren Tundra are virtually identical to our totals. Since our ground classification was done in June, it would be expected to show more standing water than Morrison's (1997) classification, which was based on a July image.

Wet Graminoid/Moss Lowlands is the class of most interest to shorebird populations, and there was reasonable concordance between ground observations and satellite classification for this habitat class. We therefore decided to use the image classification to derive habitat totals for the complete study area (Table 4) and to make direct comparisons between this study and Morrison's (1997) study.

3.4 Analyses of bird distribution and calculation of population estimates

3.4.1 Ground surveys

3.4.1.1 Bird density

We calculated densities of bird species (number of birds per km^2) and standard errors (SE) based on the plots within each stratum (plot densities). Plot densities were

Table 2
Correspondence between this study's ground habitat classification and the classification of Morrison (1997)

Habitat type (this study)	Combined habitat class (common to both studies)	Characteristics				Corresponding habitat type in Morrison (1997)
		% Vegetation	Dominant vegetation type	Moisture	Other	
Grassland	Wet Graminoid/Moss Lowlands	Most >80%	Grasses ≥ moss	Saturated to standing		Grassland1
Sedge marsh	Wet Graminoid/Moss Lowlands	>50%	Sedges ≥ moss	Saturated to standing	Can be hummocky	Wet marsh
Wet graminoid marsh	Wet Graminoid/Moss Lowlands	Most >80%	Graminoids ≥ moss	Saturated to standing		Grassland1
Saltmarsh	Wet Graminoid/Moss Lowlands	>50%	*Puccinellia, Carex ursina, Stellaria humifusa*	Most saturated		Saltmarsh
Wet moss marsh	Wet Graminoid/Moss Lowlands	>80%	Mosses at least 25% > graminoids	Saturated to standing		Saturated marsh, Grassland2
Dry graminoid tundra	Dry Vegetated Tundra	Most >80%	Graminoids ≥ moss	Moist		none
Dry moss tundra	Dry Vegetated Tundra	>50%	Mosses at least 25% > graminoid	Moist to dry		Tundra: veg
Vegetated tundra	Dry Vegetated Tundra	≥50%	Dwarf shrub dominant, occasional graminoids or moss	Moist to dry	Often on ridge slopes	Tundra: veg
Unvegetated/rocky tundra	Unvegetated/Barren Tundra	>20%, <50%	Dwarf shrub, moss	Mixed		Tundra: unveg and Tundra: poor
Beach ridge top	Unvegetated/Barren Tundra	<20%	Dwarf shrub	Dry		Ridge
Barrens	Unvegetated/Barren Tundra	<20%	Dwarf shrub	Dry		Gravel: barren and Gravel: interior and Rock
Mudflats	Unvegetated/Barren Tundra	<20%	Grasses, dwarf shrub	Mixed		Lower mudflats and Upper mudflats

Table 3
Area of habitat types in 1997 survey plots on Prince Charles Island and Air Force Island, as determined by satellite classification (Morrison 1996)[a] and ground classification in 1996 and 1997[b]

	1997 plots (ha)			
	Satellite		Ground	
Habitat class	Number of hectares	%	Number of hectares	%
Wet Graminoid/Moss Lowlands	471	60	421	53
Dry Vegetated Tundra	32	4	174	22
Unvegetated/Barren Tundra	225	28	70	9
Ponds/Lakes	11	1	5	1
Standing Water	50	7	119	15
Total	789	100	789	100

[a] Landsat TM image Path 25, Row 12, recorded on 19 July 1985.
[b] Ground habitat data collected on Prince Charles Island from 24 June to 14 July 1996 and 26 June to 15 July 1997 and on Air Force Island from 1 to 9 July 1997.

Table 4
Total area (excluding mudflats) of the three major habitat groups and two water classes on Prince Charles Island and Air Force Island[a]

	Prince Charles Island		Air Force Island		Prince Charles Island and Air Force Island combined	
Habitat Class	ha	%	ha	%	ha	%
Wet Graminoid/Moss Lowlands	402 230	40	111 355	69	513 585	45
Dry Vegetated Tundra	59 528	6	1 155	1	60 683	5
Unvegetated/Barren Tundra	353 293	36	8 546	5	361 839	31
Lakes	114 110	11	11 609	7	125 719	11
Other Water	65 373	7	28 555	18	93 928	8
Total	994 534	100	161 220	100	1 155 754	100

[a] Derived from pixel counts of Morrison's (1997) remote habitat classification of Prince Charles Island and part of Air Force Island. Habitats on the remainder of Air Force Island were calculated as the total area of the remainder × the percentage of that particular habitat type on the classified portion of the island. Outcrop habitat was not extrapolated because it does not occur on the remainder of the island.

calculated for our 11 observed habitat types and for the three combined habitat classes. We excluded classes that were composed of permanent and ephemeral water from the analysis, because we were interested in estimating density per hectare of actual nesting habitat. We calculated weighted mean densities of birds in each of three combined habitat classes, where *n* is the number of habitat-plots in a given habitat type (some plots contained more than one habitat type). Densities were weighted by number of hectares sampled to create unbiased means. In that way, a bird seen in a small piece of habitat would not have an undue influence on mean density.

Our impression was that bird densities differed between 1996 and 1997 and between plot surveys and transect surveys. We conducted Mann-Whitney *U* tests to determine how the data should be combined for analysis. We also tested to see if 1997 data from the two islands could be combined. The tests produced more significant differences between years and survey types than one would expect purely by chance at the 0.05 significance level (plots versus transects: 16 significant differences/69 tests = 0.23; 1996 plots versus 1997 plots: 8 significant differences/69 tests = 0.12). There were no significant differences between data from the two islands (4 significant differences/69 pairs = 0.05). Therefore, 1997 plot data from both islands were analysed together; data from 1996 and

from transects were analysed separately. Only 1997 plot data were used to calculate population estimates.

The overall mean weighted density for each species was calculated using the following equation:

$$\text{weighted mean density} = \frac{(\text{mdwt} \times \text{area wet}) + (\text{mdvt} \times \text{area tundra}) + (\text{mdbt} \times \text{area barren})}{\text{total area}}$$

where
area = number of pixels of area 25 m² in the study area
mdwt = mean density in Wet Graminoid/Moss Lowlands
mdvt = mean density in Dry Vegetated Tundra
mdbt = mean density in Unvegetated/Barren Tundra

3.4.1.2 Habitat preferences

We analysed the data to determine if birds (particularly shorebirds) were preferentially using some habitats on Prince Charles Island and Air Force Island. The habitats used by common bird species were compared. Specifically, use of the five wet graminoid habitat types (Grassland, Sedge marsh, Wet graminoid marsh, Saltmarsh, and Wet moss marsh), of the three dry vegetated tundra habitat types (Dry graminoid tundra, Dry moss tundra, and Vegetated tundra), and of the three unvegetated tundra habitat types (Unvegetated/rocky tundra, Beach ridge top, and Barrens) (Table 2) was compared. For less numerous species, analyses were restricted to the three major habitat classes (i.e., Wet Graminoid/Moss Lowlands, Dry Vegetated Tundra, and Unvegetated/Barren Tundra). We performed chi-square tests (1997 plot data from both islands combined) to test for differences among habitat types and then applied the technique of Neu et al. (1974) to determine preference for or avoidance of a given habitat. The sample unit for shorebirds was indicated breeding pairs (see section 3.2.1); the sample unit for all other species was individuals.

3.4.1.3 Population estimation

We estimated the total combined population for Prince Charles Island and Air Force Island for a given species by multiplying the weighted mean density (pairs or individuals per hectare) by the total area of the islands (1 155 754 ha). We also calculated population estimates and 95% confidence intervals for each island separately and for each of the three combined habitat classes (Wet Graminoid/ Moss Lowlands, Dry Vegetated Tundra, and Unvegetated/ Barren Tundra). We used coefficients of variation (CV) as a measure of precision of our population estimates. A CV of 0.20 or lower is considered reasonable for ecological studies (Krebs 1999).

Morrison (1997) maintained that shorebird populations on Prince Charles Island were more accurately estimated by modelling for distance from the coast. We also investigated this possibility by running linear regression analyses of habitat-specific bird densities against distance of plot (plot-habitat combinations; $n = 69$, 1997 plots only) from the coast. We used the three combined habitat classes, and distance from the coast was measured in pixels. Modelling did not improve the population estimates. In 1997, only Ruddy Turnstone individual densities in the Wet Graminoid/Moss Lowlands habitat class were significantly related to distance from the coast ($t = -2.17$, $P = 0.036$). However, the slope of the resulting regression equation was very small ($b = -0.0001$). This small slope would produce a small reduction in density (e.g., at 20 km inland, densities would be reduced by only 0.7 birds/km²), so no modelling was undertaken. No other species densities were significantly related to distance from the coast.

3.4.2 Aerial surveys

We calculated densities, population estimates, and standard errors of large bird species in the survey area using the Ratio Method (Jolly 1969 *in* Krebs 1999) for transect sampling with unequal transect lengths. Prior to calculating population estimates, we stratified the islands according to the density and distribution of each species, as depicted in Figure 3.

3.5 Changes in bird populations over time

3.5.1 Shorebirds

We compared the 1997 plot survey results with those from Morrison's 1989 study on the basis of shorebird pair densities and species population estimates. We used only data from Prince Charles Island so that we could do a direct comparison with Morrison's (1997) earlier study, which did not include Air Force Island.

We compared each species' population estimates with those of Morrison's (1997) by using weighted mean densities for the three combined terrestrial habitat classes (Table 2; Fig. 2). We examined the occurrence and magnitude of overlaps in the confidence intervals of this study's population estimates and Morrison's (1997) population estimates. If the overlap was less than 25% (Van Belle 2002), we considered the estimates to be significantly different from each other.

3.5.2 Waterfowl and gulls

An aerial survey of large birds of Prince Charles Island and Air Force Island was undertaken in 1984 by Gaston et al. (1986). They published maps with density "zones" (birds per kilometre) along the islands' coasts for a number of large bird species. We developed similar maps using the coastal transect data from the aerial surveys, and we looked for changes in distribution patterns that might have occurred in the 13-year interval between the two studies.

3.6 Comparison with other breeding locations in the Arctic

To determine the relative importance of Prince Charles Island to individual shorebird species and the shorebird community *in toto*, we compared our population densities with those reported in the literature for other sites that are within the breeding range of a given species (Appendix 3).

To improve the comparison, we narrowed the breeding locations to mid-Arctic sites that had a similar breeding species component and had been surveyed using multi-year, systematic, plot-based methods. In most cases, data from June and early July were used in order to ensure the best possible comparison with this study.

4. Results

4.1 Weather

There were major differences in weather conditions at our base camps on Prince Charles Island in 1996 (19 June to 16 July) and 1997 (24 June to 16 July). In 1996, the survey period was cooler, sunnier, and less windy than in 1997 (Table 5). Snow cover in 1996 was greater than 90% upon our arrival, and it persisted until the end of June, when rapid melting caused flooding over much of the island. In contrast, there was very little (<5%) snow upon our arrival on 24 June in 1997, and meltwater had drained off of the land.

Table 5
Weather conditions on Prince Charles Island, 19 June to 16 July 1996 and 24 June to 16 July 1997[a]

	Parameter			
Year	Mean daily minimum temperature (°C)	Mean daily maximum temperature (°C)	Mean daily wind speed (km/h)	Mean daily cloud cover (%)
1996	1.9	7.8	5.9	20.6
1997	5.0	9.3	19.1	54.0

[a] Weather data courtesy J-L Martin.

We compared mean daily temperatures from the weather station at nearby Longstaff Bluff on Baffin Island over the 1989, 1996, and 1997 breeding seasons (1 June to 31 August). The warmest season was 1997 and the coolest was 1996; 1989 fell between these two (Fig. 4).

For analysis, we divided the summer breeding season into four periods: pre-laying (1 to 15 June), incubation (16 June to 15 July), brood-rearing (16 July to 7 August), and post-fledge (8 to 31 August). We performed Wilcoxon Signed Rank tests to determine which parts of the breeding season showed significant differences in temperature from the 26-year mean. In 1996, the pre-laying period was significantly colder ($P < 0.05$) than the 26-year mean; in 1997, this period was significantly warmer than the 26-year mean. Temperatures during the incubation period were not significantly different from the 26-year mean in any year. The brood-rearing period in 1996 and the post-fledge period in 1997 were significantly colder than the 26-year mean.

4.2 Ground surveys

4.2.1 Species composition

A total of 42 bird species was recorded during field work in 1996 and 1997. We confirmed breeding for 25 of these (Appendix 4). We recorded 12 shorebird species (in decreasing order of abundance: Red Phalarope, White-rumped Sandpiper, Ruddy Turnstone, American Golden-Plover, Black-bellied Plover, Dunlin, Semipalmated Sandpiper, Purple Sandpiper, Pectoral Sandpiper, Baird's Sandpiper, Semipalmated Plover, and Red Knot *Calidris canutus rufa*) (Fig. 5). We confirmed breeding for the first 7 species. We believe that Red Knot and Purple Sandpiper were migrants on Prince Charles Island and Air Force Island in 1996 and 1997. Baird's Sandpiper and Pectoral Sandpiper likely breed on Prince Charles Island, but we could not confirm this. There is ample breeding habitat for Semipalmated Plovers on Prince Charles Island, but our observations of Semipalmated Plovers were all off-transect and too few to form any opinion regarding its breeding status. Red Phalaropes and White-rumped Sandpipers were observed most frequently (they were present in approximately half of all ground surveys).

Figure 4
Mean daily temperatures in the breeding season by period and the season as a whole for the years 1989, 1996, 1997, and 1970–1995 (26-year mean), Longstaff Bluff, Baffin Island

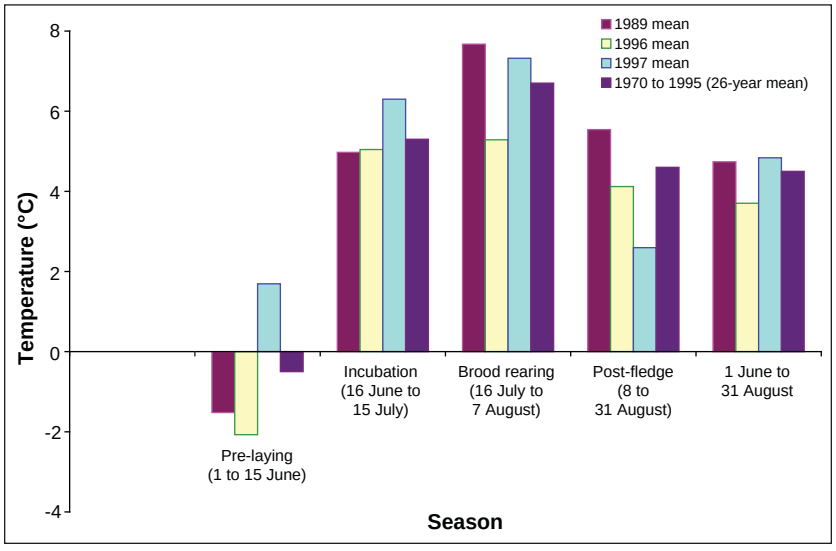
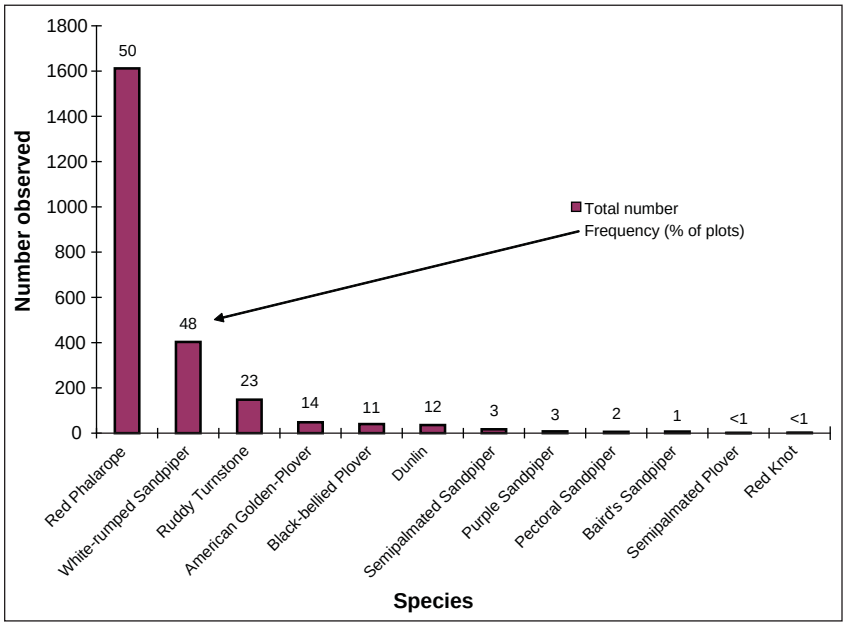


Figure 5
Total numbers (sum of 1996 and 1997 individuals) and frequencies of shorebird species observed in ground surveys carried out on Prince Charles Island from 24 June to 14 July 1996 and 26 June to 15 July 1997 and on Air Force Island from 1 to 9 July 1997



We recorded 30 non-shorebird species, 17 of them during ground surveys and 13 on the islands outside of surveys (off-transect) (Appendix 4). These observations include a breeding range extension for Ross's Gull *Rhodostethia rosea* obtained by our associate, J-L Martin, and his team in 1996 (Brechet et al. 2000). Lapland Longspurs *Calcarius lapponicus* were by far the most numerous non-shorebird species observed (Fig. 6) and were present in over half of all plots/transects. Sabine's Gull was the only other non-shorebird species that was observed on more than 10% of plots or transects. Lesser Snow Geese *Chen caerulescens caerulescens*, although present in extremely high numbers in one plot on Air Force Island (1113 individuals), were not frequently observed (Fig. 6).

4.2.2 Habitat use by birds

4.2.2.1 Shorebirds

Habitat use by shorebirds varied considerably among species and between years, depending on spring phenology. There was a late snowmelt in 1996, and that year we observed considerable "packing" of individuals into whatever habitat was available. Early in 1996, when there was very little bare ground, we obtained densities of more than 1000 birds/km^2 in some habitats (e.g., Red Phalaropes in Grassland habitat; Appendix 5a). Overall, shorebird densities were 2 to 21 times higher early in the 1996 season (on transects) than later in the season in 1996 (on plots; Appendix 5b) or at any time in 1997 (plots only) (Appendix 5c; Table 6). Shorebird densities in most habitats decreased in 1996 as the season progressed and more snow-free land became available.

We used the 1997 plot data to investigate habitat selection by shorebird species. As expected, Wet Graminoid/Moss Lowlands had far higher densities of all shorebirds (as a group) than either Dry Vegetated Tundra or Unvegetated/Barren Tundra (Table 6). Within the Wet Graminoid/Moss Lowlands class, the highest densities of shorebird pairs occurred in the Wet graminoid marsh and the highest densities of individuals occurred in the Sedge marsh habitat types (Appendix 5c). High densities of Red Phalarope pairs occurred in all wet graminoid habitat types except Grassland. White-rumped Sandpiper pairs occurred in highest densities in both wet graminoid (Wet graminoid marsh, Sedge marsh) and vegetated tundra (Vegetated tundra, Dry graminoid tundra) habitat types. Ruddy Turnstones also occurred in highest densities in wet graminoid (Wet graminoid marsh, Saltmarsh) and dry tundra (Dry moss tundra) habitat types. Black-bellied Plovers occurred in nearly equal densities in one wet graminoid (Wet moss marsh) and in one dry tundra (Vegetated tundra) habitat type. American Golden-Plovers occurred almost exclusively in Vegetated tundra. Few species were present in unvegetated habitats; surprisingly, the highest densities of Dunlin occurred in this habitat class (Unvegetated/Barren Tundra). We consider this to be a spurious result caused by birds that were observed beside a coastal pond in rocky tundra on Air Force Island. Shorebird species other than the ones discussed above were observed so infrequently that we could not establish their habitat use.

Generally, the density pattern of shorebird pairs was similar to the density pattern of individual shorebirds (Table 6). However, Ruddy Turnstones, White-rumped Sandpipers, and Red Phalaropes had much higher densities

Figure 6
Total numbers (sum of 1996 and 1997 individuals) and frequencies of common non-shorebird species observed in ground surveys carried out on Prince Charles Island from 24 June to 14 July 1996 and 26 June to 15 July 1997 and on Air Force Island from 1 to 9 July 1997

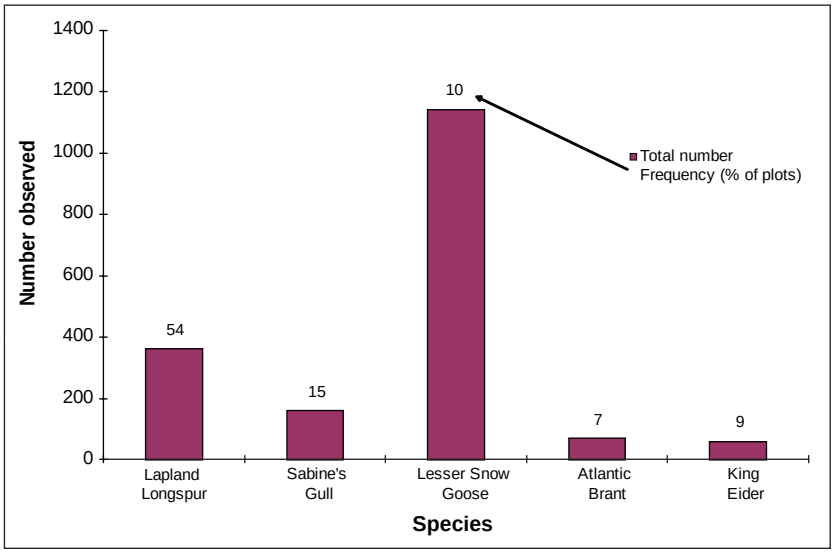


Table 6
Mean weighted densities of shorebird pairs and individuals (number/km^2 (SE)) and mean weighted densities of non-shorebird individuals (number/km^2 (SE)) in plots and transects, 1996 (Prince Charles Island only) and 1997 (Prince Charles Island and Air Force Island). Number of plots or transects surveyed in each year and number of plots or transects in which birds were found are shown in parentheses. Only plots were surveyed in 1997.

	Wet Graminoid/Moss Lowlands[a]							
	1996 transects (26)		1996 plots (33)		1997 (48)		1996 transects (29)	
Species	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals
Shorebirds								
Red Phalarope	157.9 (89.4)	494.2 (187.9)	26.0 (6.0)	136.7 (28.6)	23.3 (3.4)	60.0 (9.1)	17.1 (6.7)	49.9 (15.6)
White-rumped Sandpiper	46.9 (43.5)	70.8 (43.7)	5.4 (1.5)	29.4 (7.8)	11.0 (2.5)	35.1 (8.4)	3.4 (1.6)	20.0 (9.3)
Ruddy Turnstone ssp. *morinella*	3.1 (2.7)	12.1 (5.7)	12.6 (6.5)	24.6 (8.5)	2.7 (1.5)	4.4 (1.8)	5.4 (3.8)	23.6 (9.0)
American Golden-Plover	8.8 (8.5)	93.9 (75.2)	0.3 (0.3)	1.5 (1.3)	0	2.1 (2.1)	7.1 (4.7)	11.8 (5.1)
Black-bellied Plover	1.0 (1.0)	2.7 (1.5)	1.3 (0.9)	5.6 (2.9)	1.6 (1.4)	1.8 (1.5)	5.0 (4.5)	11.8 (9.1)
Dunlin ssp. *hudsonia*	4.8 (3.3)	25.8 (21.8)	0.2 (0.2)	1.2 (6.3)	1.2 (0.8)	2.0 (1.1)	3.2 (3.2)	6.3 (3.8)
Semipalmated Sandpiper	1.3 (1.3)	2.6 (2.6)	2.1 (1.5)	8.7 (5.8)	0	0	1.6 (1.6)	3.3 (3.3)
Pectoral Sandpiper	0	0	0	0	0.2 (0.2)	2.0 (0.4)	0	0
Baird's Sandpiper	0	0	0.8 (0.8)	3.8 (3.8)	0	0	1.6 (1.6)	1.6 (1.6)
Purple Sandpiper ssp. *maritima*	1.3 (1.3)	1.3 (1.3)	0	0	0.1 (0.1)	0.4 (0.4)	0	0
Red Knot ssp. *rufa*	0	0	0	0	0	0.4 (0.4)	0	0
Total	225.1 (131.0)	703.4 (247.8)	48.7 (9.2)	211.5 (85.0)	40.1 (6.2)	108.2 (16.7)	44.4 (11.4)	128.3 (37.2)
Non-shorebirds								
Lesser Snow Goose		0.5 (0.5)		0		172.7 (164.5)		7.5 (5.5)
Cackling Goose		4.9 (3.3)		1.1 (0.6)		0.9 (0.8)		6.7 (6.3)
Atlantic Brant		32.2 (31.9)		3.8 (2.2)		3.9 (3.5)		9.4 (6.5)
Sabine's Gull		11.4 (4.9)		18.6 (6.6)		9.5 (4.2)		2.9 (2.1)
King Eider		35.5 (25.7)		4.3 (1.3)		1.1 (1.0)		0.2 (0.2)
Long-tailed Duck		8.5 (4.7)		0.8 (0.5)		1.1 (0.7)		1.1 (1.1)
Pomarine Jaeger		0		1.1 (0.6)		3.1 (1.6)		1.4 (1.0)
Long-tailed Jaeger		0.2 (0.2)		0		1.6 (1.0)		5.8 (3.1)
Arctic Tern		3.2 (2.6)		0.5 (0.5)		0.9 (0.5)		5.4 (3.7)
Lapland Longspur		309.1 (220.8)		19.2 (5.6)		13.9 (2.8)		66.3 (15.0)
Snow Bunting		0		0		0		0
Total		351.1 (458.9)		48.9 (9.2)		44.8 (14.9)		82.0 (41.8)

[a] Ground habitat data collected on Prince Charles Island from 24 June to 14 July 1996 and 26 June to 15 July 1997 and on Air Force Island from 1 to 9 July 1997.

of individuals than of pairs in specific wet graminoid habitats (Appendices 5a–c).

All species with sufficient sample sizes for chi-square tests (Red Phalarope, Ruddy Turnstone, White-rumped Sandpiper, American Golden-Plover, Black-bellied Plover, and Dunlin) showed significant differences in habitat use. Shorebird pairs showed a more narrow range of habitat preferences than individual birds. Both of the large plover species showed a preference for dry vegetated tundra, and both species avoided barren areas and wet habitats. All shorebird species avoided barren habitats.

With the exception of the American Golden-Plover and the Black-bellied Plover, shorebirds selected specific habitats within the wet graminoid tundra class. Red Phalarope and White-rumped Sandpiper pairs clearly preferred Sedge marsh, and Red Phalarope pairs also selected Wet moss marsh. Ruddy Turnstones showed a clear preference for Grassland. Phalaropes did not avoid any wetland habitats, whereas White-rumped Sandpipers and Turnstones both avoided certain wet habitats (Table 7).

4.2.2.2 Non-shorebird species

Non-shorebird species as a whole exhibited the same packing on transects early in the 1996 season as did shorebirds (Table 6; Appendix 6a). Non-shorebird densities were 5 to 14 times higher early in the season than later in the season in 1996 and in 1997. The majority of species densities decreased in 1996 as the breeding season progressed and more snow-free land became available (Appendices 6a and 6b). However, Sabine's Gull densities decreased little or not at all as the season progressed. Non-shorebird densities in most habitats were higher in plots in 1997 than in 1996. However, Lapland Longspurs had higher densities in all habitats in 1996 (Table 6).

In 1997, Sabine's Gull densities were higher in Saltmarsh than in any other habitat type (Appendix 6c). Its next highest densities were not recorded in a wet graminoid habitat type at all, but in Dry moss tundra (Appendix 6c). This led to the rather unusual result that Sabine's Gull densities were, on the whole, as high in the Dry Vegetated Tundra habitat class as they were in the Wet Graminoid/Moss Lowlands class (Table 6). Lapland Longspurs were present in every habitat type except Beach ridge top and Barrens; densities were highest in the Sedge marsh and Wet graminoid marsh habitat types (Appendix 6c).

Waterfowl were present at highest densities in the Wet Graminoid/Moss Lowlands habitat class in 1997, with a couple of notable exceptions (Long-tailed Ducks *Clangula hyemalis* were present at highest densities in the Unvegetated/Barren Tundra class; Cackling Geese were present at roughly equal densities in the Dry Vegetated Tundra and Wet Graminoid/Moss Lowland classes). Atlantic Brant were found only in wet graminoid habitats, although they were absent from the Saltmarsh habitat type (Appendix 6c), where one

Dry Vegetated Tundra[a]				Unvegetated/Barren Tundra[a]					
1996 plots (10)		1997 (31)		1996 transects (24)		1996 plots (7)		1997 (8)	
Pairs	Individuals	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals
0	2.5 (2.5)	5.4 (4.4)	8.5 (4.9)	15.0 (12.8)	48.5 (38.0)	0	20.2 (20.2)	0	0
2.2 (1.6)	10.4 (3.5)	12.5 (4.6)	36.6 (10.6)	0.7 (0.7)	1.1 (1.0)	0	3.7 (2.4)	0	2.0 (2.0)
1.6 (1.6)	6.2 (6.2)	3.8 (1.8)	6.5 (2.4)	5.3 (3.5)	12.2 (6.3)	1.2 (1.2)	4.9 (3.7)	0	0
0	0	4.4 (1.7)	4.6 (1.7)	7.0 (7.0)	8.4 (4.0)	0	1.9 (1.9)	1.1 (1.1)	3.0 (2.1)
1.6 (1.6)	5.5 (4.7)	2.7 (1.6)	4.0 (2.2)	0	2.5 (2.1)	0	0	0	0
0	0	0	0.7 (0.7)	8.1 (6.4)	9.5 (6.4)	0	0	2.0 (1.3)	4.1 (2.7)
0	0	0	0	0	0	1.2 (1.2)	1.2 (1.2)	0	0
0	0	1.0 (1.0)	1.0 (1.0)	0	0	0	0.9 (0.9)	0	0
0	0	0	0	0	0	0	0.9 (0.9)	0	0
0	0	0	0	0	3.0 (1.8)	0.9 (0.9)	0.9 (0.9)	0	0
0	0	0	0	0	0	0	0	0	0
5.4 (3.3)	24.6 (10.4)	29.8 (8.1)	61.9 (15.5)	36.1 (19.2)	85.2 (105.8)	3.3 (2.4)	34.6 (21.5)	3.1 (2.2)	9.1 (4.2)
	2.1 (2.1)		5.8 (3.3)		19.6 (13.0)		0		0
	0		0.7 (0.7)		0.8 (0.8)		0		1.0 (1.0)
	0		0		5.2 (3.6)		3.6 (3.6)		0
	3.1 (3.1)		10.4 (7.6)		2.8 (2.8)		1.2 (1.2)		0
	3.1 (3.1)		0.4 (0.4)		0		0		0
	0		1.6 (1.4)		0		0		2.1 (2.1)
	0		2.9 (2.3)		2.6 (1.3)		0		0
	0		0.4 (0.4)		2.2 (1.6)		0		3.5 (2.3)
	0		0		5.6 (2.9)		3.1 (3.1)		0
	19.5 (7.8)		12.0 (2.9)		41.9 (10.5)		9.4 (6.2)		2.0 (2.0)
	0		4.5 (4.0)		0.7 (2.6)		2.9 (2.0)		2.8 (2.8)
	27.8 (8.2)		34.2 (11.7)		75.1 (48.1)		20.2 (21.5)		7.6 (6.3)

would expect to find them at this latitude (Barry 1956; Reed et al. 1998). Pomarine Jaegers *Stercorarius pomarinus* were found at highest densities in wet habitats, whereas the highest densities of Long-tailed Jaegers *Stercorarius longicaudus* were in the Unvegetated/Barren Tundra class (Table 6). We observed other non-shorebird species so infrequently that we could not determine their habitat use.

Lapland Longspur, Lesser Snow Goose, Atlantic Brant, Pomarine Jaeger, Sabine's Gull, and Snow Bunting *Plectrophenax nivalis* had sufficient sample sizes for chi-square tests of habitat selection (1997 data only). Lesser Snow Geese, Atlantic Brant, Sabine's Gulls, and Pomarine Jaegers all preferred wet graminoid tundra and avoided dry and/or barren habitats. Sabine's Gulls and Lesser Snow Geese selected more narrowly within the wet habitats—they preferred Grassland (and, for Sabine's Gulls, Saltmarsh) habitats. Lesser Snow Geese did not avoid any wetland habitats; Sabine's Gulls avoided Wet moss marsh. Snow Buntings clearly preferred dry upland and barren habitats and avoided wet habitats. Lapland Longspurs did not exhibit a preference for any habitat type, but they did avoid Grassland and barren habitats (Table 7).

4.3 Differences in shorebird populations between years

The two years of this study were at opposite ends of the spectrum for early breeding season weather. In 1996, snowmelt was extremely late. When the snow did melt, flood conditions occurred over much Prince Charles Island (Fig. 7). Most breeding habitat was not available until after 4 July. In 1997, breeding habitat was available prior to 24 June, likely by the middle of June. According to Environment Canada climate data, snow was gone from the ground in Hall Beach, 210 km to the northwest of Prince Charles Island, by 17 June (http://www.climate.weatheroffice.ec.gc.ca/, accessed 26 January 2006).

In the study area as a whole, Semipalmated Sandpipers were present in relatively large numbers in 1996 but were nearly absent in 1997. Across all species, there was a large difference in the ratios of individual density to pair density in 1996 and 1997 (Table 8). Overall, shorebird pair densities in plots were nearly two times higher in 1997 than in 1996. The decrease in the ratio of individual density to pair density in plots was especially large for American Golden-Plovers and for Dunlin (Table 8).

4.4 Population estimates

4.4.1 Ground surveys (shorebirds and non-shorebirds)

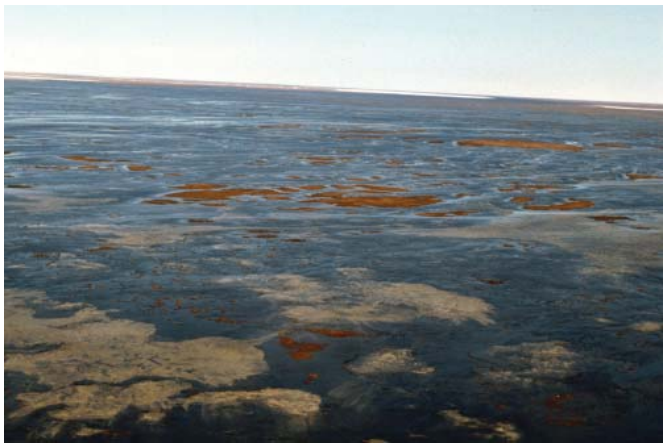
Population estimates of shorebirds breeding in the study area in 1997 are presented in Table 9. Population estimates for Prince Charles Island in 1996 are included in Table 11. Precision of estimates for 1996 (as determined by confidence limits) is low and, because of the extremely late snowmelt in

Table 7
Significant differences in use of habitat types[a] by birds on Prince Charles Island and Air Force Island, 1997

Species	Overall differences (χ^2; $P < 0.05$)	Specific differences (confidence intervals generated using Bonferroni z statistic)
Shorebird pairs		
Red Phalarope	significant	• prefers Sedge marsh, Wet moss marsh • avoids Dry Vegetated Tundra, Unvegetated/Barren Tundra
Ruddy Turnstone ssp. *morinella*	significant	• prefers Grassland • avoids Sedge marsh, Wet moss marsh, Unvegetated/Barren Tundra
White-rumped Sandpiper	significant	• prefers Sedge marsh • avoids Grassland, Unvegetated/Barren Tundra
American Golden-Plover[b]	significant	• prefers Dry Vegetated Tundra • avoids Wet Graminoid/Moss Lowlands
Black-bellied Plover[b]	significant	• prefers Dry Vegetated Tundra • avoids Wet Graminoid/Moss Lowlands, Unvegetated/Barren Tundra
Dunlin ssp. *hudsonia*[b]	significant[c]	• prefers Wet Graminoid/Moss Lowlands, Unvegetated/Barren Tundra • avoids Dry Vegetated Tundra
All shorebird pairs	significant	• prefer Sedge tundra • avoid Dry Vegetated Tundra, Unvegetated/Barren Tundra
Non-shorebirds		
Lapland Longspur	significant	• avoids Grassland, Unvegetated/Barren Tundra
Lesser Snow Goose	significant	• prefers Grassland • avoids Dry Vegetated Tundra, Unvegetated/Barren Tundra
Atlantic Brant	significant	• prefers Wet Graminoid/Moss Lowlands, avoids Dry Vegetated Tundra, Unvegetated/Barren Tundra
Pomarine Jaeger	significant	• prefers Wet Graminoid/Moss Lowlands, avoids Unvegetated/Barren Tundra
Sabine's Gull	significant	• prefers Grassland, Saltmarsh • avoids Wet moss marsh, Unvegetated/Barren Tundra
Snow Bunting	significant	• prefers Dry Vegetated Tundra and Unvegetated/Barren tundra; avoids Wet Graminoid/Moss Lowlands

[a] Habitat data from ground surveys conducted on Prince Charles Island from 26 June to 15 July 1997 and on Air Force Island from 1 to 9 July 1997.
[b] Sample sizes for Dunlin, American Golden-Plover, and Black-bellied Plover were too small to allow habitat preferences by individual wet graminoid habitat type to be analyzed. Analysis was conducted instead on the combined Wet Graminoid/Moss Lowlands habitat class.
[c] We consider this to be a spurious finding caused by Dunlin recorded beside a pond in rocky habitat on Air Force Island.

Figure 7
Flood conditions on Prince Charles Island, 6 July 1996. Light-coloured areas are unvegetated pond bottoms.



©V. Johnston, CSF

Table 8
Ratios of the density of individual shorebirds to the density of shorebird pairs, Prince Charles Island and Air Force Island, 1996 and 1997

Species	Individual density : pair density		
	1996 transects[a]	1996 plots[b]	1997 plots[c]
Black-bellied Plover	2.7 (5.6:2.1)	3.1 (3.7:1.2)	1.3 (2.4:1.8)
American Golden-Plover	6.7 (40.1:6.0)	6.0 (1.2:0.2)	1.2 (2.1:1.7)
Ruddy Turnstone ssp. *morinella*	3.3 (16.4:4.9)	2.1 (18.2:8.8)	2.0 (5.5:2.8)
White-rumped Sandpiper	3.7 (66.2:18.0)	5.5 (22.0:4.0)	3.1 (32.6:10.5)
Pectoral Sandpiper	0	*	1.7 (0.7:0.4)
Dunlin ssp. *hudsonia*	3.6 (14.5:4.0)	8.0 (0.8:0.1)	2.1 (1.7:0.8)
Red Phalarope	3.1 (204.5:65.5)	5.4 (93.6:17.2)	2.4 (36.1:14.7)
Baird's Sandpiper	1.0 (0.6:0.6)	5.2 (2.6:0.5)	0
Semipalmated Sandpiper	2.0 (2.2:1.1)	3.9 (5.9:1.5)	0
All	3.4 (351.5:102.7)	4.4 (148.2:33.6)	2.5 (81.5:32.8)

* No pairs recorded.
[a] Transects surveyed 24 June to 11 July 1996, Prince Charles Island only.
[b] Plots surveyed 28 June to 14 July 1996, Prince Charles Island only.
[c] Plots surveyed on Prince Charles Island from 26 June to 15 July 1997 and on Air Force Island from 1 to 9 July 1997.

that year, we believe that estimates from 1997 present a more accurate picture of shorebird populations. Accuracy of estimates (as determined by coefficients of variation) in 1997 is generally lower for Air Force Island because fewer plots were surveyed there; however, the coefficients of variation for four of the six most common shorebird species are close to 0.20. With the exception of Dunlin, which were nearly absent from Air Force Island, the order of shorebird species abundance was identical on each island. Order of abundance was very similar for pairs and individuals.

The total estimated number of breeding pairs of shorebirds in 1997 on the two islands combined is 272 470 ± 53 982; the total estimated number of individual shorebirds is 626 045 ± 124 325 (Table 9).

The most reliable non-shorebird population estimate (coefficient of variation ≤ 0.20) was obtained for Lapland Longspur (Table 9). Population estimates for most waterfowl were derived from aerial surveys (section 4.4.2). Lapland Longspurs were by far the most numerous non-shorebird species.

Table 9
Population estimates of birds on Prince Charles Island and Air Force Island, 1997, ± 95% confidence limits.[a] For scientific names see Appendix 4.

Species	Prince Charles Island (994 534 ha)[b]				Air Force Island (161 220 ha)[b]				Overall (1 155 754 ha)[b]				% of estimated continental population (individuals)[d, e]
	Estimated number of pairs	CV[c]	Estimated number of individuals	CV[c]	Estimated number of pairs	CV[c]	Estimated number of individuals	CV[c]	Estimated number of pairs	CV[c]	Estimated number of individuals	CV[c]	
Shorebirds													
Red Phalarope	107 648 ± 23 040	0.11	265 601 ± 61 328	0.12	12 718 ± 7 246	0.11	39 671 ± 20 264	0.74	118 054 ± 24 910	0.11	300 767 ± 65 634	0.11	24.1
White-rumped Sandpiper	50 710 ± 16 791	0.17	171 963 ± 58 784	0.17	9 896 ± 7 023	0.15	25 803 ± 17 219	0.50	61 659 ± 18 234	0.15	201 604 ± 61 176	0.15	18.0
Dunlin ssp. *hudsonia*	72 542 ± 38 894	0.27	77 149 ± 39 325	0.26	67 ± 44	0.23	134 ± 87	0.11	59 255 ± 30 141	0.26	66 974 ± 30 613	0.23	30.0
Ruddy Turnstone ssp. *morinella*	14 827 ± 11 027	0.38	16 372 ± 7 495	0.23	1 506 ± 2 411	0.27	8 000 ± 10 847	0.15	15 822 ± 11 199	0.36	24 456 ± 13 016	0.27	13.6
Black-bellied Plover	10 086 ± 10 564	0.53	11 893 ± 10 823	0.46	0	0.49	0	0.20	9 621 ± 10 506	0.56	11 298 ± 10 756	0.49	7.5
American Golden-Plover	3 032 ± 1 413	0.24	8 414 ± 3 187	0.19	67 ± 43.7	0.17	134 ± 87.2	0.36	5 990 ± 2 307	0.20	13 596 ± 4 535	0.17	6.8
Pectoral Sandpiper	1 485 ± 1 424	0.49	3 020 ± 2 650	0.45	0	0.40	580 ± 929	0.26	1 385 ± 1 352	0.50	3 514 ± 2 750	0.40	0.9
Purple Sandpiper ssp. *maritima*	706 ± 1 000	0.72	2 118 ± 2 997	0.72	0	0.74	0		684 ± 996	0.74	2 051 ± 2 987	0.74	20.5
Red Knot ssp. *rufa*	0		1 843 ± 2 609	0.72	0	0.74	0	0.10	0		1 785 ± 2 599	0.74	7.1-8.5
All shorebirds	261 036 ± 57 745	0.11	558 373 ± 121 106	0.11	24 254 ± 9 894	0.10	74 322 ± 33 477	0.23	272 470 ± 53 982	0.10	626 045 ± 124 325	0.10	
Non-shorebirds													
Lapland Longspur			55 073 ± 15 672	0.14			20 405 ± 12 840	0.32			82 313 ± 20 451	0.13	0.2[f, g]
Long-tailed Jaeger			23 049 ± 9 055	0.20			0				19 139 ± 8 463	0.22	13.0[h, i]
Northern Pintail			0				753 ± 1 205	0.82			835 ± 1 215	0.74	
Long-tailed Duck			1 969 ± 1 866	0.48			4 051 ± 4 334	0.55			12 882 ± 6 203	0.24	1.6[j]
King Eider			5 088 ± 6 854	0.69			616 ± 986	0.82			5 591 ± 6 876	0.63	
Parasitic Jaeger			1 604 ± 2 270	0.72			0				1 553 ± 2 262	0.74	
Pomarine Jaeger			16 972 ± 11 370	0.34			682 ± 1 092	0.82			17 036 ± 11 392	0.34	
Willow Ptarmigan			4 629 ± 2 477	0.27			0				3 632 ± 2 007	0.28	
Pacific Loon			1 840 ± 1 835	0.51			682 ± 1 092	0.82			2 538 ± 2 111	0.42	
Red-throated Loon			0				134 ± 86	0.33			6 596 ± 3 920	0.30	
Arctic Tern			421 ± 9 253	0.43			0				4 572 ± 2 599	0.74	
Snow Bunting			142 ± 174	0.63			574 ± 351	0.31			12 240 ± 6 348	0.26	0.3[g, k]

[a] Estimates derived from ground survey data collected on Prince Charles Island from 26 June to 15 July 1997 and on Air Force Island from 1 to 9 July 1977.
[b] Areas exclude mudflats.
[c] Coefficient of variation.
[d] Shorebird continental population estimates from Morrison et al. (2006).
[e] Population estimate; individuals used for comparison.
[f] National estimate from Hussell and Montgomerie (2002).
[g] National estimate from Dunn (2005).
[h] National estimate from Kushlan et al. (2002).
[i] National estimate from Milko et al. (2003).
[j] National estimate from Sea Duck Joint Venture (2003).
[k] National estimate from Lyon and Montgomerie (1995).

4.4.2 Aerial surveys (non-shorebirds)

From aerial surveys we generated density and population estimates for four waterfowl species (Atlantic Brant, Cackling Goose, Lesser Snow Goose, and Tundra Swan) and for Sabine's Gull (Table 10). Estimates were not obtainable for King Eider. In 1997 and to a lesser degree in 1996, the survey occurred after most male King Eiders had left their mates, and it is likely that a high proportion of breeding females, which were well camouflaged, were not detected.

Densities of all species were higher on Air Force Island than on Prince Charles Island, although total population estimates were higher for most species on Prince Charles Island, which is the larger of the two islands. Two exceptions were Lesser Snow Geese and Cackling Geese, both of which had larger populations on Air Force Island.

Bird densities were highest in the coastal transects of Prince Charles Island and on the eastern part of Air Force Island (Figures 8 and 9). Lesser Snow Geese were much more numerous on the southern half of Air Force Island (Fig. 9).

4.5 Changes in bird populations over time

There was no consistent pattern of increase or decrease in population estimates among shorebird species between 1989 and 1997; the populations of three out of seven species (Black-bellied Plover, American Golden-Plover, and Dunlin) increased, and the populations of the other four species (Ruddy Turnstone, Semipalmated Sandpiper, White-rumped Sandpiper, and Red Phalarope) apparently decreased (Table 11). The population estimate for all shorebird species together was lower in 1997 than in 1989.

With the exception of White-rumped Sandpiper, Dunlin, and Red Phalarope, confidence intervals for population estimates overlap by more than 25% (Prince Charles Island data only) (Table 11). Thus, we consider that there were likely significant changes in population size over the eight-year period between surveys for these three species. No Dunlin were recorded by Morrison (1997) in his 1989 surveys. The situation with Semipalmated Sandpipers is not clear. Although we observed very few in 1997, the 1996 plot-based population estimate is very close to the estimate in 1989, with complete overlap in confidence intervals.

We compared non-shorebirds observed per kilometre of coastal aerial transects in 1984 (Gaston et al. 1986) and in 1996 and 1997 (this study). Distribution and abundance of Tundra Swans were higher in 1996 and 1997 than in 1984 (Fig. 8). The area of high Lesser Snow Goose density on Air Force Island was considerably larger in 1997 than in 1984, and Lesser Snow Geese have actually colonized Prince Charles

Table 10
Density and population estimates of larger bird species from aerial surveys carried out on Prince Charles Island on 3, 4, and 6 July 1996 and on Air Force Island on 5 July 1997

Species	Location	Stratum[a]	Density (individuals/km^2) (SE)	Population estimate (± 95% CL)	CV[b]	% of estimated continental population[d, e]
Atlantic Brant	Prince Charles Island	coastal	12.10 (2.60)	9 303 ± 3 855	0.21	
		interior	0.05 (0.03)	437 ± 531	0.62	
		total	**1.00 (0.20)**	**9 740 ± 3 893**	**0.21**	
	Air Force Island	east	12.20 (4.40)	5 789 ± 4 134	0.36	12.2[f]
		west	0.30 (0.10)	339 ± 233	0.35	
		total	**3.50 (1.20)**	**6 128 ± 4 140**	**0.34**	
Cackling Goose	Prince Charles Island	coastal	0.70 (0.10)	539 ± 169	0.16	
		interior	0.02 (0.01)	133 ± 231	0.89	
		total	**0.07 (0.02)**	**672 ± 286**	**0.22**	
	Air Force Island	east	5.00 (1.50)	2 360 ± 1 406	0.30	0.9[f]
		west	0.80 (0.40)	932 ± 825	0.45	
		total	**1.90 (0.50)**	**3 292 ± 1 629**	**0.25**	
Lesser Snow Goose[c]	Prince Charles Island	coastal	1.90 (0.60)	6 390 ± 4 265	0.34	
		interior	0.10 (0.10)	694 ± 1348	0.99	
		total	**0.70 (0.20)**	**7 084 ± 4 472**	**0.32**	
	Air Force Island	north	1.00 (0.80)	843 ± 1133	0.69	2.8[f]
		south	53.70 (10.80)	51 895 ± 20 400	0.20	
		total	**30.90 (6.10)**	**52 738 ± 20 431**	**0.20**	
Tundra Swan	Prince Charles Island	coastal	0.07 (0.03)	53 ± 43	0.42	
		interior	0.02 (0.01)	133 ± 276	1.10	
		total	**0.02 (0.02)**	**186 ± 280**	**0.77**	
	Air Force Island	east	0.03 (0.03)	15 ± 27	0.93	0.3[f]
		west	0.05 (0.03)	68 ± 71	0.53	
		total	**0.04 (0.02)**	**83 ± 76**	**0.46**	
Sabine's Gull	Prince Charles Island	coastal	6.00 (0.90)	20 498 ± 6 246	0.16	
		interior	0.08 (0.06)	463 ± 755	0.83	
		total	**2.20 (0.30)**	**20 961 ± 6 292**	**0.15**	9–18[g, h]
	Air Force Island	total	8.80 (1.30)	15 091 ± 4 284	**0.14**	

[a] Strata are depicted in Figure 3.
[b] Coefficient of variation.
[c] National estimate from Canadian Wildlife Service Waterfowl Committee (2006).
[d] Shorebird continental population estimates from Morrison et al. (2006).
[e] Population estimate; individuals used for comparison.
[f] National estimate from Canadian Wildlife Service Waterfowl Committee (2006).
[g] National estimate from Kushlan et al. (2002).
[h] National estimate from Milko et al. (2003).

Figure 8
Distribution and abundance of Tundra Swans, Atlantic Brant, and Cackling Geese on Prince Charles Island, 1984 and 3, 4, and 6 July 1996, and on Air Force Island, 1984 and 5 July 1997. Data for 1984 reproduced from Gaston et al. (1986). (The Canada Goose *Branta canadensis* mapped by Gaston et al. (1986) has since been renamed Cackling Goose.) Data for 1996 (Prince Charles Island) and 1997 (Air Force Island) combined.

Data for 1984 from figures 3, 4, and 5 on pages 288 and 289 of "The distribution of larger species of birds breeding on the coasts of Foxe Basin and northern Hudson Bay, Canada" by A.J. Gaston, R. Decker, F.G. Cooch, and A. Reed, *Arctic* 39 (1986). Reproduced with permission of the Arctic Institute of North America.

Figure 9
Distribution and abundance of Lesser Snow Geese and Sabine's Gulls on Prince Charles Island, 1984 and 3, 4, and 6 July 1996, and on Air Force Island, 1984 and 5 July 1997. Data for 1984 reproduced from Gaston et al. (1986). Data for 1996 (Prince Charles Island) and 1997 (Air Force Island) combined.

Data for 1984 from figures 5 and 11 on pages 289 and 292 of "The distribution of larger species of birds breeding on the coasts of Foxe Basin and northern Hudson Bay, Canada" by A.J. Gaston, R. Decker, F.G. Cooch, and A. Reed, *Arctic* 39 (1986). Reproduced with permission of the Arctic Institute of North America.

Island since 1984 (Fig. 9). Cackling Geese had a far greater distribution (but similar density) on both islands during the surveys in 1996 and 1997 (Fig. 8). Atlantic Brant were present in higher densities along a greater portion of the coastline of Air Force Island in 1984; in 1997, Atlantic Brant were mostly restricted to the south and east coasts of the island. Atlantic Brant were more widespread, but occurred at lower densities, along the coast of Prince Charles Island in 1996 than in 1984 (Fig. 8). Finally, Sabine's Gulls were present in both 1996 and 1997 along the entire coastline of both islands, but they were present in much higher densities in 1984 (Fig. 9).

4.6 Comparison with other locations in the Arctic

In terms of species richness, the number of shorebird species on Prince Charles Island is equal to or greater than the number on the Rasmussen Lowlands, on West Baffin Island (Great Plains of the Koukdjuak), on southern Southampton Island, or on Coats Island (Table 12; Appendix 3). Relative to other mid-Arctic sites, Prince Charles Island has high shorebird densities—only Prudhoe Bay in northern Alaska has higher densities (Table 12).

On an individual species basis, Prince Charles Island is in the top 5% of all sites in which Red Phalarope and White-rumped Sandpiper densities have been investigated (Appendix 3). Prince Charles Island is in the top 10% of all sites in which Ruddy Turnstone densities have been investigated.

Prince Charles Island and Air Force Island together constitute one of the most species-rich locations for breeding shorebirds in the North American Arctic, and they are probably the most important site for breeding Red Phalaropes and White-rumped Sandpipers in North America.

Table 11
Comparison of densities and population estimates of shorebird species (indicated breeding pairs) on Prince Charles Island and Air Force Island in 1989 and in 1996 and 1997

	1989[a]		Prince Charles Island plots, 1996		Prince Charles Island plots, 1997		Prince Charles Island and Air Force Island plots, 1997	
Species	Density (pairs/km²)[c] (SE)[d]	Population estimate (pairs) ± 95% CL[e]	Density (pairs/km²) (SE)[b]	Population estimate (pairs) ± 95% CL	Density (pairs/km²) (SE)[b]	Population estimate (pairs) ± 95% CL	Density (pairs/km²) (SE)	Population estimate (pairs) ± 95% CL
Black-bellied Plover	1.7 (9.0)	6 205 ± 12 219	1.2 (0.7)	5 972 ± 5 573	1.3 (1.1)	10 086 ± 10 564	1.8 (1.0)	9 621 ± 10 506
American Golden-Plover	0.3 (4.6)	1 726 ± 4 731	0.2 (0.2)	1 236 ± 1 968	0.4 (0.2)	3 032 ± 1 413	1.7 (0.7)	5 990 ± 2 307
Ruddy Turnstone ssp. *morinella*	3.5 (22.6)	25 066 ± 21 948	8.8 (4.3)	52 833 ± 39 639	1.9 (1.2)	14 827 ± 11 027	2.8 (1.1)	15 822 ± 11 199
Semipalmated Sandpiper	1.2 (13.2)	12 022 ± 19 508	1.5 (1.3)	11 558 ± 9 801	0	0	0	0
Dunlin ssp. *hudsonia*	0	0	0.1 (0.1)	724 ± 1 152	9.5 (9.3)	72 542 ± 38 894	0.8 (0.4)	59 255 ± 30 141
White-rumped Sandpiper	15.7 (73.5)	129 846 ± 69 274	4.0 (1.1)	21 960 ± 9 382	6.7 (1.8)	50 710 ± 16 791	10.5 (2.2)	61 659 ± 18 234
Red Phalarope	16.6 (84.2)	188 684 ± 49 282	17.2 (4.4)	99 492 ± 36 817	14.1 (2.5)	107 648 ± 23 040	14.7 (2.7)	118 054 ± 24 910
All species[f]	36.5 (48.8)	363 549 ± 130 211	33.6 (6.8)	199 586 ± 56 222	34.3 (13.4)	261 037 ± 57 745	32.8 (4.6)	272 470 ± 53 982

[a] Data for 1989 from Morrison (1997).
[b] Densities calculated with area of lakes and permanent ponds excluded.
[c] Using nesting densities for all habitats in Figure 2a (Morrison 1997: Table 3).
[d] Morrison (1997) reported standard deviations, from which we calculated standard error.
[e] Using Morrison's unmodelled population estimates (Morrison 1997: Table 4).
[f] Purple Sandpiper and Pectoral Sandpiper were not recorded from the islands in 1989, so are not included in this table as individual species. However, small numbers were seen in 1996 and 1997; these numbers are included in the "All species" totals.

Table 12
Comparison of Prince Charles Island shorebird population with most similar studies/sites across the Arctic.[a] Site numbers correspond to Figure 11 and Appendix 3.

Site[b] (see Appendix 3)	Similarity rating[c]	Number of breeding species in common	Total number of species present (species richness)	Pair density (pairs/km²)	Density (individuals/ km²)	Source
24 Prince Charles Island, Nunavut	15	9	12	34.3	89.9	This study
12 Prudhoe Bay, Alaska (MW)	14	9	17	43.2	n/a	Troy Ecological Research Associates (TERA) (unpubl. report)[1]
17 Rasmussen Lowlands, Nunavut (ME)*	14	8	12	11.7	15.2	Johnston et al. (2000)
15 Banks Island Migratory Bird Sanctuary No. 1, Northwest Territories (MW)*	14	8	10		27.0	Latour et al. (unpubl. manuscript)[2]
13 Storkersen Point, Alaska (MW)	13	8	10	n/a	80.7	Bergman et al. (1977)
23 East Bay, Southampton Island, Nunavut (ME)	13	7	10		53.0	P. Smith (unpubl. data)
21 Sarcpa Lake, Melville Peninsula, Nunavut (ME)	12	7	8	10.0	n/a	Montgomerie et al. (1982, 1983)
16 Melbourne Island, Nunavut (ME)	11	7	9	20.0		J. Bart and V. Johnston (unpubl. data)
25 Prince Charles Island, Nunavut (ME)	11	6	??	36.5	n/a	Morrison (1997)
26 West Baffin Island, Nunavut (ME)*	10	5	10	34.0	n/a	J. Bart and V. Johnston (unpubl. data)
22 Southern Southampton Island, Nunavut (ME)*	10	6	10	25.9	n/a	J. Bart and V. Johnston (unpubl. data)
20 Igloolik Island, Nunavut (ME)	10	8	13	12.1	n/a	Forbes et al. (1992)
11 Coats Island, Nunavut (ME)*	10	6	8	n/a	41.1	P. Smith (unpubl. data)

*Areas used for comparison of species richness.
[a] Only sites with a similarity rating of 10 or higher are presented.
[b] MW = western mid-Arctic site; ME = eastern mid-Arctic site.
[c] Higher number denotes greater similarity to this study. Rankings based on points awarded for location (same ecological zone as Prince Charles Island): exclusion of water bodies in density calculations (1 point); densities weighted (1 point); survey systematic (1 point); same survey methodology as present study (1 point); study conducted over two or more years (1 point); and 1 point for each breeding species in common with this study.

[1] Troy Ecological Research Associates (TERA). 1993. Population dynamics of birds in the Pt. McIntyre Reference Area 1981-1992. Prepared for BP Exploration (Alaska), Anchorage, Alaska. [unpubl. report].
[2] Latour, P.B.; Machtans, C.S.; Hines, J.E. 2006. The abundance of breeding shorebirds and songbirds in relation to the expanding Lesser Snow Goose colony on Banks Island, NWT. Canadian Wildlife Service, Yellowknife, N.W.T. [unpubl. manuscript].

5. Discussion

5.1 Effects of weather on shorebird behaviour and survey results

The earlier availability of nesting habitat in 1997 is reflected in inferred dates of nest initiation. All six common breeding shorebird species (Red Phalarope, White-rumped Sandpiper, Dunlin, Ruddy Turnstone, Black-bellied Plover, and American Golden-Plover) initiated nests a minimum of 15 days earlier in 1997 (Table 13). No shorebird broods were seen by the time the surveys ended in 1996 (16 July), yet in 1997 broods were seen as early as 3 July. Many of the shorebirds hatched in 1996 would not have fledged until the middle of August. These dates are still within the window of successful breeding reported for the six species at this latitude (Parmelee 1992; Paulson 1995; Johnson and Connors 1996; Warnock and Gill 1996; Nettleship 2000; Tracy et al. 2002). However, these projected fledging dates are mean dates, and some young would be expected to fledge after that date. It is likely that some proportion of these birds died before fledging or failed to begin migration before winter set in. In contrast, in 1997, all species had projected fledging dates on or before the first week of August. It is likely that the majority of chicks would have had enough time to mature and migrate south in 1997.

It is possible that our definition of indicated breeding (see section 3.2.1) resulted in some breeding birds being recorded as individuals. If overt display was not evident, the bird was determined to be unpaired. This likely led to an overestimation of the number of individual (unpaired) birds and of the ratio of individual birds to paired birds in both years of the study. However, this overestimate was constant over both years and should not affect differences in magnitude of the ratio.

Differences in ratios of shorebird individuals to pairs between 1996 and 1997 may be a function of late snowmelt and subsequent flooding on Prince Charles Island in 1996. In 1997, there were roughly twice as many individual as paired shorebirds in the plots. In 1996, we observed three to six times as many individual birds as pairs (Table 8). For most species this ratio either continued or increased as the season progressed in 1996. It is possible that the trigger for initiation of courtship activity—sufficient food for the females to produce eggs—was not strong enough in 1996 for many birds to pair. Alternatively, pair bonds could have formed early in the season but dissolved when, because of a lack of suitable nest sites, nest initiation could not proceed.

Semipalmated Sandpipers were present in moderate numbers in 1996 but were nearly absent in 1997. This finding could be related to weather conditions in 1996. Gratto (1988) concluded that fidelity to breeding area in this species is related to the success of a pair's breeding attempt in the previous year. If most of the birds were unsuccessful in 1996, then it follows that few would return to the area in 1997. We could not find reference to a similar pattern of success-dependent nest site fidelity for other species.

The extremely limited amount of bare ground in June 1996 led to a marked degree of "packing" of shorebirds into small areas and thus very high plot densities for some species. This situation persisted into the first week of July, when the snow in the snow-covered areas melted and these areas were flooded. Plots surveyed after the peak of flooding showed pair densities that were more consistent with those observed in 1997. Our results demonstrate that those conducting surveys must exercise caution when extrapolating plot or transect densities to large areas. Extrapolation is based on total areas of habitat derived from satellite or other habitat classifications. In years when bird packing occurs during surveys, abnormally large numbers of birds are recorded in habitats where they will not actually breed. In June and early July 1996, available habitat consisted of roughly equal parts Unvegetated/Barren Tundra (Beach ridge top) and Wet Graminoid/Moss Lowlands (bases of beach ridges). Although Wet Graminoid/Moss Lowlands are the appropriate breeding habitat for most shorebirds that breed on Prince Charles Island, densities in this habitat were grossly overestimated because of packing. Even Beach ridge tops hosted densities of shorebirds that are clearly abnormal (Appendix 5a). Extrapolation of shorebird numbers based on an existing habitat classification would not be able to detect the fact that most habitat was unavailable in that particular year and that inflated population estimates would be the result.

All but two shorebird species registered higher population estimates in 1997 than in 1996 (only plot data used; Table 11). This finding supports the hypothesis that many of the birds that were packed into snow-free areas on Prince Charles Island early in the 1996 season later dispersed, presumably failed to breed, and left the island. One of the species that was more numerous in 1996, Ruddy Turnstone, prefers to nest on beach ridges and other raised, barren areas close to wetlands. These were the habitats that were snow-free first in 1996, and so one would expect that their 1996 populations would be at least as great as those in 1997. In fact, their 1996 population estimate was more than three times greater than the 1997 estimate. It is possible that Ruddy Turnstones from other areas were attracted to Prince

Table 13
Breeding phenology of birds on Prince Charles Island.[a, b] For scientific names see Appendix 4.

	Date first observed		Date first nest observed		Earliest date of nest initiation		Date first brood observed		Earliest date of hatch	
Species	1996	1997	1996	1997	1996	1997	1996	1997	1996	1997
Red-throated Loon	25 June	30 June	not seen	2 July	n/a	?	not seen	not seen	n/a	?
Pacific Loon	24 June	29 June	not seen	13 July	n/a	after 18 June	n/a	not seen	n/a	after 13 July
Northern Fulmar	29 June	not seen	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Tundra Swan	23 June	1 July	not seen	not seen	n/a	n/a	not seen	not seen	n/a	n/a
Lesser Snow Goose	19 June	24 June	20 June	27 June	16 June	10 June	not seen	9 July	?	7 July
Cackling Goose	23 June	29 June	25 June	2 July	19 June	16 June	not seen	not seen	?	?
Atlantic Brant	19 June	5 July	29 June	9 July	25 June	before 4 July	not seen	not seen	?	?
Northern Pintail	not seen	1 July	n/a	not seen	n/a	n/a	n/a	n/a	n/a	n/a
Common Eider	28 June	not seen	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
King Eider	19 June	29 June	1 July	2 July	13 June	16 June	n/a	n/a	12 July	n/a
Long-tailed Duck	19 June	26 June	5 July	not seen	26 June	after 12 June	not seen	not seen	?	?
Peregrine Falcon	27 June	27 June	not seen	not seen	n/a	n/a	n/a	n/a	n/a	n/a
Gyrfalcon	29 June	5 July	not seen	not seen	n/a	n/a	n/a	n/a	n/a	n/a
Rock Ptarmigan	19 June		not seen	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Willow Ptarmigan	26 June	29 June	28 June	30 June	before 20 June	?	not seen	not seen	n/a	n/a
American Golden-Plover	19 June	28 June	3 July	29 June	30 June	13 June	not seen	15 July	13 July	15 July
Black-bellied Plover	24 June	2 July	1 July	?	26 June	7 June	not seen	not seen	8 July	n/a
Semipalmated Plover	24 June	not seen	not seen	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ruddy Turnstone ssp. *morinella*	19 June	29 June	29 June	1 July	26 June	11 June	not seen	not seen	7 July	n/a
Purple Sandpiper ssp. *maritime*	20 June	11 July	not seen	not seen	n/a	n/a	n/a	n/a	n/a	n/a
Red Knot ssp. *rufa*	25 June	1 July	not seen	not seen	n/a	n/a	n/a	n/a	n/a	n/a
Dunlin ssp. *hudsonia*	21 June	1 July	2 July	2 July	before 27 June	12 June	not seen	13 July	8 July	?
Semipalmated Sandpiper	28 June	not seen	not seen	not seen	n/a	not seen	n/a	n/a	9 July	n/a
White-rumped Sandpiper	21 June	27 June	1 July	27 June	29 June	10 June	n/a	8 July	6 July	6 July
Baird's Sandpiper	24 June	not seen	not seen	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Pectoral Sandpiper	30 June	27 June	not seen	not seen	n/a	n/a	n/a	n/a	n/a	n/a
Red Phalarope	19 June	27 June	30 June	27 June	26 June	9 June	not seen	3 July	1 July	?
Pomarine Jaeger	19 June	28 June	29 June	30 June	before 27 June	after 20 June	not seen	not seen	n/a	n/a
Parasitic Jaeger	19 June	29 June	22 June	12 July	before 17 June	?	not seen	12 July	n/a	12 July
Long-tailed Jaeger	19 June	28 June	19 June	28 June	before 17 June	18 June	not seen	11 July (mobile young)	13 July	?
Ross's Gull	not seen	8 July	n/a	8 July	n/a	?	n/a	not seen	n/a	n/a
Herring Gull	24 June	29 June	25 June	not seen	21 June	15 June	not seen	n/a	13 July	n/a
Glaucous Gull	24 June	9 July	not seen	not seen	n/a	n/a	n/a	n/a	n/a	n/a
Thayer's Gull	19 June	4 July	not seen	not seen	n/a	n/a	n/a	n/a	n/a	n/a
Sabine's Gull	19 June	29 June	1 July	1 July	29 June	16 June	not seen	8 July	10 July	?
Arctic Tern	23 June	1 July	28 June	12 July	27 June	19 June	not seen	not seen	12 July	n/a
Snowy Owl	19 June	28 June	20 June	28 June	26 May	28 May	27 June	4 July	27 June	30 June
Horned Lark	19 June	12 July	not seen	not seen	n/a	n/a	n/a	n/a	n/a	n/a
American Pipit	24 June	not seen	not seen	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Lapland Longspur	19 June	27 June	27 June	29 June	27 June	14 June		30 June	26 June	28 June
Snow Bunting	24 June	29 June	not seen	2 July	n/a	29 June	n/a	not seen	n/a	n/a

[a] Study start date 1996 was 19 June; study start date 1997 was 24 June.
[b] Some data courtesy of J-L Martin.

Charles Island in 1996 because it had rare, snow-free nesting habitat. The only other species that was more numerous in 1996 was Semipalmated Sandpiper, which was not present at all in 1997. A possible explanation for its pattern is outlined above in this section.

Our study illustrates the importance of conducting more than one season of surveys before attempting to generate shorebird breeding population estimates for a given area in the Arctic. The most useful estimate is an average estimate. Very few years are truly "average," and some are so exceptional that they should not be used in calculations at all. With two seasons of data, one can minimize the risk of producing flawed estimates or of having to discard the entire dataset.

5.2 Limitations to use of satellite habitat classification

Remotely-sensed habitat imagery provides a way to classify bird habitat over large areas and then produce species population estimates by extrapolating the results of habitat-based ground surveys to the entire classified area. Because of the time, expertise, and expense involved in creating remotely-sensed habitat classifications, it is common practice to use existing classifications instead of creating a new one for each study. We used Morrison's (1997) remotely-sensed classification of Prince Charles Island, and we checked its accuracy by identifying the habitats in our ground survey plots and comparing them to the classified image.

The classified image was appropriate for use in this study, with one exception. We described more than twice as much standing water as the satellite classification showed (Table 3). We attribute this difference to progressive drying of the land over the breeding season. Morrison's (1997) satellite classification was based on a Landsat image taken on 19 July 1985, whereas our ground classification described conditions in late June and early July (19 June to 16 July 1996 and 24 June to 16 July 1997). The difference was especially pronounced in 1996, when half of surveys occurred when most of the island was still under snow or water because of the late snowmelt. The satellite classification overestimated the amount of Wet Graminoid/Moss Lowlands habitat that we actually surveyed in 1996 and 1997; presumably, by mid-July (when the satellite image used by Morrison (1997) was taken), many ephemeral water bodies had dried to Wet Graminoid/Moss Lowlands.

The difference between water cover estimated by us on the ground in 1996 and 1997 and water cover estimated on the satellite classification has implications for the estimation of shorebird population size. In reality, there is less wet graminoid habitat available on the islands for nesting than is indicated by satellite imagery, a fact that could lead to overestimates of population size.

Underestimates of the amount of habitat covered by water (and therefore unavailable to nesting birds at the point in the season when nesting is initiated) is common in remotely-sensed habitat classifications in the Arctic. Images selected for classification tend to be from mid-summer to late summer because there are more cloud-free images from that time period and because vegetation is green and growing by that time. Water conditions at that point in the season, however, are very different from the period of nest initiation (generally mid-June in this region). One solution to this discrepancy is to procure a late June image of the area in question, superimpose it on the classified imagery, and mask out areas that are covered by water to exclude them from later habitat totals. It would also be helpful to use the late June image in the pre-selection of plots that will be suitable for surveying. Alternatively, June aerial photos can be used in conjunction with summer Landsat imagery. This is a satisfactory solution for small areas, but the number of photos needed for large areas would be cumbersome.

5.3 Habitat use by shorebirds

There were few surprises in the results for habitat selection by shorebirds. All shorebirds used habitat in disproportionate amounts, and all species except Black-bellied Plover and American Golden-Plover preferred various wet graminoid habitats to Dry Vegetated Tundra or unvegetated tundra. Similarly, we believe that the fact that Ruddy Turnstones avoid unvegetated habitat is an artefact of the habitat classification. The habitat unit for Ruddy Turnstones should be designated "ridge-wetland complex," since on Prince Charles Island Ruddy Turnstones were found breeding only in areas where wetlands and beach ridges were in close proximity. It is likely that we simply observed Ruddy Turnstones more often in the wetland part of the complex than in the barren part.

In shorebird pairs as a whole and in several individual species, Sedge marsh was the preferred type of Wet Graminoid/Moss Lowlands. There was no clear pattern regarding preference for or avoidance of other wet tundra types, as species preferred different types. Often these wet tundra types occurred in close proximity to each other, so it is difficult to know if the observed patterns indicate true preferences or if the patterns simply reflect the chance observation of birds within a larger network of wet habitat types. However, it does appear that Sedge marsh was actually preferred by shorebirds. The feature of Sedge marsh that most distinguishes it from the other wet habitat types is hummock development. Hummocks would make the habitat more attractive to shorebirds because the hummocks provide nest sites within a matrix of food-producing habitat.

5.4 Changes in bird populations over time

5.4.1 Shorebirds

The populations of three species clearly changed on Prince Charles Island between 1989 and 1997. Dunlin increased the most—they were not recorded in Morrison's plots in 1989 (Table 11). The subspecies of Dunlin that breeds on Prince Charles Island (ssp. *hudsonia*) is considered to be declining, based on information from migration counts, although its overall Canadian population estimate did not change in the most recent update to these estimates (Morrison et al. 2006). It is also a highly philopatric species (Warnock and Gill 1996), so there is no reason to suspect that poor weather conditions in 1989 or the year preceding had any bearing on the absence of Dunlin.

It is possible that the regular occurrence of breeding Dunlin in the Foxe Basin is a relatively new phenomenon. On nearby West Baffin Island (Great Plains of the Koukdjuak), Soper (1940) recorded a few Dunlin but over an entire summer saw no sign of breeding. The first breeding record for the Great Plains is relatively recent. Martin et al. (1988) recorded Dunlin breeding in 1986, and by 2003–2004 Dunlin were being recorded as a regular breeder at the same location (J. Bart and V. Johnston, unpubl. data). If Dunlin have extended their breeding range to this part of the Canadian Arctic since only the mid-1980s, that could explain their absence on Prince Charles Island in 1989 and their regular occurrence in 1996 and 1997.

White-rumped Sandpipers apparently experienced a 61% decline in population on Prince Charles Island between 1989 and 1997 (Table 11). The estimates in 1996 and 1997 were both well below the 1989 estimate, so it is likely that this is a real decline and not a "blip" caused by different weather or predation effects between years. This species has been little studied, and although its continental population estimate was recently adjusted upward (Morrison et al. 2006), there is low confidence in the estimate and no indication whether the population is increasing, stable, or declining (U.S. Fish and Wildlife Service 2004). At other sites in the Canadian Arctic, no significant population trend has been reported (Gratto-Trevor et al. 1998; P. Smith, unpubl. data), but data are few.

There is growing evidence that Red Phalaropes, although still numerous, are declining in numbers in the central and eastern Canadian Arctic. The 1997 population estimate for Prince Charles Island was 43% lower than the estimate from eight years before (Table 11). It is unlikely

that the lower estimate from 1997 was caused by poor weather (in which Red Phalaropes, which have low breeding site philopatry, would have moved to a more clement area to breed), because the 1996 and 1997 estimates were similar. Gratto-Trevor et al. (1998) recorded a 76% decrease in Red Phalarope numbers between 1976 and 1994–1995 on the Rasmussen Lowlands in the central Canadian Arctic. Annual surveys show that Red Phalaropes decreased by 93% between 1999 and 2005 at East Bay, Southampton Island (P. Smith, unpubl. data). Those data, coupled with persistent and significant declines from eastern North American migration counts (Morrison et al. 2006), provide considerable evidence that something is going wrong with the population of Red Phalaropes in the eastern Arctic.

A fourth species had unusually high variability in abundance between 1996 and 1997. The Semipalmated Sandpiper was present in 1996 in numbers that were similar to those estimated in 1989, but it was absent in 1997 (Table 11). A possible explanation for this phenomenon is provided in section 5.1.

5.4.2 Large birds

The nesting densities and distributions of several waterfowl species changed markedly since 1984. The most obvious of these is the growth in size and numbers of the Lesser Snow Goose colony on Air Force Island. Recent aerial surveys of Air Force Island have shown that the population of Lesser Snow Geese breeding on the island has grown from approximately 53 000 in 1997 to 200 000 in 2001–2005 (D. Caswell, pers. comm.). The Lesser Snow Goose nesting area has also expanded on Air Force Island since 1984 (Fig. 9), and Lesser Snow Geese are now seen on Prince Charles Island (Table 10), where none were observed in 1984 (Fig. 9). It is possible that the increase in the Lesser Snow Goose numbers on Air Force Island is the result of overflow from the burgeoning colony of Lesser Snow Geese on the Great Plains of the Koukdjuak, on nearby west Baffin Island. Non-nesting birds from the Great Plains historically moved to Air Force Island to moult (Riewe 1992). Numbers of Lesser Snow Geese on Air Force Island seem to have levelled off since the early part of the first decade of the 21st century, although it is not known if this finding is due to habitat saturation or to a stabilization of the goose population itself (D. Caswell and J. Leafloor, pers. comm.). If the habitat on Air Force Island is being fully utilized, excess nesting birds may now be spreading to Prince Charles Island. Another round of aerial surveys on Prince Charles Island is needed to determine if this is happening.

The spread in the distribution of Lesser Snow Geese on Air Force Island between 1984 and 1997 was paralleled by a reduction in the coastal density of Altantic Brant (Fig. 8). There are no recent population estimates for Atlantic Brant on the island, but it is likely that a decrease in population size has accompanied the decrease in breeding distribution. This apparent decrease in population size could be due to competition with Lesser Snow Geese for food resources, since both species eat coastal graminoid plants (Batt 1997; Reed et al. 1998; Mowbray et al. 2000).

In 1984 and 1996, Sabine's Gulls had the same distribution on Prince Charles Island (Fig. 9), but there was a decrease in density between the 1984 surveys (Gaston et al. 1986) and the 1996 surveys. In 1984, roughly 75% of the island coastline had gull densities of more than 5 birds/km; in 1996, less than 10% of the coastal aerial transects reached that density (Fig. 9). There is no obvious reason for this reduction in density. It is doubtful that the differences are an artefact of differing survey methods between studies. The 1996 coastal stratum included all transects up to 6 km inland; this stratum is at least as wide as the stratum in the 1984 surveys, where everything that could be seen was counted, regardless of distance from the plane (Gaston et al. 1986). Gaston et al. (1986) were also surveying at a higher altitude and higher speed than we were, so if the numbers were an artefact of method, our densities should have been higher. At East Bay, Southampton Island, densities of nesting Sabine's Gulls increased between 1980 and 1998–1999 from 7 nests/km^2 to 10–12 nests/km^2 (Stenhouse 2003) (the mean density in "good" (Graminoid/Moss Lowland) plots on Prince Charles Island and Air Force Island in 1997 was 9.5 birds/km^2 (Table 6)). Sabine's Gulls exhibit very high, almost continuous, nest attendance by one parent (Stenhouse 2003) and they are conspicuous on the nest, so it is doubtful that we were simply missing birds on the survey. Sabine's Gull nests and chicks form alternative prey for jaegers and Arctic foxes in low lemming years (Day et al. 2001), and nest predation and abandonment would cause a temporary decline, but lemmings were abundant in 1996. It could be that because of the late snowmelt in 1996, some Sabine's Gulls abandoned attempts to nest and left Prince Charles Island by the time of the aerial surveys in early July. However, the ground (plot) surveys in early and mid-July recorded numerous Sabine's Gull nests and densities similar to those recorded by Stenhouse (2003) (Table 6). We can only conclude that there has been a real decrease in densities of Sabine's Gulls and therefore in population size (because distribution did not change) between the 1980s and the 1990s.

5.5 Importance of the islands to birds

Prince Charles Island and Air Force Island are major breeding sites for shorebirds. Our population estimates for eight species (Table 9) are greater than 1% of the current North American population estimate (Morrison et al. 2006) for that species or subspecies (a standard criterion for the nomination of a site as a protected area: see Alexander et al. 1991; Ramsar Convention on Wetlands 1999; Wilcox and Chaundy-Smart 2001) and greater than 10% of the continental population estimates for five species. It is very surprising, however, that the islands' breeding population of Dunlin would constitute 30% of the entire population for the subspecies *hudsonia.* Prince Charles Island is on the eastern edge of the breeding range for the subspecies, and the edge of a range generally does not comprise a high percentage of the total population. Our results suggest that the total population estimate listed in Morrison et al. (2006) may be substantially lower than the reality.

While there is no doubt that Prince Charles Island and Air Force Island are extremely important breeding areas for a number of shorebird species, the percentages presented in Table 9 likely overestimate their importance to the continental populations of those species. Populations of North American shorebirds, particularly those that disperse on migration, those that are dispersed on the wintering

grounds, or those that are marine during the non-breeding season, are generally thought to be underestimated (Meltofte 2001; V. Johnston, pers. obs.; J. Bart, pers. comm.; R.I.G. Morrison, pers. comm.). In a recent update of North American shorebird population estimates, the estimates were revised upwards for nearly 70% (18/26) of the species for which new information was available (Morrison et al. 2006). So, while there is little doubt that many shorebird populations are declining, it is probable that most species are starting at a higher population level than the current estimates suggest.

The observations that we made confirm the status of Prince Charles Island and Air Force Island as extremely important breeding sites for shorebirds in the Arctic. Along with the Great Plains of the Koukdjuak (West Baffin Island), Prince Charles Island and Air Force Island are the most important known breeding sites for Red Phalaropes and White-rumped Sandpipers in the entire Canadian Arctic.

In addition, the islands appear to be extremely important for several non-shorebird species. Five have populations on the islands at or above 1% of the national or flyway population: Long-tailed Jaeger, Long-tailed Duck (Table 9), Atlantic Brant, Lesser Snow Goose, and Sabine's Gull (Table 10). The islands appear to be especially important to Sabine's Gulls, Long-tailed Jaegers, and the Atlantic subspecies of Brant. For each of these species or subspecies, the islands comprise more than 10% of their total estimated population. However, in light of the expanding Lesser Snow Goose populations and the shrinking Atlantic Brant densities on Air Force Island and the declining densities of Sabine's Gull on Prince Charles Island (see 5.4.2 above), it would be well worth while to re-survey both islands to confirm their importance to Atlantic Brant and Sabine's Gull.

5.6 Recommendations

1. We recommend that National Wildlife Area designation be pursued for Prince Charles Island and Air Force Island. They meet the criteria (Canadian Wildlife Service 1994) for this type of legislated protection.
   - The islands are of continental importance to breeding Black-bellied Plovers, American Golden-Plovers, Ruddy Turnstones (ssp. *morinella*), White-rumped Sandpipers, Dunlin (ssp. *hudsonia*), Red Phalaropes, Sabine's Gulls, Atlantic Brant, Long-tailed Jaegers, and migratory (possibly breeding?) Purple Sandpipers (ssp. *maritima*) and Red Knots (ssp. *rufa*).
   - The islands have high shorebird species richness (12 species).
   - The islands host three bird species designated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Red Knot ssp. *rufa*—Endangered; Ross's Gull—Threatened; and Peregrine Falcon *Falco peregrinus* ssp. *tundrius*—Special Concern) and one mammal designated by COSEWIC (polar bear—Special Concern) (Committee on the Status of Endangered Wildlife in Canada 2007). They also host nine bird species considered Sensitive in the Northwest Territories' species status ranking (Northwest Territories General Status Ranking Program 2007). Nunavut has not completed a status ranking exercise yet, but the Northwest Territories listings provide a good surrogate for most species.
2. We propose a boundary 10 km out from the two islands and including Cockram Strait, which runs between the two islands, as depicted in Figure 10. The protected area would encompass the islands themselves and the adjacent marine area.
3. Shorebird surveys should be undertaken periodically to monitor population levels on these islands. Particular attention should be paid to Red Phalarope populations here, at East Bay, and on the Rasmussen Lowlands to determine whether the identified declining trend in this species continues.
4. There is an excellent opportunity to chart the effects of increasing Lesser Snow Goose populations on the breeding success of Atlantic Brant on Air Force Island. Current annual surveys of Lesser Snow Geese should be modified or supplemented to include accurate annual censusing of Atlantic Brant populations. These surveys should be undertaken in such a way that Sabine's Gulls can also be adequately surveyed.

Figure 10
Boundaries for a proposed National Wildlife Area in the Foxe Basin, Nunavut

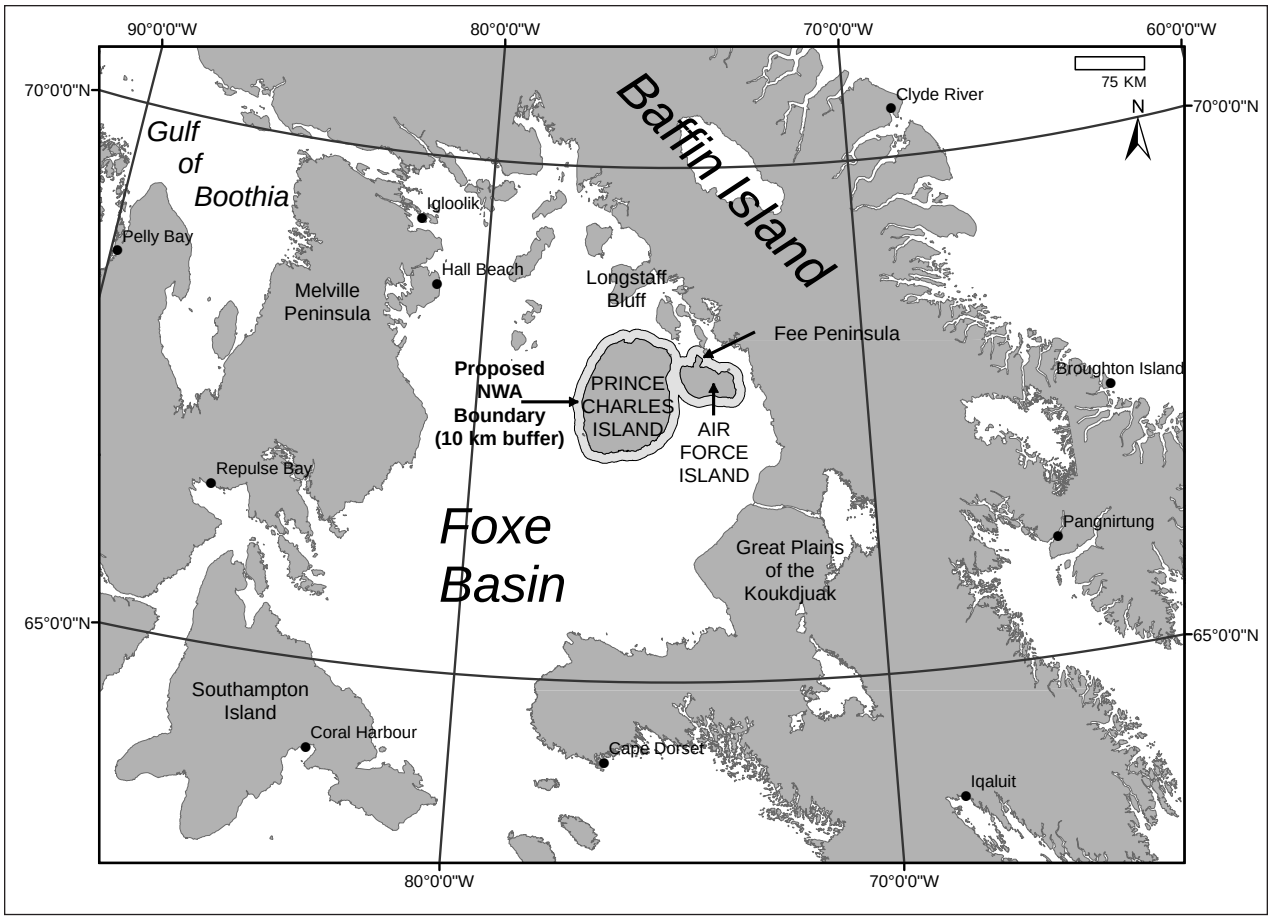
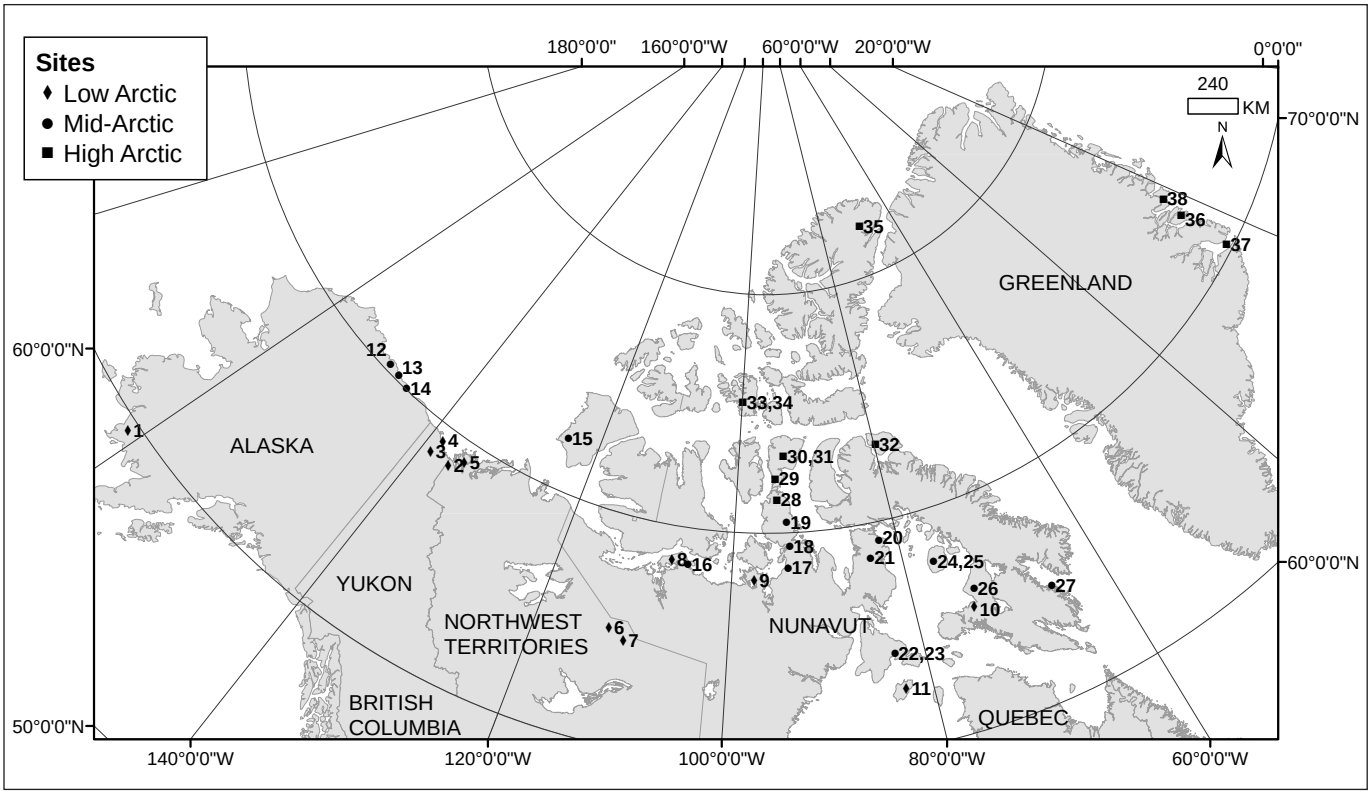


Figure 11
Shorebird survey locations across the Arctic (see Appendix 3 for site information)



Literature cited

Alexander, S.A.; Ferguson, R.S.; McCormick, K.J. 1991. Key migratory bird terrestrial habitat sites in the Northwest Territories. Can. Wildl. Serv. Occ. Pap. 71. Canadian Wildlife Service, Environment Canada, Ottawa, Ont.

Andrews, J.T. 1974. Post-glacier rebound. National atlas of Canada. Fourth edition. http://atlas.gc.ca/site/english/maps/archives/4thedition/environment/land/.

Anonymous. 1948. Discovery of two islands in eastern Foxe Basin. Arctic Circular 1: 73–74.

Baldwin, W.K.W. 1953. List of plants collected on Prince Charles and Air Force Islands in Foxe Basin, Northwest Territories. Ann. Rep. Mus. Canada #123, Ottawa.

Barry, T.W. 1956. Observation of a nesting colony of American Brant. Auk 73: 193–202.

Batt, B. (ed). 1997. Arctic ecosystems in peril: report of the Arctic Goose Habitat Working Group. Arctic Goose Joint Venture Species Publication. U.S. Fish and Wildlife Service, Washington, D.C., and Canadian Wildlife Service, Ottawa, Ont.

Bergman, R.D.; Howard, R.L.; Abraham, K.F.; Weller, M.W. 1977. Water birds and their wetland resources in relation to oil development at Storkersen Point, Alaska. U.S. Fish Wildl. Serv. Res. Publ. 129. Washington, D.C.

Bibby, C.J.; Burgess, N.D.; Hill, D.A. 1993. Bird census techniques. Academic Press, Toronto, Ont.

Brechet, A.; Martin, J-L.; Meister, P.; Rabouam, C. 2000. A second breeding site for Ross' gull (*Rhodostethia rosea*) in Nunavut, Canada. Arctic 53: 234–236.

Canadian Wildlife Service. 1993. Habitat conservation strategy and plan for the Northwest Territories, 1993-2003. Canadian Wildlife Service, Environment Canada, Yellowknife, N.W.T.

Canadian Wildlife Service. 1994. Criteria for selecting candidate National Wildlife Areas. Internal report, Canadian Wildlife Service Headquarters, Environment Canada, Ottawa, Ontario. http://www.cws-scf.ec.gc.ca/habitat/default.asp?lang=en&n=39C49EBC.

Canadian Wildlife Service. 2006. Shorebird conservation strategy and action plan: Northern Conservation Division. Canadian Wildlife Service, Environment Canada, Yellowknife, N.W.T.

Canadian Wildlife Service Waterfowl Committee. 2006. Population status of migratory game birds in Canada: November 2006. CWS Migr. Birds Regul. Rep. No. 19. Canadian Wildlife Service, Environment Canada, Ottawa, Ont.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2007. Canadian Species at Risk. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ont. http://www.cosewic.gc.ca/eng/sct0/rpt/rpt_csar_e.cfm [accessed 29 March 2007].

Crowe, K.J. 1969. A cultural geography of northern Foxe Basin, NWT. M.Sc. thesis, University of British Columbia, Vancouver, B.C.

Day, R.H.; Stenhouse, I.J.; Gilchrist, H.G. 2001. Sabine's Gull (*Xema sabini*). *In* The birds of North America, No. 593 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, Penn.

Dickson, D.L.; Dickson, H.L.; Aiudi, G.M. 1988. Bird surveys at Stokes Point and Phillips Bay, Yukon in 1983. Can. Wildl. Serv. Tech. Rept. 40. Canadian Wildlife Service, Environment Canada, Edmonton, Alta.

Dunn, E.H. 2005. National action needs for Canadian landbird conservation, Version 1. Canadian Wildlife Service Landbird Committee, Canadian Wildlife Service, Environment Canada, Ottawa, Ont. http://www.cws-scf.ec.gc.ca/mgbc/action/index_e.cfm.

Edwards, D.K.; Dorsey, G.L.; Crawford, J.A. 1981. A comparison of three avian census methods. Stud. Avian Biol. 6: 170–176.

Ellis, D.V.; Evans, J. 1960. Comments on the distribution and migration of birds in Foxe Basin, Northwest Territories. Can. Field-Nat. 74: 59–70.

Forbes, G.; Robertson, K.; Ogilvie, C.; Seddon, L. 1992. Breeding densities, biogeography, and nest depredation on birds on Igloolik Island, NWT. Arctic 45: 295–303.

Gaston, A.J.; Decker, R.; Cooch, F.G.; Reed, A. 1986. The distribution of larger species of birds breeding on the coasts of Foxe Basin and northern Hudson Bay, Canada. Arctic 39: 285–296.

Godfrey, W.E. 1986. The birds of Canada. Revised edition. National Museum of Natural Sciences, Ottawa, Ont.

Gratto, C.L. 1988. Natal philopatry and age of first breeding of the Semipalmated Sandpiper. Wilson Bull. 100: 660–663.

Gratto-Trevor, C.L. 1992. Semipalmated Sandpiper (*Calidris pusilla*). *In* A. Poole, P. Stettenheim, and F. Gill (eds.). The birds of North America, No. 6. The Academy of Natural Sciences, Philadelphia, and the American Ornithologists' Union, Washington, D.C.

Gratto-Trevor, C.L. 1994. Use of Landsat TM imagery in determining priority shorebird habitat in the outer Mackenzie Delta, NWT. Northern Oil and Gas Action Plan (NOGAP) Rept. C-24. Canadian Wildlife Service, Environment Canada, Saskatoon, Sask.

Gratto-Trevor, C.L. 1996. Use of Landsat TM imagery in determining important shorebird habitat in the outer Mackenzie Delta, Northwest Territories. Arctic 49: 11–22.

Gratto-Trevor, C.L.; Johnston, V.H.; Pepper, S.T. 1998. Changes in shorebird and eider abundance in the Rasmussen Lowlands, NWT. Wilson Bull. 110: 316–325.

Holmes, R.T.; Pitelka, F.A. 1998. Pectoral Sandpiper (*Calidris melanotos*). *In* The birds of North America, No. 348 (A. Poole and F. Gill, eds.). The Birds of North America Inc., Philadelphia, Penn.

Hussell, D.J.T.; Montgomerie, R. 2002. Lapland Longspur (*Calcarius lapponicus*). *In* The birds of North America, No. 656 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, Penn.

Johnson, O.W.; Connors, P.G. 1996. American Golden-Plover (*Pluvialis dominica*), Pacific Golden-Plover (*Pluvialis fulva*). *In* The birds of North America, No. 201–202 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, and the American Ornithologists' Union, Washington, D.C.

Johnston, V.H. 2005. Prince Charles Island. Pages 1693–1694 *in* Mark Nuttall (ed.), Encyclopedia of the Arctic. Vol. 3. Routledge, London.

Johnston, V.H.; Gratto-Trevor, C.L.; Pepper, S.T. 2000. Assessment of bird populations in the Rasmussen Lowlands, Nunavut. Can. Wildl. Serv. Occ. Pap. 101. Environment Canada, Ottawa, Ont.

Jolly, G.M. 1969. Sampling methods for aerial censuses of wildlife populations. East African Agricultural and Forestry Journal 34: 46–49.

Kerbes, R.H. 1969. Biology and distribution of nesting blue geese on Koukdjuak Plain, Baffin Island, NWT. M.Sc. thesis, University of Western Ontario, London, Ont.

Krebs, C.J. 1999. Ecological methodology. Benjamin/Cummings, Menlo Park, Calif.

Kushlan, J.A.; Steinkamp, M.J.; Parsons, K.C.; Capp, J.; Cruz, M.A.; Coulter, M.; Davidson, I.; Dickson, L.; Edelson, N.; Elliot, R.; Erwin, R.M.; Hatch, S.; Kress, S.; Milko, R.; Miller, S.; Mills, K.; Paul, R.; Phillips, R.; Saliva, J.E.; Sydeman, B.; Trapp, J.; Wheeler, J.; Wohl, K. 2002. Waterbird conservation for the Americas: The North American waterbird conservation plan, Version 1. Waterbird Conservation for the Americas, Washington, D.C. http://www.manomet.org/pdf/complete.pdf.

Latour, P.; Machtans, C.; Beyersbergen, G. 2005. Shorebird and passerine abundance and habitat use at a High Arctic breeding site: Creswell Bay, Nunavut. Arctic 58: 55–65.

Latour, P.B.; Leger, J.; Hines, J.E.; Mallory, M.L.; Mulders, D.L.; Gilchrist, H.G.; Smith, P.A.; Dickson, D.L. 2008. Key migratory bird terrestrial habitat sites in the Northwest Territories and Nunavut. Third ed. Can. Wildl. Serv. Occ. Pap. 114. Environment Canada, Ottawa, Ont. http://www.cws-scf.ec.gc.ca/publications/papers/114/index_e.cfm.

Lyon, B.; Montgomerie, R. 1995. Snow Bunting and McKay's Bunting (*Plectrophenax nivalis* and *Plectrophenax hyperboreus*). *In* The birds of North America, No. 198–199 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, and the American Ornithologists' Union, Washington, D.C.

MacPherson, A.H.; Manning, T.H. 1959. The birds and mammals of Adelaide Peninsula, NWT. Nat. Mus. Can. Bull. 161. Ottawa, Ont.

Markham, W.E. 1986. Ice cover. Chapter 6 *in* I.P. Martini (ed.), Canadian inland seas. Elsevier Oceanography Series, No. 44. Elsevier, New York, N.Y.

Martin, P.D. 1983. Bird use of arctic tundra habitats at Canning River Delta, Alaska. M.Sc. thesis, University of Alaska, Fairbanks, Alaska.

Martin, J-L. 1998. Réponse au stress climatique et biotique dans une communauté de l'Arctique canadien. Rapport d'activité 1997. Institut français pour la recherche et la technologie polaires, Plouzané, France.

Martin, J-L.; Clamens, A.; Blangy, S. 1988. First breeding record of the Dunlin, *Calidris alpina,* on Baffin Island, Northwest Territories. Can. Field-Nat. 102: 257–258.

Maxwell, J.B. 1986. A climate overview of the Canadian inland seas. Chapter 5 *in* I.P. Martini (ed.), Canadian inland seas. Elsevier Oceanography Series, No. 44. Elsevier, New York, N.Y.

Mayfield, H.F. 1983. Densities of breeding birds at Polar Bear Pass, Bathurst Island, Northwest Territories. Can. Field-Nat. 97: 371–376.

Meltofte, H. 1985. Populations and breeding schedules of waders, *Charadrii*, in high arctic Greenland. Medd. om Gronland. Reprinted *in* Bioscience 16: 3–43.

Meltofte, H. 2001. Wader population censuses in the Arctic: getting the timing right. Arctic 54: 367–376.

Milko, R.; Dickson, L.; Elliot, R.; Donaldson, G. 2003. Wings over water: Canada's waterbird conservation plan. Canadian Wildlife Service, Environment Canada, Ottawa, Ont. http://www.cws-scf.ec.gc.ca/publications/wow/Wings-EN-2003.pdf.

Montgomerie, R.D.; Cartar, R.V.; Lyon, B.E.; McLaughlin, R.L. 1982. Shorebird studies at Sarcpa Lake, Melville Peninsula, Northwest Territories. Wader Study Group Bulletin 34: 30–32.

Montgomerie, R.D.; Cartar, R.V.; McLaughlin, R.L.; Lyon, B. 1983. Birds of Sarcpa Lake, Melville Peninsula, Northwest Territories: breeding phenologies, densities and biogeography. Arctic 36: 65–75.

Morrison, R.I.G. 1997. The use of remote sensing to evaluate shorebird habitats and populations on Prince Charles Island, Foxe Basin, Canada. Arctic 50: 55–75.

Morrison, R.I.G.; McCaffery, B.J.; Gill, R.E.; Skagen, S.K.; Jones, S.L.; Page, G.W.; Gratto-Trevor, C.L.; Andres, B.A. 2006. Population estimates of North American shorebirds, 2006. Wader Study Group Bull. 111: 67–85.

Moskoff, W.; Montgomerie, R. 2002. Baird's Sandpiper (*Calidris bairdii*). *In* The birds of North America, No. 661 (A. Poole and F. Gill, eds.). The Birds of North America Inc., Philadelphia, Penn.

Mowbray, T.B.; Cooke, F.; Ganter, B. 2000. Snow Goose (*Chen caerulescens*). *In* The birds of North America, No. 514 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, Penn.

Nettleship, D.N. 1973. Breeding ecology of turnstones *Arenaria interpres* at Hazen Camp, Ellesmere Island, NWT. Ibis 115: 202–217.

Nettleship, D.N. 2000. Ruddy Turnstone (*Arenaria interpres*). *In* The birds of North America, No. 537 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, Penn.

Neu, C.W.; Beyers, C.R.; Peek, J.M.; Boy, V. 1974. A technique for analysis of utilization-availability data. Journal of Wildlife Management 38: 541–545.

Nol, E.; Blanken, M.S. 1999. Semipalmated Plover (*Charadrius semipalmatus*). *In* The birds of North America, No. 444 (A. Poole and F. Gill, eds.). The Birds of North America Inc., Philadelphia, Penn.

Northwest Territories General Status Ranking Program. 2007. NWT Species Monitoring Infobase, Version 2007.2. Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, N.W.T. http://www.nwtwildlife.com/monitoring/speciesmonitoring/default.htm.

Parmelee, D.F. 1992. White-rumped Sandpiper (*Calidris fuscicollis*). *In* The birds of North America, No. 29 (A. Poole, P. Stettenheim, and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, and the American Ornithologists' Union, Washington, D.C.

Patterson, L.A.; Alliston, W.G. 1978. Breeding bird surveys at selected sites on southern Somerset Island and Boothia Peninsula, July 1977. LGL Limited for Polar Gas Project, Toronto, Ont.

Paulson, D.R. 1995. Black-bellied Plover (*Pluvialis squatarola*). *In* The birds of North America, No. 186 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, and the American Ornithologists' Union, Washington, D.C.

Payne, L.X.; Pierce, E.P. 2002. Purple Sandpiper (*Calidris maritima*). *In* The birds of North America, No. 706 (A. Poole and F. Gill, eds.). The Birds of North America Inc., Philadelphia, Penn.

Ramsar Convention on Wetlands. 1999. The criteria for identifying wetlands of international importance. http://www.ramsar.org/key_criteria.htm.

Reed, A.; Dupuis, P.; Fischer, K.; Moser, J. 1980. An aerial survey of breeding geese and other wildlife in Foxe Basin and northern Baffin Island, Northwest Territories, July 1979. Can. Wild. Serv. Prog. Notes No. 114. Canadian Wildlife Service, Environment Canada, Ottawa, Ont.

Reed, A.; Ward, D.H.; Derksen, D.V.; Sedinger, J.S. 1998. Brant (*Branta bernicla*). *In* The birds of North America, No. 337 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, Penn.

Richardson, W.J.; Gollop, M.A. 1974. Populations of birds at Babbage River, Yukon Territory, during the breeding season, 1973: a monitoring and methodological study. Arctic Gas Biological Report Series 26(2). LGL Limited.

Riewe, R. 1992. Nunavut atlas. Canadian Circumpolar Institute, Edmonton, Alta.

Sea Duck Joint Venture. 2003. Long-tailed Duck (*Clangula hyemalis*). Sea Duck Information Series. http://www.seaduckjv.org/infoseries/ltdu_sppfactsheet.pdf.

Smith, A.C.; Virgl, J.A.; Panayi, D.; Armstrong, A.R. 2005. Effects of a diamond mine on tundra-breeding birds. Arctic 58: 295–304.

Soper, J.D. 1940. Local distribution of some eastern Canadian Arctic birds. Auk 57: 13–21.

Stenhouse, I.J. 2003. The reproductive behaviour and ecology of Sabine's Gulls (*Xema sabini*) in the eastern Canadian Arctic. Ph.D. thesis, Memorial University of Newfoundland, St. John's, Nfld.

Stirling, W.E.; Cleator, H. 1981. Polynyas in the Canadian Arctic. Can. Wildl. Serv. Occ. Pap. 45. Canadian Wildlife Service, Environment Canada, Ottawa, Ont.

Tracy, D.M.; Schamel, D.; Dale, J. 2002. Red Phalarope (*Phalaropus fulicarius*). *In* The birds of North America, No. 698 (A. Poole and F. Gill, eds.). The Birds of North America Inc., Philadelphia, Penn.

U.S. Fish and Wildlife Service. 2004. High priority shorebirds: 2004. U.S. Shorebird Conservation Plan. http://www.fws.gov/shorebirdplan/USShorebird/downloads/ShorebirdPriorityPopulationsAug04.pdf.

Van Belle, G. 2002. Statistical rules of thumb. Wiley and Sons, Toronto, Ont.

Warnock, N.D.; Gill, R.E. 1996. Dunlin (*Calidris alpina*). *In* The birds of North America, No. 203 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, and the American Ornithologists' Union, Washington, D.C.

Watson, A. 1958. Bird numbers on tundra in Baffin Island. Arctic 16: 101–108.

Wilcox, S.; Chaundy-Smart, R. 2001. Canadian Important Bird Area criteria. http://www.bsc-eoc.org/iba/ibacriteria.jsp.

Appendices

Appendix 1
Dates and locations of weather, habitat, and bird data collection, Prince Charles Island and Air Force Island, 1996 and 1997

Activity	Location	Date
Collection of base camp weather data	Prince Charles Island	19 June – 16 July 1996 24 June – 16 July 1997
Collection of ground habitat data	Prince Charles Island	24 June – 14 July 1996 26 June – 15 July 1997
	Air Force Island	1–9 July 1997
Ground surveys		
Transect surveys	Prince Charles Island	24 June – 11 July 1996
Plot surveys	Prince Charles Island	28 June – 14 July 1996 26 June – 15 July 1997
	Air Force Island	1–9 July 1997
Aerial surveys	Prince Charles Island	3, 4, and 6 July 1996
	Air Force Island	5 July 1997

Appendix 2
Vascular plants (in alphabetical order) identified from Air Force Island and Prince Charles Island, 1996 and 1997

Scientific name	Common name	Air Force Island	Prince Charles Island
Alopecurus alpinus	grass	✓	✓
Arctagrostis arundinacea	grass		✓
Arctagrostis latifolia	grass	✓	✓
Arctophila fulva	grass		✓
Cardamine pratensis	bitter cress	✓	✓
Carex aquatilis	sedge	✓	✓
Carex atrofusca	sedge		✓
Carex membranacea	sedge	✓	✓
Carex misandra	sedge	✓	✓
Carex rariflora	sedge		✓
Carex saxatilis	sedge	✓	✓
Carex ursina	sedge		✓
Cassiope sp.	Arctic heather	✓	
Cerastium alpinum	chickweed		✓
Cerastium beeringianum	chickweed	✓	✓
Cerastium regelii	chickweed		✓
Chrysosplenium tetrandrum	water carpet		✓
Chrysosplenium wrightii	water carpet		✓
Cochlearia officinalis	scurvy grass	✓	✓
Draba alpina	alpine whitlow grass	✓	✓
Draba corymbosa	whitlow grass		✓
Draba lactea	whitlow grass		✓
Dryas integrifolia	mountain avens		✓
Dupontia fisheri	grass	✓	✓
Epilobium anagallifolium	dwarf fireweed		✓
Eriophorum angustifolium	cotton grass	✓	✓
Eriophorum russeolum	cotton grass	✓	✓
Eriophorum scheuchzeri	cotton grass		✓
Eriophorum triste	cotton grass		✓
Eutrema edwardsii	Edwards mock wallflower	✓	✓
Festuca baffinensis	grass		✓
Festuca brachyphylla	grass	✓	
Hierochloe alpina	grass	✓	
Hierochloe pauciflora	grass		✓
Hippuris vulgaris	mare's tail		✓
Juncus albescens	rush		✓
Juncus biglumis	rush		✓
Luzula confusa	wood rush	✓	
Luzula nivalis	wood rush	✓	✓
Papaver radicatum	Arctic poppy		✓
Pedicularis flammea	lousewort		✓
Pedicularis hirsuta	lousewort	✓	✓
Pleuropogon sabinei	sedge		✓
Poa alpigena	grass		✓
Poa arctica	grass		✓
Puccinellia phryganodes	grass	✓	
Ranunculus nivalis	snow buttercup		✓
Ranunculus sulphureus	sulphur buttercup		✓
Salix arctica	Arctic willow	✓	✓
Salix reticulata	net-veined willow	✓	✓
Saxifraga aizoides	yellow mountain saxifrage		✓
Saxifraga caespitosa	saxifrage	✓	✓
Saxifraga cernua	bublet saxifrage	✓	✓
Saxifraga hieracifolia	saxifrage		✓
Saxifraga hirculus	yellow marsh saxifrage	✓	✓
Saxifraga nivalis	snow saxifrage		✓
Saxifraga oppositifolia	purple mountain saxifrage		✓
Saxifraga rivularis	brook saxifrage		✓
Saxifraga tricuspidata	prickly saxifrage		✓
Senecio congestus	mastodon flower	✓	✓
Silene involucrata (= *Melandrium*)	bladder campion	✓	✓
Silene uralensis (= *Melandrium apetalum*)	bladder campion		✓
Stellaria humifusa	stitchwort	✓	✓

Appendix 3
Comparison of shorebird densities on Prince Charles Island with densities reported for other breeding sites in the Arctic. Locations are shown on Figure 11. The total number of shorebird species at each site is shown in parentheses.

Location	Shorebird species[a] Birds/km²	Pairs/km²	Habitat	Length of study in years	Survey method	Source
A. Low Arctic sites						
1 Yukon River delta, Alaska		BBPL 1.9 DUNL 66.3 RUTU 0.4 SESA 24.9 PESA 1.8 REPH 2.0 All (13) 169.7	88% wetlands, 12% upland	2 (June)	Area search; results adjusted with detection ratios	J. Bart (unpubl. data)
2 Whitefish Station, Yukon		PESA 9.2 SESA 50.8 All (4) 93.3	Lowland coastal tundra	1 (June–July)	Whole count; rope drags	Hawking (unpubl. manuscript)[1]
3 Babbage River, Yukon		AMGP 5.0 PESA 3.1 SESA 0.6 All (7) 14.4	Tussock tundra	2 (30 May–25 June)	Territory mapping in six plots, repeated a number of times	Richardson and Gollop (1974)
4 Phillips Bay/Stokes Point, Yukon	AMGP 12.4 PESA 28.7 BASA 0.3 SESA 19.0 REPH 1.6 All (12) 91.6		All[b]	1 (9–29 June)	Ground transects	Dickson et al. (1988)
5 Outer Mackenzie River delta, Northwest Territories		AMGP 0.4 PESA 0.4 SESA 1.4 All (10) 21.4	Low-centred polygon/wet sedge; uplands; willow thicket; sedge/willow/emergents; gravel pads	2 (16 June–14 July)	Area search (transects within plots); some repeated	Gratto-Trevor (1996)
6 Daring Lake, Northwest Territories		SESA 2.0 All (5) 9.3	??	2+ (June)	Whole count	Obst (unpubl. reports)[2, 3]
7 Ekati, Northwest Territories	AGPL 2.0 BASA 0.8 All (6) 13.3		Heath tundra; sedge wetland	8 (June)	Strip transect	Smith et al. (2005)
8 Kent Peninsula, Nunavut		AMGP 1.3 BASA 0.1 DUNL 0.5 PESA 2.7 SESA 0.6 WRSA 0.1 All (8) 6.1	All[l]	2 (15–30 June)	Area search; results adjusted with detection ratios	J. Bart and V. Johnston (unpubl. data)
9 Adelaide Peninsula, Nunavut	AMGP 0.8 BBPL 0.6 PESA 2.2 BASA 1.9 REPH 2.6 All (10)[c] 8.1		Tussock marsh (65%), dry stony ridges (12%), outcrop/boulder plains/barren areas (13%), lakes and rivers (10%)	1 (June–Sept.)	Number of birds per hour of walking	MacPherson and Manning (1959)
10 Bowman Bay, Baffin Island, Nunavut (three sites)	PUSA 1.2 BBPL 2.9 RUTU 3.3 WRSA 7.5 SESA 2.6 REPH 11.5 All (7) 28.8		Grass tundra with granite outcrops	1 (1–11 July)	Walkabout?	Soper (1940)
11 Coats Island, Nunavut	AMGP 0.9 BBPL 2.9 REPH 4.0 RUTU 0.4 SESA 32.7 WRSA 0.2 All (6) 41.1		Wetland hummock tundra, river drainages, upland tundra ridges, and raised beaches	2 (1 June–1 August)	Whole count; territory mapping	P. Smith (unpubl. data)

Appendix 3 (continued)

Location	Shorebird species[a] Birds/km^2	Shorebird species[a] Pairs/km^2	Habitat	Length of study in years	Survey method	Source
B. Mid-Arctic sites						
12 Prudhoe Bay, Alaska		BBPL 0.6 AMGP 2.7 RUTU 0.1 SESA 12.5 WRSA 0.6 BASA 0.7 PESA 8.7 DUNL 7.5 REPH 6.8 All (14) 43.2	Saline tundra; non-saline tundra; dry tundra	10 (June–August)	Transects in plots, repeated eight times annually	Troy Ecological Research Associates (TERA) (unpubl. report)[4]
13 Storkersen Point, Alaska	AMGP 2.0 BBPL 0.3 RUTU 1.6 PESA 12.9 DUNL 15.1 BASA 2.0 SESA 15.5 REPH 26.3 All (10) 80.7		All[f]	5 (1 June–August (only June densities shown here))	Weekly plot census	Bergman et al. (1977)
14 Canning River delta, Alaska		AMGP 1.8 SESA 9.1 PESA 11.1 DUNL 2.9 REPH 17.8 All (7) 50.0	All[m]	2 (6 June–7 July)	Weekly plot census; considered conservative estimate	Martin (1983)
15 Banks Island Migratory Bird Sanctuary No. 1, Northwest Territories	AMGP 3.5 BBPL 7.4 RUTU 1.7 SESA 0.6 PESA 4.7 BASA 1.6 WRSA 4.4 REPH 1.5 All (10) 27.0		All[n]	2 (June)	Ground transects	Latour et al. (unpubl. manuscript)[5]
16 Melbourne Island, Nunavut		AMGP 0.8 BASA 0.7 DUNL 3.2 PESA 5.8 REPH 4.4 SESA 2.8 WRSA 0.7 All (9) 20.0	All[k]	2 (15–30 June)	Area search; results adjusted with detection ratios	J. Bart and V. Johnston (unpubl. data)
17 Rasmussen Lowlands, Nunavut	BBPL 0.5 AMGP 0.8 SEPL 0.1 RUTU 0.2 SESA 1.7 WRSA 3.0 BASA 0.7 PESA 3.3 DUNL 0.9 REPH 4.2 All (12) 15.2	BBPL 0.4 AMGP 0.7 SEPL 0.1 RUTU 0.2 SESA 1.2 WRSA 1.9 BASA 0.7 PESA 2.5 DUNL 0.9 REPH 2.8 All (11) 11.7	All[h]	2 (16 June–13 July)	Area search	Johnston et al. (2000)
18 Southern Boothia Peninsula (Middle Lake/ Jekyll Lake), Nunavut (two transects)	AMGP 11.9 PESA 8.9 WRSA 33.9 BASA 2.8 SESA 6.0 REPH 19.2 All (6) 82.7		All[d]	1 (5–14 July)	Ground transect	Patterson and Alliston (1978)

Appendix 3 (continued)

Location	Shorebird species[a] Birds/km²	Shorebird species[a] Pairs/km²	Habitat	Length of study in years	Survey method	Source
19 Southern Boothia Peninsula (Sanagak Lake), Nunavut (four sites)	AMGP 14.1 WRSA 8.4 BASA 16.4 REPH 1.5 All (4) 40.4		All[d]	1 (5–14 July)	Ground transect	Patterson and Alliston (1978)
20 Igloolik Island, Nunavut		BBPL 0.5 AMGP 0.3 SEPL 0.1 RUTU 0.8 SESA 1.5 WRSA 3.5 REPH 5.0 All (7) 12.1	Wet meadow (65%), *Dryas*/heath slope (25%), rocky shoreline (5%), dry ridge (4%), disturbed area (1%)	1 (1 June–31 August)	Ground transects, repeated weekly	Forbes et al. (1992)
21 Sarcpa Lake, Melville Peninsula, Nunavut		AMGP 3.8 SESA 0.1 WRSA 1.5 BASA 3.8 PESA 0.1 DUNL 0.1 REPH 0.3 All (8) 10.0	All[e]	2 (May–August)	Territory mapping; nest search	Montgomerie et al. (1982, 1983)
22 Southern Southampton Island, Nunavut		AMGP 0.6 DUNL 7.1 REKN 0.1 REPH 1 0.4 SESA 4.6 WRSA 2.8 All (7) 25.9	Wet sedge lowland; barren tundra; dry vegetated tundra	1 (17–27 June)	Area search; results adjusted with detection ratios	J. Bart and V. Johnston (unpubl. data)
23 East Bay, Southampton Island, Nunavut	AMGP 0.2 BBPL 3.1 DUNL 1.2 REPH 12.9 RUTU 14.5 SESA 0.6 WRSA 13.0 All (10) 53.0		Wetland ponded tundra; raised beaches; rocky intertidal areas	6 (10 June–15 July)	Whole count; rope drags	P. Smith (unpubl. data)
24 Prince Charles Island, Foxe Basin, Nunavut	AMGP 2.1 BBPL 2.4 RUTU 5.5 DUNL 1.7 SESA 5.9 WRSA 32.6 REPH 36.1 PESA 0.7 BASA 2.6 PUSA 0.2 All (10) 89.9	AMGP 0.4 BBPL 1.3 RUTU 1.9 DUNL 0.8 SESA 1.5 WRSA 6.7 REPH 14.1 PESA 0.4 BASA 0.5 PUSA 0.1 All (10) 36.4	All[k]	2, but only 1997 results used here (and 1996 for SESA, BASA)	Area search	This study
25 Prince Charles Island, Foxe Basin, Nunavut		BBPL 1.7 AMGP 0.3 RUTU 3.5 SESA 1.2 WRSA 15.7 REPH 16.6 All (6) 39.0	All[g]	1 (5–13 July)	Transects within plots	Morrison (1997)
26 West Baffin Island, Nunavut	AMGP 0.2 BBPL 0.1 REPH 21.5 DUNL 0.9 WRSA 11.3 All (5) 34.0		Mostly saturated sedge plain; some vegetated uplands	2 (15 June–30 June)	Area search; results adjusted with detection ratios	J. Bart and V. Johnston (unpubl. data)
27 Cumberland Sound, Baffin Island, Nunavut	BASA 0.4 All (2) 0.4		Wet sedge lowland	1 (June–August)	Whole count	Watson (1958)

Appendix 3 (continued)

Location	Shorebird species[a] Birds/km²	Pairs/km²	Habitat	Length of study in years	Survey method	Source
C. High Arctic sites						
28 Northern Boothia Peninsula, Nunavut (two sites)	BBPL 2.8 AMGP 1.4 PESA 1.4 WRSA 12.0 REPH 18.1 All (6) 35.7		All[d]	1 (5–14 July)	Ground transect	Patterson and Alliston (1978)
29 Southeast Somerset Island, Nunavut (four sites)	BBPL 5.1 AMGP 0.8 WRSA 18.6 BASA 5.7 RUTU 11.1 REPH 15.4 All (7) 56.7		All[d]	1 (5–14 July)	Ground transect	Patterson and Alliston (1978)
30 Creswell Bay/Stanwell-Fletcher Lake, Somerset Island, Nunavut (six sites)	AMGP 8.1 PESA 0.5 WRSA 12.3 BASA 5.4 REPH 6.6 All (5) 32.9		All[d]	1 (5–14 July)	Ground transect	Patterson and Alliston (1978)
31 Creswell Bay (north side), Somerset Island, Nunavut	AMGP 1.1 BBPL 2.2 WRSA 15.6 PESA 2.8 BASA 0.4 SESA 0.3 RUTU 1.1 REPH 10.4 All (10) 36.0		All[j]	2 (16 June–4 July)	Area search	Latour et al. (2005)
32 Southwest Bylot Island, Nunavut		AMGP 6.4 BASA 1.9 WRSA 0.9 BBPL 0.3 REPH 0.1 All (5) 9.6	Sparse heath tundra (77%), sedge meadow (15%), heath/herb slope, dry barrens, gravel/sand flood plains (8%)	1 (27 June–12 July)	Area search, repeated twice	Crockford (unpubl. report)[6]
33 Polar Bear Pass, Bathurst Island	WRSA 8.0	BBPL 1.25 REPH 7.00 All (3) 8.75	Sedge/moss meadow	4 (June–July)	Nest search	Mayfield (1983)
34 Polar Bear Pass, Bathurst Island, Nunavut		BBPL 0.13 All (2) 1.1	Upland *Saxifraga* semi-desert	4 (June–July)	Nest search	Mayfield (1983)
35 Lake Hazen, Ellesmere Island, Nunavut		RUTU 3.04–5.0 (only RUTU presented)	All,[i] with most nests in *Dryas* hummocks or clay–*Dryas*, and close to wet area	1 (June–August)	Nest search	Nettleship (1973)
36 Vega Sund, northeast Greenland		RUTU 0.58 DUNL 1.58 All (7) 2.85	Coastal slopes; lowland (60% vegetated)	1 (June–July)	Repeated area searches	Meltofte (1985)
37 Kaerelv, northeast Greenland (two sites)		RUTU 0.43 DUNL 0.59 All (6) 1.89	Vegetated tundra (70% vegetated)	1 (June–July)	Repeated area searches	Meltofte (1985)
38 Myggbukta, northeast Greenland		RUTU 1.48 DUNL 2.15 REPH 0.16 All (7) 6.72	Barren mixed with vegetated beach ridges and many ponds	1 (June–July)	Repeated area searches	Meltofte (1985)

AMGP = American Golden-Plover; BASA = Baird's Sandpiper; BBPL = Black-bellied Plover; DUNL = Dunlin; PESA = Pectoral Sandpiper; PUSA = Purple Sandpiper; REPH = Red Phalarope; RUTU = Ruddy Turnstone; SEPL = Semipalmated Plover; SESA = Semipalmated Sandpiper; WRSA = White-rumped Sandpiper

[a] Breeding species not found on Prince Charles Island and Air Force Island omitted, but All species in parentheses includes all breeding species recorded at site.
[b] Main habitats sampled: wet sedge/polygonal tundra; wet sedge tundra; tussocky tundra; graminoid/dwarf shrub tundra; tussocky/polygonal tundra.
[c] Minimum estimate. Densities were not calculated for less common breeding species.
[d] Main habitats sampled: evergreen shrub (closed, open, and sparse); sedge marsh (closed); sedge meadow (closed); evergreen shrub/sedge (open).
[e] Main habitats sampled: solifluction zones (30%); boulder fields/outcrop (25%); *Dryas*-lichen ridges (20%); disturbed areas (10%); wet sedge meadow (10%); ponds/small lakes (5%).

Appendix 3 (continued)

[f] Flooded tundra; *Carex* ponds (shallow and deep); *Arctophila* ponds (shallow and deep); deep, open ponds; mixed open and vegetated lakes; beaded streams; coastal wetlands.
[g] Ponds and streams; saltmarsh; grassland (two types); marsh (wet and saturated); tundra (vegetated, poorly vegetated, and unvegetated); flats (lower and upper); beach ridge; gravel barrens (coastal and interior); rock outcrop.
[h] Low tundra; hummocky tundra; tussocky tundra; interrupted tundra; raised tundra; high-centred polygons; beach ridges/eskers; sand flats; rock outcrop.
[i] Main habitats sampled: *Dryas* hummocks and tundra; clay-*Dryas* tundra; clay plain/slope; marsh (*Carex, Eriophorum, Arctagrostis, Polygonum, Dryas,* moss); gravel or sand.
[j] Main habitats sampled: dry sedge tundra; wet sedge tundra; sparsely vegetated gravel outwash; sparsely vegetated *Dryas* tundra; *Dryas/Salix/*sedge tundra.
[k] Wet graminoid marsh; wet moss marsh; grassland; sedge marsh; saltmarsh; vegetated tundra; dry graminoid tundra; dry moss tundra; unvegetated/rocky tundra; beach ridge; barrens.
[l] Wetland tundra; vegetated tundra/esker complexes; rocky, poorly vegetated habitats.
[m] Wet, flooded, ponded polygonal sedge tundra; mix of dry polygons and frost boils with some sedge ponds; moist to wet sedge tundra; some ponds and polygons.
[n] Moist-wet tundra, dry-mesic tundra, dwarf shrub-herb barrens.

[1]**Hawking, J. 1985**. Breeding bird survey of the Whitefish Station area, Mackenzie Delta. Canadian Wildlife Service, Whitehorse, Yukon. [unpubl. report].
[2]**Obst, J. 2000**. Shorebird studies at Daring Lake, NWT. Dept. of the Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, N.W.T. [unpubl. report].
[3]**Obst, J. 2001**. Shorebird studies at Daring Lake, NWT. Dept. of the Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, N.W.T. [unpubl. report].
[4]**Troy Ecological Research Associates (TERA). 1993**. Population dynamics of birds in the Pt. McIntyre Reference Area 1981-1992. Prepared for BP Exploration (Alaska), Anchorage, Alaska. [unpubl. report].
[5]**Latour, P.B.; Machtans, C.S.; Hines, J.E. 2006**. The abundance of breeding shorebirds and songbirds in relation to the expanding Lesser Snow Goose colony on Banks Island, NWT. Canadian Wildlife Service, Yellowknife, N.W.T. [unpubl. manuscript].
[6]**Crockford, N. 1994**. Breeding waders on Bylot Island, NWT, Canada: testing a survey method. Royal Society for the Preservation of Birds, Bedfordshire, U.K. [unpubl. report].

Appendix 4
Bird species and numbers recorded from ground surveys, Prince Charles Island (24 June to 14 July 1996 and 26 June to 15 July 1997) and Air Force Island (1 to 9 July 1997)[a]

Species	Scientific name	Confirmed breeding	Observed off-transect	Number of individuals in plots and/or transects[b] 1996	1997
Red-throated Loon	*Gavia stellata*	✓		1	2
Pacific Loon	*Gavia pacifica*	✓		0	4
Northern Fulmar	*Fulmarus glacialis*		✓		
Tundra Swan	*Cygnus columbianus*		✓		
Lesser Snow Goose	*Chen caerulescens caerulescens*	✓		13	1166
Cackling Goose	*Branta hutchinsii*	✓		14	9
Atlantic Brant	*Branta bernicla hrota*	✓		25	45
Northern Pintail	*Anas acuta*			0	1
Common Eider	*Somateria mollissima*		✓		
King Eider	*Somateria spectabilis*	✓		49	11
Long-tailed Duck	*Clangula hyemalis*	✓		9	11
Peregrine Falcon	*Falco peregrinus*		✓		
Gyrfalcon	*Falco rusticolus*		✓		
Rock Ptarmigan	*Lagopus muta*		✓		
Willow Ptarmigan	*Lagopus lagopus*	✓		24	2
Sandhill Crane	*Grus canadensis*		✓		
American Golden-Plover	*Pluvialis dominica*	✓		35	13
Black-bellied Plover	*Pluvialis squatarola*	✓		28	12
Semipalmated Plover	*Charadrius semipalmatus*		✓		
Ruddy Turnstone	*Arenaria interpres morinella*	✓		112	36
Purple Sandpiper	*Calidris maritima maritima*			5	3
Red Knot	*Calidris canutus rufa*			0	2
Dunlin	*Calidris alpina hudsonia*	✓		21	15
Semipalmated Sandpiper	*Calidris pusilla*	✓		17	0
White-rumped Sandpiper	*Calidris fuscicollis*	✓		143	260
Baird's Sandpiper	*Calidris bairdii*			7	0
Pectoral Sandpiper	*Calidris melanotos*			1	5
Red Phalarope	*Phalaropus fulicarius*	✓		1272	340
Pomarine Jaeger	*Stercorarius pomarinus*	✓		10	15
Parasitic Jaeger	*Stercorarius parasiticus*	✓		6	2
Long-tailed Jaeger	*Stercorarius longicaudus*	✓		9	13
Ross's Gull	*Rhodostethia rosea*	✓	✓		
Herring Gull	*Larus argentatus*	✓		2	0
Glaucous Gull	*Larus hyperboreus*		✓		
Thayer's Gull	*Larus thayeri*		✓		
Sabine's Gull	*Xema sabini*	✓		101	60
Arctic Tern	*Sterna paradisaea*	✓		15	5
Snowy Owl	*Bubo scandiacus*	✓	✓		
Horned Lark	*Eremophila alpestris*		✓		
American Pipit	*Anthus rubescens*		✓		
Lapland Longspur	*Calcarius lapponicus*	✓		239	124
Snow Bunting	*Plectrophenax nivalis*	✓		4	6

[a]Includes records by J-L Martin in 1996 and 1997.
[b]In 1996 $n = 122$; in 1997 $n = 96$.

Appendix 5a
Mean weighted densities of shorebird pairs and individuals (number/km^2 (SE)) in 11 habitat types, 1996 transects

	Red Phalarope		White-rumped Sandpiper		Ruddy Turnstone ssp. *morinella*		American Golden-Plover		Black-bellied Plover	
Habitat type (n)[a]	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals
Wet graminoid marsh (7)	5.6 (3.7)	322.2 (259.3)	0	9.1 (5.2)	0	9.2 (5.9)	1.0 (1.0)	5.7 (3.9)	0	2.7 (2.7)
Wet moss marsh (6)	152.9 (107.0)	451.2 (244.1)	4.5 (4.5)	34.7 (17.9)	2.3 (2.3)	12.1 (8.0)	0	0	4.5 (4.5)	4.5 (4.5)
Grassland (6)	523.0 (371.9)	1118.5 (734.5)	196.1 (196.1)	234.3 (192.1)	11.8 (11.8)	23.6 (23.6)	38.3 (38.3)	76.6 (76.6)	0	0
Sedge marsh (7)	24.0 (13.1)	97.8 (43.5)	9.1 (6.0)	33.3 (16.1)	0	5.2 (5.2)	0	2.9 (2.8)	0	3.8 (3.8)
Saltmarsh (0)										
Wet Graminoid/Moss Lowlands (26)	157.9 (89.4)	494.2 (187.9)	46.9 (43.5)	70.8 (43.7)	3.1 (2.7)	12.1 (5.7)	8.8 (8.5)	93.9 (75.2)	1.0 (1.0)	2.7 (1.5)
Vegetated tundra (28)	16.5 (6.7)	47.3 (15.7)	3.4 (1.6)	21.0 (9.3)	5.4 (3.8)	23.6 (9.0)	7.1 (4.7)	12.1 (5.1)	5.0 (4.5)	12.1 (9.1)
Dry graminoid tundra (0)										
Dry moss tundra (1)	1.0	75.2	0	0	0	0	0	0	0	0
Dry Vegetated Tundra (29)	17.1 (6.7)	49.9 (15.6)	3.4 (1.6)	20.0 (9.3)	5.4 (3.8)	23.6 (9.0)	7.1 (4.7)	11.8 (5.1)	5.0 (4.5)	11.8 (9.1)
Unvegetated/rocky tundra (14)	4.0 (4.0)	16.2 (9.1)	1.4 (1.4)	6.1 (4.1)	5.7 (5.0)	13.8 (10.1)	0	5.2 (3.8)	0	0
Beach ridge top (8)	39.7 (39.7)	123.4 (118.5)	0	319.3 (311.6)	6.8 (6.8)	13.9 (9.1)	2.2 (2.2)	15.9 (10.5)	0	6.5 (6.5)
Barrens (2)	0	0	0	0	0	0	0	0	0	0
Unvegetated/Barren Tundra (24)	15.0 (12.8)	48.5 (38.0)	0.7 (0.7)	1.1 (1.0)	5.3 (3.5)	12.2 (6.3)	7.0 (7.0)	8.4 (4.0)	0	2.5 (2.1)
Total (79)	65.5 (32.3)	204.5 (70.7)	18.0 (15.3)	66.2 (35.7)	4.9 (2.0)	16.4 (4.4)	6.0 (3.5)	40.1 (26.6)	2.1 (1.7)	5.6 (3.5)

[a]n = number of habitat-plots.

Appendix 5b
Mean weighted densities of shorebird pairs and individuals (number/km^2 (SE)) in 11 habitat types, 1996 plots

	Red Phalarope		White-rumped Sandpiper		Ruddy Turnstone ssp. *morinella*		American Golden-Plover		Black-bellied Plover	
Habitat type (n)[a]	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals
Wet graminoid marsh (10)	13.5 (5.3)	91.5 (24.6)	4.7 (2.5)	33.2 (14.8)	4.6 (3.7)	15.9 (8.3)	0	0	0	1.9 (1.9)
Wet moss marsh (12)	31.5 (13.2)	148.1 (63.4)	2.4 (1.8)	15.1 (7.6)	20.8 (17.4)	31.2 (21.2)	0.9 (0.9)	3.6 (3.6)	2.4 (2.4)	10.6 (7.6)
Grassland (9)	28.5 (10.7)	166 (55.0)	9.3 (3.8)	42.7 (20.1)	13.2 (4.7)	30.8 (11.0)	0	0.7 (0.7)	1.7 (1.1)	4.2 (2.3)
Sedge marsh (2)	44.8 (32.3)	163.4 (125.9)	9.6 (9.6)	36.9 (30.6)	0	0	0	0	0	0
Saltmarsh (0)										
Wet Graminoid/Moss Lowlands (33)	26.0 (6.0)	136.7 (28.6)	5.4 (1.5)	29.4 (7.8)	12.6 (6.5)	24.6 (8.5)	0.3 (0.3)	1.5 (1.3)	1.3 (0.9)	5.6 (2.9)
Vegetated tundra (9)	0	2.8 (2.8)	2.5 (1.8)	11.5 (3.7)	1.7 (1.7)	6.9 (6.9)	0	0	1.7 (1.7)	6.1 (5.2)
Dry graminoid tundra (0)										
Dry moss tundra (1)	0	0	0	0	0	0	0	0	0	0
Dry Vegetated Tundra (10)	0	2.5 (2.5)	2.2 (1.6)	10.4 (3.5)	1.6 (1.6)	6.2 (6.2)	0	0	1.6 (1.6)	5.5 (4.7)
Unvegetated/rocky tundra (3)	0	0	0	4.5 (4.5)	0	8.7 (8.7)	0	4.3 (4.3)	0	0
Beach ridge top (0)										
Barrens (4)	0	35.4 (35.4)	0	3.2 (3.2)	2.1 (2.1)	2.1 (2.1)	0	0	0	0
Unvegetated/Barren Tundra (7)	0	20.2 (20.2)	0	3.7 (2.4)	1.2 (1.2)	4.9 (3.7)	0	1.9 (1.9)	0	0
Total (50)	17.2 (4.4)	93.6 (20.9)	4.0 (1.1)	22.0 (5.4)	8.8 (4.3)	18.2 (5.9)	0.2 (0.2)	1.2 (0.9)	1.2 (0.7)	3.7 (2.5)

[a]n = number of habitat-plots.

Dunlin ssp. *hudsonia*		Semipalmated Sandpiper		Pectoral Sandpiper		Baird's Sandpiper		Purple Sandpiper ssp. *maritima*		Red Knot ssp. *rufa*		Total pair densities	Total individual densities
Pairs	Individuals	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals		
1.8 (1.2)	2.7 (1.9)	0	0	0	0	0	0	0	0	0	0	8.4 (4.7)	351.6 (265.3)
0	0	0	0	0	0	0	0	0	0	0	0	164.2 (105.2)	502.5 (241.6)
0	98.0 (98.0)	5.9 (5.9)	11.8 (11.8)	0	0	0	0	5.9 (5.9)	5.9 (5.9)	0	0	781.0 (552.7)	1568.7 (898.2)
0	12.6 (9.0)	0	0	0	0	0	0	0	0	0	0	33.1 (16.2)	155.6 (262.3)
4.8 (3.3)	25.8 (21.8)	1.3 (1.3)	2.6 (2.6)	0	0	0	0	1.3 (1.3)	1.3 (1.3)	0	0	225.1 (131.0)	703.4 (247.8)
3.2 (3.2)	6.6 (3.8)	1.6 (1.6)	3.3 (3.3)	0	0	1.6 (1.6)	1.6 (1.6)	0	0	0	0	43.8 (11.4)	127.6 (37.2)
0	0	0	0	0	0	0	0	0	0	0	0	1.0	75.2
3.2 (3.2)	6.3 (3.8)	1.6 (1.6)	3.3 (3.3)	0	0	1.6 (1.6)	1.6 (1.6)	0	0	0	0	44.4 (11.4)	128.3 (37.2)
3.1 (1.7)	5.0 (2.7)	0	0	0	0	0	0	0	4.5 (3.1)	0	0	14.2 (7.9)	50.8 (18.3)
19.8 (19.8)	19.8 (19.8)	0	0	0	0	0	0	0	1.4 (1.4)	0	0	68.5 (58.6)	500.2 (314.0)
0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.1 (6.4)	9.5 (6.4)	0	0	0	0	0	0	0	3.0 (1.8)	0	0	36.1 (19.2)	85.2 (105.8)
4.0 (2.4)	14.5 (8.0)	1.1 (0.8)	2.2 (1.5)	0	0	0.6 (0.6)	0.6 (0.6)	0.5 (0.5)	1.4 (0.8)	0	0	102.7 (47.0)	351.5 (97.9)

Dunlin ssp. *hudsonia*		Semipalmated Sandpiper		Pectoral Sandpiper		Baird's Sandpiper		Purple Sandpiper ssp. *maritima*		Red Knot ssp. *rufa*		Total pair densities	Total individual densities
Pairs	Individuals	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals		
0	2.6 (1.8)	0	0	0	0	0	0	0	0	0	0	22.8 (7.4)	145.1 (21.3)
0	0	0.9 (0.9)	8.7 (7.1)	0	0	0	0	0	0	0	0	58.9 (20.6)	217.3 (82.6)
0.7 (0.7)	1.5 (1.0)	6.2 (5.5)	20.1 (19.4)	0	0	2.8 (2.8)	13.9 (13.9)	0	0	0	0	62.4 (14.5)	279.9 (79.6)
0	0	0	0	0	0	0	0	0	0	0	0	54.4 (42.0)	200.3 (156.5)
0.2 (0.2)	1.2 (6.3)	2.1 (1.5)	8.7 (5.8)	0	0	0.8 (0.8)	3.8 (3.8)	0	0	0	0	48.7 (9.2)	211.5 (85.0)
0	0	0	0	0	0	0	0	0	0	0	0	5.9 (3.6)	27.3 (11.3)
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	5.4 (3.3)	24.6 (10.4)
0	0	0	0	0	0	0	0	0	0	0	0	0	17.5 (11.5)
0	0	2.1 (2.1)	2.1 (2.1)	0	1.6 (1.6)	0	1.6 (1.6)	1.6 (1.6)	1.6 (1.6)	0	0	5.8 (3.9)	47.6 (37.7)
0	0	1.2 (1.2)	1.2 (1.2)	0	0.9 (0.9)	0	0.9 (0.9)	0.9 (0.9)	0.9 (0.9)	0	0	3.3 (2.4)	34.6 (21.5)
0.1 (0.1)	0.8 (0.4)	1.5 (1.3)	5.9 (3.8)	0	0.1 (0.1)	0.5 (0.5)	2.6 (2.5)	0.1 (0.1)	0.1 (0.1)	0	0	33.6 (6.8)	148.2 (40.0)

Appendix 5c
Mean weighted densities of shorebird pairs and individuals (number/km² (SE)) in 11 habitat types, 1997 plots

	Red Phalarope		White-rumped Sandpiper		Ruddy Turnstone ssp. *morinella*		American Golden-Plover		Black-bellied Plover	
Habitat type (*n*)[a]	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals
Wet graminoid marsh (7)	25.8 (7.5)	46.5 (14.7)	16.0 (9.5)	22.9 (9.9)	9.6 (25.5)	9.6 (25.3)	0	0	1.2 (1.2)	2.4 (2.4)
Wet moss marsh (20)	22.8 (5.0)	49.4 (11.6)	7.2 (2.5)	17.9 (6.9)	1.4 (1.4)	2.5 (1.5)	0	0	3.5 (3.5)	3.5 (3.5)
Grassland (4)	5.4 (1.9)	54.5 (26.4)	4.7 (4.7)	6.3 (6.3)	0	0	0	0	0	0
Sedge marsh (14)	27.8 (8.2)	85.7 (23.7)	17.9 (5.7)	78.4 (23.3)	1.5 (1.1)	6.2 (2.7)	0	0.7 (0.7)	0	0
Saltmarsh (3)	22.4 (11.9)	49.4 (24.0)	0	13.5 (13.5)	5.4 (5.4)	24.4 (24.4)	0	0	0	0
Wet Graminoid/Moss Lowlands (48)	23.3 (3.4)	60.0 (9.1)	11.0 (2.5)	35.1 (8.4)	2.7 (1.5)	4.4 (1.8)	0	2.1 (2.1)	1.6 (1.4)	1.8 (1.5)
Vegetated tundra (21)	6.5 (6.5)	8.1 (6.6)	15.5 (6.6)	42.6 (12.5)	3.1 (1.8)	4.5 (2.5)	6.6 (2.4)	6.9 (2.4)	3.9 (2.3)	4.9 (3.1)
Dry graminoid tundra (2)	0	31.2 (31.2)	15.6 (15.6)	15.6 (15.6)	0	15.6 (15.6)	0	0	0	0
Dry moss tundra (8)	3.8 (2.9)	3.8 (2.9)	3.8 (2.9)	26.1 (25.0)	6.6 (5.2)	9.4 (5.5)	0	0	0	2.8 (2.8)
Dry Vegetated Tundra (31)	5.4 (4.4)	8.5 (4.9)	12.5 (4.6)	36.6 (10.6)	3.8 (1.8)	6.5 (2.4)	4.4 (1.7)	4.6 (1.7)	2.7 (1.6)	4.0 (2.2)
Unvegetated/rocky tundra (5)	0	0	0	3.2 (3.2)	0	0	1.6 (1.6)	4.8 (3.3)	0	0
Beach ridge top (1)	0	0	0	0	0	0	0	0	0	0
Barrens (2)	0	0		0	0	0	0	0	0	0
Unvegetated/Barren Tundra (8)	0	0	0	2.0 (2.0)	0	0	1.1 (1.1)	3.0 (2.1)	0	0
Total (87)	14.7 (2.7)	36.1 (6.0)	10.5 (2.2)	32.6 (6.0)	2.8 (1.1)	5.5 (1.5)	1.7 (0.7)	2.1 (0.7)	1.8 (1.0)	2.4 (1.1)

[a]*n* = number of habitat-plots.

Appendix 6a
Mean weighted densities of non-shorebirds (number of individuals/km² (SE)) in 11 habitat types, 1996 transects

Habitat type (*n*)[a]	Red-throated Loon	Pacific Loon	Tundra Swan	Lesser Snow Goose	Cackling Goose	Atlantic Brant	Northern Pintail	King Eider	Long-tailed Duck
Wet graminoid marsh (7)	0	0	0	1.8 (1.8)	2.7 (2.7)	0	0	2.7 (1.8)	0
Wet moss marsh (6)	0	0	0	0	4.5 (4.5)	0	0	0	0
Grassland (6)	0	0	0	0	0	0	0	0	11.8 (11.8)
Sedge marsh (7)	0	0	0	0	12.3 (12.3)	123.2 (123.2)	0	130.4 (94.6)	22.7 (14.7)
Saltmarsh (0)									
Wet Graminoid/Moss Lowlands (26)	0	0	0	0.5 (0.5)	4.9 (3.3)	32.2 (31.9)	0	35.5 (25.7)	8.5 (4.7)
Vegetated tundra (28)	0	0.5 (0.5)	0	2.6 (2.6)	6.9 (6.5)	9.7 (6.8)	0	0.3 (0.3)	1.1 (1.1)
Dry graminoid tundra (0)									
Dry moss tundra (1)	0	0	0	15.0	0	0	0	0	0
Dry Vegetated Tundra (29)	0	0.5 (0.5)	0	7.5 (5.5)	6.7 (6.3)	9.4 (6.5)	0	0.2 (0.2)	1.1 (1.1)
Unvegetated/rocky tundra (14)	0	0	0	12.2 (6.7)	1.5 (1.5)	7.9 (7.9)	0	0	0
Beach ridge top (8)	0	0	0	39.7*	0	0	0	0	0
Barrens (2)	0	0	0	0	0	0	0	0	0
Unvegetated Barren/Tundra (24)	0	0	0	19.6 (13.0)	0.8 (0.8)	5.2 (3.6)	0	0	0

[a]*n* = number of habitat-plots.
*Standard error could not be calculated because the species was seen in only one plot.

Dunlin ssp. *hudsonia*		Semipalmated Sandpiper		Pectoral Sandpiper		Baird's Sandpiper		Purple Sandpiper ssp. *maritima*		Red Knot ssp. *rufa*		Total pair densities	Total individual densities
Pairs	Individuals	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals	Pairs	Individuals		
0	1.1 (1.1)	0	0	1.1 (1.1)	3.1 (2.3)	0	0	0	0	0	0	53.7 (20.1)	85.6 (22.5)
0	0.3 (0.3)	0	0	0	0	0	0	0	0	0	0	35.0 (7.9)	73.6 (15.6)
0	0	0	0	0	0	0	0	0	0	0	0	10.1 (2.9)	60.8 (23.1)
4.0 (2.5)	5.7 (3.7)	0	0	0	0.5 (0.5)	0	0	0.5 (0.5)	1.4 (1.4)	0	1.2 (1.2)	51.7 (14.4)	179.8 (45.5)
0	0	0	0	0	0	0	0	0	0	0	0	27.8 (16.4)	87.3 (61.9)
1.2 (0.8)	2.0 (1.1)	0	0	0.2 (0.2)	2.0 (0.4)	0	0	0.1 (0.1)	0.4 (0.4)	0	0.4 (0.4)	40.1 (6.2)	108.2 (16.7)
0	1.1 (1.1)	0	0	1.4 (1.4)	1.4 (1.4)	0	0	0	0	0	0	37.1 (11.3)	69.5 (19.7)
0	0	0	0	0	0	0	0	0	0	0	0	15.6 (15.6)	62.4 (62.5)
0	0	0	0	0	0	0	0	0	0	0	0	14.2 (8.0)	42.1 (29.6)
0	0.7 (0.7)	0	0	1.0 (1.0)	1.0 (1.0)	0	0	0	0	0	0	29.8 (8.1)	61.9 (15.5)
2.7 (1.7)	5.4 (3.4)	0	0	0	0	0	0	0	0	0	0	4.3 (2.9)	13.4 (5.5)
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.0 (1.3)	4.1 (2.7)	0	0	0	0	0	0	0	0	0	0	3.1 (2.2)	9.1 (4.2)
0.8 (0.4)	1.7 (0.7)	0	0	0.4 (0.4)	0.7 (0.4)	0	0	0.1 (0.1)	0.2 (0.2)	0	0.2 (0.2)	32.8 (4.6)	81.5 (11.2)

Rock Ptarmigan	Willow Ptarmigan	Pomarine Jaeger	Parasitic Jaeger	Long-tailed Jaeger	Herring Gull	Glaucous Gull	Sabine's Gull	Arctic Tern	Snowy Owl	Lapland Longspur	Snow Bunting
0	1.8 (1.8)	0	0	0.9 (0.9)	0	0	16.3 (8.6)	1.8 (1.8)	0	53.3 (19.7)	0
0	0	0	0	0	0	0	0	0	0	53.9 (34.2)	0
0	0	0	0	0	0	0	5.9 (5.9)	11.8 (11.8)	0	165.7 (107.0)	0
0	5.2 (5.2)	0	0	0	17.6 (17.6)	0	15.6 (15.6)	0	0	950.8 (843.3)	0
0	1.8 (1.4)	0	0	0.2 (0.2)	4.6 (4.6)	0	11.4 (4.9)	3.2 (2.6)	0	309.1 (220.8)	0
0	6.3 (2.8)	1.4 (1.1)	0.6 (0.6)	6.0 (3.2)	0	0	3.0 (2.1)	5.1 (3.8)	0	68.6 (15.4)	0
0	0	0	0	0	0	0	0	15.0	0	0	0
0	6.1 (2.8)	1.4 (1.0)	0.6 (0.6)	5.8 (3.1)	0	0	2.9 (2.1)	5.4 (3.7)	0	66.3 (15.0)	0
0	19.3 (16.2)	3.4 (1.9)	0	0	0		5.0 (5.0)	14.4 (14.4)	0	39.6 (13.4)	0.7 (0.7)
0	23.4 (19.5)	2.2*	0	4.4*	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	18.8 (15.7)	2.6 (1.3)	0	2.2 (1.6)	0	0	2.8 (2.8)	5.6 (2.9)	0	41.9 (10.5)	0.7 (2.6)

Appendix 6b
Mean weighted densities of non-shorebirds (number of individuals/km^2 (SE)) in 11 habitat types, 1996 plots

Habitat type (n)[a]	Red-throated Loon	Pacific Loon	Tundra Swan	Lesser Snow Goose	Cackling Goose	Atlantic Brant	Northern Pintail	King Eider	Long-tailed Duck
Wet graminoid marsh (10)	1.6 (1.6)	0	0	0	1.9 (1.3)	0.6 (0.6)	0	5.4 (2.9)	0.6 (0.6)
Wet moss marsh (12)	0	0	0	0	0	5.7 (4.7)	0	2.7 (1.5)	0
Grassland (9)	0	0	0	0	2.2 (1.4)	5.6 (5.6)	0	5.4 (2.9)	2.2 (1.6)
Sedge marsh (2)	0	0	0	0	0	0	0	3.1 (3.1)	0
Saltmarsh (0)									
Wet Graminoid/Moss Lowlands (33)	0.5 (0.5)	0	0	0	1.1 (0.6)	3.8 (2.2)	0	4.3 (1.3)	0.8 (0.5)
Vegetated tundra (9)	0	0	0	2.3*	0	0	0	3.5 (3.5)	0
Dry graminoid tundra (0)									
Dry moss tundra (1)	0	0	0	0	0	0	0	0	0
Dry Vegetated Tundra (10)	0	0	0	2.1 (2.1)	0	0	0	3.1 (3.1)	0
Unvegetated/rocky tundra (3)	0	0	0	0	0	0	0	0	0
Beach ridge top (0)					0	0	0	0	0
Barrens (4)	0	0	0	0	0	6.4 (6.4)	0	0	0
Unvegetated/Barren Tundra (7)	0	0	0	0	0	3.6 (3.6)	0	0	0

[a]n = number of habitat-plots.
*Standard error could not be calculated because the species was seen in only one plot.

Appendix 6c
Mean weighted densities of non-shorebirds (number of individuals/km^2 (SE)) in 11 habitat types, 1997 plots

Habitat type (n)[a]	Red-throated Loon	Pacific Loon	Tundra Swan	Lesser Snow Goose	Cackling Goose	Atlantic Brant	Northern Pintail	King Eider	Long-tailed Duck
Wet graminoid marsh (7)	0	0	0	22.5 (15.3)	0	23.9 (23.9)	0	0	3.7 (3.7)
Wet moss marsh (20)	0	1.2 (0.7)	0	3.8 (3.3)	0	0	0	0	4.9 (4.9)
Grassland (4)	0	0	0	1852.0 (1852.0)	1.7 (1.7)	0	0	1.7 (1.7)	0
Sedge marsh (14)	0	0	0	9.13 (6.2)	2.7 (2.7)	1.4 (1.4)	0	3.2 (3.2)	0
Saltmarsh (3)	0	0	0	0	0	0	2.7 (2.7)	0	5.4 (5.4)
Wet Graminoid/Moss Lowlands (48)	0	0.5 (0.3)	0	172.7 (164.5)	0.9 (0.8)	3.9 (3.5)	0	1.1 (1.0)	1.1 (0.7)
Vegetated tundra (21)	0	0	0	7.6 (4.7)	0	0	0	0	0.3 (0.3)
Dry graminoid tundra (2)	0	0	0	0	0	0	0	0	0
Dry moss tundra (8)	0	0	0	2.6 (2.6)	2.6 (2.6)	0	0	1.4 (1.4)	5.2 (5.2)
Dry Vegetated Tundra (31)	0	0	0	5.8 (3.3)	0.7 (0.7)	0	0	0.4 (0.4)	1.6 (1.4)
Unvegetated/rocky tundra (5)	3.3 (3.3)	0	0	0	1.6 (1.6)	0	0	0	3.3 (3.3)
Beach ridge top (1)	0	0	0	0	0	0	0	0	0
Barrens (2)	0	0	0	0	0	0	0	0	0
Unvegetated/Barren Tundra (8)	2.0 (2.0)	0	0	0	1.0 (1.0)	0	0	0	2.1 (2.1)

[a]n = number of habitat-plots.

Rock Ptarmigan	Willow Ptarmigan	Pomarine Jaeger	Parasitic Jaeger	Long-tailed Jaeger	Herring Gull	Glaucous Gull	Sabine's Gull	Arctic Tern	Snowy Owl	Lapland Longspur	Snow Bunting
0	0	0	1.1 (1.1)	0	0	0	12.4 (4.8)	1.6 (1.6)	0	20.5 (4.8)	0
0	0	0.9 (0.9)	0	0	0	0	11.5 (10.4)	0	0	30.5 (13.8)	0
0	0	1.6 (1.6)	0	0	0	0	39.0 (18.1)	0	0	0.7 (0.7)	0
0	0.4 (0.4)	4.8 (4.8)	0	0	0	0	0	0	0	0	0
							0	0	0	0	0
0	0.3 (0.3)	1.1 (0.6)	0.4 (0.4)	0	0	0	18.6 (6.6)	0.5 (0.5)	0	19.2 (5.6)	0
0	0	0	0	0	0	0	3.5 (3.5)	0	0	21.6 (8.4)	0
							0	0	0		0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	3.1 (3.1)	0	0	19.5 (7.8)	0
0	0	0	0	0	0	0	3.5 (3.5)	0	0	22.0 (11.5)	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	2.1 (2.1)	3.2 (3.2)	0	0	5.8 (3.9)
0	0	0	0	0	0	0	1.2 (1.2)	3.1 (3.1)	0	9.4 (6.2)	2.9 (2.0)

Rock Ptarmigan	Willow Ptarmigan	Pomarine Jaeger	Parasitic Jaeger	Long-tailed Jaeger	Herring Gull	Glaucous Gull	Sabine's Gull	Arctic Tern	Snowy Owl	Lapland Longspur	Snow Bunting
0	0	10.8 (9.5)	0	1.2 (1.2)	0	0	9.6 (9.6)	0	0	20.3 (11.7)	0
0	0	1.7 (1.0)	0	1.4 (1.4)	0	0	3.7 (3.7)	1.0 (1.0)	0	7.6 (2.5)	0
0	0	0	0	0	0	0	1.7 (1.7)	0	0	13.7 (6.8)	0
0	0.4 (0.4)	2.8 (2.2)	1.1 (1.1)	2.9 (2.9)	0	0	10.8 (8.3)	1.8 (1.2)	0	21.8 (6.0)	0
0	0	0	0	0	0	0	75.2 (37.9)	0	0	4.4 (4.4)	0
0	0.1 (0.1)	3.1 (1.6)	0.3 (0.3)	1.6 (1.0)	0	0	9.5 (4.2)	0.9 (0.5)	0	13.9 (2.8)	0
0	0	4.2 (3.4)	0	0.6 (0.6)	0	0	0	0	0	14.5 (3.9)	6.9 (5.9)
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	40.3 (27.8)	0	0	8.5 (4.2)	0
0	0	2.9 (2.3)	0	0.4 (0.4)	0	0	10.4 (7.6)	0	0	12.0 (2.9)	4.5 (4.0)
0	0	0	0	0	0	0	0	0	0	3.2 (3.2)	4.7 (4.7)
0	0	0	0	0	0	0	0	0	0	0	0
0	3.7 (3.7)	0	0	13.8 (1.1)	0	0	0	0	0	0	0
0	1.6 (1.6)	0	0	3.5 (2.3)	0	0	0	0	0	2.0 (2.0)	2.8 (2.8)

Other publications in the Occasional Papers series

No. 30
Dynamics of snowshoe hare populations in the Maritime Provinces, by Thomas J. Wood and Stanley A. Munroe.
Cat. No. CW69-1/30. Publ. 1977.
No. 31
Migration and population dynamics of the Peace-Athabasca Delta goldeye population, by D.B. Donald and A.H. Kooyman.
Cat. No. CW69-1/31. Publ. 1977.
No. 32
The effects of fire on the ecology of the Boreal Forest, with particular reference to the Canadian north; a review and selected bibliography, by John P. Kelsall, E.S. Telfer and Thomas D. Wright.
Cat. No. CW69-1/32. Publ. 1977.
No. 33
The ecology of the polar bear (Ursus maritimus) along the western coast of Hudson Bay, by Ian Stirling, Charles Jonkel, Pauline Smith, Richard Robertson and Dale Cross.
Cat. No. CW69-1/33. Publ. 1977.
No. 34
Canvasback habitat use and production in Saskatchewan parklands, by Lawson G. Sugden.
Cat. No. CW69-1/34. Publ. 1978.
No. 35
The diets of muskoxen and Peary caribou on some islands of the Canadian High Arctic, by Gerald R. Parker.
Cat. No. CW69-1/35. Publ. 1978.
No. 36
Observations of Mallards in the parkland of Alberta, by Michael F. Sorensen.
Cat. No. CW69-1/36. Publ. 1978.
No. 37
The wildlife valuation problem: A critical review of economic approaches, by William A. Langford and Donald J. Cocheba.
Cat. No. CW69-1/37. Publ. 1978.
No. 38
Spatial changes in waterfowl habitat, 1964–74, on two land types in the Manitoba Newdale Plain, by G.D. Adams and G.G. Gentle.
Cat. No. CW69-1/38. Publ. 1978.
No. 39
Patterns of pelagic distribution of seabirds in western Lancaster Sound and Barrow Strait, Northwest Territories, in August and September 1976, by D.N. Nettleship and A.J. Gaston.
Cat. No. CW69-1/39. Publ. 1978.
No. 40
Responses of Peary caribou and muskoxen to turbo-helicopter harassment, Prince of Wales Island, Northwest Territories, by Frank L. Miller and Anne Gunn.
Cat. No. CW69-1/40. Publ. 1979.
No. 41
Avian community structure of six forest stands in La Mauricie National Park, Quebec, by J.-L. DesGranges. Disponible également en français.
Cat. No. CW69-1/41E. Publ. 1979.
No. 42
Population ecology studies of the polar bear in northern Labrador, by Ian Stirling and H.P.L. Kiliaan. Disponible également en français.
Cat. No. CW69-1/42E. Publ. 1980.
No. 43
Census methods for murres, Uria species; a unified approach, by T.R. Birkhead and D.N. Nettleship. Disponible également en français.
Cat. No. CW69-1/43E. Publ. 1980.
No. 44
Population ecology studies of the polar bear in the area of southeastern Baffin Island, by Ian Stirling, Wendy Calvert, and Dennis Andriashek. Disponible également en français.
Cat. No. CW69-1/44E. Publ. 1980.
No. 45
Polynyas in the Canadian Arctic, by Ian Stirling and Holly Cleator, eds. Disponible également en français.
Cat. No. CW69-1/45E. Publ. 1981.
No. 46
The Lesser Snow Geese of the eastern Canadian Arctic, by H. Boyd, G.E.J. Smith, and F.G. Cooch. Disponible également en français.
Cat. No. CW69-1/46E. Publ. 1982.
No. 47
The distribution and abundance of seals in the eastern Beaufort Sea, 1974–79, by Ian Stirling, Michael Kingsley, and Wendy Calvert. Disponible également en français.
Cat. No. CW69-1/47E. Publ. 1982.
No. 48
Foraging behaviour of Peary caribou in response to springtime snow and ice conditions, by F.L. Miller, E.J. Edmonds, and A. Gunn. Disponible également en français.
Cat. No. CW69-1/48E. Publ. 1982.
No. 49
A review of some important techniques in sampling wildlife, by A.R. Sen. Disponible également en français.
Cat. No. CW69-1/49E. Publ. 1982.
No. 50
Intensive regulation of duck hunting in North America: its purpose and achievements, by Hugh Boyd. Disponible également en français.
Cat. No. CW69-1/50E. Publ. 1983.
No. 51
Human dimensions of migratory game-bird hunting in Canada, by Shane A.D. Parker and Fern L. Filion. Disponible également en français.
Cat. No. CW69-1/51E. Publ. 1984.
No. 52
Components of hunting mortality in ducks, by G.S. Hochbaum and C.J. Walters. Disponible également en français.
Cat. No. CW69-1/52E. Publ. 1984.
No. 53
The interpretation of aerial surveys for seabirds: some effects of behaviour, by A.J. Gaston and G.E.J. Smith. Disponible également en français.
Cat. No. CW69-1/53E. Publ. 1984.
No. 54
Waterfowl studies in Ontario, 1973–81, by S.G. Curtis, D.G. Dennis, and H. Boyd, eds. Disponible également en français.
Cat. No. CW69-1/54E. Publ. 1985.
No. 55
The reported kill of ducks and geese in Canada and the USA, 1974–82, by Hugh Boyd. Disponible également en français.
Cat. No. CW69-1/55E. Publ. 1985.

No. 56
Population dynamics of the Common Loon (Gavia immer) associated with mercury-contaminated waters in northwestern Ontario, by J.F. Barr. Disponible également en français.
Cat. No. CW69-1/56E. Publ. 1986.
No. 57
The Ring-billed Gull in Ontario: a review of a new problem species, by H. Blokpoel and G.D. Tessier. Disponible également en français.
Cat. No. CW69-1/57E. Publ. 1986.
No. 58
The birds of the Creston Valley and southeastern British Columbia, by R.W. Butler, B.G. Stushnoff, and E. McMackin. Disponsible également en français.
Cat. No. CW69-1/58E. Publ. 1986.
No. 59
Estimating densities of birds at sea and the proportion in flight from counts made on transects of indefinite width, by A.J. Gaston, B.T. Collins, and A.W. Diamond. Disponible également en français.
Cat. No. CW69-1/59E. Publ. 1987.
No. 60
Waterfowl breeding population surveys, Atlantic Provinces, edited by Anthony J. Erskine. Disponible également en français.
Cat. No. CW69-1/60E. Publ. 1987.
No. 61
A survey of Lesser Snow Geese on Southampton and Baffin islands, NWT, 1979, by A. Reed, P. Dupuis, and G.E.J. Smith. Disponible également en français.
Cat. No. CW69-1/61E. Publ. 1987.
No. 62
Studies of the effects of acidification on aquatic wildlife in Canada: waterfowl and trophic relationships in small lakes in northern Ontario, by D.K. McNicol, B.E. Bendell, and R.K. Ross. Disponible également en français.
Cat. No. CW69-1/62E. Publ. 1987.
No. 63
Bison ecology in relation to agricultural development in the Slave River lowlands, NWT, by H.W. Reynolds and A.W.L. Hawley, eds.
Cat. No. CW69-1/63E. Publ. 1987.
No. 64
A simulation model for the Greater Snow Goose population, by J. Gauvin and A. Reed. Disponible également en français.
Cat. No. CW69-1/64E. Publ. 1987.
No. 65
The birds of the Fraser River delta: populations, ecology and international significance, by Robert W. Butler and R. Wayne Campbell.
Cat. No. CW69-1/65E. Publ. 1987.
No. 66
Mortality of migratory barren-ground caribou on the calving grounds of the Beverly herd, Northwest Territories, 1981–83, by Frank L. Miller, Eric Broughton, and Anne Gunn.
Cat. No. CW69-1/66E. Publ. 1988.
No. 67
Studies of the effects of acidification on aquatic wildlife in Canada: Lacustrine birds and their habitats in Quebec, by Jean-Luc DesGranges, ed. Disponible également en français.
Cat. No. CW69-1/67E. Publ. 1989.
No. 68
Studies of high-latitude seabirds. 1. Behavioural, energetic, and oceanographic aspects of seabird feeding ecology, by W.A. Montevecchi and A.J. Gaston, eds.
Cat. No. CW69-1/68E. Publ. 1991.
No. 69
Studies of high-latitude seabirds. 2. Conservation biology of Thick-billed Murres in the Northwest Atlantic, by A.J. Gaston and R.D. Elliot, eds.
Cat No. CW69-1/69E. Publ. 1991.
No. 70
Habitats of the northeast coast of James Bay, by N. Dignard, R. Lalumière, A. Reed, and M. Julien. Disponible également en français.
Cat. No. CW69-1/70E. Publ. 1991.
No. 71
Key migratory bird terrestrial habitat sites in the Northwest Territories (2nd edition), by Stuart A. Alexander, Robert S. Ferguson, and Kevin J. McCormick.
Cat. No. CW69-1/71E. Publ. 1991.
No. 72
Atlas of pelagic birds of western Canada, by K.H. Morgan, K. Vermeer, and R.W. McKelvey.
Cat. No. CW69-1/72E. Publ. 1991.
No. 73
The Red-throated Loon as an indicator of environmental quality, by D. Lynne Dickson. Disponible également en français.
Cat. No. CW69-1/73E. Publ. 1992.
No. 74
Aerial radio-tracking of Whooping Cranes migrating between Wood Buffalo National Park and Aransas National Wildlife Refuge, 1981–84, by E. Kuyt.
Cat. No. CW69-1/74E. Publ. 1992.
No. 75
The ecology, status, and conservation of marine and shoreline birds on the west coast of Vancouver Island, by K. Vermeer, R.W. Butler, and K.H. Morgan, eds.
Cat. No. CW69-1/75E. Publ. 1992.
No. 76
Declines in Canadian amphibian populations: designing a national monitoring strategy, by C.A. Bishop, K.E. Pettit, eds.
Cat. No. CW69-1/76E. Publ. 1992.
No. 77
Studies of high-latitude seabirds. 3. A model of the energy demands of the seabirds of eastern and Arctic Canada, by A.W. Diamond, A.J. Gaston, and R.G.B. Brown (edited by W.A. Montevecchi).
Cat. No. CW69-1/77E. Publ. 1993.
No. 78
Historical review of water bird populations and annotated list of water birds associated with Burlington Bay, Lake Ontario, 1857–1990, by M.B. Gebauer, R.Z. Dobos, and D. Vaughn Weseloh.
Cat. No. CW69-1/78E. Publ. 1993.
No. 79
Hydrological classification of Canadian prairie wetlands and prediction of wetland inundation in response to climatic variability, by Ming-ko Woo, Robert D. Rowsell, and Robert G. Clark.
Cat. No. CW69-1/79E. Publ. 1993.
No. 80
Monitoring Thick-billed Murre populations at colonies in northern Hudson Bay, 1972–92, by A.J. Gaston, L.N. de Forest, G. Gilchrist, and D.N. Nettleship.
Cat. No. CW69-1/80E. Publ. 1994.
No. 81
Colonies and numbers of Ross' Geese and Lesser Snow Geese in the Queen Maud Gulf Migratory Bird Sanctuary, by R.H. Kerbes.
Cat. No. CW69-1/81E. Publ. 1994.
No. 82
The 1991 International Piping Plover Census in Canada, by S.P. Flemming.
Cat. No. CW69-1/82E. Publ. 1994.
No. 83
The abundance and distribution of estuarine birds in the Strait of Georgia, British Columbia, by R.W. Butler and K. Vermeer, eds.
Cat. No. CW69-1/83E. Publ. 1994.
No. 84
Wintering populations of Lesser Snow Geese and Ross' Geese in the Northern Highlands of México, 1988–1990, by Bruce Turner, Roy Tomlinson, Raquel Leyva, and Pablo Dominguez.
Cat. No. CW69-1/84E. Publ. 1994.
No. 85
Caspian Terns on the Great Lakes: organochlorine contamination, reproduction, diet, and population changes, 1972–91, by Peter J. Ewins, D.V. (Chip) Weseloh, Ross J. Norstrom, Karin Legierse, Heidi J. Auman, and James P. Ludwig.
Cat. No. CW69-1/85E. Publ. 1994.

No. 86
The patient predator: foraging and population ecology of the Great Blue Heron *Ardea herodias* in British Columbia, by Robert W. Butler.
Cat. No. CW69-1/86E. Publ. 1995.
No. 87
Use of various habitat types by nesting ducks on islands in the St. Lawrence River between Montréal and Trois-Rivières, by Luc Bélanger and Denis Lehoux. Disponible également en français.
Cat. No. CW69-1/87E. Publ. 1995.
No. 88
A review of the environmental impacts of lead shotshell ammunition and lead fishing weights in Canada, by A.M. Scheuhammer and S.L. Norris. Disponible également en français.
Cat. No. CW69-1/88E. Publ. 1995.
No. 89
The colonial waterbirds of Great Slave Lake, Northwest Territories: an annotated atlas, by J. Sirois, M.A. Fournier, and M.F. Kay.
Cat. No. CW69-1/89E. Publ. 1995.
No. 90
Duck use of the coastal habitats of northeastern James Bay, by Austin Reed, Réjean Benoit, Richard Lalumière, and Michel Julien. Disponible également en français.
Cat. No. CW69-1/90E. Publ. 1996.
No. 91
Studies of high-latitude seabirds. 4. Trophic relationships and energetics of endotherms in cold ocean systems, by W.A. Montevecchi, ed.
Cat. No. CW69-1/91E. Publ. 1996.
No. 92
Goose use of the coastal habitats of northeastern James Bay, by Austin Reed, Réjean Benoit, Michel Julien, and Richard Lalumière. Disponible également en français.
Cat. No. CW69-1/92E. Publ. 1996.
No. 93
The ecology, status, and conservation of marine and shoreline birds of the Queen Charlotte Islands, by K. Vermeer and K.H. Morgan, eds.
Cat. No. CW69-1/93E. Publ. 1997.
No. 94
King and Common eiders of the western Canadian Arctic, by D. Lynne Dickson, ed.
Cat. No. CW69-1/94E. Publ. 1997.
No. 95
Monitoring bird populations: the Canadian experience, by Erica H. Dunn, Michael D. Cadman, and J. Bruce Falls, eds.
Cat. No. CW69-1/95E. Publ. 1997.
No. 96
Winter distributions of Thick-billed Murres from the eastern Canadian Arctic and western Greenland in relation to age and time of year, by G.M. Donaldson, A.J. Gaston, J.W. Chardine, K. Kampp, D.N. Nettleship, and R.D. Elliot.
Cat. No. CW69-1/96E. Publ. 1997.
No. 97
Shorebird migration and staging at a large prairie lake and wetland complex: the Quill Lakes, Saskatchewan, by Stuart A. Alexander and Cheri L. Gratto-Trevor.
Cat. No. CW69-1/97E. Publ. 1997.
No. 98
Distribution, survival, and numbers of Lesser Snow Geese of the Western Canadian Arctic and Wrangel Island, Russia, by Richard H. Kerbes, Katherine M. Meeres, and James E. Hines, eds.
Cat. No. CW69-1/98E. Publ. 1999.
No. 100
Behaviour and ecology of sea ducks, by R. Ian Goudie, Margaret R. Petersen, and Gregory J. Robertson, eds.
Cat. No. CW69-1/100E. Publ. 1999.
No. 101
Assessment of bird populations in the Rasmussen Lowlands, Nunavut, by Victoria H. Johnston, Cheri L. Gratto-Trevor, and Stephen T. Pepper.
Cat. No. CW69-1/101E. Publ. 2000.
No. 102
Population modelling and management of Snow Geese, by Hugh Boyd, ed. Disponible également en français.
Cat. No. CW69-1/102E. Publ. 2000.
No. 103
Towards conservation of the diversity of Canada Geese (*Branta canadensis*), by Kathryn M. Dickson, ed.
Cat. No. CW69-1/103E. Publ. 2000.
No. 104
Estimates of shorebird populations in North America, by R.I.G. Morrison, R.E. Gill, Jr., B.A. Harrington, S. Skagen, G.W. Page, C.L. Gratto-Trevor, and S.M. Haig.
Cat. No. CW69-1/104E. Publ. 2001.
No. 105
Status and population trends of the Razorbill in eastern North America, by G. Chapdelaine, A.W. Diamond, R.D. Elliot, and G.J. Robertson.
Cat. No. CW69-1/105E. Publ. 2001.
No. 106
Studies of high-latitude seabirds. 5. Monitoring Thick-billed Murres in the eastern Canadian Arctic, 1976–2000, by A.J. Gaston.
Cat. No. CW69-1/106E. Publ. 2002.
No. 107
Changes in reported waterfowl hunting activity and kill in Canada and the United States, 1985–1998, by H. Boyd, H. Lévesque, and K.M Dickson. Disponible également en français.
Cat. No. CW69-1/107E. Publ. 2002.
No. 108
Lead fishing sinkers and jigs in Canada: Review of their use patterns and toxic impacts on wildlife, by A.M. Scheuhammer, S.L. Money, D.A. Kirk, and G. Donaldson. Disponible également en français.
Cat. No. CW69-1/108E. Publ. 2003.
No. 109
Key marine habitat sites for migratory birds in Nunavut and the Northwest Territories, by Mark L. Mallory and Alain J. Fontaine. Disponible également en français.
Cat. No. CW69-1/109E. Publ. 2004.
No. 110
The 1995 Peregrine Falcon survey in Canada, by Ursula Banasch and Geoff Holroyd, eds. Disponible également en français.
Cat. No. CW69-1/110E. Publ. 2004.
No. 111
Land cover mapping of Queen Maud Gulf Migratory Bird Sanctuary, Nunavut, by Andrew B. Didiuk and Robert S. Ferguson
Cat. No. CW69-1/111E. Publ. 2005.
No. 112
Surveys of geese and swans in the Inuvialuit Settlement Region, Western Canadian Arctic, 1989–2001, by James E. Hines and Myra O. Wiebe Robertson, eds. Disponible également en français.
Cat. No. CW69-1/112E. Publ. 2006.
No. 113
Breeding distribution and population trends of the Great Blue Heron in Quebec, 1977–2001, by Jean-Luc DesGranges and Alain Desrosiers. Disponible également en français.
Cat No. CW69-1/113E. Publ. 2006.
No. 114
Key migratory bird terrestrial habitat sites in the Northwest Territories and Nunavut, by P.B. Latour, J. Leger, J.E. Hines, M.L. Mallory, D.L. Mulders, H.G. Gilchrist, P.A. Smith, and D.L. Dickson. Third edition. Disponible également en français.
Cat. No. CW69/-1/114E. Publ. 2008.
No. 115
Productivity of Lesser Snow Geese on Banks Island, Northwest Territories, Canada, in 1995–1998, by Gustaf Samelius, Ray T. Alisauskas, and James E. Hines. Disponible également en français.
Cat. No. CW69-1/115E. Publ. 2008.
No. 116
Geographic distribution of selected contaminants in Great Blue Herons from the St. Lawrence River system, Quebec (1989–1994), by Jean-Luc DesGranges, Jean Rodrigue, and Louise Champoux. Disponible également en français.
Cat. No. CW69-1/116E. Publ. 2009.

Canadian Wildlife Service Occasional Papers

Occasional Papers report the peer-reviewed results of original research carried out by members of the Canadian Wildlife Service or supported by the Canadian Wildlife Service.

Editor-in-Chief

Editorial Board

Environment Canada's role in wildlife matters

Environment Canada manages wildlife matters that are the responsibility of the federal government. These include the protection and management of migratory birds, nationally significant habitat, and species at risk, as well as work on other wildlife issues of national and international importance. In addition, the department does research in many fields of wildlife biology and provides incentive programs for wildlife and habitat stewardship.

For more information about Environment Canada, to notify us of an address change, or to ask to be added to or removed from our mailing list, please contact:

Inquiry Centre
Environment Canada
Ottawa, Ontario K1A 0H3
Phone: 819-997-2800 or 1-800-668-6767 (toll-free in Canada)
Fax: 819-994-1412
Email: enviroinfo@ec.gc.ca
Website: www.ec.gc.ca

Canadian Wildlife Service Occasional Papers are published by Environment Canada. For more information about Canadian Wildlife Service publications, go to www.cws-scf.ec.gc.ca/publications.

www.**ec**.**gc**.**ca**

Additional information can be obtained at:

Environment Canada
Inquiry Centre
351 St. Joseph Boulevard
Place Vincent Massey, 8th Floor
Gatineau, Quebec K1A 0H3
Telephone: 1-800-668-6767 (in Canada only) or 819-997-2800
Fax: 819-994-1412
TTY: 819-994-0736
Email: enviroinfo@ec.gc.ca