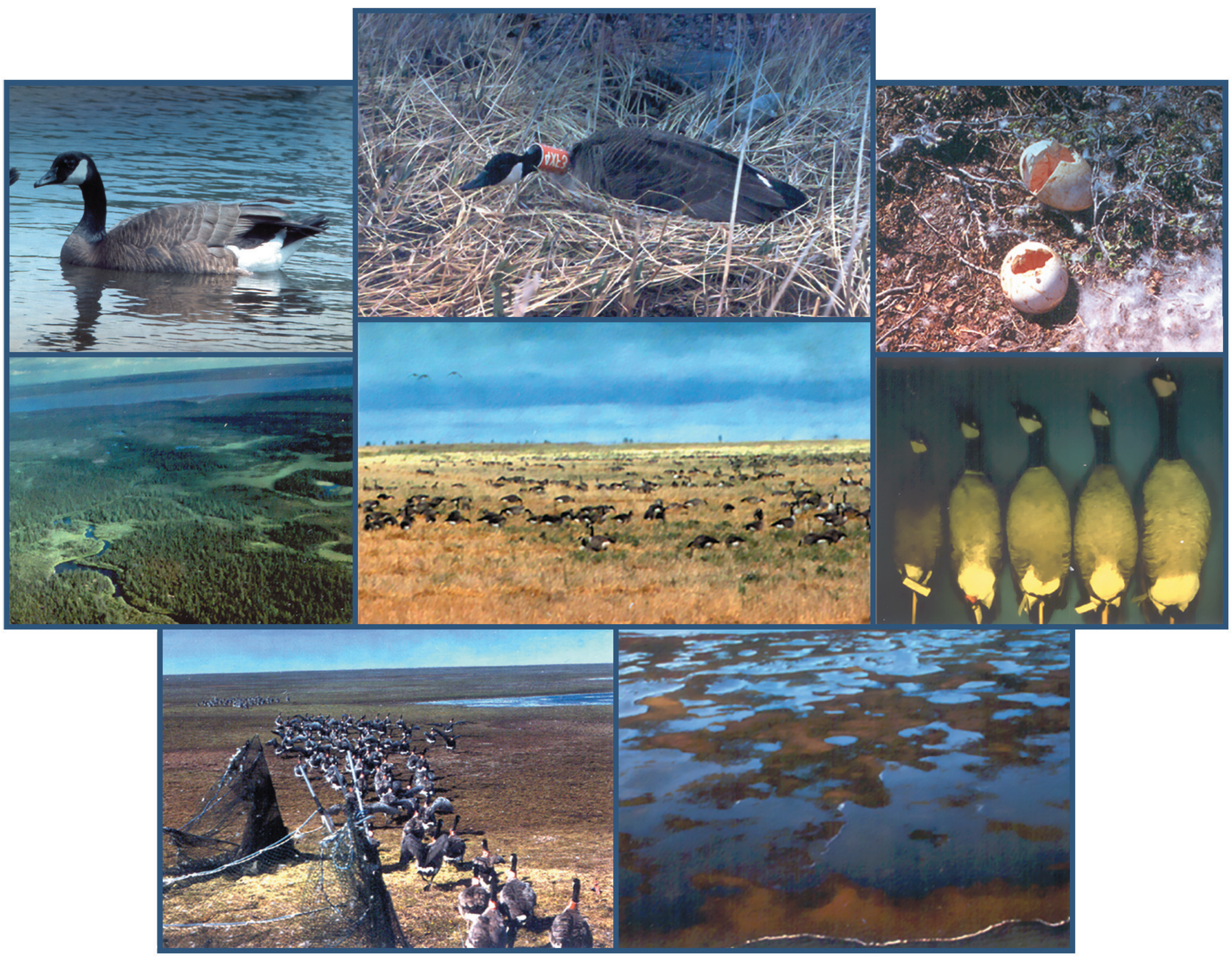
Kathryn M. Dickson
(Editor)

Towards conservation of the diversity of Canada Geese (*Branta canadensis*)

Occasional Paper
Number 103
Canadian Wildlife Service



Canada

Environment Canada
Canadian Wildlife Service

Environnement Canada
Service canadien de la faune

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.

The Canadian Wildlife Service

The Canadian Wildlife Service of Environment Canada handles wildlife matters that are the responsibility of the Canadian government. These include protection and management of migratory birds as well as nationally significant wildlife habitat. Other responsibilities are endangered species, control of international trade in endangered species, and research on wildlife issues of national importance. The service cooperates with the provinces, territories, Parks Canada, and other federal agencies in wildlife research and management.

For more information about the Canadian Wildlife Service or its other publications, please contact:

Publications
Canadian Wildlife Service
Environment Canada
Ottawa, Ontario K1A 0H3
(819) 997-1095
(819) 997-2756 (fax)
cws-scf@ec.gc.ca
http://www.cws-scf.ec.gc.ca

Kathryn M. Dickson[1]
(Editor)

Towards conservation of the diversity of Canada Geese (*Branta canadensis*)

Occasional Paper
Number 103
Canadian Wildlife Service

A product of the
Canadian Wildlife Service
Waterfowl Committee

[1] Canadian Wildlife Service, Ottawa, Ontario K1A 0H3

A member of the Environmental Conservation family

Cover photos: left top: Harry Lumsden
left centre: Ted Nichols
left bottom: Kathryn Dickson
middle top: Ken Abraham
middle bottom: Kathryn Dickson
right top: Kathryn Dickson
right centre: Harry Lumsden
right bottom: Steve Wendt

Published by Authority of the
Minister of Environment
Canadian Wildlife Service

Catalogue No. CW69-1/103E
ISBN 0-662-29699-0
ISSN 0576-6370

Canadian Cataloguing in Publication Data

Main entry under title:

Towards conservation of the biodiversity of Canada Geese
(*Branta canadensis*)

(Occasional paper, ISSN 0576-6370; no. 103)
ISBN 0-662-29699-0
Cat. No. CW69-1/103E

1. Canada goose — Ecology — Canada.
2. Branta — Ecology — Canada.
I. Dickson, Kathryn Marie.
II. Canadian Wildlife Service.
III. Series: Occasional paper (Canadian Wildlife Service); no. 103.

QL696.A52T68 2000 598.417'8'0971 C00-980499-4

Contents

Contributors

Kenneth F. Abraham
Ontario Ministry of Natural Resources
300 Water Street
Peterborough, ON K9J 8M5

Sam J. Barry
Canadian Wildlife Service
Environment Canada
4999-98th Avenue
Edmonton, AB T6B 2X3

Thomas A. Barry
Canadian Wildlife Service
Environment Canada
4999-98th Avenue
Edmonton, AB T6B 2X3
(retirement address: 14322 Ravine Drive, Edmonton, AB T5N 3M3)

Myrtle C. Bateman
Canadian Wildlife Service
Environment Canada
P.O. Box 6227
17 Waterfowl Lane
Sackville, NB E4L 1G6

Renée Bergeron
116, rue de l'Écumease
St-Augustin-de-des Maures, QC G3A 1W8

André Bourget
Service canadien de la faune
Environnement Canada
1141, route de l'Église
C.P. 10100
Sainte-Foy, QC G1V 4H5
(retraite : 1044, rue Lamber, St-Jean-Chrysostome, QC G6Z 3H1)

Louis Breton
Division des Évaluations Environnementales
Environnement Canada
1141, route de l'Église
C.P. 10100
Sainte-Foy, QC G1V 4H5

Robert G. Bromley
Department of Renewable Resources
Government of the Northwest Territories
Suite 600, 5102-50th Avenue
Yellowknife, NT X1A 3S8
(present address: Box 1177, Yellowknife, NT X1A 3S8)

F. Dale Caswell
Canadian Wildlife Service
Environment Canada
Suite 150, 123 Main Street
Winnipeg, MB R3C 4W2

Richard C. Cotter
Canadian Wildlife Service
Environment Canada
1141 Route de L'Église
P.O. Box 10100
Sainte-Foy, QC G1V 4H5
(present address: 620 Chemin Craig, St. Sylvestre, QC G0S 3C0)

Darrell G. Dennis
Canadian Wildlife Service
Environment Canada
P.O. Box 490, Lambeth Station
London, ON N6P 1R1
(retirement address: 44571 Mapleton Line, St. Thomas, ON N5P 3T3)

D. Lynne Dickson
Canadian Wildlife Service
Environment Canada
4999-98th Avenue
Edmonton, AB T6B 2X3

Kathryn M. Dickson
Canadian Wildlife Service
Environment Canada
351 St. Joseph Boulevard
Hull, QC K1A 0H3

Andrew B. Didiuk
Canadian Wildlife Service
Environment Canada
Prairie and Northern Wildlife Research Centre
115 Perimeter Road
Saskatoon, SK S7N 0X4

Anthony J. Erskine
Scientist Emeritus
Canadian Wildlife Service
Environment Canada
P.O. Box 6227
17 Waterfowl Lane
Sackville, NB E4L 1G6

Michael A. Fournier
Canadian Wildlife Service
Environment Canada
Suite 301, 5204-50th Avenue
Yellowknife, NT X1A 1E2

Murray Gillespie
Manitoba Department of Natural Resources
200 Saulteaux Crescent, Box 24
Winnipeg, MB R3J 3W3

William F. Harvey
Maryland Department of Natural Resources
Wildlife and Heritage Division
P.O. Box 68
Wye Mills, MD 21679
U.S.A.

Jay B. Hestbeck
U.S. Geological Survey
Massachusetts Cooperative Fish and Wildlife Research Unit
204 Holdsworth Hall
University of Massachusetts
Amherst, MA 01003-4220
U.S.A.
(current address: U.S. Geological Survey, Patuxent Wildlife Research Center,
11410 American Holly Drive, Laurel, MD 20708-4015, U.S.A.)

Michael R.J. Hill
Ducks Unlimited Canada
Suite 13, 301-45th Street West
Saskatoon, SK S7L 5Z9

James E. Hines
Canadian Wildlife Service
Environment Canada
Suite 301, 5204-50th Avenue
Yellowknife, NT X1A 1E2

R. John Hughes
Canadian Wildlife Service
Environment Canada
1141 Route de L'Église
P.O. Box 10100
Sainte-Foy, QC G1V 4H5

Dale D. Humburg
Missouri Department of Conservation
1110 South College Avenue
Columbia, MO 65201
U.S.A.

Robert L. Jarvis
Department of Fisheries and Wildlife
Nash 104
Oregon State University
Corvallis, OR 97331
U.S.A.

Maureen F. Kay
Canadian Wildlife Service
Environment Canada
Suite 301, 5204-50th Avenue
Yellowknife, NT X1A 1E2

Richard H. Kerbes
Canadian Wildlife Service
Environment Canada
115 Perimeter Road
Saskatoon, SK S7N 0X4

James O. Leafloor
Ontario Ministry of Natural Resources
P.O. Box 730
Cochrane, ON P0L 1C0

Harry G. Lumsden
Ontario Ministry of Natural Resources
300 Water Street
Peterborough, ON K9J 8M5
(retirement address: 144 Hillview Road, Aurora, ON L4G 2M5)

Daniel J. Nieman
Canadian Wildlife Service
Environment Canada
115 Perimeter Road
Saskatoon, SK S7N 0X4

Norman R. North
Canadian Wildlife Service
Environment Canada
P.O. Box 490, Lambeth Station
London, ON N6P 1R1

Linda Rancourt
Société d'énergie de la Baie James
500 Boulevard René-Lévesque Ouest
Montreal, QC H2L 4M8

Austin Reed
Canadian Wildlife Service
Environment Canada
1141 Route de L'Église
P.O. Box 10100
Sainte-Foy, QC G1V 4H5

R. Kenyon Ross
Canadian Wildlife Service
Environment Canada
49 Camelot Drive
Ottawa, ON K1A 0H3

Donald H. Rusch
Department of Wildlife Ecology
226 Russell Labs
University of Wisconsin
Madison, WI 53562
U.S.A.
(deceased)

Dave W. Smith
Canadian Wildlife Service
Environment Canada
Pacific Wildlife Research Centre
RR#1, 5421 Robertson Road
Delta, BC V4K 3N2

Jack R. Smith
Canadian Wildlife Service
Environment Canada
Prairie and Northern Wildlife Research Centre
115 Perimeter Road
Saskatoon, SK S7N 0X4

Paul Telander
Minnesota Department of Natural Resources
Thief Lake Wildlife Management Area
HCR 3, Box 17
Middle River, MN 56737
U.S.A.

Bruce C. Turner
Canadian Wildlife Service
Environment Canada
6 Bruce Street
Mount Pearl, NF A1N 4T3

J. Stephen Wendt
Canadian Wildlife Service
Environment Canada
351 St. Joseph Boulevard
Hull, QC K1A 0H3

Myra O. Wiebe
Canadian Wildlife Service
Environment Canada
Suite 301, 5204-50th Avenue
Yellowknife, NT X1A 1E2

Reviewers:

Hugh Boyd, Bob Bromley, John Bruggink, Susan Burns, Myke Chutter, Chris Davies, Randy Dibblee, Kathy Dickson, Dave Duncan, Erica Dunn, Tony Erskine, Ken Gamble, Gilles Gauthier, Scott Gilliland, Pat Kehoe, Hélène Lévesque, Harry Lumsden, Paul Merola, Randy Milton, Alena Mudroch, Ken Ross, Norm Seymour, Dave Sharp, Steve Wendt

Foreword

J. Stephen Wendt

Throughout Canada, biologists have been working to improve our understanding of the status and trends of Canada Geese (*Branta canadensis*). There is no part of the country that is not touched by this species. Yet, despite its apparent commonness and widespread distribution, the knowledge of some types is imperfect. Some Canada Goose populations, such as those breeding in the Arctic, are doing reasonably well (this publication: Hines et al.; Dickson), as are temperate-breeding Canada Geese (this publication: Nieman et al.; Dennis et al.; Smith). In contrast, some of those breeding in boreal or subarctic regions of Canada have experienced recent declines, for reasons that are only partly understood (this publication: Leafloor et al.; Breton et al.).

The Waterfowl Committee of the Canadian Wildlife Service resolved in 1994 to produce this publication to report on the great advances in understanding Canada Goose populations that have occurred in recent years. Some forward strides resulted from concerted large-scale efforts such as a range-wide neck-banding program aiming to update our knowledge of the distributions of Canada Geese and White-fronted Geese breeding throughout the Arctic. Much new information resulted from this extensive study, supported by concerned wildlife agencies throughout Canada and the United States (this publication: Hines et al.; Dickson). Other progress was possible because of scientific studies in support of environmental assessments for developments like reservoir creation (Hughes et al., this publication) and activities of the wildlife habitat mitigation program of the Department of National Defence (Bateman, this publication).

Although waterfowl managers have relied in the past on winter surveys to track population trends for these management units of Canada Geese, the distribution of different groups of birds on wintering areas is becoming less discrete and predictable. The growth explosion of "giant"[1] (or "resident" or "temperate-breeding") Canada Geese (Dennis et al., this publication), along with changes in winter distributions of migrant geese, means that winter counts are less useful for measuring trends in each Canada Goose population. In some cases, reliance on winter counts has masked serious declines in migrant populations (e.g., Atlantic Population, Southern James Bay Population), delaying and complicating the implementation of conservation plans. Whenever possible, we must adopt a "breeding grounds approach," taking measures of status and population health from the nesting areas.

This fundamental change in philosophy is reflected in every paper in this publication. To say that we wish to change perspective to enable management of geese based on breeding ground distributions reflects what we believe should be our foremost goal. That is, we should strive to conserve species throughout their ranges, in this case, by conserving the diversity of Canada Geese from Alaska to Newfoundland, and south to Mexico.

We do not mean to suggest that by focusing on the breeding grounds we will eliminate all difficulties associated with estimating population status. For example, spring surveys of every population of *B. c. interior* (included in the Mississippi Valley, Eastern Prairie, Southern James Bay, and Atlantic populations; see Figs. 5–8 in Dickson, this publication) are confounded to a lesser or greater degree every year by the presence of other Canada Geese arriving from southern breeding areas to spend the moulting period farther north. The degree of confusion is related to the phenology of the spring: early springs in the south may lead to earlier appearances of moult-migrants in the north. If spring is average, or even later than average, on the northern breeding areas, the moult-migrants may arrive before the northern geese are well into the incubation period. In such cases surveys of breeding birds may well include nonbreeding individuals from other stocks. In 1998, however, spring arrived early throughout the breeding range of *B. c. interior*, and surveys could be conducted before the arrival of moult-migrants. Even so, the surveys that year were compromised by another effect of the extremely early spring: the geese nested so much earlier than usual that survey crews could not arrive at the optimal time. Such difficulties are discussed by Leafloor and Abraham, Humburg et al., Leafloor et al., and Breton et al. in later chapters.

It is important that information and results from studies be made available as quickly as possible for use by management agencies. For some populations, estimates of breeding population size and production rates are used immediately to produce estimates of allowable harvests, and we must continue to evaluate survey methodologies and their

[1] Quotation marks are used to indicate our failure to come up with a suitable term for these Canada Geese that resulted from restoration efforts after settlers nearly exterminated the giant Canada Goose (*B. c. maxima*) (see Dennis et al., this publication). These birds may represent a genetic mix of several races. The birds are not truly "resident," many of them migrating hundreds of kilometres between the winter terminus and breeding or moulting areas.

predictions (Leafloor and Abraham, this publication). Not only is the information immediately useful, it also becomes more difficult to work with as time passes. An example is the exceptional job by Tony Erskine to accumulate and make sense of 40 years of information. We hope that this publication will also serve the purpose of comprehensive and timely presentation of information.

Avant-propos

J. Stephen Wendt

Partout au Canada, des biologistes ont travaillé à acquérir une meilleure compréhension de la situation de la Bernache du Canada (*Branta canadensis*) et des tendances propres à celle-ci. Aucun endroit au pays n'est étranger à cette espèce. Pourtant, même si elle nous semble familière et répandue, quelques types de l'espèce restent moins connus. Certaines populations de Bernaches du Canada, comme celles qui nichent dans l'Arctique (la présente publication : Hines et al.; Dickson) et dans les zones tempérées (la présente publication : Nieman et al.; Dennis et al.; Smith), se portent raisonnablement bien. Par contre, certaines des populations qui nichent dans les régions boréales ou subarctiques du Canada ont récemment connu un déclin pour des raisons qu'on ne comprend que partiellement (la présente publication : Leafloor et al.; Breton et al.).

Le Comité sur la sauvagine du Service canadien de la faune a décidé, en 1994, de produire une publication qui ferait rapport sur les grands progrès réalisés ces dernières années, progrès qui ont amélioré la compréhension que l'on a des populations de Bernaches du Canada. De grands pas vers l'avant ont été faits grâce aux initiatives concertées à grande échelle, comme le programme de baguage au cou dans toute l'aire de répartition de l'espèce, visant à faire une mise à jour de nos connaissances sur la répartition des Bernaches du Canada et des Oies rieuses qui nichent dans tout l'Arctique. Cette étude approfondie, appuyée par les organismes de la faune concernés du Canada et des États-Unis, a recueilli nombre de nouveaux renseignements (la présente publication : Hines et al.; Dickson). D'autres progrès ont été faits grâce aux études scientifiques appuyant l'évaluation environnementale relativement à des projets, comme la création de réservoirs (Hughes et al., la présente publication) et les activités du programme d'atténuation des impacts sur les habitats fauniques, du ministère de la Défense nationale (Bateman, la présente publication).

Même si, par le passé, les gestionnaires de la sauvagine se sont fié aux relevés d'hiver pour suivre les tendances des populations de ces unités de gestion de Bernaches du Canada, la répartition des différents groupes d'oiseaux dans les aires d'hivernage devient de moins en moins discrète et prévisible. L'explosion démographique de la Bernache du Canada « géante »[1] [ou « résidente » ou « nichant en zone tempérée » (Dennis et al., la présente publication)], de pair avec les changements dans la distribution hivernale des Bernaches migratrices, rend les comptes d'hiver moins utiles comme mesure des tendances de chaque population de Bernaches du Canada. Dans certains cas, le fait de s'être fié aux comptes d'hiver a masqué de sérieux déclins des populations migratrices (p. ex. la population de l'Atlantique, la population du Sud de la baie James), retardant et compliquant la mise en œuvre des plans de conservation. À chaque fois que cela est possible, nous devons adopter une « approche axée sur les sites de reproduction » et évaluer la situation et la santé de la population d'après les aires de nidification.

Tous les documents de la présente publication expriment ce changement fondamental de philosophie. La déclaration de notre volonté de changer de perspective pour permettre une gestion des Bernaches fondée sur la distribution des individus dans les aires de reproduction témoigne de ce que nous considérons devrait être notre objectif le plus important. Autrement dit, nous devrions nous efforcer à conserver les espèces dans toutes leurs aires de répartition, dans ce cas-ci, en conservant la diversité de la Bernache du Canada depuis l'Alaska jusqu'à Terre-Neuve, et au sud jusqu'au Mexique.

Nous ne prétendons pas que le simple fait de se concentrer sur les aires de reproduction éliminera toutes les difficultés associées à l'évaluation de la situation des populations. Par exemple, les relevés de printemps de toutes les populations de *B. c. interior* (populations comprises dans les populations de la vallée du Mississippi, des prairies de l'Est, du Sud de la baie James et de l'Atlantique; voir les figures 5 à 8 dans Dickson, dans la présente publication) sont plus ou moins embrouillés chaque année par la présence d'autres Bernaches du Canada qui arrivent d'aires de reproduction situées au Sud pour passer leur période de mue plus au Nord. Le niveau de confusion dépend de la phénologie du printemps : des printemps précoces dans le Sud peuvent provoquer une arrivée hâtive des migrateurs en mue dans le Nord. S'il s'agit d'un printemps normal ou même tardif dans les aires de reproduction du Nord, les migrateurs en mue

[1] Les guillemets servent à indiquer notre incapacité à trouver un terme juste pour cette catégorie de Bernache du Canada qui est issue des initiatives de rétablissement effectuées après la quasi-extermination de la Bernache du Canada géante (*B. c. maxima*) par les colons (voir Dennis et al., la présente publication). Ces oiseaux peuvent être le résultat d'un mélange génétique de plusieurs races. Les oiseaux ne sont pas vraiment « résidents » non plus; nombre d'entre eux migrent sur une distance de plusieurs centaines de kilomètres entre leur lieu d'hivernage et leurs aires de nidification ou de mue.

peuvent arriver avant que les Bernaches du Nord aient bien entrepris leur période d'incubation. Dans de tels cas, les relevés d'oiseaux nicheurs peuvent très bien inclure des individus non nicheurs appartenant à d'autres populations. D'autre part, en 1998, le printemps est arrivé tôt dans toute l'aire de reproduction de *B. c. interior*, et les relevés ont pu être réalisés avant l'arrivé des migrateurs en mue. Malgré tout, les relevés de cette année-là ont été compromis par un autre effet dû à un printemps trop hâtif : la nidification des Bernaches a été tellement plus précoce qu'à l'habitude que les équipes de relevés n'ont pas pu arriver au moment optimal. De telles difficultés sont prises en considération par Leafloor et Abraham, Humburg et al., Leafloor et al., et Breton et al. dans des chapitres subséquents.

Il est important que l'information et les résultats des études soient rendus disponibles aussitôt que possible pour utilisation par les organismes de gestion. Pour certaines populations, les évaluations de la taille de la population nicheuse et des taux de production sont immédiatement utilisées pour faire l'estimation du nombre de prises permis; en outre, nous devons continuer à évaluer les méthodologies des relevés et leurs prédictions (Leafloor et Abraham, la présente publication). Non seulement l'information est-elle immédiatement utile, mais plus le temps passe, plus il devient difficile de s'en servir. On peut donner comme exemple le travail exceptionnel de Tony Erskine qui a accumulé 40 ans d'information et qui en a tiré des résultats utiles. Nous espérons que cette publication répondra également au besoin d'une information complète et opportune.

The diversity of Canada Geese

Kathryn M. Dickson

Summary

Canada Geese exhibit remarkable variation in appearance and behaviour. They use the most diverse set of breeding habitats among waterfowl, successfully occupying tundra, taiga, boreal, farmland, and urban regions. Canada Geese have developed a highly variable morphology; both the world's largest and smallest geese are found in this single North American species. The Canada Goose lineage separated into two major groups of large- and small-bodied types about 1 million years ago; however, the designation of subspecies is not at all clear, with as few as 8 and more than 186 having been proposed. To focus conservation efforts in the face of this diversity, Canada Geese are grouped by wildlife management agencies into units, or populations, originally based mainly on the distribution of geese during winter. The populations do not correspond precisely to subspecies; a population may be one of several that together include all the individuals of a subspecies, while other populations combine subspecies in a single unit, although this is relatively uncommon. Molecular genetics may assist in defining appropriate conservation units. At this time, populations breeding in the Canadian Arctic are doing well, as are the temperate-breeding birds. In contrast, some of those breeding in boreal or subarctic regions of Canada have experienced recent declines. Waterfowl managers have relied in the past on winter surveys to track population trends for populations of Canada Geese. These data are becoming more difficult to interpret, because of the rapid growth of temperate-breeding populations and probable changes in winter distributions of northern migrant geese. In fact, reliance on winter counts has masked serious declines in migrant populations, delaying and complicating the implementation of conservation plans. Our goal should be to conserve the diversity of types of Canada Geese throughout their ranges; this means that we must seek ways to evaluate, and react to, the status of each type, an approach that may mean reevaluation of suitable conservation units.

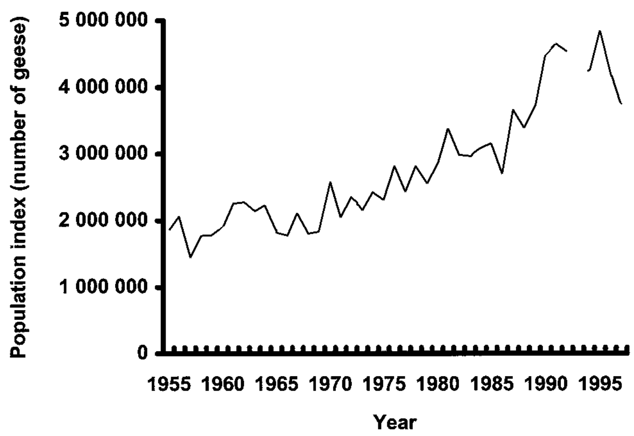
Résumé

Les Bernaches du Canada font preuve d'une variation remarquable dans leur apparence et leur comportement. Parmi la sauvagine, ce sont elles qui utilisent les habitats de reproduction les plus diversifiés, occupant avec succès la toundra, la taïga, les régions boréales, les terres agricoles et les régions urbaines. La morphologie des Bernaches du Canada est devenue très variée : parmi cette même espèce nord-américaine se trouvent à la fois le plus petit et le plus grand type d'oie du monde. La lignée de la Bernache du Canada s'est séparée en deux groupes principaux de types à gros corps et à petit corps il y a environ un million d'années. Cependant, la désignation de sous-espèces n'est pas claire du tout : entre huit et 186 sous-espèces ont été proposées. Pour focaliser les initiatives de conservation devant cette diversité, les Bernaches du Canada sont regroupées par les organismes de gestion des espèces sauvages en unités, ou populations, initialement fondées principalement sur la distribution des oies pendant la période d'hiver. Les populations ne correspondent pas précisément aux sous-espèces; une population peut être une parmi plusieurs qui comprennent ensemble tous les individus d'une sous-espèce, alors que d'autres populations peuvent combiner un certain nombre de sous-espèces en une seule unité, bien que cela soit relativement rare. La génétique moléculaire pourrait peut être aider à définir les unités de conservation pertinentes. Présentement, les populations reproductrices de l'Arctique canadien, ainsi que celles qui nichent dans les régions tempérées, se portent bien. Par contre, certaines populations qui nichent dans les régions boréales ou subarctiques du Canada ont récemment connu des déclins. Par le passé, les gestionnaires de la sauvagine se sont fiés aux enquêtes d'hiver pour relever les tendances dans les populations de Bernaches du Canada. Ces données deviennent de plus en plus difficiles à interpréter à cause de la croissance rapide des populations qui nichent en régions tempérées et des changements probables dans les distributions hivernales des oies nordiques migratrices. En effet, le recours aux décomptes d'hiver a masqué de sérieux déclins parmi les populations migratrices, retardant et compliquant la mise en œuvre des plans de conservation. Notre objectif devrait être la conservation de la diversité des types de Bernaches du Canada dans l'ensemble de leurs aires de distribution; ainsi, nous devons trouver des façons d'évaluer la situation de chaque type et réagir en conséquence. Une telle approche imposerait peut-être une redéfinition des unités de conservation appropriées.

1. Introduction

The number of Canada Geese indexed annually on the wintering grounds over the past few decades is shown in Figure 1. In the 1940s, there were about 1 million Canada

Figure 1
Number of Canada Geese observed during midwinter inventories in the United States, 1955–97



Geese wintering in the United States (Malecki and Trost 1998). This number has increased steadily and rapidly to the point where now there are well over 4 million counted every year. These index data are for major concentration areas, but are not adjusted to account for the more dispersed geese not observed during the inventories. If it were possible to correct the count, we may find that there are 8 million Canada Geese, or more. As a species, *Branta canadensis* is doing well and increasing rapidly in abundance and range.

Within the species, there is a tremendous amount of variation in morphology, habitat use, and behaviour. One way that this can be demonstrated is to examine the types of breeding habitat that the species occupies across the country. In the arctic tundra at the farthest northern part of the breeding range (such as the southwestern section of Baffin Island at about 67°N latitude), nest sites of Canada Geese are located on raised dry areas surrounded by fresh water and distributed over a large flat wet plain of short arctic grasses and sedges. In the southern arctic tundra, where there is more exposed rock and rougher terrain (such as is found in northern Quebec), about three-quarters of the nests of Canada Geese are found near the shore of ponds or small lakes, mostly in association with dwarf birch or other small shrubs (Hughes, pers. commun.). Also in northern Quebec, Canada Geese have been found nesting on cliffs in association with Peregrine Falcons (*Falco peregrinus*) and Rough-legged Hawks (*Buteo lagopus*) (Hughes, pers. commun.). Cliff nesting has been recorded for several areas, such as Colorado, Montana, the Aleutian Islands, and the northern mainland of Alaska (Palmer 1976), where nests may be near those of these two raptors. In the central mainland of the Northwest Territories, hundreds of a small race of Canada Geese were observed nesting along the cliffs and steep slopes of the Clarke River (Norment et al. 1999).

Farther south, in the Hudson Bay Lowlands, Canada Geese occupy the flat, poorly drained, swampy plain left after the retreat of the Wisconsin glacier (Raveling and Lumsden 1977). Preferred nesting sites were ponds of 0.4–2 ha in size containing two or more small islands or hummocks in fen areas, and nests were commonly found at the base of spruce or tamaracks (Raveling and Lumsden 1977). Hughes et al. (2000) found similar results in their study of breeding ecology in north-central Quebec, where nests were almost always on islands in ponds or small lakes, or on moss strips in structured bogs; the shores of larger lakes or small ponds without islands were used occasionally.

Canada Geese also breed successfully in the agricultural and urban areas of southern Canada (Cadman et al. 1987; Dennis et al. 2000; Nieman et al. 2000; Smith 2000). Campbell et al. (1990) reported that, in southern British Columbia, Canada Goose nests are found in agricultural fields, near irrigation ditches, reservoirs, ditches, dykes, and sewage lagoons. In southern Ontario, Canada Geese may occasionally be found nesting in trees (North, pers. commun.), something that has also been recorded as a common event in British Columbia and parts of Alaska (Palmer 1976), or on ledges of apartment buildings (Abraham, pers. commun.).

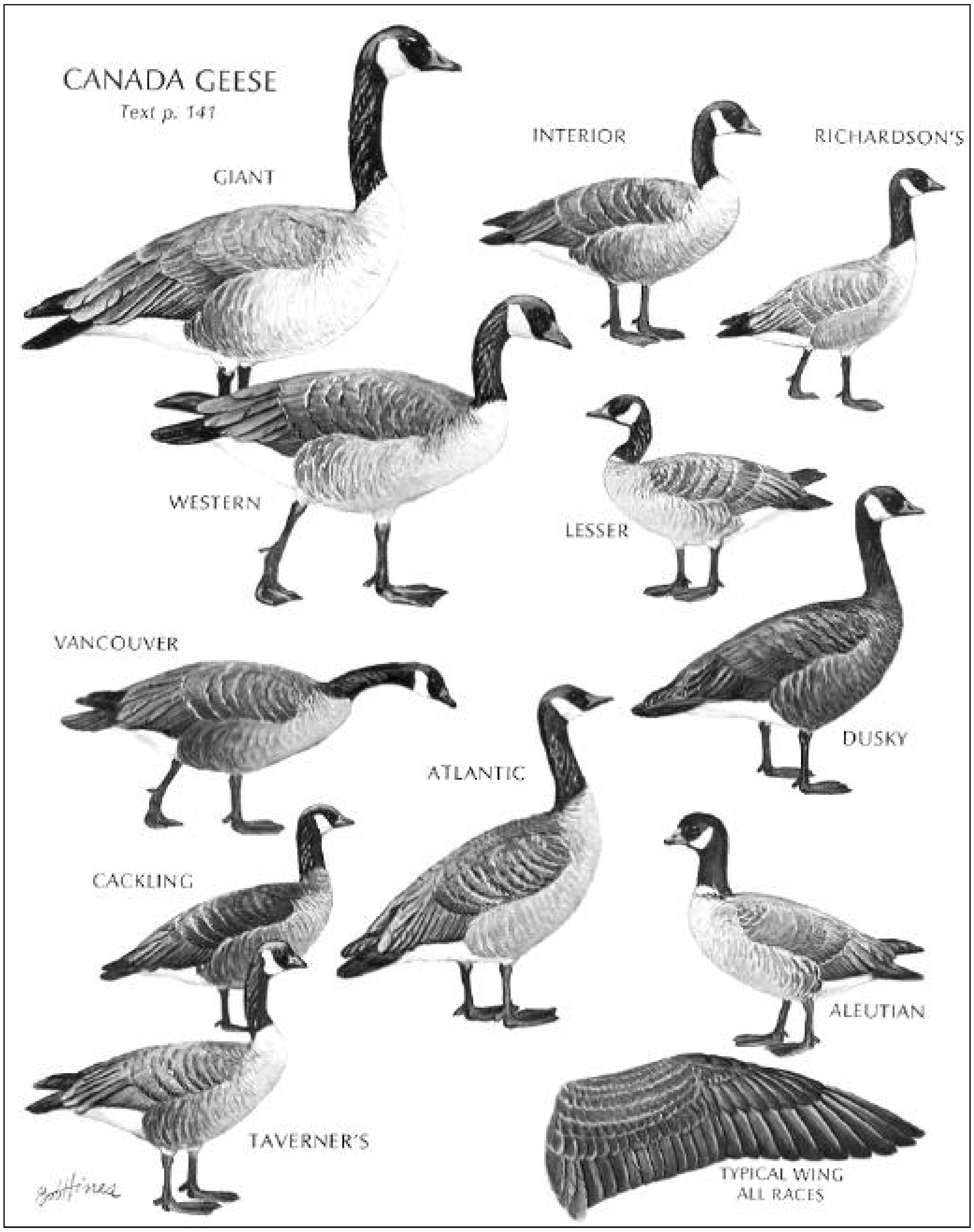
The fact that Canada Geese breed successfully under such a wide range of conditions and in a variety of habitats is in itself a good indicator of the diversity within the species. Each type of habitat leads to a different set of constraints; there are differences in vegetation available for food and the related contrasts in structural characteristics of the landscape. These have implications for behaviour; for example, during the incubation period, *B. c. hutchinsii* (Richardson's Canada Goose) spends longer periods off the nest than has been reported for larger subspecies (Jarvis and Bromley 2000). Behavioural differences among races may also be related to avoidance of predators, and associated with differences of body characteristics. For example, McWilliams and Raveling (1998) suggested that the relatively weak family and pair associations of the very small *B. c. minima* (Cackling Canada Goose) during the nonbreeding season may be related to high predation rates by eagles, which could select for gregarious behaviour.

2. Classification

A number of subspecies or races have been suggested, but the taxonomy of Canada Geese remains controversial. As few as 8 (Palmer 1976) and more than 186 races (page xvii in Hanson 1997) have been advocated. Separate species status has been recommended for some races; for example, Aldrich (1946) and Conover and Conover (1948) proposed species status for *B. c. hutchinsii*. Conover and Conover (1948) also proposed separate species status for *B. c. leucopareia* (Aleutian Canada Goose) and *B. c. minima*. The American Ornithologists' Union (1983) suggested that the Canada Goose complex probably consists of at least two species: a large one, *B. canadensis*, and a small one, *B. hutchinsii*. Hanson (1997) suggested that the Canada Goose group may include five species. Although these proposals have not been adopted, they do indicate the great diversity present among types. Figure 2 shows the 11 subspecies described by Bellrose (1980), and his terminology is used throughout this paper.

The proposed races of Canada Geese are based mainly on differences in phenotype — body size, relative proportions of body parts, and plumage characteristics — with consideration also of the degree of geographic isolation among groups. One example of their striking diversity is that among all the kinds of geese in the world, both the largest and the smallest are races of Canada Geese (Delacour 1954). Bellrose (1980) summarized information on body size and reported that adult male *B. c. maxima* (Giant Canada Goose)

Figure 2
Some races of Canada Geese (with permission, from Bellrose 1980)



averaged about 5.7 kg, and adult female *B. c. minima* averaged only about 1.3 kg.

The general trend in body size among the races of Canada Geese shows a decline from the breeding populations in the south through to the north. The southernmost, or temperate-breeding, birds are the largest, with the birds breeding in the arctic being the smallest. This is true even within a single race, *B. c. interior* (Interior Canada Goose), which shows a decrease in body size from the southern part of the range on the mainland near southern James Bay to the northern birds at west Hudson Bay (Leafloor and Rusch 1997).

A confounding factor in use of body size to describe races is that in addition to being influenced by genetics, body size can be affected by environmental stresses. Leafloor et al. (1998) studied goslings originating from two separate groups in geographic proximity, both considered to belong to the *B. c. interior* race, but characterized by significantly different adult body size. The goslings exhibited no differences in asymptotic size or growth period when raised in a common environment. Leafloor et al. (1998) suggested that lower food availability in the wild for one group over at least the past two decades, with a possible contribution by the more severe climate, resulted in smaller individuals in that group.

There is also a general trend for birds breeding in the eastern part of the continent to be lighter in colour than those breeding farther west. For example, the relatively light-coloured *B. c. canadensis* (Atlantic Canada Goose) and *B. c. hutchinsii* are found in the east, whereas in Alaska darker forms such as *B. c. occidentalis* (Dusky Canada Goose) and

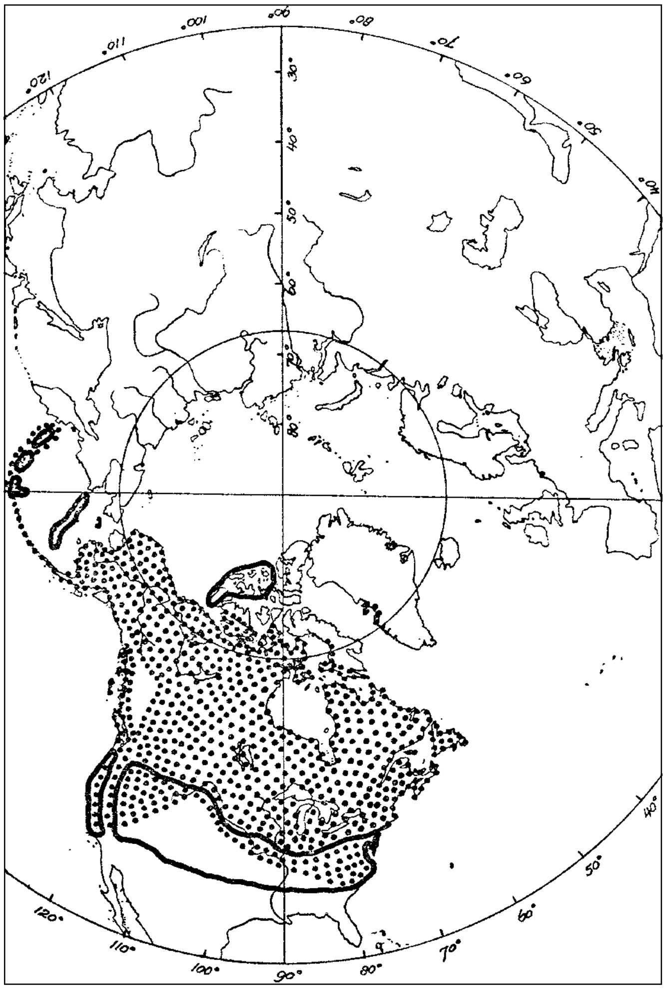


Figure 3
Present breeding range of *Branta canadensis* (stippled area) and borders of the potential breeding grounds (solid lines) during the Wisconsin glacial period (with permission, from Ploeger 1968)

B. c. minima are found. There are additional plumage characteristics that tend to differ among subspecies; Palmer (1976) provided some examples. For instance, *B. c. leucopareia* commonly has a distinct white collar, which is also found to a lesser extent on *B. c. parvipes* (Lesser Canada Goose). Some races tend to have white feathers on the forehead, and some show a black stripe through the white chin.

Another morphological feature that varies among the races is the shape of the head profile. The faces of *B. c. hutchinsii, B. c. leucopareia*, and *B. c. minima* tend to be relatively stubby in profile, in comparison with the more elongated profiles of *B. c. maxima*, *B. c. moffitti* (Western Canada Goose), and *B. c. canadensis* (Atlantic Canada Goose). Also, some races have relatively longer or shorter necks or relatively longer or shorter legs. For example, *B. c. minima* has relatively long legs and wings for a goose of its size.

Identification of races based solely on phenotypic characteristics can be ambiguous. Newer information from studies of parts of the genome of different types of Canada Geese may help to clarify some relationships among races. These studies demonstrated that the types fell into two groups: one group of seven races that are primarily large-bodied, and four that are small-bodied (Quinn et al. 1991; Baker and Marshall 1997; Baker 1998; Shields and Cotter 1998). Baker (1998) analyzed material from 10 subspecies and was able to distinguish them all based on their composite mitochondrial DNA (mtDNA) haplotypes. Although these studies demonstrated quantifiable genetic differentiation among subspecies of Canada Geese, Avise et al. (1990) found no evidence of genetic differentiation between Mallards (*Anas platyrhynchos*) and American Black Ducks (*Anas rubripes*), even though these are recognized as separate species.

Much of this new work was based on relatively small sample sizes; currently ongoing studies will help to clarify these early results. However, the results so far suggest that typological classifications may be confirmed by molecular techniques (Soltis and Gitzendanner 1999), and relationships among types may be clarified. On the other hand, previously unrecognized lineages may be identified and also demand attention.

3. Development of diversity

The great climatic changes of the past were important in the development of the extensive variation now observed within *Branta canadensis*. About 1 million years ago, the Canada Goose lineage separated into two major groups, representing the large-bodied and small-bodied Canada Geese, and over the subsequent hundreds of thousands of years, the two clones diversified and developed (Baker 1998). Ploeger (1968) considered the current distribution pattern and variation of arctic waterfowl and reconstructed the former locations of possible breeding grounds just prior to the most recent ice age. This was the Wisconsin glaciation period, which reached its maximum about 18 000 years ago (Pielou 1991). Ploeger (1968) made the assumptions that the social and migratory behaviour of Canada Geese were then the same as they are today. His map of the present breeding range of *Branta canadensis* and the borders of the potential refugial breeding grounds during the glacial maximum is shown in Figure 3.

Ploeger (1968) suggested the following distribution of Canada Goose stocks during the Wisconsin glacial maximum: the *B. c. hutchinsii* type may have nested in an ice-free area in the high Canadian Arctic, ice-free locations on the Bering Shelf could have provided breeding areas for the *B. c. minima* type, whereas the *B. c. leucopareia* type may have found breeding refugia on the south coast of the Bering Sea. Breeding areas for the large-bodied type of Canada Geese would have existed south of the ice sheets in boreal and temperate climatic zones. The Pacific coastal region south of the Cordilleran ice sheet may have supported the *B. c. occidentalis* type, and areas south of the Laurentide ice sheet could have supported the group that includes the present-day *B. c. canadensis*, *B. c. interior*, *B. c. maxima*, *B. c. moffitti*, and *B. c. parvipes*. The breeding area south of the Laurentide ice sheet would have comprised a great diversity of breeding habitats, leading to ecoclimatological separation among the large-bodied types. Nevertheless, there would have been opportunity for interbreeding and intergradation. Quinn et al. (1991) showed that all large-bodied Canada Geese had identical sequences for the cytochrome b gene, a feature that is consistent with their reinvasion of the breeding grounds in the last 10 000 – 14 000 years (Baker and Marshall 1997).

Pielou (1991) described the withdrawal of the ice sheets and the subsequent colonization of newly exposed land by plants and animals. By 11 000 years ago, southern Ontario became ice free, and by 3000 or 4000 years ago, southern Baffin Island (which supports the largest goose-nesting aggregation in the world) became ice free. During the past few thousand years, the various types of Canada Geese shifted their ranges and developed the distributions that exist today.

4. Conservation of diversity

The maintenance of geographically distinct groups of Canada Geese is a function of fidelity to nesting sites, migratory stopovers, and winter areas, as well as strong family ties and, at least for the northern groups, a tendency towards colonial or semi-colonial nesting (Mayr 1942; Delacour 1954; Raveling 1978; Malecki and Trost 1998). These features tend to restrict the gene flow among groups. However, recent changes to the landscape, such as establishment of refuges, agricultural practices, and other land-use patterns, as well as differential hunting pressure, have likely affected distributions (Palmer 1976) during migration and in winter and in the breeding season of temperate-breeding populations. Thus, current distributions may not reflect those of the past, and these factors may contribute to an increased degree of contact and overlap among types at different times of the year. Conservation agencies relied in the past on winter surveys to track population trends for populations of Canada Geese, but distributional changes are making the data more difficult to interpret.

If we are to conserve diversity, it must first be described. New developments in the field of genetic studies are likely to help; for example, *B. c. taverneri* (Taverner's Canada Goose) and *B. c. parvipes* approximate each other in size and may overlap breeding ranges in interior Alaska. Some authors combine the two types within the *B. c. parvipes* race (e.g., page 205 in Palmer 1976). However, Shields and Cotter (1998) showed that, based on analyses of mtDNA, the two races grouped into different clades; the former shared a type of mtDNA found only in the other large-bodied Canada Geese, whereas the latter shared a type of mtDNA found only in the small-bodied group.

To focus conservation efforts in the face of such diversity, Canada Geese throughout the continent are grouped into management populations based on relatively distinct breeding ranges, migration routes, and winter areas. However, these populations do not correspond precisely to subspecies; they may include more than one subspecies, or only a fraction of one subspecies. Some management groups, such as the Shortgrass Prairie Population, comprise at least two races; in this case, both *B. c. parvipes* and *B. c. hutchinsii* are included. In another example, the birds of the Eastern Prairie, Mississippi Valley, Southern James Bay, and Atlantic populations are all classified as *B. c. interior*.

Refinement of the delineation of management populations is usually accomplished through marking programs. Representative samples of birds are marked on the breeding grounds, with either leg bands or neck collars, or both. The locations of the recovery of leg bands, usually from hunters, can illustrate the migration routes taken as well as the winter terminus. The dates of recovery provide information on the temporal distributions. However, these apparent distributions are biased according to the locations of hunters and hunting areas, and so do not provide information on movements when and where there is no hunting.

Use of neck collars, markers that can be seen from a distance on a living bird, can fill in the gaps. Observer networks can be set up throughout the migration and wintering areas, and the movements of individual birds can be tracked throughout the year. Birds marked with radio transmitters can also be followed to describe movements. More recently, marking birds with satellite transmitters has allowed tracking of Canada Geese even through areas where observer networks are not possible (Malecki, pers. commun.), and molecular markers have been used successfully to sort out a mixed group of Canada Geese in a shared winter area (Pearce et al. 2000). The resulting descriptions of temporal and geographic distributions are more complete than those described only on the basis of leg-band recoveries.

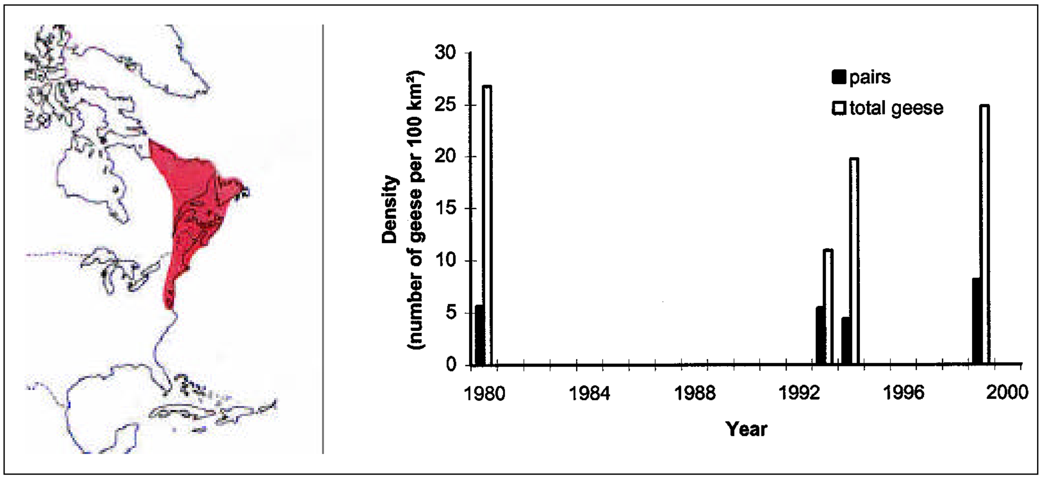
Marking programs can assist where the delineation of populations is still less than optimal. For example, the Shortgrass Prairie Population breeds in the northwestern part of the Canadian Arctic and migrates through Saskatchewan and Alberta and through the Central Flyway of the United States. Although midwinter inventories show that this population as a whole is doing very well (see Fig. 10 below), one of the two types of Canada Geese that comprise it could decline significantly without being noticed, provided that the decline were made up for by an increase in abundance of the other. In this example, recent work done on the breeding grounds by the Canadian Wildlife Service concluded that the number of *B. c. parvipes* is stable, and that most of the overall population growth is a result of increased abundance of *B. c. hutchinsii* (Hines et al. 2000).

5. Status of races

5.1 North Atlantic Population (NAP)

Figure 4 shows the distribution of the NAP, which is considered to consist of the race *B. c. canadensis*. This population has been stable for many years, based on breeding ground surveys undertaken in 1980, 1993, and 1994 (Bateman 2000). The surveys were repeated in 1998 and 1999. The estimated density of Canada Goose pairs per 100 km^2 was 8.1 in 1999, which is considerably higher than the densities from comparable surveys conducted in 1980, 1993, and 1994, when the densities ranged from 5.5 to 5.7 pairs per 100 km^2 (Bateman 2000). In 1999, the density of total geese, which includes breeding and nonbreeding birds, was 24.8 birds per 100 km^2, similar to the estimate of 26.8 in 1980 and higher than the estimates of 10.9 and 19.7 in 1993 and 1994, respectively (Bateman, pers. commun.; Canadian Wildlife Service Waterfowl Committee 1999). It was suggested that the growing population of Canada Geese breeding in southwestern Greenland was of the *B. c. interior* race, but recoveries of marked birds indicated an association with this North Atlantic group (Fox et al. 1996). A new study of Canada Geese marked there with satellite transmitters will assist in clarifying the affiliation of these birds (Malecki, pers. commun.).

Figure 4
Distribution of the North Atlantic Population of Canada Geese, and indices of the number of breeding pairs and total geese on the study area in Labrador, 1980–99. Data from Bateman (2000) and Canadian Wildlife Service Waterfowl Committee (1999).



5.2 Atlantic Population (AP)

The distribution of the AP is shown in Figure 5. This population comprises the easternmost group of the race *B. c. interior*. Its abundance appears to be increasing following a period of significant decline (Canadian Wildlife Service Waterfowl Committee 1999; Harvey and Rodrigue 1999). This population provides a good example demonstrating the need for counts on the breeding grounds where types are separated. There was a rapid and steady increase in the number of Canada Geese counted on the winter grounds in the Atlantic Flyway up until the late 1980s, when the counts began to level off and then to decline. The winter counts represent the total number of Canada Geese present but give no indication of the status of the different types, in this case, the Southern James Bay, Atlantic, North Atlantic, and Giant populations. The rapid growth of the Giant Population during that period was well known, indicating that the decline in overall abundance reflected a serious decline in the number of migrant birds (*B. c. interior* and/or *B. c. canadensis*). Subsequent surveys on the breeding grounds showed a decrease in the number of breeding pairs, reaching a low of 29 000 in 1995. The hunting season was closed temporarily to reduce mortality rates, and a simultaneous increase in productivity as a result of improved weather conditions resulted in the recovering number of breeding pairs estimated in 1999.

5.3 Southern James Bay Population (SJBP)

Figure 6 shows the distribution of the SJBP, a population that consists of birds of the *B. c. interior* race. For some years now, there has been concern about the status of this population. From 1985 to 1988, the midwinter estimate averaged about 154 000 birds, but in 1990, a survey on the breeding grounds reported only about half that number. Spring estimates over the last 10 years (1990–99) indicated that the population remains at a low level, but that it is slightly increasing. The 1999 spring survey on the mainland of southern James Bay and on Akimiski Island, Nunavut, recorded an overall population estimate of 136 623 geese, an increase of 17% over last year's estimate (117 060 geese),

Figure 5
Distribution of the Atlantic Population of Canada Geese, and indices of the number of breeding pairs in northern Quebec, 1988–99. Data from Harvey and Rodrigue (1999) and Canadian Wildlife Service Waterfowl Committee (1999).

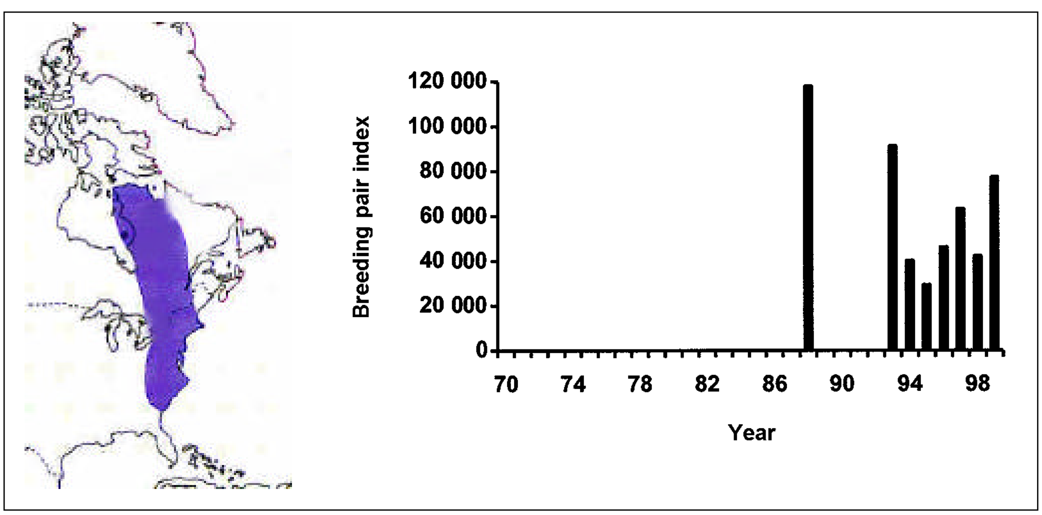
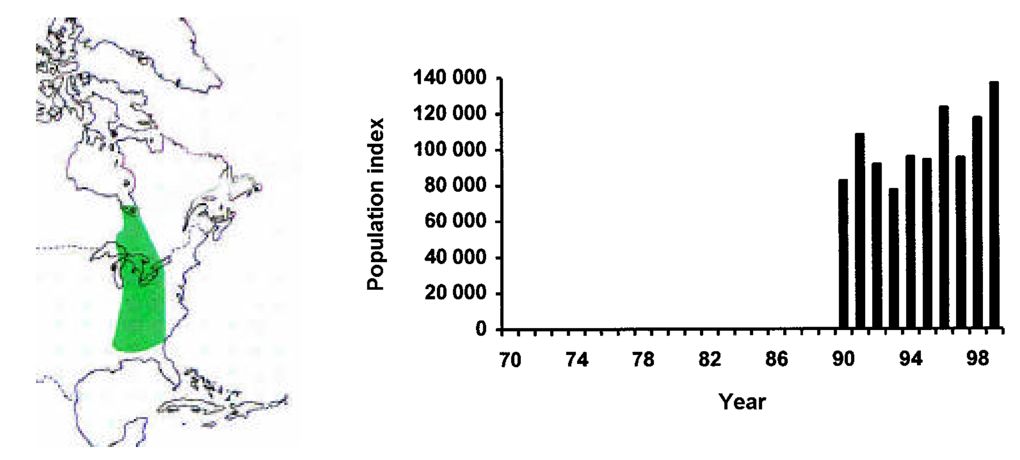


Figure 6
Distribution of the Southern James Bay Population of Canada Geese, and index to total population size in spring on the breeding grounds in northern Ontario, 1990–99. Data from Leafloor and Ross (1999) and Canadian Wildlife Service Waterfowl Committee (1999).



and the highest estimate since the inception of the survey in 1990 (Leafloor and Ross 1999).

5.4 Mississippi Valley Population (MVP)

The MVP consists of birds of the *B. c. interior* race; the distribution of this population is shown in Figure 7. Aerial spring surveys of MVP Canada Geese, initiated in 1989, provided estimates that are generally comparable to those obtained in the midwinter survey (Rusch et al. 1996). Since 1989, there has been no apparent trend in spring population estimates, but there was a decline in the number of nests until 1999. The spring population estimate for 1999 was 969 499 geese, an increase of 32% over the 1997 estimate of 735 880 (1998 estimates are not used here for comparison, because they were believed to be biased low). As well, in 1999, the number of nests increased by 9% compared with 1997 (Leafloor et al. 1999).

5.5 Eastern Prairie Population (EPP)

The EPP consists of birds of the *B. c. interior* race, and its distribution is shown in Figure 8. Spring surveys of the EPP have been flown annually since 1971, providing good baseline data for this population (Humburg et al. 2000). In 1999, the spring population was estimated at 270 500 geese, a large increase (+68%) over the 1998 estimate of 160 600 (±23 300) geese. The 1998 estimate was the lowest estimate observed since 1982, but it may have been confounded by adverse survey conditions. Compared to the 1997 survey results, the spring estimate for 1999 was similar. The estimated population size in 1999 was similar to the 10-year average, but remains below the population goal of 300 000 geese (Humburg et al. 1999).

5.6 Tallgrass Prairie Population (TGPP)

This population consists mainly of the *B. c. hutchinsii* race, but may also include some *B. c. parvipes*. The TGPP distribution is shown in Figure 9. Midwinter inventories

Figure 7
Distribution of the Mississippi Valley Population of Canada Geese, and the total population index from surveys of the breeding grounds in spring, 1990–99. Data from Leafloor et al. (1999) and Canadian Wildlife Service Waterfowl Committee (1999).

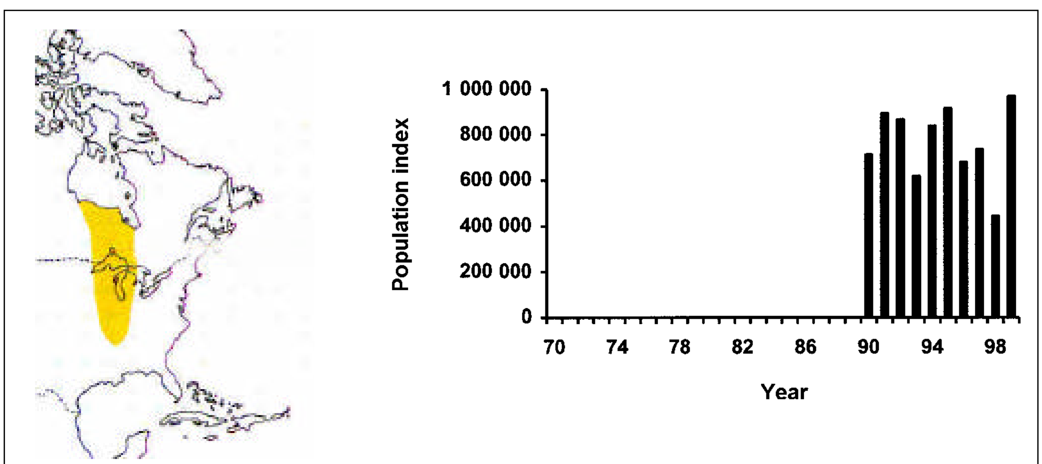


Figure 8
Distribution of the Eastern Prairie Population of Canada Geese, and the total population index from surveys of the breeding grounds in spring, 1972–99. Data from Humburg et al. (1999, 2000), Canadian Wildlife Service Waterfowl Committee (1999), and Wilkins and Cooch (1999).

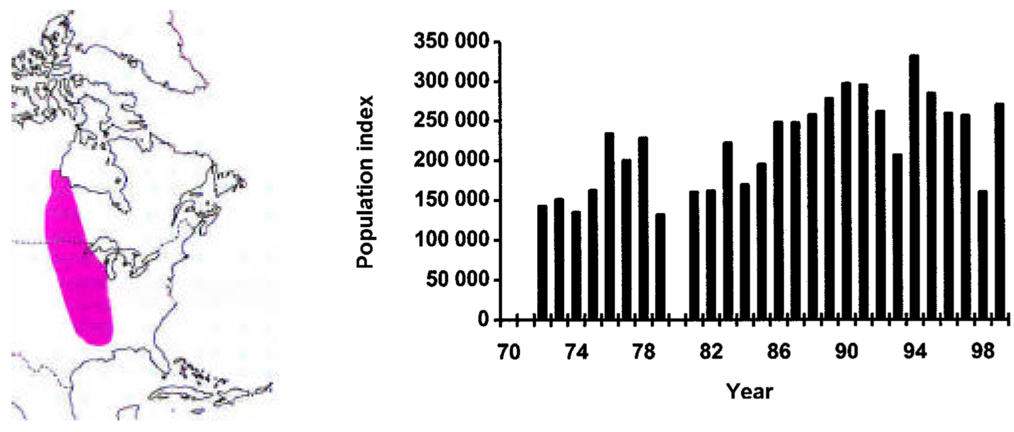
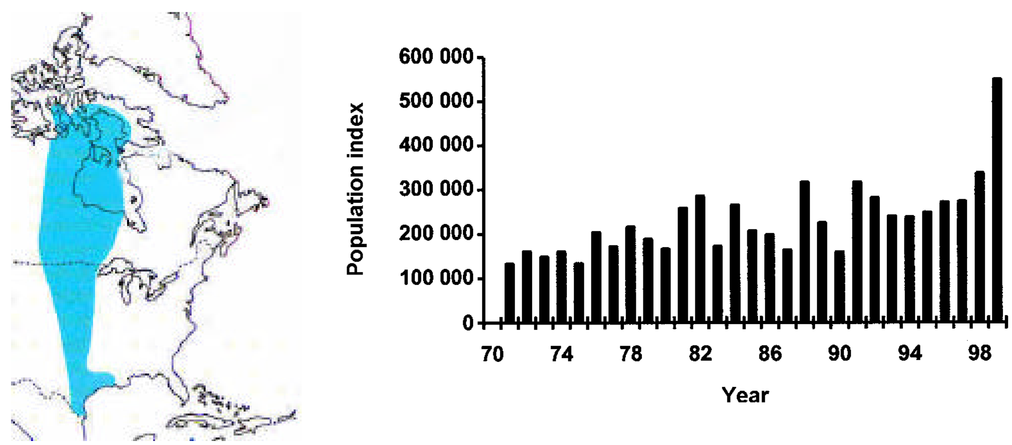


Figure 9
Distribution of the Tallgrass Prairie Population of Canada Geese, and index to population abundance on the wintering grounds, 1971–99. Data from Canadian Wildlife Service Waterfowl Committee (1999) and Wilkins and Cooch (1999).

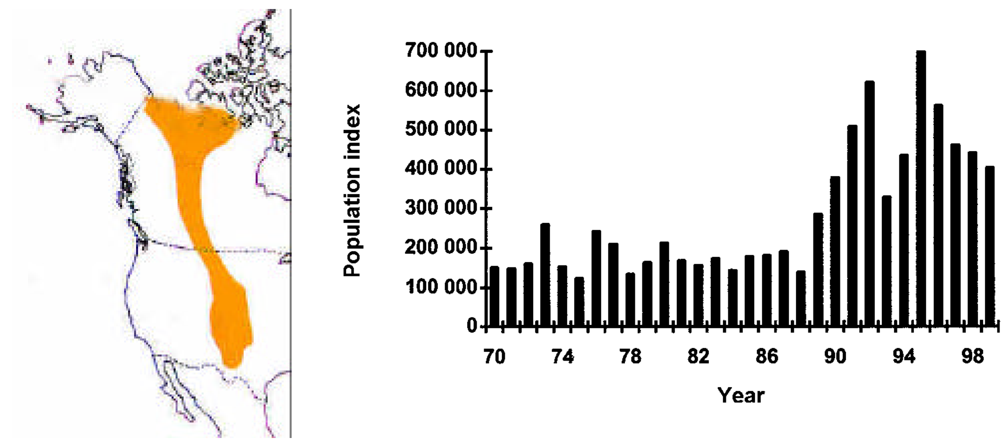


show an overall increase in the total numbers. Helicopter surveys of TGPP Canada Geese were initiated in 1992 (Rusch et al. 1996) and, unlike other spring surveys, are conducted during the brood-rearing period. Population estimates available from Baffin Island from 1993 through 1999 indicate a population of about 100 000 adult and subadult birds. In the past seven years of study, there were three years when there was nearly no production of young (1992, 1996, and 1999). However, 1997 and 1998 were both good years for production, with about 70–80% of the 100 000+ geese identified as breeding birds (Caswell, pers. commun.).

5.7 Shortgrass Prairie Population (SGPP)

Figure 10 shows the distribution of the SGPP, a population that comprises two subspecies, *B. c. parvipes* and *B. c. hutchinsii*. Counts in winter show long-term gradual population growth. Helicopter transect surveys, covering much of the breeding range of this Canada Goose population in the Inuvialuit Settlement Region of the NWT mainland and on Victoria and Banks islands, were conducted in June 1989–94 (Hines et al. 2000). The aerial counts indicated that there were likely 70 000 – 80 000 SGPP Canada Geese in the survey area. Canada Geese on Victoria and Banks islands (primarily *B. c. hutchinsii*) appear to have increased in numbers and possibly extended their breeding range northward over the past few decades. Although this study did not include the subarctic segment of the population, the results suggested, based on the traditional spring waterfowl air–ground survey, that SGPP Canada Geese in the boreal forest and subarctic taiga of the Northwest Territories, Yukon, and eastern Alaska had remained relatively stable since the 1960s (Hines et al. 2000).

Figure 10
Distribution of the Shortgrass Prairie Population of Canada Geese, and index to population abundance on the wintering grounds, 1970–99. Data from Canadian Wildlife Service Waterfowl Committee (1999) and Wilkins and Cooch (1999).



5.8 Western Prairie Population (WPP)

Rutherford (1965) considered that the WPP comprised several large and intermediate size races, including *B. c. moffitti*, *B. c. maxima*, and *B. c. interior*. Its distribution is shown in Figure 11. A review by Nieman et al. (2000) indicated a significant increase in the abundance of this population between 1970 and 1999 (1027%), and it remains above the population goal. These birds cannot be distinguished on the wintering grounds from those belonging to the Great Plains Population.

5.9 Great Plains Population (GPP)

The GPP is composed mainly of the *B. c. moffitti* race; the distribution of the GPP is shown in Figure 12. Between 1970 and 1999, this population increased in abundance by about 2117% (Nieman et al. 2000). At present, this population remains above the population goal.

5.10 Hi-line Population (HLP)

The distribution of the HLP is shown in Figure 13, and the population is believed to comprise the *B. c. maxima* and *B. c. moffitti* races. A review of trends in the breeding population of HLP Canada Geese indicated a significant increase of 1089% between 1970 and 1999 (Nieman et al. 2000). The midwinter survey provided a population index of 119 500 geese in 1999, a 37% decrease from the previous year's index of 191 000 geese. Over the last 10 years, the number of HLP geese (based on the midwinter survey) has increased by 7% per year, on average (Wilkins and Cooch 1999).

5.11 Rocky Mountain Population (RMP)

The distribution of the RMP is shown in Figure 14, and the population consists mainly of the race *B. c. moffitti.* The review of trends indicated an increase of 508% in the population of RMP Canada Geese between 1970 and 1999 (Nieman et al. 2000). The 1999 midwinter survey recorded

Figure 11
Distribution of the Western Prairie Population of Canada Geese, and index to population abundance on the breeding grounds, 1970–95. Data from Nieman et al. (2000).

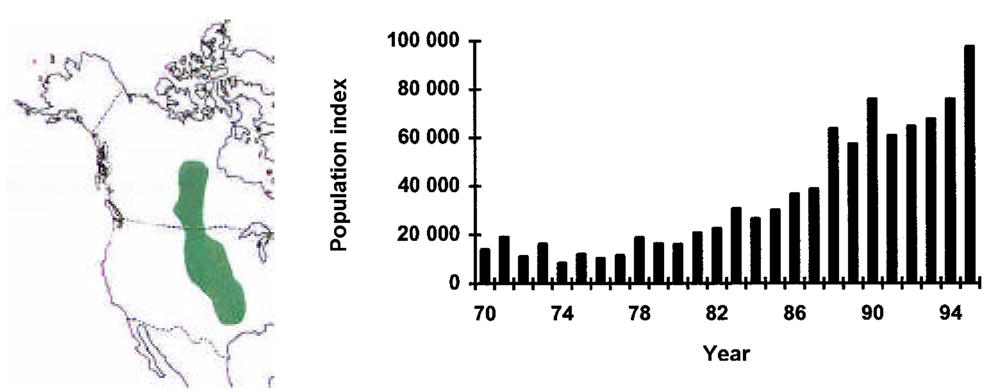


Figure 12
Distribution of the Great Plains Population of Canada Geese, and index to population abundance on the breeding grounds, 1970–95. Data from Nieman et al. (2000).

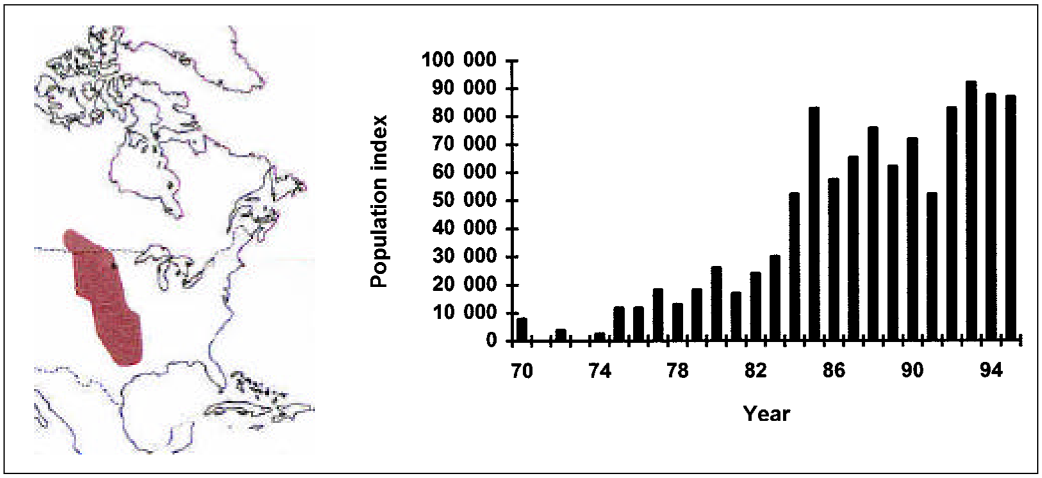


Figure 13
Distribution of the Hi-Line Population of Canada Geese, and index to population abundance on the breeding grounds, 1970–95. Data from Nieman et al. (2000).

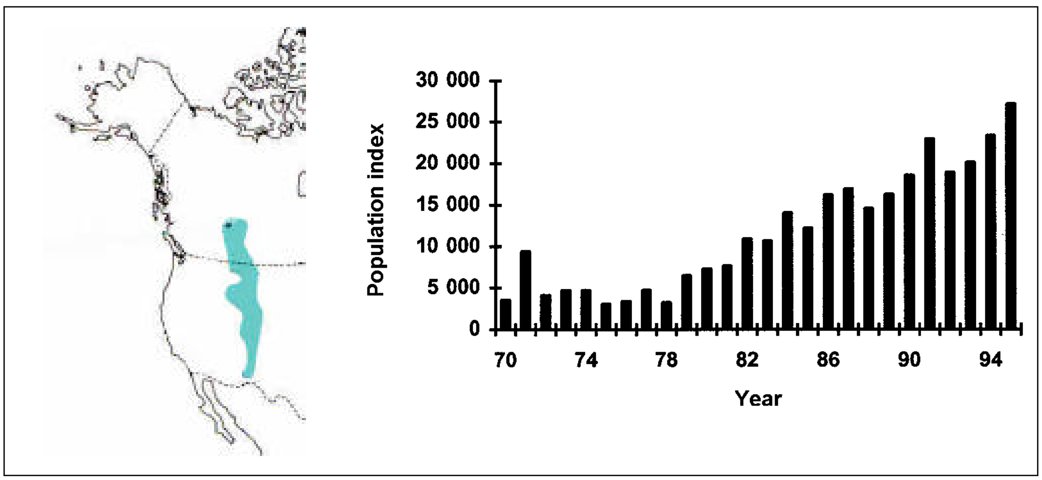
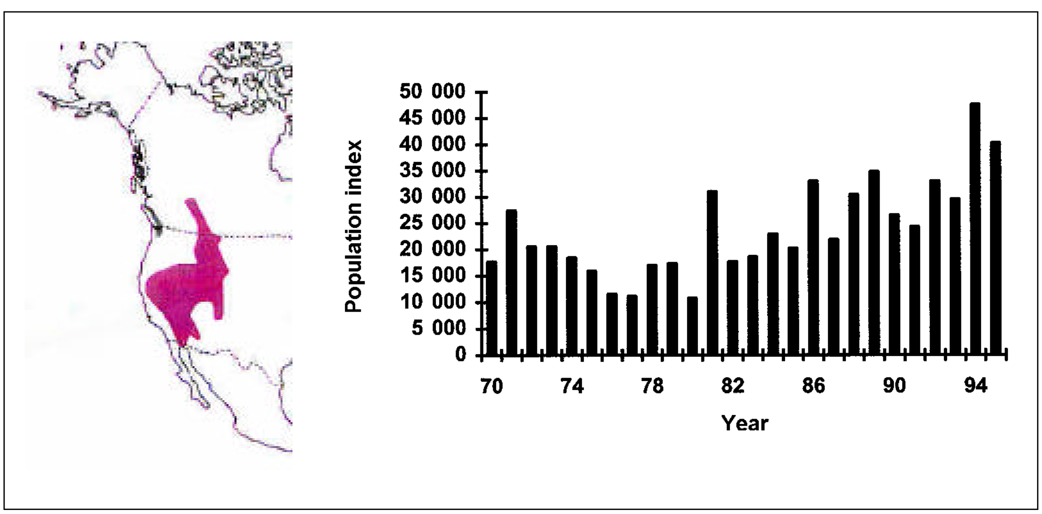


Figure 14
Distribution of the Rocky Mountain Population of Canada Geese, and index to population abundance on the breeding grounds, 1970–95. Data from Nieman et al. (2000).

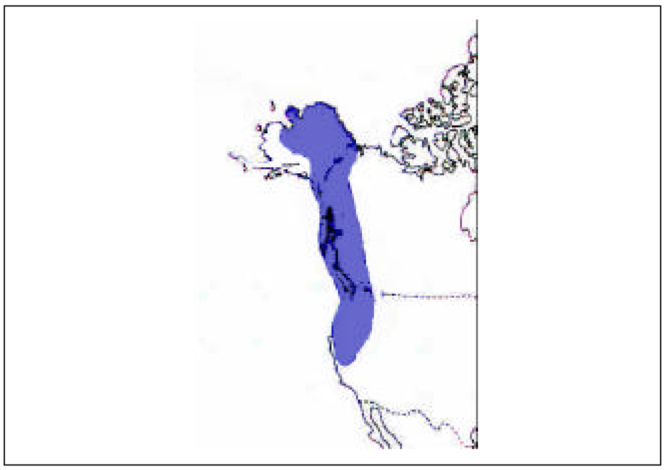


114 416 geese, which represents a 9% increase compared with the 1998 estimate. The midwinter survey data show no statistically significant trend over the last 10 years (Wilkins and Cooch 1999). Also, the 1999 Breeding Waterfowl and Habitat Survey recorded an estimated population of 175 700 RMP Canada Geese in southern Alberta, southwestern Saskatchewan, and Montana. Spring estimates have increased significantly by 8% per year on average since 1989 ($P < 0.01$) (Wilkins and Cooch 1999).

5.12 Lesser Population (LP)

The LP consists of the race *B. c. parvipes*; its distribution is shown in Figure 15. There are no reliable abundance indices for this population, which breeds throughout much of Alaska and migrates along the Pacific coast to winter mixed with other populations in Washington, Oregon, and California (Wilkins and Cooch 1999).

Figure 15
Distribution of the Lesser Population of Canada Geese. There are no reliable abundance indices for this population (Wilkins and Cooch 1999).



5.13 Dusky Population (DP)

The DP comprises the race *B. c. occidentalis.* The distribution of the population is shown in Figure 16. The long-term decline is attributed to the effects of vegetation succession and a subsequent increase of mammalian predators on the Copper River Delta following an earthquake in 1964 (Butler and Eldridge 1998).

5.14 Cackling Population (CP)

The race *B. c. minima* comprises the CP, the distribution of which is shown in Figure 17. The entire population nests on the coast of the Yukon–Kuskokwim Delta, Alaska. Following a significant population decline in the 1980s, indices of the size of the breeding population now show an increase in abundance (Butler et al. 1998).

5.15 Aleutian Population

This population consists of geese of the *B. c. leucopareia* race, which inhabit the Aleutian Islands of Alaska (Fig. 18). This population was nearly extirpated by the introduction of arctic and red foxes and was listed as endangered under the U.S. *Endangered Species Act* in 1973 (Byrd 1998). Following a successful recovery program, its status is now being reevaluated.

5.16 Temperate-breeding populations

These are the newly established or restored populations of Canada Geese, largely of the race *B. c. maxima*, that breed in much of the southern part of Canada and in the United States, and include the Canada Geese breeding and moulting in southern Ontario. The distribution of the temperate-breeding Canada Geese of the Atlantic Flyway is shown in Figure 19. Counts on the breeding areas in Ontario show a rapid and sustained increase in abundance and range (Atlantic Flyway Council Technical Section 1999; Dennis et al. 2000).

Figure 16
Distribution of the Dusky Population of Canada Geese, and index to population abundance on the wintering grounds, 1970–99. Data from Wilkins and Cooch (1999).

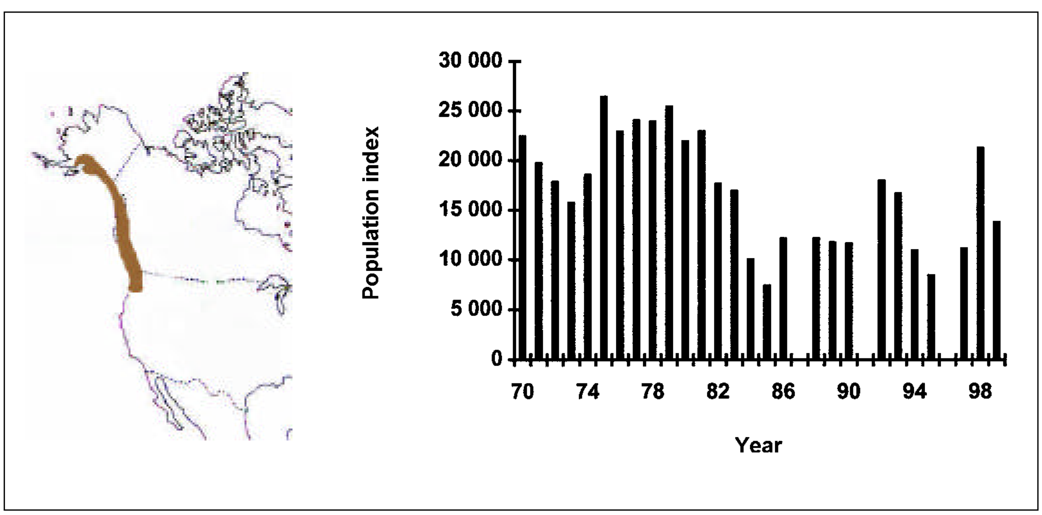


Figure 17
Distribution of the Cackling Population of Canada Geese, and index to population abundance in late fall, 1980–99. Data from Wilkins and Cooch (1999).

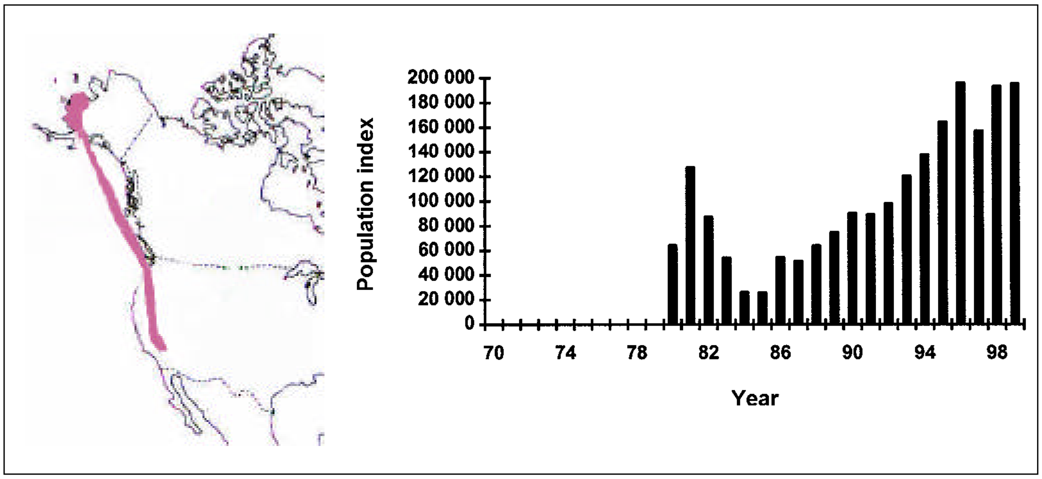


Figure 18
Distribution of the Aleutian Population of Canada Geese

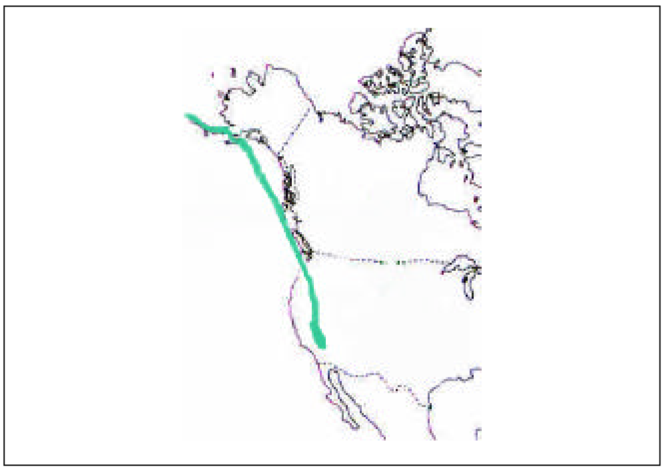
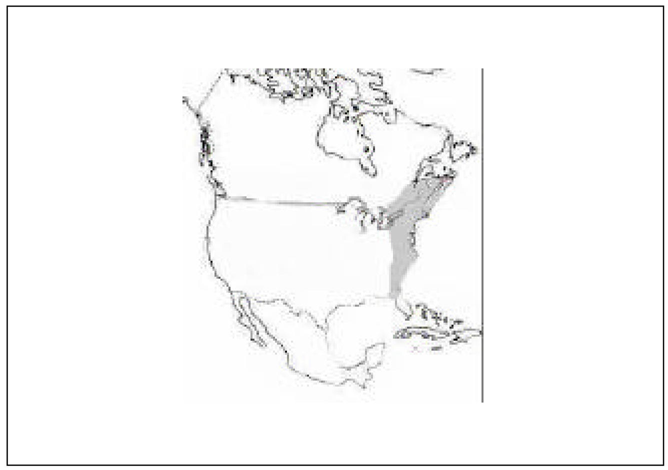


Figure 19
Distribution of Atlantic Flyway temperate-breeding Canada Geese



6. Conclusion

Description of the full diversity of members of a species may lead to delineation of subspecies; these can be defined as geographically isolated groups of which the members can be morphologically distinguished, if only on average, from the members of other groups of the species (Campbell and Lack 1985). Mayr (1988) argued that while the species categorization has real biological meaning apart from the human wish to categorize, designation at the subspecies level serves a more practical function. This desire to categorize is useful in the context of conservation, even when subspecies designations may only represent clinal patterns of variation. If the goal is to maintain the diversity of Canada Goose populations throughout their ranges, then it is not important whether subspecies are incipient species; rather, the use of smaller, identifiable units allows for conservation planning that is more likely to reflect the diversity present. This means that we should continue to verify the description of types of Canada Geese, as well as ensure that we can react to changes in the status of each type, to the extent that it is within human capacity to do so.

7. Acknowledgements

The data reported on in this summary of the status of Canada Geese were collected by hundreds of dedicated biologists. I thank Steve Wendt and Hugh Boyd for our discussions about Canada Geese. I also thank Ken Abraham and Kim Scribner for their suggestions and questions that improved an earlier draft of this paper. Special thanks to Dale Caswell, who invited me to be part of the multispecies goose study on the Great Plain of the Koukdjuak, Baffin Island, Nunavut, and to Jack Hughes, who helped me explore the Canada Goose breeding area near Povungnituk, Quebec. I particularly wish to acknowledge all the partners in the Atlantic Flyway, who made substantial contributions to develop and implement the research plans now providing new information about AP and NAP Canada Geese. There are similar activities ongoing in the other three flyways as well.

8. Literature cited

Aldrich, J.W. 1946. Speciation in the white-cheeked geese. Wilson Bull. 58(2):94–103.

American Ornithologists' Union. 1983. Pages 59–60 *in* Checklist of North American Birds. 7th edition. American Ornithologists' Union, Washington, D.C.

Atlantic Flyway Council Technical Section. 1999. Atlantic Flyway Resident Canada Goose Management Plan. Unpublished report of the Technical Section of the Atlantic Flyway Council, Albany, N.Y. 42 pp.

Avise, J.C., C.D. Ankney and W.S. Nelson. 1990. Mitochondrial gene trees and the evolutionary relationship of mallard and black ducks. Evolution 44:1109–1119.

Baker, A.J. 1998. Identification of Canada Goose stocks using restriction analysis of mitochondrial DNA. Pages 435–443 *in* Rusch, D.H., M.D. Samuel, D.D. Humburg and B.D. Sullivan (eds.), Biology and management of Canada Geese: Proceedings of the International Canada Goose Symposium. Milwaukee, Wisconsin.

Baker, A.J. and H.D. Marshall. 1997. Mitochondrial control region sequences as tools for understanding evolution. Pages 51–79 *in* Mindell, D.P. (ed.), Avian molecular evolution and systematics. Academic Press, San Diego, California.

Bateman, M.C. 2000. Breeding ground surveys for the North Atlantic Population of Canada Geese in Labrador, 1993 and 1994. *In* Dickson, K.M. (ed.), Towards conservation of the diversity of Canada Geese (*Branta canadensis*). Can. Wildl. Serv. Occas. Pap. No. 103.

Bellrose, F.C. 1980. Ducks, geese and swans of North America. 3rd edition. Stackpole Books, Harrisburg, Pennsylvania. 540 pp.

Butler, W.I. and W.D. Eldridge. 1998. Development of an aerial survey for Dusky Canada Geese on the Copper River Delta (abstract). Page 39 *in* Rusch, D.H., M.D. Samuel, D.D. Humburg and B.D. Sullivan (eds.), Biology and management of Canada Geese: Proceedings of the International Canada Goose Symposium. Milwaukee, Wisconsin.

Butler, W.I., R.A. Stehn and W.D. Eldridge. 1998. Aerial surveys of Cackling Canada Geese nesting on the Yukon–Kuskokwim Delta, Alaska (abstract). Page 40 *in* Rusch, D.H., M.D. Samuel, D.D. Humburg and B.D. Sullivan (eds.), Biology and management of Canada Geese: Proceedings of the International Canada Goose Symposium. Milwaukee, Wisconsin.

Byrd, G.V. 1998. Current breeding status of the Aleutian Canada Goose, a recovering endangered species. Pages 21–28 *in* Rusch, D.H., M.D. Samuel, D.D. Humburg and B.D. Sullivan (eds.), Biology and Management of Canada Geese: Proceedings of the International Canada Goose Symposium. Milwaukee, Wisconsin.

Cadman, M.D., P.F.J. Eagles and F.M. Heilleiner. 1987. Atlas of the breeding birds of Ontario. University of Waterloo Press. 617 pp.

Campbell, B. and E. Lack. 1985. A dictionary of birds. The British Ornithologists' Union. T & AD Poyser Ltd., Staffordshire, England. 670 pp.

Campbell, R.W., N.K. Dawe, I. McTaggart-Cowan, J.M. Cooper, G.W. Kaiser and M.C.E. McNall. 1990. The birds of British Columbia. Volume 1: Non-passerines. Introduction through waterfowl. Royal British Columbia Museum, Victoria, British Columbia. 514 pp.

Canadian Wildlife Service Waterfowl Committee. 1999. Filion, A. and K.M. Dickson (eds.), Status of migratory game birds in Canada — November 2, 1999. Unpublished report. Canadian Wildlife Service, Ottawa, Ontario.

Conover, Boardman of Hellmayr, C.E. and B. Conover. 1948. Catalogue of birds of the Americas and adjacent islands. Field Mus. Nat. Hist., Zool. Ser. 13, Publ. 615, Part 1, No. 2, 434 pp. Reported in R.E. Marquardt. 1962. Ecology of the migrating and wintering flocks of the small white-cheeked geese within the south central United States. Ph.D. thesis, Oklahoma State University, Oklahoma City. 179 pp.

Delacour, J. 1954. The waterfowl of the world. Volume 1. Country Life Ltd., London, U.K. 284 pp.

Dennis, D.G., N.R. North and H.G. Lumsden. 2000. Range expansion and population growth of Giant Canada Geese in southern Ontario: benefits, drawbacks, and management techniques. *In* Dickson, K.M. (ed.), Towards conservation of the diversity of Canada Geese (*Branta canadensis*). Can. Wildl. Serv. Occas. Pap. No. 103.

Fox, A.D., C. Glahder, C.R. Mitchell, D.A. Stroud, H. Boyd and J. Fikke. 1996. North American Canada Geese (*Branta canadensis*) in West Greenland. Auk 113(1):231–233.

Hanson, H.C. 1997. The Giant Canada Goose. Revised edition. Illinois Natural History Survey, Southern Illinois University Press, Urbana, Illinois. 252 pp.

Harvey, W.F. and J. Rodrigue. 1999. A breeding pair survey of Canada Geese in northern Quebec — 1999. Unpublished report. Maryland Department of Natural Resources and Canadian Wildlife Service, Quebec Region, Sainte-Foy, Quebec.

Hines, J.E., D.L. Dickson, B.C. Turner, M.O. Wiebe, S.J. Barry, T.A. Barry, R.H. Kerbes, D.J. Nieman, M.F. Kay, M.A. Fournier and R.C. Cotter. 2000. Population status, distribution, and survival of Shortgrass Prairie Canada Geese from the Inuvialuit Settlement Region, Western Canadian Arctic. *In* Dickson, K.M. (ed.), Towards conservation of the diversity of Canada Geese (*Branta canadensis*). Can. Wildl. Serv. Occas. Pap. No. 103.

Hughes, R.J., A. Reed, L. Rancourt and R. Bergeron. 2000. Breeding ecology of Canada Geese near the Laforge-1 hydroelectric reservoir in north-central Quebec. *In* Dickson, K.M. (ed.), Towards conservation of the diversity of Canada Geese (*Branta canadensis*). Can. Wildl. Serv. Occas. Pap. No. 103.

Humburg, D.D., P. Telander and R. Foster. 1999. 1999 EPP breeding population survey. Unpublished report. Mississippi Flyway Council.

Humburg, D.D., F.D. Caswell, D.H. Rusch, M. Gillespie and P. Telander. 2000. Status and trends of the Eastern Prairie Population of Canada Geese. *In* Dickson, K.M. (ed.), Towards conservation of the diversity of Canada Geese (*Branta canadensis*). Can. Wildl. Serv. Occas. Pap. No. 103.

Jarvis, R.L. and R.G. Bromley. 2000. Incubation behaviour of Richardson's Canada Geese on Victoria Island, Nunavut, Canada. *In* Dickson, K.M. (ed.), Towards conservation of the diversity of Canada Geese (*Branta canadensis*). Can. Wildl. Serv. Occas. Pap. No. 103.

Leafloor, J.O. and K. Ross. 1999. 1999 spring population estimates for SJBP Canada Geese. Unpublished report. Ontario Ministry of Natural Resources and Canadian Wildlife Service, Ontario Region, Nepean, Ontario.

Leafloor, J.O. and D.H. Rusch. 1997. Clinal size variation in Canada Geese affects morphometric discrimination techniques. J. Wildl. Manage. 61(1):183–190.

Leafloor, J.O., C.D. Ankney and D.H. Rusch. 1998. Environmental effects on body size of Canada Geese. Auk 115(1):26–33.

Leafloor, J., K. Ross and D. Fillman. 1999. Preliminary spring survey results for MVP Canada Geese — 1999. Unpublished report. Ontario Ministry of Natural Resources, Cochrane, Ontario, and Canadian Wildlife Service, Ontario Region, Nepean, Ontario.

Malecki, R.A. and R.E. Trost. 1998. Status of breeding Canada Geese in North America. Pages 3–8 *in* Rusch, D.H., M.D. Samuel, D.D. Humburg and B.D. Sullivan (eds.), Biology and management of Canada Geese: Proceedings of the International Canada Goose Symposium. Milwaukee, Wisconsin.

Mayr, E. 1942. Systematics and the origin of species. Columbia University Press, New York. 334 pp.

Mayr, E. 1988. Toward a new philosophy of biology. Observations of an evolutionist. Harvard University Press, Cambridge, Massachusetts. 564 pp.

McWilliams, S.R. and D.G. Raveling. 1998. Habitat use and foraging behaviour of Cackling Canada and Ross' Geese during spring: implications for the analysis of ecological determinants of goose social behavior. Pages 167–178 *in* Rusch, D.H., M.D. Samuel, D.D. Humburg and B.D. Sullivan (eds.), Biology and management of Canada Geese: Proceedings of the International Canada Goose Symposium. Milwaukee, Wisconsin.

Nieman, D.J., A.B. Didiuk and J.R. Smith. 2000. Status of Canada Geese of the Canadian prairies. *In* Dickson, K.M. (ed.), Towards conservation of the diversity of Canada Geese (*Branta canadensis*). Can. Wildl. Serv. Occas. Pap. No. 103.

Norment, C.J., A. Hall and P. Hendricks. 1999. Important bird and mammal records in the Thelon River valley, Northwest Territories: range expansions and possible causes. Can. Field-Nat. 113(3):375–385.

Palmer, R.S. (ed.). 1976. Handbook of North American birds. Volume 2. Waterfowl (first part). Yale University Press, New Haven, Connecticut.

Pearce, J.M., B.J. Pierson, S.L. Talbot, D.V. Derksen, D. Kraege and K.T. Scribner. 2000. A genetic evaluation of morphology used to identify harvested Canada Geese. J. Wildl. Manage. 64(3):863–874.

Pielou, E.C. 1991. After the ice age. University of Chicago Press, Chicago, Illinois. 366 pp.

Ploeger, P.L. 1968. Geographical differentiation in arctic Anatidae as a result of isolation during the last glacial. Ardea 56(1–2):1–155.

Quinn, T.W., G.F. Shields and A.C. Wilson. 1991. Affinities of the Hawaiian Goose based on two types of mitochondrial DNA data. Auk 108:585–593.

Raveling, D.G. 1978. Dynamics of distribution of Canada Geese in winter. Trans. North Am. Wildl. Nat. Resour. Conf. 43:206–225.

Raveling, D.G. and H.G. Lumsden. 1977. Nesting ecology of Canada Geese in the Hudson Bay Lowlands of Ontario: evolution and population regulation. Ontario Ministry of Natural Resources, Fish and Wildlife Research Report No. 98. 77 pp.

Rusch, D.H., F.D. Caswell, M.M. Gillespie and J.O. Leafloor. 1996. Research contributions to management of Canada Geese in the Mississippi Flyway. Trans. North Am. Wildl. Nat. Resour. Conf. 61:161–173.

Rutherford, W.H. 1965. Description of Canada Goose populations common to the Central Flyway. Unpublished report. Central Flyway Waterfowl Council. 18 pp.

Shields, G.F. and J.P. Cotter. 1998. Phylogenies of North American geese: the mitochondrial DNA record. Pages 405–411 *in* Rusch, D.H., M.D. Samuel, D.D. Humburg and B.D. Sullivan (eds.), Biology and management of Canada Geese: Proceedings of the International Canada Goose Symposium, Milwaukee, Wisconsin.

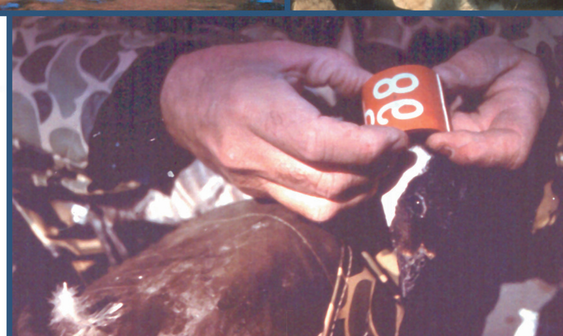
Smith, D.W. 2000. Management of Canada Geese in the Lower Fraser Valley, southwestern British Columbia. *In* Dickson, K.M. (ed.), Towards conservation of the diversity of Canada Geese (*Branta canadensis*). Can. Wildl. Serv. Occas. Pap. No. 103.

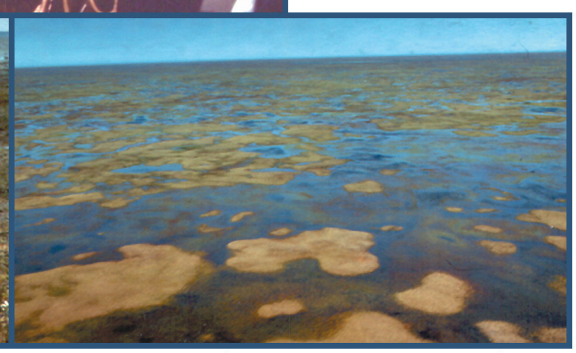
Soltis, P.S. and M.A. Gitzendanner. 1999. Molecular systematics and the conservation of rare species. Conserv. Biol. 13(3):471–483.

Wilkins, K.A. and E.G. Cooch. 1999. Waterfowl population status, 1999. U.S. Fish and Wildlife Service, Department of the Interior, Washington, D.C. 33 pp. + appendices.

Arctic-breeding populations







Photos: top left – Kathryn Dickson
top right – Steve Wendt
centre – Kathryn Dickson
bottom left – Ken Abraham
bottom right – Steve Wendt

Population status, distribution, and survival of Shortgrass Prairie Canada Geese from the Inuvialuit Settlement Region, Western Canadian Arctic

James E. Hines, D. Lynne Dickson, Bruce C. Turner, Myra O. Wiebe, Sam J. Barry, Thomas A. Barry, Richard H. Kerbes, Daniel J. Nieman, Maureen F. Kay, Michael A. Fournier, and Richard C. Cotter

Summary

The purpose of this paper is to summarize results from several recent field studies undertaken in the Inuvialuit Settlement Region (ISR) of the Western Canadian Arctic that further our understanding of the Shortgrass Prairie Population (SGPP) of Canada Geese. Helicopter transect surveys, which covered much of the breeding range of Canada Geese in the ISR, indicated that in June of each year (1989–93), >84 000 adult Canada Geese were present in the three main survey areas: the mainland (>22 000 geese), western Victoria Island (61 000 geese), and Banks Island (<1000 geese). Later in summer, large concentrations of flightless, moulting adult geese were observed on the mainland, particularly in the vicinity of the Harrowby Bay/Old Horton Channel (≥10 000 geese) and at the delta of the Smoke and Moose rivers (>2500 geese). Canada Geese on Victoria Island and Banks Island have apparently increased in numbers and extended their breeding range northwards over the past few decades. Independent evidence suggests that numbers of SGPP Canada Geese nesting in the boreal forest and subarctic taiga of the Northwest Territories, Yukon, and eastern Alaska (probable sources of many of the geese seen at moulting areas in the ISR) have remained relatively stable since the 1960s.

Banding and neck-collaring of adult geese were carried out at the mainland moulting areas from 1990 to 1994 and on western Victoria Island in 1993, and banding data were also available for the mainland for 1975–79. Based on measurements of captured and hunter-shot geese and the year-round distribution of the marked birds, there are likely two different population segments: (1) a subarctic/boreal stock comprising largely Lesser Canada Geese (*B. c. parvipes*) nesting below the tree line and mainly outside the ISR, staging in northwestern Alberta, and wintering mainly in eastern Colorado; and (2) an arctic stock comprising mainly Richardson's Canada Geese (*B. c. hutchinsii*) nesting on Victoria Island, Banks Island, and the mainland north and east of the tree line, staging in southwestern Saskatchewan and southeastern Alberta, and wintering primarily in northern Texas and, to a lesser extent, in eastern Colorado. In general, the SGPP seems to be doing well, and the arctic segment of the population could possibly absorb increased harvest.

Résumé

L'objectif du présent travail est de résumer les résultats de plusieurs études récentes effectuées sur le terrain dans la région désignée des Inuvialuits, dans l'Arctique de l'Ouest du Canada; ces résultats nous aident à approfondir notre compréhension des Bernaches du Canada de la population des prairies de graminées basses (PPGB). Des relevés par transects faits en hélicoptère et couvrant la majeure partie de l'aire de reproduction de la Bernache du Canada de la région désignée des Inuvialuits, ont indiqué qu'au mois de juin de chaque année (de 1989 à 1993), >84 000 Bernaches du Canada adultes étaient présentes dans les trois principales zones de l'étude : la zone continentale (>22 000 bernaches), l'Ouest de l'île Victoria (61 000 bernaches) et l'île Banks (<1000 bernaches). Plus tard en été, de grandes concentrations de bernaches adultes en mue et incapables de voler ont été observées dans la zone continentale, surtout dans les environs de Harrowby Bay/Old Horton Channel (≥10 000 bernaches) et dans le delta des rivières Smoke et Moose (>2500 bernaches). Depuis quelques décennies, les Bernaches du Canada de l'île Victoria et de l'île Banks semblent avoir accru leurs nombres d'individus et avoir agrandi leur aire de reproduction vers le nord. Des indications de sources indépendantes font croire que les nombres d'individus de Bernaches du Canada de la PPGB nichant dans la forêt boréale et dans la taïga subarctique des Territoires du Nord-Ouest, du Yukon et de l'Est de l'Alaska (une source probable de nombreuses bernaches aperçues dans les aires de mue de la région désignée des Inuvialuits sont demeurées relativement stables depuis les années 1960.

On a bagué et posé des colliers à des bernaches adultes dans les aires de mue de la zone continentale de 1990 à 1994 et dans la partie ouest de l'île Victoria en 1993, et on dispose aussi, pour la zone continentale, de données sur le baguage pour les années de 1975 à 1979. Selon les dimensions des bernaches capturées pour l'étude ou prélevées par les chasseurs et la répartition annuelle des oiseaux marqués, il y a vraisemblablement deux segments de population : (1) une population subarctique/boréale comprenant surtout des petites Bernaches du Canada (*B. c. parvipes*) nichant sous la limite des arbres et en grande partie hors de la région désignée des Inuvialuits, se rassemblant dans le Nord-Ouest des l'Alberta et hivernant surtout dans l'Est du Colorado; (2) une population arctique comprenant surtout des Bernaches du Canada de Richardson (*B. c. hutchinsii*) qui

nichent sur l'île Victoria, sur l'île Banks et dans la zone continentale, à l'est et au nord de la limite des arbres, se rassemblant dans le Sud-Ouest de la Saskatchewan et dans le Sud-Est de l'Alberta et hivernant surtout dans la partie nord du Texas, et de façon moindre, dans l'Est du Colorado. En général, la PPGB semble bien se porter et le segment arctique de la population pourrait probablement supporter un nombre de prises plus élevé.

1. Introduction

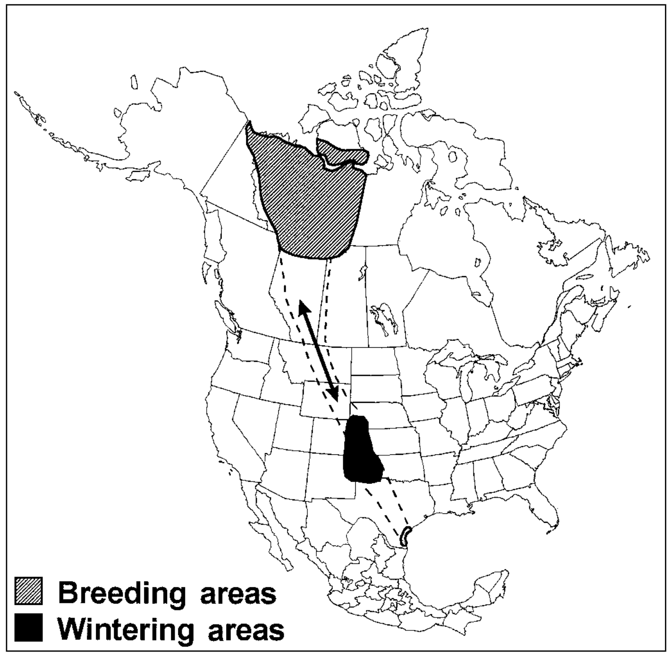
The Shortgrass Prairie Population (SGPP) is one of 15 populations of Canada Geese (*Branta canadensis*) recognized by the North American Waterfowl Management Plan (Environment Canada and U.S. Department of the Interior 1986). The population has been broadly defined as the group of Canada Geese nesting near the arctic coast from eastern Queen Maud Gulf and Victoria Island westward to the Mackenzie River, and southward through the taiga and boreal forest to northern Alberta and Saskatchewan (Fig. 1). An important part of the breeding range falls in the Inuvialuit Settlement Region (ISR)[1] of the Western Canadian Arctic (Committee for Original Peoples Entitlement 1984, and Fig. 2).

The traditional wintering grounds of the SGPP are east of the Rocky Mountains in the dry agricultural lands of eastern Colorado, northern Texas, and neighbouring parts of Nebraska, Wyoming, Kansas, Oklahoma, and New Mexico — a region originally occupied by shortgrass prairie. Studies on the wintering grounds suggest that the population comprises two subspecies, the Lesser Canada Goose (*B. c. parvipes*) and Richardson's Canada Goose (*B. c. hutchinsii*), with the former race comprising >90% of the population (Grieb 1970).[2]

The current understanding of the distribution and abundance of the SGPP is based mainly on banding records (1950–65) from the wintering grounds (Grieb 1970) and annual winter surveys. A difficulty with this approach is that different populations of geese mix on the wintering grounds. The uncertain status and recent changes in the numbers and distributions of many populations on the wintering grounds have prompted wildlife agencies to focus on a breeding ground approach for the management of arctic geese (Canadian Wildlife Service 1991). Land claim settlements, which have encouraged northern people to become more actively involved in wildlife management programs, and amendments to the Migratory Birds Convention that legalize spring hunting of geese make it even more important to understand the breeding ground affinities of the different wintering populations.

In the Western Canadian Arctic, several recent programs supported through the Inuvialuit Final Agreement (Committee for Original Peoples Entitlement 1984) have enhanced our understanding of the SGPP. These programs include widespread aerial surveys of waterfowl on the mainland, Victoria Island, and Banks Island during 1989–94 and an extensive leg-banding and collaring effort, carried out from 1990 to 1994. Here, we report on recent findings concerning the SGPP of Canada Geese from the ISR, including distribution and abundance during the breeding season, fall–winter–spring distribution, taxonomic status, survival rates, and harvest rates. Where possible, we compare the recent data with information collected in earlier years in order to better understand recent changes that have occurred in the population.

Figure 1
Distribution of the Shortgrass Prairie Population of Canada Geese (after Bellrose 1976



2. Methods

2.1 Breeding distribution

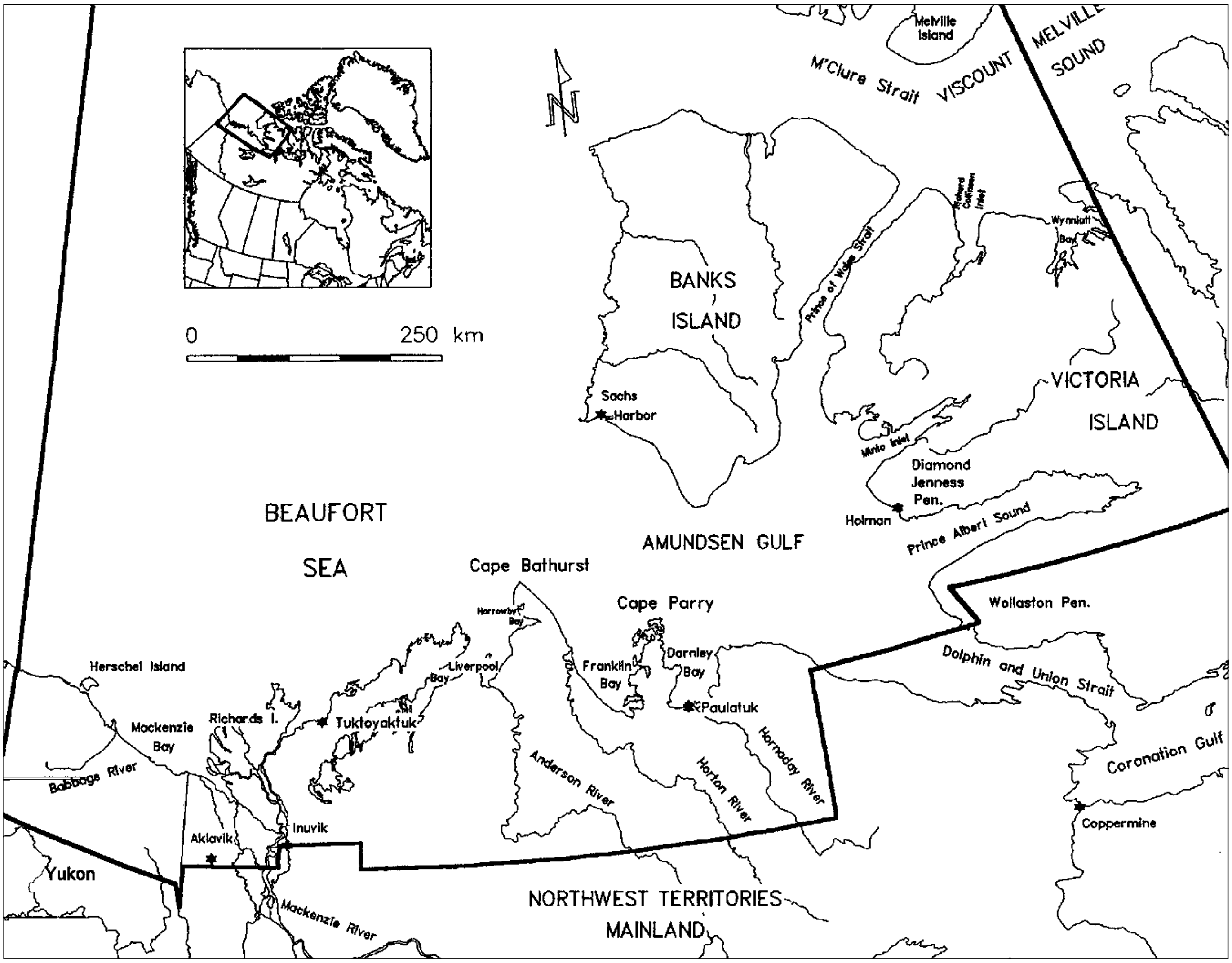
Canada Geese breed in the ISR on the mainland, Victoria Island, and Banks Island. The mainland of the ISR is characterized by rolling lowland plains and many wetland areas (Bostock 1970; Wiken 1986), especially near the Mackenzie River delta and the Tuktoyaktuk Peninsula. Summers are short and cool with long periods of daylight. Mean daily temperatures in summer range from 0 to 15°C (Atmospheric Environment Service 1982). Precipitation is low, but snow is possible in any season. Dominant plant communities on the mainland include forest–tundra near the southern edge of the region, grasses and sedges in lowland and coastal areas, tall shrubs near some streams and lakes, and widespread tundra comprising shorter shrubs, cotton grass (*Eriophorum*), and scattered herbs (Bliss et al. 1973; Corns 1974; Wiken 1986).

Hills, plateaus, and lowland plains characterize the topography of Victoria and Banks islands (Porsild 1955; Wiken 1986). The environment is harsher than on the mainland, with mean daily temperatures ranging from 0 to

[1] The land claim settlement region created as part of the Inuvialuit Final Agreement in 1984.

[2] In taking a breeding ground approach to defining populations, we have excluded the prairie-breeding subspecies *B. c. moffitti*, which was included by Grieb (1970) in the counts of wintering SGPP.

Figure 2
The study area. Boundaries of the Inuvialuit Settlement Region are indicated by solid dark lines.



10°C in summer (Atmospheric Environment Service 1982). Wetlands are less numerous, and plant communities are sparser, less productive, and less diverse than on the mainland. Lowland communities dominated by grasses, sedges, and dwarf shrubs are found in the more hospitable sites for plant growth, and sparser vegetation of a “polar semi-desert” nature is prevalent on higher, drier, and more exposed areas.

Breeding distributions of Canada Geese were determined by aerial surveys conducted between 11 June and 1 July from 1989 to 1994. Surveys were carried out on the mainland of the ISR, western Victoria Island, and Banks Island. The survey areas were divided into 18 strata based on general geographic, physiographic, and habitat differences. Seven main strata (totalling 26 605 km^2) were surveyed on the mainland, eight on western Victoria Island (104 854 km^2), and three on Banks Island (28 414 km^2). In addition, seven smaller areas (totalling 512 km^2) of known importance to moulting geese (Barry 1967; Alexander et al. 1988) were surveyed on the mainland.

The boundaries of strata were determined using topographic maps and descriptions of the geology, physical features, and vegetation. In addition, Landsat Thematic Mapper satellite imagery that had been enhanced to display the amount of vegetation was used to help define strata for Victoria Island. Although many of the strata were surveyed in several years, none of the strata was surveyed in all of the six years (see Tables 1–8 below).

We flew straight transects in a Bell 206B or 206L helicopter. We maintained an elevation of 45 m and ground speed of 80–100 km/h during the surveys, except on Victoria Island, where the elevation was 30 m and the ground speed was 145 km/h. We do not believe that the variation in survey methodology greatly influenced the overall results.

Transects outside moulting areas were spaced at intervals of 10 km, except in a few areas of prime waterfowl habitat, where transects were 5 km apart. Most transects were oriented perpendicular to the coastline. Transects outside moulting areas averaged 25 km in length on the mainland and 50 km in length on Victoria and Banks islands. Transects in the moulting areas were spaced 2 km apart and were generally less than 10 km long. All transects were divided into 2-km segments, which served as a basis for recording data.

All surveys were conducted with two observers, one seated in the left front seat and the other in the right rear seat, which was equipped with a bubble window for easier viewing. All observations of Canada Geese within an estimated 200 m of the flight path were recorded on audio tape and later transcribed.

Population estimates and densities (± standard errors) for each stratum were calculated using the ratio method (Jolly 1969). Population densities for all years were averaged to calculate the average number of geese in the stratum. The standard error (SE) of the mean population estimate for each stratum was determined:

$$SE = \frac{\sqrt{\Sigma S_i^{\,2}}}{n}$$

where $S_i^{\,2}$ is the variance of the stratum population estimate in year i and n is the number of years the stratum was surveyed. If the size of the stratum varied among years, then the largest area surveyed in any of the years was used in the calculation of the average population estimate for the stratum. The total population estimate for the region was the sum of the individual stratum population estimates, and the variance for the total population estimate was the sum of all stratum variances.

As female Canada Geese on nests are infrequently seen from the air, each observation of one or two Canada Geese was treated as an indicated breeding pair (i.e., two birds) in calculating numbers of breeding geese and total population estimates (U.S. Department of the Interior and Environment Canada 1987).

Not all geese present on each transect (whether they occur as singles, pairs, or groups) are sighted from the air. Using data presented by Bromley et al. (1995) for the Central Canadian Arctic, we calculated an average visibility correction factor (VCF) of 1.7 Canada Geese present on the ground for every one seen from the air. This estimate considered both paired and flocked geese to make it applicable to the surveys reported here. Using a mark–resight approach (similar to mark–recapture), we obtained a VCF of 1.8 for a small sample of Canada Geese in the central Arctic (Hines and Kay, unpubl.), and 1.4 for a large sample of dark geese (White-fronted, Canada, and unidentified) in the central and western Arctic. Based on this information, we believe that using a VCF of 1.5 provides a conservative estimate of the number of Canada Geese present on a given area (despite the uncertain nature of the variance of the VCF). We applied this VCF to both breeding pair and total population estimates (and their standard errors) for all strata except for the moulting areas, where geese were typically in large flocks and were readily seen from the air.

2.2 Fall, winter, and spring distributions

The distribution of the SGPP of Canada Geese during the nonbreeding season was determined from locations where banded geese were recovered and collared geese were sighted. We had two sets of banding data: geese banded on the mainland of the ISR during 1975–79, and geese banded on the mainland in 1990–94 and on Victoria Island in 1993. Most geese banded in 1991–94 were also equipped with collars.

Adult geese are unable to fly for three to four weeks each summer as they moult their flight feathers. Flightless geese were captured by using helicopters to herd the birds into nets (see Heyland 1970; Timm and Bromley 1976; Maltby 1977). On the mainland, most geese were caught close to major moulting sites such as Harrowby Bay, the Smoke–Moose delta, and the Mason River delta. On Victoria Island, geese were banded at several sites in the vicinity of the Kagloryuak River. Captured geese were banded with standard U.S. Fish and Wildlife Service (USFWS) aluminum leg bands and, in some cases, equipped with yellow plastic collars. Each collar had a unique combination of black numbers and letters.

Band recoveries and resightings of collared geese were used to determine fall through spring distribution and survival rates. Recoveries were used only for bands of hunter-killed birds that were reported to the Bird Banding Offices of the Canadian Wildlife Service (CWS) or the USFWS. Sightings of collared geese were obtained by observers on fall staging areas, wintering grounds, and spring migration paths of geese. Using spotting scopes, observers were able to read many of the codes on the neck collars, thus identifying individual geese. Approximately 145 observers from provincial, state, federal, and private wildlife management organizations in both Canada and the United States obtained the collar observations used in this report.

Canada Geese gather in early September on their fall staging areas and remain there until weather conditions force them southward (Grieb 1970). Thus, we used band recoveries and collar sightings during the months of September and October to determine the fall staging locations of geese. Most SGPP geese have reached the wintering grounds by early December (Grieb 1970), so we used the months of December and January to determine wintering locations. There were few spring band recoveries, so we used only collar sightings from March, April, and May to determine the spring migration path of the geese.

Almost all band recoveries and collar sightings in September and October were in one of two clearly separated areas. We used the chi-squared test based on 2 × 2 contingency tables to determine if the number of geese in each area was different than expected if geese in the compared categories were distributed at random.

In situations where distributions of geese overlapped, comparisons of distributions were made using Mardia’s test (Batschelet 1981). This is a nonparametric test that involves calculating new coordinates for each bird based on a new origin in the common centre for the entire data set and, disregarding distances (i.e., latitude) from the new origin, comparing the directions (i.e., longitude) of the two samples using a circular two-sample test. Ties between sample points during ranking were broken by random allocation.

One difficulty with performing analyses on the data from the collared geese was that individuals were frequently seen more than once in the same general location. For this reason, sightings of an individual that occurred within 5° latitude and 5° longitude of a previous sighting in the same time period (e.g., September–October of a given year) were averaged and treated as a single observation.

2.3 Taxonomic status

Measurements were taken of Canada Geese captured during banding operations on Victoria Island in 1993 and on the mainland of the ISR in 1994, including culmen length, tarsus length, total tarsus length, and skull length, although not all measurements were taken at all locations. Definitions of measurements followed Dzubin and Cooch (1992) except for culmen length, which was measured as the distance from the first follicle (feathered or unfeathered) to the distal tip of the bill nail. The measurements were compared with previously published measurements to help determine the taxonomic status of Canada Geese in the ISR.

2.4 Survival, recovery, and harvest rates

We computed survival rates of Canada Geese using both band-recovery and mark–resight methods (Brownie et al. 1985; Hestbeck et al. 1990; Pollock et al. 1990) from the same data that were used for determining the fall and winter distributions of the geese.

The rates of survival of banded birds are reflected in the gradual reduction in the number of bands recovered each successive year after banding. The number of band returns for a given cohort of geese is a function of survival rates (the probability that a bird alive at the time of banding in one year is alive at the same time the following year), recovery rates (the probability that a bird alive at the time of banding in one year is shot or found dead during the hunting season of that year and its band is turned in to the Bird Banding Office), and the number of geese banded. Both survival and recovery rates were estimated using the methods and computer software described by Brownie et al. (1985) and Conroy et al. (1989). These programs evaluate the basic fit of different models and provide maximum likelihood estimates of survival and recovery rates. We used the ESTIMATE subroutine of the MULT computer program (Conroy et al. 1989) for the analyses as we were considering adult (after hatch year) geese only. The band-recovery data were tested for the fit of three models: M1 (both survival rates and recovery rates are year dependent), M2 (survival rates are constant from year to year, but recovery rates are variable), and M3 (survival rates and recovery rates are constant each year).

The data from field observations of collared geese were used for a capture–recapture (mark–resight) analysis for open populations (Hestbeck et al. 1990; Pollock et al. 1990; Ebbinge et al. 1991; Lebreton et al. 1992). We used the Jolly–Seber method to estimate annual and average survival rates and probabilities of resighting (program JOLLY; Pollock et al. 1990). This method assumes that survival rates and probabilities of resighting are likely to be time-dependent (Jolly 1965; Seber 1965).

Previous studies have indicated that collar-loss rates can be high for geese (e.g., Samuel et al. 1990; Johnson et al. 1995). If rates of collar loss can be measured, they can be accounted for in estimating population parameters (Arnason and Mills 1981; Pollock et al. 1990; Hestbeck et al. 1990; Nichols et al. 1992). The average survival estimate was adjusted for collar loss by dividing the unadjusted rate by the annual collar-retention rate (Pollock 1981).

From a sample of 140 geese recaptured during banding drives, we determined that rates of collar loss for male Canada Geese during the first two years after banding were very high. The rate of collar loss for males increased with the age of the collar and was also dependent on the year of banding (Hines, unpubl. data).[3] Therefore, we limited survival analyses to females, which had lower rates of collar loss than males.

Although Canada Geese were marked during July of each year, we used only birds observed during September and October for the Jolly–Seber analyses. Hence, our survival estimates refer to the midpoints of the consecutive sampling periods, that is from 1 October of one year to 1 October of the next.

3. Results

3.1 Breeding distribution

Results of the annual aerial surveys are summarized in Figure 3, and the details are given in Tables 1–8. We estimated an average of 84 644 Canada Geese, including 29 219 breeding pairs, in the surveyed area. Approximately 72% of the geese were on western Victoria Island, 27% were on the mainland, and <1% were on Banks Island. Eighty-eight percent of the breeding pairs were on western Victoria Island, 12% were on the mainland, and <1% were on Banks Island.

The mainland of the ISR had the highest density of Canada Geese (0.84 geese/km^2). There was an average of 17 974 ± 3566 Canada Geese (0.68 ± 0.13 geese/km^2) in the seven nonmoulting strata plus an additional 4775 ± 2304 geese in the moulting areas (9.31 ± 4.49 geese/km^2) (Tables 1 and 2). Breeding pair numbers were relatively low in all mainland strata except the Parry Peninsula, which supported 53% of the breeding pairs (Tables 3 and 4) and 46% of the total geese on the mainland (Tables 1 and 2).

Moulting areas supported an average of 21% of the geese seen on the mainland, and thus the combined moulting areas comprised the second most important stratum for mainland geese. Except in 1991, our surveys preceded the arrival of most Canada Geese at the moulting areas, and numbers would have been much greater later in the summer. The high degree of yearly variation in numbers of geese counted at moulting sites (Table 2) undoubtedly reflected variations in spring weather. For example, in 1991, when snowmelt occurred relatively early in the spring, there were nearly 12 000 Canada Geese in the moulting areas by mid-June. In 1992, a year of late snowmelt, fewer than 300 geese had returned to the moulting areas by this date.

Western Victoria Island supported an average of 61 220 ± 2425 Canada Geese. The overall population density there (0.58 ± 0.02 geese/km^2) was slightly lower than on the mainland (Table 5), but the density of breeding pairs (0.24 ± 0.01 pairs/km^2) was twice as high as the mainland average (Table 6). About 72% of the geese on western Victoria Island were found in the four southernmost strata (Fig. 3), which together had an average density of 1.42 geese/km^2 and 0.61 pairs/km^2 (compared with 0.24 geese/km^2 and 0.10 pairs/km^2 in the north). The Kagloryuak River (2.46 geese/km^2) and the Tassijuak River (2.22 geese/km^2) strata appeared to be especially important for Canada Geese on western Victoria Island.

[3] Only 70.5% (43 of 61) adult male geese retained their collars after one year, and only 25.0% (4 of 164 males) retained their collars over a two-year period. The average annual rate of collar retention for adult male geese was 0.650 ± 0.052. Thirty-nine (86.7%) of 45 adult female geese retained their collars after one year, and 8 (57.1%) of 14 recaptured females retained collars for at least two years. The average annual retention rate for females was 0.826 ± 0.044.

Figure 3
Mean annual number of Canada Geese in the different survey strata in the Inuvialuit Settlement Region, June 1989–94

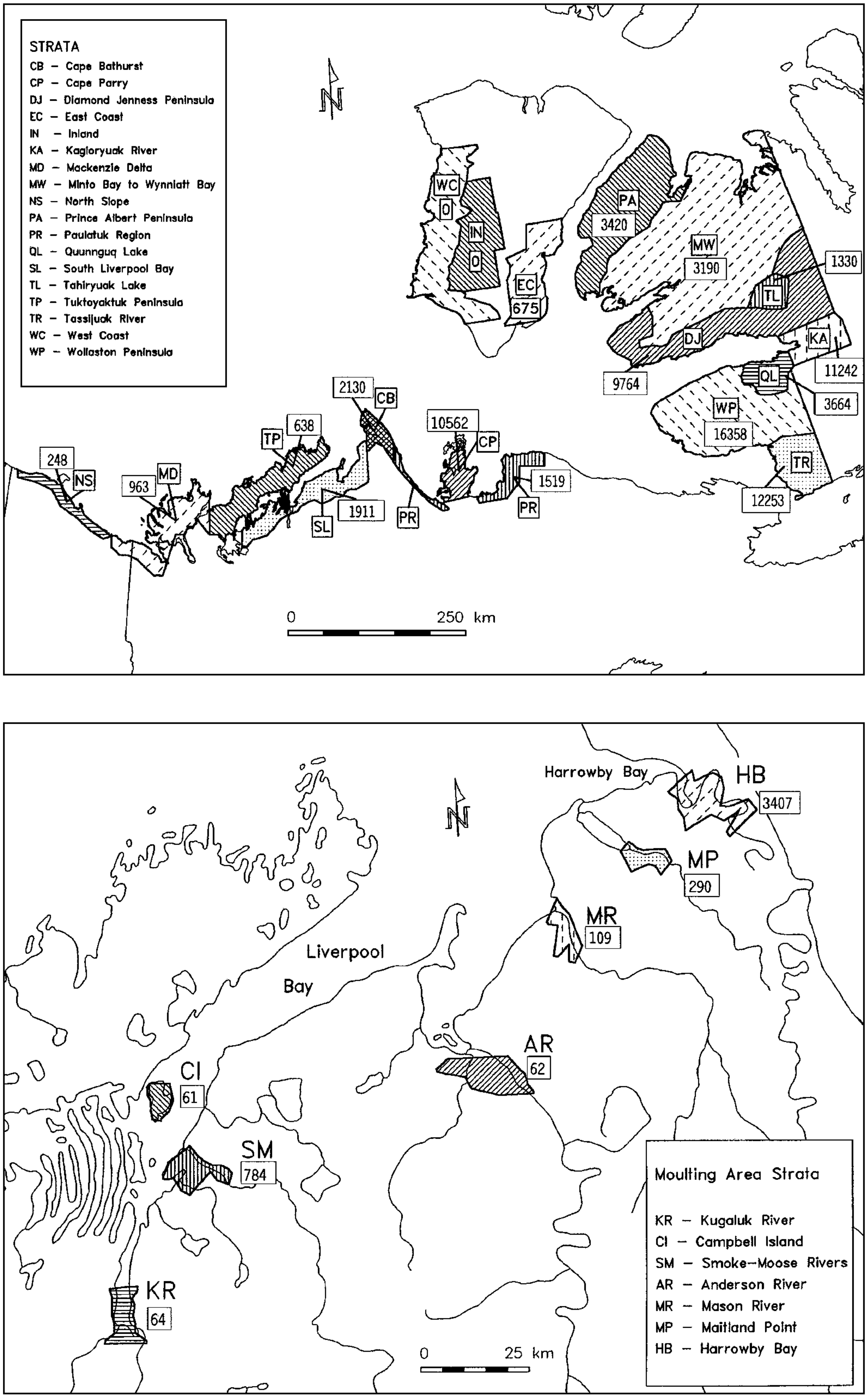


Table 1
Estimated densities and numbers of Canada Geese in survey strata on the mainland of the Inuvialuit Settlement Region, June 1989–93 (VCF is the visibility correction factor)

Stratum	Year	No. of transects	Area (km^2)	Density ± SE ($geese/km^2$)	No. of geese ± SE
Mackenzie Delta (MD)	1989	9	3 668	0.12 ± 0.05	425 ± 186
	1990	23	6 091	0.05 ± 0.02	326 ± 107
	1991	24	6 091	0.10 ± 0.04	605 ± 220
	1992	24	6 091	0.15 ± 0.06	940 ± 350
	1993	24	6 091	0.10 ± 0.02	637 ± 141
	Average (no VCF)[a]		6 091	0.11 ± 0.02	643 ± 109
	Average (adjusted by VCF)[a]		6 091	0.16 ± 0.03	964 ± 164
Tuktoyaktuk Peninsula (TP)	1989	17	6 652	0.18 ± 0.09	1 188 ± 582
	1990	17	6 652	0.04 ± 0.04	297 ± 254
	1991	17	6 652	0.03 ± 0.01	198 ± 92
	1992	17	6 652	0.02 ± 0.01	148 ± 75
	1993	17	6 652	0.04 ± 0.02	297 ± 163
	Average (no VCF)[a]		6 652	0.06 ± 0.02	426 ± 133
	Average (adjusted by VCF)[a]		6 652	0.10 ± 0.03	638 ± 200
South Liverpool Bay (SL)	1989	15	3 280	0.49 ± 0.37	1 607 ± 1 212
	1990	15	3 500	0.14 ± 0.05	497 ± 166
	1991	21	4 721	0.22 ± 0.09	1 061 ± 417
	1992	21	4 721	0.14 ± 0.06	641 ± 286
	1993	21	5 796	0.11 ± 0.03	618 ± 171
	Average (no VCF)[a]		5 796	0.22 ± 0.08	1 274 ± 451
	Average (adjusted by VCF)[a]		5 796	0.33 ± 0.12	1 911 ± 676
Cape Bathurst (CB)	1991	7	1 737	1.97 ± 1.13	3 425 ± 1 968
	1992	4	1 279	0.37 ± 0.14	467 ± 175
	1993	4	1 279	0.12 ± 0.05	148 ± 58
	Average (no VCF)[a]		1 737	0.82 ± 0.38	1 420 ± 661
	Average (adjusted by VCF)[a]		1 737	1.23 ± 0.57	2 130 ± 992
North Slope (NS)	1990	11	1 821	0.09 ± 0.05	166 ± 90
	Adjusted by VCF		1 821	0.14 ± 0.07	248 ± 135
Parry Peninsula (CP)	1991	6	2 784	2.53 ± 0.78	7 042 ± 2 183
	Adjusted by VCF		2 784	3.79 ± 1.18	10 562 ± 3 275
Paulatuk Region (PR)	1991	10	1 724	0.59 ± 0.26	1 013 ± 457
	Adjusted by VCF		1 724	0.88 ± 0.40	1 519 ± 685
All nonmoulting strata on mainland (adjusted by VCF)			26 605	0.68 ± 0.13	17 974 ± 3 566

[a] Average density applied to largest stratum surveyed.

Table 2
Estimated densities and numbers of Canada Geese in the moulting areas on the mainland in the Inuvialuit Settlement Region, June 1991–93 (VCF is the visibility correction factor)

Area	Year	No. of transects	Area (km^2)	Density ± SE ($geese/km^2$)	No. of geese ± SE
Kugaluk River (KR)	1991	7	64	1.02 ± 0.70	65 ± 45
	1992	7	64	1.80 ± 1.08	115 ± 69
	1993	7	64	0.16 ± 0.14	10 ± 9
	Average (no VCF)[a]		64	0.99 ± 0.43	64 ± 28
Campbell Island (CI)	1991	5	41	4.50 ± 4.55	183 ± 185
	1992	5	41	0.00 ± 0.00	0 ± 0
	1993	5	41	0.00 ± 0.00	0 ± 0
	Average (no VCF)[a]		41	1.50 ± 1.52	61 ± 62
Smoke–Moose rivers (SM)	1991	7	82	26.85 ± 14.75	2213 ± 1216
	1992	7	82	0.42 ± 0.25	34 ± 20
	1993	7	82	1.25 ± 0.60	103 ± 50
	Average (no VCF)[a]		82	9.50 ± 4.92	784 ± 406
Anderson River (AR)	1991	4	104	0.53 ± 0.33	55 ± 34
	1992	4	104	1.15 ± 0.77	120 ± 81
	1993	4	104	0.10 ± 0.10	10 ± 10
	Average (no VCF)[a]		104	0.59 ± 0.28	62 ± 29
Mason River (MR)	1991	5	68	1.03 ± 1.02	70 ± 70
	1992	5	68	0.00 ± 0.00	0 ± 0
	1993	5	68	3.75 ± 3.49	256 ± 238
	Average (no VCF)[a]		68	1.59 ± 1.21	109 ± 83
Maitland Point (MP)	1991	6	40	20.13 ± 12.59	813 ± 509
	1992	6	4	0.00 ± 0.00	0 ± 0
	1993	6	40	1.38 ± 1.19	56 ± 48
	Average (no VCF)[a]		40	7.17 ± 4.22	290 ± 170
Harrowby Bay (HB)	1991	7	101	83.90 ± 60.05	8486 ± 6073
	1992	9	113	0.29 ± 0.29	33 ± 32
	1993	9	113	6.58 ± 3.95	741 ± 445
	Average (no VCF)[a]		113	30.26 ± 20.06	3407 ± 2258
Entire moulting stratum (no VCF)			512	9.31 ± 4.49	4775 ± 2304

[a] Average density applied to largest stratum surveyed.

Table 3
Estimated densities and numbers of breeding pairs of Canada Geese in survey strata on the mainland of the Inuvialuit Settlement Region, June 1989–93 (VCF is the visibility correction factor)

Stratum	Year	No. of transects	Area (km^2)	Density ± SE (pairs/km^2)	No. of pairs ± SE
Mackenzie Delta (MD)	1989	9	3 668	0.05 ± 0.03	165 ± 94
	1990	23	6 091	0.03 ± 0.01	137 ± 52
	1991	24	6 091	0.04 ± 0.01	223 ± 73
	1992	24	6 091	0.04 ± 0.02	239 ± 107
	1993	24	6 091	0.05 ± 0.01	319 ± 70
	Average (no VCF)[a]		6 091	0.04 ± 0.01	239 ± 45
	Average (adjusted by VCF)[a]		6 091	0.06 ± 0.01	358 ± 68
Tuktoyaktuk Peninsula (TP)	1989	17	6 652	0.03 ± 0.02	198 ± 100
	1990	17	6 652	0.00 ± 0.00	24 ± 23
	1991	17	6 652	0.02 ± 0.01	99 ± 46
	1992	17	6 652	0.01 ± 0.01	74 ± 37
	1993	17	6 652	0.02 ± 0.01	148 ± 82
	Average (no VCF)[a]		6 652	0.02 ± 0.01	109 ± 29
	Average (adjusted by VCF)[a]		6 652	0.02 ± 0.01	164 ± 43
South Liverpool Bay (SL)	1989	15	3 280	0.07 ± 0.02	222 ± 73
	1990	15	3 500	0.05 ± 0.02	163 ± 62
	1991	21	4 721	0.08 ± 0.03	398 ± 126
	1992	21	4 721	0.05 ± 0.02	221 ± 75
	1993	21	5 796	0.05 ± 0.01	277 ± 83
	Average (no VCF)[a]		5 796	0.06 ± 0.01	338 ± 51
	Average (adjusted by VCF)[a]		5 796	0.09 ± 0.01	508 ± 77
Cape Bathurst (CB)	1991	7	1 737	0.01 ± 0.01	22 ± 23
	1992	4	1 279	0.08 ± 0.04	98 ± 53
	1993	4	1 279	0.06 ± 0.02	74 ± 29
	Average (no VCF)[a]		1 737	0.05 ± 0.02	85 ± 28
	Average (adjusted by VCF)[a]		1 737	0.07 ± 0.02	128 ± 43
North Slope (NS)	1990	11	1 821	0.05 ± 0.03	83 ± 45
	Adjusted by VCF		1 821	0.07 ± 0.04	124 ± 68
Parry Peninsula (CP)	1991	6	2 784	0.43 ± 0.11	1 196 ± 310
	Adjusted by VCF		2 784	0.65 ± 0.17	1 794 ± 465
Paulatuk Region (PR)	1991	10	1 724	0.10 ± 0.03	172 ± 52
	Adjusted by VCF		1 724	0.15 ± 0.05	259 ± 79
All nonmoulting strata on mainland (adjusted by VCF)			26 605	0.13 ± 0.02	3 335 ± 491

[a] Average density applied to largest stratum surveyed.

Table 4
Estimated densities and numbers of breeding pairs of Canada Geese in the moulting areas on the mainland of the Inuvialuit Settlement Region, June 1991–93 (VCF is the visibility correction factor)

Area	Year	No. of transects	Area (km^2)	Density ± SE (pairs/km^2)	No. of pairs ± SE
Kugaluk River (KR)	1991	7	64	0.00 ± 0.00	0 ± 0
	1992	7	64	0.16 ± 0.09	10 ± 6
	1993	7	64	0.08 ± 0.07	5 ± 5
	Average (no VCF)[a]		64	0.08 ± 0.04	5 ± 2
Campbell Island (CI)	1991	5	41	0.13 ± 0.13	5 ± 5
	1992	5	41	0.00 ± 0.00	0 ± 0
	1993	5	41	0.00 ± 0.00	0 ± 0
	Average (no VCF)[a]		41	0.04 ± 0.04	2 ± 2
Smoke–Moose rivers (SM)	1991	7	82	0.24 ± 0.19	20 ± 16
	1992	7	82	0.12 ± 0.11	10 ± 9
	1993	7	82	0.24 ± 0.14	20 ± 11
	Average (no VCF)[a]		82	0.20 ± 0.09	16 ± 7
Anderson River (AR)	1991	4	104	0.05 ± 0.05	5 ± 5
	1992	4	104	0.00 ± 0.00	0 ± 0
	1993	4	104	0.05 ± 0.05	5 ± 5
	Average (no VCF)[a]		104	0.03 ± 0.02	3 ± 2
Mason River (MR)	1991	5	68	0.00 ± 0.00	0 ± 0
	1992	5	68	0.00 ± 0.00	0 ± 0
	1993	5	68	0.07 ± 0.07	5 ± 5
	Average (no VCF)[a]		68	0.02 ± 0.02	2 ± 2
Maitland Point (MP)	1991	6	40	0.25 ± 0.15	10 ± 6
	1992	6	40	0.00 ± 0.00	0 ± 0
	1993	6	40	0.00 ± 0.00	0 ± 0
	Average (no VCF)[a]		40	0.08 ± 0.05	3 ± 2
Harrowby Bay (HB)	1991	7	101	0.10 ± 0.60	10 ± 6
	1992	9	113	0.00 ± 0.00	0 ± 0
	1993	9	113	0.13 ± 0.07	14 ± 7
	Average (no VCF)[a]		113	0.08 ± 0.03	8 ± 3
Entire moulting stratum (no VCF)			512	0.08 ± 0.02	40 ± 9

[a] Average density applied to largest stratum surveyed.

The estimated number of Canada Geese in the three Banks Island strata was only 675 ± 587 (Table 7). The few geese observed there during aerial surveys were on two transects on the southeastern part of the island. Both the total population density (0.09 geese/km^2) and the breeding pair density (0.02 pairs/km^2) were extremely low in this stratum (Tables 7 and 8).

3.2 Fall and winter distribution

Analyses of fall and winter distribution were based on 864 recoveries of the 4531 geese banded from 1975 to 1979, 340 recoveries of the 4541 geese banded from 1990 to 1994, and 9445 sightings of 2593 of the 3909 collared geese. The distribution of band recoveries for the two banding periods and observations of collared geese are summarized by province, territory, or state in Appendices 1–7 and depicted on maps in Figures 4–10.

Based on both band recoveries and collar observations, we identified four broad areas used by Canada Geese from the Inuvialuit Settlement Region during fall and winter (Fig. 4). The four areas accounted for >95% of the collar resightings and >90% of the band recoveries and, for the most part, corresponded to areas outlined in previous reports (Rutherford 1965; Grieb 1970; Bellrose 1976).

Two major fall staging areas occurred in the Prairie provinces: (1) the Peace River country of northern Alberta, and (2) southwestern Saskatchewan and southeastern Alberta. There were also two broad wintering areas for Canada Geese from the ISR. Most geese (>80% of the band recoveries, >90% of the collar observations) wintered within the traditional wintering range of the SGPP in Colorado, northern Texas, and neighbouring parts of Nebraska, Oklahoma, and New Mexico (Grieb 1970). In addition, a small but significant percentage of the geese (15% based on band recoveries, 5% based on collar observations) wintered in the Pacific Flyway, especially in Nevada, California, and Idaho.

With the exception of a few outlying observations, the remaining band recoveries and collar sightings were scattered between the main staging and wintering areas. This latter group of observations comprised <10% of the band recoveries for 1975–79 and 1990–94 and <5% of the collar sightings, and likely included both migrating and wintering geese.

Table 5
Estimated densities and numbers of Canada Geese in survey strata on Victoria Island, June 1992–94 (VCF is the visibility correction factor)

Stratum	Year	No. of transects	Area (km^2)	Density ± SE ($pairs/km^2$)	No. of pairs ± SE
Tassijuak River (TR)	1993	12	5 508	1.48 ± 0.14	8 169 ± 780
	Adjusted by VCF		5 508	2.22 ± 0.21	12 253 ± 1 169
Wollaston Peninsula (WP)	1993	6	16 596	0.66 ± 0.04	10 905 ± 663
	Adjusted by VCF		16 596	0.99 ± 0.06	16 358 ± 994
Quunnguq Lake (QL)	1992	7	3 971	0.23 ± 0.10	923 ± 392
	1993	7	3 971	0.95 ± 0.18	3 769 ± 722
	1994	7	3 971	0.66 ± 0.06	2 635 ± 248
	Average (no VCF)[a]		3 971	0.62 ± 0.07	2 442 ± 286
	Average (adjusted by VCF)[a]		3 971	0.92 ± 0.11	3 664 ± 429
Kagloryuak River (KA)	1992	8	4 573	1.53 ± 0.25	7 014 ± 1 131
	1993	9	4 573	1.51 ± 0.31	6 913 ± 1 433
	1994	9	4 573	1.87 ± 0.13	8 558 ± 596
	Average (no VCF)[a]		4 573	1.64 ± 0.14	7 495 ± 640
	Average (adjusted by VCF)[a]		4 573	2.46 ± 0.21	11 242 ± 960
Diamond Jenness (DJ)	1992	24	15 866	0.58 ± 0.08	9 224 ± 1 278
	1993	16	15 866	0.19 ± 0.06	3 086 ± 1 008
	1994	21	15 866	0.45 ± 0.09	7 217 ± 1 417
	Average (no VCF)[a]		15 866	0.41 ± 0.05	6 509 ± 719
	Average (adjusted by VCF)[a]		15 866	0.62 ± 0.07	9 764 ± 1 079
Tahiryuak Lake (TL)	1992	8	2 298	0.38 ± 0.11	876 ± 258
	1993	9	2 298	0.30 ± 0.06	678 ± 128
	1994	9	2 298	0.48 ± 0.09	1 106 ± 205
	Average (no VCF)[a]		2 298	0.39 ± 0.05	887 ± 118
	Average (adjusted by VCF)[a]		2 298	0.58 ± 0.08	1 330 ± 177
Minto Bay to Wynniatt Bay (MW)	1992	16	39 676	0.07 ± 0.03	2 875 ± 1 323
	1993	6	39 676	0.01 ± 0.01	587 ± 592
	1994	9	39 676	0.07 ± 0.03	2 917 ± 1 242
	Average (no VCF)[a]		39 676	0.05 ± 0.02	2 126 ± 636
	Average (adjusted by VCF)[a]		39 676	0.08 ± 0.02	3 190 ± 955
Prince Albert Peninsula (PA)	1992	29	16 365	0.13 ± 0.04	2 164 ± 644
	1993	26	16 365	0.09 ± 0.03	1 432 ± 455
	1994	29	16 365	0.20 ± 0.05	3 243 ± 788
	Average (no VCF)[a]		16 365	0.14 ± 0.02	2 280 ± 371
	Average (adjusted by VCF)[a]		16 365	0.21 ± 0.03	3 420 ± 557
All Victoria Island strata (adjusted by VCF)			104 854	0.58 ± 0.02	61 220 ± 2 425

[a] Average density applied to largest stratum surveyed.

Table 6
Estimated densities and numbers of breeding pairs of Canada Geese in survey strata on Victoria Island, June 1992–94 (VCF is the visibility correction factor)

Stratum	Year	No. of transects	Area (km^2)	Density ± SE ($pairs/km^2$)	No. of pairs ± SE
Tassijuak River (TR)	1993	12	5 508	0.62 ± 0.06	3 412 ± 307
	Adjusted by VCF		5 508	0.93 ± 0.09	5 118 ± 461
Wollaston Peninsula (WP)	1993	6	16 596	0.31 ± 0.03	5 202 ± 439
	Adjusted by VCF		16 596	0.47 ± 0.05	7 803 ± 659
Quunnguq Lake (QL)	1992	7	3 971	0.07 ± 0.03	289 ± 111
	1993	7	3 971	0.35 ± 0.08	1 409 ± 302
	1994	7	3 971	0.25 ± 0.02	1 011 ± 85
	Average (no VCF)[a]		3 971	0.22 ± 0.03	903 ± 111
	Average (adjusted by VCF)[a]		3 971	0.34 ± 0.04	1 355 ± 166
Kagloryuak River (KA)	1992	8	4 573	0.56 ± 0.06	2 576 ± 297
	1993	9	4 573	0.61 ± 0.10	2 775 ± 453
	1994	9	4 573	0.70 ± 0.05	3 190 ± 247
	Average (no VCF)[a]		4 573	0.62 ± 0.04	2 847 ± 198
	Average (adjusted by VCF)[a]		4 573	0.94 ± 0.06	4 271 ± 298
Diamond Jenness (DJ)	1992	24	15866	0.22 ± 0.03	3 544 ± 478
	1993	16	15 866	0.08 ± 0.03	1 280 ± 432
	1994	21	15 866	0.17 ± 0.04	2 685 ± 561
	Average (no VCF)[a]		15 866	0.16 ± 0.02	2 503 ± 285
	Average (adjusted by VCF)[a]		15 866	0.24 ± 0.03	3 755 ± 427
Tahiryuak Lake (TL)	1992	8	2 298	0.16 ± 0.05	367 ± 110
	1993	9	2 298	0.15 ± 0.03	339 ± 64
	1994	9	2 298	0.15 ± 0.04	339 ± 81
	Average (no VCF)[a]		2 298	0.15 ± 0.02	348 ± 50
	Average (adjusted by VCF)[a]		2 298	0.23 ± 0.04	523 ± 75
Minto Bay to Wynniatt Bay (MW)	1992	16	39 676	0.04 ± 0.02	1 538 ± 662
	1993	6	39 676	0.01 ± 0.01	293 ± 296
	1994	9	39 676	0.03 ± 0.01	1 042 ± 339
	Average (no VCF)[a]		39 676	0.03 ± 0.01	958 ± 267
	Average (adjusted by VCF)[a]		39 676	0.04 ± 0.01	1 437 ± 400
Prince Albert Peninsula (PA)	1992	29	16 365	0.05 ± 0.02	849 ± 255
	1993	26	16 365	0.04 ± 0.01	716 ± 227
	1994	29	16 365	0.08 ± 0.02	1 72 ± 350
	Average (no VCF)[a]		16 365	0.06 ± 0.01	979 ± 163
	Average (adjusted by VCF)[a]		16 365	0.09 ± 0.02	1 469 ± 244
All Victoria Island strata (adjusted by VCF)			104 854	0.24 ± 0.01	25 731 ±1 082

[a] Average density applied to largest stratum surveyed.

Table 7
Estimated densities and numbers of Canada Geese in survey strata on Banks Island, June 1992–93 (VCF is the visibility correction factor)

Stratum	Year	No. of transects	Area (km^2)	Density ± SE ($pairs/km^2$)	No. of pairs ± SE
East Coast (EC)	1993	14	7 000	0.06 ± 0.06	450 ± 391
	Adjusted by VCF		7 000	0.09 ± 0.09	675 ± 587
West Coast (WC)	1992	50	12 436	0.00 ± 0.00	0 ± 0
	1993	50	12 436	0.00 ± 0.00	0 ± 0
	Average (no VCF)		12 436	0.00 ± 0.00	0 ± 0
	Average (adjusted by VCF)		12 436	0.00 ± 0.00	0 ± 0
Inland (IN)	1992	16	8 978	0.00 ± 0.00	0 ± 0
	1993	16	8 978	0.00 ± 0.00	0 ± 0
	Average (no VCF)		8 978	0.00 ± 0.00	0 ± 0
	Average (adjusted by VCF)		8 978	0.00 ± 0.00	0 ± 0
All Banks Island strata (adjusted by VCF)			28 414	0.02 ± 0.02	675 ± 587

Table 8
Estimated densities and numbers of breeding pairs of Canada Geese in survey strata on Banks Island, June 1992–93 (VCF is the visibility correction factor)

Stratum	Year	No. of transects	Area (km^2)	Density ± SE ($pairs/km^2$)	No. of pairs ± SE
East Coast (EC)	1993	14	7 000	0.01 ± 0.01	75 ± 53
	Adjusted by VCF		7 000	0.02 ± 0.01	113 ± 80
West Coast (WC)	1992	50	12 436	0.00 ± 0.00	0 ± 0
	1993	50	12 436	0.00 ± 0.00	0 ± 0
	Average (no VCF)[a]		12 436	0.00 ± 0.00	0 ± 0
	Average (adjusted by VCF)[a]		12 436	0.00 ± 0.00	0 ± 0
Inland (IN)	1992	16	8 978	0.00 ± 0.00	0 ± 0
	1993	16	8 978	0.00 ± 0.00	0 ± 0
	Average (no VCF)[a]		8 978	0.00 ± 0.00	0 ± 0
	Average (adjusted by VCF)[a]		8 978	0.00 ± 0.00	0 ± 0
All Banks Island strata (adjusted by VCF)			28 414	0.004 ± 0.03	113 ± 80

[a] Average density applied to largest stratum surveyed.

3.2.1 Distribution of Canada Geese from the mainland

Sixty-five percent of the fall (September–October) recoveries from geese banded on the mainland from 1975 to 1979 were in northern Alberta, 31% were in southeastern Alberta or southwestern Saskatchewan, and the remaining 4% were widely scattered over a broad geographic area (Fig. 5A). By 1990–94, the distribution of fall band recoveries had shifted, to 82% at the northern staging site and 18% at the southern site (Fig. 5B). This northward shift in the distribution of band recoveries in fall was significant (χ^2 = 6.30, P = 0.01).

Dates of band recoveries indicated that the use of the more southern fall staging area by mainland geese in recent years was mainly in late October (9 of 15 recoveries occurred after 20 October). In contrast, 80% of the band recoveries (n = 104) during the late 1970s and early 1980s in the staging area in southeastern Alberta and southwestern Saskatchewan occurred before 20 October.

Of 105 band recoveries from the southern staging area for the 1975–79 banding period, 85% were in Alberta and only 15% were in Saskatchewan. Although the sample size was small (n = 15), the proportion of the band recoveries from the southern staging area occurring in each province (87% were in Alberta, 13% in Saskatchewan) did not seem to have changed by 1990–94.

Collar resightings offered a somewhat different picture of fall goose distribution in 1991–94. Ninety-six percent of the resightings were in northern Alberta, and only 3% were in the staging area in southern Alberta and southwestern Saskatchewan (Fig. 6A). The collar resightings also provided a somewhat different impression of the proportion of the geese in the southern staging area that were in Alberta (only 12 of the 40 sightings) and Saskatchewan (28). Much of the indicated difference in distribution of geese based on collar resightings and band recoveries undoubtedly reflected geographic differences in observation effort and distribution of hunters.

Geese staging in northern Alberta were infrequently sighted in the southern staging area. Over the five years of observations, only 17 collared individuals were seen in both staging areas, and only five of those observations were in the same year.

During December and January, most band recoveries for mainland Canada Geese (84% for 1975–79 bandings, 75% for 1990–94) were in the traditional wintering area of the SGPP in eastern Colorado, northern Texas, and neighbouring states (Fig. 5C and 5D). Approximately 14% of the band recoveries in 1975–79 and 23% of those for 1990–94 were in the Pacific Flyway states. Thus, there had been a significant westward shift in band recoveries between the two periods (Mardia's test statistic = 39.36, P < 0.01).

For the most recent period, a much greater percentage of collar observations (>90%) than band recoveries (75%) was from the traditional part of the SGPP range (Fig. 6B), presumably reflecting variation in hunting and collar-observation effort among regions.

Within the traditional wintering area of the SGPP, there appeared to be a northward shift between the late 1970s and early 1990s (Figs. 7 and 8). Sixty-seven percent of the recoveries of geese banded on the mainland in 1975–79 were from Colorado, compared with 82% of the recoveries and 79% of the collar observations from the 1990–94 banding efforts. Twenty-seven percent of the recoveries occurred in Texas and New Mexico in the late 1970s, compared with only 6% of the recoveries (7 of 108 geese) and 16% of the collar observations in the 1990s. This northward shift was significant (Mardia's test statistic = 40.70, P < 0.01).

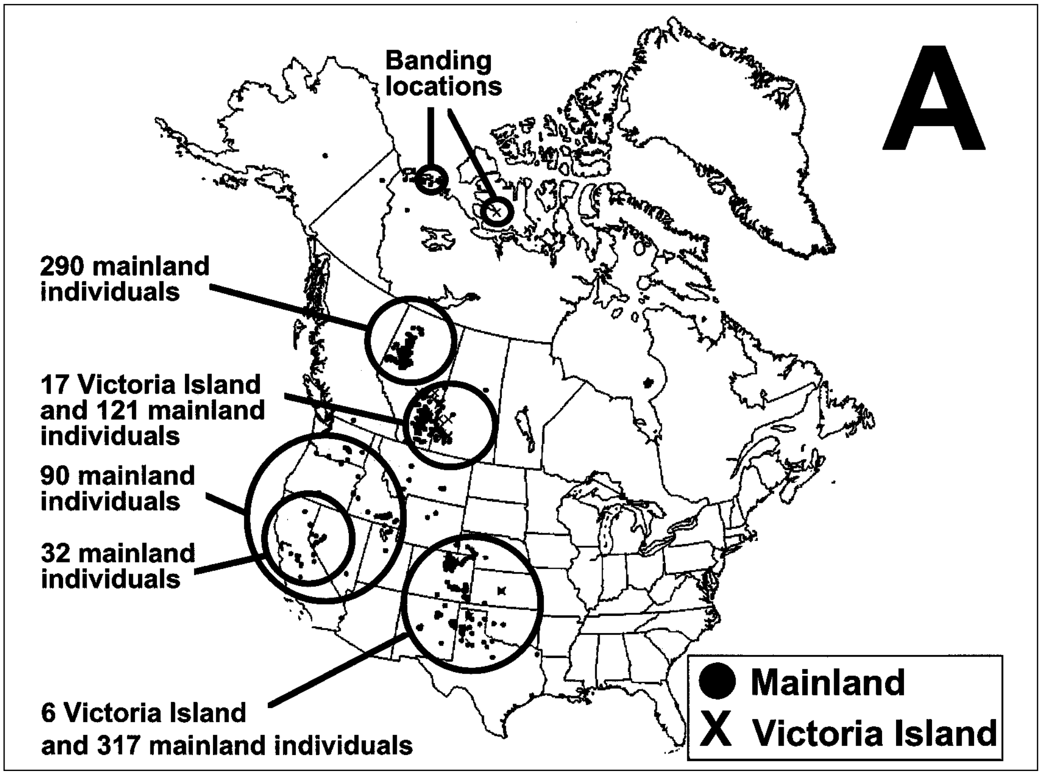
Sightings of individual geese on both staging areas and wintering grounds demonstrated the strong connection between the northwestern Alberta staging area and the traditional wintering grounds of the SGPP (Fig. 9). A significant number of the geese staging in northwestern Alberta also were sighted in the Pacific Flyway.

3.2.2 Fall–winter distribution of Victoria Island geese

Both collar observations and the relatively limited number of band recoveries indicated that the Canada Geese marked in the Kagloryuak River area of Victoria Island staged almost entirely in southern Alberta and southwestern Saskatchewan. Within this staging area, the small number of band recoveries was divided nearly equally between the two provinces (nine in Alberta, eight in Saskatchewan). In contrast, only 36% of the collar observations were in Alberta, compared with 64% in Saskatchewan.

In winter, all the band recoveries (n = 6) and most of the collar resightings (n = 487) of the Victoria Island geese were in the traditional wintering grounds of the SGPP. The

Figure 4
Major areas used during fall and winter by Canada Geese banded in the Inuvialuit Settlement Region. A indicates band recoveries from geese banded during 1975–79 and 1990–94, and B indicates sightings of geese collared in 1991–94.



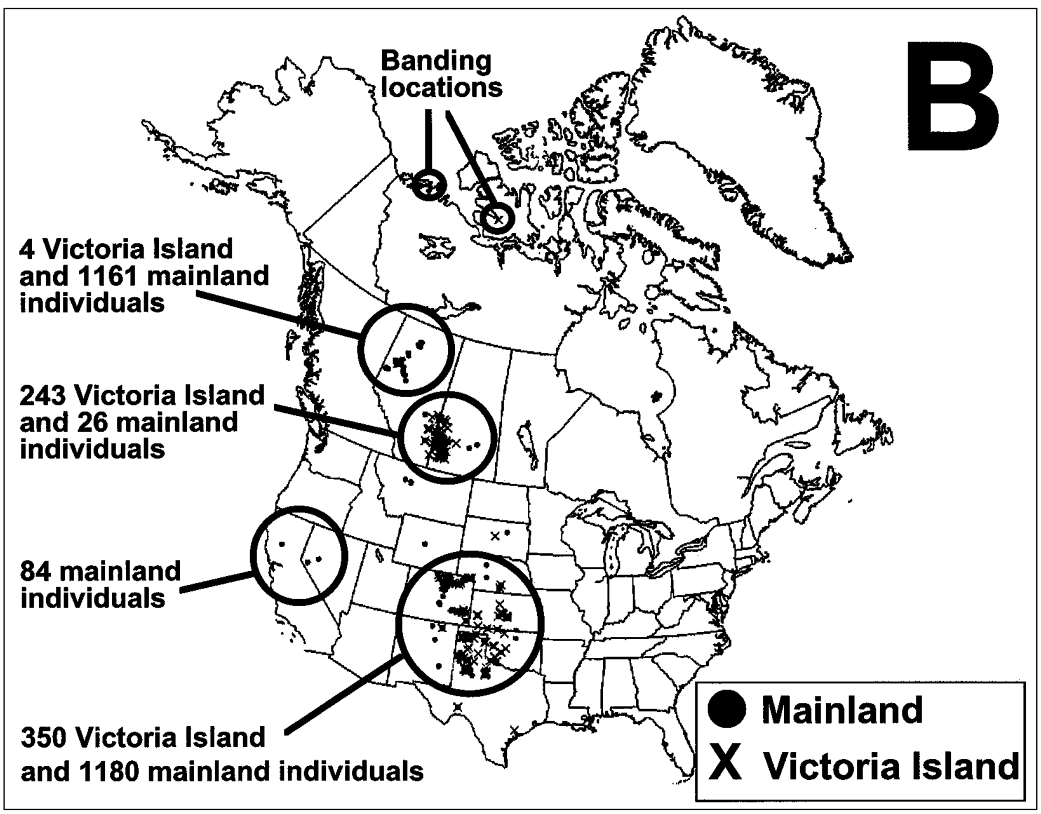
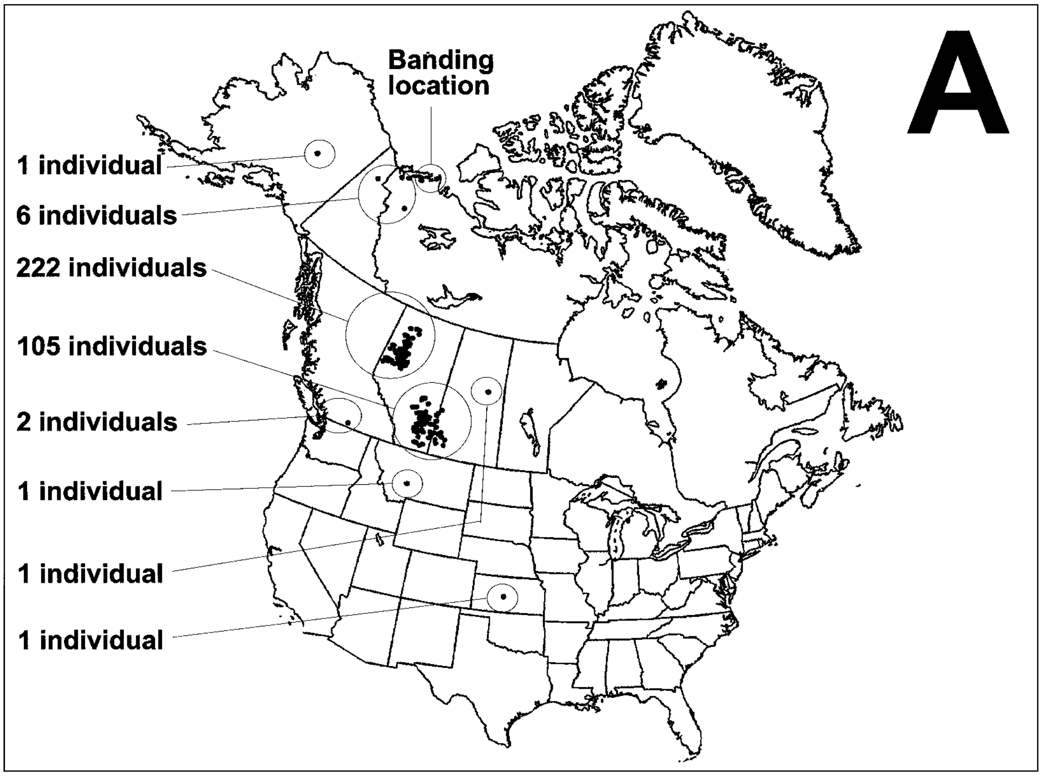


Figure 5
The locations of band recoveries during September and October from hunter-killed Canada Geese that were banded in the Inuvialuit Settlement Region in 1975–79 (A) and 1990–94 (B), and during December and January from geese that were banded in 1975–79 (C) and 1990–94 (D). No Canada Geese were banded on Victoria Island during 1975–79.



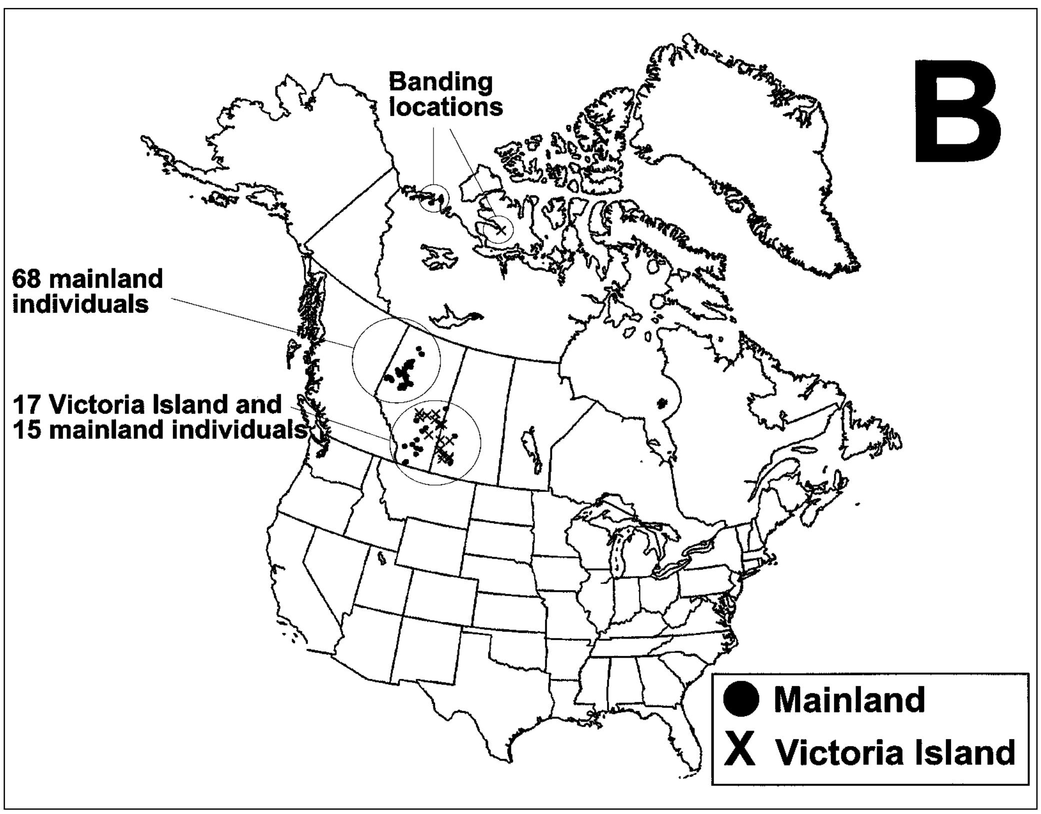
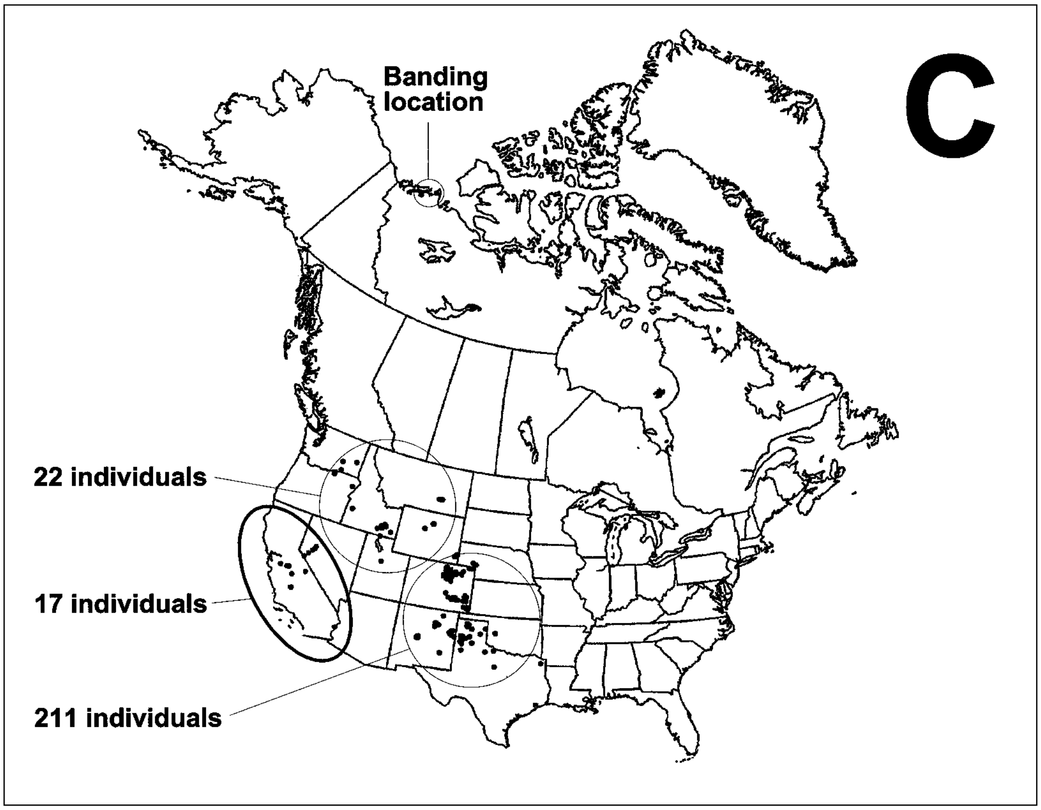


Figure 5 (*cont'd*)
The locations of band recoveries during September and October from hunter-killed Canada Geese that were banded in the Inuvialuit Settlement Region in 1975–79 (A) and 1990–94 (B), and during December and January from geese that were banded in 1975–79 (C) and 1990–94 (D). No Canada Geese were banded on Victoria Island during 1975–79.



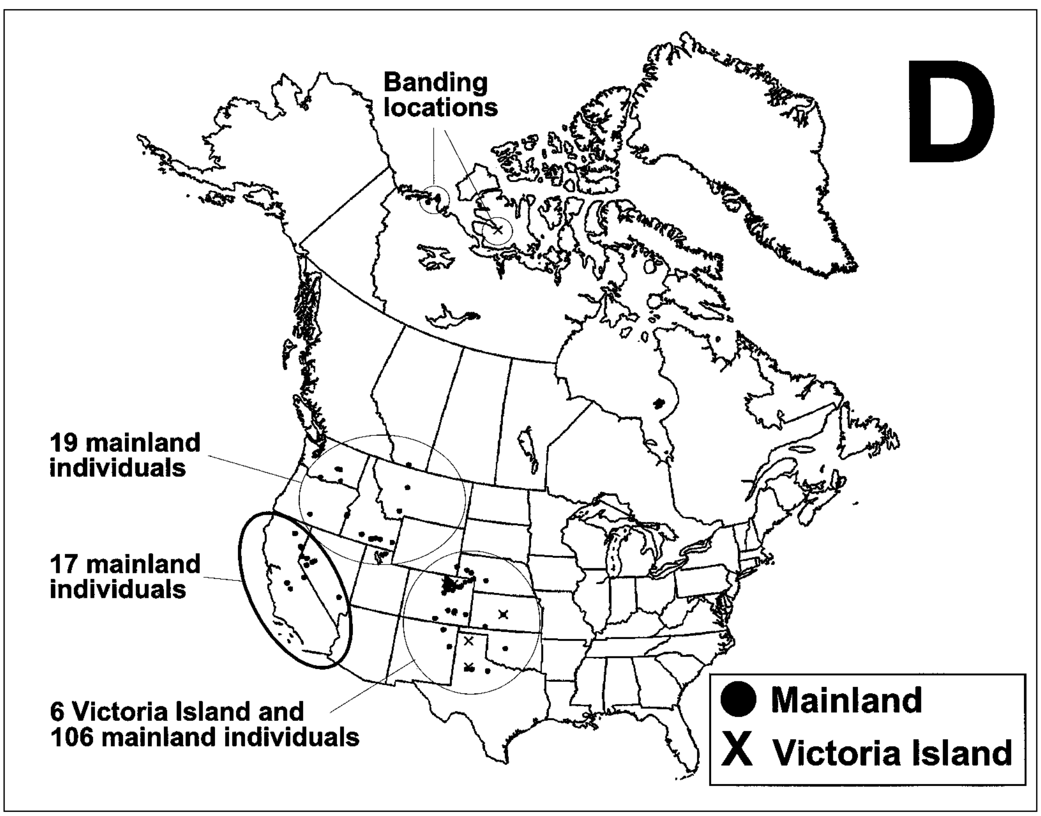
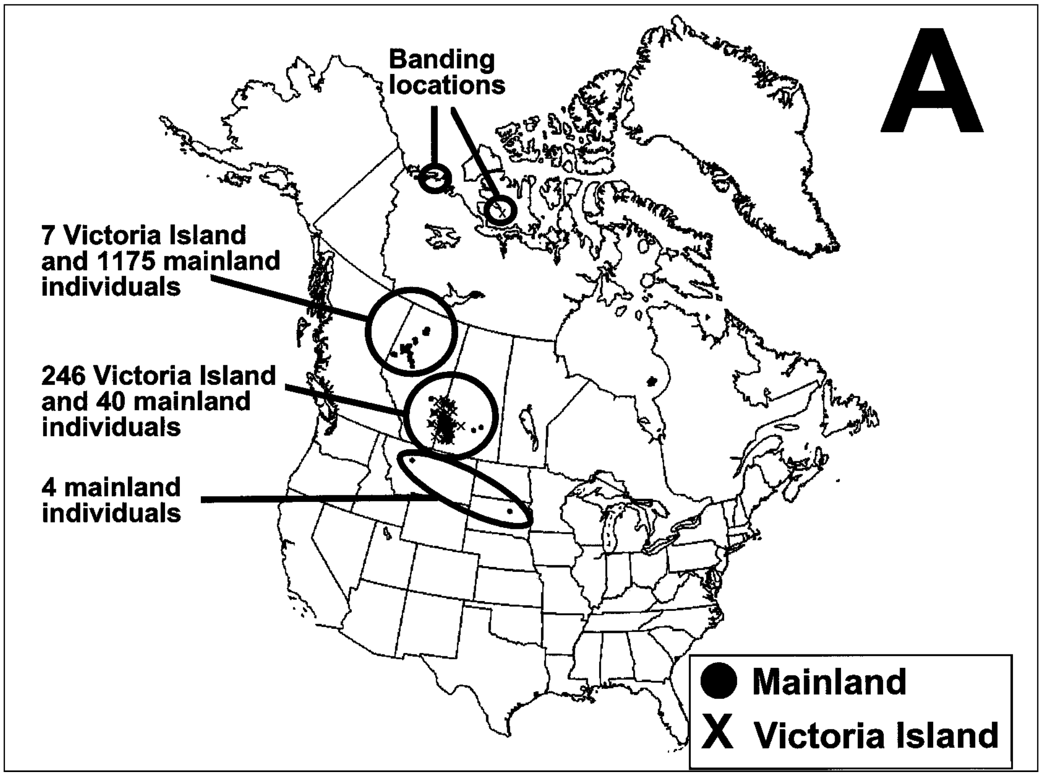


Figure 6
The locations of sightings of collared Canada Geese in September and October (A) and December and January (B) for geese collared in the Inuvialuit Settlement Region during 1991–94



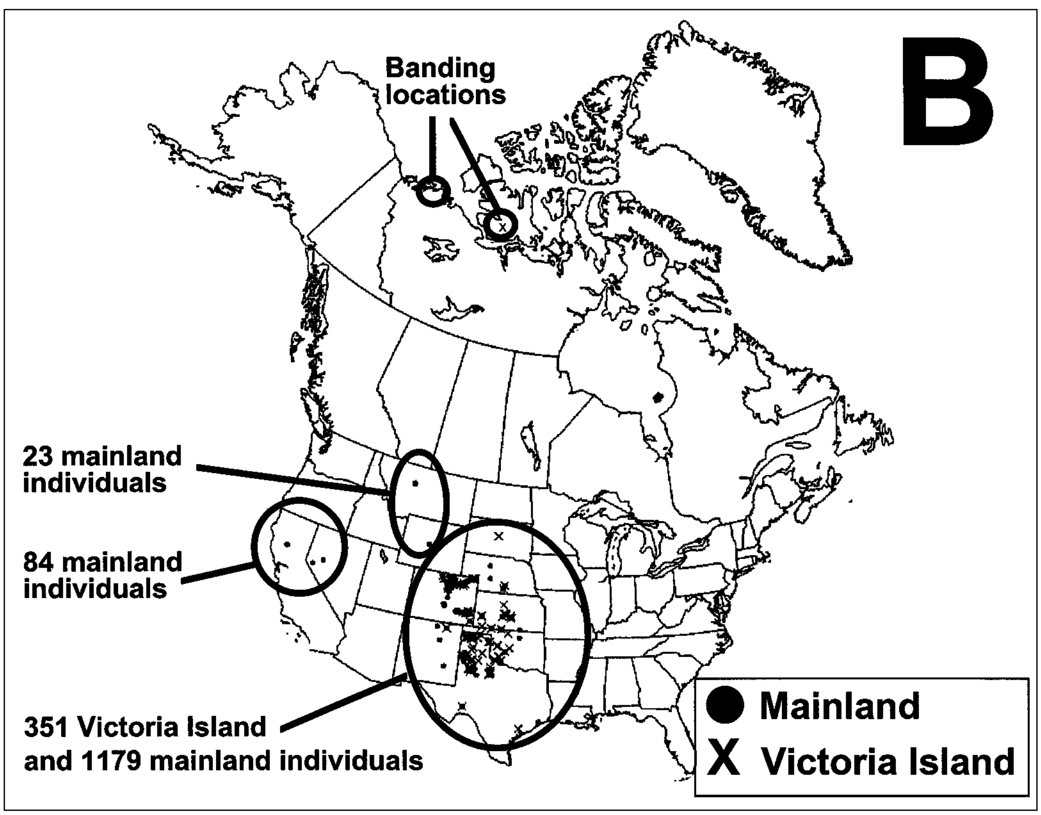


Figure 7
The locations of December–January recoveries in the Central Flyway of hunter-killed Canada Geese that were banded in the Inuvialuit Settlement Region

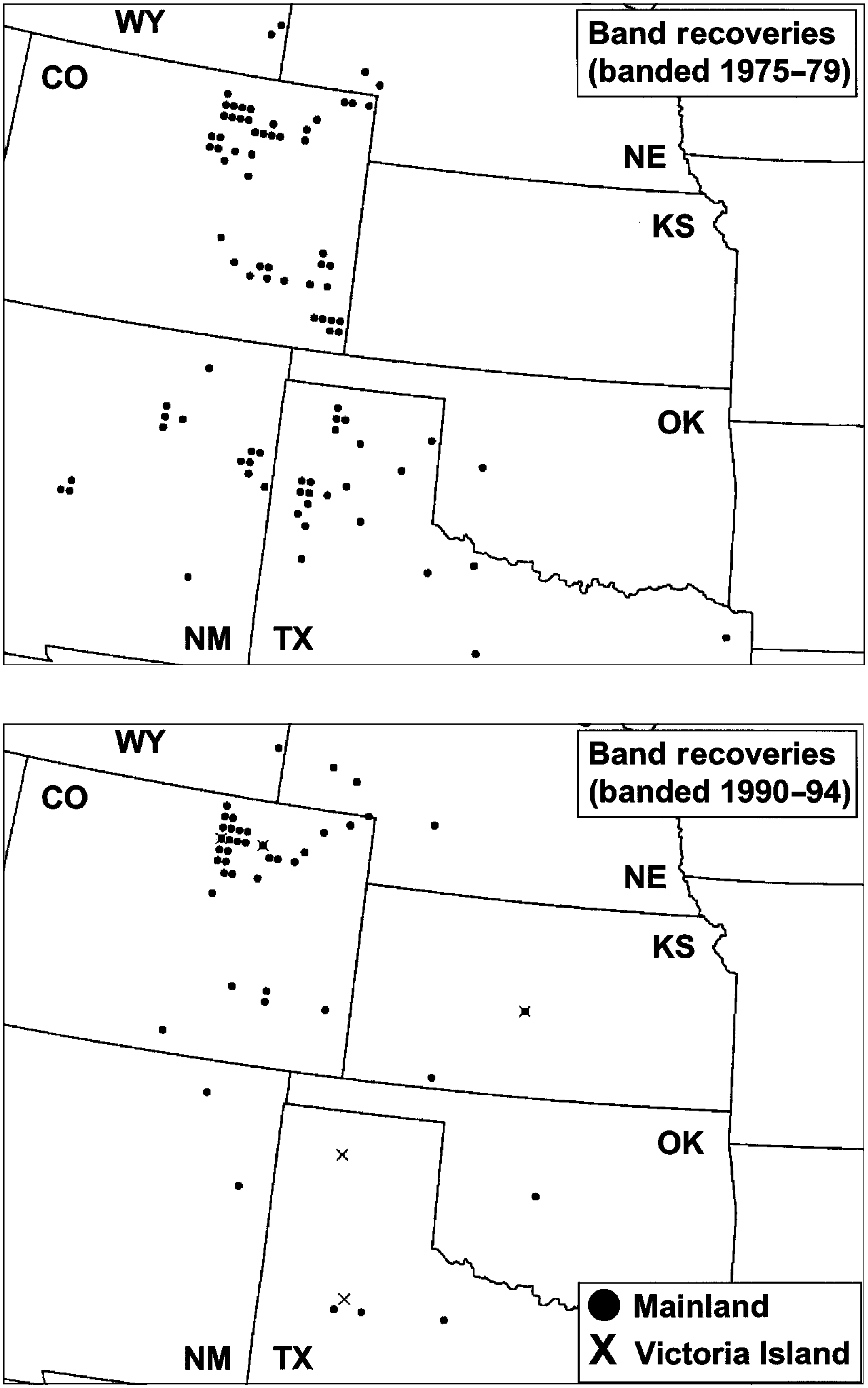
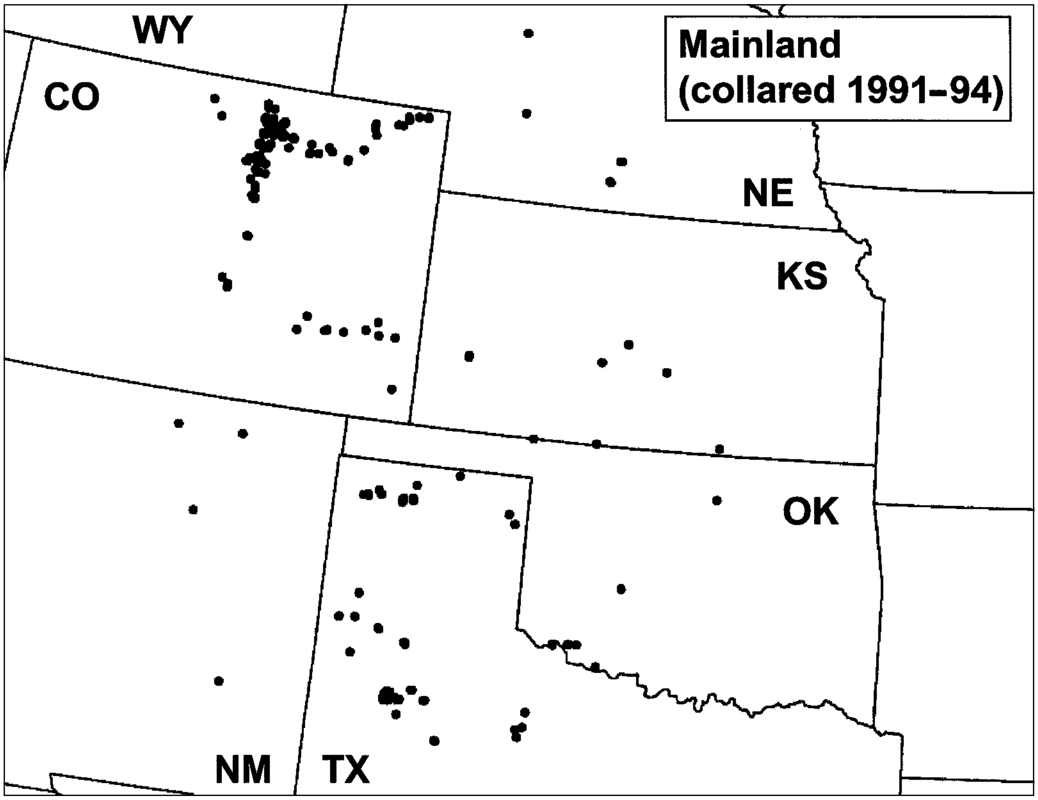


Figure 8
The locations of December–January collar observations in the Central Flyway of Canada Geese that were collared in the Inuvialuit Settlement Region



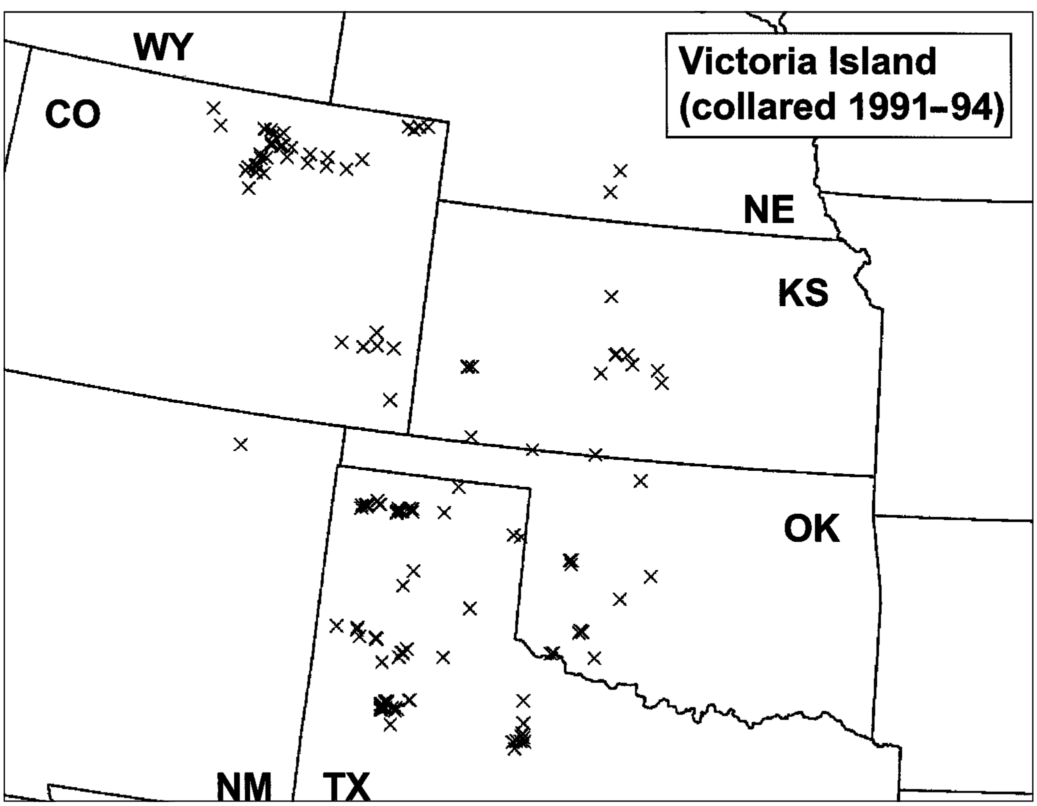
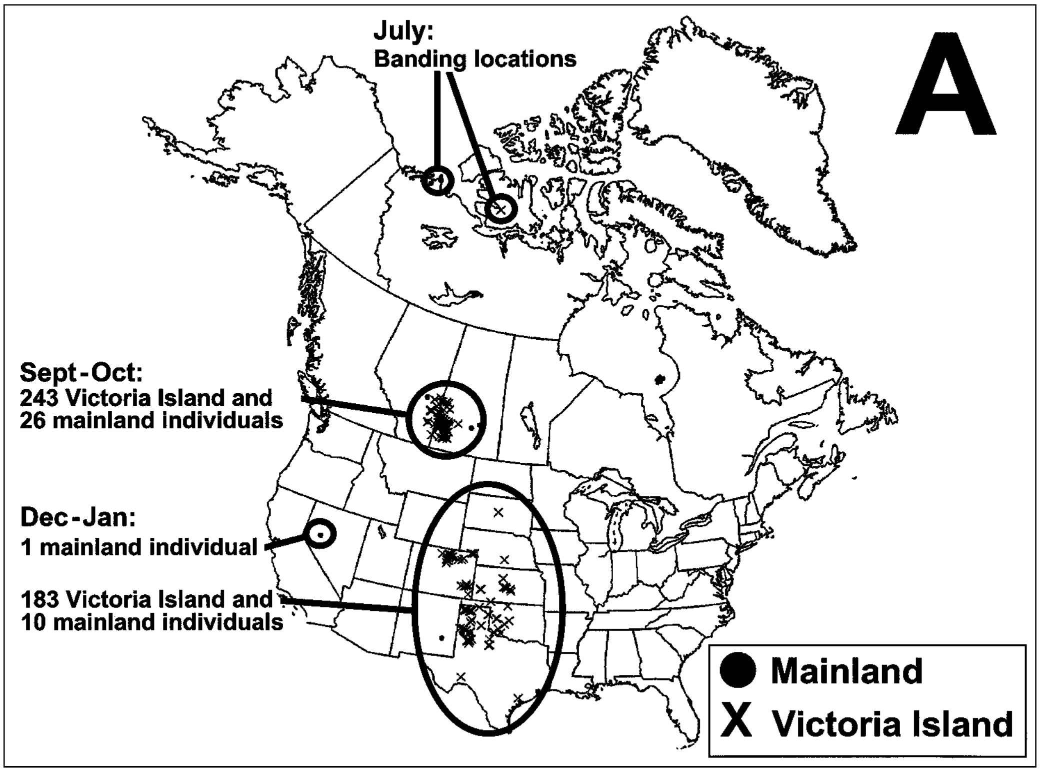


Figure 9
Migration connections between fall staging areas and wintering grounds for Canada Geese collared in the Inuvialuit Settlement Region in 1991–94 and sighted during both the September–October and December–January periods. The December–January locations of individuals that were seen only in southeastern Alberta/southwestern Saskatchewan during September–October (A) and only in northern Alberta (B) are indicated.



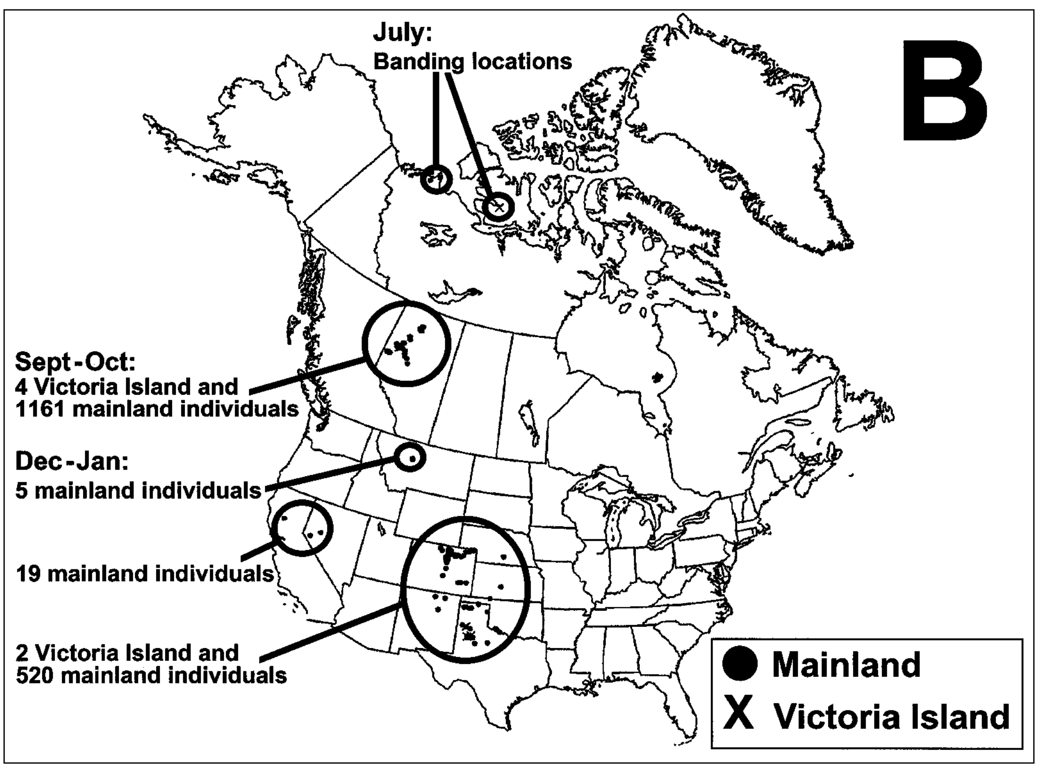
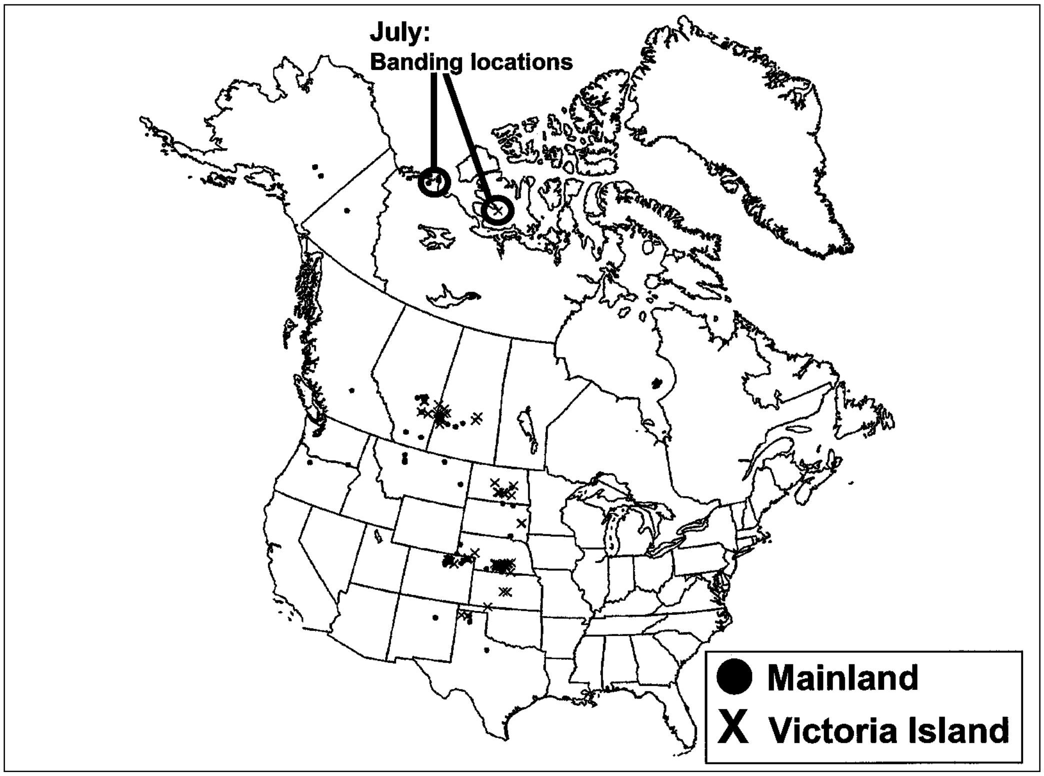


Figure 10
The locations of sightings during March, April, and May of Canada Geese collared in the Inuvialuit Settlement Region in 1991–94



"panhandle" of northern Texas (55%), Colorado (22%), and Nebraska (13%) accounted for 90% of the collar resightings.

The strong connection between the staging area in the southern Prairie provinces and the traditional SGPP wintering grounds is clearly demonstrated by the large number of geese sighted in both areas (Fig. 9).

3.2.3 Spring and summer distribution

Spring migration paths were determined from March–May observations of collared Canada Geese. In general, spring migration took many geese along a path somewhat to the east of their southward migration route (Fig. 10), with mainland birds following a route slightly west of that used by Victoria Island birds. An important staging area for both mainland and western Victoria Island geese was in south-central Nebraska.

Compared with geese marked on the mainland, Victoria Island birds seemed to be disproportionately well represented in the samples of spring observations. Given the larger numbers of birds marked on the mainland, we would expect to have a much larger number of these birds in the sample. We infer from this observation that many of the mainland birds were migrating west of the observation sites.

3.2.4 Seasonal comparisons of the distribution of mainland and Victoria Island geese

Significant spatial segregation between mainland and Victoria Island birds existed during many periods (Table 9). Where differences occurred, mainland geese were usually west or northwest of Victoria Island geese.

3.3 Taxonomic status

Canada Geese from Victoria Island were, on average, smaller than geese from the mainland (Fig. 11, Table 10). The average culmen length was significantly shorter for geese from Victoria Island than for geese from the mainland (males: $t = 23.8$, $P < 0.001$, females: $t = 21.8$, $P < 0.001$), as was average tarsus length (males: $t = 8.7$, $P < 0.001$, females: $t = 5.2$, $P < 0.001$). Two measurements taken only for Victoria Island geese were "total tarsus length" (see Dzubin and Cooch [1992] for definition) and skull length. The average "total tarsus length" for Victoria Island Canada Geese was 88.0 ± 0.5 mm for males and 83.4 ± 0.4 mm for females, and average skull length was 95.9 ± 0.3 mm for males and 91.7 ± 0.29 mm for females.

Comparisons with published information (Table 10) suggest that geese captured on the mainland were similar to *B. c. parvipes* in terms of culmen and tarsus length, whereas those captured on Victoria Island corresponded to *B. c. hutchinsii*.

3.4 Survival, recovery, and harvest rates

3.4.1 Survival, recovery, and harvest rates (1975–79)

A total of 4531 adult Canada Geese was banded on the mainland during 1975–79. Hunters recovered and returned 863 of these bands to the bird banding office by the end of the 1991–92 hunting season.

All three survival/recovery models for adult birds fit the data adequately ($P > 0.10$ in all instances). Model M2 (variable recovery rates, constant annual survival rates) is the most parsimonious model. A constant survival rate of 0.782

Table 9
Comparisons of the geographic distributions of Canada Geese banded on the mainland and Victoria Island in the ISR, 1990–94

	Average location of recoveries or sightings of birds						Mardia's test results	
	Mainland			Victoria Island				
Period/location	lat. °	long. °	(n)	lat. °	long. °	(n)	Test statistic	P
Band recoveries								
Fall staging	55.35	116.28	(83)	52.17	110.19	(17)	35.77	<0.01
Fall staging (southern area only)	50.98	112.12	(15)	52.17	110.19	(17)	16.49	<0.01
Wintering grounds	40.29	107.24	(142)	37.39	102.04	(6)	4.59	0.10
Wintering grounds (Central Flyway only)	39.80	104.09	(106)	37.39	102.04	(6)	4.93	0.08
Collar sightings								
Fall staging	56.01	117.52	(1201)	51.42	109.46	(250)	591.15	<0.01
Fall staging (southern area only)	51.38	109.22	(40)	51.31	109.29	(246)	5.44	0.07
Wintering grounds	39.51	105.03	(1263)	36.51	101.57	(351)	504.95	<0.01
Wintering grounds (Central Flyway only)	39.42	104.06	(1179)	36.51	101.57	(351)	498.50	<0.01
Spring migration (March)	40.62	103.80	(397)	40.52	99.61	(198)	251.69	<0.01
Spring migration (April–May)	53.95	114.45	(51)	51.94	109.36	(67)	10.89	<0.01

± SE 0.020 was calculated for this population for the late 1970s.

Recovery rates averaged 0.0375 ± 0.0020 during this period. If, as reported by Martinson and McCann (1966), Conroy and Blandin (1984), and others, only 35–40% of the bands from hunter-killed birds are actually reported, an average of 9–11% of the adult population was being taken by recreational hunters each year in the late 1970s and 1980s. Harvest rates calculated in this manner do not include "crippling loss" or "unretrieved kill," which would increase the overall harvest rate by at least 25% (see Nieman et al. 1987). Therefore, 12–14% of the banded geese were probably killed by recreational hunters each year in the late 1970s.

3.4.2 *Survival, recovery, and harvest rates (1990–94)*

A total of 3617 Canada Geese was collared on the mainland between 1991 and 1994 (367 in 1991, 1127 in 1992, 1067 in 1993, and 1056 in 1994). In addition, 559 geese were leg-banded only in 1990, and 14 others were leg-banded only during 1991–94.

We obtained 326 recoveries of the 4541 collared and/or banded geese, but the number of years of band recoveries may have been too few to provide good estimates of survival rates. Although none of the band-recovery models adequately fit the data ($P < 0.05$ in all instances), all three average estimates of survival were similar (0.617 ± 0.043 for M1, 0.619 ± 0.039 for M2, and 0.637 ± 0.034 for M3).

The collar-resighting data for adult females adequately fit the Jolly–Seber model ($P = 0.18$). Minimum survival rates (i.e., unadjusted for collar loss) averaged 0.643, with a large standard error of 0.121. Adjusting for average collar-retention rate increased the survival estimate to 0.778 and the standard error to 0.152. The survival estimate was considerably higher than that obtained from the band-recovery analysis, although the difference was not statistically significant.

Recovery rates for 1990–95 were very similar for all three models (0.034 ± 0.003, 0.033 ± 0.002, and 0.034 ± 0.002 for M1, M2, and M3, respectively). Based on the assumption of 35–40% band-reporting rates and 25% crippling loss, harvest rates were estimated to be 11–13%. If collaring of geese raised the rate at which bands were reported (Samuel et al. 1990), then the actual harvest rates may have been somewhat lower than 11–13%.

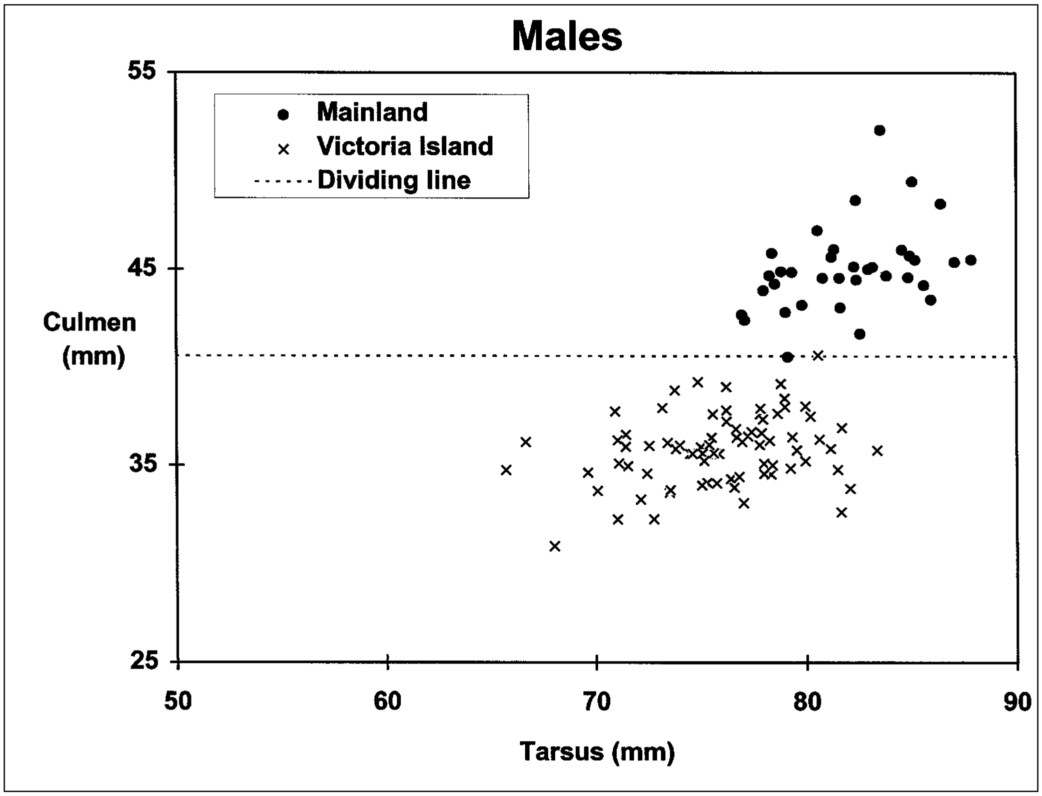
4. Discussion

4.1 Distribution and abundance during spring and summer

Our aerial counts indicated there were >84 000 SGPP Canada Geese in or near the surveyed part of the Inuvialuit Settlement Region from 1989 to 1994. However, the surveys did not cover all the breeding range of Canada Geese in the ISR, and a 101 000-km^2 area of expected low population densities near the south boundary of the ISR mainland was not covered. Some of this area is dry uplands and is not suitable habitat for geese, but the rest of the area likely supported population densities similar to those of nearby surveyed areas. Based on our data for nearby parts of the mainland (population densities of 0.25 geese/km^2 in relatively "good" habitat), other estimates of population densities south of the tree line (0.09 geese/km^2 over an extensive area that included both good and poor habitat, USFWS, unpubl. data)[4] and our understanding of the physiography and general habitat in the region, we suspect there may have been an additional 5000 – 10 000 Canada Geese present in the unsurveyed portions of the ISR. If so, there would have been 90 000 – 95 000 Canada Geese in or near the Inuvialuit Settlement Region during mid June of recent years.

[4] Average densities during 1985–95 for Canada Geese in a 127 500-km^2 region that stretched from Liverpool Bay to the northwest corner of Great Bear Lake. Corrected for visibility bias (VCF for fixed-wing surveys of 2.5).

Figure 11
Culmen and tarsus measurements of Canada Geese captured on the mainland and western Victoria Island in the Inuvialuit Settlement Region



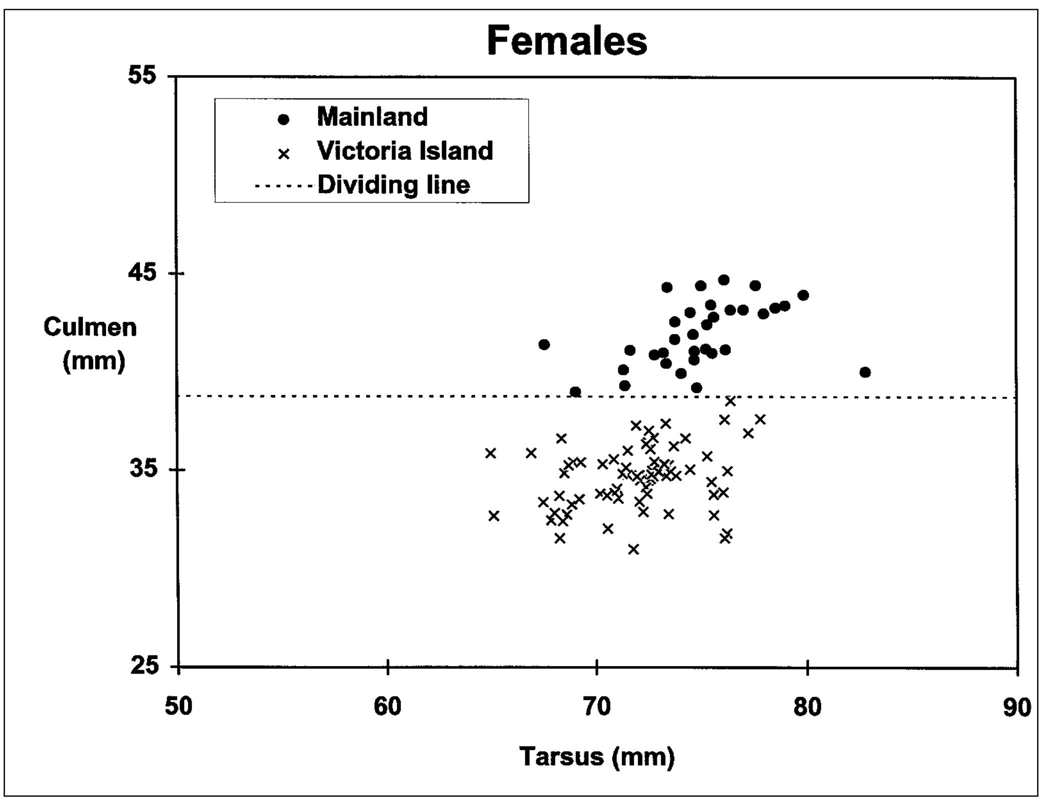


Table 10
Culmen length and tarsus length from Canada Geese banded in the Inuvialuit Settlement Region and from published literature

Average culmen length ± SE, mm		Average tarsus length ± SE, mm				
Males (n)	Females (n)	Males (n)	Females (n)	Banding location	Subspecies	Reference
45.0 ± 0.4 (35)	41.9 ± 0.3 (33)	82.1 ± 0.5 (35)	74.9 ± 0.5 (33)	ISR — mainland	*parvipes*?	Our data 1994
35.8 ± 0.2 (78)	34.7 ± 0.2 (76)	75.9 ± 0.4 (79)	71.9 ± 0.3 (76)	ISR — Victoria Island	*hutchinsii*?	Our data 1993
38.7 ± 0.6 (22)	37.8 ± 0.6 (24)			ISR — mainland and Banks Island		R. Bromley (unpubl.)
42.4 ± 0.2 (109)	41.1 ± 0.2 (87)	83.7 ± 0.3 (109)	78.1 ± 0.4 (87)	Northern Alberta on fall staging area	*parvipes*	B. Turner (unpubl.)
44.2 ± 0.4 (184)	42.5 ± 0.3 (194)	81.8 ± 0.1 (184)	77.0 ± 0.3 (194)	Colorado on wintering ground	mostly *parvipes*	Grieb 1970
43.0 ± 2.6 (SD)	40.2 ± 2.1[a] (SD)	80.8 ± 3.3[a] (SD)	75.3 ± 3.3[a] (SD)	Cook Inlet, forested N.W.T. and Yukon, interior Alaska	*parvipes*	Johnson et al. 1979
42.6 (7)	40.8 (2)	81.7 (7)	77.5 (2)	Museum specimens	*parvipes*	Aldrich 1946
40.4 ± 0.2 (102)	38.5 ± 0.2 (90)	75.3 ± 0.4 (102)	70.3 ± 0.3 (90)	McConnell River (60°50'N)	*hutchinsii*	MacInnes 1966
37.4 ± 0.2 (127)	35.6 ± 0.2 (115)	74.2 ± 0.3 (127)	69.8 ± 0.3 (115)	Southhampton Island	*hutchinsii*	MacInnes 1966
33.7 (6)	31.6 (7)	70.3 (6)	67.4 (7)	Museum specimens	*hutchinsii*	Aldrich 1946

[a] Sample size not reported.

The most important area for nesting Canada Geese on the mainland of the study area was the Parry Peninsula; densities of breeding geese were much lower on most other parts of the mainland. Despite the relatively sparse distribution of Canada Geese on much of the mainland, the area is large, and the total number of geese present is significant.

Major moulting areas for geese on the mainland supported an average of 5000 geese at the time of our surveys, but as many as 12 000 were observed in 1991. Observations made during goose-banding operations suggested there were 15 000 or more Canada Geese in these areas during early July of each year (see also Alexander et al. 1988). The Harrowby Bay/Old Horton Channel area (probably >10 000 flightless geese) and the Smoke–Moose river delta (>2500 flightless geese) were the most important moulting areas for Canada Geese.

Geese were distributed at moderate to high densities throughout much of southwestern Victoria Island. The most important areas were the Kagloryuak River and the Tassijuak River strata. McLaren and Alliston (1981) flew aerial surveys in the Kagloryuak River valley in 1980 and noted a density of 1.2 Canada Geese/km^2, which is slightly lower than our uncorrected density of 1.6 geese/km^2 in this area.

Significant numbers of Canada Geese were found scattered at lower densities throughout a broad area north of Prince Albert Sound and the Kagloryuak River. Both Allen (1982) and McLaren and Alliston (1981) found few Canada Geese in this area in the early 1980s. Detailed interviews with Inuvialuit hunters from Holman on western Victoria Island also suggested that geese were uncommon there 20 years ago, but had increased greatly in numbers since (D. Kay, pers. commun.). This area lies beyond the range of the SGPP as expressed in the standard references on this population (Grieb 1970; Bellrose 1976). Apparently, a northward expansion of the geese nesting on Victoria Island has occurred in the past few decades.

Small numbers of Canada Geese were found on southeastern Banks Island during our surveys. We also recorded several observations of broods and moulting adults as well as one nest during other field work there (Cotter and Hines 1999). To our knowledge, these sightings represent the first records of breeding Canada Geese on Banks Island. Observations in 1996 of a breeding pair of geese and small numbers of moulting birds near the northern end of Banks Island (D. Henry, Parks Canada, pers. commun.) suggest that the population has spread farther northwards than documented in our surveys. Thus, we suspect that overall numbers on Banks Island are somewhat larger (perhaps >1000 birds?) than our surveys indicated.

4.2 Taxonomic status

The measurements of geese suggested there were at least two different races present in the banded samples (Fig. 11, Table 10). The birds captured on the mainland, at moulting areas near the Old Horton Channel, Mason River, Smoke–Moose deltas, and Anderson River, conformed in size to Lesser Canada Geese (*B. c. parvipes*), whereas those from Victoria Island were smaller and similar to Richardson's Canada Geese (*B. c. hutchinsii*) in terms of both bill and leg measurements. Geese shot on the mainland by Inuvialuit hunters during the spring hunt (Bromley 1996) also corresponded to the *B. c. hutchinsii* size range (Table 10). Most of these hunter-killed birds were taken near Paulatuk (R. Bromley, pers. commun.), so it seems possible that the numerous birds nesting on the nearby Parry Peninsula were of the *hutchinsii* type.

The origin of the *parvipes*-like birds moulting in large numbers in the vicinity of the Old Horton Channel, Mason River, and Smoke–Moose deltas was hypothesized to be to the south in the subarctic taiga of the Mackenzie River drainage (Sterling and Dzubin 1967). The small number of band recoveries from spring and summer (n = 11)[5] provides support for this viewpoint. However, there were also several observations of collared geese from the mainland of the ISR in the interior of the Yukon (n = 11) and eastern Alaska (n = 5), suggesting some connection with these areas also. It is uncertain whether the observations reflect movement of moulting birds from the Pacific Flyway to moulting areas farther east, a more westerly distribution of breeding SGPP geese than previously realized, or increased mixing of goose stocks from the Central and Pacific flyways.

[5] Distribution of spring and summer band recoveries for 1975–79 and 1990–94: Mackenzie River valley (8), Yukon interior (1), northern Alberta (1), and mainland ISR (1).

4.3 Fall, winter, and spring distribution

The birds from the ISR staged in two main areas in fall. The *parvipes*-like goose, marked as moulters on the mainland, staged primarily in the Peace River country of northwestern Alberta.[6] Few collared individuals sighted in northern Alberta in the fall were later seen in the other major staging area in southeastern Alberta and southwestern Saskatchewan. Compared with collar observations, band recoveries suggested that a slightly larger proportion of the geese were using southern Alberta in the fall (18%), but many of these recoveries were from late October and perhaps reflected a rapid late season passage through the area by some of the geese. Thus, it appeared that most of the mainland geese flew over or stopped only briefly in the southern part of the Canadian Prairies. This was a significant change in pattern from 1975–79, when larger numbers of the mainland geese staged in southern Alberta (nearly one-third of the recoveries) and apparently were there for much longer. Thus, there appears to have been a shift northwards in staging Canada Geese in Alberta since the late 1970s. When the northward shift began is not known, but it seems probable that it has been influenced greatly by agricultural expansion in northern Alberta.

Two apparent changes in the winter distribution of mainland geese have occurred since the 1970s: (1) a northward shift with more geese wintering in northeastern Colorado and a lower proportion of the geese moving to northern Texas and New Mexico; and (2) increasing numbers of birds found in the Pacific Flyway. Many of the winter resightings are from the Carson Sink – Stillwater Refuge area of western Nevada. W.G. Henry (pers. commun.) indicated that small Canada Geese started wintering in this region in the late 1960s or early 1970s, and the local wintering population has gradually grown to 5000 or more birds. Again, the significance of the distribution of observations west of the traditional distribution of the SGPP is not clear.

The Victoria Island geese staged almost entirely in southwestern Saskatchewan and southeastern Alberta, an area they shared with geese from other sites in the central Canadian Arctic (Kerbes and Meeres 1995). Whether significant changes in the fall–winter distribution of the western Victoria Island Canada Geese have occurred in recent years is not known, as no previous sample of birds was banded in this area.

There were relatively few band recoveries in the spring, and the collar-observation effort was lower and less extensive, so we have little information on spring migration routes of the different stocks of geese. As reported by Bellrose (1976) for other species of geese wintering in the Central Flyway, the path followed in northward migration was somewhat east of the southward route. Numerous geese from both the mainland and Victoria Island areas apparently staged in central Nebraska in spring, but overall the mainland birds seemed to follow a more westerly route on their return northward than did the Victoria Island geese. Our data provide little information on the migration path of the birds that wintered in the Pacific Flyway.

4.4 Survival estimates and harvest rates

The average survival rate of Canada Geese banded on the mainland during 1975–79 was high (0.78), and the band-recovery rates (0.0375) indicated that as much as 14% of the population may have been shot by hunters each year. The survival rates of the birds during the early 1990s are less certain, as band-recovery and collar-resighting analyses provided ambiguous results. Recovery rates from 1990–94 were similar to those from previous years, so recent harvest rates are likely much the same as in the late 1970s.

In the 1950s and early 1960s, survival rates of SGPP geese averaged 0.73 (Grieb 1970) and, with high band-recovery rates (>0.07 on average), the annual harvest probably exceeded 20% of the adult population. Thus, harvest rates are lower and survival rates possibly higher in recent years than in the 1950s and 1960s.

4.5 Management implications and information requirements

For management purposes, it would be useful to recognize the existence of two different stocks of Canada Geese present in the ISR and neighbouring parts of the Western Canadian Arctic: (1) a subarctic–boreal group breeding mainly below the tree line; and (2) a group of arctic nesters breeding farther north. The subarctic and arctic groupings correspond in many ways to the earlier designation of a western and an eastern segment of the SGPP (Marquardt 1962; Grieb 1968, 1970), but are based on a breeding ground definition of the population rather than a wintering ground one. Thus, the maximum geographic overlap of the two groups of birds occurs in winter, and minimum overlap occurs during the breeding season. Table 11 presents some of the important attributes of these two stocks of geese.

Management of the subarctic group of geese can be mainly attained by managing the harvest in northern Alberta and eastern Colorado, their most important staging and wintering areas. At current levels, the harvest in northern Canada probably averages only a few hundred birds per year and should not affect the population significantly.

The arctic group of geese nesting north of the tree line within the ISR is part of a larger stock of Canada Geese that nests across the central Arctic as far east as Rasmussen Lowlands (93°W longitude) or possibly even farther eastward. Combined evidence from a number of sources[7] suggests that the arctic segment of the population has increased in size, whereas the numbers of boreal–subarctic birds have remained relatively stable (Fig. 12). If so, the *B. c. hutchinsii* component of the population, estimated to make up <10% of the population in the 1950s and 1960s (Grieb

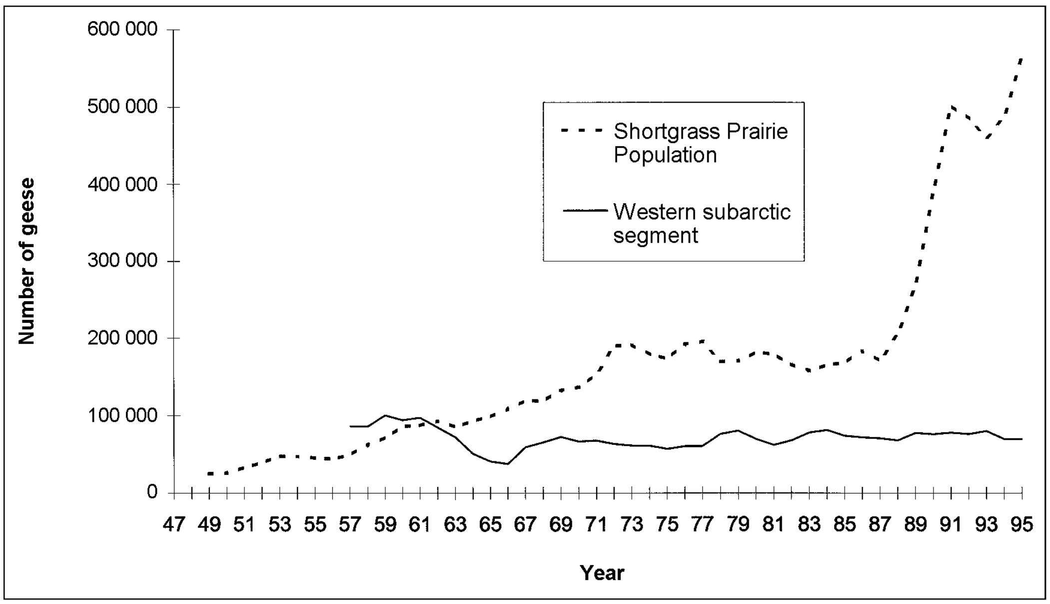
[6] Measurements of 311 hunter-shot small Canada Geese in northwestern Alberta indicated there were approximately 77% *B. c. parvipes* and 23% *B. c. hutchinsii* present (B. Turner, unpubl. data). Smaller numbers of a larger race (*B. c. moffitti)* were also present.

[7] Hunter interviews and aerial surveys described previously in this report, annual breeding ground surveys in parts of the Northwest Territories, the Yukon, and Alaska (see Smith 1995; Hodges et al. 1996), and annual wintering ground inventories of the SGPP (Grieb 1970; Sharp 1995).

Table 11
Attributes of the two probable subpopulations of Canada Geese in the Western Canadian Arctic

	Subpopulation	
Attribute	Subarctic/boreal	Arctic
Subspecies	mainly *B. c. parvipes*	mainly *B. c. hutchinsii*
Nesting distribution	taiga and closed boreal forest of the Northwest Territories	Victoria Island Parry Peninsula (?) Banks Island
Population trend	stable	increasing slowly
Numbers	70 000 in Northwest Territories, Alaska, and Yukon	>70 000 – 75 000 in or near the ISR
Fall staging	northern Alberta	southwestern Saskatchewan / southeastern Alberta
Wintering	eastern Colorado northern Texas Pacific Flyway	northern Texas eastern Colorado

Figure 12
Growth of Shortgrass Prairie Population of Canada Geese and its subarctic/boreal subpopulation



1970), may now exceed 60% of the population.[8] The arctic stock of geese appears to be doing well and presumably can safely absorb somewhat greater harvest than it currently sustains.

There are information gaps that need to be filled if we are to manage SGPP Canada Geese intensively. Many questions about the arctic-nesting segment will be resolved by analyses of the banding, collaring, and survey data recently collected for other parts of the SGPP breeding range, but the origin of the subarctic–boreal geese moulting on the mainland of the ISR is unresolved, and the western boundary of the SGPP remains unclear. Additional banding, radio-marking, and collecting of geese from various parts of the boreal–subarctic area might be required to determine the geographic limits of the population.

Arctic goose populations are dynamic, and the distribution and abundance of many populations are changing. Adequate monitoring of SGPP geese will require periodic repetition of some of the breeding ground surveys (for example, by repeating some of the transects at five-year intervals) and banding of birds to detect changes in distribution, annual harvest rates, and survival rates.

8 Estimated proportion of *B. c. hutchinsii* and *B. c. parvipes* in the population was based on samples taken from the western part of the winter range. This would underestimate the proportion of *hutchinsii*, which tends to have a more eastern distribution, in the population.

5. Summary

Several investigations undertaken in the Inuvialuit Settlement Region (ISR) further our understanding of the Shortgrass Prairie Population of Canada Geese (SGPP), which nests in the Western Canadian Arctic. Helicopter transect surveys of much of the breeding range of Canada Geese in the ISR indicated that in June of 1989 to 1993, more than 84 000 adult Canada Geese were present in the three main survey areas: the mainland (>22 000 geese), western Victoria Island (61 000 geese), and Banks Island (<1000 geese). Geese were widespread at low (<0.2 geese/km^2) to moderate densities (<1.0 geese/km^2) over most of the 160 385-km^2 study area. Three extensive areas where geese nested in relatively high densities were the Parry Peninsula on the mainland (10 562 geese, 3.8 geese/km^2) and the Kagloryuak River valley (11 242 geese, 2.5 geese/km^2) and the area south of the Tassijuak River (12 253 geese, 2.2 geese/km^2) on Victoria Island. Later in summer, large concentrations of flightless moulting adult geese were observed on the mainland, particularly in the vicinity of Harrowby Bay – Old Horton Channel (>10 000 geese) and at the delta of the Smoke and Moose rivers (>2 500 geese). Canada Geese on Victoria and Banks islands have increased in numbers and have extended their breeding range northwards over the past few decades. Independent evidence suggested that the general population of Canada Geese in the boreal forest and subarctic taiga of the Northwest Territories, Yukon, and eastern Alaska (largely breeding south of the ISR but a probable source of many of the geese seen at moulting areas in the ISR) had remained relatively stable since the 1960s.

We banded and neck-collared adult geese at the mainland moulting areas from 1990 to 1994 and on western Victoria Island in 1993, and banding data were available for the mainland for 1975–79. Measurements of geese captured during banding suggested that at least two subspecies were present in our samples: Lesser Canada Geese (*B. c. parvipes*), which made up most birds in the moulting areas; and Richardson's Canada Geese (*B. c. hutchinsii*), which were present on western Victoria Island and likely in other breeding areas north of the tree line. Band recoveries and collar resightings revealed that most of the mainland geese staged in agricultural areas of northwestern Alberta, whereas the western Victoria Island birds staged in southwestern Saskatchewan and southeastern Alberta. Geese from Victoria Island wintered primarily in the Texas Panhandle and eastern Colorado. Most of the mainland geese wintered in eastern Colorado and northern Texas, but in recent years increased numbers wintered west of the Rocky Mountains in the Pacific Flyway. Also, there appeared to have been a slight northward shift in winter distribution of the geese in the Central Flyway. Spring migration followed a path that took the geese somewhat east of the southward routes. In spring, the geese marked on Victoria Island followed a more eastern route than did the mainland geese.

Based on the year-round distribution of the geese, it would be useful to recognize two different population segments: (1) a subarctic/boreal stock comprising largely *B. c. parvipes* nesting below the tree line, staging in northwestern Alberta, and wintering mainly in eastern Colorado; and (2) an arctic stock comprising mainly *B. c. hutchinsii* nesting on Victoria Island, Banks Island, and the mainland north and east of the tree line, staging in southwestern Saskatchewan and southeastern Alberta, and wintering primarily in northern Texas and, to a lesser extent, in eastern Colorado. A significant number of geese (>20% of the wintering birds based on band recoveries) marked on the mainland of the ISR were sighted or recovered in the Pacific Flyway during both spring/summer and fall/winter. This could be an artifact of our banding of geese in moulting areas, reflect increased mixing of geese between the Central and Pacific flyways, or indicate a more western limit to the range of the SGPP than previously identified.

The annual survival rate of adult geese banded on the mainland (1975–79) was high (0.782 ± 0.020), and harvest rates (adjusted for crippling loss) were 12–14%. More recent band-recovery and collar-resighting data offered ambiguous results with regard to survival rates but suggested that harvest rates were no higher than in the late 1970s. The arctic-nesting component of the population seems to have grown faster than the subarctic component, suggesting that the proportion of *B. c. hutchinsii* in the population has increased since the 1950s and 1960s, when the population was described. In general, the SGPP seems to be doing well, and the arctic segment of the population could possibly absorb increased harvest.

6. Acknowledgements

We thank the numerous individuals and agencies that participated in various aspects of the field work, including the aerial surveys of breeding geese, the banding and marking programs, and the observations of collared birds. Our surveys and banding of geese in the Inuvialuit Settlement Region have been generously funded through the Inuvialuit Wildlife Management Advisory Council (N.W.T.) and the Polar Continental Shelf Project (Natural Resources Canada). We wish to thank Dave Duncan and Dave Sharp for reviewing the manuscript, Bob Bromley for providing measurements of hunter-killed geese from the mainland of the Settlement Region, Brian Collins for statistical advice, and Kevin McCormick for his efforts in obtaining support for the northern field programs.

7. Literature cited

Aldrich, J.W. 1946. Speciation in the white-cheeked geese. Wilson Bull. 58:94–103.

Alexander, S.A., T.W. Barry, D.L. Dickson, H.D. Prus and K.E. Smyth. 1988. Key areas for birds in coastal regions of the Canadian Beaufort Sea. Canadian Wildlife Service, Edmonton, Alberta.

Allen, L. 1982. Bird migration and nesting observations, western Victoria Island, N.W.T., June, 1980. Unpublished report. Canadian Wildlife Service, Yellowknife, Northwest Territories. 81 pp.

Arnason, A.N. and K.H. Mills. 1981. Bias and loss of precision due to tag loss in Jolly–Seber estimates for mark recapture experiments. Can. J. Fish. Aquat. Sci. 38:1077–1095.

Atmospheric Environment Service. 1982. Canadian climate normals 1951–1980, temperature and precipitation: the North – Y.T. and N.W.T. Canadian Climate Program, Environment Canada. 55 pp.

Barry, T.W. 1967. The geese of the Anderson River delta, Northwest Territories. Ph.D. Thesis, University of Alberta, Edmonton, Alberta.

Batschelet, E. 1981. Circular statistics in biology. Academic Press, London. 371 pp.

Bellrose, F.C. 1976. Ducks, geese, and swans of North America. Stackpole Books, Harrisburg, Pennsylvania. 544 pp.

Bliss, L.C., G.M. Courtin, D.L. Pattie, R.R. Riewe, D.W.A. Whitfield and P. Widden. 1973. Arctic tundra ecosystems. Annu. Rev. Ecol. Syst. 4:359–397.

Bostock, H.S. 1970. Physiographic subdivisions of Canada. Pages 10–30 *in* Douglas, R.J.W. (ed.), Geology and economic minerals of Canada. Economic Geology Report No. 1. Geological Survey of Canada, Ottawa, Ontario.

Bromley, R.G. 1996. Characteristics and management implications of the spring waterfowl hunt in the Western Canadian Arctic, Northwest Territories. Arctic 49(1):70–85.

Bromley, R.G., D.C. Heard and B. Croft. 1995. Visibility bias in aerial surveys relating to nest success of arctic geese. J. Wildl. Manage. 41:605–615.

Brownie, C., D.R. Anderson, K.P. Burnham and D.S. Robson. 1985. Statistical inference from band recovery data: a handbook. 2nd ed. U.S. Dep. Inter. Fish Wildl. Serv. Res. Publ. No. 156. 305 pp.

Canadian Wildlife Service. 1991. Arctic goose joint venture: a prospectus. Environment Canada, Edmonton, Alberta. 14 pp.

Committee for Original Peoples Entitlement. 1984. The western Arctic claim: the Inuvialuit Final Agreement. Indian and Northern Affairs Canada, Ottawa, Ontario.

Conroy, M.J. and W.W. Blandin. 1984. Geographic and temporal differences in band reporting rates for American Black Ducks. J. Wildl. Manage. 48:23–36.

Conroy, M.J., J.E. Hines and B.K. Williams. 1989. Procedures for the analysis of band-recovery data and user instructions for program MULT. U.S. Dep. Inter. Fish Wildl. Serv. Res. Publ. 175. 61 pp.

Corns, I.G.W. 1974. Arctic plant communities east of the Mackenzie Delta. Can. J. Bot. 52:1731–1747.

Cotter, R.C. and J.E. Hines. 1999. Distribution and population estimates of breeding birds on Banks Island, Northwest Territories, in 1992 and 1993. Unpublished report. Canadian Wildlife Service, Yellowknife, Northwest Territories.

Dzubin, A. and E.G. Cooch. 1992. Measurements of geese: general field methods. California Waterfowl Association, Sacramento. 20 pp.

Ebbinge, B.S., J.B. VanBiezen and H. Van der Voet. 1991. Estimation of annual adult survival rates of Barnacle Geese *Branta leucopsis* using multiple resightings of marked individuals. Ardea 79:73–112.

Environment Canada and U.S. Department of the Interior. 1986. North American Waterfowl Management Plan. Available from the Canadian Wildlife Service, Ottawa, Ontario. 19 pp.

Grieb, J.R. 1968. Canada Goose populations of the Central Flyway — their status and future. Pages 31–41 *in* Hine, R.L. and C. Schoenfeld (eds.), Canada goose management: current continental problems and programs. Dembar Educational Research Services, Madison, Wisconsin. 195 pp.

Grieb, J.R. 1970. The Shortgrass Prairie Canada Goose Population. Wildl. Monogr. 22:1–49.

Hestbeck, J.B., D.H. Rusch and R.A. Malecki. 1990. Estimating population parameters for geese from band-recovery and mark–recapture data. Trans. North Am. Wildl. Nat. Resour. Conf. 55:350–373.

Heyland, J.D. 1970. Aircraft-supported Canada Goose banding operations in arctic Quebec. N.E. Fish Wildl. Conf. Trans. 27:187–198.

Hodges, J.I., J.G. King, B. Conant and H.A. Hanson. 1996. Aerial surveys of waterbirds in Alaska 1957–94: population trends and observer variability. National Biological Service Information and Technology Report 4. 24 pp.

Johnson, D.H., D.E. Timm and P.F. Springer. 1979. Morphological characteristics of Canada Geese in the Pacific Flyway. Pages 56–80 *in* Jarvis, R.L. and J.C. Bartonek (eds.), Management and biology of Pacific flyway geese. Oregon State Univ. Book Stores, Inc., Corvallis. 346 pp.

Johnson, S.R., J.O. Schiek and G.F. Searing. 1995. Neck band loss rates for Lesser Snow Geese. J. Wildl. Manage. 59:747–752.

Jolly, G.M. 1965. Explicit estimates from capture–recapture data with both death and immigration: stochastic model. Biometrika 52:225–247.

Jolly, G.M. 1969. Sampling methods for aerial censuses of wildlife populations. East Afr. Agric. For. J. 34:46–49.

Kerbes, R.H. and K. Meeres. 1995. Arctic neckbanding and continental monitoring of geese progress report, 1994–95. Unpublished report. Canadian Wildlife Service, Saskatoon, Saskatchewan. 22 pp.

Lebreton, J.D., K.P. Burnham, J. Clobert and D.R. Anderson. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. Ecol. Monogr. 62:67–118.

MacInnes, C.D. 1966. Population behaviour of eastern Arctic Canada Geese. J. Wildl. Manage. 30:536–553.

Maltby, L.S. 1977. Techniques used for the capture, handling and marking of brant in the Canadian High Arctic. Can. Wildl. Serv. Prog. Notes No. 72. Ottawa, Ontario. 6 pp.

Marquardt, R.E. 1962. Ecology of the migrating and wintering flocks of the small white-cheeked geese within the south-central United States. Ph.D. Thesis, Oklahoma State Univ., Stillwater. 179 pp.

Martinson, R.K. and J.A. McCann. 1966. Proportion of recovered goose and brant bands that are reported. J. Wildl. Manage. 30:856–858.

McLaren, M.A. and W.G. Alliston. 1981. Summer bird populations on western Victoria Island, N.W.T., July 1980. Unpublished report. LGL Limited, Environmental Research Associates.

Nichols, J.D., J. Bart, R.J. Limpert, W.J.L. Sladen and J.E. Hines. 1992. Annual survival rates of adult and immature eastern population Tundra Swans. J. Wildl. Manage. 56:485–494.

Nieman, D.J., G.S. Hochbaum, F.D. Caswell and B. Turner. 1987. Monitoring hunter performance in prairie Canada. Trans. North Am. Wildl. Nat. Resour. Conf. 52:233–245.

Pollock, K.H. 1981. Capture–recapture models allowing for age dependent survival and capture rates. Biometrics 37:521–529.

Pollock, K.H., J.D. Nichols, C. Brownie and J.E. Hines. 1990. Statistical inference for capture–recapture experiments. Wildl. Monogr. 7:1–97.

Porsild, A.E. 1955. The vascular plants of the Western Canadian arctic archipelago. Natl. Mus. Can. Bull. 135. Biol. Ser. 45. Ottawa. 226 pp.

Rutherford, W.H. (ed.). 1965. Description of Canada Goose populations common to the Central Flyway. Central Flyway Waterfowl Council Technical Committee. 24 pp.

Samuel, M.D., N.T. Weiss, D.H. Rusch, S.R. Craven, R.E. Trost and F.D. Caswell. 1990. Neck-band retention for Canada Geese in the Mississippi Flyway. J. Wildl. Manage. 54:612–621.

Seber, G.A.F. 1965. A note on the multiple-recapture census. Biometrika 52:249–259.

Sharp, D.E. 1995. Central Fyway: harvest and population survey data book 1995. U.S. Department of the Interior, Fish and Wildlife Service, Golden, Colorado. 111 pp.

Smith, G.W. 1995. A critical review of the aerial and ground surveys of breeding waterfowl in North America. U.S. Dep. Inter. Biol. Sci. Rep. 5. Washington, D.C. 252 pp.

Sterling, T. and A. Dzubin. 1967. Canada goose molt migrations to the Northwest Territories. Trans. North Am. Wildl. Conf. 32:355–371.

Timm, D.E. and R.G. Bromley. 1976. Driving Canada Geese by helicopter. Wildl. Soc. Bull. 4:180–181.

U.S. Department of the Interior and Environment Canada. 1987. Standard operating procedures for aerial waterfowl breeding ground population and habitat surveys in North America. Unpublished report. U.S. Department of the Interior, Fish and Wildlife Service, Branch of Surveys, Laurel, Maryland. 102 pp.

Wiken, E. 1986. Terrestrial ecozones of Canada. Ecol. Land Classif. Ser. No. 19. Lands Directorate, Environment Canada, Ottawa, Ontario. 26 pp.

Appendix 1
The number and percentage of band recoveries in each province or state from hunter-killed birds banded on the mainland in 1975–79 and 1990–94 and on Victoria Island in 1990–94. All months of the year were included.

	Banded on the mainland in 1975–79		Banded on the mainland in 1990–94		Banded on Victoria Island in 1990–94	
Province/state	No.	(% of total)	No.	(% of total)	No.	(% of total)
Canada						
Yukon	2	(0.3)	0	(0.0)	0	(0.0)
Northwest Territories	5	(0.7)	1	(0.4)	1	(3.6)
British Columbia	2	(0.3)	0	(0.0)	0	(0.0)
Alberta	345	(46.5)	93	(34.6)	9	(32.1)
Saskatchewan	20	(2.7)	2	(0.7)	8	(28.6)
Subtotal (Canada)	374	(50.4)	96	(35.7)	18	(64.3)
Western U.S.						
Alaska	1	(0.1)	0	(0.0)	0	(0.0)
Washington	6	(0.8)	4	(1.5)	0	(0.0)
Oregon	3	(0.4)	3	(1.1)	0	(0.0)
Idaho	16	(2.2)	9	(3.3)	0	(0.0)
California	8	(1.1)	8	(3.0)	0	(0.0)
Nevada	13	(1.8)	14	(5.2)	0	(0.0)
Utah	4	(0.5)	3	(1.1)	0	(0.0)
Subtotal (western U.S.)	51	(6.9)	41	(15.2)	0	(0.0)
Central U.S.						
Montana	8	(1.1)	6	(2.2)	0	(0.0)
South Dakota	1	(0.1)	0	(0.0)	0	(0.0)
Wyoming	10	(1.3)	1	(0.4)	0	(0.0)
Nebraska	8	(1.1)	9	(3.3)	1	(3.6)
Colorado	215	(29.0)	105	(39.0)	5	(17.9)
Kansas	3	(0.4)	2	(0.7)	1	(3.6)
New Mexico	28	(3.8)	3	(1.1)	0	(0.0)
Texas	40	(5.4)	5	(1.9)	3	(10.7)
Oklahoma	4	(0.5)	1	(0.4)	0	(0.0)
Subtotal (central U.S.)	317	(42.7)	132	(49.1)	10	(35.7)
Total (Canada and U.S.)	742		269		28	

Appendix 2
The number and percentage of band recoveries in September and October in each province or state from hunter-killed birds banded on the mainland in 1975–79 and 1990–94 and on Victoria Island in 1990–94

	Banded on the mainland in 1975–79		Banded on the mainland in 1990–94		Banded on Victoria Island in 1990–94	
Province/state	No.	(% of total)	No.	(% of total)	No.	(% of total)
Canada						
Yukon	1	(0.3)	0	(0.0)	0	(0.0)
Northwest Territories	5	(1.5)	0	(0.0)	0	(0.0)
British Columbia	2	(0.6)	0	(0.0)	0	(0.0)
Alberta	313	(91.8)	81	(97.6)	9	(52.9)
Saskatchewan	16	(4.7)	2	(2.4)	8	(47.1)
Subtotal (Canada)	337	(98.8)	83	(100)	17	(100)
Western U.S.						
Alaska	1	(0.3)	0	(0.0)	0	(0.0)
Washington	1	(0.3)	0	(0.0)	0	(0.0)
Subtotal (western U.S.)	2	(0.6)	0	(0.0)	0	(0.0)
Central U.S.						
Montana	1	(0.3)	0	(0.0)	0	(0.0)
Kansas	1	(0.3)	0	(0.0)	0	(0.0)
Subtotal (central U.S.)	2	(0.6)	0	(0.0)	0	(0.0)
Total (Canada and U.S.)	**341**		**83**		**17**	

Appendix 3
The number and percentage of band recoveries in December and January in each province or state from hunter-killed birds banded on the mainland in 1975–79 and 1990–94 and on Victoria Island in 1990–94

	Banded on the mainland in 1975–79		Banded on the mainland in 1990–94		Banded on Victoria Island in 1990–94	
Province/state	No.	(% of total)	No.	(% of total)	No.	(% of total)
Canada						
Alberta	0	(0.0)	1	(0.7)	0	(0.0)
Subtotal (Canada)	0	(0.0)	1	(0.7)	0	(0.0)
Western U.S.						
Oregon	3	(1.2)	3	(2.1)	0	(0.0)
Idaho	11	(4.4)	6	(4.2)	0	(0.0)
California	7	(2.8)	6	(4.2)	0	(0.0)
Nevada	10	(4.0)	11	(7.7)	0	(0.0)
Utah	1	(0.4)	3	(2.1)	0	(0.0)
Subtotal (western U.S.)	35	(14.0)	33	(21.4)	0	(0.0)
Central U.S.						
Wyoming	5	(2.0)	1	(0.7)	0	(0.0)
Nebraska	2	(0.8)	6	(4.2)	0	(0.0)
Colorado	144	(57.6)	89	(62.7)	2	(33.3)
Kansas	0	(0.0)	2	(1.4)	1	(16.7)
New Mexico	25	(10.0)	3	(2.1)	3	(50.0)
Texas	34	(13.6)	4	(2.8)	0	(0.0)
Oklahoma	3	(1.2)	1	(0.7)	0	(0.0)
Subtotal (central U.S.)	215	(86.0)	108	(76.6)	6	(100)
Total (Canada and U.S.)	**250**		**142**		**6**	

Appendix 4
The number and percentage of sightings of collared Canada Geese in each province or state from birds collared in 1991–94 on the mainland of the Inuvialuit Settlement Region and Victoria Island. Individuals that were seen in more than one province or state were included in the totals for each area where they were seen.

	Mainland		Victoria Island	
Province/state	No.	(% of total)	No.	(% of total)
Canada				
Yukon	3	(0.1)	0	(0.0)
British Columbia	1	(0.0)	0	(0.0)
Alberta	1202	(38.2)	131	(11.9)
Saskatchewan	35	(1.1)	201	(18.2)
Subtotal (Canada)	1241	(39.5)	332	(30.0)
Western U.S.				
Alaska	5	(0.2)	0	(0.0)
Washington	2	(0.1)	0	(0.0)
California	1	(0.0)	0	(0.0)
Nevada	115	(3.7)	0	(0.0)
Subtotal (western U.S.)	123	(3.9)	0	(0.0)
Central U.S.				
Montana	66	(2.1)	0	(0.0)
North Dakota	5	(0.2)	13	(1.2)
South Dakota	4	(0.1)	6	(0.5)
Wyoming	5	(0.2)	0	(0.0)
Nebraska	140	(4.5)	246	(22.3)
Iowa	1	(0.0)	0	(0.0)
Colorado	1261	(40.1)	134	(12.1)
Kansas	24	(0.8)	38	(3.4)
New Mexico	65	(2.1)	3	(0.3)
Texas	197	(6.3)	299	(27.1)
Oklahoma	12	(0.4)	34	(3.1)
Subtotal (central U.S.)	1780	(56.6)	773	(70.0)
Total (Canada and U.S.)	**3144**		**1105**	

Appendix 5
The number and percentage of sightings in September and October of collared Canada Geese in each province or state from birds collared in 1991–94 on the mainland of the Inuvialuit Settlement Region and Victoria Island. Individuals that were seen in more than one province or state were included in the totals for each area where they were seen.

	Mainland		Victoria Island	
Province/state	No.	(% of total)	No.	(% of total)
Canada				
Alberta	1182	(97.4)	102	(36.2)
Saskatchewan	28	(2.3)	180	(63.8)
Subtotal (Canada)	1210	(99.7)	282	(100)
Central U.S.				
Montana	3	(0.2)	0	(0.0)
South Dakota	1	(0.1)	0	(0.0)
Subtotal (central U.S.)	4	(0.3)	0	(0.0)
Total (Canada and U.S.)	**1214**		**282**	

Appendix 6
The number and percentage of sightings in December and January of collared Canada Geese in each province or state from birds collared in 1991–94 on the mainland of the Inuvialuit Settlement Region and Victoria Island. Individuals that were seen in more than one province or state were included in the totals for each area where they were seen.

	Mainland		Victoria Island	
Province/state	No.	(% of total)	No.	(% of total)
Western U.S.				
California	1	(0.1)	0	(0.0)
Nevada	84	(6.1)	0	(0.0)
Subtotal (western U.S.)	85	(6.2)	0	(0.0)
Central U.S.				
Montana	22	(1.6)	0	(0.0)
South Dakota	0	(0.0)	2	(0.4)
Wyoming	1	(0.1)	0	(0.0)
Nebraska	26	(1.9)	62	(12.7)
Colorado	1019	(73.7)	105	(21.6)
Kansas	10	(0.7)	19	(3.9)
New Mexico	46	(3.3)	2	(0.4)
Texas	164	(11.9)	268	(55.0)
Oklahoma	9	(0.7)	29	(6.0)
Subtotal (central U.S.)	1297	(93.8)	487	(100)
Total (Canada and U.S.)	**1382**		**487**	

Appendix 7
The number and percentage of sightings of collared Canada Geese in March, April, and May in each province or state from birds collared in 1991–94 on the mainland of the Inuvialuit Settlement Region and Victoria Island. Individuals that were seen in more than one province or state were included in the totals for each area where they were seen.

	Mainland		Victoria Island	
Province/state	No.	(% of total)	No.	(% of total)
Canada				
Yukon	3	(0.6)	0	(0.0)
British Columbia	1	(0.2)	0	(0.0)
Alberta	32	(6.9)	40	(14.4)
Saskatchewan	7	(1.5)	20	(7.2)
Subtotal (Canada)	43	(9.3)	60	(21.6)
Western U.S.				
Alaska	5	(1.1)	0	(0.0)
Washington	2	(0.4)	0	(0.0)
Subtotal (western U.S.)	7	(1.5)	0	(0.0)
Central U.S.				
Montana	10	(2.2)	0	(0.0)
North Dakota	5	(1.1)	13	(4.7)
South Dakota	3	(0.6)	2	(0.7)
Wyoming	2	(0.4)	0	(0.0)
Nebraska	69	(14.9)	172	(61.9)
Colorado	317	(68.6)	25	(9.0)
Kansas	0	(0.0)	4	(1.4)
New Mexico	1	(0.2)	0	(0.0)
Texas	5	(1.1)	2	(0.7)
Subtotal (central U.S.)	412	(89.2)	218	(78.4)
Total (Canada and U.S.)	**462**		**278**	

Incubation behaviour of Richardson's Canada Geese on Victoria Island, Nunavut, Canada

Robert L. Jarvis and Robert G. Bromley

Summary

Nesting Canada Geese (*Branta canadensis*) rely extensively upon endogenous reserves to sustain a high level of incubation constancy, but foraging during incubation, especially during the latter stages, is essential for successful nesting. Inattentiveness at nests, however, increases the likelihood of predation. Thus, energetic and anti-predator strategies must be coordinated to maximize the probability of successful nesting. This coordination should be most apparent in small-bodied Canada Geese nesting in the High Arctic. We used time-lapse photography and time-budget observations to study incubation behaviour of Richardson's Canada Geese (*B. c. hutchinsii*) near the northern edge of their breeding range on Victoria Island, Nunavut (formerly Northwest Terrritories), Canada. Our study took place in 1989, a year of early phenology on our study area. Incubating females took incubation breaks during all hours of the 24-hour day, but 43% of breaks occurred between 09:00 and 15:00 h. Females took an average of about four recesses per day for about 20 minutes each. Total recess time increased from about 70 minutes per day in the first eight days of incubation to about 94 minutes per day in the third eight days of incubation. Females were off the nest for less than 60 minutes per day during the hatching phase. During incubation breaks, females fed for about 55% of the time and foraged within sight of the nest (<200 m). Males either accompanied their mates or remained adjacent to the nest, but mates synchronized their activity such that at least one was vigilant 89% of the time. Pairs successfully defended their nests, which were on mini-islands, from arctic foxes (*Alopex lagopus*). Glaucous Gulls (*Larus hyperboreus*) only took exposed, unprotected eggs, and geese did not aerially pursue them. Long migration and small body size both probably contribute to the need to supplement endogenous reserves. Nesting on mini-islands and foraging close to nests are anti-predator strategies. We conclude that suitable nesting sites surrounded by abundant forage are necessary for small geese nesting in the Arctic.

Résumé

En période de nidification, les Bernaches du Canada (*Branta canadensis*) comptent largement sur leurs réserves endogènes pour maintenir un niveau élevé de constance de couvaison, mais l'alimentation durant l'incubation, surtout dans les dernières étapes, est essentielle au succès de la nidification. Toutefois, le manque d'attention aux nids augmente les possibilités de prédation. Il faut donc coordonner les stratégies rigoureuses contre les prédateurs pour maximiser les probabilités d'une nidification réussie. Cette coordination devrait être particulièrement évidente chez les Bernaches du Canada à petit corps qui nichent dans l'Extreme-Arctique. Nous avons eu recours à la chronophotographie et aux observations temps-budget pour étudier le comportement de couvaison de la Bernache du Canada de Richardson (*B. c. hutchinsii*) près de la limite nord de leur aire de reproduction sur l'île Victoria, au Nunavut (anciennement une partie des T. N.-O) au Canada. Notre étude a eu lieu en 1989, une année de phénologie précoce sur notre aire d'étude. Les femelles couveuses pouvaient prendre des pauses à toute heure de la journée de 24 heures, mais 43 p. 100 des pauses avaient lieu entre 9 h et 15 h. Elles prenaient en moyenne quatre pauses par jour d'environ 20 minutes chacune. Le total du temps de pause a passé d'environ 70 minutes par jour durant les premiers huit jours de couvaison à environ 94 minutes par jour durant la troisième tranche de huit jours. Les femelles étaient hors du nid moins de 60 minutes par jour durant la phase d'éclosion. Pendant les pauses, durant l'incubation, les femelles se nourrissaient environ 55 p. 100 du temps et cherchaient de la nourriture en gardant le nid en vue (<200 m). Les mâles accompagnaient leur compagne ou restaient tout près du nid; le couple synchronisait ses activités de façon à ce qu'au moins un des deux reste vigilant 89 p. 100 du temps. Les couples défendaient avec succès leurs nids, qui se trouvaient sur des îlots, contre les renards arctiques (*Alopex lagopus*). Le Goéland bourgmestre (*Larus hyperboreus*) ne prenait que les œufs exposés et sans protection et les bernaches ne les poursuivaient pas dans les airs. La longue migration et le petit corps des bernaches contribuaient probablement à la nécessité pour elles d'augmenter leurs réserves endogènes. Le fait de nicher sur des îlots et de chercher de la nourriture près du nid constitue des stratégies contre les prédateurs. Nous en concluons que des sites de reproduction appropriés entourés de nourriture abondante sont essentiels aux petites bernaches qui nichent dans l'Arctique.

1. Introduction

Sherry et al. (1980) postulated that for birds in which females alone incubate the clutch, fasting is an adaptation to permit high nest attentiveness by females. Canada Geese (*Branta canadensis*) are attentive incubators and fast during incubation (Hanson 1962; Raveling 1979a,b; Bromley 1984; Mainguy and Thomas 1985; Murphy and Boag 1989). Much of the energy required for reproduction is acquired prior to and during the early stages of migration (McLandress and Raveling 1981; Bromley and Jarvis 1993). Upon arrival on nesting areas, females lay large eggs and clutches, and this egg production makes heavy demands on remaining energy reserves (Thompson and Raveling 1987). Additionally, constancy of incubation reduces the likelihood of predation (Harvey 1971; Inglis 1977; Raveling and Lumsden 1977), but requires utilization of endogenous reserves.

Incubation recesses in Canada Geese typically increase as incubation progresses; in some races, daily recess time is nearly twice as long near the end of incubation as at the beginning (Aldrich 1983; Aldrich and Raveling 1983; Bromley 1984; Murphy and Boag 1989). Longer daily recess time and increased dependence on exogenous energy may become necessary to maintain body weight above a minimum threshold (Sherry et al. 1980).

Despite similarity in the pattern of decreasing incubation constancy among races of Canada Geese, total daily recess time varies considerably. *B. c. maxima* (Cooper 1978) and *B. c. moffitti* (Aldrich and Raveling 1983) had average recess times of 20–40 minutes per day, *B. c. occidentalis*, 84–170 minutes per day (Bromley 1984), and *B. c. minima*, 60–130 minutes per day (Aldrich 1983). Size of the bird, length of migration, and availability of food during migration all probably influence the reserves retained upon arrival on the breeding grounds. Production of eggs has highest priority for endogenous reserves (Thompson and Raveling 1987), and incubation behaviour must be adjusted to supplement declining endogenous reserves during incubation. However, high likelihood of predation of unattended nests restricts the flexibility of incubation behaviour, unless predator-avoidance and nest-defence strategies also are employed (Thompson and Raveling 1987).

Richardson's Canada Geese (*B. c. hutchinsii*) are a small-bodied race with a long migration (~4500 km) (Palmer 1976); we predicted that females would (i) have long daily recess time because of a need to supplement endogenous reserves, and (ii) employ nest-defence and predator-avoidance strategies that would permit long daily recess time. We studied incubation behaviour of Richardson's Canada Geese near the northern limit of their breeding distribution on southeast Victoria Island, Nunavut (formerly Northwest Territories), Canada. To test our predictions, we examined the frequency, duration, and diel distribution of incubation recesses and the behaviour of pairs during recesses, including the proportion of time spent feeding.

2. Study area

The Albert Edward Bay study area is on southeastern Victoria Island about 95 km northeast of the community of Cambridge Bay and 350 km north of the Arctic Circle; during the study there was 24-hour daylight. The area consists of lowland tundra with many wetlands and rocky upland tundra ridges with a few large ponds (1–5 ha). The study area was bordered on parts of two sides by large lakes and an interconnecting river. Wetlands in the lowlands varied from boggy tundra to small ponds (0.01–0.5 ha) to large ponds (>1 ha). Geese nested in all wetlands, in both the lowland and upland areas.

Richardson's Canada Geese were the most abundant geese nesting in the area; a few Greater White-fronted Geese (*Anser albifrons frontalis*) and Lesser Snow Geese (*A. caerulescens caerulescens*) also nested. Spring phenology was earlier in 1989 than in any other year during 1987–92, a period when geese in the study area were intensively monitored (R.G. Bromley, unpubl. data). Nesting of Richardson's Canada Geese was highly synchronized, and nest success was high (80%) in 1989 (R.L. Jarvis, unpubl. data). The only other waterfowl nesting in the area were King Eiders (*Somateria spectabilis*), Oldsquaws (*Clangula hyemalis*), and Tundra Swans (*Cygnus columbianus*). Numerous sandpipers (Scolopacidae), plovers (Charadriidae), Arctic Terns (*Sterna paradisaea*), and gulls (*Larus* spp.) were present during the study. At least two arctic foxes (*Alopex lagopus*) were regularly observed in the study area.

3. Methods

Activity budgets of geese were obtained by visual observation with focal bird sampling procedures (Altmann 1974). Activity of both members of a pair was recorded at 30-second intervals during 15-minute sampling periods. A metronome timing device (Wiens et al. 1970) was used to key behavioural observations. The sex of each bird was identified by behavioural interaction of the pair; females were generally less aggressive and smaller than males. Prior to initiation of incubation, a breeding pair was identified as two birds together, one of which had the rounded belly contour of a female (Owen 1981). After initiation of incubation, we only recorded activity of pairs when we saw the female leave her nest.

Activities were categorized as feeding, alert, walking, swimming, resting, flying, social, comfort, sleep, or incubation. Birds were classified as feeding if they had their head down and were "pecking" at the vegetation, even if not taking a bite at the exact instant the metronome clicked. Most observations were made from tundra ridges where 4–10 nests could be monitored simultaneously. Observations were conducted throughout the day (24 hours of daylight), but most time-budget recordings occurred in mid morning through late afternoon, corresponding to periods of peak recess activity. Behavioural observations continued until hatching began. Activity budgets during recesses from the nest were recorded on 53 occasions for a total observation time of 12.8 hours.

Activities were summarized as percentage occurrence for each 15-minute observation session. Percentage occurrence of feeding was transformed (arcsin square root) and grouped into five six-day periods beginning with the laying of first eggs.

Attentiveness of incubating females was recorded by 8-mm movie cameras set to expose one frame per minute. Three cameras were used to record activities of nine incubating females, and cameras were moved among the nests at about 2.5-day intervals. Thus, activity of each female was recorded for about 60 hours during each 7.5-day interval of the incubation period. Females rarely left their nests when cameras were placed or removed. A clock was placed between the nest and camera such that it was visible in each exposed frame. Film was examined with a binocular microscope (7–15×), and number and duration of recesses were recorded. Additional information recorded included identification code of the female, date and time of recess, and day of incubation. Number of recesses and total recess time were calculated on a per day basis (24 hours) for each day on which film images were recorded for at least eight hours. Lengths of all recesses were recorded regardless of the length of time the camera was active during any 24-hour day. Stage of incubation was grouped into four eight-day intervals; the last interval (days 25–32) represented the hatching stage of the 26–27-day incubation period. Recesses were recorded on film during a total of 1459 nest-hours of photography; each hour of the 24-hour day was sampled for 57–63 hours.

A contingency table analysis was used to examine the distribution of recesses during the 24-hour day. All other data (feeding time, recess length, recesses per day, and recess time per day) were analyzed with one-way ANOVA using the GLM Procedure of SAS (SAS Institute Inc. 1987). Not all nests were sampled at all stages of incubation, resulting in an incomplete design, so two-way ANOVA (nest by stage) was inappropriate. Thus, our analytic strategy was to examine the full data set via one-way ANOVA for differences among nests (females) and among stages of incubation. Where significant differences existed among females, the females with the largest and/or smallest values were sequentially eliminated until no differences existed among females. This reduced data set was then examined with one-way ANOVA for differences among stages of incubation, and results were compared with those from the full data set. Results from the reduced data set never differed from those of the full data set, so we used the full data set in our final analysis. In all analyses we used p # 0.05 as the minimum level of significance.

4. Results

4.1 Feeding

While not on the nest, female geese spent significantly more time feeding during the laying stage (71%) than during incubation (55%) (Table 1). During incubation, feeding progressively increased from 49% of recess time during the first six days to 59% during the last six days, but the differences were not significant.

Table 1
Proportion of recess time spent feeding by female Canada Geese during the laying and incubation periods, Victoria Island, 1989. The means are significantly different at $p \le 0.05$

Stage	No. of observation bouts	Mean proportion of recess time spent feeding	Standard deviation
Laying	12	70.7	18.0
Incubation	41	55.1	20.0

4.2 Incubation recesses

4.2.1 Timing

Recesses occurred at all hours of the day (Fig. 1), but were most common during the middle of the day; 43% occurred between 09:00 and 15:00 h. Nonetheless, recesses occurred at modest, but fairly uniform, rates, from 20:00 to 08:00 h, and during 01:00–02:00 h only one recess was recorded in 61 hours of filmed observation. The timing of recesses did not change significantly during the four stages of the incubation period ($\chi^2 = 13.0$, d.f. = 25, $p > 0.95$).

4.2.2 Number and duration of recesses

Females took an average of 4.09 recesses per day, varying from 2.81 (female no. 41) to 5.64 (female no. 54), but the number of recesses per day was not significantly different among females (Table 2). The mean duration of 271 recesses varied from less than 15 minutes for female no. 13 to more than 27 minutes for female no. 2 and averaged 19.9 minutes for all females combined. Female no. 2 took significantly longer recesses than those of the other eight females, all of which were not significantly different from each other. Total time off the nest averaged 80.3 minutes per day but was quite variable among females. Female no. 41 spent significantly less time off the nest (43.1 minutes per day) than did female no. 54 (119.7 minutes per day), but neither was significantly different from the other seven females. Female no. 41 spent more than 48 continuous hours on her nest early in incubation. Even disregarding those two days, she had the lowest total recess time (55.4 minutes per day) of the nine females.

Fewer recesses were taken during the first stage of incubation (3.10 recesses per day) than during the third (5.00 recesses per day) stage; there were no other significant differences (Table 3). Recesses were significantly longer during the first stage of incubation (during days 1–8, mean recess length was 23.2 minutes) than during the third (during days 17–24, mean recess length was 18.9 minutes) and fourth stages (during days 25–28, mean recess length was 16.7 minutes). Regression analysis indicated a significant decline in duration of recesses as incubation progressed, but the relationship was weak ($r^2 = 0.08$). Total recess time per day did not vary significantly among the four stages of incubation, although numerically there was an increasing trend from the first period (69.7 minutes per day) through the third period (94.1 minutes per day). Daily recess time was shortest (58.9 minutes per day) during the last period of incubation when goslings were hatching.

4.2.3 Behaviour during recesses

Recesses were initiated by females covering the eggs with down and walking quickly from their nests. They displayed little of the restlessness prior to departure reported by Cooper (1978) for giant Canada Geese. Females usually remained within 100–200 m of the nest. Males either remained at the nest site, often sitting or standing adjacent to the nest throughout the recess, or attended their mates while on recess. In either case, mates were rarely visually isolated from each other or from their nest. Females usually preened and/or bathed for short periods (five minutes) at either the beginning or end of the recess; comfort activities accounted for 12% (n = 41) of recorded activities of females during recesses. Males were alert 64% of the time that females were

Figure 1
Diel pattern of recesses taken by nine incubating Canada Geese, Victoria Island, Nunavut, 1989

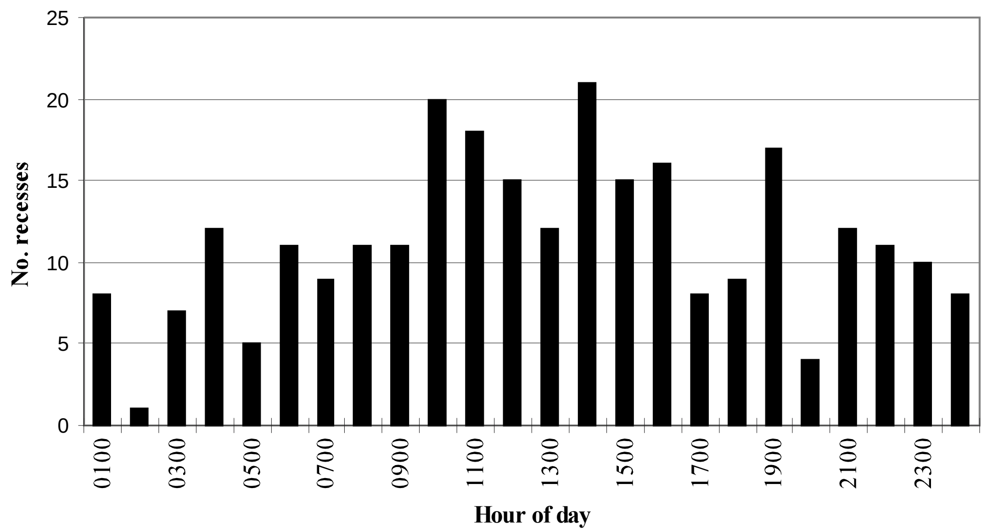


Table 2
Recesses taken by nine incubating female Canada Geese, Victoria Island, 1989. Values within columns with different superscripts are significantly different (P ≤ 0.05) from each other.

Female no.	N = No. of observed recesses	Mean duration of recess, min	N = No. of days with observation sessions of more than 8 h	Mean no. of recesses per day	Mean min per day
2	33	27.2[a]	11	3.63	96.3[ab]
5	30	18.5[b]	5	4.52	75.9[ab]
8	24	20.5[b]	7	3.74	77.6[ab]
10	25	20.6[b]	8	3.74	77.6[ab]
13	30	14.9[b]	9	3.69	52.8[ab]
14	37	20.0[b]	11	5.22	105.4[ab]
35	38	19.7[b]	9	4.12	71.4[ab]
41	20	15.2[b]	9	2.81	43.1[a]
54	34	20.7[b]	7	5.64	119.7[b]
Total/average	271	19.9	76	4.09	80.3

Table 3
Recesses taken by nine incubating female Canada Geese during four stages of the incubation period, Victoria Island, 1989. Items within columns with different superscripts are significantly different (P ≤ 0.05) from each other.

Incubation stage, days	N = No. of observed recesses	Mean duration of recess, min	N = No. of days with observation sessions of more than 8 h	Mean no. of recesses per day	Mean min per day
1–8	46	23.2[a]	16	3.10[a]	69.7
9–16	82	20.8[ab]	25	3.93[ab]	80.6
17–24	116	18.9[b]	26	5.00[b]	94.1
25–28	27	16.7[b]	9	3.72[ab]	58.9
Total/average	271	19.9	76	4.09	80.3

off the nest, and females spent 33% of their nonfeeding time alert.

Males were alert 70% of the time that females were engaged in feeding or comfort activities. Females were alert 18% of the time that males were simultaneously in non-alert postures. At least one member of the pair was almost always alert (89%, including instances when both were alert) during recesses. This synchronized activity occurred even when mates were 100 m or more apart.

5. Discussion

Richardson's Canada Geese displayed a high degree of constancy of incubation, with individual females absent from their nests during only 3–7% of the incubation period. As incubation progressed, length of recesses decreased but number of recesses per day increased. Although not statistically significant, daily recess time increased as incubation progressed. Feeding time increased from about 39 minutes per day in early incubation to 55 minutes per day in late incubation, but differences were again not significant. We conclude that the increase in feeding by Richardson's Canada Geese as incubation progressed was biologically real, despite the lack of statistical significance.

The increase in daily recess time by Richardson's Canada Geese as incubation progressed was much less than has been reported for several other races of Canada Geese. Dusky Canada Geese spent twice as much time off the nest (210 minutes per day) during the last nine days of incubation as during the first 18 days (102 minutes per day; Bromley 1984). In cackling Canada Geese, recess time increased from 60 to 130 minutes per day from the beginning to the end of incubation (Aldrich 1983), and in western Canada Geese in captivity the increase was from 20 to 60 minutes per day (Aldrich and Raveling 1983). However, Cooper (1978) reported that daily recess time in giant Canada Geese remained constant at about 20 minutes per day throughout the incubation period. The relatively long daily recess time (70–94 minutes per day), the slight increase in recess time during incubation, and the intensity of feeding (71%) during laying all imply that Richardson's Canada Geese rely upon exogenous energy to a greater extent than has been reported for large Canada Geese, except dusky Canada Geese. Reliance upon exogenous energy is probably influenced by the small body size and long migration of Richardson's Geese and, perhaps in 1989, by the favourable spring phenology. Richardson's and cackling Canada geese are similar in their apparent reliance upon exogenous energy.

Thompson and Raveling (1987) argued that the small cackling Canada Geese invested a large proportion of their endogenous reserves in eggs, nested on islands to avoid predation by arctic foxes, repulsed attacks by gulls and jaegers, and had long daily recess times in which females fed within nesting territories and/or males protected nest sites during incubation recesses. The incubation behaviour of the small Richardson's Canada Goose fits within that scenario.

Nearly all Richardson's Canada Geese on our study area nested on islands, and we observed four instances of foxes being driven from the vicinity of the nest by both members of the pair (R.L. Jarvis, unpubl.). Glaucous Gulls (*Larus hyperboreus*) were only observed to take exposed eggs (uncovered) from unoccupied nests; they were unable to take eggs when pairs were present at the nest. However, we did not observe Richardson's Canada Geese aerially pursuing gulls as do cackling Canada Geese (Thompson and Raveling 1987).

Defensive tactics used by Richardson's Canada Geese required close attendance at the nest, usually by both members of the pair. During recesses, female Richardson's Canada Geese normally fed within 100 m of the nest, and mates synchronized their behaviour so that one was almost always alert, as Aldrich (1983) observed in cackling Canada Geese. In contrast, females of the giant Canada Goose were always accompanied by their mate during recesses and flew to feeding areas up to 1 km from the nest (Cooper 1978). Thus, the nest was left undefended during recesses, but total recess time was short. In cackling and Richardson's Canada geese, where total recess times were long, nests were defended by males, and females fed close enough to help defend the nest.

The energetics of migration must influence the incubation strategies available to breeding geese (Bromley 1984; Bromley and Jarvis 1993). Migration is energetically expensive and must have a strong influence on the endogenous energy reserves available for producing and incubating eggs. Small Canada Geese have long migrations (about 4000 km for both cackling and Richardson's Canada geese [Palmer 1976]), lay small clutches (but large as a percentage of body weight; Dunn and MacInnes 1987), and do much feeding during incubation. Dusky Canada Geese, a moderately large subspecies (3.1–3.7 kg), migrate about 2600 km with only brief stopovers, but replenish lipid stores on their coastal breeding grounds prior to initiation of egg laying (Bromley 1984; Bromley and Jarvis 1993). Dusky Canada Geese have large clutches (~5.5 eggs) but are the least attentive (85–93%; Bromley 1984) of the Canada Geese studied. Large Canada Geese (*B. c. maxima* and *B. c. moffitti*) have short migrations, usually less than 500 km, and are highly attentive to their nests (>97%; Cooper 1978; Aldrich and Raveling 1983). Emperor Geese (*Anser canagica*) are the most attentive (99.5%) of the geese investigated (Thompson and Raveling 1987) and have short migrations (700 km), with staging areas near (300–350 km) their breeding areas (Palmer 1976). At the other extreme, Brant (*B. bernicla*) have long migrations (more than 4000 km; Palmer 1976), arrive on breeding areas with small lipid reserves, and rely heavily on exogenous energy during egg laying and incubation (Ankney 1984). Brant also "...graze in the vicinity of the nest during egg laying and incubation ... thus are able to return quickly to defend the nest if a predator appears" (Ankney 1984), a behaviour pattern similar to that of Richardson's Canada Geese. Long migrations by small geese combined with the advantages of large clutches must place a premium on habitats that contain secure nest sites (islands in the case of Canada Geese) in a matrix of abundant and nutritious food that is available upon or shortly after arrival. The dispersed and patchy distribution of nesting geese across the Arctic may reflect the concurrent distribution of those two features: nutritious food and defensible nest sites. An essential step in assessing population status is to determine the capacity of the land for the species being assessed. For Richardson's Canada Geese, landscapes that provide island nesting sites in a matrix of nutritious forage are likely to be a strong determinant of potential population size.

6. Acknowledgements

Logistic support was provided by the Polar Continental Shelf Project, Natural Resources Canada, and the N.W.T. Department of Resources, Wildlife and Economic Development. The senior author was partially supported by an L.L. Steward Faculty Development Grant from Oregon State University. Data collection was assisted by Brent Gurd and Jorgan Aitoak. Bruce Coblentz and an anonymous reviewer provided helpful comments on drafts of the manuscript.

7. Literature cited

Aldrich, T.W. 1983. Behaviour and energetics of nesting Canada Geese. M.S. thesis, Univ. California, Davis.

Aldrich, T.W. and D.G. Raveling. 1983. Effects of experience and body weights on incubation behaviour of Canada Geese. Auk 100:670–679.

Altmann, J. 1974. Observational study of behaviour: sampling methods. Anim. Behav. 49:227–267.

Ankney, C.D. 1984. Nutrient reserve dynamics of breeding and molting Brant. Auk 101:361–370.

Bromley, R.G. 1984. The energetics of migration and reproduction of dusky Canada Geese (*Branta canadensis occidentalis*). Ph.D. dissertation, Oregon State Univ., Corvallis.

Bromley, R.G. and R.L. Jarvis. 1993. The energetics of migration and reproduction of dusky Canada Geese. Condor 95:193–210.

Cooper, J.A. 1978. The history and breeding biology of the Canada Geese of Marshy Point, Manitoba. Wildl. Monogr. 61:1–87.

Dunn, E.H. and C.D. MacInnes. 1987. Geographic variation in clutch size and body size of Canada Geese. J. Field Ornithol. 58(3):355–371.

Hanson, H.C. 1962. The dynamics of condition factors in Canada Geese and their relation to seasonal stresses. Tech. Pap. Arct. Inst. North Am. No. 12.

Harvey, J.M. 1971. Factors affecting Blue Goose nesting success. Can. J. Zool. 49:223–233.

Inglis, I.R. 1977. The breeding behaviour of the Pink-footed Goose: behavioural correlates of nesting success. Anim. Behav. 25:747–764.

Mainguy, S.K. and V.G. Thomas. 1985. Comparisons of body reserve buildup and use in several groups of Canada Geese. Can. J. Zool. 63:1765–1772.

McLandress, M.R. and D.G. Raveling. 1981. Change in diet and body composition of Canada Geese before spring migration. Auk 98:65–79.

Murphy, S.K. and D.A. Boag. 1989. Body reserve and food use by incubating Canada Geese. Auk 106:439–446.

Owen, M. 1981. Abdominal profile — a condition index for wild geese in the field. J. Wildl. Manage. 45:227–230.

Palmer, R.S. (ed.). 1976. Handbook of North American birds. Vol. 2, Waterfowl (part 1). Yale Univ. Press, New Haven, Connecticut.

Raveling, D.G. 1979a. The annual cycle of body composition of Canada Geese with special reference to control of reproduction. Auk 96:234–252.

Raveling, D.G. 1979b. The annual energy cycle of the cackling Canada Goose. Pages 81–93 *in* Jarvis, R.L. and J.C. Bartonek (eds.), Management and biology of Pacific flyway geese: a symposium. OSU Bookstores, Inc., Corvallis, Oregon.

Raveling, D.G. and H.G. Lumsden. 1977. Nesting ecology of Canada Geese in the Hudson Bay lowlands of Ontario: evolution and population regulation. Ont. Min. Nat. Resour. Fish Wildl. Res. Rep. 98.

SAS Institute Inc. 1987. SAS/STAT guide for personal computers. 6th edition. SAS Institute Inc., Cary, N.C. 1028 pp.

Sherry, D.T., N. Mrosovsky and J.A. Hogan. 1980. Weight loss and anorexia during incubation in birds. J. Comp. Physiol. Psychol. 94:89–98.

Thompson, S.C. and D.G. Raveling. 1987. Incubation behaviour of Emperor Geese compared with other geese: interactions of predation, body size, and energetics. Auk 104:707–716.

Wiens, J.A., S.G. Martin, W.R. Holthous and A.R. Iwen. 1970. Metronomic timing in behavioural ecology studies. Ecology 51:350–352.

Subarctic- and boreal-breeding populations





Photos: upper left – Ted Nichols
upper right – Austin Reed
centre – Ken Abraham
bottom left – Kathryn Dickson
bottom right – Ted Nichols

Breeding ground surveys for the North Atlantic Population of Canada Geese in Labrador, 1993 and 1994

Myrtle C. Bateman

Summary

Migrant Canada Geese in the Atlantic Flyway were reported to be declining in the late 1980s. Because those of the North Atlantic Population make up some proportion of the total migrant Canada Geese of the Atlantic Flyway, the status of these birds was of concern. Fixed-wing surveys of Labrador south of 55°N latitude were carried out in June 1993 and 1994. Fifteen of 24 transects were similar to transects flown in 1980. Comparison of the data suggested no change in the population between 1980 and 1993 or 1994. The Canada Goose breeding population in Labrador was estimated to be 28 000 pairs (SE = 4200) in 1994. Canada Goose densities were estimated for each ecoregion sampled by the transect survey.

Résumé

Vers la fin des années 1980, on rapportait que la Bernache du Canada migratrice de la voie de migration de l'Atlantique subissait un déclin. Étant donné que la population nord-atlantique constitue une bonne proportion du total des Bernaches du Canada migratrices de la voie de migration de l'Atlantique, la situation de ces oiseaux constituait une source d'inquiétude. En juin 1993 et 1994, des relevés en avion ont été effectués au Labrador, au sud du 55° de latitude Nord. Quinze des 24 transects étaient semblables aux transects survolés en 1980. La comparaison des données indiquait qu'il n'y avait pas eu de changement dans la population entre 1980 et 1993 ou 1994. La population reproductrice de la Bernache du Canada au Labrador a été estimée à 28 000 couples (SE = 4200) en 1994. Les densités de Bernaches du Canada ont été évaluées pour chaque écorégion échantillonnée par le relevé par transect.

1. Introduction

In the late 1980s there were indications, primarily from the midwinter inventory, that the migrant Canada Geese (*Branta canadensis*) in the Atlantic Flyway were not as numerous as in the early 1980s (Atlantic Flyway Council 1989). A decline in population growth rate was suggested by Trost and Malecki (1985), and results of neck-band studies showed low survival in some groups of geese (Hestbeck and Malecki 1989). Wintering geese in the Atlantic Flyway included geese from the North Atlantic Population as well as from the Atlantic Population and the resident population. Because the North Atlantic Population shares wintering areas with, and for practical purposes is indistinguishable from, the Atlantic Population and resident birds, it was not known whether the decline had occurred throughout the breeding ranges or was concentrated in one population or area. An opportunity to evaluate the status of Canada Geese breeding in Labrador arose in 1993 and 1994 when the Department of National Defence funded surveys to determine the distribution and relative densities of Canada Geese as part of their wildlife mitigation program associated with low-level jet training in Labrador and Quebec.

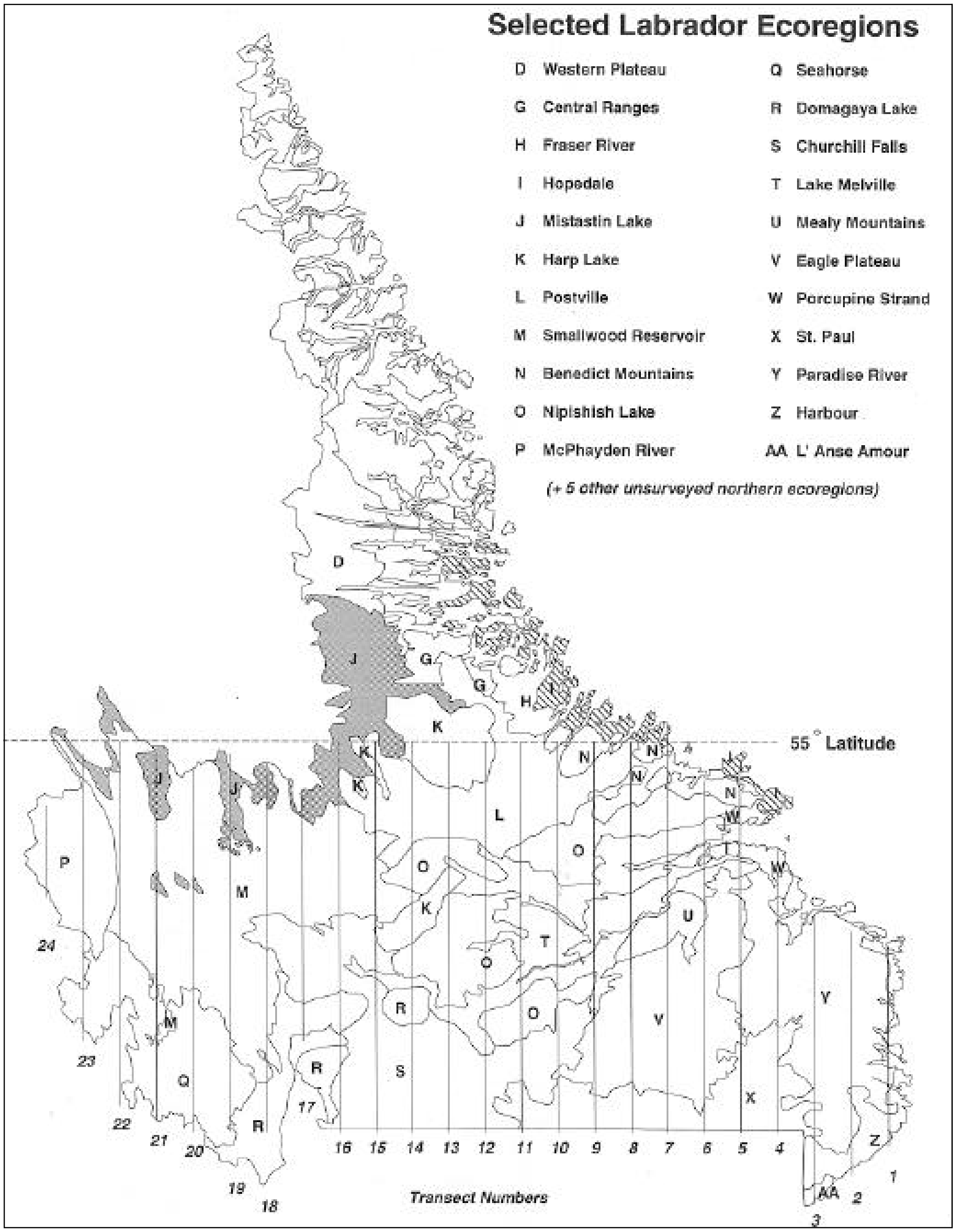
Canada Geese breeding in Labrador make up a large part of the North Atlantic Population of geese (Bellrose 1980). The remainder of the population breeds in adjacent eastern Quebec, insular Newfoundland, and the Maritimes. An estimated 4000 pairs breed on insular Newfoundland, a few hundred pairs in the Maritimes (Erskine 1987), and an unknown number in eastern Quebec. The U.S. Fish and Wildlife Service (USFWS) conducted fixed-wing aerial surveys for breeding waterfowl in Labrador in 1952, 1956, 1963, and 1964 (Chamberlain and Kaczynski 1965). In 1970, 1971, and 1972, Gillespie and Wetmore (1974) carried out fixed-wing and helicopter surveys. Goudie and Whitman (1987) reported on surveys done in Labrador using several techniques in 1980, 1981, and 1982. In 1996, the USFWS began a fixed-wing transect survey for waterfowl breeding in Labrador.

The objectives of the surveys reported here were to determine distribution and relative densities of geese breeding in Labrador, to derive a population estimate, and to compare the present population with results from a survey in 1980. The results could not be compared with the older surveys except in general terms because of differences in techniques and equipment.

2. Study area

The study area was approximately 247 000 km^2, located south of 55°N latitude in Labrador. The total area of Labrador is approximately 288 000 km^2. Normal winters are long and harsh, with snow common from November to early June. Mean annual temperatures are between 5°C and 0°C, depending on latitude, elevation, and proximity to the coast. Mean annual precipitation ranges from 600 mm at northern

Figure 1
Approximate locations of north–south transects flown with fixed-wing aircraft in Labrador on 1–15 June 1993 and ecoregion locations (from Lopoukine et al. 1977). The same transects were flown in 1994 with modifications noted in text. Transects 1–15 were also flown in 1980.



latitudes to 1200 mm at the Quebec–Labrador boundary (Lopoukhine et al. 1977).

Lopoukhine et al. (1977) described 27 ecoregions in Labrador, of which 20 were sampled by fixed-wing transects (Fig. 1). Ten of the most important for Canada Geese are described here (Lopoukhine et al. 1977):

Hopedale — a coastal region typified by mosses and lichens on bedrock; scrub spruce and birch on the plateau; patches of spruce, fir, white birch, alders, and willows on valley tills and outwash deposits; spruce–lichen forest on better drained river terraces, and bogs on marine clays and silts.

Mistastin Lake — an inland region with expanses of lichen and scattered stunted spruce; better tree growth occurs on lower slopes and along water courses.

Harp Lake — an upland region dominated by exposed bedrock with sharply incised valleys; vegetation is typically dwarf spruce and larch mixed with ericaceous shrubs, lichens, and mosses around bare rock and boreal forest stands of black and white spruce on sheltered slopes.

Smallwood Reservoir — the largest land region in Labrador consists of esker and drumlin ridges, deep till and glaciofluvial deposits; string bogs and fens are prominent in south and central portions of the region; vegetation is

Table 1
Comparison of the 1980 fixed-wing transect results (Goudie and Whitman1987) with results from transects 1–15 in 1993 and 1994 (uncorrected for visibility)

	Year		
	1980	1993	1994
Total transect length (km)	4 252	4 379	4 320
Total area surveyed (km^2)	850	876	864
Average density (indicated pairs per 100 km^2)	5.6	5.4	4.4
Average density (total geese per 100 km^2)	26.8	10.9	19.7
Estimated indicated pairs in area sampled (138 520 km^2)	7 756	7 480 ± 1 077[a]	6 094 ± 914
Estimated number of total geese in area sampled (138 520 km^2)	37 100	15 100 ± 2 627	27 284 ± 4 092

[a] One standard error.

dominated by open lichen woodlands with numerous bogs, but closed forest stands occur on well drained sites.

Nipishish Lake — a rolling plateau dominated by varying depths of till; forest cover is dominated by black spruce, but protected sites have balsam fir, white spruce, and larch; organic terrain is dominated by fens.

Seahorse — relatively level land covered with large expanses of organic terrain interspersed with rolling hills covered with black spruce forest.

Churchill Falls — broad river valleys and rolling topography with organic terrain in river valleys and areas of impeded drainage; typical vegetation is lichen – black spruce forest, but larch and closed-canopy white spruce – balsam fir – black spruce woodlands occur in favourable sites.

Eagle Plateau — vast tracts of level and boggy terrain in the south and a plateau adjacent to the Mealy Mountains in the north; widespread string and blanket bog surrounded by black spruce and larch in the south; the upland in the north is lichen–spruce forest.

St. Paul — rolling hills dissected by broad river valleys with common organic terrain; vegetation is generally closed-canopy black spruce forest, but lichen–spruce forest and bog occur.

Paradise River — an undulating landscape with poor drainage, resulting in organic terrain; productive black spruce – balsam fir – white spruce forest is common, and blanket and string bogs occur.

3. Methods

North–south transects were established at 0.5° intervals of longitude from 56°W longitude in the east to 67.5°W longitude in the west. The transects extended from the south coast of Labrador or the Quebec border in the south to as far north as the Quebec border or 55°N latitude (Fig. 1). The 15 easternmost transects (transects 1–15) were similar to those flown by Whitman in 1980 (Goudie and Whitman 1987). In 1994, transects 12 and 13 were not completed because of poor weather, but transects 14 and 15 were flown north to 56°N latitude.

The survey was flown in a Cessna 206 on wheels with a pilot, a navigator/observer, and one observer. All observations of Canada Geese were recorded on 1:250 000 National Topographic Series maps and later assigned to the appropriate ecoregion. Navigation was assisted by the use of a Geographical Positioning System. The transects were flown at ground speeds of 120–130 km/h at an altitude of about 30 m above ground level. Aircraft struts were marked for transect widths of 200 m (100 m each side) and 400 m (200 m each side). All geese recorded were within the 200-m transect width, and it was assumed that this was the effective transect width for the survey. A single Canada Goose or two geese together were considered an indicated pair. Groups of more than two birds were treated as nonbreeders. Densities were calculated for observed birds and indicated pairs (indicated pairs were not doubled to get an assumed number) and extrapolated to the area sampled. A visibility correction of two was used to calculate population estimates (see Discussion), but not when comparing with results from Goudie and Whitman (1987). Standard errors were calculated using 50-km segments of transects. Relative densities of geese in ecoregions sampled were calculated by combining the results from the 1993 and 1994 surveys (transect length and geese observed in each ecoregion were summed). Statistical comparisons between the 1980 and 1993–1994 results were not possible because only totals were available for the 1980 data. A paired t-test was used to compare 1993 and 1994 results on identical transects.

4. Results

The surveys were flown between 1 and 15 June 1993 and 1994. Timing of the surveys was judged appropriate for breeding geese based on the number of nests seen. All bogs and ponds were snow- and ice-free, but large bodies of water, such as the Smallwood Reservoir, had significant ice cover remaining. Although nesting chronology can vary from year to year depending on weather conditions, early June generally corresponds to nest initiation for geese in Labrador. In 1993, 24 transects totalling 6687 km were flown; in 1994, the total length of surveyed transects was 6754 km.

The results for the 15 comparable transects flown in 1980, 1993, and 1994 are shown in Table 1. Transects 1–15 in the 1993 and 1994 surveys were the same as those flown in 1980, also using a fixed-wing aircraft (Goudie and Whitman 1987). The precise locations of geese observed in the 1980 survey were unavailable, but all geese observed were recorded (Whitman, pers. commun.). Thus, the raw data from the 1980, 1993, and 1994 surveys were assumed to be comparable.

The number of indicated pairs of geese estimated on the 1980 transects and on transects 1–15 in 1993 and 1994 were similar (Table 1). The total number of geese in 1994 was significantly more than was recorded in 1993 ($P < 0.05$) and probably not different from the number in 1980 (statistical parameters could not be calculated for the 1980 data). There was little difference in the number of pairs of geese

Figure 2
Age ratios (immature/adult) calculated from Canada Goose tail fans in the Species Composition Survey for the Atlantic provinces, 1975–96 (sample size approximates 450 annually; adults are at least one year old)

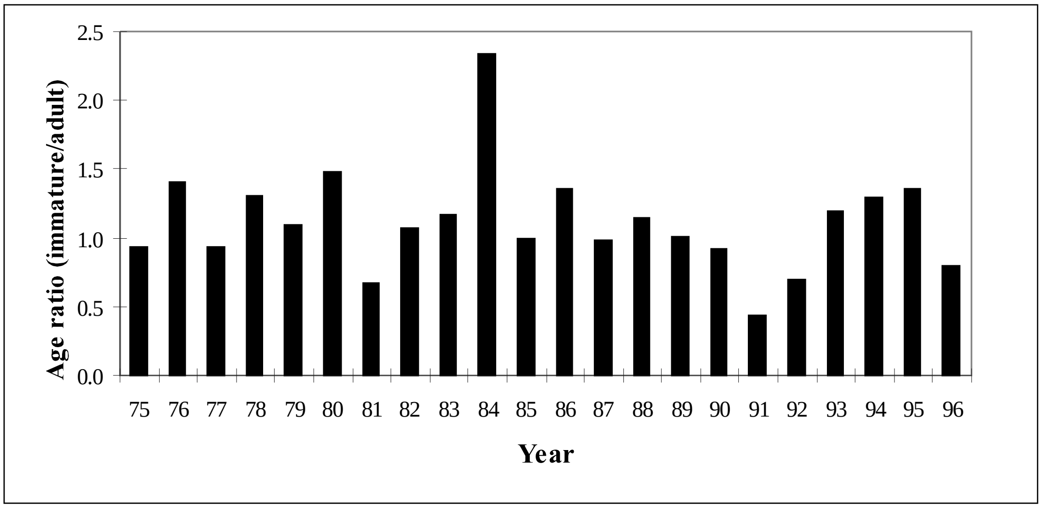


Table 2
A comparison of Canada Goose observations on helicopter plots in 1992 and on fixed-wing transects in 1993 in the same area of Labrador

	Surveyed area (km^2)	Mean no. indicated pairs per 100 km^2	Mean no. total geese per 100 km^2
Helicopter plots 1992	1900	15.5 ± 2.2[a]	35.9 ± 6.1
Fixed-wing transects 1993	95	5.8 ± 0.75	11.5 ± 1.8

[a] ± 1 standard error.

Table 3
Results of fixed-wing transect surveys for Canada Geese in Labrador in June 1993 and 1994 (visibility correction factor = 2)

	1993	1994
Total transect length (km)	6 687	6 754
Total area surveyed (km^2)	1 337	1 350
Average density (indicated pairs per 100 km^2)	11.0	11.4
Average density (total number of geese per 100 km^2)	21.8	38.8
Estimated indicated pairs in area sampled (247 000 km^2)	27 000 ± 3 532[a]	28 000 ± 4 200
Estimated total number of geese in area sampled (247 000 km^2)	53 800 ± 8 600	95 800 ± 14 400

[a] ± 1 standard error.

observed on the 1980 transects and those from 1993 and 1994 (Table 1).

In 1993, the total number of geese observed was approximately double the number of indicated pairs. In comparison, the total number of geese in 1980 and 1994 was four to five times the number of indicated pairs (Table 1). These differences probably are an accurate reflection of fewer nonbreeding subadults in the population in 1993, following relatively low production in 1991 and 1992 as evidenced by low age ratios in the Species Composition Survey (National Harvest Survey data) (Fig. 2).

The visibility correction factor (VCF) that should be applied to fixed-wing survey results for Canada Geese in Labrador is unknown. Malecki et al. (1981) suggested that a VCF of 1.4 would be appropriate for the Eastern Prairie Population breeding grounds. Schneider et al. (1994) determined that a VCF of 1.4 applied to indicated pairs on the breeding ground of the Mississippi Valley Population overestimated the number of breeding pairs. Comparison of the number of Canada Geese observed on fixed-wing transects in western Labrador in 1993 with results from helicopter surveys of rectangular plots in the same area in 1992 (Canadian Wildlife Service, unpubl.) suggested that a helicopter survey may record up to three times the number of geese observed from fixed-wing aircraft (Table 2).

Using data from all transects in the survey area (247 000 km^2), the estimated number of pairs of Canada Geese (using a VCF of two) was 27 000 (SE = 3532) in 1993 and 28 000 (SE = 4200) in 1994 (Table 3). The total number of geese estimated for this area was 53 800 (SE = 8600) in 1993 and 95 800 (SE = 14 400) in 1994.

Table 4
Estimated densities of Canada Geese (indicated pairs per 100 km^2 and total birds per 100 km^2) in ecoregions of Labrador surveyed by fixed-wing transects in 1993 and 1994 (visibility correction factor = 2)

Ecoregion	Surveyed area (km^2)	Mean no. indicated pairs per 100 km^2	Mean no. total geese per 100 km^2
Mistastin Lake	116.0	70.0	46.6
Hopedale	10.8	37.0	74.0
St. Paul	140.0	23.0	80.0
Smallwood Reservoir	468.0	17.0	40.6
Eagle Plateau	220.0	16.0	52.6
Seahorse	162.0	13.6	24.8
Nipishish Lake	209.0	13.4	35.6
Fraser River	16.2	11.8	12.2
Domagaya Lake	89.0	11.6	15.6
Churchill Falls	298.0	10.0	20.8
Porcupine Strand	24.0	8.6	17.0
Paradise River	238.0	7.6	31.0
Benedict Mountains	30.0	6.8	6.6
McPhayden River	96.0	6.0	8.2
Lake Melville	247.0	3.4	6.4
Postville	180.0	3.2	8.4
Harp Lake	56.0	0.0	25.4
Harbour	48.0	0.0	21.2
Mealy Mountains	36.0	0.0	0.0
Central Ranges	6.0	0.0	0.0
Total	2690.0		

Canada Goose densities for each ecoregion sampled by transects were calculated using the Labrador ecoregions defined by Lopoukhine et al. (1977). Locations of geese were easily assigned to the appropriate ecoregion from the topographic maps used during the survey. Twenty ecoregions were sampled, although sample size was small in some regions (Table 4). The results of the two surveys were combined (the samples were added and a single density calculated for each ecoregion) to provide an improved estimate of relative density for each ecoregion.

The ecoregions with the highest densities of breeding geese (Table 4) were Mistastin Lake (70 indicated pairs per 100 km^2), Hopedale (37 indicated pairs per 100 km^2 but small sample size), St. Paul (23 indicated pairs per 100 km^2), Smallwood Reservoir (17 indicated pairs per 100 km^2), and Eagle Plateau (16 indicated pairs per 100 km^2). The highest densities of total birds were recorded in St. Paul (80 birds per 100 km^2), Hopedale (74 birds per 100 km^2 but sample size was small), Eagle Plateau (52.6 birds per 100 km^2), Mistastin Lake (46.6 birds per 100 km^2), and Smallwood Reservoir (40.6 birds per 100 km^2). The Smallwood Reservoir also had relatively high densities of geese on the 1980–82 surveys (Goudie and Whitman 1987).

Comparison of the number of Canada Geese observed on fixed-wing transects in western Labrador in 1993 with results from helicopter plot surveys in the same area in 1992 suggests that a VCF of two was conservative (Table 2). There are difficulties associated with the comparison of results from helicopter plots and fixed-wing transects in different years and from not precisely the same areas. It is also likely that the VCF for nesting geese differs among habitats.

5. Discussion

The declining population of migrant Canada Geese in the Atlantic Flyway has led to considerable concern for the North Atlantic Population. These surveys suggest that the population in Labrador did not change greatly between 1980 and 1994. Although the status of this population may be stable, survival estimates calculated by Hestbeck (USFWS, pers. commun.) from neck-banded birds were low (65–70%) in the early 1980s. The recent estimate of survival in 1995–96 was higher at 78%, perhaps because of the closed hunting season that began that year in the states of the Atlantic Flyway.

There appears to be a contribution to the North Atlantic Population by birds originating in West Greenland, where the population is increasing and expanding (Fox et al. 1996). A group of 10 individuals was captured and banded in Isungua, Greenland, and of these three were later recovered in Labrador during the hunting season (Fox et al. 1996). The significance of these birds to the overall population is not yet known.

It is important that the status of the North Atlantic Population continue to be monitored, and a breeding ground survey is a relatively inexpensive and reliable monitoring tool. The density information now available for ecoregions in Labrador may permit a more effective survey design.

6. Acknowledgements

I thank the Environmental Mitigation Program, Goose Bay Office, of National Defence Headquarters for funding the surveys.

7. Literature cited

Atlantic Flyway Council. 1989. A management plan for the Atlantic Flyway Population of Canada Geese. Canada Goose Committee of the Atlantic Flyway Council Technical Section, Quebec City, Quebec. 39 pp.

Bellrose, F.C. 1980. Ducks, geese, and swans of North America. 3rd edition. Wildl. Manage. Inst. and Stackpole Books, Harrisburg, Pennsylvania. 544 pp.

Chamberlain, E.B. and C.F. Kaczynski. 1965. Problems in aerial surveys of waterfowl in eastern Canada. Spec. Rep. Wildl. No. 93. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 21 pp.

Erskine, A.J. 1987. A preliminary waterfowl population budget for the Atlantic provinces, 1978–85. Pages 65–72 *in* Erskine, A.J. (ed.), Waterfowl breeding population surveys, Atlantic provinces. Can. Wildl. Serv. Occas. Pap. No. 60.

Fox, A.D., C. Glahder, C.R. Mitchell, D.A. Stroud, H. Boyd and J. Frikke. 1996. North American Canada Geese (*Branta canadensis*) in West Greenland. Auk 113(1):231–233.

Gillespie, D.I. and S.P. Wetmore. 1974. Waterfowl surveys in Labrador–Ungava, 1970, 1971, 1972. Pages 8–18 *in* Boyd, H. (ed.), Waterfowl studies in eastern Canada, 1969–73. Can. Wildl. Serv. Rep. Ser. No. 29.

Goudie, R.I. and W.R. Whitman. 1987. Waterfowl populations in Labrador, 1980–1982. Pages 45–63 *in* Erskine, A.J. (ed.), Waterfowl breeding population surveys, Atlantic provinces. Can. Wildl. Serv. Occas. Pap. No. 60.

Hestbeck, J.B. and R.A. Malecki. 1989. Estimated survival rates of Canada Geese within the Atlantic Flyway. J. Wildl. Manage. 53(1):91–96.

Lopoukhine, N., N.A. Prout and H.E. Hirvonen. 1977. Ecological land classification of Labrador: a reconnaisance. Fish. Environ. Can. Ecol. Land Classif. Ser. No. 4. 85 pp.
Malecki, R.A., F.D. Caswell, R.A. Bishop, K.M. Babcock and M.M. Gillespie. 1981. A breeding-ground survey of EPP Canada Geese in northern Manitoba. J. Wildl. Manage. 45(1):46–53.
Schneider, J.P., T.C. Tacha and J.O. Leafloor. 1994. Potential predictors of numbers of Canada Goose nests from aerial surveys. Wildl. Soc. Bull. 22:431–436.
Trost, R.E. and R.A. Malecki. 1985. Population trends in Atlantic Flyway Canada Geese: implications and management. Wildl. Soc. Bull. 13:502–508.

Breeding, migration, and wintering affinities of Canada Geese marked in the Atlantic provinces

Jay B. Hestbeck and Myrtle C. Bateman

Summary

Nearly 2500 Canada Geese (*Branta canadensis*) were leg-banded (642) or neck-banded (1850) in the Atlantic provinces and observed or recovered in the Maritimes and eastern United States during the 1980s and 1990s. Geographic distributions of leg-band recoveries and neck-band observations were similar for geese banded in Labrador or on the island of Newfoundland during summer and those banded in the Maritimes during spring or fall migration. Geese banded in Labrador were recovered primarily in eastern Quebec, New Brunswick, New England, and Long Island, New York. Fall and winter observations of geese neck-banded in western Labrador were reported principally from New Brunswick, New England, and Long Island; spring observations came from Prince Edward Island. Geese banded on the island of Newfoundland were recovered primarily in Nova Scotia and secondarily from Prince Edward Island, New England, and Long Island. Observations were reported from Prince Edward Island in the fall and spring and New England and Long Island during the winter. Geese banded in the Maritimes during migrations were recovered primarily in Atlantic Canada and New England. Geese neck-banded in the Maritimes during migrations were principally observed on Prince Edward Island in the spring and fall and New England and Long Island during the winter. Geese breeding in Labrador or on Newfoundland island migrated during the fall along the St. Lawrence River to New England or through the Maritimes to New England. Geese from western Labrador migrated farther west than geese from insular Newfoundland, and geese banded in the Maritimes moved primarily through Prince Edward Island. Geese neck-banded in western Labrador or the Maritimes wintered primarily in southern New England, New Jersey and Long Island; geese neck-banded in western Ungava Bay, Quebec, wintered principally from central New York to Maryland and Delaware.

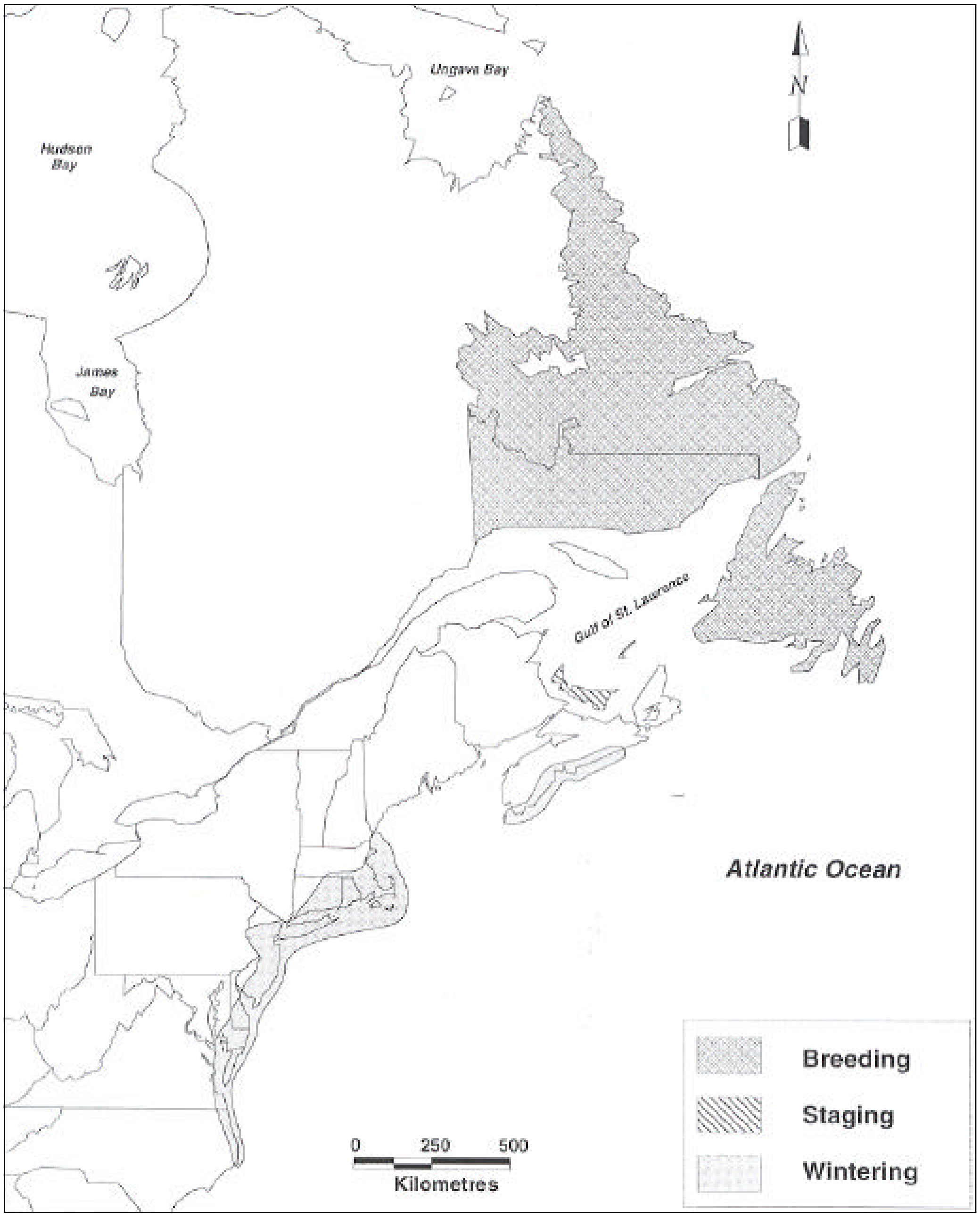
Résumé

Près de 2 500 Bernaches du Canada (*Branta canadensis*) ont été bagués à la patte (642) ou au cou (1850) dans les provinces de l'Atlantique puis ont été observées ou récupérées dans les États maritimes et de l'Est durant les années 1980 et 1990. La répartition géographique des oiseaux bagués à la patte récupérés et des oiseaux bagués au cou observés était la même pour les bernaches baguées au Labrador ou sur l'île de Terre-Neuve pendant l'été et pour celles qui avaient été baguées dans les Maritimes durant les migrations de printemps ou d'automne. Les bernaches baguées au Labrador ont été récupérées principalement dans l'Est du Québec, au Nouveau-Brunswick, en Nouvelle-Angleterre et à Long Island, New York. Des observations en automne et en hiver de bernaches baguées au cou dans l'Ouest du Labrador ont été rapportées surtout du Nouveau-Brunswick, de la Nouvelle-Angleterre et de Long Island, alors que les observations de printemps provenaient de l'Île-du-Prince-Édouard. Des bernaches baguées à Terre-Neuve ont été récupérées surtout en Nouvelle-Écosse, puis à l'Île-du-Prince-Édouard, en Nouvelle-Angleterre et à Long Island. Des observations ont été rapportées de l'Île-du-Prince-Édouard en automne et au printemps, et de la Nouvelle-Angleterre et de Long Island durant l'hiver. Des bernaches baguées dans les Maritimes pendant les migrations ont été récupérées surtout dans les régions atlantiques du Canada et en Nouvelle-Angleterre. Des bernaches qui avaient été baguées au cou dans les Maritimes pendant les migrations ont été observées surtout à l'Île-du-Prince-Édouard au printemps et à l'automne, et en Nouvelle-Angleterre et à Long Island durant l'hiver. Les bernaches qui nichaient au Labrador ou à Terre-Neuve ont migré pendant l'automne le long du fleuve Saint-Laurent jusqu'en Nouvelle-Angleterre ou à travers les Maritimes jusqu'en Nouvelle-Angleterre. Des bernaches de l'Ouest du Labrador ont migré plus à l'ouest que les bernaches de l'île de Terre-Neuve, et des bernaches baguées dans les Maritimes ont en grande partie traversé l'Île-du-Prince-Édouard. Les bernaches baguées au cou dans l'Ouest du Labrador ou dans les Maritimes ont hiverné surtout dans le Sud de la Nouvelle-Angleterre, au New Jersey et à Long Island; les bernaches baguées au cou dans l'Ouest de la baie d'Ungava, au Québec, ont surtout hiverné du centre de l'État de New York jusqu'au Maryland et au Delaware.

1. Introduction

Canada Geese (*Branta canadensis*) display strong fidelity to breeding, wintering, and migration areas, resulting in localized populations possibly composed of different subspecies (Bellrose 1980). Todd (1963) described the Canada Geese that breed in Labrador and Newfoundland as belonging to the subspecies *B. c. canadensis*, assigning those

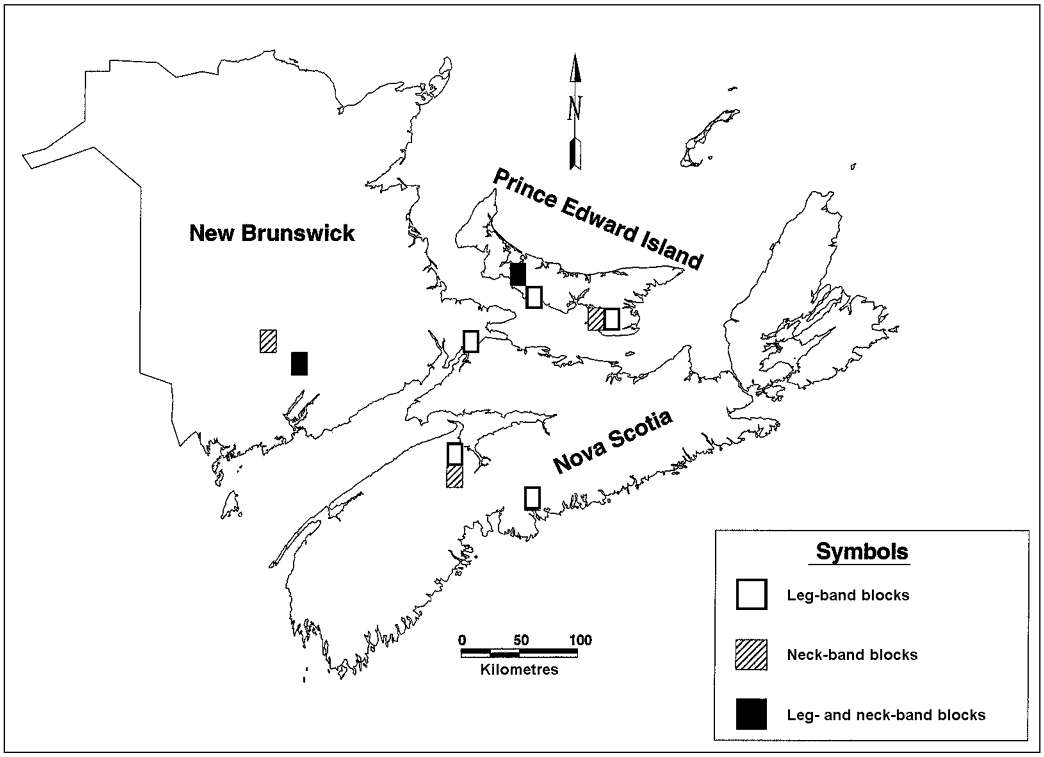
Figure 1
Approximate breeding and wintering ranges and a major migration staging area of the North Atlantic Population of Canada Geese



breeding along the eastern shore of Hudson Bay to the subspecies *B. c. interior*. Hanson and Nelson (1964) recognized populations in 12 geographic ranges across Canada and the United States, including a "North Atlantic" population (NAP) that nested in eastern Labrador and Newfoundland and wintered along the coast from Nova Scotia to the Chesapeake Bay and beyond. Bellrose (1980) refined the delineation of the NAP by stating that breeding occurred in Newfoundland and through the Labrador Peninsula east of the height of land from Hopes Advance Bay to the North Shore of the St. Lawrence and wintered along the coast from southeast Newfoundland to Pea Island National Wildlife Refuge, North Carolina. Bellrose (1980) further speculated that 50% of the U.S. wintering population would be located in New England and Long Island, 10% would occur from New Jersey to Virginia, and 40% would occur in Pea Island, North Carolina. Others have generally used this basic delineation of breeding and wintering areas (Fig. 1) (Goudie 1987; Goudie and Whitman 1987). More recently, Fox et al. (1996) reported that Canada Geese breeding in western Greenland were recovered in Labrador, indicating a larger breeding area for the NAP. In addition, Erskine (1997) noted that the NAP and breeding populations in Quebec were reasonably discrete, considering that they shared wintering areas in the Atlantic coastal regions of the U.S.

Bellrose (1980) described a single migration corridor for the NAP that extended down the Labrador coast to New Brunswick and Prince Edward Island or Newfoundland to Nova Scotia. The corridor then went along the New England coast, across Long Island, and down the coast to Pea Island,

Figure 2
Locations (10-minute blocks) of Canada Goose leg-banding and neck-banding sites in New Brunswick, Nova Scota, and Prince Edward Island



North Carolina. Erskine et al. (1997) refined this definition by suggesting Labrador-breeding geese migrate through New Brunswick and not Prince Edward Island in the fall but do move through Prince Edward Island in spring. Most Maritime-marked geese would use a narrow migration corridor along the Atlantic coast, and Newfoundland geese migrate to Nova Scotia (Erskine et al. 1997).

In the 1980s and 1990s, large numbers of Canada Geese were neck-banded in the Atlantic provinces and observed or recovered in the Maritimes and eastern United States. These new data provide further information on associations between the breeding and wintering grounds, on migration corridors, and on migration chronology. These data also allowed a test of the hypothesis that Canada Geese neck-banded in summer in western Labrador and those neck-banded on migration in the Maritime provinces would have wintering areas similar to those of geese neck-banded in western Ungava Bay in northern Quebec.

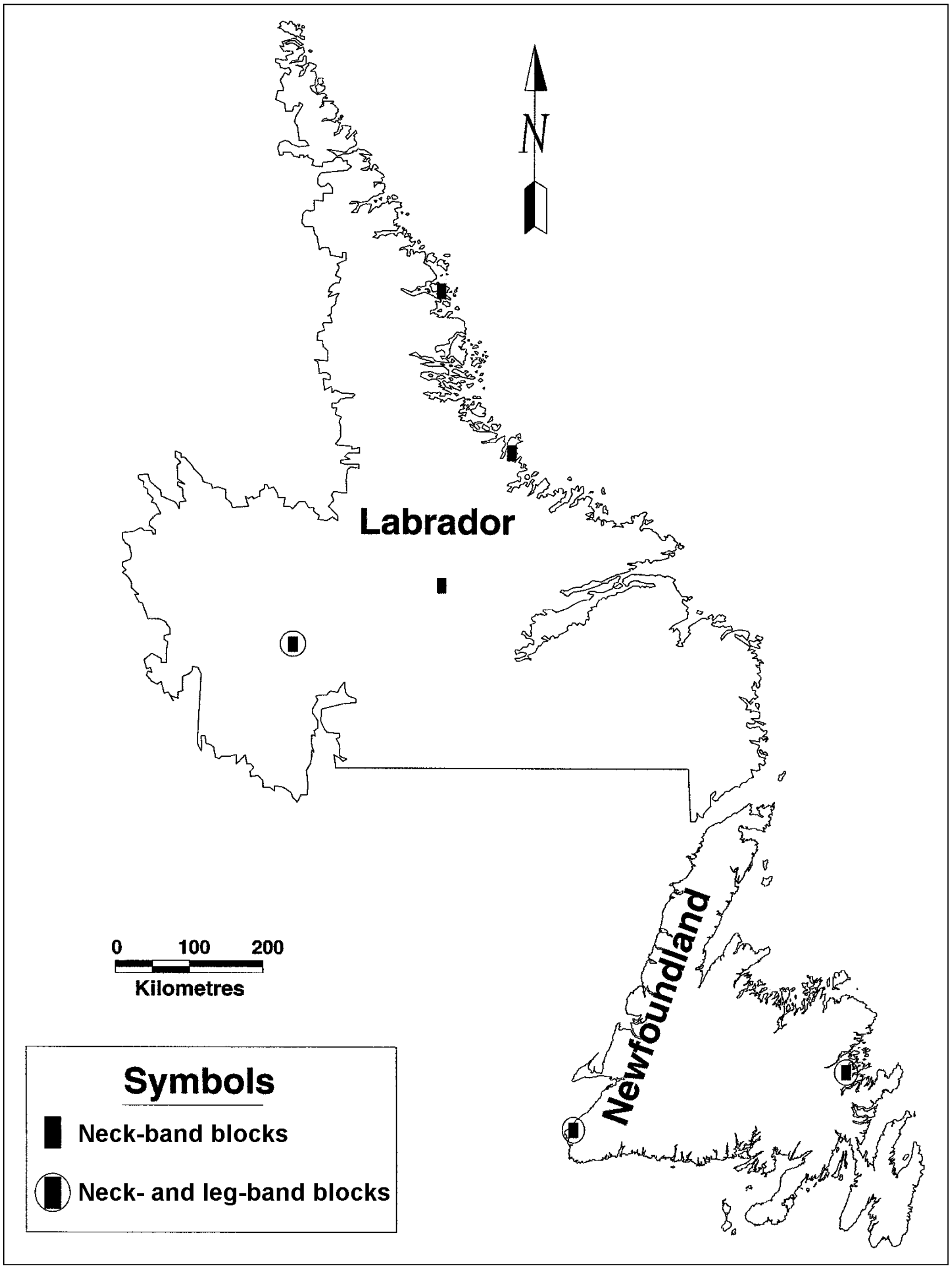
2. Methods

2.1 Leg-band data

Adult, subadult, or hatch-year Canada Geese were leg-banded during the spring or fall migration on Prince Edward Island, New Brunswick, or Nova Scotia (Fig. 2) or during the summer in Labrador or on the island of Newfoundland (Fig. 3). All geese were marked with standard aluminum leg-bands. Recoveries were restricted to normal, wild geese (status codes of 300, 304, 370, 500, 700, or 800) shot or found dead during the hunting season. There were almost no out-of-season recoveries. The recoveries during the hunting season provide an index of hunting pressure. Recoveries were combined for both sexes and all ages. Geographic distributions of band recoveries from different banding areas allow the identification of migration corridors and associations between wintering and breeding regions (Hickey 1951; Crissey 1955).

To facilitate our analyses, we grouped recoveries as originating from three regions: 1) the Maritime provinces (Prince Edward Island, Nova Scotia, and New Brunswick); 2) Labrador; and 3) the island of Newfoundland. We arbitrarily grouped recoveries as occurring during either 1920–86 or 1987 – August 1995 to detect possible temporal variation. We attempted to split the data evenly between two time periods (more of the data were recent) while ensuring that each period was long enough to provide an interesting comparison. Recovery distributions may be a misleading numerical indicator of geographic distribution, as recovery rates are not likely to be uniform across the wintering or migration areas. Variation in recovery rates may be caused by regional differences in harvest and/or reporting rates. Temporal variations in recoveries may result from changes in population affinities among regions, but may also reflect changes in hunter activity or in harvest regulations. In fact, hunting regulations in the United States did change during our study, becoming more restrictive in Maryland for the 1988–89 season, and the hunting season was closed in eastern North Carolina starting with the 1992–93 season. In addition, the regular hunting season was closed throughout the states of the U.S. Atlantic Flyway starting with the 1995–96 season.

Figure 3
Locations (10-minute blocks) of Canada Goose leg-banding and neck-banding sites in Newfoundland and Labrador



2.2 Neck-band data

Adult, subadult, and hatch-year Canada Geese were marked during spring or fall migration on Prince Edward Island, New Brunswick, or Nova Scotia and during summer in Labrador or Newfoundland island (Fig. 3). All geese were marked with a standard aluminum leg band and either an inflexible yellow tube-style neck band (1987–90) or a flexible white polyurethane cone-style neck band (1991–96). All neck bands were fastened with glue. The cone-style design was used to reduce the probability of icing mortality (E. Hayakawa, Canadian Wildlife Service, pers. commun.).

The distribution of observations of neck-collared birds can also provide an indicator of affinities between breeding and wintering regions and of migration chronology and corridors (Craven and Rusch 1983). Although observation distributions do not contain biases due to differential harvest or reporting rates among regions, they may be biased by geographic differences in observation rates. We attempted to control variation in observation rate by having personnel from each state or province survey their region completely every two weeks. This level of observation effort, however, was not possible for all states or provinces. Consequently, we developed a crude index of observation effort to assess

Table 1
Index of observation effort (IOE) for Maritime provinces and Atlantic Flyway states using total observations from June 1991 to May 1996 and total numbers of geese neck-banded from January 1991 to September 1994

Province/state	Total no. of observations of neck-bands	Total no. of neck-banded geese	IOE
Prince Edward Island	2 823	862	3.3
New Brunswick	51	58	0.9
Nova Scotia	4	5	0.8
Maine	312	290	1.1
New Hampshire	3 513	804	4.4
Vermont	455	184	2.5
Massachusetts	11 471	2 447	4.7
Rhode Island	4 643	438	10.6
Connecticut	13 994	1 466	9.5
New York	29 158	6 578	4.4
New Jersey	47 715	4 675	10.2
Pennsylvania	35 019	5 122	6.8
Delaware	11 129	652	17.1
Maryland	35 353	8 043	4.4
Virginia	10 877	3 980	2.7
North Carolina	16 646	4 230	3.9

variation in observation rate, by dividing the total number of observations during June 1991 to May 1996 by the total number of geese neck-banded from January 1991 to September 1994. The results showed low observation efforts in New Brunswick, Nova Scotia, Maine, and Vermont (Table 1), indicating that our observation distributions would be negatively biased for these states and provinces.

Multiple observations of single geese may also bias the observation distribution. To maximize the distribution while controlling for duplicate data we used observations: i) unique within state or province by time period; or ii) unique within 20-minute block by time period. For example, if a goose was observed once in Connecticut and Long Island during the third period, twice in Connecticut during the sixth period, and three times on Prince Edward Island for the eighth period, we would count that goose once for Connecticut and Long Island during the third period, once in Connecticut during the sixth period, and once for Prince Edward Island during the eighth period.

We reported observation distributions for nine time periods for geese neck-banded in the Maritimes and Labrador to estimate migration chronology. There were too few observations for geese neck-banded in Newfoundland to allow this estimation. The time periods were 16–30 September, 1–15 October, 16–30 October, 1–30 November, 1–31 December, 1–31 January, 1–28 February, 1–31 March, and 1 April – 15 May. We used observations from September 1991 to November 1996. We terminated our observation distribution at November 1996 because of the limited observation effort in the Atlantic Flyway states south of Long Island, N.Y., during the 1996–97 observation year.

The degree of similarity among wintering distributions of Maritime, western Labrador, and western Ungava Bay geese was determined by a comparison of observation distributions. Geese were neck-banded in western Labrador during the summers from 1989 to 1992 and observed from December through February 1991–96. In the Maritimes, geese were neck-banded during spring or fall migration, 1987–93, and observed during January and February 1991–96. Geese in western Ungava Bay were neck-banded during the summers from 1986 to 1989 (Menkens and Malecki 1991) and were observed during January and February 1987–96. As above, we used multiple observations among 20-minute blocks but unique within 20-minute block for the winter time period. The observation distributions were compared using the nonparametric test of Mardia (1967, pp. 197–201). The null hypothesis of no difference in wintering observation distributions for geese neck-banded in different areas was tested to compare western Ungava Bay with the Maritimes and to compare western Ungava Bay with western Labrador, using a statistic distributed as χ^2 with two degrees of freedom.

3. Results

3.1 Leg-band data

Geographic distributions of recoveries varied among banding regions and between time periods. Some of this variation was due to differences in banded samples. Unbiased recovery distributions require uniform banding and recovery rates, but banding effort was far from uniform over space or time (Table 2). For geese banded in the Maritimes during spring and fall migrations, recoveries (Fig. 4) primarily occurred in the Atlantic provinces and eastern Quebec (36% for 1920–86 and 52% for 1987–95) and New England (34% for 1920–86 and 37% for 1987–95) (Table 3). The number of recoveries declined in our southern region (DE, MD, VA, and NC) from 30% for 1920–86 to 6% for 1987–95. When only U.S. recoveries were considered, the ratio of recoveries from New England to the southern region changed between time periods from roughly 1:1 to 6:1. The temporal differences found for Nova Scotia and Prince Edward Island may have been caused by variation in banding levels.

Although scarcity of recoveries precluded estimation of temporal variation for geese banded in Labrador or Newfoundland, we did detect geographic differences between recoveries from the banded samples. Geese banded in Labrador were recovered (Fig. 5) primarily in the Atlantic provinces and eastern Quebec (32%; eastern QC [5], NB [2], LB [1]), and New England (36%; Long Island, NY [3], ME [2], NH [2], MA [2]). Geese banded in Labrador were also recovered in the southern region (24%; MD [3], DE [1], VA [1], NC [1]) and the mid-Atlantic region (8%; NJ [1], lower Hudson River, N.Y. [1]). Geese banded on the island of Newfoundland were recovered (Fig. 6) primarily in the Maritimes (85%; NS [8], NF [2], PE [1]) and secondarily in New England (15%; MA [1], Long Island, NY [1]).

3.2 Neck-band data

Large numbers of Canada Geese neck-banded in the Maritimes during the spring or fall migration were observed in the Maritimes from 16 September to 31 October and from 1 March to 15 May and in southern New England, including Long Island, from 1 November to 28 February (Table 4). Large numbers of geese remained in the Maritimes up to 30 November. Low numbers of observations occurred in New England in early October, but steadily increased to 77% in January. Moderate numbers of geese (17–20%) were also observed in the mid-Atlantic region from 1 December to 28

Table 2
Numbers of normal, wild Canada Geese leg-banded (leg) or neck-banded (neck) during spring or fall in Prince Edward Island (PE), New Brunswick (NB), or Nova Scotia (NS) or banded during summer on the island of Newfoundland (NF) or in Labrador (LB)

Time	PE		NB		NS		NF		LB	
period	leg	neck	leg	neck	leg	neck	leg	neck	leg	neck
1920s	0	0	13	0	0	0	0	0	0	0
1930s	0	0	0	0	1	0	0	0	0	0
1940s	0	0	0	0	0	0	0	0	0	0
1950s	18	0	9	0	2	0	10	0	0	0
1960s	4	0	2	0	86	0	0	0	0	0
1970s	0	0	0	0	77	0	0	0	0	0
1980s	184	205	0	0	10	0	3	9	157	29
1990s[a]	112	1440	49	77	0	5	19	54	6	37

[a] Analyses reported in this paper using recoveries from geese banded in P.E.I. during the 1990s were based on 974 bands (112 leg-bands and 862 neck-bands). Analyses using observations of neck-banded geese from the 1990s were based on 1440 neck-bands.

Figure 4
Location and number of recoveries of Canada Geese banded in the Maritime provinces during spring or fall migration

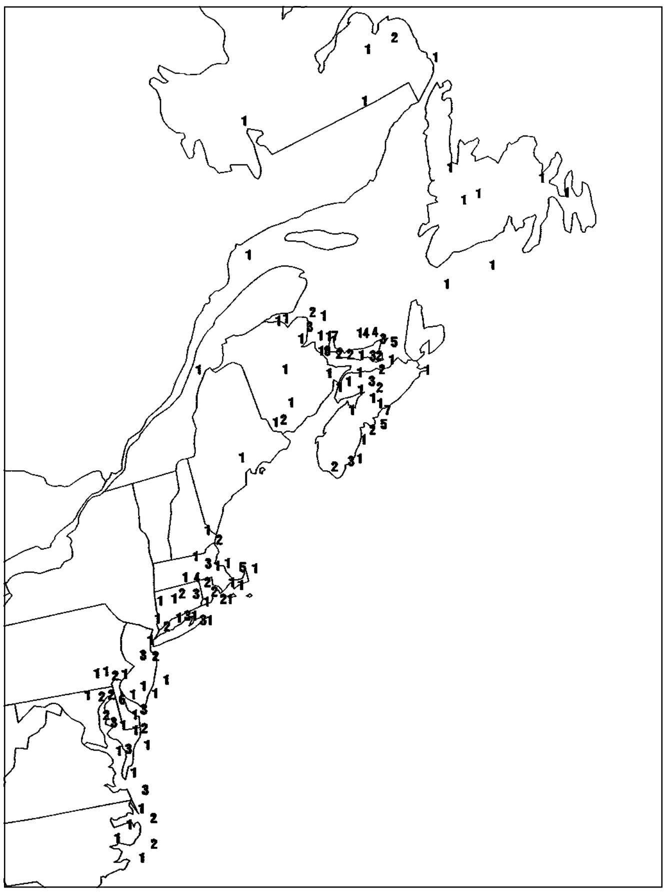


Table 3
Number and percent of recoveries of normal, wild Canada Geese leg- or neck-banded in Prince Edward Island, New Brunswick, and Nova Scotia during spring or fall and shot or found dead during the hunting seasons during 1920–86 or between 1987 and August 1995

	1920–86		1987–95	
	No.	%	No.	%
Labrador	1	1	5	2
Newfoundland island	1	1	6	3
New Brunswick	7	6	10	4
Nova Scotia	17	16	17	7
Prince Edward Island	12	11	78	34
Quebec	1	1	3	1
Subtotal	39	36	119	52
Maine	0	0	1	0
New Hampshire	0	0	1	0
Massachusetts	2	2	27	12
Rhode Island	0	0	10	4
Connecticut	1	1	13	6
Long Island, N.Y.	34	31	33	14
Subtotal	37	34	85	37
New York[a]	0	0	0	0
New Jersey	0	0	10	4
Pennsylvania	0	0	0	0
Subtotal	0	0	10	4
Delaware	6	6	6	3
Maryland	16	15	5	2
Virginia	1	1	1	0
North Carolina	9	8	2	1
Subtotal	32	30	14	6
Total	108		228	

[a] New York excluding Long Island.

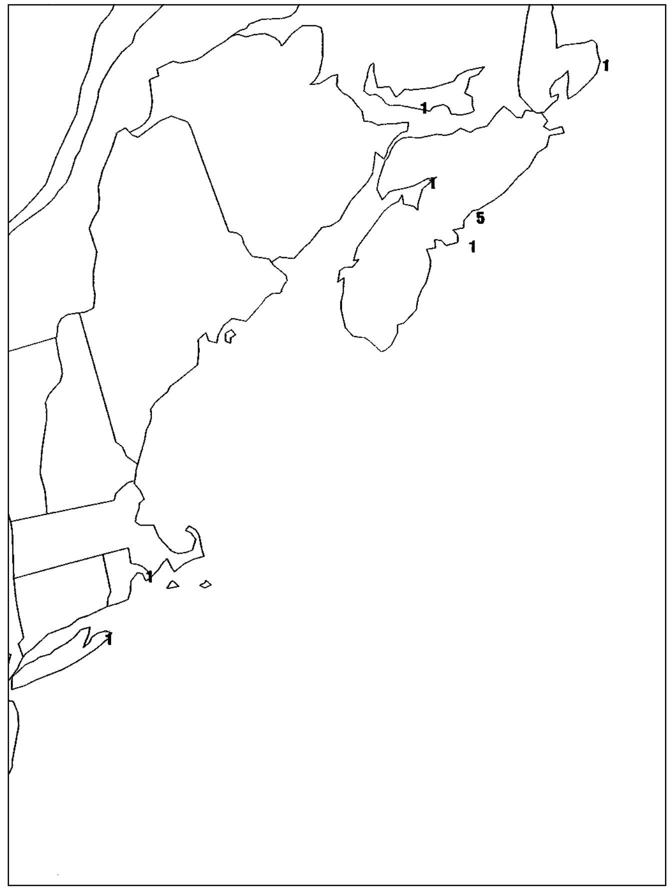
February. Low numbers (5–6%) were observed in Delaware, Maryland, Virginia, and North Carolina from 1 December to 28 February.

Canadian observations of geese neck-banded in western Labrador were primarily located in New Brunswick during the fall and Prince Edward Island during the spring (Table 5). Observations from New England started in October and remained high from November to February. Low numbers of observations occurred in the mid-Atlantic region from October to April. No observations were made in the southern region.

The observation distribution for geese neck-banded in Newfoundland was very sparse and had a negative bias for the number of geese occurring in Nova Scotia due to the low observer effort (Table 1). Observations were reported during: 1) 16–30 September on Prince Edward Island [2 geese]; 2) 16–30 October on Prince Edward Island [1 goose] and in Newfoundland [1 goose]; 3) February in Massachusetts [1

Figure 5
Location and number of recoveries of Canada Geese banded in Labrador during summers

Figure 6
Location and number of recoveries of Canada Geese banded on the island of Newfoundland during summers



goose]; and 4) 1 April – 15 May on Prince Edward Island [1 goose].

Canada Geese neck-banded in western Ungava Bay spent the winter in a different area from geese neck-banded in the Maritimes or western Labrador (Table 6). Observations during January and February of geese neck-banded during migration through the Maritimes were clustered in southern New England, Long Island, and the northeastern mid-Atlantic region (Fig. 7). Observations in December–February of geese neck-banded during summer in western Labrador were also clustered in New England, Long Island, and the northeastern mid-Atlantic region (Fig. 8). In contrast, observations in January–February of geese neck-banded in summer in western Ungava Bay were clustered in central New York, western New Jersey, southeastern Pennsylvania, and the Delmarva peninsula (Fig. 9).

4. Discussion

Geographic distributions of band recoveries and neck-band observations of Canada Geese marked in the Atlantic provinces suggested a strong association between geese banded in Labrador or Newfoundland during summer and those banded in the Maritimes during spring or fall migration. Our analysis supported the general delineation of the NAP breeding areas described by Todd (1963), Hanson and Nelson (1964), Bellrose (1980), and Erskine (1997), but suggested that the dividing line between the NAP and Ungava and Hudson Bay breeding birds was farther west than earlier suspected. The eastern boundary of the NAP has also expanded beyond that described by the earlier workers. An upsurge in breeding numbers of Canada Geese in Greenland has occurred over the past decades, so that it is now the most common breeding and summering goose in western Greenland (Bennike 1990; Fox et al. 1996). Canada Geese marked in western Greenland by Fox et al. (1996) have been recovered in Labrador and observed at Long Island (40°50'N, 72°40'W), in New Jersey (40°16'N, 74°10'W; 39°58'N, 74°10'W), and in eastern Pennsylvania (40°15'N, 74°55'W).

Our analysis also indicated that higher percentages of NAP geese winter farther north than earlier reported. Bellrose (1980) suggested that the NAP wintered from Newfoundland to North Carolina with the U.S. distribution of 50% in New England and Long Island, 10% in the mid-Atlantic, and 40% in North Carolina. In contrast, band recoveries from 1987–95 revealed a U.S. distribution of 79% in New England and Long Island, 19% in the mid-Atlantic region, and 2% in North Carolina. Observation data during 1991–96 were consistent with the recovery data showing a U.S. distribution of 77% in New England and Long Island, 22% in mid-Atlantic, and 1% in North Carolina. A northward shift is not uncommon for wintering populations of Canada Geese. Increasing percentages of individuals wintering farther north have been reported for the Mississippi Valley Population (Rusch et al. 1985), Eastern Prairie Population

Table 4
Number and percent of observations of Canada Geese from 16 September to 15 May for geese neck-banded on Prince Edward Island, New Brunswick, and Nova Scotia during spring 1987–95 and observed from September 1991 through November 1996

	16–30 Sept.		1–15 Oct.		16–30 Oct.		1–30 Nov.		1–31 Dec.		1–31 Jan.		1–28 Feb.		1–31 Mar.		1 Apr.–15 May	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
New Brunswick	6	15	1	1	2	1	3	1	0	0	0	0	0	0	0	0	1	0
Nova Scotia	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Prince Edward I.	21	54	115	71	182	59	154	44	14	8	0	0	0	0	134	53	655	98
Subtotal	27	69	116	72	184	60	157	44	14	8	0	0	1	1	134	53	656	98
Maine	0	0	0	0	4	1	0	0	0	0	0	0	1	1	0	0	0	0
New Hampshire	0	0	1	1	5	2	2	1	2	1	0	0	0	0	0	0	0	0
Massachusetts	1	3	5	3	14	5	32	9	22	12	37	20	21	11	5	2	0	0
Rhode Island	1	3	7	4	15	5	33	9	23	12	31	17	26	12	24	10	3	0
Connecticut	1	3	14	9	49	16	79	22	40	22	36	19	26	12	39	15	9	1
Long Island, N.Y.	7	18	13	8	17	6	22	6	41	23	38	21	83	39	14	6	2	0
Subtotal	10	26	40	25	104	34	168	47	128	69	142	77	157	74	82	33	14	2
New York[a]	1	3	4	2	6	2	5	1	4	2	2	1	2	1	8	3	1	0
New Jersey	0	0	0	0	11	4	18	5	20	11	26	14	34	16	16	6	0	0
Pennsylvania	0	0	0	0	0	0	1	0	9	5	3	1	5	2	4	2	0	0
Subtotal	1	3	4	2	17	6	24	7	33	18	31	17	41	20	28	11	1	0
Delaware	0	0	0	0	0	0	0	0	1	1	0	0	2	1	0	0	0	0
Maryland	1	3	1	1	3	1	2	0	5	3	10	5	7	3	4	2	0	0
Virginia	0	0	1	1	0	0	0	0	1	1	1	1	0	0	2	1	0	0
North Carolina	0	0	0	0	0	0	3	1	3	2	1	1	3	1	2	1	0	0
Subtotal	1	3	2	1	3	1	5	1	10	5	12	6	12	6	8	3	0	0
Total	39		162		308		354		185		185		211		252		671	

[a] The state of New York without Long Island.

Table 5
Number of observations of Canada Geese from 16 September to 15 May for geese neck-banded in western Labrador during summer 1987–93 and observed from April 1991 through November 1996

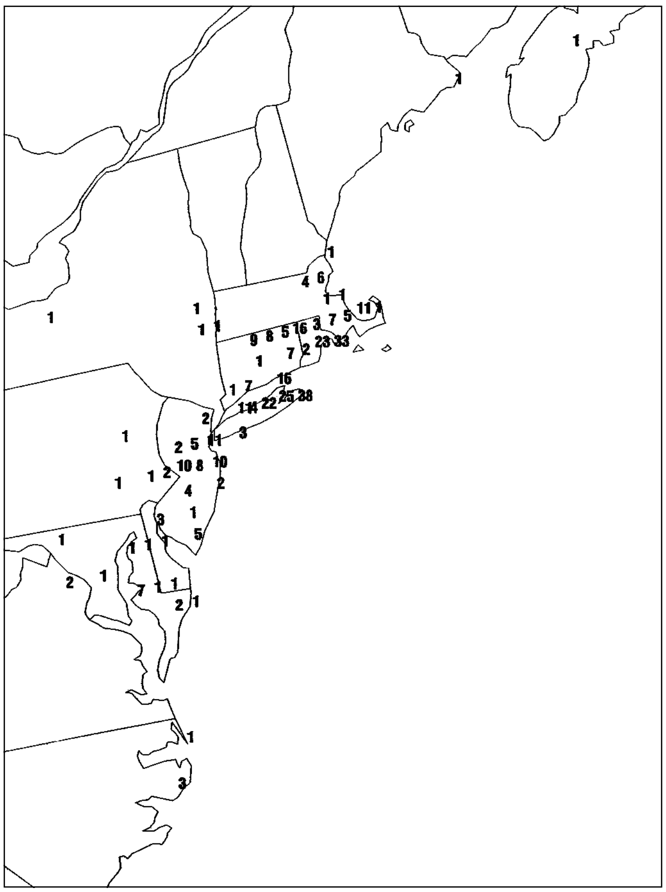
	Observation period								
	16–30 Sept.	1–15 Oct.	16–30 Oct.	1–30 Nov.	1–31 Dec.	1–31 Jan.	1–28 Feb.	1–31 Mar.	1 Apr.–15 May
New Brunswick	1	3	1	0	0	0	0	0	0
Nova Scotia	0	0	0	0	0	0	0	0	0
Prince Edward I.	0	0	0	1	0	0	0	3	10
Subtotal	1	3	1	1	0	0	0	3	10
Maine	0	0	0	0	0	0	0	0	0
New Hampshire	0	0	1	1	1	0	0	0	0
Massachusetts	0	1	0	2	1	3	1	0	0
Rhode Island	0	0	0	0	1	2	0	0	0
Connecticut	0	0	5	9	5	3	2	1	0
Long Island, N.Y.	0	0	0	1	0	3	1	1	0
Subtotal	0	1	6	13	8	11	4	2	0
New York[a]	0	1	1	0	3	0	0	1	1
New Jersey	0	0	0	2	2	0	3	0	0
Pennsylvania	0	0	0	0	0	0	1	0	0
Subtotal	0	1	1	2	5	0	4	1	1
Total	1	5	8	16	13	11	8	6	11

[a] The state of New York excluding Long Island.

Table 6
Comparison of the distributions of observations in winter of Canada Geese neck-banded in western Ungava Bay, western Labrador, and the Maritimes, using Mardia's test

Neck-banding region	No.	Mean latitude (°N)	Mean longitude (°W)	χ^2	p
Western Ungava Bay	436	39.83	75.54	383	<0.0001
Maritime provinces	369	40.94	72.79		
Western Ungava Bay	436	39.83	75.54	45	<0.0001
Western Labrador	29	41.55	72.65		

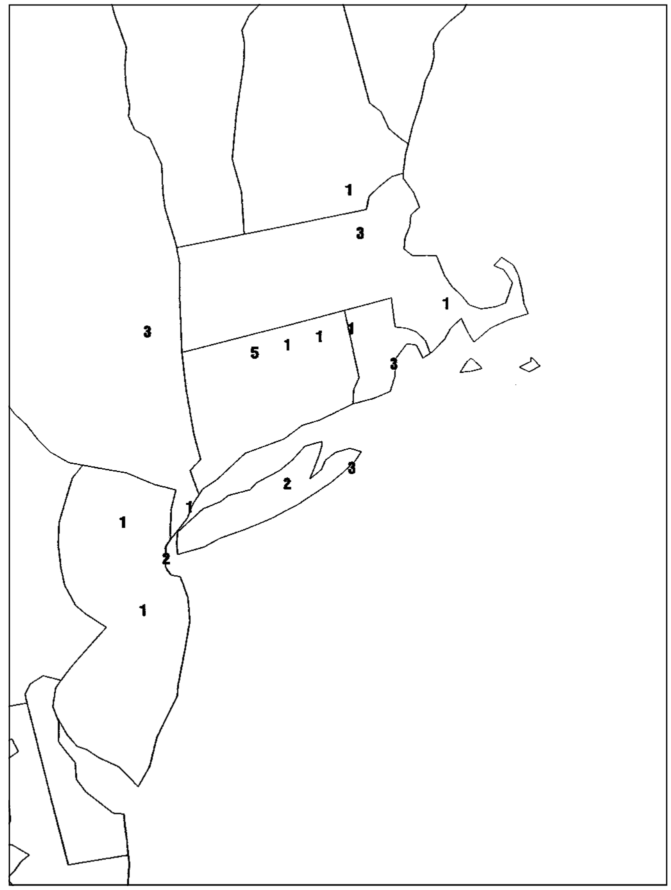
Figure 7
Location and number of observations in January–February for Canada Geese neck-banded during migration in the Maritime provinces. The numbers were plotted in the centre of 20-minute blocks.



(Humburg et al. 1985), Hi-line Population (Szymczak 1975), Rocky Mountain Population (Krohn and Bizeau 1988), and Atlantic Population (Hestbeck et al. 1991; Hestbeck 1995).

Erskine et al. (1997) reported that Canada Geese that migrate through the Maritime provinces winter from New Jersey to North Carolina, based on data collected prior to the 1990s and by mixing bandings from breeding, migration, and winter areas. Winter banding provides a biased representation of wintering ground affiliations when banding is not conducted uniformly over the entire wintering area. For the period of the Erskine et al. (1997) analysis, much larger numbers of wintering geese were banded from New Jersey to North Carolina than from southern New England or Long Island. The total number of wintering geese neck-banded

Figure 8
Location and number of observations in December–February for Canada Geese neck-banded in summer in Labrador. The numbers were plotted in the centre of 20-minute blocks.

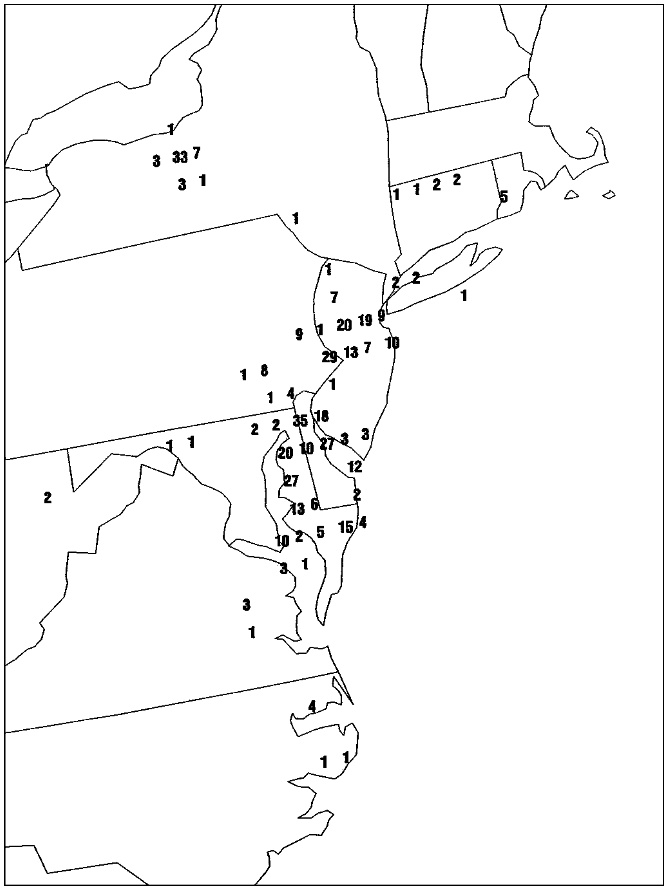


from 1983 to 1992 was 30 932 for New Jersey to North Carolina and 941 for southern New England and Long Island. Consequently, Erskine et al. (1997) would have overemphasized the New Jersey to North Carolina wintering area.

Due to this northward shift, the distribution of wintering Canada Geese was shown to be distinctly different between those neck-banded in either western Labrador or the Maritimes and those neck-banded in western Ungava Bay. Geese neck-banded in western Labrador or the Maritimes were primarily observed in southern New England and Long Island during January and February. Geese neck-banded in western Ungava Bay were observed principally in Maryland, Delaware, southeastern Pennsylvania, central New Jersey, and central New York. Erskine (1997) suggested that the wintering distributions overlapped for geese from these two regions. As noted above, Erskine (1997) reached his conclusion based on data collected prior to a recent northward shift in wintering distribution and from biases in non-uniform winter banding data.

Geographic distributions of band recoveries from different banding sites can allow the identification of migration corridors (Hickey 1951; Crissey 1955). These recovery or observation distributions may, however, be misleading if birds travelling or wintering in different areas have large differences in the probability of being detected. Examples of biased distributions can be found for giant Canada Geese (*B. c. maxima*) (Raveling 1978) and

Figure 9
Location and number of observations in January–February for Canada Geese neck-banded in summer in western Ungava Bay, northern Quebec. Numbers were plotted in the centre of 20-minute blocks.



Vancouver Canada Geese (*B. c. fulva*) (Ratti and Timm 1979). We believe that large differences in hunting pressure did not exist among Maritimes provinces and eastern Quebec, but large differences in observation effort did occur. Consequently, recovery distributions may be representative but the low number of observations from eastern Quebec, New Brunswick, and Nova Scotia would have under-represented the total number of geese moving through these areas.

With this caution, we suggest that geese banded in the Atlantic provinces migrated during the fall either through the Maritime provinces to New England, up the St. Lawrence River to New England, or up the St. Lawrence, through Lake Champlain to the lower Hudson River Valley. Geese banded in Labrador migrated using the western segments. Most recoveries occurred in eastern Quebec and New Brunswick, and no recoveries came from Prince Edward Island. For geese neck-banded in western Labrador, five observations came from New Brunswick and one from Prince Edward Island. Geese banded in Newfoundland migrated to the east, along the coast, with recoveries coming primarily from Nova Scotia and secondarily from Prince Edward Island. Geese banded during migrations in the Maritimes migrated primarily through the Maritimes to New England. Most recoveries and observations of geese marked in the Maritimes came from Prince Edward Island.

Our analysis of geese breeding in Labrador adds a migration segment farther to the west than reported by Erskine et al. (1997) and much farther to the west than described by Bellrose (1980). Our suggestions for the geese marked in the Maritimes were consistent with those reported for the NAP by Bellrose (1980) and Erskine et al. (1997). We suggest that geese marked in Newfoundland migrated primarily through Nova Scotia but also through Prince Edward Island. Bellrose (1980) and Erskine et al. (1997) reported the Nova Scotia segment only.

We also suggest that geese breeding in Labrador migrated through Prince Edward Island in the spring. All spring observations of geese neck-banded in western Labrador occurred on Prince Edward Island. Spring migrants on Prince Edward Island appeared to be more representative of the Labrador breeding population than were the fall migrants. Hence, marking spring migrants on Prince Edward Island may suffice as a sample for the NAP until breeding concentrations sufficient for an efficient banding program can be located.

A majority of geese marked in the Maritimes during migration remained in Canada until mid November and returned by mid March. Our data suggested that more than 60% of Maritimes-marked geese were present in the Maritimes during late October, more than 44% were present during November, and 53% were present in March. The percentages for the fall were negatively biased due to the lower fall observer effort in the Maritimes compared with the fall observer effort in the U.S.

Recent research has helped delineate the NAP. However, further research is needed to explore the breeding range, study population biology, estimate harvest, and decouple measurements of the NAP from an expanding population of resident Canada Geese in the Maritimes. Exploratory work is needed to locate breeding concentration sites in Labrador, insular Newfoundland, and Greenland. Surveys are needed to estimate production and size of the breeding and total population. Banding, initially during spring on Prince Edward Island and later during summer on breeding areas, is needed to estimate harvest rates and survival. This additional research with continual monitoring is essential for the suitable management of the NAP.

5. Acknowledgements

We would like to thank all federal, state, provincial, and private biologists who banded or observed geese during this study. The data would not be available without their efforts. We especially thank Rich Malecki for neck-banding Canada Geese in western Ungava Bay and coordinating the neck-band observation effort during 1983–89. We also thank Hugh Boyd, Randall Dibblee, A.J. Erskine, Paul Merola, HW Heusman, and Randy Milton for reviewing and making constructive comments on the manuscript.

6. Literature cited

Bellrose, F.C. 1980. Ducks, geese, and swans of North America. 3rd ed. Stackpole Books, Harrisburg, Pennsylvania. 540 pp.

Bennike, O. 1990. Observations of geese and other birds in West Greenland, 1989 and 1990. Dan. Ornithol. Foren. Tidsskr. 84:145–150.

Craven, S.R. and D.H. Rusch. 1983. Winter distribution and affinities of Canada Geese marked on Hudson and James bays. J. Wildl. Manage. 47:307–319.

Crissey, W.F. 1955. The use of banding data in determining waterfowl migration and distribution. J. Wildl. Manage. 19:75–84.

Erskine, A.J. 1997. The distribution patterns, movements, and affinities of Canada Geese that stage or winter in Canada's Maritime provinces. Pages 170–179 *in* Erskine, A.J. (ed.), Canada Goose studies in the Maritime provinces 1950–1992. Occas. Rep. No. 7. Environment Canada, Atlantic Region, Sackville, N.B.

Erskine, A.J., M.C. Bateman and W.R. Barrow. 1997. Movements of Canada Geese within, to, and from the Maritime provinces, shown by band recoveries and neck-collar sightings. Pages 131–154 *in* Erskine, A.J. (ed.), Canada Goose studies in the Maritime provinces 1950–1992. Occas. Rep. No. 7. Environment Canada, Atlantic Region, Sackville, N.B.

Fox, A.D., C. Glahder, C.M. Mitchell, D.A. Stroud, H. Boyd and J. Frikke. 1996. North American Canada Geese (*Branta canadensis*) in West Greenland. Auk 113:231–233.

Goudie, R.I. 1987. Preliminary estimates of waterfowl breeding populations in Newfoundland, 1978–79. Pages 36–44 *in* Erskine, A.J. (ed.), Waterfowl breeding population surveys, Atlantic provinces. Can. Wildl. Serv. Occas. Pap. No. 60.

Goudie, R.I. and W.R. Whitman. 1987. Waterfowl populations in Labrador, 1980–82. Pages 45–63 *in* Erskine, A.J. (ed.), Waterfowl breeding population surveys, Atlantic provinces. Can. Wildl. Serv. Occas. Pap. No. 60.

Hanson, H.A. and H.K. Nelson. 1964. Honkers large and small. Pages 109–124 *in* Linduska, J.P. (ed.), Waterfowl tomorrow. U.S. Fish and Wildlife Service, Department of the Interior, Washington, D.C.

Hestbeck, J.B. 1995. Population study and management of Atlantic flyway Canada Geese. J. Appl. Stat. 22:877–890.

Hestbeck, J.B., J.D. Nichols and R.A. Malecki. 1991. Estimates of movement and site fidelity using mark–resight data of wintering Canada Geese. Ecology 72:523–533.

Hickey, J.J. 1951. Mortality records as indices of migration in the mallard. Condor 53:284–297.

Humburg, D.D., D.A. Graber and K.M. Babcock. 1985. Factors affecting autumn and winter distribution of Canada Geese. Trans. North Am. Wildl. Nat. Resour. Conf. 50:525–539.

Krohn, W.B. and E.G. Bizeau. 1988. Changes in winter distribution of the Rocky Mountain Canada Goose population. Wildl. Soc. Bull. 16:272–277.

Mardia, K.V. 1967. A non-parametric test for the bivariate two-sample location problem. J. R. Stat. Soc. Ser. B, 29:320–342.

Menkens, G.E., Jr. and R.A. Malecki. 1991. Wintering sightings of Canada Geese, *Branta canadensis*, banded in northern Quebec and James Bay. Can. Field-Nat. 105:350–353.

Ratti, J.T. and D.E. Timm. 1979. Migratory behavior of Vancouver Canada Geese: recovery rate bias. Pages 208–212 *in* Jarvis, R.L. and J.C. Bartonek (eds.), Management and biology of Pacific Flyway Geese. Oregon State University, Corvallis, Oregon.

Raveling, D.G. 1978. Dynamics of distribution of Canada Geese in winter. Trans. North Am. Wildl. Nat. Resour. Conf. 43:206–225.

Rusch, D.H., S.R. Craven, R.E. Trost, J.R. Cary, R.L. Drieslein, J.W. Ellis and J. Wetzel. 1985. Evaluation of efforts to redistribute Canada Geese. Trans. North Am. Wildl. Nat. Resour. Conf. 50:506–524.

Szymczak, M.R. 1975. Canada Goose restoration along the foothills of Colorado. Colorado Division of Wildlife Technical Publication 31. 64 pp.

Todd, W.E.C. 1963. Birds of the Labrador Peninsula and adjacent areas. Carnegie Museum and University of Toronto Press, Toronto. 819 pp.

Canada Geese in the Maritime provinces

Anthony J. Erskine

Summary

This paper summarizes the findings, through 1992, of previously unpublished information examined more fully by Erskine (1997a). Canada Geese (*Branta canadensis*) migrate through and winter in Canada's Maritime provinces, a few local breeding birds having been introduced. Two discrete stocks (subgroups of Bellrose's North Atlantic population) are recognized: the Newfoundland stock, breeding (4000 pairs) on the island of Newfoundland and wintering (20 000 birds) mainly on the Atlantic coasts of Nova Scotia; and the Labrador stock, breeding (20 000 pairs) in Labrador and adjacent Quebec, staging around the southern Gulf of St. Lawrence, especially Prince Edward Island (up to 50 000 birds at once), and wintering in mid-Atlantic coastal states (along with geese from the Ungava region of northern Quebec that belong to the Atlantic population). The Labrador geese forage on farmland as well as on eelgrass and saltmarsh grasses; wintering birds (Newfoundland geese) rely largely on eelgrass. Numbers in the southern gulf increased from the 1960s to the 1980s, concurrent with adoption of field-feeding and opportunities for earlier spring staging in Prince Edward Island, and no recent decline was detected. No change in numbers was apparent in the wintering population, but a shift in geese from the Port Joli area to 20–50 km east of Halifax, N.S., has occurred since 1975.

Résumé

Le présent document résume les résultats, jusqu'à 1992, de travaux antérieurs non publiés étudiés plus profondément par Erskine (1997a). Les Bernaches du Canada (*Branta canadensis*) migrent et hivernent dans les provinces maritimes du Canada, quelques oiseaux reproducteurs locaux s'y étant ajoutés. Deux stocks discrets (des sous-groupes de la population nord-atlantique de Bellrose) sont reconnus : le stock de Terre-Neuve, qui niche (4 000 paires) sur l'île de Terre-Neuve et qui hiverne (20 000 oiseaux) surtout sur les côtes atlantiques de la Nouvelle-Écosse; et le stock du Labrador, qui niche (20 000 paires) au Labrador et dans la région adjacente du Québec, se rassemble dans le Sud du golfe du Saint-Laurent, surtout à l'Île-du-Prince-Édouard (jusqu'à 50 000 oiseaux à la fois), et hiverne dans les États côtiers du littoral central de l'Atlantique (avec les bernaches de la région de l'Ungava du Nord du Québec qui appartiennent à la population de l'Atlantique). Les bernaches du Labrador se nourrissent des produits des terres agricoles, de zostère marine et d'herbes des marais salants; les oiseaux hivernants (les bernaches de Terre-Neuve) dépendent largement de la zostère marine. Le nombre d'individus du Sud du golfe a augmenté entre les années 1960 et 1980, en même temps que l'adoption des mesures d'alimentation sur le terrain et les possibilités de rassemblement printaniers précoces à l'Île-du-Prince-Édouard, et aucun déclin récent n'a été relevé. Il n'y a eu aucun changement apparent dans le nombre d'individus des populations d'hivernage, mais depuis 1975, il y a un déplacement des bernaches de la région de Port Joli vers la Nouvelle-Écosse, de 20 à 50 km à l'est d'Halifax.

1. Introduction

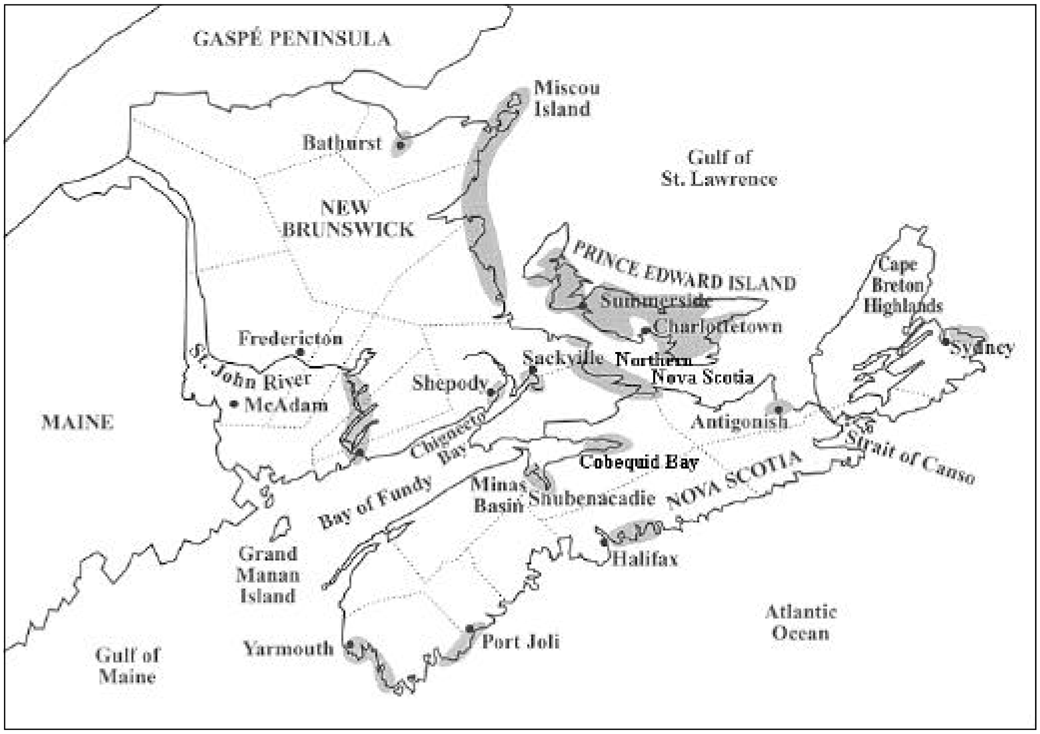
Canada Geese (*Branta canadensis*) visit the Maritime provinces (New Brunswick, Nova Scotia, and Prince Edward Island) mainly for staging and wintering. Earlier summaries for this region were based on generalities or anecdotal information, only Martin and Guignon (1983) having published on their studies. The purpose of this paper is to summarize the findings, through 1992, of previously unpublished information examined more fully by Erskine (1997a). That document should be consulted for additional details and references and for much fuller discussion of the occurrence and habits of those birds. Since 1992, more recent information on Canada Geese in the Maritime provinces has become available, and it is discussed in Bateman (this publication) and Hestbeck and Bateman (this publication).

Native breeding geese were extirpated from New Brunswick by about 1900 (references in Squires 1952), and no evidence of former breeding in Nova Scotia and Prince Edward Island has been found. The few hundreds now breeding derived mainly from planned introductions or free-flying avicultural flocks (Erskine 1992, 1997b) in all three provinces, mainly between 1960 and 1980. Only the birds breeding around McAdam, N.B., and Shubenacadie Wildlife Park, N.S., date from releases in the 1950s or earlier.

2. Regional goose stocks

Figure 1 shows areas in the Maritimes where Canada Geese stage, winter, or breed regularly. The band recoveries

Figure 1
Place names in the Maritime provinces. Shading shows areas mentioned in the text where Canada Geese stage, winter, or breed.



and neck-collar resightings through 1990 (see Erskine et al. 1997), in combination with observational evidence, indicated that two largely discrete stocks are involved. Earlier references to these geese sometimes applied the name North Atlantic Population to both Labrador and Newfoundland birds and sometimes only to the latter.

The four goose areas along the Atlantic coasts of Nova Scotia were almost unrepresented by local marking of geese or by recoveries of geese marked elsewhere. Geese in those areas breed on the island of Newfoundland and winter in Nova Scotia, with only a small proportion (<20%) reaching the United States in (recent) winters (Erskine and Payne 1997). These geese numbered some 4000 breeding pairs and about 20 000 wintering birds and are termed here the "Newfoundland stock."

All other Canada Geese that pass through the Maritimes comprise a stock that breeds separately in Labrador and adjacent parts of eastern Quebec but mingles on the winter range with (formerly) much larger numbers of geese that breed in the Ungava region of northern Quebec. These geese are here designated the "Labrador stock." Morphologically, the Labrador stock is somewhat differentiated (*B. c. canadensis*) from Ungava birds (*B. c. interior*). In form they are indistinguishable from geese of insular Newfoundland, but the migration and wintering patterns of those two groups are distinct (Erskine 1997c; Erskine et al. 1997). The few geese (max. 1200) that use the Antigonish (N.S.) area (Seymour 1997) cannot be assigned now to one stock rather than the other.

3. Feeding and habitat use

Canada Geese in the Maritimes use one or more of three foraging patterns (Erskine 1997d). First, eelgrass (*Zostera marina*) growing in shallow coastal waters is a major food plant for Canada Geese in most maritime areas. Wintering is restricted to areas where limited ice cover allows access to eelgrass beds through most of the winter (Erskine 1997a, Chapters III and IV). Second, around the upper Bay of Fundy, where silt-laden waters preclude growth of eelgrass, and to a more limited extent on other coasts, Canada Geese feed on saltmarsh grasses including *Puccinellia americana* and perhaps *Spartina* spp. (Erskine 1997a, Chapter XI). Finally, wherever extensive agricultural fields adjoin shallow coastal waters, mainly around the southern Gulf of St. Lawrence, Canada Geese have learned over the past half century to exploit agricultural wastage, including grain, corn, and potatoes (Martin and Guignon 1983). When disturbed during farmland foraging, as by hunting in fall or cultivation in spring, they retreat to nearby marine areas where eelgrass or saltmarsh grasses are available.

The farmland habitat use pattern of the Labrador stock in spring is paralleled in other eastern Canada Goose populations. These birds winter together in the mid-Atlantic states, often using agricultural areas close to coastal waters. All stage on the northernmost major agricultural areas along their migration corridors, whether in upper New York state, in the Ottawa (Ross 1984) or St. Lawrence River valleys (Reed et al. 1977; Lehoux et al. 1985), or in Prince Edward Island. Farther north, these geese fan out to breed, scattered across the open bogs and forest–tundra of northeastern Quebec, Labrador, and insular Newfoundland. In contrast, major agricultural lands are absent nearly everywhere in the range of the Newfoundland stock, which has not evolved a pattern of using farmlands, presumably owing to lack of opportunity.

4. Recent changes in distribution

All recent farmlands in the Maritimes were occupied by forests or marshes 400 years ago, and use by geese of agricultural lands here evolved since then, especially after World War II. Diminished hunting pressure, owing to stringent restrictions after 1916, when goose numbers had been reduced by unregulated harvest in the 19th century, also allowed geese in recent decades to use some areas where hunting previously had limited their foraging opportunities. Goose kill subsequently increased through 1990, especially in Prince Edward Island.

In winters of the 1960s and early 1970s, a period with sustained cold and much snow, large numbers of Canada Geese regularly staged in early spring on saltmarshes and dykelands around Chignecto Bay (shown on Fig. 1 as shaded areas at Shepody and Sackville), and also along the lower St. John River (fresh) marshes, before moving onward to Prince Edward Island in mid-April or direct to the breeding range two or three weeks later (Erskine 1997a, Chapters XI–XIII, XV). With warmer temperatures and less snow in April since about 1975, use of those intermediate staging areas in spring has dwindled to insignificant numbers (Table 1); those areas were never much used during the fall migrations.

Another impressive shift occurred among wintering areas of the Newfoundland stock. Traditionally, largest numbers, and the northernmost flock that persisted every winter, were at ice-free inlets around Port Joli, 150 km southwest of Halifax. Smaller groups attempted to winter farther northeast, but those frequently were forced by ice to leave those areas. Starting around 1975, wintering goose numbers at inlets 20–50 km east of Halifax increased and began to persist throughout the winters; about that time, those areas began to remain ice-free all winter. At the same time, wintering goose numbers around Port Joli declined by an equivalent number (compare Tables 2 and 3; Erskine 1997a, Chapters II, III, V, VI). An impression of “milder recent winters” is widely held, but climatic data did not confirm such warming (Erskine 1997a, Chapter XX). The possibility of more variable weather, resulting in more frequent thaws that remove snow cover and perhaps ice cover, without change in mean temperatures, remains to be explored rigorously. A game sanctuary 50 km east of Halifax, formally established in 1974, now provides refuge from hunting in that area. Refuge without adequate ice-free foraging areas nearby will not hold geese through the winter, as a migratory bird sanctuary existed in the Cape Breton Island goose area from 1939 without wintering becoming regular there.

Table 1
Approximate peak numbers of Canada Geese belonging to the southern Gulf of St. Lawrence/Labrador stock that stage in the Maritime provinces (Erskine 1997a)

	Spring		Fall	
	1960s	1980s	1960s	1980s
Prince Edward Island	15 000	32 000	8 000	26 000
Northern Nova Scotia	1 000	1 000	5 000	5 000
Eastern New Brunswick	1 000	1 000	5 000	10 000
Minas Basin–Cobequid Bay	2 000	7 000	1 000	2 000
Sackville area (NS/NB border marshes)	5 000	1 000	300	300
Shepody area	4 000	500	200	200
Lower St. John River	3 000	500	1 000	1 000
Total	31 000	43 000	20 500	44 500

Table 2
Chronology and numbers of Canada Geese in coastal inlets 20–50 km east of Halifax, Nova Scotia, summarized from *N.S. Bird Society Newsletter* and *Nova Scotia Birds*, September to April 1955–92 (Erskine 1997a, Chapter VI). The three highest estimates in different years (records were not available for three years in all months) are shown.

Month	1955–75	1976–92
September	50, 125, 150	n.d.[a]
October	150, 240, 700	1500, 1800, 2500
November	600, 900, 1000	1000, 2000, 2150
December	2000, 2350, 3220	6063, 6606, 10 666
January	200, 200, 1500	4050, 5000, 5000
February	250, 650	3500, 4000, 5000
March	4000, 4000, 5500	7000, 8000, 9850
April	300, 1000	3000

[a] n.d. = no data reported.

Table 3
Summary of midwinter goose numbers in the Port Joli area, from data tabulated by Erskine (1997a, Chapter V). January counts (Midwinter Waterfowl Inventory) used when available, with late-December counts (Christmas Bird Counts) for years with no January data; only the highest count in a year shown.

	No. of years in period with maximum counts in each range				
Period	<2000	2000–3000	3000–4000	4000–5000	>5000
1914–31[a]		1	1	1	2
1945–49[a]		2		1	1
1950–54			1	1	3
1955–59	1	1			3
1960–64	1			3	1
1965–69	1		2	1	1
1970–74		2	1		2
1975–79	4	1			
1980–84	2	1	2		
1985–89	2	2	1		
1990–92	1	1	1		

[a] Data available for only five winters during 1914–31 and for four winters during 1945–49. All other winters had relevant counts.

5. Population size

Despite many surveys of staging or wintering areas, data from the Maritimes give only general impressions of long-term trends. No suggestion of substantial change in numbers of the Newfoundland stock emerged between 1960 and 1990, only the partial shift to wintering east of Halifax rather than near Port Joli (noted above). For the Labrador stock, evidence, though incomplete and unstandardized, suggested an important increase between the 1960s and 1980s (Table 1). The ongoing but weakly standardized fall surveys around Prince Edward Island (Table 4; Erskine 1997a, Chapter IX) gave no suggestion of an obvious decrease after 1984, when decline in overall numbers of the Atlantic Population Canada Geese was first detected. In the absence of inclusive surveys, the following estimates of Canada Goose numbers in the Maritimes (Erskine 1997, Chapter XXI) provide perspective.

Table 4
Number of Canada Geese on fall aerial surveys in Prince Edward Island, 1953–92; data for coastal survey blocks summarized into major sectors[a] (Erskine 1997a, Chapter IX)

Month year-day	Number of geese in sector[a] NW	NC	E	SCE	SCW	SW	Total[b]
(a) September							
1965 - 29	15	3	0	350	35	0	403
1966 - 29	75	700	0	850	0	0	1 625
1970 - 17	89	314	0	502	88	156	1 149
1974 - 23	55	0	0	978	222	90	1 345
(b) October							
1953 - 9	69	185	0	183	—	—	437
1965 - 14	531	75	0	500	0	75	1 181
1966 - 18	1 675	2 935	25	1 000	444	450	6 604
1967 - 27	1 449	1 607	80	755	—	553	4 444
1968 - 28	3 267	725	45	—	679	745	5 461
1969 - 16	(2 886)[c]			(2 318)[c]			5 194
1970 - 21	2 017	1 494	109	1 796	1 314	733	7 463
1972 - 10	2 418	1 938	—	2 518	350	384	7 608
1987 - 27	6 933	3 004	3 456	3 763	6 383	2 797	26 336
(c) November							
1967 - 27	996	841	105	685	140	415	3 182
1969 - 19	2 065	1 301	250	1 775	1 801	1 030	8 737
1970 - 18	3 131	2 115	276	1 911	2 346	841	10 620
1971 - 19	1 572	843	125	519	301	246	3 506
1972 - 19	4 268	1 114	180	1 201	1 077	1 059	9 014
1973 - 17	4 065	841	318	1 543	1 278	222	8 492
1973 - 27	688	696	—	—	790	65	2 239
1975 - 18	4 881	2 295	0	—	2 060	460	9 721
1976 - 17	4 065	841	80	1 740	1 351	222	8 299
1976 - 19	4 268	1 106	95	1 316	1 077	1 053	8 915
1977 - 23	5 342	1 889	167	3 903	2 792	1 037	15 130
1978 - 21	5 600	2 842	1 145	2 673	2 640	2 541	17 411
1979 - 20	5 647	2 172	1 417	4 290	2 091	2 568	18 260
1982 - 19	4 791	2 219	3 358	3 852	1 951	2 243	18 414
1987 - 15	3 333	1 796	3 684	3 008	3 590	1 783	17 296
1988 - 24	5 223	1 526	2 336	2 955	3 857	1 466	17 066
1990 - 15	3 422	1 811	495	2 313	1 404	761	10 206
1992 - 10	3 074	1 755	2 731	1 943	4 017	1 600	15 120
(d) December							
1969 - 16	(825)[b]			(3 300)[b]			4 125
1976 - 1	9 989	2 980	739	5 351	5 855	1 091	26 005
1987 - 15	3 645	1 159	893	573	1 437	1 145	8 852

[a] Key to sectors (survey block numbers in parentheses):
NW = Alberton to Darnley (blocks 382–385);
NC = New London to St. Peter's bays (386–390);
E = East Point to Murray Harbour (395–404);
SCE = Pinette River to Charlottetown (406–410);
SCW = Charlottetown to Summerside (411–413);
SW = Miscouche to West Point (414–416).

[b] Totals include a few records in other coastal blocks where geese were noted too seldom to warrant tabulation.

[c] Numbers available only as totals for north and south (the latter including east) shores.

5.1 Newfoundland stock

Peak counts during spring in Cape Breton, N.S., may represent one-third to one-half of the total spring flight up the Atlantic coast. With peaks of 5000–6000 geese reported there, the spring flight through Cape Breton might total 10 000–18 000 birds, equivalent to 2600–4700 breeding pairs (using conversion factors from Erskine [1987]).

A second estimate was derived from combined maximum wintering totals in the Yarmouth, Port Joli, Halifax County, and Sydney areas. These totalled 12 000–15 000 geese, perhaps including 10–20% heading for Labrador. With the latter deducted, and with 2000–3000 birds that continued from Yarmouth County into New England (or farther south) added, the estimates of 11 600–16 500 geese fell entirely within the range derived from Cape Breton spring counts.

Breeding ground surveys in insular Newfoundland (Goudie 1987) suggested 3000–4000 pairs of Canada Geese, and an earlier survey there in 1968 (Gillespie and Roberts, Canadian Wildlife Service, Atlantic Region, unpubl.) gave an estimate of 3800 pairs plus 4400 nonbreeding birds, in the same range as recent estimates based on spring migrants and wintering geese. Those estimates confirmed that the migrant and wintering groups here identified with the Newfoundland stock included numbers similar to those of geese breeding there.

5.2 Labrador stock

The peak spring estimates for geese in the southern Gulf of St. Lawrence were: 1000 (composite of several years) in northern N.S., 32 128 (1983) in P.E.I., and 1000 (composite of several years) in eastern N.B. Assuming that the total flight was two to three times the maximum present at one time, those figures suggested 70 000–100 000 geese returning to Labrador in spring, equivalent to 17 500–25 000 breeding pairs (conversion factors from Erskine [1987]).

The peak fall counts provided another estimate, with: 3711 (mid-Nov./74) in northern N.S., 26 336 (late Oct./87) in P.E.I., 3393 (mid-Nov./73) in eastern N.B., and 5810 (late Oct./87) in the area of Bathurst, N.S. These counts combined for a total of 39 250 (unadjusted), suggesting at least 80 000 and likely 120 000 or more in the fall flight, equivalent to 12 000–18 000 breeding pairs. Goudie and Whitman (1987) estimated a Labrador breeding population of 22 550 ± 8900 breeding pairs of Canada Geese, which is equivalent to a fall flight of 153 000 ± 60 300 geese. Bateman (this publication) estimated, from aerial surveys of southern Labrador in summers 1993–94, goose populations including some 28 000 (± SE 4200) breeding pairs, suggesting no decrease since the early 1980s.

5.3 Summary of population size

All of these crude estimates for each stock were of similar order of magnitude. Given that none of the parameters used in relating breeding pairs to spring or fall flights was estimated in the Atlantic Region, the agreement between the various estimates for each stock was surprisingly close. Much lower estimates, derived from very low intensity aerial sampling in Labrador and Newfoundland in 1992 (Malecki et al. 1995), were not supported by this accumulated evidence.

6. Conclusion

The Atlantic provinces (comprising the Maritimes plus Newfoundland and Labrador) have never been perceived as holding a major concentration of Canada Geese. Malecki and Trost (1990) estimated that close to 90% of the

Canada Geese of the Mid-Atlantic Population bred in the western Ungava region of northern Quebec. Their surveys did not overlap with those of Gillespie and Wetmore (1974) and of Goudie and Whitman (1987) in Labrador and adjacent parts of Quebec. Estimates from the latter sources suggested those areas harboured about 15% of the (former) combined total for Ungava and Labrador, a minor proportion, but (by plausible extrapolation) giving rise to fall flights of the order of 100 000–150 000 geese.

The conclusion, that the Canada Goose stocks that stage and winter in the Maritimes are stable or increasing in numbers, was not based on rigorous statistical treatment of standardized data. Such data do not now exist on any broad scale, and there is no realistic prospect of obtaining them in the future. The accumulated evidence from many kinds of surveys over more than 40 years provided a reasonably consistent picture, with few anomalies. Long-term familiarity with most of these goose flocks, giving rise to several independent but similar estimates, may be preferable to reliance on single surveys of uncertain significance. We look forward with interest to the results of localized studies now under way on Canada Geese in Newfoundland and Labrador.

7. Literature cited

Erskine, A.J. (ed.). 1987. Waterfowl breeding population surveys, Atlantic provinces. Can. Wildl. Serv. Occas. Pap. No. 60. 80 pp.

Erskine, A.J. 1992. Atlas of breeding birds of the Maritime provinces. Nimbus Publishing Ltd. and Nova Scotia Museum, Halifax. 270 pp.

Erskine, A.J. (ed.). 1997a. Canada Goose studies in the Maritime provinces 1950–1992. Occas. Rep. No. 7. Environment Canada, Atlantic Region, Sackville, New Brunswick. 179 pp.

Erskine, A.J. 1997b. Wild-breeding Canada Geese in the Maritime provinces. Pages 124–127 *in* Erskine, A.J. (ed.), Canada Goose studies in the Maritime provinces 1950–1992. Occas. Rep. No. 7. Environment Canada, Atlantic Region, Sackville, New Brunswick.

Erskine, A.J. 1997c. The distribution patterns, movements, and affinities of Canada Geese that stage or winter in Canada's Maritime provinces. Pages 170–179 *in* Erskine, A.J. (ed.), Canada Goose studies in the Maritime provinces 1950–1992. Occas. Rep. No. 7. Environment Canada, Atlantic Region, Sackville, New Brunswick.

Erskine, A.J. 1997d. Feeding and habitat use by Canada Geese in the Maritime provinces. Pages 128–130 *in* Erskine, A.J. (ed.), Canada Goose studies in the Maritime provinces 1950–1992. Occas. Rep. No. 7. Environment Canada, Atlantic Region, Sackville, New Brunswick.

Erskine, A.J. and F. Payne. 1997. Canada Geese staging and wintering in Yarmouth County, Nova Scotia. Pages 14–16 *in* Erskine, A.J. (ed.), Canada Goose studies in the Maritime provinces 1950–1992. Occas. Rep. No. 7. Environment Canada, Atlantic Region, Sackville, New Brunswick.

Erskine, A.J., M.C. Bateman and W.R. Barrow. 1997. Movements of Canada Geese within, to, and from the Maritime provinces, shown by band recoveries and neck-collar sightings. Pages 131–154 *in* Erskine, A.J. (ed.), Canada Goose studies in the Maritime provinces 1950–1992. Occas. Rep. No. 7. Environment Canada, Atlantic Region, Sackville, New Brunswick.

Gillespie, D.I. and S.P. Wetmore. 1974. Waterfowl surveys in Labrador–Ungava, 1970, 1971, 1972. Pages 8–18 *in* Boyd, H. (ed.), Canadian Wildlife Service waterfowl studies in eastern Canada, 1969–73. Can. Wildl. Serv. Rep. Ser. No. 29.

Goudie, R.I. 1987. Preliminary estimates of waterfowl breeding populations in Newfoundland, 1978–79. Pages 36–44 *in* Erskine, A.J. (ed.), Waterfowl breeding population surveys, Atlantic provinces. Can. Wildl. Serv. Occas. Pap. No. 60.

Goudie, R.I. and W.R. Whitman. 1987. Waterfowl populations in Labrador, 1980–82. Pages 45–63 *in* Erskine, A.J. (ed.), Waterfowl breeding population surveys, Atlantic provinces. Can. Wildl. Serv. Occas. Pap. No. 60.

Lehoux, D., A. Bourget, P. Dupuis and J. Rosa. 1985. La sauvagine dans le système du Saint-Laurent. Environment Canada, Canadian Wildlife Service, Quebec Region. 76 pp. + 72-p. appendix.

Malecki, R.A. and R.E. Trost. 1990. A breeding ground survey of Atlantic Flyway Canada Geese, *Branta canadensis*, in northern Quebec. Can. Field-Nat. 104:575–578.

Malecki, R.A., R.E. Trost and J.R. Goldsberry. 1995. An aerial survey of nesting Canada Geese in Labrador and Newfoundland. Northeast Wildl. 52:71–76.

Martin, K. and D. Guignon. 1983. Canada Goose numbers, daily movements and foraging patterns on Prince Edward Island. Proc. N.S. Inst. Sci. 33:107–114.

Reed, A., G. Chapdelaine and P. Dupuis. 1977. Use of farmland in spring by migrating Canada Geese in the St. Lawrence valley, Quebec. J. Appl. Ecol. 14:667–680.

Ross, R.K. 1984. Migrant waterfowl use of the major shorelines of eastern Ontario. Pages 53–62 *in* Curtis, S.G., D.G. Dennis and H. Boyd (eds.), Waterfowl studies in Ontario, 1973–81. Can. Wildl. Serv. Occas. Pap. No. 54.

Seymour, N. 1997. Distribution, abundance and activity of migrant Canada Geese in Antigonish Harbour, Nova Scotia. Pages 70–80 *in* Erskine, A.J. (ed.), Canada Goose studies in the Maritime provinces 1950–1992. Occas. Rep. No. 7. Environment Canada, Atlantic Region, Sackville, New Brunswick.

Squires, W.A. 1952. The birds of New Brunswick. N.B. Mus. Monogr. Ser. No. 4. 164 pp.

Inventaire des couples nicheurs de Bernaches du Canada dans le Nord québécois

Louis Breton, André Bourget, et William F. Harvey

Résumé

Des inventaires aériens de Bernaches du Canada mis en place en 1988 sont maintenant réalisés sur une base annuelle depuis 1993 dans la péninsule d'Ungava. La population de bernaches qui y niche a subi une chute importante d'environ 75 % entre 1988 et 1995 mais, en 1997, à la suite des restrictions de la chasse sportive établies au Canada et aux États-Unis, les effectifs ont plus que doublé par rapport à leur niveau le plus bas. On retrouve les densités de bernaches les plus élevées dans les zones côtières de la péninsule, le secteur le plus productif étant localisé le long du littoral de la baie d'Hudson où l'on rencontre 80 % des oiseaux nicheurs. Cette partie du territoire semble offrir des conditions plus favorables qu'ailleurs dans la péninsule d'Ungava pour assurer le succès de la reproduction sur une base plus régulière. De même, 91 % des bernaches non reproductrices qui viennent dans le territoire pour la mue utilisent aussi la zone côtière de la baie d'Hudson.

Summary

Aerial surveys of Canada Geese breeding in the Ungava Peninsula were implemented in 1988 and have been carried out annually since 1993. The population of breeding geese experienced a major decline (about 75%) between 1988 and 1995; however, in 1997, after recreational hunting was restricted in Canada and the United States, the nesting population more than doubled in comparison with its lowest level. The highest goose densities are found along the coast of the peninsula, the most productive sector being along the Hudson Bay shore, where 80% of the breeding birds are found. Conditions in that part of the territory seem to be more propitious than those elsewhere in Ungava for success of reproduction on a regular basis. Moreover, 91% of the nonbreeding geese that come to the area for moulting also use the Hudson Bay coast.

1. Introduction

Jusqu'à tout récemment, le suivi de l'état des diverses populations de Bernaches du Canada (*Branta canadensis*) qui utilisent la voie de migration de l'Atlantique s'est fait principalement à partir d'inventaires aériens effectués au milieu de l'hiver dans les aires d'hivernage (Hindman et Ferrigno, 1990). Au cours de la période de 1960 à 1980, selon les estimations, le niveau de population de Bernaches du Canada hivernant dans la voie de migration de l'Atlantique avait plus que doublé. Depuis 1985, le niveau de population enregistré dans les relevés de la mi-hiver a diminué d'environ 60 % du niveau enregistré au début des années 1980. D'autre part, au cours de la même période, le nombre de bernaches dites « résidentes », soit des oiseaux qui ne migrent pas vers le nord pour se reproduire et qui hivernent dans les mêmes régions que les bernaches migratrices, a augmenté de façon phénoménale. Des inventaires récents effectués dans les États de la côte Atlantique et du Nord-Est américain indiquent que les effectifs reproducteurs chez les bernaches résidentes ont augmenté de 219 % entre 1989 et 1995 (Hindman et coll., 1996).

On peut donc conclure que l'accroissement du nombre de bernaches résidentes présentes dans les aires d'hivernage en même temps que les migratrices masque vraisemblablement une plus forte baisse des populations de migratrices que ne l'indiquent les relevés de la mi-hiver depuis 1985. La préoccupation que suscite cette baisse rend donc d'autant plus nécessaire l'établissement d'inventaires sur les lieux de reproduction des régions nordiques, où il n'y a aucune bernache résidente, donc aucun risque de confusion.

Les données quantitatives sur les niveaux des populations reproductrices de sauvagine dans l'est de l'Amérique du Nord ont toujours fait défaut, et le cas de la Bernache du Canada ne fait pas exception. Ce n'est qu'au début des années 1960 que des inventaires exploratoires ont été dressés pour évaluer la distribution et l'abondance relative de diverses espèces. Ainsi Kaczynski et Chamberlain (1968) ont montré que la péninsule d'Ungava, dans le nord du Québec, représentait la région la plus importante pour la nidification des Bernaches du Canada qui empruntent la voie de migration de l'Atlantique. Par la suite, pendant plus de 20 ans, aucun relevé des populations reproductrices de Bernaches de Canada n'a été effectué dans l'ensemble du nord du Québec. Ce n'est qu'en 1988 que Malecki et Trost (1990) ont fait un premier inventaire afin de mieux quantifier le nombre de couples nicheurs dans l'ensemble de la forêt boréale et de la péninsule d'Ungava, par suite des craintes suscitées par les baisses enregistrées dans l'indice du niveau des populations hivernantes. Leurs résultats ont confirmé les observations de Kaczynski et Chamberlain (1968) et ont démontré que les populations les plus denses de bernaches nicheuses se trouvent dans une bande localisée le long des côtes de la baie d'Ungava et de la baie d'Hudson. C'est à partir de 1993 qu'un programme conjoint du Service canadien de la faune, de l'US Fish & Wildlife Service et du Conseil de la voie de migration de l'Atlantique a été mis en œuvre afin d'effectuer des relevés annuels dans le nord du Québec en utilisant les méthodes mises au point par Malecki et Trost (1990) et Bordage et Plante (1993). Ces relevés ont pour but de d'évaluer et de suivre l'état de la population de bernaches migratrices par l'estimation du nombre de couples nicheurs à chaque année. Cet article présente les résultats des relevés effectués sur les lieux de reproduction depuis la première série d'inventaires amorcée en 1988.

2. Zone d'étude

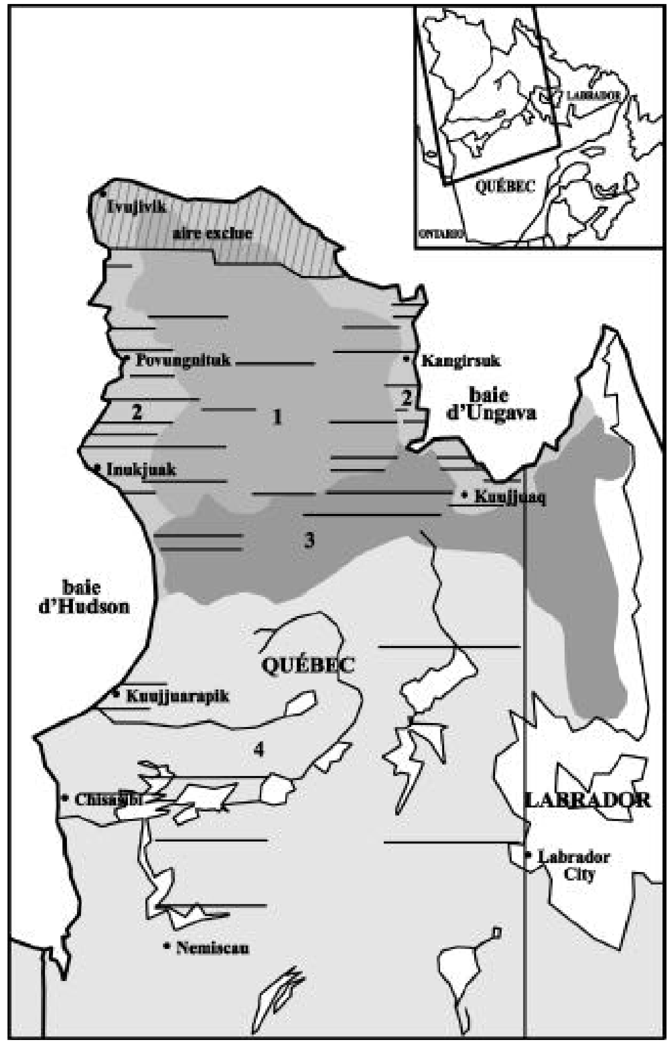
La zone d'inventaire dans le nord du Québec comprend approximativement tout le territoire situé au nord du 51e degré de latitude et à l'ouest du 67e degré de longitude (figure 1). Elle a été stratifiée en quatre régions par Malecki et Trost (1990), suivant les écorégions du Nord québécois décrites par Gilbert et coll. (1985). La région 1 correspond à la toundra de l'intérieur caractérisée par la présence de grandes quantités de blocs erratiques à la surface du sol. La région 2 est formée de toundra côtière plate avec de nombreux étangs; une partie de la zone côtière, soit la pointe nord de la péninsule allant d'Ivujivik jusqu'à 150 kilomètres environ au nord de Kangirsuk n'est pas couverte par l'inventaire (figure 1, aire exclue), car des relevés aériens exploratoires effectués en 1993 ont indiqué que cette zone montagneuse est peu fréquentée par les bernaches (Bordage et Plante, 1993). La région 3 représente une zone de transition composée surtout de lichens et de quelques arbres rabougris, entre la forêt boréale et la toundra. Les trois régions précédemment décrites composent donc le territoire appelé « péninsule d'Ungava » et sont recensées annuellement (figure 1).

La forêt boréale (région 4), comprise à peu près entre les 51e et 57e degrés de latitude, a été couverte seulement pendant les inventaires de 1988, de 1993 et de 1996, mais pas dans ceux de 1994, de 1995 et de 1997. La densité de bernaches nicheuses y est relativement faible (Malecki et Trost, 1990; Bordage et Plante, 1993) et celle-ci varie peu d'une année à l'autre (Reed, 1994). C'est pourquoi cette région n'est pas couverte de façon régulière et il est prévu de ne l'inclure dans l'inventaire que tous les trois ans.

3. Méthodes

Les inventaires sont effectués d'après la méthode décrite par Malecki et Trost (1990). Nous survolons les transects à bord d'un avion à ailes hautes, à 30 mètres d'altitude et à une vitesse-sol d'environ 140 km/h. Différents modèles d'avion ont été utilisés au cours des premières années de l'inventaire, mais, depuis 1995, nous utilisons un bimoteur Partenavia. Deux observateurs, un à la place du copilote à droite de l'appareil et le second assis derrière le pilote à gauche de l'appareil, enregistrent sur magnétophone le nombre de bernaches solitaires, de couples et de groupes (formés d'au moins trois individus) aperçus à moins de 200 mètres de chaque côté de l'avion. La largeur des transects a fait l'objet d'une calibration avant le début de l'inventaire afin d'établir la fenêtre d'observation de chaque personne. Depuis 1995, nous utilisons un système de positionnement GPS pendant les survols de tous les transects afin de faciliter la navigation.

Figure 1
La zone d'inventaire dans le Nord québécois, les quatre régions et les transects survolés



Depuis 1994, nous survolons les mêmes transects, ce qui nous permet de mieux cerner les différences d'une année à l'autre. La longueur totale des transects à survoler dans chaque région a été déterminée par estimation de la variance par rapport à l'inventaire de 1993 et à partir d'un coefficient de variation cible de 10 % (Bordage et Plante, 1994). Les transects ont été localisés au hasard dans les diverses régions jusqu'à ce que la longueur totale requise soit atteinte. Tous les transects sont orientés dans l'axe est-ouest.

Le nombre de couples nicheurs estimé dans un transect donné équivaut à la somme des oiseaux solitaires et des couples dénombrés par les deux observateurs sur toute la longueur du transect. L'estimation de la densité des couples nicheurs dans chaque région est basée sur un estimateur par quotient tandis que celle de la taille de la population totale provient d'un estimateur par quotient stratifié séparé (Cochran, 1977). Les variances ont été estimées par la technique du « jackknife » (Cochran, 1977). Les estimations de populations présenté ici ne sont pas corrigées en fonction d'un facteur de visibilité; elles ne représentent donc qu'un indice de la population.

4. Résultats

4.1 Conditions de l'habitat

Depuis le début du programme de suivi annuel amorcé en 1993 dans le nord du Québec, les transects sont survolés durant la seconde moitié de juin (tableau 1). Cela représente cependant un délai d'environ trois semaines par rapport au premier inventaire effectué par Malecki et Trost (1990). Ce délai a pour but de maximiser le nombre de couples observés le long de chacun des transects.

Les conditions de dégel printanier sont assez variables d'une année à l'autre dans le territoire de l'Ungava. En général, dans la seconde moitié de juin, 75 % de la superficie des grands plans d'eau sont gelés et il y a encore de la glace sur quelques petits étangs; seule la végétation herbacée près de ces derniers et la végétation arbustive localisée dans les dépressions commencent à montrer des signes de croissance. Cependant, les deux dernières années ont représenté des extrêmes : en 1996, le dégel s'est fait très tardivement et en 1997, très hâtivement. Ainsi, en 1996, les seules zones d'eau libre observées sur le territoire se trouvaient dans certaines des parties de petits étangs à moins de 15 kilomètres environ de la côte de la baie d'Ungava alors que la zone littorale de la baie d'Hudson était un peu plus dégagée, mais avec toujours au moins un tiers des petits étangs encore gelés. Par contre, en 1997, le peu de neige au cours de l'hiver et les températures printanières plus élevées ont occasionné un dégel rapide des grands plans d'eau. Une végétation bien développée partout dans la péninsule confirmait le passage d'un printemps chaud et clément.

Au cours de chacune des années d'inventaire, la croissance de la végétation et le taux de dégel des petits plans d'eau ont permis d'observer que les conditions climatiques du côté de la baie d'Hudson étaient meilleures que celles du côté de la baie d'Ungava. De façon générale, la végétation est plus avancée le long de la baie d'Hudson qu'elle ne l'est du côté de la baie d'Ungava, et certains étangs sont complètement asséchés dans la zone côtière de la baie d'Hudson.

Tableau 1
Périodes d'inventaire des couples de Bernaches du Canada dans le Nord québécois[a] en 1988 et de 1993 à 1997

Année	Période d'inventaire
1988	Du 23 mai au 3 juin
1993	Du 11 au 21 juin
1994	Du 21 juin au 1er juillet
1995	Du 18 au 24 juin
1996	Du 17 au 25 juin
1997	Du 21 au 26 juin

[a] En 1988, 1993 et 1996, l'inventaire de la forêt boréale a eu lieu avant celui de la péninsule d'Ungava.

4.2 Estimation du nombre de couples nicheurs et de la population totale

4.2.1 Péninsule d'Ungava (écorégions 1, 2 et 3)

On a estimé à 63 216 le nombre de couples nicheurs dans la péninsule d'Ungava en 1997, comparativement à 46 058 en 1996 (tableau 2, figure 2). Ce nombre représente donc une augmentation significative (P = 0,032) de 37 % par rapport à l'année précédente, ce qui est inférieur à l'augmentation enregistrée en 1996 (+ 59 %) par rapport à la situation de 1995. Depuis maintenant deux ans, on a observé que le nombre de couples a augmenté sur 2/3 des 36 transects survolés. Ainsi, en 1997, il y a eu augmentation le long de 23 transects par rapport à 1996, alors qu'en 1996 le nombre de couples était supérieur dans 24 des transects par rapport à 1995. Le nombre de couples estimé en 1997 est, pour l'ensemble de la péninsule, significativement plus élevé qu'il ne l'était en 1995 et en 1994 (P < 0,002), mais significativement (P < 0,05) toujours inférieur à l'estimation de 1993, ainsi qu'à celle de 1988 (tableau 2).

Dans la région 1 (toundra de l'intérieur), le nombre de couples nicheurs (21 772) inventorié en 1997 était significativement (P < 0,01) supérieur à celui de 1995 et 1994, mais n'était pas significativement (P > 0,05) différent de l'estimation de 1996, de 1993 et 1988 (tableau 2). Dans la région 2 (toundra côtière), le nombre de couples nicheurs (32 301) estimé en 1997 n'était pas significativement différent à celui de 1996, mais il était plus élevé (P < 0,05) qu'en 1995 et 1994 (tableau 2). Toutefois, il était encore très inférieur aux estimations (P < 0,01) de 1993 et de 1988. Enfin, dans la région 3 (zone de transition), malgré une hausse de l'estimation de 1997, aucune différence n'a été décelée entre les estimations de toutes les années de l'inventaire (P > 0,20) (tableau 2).

La population totale estimée (392 956 individus = couples nicheurs + non-nicheurs) était significativement plus grande (P < 0,06) en 1997 que celle de toutes les années antérieures, à l'exception de celle de 1988 (tableau 3). Cette situation provient surtout du fait qu'en 1997, le nombre de bernaches non reproductrices (266 524 individus) était de loin supérieur à celui des années antérieures (de 58 593 à 180 102 individus), et représentait même une estimation deux fois plus élevée que celle produite lors du premier inventaire en 1988 (tableau 3).

4.2.2 La forêt boréale

Dans le cadre de ce programme, on a dressé des inventaires de Bernaches du Canada au niveau de la forêt boréale seulement en 1988, 1993 et 1996. En 1993, une zone de 92 200 km² située au nord de Labrador City n'a pas été survolée (Bordage et Plante, 1993). Une comparaison des relevés effectués dans cette zone en 1988 et en 1996 avec les données provenant de l'ensemble de la région de la forêt boréale n'indiquent pas de grandes différences dans la densité des couples de Bernaches du Canada. Dans la zone exclue en 1993, la densité observée de couples nicheurs en 1996 était de 0,033 couple/km², alors qu'elle était de 0,026 couple/km² en 1988. Pour l'ensemble de la forêt boréale, la densité de couples nicheurs est passée de 0,028 couple/km² en 1988 à 0,020 couple/km² en 1996. En incluant la zone de 92 200 km² dans l'ensemble de la région associée à la forêt boréale, le nombre estimé de couples nicheurs (11 062) en 1996 était comparable (P > 0,05) à celui de 1993 et à celui de 1988 (tableau 4). De même, la population totale estimée en 1996 (51 623 individus) était comparable (P > 0,05) à celle de 1993 et à celle de 1988 (tableau 4).

4.2.3 Les indicateurs de couples

Le nombre de couples nicheurs par transect a été obtenu en additionnant les bernaches que nous avons

Tableau 2
Nombre estimé de couples nicheurs de Bernaches du Canada dans la péninsule d'Ungava, dans le Nord québécois

		Transects survolés			
Écorégions[a] (superficie totale)	Année[b]	Nombre	Superficie km²	Couples/km² (erreur type)	Nombre total de couples (erreur type)
1	1988	6	285	0,30 (0,084)	35 016 (9 744)
	1993	4	242	0,16 (0,063)	18 185 (7 308)
(116 000 km²)	1994	11	458	0,09 (0,022)	10 633 (2 542)
	1995	11	458	0,07 (0,014)	8 101 (1 635)
	1996	11	458	0,13 (0,034)	14 941 (3 956)
	1997	11	458	0,19 (0,029)	21 772 (3 956)
2	1988	7	119	1,63 (0,245)	70 833 (10 744)
	1993	25	420	1,31 (0,166)	57 122 (7 221)
(43 500 km²)	1994	21	491	0,48 (0,062)	20 917 (2 692)
	1995	21	488	0,36 (0,041)	15 705 (1 799)
	1996	21	488	0,60 (0,067)	25 865 (2 928)
	1997	21	488	0,74 (0,099)	32 301 (4 298)
3	1988	3	171	0,18 (0,067)	11 491 (4 253)
	1993	6	176	0,26 (0,110)	16 432 (6 952)
(63 200 km²)	1994	4	265	0,13 (0,038)	8 124 (2 421)
	1995	4	265	0,09 (0,027)	5 496 (1 702)
	1996	4	265	0,08 (0,018)	5 258 (1 165)
	1997	4	265	0,15 (0,046)	9 144 (2 906)
1, 2, 3	1988	16	575	0,53 (0,068)	118 031 (15 144)
	1993	35	838	0,41 (0,056)	91 307 (12 471)
(222 700 km²)	1994	36	1 214	0,18 (0,020)	40 086 (4 454)
	1995	36	1 211	0,13 (0,013)	29 302 (2 967)
	1996	36	1 211	0,21 (0,023)	46 058 (5 052)
	1997	36	1 211	0,28 (0,028)	63 216 (6 201)

[a] Région 1 – toundra de l'intérieur; région 2 – toundra côtière; région 3 – zone de transition entre la forêt boréale et la toundra.
[b] 1988 (Malecki et Trost, 1990); 1993 (Bordage et Plante, 1993); 1994 (Harvey, 1994); 1995, 1996, 1997 (Harvey et Bourget, 1995, 1996, 1997).

observées seules ou par deux. Les bernaches solitaires sont vraisemblablement des mâles appariés à une femelle qui couve tandis que les paires observées peuvent se composer d'oiseaux nicheurs ou de deux individus sous-adultes ou encore d'adultes qui ont raté leur tentative de se reproduire. Ainsi, la proportion de bernaches solitaires observées pourrait fournir une indication plus fiable de l'importance de la population nicheuse. De 1993 à 1997, on a observé en moyenne 53 % (entre 44 % et 60 %) de couples nicheurs sous la forme d'individus seuls dans l'ensemble de la péninsule d'Ungava (figure 3). En 1993 et en 1995, cette proportion était semblable dans les deux secteurs côtiers (région 2). Toutefois, en 1994, en 1996 et en 1997, le pourcentage de bernaches seules était plus élevé le long de la côte de la baie d'Hudson (figure 3), ce qui permet de croire que les conditions seraient en général meilleures de ce côté de la péninsule. Ce phénomène a d'ailleurs été confirmé par les études de nidification sur le terrain en 1996 et 1997 (Reed et Hughes, 1996, 1997).

4.2.4 Comparaison entre les côtes des baies d'Ungava et d'Hudson

De 1993 à 1997, la côte de la baie d'Hudson a accueilli annuellement près de 80 % (entre 74 % et 82 %) des couples qui ont été estimés comme nicheurs dans les secteurs côtiers (région 2) de la péninsule d'Ungava. Ainsi en 1997, l'augmentation du nombre de paires estimées était de 28 % le long de la baie d'Hudson comparativement à seulement 17 % sur la côte de la baie d'Ungava. Cette tendance à la hausse est en cours depuis 1995 et les changements sont plus significatifs le long de la baie d'Hudson (figure 4). De même, on estime qu'en moyenne 91 % (entre 82 % et 95 %) des bernaches non reproductrices dans la zone côtière se retrouvent aussi du côté de la baie d'Hudson au niveau de la zone côtière (figure 4). Leur nombre a pratiquement doublé entre 1996 et 1997 près de la baie d'Hudson alors qu'on a enregistré un déclin de 24 % à la baie d'Ungava (figure 4).

5. Discussion

Le nombre de couples de Bernaches du Canada a augmenté à nouveau de 37 % en 1997 dans l'ensemble du territoire de l'Ungava par rapport à l'année précédente. La population a maintenant plus que doublé (+ 117 %) depuis 1995, année où on avait enregistré le niveau le plus bas. Ces augmentations concordent avec la hausse prévue du taux de survie des adultes et des sous-adultes à la suite de l'interdiction de la chasse sportive en vigueur depuis 1995.

L'habitat côtier des baies d'Ungava et d'Hudson est reconnu pour la densité des populations nicheuses de Bernaches du Canada de l'Atlantique qu'il accueille (Malecki et Trost, 1990). Des analyses distinctes des populations de bernaches de chaque côte révèlent cependant que le littoral de la baie d'Hudson accueille une population nicheuse beaucoup plus grande que celle de la baie d'Ungava. La différence s'explique principalement par l'étendue du territoire qui est plus petite dans cette dernière région (baie d'Ungava : 9 700 km²; baie d'Hudson : 33 800 km²) et par le fait que la densité des couples nicheurs y est quelque peu inférieure. Le dégel particulièrement tardif observé sur la côte de la baie d'Ungava, en 1996, indique que certaines années les conditions de l'habitat (et probablement

Figure 2
Nombre total estimé de couples nicheurs de Bernaches du Canada et nombre total dans le Nord québécois en 1988 et de 1993 à 1997

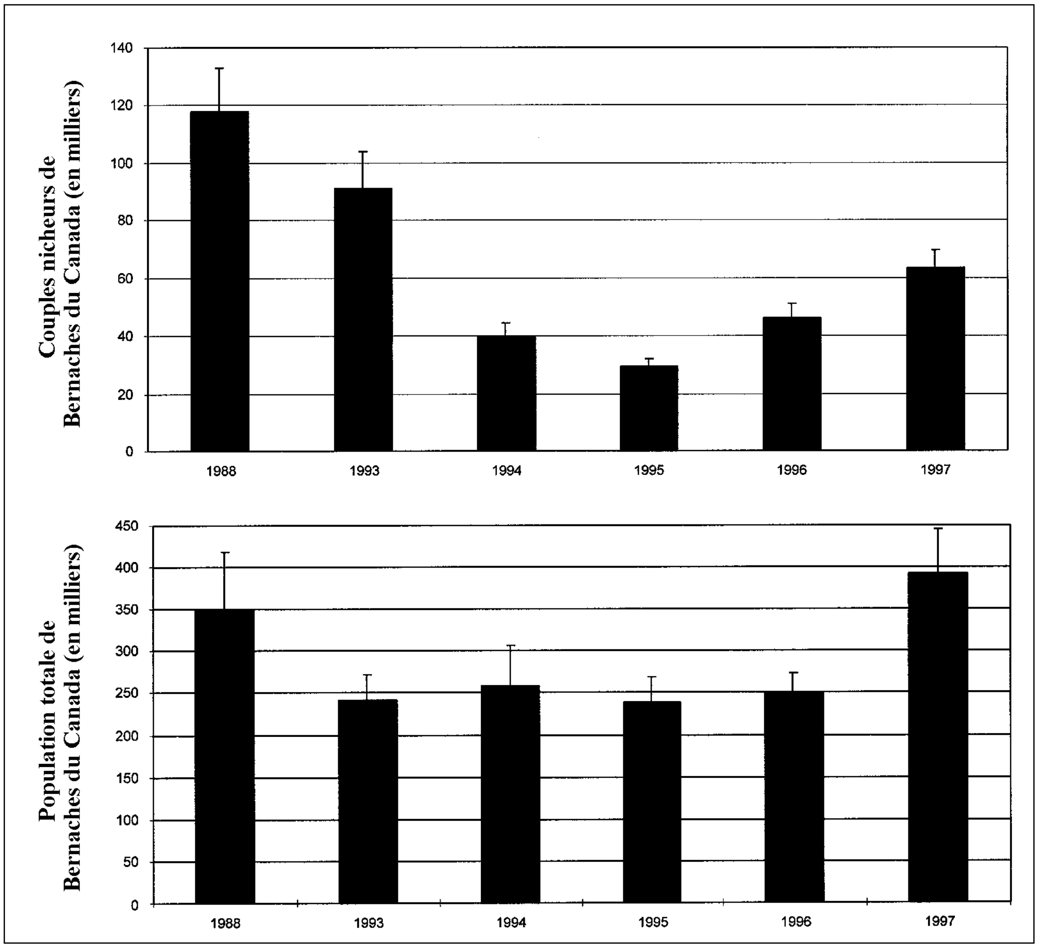


Tableau 3
Évolution des estimations des divers groupes de Bernaches du Canada dans l'ensemble de la péninsule de l'Ungava

Année[a]	Nombre de couple	Nombre de bernaches non reproductrices	Nombre total de Bernaches du Canada
1988	118 031	112 888	348 950
1993	91 307	58 593	241 407
1994	40 086	178 160	258 332
1995	29 302	180 102	238 706
1996	46 058	158 978	251 094
1997	63 216	266 524	392 956

[a] 1988 (Malecki et Trost, 1990);
1993 (Bordage et Plante, 1993);
1994 (Harvey, 1994);
1995 1996, 1997 (Harvey et Bourget, 1995, 1996, 1997).

Tableau 4
Population totale et nombre estimé de couples nicheurs de Bernaches du Canada dans la forêt boréale[a] du Nord québécois

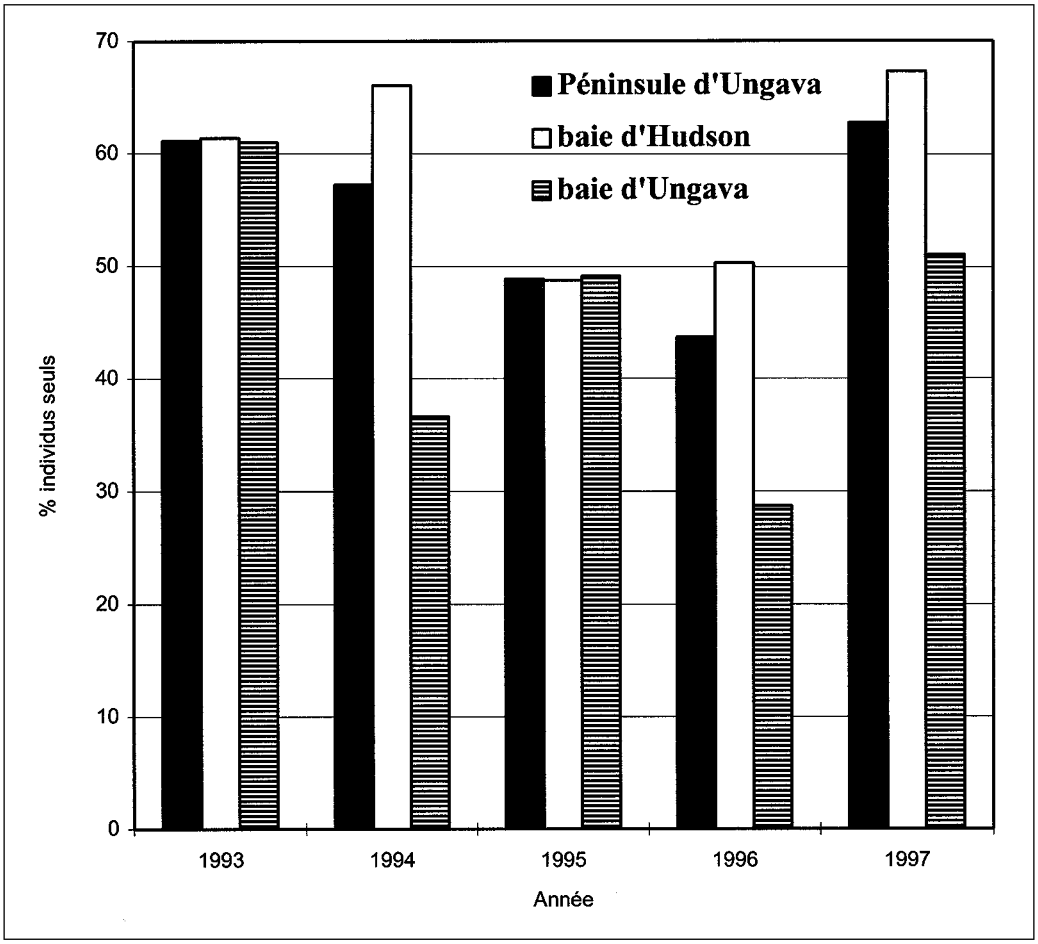
	Transects survolés			
Année[b]	nombre	superficie, km^2	Nombre total de couples (erreur type)	Nombre total de Bernaches du Canada (erreur type)
1988	11	775	13 775 (1 184)	30 830 (5 836)
1993	8	556	22 846[c] (6 450)	61 226[c] (12 980)
1996	8	551	11 062 (2 504)	51 623 (20 710)

[a] Superficie de la forêt boréale = 508 100 km².
[b] 1988 (Malecki et Trost, 1990);
1993 (Bordage et Plante, 1993);
1996 (Harvey et Bourget, 1996).
[c] Valeurs ajustées pour inclure la région de 92 200 km^2.

le nombre d'oisons) peuvent être très différentes de celles de la côte de la baie d'Hudson. Notre expérience limitée des conditions dans la région nous porte à croire que le dégel tardif peut être plus fréquent sur le littoral de la baie d'Ungava. Il est reconnu que, sur la côte de la baie d'Hudson, des vents qui soufflent du large produisent souvent du brouillard qui peut avoir tendance à faire monter les températures. Le fait que les conditions météorologiques semblent un peu moins difficiles à la baie d'Hudson a aussi été observé lors des études sur la reproduction en 1996 et 1997, alors que l'effort de nidification était plus important sur la côte de la baie d'Hudson que le long de la côte de la baie d'Ungava (Reed et Hughes, 1996, 1997).

Étant donné qu'un nombre inférieur de bernaches se reproduisent dans la région de la baie d'Ungava comparativement à la baie d'Hudson, que le taux de recrutement peut être différent (et peut-être moindre) certaines années et que les bernaches suivent des voies migratoires différentes (donc que le nombre de victimes de la chasse soit différent), il serait souhaitable de surveiller la

Figure 3
Pourcentage des couples nicheurs de Bernaches du Canada qui ont été observés sous la forme d'individus seuls dans la péninsule et la zone cotière des baies d'Ungava et d'Hudson de 1993 à 1997



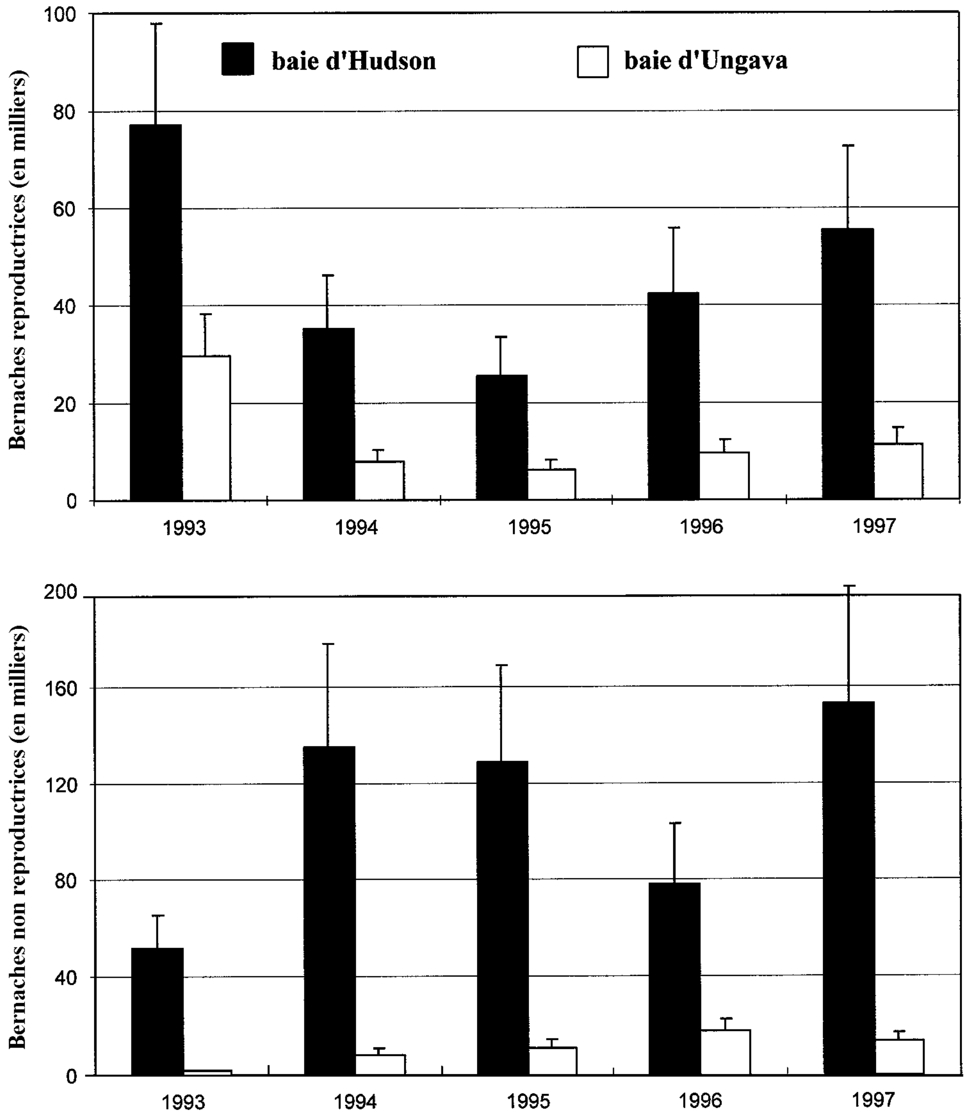
productivité et les niveaux de population des deux côtes séparément. La distribution des retours de bagues de bernaches marquées sur les côtes des baies d'Hudson et d'Ungava indique que la plupart hivernent dans la région de la baie de Chesapeake, mais qu'elles peuvent emprunter des voies migratoires différentes (J. Hestbeck, Mass. Coop. Fish and Wildl., Res. Unit, données inédites).

Le niveau estimé de la population nicheuse dans la péninsule d'Ungava a connu une forte baisse entre 1988 et 1995, mais a montré des signes évidents de récupération en 1996 et en 1997. Par ailleurs, la population totale estimée fréquentant le territoire a peu changé, particulièrement entre 1993 et 1996. L'importante baisse (–31 %) enregistrée entre 1988 (348 950 individus) et 1993 (241 407 individus) a été récupérée en 1997 (392 956 individus), puisque cette dernière estimation de la population totale représente une augmentation de 56 % par rapport à 1996 (251 094 individus), le niveau le plus élevé obtenu depuis la première évaluation faite en 1988 (348 950 individus). La population totale englobe les couples nicheurs, les non-nicheurs (c.-à-d. les individus qui ne sont pas en âge de se reproduire), les adultes qui ne se sont pas reproduits et les individus en migration de mue qui proviennent d'autres secteurs. Les bernaches incapables de voler, qui ont été baguées le long de la côte de la baie d'Hudson, sont souvent recapturées le long de la voie de migration du Mississippi (Malecki et Trost, 1990). À l'occasion de la chasse printanière le long des côtes de la baie James, des chasseurs cris récupèrent des bagues dont un certain nombre provient aussi de bernaches marquées en été dans l'île Akiminski et dans d'autres sites du sud de la baie James, ainsi que d'oiseaux provenant du sud de l'Ontario, du Michigan et de l'Ohio (Hughes et coll., 1997). Des données morphométriques provenant de bernaches tuées près de Povungnituk, le long de la côte de la baie d'Hudson, suggèrent que des bernaches résidentes représentent une partie substantielle des oiseaux récoltés dans cette région (Hughes et coll., 1997). Les bernaches non reproductrices dénombrées le long du littoral de la baie d'Hudson semblent donc inclure des oiseaux pouvant provenir de plusieurs populations des voies de migration de l'Atlantique et du Mississippi.

Par ailleurs, le long de la baie d'Ungava, le nombre de bernaches non reproductrices recensées est beaucoup moindre. Des informations préliminaires indiquent que seulement quelques bernaches abattues par les chasseurs inuit dans le sud de la baie d'Ungava peuvent être associées par leur taille à des populations de bernaches résidentes (Hughes et coll., 1997). De plus, les récupérations d'oiseaux bagués dans le passé à la baie d'Ungava montrent que toutes ces bernaches appartiennent à la voie de migration de l'Atlantique.

L'interprétation des estimations de la population totale est donc très difficile sans connaître le nombre d'individus en migration de mue provenant d'autres

Figure 4
Nombre total estimé de Bernaches du Canada (couples nicheurs et groupes) et nombre total estimé de couples nicheurs de Bernaches du Canada dans les zones cotières des baies de Hudson et d'Ungava de 1993 à 1997



populations qui entrent dans la région étudiée ainsi que le moment de leur arrivée et la variation annuelle de leur nombre. De légères différences quant aux dates des inventaires ou d'arrivée des bernaches en mue peuvent faire varier grandement les estimations de la population. Ainsi, l'inventaire de 1988 a eu lieu à la fin de mai et au début de juin, bien avant l'arrivée de la plupart des bernaches en migration de mue. D'autre part, l'inventaire de 1993, pourtant plus tardif que celui de 1988 a révélé la présence d'un très petit nombre de bernaches non reproductrices pour des raisons inconnues. En revanche, les inventaires depuis 1994 ont tous été complétés à la fin de juin, au moment où de nombreux groupes (vraisemblablement d'oiseaux en migration de mue) arrivaient sur la côte de la baie d'Hudson. Une différence annuelle dans le patron de déplacement des bernaches qui arrivent dans le Nord québécois pour effectuer leur mue peut aussi faire varier de façon importante l'estimation faite de ce groupe d'oiseaux. Ainsi, en 1997, le nombre de bernaches non reproductrices était beaucoup plus élevé qu'au cours des deux années précédentes, malgré des dates très rapprochées de fin d'inventaire (tableaux 1 et 3).

Concernant les populations de bernaches au niveau de la forêt boréale, le nombre estimé de couples nicheurs en 1996 s'établissait à environ la moitié de celui de 1993, mais la différence n'était pas significative. De même, la population totale estimée était semblable dans cette région en 1993 et en 1996. Les variances des estimations des populations dans la forêt boréale découlant de cet inventaire sont importantes (erreur type > 20 %) (tableau 4). Dans cette région, il faudrait augmenter la taille des échantillons pour accroître la pertinence des estimations. Par ailleurs, d'autres sources d'information sur la nidification des Bernaches du Canada dans la forêt boréale indiquent que la densité et les variations annuelles sont faibles dans ce type de milieu (Reed et Hughes, 1996).

6. Remerciements

Les inventaires des couples nicheurs réalisés depuis 1993 sont financés conjointement par le Plan des Oies de l'Arctique du PNAGS, le Service canadien de la faune (SCF), l'U.S. Fish and Wildlife Service (USFWS) et le Conseil de la voie de migration de l'Atlantique. En 1993, les observateurs étaient Daniel Bordage (SCF, Québec) et Bill Harvey (DNR, Maryland). Ce dernier et André Bourget (SCF, Québec) ont effectué tous les autres inventaires de 1994 à 1997. Les pilotes ont été au cours des années : Thierry Pandreau (Grondair), Richard Knoxleet (Air Inuit), Ted Curtis (USFWS), Glen Cullingford (USFWS) et Jim Goldsberry (USFWS). La Société Makivik et, en particulier, Stas Olpinski et Bill Doidge ont fourni un appui logistique très aprécié. Des observateurs supplémentaires ont aussi participé dans les communautés suivantes : Sammy Angnatuk et Alix Gordon à Kuujjuaq; Johnny Angutiguluk et Andrew Novalinga à Povungnituk; Daniel Oweetaluktuk Kadsudluak à Inukjuak. D'autres personnes ont aussi prêté leur concours à différentes étapes de ce projet : Aliva Tulugak (Povungnituk), Daniel Bordage, Nathalie Plante et Charles Drolet (SCF, Québec), Kathryn Dickson (SCF), Jerry Serie (USFWS), Rich Malecki (USFWS) et Larry Hindman (DNR, Maryland).

7. Ouvrages cités

Bordage, D. et N. Plante. 1993. Inventaire des couples nicheurs de Bernaches du Canada dans le Nord québécois — 1993. Rapport inédit, Serv. can. de la faune, région du Québec, Sainte-Foy.

Bordage, D. et N. Plante. 1994. A breeding ground survey of Atlantic flyway Canada Geese in northern Quebec — cost estimates. Rapport inédit, Serv. can. de la faune, région du Québec, Sainte-Foy. 9 p.

Cochran, W.G. 1977. Sampling techniques. 3e éd., John Wiley and Sons, Inc. New York. 428 p.

Gilbert, G., R.G. Helie et J.M. Mondoux. 1985. Sensibilité de l'écosystème aux précipitations acides au Québec. Partie a — Écorégions et écodistricts du Québec. Série de la classification écologique des terres, no 20. Direction générale des terres, Service de la conservation de l'environnement, Environnement Canada, Ottawa, vii, 96 p. : ill., cartes.

Harvey, W.F. 1994. A breeding pair survey of Canada Geese in northern Quebec — 1994. Rapport inédit, Maryland Department of Natural Resources, Wye Mills, Maryland. 9 p.

Harvey, W.F. et A. Bourget. 1995. A breeding pair survey of Canada Geese in northern Quebec — 1995. Rapport inédit, Maryland Department of Natural Resources, Wye Mills, Maryland, et Serv. can. de la faune, région du Québec, Sainte-Foy. 10 p.

Harvey, W.F. et A. Bourget. 1996. A breeding pair survey of Canada Geese in northern Quebec — 1996. Rapport inédit, Maryland Department of Natural Resources, Wye Mills, Maryland, et Serv. can. de la faune, région du Québec, Sainte-Foy. 17 p.

Harvey, W.F. et A. Bourget. 1997. A breeding pair survey of Canada Geese in northern Quebec — 1997. Rapport inédit, Maryland Department of Natural Resources, Wye Mills, Maryland, et Serv. can. de la faune, région du Québec, Sainte-Foy. 17 p.

Hindman, L.J. et F. Ferrigno. 1990. Atlantic flyway goose populations: status and management. Trans. North Am. Wildl. Nat. Resour. Conf. 55:293–311.

Hindman, L.J., R.A. Malecki et J.R. Serie. 1996. Status and management of Atlantic population Canada Geese. Int. Waterfowl Symp. Proc. 7:109–116.

Hughes, R.J., A. Reed, E. Gilpin et R. Dion. 1997. Population affiliation of Canada Geese in the 1996 subsistence harvest in the James Bay region of northern Quebec. Rapport inédit, Serv. can. de la faune, région du Québec, Sainte-Foy. 8 p.

Kaczynski, C.F. et E.B. Chamberlain. 1968. Aerial surveys of Canada Geese and Black Ducks in eastern Canada. Spec. Sci. Rep. Wildl. 118. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 29 pp.

Malecki, R.E. et R.A. Trost. 1990. A breeding ground survey of Atlantic flyway Canada Geese in northern Quebec. Can. Field-Nat. 104(4):575–578.

Reed, A. 1994. Forecast for nesting effort and breeding success of Atlantic flyway Canada Geese and greater Snow Geese: summer 1994. Rapport inédit, Serv. can. de la faune, région du Québec, Sainte-Foy. 6 p.

Reed, A. et J. Hughes. 1996. Preliminary observations on breeding success of Canada Geese in northern Quebec in 1996. Rapport inédit, Serv. can. de la faune, région du Québec, Sainte-Foy. 5 p.

Reed, A. et J. Hughes. 1997. Preliminary observations on breeding success of Canada Geese in northern Quebec in 1997. Rapport inédit, Serv. can. de la faune, région du Québec, Sainte-Foy. 4 p.

Breeding ecology of Canada Geese near the Laforge-1 hydroelectric reservoir in north-central Quebec

R. John Hughes, Austin Reed, Linda Rancourt, and Renée Bergeron

Summary

We studied the breeding ecology of Canada Geese (*Branta canadensis interior*) in the vicinity of the Laforge-1 hydroelectric reservoir in Quebec's northern interior (54°N, 72°W) from 1992 to 1996. Each spring, nesting was initiated in either the second or third week of May and peaked one week later. Nest density was low (<3/100 km^2) even though small ponds and structured bogs, the main nesting habitats, were abundant. Observed brood density was very low (<1/100 km^2) despite apparent nest success >70% in four of the five years studied. Population density was generally stable from 1992 to 1996; however, the observed number of breeding pairs was lower in 1995 than in other years, and nest numbers were lower in 1992. Breeding ecology did not appear to be negatively affected after creation of the reservoir in August 1993. Because population density is very low in the area under development, even the loss of nearly 1000 km^2 of habitat to flooding will have no measurable impact on the Atlantic Population of Canada Geese.

Résumé

Nous avons étudié l'écologie de reproduction de la Bernache du Canada (*Branta canadensis interior*) dans la région du réservoir hydroélectrique de Laforge-1, situé à l'intérieur du nord du Québec (54°N, 72°O) entre 1992 et 1996. Chaque printemps, la nidification a été amorcée dans la deuxième ou la troisième semaine de mai et a atteint son maximum une semaine plus tard. La densité des nids était faible (< 3/100 km^2) malgré une abondance des principaux habitats de nidification, soit des petits étangs et des tourbières structurées. La densité observée des couvées était très faible (< 1/100 km^2) bien que le taux apparent de succès de nidification s'est élevé à plus de 70 p. 100 quatre ans sur cinq. La densité de la population était constante dans l'ensemble entre 1992 et 1996, mais le nombre observé de couples nicheurs était plus bas en 1995 que les autres années et la quantité de nids était plus basse en 1992. La création du réservoir en août 1993 ne semble pas avoir eu d'impact négatif sur l'écologie de la reproduction. Puisque la densité de la population est très faible dans la région en développement, la perte de presque 1 000 km^2 d'habitats à cause d'inondations n'aura aucun effet significatif sur la population de Bernaches du Canada de la voie migratrice de l'Atlantique.

1. Introduction

Atlantic Population (AP) Canada Geese have enormous social and economic importance. In northern Quebec they are a traditional source of fresh meat for native communities, and the springtime "goose break" is a much awaited event after the long winter season (Reed 1991). On the east coast of North America, the Canada Goose is a prized game bird and was the waterfowl species most harvested by recreational hunters in the Atlantic Flyway (Hindman et al. 1996). Atlantic Population Canada Geese belong to the subspecies *Branta canadensis interior* and breed throughout northern Quebec. Breeding concentrations occur in coastal areas of the Ungava Peninsula and Ungava Bay (Kaczynski and Chamberlain 1968; Malecki and Trost 1990). Farther south, in the northern boreal forest of Quebec's interior, breeding pair density is much lower. However, due to the vast size of this region, these birds represent a sufficiently large proportion of northern Quebec's total Canada Goose population (between 9 and 18%; Malecki and Trost 1990; Bordage and Plante 1993) to deserve management consideration. Wintering areas range from southern Ontario and Maine along the eastern seaboard to North Carolina, with the Chesapeake Bay and Delmarva Peninsula region supporting the greatest concentrations. Based on midwinter surveys, this population grew steadily from the 1940s to the mid 1980s, but has declined dramatically since (Hindman et al. 1996). Exact numbers are difficult to determine because geese from many populations, including increasing numbers of resident birds, mix together in wintering areas. Further evidence of the decline in the northern Quebec population comes from breeding pair surveys conducted by the Canadian Wildlife Service and the U.S. Fish and Widlife Service in 1988 (Malecki and Trost 1990) and annually from 1993 to 1997 (Bordage and Plante 1993; Breton et al., this publication; Harvey 1994; Harvey and Bourget 1995, 1996, 1997). The estimated number of breeding pairs in northern Quebec (north of 51°N) decreased from about 132 000 in 1988 to 57 000 by 1996.

Hydroelectric development in northern Quebec over the past 20 years has resulted in considerable localized modification of natural habitats, principally due to the creation of reservoirs several hundred square kilometres in size. Although several surveys have been conducted in Quebec's northern boreal forest (Kaczynski and Chamberlain 1968; Gillespie and Wetmore 1974; Lamothe 1982; Malecki and

Trost 1990; Bordage and Plante 1993), little is known about the ecology of the geese breeding there, in part because the low densities mean that data collection is dependent on intensive use of helicopters. Few ground studies have been conducted (e.g., Hickey 1979), and results are not readily available to researchers and managers. Furthermore, despite the construction of several large reservoirs, little information is available on the effects of this kind of development on boreal-nesting geese. We studied Canada Goose breeding ecology in Quebec's northern boreal forest as part of a larger program of environmental monitoring conducted by the Société d'énergie de la Baie James (SEBJ) to investigate the ecological effects of reservoir creation along the La Grande River system.

Our objectives were to determine population density of Canada Geese in the boreal forest of northern Quebec and to investigate their reproductive ecology (chronology, clutch size, and nest and rearing success), habitat use, and behaviour (site fidelity, brood movements, home range size). We collected data before (1992, 1993) and after (1994, 1995, 1996) creation of the Laforge-1 reservoir to evaluate the effects of flooding on the numbers of geese, their breeding ecology, and the behaviour of individually marked birds.

2. Study area

The study was conducted in a 9700-km^2 area surrounding and including the Laforge-1 reservoir in north-central Quebec (54°N, 72°W) (Fig. 1). The reservoir, located approximately 600 km east of James Bay, is part of the La Grande hydroelectric complex. Already present at the site when this study began was the 313-km^2 Vincelotte impoundment, created in 1984 by the damming of the Vincelotte and Laforge rivers. Creation of the Laforge-1 reservoir in August 1993 brought the total flooded area to its present and final size of 1288 km^2.

The Laforge-1 area is relatively flat with low hills formed by glacial deposits or solid rock. The sparse forest cover of the region consists mainly of black spruce (*Picea mariana*) mixed with tamarack (*Larix laricina*) in low-lying areas and jack pine (*Pinus banksiana*) in drier locations. Steep, south-facing slopes have stands of trembling aspen (*Populus tremuloides*). A complex hydrographic network consisting of innumerable lakes, ponds, and structured bogs covers the low-lying areas. Bogs range in size from <1 to several hectares in size and consist of a series of pools separated by narrow strips of mossy ground. These pools, as well as ponds and small lakes, often contain small islands. Islands, mossy strips, and the shore of bogs, ponds, and many small lakes are colonized by graminaceous plants, mainly *Carex* spp. Shores of streams and larger lakes are often characterized by a narrow band of shrubby plants most commonly dominated by *Alnus–Myrica* or *Salix–Alnus* communities. The climate type is cold continental with temperatures ranging from !50 to +30°C and a mean annual temperature of !4°C. Nearly one-third of the annual precipitation falls as snow (SEBJ, unpubl.).

To evaluate the effects of creation of the reservoir, we collected data within the boundaries of that part of the study area to be flooded by the new reservoir for comparison with similar data collected in the surrounding area. This led to the designation of two zones: (1) the affected zone, all 10 × 10 km squares corresponding to the Universal Transverse Mercator (UTM) grid, which would be subject to flooding; and (2) the control zone, all 10 × 10 km squares in a 30-km-wide band to the north and south of the affected zone (Fig 1). The affected zone and the control zone represented 23.4% and 76.6%, respectively, of the study area.

3. Methods

3.1 Spring weather

Meteorological data were obtained from weather records collected at the La Grande-4 airport located approximately 100 km west of the study area (SEBJ, unpubl. data).

3.2 Population density

We counted geese during aerial surveys of 100-km^2 plots, following the method described by Bordage (1987). We randomly selected three such plots in the affected zone and seven in the control zone in order to determine densities in the two zones and to generate estimates (stratified random sampling, Cochran 1963) for the entire study area. We conducted surveys of the same 10 plots in two years before (1992–93) and three years after (1994–96) creation of the reservoir. Two surveys were conducted on the selected plots each year, one in mid June, for nests, and the other in mid July, for broods.

Surveys were conducted by helicopter (Bell 206L) at an altitude of 10–30 m and a speed ranging from ≤60 km/h over large bogs up to 140 km/h along rocky shores of large lakes. The survey crew consisted of the pilot and a navigator seated in front, and one or two observers in the back. We prepared flight plans covering all of the wetlands within each plot before beginning the surveys, and the same flight plans were used each year. We recorded observations on 1:50 000 topographical maps and noted the number of geese and their status (breeding pair, brood, nonbreeder). In June, single geese or pairs were recorded as indicated breeding pairs. No correction was made for visibility bias. We compared density between years using ANOVA with sample plots as blocks to control for among-plot variation. We used Tukey's test for comparisons among means.

3.3 Breeding ecology

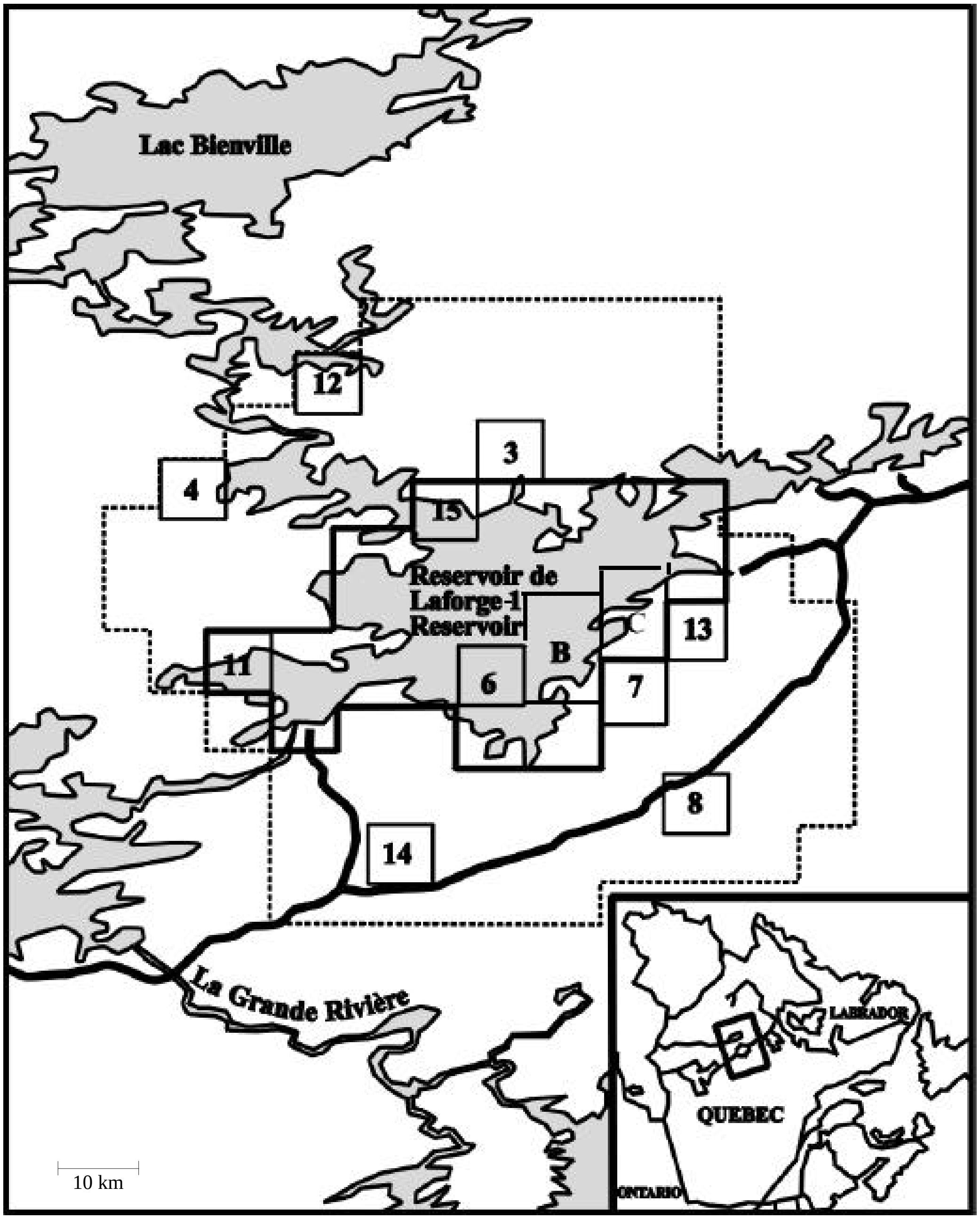
We located nests during aerial surveys of the 10 sample plots. In order to increase our sample of nests, we subjectively selected two additional areas with an abundance of bogs and ponds. These areas, B and C (Fig. 1), measured 208 and 170 km^2 respectively and were surveyed in 1993–96. We did not use data from these areas to estimate nest density. Nest locations were recorded using a Global Positioning System (GPS) receiver.

3.3.1 Nesting chronology

We determined initiation date by backdating from hatch date or, more often, by using an index of egg density, based on the principle that eggs gradually lose mass over the course of incubation:

$$\text{Density index (DI)} = \text{mass}/(\text{length} \times \text{width}^2)$$

Figure 1
The Laforge-1 study area in north-central Quebec showing the affected zone (solid line) and the control zone (dashed line). Squares with numbers are 100-km^2 survey plots, and rectangles with letters are additional nest search areas (B = 208 km^2, C = 170 km^2). Note that only the major water bodies are shown.



Number of days incubation = (DI of fresh eggs ! DI of measured egg) / Daily rate of change in density

The standard DI of fresh eggs (0 = 0.5551 g/cm^3, SE = 0.0026) was determined using Cooper's (1978) equation for fresh egg mass, as we had no data on fresh eggs in our study. The daily rate of change in density (x = 0.0030 g/cm^3, SE = 0.00016) was established using eggs that were weighed during incubation and for which hatch date was known (n = 13 nests). Density of fresh eggs and rate of change for Canada Geese were similar to those described by Ely and Raveling (1984) for Pacific White-fronted Geese (*Anser albifrons*).

3.3.2 Clutch size and nest success

We recorded clutch size when nests were located in mid June. Clutch size was compared between years using ANOVA. Nests were revisited by helicopter after hatch in late June or mid July. We calculated apparent nest success as the proportion of nests in which one or more eggs hatched (Cooper 1978) based on the presence of hatching eggs or egg membranes (Klett et al. 1986). The standard error for nest success was calculated as for a binomial distribution (i.e., $SE = \sqrt{(p \times q)/n}$, where p = apparent nest success, q = [1 ! p], and n = total nests). Nest success comparisons were conducted using a Chi-square test.

3.3.3 Nesting and brood-rearing habitats

Wetland types, recorded during aerial surveys, were streams, bogs, ponds, and lakes, the latter being subdivided into four size classes: ≤5 ha, 6–20 ha, 21–100 ha, and >100 ha. For each nest we also recorded the distance from the nest to water, water depth, height of the nest above water (1994–96), and the dominant plant species within a 1-m radius of the nest. For nests located on islands, we also recorded the size (diameter) of the island (≤5 m, >5 m) and the distance to solid ground. Wetland use and nest location were compared between years using Chi-square tests.

3.4 Radio-tracking of breeding females

3.4.1 Capture and marking

We captured geese on the nest, late in incubation, using a bow trap. We usually installed the trap the day before a capture attempt was made, and from two to four traps were in use at any given time. In 1993, we also marked geese during brood rearing by using a helicopter to drive broods toward a funnel-shaped net installed along a portion of the shoreline that was free of obstacles such as large rocks and fallen trees. Suitable capture sites had a dense stand of trees 10–20 m from shore because flightless geese always attempted to escape into heavy vegetation when approached by the helicopter. Captured geese were weighed to the nearest 50 g and marked with standard aluminum leg bands, coded plastic neck collars, and harness-mounted (Dwyer 1972) radio transmitters. Transmitters (Holohil Systems, Woodlawn, Ontario) weighed 41 g or <2% of mean body weight and had an expected battery duration of 14 months.

3.4.2 Radio-tracking

We relocated nest-captured geese up to four times during brood rearing to determine habitat use, brood survival, and home range size (minimum convex polygon, Mohr 1947). We used a helicopter equipped with one Yagi antenna (oriented toward the front of the aircraft) or two antennae (on the right and left). When it was impossible to get a visual sighting from the air because geese were in heavy cover, we located geese on the ground using a portable antenna. We recorded positions on 1:50 000 maps and noted the habitat, the number of adults and young, and the geographic coordinates (GPS).

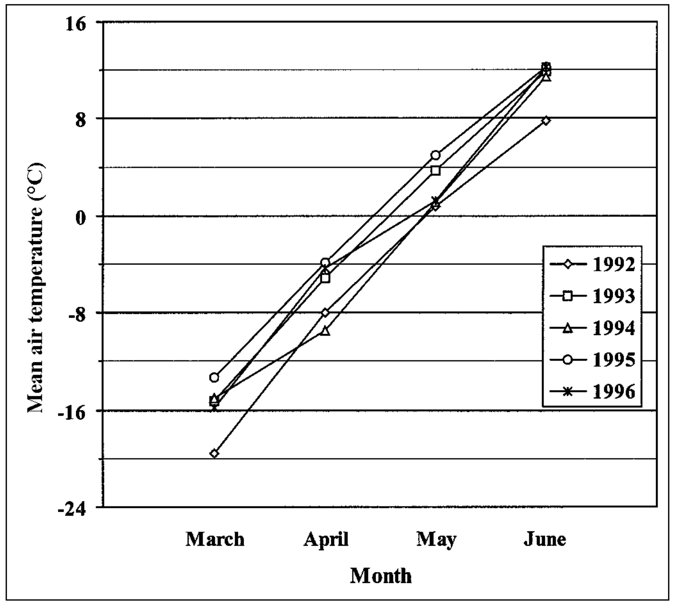
In the year following marking, we flew transects 10 km apart within the study area in June (1993) or May (1994 and 1995) in order to locate geese that had returned. In 1994, the year after we marked the greatest number of geese and the year immediately following creation of the reservoir, we also flew transects up to 50 km to the north and south of the study area to detect birds that may have resettled farther away.

4.0 Results

4.1 Spring weather

Spring temperatures were 3–4°C cooler in 1992, 1994, and 1996 than in 1993 and 1995 (Fig. 2). The lower temperatures occurred during May in 1996, in April and May in 1994, and from March through June in 1992. In 1992, the thaw was one to two weeks later than in other years. Also, 24-h snowfalls of >1 cm occurred four times in June 1992 compared with once in all other years combined (SEBJ, unpubl. data).

Figure 2
Mean monthly spring air temperature near the Laforge-1 study area, 1992–96



4.2 Population density and breeding ecology

4.2.1 Breeding pair density

Pair counts varied greatly among 100-km² plots over the five years, with observed values ranging from 1 to 24. Observed mean breeding pair density and total mid-June population density (pairs and nonbreeders) were constant in the study area over the five years except in 1995, when both declined by nearly half (Table 1).

4.2.2 Nesting chronology

We visited the study area prior to nest initiation in 1994. From 7 to 12 May, we observed several flocks of 5–59 geese arriving from the direction of the James Bay coast. At this time, the study area was covered with snow and ice with the exception of small portions of rivers and streams. Most of the geese already present upon our arrival had congregated in groups of up to 136 birds, in open water along large rivers. However, many pairs and groups of three or four geese were also present in smaller streams, suggesting that dispersal to nesting areas had begun.

Egg-laying began in the second or third week of May, depending on the year, and peaked one week later (Fig. 3). Estimated mean nest initiation dates varied by about one week over the five years (Table 2), and the timing of nesting was related to spring temperature.

4.2.3 Nest density

Nests were discovered when geese flushed at the approach of the helicopter or occasionally by observation of uncovered eggs, which were highly visible from the air. Because of the low altitude of the helicopter, most geese encountered probably flushed, though some nests may have

Table 1
Density of adult Canada Geese, breeding pairs, and nests in mid June and density of broods in mid July at Laforge, 1992–96. There were three 100-km^2 plots in the affected zone and seven in the control zone, for a total of 10 in the study area. For significant ANOVA, lowercase letters denote differences between years; means within rows having the same letter are not significantly different (Tukey's[a] test, $p < 0.05$).

	Annual density (no./100 km^2)										
	1992		1993		1994		1995		1996		ANOVA
	0	SE	0	SE	0	SE	0	SE	0	SE	p
Adult geese											
Affected zone	23.3	9.8	34.3	16.3	17.3	4.8	11.3	6.0	19.7	7.0	0.127
Control zone	20.0	3.0	16.6	2.6	17.4	3.7	12.0	3.6	24.3	7.0	0.161
Study area	20.8	1.5	20.7	2.2	17.4	1.2	11.8	1.2	23.2	2.1	0.080
Breeding pairs											
Affected zone	10.0ab	3.5	13.0b	5.9	8.0ab	2.5	5.0a	3.0	7.0ab	3.5	0.041
Control zone	6.9ab[a]	1.5	8.4b[a]	1.9	7.9b[a]	1.9	4.1a[a]	1.1	8.3b[a]	2.3	0.046
Study area	7.6ab	0.6	9.5b	0.9	7.9ab	0.6	4.3a	0.5	8.0ab	0.8	0.003
Nests											
Affected zone	1.7	1.2	3.7	2.7	2.7	1.2	3.0	2.0	1.0	0.0	0.454
Control zone	0.6a	0.4	2.3ab	1.2	3.0b	0.9	2.0ab	0.8	3.0b	0.6	0.017
Study area	0.8	0.2	2.6	0.5	2.9	0.3	2.2	0.3	2.5	0.2	0.059
Broods											
Affected zone	1.0ab	0.6	0.3ab	0.3	2.0a	1.0	1.7ab	0.7	0.0b	0.0	0.038
Control zone	0.9	0.4	1.6	0.4	0.7	0.3	0.7	0.4	0.4	0.2	0.259
Study area	0.9	0.1	1.3	0.1	1.0	0.1	0.9	0.1	0.3	0.1	0.376

[a] Tukey's test did not reveal any significant differences among years; the letters reflect the results of Duncan's test.

Figure 3
Canada Goose nest initiation dates at Laforge, 1993–96. We did not calculate nest initiation dates for 1992 because of the small sample size of nests and because egg densities (from which initiation date is determined) were abnormally low in five of the eight nests.

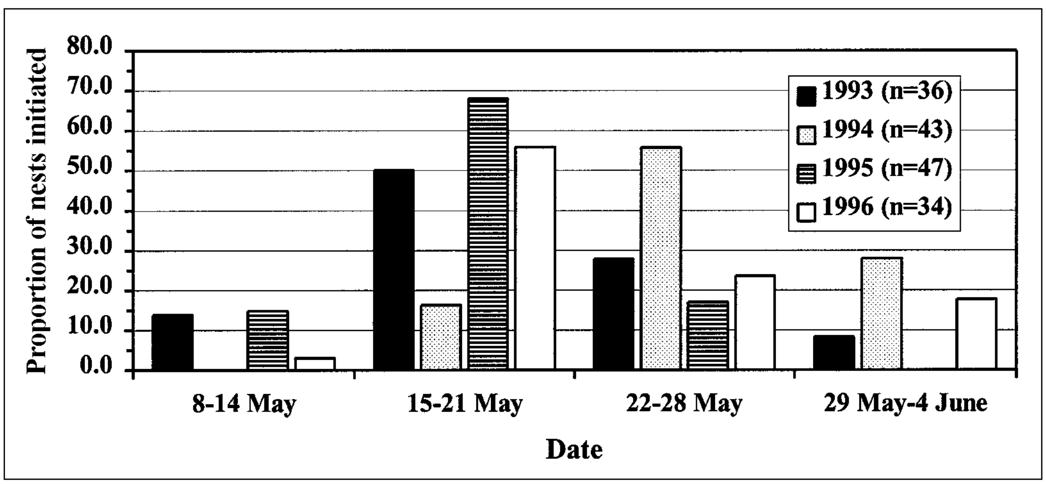


Table 2
Mean nest initiation date, clutch size, and nest success of Canada Geese at Laforge, 1992–96

		Initiation date			Clutch size			Nest success			No. of days incubation[a]			
Year	Total nests	0	SE	n	0	SE	n	p	SE	n	0	SE	n	Nest searches
1992	9	—[b]	—	—	4.0	0.5	9	0.25	0.153	8	—[b]	—	—	15–21 June
1993	41	19 May	0.9	36	4.3	0.2	39	0.73	0.073	37	22	1.0	36	8–18 June
1994	43	25 May	0.7	43	4.2	0.2	43	0.74	0.076	34	19	0.9	43	7–20 June
1995	49	18 May	0.6	47	4.8	0.2	48	0.91	0.041	47	24	0.7	47	8–18 June
1996	37	21 May	0.9	34	3.7	0.2	36	0.85	0.062	33	23	1.0	34	11–18 June

[a] Estimated number of days incubation elapsed when nests were found based on egg density.
[b] We did not calculate the mean number of days incubation or the mean initiation date for 1992 because of the small sample size of nests and because egg densities (from which those parameters are determined) were abnormally low in five of the nests.

been missed, particularly in rarely used habitats such as on islands in medium to large (>5 ha) lakes. Also, nests that failed prior to mid incubation were not detected. Mean nest density in the sample plots was similar in all years except 1992, when it was much lower (Table 1). Nest density (mean ± SE) in the two supplementary nest search areas was similar to that in the sample plots in 1994 and 1996 (3.0 ± 0.4, 2.9 ± 2.3 nests/100 km^2 respectively) but tended to be greater in early years (1993: 3.7 ± 0.2, 1995: 5.8 ± 3.4).

4.2.4 Nesting habitats

Nesting geese used two main wetland types, together accounting for >95% of the 179 nests located over five years. Approximately 60% were associated with ponds and lakes ≤5 ha containing islands, and 35% with structured bogs. Occasionally larger (>5 ha) lakes (n = 5) or ponds without islands (n = 2) were used. Proportional use of the two principal wetland types was similar in all five years (χ^2 = 4.585, 4 df, p = 0.333); thus, selection of wetlands for nesting was apparently not dependent on spring conditions. Habitat choice did not appear to be related to nest initiation date of individual nests; however, we did not conduct a statistical comparison due to the approximate nature of the laying dates calculated from egg density. Nests were nearly always constructed on islands: 83% on mossy or rock islands ≤5 m in diameter, and 5% on larger islands. The remaining nests were on moss strips in bogs (10%) or on the shore of ponds (2%). This pattern was similar in all years, though sample sizes in the lesser-used habitats were too small to permit a statistical comparison. On average, nests were located 0.82 m from water (SE = 0.04, n = 176) and 0.36 m above water (SE = 0.02, n = 105). For 155 nests located on islands, mean distance to mainland was 8.50 m (SE = 0.42) and mean water depth was 0.65 m (SE = 0.04). The most common plant species within 1 m of nests were leatherleaf (*Cassandra calyculata*), sedges (*Carex* spp.), black spruce (*Picea marina*), Labrador tea (*Ledum groenlandicum*), tufted club rush (*Scirpus caespitosus*), and black crowberry (*Empetrum nigrum*).

4.2.5 Clutch size and nest success

Mean clutch size over the five years was 4.23 (SE = 0.11, n = 175) and differed significantly only between the extreme years of 1995 and 1996 (F = 4.299, 4, 170 df, p = 0.002) (Table 2). The high value observed in 1995 may have been related to the very warm spring that year. Apparent nest success was >70% in all years except 1992 and was significantly different among years (χ^2 = 20 300, 4 df, p = 0.0004) (Table 2). Over all years, nest success did not differ between the two principal wetland types (pond/lake ≤5 ha and bog) (χ^2 = 0.141, 1 df, p = 0.707) nor between nests constructed on islands versus the mainland (χ^2 = 0.730, 1 df, p = 0.393). We were unable to evaluate the exact causes of nest failure; however, several potential predators occur in the study area: red fox (*Vulpes fulva*), gray wolf (*Canis lupus*), black bear (*Ursus americanus*), Herring Gull (*Larus argentatus*), and Common Raven (*Corvus corax*). Most of the habitats where nests were found were not subject to seasonal flooding.

4.2.6 Broods

Detecting broods was difficult because of their use of dense cover. Observed brood density (July) in the study area was constant from 1992 to 1996 (Table 1), despite considerable variation in nest density and nest success. In 1996, no broods were observed in the affected zone. Most (89%) of the broods observed were individual broods. Brood size tended to decrease with age class in three of the four years for which sufficient information is available (Table 3). The mean size of class III broods ranged from 1.0 to 2.3 over three years.

Unlike nesting geese, broods made considerable use of lakes >5 ha and tended to move from bogs and ponds to larger water bodies later in brood rearing. Two broods were observed using streams, and one was in open spruce forest several hundred metres from the nearest wetland.

4.3 Radio-tracking of breeding females

4.3.1 Number of geese marked

Three females were captured on nests in 1992 and fitted with transmitters. Eight of 13 females marked in 1993 were captured while nesting, the five others while raising broods. One of the nesting females had been marked in 1992 and was recaptured on the nest in 1993 and a new transmitter installed. The second female marked in 1992 was also relocated on a nest in 1993 but was not recaptured. Four females were marked on the nest in 1994.

4.3.2 Fate of nest-marked females during the brood-rearing period

In 1992, one female was killed by a predator near her nest shortly after being marked. We relocated the two surviving birds once each in July and August. Both females failed to hatch any goslings and joined groups of adults without young. Of those marked on the nest in 1993, one died soon after hatch, and no signal was obtained from a second, suggesting she had left the study area or her transmitter had failed. Thus, we were able to track seven females during the brood-rearing season (relocated twice in both July and August) as well as the second 1992 female until her transmitter failed in late July. Of the eight females radio-tracked in 1993, three were observed with broods, including the female that was captured only in 1992. All others were observed with one or more adult geese but no goslings. All four geese captured on the nest in 1994 were relocated in both July and August. In 1994, two of the four marked females raised broods. The other two were observed with one or more adult geese, and one of them was found dead in August. Nests where traps were used were as successful as nests where trapping did not occur, in both 1993 (n = 13 and 24, respectively, χ^2 = 0.142, 1 df, p = 0.706) and 1994 (n = 7 and 27, respectively, χ^2 = 0.020, 1 df, p = 0.888). Both birds that died shortly after being marked had low body mass when captured (2300 g and 2530 g, respectively) compared with the overall mean for all geese marked during incubation ($\bar{x}$ = 2764 g, SE = 53, n = 16).

4.3.3 Movements and home range

Whether raising a brood or not, all marked geese remained within about 6 km of their nest throughout July and August (Table 4). In 1993, the mean home range of two

Table 3
Canada Goose brood size by age-class at Laforge, 1992–96

	Age-class								
	I			II			III		
Year	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n
1992	3.5	—	2	3.0	0.3	9	2.3	0.4	10
1993	2.9	0.3	7	2.0	0.4	10	2.0	—	2
1994	2.6	0.3	10	1.7	0.3	7	1.0	—	2
1995	2.8	0.7	9	3.4	0.8	7	—	—	—
1996	2.0	0.6	3	—	—	—	—	—	—

Table 4
Distance moved within and between survey periods and minimum convex-polygon home range from radio-marked Canada Geese at Laforge, 1992–95. n.s. = no signal; b.f. = battery failure.

		Distance (km)						
Year	No.	June	June–July	July	July–Aug.	Aug.	Max. distance from nest	Home range (km^2)
Geese with broods								
1993	F02A[a]	—	3.1	3.1	b.f.	b.f.	3.1	—
	F06A	1.3	1.6	1.8	3.6	7.1	3.7	7.3
	F11A	—	0.6	2.1	6.0	7.0	6.4	13.7
1994	F17A	—	1.1	0.7	1.9	0.3	2.1	1.8
	F20A	—	1.0	0.4	1.8	0.8	1.5	1.1
1995	F05A[b]	—	0.7	—	—	—	—	—
Geese without broods								
1992	F01A	—	1.0	—	3.3	—	3.3	—
	F02A	—	3.0	—	1.5	—	3.0	—
1993	F01A[c]	—	3.4	2.1	5.7	7.8	5.3	14.0
	F04A	0.9	2.0	1.4	0.8	0.6	2.0	1.7
	F05A	—	3.3	2.3	3.5	1.6	4.2	4.1
	F07A	0.7	1.4	1.7	3.0	1.6	3.7	3.7
	F08A	—	3.7	3.0	3.8	1.5	5.7	8.2
	F09A	2.0	n.s.	n.s.	n.s.	n.s.	—	—
1994	F05A[b]	—	2.0	3.5	n.s.	n.s.	no nest	—
	F11A[d]	—	3.4	b.f.	b.f.	b.f.	no nest	—
	F18A	—	2.3	1.5	4.1	dead	3.6	2.1
	F21A	—	2.7	1.5	2.4	3.4	2.7	2.5

[a] Marked in 1992.
[b] Marked in 1993, transmitter replaced July 1994.
[c] Marked in 1992, transmitter replaced June 1993.
[d] Marked in 1993.

brood-rearing geese was 10.5 km^2 compared with 6.3 km^2 for five females observed without young. In 1994, the home ranges were much smaller for both females with broods ($\bar{x}$ = 1.5 km^2, n = 2) and failed breeders ($\bar{x}$ = 2.3 km^2, n = 2). The apparent difference between years may be attributable to the fact that in 1994 the geese were captured on large islands in the newly created reservoir. Although the home ranges of most marked geese contained several bogs, ponds, and small lakes, all of the recorded movements of four failed breeders, two in 1993 and two in 1994, were confined to one large body of water.

4.3.4 Nest site fidelity

Canada Geese at Laforge-1 returned to the same area in subsequent years. Two females marked in 1992 returned in 1993 and nested 0.9 and 1.1 km from their previous year's nest site. In the spring of 1994, three females marked on the nest in 1993 were observed in the study area. Two of the three, which apparently did not nest, were observed 1.3 and 1.6 km from their nest sites of the previous year. The third female nested 7.7 km from her nest site of the previous year; however, because the reservoir was created late in the summer of 1993, birds (like this one) that had nested within the affected zone returned to find previously familiar nest and brood-rearing sites drastically modified. In 1995, five females marked on the nest in previous years (one in 1992, two in 1993, two in 1994) were observed nesting in the study area. The mean distance between the 1995 and previous nest sites was 1.2 km (range 0.2–2.7 km, n = 5). Finally, in 1996, one marked female was observed. Her new nest was within 300 m of her two most recent known nesting sites (1993 and 1995) and within 1.2 km of her 1992 nest.

5.0 Discussion

5.1 Breeding ecology

Canada Geese arrived in the Laforge area in early May in 1994. Their flight direction indicated they were arriving from staging areas along the James Bay coast. Like Raveling and Lumsden (1977), we observed geese congregating in open sections of large rivers before dispersal to nesting areas. The low nest density observed in 1992 when the spring was very late may have been the result of delayed availability of nest sites or high nest loss during laying and early incubation. Cold weather at staging and nesting areas may have reduced feeding opportunities and increased energy expenditure, forcing geese to use reserves normally dedicated to egg formation and possibly to abort their nesting attempt. The very low body mass of one of the three geese captured on the nest in June 1992 lends support to this hypothesis.

At Laforge, breeding pair density was constant over the years with the exception of 1995, when observed pair density declined by nearly half. Spring 1995 was warm, and both clutch size and apparent nest success were high. Bromley et al. (1995) found that population estimates determined from aerial surveys are negatively correlated with nest success. They contend that nesting birds tend to flush less readily when approached than do birds that have lost their nest. Thus, in good years, pair density will be underestimated. In 1995, low breeding pair densities were also observed during aerial surveys conducted throughout northern Quebec (Harvey and Bourget 1995; D. Bordage, unpubl. data). This pattern did not hold true at Laforge, however, in 1993, when spring conditions were also mild, nor in 1992, when we did not observe above-average pair density, even though climatic conditions were poor and nest success was low. Differential timing of surveys in relation to breeding chronology may also have influenced our density estimates, though to what degree it is impossible to determine.

Even in the best years, Canada Goose breeding pair density at Laforge is low compared with that in the coastal regions of the Ungava Peninsula and Ungava Bay

(Kaczynski and Chamberlain 1968; Malecki and Trost 1990; Bordage and Plante 1993), the Hudson Bay coast in Ontario (Bruggink et al. 1994; Schneider et al. 1994; Leafloor and Abraham, this publication), and even some inland areas in Ontario (Raveling and Lumsden 1977; Leafloor and Abraham, this publication), but similar to other boreal forest sites in northern Quebec (Tardif and Reed 1991; Morrier and Morneau 1992; Bordage and Plante 1993). Although density is low, Quebec's boreal forest region is vast, so a non-negligible proportion of Atlantic Population goose production probably originates from this region.

Because we found nests in the latter half of incubation, our estimates of nest density should be considered as minimum values. Different rates of nest success can influence the proportion of nests surviving to late incubation in a given year, so our estimates of nest density may be a better indicator of productivity than the total number of nests initiated.

Apparent nest success was >70% in all years except 1992 (Table 2), a year in which nest density was also very low (Table 1) and spring weather conditions were unfavourable. We have no evidence to suggest that the addition of new nest search areas after 1992 contributed to the observed difference in nest success. True nest success may have been considerably lower than our results indicate because nests destroyed or abandoned prior to mid incubation had little chance of being detected and most nest failure had probably already occurred. At Winisk, in northern Ontario, by the end of the third week of incubation, more than 90% of nests survived to hatch, whereas true nest success (based on nests under observation from laying to hatch) was about 60% (Bruggink et al. 1994). We were unable to measure true nest success at Laforge because the cost of locating nests during laying, when females are less attentive to their nest, would have been prohibitive. The Mayfield method (Mayfield 1961) offers a potential alternative for estimating success; however, we did not know exact laying or hatching dates for most nests and so were unable to measure exposure precisely. To do so would have called for at least two visits to each nest before hatch, requiring several additional hours of helicopter time. Given these limitations, our values for success should be taken as indices rather than a true measure of success and should be used with caution when compared with values from other studies.

Although our estimates of clutch size and apparent nest success appear to be indicative of a sound breeding population, productivity also depends on gosling survival. Brood density was low relative to nest density even though apparent nest success was high in four of the five years (Tables 1 and 2). The ratio of broods to pairs observed in the Laforge region (about 1:10) is very low for waterfowl (Johnson et al. 1992). However, Raveling and Lumsden (1977) also observed few broods in comparable habitat in northern Ontario where nests were much more abundant (three-year mean: approx. 17 nests/100 km^2) than at Laforge. The paucity of brood observations in forested parts of the species' range could be attributed either to poor gosling survival or to an inability to detect widely scattered broods in heavy vegetation. We attempted to minimize the detectability factor by radio-tracking breeding females. Only five of the 13 nest-marked females tracked during brood rearing between 1992 and 1994 were observed with young, suggesting that brood survival may be low. However, it is also possible that radio-marking may have affected the ability of some females to raise young. A reliable measure of gosling survival thus remains a key missing element in our understanding of the ecology of boreal forest-breeding Canada Geese and deserves further attention.

Obtaining good information on Canada Goose breeding ecology in Quebec's northern boreal forest is limited by the very low densities and the high costs of working in such an inaccessible area. Our measures of nest density and nest success are biased because we were unable to locate all nests in the study area early in the season. Although it would be imprudent to make definitive conclusions about the population based on these data, it may be a long time before we have better information on the breeding ecology of Canada Geese in this part of their range. Despite the limitations of the data, our results give new insight into the breeding ecology of a poorly known segment of the population and provide useful indices of several parameters related to annual productivity.

5.2 Effects of hydroelectric development

Creation of the hydroelectric reservoir at Laforge-1 appeared to have little effect on the local population of Canada Geese. In the three years after flooding, population density and nest density remained at pre-reservoir levels, and in 1995, both mean clutch size and nest success reached record high levels in the study area. The lack of any observed effect on population density, clutch size, or nest success may be partly due to the fact that no survey plots were wholly flooded. The nesting propensity of individual females may have been affected in 1994, the year immediately following flooding. Only one of five females, returning to the area where she was marked in either 1992 or 1993, nested in 1994. In contrast, in 1995, six of seven returning females settled in areas near their previous nesting sites, and five nested successfully. Although we cannot separate the effect of reservoir flooding from that of weather-related factors, it is clear that creation of the reservoir did not prevent successful reproduction in 1995.

Using mean densities for the affected zone in the two years before flooding (11.5 pairs and 2.7 nests/100 km^2) and the size of the area flooded in 1993 (975 km^2), we estimate that about 112 pairs and a minimum of 26 nests were potentially affected by creation of the reservoir. The surrounding region contains countless bogs, ponds, and lakes, only a small proportion of which were occupied by nesting or brood-rearing geese. Canada Goose breeding habitat may thus not be occupied to capacity at Laforge. This could explain the lack of change in population density and nesting habitat use, despite the loss of several hundred square kilometres of wetlands, and the ability of marked geese to successfully relocate after perturbation of their breeding habitat. Even in a worst-case scenario, only about 100 pairs would have lost their breeding territory, too small a number to have a measurable impact on the population as a whole.

6. Acknowledgements

We wish to thank field assistants Réjean Deschênes, Joël Poirier, Yves Poirier, Annie Raymond, and Eric Reed who helped with data collection and marking geese. Michel Julien of the James Bay Energy Corporation provided valuable advice and support throughout the study. The study was financed by the James Bay Energy Corporation and the Arctic Goose Joint Venture. Finally, we wish to thank Bob Bromley and an anonymous reviewer whose comments greatly improved the quality of the manuscript.

7. Literature cited

Bordage, D. 1987. Suivi des couples nicheurs de Canard noir en forêt boréale — 1985. Can. Wildl. Serv. Tech. Rep. Ser. No. 18, Environment Canada, Quebec Region, Ste-Foy. 29 pp.

Bordage, D. and N. Plante. 1993. Inventaire des couples nicheurs de Bernache du Canada dans le nord Québécois — 1993. Environment Canada, Canadian Wildlife Service, Quebec Region, Ste-Foy. 13 pp.

Bromley, R.G., D.C. Heard and B.C. Croft. 1995. Visibility bias in aerial surveys relating to nest success of arctic geese. J. Wildl. Manage. 59:364–371.

Bruggink, J.G., T.C. Tacha, J.C. Davies and K.F. Abraham. 1994. Nesting and brood-rearing ecology of Mississippi Valley population Canada Geese. Wildl. Monogr. 126. 39 pp.

Cochran, W.G. 1963. Sampling techniques. 2nd edition. Wiley and Sons, New York. 414 pp.

Cooper, J.A. 1978. The history and breeding biology of the Canada Geese of Marshy Point, Manitoba. Wildl. Monogr. 61. 87 pp.

Dwyer, T.G. 1972. An adjustable radio harness for ducks. Bird Banding 43:282–284.

Ely, C.R. and D.G. Raveling. 1984. Breeding biology of Pacific White-fronted Geese. J. Wildl. Manage. 48:823–837.

Gillespie, D.I. and S.P. Wetmore. 1974. Waterfowl surveys in Labrador–Ungava, 1970, 1971, 1972. Pages 8–18 *in* Boyd, H. (ed.), Waterfowl studies in eastern Canada, 1969–73. Can. Wildl. Serv. Rep. Ser. No. 29.

Harvey, W.F. 1994. A breeding pair survey of Canada Geese in northern Quebec — 1994. Unpublished report. Maryland Department of Natural Resources, Wye Mills, Maryland. 9 pp.

Harvey, W.F. and A. Bourget. 1995. A breeding pair survey of Canada Geese in northern Quebec — 1995. Unpublished report. Maryland Department of Natural Resources, Wye Mills, Maryland, and Canadian Wildlife Service, Ste-Foy, Quebec. 12 pp.

Harvey, W.F. and A. Bourget. 1996. A breeding pair survey of Canada Geese in northern Quebec — 1996. Unpublished report. Maryland Department of Natural Resources, Wye Mills, Maryland, and Canadian Wildlife Service, Ste-Foy, Quebec. 17 pp.

Harvey, W.F. and A. Bourget. 1997. A breeding pair survey of Canada Geese in northern Quebec — 1997. Unpublished report. Maryland Department of Natural Resources, Wye Mills, Maryland, and Canadian Wildlife Service, Ste-Foy, Quebec. 17 pp.

Hickey, E. 1979. Étude écologique de la Bernache canadienne (*Branta canadensis interior*) sur la Grande Rivière de la Baleine. Unpublished report. Hydro-Québec, Montréal. 112 pp.

Hindman, L.J., R.A. Malecki and J.R. Serie. 1996. Status and management of Atlantic Population Canada Geese. Pages 109–116 *in* Ratti, J.T. (ed.), Proceedings of the 7th International Waterfowl Symposium, Memphis, Tennessee.

Johnson, D.H., J.D. Nichols and M.D. Schwartz. 1992. Population dynamics in breeding waterfowl. Pages 446–485 *in* Batt, B.J., A.D. Afton, M.G. Anderson, C.D. Ankney, D.H. Johnson, J.A. Kadlec and G.L. Krapu (eds.), Ecology and management of breeding waterfowl. University of Minnesota Press, Minneapolis.

Kaczynski, C.F. and E.B. Chamberlain. 1968. Aerial surveys of Canada Geese and Black Ducks in eastern Canada. Spec. Sci. Rep. Wildl. 118. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 29 pp.

Klett, A.T., H.F. Duebbert, C.A. Faanes and K.F. Higgins. 1986. Techniques for studying nest success of ducks in upland habitats in the prairie pothole region. Resource Publication No. 158. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 24 pp.

Lamothe, P. 1982. Synthèse des études sur la Bernache du Canada des bassins de la Grande Rivière de la Baleine et de la Petite Rivière de la Baleine (1975–1980) et notes sur les autres espèces d'Anserinés. Unpublished report. Hydro-Québec, Montréal. 55 pp.

Malecki, R.A. and R.E. Trost. 1990. A breeding ground survey of Atlantic Flyway Canada Geese, *Branta canadensis*, in northern Quebec. Can. Field-Nat. 104:575–578.

Mayfield, H. 1961. Nesting success calculated from exposure. Wilson Bull. 73:255–261.

Mohr, C.O. 1947. Table of equivalent populations of North American small mammals. Am. Midl. Nat. 37:223–249.

Morrier, A. and F. Morneau. 1992. Densité, abondance et habitats de la sauvagine dans la région du complexe Nottaway–Broadback–Rupert. Report prepared by the Consortium Gauthier & Guillemette – G.R.E.B.E. for Hydro-Québec, Vice-présidence Environnement. Montréal, Québec. 238 pp. + appendices.

Raveling, D.G. and H.G. Lumsden. 1977. Nesting ecology of Canada Geese in the Hudson Bay Lowlands of Ontario: Evolution and population regulation. Fish Wildl. Res. Rep. No. 98. Ontario Ministry of Natural Resources, Maple, Ontario. 77 pp.

Reed, A. 1991. Subsistence harvesting of waterfowl in northern Quebec: goose hunting and the James Bay Cree. Trans. North Am. Wildl. Nat. Resour. Conf. 56:344–349.

Schneider, J.P., T.C. Tacha and J.O. Leafloor. 1994. Potential predictors of numbers of Canada Goose nests from aerial surveys. Wildl. Soc. Bull. 22:431–436.

Tardif, J. and A. Reed. 1991. Caractérisation préliminaire des habitats de nidification de la Bernache du Canada (*Branta canadensis*) dans la région du Lac Bienville. Unpublished report. Hydro-Québec, Montréal. 33 pp.

Nesting ecology and gosling survival of Canada Geese on Akimiski Island, Nunavut, Canada

James O. Leafloor, Michael R.J. Hill, Donald H. Rusch, Kenneth F. Abraham, and R. Kenyon Ross

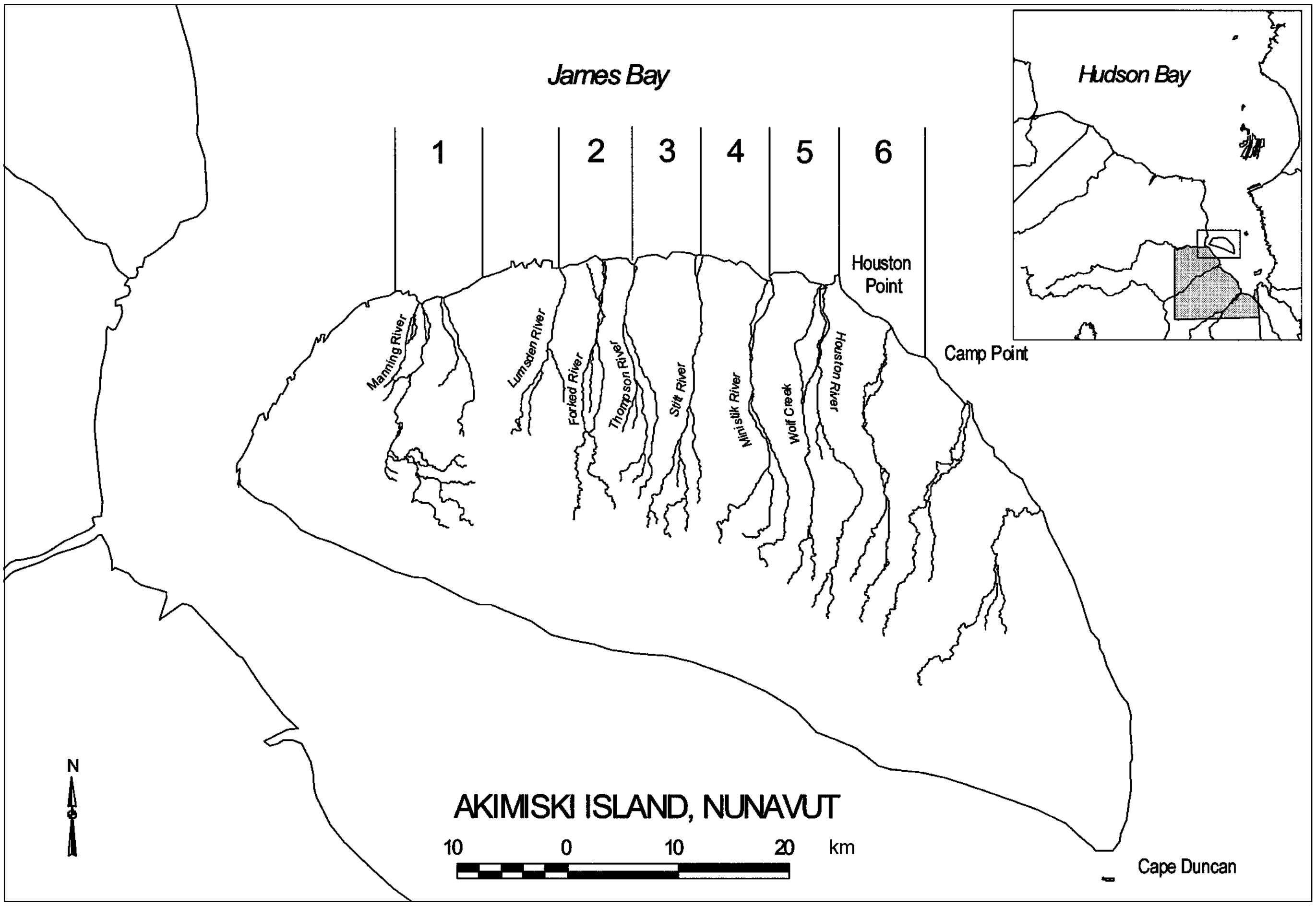
Summary

We studied nesting ecology and gosling survival of Canada Geese (*Branta canadensis interior*) on the north coast of Akimiski Island, Nunavut, from 1993 to 1999. Nest densities, adjusted for nests lost before searches began, averaged 0.12–0.32 nests/ha each year. Nest initiation began as early as 22 April in 1998, and as late as 25 May in 1996. Peak hatch usually occurred around June 10, on average, but nests began to hatch as early as 27 May in 1998, and as late as 9 June in 1994; the latest recorded hatch of any nest was 26 June in 1996. Initial clutch size averaged from 3.5 to 4.6 eggs, but partial clutch loss to predators and/or egg mortality and abandonment resulted in 2.9–4.3 goslings leaving successful nests, on average. Apparent nest success ranged from 65% in 1996 to 89% in 1995, but Mayfield estimates, which account for nests lost before nest searching began, ranged between 43% in 1996 and 79% in 1993. Hatching success (proportion of eggs hatching from when nests were first found in mid-incubation) was lowest in 1996 at 54%, and highest in 1995 at about 82%. Most nest loss resulted from depredation by Herring Gulls (*Larus argentatus*), Common Ravens (*Corvus corax*), foxes (*Vulpes vulpes* and *Alopex lagopus*), and polar bears (*Ursus maritimus*). Brood survival from hatch to banding (average age of goslings was 39–49 days) varied from 49 to 67% annually, and averaged 59% over 7 years. Predicted brood size at banding ranged from 1.94 to 2.88 for successful females. The mean number of goslings per brood patch female derived from banding statistics was usually higher than predicted brood size. We found no evidence of abnormally low gosling production during this study, but low direct recovery rates of banded goslings suggest that late summer gosling mortality may be a limiting factor in annual productivity of Canada Geese on the island. We recommend continued monitoring of nesting biology in conjunction with ongoing research, population surveys, and banding to better understand population dynamics of Canada Geese on Akimiski Island.

Résumé

Nous avons étudié l’écologie de la nidification et la survie des oisons chez la Bernache du Canada (*Branta canadensis interior*) sur la côte nord de l’île d’Akimiski, au Nunavut, de 1993 à 1999. Les densités des nids, ajustées en fonction des nids perdus avant le début des recherches, donnent une moyenne de 0,12 à 0,32 nid/ha à caque année. Le début de la construction des nids a commencé aussi tôt que le 22 avril en 1998, et aussi tard que le 25 mai en 1996. La période d’éclosion maximale a lieu en moyenne autour du 10 juin, mais les oeufs se sont mis à éclore aussi tôt que le 27 mai en 1998, et aussi tard que le 9 juin en 1994; l’éclosion la plus tardive enregistrée parmi tous les nids s’est produite le 26 juin en 1996. Les pontes initiales comptaient en moyenne de 3,5 à 4,6 œufs, mais après la prise d’œufs de la couvée par les prédateurs, la mortalité d’œufs et les abandons, une moyenne de 2,9 à 4,3 d’oisons partaient du nid avec succès. On relevait une réussite de nidification évidente s’étendant de 65 p. 100 en 1996 à 89 p. 100 en 1995, mais les estimations de Mayfield, qui tiennent compte des nids perdus avant le début des recherches, s’étendaient de 43 p. 100 en 1996 à 79 p. 100 en 1993. La réussite des éclosions (la proportion des œufs éclos à partir du moment où les nids ont été trouvés en pleine période d’incubation) était à son plus bas niveau en 1996 à 54 p. 100, et à son plus haut niveau en 1995 à environ 82 p. 100. La plupart des pertes de nids résultaient de la déprédation par des Goélands argentés (*Larus argentatus*), des Grands Corbeaux (*Corvus corax*), des renards (*Vulpes vulpes* et *Alopex lagopus*) et des ours polaires (*Ursus maritimus*). Le taux de survie des couvées de l’éclosion au baguage (l’âge moyen des oisons était de 39 à 49 jours) variait de 49 à 67 p. 100 annuellement avec une moyenne de 59 p. 100 pour 7 ans. Les prévisions du nombre d’oisons par couvée lors du baguage étaient de 1,94 à 2,88 par femelle dont la couvée avait réussi. Le nombre moyen d’oisons par femelle à plaque incubatrice, selon les statistiques de baguage, était généralement supérieur à celui qui avait été prévu. Nous n’avons trouvé aucun signe de production d’oison anormalement bas pendant cette étude, mais les faibles taux de rétablissement direct des oisons bagués semblaient indiquer que la mortalité d’oisons vers la fin de l’été constitue peut-être un facteur limitant de la productivité annuelle des Bernaches du Canada sur l’île. Nous recommandons qu’il y ait un suivi constant de la biologie de la nidification, conjointement avec une recherche continue, des relevés de populations et du baguage afin de mieux comprendre la dynamique des Bernaches du Canada sur l’île d’Akimiski.

Figure 1
Breeding range of the Southern James Bay Population of Canada geese, and location of the nesting study area on Akimiski Island, Northwest Territories



1. Introduction

The Southern James Bay Population (SJBP; formerly the Tennessee Valley Population or TVP) of Canada Geese (*Branta canadensis interior*) nests on Akimiski Island, Nunavut, and in the Hudson Bay Lowland of Ontario south of the Attawapiskat River (Fig. 1). Aerial surveys of this area were initiated in 1990 and resulted in a spring population estimate of only about 82 000 geese, well below estimates (about 230 000 geese) obtained from previous mid-January counts in the Mississippi Flyway (Leafloor et al. 1996). Subsequent spring surveys yielded similarly low estimates, suggesting that mid-January population estimates were likely confounded by large numbers of sympatric giant Canada Geese (*Branta canadensis maxima*) (Leafloor et al. 1996; Rusch et al. 1996). Numbers of SJBP Canada Geese on Akimiski Island dropped by almost 50% between 1990 and 1995, despite restrictive harvest regulations in the Atlantic and Mississippi flyways from 1991 onward (Leafloor et al. 1996). In addition, average brood sizes during July banding indicated poor production of goslings on Akimiski Island in 1990 and 1991, and only fair production in 1992 (Leafloor et al. 1996). Concern over the SJBP and the apparent low recruitment of goslings on Akimiski Island led to initiation of this study in 1993. We report our findings regarding nesting ecology and gosling survival on the island from 1993 to 1999.

2. Study area

Akimiski Island is located in western James Bay, about 20 km offshore from the mouth of the Attawapiskat River, and has an area of about 3000 km^2 (A. Jano, Ontario Centre for Remote Sensing [OCRS], pers. commun.). Our study was conducted on the north shore of the island, between our base camp (approx. 53°06' N, 80°58' W) and 81°50' W longitude (Fig. 1). The study area was divided into six areas using known landmarks, mainly rivers, for boundaries. Not all areas were monitored each year; in 1993 and 1994, we monitored areas 2–5, in 1995 areas 1–6, and during 1996–1999 areas 2–6. Our core study area (areas 2–5), which was consistently searched each year, was approximately 2114 ha in size, based on analysis of satellite imagery (A. Jano, OCRS, pers. commun.). Plant assemblages in the study area are influenced by a gradient of soil moisture, salinity, and drainage. A vegetational zonation occurs in the intertidal and supratidal areas, reflecting the influence of these factors. At the seaward end of the shore, silts and sands form mudflats. In the lower intertidal areas, plant cover is discontinuous and patchy, whereas in the upper intertidal marsh, it is continuous. The supratidal marsh is a mosaic of ponds, thickets of willow, and wetland graminoid species. Raised beaches occur occasionally in all zones, and landward-facing ridge slopes are often more heavily vegetated than seaward-facing ridges, which are subject to wave and ice action. The vegetation of the lower intertidal marsh is dominated by

Puccinellia phryganodes, and associated species include *Plantago maritima*, *Stellaria humifusa*, and *Potentilla egedii*. *Glaux maritima* forms monotypic stands lining the banks of tidal rivulets. The species composition of the mid-intertidal zone is similar except that *G. maritima* is less abundant and *Festuca rubra* occurs in the sward. Pools in this zone and the upper intertidal zone contain emergent species, such as *Hippuris vulgaris* and *Eleocharis palustris*, and submergent species, such as *Potamageton filiformis*. The abundant species in the upper intertidal graminoid swards are *F. rubra*, *Calamagrostis deschampsioides*, *Juncus arcticus*, and *J. balticus*, and *Carex subspathacea* occurs in low-lying and moist areas. In this zone, the willow shrubs *Salix brachycarpa* and *S. myrtillifolia* and herbaceous species such as *Primula stricta* and *Matricaria matricarioides* are present. In the supratidal zone, willow thickets are often 2–3 m in height and consist of *Salix* species, especially *S. candida*, *S. planifolia*, *S. lanata*, and *Myrica gale*. The vegetation of the pools and surrounding wetlands is a mixture of species that includes *Carex aquatilis*, *Calamagrostis neglecta*, *Potamageton* spp., *Myriophyllum* spp., and *Ranunculus* spp. The seaward beach ridges are sparsely colonized by *Leymus mollis* and *Honkenya peploides*, while older landward ridges have dense stands of *L. mollis* and an array of shrubs, grasses, and forbs. This area was chosen because of its high nest densities and for ease of relocating marked nests at hatch.

3. Methods

Each year in early May, two or three people were flown by Twin Otter to the island, where a base camp was established. Preliminary nest searches were conducted in coastal areas up to about 8 km from camp. Data collected from these searches were used to determine the timing of nest searching in the study area; we did not begin nest searches in the rest of the study area until egg laying was thought to be completed. A helicopter was used to transport workers to and from the study area each day. Eight to ten people searched for Canada Goose nests beginning at base camp and working westward; each area took 1–2 days to search completely, depending on the number of nests found. Data were recorded on previously numbered cards, so that each nest was given a unique identification number. We recorded the date and initial clutch size (ICS) for each nest and floated the cleanest and dirtiest eggs in nearby ponds or puddles to determine the stage of incubation and thereby estimate hatch dates. We classified eggs into one of six stages based on their float characteristics, assumed a 28-day incubation period, and estimated nest ages and the range of hatch dates in the study area (modified from Westerskov 1950; Walter and Rusch 1998). The predicted hatch dates were then used to schedule return visits to web-tag goslings (see below). Clutch size data represent minimum clutch sizes because they were recorded in mid-incubation, after some egg depredation could have occurred. All eggs were marked with the nest number and an individual egg number for later identification. We covered the eggs with down and nest material and left the nest site as quickly as possible to reduce the likelihood of human-induced depredation. All nests were marked with either wooden or wire stakes placed 20–30 m due north of the nest; fluorescent orange flagging tape was added to the stakes to facilitate relocation of the nests at hatch.

Field crews returned during the hatching period to determine nest fates, record hatching dates, and web-tag goslings in the nests. At least two people were assigned to each area, and they attempted to visit every nest in an area daily until hatching was complete. We did not visit nests when weather conditions were judged to be too severe (e.g., during rain, sleet, snow, or days with high wind chills) or when fog prevented us from leaving camp. During each visit, we recorded the number of remaining eggs and web-tagged any goslings still in the nest. The fate of nests that contained no eggs was determined by examining eggshell fragments; those that had eggshells with intact dried membranes were considered to be successful, and all others (i.e., no shell fragments present, or evidence of depredation) to be depredated. Clutch size at hatch (CSH) was the number of eggs in a nest when hatching began in that nest. When possible, we counted the number of intact membranes to determine the number of goslings leaving successful nests (GLN). If there were fewer membranes found than the number of eggs in the nest on the previous visit, GLN was recorded as unknown. If a brood was completely marked and no goslings remained in the nest on the next day, all were assumed to have departed successfully. Nests were considered to be abandoned when eggs were cold, an incubating female was not observed, and flotation of the eggs indicated that development had been arrested. Date of hatch was considered to be the date on which most eggs in a nest showed signs of hatching (eggs pipped or windowed, i.e., when a gosling had opened a gap in the membrane and shell) or the day before goslings left the nest (i.e., age of goslings at hatch = 0). For example, if goslings were found in a nest, it was assumed that they would depart from the nest that day, and the previous day was considered the date of hatch. Most goslings left nests within one day of eggs being pipped (J. Leafloor, unpubl. data).

We used individually numbered size 1 Monel web tags to mark goslings at hatch. As a general rule, we marked any available goslings in a nest, even if some eggs had not yet hatched. If most eggs in a clutch were pipped, we usually enlarged the windows, when necessary, and extracted a foot for web-tagging. If most eggs in the clutch were not pipped, we usually delayed marking until the next day. To reduce human-induced depredation, we covered goslings and eggs with nest material and down before our departure from the nest site. Nests were visited again the day after marking occurred and daily thereafter until we could determine whether all goslings eventually left the nest. We recorded dead goslings and any eggs that were abandoned after geese and their goslings left the nest, and nest stakes were then removed. We found some unmarked nests during the hatch period each year and included these in our analyses. In late July, we returned to the island to capture and leg-band Canada Geese on the north shore. Individual web-tag numbers, date, location, and sex were recorded for all recaptured goslings.

Dates of nest initiation were estimated by backdating 28 days from the date of hatch, plus an additional day for each egg laid, plus one additional day to account for skipped days. We calculated apparent nest success as the proportion of nests that hatched at least one egg (Klett and Johnson 1982) and using the Mayfield (1961) method, which accounts for nests lost prior to nest searches. In calculating the number of nest exposure days for Mayfield nest success, we used the actual date that a nest was lost or hatched when it was known. When the date of nest loss was unknown, we assumed that nests survived 40% of the interval between nest visits (Miller and Johnson 1978). For successful nests in which we could not determine the exact hatch date, we used the mean number of exposure days for successful nests with known hatch dates. Nests that were not relocated, or for which fate could not be determined, were excluded from these calculations. Daily survival rates were applied to nesting periods of 33 days, assuming a 28-day incubation period (Raveling and Lumsden 1977) and an average of 5 days of egg laying. Nest density was determined for the core study area (areas 2–5; nest density = total nests located/2114 ha), and we also included an estimate of density that was adjusted for nests lost prior to nest searching by dividing the number of nests not known to fail (i.e., successful + active + unknown) by the Mayfield estimate of nest success (Miller and Johnson 1978).

We calculated the total number of eggs on the study area as the product of the number of nests located and mean initial clutch size. We calculated the number of goslings that left nests as the product of total nests, proportion of nests (for which fate was known) that hatched at least one egg, and mean GLN. From these values, we calculated hatching success (the proportion of all eggs that hatched) as total number of goslings leaving nests/total number of eggs. This measure may overestimate hatching success because we did not correct for nests lost prior to nest searching, but nest visits likely increased the likelihood of nest loss, so the two factors may offset each other somewhat. Our measure is an accurate reflection of the proportion of eggs hatching from nests from the time they were first located, on average, around mid-incubation.

We calculated the product of mean GLN, proportion of successful nests, and total number of nests to estimate the total number of goslings available to be web-tagged each year; we then calculated the proportion of available goslings marked. Brood survival was calculated for each brood individually as the number of goslings recaptured divided by the number marked at hatch, then averaged over all broods for which we had at least one recapture. Predicted brood size at banding was calculated as the product of GLN and mean brood survival. Broods for which no goslings were recaptured were excluded from these calculations. We also divided the number of goslings captured during banding by the number of adult females that had a brood patch (Hanson 1959) to get an independent estimate of average brood size. We excluded banding drives from which large numbers of geese escaped during the drive, and also excluded moult migrant giant Canada Goose adults using measurements of skull length (Merendino et al. 1994; Abraham et al. 1999). We compared mean ICS, CSH, and GLN among years using one-way analysis of variance (ANOVA), followed by Duncan's Multiple Range Tests when differences among years were significant.

4. Results

Canada Geese usually initiated nests in early to mid-May, but egg laying began as early as 22 April in 1998, and as late as 25 May in 1996 (Table 1). On average, peak hatch occurred around 10 June, but nests began to hatch as early as 27 May in 1998, and as late as 9 June in 1994. The latest recorded hatch of any nest was on 26 June in 1996. Minimum nest densities were fairly stable over 7 years, but dropped substantially in 1996 (Table 2), which was a year of exceptionally late snowmelt. Adjustment of nest densities to account for nests lost prior to nest searching resulted in an average density of 0.257 nests/ha over the study period.

Apparent nest success ranged from 65% in 1996 to almost 89% in 1995 (Table 2), and averaged nearly 82% over 7 years. These estimates approximate the proportion of successful nests that had survived to mid-incubation, or the average age of nests when located (Table 2). Mayfield nest success ranged from 42% in 1996 to about 79% in 1993 (Table 2), and averaged 65.2% over 7 years. These estimates reflect the proportion of nests initiated that ultimately hatched at least one egg.

Mean initial clutch size, CSH, and GLN varied among years (ANOVA, $P = 0.0001$; Table 2). There were significant negative correlations between date of peak hatch and initial clutch size (r = !0.78, P = 0.04), CSH (r = !0.81, P = 0.03), and GLN (r = !0.80, P = 0.03). Partial clutch losses (calculated as ICS minus GLN) to predators, infertility, egg and gosling mortality, and abandonment resulted in declines of 0.3 to 0.6 eggs per successful nest (Table 2). Partial clutch loss and complete nest loss were highest in 1996, when nest densities were lowest. Hatching success from about mid incubation onward was over 70% in all years except 1996 (Table 2). The main source of nest loss was depredation by Herring Gulls (*Larus argentatus*), Common Ravens (*Corvus corax*), foxes (*Vulpes vulpes* and *Alopex lagopus*), and polar bears (*Ursus maritimus)* (Table 3). Nest fate was unknown for 4–9% of nests each year, either because we did not relocate some nests or because evidence of hatching versus depredation was equivocal.

We estimated that there were approximately 500–3000 goslings available to be marked in nests that we located each year (Table 4). Variation in numbers available resulted from differences in areas searched, nest density, clutch size, and nest success. We web-tagged between 42 and 88% of available goslings each year, but recaptured only 6–22% of those at banding (Table 4). Marked goslings accounted for less than 15% of all goslings captured during banding each year (J. Leafloor, unpubl. data). Proportional brood survival from hatch until banding (excluding total brood loss, which we could not detect) ranged from 49 to 67% (Table 4), and averaged 59% during 1993–99. Mean age of goslings at banding varied annually from 39 to 49 days (youngest 30 days and oldest 57 days over all years), with an overall average of about 45 days. Predicted brood sizes at banding ranged from 1.94 to 2.88 goslings; banding data suggested average brood sizes of 2.0–3.7 goslings per brood patch female (Table 4). Average brood size calculated from banding statistics was almost always higher than that calculated from nesting and brood survival data (Table 4).

5. Discussion

Nest densities of Canada Geese in our study area were among the highest recorded for this subspecies, averaging at least 0.2 nests/ha, and about 0.26 nests/ha when we accounted for early nest loss, over 7 years. Mean nest densities for *B. c. interior* from the muskeg country near

Table 1
Nesting chronology of Canada Geese on Akimiski Island, Nunavut, 1993–99

	Year						
Variable	1993	1994	1995	1996	1997	1998	1999
Nest initiation period	4–14 May	6–17 May	3–16 May	14–25 May	4–19 May	22 Apr–7 May	27 Apr–8 May
Hatching period	7–15 June	9–19 June	6–16 June	16–26 June	6–21 June	27 May–9 June	1–10 June
Estimated peak of hatch	11 June	14 June	9 June	21 June	11 June	2 June	4 June

Table 2
Mean reproductive variables for Canada Geese nesting on Akimiski Island, Nunavut, 1993–99. Standard errors are in parentheses.

	Year						
Variable	1993	1994	1995	1996	1997	1998	1999
Nest density (nests/ha)	0.265	0.235	0.251	0.075	0.221	0.185	0.198
Adjusted nest density[a]	0.295	0.323	0.292	0.119	0.271	0.252	0.247
Estimated nest age (days)[b]	9.6 (0.45) n = 261	15.1 (0.25) n = 373	14.3 (0.20) n = 444	14.2 (0.35) n = 135	12.7 (0.25) n = 429	16.1 (0.32) n = 303	14.2 (0.26) n = 428
Initial clutch size[c] (or ICS)	4.61 (0.04)**A** n = 562	4.01 (0.05)**C** n = 501	4.52 (0.04)**A** n = 813	3.51 (0.08)**D** n = 262	4.11 (0.05)**C** n = 635	4.30 (0.05)**B** n = 503	4.62 (0.05)**A** n = 573
Clutch size at hatch[c] (or CSH)	4.36 (0.07)**AB** n = 332	3.71 (0.06)**E** n = 363	4.23 (0.06)**BC** n = 525	3.11 (0.11)**F** n = 140	4.01 (0.06)**D** n = 435	4.07 (0.07)**CD** n = 292	4.47 (0.06)**A** n = 435
Goslings leaving nest[c] (or GLN)	4.3 (0.08)**A** n = 251	3.59 (0.07)**C** n = 339	4.16 (0.06)**AB** n = 501	2.91 (0.12)**D** n = 128	3.72 (0.07)**C** n = 379	3.95 (0.08)**B** n = 244	4.32 (0.07)**A** n = 336
Apparent nest success (%)	86.3 n = 480	80.6 n = 464	88.7 n = 753	65.0 n = 230	84.6 n = 545	82.2 n = 455	84.5 n = 509
Mayfield nest success (%)	79.3 n = 518	58.7 n = 479	76.7 n = 779	41.9 n = 250	71.8 n = 585	60.7 n = 476	67.1 n = 523
Hatching success (%)	80.5	72.2	81.6	53.9	76.6	75.5	79.0

[a] Nest density was adjusted for nests lost before they were located by use of the following formula: Number of nests not destroyed / Mayfield nest success = Number of nests initiated (Miller and Johnson 1978).
[b] Number of days since the last egg was laid in the nest.
[c] Within each row, means followed by the same letter were not significantly different (Duncan's Multiple Range Test, $P > 0.05$).

Table 3
Fates of Canada Goose nests on Akimiski Island, Nunavut, 1993–99

	Year						
Nest fate	1993	1994	1995	1996	1997	1998	1999
Number of nests	562	501	813	262	635	507	573
Hatched ≥ 1 egg	414	374	668	150	461	374	430
Depredated	59	84	80	79	83	81	76
Abandoned	7	6	5	1	1	0	3
Active[a]	38	15	26	20	40	21	14
Unknown/not relocated	44	22	34	12	50	31	50

[a] Nests that were still being incubated when we left the island, or when last located during the hatch period.

Kinoje Lake, Ontario (located about 210 km southwest of Akimiski Island), ranged from about 0.003 to 0.0009 nests/ha in 1967–1969; the most densely occupied areas had densities of about 0.06 nests/ha (Raveling and Lumsden 1977). Bruggink et al. (1994) found nest densities for Canada Geese of the Mississippi Valley Population (MVP) that ranged from 0.05 to 0.09 nests/ha near the Hudson Bay coast at Winisk, Ontario, about 330 km northwest of Akimiski. Minimum nest densities of Eastern Prairie Population (EPP) Canada Geese at Cape Churchill, Manitoba, declined from 1976 to 1996, ranged from 0.05 to 0.38 nests/ha, and averaged 0.15 nests/ha when water bodies were excluded from the area searched (Walter 1999). When nest densities of EPP Canada Geese were adjusted for nests not located (by a different technique from the one we used), densities ranged from 0.07 to 0.51 nests/ha, and averaged 0.22 nests/ha over 21 years (Walter 1999). Nest densities in the coastal zone are not representative of Akimiski Island as a whole; breeding pair densities estimated from spring aerial surveys of the entire island during 1993–99 averaged only 0.030 nests/ha (adjusted upward by 40% to account for visibility bias; J. Leafloor, unpubl. data). Given the recent steep decline in numbers of Canada Geese on Akimiski Island, it is likely that historical densities were even higher than those that we found. Goose densities over the whole island, uncorrected for visibility bias but including some birds that likely did not nest, averaged 0.25 birds/ha in 1985, before numbers dropped by almost 70% in the following decade (Leafloor et al. 1996).

Table 4
Numbers of goslings marked and recaptured, and estimates of brood survival from hatching until late July 1993–99 on Akimiski Island, Nunavut (standard errors in parentheses)

	Year						
Variable	1993	1994	1995	1996	1997	1998	1999
Goslings available[a]	2086	1450	3000	496	1999	1634	2092
Goslings marked (n)	875	1272	1676	318	1470	981	1385
Goslings marked (%)	41.9	87.7	55.9	64.1	73.5	60.0	66.2
Broods completely marked	149	314	358	95	306	186	246
Broods partially marked	159	60	310	55	155	188	184
Marked goslings recaptured (n)	140	175	173	69	148	62	222
Marked goslings recaptured (%)	16.0	13.8	10.3	21.7	10.1	6.3	16.0
Marked broods represented	55	81	77	35	78	33	87
Mean age of goslings (days)	44.8 (0.4)	45.3 (0.3)	48.0 (0.5)	39.1 (0.7)	44.5 (0.5)	46.9 (0.7)	49.0 (0.5)
Age range of goslings	40–52	35–51	37–57	32–47	30–52	39–55	40–57
Brood survival (%)	67 (4)	60 (3)	58 (3)	67 (4)	54 (3)	49 (4)	61 (3)
Predicted brood size[b]	2.88	2.15	2.41	1.95	2.01	1.94	2.64
Brood size at banding	2.19	2.42	3.74	2.33	3.11	2.02	2.64

[a] Calculated as follows: Number of nests located × Apparent nest success × Mean number of goslings leaving nests.
[b] Calculated as follows: Mean number of goslings leaving successful nests × Mean brood survival to banding.

Nesting chronology was generally later than that reported from around Kinoje Lake (Raveling and Lumsden 1977). This was confirmed in 1993, when an independent sample of eggs was collected from 26 nests near Kinoje Lake and from 40 nests on Akimiski Island. There was little overlap in hatch dates between the two samples, and the mean date of hatch for eggs from Akimiski was 6 days later than for mainland eggs (Leafloor et al. 1998). Nesting chronology on Akimiski was similar, but perhaps slightly earlier than that reported for MVP geese, where median hatch dates ranged from 10 to 19 June (Bruggink et al. 1994) and averaged 2–3 weeks earlier than at Cape Churchill (Walter 1999). Nesting along the coast may occur later than in muskeg habitats in the interior of Akimiski and the adjacent mainland because of effects of surrounding ice cover. Martini and Glooschenko (1984) reported that "The coasts of the Island are anomalously cold for their latitude because of exposure to consistently frigid waters of James Bay."

Canada Geese generally lay smaller clutches of eggs in later nesting seasons (MacInnes and Dunn 1988), and mean clutch size declines with increasing latitude (Dunn and MacInnes 1987). Mean initial (minimum) clutch sizes on Akimiski were similar to those reported at Kinoje Lake (4.4–4.7 eggs; Raveling and Lumsden 1977) and Winisk (4.4–5.0 eggs; Bruggink et al. 1994) and were slightly larger than those at Cape Churchill, where clutches averaged 3.85 eggs during 1976–96 (Walter 1999). As with other studies, clutch size declined in late years.

Nest success on Akimiski Island was at least as high as that reported for other populations of *B. c. interior*. Mayfield estimates averaged 56% over 6 years for MVP Canada Geese at Winisk (Bruggink et al. 1994), and only 35.5% during 1976–93 at Cape Churchill (Walter 1999). Apparent nest success estimates reported by Raveling and Lumsden (1977) for Canada Geese nesting in muskeg habitat near Kinoje Lake were similar to those on Akimiski Island. We originally hypothesized that nest depredation by foxes could be high on the island because of reduced furbearer trapping there in recent years. It was often impossible to ascertain the identity of nest predators, but depredation by Herring Gulls and Common Ravens was observed on several occasions, and in some cases was likely caused by our presence (see MacInnes and Misra 1972). In 1996, approximately 30% of depredated nests were taken by polar bears (see also Smith and Hill 1996). Overall, nest depredation was not unusually high, and we found no evidence of high fox numbers. The number of goslings leaving successful nests was 7–17% lower than mean clutch size each year, indicating that infertility, egg and gosling mortality, and partial depredation of clutches resulted in some loss of potential productivity. Nest abandonment occurred in less than 1% of nests located, on average, lower than rates reported by Bruggink et al. (1994), in a study where nest visits were more frequent than ours. Ewaschuk and Boag (1972) reported abandonment rates of around 20% for a densely nesting population of Canada Geese on a 6.5-ha island in Alberta, mostly due to aggressive interactions among nesting pairs; however, nest densities there were 20–25 times higher than those we found in this study.

Brood survival from hatch to banding in late July (about 45 days) was about the same as that reported for MVP Canada Geese (59%; Bruggink et al. 1994), but their estimates accounted for total brood loss, and ours did not. We probably overestimated gosling survival because we were unable to detect complete brood loss. Predicted brood sizes were still lower than those calculated from banding data. Higher age ratios at banding may occur because some adult females are not captured with their young, either because they escape or because they have abandoned their broods. Bruggink et al. (1994) reported several instances where goslings were captured during banding without their marked parents being captured. Average brood size in some banding drives exceeded the average clutch size measured in the same year (J. Leafloor, unpubl. data), suggesting that some form of brood amalgamation had occurred, either permanently or temporarily. Average brood size at banding (1.9–3.7 goslings per brood patch female) was higher during this study than it was in 1990 and 1991 (1.4 and 1.6 goslings per brood patch female, respectively), when poor gosling production on the island first became a concern. Circumstances may have changed substantially during the 1990s.

We marked at least 40% of available goslings in our study area each year, yet marked goslings accounted for less than 15% of goslings captured at banding in late July. We can think of two possible explanations for this: (1) marked goslings suffered drastically higher mortality than did unmarked goslings, or (2) geese that nested elsewhere moved onto the study area to raise their broods. We believe the former explanation to be unlikely, because gosling mortality would have to have been at least 5–6 times higher among marked goslings to account for the low proportion recaptured. Brood survival among broods with at least one gosling captured at banding averaged 59%, suggesting reasonable survival rates for at least some of the marked broods. Additionally, estimates of average brood size of marked broods were similar to estimates of average brood size from the overall sample of geese captured during July banding in several years. Therefore, we conclude that the low proportion of web-tagged goslings encountered during banding resulted from an influx of untagged goslings from inland nesting areas adjacent to our study area. Didiuk (1979) similarly noted that most geese nesting <5 km from the coast of Hudson Bay at Cape Churchill congregated along the coast during brood rearing. Coastal habitats on Akimiski provide higher-quality forage plants (e.g., *Puccinellia phryganodes, Carex subspathacea*) than do inland areas and ready access to James Bay for escape from predators during the flightless period.

We found no evidence of poor gosling production through the banding period on Akimiski Island from 1993 to 1999, except possibly in 1996. Average clutch size, nest success, and gosling survival from hatch to banding in late July were all within the normal or high range of values previously reported for other populations of *B. c. interior*. In 1996, the latest spring on record in the past 50 years, we recorded reduced nesting effort, clutch sizes, and nest success. Gosling survival was highest in 1996, though, and may have been a result of reduced competition for food resources on brood-rearing areas (see also Sedinger et al. 1998). High densities of geese foraging on brood-rearing areas have been implicated as the cause of smaller structural size of Canada Geese nesting on Akimiski Island compared with those on the mainland of James Bay (Leafloor et al. 1998).

Ongoing research suggests that much of the brood-rearing habitat on the north shore of Akimiski Island has been severely degraded by intensive foraging activities of geese (K.F. Abraham, R.L. Jefferies, P. Kotanen, unpubl. data). Similar degradation caused declines in body size (Cooch et al. 1991) and survival (Williams et al. 1993a) of Snow Geese (*Chen caerulescens*) at La Perouse Bay, Manitoba. Poor body condition of goslings resulted in increased banding mortality (Williams et al. 1993b), and declining direct recovery rates suggested lowered first-year survival of goslings between banding and fall migration (Francis et al. 1992, 1993). Direct recovery rates of goslings banded on Akimiski Island have been declining since 1987 and may suggest high mortality late in brood rearing or early in fall migration (Leafloor et al. 1996). Hill (1999) found that large goslings on Akimiski were most likely to be recovered by hunters, whereas small goslings were rarely encountered again after banding, suggesting that only the largest goslings survived to migrate southward. We recommend continued monitoring of nest success and gosling survival on Akimiski Island as part of a comprehensive, long-term population monitoring program that includes spring population surveys, banding, and habitat assessment.

6. Acknowledgements

This study was funded by the Ontario Ministry of Natural Resources and state and federal agencies of the Mississippi and Atlantic flyways. We gratefully acknowledge the annual provision of a helicopter and personnel by the Ohio Division of Wildlife. We thank the many dedicated people who helped us during the study and made it so enjoyable: E. Abraham, A. Admire, R. Ainslie, C. Alexander, P. Alisappi, G. Anderson, D. Ankney, R. Argue, L. Armer, B. Arquilla, C. Ayotte, F. Babineau, S. Badzinski, T. Baker, B. Barlow, T. Barney, S. Barry, D. Bascello, B. Batt, L. Beaudin, J. Bish, C. Blackburn, S. Blaney, J. Bull, D. Byers, K. Charleston, M. Checkett, C. Chenier, J. Coluccy, B. Conrad, K. Corston, G. Costanzo, D. Coulson, M.J. Croonquist, L. D'Andrea, T. Daniels, J. Daugherty, L. Delean, R. D'eon, M. Deschamps, U. Dias, M. Donovan, P. Dorian, Y. Duguay, G. Dunn, J. Dunn, A. Dzubin, D. Eggleton, A. Fejes, B. Ffrench, K. Fritz, Z. Gadallah, A. Gagnon, T. Giesler, P. Gilboe, J. Gleason, T. Gouza, G. Grabas, B. Gurd, M. Hendry, T. Henry, L. Hildebrandt, L. Hilden, B. Hill, M. Hill, S. Hill, M. Hortiguela, B. Hunter, J. Hunter, T. Hunter, D. Hurd, K. Jacobs, L. Jagger, A. Jano, T. Jeffery, G. Johnson, J. Johnson, M. Johnson, S. Johnson, E. Kafkas, N. Kafkas, P. Kapashesit, C. Kapke, A. Karr, J.M. Kelley, P. Kotanen, R. Kroll, D. Kunkle, C. Lamey, J. Lane, A. Lawson, M. Lazarus, M. Lindberg, F. Long, M. MacCluskie, J. MacDonald, J. Marshall, G. Martin, R. Martin, B. May, B. McComb, D. McCrae, T. McVey, S. McWilliams, J. Moller, P. Moon, B. Moore, L. Moore, D. Morrison, R. Nakogee, M. Obbard, B. Odum, K. Patton, R. Petrie, S. Petrie, A. Pineault, B. Pollard, B. Pott, P. Prevett, S. Repasky, B. Reuben, E. Reuben, M. Reuben, G. Richer, T. Rickard, G. Ritchie, R. Rockwell, D. Ross, G. Ross, M. Roy, M. Sanborn, M. Sawyer, S. Scholten, D. Sherman, J. Shott, B. Sigouin, A. Smith, L. Smith, D. Solin, S. Stevens, A. Stewart, R. Stewart, R. Stitt, D. Sutherland, M. Sutherland, P. Sutherland, R. Tapley, S. Taylor, R. Teunisson, J. Thompson, C. Timmermans, S. Timmermans, V. Tisch, S. Todtz, B. Triplett, G. Tupling, M. Vrtiska, J. Walker, S. Walter, B. Warren, B. Weikert, S. Weyers, T. Williams, K. Willinger, N. Wilson, T. Winninghoff, M. Witt, and J. Wood. Special thanks to our helicopter and twin otter pilots: J. Barber, B. Beaulac, J. Clem, P. Crosby, B. Crowell, J. Delean, B. Fahlgren, D. Filliter, D. Flieler, B. Gibson, G. Gorgichuk, R. Heard, D. Holtby, D. Ireland, J. Karras, R. Lamont, K. Mulcair, M.E. Pauli, A. Quinn, R. Seguin, G. Smith, and K. Walls. Thanks to A. Jano for supplying the figure, and to K. Dickson for editorial assistance.

7. Literature cited

Abraham, K.F., J.O. Leafloor, and D.H. Rusch. 1999. Molt migrant Canada Geese in northern Ontario and western James Bay. J. Wildl. Manage. 63:649–655.

Bruggink, J.G., T.C. Tacha, J.C. Davies, and K.F. Abraham. 1994. Nesting and brood-rearing ecology of Mississippi Valley Population Canada Geese. Wildl. Monogr. 126. 39 pp.

Cooch, E.G., D.B. Lank, R.F. Rockwell, and F. Cooke. 1991. Long-term decline in body size in a Snow Goose population: evidence of environmental degradation? J. Anim. Ecol. 60:483–496.

Didiuk, A.B. 1979. Movements and distribution of Canada Geese near Cape Churchill, Manitoba. Unpublished M.Sc. Thesis, University of Wisconsin, Madison. 45 pp.

Dunn, E.H., and C.D. MacInnes. 1987. Geographic variation in clutch size and body size of Canada Geese. J. Field Ornithol. 58:355–371.

Ewaschuk, E., and D.A. Boag. 1972. Factors affecting hatching success of densely nesting Canada Geese. J. Wildl. Manage. 36:1097–1106.

Francis, C.M., M.H. Richards, F. Cooke, and R.F. Rockwell. 1992. Long-term changes in survival rates of lesser Snow Geese. Ecology 73:1346–1362.

Francis, C.M., M.H. Richards, F. Cooke, and R.F. Rockwell. 1993. Changes in survival rates of lesser Snow Geese with age and breeding status. Auk 109:731–747.

Hanson, H.C. 1959. The incubation patch of wild geese: its recognition and significance. Arctic 12:139–150.

Hill, M.R.J. 1999. Factors influencing pre- and post-fledging growth and survival of Canada Goose goslings on Akimiski Island, Nunavut. Ph.D. Dissertation, The University of Western Ontario, London, Ontario. 155 pp.

Klett, A.T., and D.H. Johnson. 1982. Variability in nest survival rates and implications to nesting studies. Auk 99:77–87.

Leafloor, J.O., K.F. Abraham, D.H. Rusch, R.K. Ross, and M.R.J. Hill. 1996. Status of the Southern James Bay Population of Canada Geese. Pages 103–108 *in* Ratti, J.T. (ed.), Proceedings of the 7th International Waterfowl Symposium, Memphis, Tennessee.

Leafloor, J.O., C.D. Ankney, and D.H. Rusch. 1998. Environmental effects on body size of Canada Geese. Auk 115:26–32.

MacInnes, C.D., and E.H. Dunn. 1988. Components of clutch size variation in arctic-nesting geese. Condor 90:83–89.

MacInnes, C.D., and R.K. Misra. 1972. Predation on Canada Goose nests at McConnell River, Northwest Territories. J. Wildl. Manage. 36:414–422.

Martini, I.P., and W.A. Glooschenko. 1984. Emergent coasts of Akimiski Island, James Bay, Northwestern Territories, Canada: geology, geomorphology, and vegetation. Sediment. Geol. 37:229–250.

Mayfield, H. 1961. Nesting success calculated from exposure. Wilson Bull. 73:255–261.

Merendino, M.T., C.D. Ankney, D.G. Dennis, and J.O. Leafloor. 1994. Morphometric discrimination of giant and Akimiski Island Canada Geese. Wildl. Soc. Bull. 22:14–19.

Miller, H.W., and D.H. Johnson. 1978. Interpreting the results of nesting studies. J. Wildl. Manage. 42:471–476.

Raveling, D.G., and H.G. Lumsden. 1977. Nesting ecology of Canada Geese in the Hudson Bay Lowlands of Ontario: evolution and population regulation. Ont. Min. Nat. Resour. Fish Wildl. Res. Rep. 98. 77 pp.

Rusch, D.H., F.D. Caswell, M.M. Gillespie, and J.O. Leafloor. 1996. Research contributions to management of Canada Geese in the Mississippi Flyway. Trans. North Am. Wildl. Nat. Resour. Conf. 61:437–449.

Sedinger, J.S., M.S. Lindberg, B.T. Person, M.W. Eichholz, M.P. Herzog, and P.L. Flint. 1998. Density-dependent effects on growth, body size, and clutch size in Black Brant. Auk 115:613–620.

Smith, A.E., and M.R.J. Hill. 1996. Polar bear, *Ursus maritimus*, depredation of Canada Goose, *Branta canadensis*, nests. Can. Field-Nat. 110:339–340.

Walter, S.E. 1999. Nesting ecology of Eastern Prairie Population Canada Geese. Ph.D. Dissertation, University of Wisconsin, Madison. 204 pp.

Walter, S.E., and D.H. Rusch. 1998. Accuracy of egg flotation in determining age of Canada Goose nests. Wildl. Soc. Bull. 25:854–857.

Westerskov, K. 1950. Methods for determining the age of game bird eggs. J. Wildl. Manage. 14:56–67.

Williams, T.D., E.G. Cooch, R.L. Jefferies, and F. Cooke. 1993a. Environmental degradation, food limitation and reproductive output: juvenile survival in Lesser Snow Geese. J. Anim. Ecol. 62:766–777.

Williams, T.D., F. Cooke, E.G. Cooch, and R.F. Rockwell. 1993b. Body condition and gosling survival in mass-banded Lesser Snow Geese. J. Wildl. Manage. 57:555–562.

Procedures for monitoring the Mississippi Valley Population of Canada Geese and suggestions for improvement

James O. Leafloor and Kenneth F. Abraham

Summary

The Mississippi Valley Population (MVP) of Canada Geese (*Branta canadensis interior*) nests in the Hudson Bay Lowland of Ontario and northeastern Manitoba and winters mainly in Wisconsin and southern Illinois. Spring surveys begun in 1989 were designed to estimate population size and numbers of nests of MVP geese when the population was distributed over a discrete breeding area. Fall flight forecasts have been used to determine appropriate harvest levels to ensure a sustainable population of MVP geese. From 1989 to 1996, the MVP averaged 789 000 geese in spring, with no clear trend in numbers. Number of nests averaged 215 000 annually but declined by 28% from 264 000 in 1990 to 189 000 in 1996. Nest densities were highest in coastal tundra habitats and areas immediately inland from the coast. We review current procedures for monitoring the distribution and numbers of MVP Canada Geese on the breeding grounds, describe recent trends in their distribution and numbers, and make suggestions for improving our understanding of population trends in MVP Canada Geese.

Résumé

Les Bernaches du Canada (*Branta canadensis interior*) de la population de la vallée du Mississippi (PVM) nichent sur les basses-terres de la baie d'Hudson d l'Ontario et du Nord-Est du Manitoba, et elles hivernent principalement au Wisconsin et dans le Sud de l'Illinois. Les relevés du printemps entrepris en 1989 ont été conçus pour estimer le nombre d'individus de la population et le nombre de nids des bernaches de la PVM à un moment où la population était répartie dans une aire de nidification discrète. Les prévisions concernant les volées d'automne ont été utilisées pour déterminer les quantités appropriées de prises permises pour s'assurer qu'il y ait une population durable de bernaches de la PVM. De 1989 à 1996, la PVM comptait en moyenne 789 000 bernaches au printemps et ne présentait aucune tendance marquée relative au nombre d'individus. Le nombre de nids était en moyenne de 215 000 par année mais il a diminué de 28 p. 100, passant de 264 000 en 1990 à 189 000 en 1996. Les densités de nids étaient à leur point maximal dans les habitats de la toundra côtière et dans les zones intérieures adjacentes à la côte. Nous révisons les procédures actuelles de contrôle de la distribution et du nombre d'individus de Bernaches du Canada de la PVM dans les aires de reproduction, nous décrivons les tendances récentes de leur distribution et de leur nombre et nous faisons des suggestions pour améliorer notre compréhension des tendances des populations de Bernaches du Canada de la PVM.

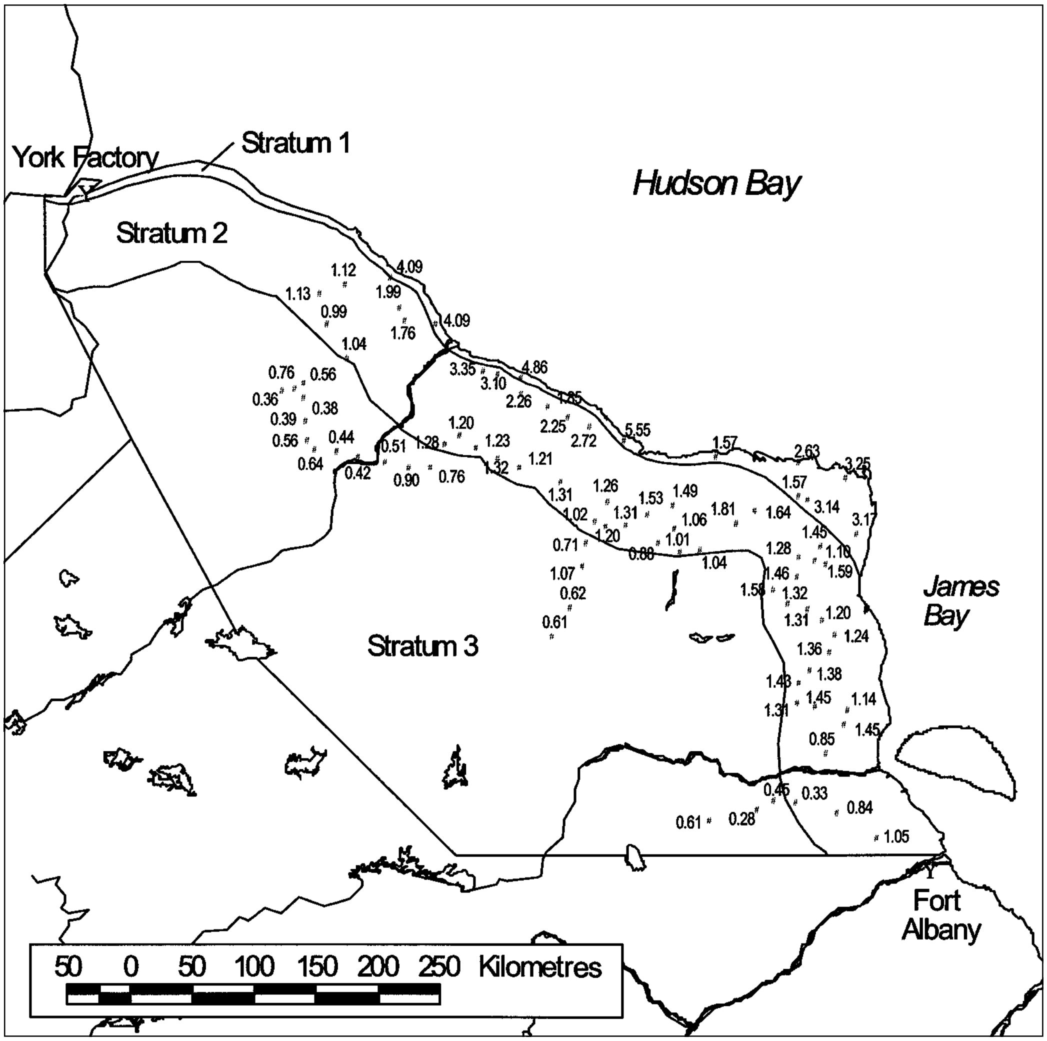
1. Introduction

The Mississippi Valley Population (MVP) of Canada Geese (*Branta canadensis interior*) nests from the Hudson Bay Lowland of Ontario north of the Albany River into northeastern Manitoba near York Factory (Hanson and Smith 1950; Vaught and Arthur 1965; Reeves et al. 1968; Craven and Rusch 1983; Tacha et al. 1988; Fig. 1). Migration routes extend from the Hudson Bay Lowland southwards through Wisconsin, Indiana, and the upper peninsula of Michigan, to terminal wintering sites in southern Illinois and Wisconsin, western Kentucky, and western Tennessee (Hanson and Smith 1950).

Until recently, most population monitoring of Canada Geese in the Mississippi Flyway was based on winter surveys termed "midwinter indices," or MWI (Rusch et al. 1995). The migrant *B. c. interior* subspecies was segregated on wintering areas into manageable populations (MVP, Eastern Prairie Population [EPP], and Tennessee Valley Population [TVP]; Hanson and Smith 1950). This situation changed after reintroduction of large subspecies (*B. c. maxima*, *B. c. moffitti*, hereafter termed "giants" or "giant Canada Geese") to temperate breeding areas in the 1960s and 1970s. By the mid 1980s, it was no longer possible to separate migrants from giants during winter surveys, and thus the MWI became unreliable (Rusch et al. 1996a,b).

In the cases of at least two migrant populations (Southern James Bay Population [SJBP, formerly the TVP] and Atlantic Population [AP]), increases in giant Canada Geese appeared to have masked concomitant declines in migrants sharing the same wintering ranges (Leafloor et al. 1996; Hindman et al. 1996). In each case, winter surveys overestimated the size of the *B. c. interior* population and underestimated the size of the giant Canada Goose population. These declines in migrants went unnoticed until spring surveys revealed lower numbers than expected. In fact, spring surveys of Mississippi Flyway populations of *B. c. interior* have usually resulted in estimates of population size that were lower than the previous MWI (i.e., lower than

Figure 1
Survey strata and nesting range of the Mississippi Valley Population of Canada Geese. Numbers indicate the average number of nests per square kilometre on fixed transects, 1989–96. Nest densities were estimated using methods described in the text.



expected, even including losses to late season and posthunting mortality).

Tacha et al. (1991) suggested that mid-December surveys underestimated the size of the MVP by 14–58% from 1984 to 1987, which might suggest that spring surveys underestimate the MVP by an even larger margin (Table 1). However, recent spring surveys in southern Canada and the United States revealed that there were approximately three to four times as many giant Canada Geese in the Mississippi Flyway as was previously thought based on winter counts (Rusch et al. 1996b). Thus, we believe that increasing numbers of giants confounded winter estimates of the MVP, and it is likely that MWIs in the late 1980s and early 1990s overestimated the size of the MVP, rather than the reverse. Historical data from the midwinter counts were recently reanalyzed in an attempt to account for the larger number of giant Canada Geese on wintering areas (D.H. Rusch, pers. commun.), and the MVP showed population trends similar to those from the spring survey (Table 1).

Accurate estimation of population size is essential to management of hunted species such as Canada Geese; population estimates lead directly to fall flight forecasts and decisions about allowable harvest. Allocation decisions determine the effect that hunting mortality (usually the largest source of mortality among postfledging geese) has on subsequent population size. Under the current management plan for MVP Canada Geese, the spring population objective is 900 000 birds, and harvest allocations (including unretrieved losses) are based on allowing a total take equivalent to the number of geese in the fall flight above that objective. For example, in a year with a projected fall flight of 1.3 million birds, there would be 400 000 geese available to be harvested. Thus, any inflationary biases in methods of calculating fall flight could lead to overharvest of MVP Canada Geese. Below we review current procedures being used to monitor MVP Canada Geese, describe recent trends in their numbers and distribution on the breeding grounds, identify potential sources of bias in estimating population size and fall flights, and make recommendations for improving current estimation methods.

2. Spring survey methods

To estimate spring population size and number of nests, the breeding range was divided into three strata

Table 1
Comparison of midwinter indices and spring population estimates for the Mississippi Valley Population of Canada Geese, 1989–96

	Midwinter survey[a]			Spring survey	
Year	Mid December[c]	Mid January	Revised estimates[b]	Nests	Total population
1989	734 600	930 000	787 885	204 844	712 023
1990	1 098 200	1 314 412	1 263 501	263 563	893 209
1991[d]	939 700	1 093 666	1 005 222	128 812	717 698
1992	766 800	525 215	697 938	222 289	866 514
1993	673 400	660 430	540 443	213 770	617 814
1994	843 700	588 259	690 970	208 777	838 148
1995	931 100	539 439[e]	787 522	201 596	915 764
1996	–	–	–	188 590	678 805

[a] Compiled by Ken Gamble, USFWS.
[b] Revised midwinter estimates courtesy of D.H. Rusch.
[c] Mid-December counts are from the previous calendar year to make them comparable with mid-January and spring surveys.
[d] Spring survey flown after hatch had begun.
[e] Incomplete survey; Michigan excluded.

reflecting differences in breeding pair distribution (Tacha et al. 1988). Stratum 1 included the subarctic tundra and fens along the coasts of Hudson and James bays (high density), stratum 2 included the lowlands within 80 km of the coasts (intermediate density), and stratum 3 included the remainder of the interior lowlands (low density; Fig. 1). Within each stratum, starting coordinates and direction (N, NE, E, SE, S, SW, W, or NW) for 0.5 km × 10 km transects (area = 5 km^2) were randomly selected. Stratum 1 had 10 transects and encompassed 8560 km^2; stratum 2 had 50 transects and an area of 67 830 km^2; and stratum 3 had 20 transects and was 137 380 km^2 in size. From 1989 to 1996, all transects in stratum 1 and half of the transects in strata 2 and 3 were fixed, while the other half were randomly selected each year. From 1996 onward, all 80 transects will remain fixed. In addition to these data, 10 transects (length 10 km) were flown along the coasts to tally additional nonbreeding birds that congregated there; number of geese per linear kilometre was then multiplied by 1.4 to account for visibility bias, then again by 1100 (the length of the coastline in kilometres) to estimate total numbers of nonbreeders in intertidal areas of the MVP range.

Transects were flown at an altitude of 65 m above ground level and speeds averaging approximately 130–140 km/h in a de Havilland Twin Otter aircraft. A Global Positioning System (GPS) was used to navigate to start points of transects and to maintain the course of the aircraft until transects were completed. Surveys were usually flown after the second week of incubation, based on information from ground searches of known nesting areas. Observers on each side of the plane counted pairs, pairs on nests, singles, singles on nests, and flocks ($\geq$ 3 geese) within 250 m of the aircraft.

2.1 Estimating the number of nests

When spring surveys first began in 1989, we used the number of indicated breeding pairs (IBP = all singles + all pairs), multiplied by 1.4 to account for visibility bias (Malecki et al. 1981), as an estimate of the number of breeding geese on each transect. Beginning in 1992, the number of nests on each transect in strata 1 and 2 was calculated from regression equations developed by Schneider et al. (1994). The equations predicted the actual number of nests from aerial survey data as follows:

Stratum 1: number of nests = 2.41 + (2.15) (number of singles)
Stratum 2: number of nests = 3.63 + (0.594) (number of singles + number of pairs)
(Note: Number of singles included both singles and singles on nests. Number of pairs included both pairs and pairs on nests.)

This technique accounted for both visibility bias (i.e., birds present but not seen) and pairs and single geese that were present but not nesting (Schneider et al. 1994). Number of nests per transect in stratum 3 was estimated as the number of indicated breeding pairs multiplied by 1.4 to account for pairs that were not seen (Malecki et al. 1981). Nest estimates were converted to density estimates (nests/km^2) by dividing transect totals by 5, and then averaging all transects within each stratum to obtain mean nest density. Mean nest densities were then multiplied by the area of the stratum and summed across strata to obtain an estimate of total number of nests in the MVP range.

2.2 Estimating spring population size

Total geese per transect was obtained by multiplying IBP by 2, and adding flocked birds. Total number of geese per stratum was estimated by multiplying the number of geese on each 0.5 × 10 km transect by 1.4, dividing that product by 5 to convert to density (geese/km^2), calculating the mean density of geese per stratum, then multiplying the stratum mean density by its area to give total geese per stratum. Estimates of coastal nonbreeders were then added to strata estimates to obtain a spring population estimate.

2.3 Estimating annual production and fall flight forecasts

Estimates of recruitment were added to the spring population estimate to generate a fall flight forecast prior to summer regulation meetings. Gosling production was estimated by multiplying the estimated number of nests (from the foregoing aerial survey) by a set of average values of nest success, number of goslings leaving nests, and gosling survival reported by Bruggink et al. (1994) from their six-year study of MVP Canada Geese at Winisk (i.e., these values were not determined annually and were therefore not sensitive to annual variations in nesting phenology). Bruggink et al. (1994) found that 82% of nests surviving to the end of the second week of incubation (when aerial surveys were usually flown) hatched successfully. The average number of goslings leaving each successful nest was 3.85 (1986–90 only; in 1985, localized flooding destroyed nests during the week of hatch). On average, only 41% of goslings survived from hatch to fledging from 1986 to 1988 and in 1990 (Bruggink et al. 1994). Annual gosling production estimates have been based on these values (with one exception, see below), resulting in estimates that may be biased upward in some years. Thus, to estimate production, the total number of nests was multiplied by 0.82 to determine number of successful nests, then this figure was multiplied by 3.85 to estimate number of goslings at hatch. The

Table 2
Estimated number of nests, nonbreeding geese (NB), and spring population size of MVP Canada Geese, 1989–96

	Stratum 1		Stratum 2		Stratum 3		Coast	
Year	Nests	NB[b]	Nests	NB	Nests	NB	NB	Total population[a]
1989	23 020	73 572	107 850	202 133	73 974	26 630	–	712 023
1990	27 272	127 613	108 069	173 966	128 221	51 289	13 217	893 209
1991[c]	16 250	116 102	79 866	188 589	32 696	103 860	51 524	717 698
1992	25 435	144 949	106 458	170 351	90 396	75 010	36 421	866 514
1993	39 641	40 558	83 733	71 458	90 396	42 313	35 944	617 814
1994	24 333	100 655	94 048	197 070	90 396	78 856	44 013	838 148
1995	23 965	127 276	98 561	287 944	79 070	40 603	56 749	915 764
1996	26 694	123 975	97 110	110 798	64 786	22 269	46 123	678 805

[a] Total population = (number of nests × 2) + nonbreeding geese in all strata.
[b] Number of nonbreeding geese = Total geese ! (number of nests × 2) in each stratum.
[c] Surveys were flown after hatch had begun in 1991.

Table 3
Mean nest densities (and standard errors) for Mississippi Valley Population Canada Geese by stratum, 1989–96

	Nests per square kilometre (SE)		
Year	Stratum 1	Stratum 2	Stratum 3
1989	2.69 (0.31)	1.59 (0.15)	0.54 (0.11)
1990	3.19 (0.38)	1.59 (0.10)	0.93 (0.15)
1991	1.90 (0.39)	1.18 (0.09)	0.24 (0.09)
1992	2.97 (0.60)	1.57 (0.12)	0.66 (0.14)
1993	4.63 (0.85)	1.23 (0.06)	0.66 (0.07)
1994	2.84 (0.40)	1.39 (0.10)	0.66 (0.17)
1995	2.80 (0.41)	1.45 (0.11)	0.58 (0.11)
1996	3.12 (0.67)	1.43 (0.08)	0.47 (0.09)
1989–96	2.95	1.42	0.59

exception noted above was that the number of goslings at hatch was multiplied by 0.64, the estimated survival rate from hatch to banding at age 35–40 days (rather than 0.41, the Mayfield estimate of survival to fledging at 56 days), to estimate the number of goslings fledged. The number of goslings fledged added to the spring population estimate yielded the fall flight forecast.

3. Recent trends in MVP Canada Geese

From 1989 to 1996, the spring population averaged 789 000, with a low of 618 000 in 1993 and a high of 916 000 in 1995, with no clear trend over that period (Table 1). Variation in numbers of nonbreeders was primarily responsible for annual fluctuations (Table 2). This variation can be explained by fluctuations in annual production and first-year survival, as well as inclusion of a variable proportion of moult migrant giant Canada Geese (dependent on survey timing) in a given year. Estimated number of nests averaged 215 000 from 1989 to 1996, but declined by 28% from a high of 264 000 in 1990 to 189 000 in 1996 (Table 1). This trend is more difficult to explain than the variation in nonbreeders, but may be an indirect result of overestimation of spring population size and fall flight (see below).

Nest densities varied among years and strata, with the highest densities occurring in stratum 1 and the lowest in stratum 3 in all years (Table 3). Nesting distributions were not random with respect to strata; stratum 1 accounted for 4% of the breeding range, but averaged 13% of all nests from 1989 to 1996. Stratum 2 accounted for 32% of the range and 49% of all nests, and stratum 3 made up 64% of the range, but only 39% of nests, on average.

The proportion of nonbreeding geese averaged 66% in stratum 1, 46% in stratum 2, and only 26% in stratum 3. The higher proportion of nonbreeding geese in strata 1 and 2 resulted in part from using the Schneider et al. (1994) equations to account for singles and pairs that were present but not nesting in those strata. However, when we calculated the number of nests in strata 1 and 2 using indicated breeding pairs and a 40% visibility correction (as was done in stratum 3), the proportion of nonbreeding geese was 53, 38, and 26% in strata 1–3, respectively. Thus, nonbreeding geese tended to be found in higher numbers in strata 1 and 2 regardless of methods used to estimate the nesting population.

Because the method of calculating numbers of nests has been consistent over the period of study, the trend of declining nests is likely to be real. It may be associated with a systematic overestimation of population size, possibly leading to overharvest. We examine possible sources of bias that may result in overestimation of the number of nests and gosling production. Despite any concerns we raise here about the accuracy of the spring survey, we believe that it is still the best monitoring tool available, given the demonstrated problems with winter surveys and budget-induced tendencies for some states to discontinue them.

4. Potential sources of bias in MVP spring surveys

Tacha et al. (1988) described the breeding range of MVP Canada Geese based on radio telemetry of breeding-aged females returning to nest and a review of earlier distribution papers. They found that 84% of females were relocated within 80 km of the Hudson Bay and James Bay coasts, now incorporated in strata 1 and 2 of the spring survey (Fig. 1). The present survey area may be larger than necessary based on Tacha et al.’s (1988) map of radio locations. Instead of basing the inland boundary of stratum 3 on a minimum polygon connecting all of the farthest inland radio locations, only selected locations were connected. This resulted in incorporation of large areas without radio locations or other evidence of nesting. This may have been done because of the small number of inland radio locations (i.e., smoothing the polygon), or perhaps with some habitat boundary in mind (e.g., the inland extent of post-glacial marine inundation [MacInnes 1966]). In either case, it may have resulted in stratum 3 being too large. This should not affect the estimate of nest density if the stratum is sampled randomly, but we note that most transects tend to be on the coastal side of stratum 3 (see Fig. 1). If nest densities farther inland tend to be lower, or if nesting does not occur farther inland, then stratum 3 estimates may be biased high. Tacha et al. (1988) found only 16% of radio-marked females in stratum 3, and a proportion significantly or consistently higher than this may be a result of the stratum being too large. In fact, from 1989 to 1996, stratum 3 accounted for 25.4 to 48.6% (0 = 39%) of the total number of nests in the MVP each year (Table 2). This suggests that (1) we may be overestimating the number of nests in stratum 3; (2) we may be underestimating the number of nests in strata 1 and 2; (3) the Tacha et al. (1988) study years may represent an atypical period of distribution among strata; or (4) there may have been an increase in use of stratum 3, but not in the other strata. We have no evidence for the third possibility, and trends in the number of nests in stratum 3 do not support the fourth (Table 2). We consider the first explanation more likely than the second, given the higher relative density of transects in strata 1 and 2, and concerns outlined above.

A second issue with stratum definition is the inland boundary (and thus size) of stratum 2. Presumably, it is also based on the distribution of radio-marked birds (i.e., defining the distance from the coast where 84% of radio locations occurred). However, we know of no corresponding change in habitat that occurs 80 km inland from the coasts. Mean nest densities are indeed different between strata 2 and 3, but they would likely also be different if the boundary between the strata was located, for example, 30–60 km inland. We note that fixed transects located close to the stratum 1–2 boundary contained very high nest densities from 1989 to 1996. Nest densities near the coast, but in stratum 2, were up to eight times higher than those farther inland in stratum 2 (Fig. 1). Ground searches in 1992 revealed similarly high nest densities ($\bar{x}$ = 5.6 nests/km^2, SE = 0.69, n = 30) in areas of stratum 2 that were within 10–15 km of the coast near Winisk (Schneider 1993). Again, this should not be problematic for estimating nest density unless these high-density areas are surveyed at a disproportionately high rate. Our impression is that geese nest in high densities in coastal stratum 1 and also in areas of stratum 2 immediately adjacent to it where coastal brood-rearing areas are still accessible to them, but that densities are not as high farther inland. Changes in stratification that combine all areas of similar nest density will likely improve the precision of population and nest estimates. Spatial analysis of survey data should be pursued to better delineate strata used in spring surveys, and inland areas of stratum 3 should be surveyed to determine the inland extent of nesting by Canada Geese. Improved stratification should reduce the variance in our population estimates and may also improve the accuracy of the estimates by making sampling within strata more representative.

5. Potential sources of bias in estimating annual production

The value used to estimate gosling survival to fledging should be 0.41, instead of the 0.64 value previously used. In 1996, use of the higher survival figure for gosling production resulted in an additional 137 000 geese in the fall flight forecast. The MVP Committee of the Mississippi Flyway Council Technical Section adopted the use of the lower gosling survival figure beginning in 1997. Except for the number of nests, the values used to calculate production (nest success, goslings hatched per nest, and gosling survival to fledging) were averages used every year (i.e., values reflecting prevailing breeding conditions are not determined annually). Average values, by definition, will result in overestimates in about half of the years. As one example, nest success after week two of incubation averaged 82% from 1986 to 1990 at Winisk (Bruggink et al. 1994), but it ranged from 75 to 90% among years. Additionally, the nesting area spans over four degrees of latitude and a coastline of 1100 km, and this value of nest success from the Winisk area may not be representative of conditions across the entire range. Another example is the number of goslings leaving successful nests. Although this value did not vary significantly among years, it did differ from !0.29 to +0.41 goslings around that average between the best and worst years (Bruggink et al. 1994); this corresponds to 54 500 fewer or 77 000 more goslings, respectively, in 1996. It is not certain, however, that underallocations in years when production is underestimated will compensate for overallocations in other years.

It may be possible to adjust annual production estimates according to spring phenology. Canada Geese generally lay smaller clutches of eggs when nesting is delayed (Raveling and Lumsden 1977; Dunn and MacInnes 1987; Leafloor et al. 2000), and overall productivity can therefore be expected to decline in years of late spring thaw. Further research into the relationship between spring phenology and overall gosling production may eventually account for some of the annual variation in gosling production. Alternatively, we could collect these data over a large area on an annual basis, but costs are likely to be prohibitive, and the relative benefits unknown.

If we are overestimating the number of nests, then we are also overestimating annual production, because in the current method of calculating it, all variation in production is derived from the estimated number of nests. From 1989 to 1996, breeding pairs accounted for 36–69% ($\bar{x}$ = 53%) of spring population estimates, not including geese that made attempts but lost their nests before surveys were flown (which would inflate the proportion of breeding birds even more). However, studies of age-specific breeding rates of *B. c. interior* suggest that few geese begin to nest before 4 years of age (Moser and Rusch 1989; Hardy and Tacha 1989). Hardy and Tacha (1989) reported that MVP geese $\geq$4 years of age accounted for only 31% of the posthunting population. Thus, it appears that our current methods result in overestimates of the proportion of breeding birds. The addition of coastal transects to tally nonbreeding geese using the intertidal zone beginning in 1990 was a response to this perception (T.C. Tacha, pers. commun., 1990). Again, the high proportion of breeding birds could be related to the possible overestimation of nests in stratum 3, where the proportion of nonbreeding birds (0 = 26%) was consistently the lowest among strata (Table 2).

The regression equations developed by Schneider et al. (1994) accounted for pairs that are observed but not nesting, but such equations could not be developed for stratum 3 because of the costs and logistical difficulties of working in these interior habitats. Although the relationships between aerial survey data and actual number of nests were significant, 63–82% of variation in number of nests in strata 1 and 2 was unexplained by aerial survey data (Schneider et al. 1994: Table 2). Stratum 2 equations were developed in boreal habitat in close proximity to coastal stratum 1, and it is possible that the high nest densities found during the study were not representative of nest densities in much of stratum 2 (Fig. 1). We note that using the Schneider et al. (1994) equations resulted in minimum estimates of 2.41 and 3.63 nests per transect for stratum 1 and 2, respectively, even if no birds were seen during aerial surveys. It is uncertain whether or not these densities should be expected, for example, if the MVP declined to the low levels that occurred in the early 1980s. Nevertheless, using Schneider et al.'s (1994) methods resulted in a more conservative estimate of nests than would occur if we used a 40% correction factor in all strata, and a more realistic proportion of nonbreeding geese.

We recommend a detailed evaluation of the spring survey for MVP Canada Geese using all available data. Specifically, the current breeding range boundaries and stratification should be reviewed to ensure that the area surveyed is representative, and that stratification is optimal. Spatial analysis of survey data using krieging techniques may provide a more accurate and/or more precise estimate of spring population size and number of nests (C. Ribic, Wisconsin Cooperative Wildlife Research Unit, pers. commun.). Gosling survival from hatching to fledging (41%) will replace the previous value of gosling survival from hatch to banding (64%) to make production estimates more realistic. We also suggest that further refinements to methods of estimating annual production should consider the relationship between seasonal phenology and annual production of goslings.

6. Acknowledgements

Surveys were funded by MVP harvest states of the Mississippi Flyway Council, Ontario Ministry of Natural Resources (OMNR), and the Canadian Wildlife Service. We thank observers C. Davies, D. Fillman, and K. Ross and OMNR pilots J. Delean, D. Ladouceur, and A. Quinn for their expert assistance. K. Gamble, K. Ross, and the MVP committee of the Mississippi Flyway Technical Section provided helpful comments on an earlier draft of the manuscript. We thank A. Jano for preparing the figure, and K. Dickson for editorial assistance.

7. Literature cited

Bruggink, J.G., T.C. Tacha, J.C. Davies and K.F. Abraham. 1994. Nesting and brood-rearing ecology of Mississippi Valley Population Canada Geese. Wildl. Monogr. 126. 39 pp.

Craven, S.R. and D.H. Rusch. 1983. Winter distribution and affinities of Canada Geese marked on Hudson and James bays. J. Wildl. Manage. 47:307–319.

Dunn, E.H. and C.D. MacInnes. 1987. Geographic variation in clutch size and body size of Canada Geese. J. Field Ornithol. 58:355–371.

Hanson, H.C. and R.H. Smith. 1950. Canada Geese of the Mississippi Flyway: with special reference to an Illinois flock. Ill. Nat. Hist. Surv. Bull. 25:67–210.

Hardy, J.D. and T.C. Tacha. 1989. Age-related recruitment of Canada Geese from the Mississippi Valley Population. J. Wildl. Manage. 53:97–98.

Hindman, L.J., R.A. Malecki and J.R. Serie. 1996. Status and management of Atlantic Population Canada Geese. Pages 109–116 *in* Ratti, J.T. (ed.), Proceedings of the 7th International Waterfowl Symposium, Memphis, Tennessee.

Leafloor, J.O., K.F. Abraham, D.H. Rusch, R.K. Ross and M.R.J. Hill. 1996. Status of the Southern James Bay Population of Canada Geese. Pages 103–108 *in* Ratti, J.T. (ed.), Proceedings of the 7th International Waterfowl Symposium, Memphis, Tennessee.

MacInnes, C.D. 1966. Population behavior of eastern arctic Canada Geese. J. Wildl. Manage. 30:536–553.

Malecki, R.A., F.D. Caswell, R.A. Bishop, K.M. Babcock and M.M. Gillespie. 1981. A breeding-ground survey of EPP Canada Geese in northern Manitoba. J. Wildl. Manage. 45:46–53.

Moser, T.J. and D.H. Rusch. 1989. Age-specific breeding rates of female interior Canada Geese. J. Wildl. Manage. 53:734–740.

Raveling, D.G. and H.G. Lumsden. 1977. Nesting ecology of Canada Geese in the Hudson Bay Lowlands of Ontario: evolution and population regulation. Ont. Min. Nat. Resour. Fish Wildl. Res. Rep. No. 98. 77 pp.

Reeves, H.M., H.H. Dill and A.S. Hawkins. 1968. A case study in Canada Goose management: The Mississippi Valley Population. Pages 150–165 *in* R.L. Hine and C.A. Schoenfeld (eds.), Canada Goose management. Dembar Ed. Res. Serv., Madison, Wisconsin. 195 pp.

Rusch, D.H., R.E. Malecki and R.E. Trost. 1995. Canada Geese in North America. Pages 26–34 *in* LaRoe, E.T., G.S. Farris, C.E. Puckett, P.D. Doran and M.J. Mac (eds.), Our living resources: a report to the nation on the distribution, abundance and health of U.S. plants, animals and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C.

Rusch, D.H., F.D. Caswell, M.M. Gillespie and J.O. Leafloor. 1996a. Research contributions to management of Canada Geese in the Mississippi Flyway. Trans. North Am. Wildl. Nat. Resour. Conf. 61:437–449.

Rusch, D.H., J.C. Wood and G.G. Zenner. 1996b. The dilemma of giant Canada Goose management. Pages 72–78 *in* Ratti, J.T. (ed.), Proceedings of the 7th International Waterfowl Symposium, Memphis, Tennessee.

Schneider, J.P. 1993. Predicting numbers of MVP Canada goose nests from spring aerial surveys. Unpubl. M.Sc. thesis, Texas A&I University, Kingsville, Texas. 22 pp.

Schneider, J.P., T.C. Tacha and J.O. Leafloor. 1994. Potential predictors of numbers of Canada Goose nests from aerial surveys. Wildl. Soc. Bull. 22:431–436.

Tacha, T.C., A. Woolf and W.D. Klimstra. 1988. Breeding distribution and subpopulations of the Mississippi Valley Population of Canada Geese. J. Wildl. Manage. 52:689–693.

Tacha, T.C., A. Woolf, W.D. Klimstra and K.F. Abraham. 1991. Migration patterns of the Mississippi Valley Population of Canada Geese. J. Wildl. Manage. 55:94–102.

Vaught, R.W. and G.C. Arthur. 1965. Migration routes and mortality rates of Canada Geese banded in the Hudson Bay Lowlands. J. Wildl. Manage. 29:244–252.

Status and trends of the Eastern Prairie Population of Canada Geese

Dale D. Humburg, F. Dale Caswell, Donald H. Rusch, Murray Gillespie, and Paul Telander

Summary

A breeding ground survey of the Eastern Prairie Population (EPP) of Canada Geese (*Branta canadensis interior*) was developed during 1972–75 and has been operational since 1976. Range-wide densities of EPP Canada Geese increased from less than one goose per square kilometre during the early 1970s to more than two geese per square kilometre by 1994. Densities were higher and more variable among years in "coastal" than in "interior" strata. The EPP increased by 100 000 geese from the early 1970s to 234 000 ± 30 400 in 1976, declined to 130 800 ± 39 600 in 1979, and increased to 332 300 ± 70 200 by 1994. Single geese accounted for an average of 27.9% of the EPP during 1972–97 (range = 13.6–43.6%). Single geese as a proportion of the population in the coastal strata correlated (1972–95, $r = 0.71$, $P = 0.0001$, $n = 23$) with age ratios of geese killed the subsequent fall on EPP harvest areas. Estimates of numbers of geese in groups ranged between 22 100 ± 7 400 and 156 400 ± 66 400 and accounted for an average of 31.2% (range = 14.6–49.2%) of the EPP. The numbers of large groups away from coastal strata may result in more variable and possibly inflated estimates of the EPP. The EPP breeding ground survey has provided long-term insights into changes in population size and distribution. During the 1990s, apparent growth of the EPP occurred because of population increases in the interior, yet variation in productive components occurred in coastal habitats. Instead of basing harvest strategies on the status of the EPP range-wide, population managers may find it more useful to base strategies on the status of singles or productive geese in coastal regions.

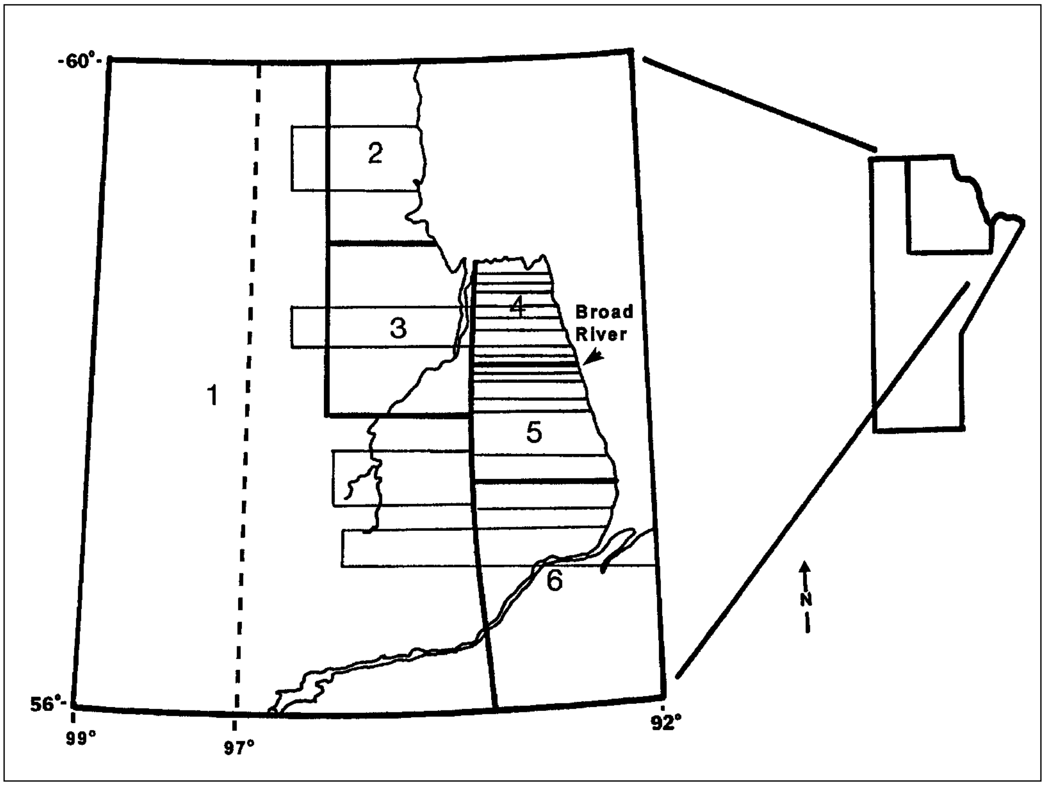
Résumé

Une enquête sur les aires de reproduction de la population de l'Est des Prairies (PEP) de la Bernache du Canada (*Branta canadensis interior*) a été élaborée de 1972 à 1975 et est en cours depuis 1976. Les densités de l'entière aire de distribution des Bernaches du Canada de la PEP ont augmenté de moins d'une bernache par kilomètre carré au début des années 1970 à plus de deux bernaches par kilomètre carré en 1994. Les densités étaient supérieures et plus variables par année dans les strates « côtières » que dans les strates « intérieures ». La PEP a augmenté de 100 000 bernaches depuis le début des années 1970 à 234 000 ± 30 400 en 1976, a diminué à 130 800 ± 39 600 en 1979 et a augmenté à 332 300 ± 70 200 en 1994. Les bernaches individuelles comptaient pour une moyenne de 27,9 p. 100 de la PEP entre 1972 et 1997 (portée = de 13,6 à 43,6 p. 100). La proportion de bernaches individuelles dans la population de la strate côtière correspondait (1972–1995, $r = 0,71$, $P = 0,0001$, $n = 23$) aux ratios d'âge des bernaches tuées à l'automne suivant dans les aires de prises de la PEP. Les estimations des nombres de bernaches en groupes s'échelonnaient entre 22 100 ± 7 400 et 156 400 ± 66 400 et représentaient une moyenne de 31,2 p. 100 (portée = de 14,6 à 49,2 p. 100) de la PEP. Le nombre d'individus des grands groupes éloignés de la strate côtière peuvent donner des estimations de la PEP plus variables et peut-être gonflées. L'enquête sur les aires de reproduction de la PEP a fourni des aperçus à long terme des changements dans les dimensions et la distribution de la population. Durant les années 1990, la PEP a connu une croissance évidente à cause des croissances des populations des terres intérieures; mais, des variations se sont manifestées dans les composantes productives des habitats côtiers. Au lieu de fonder les stratégies de prise sur la situation de la PEP dans toute son aire de répartition, les gestionnaires des populations peuvent considérer qu'il est plus utile de fonder les stratégies sur la situation des bernaches individuelles ou prolifiques dans les régions côtières.

1. Introduction

Canada Geese (*Branta canadensis interior*) of the Eastern Prairie Population (EPP) nest in northern Manitoba west of Hudson Bay (Malecki et al. 1980). Primary migration occurs through Manitoba, Minnesota, and Iowa (Vaught and Kirsch 1966; Malecki et al. 1980; Samuel et al. 1991). In the 1930s, EPP geese wintered primarily in Louisiana (Mississippi Flyway Technical Section 1992); however, by the 1960s and through the early 1980s, most of the EPP wintered at Swan Lake National Wildlife Refuge in Missouri (Vaught and Kirsch 1966; Mississippi Flyway Technical Section 1993). Winter surveys revealed a shift during the 1980s: greater numbers of EPP geese delayed southern migration until December or later. For example, the surveys recorded an average 64% of EPP Canada Geese in Iowa and Minnesota during December 1991–95 surveys (range = 59–73%), compared with 16% in the area at that date 10 years earlier (1981–85 range = 4–36%), and 5% 20 years

Figure 1
Location of the EPP breeding range in northern Manitoba. Heavy lines represent the boundaries of the breeding range and the six habitat/survey strata. Thin lines approximate the location of EPP transects. The dotted line is 97°W longitude.



earlier (1971–75 range = 3–9%) (Gamble and Peterson 1997).

Studies of breeding geese near Churchill, Manitoba, have been conducted since the mid-1960s to determine nesting density and phenology, brood movements, recruitment, and predation (Pakulak 1969; Malecki 1976; Didiuk and Rusch 1979; Moser and Rusch 1989; Allen 1996; Walter 1996). These efforts have incrementally increased our knowledge of EPP breeding ecology and have provided the basis for population management (Rusch et al. 1996). Breeding ground status of the EPP is determined by an aerial survey developed during 1972–75 (Malecki et al. 1981) and conducted annually in the 154 625-km^2 nesting range since 1976 (Fig. 1). Breeding population surveys complement nesting studies by providing range-wide perspective of EPP size, distribution, and production potential. We report information about trends in and relationships among numbers, density, and composition of the EPP since 1972 and discuss implications for population management.

2. Methods

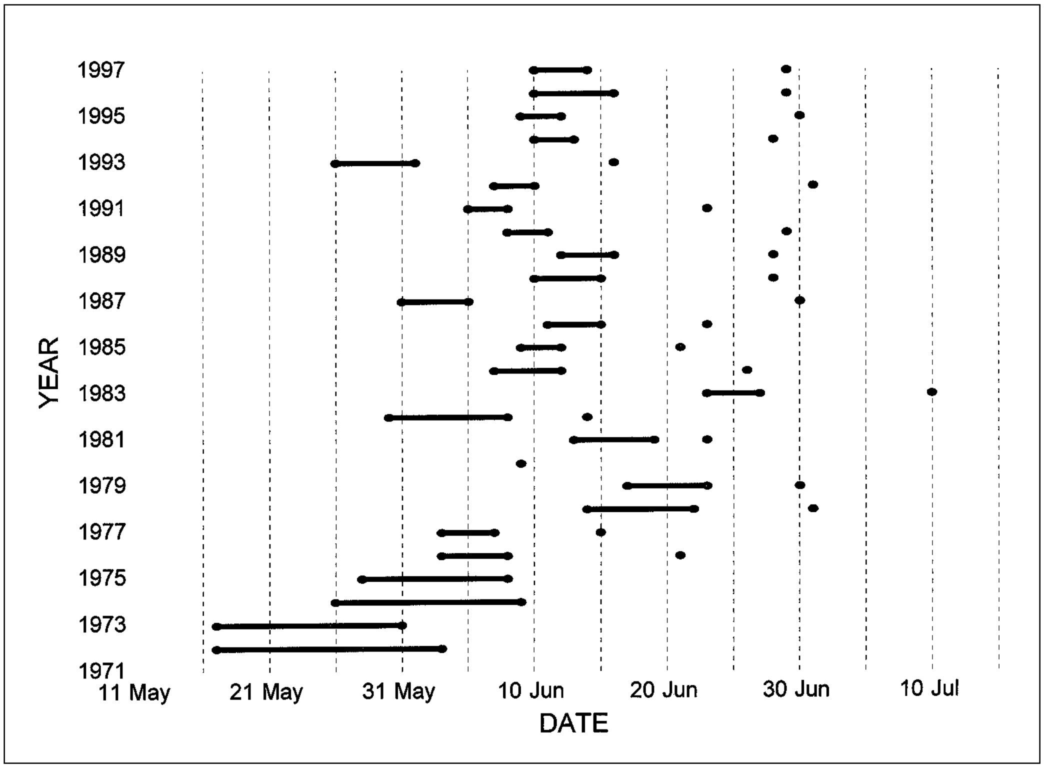
Breeding geese were counted each year (except 1980) during survey development (1972–75) and operation (1976–97). No survey was conducted in 1980 because of aircraft problems, and the eggs hatched before a replacement airplane could be obtained. The EPP survey is similar in methodology to the duck breeding ground surveys (U.S. Department of the Interior and Environment Canada 1987). Transects are flown 23–46 m above the ground, and geese observed within 200 m of each side of the aircraft are recorded. Surveys are initiated near mid-incubation when possible; however, survey timing is dictated by the earliest nesting phenology within the EPP breeding range to ensure completion of surveys prior to hatch (Fig. 2).

Canada Goose densities are estimated from birds tallied by one-minute intervals on transects among six survey strata, which are based on habitat zones (Richie 1960) and variable densities of Canada Geese (Fig. 1; Malecki 1976; Malecki et al. 1981). Strata generally correspond to tundra (strata 2 [7650 km^2], 4 [4400 km^2], and 5 [7900 km^2]), lowlands (strata 3 [14 900 km^2] and 6 [18 000 km^2]), and closed and open coniferous forest and forest tundra (stratum 1 [101 775 km^2]). We term strata 2, 4, and 5 as "coastal" (19 950 km^2) and strata 1, 3, and 6 as "interior" (134 675 km^2) habitats.

Helicopter/fixed-wing airplane comparisons showed that only 60–80% of the geese observed from a helicopter (assumed to be 100% of geese present) were subsequently observed from a fixed-wing airplane. Consequently, a visibility correction of 1.4 was used to account for the mean of 30% unobserved singles and pairs (Malecki et al. 1981). Geese observed on the survey have been recorded as singles, pairs, groups (including numbers per group), and singles or pairs with nests or broods. Estimates of numbers of geese in each of these categories reflect changing EPP composition over time. Total numbers of geese represented by observed singles (number of singles × 2 × 1.4), pairs (number of pairs × 2 × 1.4), and geese in groups (not corrected for visibility because we assume most are observed) are combined for an annual estimate of the EPP.

Canada Geese observed as singles and pairs were used by Malecki et al. (1981) as an index to nesting pairs of EPP geese. "Indicated breeding pairs" (single drakes, pairs,

Figure 2
Timing of EPP breeding ground surveys during 1972–97 (heavy line) and median hatch at Cape Churchill during 1976–97 (single dot). Source: D.H. Rusch, unpublished data.



and groups of fewer than five drakes) are considered when duck production is assessed (U.S. Department of the Interior and Environment Canada 1987); however, data from the EPP breeding ground surveys indicated that nesting effort would be overestimated if indicated breeding pairs are used to index nesting effort (Humburg et al. 1998). During EPP surveys, geese observed as pairs often flushed well ahead of the airplane and did not exhibit behaviour typical of productive pairs (Balham 1954; Sherwood 1967). In contrast, Canada Geese observed as singles often "circled back" after being flushed by the airplane (Malecki 1976). This is consistent with the behaviour of nesting Canada Geese described by Raveling and Lumsden (1977), who rarely observed individuals of a pair together once incubation began.

Single geese plus nesting pairs (as opposed to indicated pairs) were suggested as the best index to nesting effort for the EPP (Humburg et al. 1998). Nesting pairs include (1) pairs observed with a nest and (2) geese initially observed as singles (assumed to be geese flushed from nests) that were joined in flight by other singles (presumably ganders) — these are differentiated from pairs that flushed together. Nesting pairs were consistently recorded on EPP surveys beginning in 1984; thus, we report single geese plus nesting pairs for the period 1984–97 as a separate index to nesting effort (we term these "productive geese").

It is not clear how single geese observed on nests (no gander observed) were considered during development of the EPP breeding ground survey. In the past, we included all single geese in estimates of the EPP, whether observed on a nest or not (as reported by Humburg et al. 1998). We believe this interpretation potentially yielded overestimates of the breeding population and productivity. Thus, we do not include singles with nests in this report when estimating the single goose component, because geese on nests should be represented by ganders observed elsewhere.

3. Results and discussion

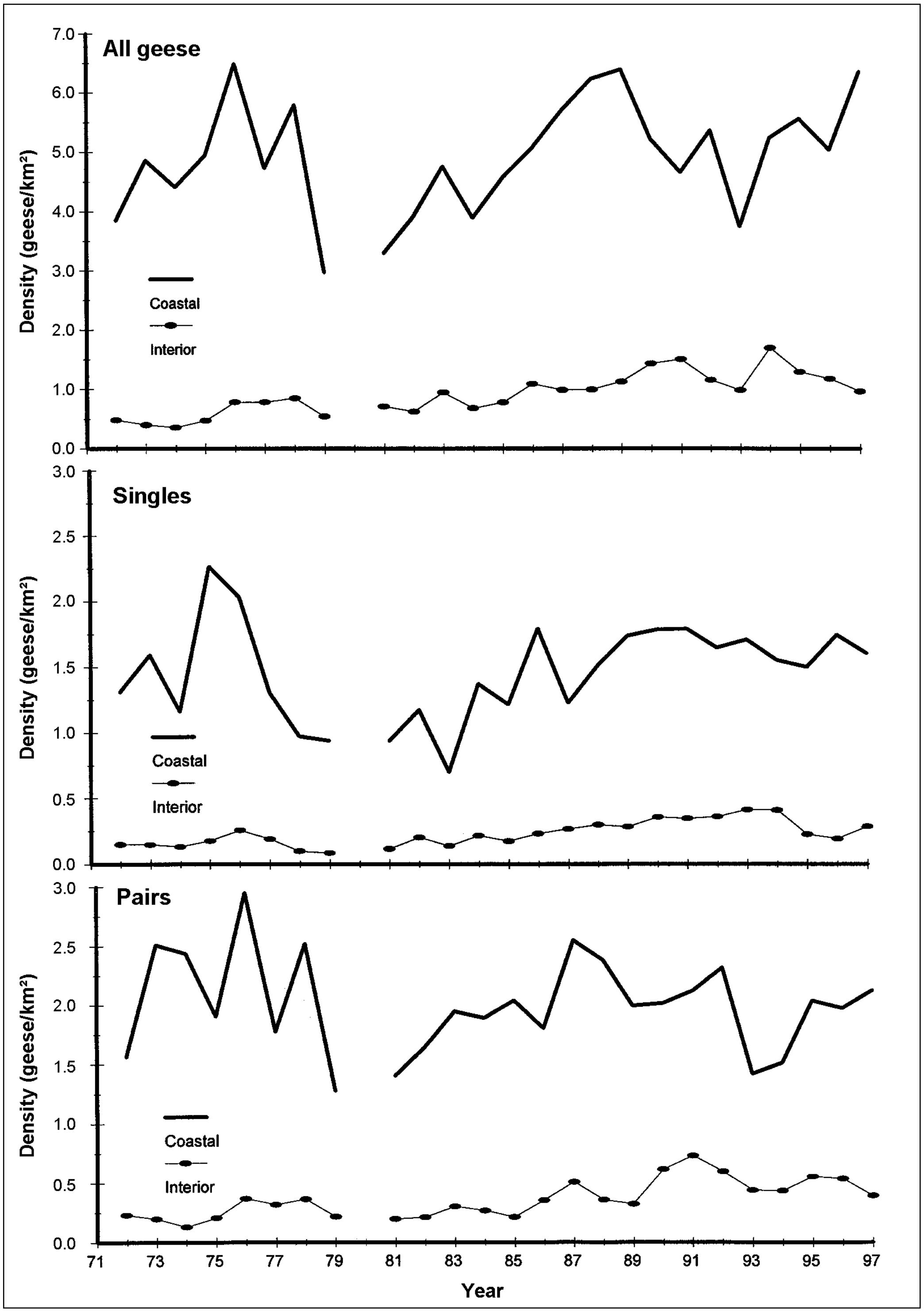
3.1 Densities

Range-wide densities of EPP Canada Geese increased from less than one goose per square kilometre during the early 1970s to more than two in 1994. Among survey strata, densities were higher and more variable among years in coastal (strata 2, 4, and 5) than interior habitat zones (strata 1, 3, and 6) (Fig. 3). Interior densities were less than 10% of coastal densities and gradually increased from less than 0.5 geese/km^2 to more than 1.0 geese/km^2 by the mid-1980s. The ranges of single and pair densities (corrected for visibility) in interior strata (range = 0.04–0.21 and range = 0.07–0.37, respectively) were similar to densities reported by Raveling (1977) for north-central Manitoba near the Little Churchill River (0.28 nests/km^2) and adjacent upland habitats (0.07 nests/km^2) (Fig. 3).

In contrast to densities in interior strata, the range of goose densities in coastal habitats (3.0–6.5 geese/km^2) was higher, although variable, throughout the 1972–97 period (Fig. 3). Precipitous declines in goose density occurred in the late 1970s and again in the early 1990s, and populations required several years to regain previous high levels. However, lower densities in the early 1990s were not accompanied by declines in the density of singles in coastal areas, as was the case in the 1970s.

In stratum 4, densities of singles (range = 0.35–1.13 geese/km^2) and pairs (range = 0.64–1.48 pairs/km^2) were lower than densities of nesting geese reported for the Cape

Figure 3
Densities (geese/km^2) of the total EPP (all geese), represented by single geese and geese in pairs (pairs) in coastal (strata 2, 4, and 5) and interior (strata 1, 3, and 6) survey strata, 1972–97



Churchill study area, which is located within 3 km of the Hudson Bay coast (range = 5–37 nests/km^2, 1976–97, D.H. Rusch, unpubl.), and the Kinoje study area near James Bay, Ontario (6.25 nests/km^2; Raveling and Lumsden 1977). Densities of singles plus pairs with nests within 20 km of the Hudson Bay coast in stratum 4 (mean = 4.72 geese/km^2, SD = 3.70, n = 296) were higher than stratum-wide densities. Combined single plus pair densities (all pairs included) for the coastal 20 km (mean = 9.51 geese/km^2, SD = 5.69, n = 296) were within the range reported from other studies.

Changes in goose density have been apparent on portions of stratum 4 since 1972 (Table 1; Fig. 4). Densities throughout the stratum during the 1980s were lower than those during the 1970s. During the 1990s, however, the density of geese in portions of the stratum away from the Cape Churchill area returned to levels comparable to the

Table 1
A comparison of mean densities of Canada Geese, observed as singles or as pairs with nests, for two coastal and one noncoastal portion of stratum 4 of the EPP breeding range, by decade, 1972–97. The coastal portions are within 20 km west of the Hudson Bay coast. Cape Churchill is the area within 40 km south of the cape, and Broad River is the area more than 40 km south of the cape to the Broad River. The noncoastal portion is more than 20 km from the Hudson Bay coast.

	Mean density, geese/km^2 (SD, no. of survey quadrats)		
Decade	Cape Churchill	Broad River	Noncoastal
1970s	6.30 (4.68, 30)	6.69 (6.42, 36)	1.70 (2.26, 368)
1980s	2.95 (1.66, 45)	3.50 (1.66, 67)	1.04 (1.16, 592)
1990s	2.95 (1.57, 42)	6.19 (3.00, 76)	1.36 (1.37, 593)

1970s; this included coastal areas south of Cape Churchill to the Broad River. Rusch et al. (1996) speculated that the decline in nest density at Cape Churchill was related to normal mortality of adults and low recruitment of young geese due to fox predation (Walter 1996) and competition with Snow Geese (*Anser caerulescens*). Aerial survey estimates for the portion of stratum 4 proximate to Cape Churchill correlated ($r = 0.71$, $P = 0.0003$, $n = 21$) with the declining densities reported from nesting studies (D.H. Rusch, unpubl.). Thus, the declining density reported for Cape Churchill appears to be a local phenomenon, which is consistent with observations from aerial surveys. Questions remain, however, about long-term changes in Canada Goose densities as Snow Goose numbers and their associated impact increase (Batt 1997).

3.2 Population estimates

The EPP increased by about 100 000 geese from the early 1970s to 234 000 ± 30 400 in 1976 (Table 2). The lowest EPP estimate in the 25 years of the survey occurred in 1979 (130 800 ± 39 600); however, the population increased again after the early 1980s to exceed 330 000 by 1994. In general, breeding ground estimates were consistent with winter indices during the 1970s; however, greater disparity between the two sources of population data during the 1980s and 1990s (Fig. 5) supported a shift in emphasis from winter indices to breeding ground surveys as recommended by Bishop and Williams (1990).

Changes in densities for interior strata from less than 0.5 during the early 1970s to more than 1.0 geese/km^2 after 1990 resulted in substantial changes in population estimates because of the large area attributed to this portion of the EPP range (134 675 km^2). Although the western boundary of the breeding area remains uncertain, we continued to use the 154 625-km^2 study area as described by Malecki et al. (1981), which extended to 99°W longitude. Raveling (1977) reported differences in recoveries of geese banded west (attributed to Western Prairie Population) versus east (attributed to EPP) of Fidler Lake (about 97°W longitude). If the actual western boundary of the EPP range is closer to 97°W, the area of stratum 1 would be reduced by about half to 48 000 km^2 (the total study area would be reduced to 101 200 km^2), and the EPP estimates would be about 20% lower than reported here (Fig. 6).

3.3 EPP components

Numbers of geese among population components (singles, pairs, and grouped geese) reflect changes in the status of the EPP. The numbers of geese represented by singles (singles × 2 × 1.4) increased to 75 100 (± 16 000) by 1976, then declined dramatically to a low of 29 000 (± 7300) in 1979 and gradually increased to the highest level of 90 500 (± 14 400) in 1993 (Table 2). Singles represented an average of 27.9% of the EPP during 1972–97 (range = 13.6–43.6%). Numbers were greater in coastal habitats than in the interior during the 1970s, similar during the 1980s, and lower as the EPP increased through 1994 (Fig. 7). Over the 1972–95 period, single geese as a proportion of the population in the coastal strata correlated ($r = 0.71$, $P = 0.0001$, $n = 23$) with age ratios of geese killed the subsequent fall on EPP harvest areas (Fig. 8).

Estimates of the EPP reported before 1997 included single geese observed on nests; however, we believe this yielded an overestimate, and we excluded singles on nests in the estimates reported here (Table 2). Without singles on nests, estimates of numbers of singles are an average of 90.4% (range = 71.9–100%) of previous estimates that included singles with nests (as reported by Humburg et al. 1998).

We believe the actual numbers of geese nesting are best reflected by a combination of single geese, pairs seen with nests, and geese initially observed as singles (e.g., a goose flushed from a nest) and joined by another bird (likely the gander). Numbers of productive geese ranged in number from 68 300 ± 13 000 (1985) to 104 200 ± 15 800 (1993) and accounted for 33.4% of the EPP during 1984–97 (range = 25.1–50.1%). On average, singles accounted for 84.5% (range = 70.0–95.6%) of total productive geese (Fig. 9).

Numbers of geese observed in pairs generally exceeded the numbers observed as singles (Table 2). The proportion of the EPP made up of paired geese averaged 41.8% (range = 26.7–50.6%). As was the case with singles, numbers of paired geese were greater in coastal strata than in the interior strata during the early 1970s; however, numbers in the interior surpassed those near the coast after the mid-1980s (Fig. 7).

Estimates of numbers of geese in groups ranged between 22 100 (± 7 400) and 156 400 (± 66 400) (Table 2) and accounted for an average of 31.2% (range = 14.6–49.2%) of the EPP. Numbers of grouped geese were similar among coastal and interior strata through the 1970s, after which they progressively were more variable (Fig. 7). Group sizes among interior strata during 1994–96 were more variable than those during most years in the period 1972–93 (Table 3) because more large-sized groups were recorded. No groups of more than 15 geese were observed during 1990–93 in interior habitats, and only 18 large groups (>15 geese per group) were observed on interior transects during 1972–93. In contrast, 13 groups of 24–44 geese per group were observed in interior strata during 1994–97. Although limited in number, a few large groups (>15 geese per group) from interior strata resulted in higher and more variable estimates of grouped geese. For example, an estimate of 332 200 (± 70 200) in 1994, which included six large groups of 24–44 individuals, was more variable than an estimate including only small interior groups (261 200 ± 30 700). The disparity of EPP estimates including large groups versus

Figure 4
Estimates of Canada Geese observed as single birds and pairs throughout stratum 4 during 1981, 1985, 1990, and 1995. Differences in estimates are reflected in contours of different shading; darker shading reflects greater goose densities (single birds and pairs/mi^2).

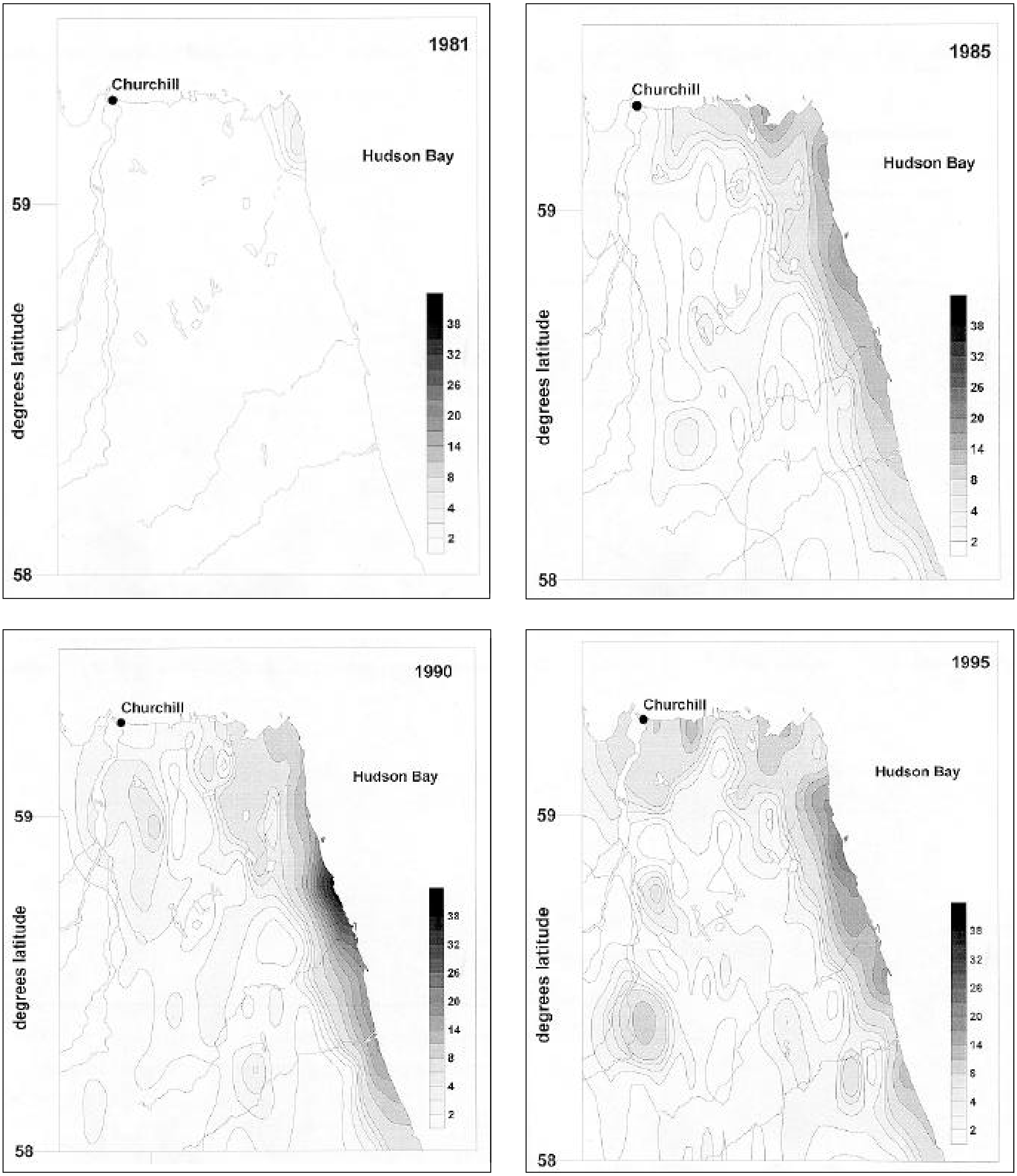


Table 2
Numbers of Canada Geese represented by single birds (singles × 2 × 1.4 visibility correction factor), pairs (pairs × 2 × 1.4), and groups of birds (not corrected for visibility) from EPP breeding population surveys, 1972–97. CI = confidence interval.

	Singles		Pairs		Groups		Total	
Year	No.	95% CI	No.	95% CI	No.	95% CI	No.	95% CI
1997	71 700	13 000	95 600	15 900	90 100	30 100	257 500	36 400
1996	61 500	11 400	112 700	20 800	85 400	40 900	259 500	47 300
1995	61 500	11 900	116 100	19 000	108 100	46 600	285 600	51 700
1994	87 100	15 500	88 800	16 600	156 400	66 400	332 300	70 200
1993	90 500	14 400	88 800	16 500	28 700	13 500	207 900	25 800
1992	82 000	15 000	126 300	21 500	53 100	14 400	261 400	29 900
1991	83 700	17 000	141 700	22 000	71 000	31 300	296 400	41 900
1990	83 700	15 100	124 600	18 600	89 600	21 400	297 900	32 200
1989	73 400	12 500	83 700	15 200	121 800	40 600	278 900	45 100
1988	70 000	12 800	95 600	15 400	90 700	29 800	256 400	35 900
1987	61 500	12 600	121 200	20 300	65 700	17 700	248 400	29 800
1986	66 600	12 800	85 400	15 400	96 100	28 600	248 100	34 900
1985	47 800	11 000	70 000	12 100	77 600	25 900	195 400	30 600
1984	56 300	10 400	75 100	13 300	38 200	19 400	169 700	25 700
1983	32 400	7 800	80 200	13 000	109 300	56 600	221 900	58 600
1982	51 200	10 400	61 500	11 300	47 800	24 200	160 500	28 700
1981	34 100	7 800	54 600	12 100	69 300	38 000	158 000	40 600
1980	No survey conducted in 1980							
1979	29 000	7 300	54 600	13 800	47 200	36 400	130 800	39 600
1978	30 700	8 500	99 000	16 000	96 100	30 200	225 900	35 200
1977	52 900	12 100	78 500	17 300	68 700	21 400	200 100	30 100
1976	75 100	16 000	109 300	20 800	49 600	15 300	234 000	30 400
1975	70 000	12 500	66 600	11 800	26 300	10 800	162 900	20 300
1974	41 000	7 600	66 600	13 600	28 100	8 400	135 600	17 700
1973	52 900	9 100	76 800	15 200	22 100	7 400	151 900	19 200
1972	46 100	9 100	63 200	11 600	32 800	11 400	142 100	18 700

Figure 5
Numbers of EPP Canada Geese estimated from breeding ground surveys (year t) and from winter surveys conducted in mid December (year t ! 1), 1972–97

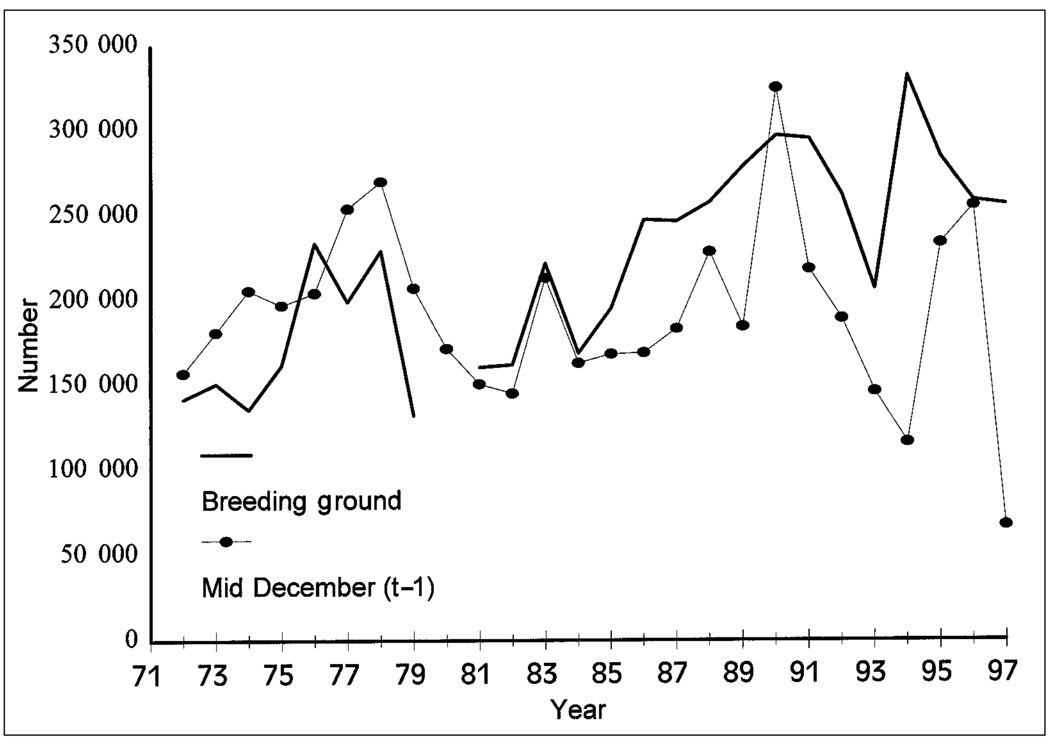
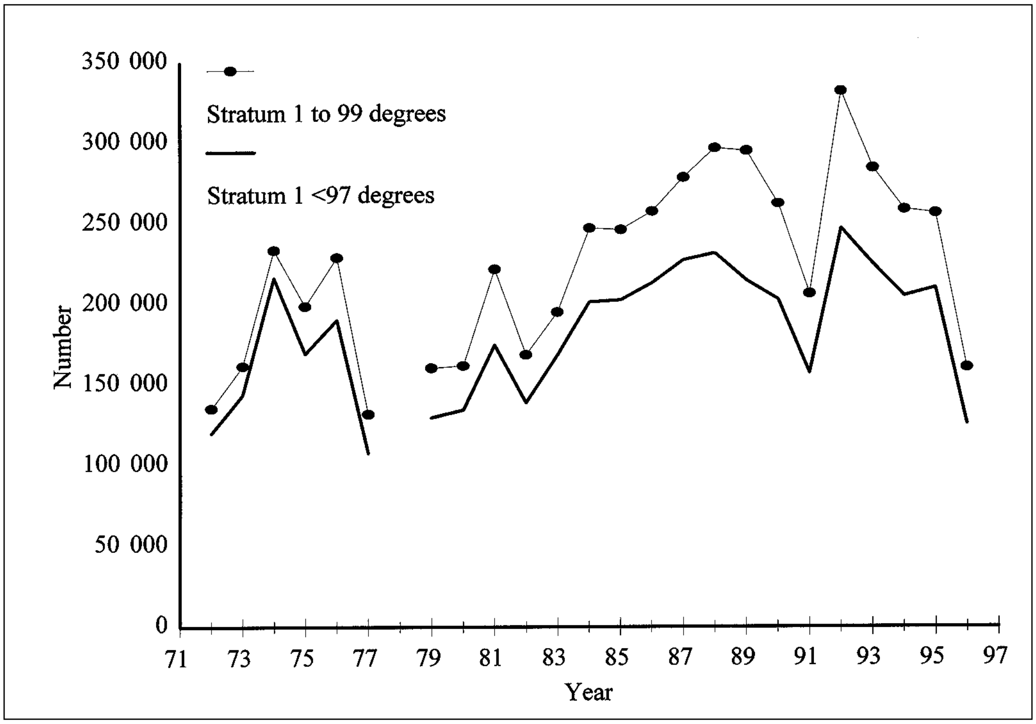


Figure 6
EPP breeding ground estimates for current study area, which extends to 99°W, versus those for a hypothetical study area extending only to 97°W, 1972–97



estimates without larger groups was greater for 1994–97 than during most other years (Fig. 10).

The population affiliation of geese in large groups is uncertain. Although geese in groups were reported in interior areas such as the Churchill River (Raveling 1977), early EPP surveys showed grouped geese primarily near the Hudson Bay coast. These were assumed to be nonproductive EPP geese (Malecki 1976) or moult migrants from several Canada Goose populations (Sterling and Dzubin 1967). Moult migrations, recorded during mid June to mid July and coincident with EPP hatch (Pakulak 1971; Malecki 1976), usually occurred after EPP surveys (Fig. 2). When the EPP survey was initiated in the 1970s, only 50 000 – 65 000 giant Canada Geese (*B. c. maxima*) were estimated in winter surveys in the Mississippi Flyway (Gamble and Peterson 1997). By 1990, giant numbers exceeded 300 000 according to winter survey indices, and spring estimates indicated about one million by 1994 (Rusch et al. 1996). Recent increases in numbers of giant Canada Geese in temperate areas and moult migrations to the North (Sterling and Dzubin 1967; Zicus 1981) prompt questions about population affiliation of geese in large groups observed in the EPP range.

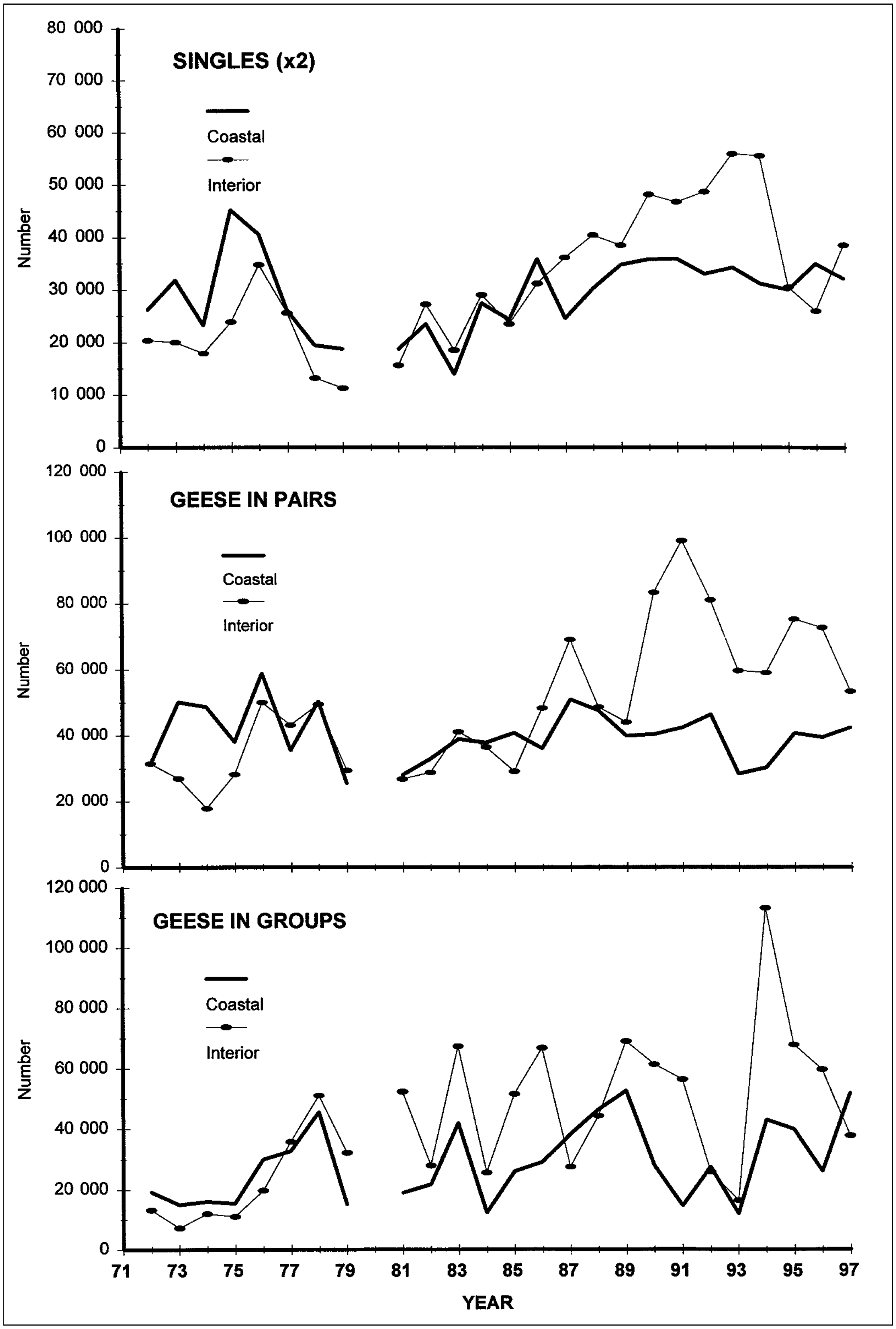
3.4 Implications for EPP management

Management of the EPP was based on winter surveys through 1991 (the objective was to support 200 000 geese; Babcock et al. 1978) and breeding ground status beginning in 1992 (the objective was to support 300 000 geese, Mississippi Flyway Technical Section 1992). After 1991, harvest restrictions were to be in effect when the EPP declined below the objective (<300 000 birds) and remain until the EPP exceeded the objective for two consecutive years (Mississippi Flyway Technical Section 1992). This was to ensure that young produced were likely to be recruited into subsequent years' breeding populations (see Moser and Rusch 1989). Additional harvest restriction in years of "bust" production (when very few young are produced) was designed to preclude acute population decline. Criteria for a bust in production (Mississippi Flyway Technical Section 1992) included: i) less than 20% of the EPP made up of single birds (1972–97 range = 13.6–43.5%), ii) average clutch size less than or equal to 3.2 (1976–97 range = 3.2–4.6 eggs per clutch, D.H. Rusch, unpubl.), and iii) median hatch later than 1 July (1976–97 range = 9 June – 10 July, D.H. Rusch, unpubl.).

We developed an index to harvest management to reflect the relative effectiveness of changes in hunting regulations in the context of variable production. Regulations were reflected in the sum of season lengths among harvest regions and among EPP harvest management zones (as restricted by either quota or season length). In 1975, for example, season lengths in Manitoba (70 days), Minnesota (45), Iowa (45), Missouri (45), Arkansas (30), the Lac qui Parle Zone (28), and the Swan Lake Zone (38) resulted in a cumulative season length of 301 days. This was weighted by the mean harvest age ratio for medium-sized geese harvested among Oak Hammock Wildlife Management Area (WMA), Lac qui Parle WMA, Thief Lake WMA (J. Lawrence, pers. commun.), and Swan Lake National Wildlife Refuge (Missouri Department of Conservation, unpubl.) (e.g., 2.14 immatures/adult in 1975). Resultant harvest indices ranged from 121 in 1973 (206 days and age ratio of 1.7) to 581 in 1978 (395 days and age ratio of 0.68).

Population declines in 1978, 1983, and 1992 corresponded to years of poor production (Rusch et al. 1996) during periods when liberal harvest regulations were retained. During these years, proportions of the EPP as

Figure 7
Estimates of geese represented by single birds, geese in pairs, and geese in groups in coastal (strata 2, 4, and 5) and interior (strata 1, 3, and 6) survey strata, 1972–97



singles (13.6%, 14.6%, and 31.3%, respectively), clutch sizes (3.2, 3.2, and 3.5, respectively), and median hatch dates (July 1, 10, and 1, respectively) often met criteria for more restrictive harvest regulations. Our index to harvest management (regulations weighted by production) corresponded inversely with changes in the EPP between years ($r = -0.60$, $P = 0.003$, $n = 22$), indicating that harvest restrictions were not adequate in some years (Fig. 11).

Despite a good outlook for production in 1993, restrictions were implemented in areas where the EPP was hunted to reduce the kill by 25–50%, because the population had declined below the objective of 300 000 geese.

Figure 8
Comparison of the proportion of single birds in the EPP in coastal strata (2, 4, and 5) and the weighted (by direct band recoveries) harvest-age age ratios of medium-sized geese at Oak Hammock WMA, Manitoba; Lac qui Parle WMA and Thief Lake WMA, Minnesota; and Swan Lake National Wildlife Refuge, Missouri, 1972–95

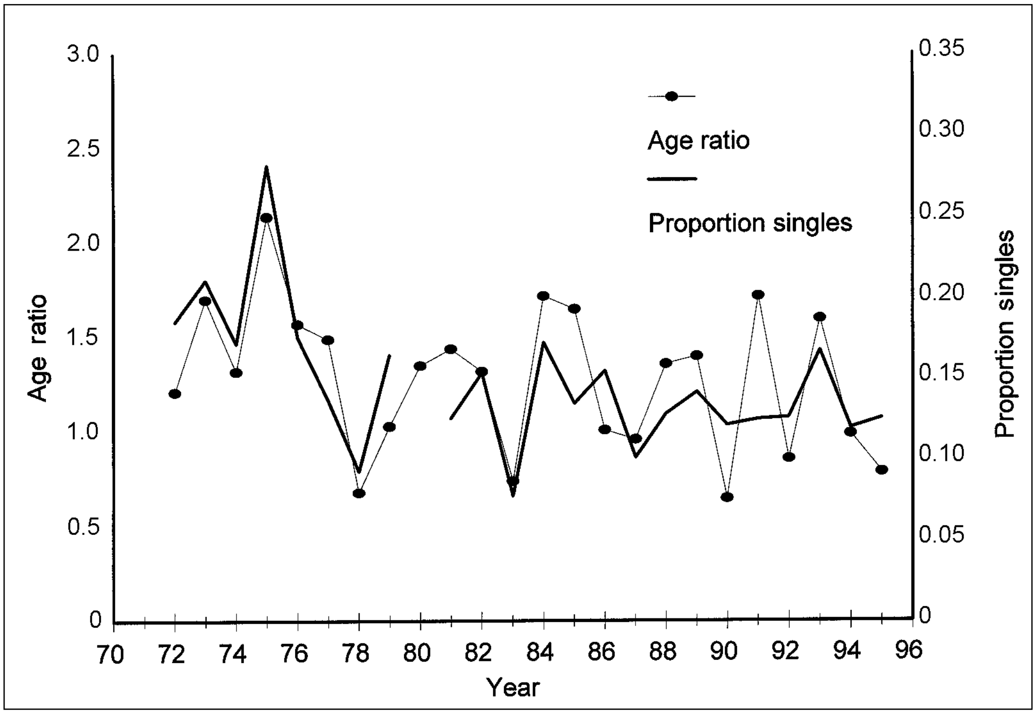


Figure 9
Estimates of numbers of single geese and of total “productive” geese. Productive geese include single geese, pairs seen with nests, and geese initially observed as a single (e.g., goose flushed from a nest) and joined by another bird (likely the gander).

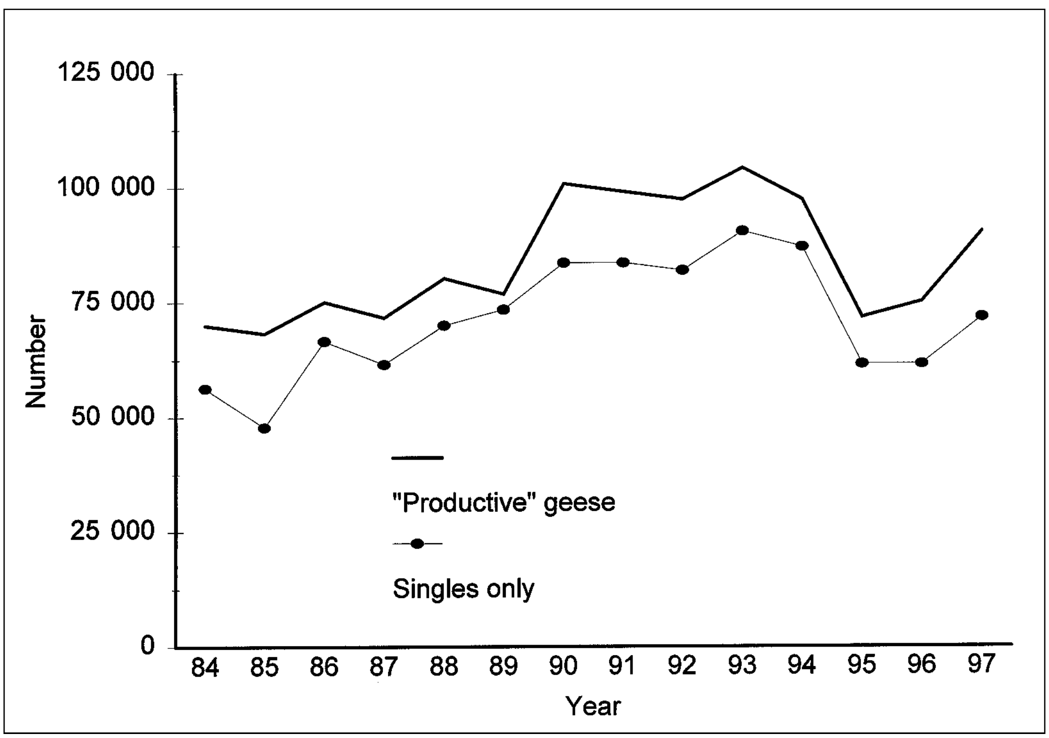


Table 3
Mean group sizes (standard deviation, number of groups) of Canada Geese observed on EPP breeding ground surveys, 1972–97, in coastal (2, 4, and 5) and interior (1, 3, and 6) strata. Numbers of groups among years are not comparable because of variable survey effort.

	Coastal strata			Interior strata		
Year	Mean group size	SD	No. of groups	Mean group size	SD	No. of groups
1997	5.87	4.56	142	8.9	8.66	20
1996	5.42	3.64	84	8.13	10.01	30
1995	5.85	5.13	163	7.47	7.53	36
1994	5.29	3.66	190	8.85	10.46	47
1993	5.00	3.49	69	4.27	2.94	11
1992	4.78	2.74	123	4.16	1.91	25
1991	4.78	2.90	91	4.79	2.09	29
1990	4.80	2.89	156	4.47	1.95	53
1989	5.60	3.25	213	6.88	7.25	35
1988	5.47	5.00	185	6.27	3.83	30
1987	5.03	2.96	201	4.64	1.73	25
1986	4.90	2.08	181	5.80	3.63	46
1985	5.24	2.76	124	7.16	5.07	32
1984	4.73	4.11	71	5.11	4.14	19
1983	5.62	3.85	199	7.91	8.83	34
1982	4.96	3.10	108	6.00	3.97	17
1981	5.32	2.52	108	6.83	5.62	30
1980	No survey in 1980					
1979	5.40	2.93	73	8.35	8.07	17
1978	5.72	3.88	218	6.85	7.60	27
1977	5.54	2.81	140	5.86	3.45	22
1976	6.31	4.72	136	5.21	3.33	19
1975	4.88	3.77	85	5.46	3.57	13
1974	6.13	5.02	89	4.50	1.89	18
1973	4.19	1.82	95	4.33	1.68	15
1972	5.48	3.96	50	4.63	2.92	38

Regulations implemented for 1993 were retained in 1994; however, some liberalized regulations (e.g., a bag limit of five Canada Geese in southern Manitoba and 70-day open seasons in Iowa and outside quota zones in Missouri) occurred in 1995. In 1994, the EPP was estimated at 332 300, which exceeded the population objective (300 000), and a sustained EPP in 1995 would have been the basis for recommended hunting liberalization. The numbers of EPP geese on the breeding grounds in 1995–97, however, were lower than 300 000, and harvest restrictions were retained where previously implemented. Questions arose about breeding population criterion and harvest management strategies when the EPP did not increase in response to harvest restrictions. Management strategies that are based on population size and recruitment may be ineffective if survey results are inaccurate or assumptions about productive components are not valid.

4. Conclusions

Breeding ground surveys of the EPP have been conducted consistently for 25 years. This long-term survey effort has provided insights into changes in population size and breeding ground distribution during a period of variable production and harvest. The survey has provided indices to EPP status and has provided guidelines for harvest management.

EPP size estimated from survey data may be affected by numbers and affiliations of geese in groups and by the actual boundaries of the EPP range (which in turn is the basis for expanded EPP estimates). In light of current assumptions about EPP range and affiliation of grouped geese, variation in EPP size recently has been a function of variable densities in interior habitats. However, annual variation in productivity

Figure 10
EPP breeding ground estimates including all groups and estimates excluding groups larger than 15 geese/group observed in interior habitat survey strata 1, 3, and 6, 1972–97

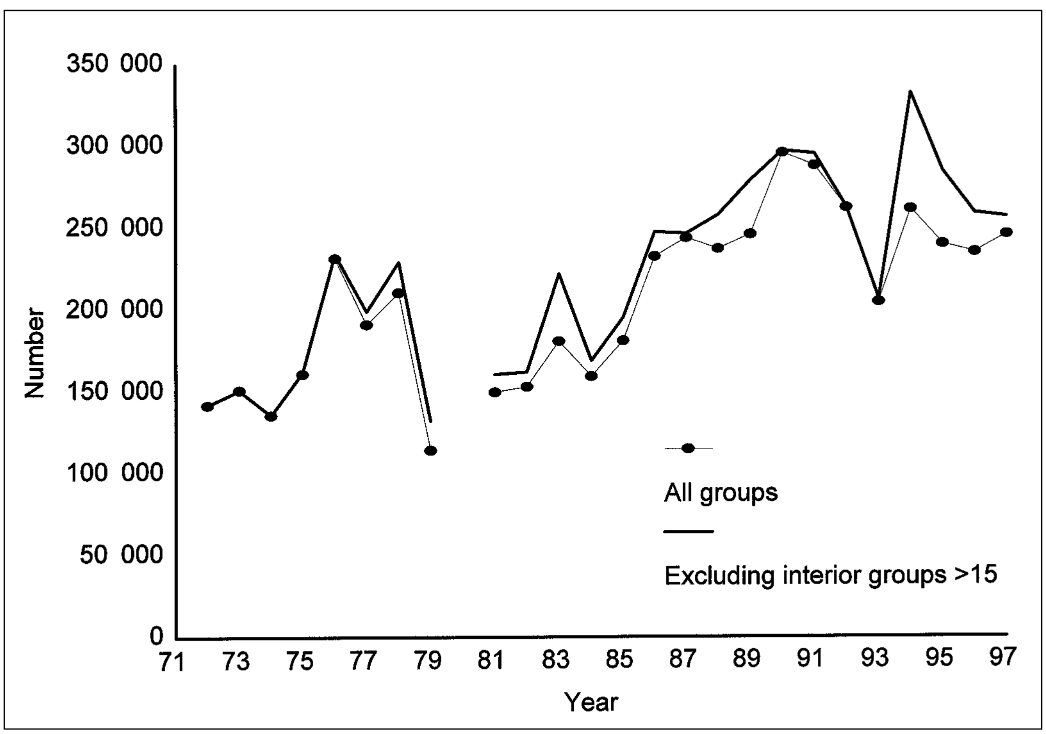
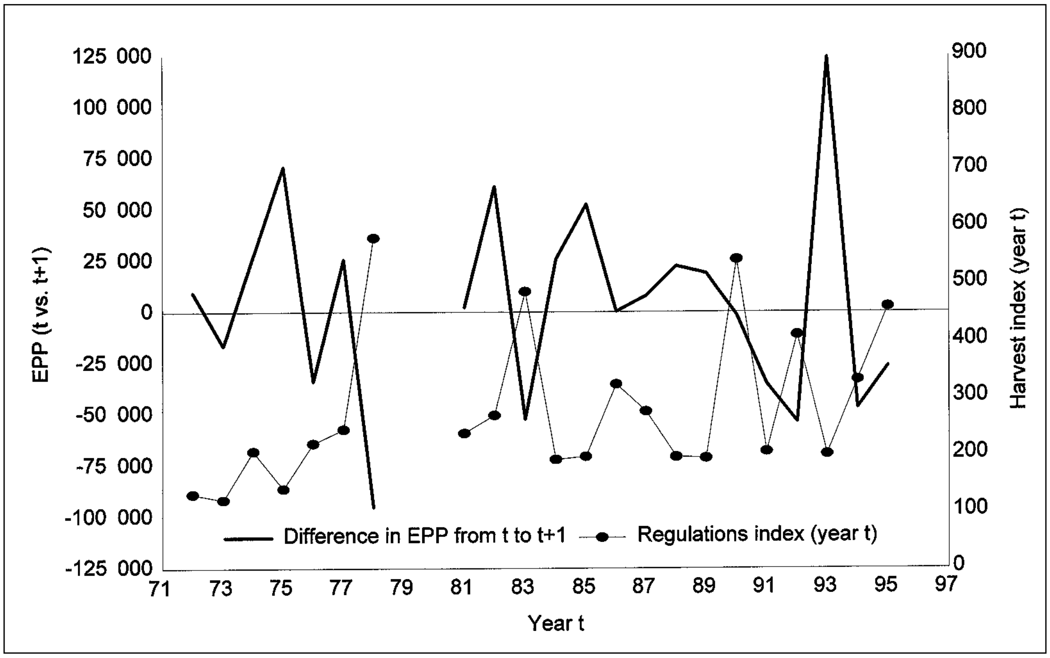


Figure 11
Year-to-year changes in EPP breeding ground estimates and an index to harvest management. The index to harvest management included an index to regulations (cumulative season lengths among EPP harvest areas) adjusted by an index to EPP production (harvest-age age ratios, of medium-sized geese at Oak Hammock WMA, Manitoba; Lac qui Parle WMA and Thief Lake WMA, Minnesota, and Swan Lake National Wildlife Refuge, Missouri), 1972–95



appears to be driven by nesting phenology (Rusch et al. 1996) and numbers of productive geese in coastal habitats. During the 1990s, apparent growth of the EPP occurred because of population increases in the interior.

Instead of basing year-specific harvest strategies on the status of all EPP components range-wide, the status of only productive geese in coastal regions may be more indicative of poor production, and singles plus pairs a better reflection of future breeding potential. Timing of EPP surveys relative to hatch and moult migration may affect survey results and interpretation, and surveys should be consistently conducted while additional studies are initiated to describe affiliations of grouped geese and to determine actual EPP range.

5. Acknowledgements

Funding for EPP breeding ground surveys was provided by the Manitoba Department of Natural Resources, Minnesota Department of Natural Resources, Iowa Department of Natural Resources, Missouri Department of Conservation (Pittman–Robertson project W-13-R), Arkansas Game and Fish Commission, U.S. Fish and Wildlife Service, Canadian Wildlife Service, University of Missouri, and University of Wisconsin. The Wildlife Management Institute provided administration of funds. Pilots have included P. Enzelberger, T. Hamm, A. Campbell, F. McMannus, N. Milne, J. Winship, and R. Foster. Observers have included R. Bishop, K. Babcock, M. Gillespie, D. Humburg, R. Malecki, L. Mechlin, D. Sohren, and P. Telander. J. Lawrence, D. Graber, K. Bataille, and S. Maxson reviewed drafts of the manuscript. S. Sheriff provided statistical support throughout the project. D. Brunette provided assistance with database management, tables, and figures. M. Schuster developed plots of goose densities used in Figure 4.

6. Literature cited

Allen, B.W. 1996. Movement and nest success of Canada geese in northern Manitoba. M.S. thesis, Univ. of Wisconsin, Madison. 47 pp.

Babcock, K.M., R.A. Malecki, J. Sayler, F.D. Caswell, R.K. Brace, R. Jessen and R.A. Bishop. 1978. A management plan for the Eastern Prairie Population of Canada Geese. Mississippi Flyway Council, Columbia, Missouri. 87 pp.

Balham, R.W. 1954. The behavior of the Canada Goose (*Branta canadensis*) in Manitoba. Ph.D. thesis, Univ. of Missouri, Columbia, Missouri. 229 pp.

Batt, B.D.J. (ed.). 1997. Arctic ecosystems in peril: report of the Arctic Goose Habitat Working Group. Arctic Goose Joint Venture Special Publication. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., and Environment Canada, Canadian Wildlife Service, Ottawa. 120 pp.

Bishop, R.A. and B.K. Williams. 1990. Needs, capabilities and prospects for the future of goose management in North America. Trans. North Am. Wildl. Nat. Resour. Conf. 55:374–377.

Didiuk, A.B. and D.H. Rusch. 1979. Ecology of broods of Canada Geese in northern Manitoba. Preliminary report. Wisconsin Cooperative Wildlife Research Unit, Madison. 216 pp.

Gamble, K. and J. Peterson. 1997. Waterfowl harvest and population survey data. Unpublished report. U.S. Department of the Interior, Fish and Wildlife Service, Columbia, Missouri. 82 pp.

Humburg, D.D., F.D. Caswell, D.H. Rusch and M.M. Gillespie. 1998. Breeding ground surveys for the Eastern Prairie Population of Canada Geese. Pages 9–19 *in* Rusch, D.H., M.D. Samuel, D.H. Humburg and B.D. Sullivan (eds.), Biology and management of Canada Geese: Proceedings of the International Canada Goose Symposium. Milwaukee, Wisconsin.

Malecki, R.A. 1976. The breeding biology of the Eastern Prairie Population of Canada Geese. Ph.D. thesis, University of Missouri, Columbia. 149 pp.

Malecki, R.A., F.D. Caswell, K.M. Babcock, R.A. Bishop and R.K. Brace. 1980. Major nesting range of the eastern prairie population of Canada Geese. J. Wildl. Manage. 44:229–232.

Malecki, R.A., F.D. Caswell, K.M. Babcock, R.A. Bishop and M.M. Gillespie. 1981. A breeding ground survey of EPP Canada Geese in northern Manitoba. J. Wildl. Manage. 45:46–53.

Mississippi Flyway Technical Section. 1992. A management plan for the Eastern Prairie Population of Canada Geese. Missouri Department of Conservation, Jefferson City. 48 pp.

Mississippi Flyway Technical Section. 1993. Harvest management strategy for Canada Geese in the western Mississippi Flyway. Missouri Department of Conservation, Jefferson City. 34 pp.

Moser, T.J. and D.H. Rusch. 1989. Age-specific breeding rates of female interior Canada Geese. J. Wildl. Manage. 53:734–740.

Pakulak, A.J. 1969. Nesting ecology of Canada Geese of the Churchill area, northern Manitoba. M.S. thesis, Colorado State University, Fort Collins. 134 pp.

Pakulak, A.J. 1971. Canada Goose moult migration in northern Manitoba, 1967–70. Unpublished Biological Report. Manitoba Department of Mines and Natural Resources, Research and Development Branch. 53 pp.

Raveling, D.G. 1977. Canada Geese of the Churchill River basin in north-central Manitoba. J. Wildl. Manage. 41:35–47.

Raveling, D.G. and H.G. Lumsden. 1977. Nesting ecology of Canada Geese in the Hudson Bay lowlands of Ontario: evolution and population regulation. Ontario Fish and Wildlife Resource Report No. 98. 77 pp.

Richie, J.C. 1960. The vegetation of northern Manitoba. V. Establishing the major zonation. Arctic 13:211–229.

Rusch, D.H., F.D. Caswell, M.M. Gillespie and J.O. Leafloor. 1996. Research contributions to management of Canada Geese in the Mississippi Flyway. Trans. North Am. Wildl. Nat. Resour. Conf. 61:437–449.

Samuel, M.D., D.H. Rusch, K.F. Abraham, M.M. Gillespie, J.P. Prevett and G.W. Swenson. 1991. Fall and winter distribution of Canada Geese in the Mississippi Flyway. J. Wildl. Manage. 55:449–456.

Sherwood, G.A. 1967. Behavior of family groups of Canada Geese. Trans. North Am. Wildl. Nat. Resour. Conf. 32:340–355.

Sterling, T. and A. Dzubin. 1967. Canada Goose molt migrations to the Northwest Territories. Trans. North Am. Wildl. Nat. Resour. Conf. 32:355–373.

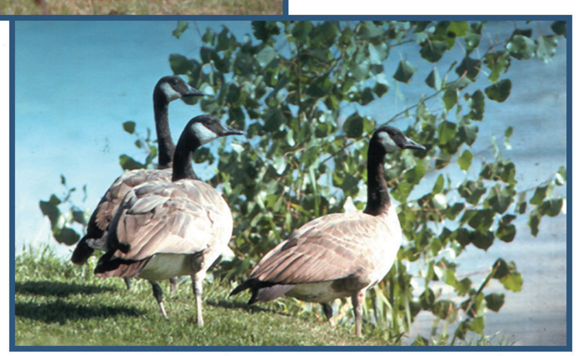
U.S. Department of the Interior and Environment Canada. 1987. Standard operating procedures for aerial waterfowl breeding ground population and habitat surveys in North America. Unpublished report. U.S. Department of the Interior, Fish and Wildlife Service, Branch of Surveys, Laurel, Maryland. 102 pp.

Vaught, R.W. and L.M. Kirsch. 1966. Canada Geese of the Eastern Prairie Population with special reference to the Swan Lake flock. Technical Bulletin 3, Missouri Department of Conservation, Jefferson City. 91 pp.

Walter, S.E. 1996. Aspects of Canada Goose nesting ecology in northern Manitoba: Age, visibility, and arctic fox predation. M.S. thesis, University of Wisconsin, Madison. 64 pp.

Zicus, M.C. 1981. Molt migration of Canada Geese from Crex Meadows, Wisconsin. J. Wildl. Manage. 45:54–63.

Temperate-breeding populations



Photos: top – Harry Lumsden
centre – Norm North
bottom – Ken Abraham

Status of Canada Geese of the Canadian prairies

Daniel J. Nieman, Andrew B. Didiuk, and Jack R. Smith

Summary

Dramatic increases in Canada Goose (*Branta canadensis*) populations nesting in prairie regions of North America have caused increasing concern because of crop depredation and other conflicts with human activities in both urban and rural environments. Counts in wintering areas to determine population trends are confounded by overlap of wintering populations, both spatially and temporally. Annual spring waterfowl surveys in prairie Canada and the northern Great Plains of the United States provide an opportunity to assess population trends of Canada Geese. Smaller-scale surveys in east-central Saskatchewan suggest these annual spring aerial surveys provide a good measure of trends in populations. Spring waterfowl surveys indicated increases of 508%, 1089%, 1027%, and 2117% in Rocky Mountain, Hi-Line, southern Western Prairie, and Great Plains populations, respectively, between 1970 and 1999. The greatest increases were in southern Alberta and the aspen parklands of Manitoba, Saskatchewan, and Alberta. Development of adequate visibility adjustment factors, consistent interpretation of social groupings of observations, and increased sampling intensity are necessary to improve the usefulness of spring waterfowl surveys to monitor trends in size of Canada Goose populations. Monitoring of individual populations on their breeding grounds is important to design hunting regulations to meet population goals, and to evaluate their effects.

Résumé

L'accroissement spectaculaire des populations de Bernaches du Canada (*Branta canadensis*) nichant dans les régions des prairies de l'Amérique du Nord est à l'origine de préoccupations croissantes relatives à la dévastation des récoltes et à d'autres conflits avec les activités humaines en milieux urbains et ruraux. Les dénombrements effectués dans les aires d'hivernage visant à déterminer les tendances des populations sont faussés par le chevauchement des populations d'hivernage, et ce du point de vue spatial et temporel. Les relevés annuels du printemps de la sauvagine vivant dans les Prairies du Canada et dans les Grandes Plaines du Nord des États-Unis constituent une occasion d'évaluer les tendances des populations de Bernaches du Canada. Des relevés à plus petite échelle effectués dans le centre Est de la Saskatchewan suggèrent que les relevés aériens annuels du printemps donnent une bonne indication des tendances des populations. Les relevés du printemps de la sauvagine ont indiqué des augmentations respectives de 508%, de 1089%, de 1027%, et de 2117% de la population des Rocheuses, de la population de « Hi-Line », de la population des Prairies de l'Ouest, et de la population des Grandes Plaines, entre 1970 et 1999. Les plus fortes croissances ont eu lieu dans le Sud de l'Alberta, dans les parcs de peupliers trembles du Manitoba, de la Saskatchewan et de l'Alberta. L'élaboration de facteurs adéquats d'ajustement de visibilité, l'interprétation uniforme des observations des regroupements sociaux et l'intensité accrue de l'échantillonnage sont nécessaires pour améliorer l'utilité des relevés du printemps de la sauvagine afin de suivre de près les tendances de la taille des populations de Bernaches du Canada. Le suivi des populations individuelles dans leur aire de reproduction est important afin d'élaborer des règlements de chasse permettant d'atteindre les objectifs visés de population et d'évaluer l'incidence de ces derniers.

1. Introduction

Nesting large Canada Geese (*Branta canadensis*) were present in varying numbers throughout the southern Canadian prairies well before European settlers came into the region. The number of Canada Geese on the prairies has varied considerably over the years, as a result of pressures exerted by settlement and agricultural development. These pressures included habitat changes and hunting.

There is no accurate assessment of how many Canada Geese were on the Canadian prairies prior to settlement. It is generally accepted that a significant decline in the number of geese within this region likely coincided with intensive agricultural settlement and the elimination of bison as a major food source for prairie natives. Hunters, trappers, and settlers eliminated Canada Geese from most of the agricultural areas by 1900.

Canada Geese, unlike some species of ducks, likely benefited from agriculture and the large-scale conversion of deciduous forests and prairies to cultivated land. After they were afforded a measure of protection by the Migratory Birds Convention in 1916, Canada Geese were able to take advantage of the development of large wetland impoundments, open landscapes, and the increased availability of food in the form of cereal grains and planted forages.

They also responded favourably to population management programs implemented by various wildlife agencies

(Rusch et al. 1996). These programs included goose restoration projects supported by provincial resource agencies, nongovernment organizations, and private individuals. For example, in the 1950s, a small group of large Canada Geese were transplanted from the Quill Lake region in Saskatchewan to Wascana Lake in the City of Regina. This flock eventually produced nearly 1000 goslings per year, many of which were used to reestablish Canada Goose populations throughout North America.

Although it is generally accepted that large Canada Geese have increased on the Canadian prairies, the magnitude of this change, by population and region, has not been documented. Gollop (1991), using data from the Cooperative Waterfowl Breeding Population Survey (CWBPS), conducted jointly by the Canadian Wildlife Service (CWS) and U.S. Fish and Wildlife Service (USFWS) (U.S. Department of the Interior and Environment Canada 1987), estimated that Canada Geese in agricultural Saskatchewan increased from about 5600 birds in 1970 to 66 000 birds in 1990. Incidental observations by resource agency staff also indicated numbers of large Canada Geese increased significantly on the prairies over the past 20 years. Short-term ground and aerial surveys of portions of the breeding areas, and counts on the wintering grounds, have confirmed this trend.

There is a need to determine the magnitude of this increase for specific populations of geese nesting on the Canadian prairies. There have been significant changes to goose hunting regulations in Canada and the U.S. in recent years, and more are expected as states and provinces respond to very successful Canada Goose restoration programs. These changes will impact prairie Canada Goose populations that winter in the same areas as the restoration birds, and the status of these populations must be carefully monitored. This paper will document changes in the large Canada Goose populations that nest in the southern regions of the Prairie provinces (Alberta, Saskatchewan, and western Manitoba).

Most Canada Geese within North America are assigned to discrete populations, often managed by detailed plans approved by individual flyway waterfowl councils. Descriptions of these populations, and hence their management, have evolved over more than 30 years. Hanson and Nelson (1964) recognized only two Canada Goose populations nesting on the Canadian prairies: Western Prairie and Great Basin. Rutherford (1965) listed three: Western Prairie, Hi-Line, and Great Plains. Williams (1967) described two: Western Prairie and Intermountain. Bellrose (1976) referred to three: Western Prairie, Intermountain, and Hi-Line.

Current management plans for the flyways (Central Flyway Council 1988, 1996; SRMCG 1992) refer to four populations: Rocky Mountain, Hi-Line, Western Prairie, and Great Plains. This paper uses these four population descriptions and their definitions in discussing Canada Geese nesting in southern prairie Canada (grasslands, aspen parklands, and the forest fringe).

1.1 Rocky Mountain Population

The Rocky Mountain Population (RMP), composed primarily of *B. c. moffitti*, nests in southwest Alberta, eastern Idaho, and northern Utah, with smaller numbers in Montana, Wyoming, Colorado, Nevada, and Arizona (SRMCG 1992 and Fig. 1). It winters from southern California to Arizona and north to central Montana.

The RMP had been declining in the 1950s. Restrictive hunting regulations were imposed in the major harvest jurisdictions, and a midwinter population goal of 50 000 (recently increased to 60 000) was established (SRMCG 1992). Regulations were gradually liberalized as the population responded during the 1980s.

RMP geese are counted in the Pacific Flyway during the Midwinter Waterfowl Survey. These surveys, although not complete population counts, indicated an upward trend from about 30 000 geese during the 1970s to 70 000 in the 1980s and over 100 000 during the late 1990s. More recent analyses, using data from the CWBPS in Alberta and Montana, indicated that the breeding population may have increased from less than 20 000 birds in the 1970s to about 50 000 in 1995 (D. Caithamer, pers. commun.).

Canada Geese of the RMP are harvested primarily in southern Alberta, northern Utah, and southeastern Idaho. In recent years, the kill has averaged over 100 000 birds per season throughout its range (SRMCG 1992). Incomplete population counts and harvest data from reference areas where RMP geese mingle with other populations make it difficult to reconcile these data.

1.2 Hi-Line Population

Rutherford (1965) described the Hi-Line Population (HLP) as a western form of Canada Goose (*B. c. moffitti*). However, Canada Geese on the southern and eastern portions of the HLP range are physically similar to *B. c. maxima*. The HLP nests primarily in southeastern Alberta, southwestern Saskatchewan, and eastern Montana (Fig. 1). Most winter in north-central Colorado, with lesser numbers in Montana, Wyoming, Nebraska, and New Mexico (Central Flyway Council 1996).

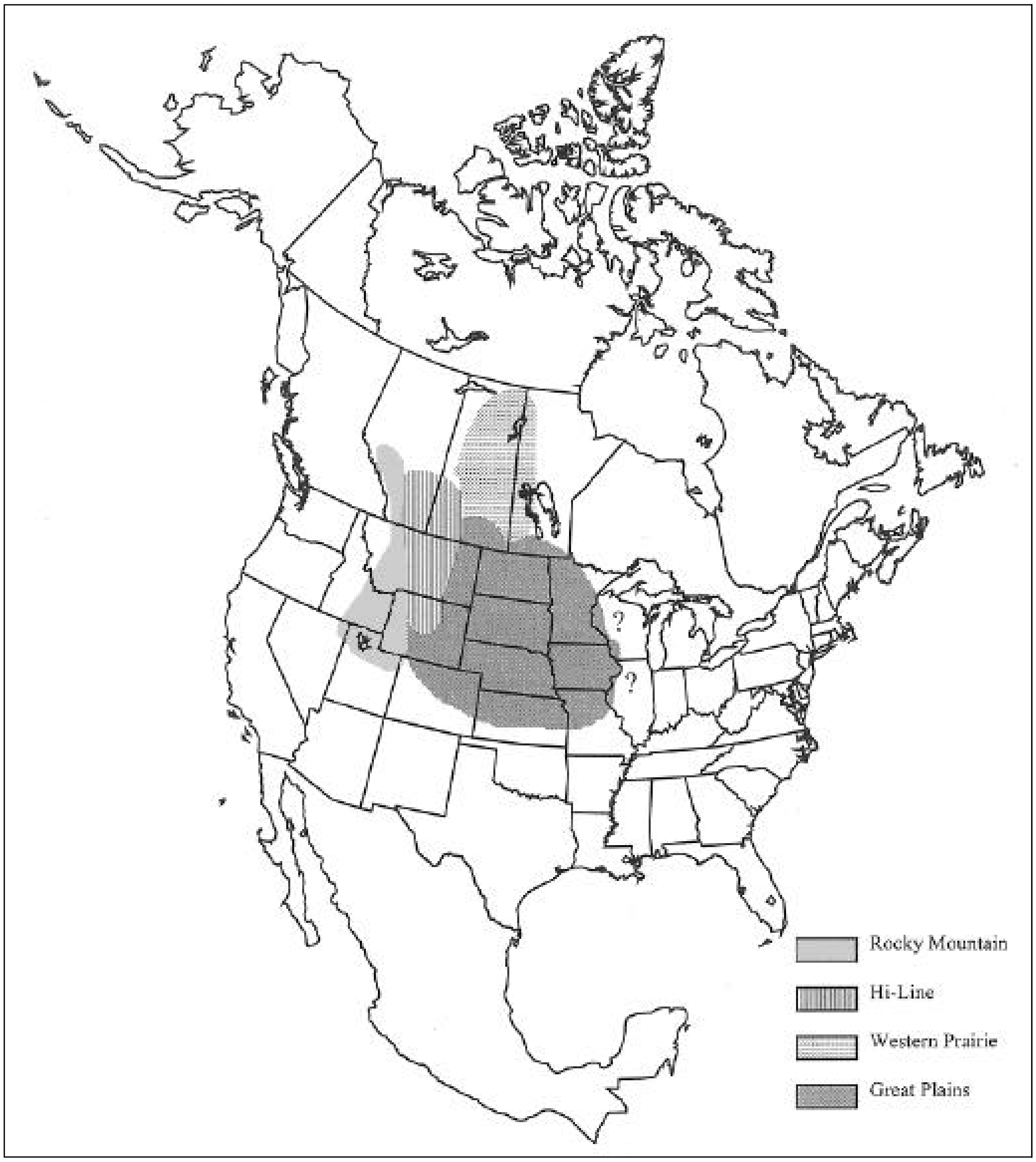
HLP geese are counted during the Mid-December Survey and the January Midwinter Waterfowl Survey, and the latter is used to assess annual population size. HLP geese have increased rapidly since the early 1960s (less than 20 000 birds) to about 190 000 in 1997 (Sharp 1997). Recent analyses of Canada Goose data from the CWBPS indicated the HLP has increased from less than 20 000 breeding birds in the 1960s to over 60 000 in 1995 (D. Caithamer, pers. commun.).

HLP Canada Geese are harvested primarily in Colorado, Alberta, Saskatchewan, Montana, and Wyoming. Lesser numbers are taken in New Mexico and Nebraska. Annual harvest has increased from less than 50 000 in the early 1960s to nearly 100 000 birds in recent years. A goal of 80 000 geese (three-year running average of January surveys) has been established for this population (Central Flyway Council 1996).

1.3 Great Plains Population

Rutherford (1965) described the Great Plains Population (GPP) as primarily *B. c. moffitti*, occupying most of agricultural (southern) Saskatchewan and overlapping both the WPP and HLP. Lee (1977) suggested the GPP included the large Canada Geese being restored into the U.S. portion of the former *B. c. maxima* range.

Figure 1
Breeding ranges of Rocky Mountain, Hi-Line, Western Prairie, and Great Plains Canada Goose populations (Central Flyway Council 1988, 1996; SRMCG 1992)



Current management plans in the Central Flyway do not refer to this population because data are inadequate to separate WPP and GPP on migration or wintering areas. Large Canada Geese of these two populations are collectively referred to as Tall Geese of the Western Prairie. For the purposes of this paper, the GPP will refer to the large Canada Geese within the Great Plains portion of the U.S. and extreme southeastern Saskatchewan and southwestern Manitoba (Fig. 1). They originated primarily from restoration efforts in southeast Saskatchewan, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas.

1.4 Western Prairie Population

Rutherford (1965) described the Western Prairie Population (WPP) as a large form of Canada Goose (*B. c. interior*, *B. c. moffitti*, and some *B. c. maxima*) nesting principally in west-central Manitoba and east-central Saskatchewan, migrating through North Dakota, and wintering in South Dakota on the Missouri River (Fig. 1). A significant number also winter in Nebraska and Kansas, with smaller numbers in Oklahoma, Missouri, and Texas. Vaught and Kirsch (1966) also included the small group of intermediate Canada Geese (*B. c. interior*), which nest throughout the boreal forest of northwestern Manitoba and northern Saskatchewan.

A portion of the southern Saskatchewan and Manitoba breeding range of the WPP and most of its wintering area overlap with the breeding and wintering ranges of the Great Plains Population (GPP). However, for the purposes of this paper, Canada Geese that nest north of 50° latitude in eastern Saskatchewan and western Manitoba are counted as belonging to the WPP, and those that nest south of this line belong to the GPP (Fig. 1).

Although recognized as two distinct populations, the WPP and GPP cannot be distinguished on the wintering areas and have been combined as one group in the management plan for Tall Geese of the Western Prairie (Central Flyway

Council 1988). The annual status of the combined populations is assessed during the mid-December goose survey in the Central Flyway. These geese have increased from about 200 000 wintering birds in the early 1980s to over 480 000 in 1997 (Sharp 1997).

WPP Canada Geese are harvested primarily in Saskatchewan, Manitoba, North Dakota, South Dakota, Nebraska, and Kansas. Lesser numbers are taken in Oklahoma and Texas. Because the fall and winter ranges of the WPP and GPP overlap, detailed harvest data by population are not available. The population goal established for the combined populations is 42 000 pairs (17 000 WPP, 25 000 GPP) and a mid-December count of 150 000–285 000 birds (Central Flyway Council 1988).

2. Methods

Our analyses and interpretations address those portions of the RMP, HLP, GPP, and WPP of the grasslands, parklands, and forest fringe of the Canadian prairies only (Fig. 2). The Canadian portions of the RMP, HLP, and GPP are south of the forest fringe. The southern Western Prairie Population (SWPP) is that portion of the WPP south of the boreal forest (Fig. 2).

Annual survey data from the CWBPS (U.S. Department of the Interior and Environment Canada 1987) were the primary source of information used to describe changes in numbers and distribution of Canada Geese in the Canadian prairies. These annual surveys (Fig. 3) include aerial and ground counts of waterfowl along transects throughout the grasslands, aspen parklands, and forest fringe of the southern prairie region.

Population estimates for Canada Geese from the CWBPS used estimates for numbers of geese for each segment of all transects in strata 26–40. Transects were aligned east to west within survey strata, and each segment of a transect was approximately 29 km long. The numbers and group sizes of geese were recorded within 200 m of each side of the transect line. Counts from the air were adjusted for visibility bias from ground counts on selected segments. Estimates of numbers of geese for each segment were derived as follows:

$$\text{estimated number of geese per segment} = \text{adjusted number of single geese} \times 2 + \text{adjusted number of pairs} \times 2 + \text{adjusted number of groups} \times 1$$

Estimates for each population were derived as follows:

$$\Sigma\,(\text{segment estimate}) \times \frac{(\text{area of population range})}{\Sigma\,(\text{area of survey segment within population range})}$$

We included groups of Canada Geese, and multiplied these by one, in our estimates to represent the number of Canada Geese within the survey area for each population during the survey. These estimates represent both the breeding component (singles and pairs representing nesting pairs) and the nonbreeding component (nest-fail adults and nonnesting subadults that have not yet departed to moulting sites). We are confident that few, if any, migrants from more northerly populations and moult migrants from more southerly populations are passing through the survey area during this survey period (usually second and third weeks of May).

We described the distribution of Canada Geese in the southern prairies of Canada by creating contour maps of goose density (number per km^2). These density estimates were derived for each survey segment by dividing the estimated number of geese of a survey segment by the area of that segment. Contour maps were created by kriging of density values (using Surfer, produced by Golden Software), with density class intervals derived from inspection of histograms of densities for all segments. Contour maps were prepared for three time periods: 1) 1955–79, a period of relatively low numbers of geese; 2) 1980–89, a period of increasing numbers of geese; and 3) 1990–99, a period of greatly increasing numbers of geese.

We compared goose estimates from the CWBPS survey with data from a survey conducted in east-central Saskatchewan from 1972 to 1980. This latter “Cruise Survey” involved inspection of the entire shorelines of and islands in lakes and wetlands in six areas: a) Lake Lenore; b) Quill Lakes; c) Last Mountain Lake; d) Leech Lake; e) Strawberry Lakes; and f) Hudson Bay (Fig. 4). No adjustments for visibility bias were made for data from either survey. Comparisons focused on trend in numbers observed rather than absolute numbers since the sampling effort was not comparable for each survey.

We used counts of these Canada Goose populations that are conducted annually in the United States during the mid-December goose surveys and the mid-winter (early January) waterfowl surveys. Although these counts include the populations of southern prairie Canada, it is difficult to accurately separate populations due to mixing in the winter survey areas. Nonetheless, these winter count data likely reflect trends in population size, and these trends were compared with trends in population estimates from the CWBPS in southern prairie Canada.

3. Results

3.1 Comparison of Cruise Survey and CWBPS estimates

A comparison of Canada Goose data from the Cruise Survey with those of CWBPS transects was possible in only one of the six areas (Area B, Quill Lakes) due to very small sample sizes in the other regions. The trend in Canada Goose populations from the Quill Lakes, which had the highest density of Canada Geese observed during the Cruise Survey, compared favourably with the CWBPS for the 1972–80 period, with both indicating an increasing population (Fig. 5).

Both surveys suggested population increases of a similar magnitude for the period 1972–80. Therefore, it appears that the CWBPS in Saskatchewan provides information on trends in Canada Goose populations similar to that provided by a more detailed, intensive survey such as the Cruise Survey.

Figure 2
Ranges of the Rocky Mountain, Hi-Line, southern Western Prairie, and Great Plains Canada Goose populations within prairie Canada

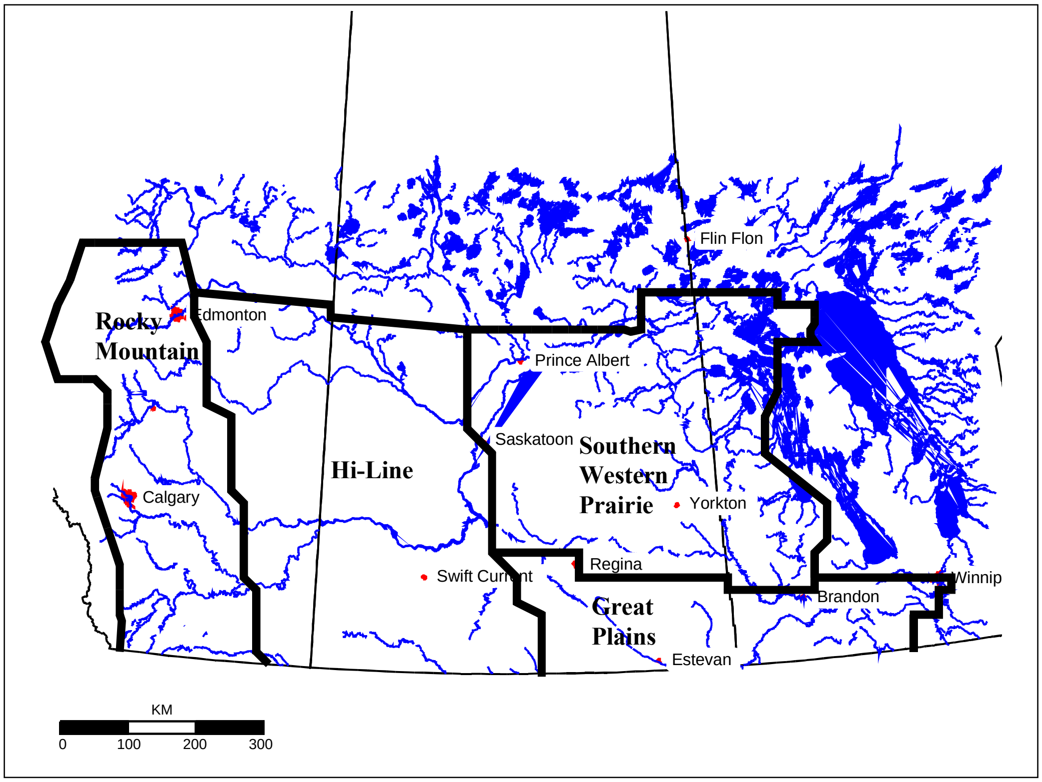


Figure 3
Centre points of survey segments from the Cooperative Waterfowl Breeding Population Survey in southern prairie Canada

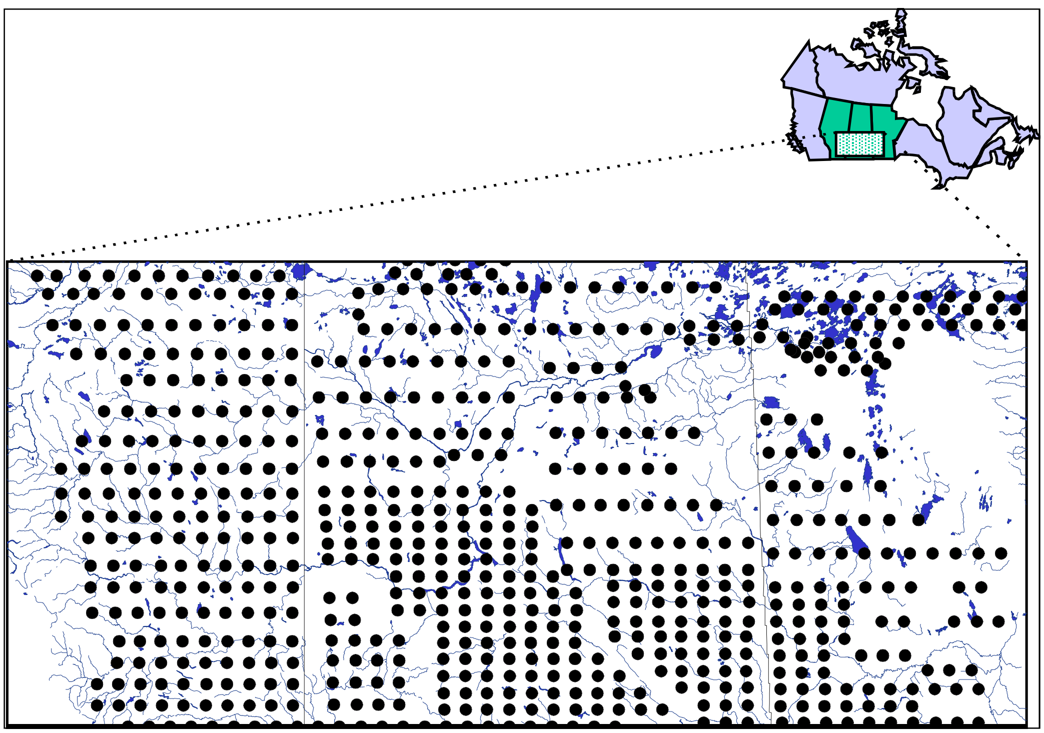
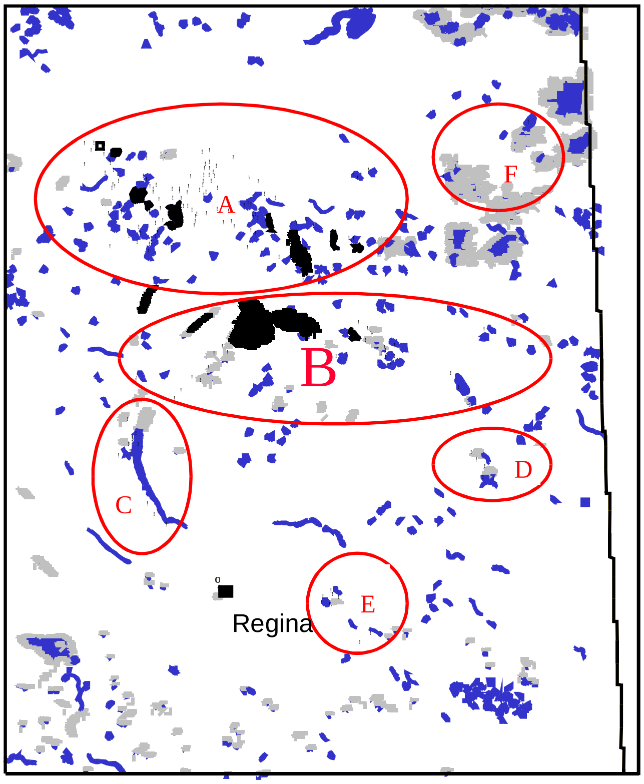


Figure 4
Areas in eastern Saskatchewan that were inventoried for Canada Geese during Cruise Surveys, 1972–80 (A = Lenore Lake, B = Quill Lakes, C = Last Mountain Lake, D = Leech Lake, E = Strawberry Lakes, and F = Hudson Bay)



3.2 Changes in densities and distribution of Canada Geese

The average densities of Canada Geese nesting in the southern Prairie provinces of Canada are presented for three time periods: 1955–79, 1980–89, and 1990–99 (Fig. 6). High population densities in the extreme eastern portion of the survey area, between Lake Winnipeg and Lake Winnipegosis/ Lake Manitoba in western Manitoba, are associated with populations of "giant" Canada Geese, which are not addressed in this report.

During 1955–79, Canada Goose numbers were relatively low and stable throughout the prairie region. Higher densities were associated with RMP geese in the Brooks, Pincher Creek, and High River regions of western Alberta, HLP geese north of Pakowki Lake in southern Alberta and in the Cypress Lake and Crane Lake regions of southwestern Saskatchewan, SWPP geese in the Quill Lakes region of east-central Saskatchewan and the Saskatchewan River delta region of Manitoba, and GPP geese in extreme southwestern Manitoba near Oak and Whitewater lakes.

During 1980–89, numbers of Canada Geese dramatically increased in the southern Canadian prairie regions. The higher-density areas of RMP geese in the Brooks, Lethbridge, and Pincher Creek areas of southwestern Alberta increased in size, but fewer geese were observed in the High River region. Additional areas of increased density of RMP geese occurred in the Strathmore, Lacombe, and Edmonton areas and the aspen parklands east of Edmonton. HLP geese increased in the area north of Pakowki Lake in southeastern Alberta and northeast of Swift Current, Saskatchewan. SWPP geese dramatically increased in numbers throughout the aspen parklands of eastern Saskatchewan from the Quill Lakes region to the area north of North Battleford and

Figure 5
Comparison in trends of southern Western Prairie Population Canada Geese in east-central Saskatchewan. Cruise refers to the estimates from a survey designed specifically to estimate Canada Geese, and CWBPS refers to the estimates from the annual spring waterfowl survey of CWS and the USFWS

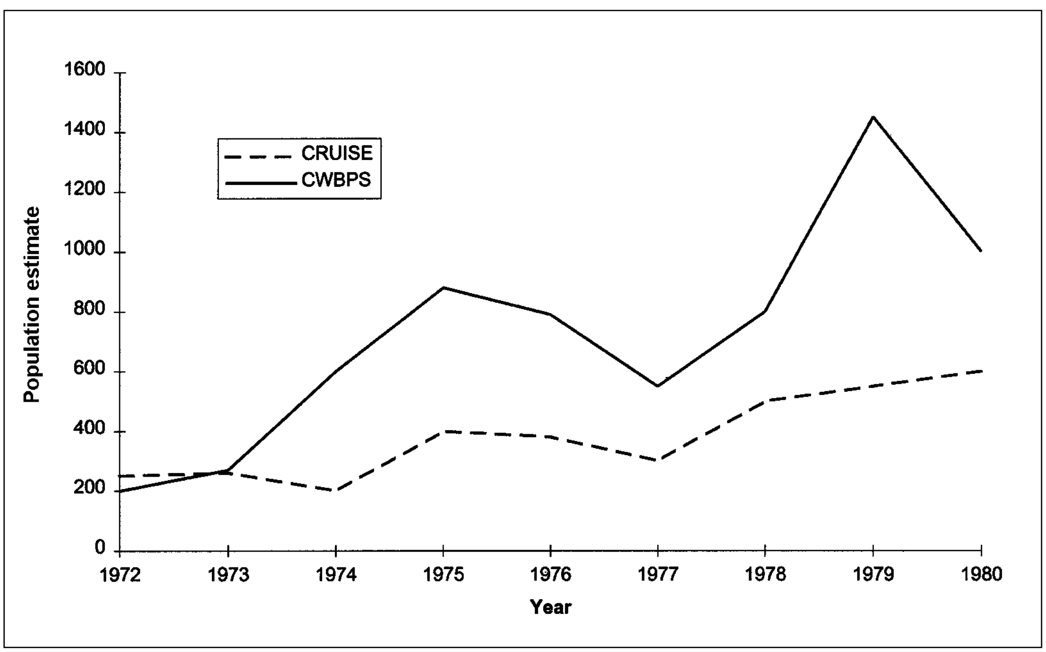
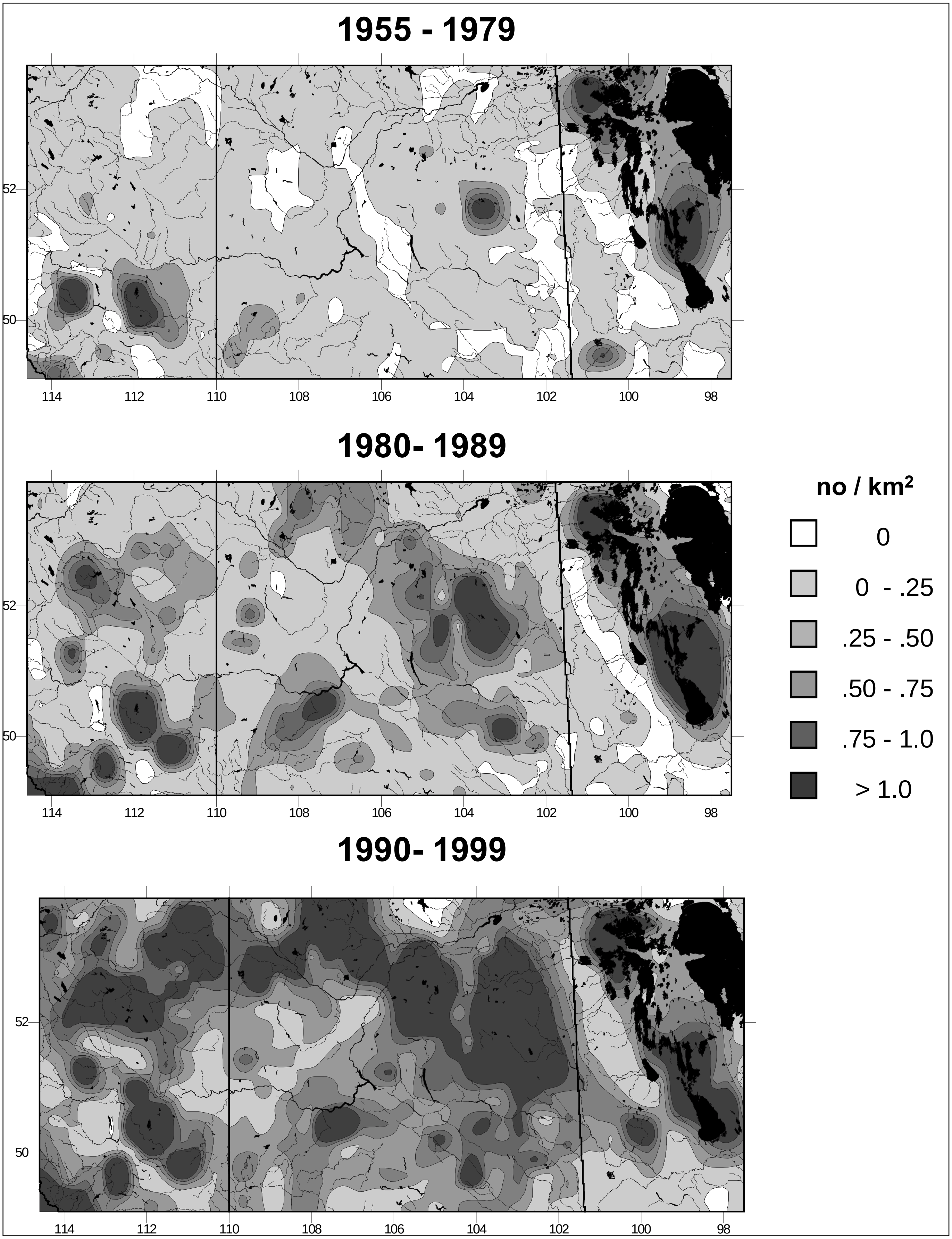


Figure 6
Density of Canada Geese on the southern Canadian prairies during three time periods (data from the CWBPS)



remained high in the Saskatchewan River delta region of Manitoba. GPP geese increased in the area northwest of Moose Mountain Provincial Park in southeastern Saskatchewan, but declined in extreme southwestern Manitoba.

During the 1990–99 period, Canada Geese continued to increase in numbers, with high densities throughout the aspen parklands and forest fringe of all three Prairie provinces. Areas of higher density in southern grassland areas persisted and expanded in all three provinces as well. Additional areas of higher density of SWPP geese occurred in the Minnedosa/Neepawa region of southwestern Manitoba and the Weyburn region of south-central Saskatchewan.

The contour maps represent interpolated densities of Canada Geese. Actual densities are not uniform throughout the surveyed area but represent variable densities within the specified density class intervals.

3.3 Canada Goose population changes

Abundance estimates for four populations of Canada Geese nesting in prairie Canada are provided in Table 1 and Figure 7. Winter counts of each population are also provided for comparison (Figs. 8, 9, and 10).

The numbers of Canada Geese observed during CWBPS aerial surveys in southern prairie Canada were low and relatively stable until the late 1970s, when a gradual increase began to occur. The number of geese increased rapidly in the 1980s, and this trend continued into the 1990s. In 1970, according to the CWBPS, there were approximately 62 000 Canada Geese of the RMP, HLP, SWPP, and GPP in Canada. By 1985, there were about 158 000, and by 1999, over 628 000, an increase of 907% from 1970.

Canada Goose estimates from the CWBPS provide an assessment of the relative abundance and population trends of the various goose populations that breed in the Canadian Prairie provinces.

3.3.1 Rocky Mountain Population

The estimated spring population of RMP Canada Geese increased by 508%, from nearly 21 000 birds in 1970 to over 125 000 in 1999 (Table 1, Figs. 7 and 8). Although there was considerable annual variability, most of this increase occurred after 1985, when the population grew from about 48 000 in 1986 to over 125 000 in 1999. The winter inventory showed a similar trend, increasing from less than 26 000 in 1970 to over 114 000 in 1999.

3.3.2 Hi-Line Population

HLP Canada Geese increased by 1089%, growing from about 17 800 in 1970 to over 200 000 birds in 1999 (Table 1, Fig. 9). Rapid increases in the spring population were apparent in the mid 1980s. The winter inventory reflected a similar trend, with the HLP increasing rapidly in the late 1980s and the early 1990s. There were about 41 000 wintering HLP geese in 1970 and about 120 000 in 1998.

3.3.3 Southern Western Prairie Population

The spring population of SWPP Canada Geese increased by 1027% during the 1970–99 period, from about 22 000 to over 247 000 (Table 1, Fig. 10). Most of this increase began after 1980, when the population grew from about 36 000 to over 247 000 geese by 1999. Winter inventories of the SWPP (combined with GPP) reflected a similar trend, with an increase from 175 000 in 1981 to about 467 000 in 1998.

3.3.4 Great Plains Population

The estimated May population of GPP Canada Geese in Saskatchewan and Manitoba increased by 2117% from 1970 to 1999 (Table 1, Fig. 10), from about 2000 to over 43 000 geese. Most of this change occurred during the mid 1980s, when the population increased from 11 000 to over 43 000 in 1999. Winter counts of the GPP and WPP combined populations increased from 175 000 in 1981 to 467 000 in 1998, reflecting a similar trend.

4. Discussion

4.1 Population changes

The CWBPS appears to be a reasonable indicator of population trends of Canada Geese in the southern Prairie provinces and confirms that Canada Geese nesting in this region have increased significantly over the past 30 years. The CWBPS provided trend data similar to at least one detailed area inventory, the Cruise Survey. When extrapolated, these data provide realistic indices of each population and demonstrate a strong relationship to winter inventory trends. Improvements in the development of visibility bias corrections for different social groups (singles, pairs, and groups) are required.

Canada Geese have responded well to changing habitat conditions and have not been adversely affected by drought and predation, which have had a negative influence on duck populations in recent years. Canada Geese, by virtue of their size, nesting strategies, and adaptability, are better equipped to deal with these conditions than most prairie ducks. All four populations discussed in this paper have increased significantly in recent years, and these population changes have been facilitated by government and private restoration efforts throughout their ranges. Abundant Canada Geese are now able to provide increased recreational opportunity for all resource users.

4.2 Conflicts in rural and urban areas

As populations increase, conflicts with human activities occur in the form of agricultural damage and public nuisance complaints. The agricultural community has reacted to changes in Canada Goose abundance and distribution in recent years. Historically, landowners welcomed the presence of small numbers of resident Canada Geese, as they were seldom an important factor in crop depredation. However, as the number of geese increased, so has the depredation of cereal grains and forage crops (Horn 1949; Bossenmaier and Marshall 1958; Hunt and Bell 1973; Sugden 1976; Clark and Jarvis 1978; Hunt 1984). These concerns have influenced the restoration and transplant programs in many jurisdictions, where Canada Goose releases are no longer welcome.

There is no good estimate of the amount of crop damage caused by Canada Geese on the Canadian prairies in spring. Much of the damage is relatively localized, caused by

Table 1
Spring[a] and winter[b] population estimates of Rocky Mountain, Hi-Line, southern Western Prairie, and Great Plains populations, and combined Western Prairie and Great Plains populations of Canada Geese

	Rocky Mountain		Hi-Line		SWP	Great Plains	WPP + GPP[c]	Total	
Year	Spring	Winter	Spring	Winter	Spring	Spring	Winter	Spring	Winter
1970	20 669	25 760	17 831	40 500	21 962	1 940		62 402	66 260
1971	37 614	25 301	48 870	31 400	34 285	375		121 144	56 701
1972	19 951	36 646	28 396	35 600	15 917	0		64 228	72 246
1973	25 266	37 146	19 086	24 500	24 099	0		68 451	61 646
1974	26 708	42 815	16 731	41 200	19 168	375		62 982	84 015
1975	24 510	46 730	12 438	55 600	25 208	1 427		63 583	102 330
1976	11 771	51 568	21 121	67 600	26 071	375		59 338	119 168
1977	11 784	54 296	21 221	65 100	25 708	1 799		60 512	119 369
1978	21 742	58 985	17 798	33 800	33 069	1 501		74 110	92 785
1979	29 284	62 159	22 134	67 300	34 591	2 255		88 264	129 459
1980	15 337	77 262	21 769	94 400	35 681	4 888		77 675	171 662
1981	35 698	93 817	29 729	81 900	46 684	2 252	175 000	114 363	350 717
1982	29 239	64 292	35 549	75 900	47 688	3 759	242 000	116 235	382 192
1983	24 104	68 184	43 761	39 500	63 230	6 008	150 000	137 103	257 684
1984	22 480	55 548	63 076	76 400	56 200	7 944	230 000	149 700	361 948
1985	24 365	90 339	50 886	69 800	60 848	22 252	115 000	158 351	275 139
1986	47 589	68 279	68 883	98 100	80 063	11 654	324 000	208 189	490 379
1987	34 293	71 491	67 133	66 800	76 568	13 521	272 100	191 515	410 391
1988	64 447	71 417	73 453	100 100	97 133	13 467	330 300	248 500	501 817
1989	55 423	73 857	60 963	105 900	133 571	15 255	271 000	265 212	450 757
1990	41 554	102 434	111 477	116 600	145 509	20 777	390 000	319 317	609 034
1991	37 470	86 682	99 466	140 500	131 966	11 632	341 900	280 534	569 082
1992	55 409	115 055	98 080	118 459	104 886	20 961	318 029	279 336	551 543
1993	52 953	74 657	89 085	164 338	126 952	19 450	272 487	288 440	511 482
1994	89 245	77 280	111 254	174 394	141 262	20 679	352 495	362 440	604 169
1995	89 325	91 832	142 174	167 524	159 105	24 145	403 318	414 749	662 674
1996	90 631	116 996	129 124	148 527	128 359	22 083	453 358	370 197	718 881
1997	60 279	98 502	151 047	190 985	168 353	71 872	482 290	451 551	771 777
1998	121 142	105 424	184 994	119 985	259 925	37 049	467 162	603 110	692 571
1999	125 732	114 416	212 102		247 510	43 011		628 355	

[a] From the Cooperative Waterfowl Breeding Population Surveys in southern prairie Canada.
[b] From mid-December and mid-winter (early January) waterfowl surveys in the United States.
[c] SWPP geese are part of the combined WPP and GPP count.

Figure 7
Prairie Canada population indices of Rocky Mountain (RMP), Hi-Line (HLP), southern Western Prairie (SWPP), and Great Plains (GPP) Canada Geese, derived from the Cooperative Waterfowl Breeding Population Survey

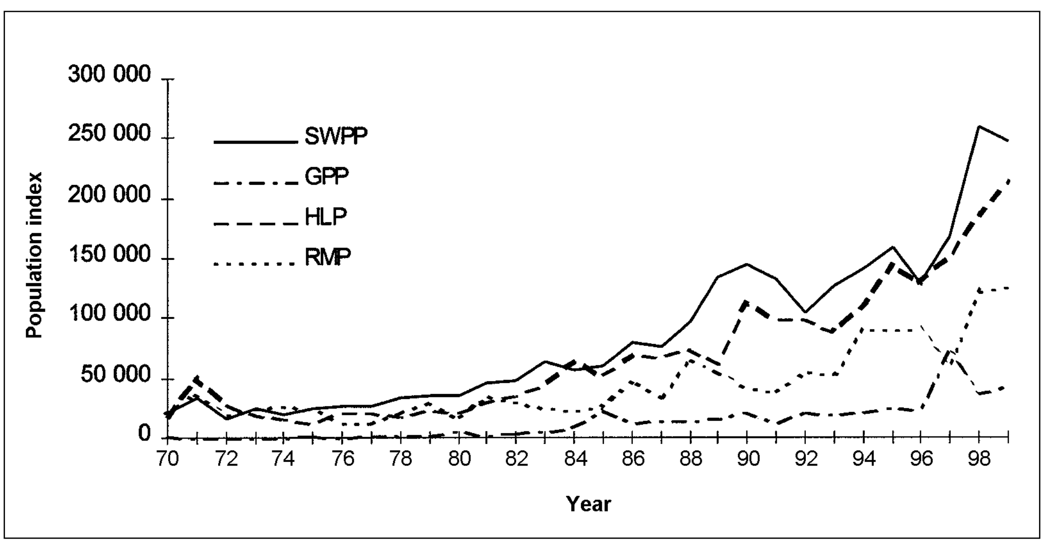


Figure 8
Population indices of Rocky Mountain Canada Geese on the Canadian prairies, derived from the Cooperative Waterfowl Breeding Population Survey and winter inventories

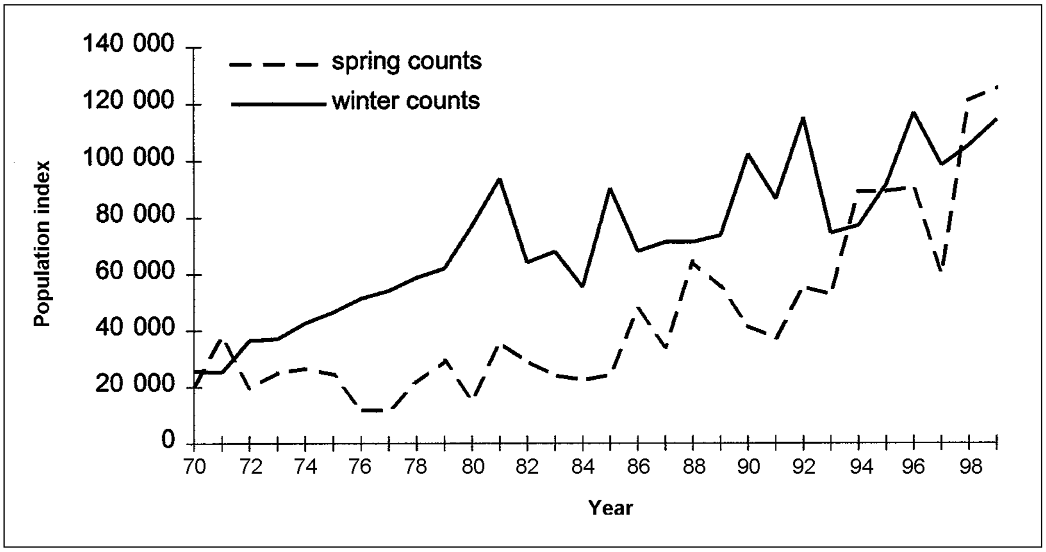
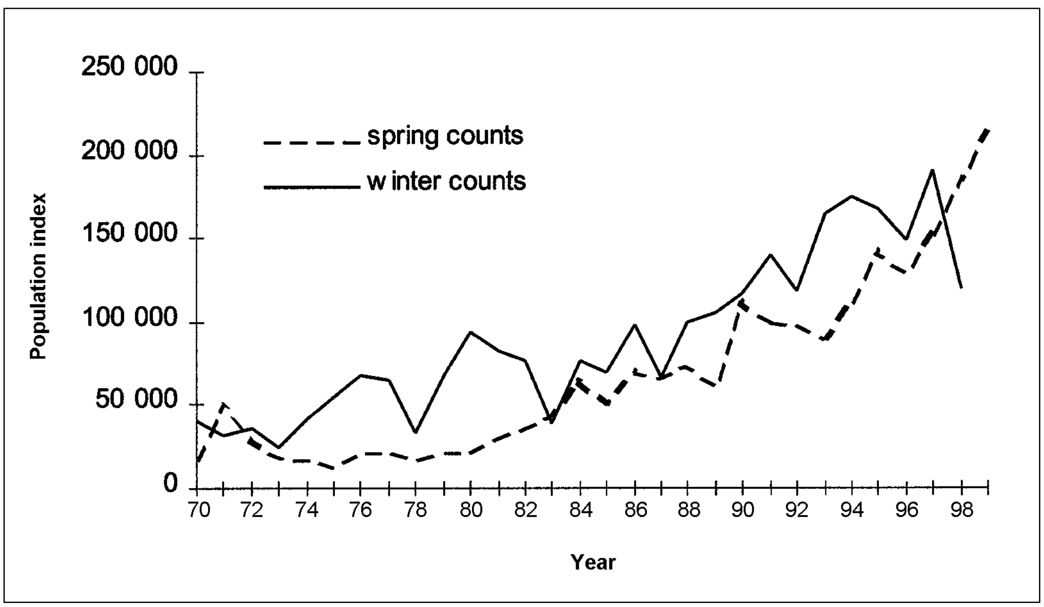


Figure 9
Population indices for Hi-Line Canada Geese on the Canadian prairies, derived from the Cooperative Waterfowl Breeding Population Survey and winter inventories



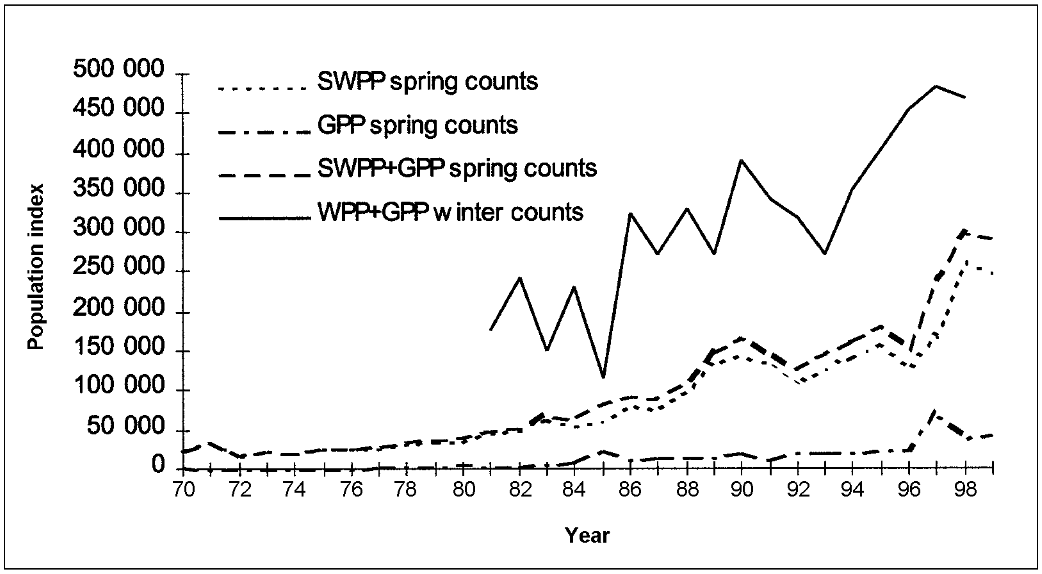
breeding geese grazing on annual seeded crops (M. Gollop 1991). Crop insurance records provide little information on the extent of damage, as claims are often paid out on only harvested crops, and it is difficult to determine the extent of damage prior to the fall season (M. Gollop, pers. commun). Although damage may be significant for individual farmers, it is generally minor compared with losses suffered during the fall migration attributed to ducks, cranes, and arctic-nesting geese.

Canada Geese are causing problems in many urban centres throughout North America as well (Dill and Lee 1970; Hawkins 1970; Laycock 1982; Conover and Chasko 1985; Smith, this publication; Dennis et al., this publication). On the Canadian prairies, such concerns have existed for nearly 30 years within large cities such as Regina and Winnipeg (Dill and Lee 1970). Today, similar situations exist in many smaller communities as well.

In Alberta, urban Canada Geese are causing major concerns in Calgary, Medicine Hat, and Lethbridge (K. Lungle, pers. commun.). The most serious conflicts are in Calgary, where up to 2000 Canada Geese graze on local golf courses and occupy the small storm-water lakes created in new housing developments. Remedial measures have included fencing of golf courses and limiting production of geese by addling their eggs.

There are similar problems in Winnipeg, Manitoba, where large Canada Geese damage golf courses and parks and graze adjacent to the airport runways (M. Gillespie, pers. commun.). They use the river system and retention ponds

Figure 10
Population indices for southern Western Prairie and Great Plains Canada Geese on the Canadian prairies, derived from the Cooperative Waterfowl Breeding Population Survey and winter inventories.



within the city for nesting. Winnipeg is currently developing a management plan to address this issue.

Canada Geese have caused considerable problems in Regina, Saskatchewan, in recent years. Over 200 pairs of geese nest within the city limits, where they damage lawns, parks, and golf courses and create a potential hazard at the Regina City Airport (Mulhern et al. 1988). The resident geese also attract nearly 20 000 fall migrant geese, which may be found in and around the city. Compensation payments for damage and additional operating costs for parks and golf courses have approached $100 000 in some years (Mulhern et al. 1988). Population control has been limited to the annual capture and relocation of goslings and adults.

The situation is similar in many other cities in Canada and throughout the U.S. In the U.S., special state permits, adjustments to existing hunting seasons, and the creation of special resident Canada Goose seasons have had limited success. Large numbers of geese remain in urban areas throughout the hunting season and are protected from harvest. Additional special control measures beyond hunting may be required. State resource agencies may be provided with additional flexibility in proceeding with lethal control measures in problem situations.

4.3 Management implications

Although the CWBPS provides reasonable trend data for several groups of large Canada Geese nesting on the Canadian prairies, a number of adjustments to this survey will provide more precise estimates of abundance and provide managers with an improved ability to monitor these populations on the breeding grounds. The development of adequate visibility correction factors, a consistent interpretation of the social groupings of geese observed, and increased sampling intensity within the ranges of specific populations will provide more useful data and facilitate the development of complementary surveys designed to obtain more detailed information on abundance. This is important as it relates to specific breeding populations rather than winter counts, which often enumerate mixed aggregations of geese from more than one population.

Abundant large Canada Geese, in part a result of successful restoration efforts in the U.S., have resulted in more liberal hunting regulations in some jurisdictions. These regulations, directed at resident large Canada Geese, will affect prairie Canada Goose populations that winter in the same areas as restoration geese. The effects of these regulations on the various populations of Canada Geese must be assessed. Improved estimates of abundance on the breeding grounds will provide that opportunity.

It is preferable to manage large Canada Goose populations from a breeding ground perspective. Although opinions vary on the distribution and abundance of the different stocks and the descriptions of the various populations, scientists agree that there are discrete groups among the large Canada Geese that nest on the Canadian prairies. These groups use specific migration and wintering areas, even though they may mix with other groups during nonbreeding seasons. The WPP, for example, appears to comprise as many as six different breeding "groups," each one affiliated with a different wintering area (Nieman and Isbister 1974). Although they mix with birds from other breeding areas, this should not preclude their individual management when practical. The preservation of these components of a much larger population must remain a priority, particularly to users at more northerly latitudes.

What does the future hold for increasing Canada Goose populations? Can we expect that at some time in the not too distant future Canada Geese will become a source of concern similar to that which now exists for Lesser Snow Geese: crop depredation, habitat destruction, and disease potential — in addition to a now nearly intolerable urban conflict issue in some areas? Canada Goose populations must be carefully monitored to ensure that they remain at manageable levels. If they continue to increase at current rates, an effort should be made to determine the magnitude of population change and to identify the contributing factors. Current definitions of the ranges of Canada Goose populations in prairie Canada are based on older banding data. Additional banding at locations throughout southern prairie Canada is required to properly delineate population affiliations.

5. Acknowledgements

It was important to get an accurate delineation of the breeding ranges of the four Canada Goose populations prior to conducting the analysis. Ken Lungle (Alberta), John Mulhern (Saskatchewan), and Murray Gillespie (Manitoba) were of great assistance in this regard. Jim Dubovsky (United States Fish and Wildlife Service) provided data and assistance in estimating populations.

6. Literature cited

Bellrose, F.C. 1976. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, Pennsylvania. 543 pp.

Bossenmaier, E.F. and W.H. Marshall. 1958. Field feeding by waterfowl in southwestern Manitoba. Wildl. Monogr. 1. 32 pp.

Central Flyway Council. 1988. Management plan for Tall Geese of the western prairie. Unpublished report. Denver, Colorado. 34 pp.

Central Flyway Council. 1996. Management guidelines for Hi-Line Canada Geese. Unpublished report. Denver, Colorado. 33 pp.

Clark, S.L. and R.L. Jarvis. 1978. Effects of winter grazing by geese on yield of rye grass seed. Wildl. Soc. Bull. 6:84–87.

Conover, M. and G. Chasko. 1985. Nuisance Canada Goose problems in the eastern United States. Wildl. Soc. Bull. 13(3):228–233.

Dill, H.H. and F.B. Lee (eds.). 1970. Home grown honkers. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 154 pp.

Gollop, M.A. 1991. Impacts of grazing on annual seeded crops by a breeding population of Canada Geese at Saskatoon. Unpublished report. Saskatchewan Parks and Renewable Resources. 55 pp.

Hanson, H.C. and H.K. Nelson. 1964. Honkers large and small. Pages 109–124 *in* Linduska, J.P. (ed.), Waterfowl tomorrow. U.S. Government Printing Office, Washington, D.C. 770 pp.

Hawkins, A.S. 1970. Honkers move to the city. Pages 120–130 *in* Dill, H.H. and F.B. Lee (eds.), Home grown honkers. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C.

Horn, E.E. 1949. Waterfowl damage to agricultural crops and its control. Trans. North Am. Wildl. Conf. 14:577–585.

Hunt, R.A. 1984. Crop depredations by Canada Geese in east-central Wisconsin. Pages 245–254 *in* Proceedings of the Eastern Wildlife Damage Control Conference, Cornell University, Ithaca, New York, Vol. 1.

Hunt, R.A. and J.G. Bell. 1973. Crop depredation by waterfowl in Wisconsin. Bird Control Semin. Proc. 6:85–101.

Laycock, G. 1982. The urban goose. Audubon 84:44–47.

Lee, F.B. 1977. A preliminary appraisal of Canada Goose populations in the eastern tier states of the Central Flyway. Unpublished admininistrative report. Northern Prairie Wildlife Research Center, U.S. Department of the Interior, Fish and Wildlife Service, Jamestown, North Dakota.

Mulhern, J., D. Nieman and R. MacFarlane. 1988. Wascana Creek Canada Geese — management recommendations. Unpublished report. Saskatchewan Waterfowl Technical Advisory Committee, Regina, Saskatchewan. 32 pp.

Nieman, D.J. and R.J. Isbister. 1974. Management of the Western Prairie Canada Goose Population. Unpublished project progress report. Canadian Wildlife Service, Saskatoon, Saskatchewan. 31 pp.

Rusch, D.H., F.D. Caswell, M.M. Gillespie and J.O. Leafloor. 1996. Research contributions to management of Canada Geese in the Mississippi Flyway. Trans. North Am. Wildl. Nat. Resour. Conf. 61:437–449.

Rutherford, W.H. 1965. Description of Canada Goose populations common to the Central Flyway. Unpublished report. Central Flyway Waterfowl Council. 18 pp.

Sharp, D.E. 1997. Central Flyway winter survey results. Unpublished report. U.S. Department of the Interior, Fish and Wildlife Service, Denver, Colorado. 29 pp.

SRMCG (Subcommittee on Rocky Mountain Canada Geese). 1992. Pacific Flyway management plan for the Rocky Mountain Population of Canada Geese. Unpublished report. Pacific Flyway Study Commission, U.S. Fish and Wildlife Service, Portland, Oregon. 38 pp.

Sugden, L.G. 1976. Waterfowl damage to Canadian grain. Can. Wildl. Serv. Occas. Pap. 24:1–24.

U.S. Department of the Interior and Environment Canada. 1987. Standard operating procedures for aerial waterfowl breeding ground population and habitat surveys in North America. Unpublished report. U.S. Department of the Interior, Fish and Wildlife Service, Branch of Surveys, Laurel, Maryland. 102 pp.

Vaught, R.W. and L.M. Kirsch, 1966. Canada Geese of the eastern prairie population, with special reference to the Swan Lake flock. Missouri Dep. Conserv. Tech. Bull. 3. 91 pp.

Williams, C.S. 1967. Honker. D. Van Nostrand Co., Princeton, New Jersey. 179 pp.

Management of Canada Geese in the Lower Fraser Valley, southwestern British Columbia

Dave W. Smith

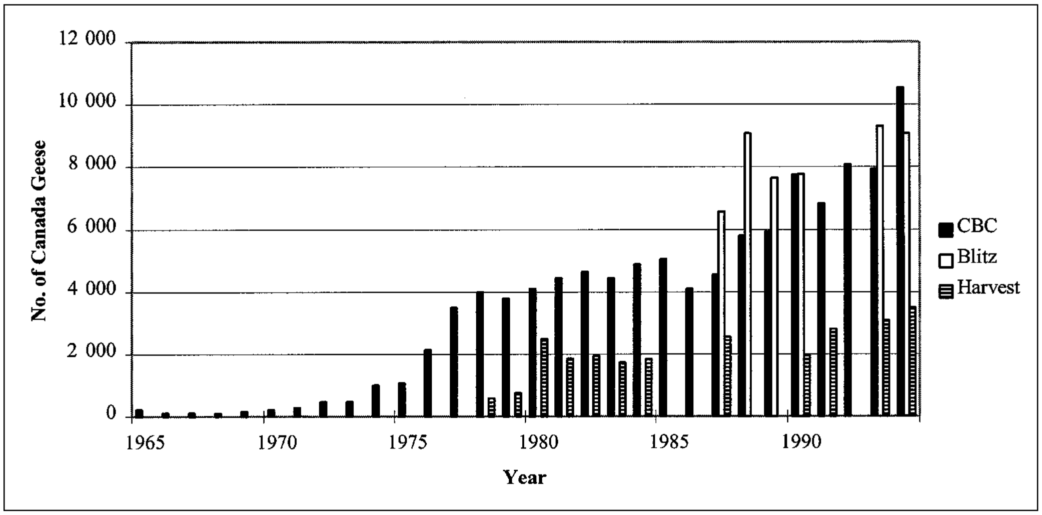
Summary

Canada Geese (*Branta canadensis*) were introduced in the Lower Fraser Valley (LFV) in the late 1960s and early 1970s to provide a breeding population for recreational use. These birds originated from Minnesota, Ontario, Saskatchewan, Alberta, and south-central British Columbia and included birds of the subspecies *B. c. moffitti* and hybrids of *B. c. interior* and *B. c. maxima*. Increased urbanization in the LFV brought local hunting closures to some areas, and harvest rates did not restrict the growth of the population, which increased to over 12 600 individuals in fall 1995. An overabundance of geese in the urban setting created problems with geese and humans competing for the same habitats. High densities of geese cause excessive noise, territorial threats, contamination of public areas, and damage to agricultural fields. Nesting and moulting flocks also present problems when they occur at inappropriate locations. Present management prescriptions include egg addling — to limit recruitment; flock relocation — to relieve pressures of too many geese in urban areas and to expose the geese to hunting pressure by moving them into huntable areas; and modification of hunting seasons and bag limits — to increase hunter harvest. In the LFV, over 8200 eggs have been addled within urban areas since 1988, over 12 000 geese have been relocated from urban settings to huntable areas, bag limits have been increased to five birds a day, and a triple-split hunting season was introduced in part of the valley. Band-return data indicated that the majority of geese harvested in the LFV originated there, and that relocated geese showed a strong fidelity to their original capture site. Present management practices are, for the most part, accepted by the public and allow monitoring of control activity through reporting requirements of the permit. Management objectives are to maintain appropriate numbers of geese for viewing and hunting, while minimizing nuisance complaints. To achieve these goals, other means may need to be applied, such as liberalization of local firearm restrictions, changes to traditional habitat management practices, and culling of flocks. Canada Goose management in the LFV requires a long-term commitment among multiple levels of governments and property managers to determine and maintain acceptable Canada Goose population levels.

Résumé

La Bernache du Canada (*Branta canadensis*) a été introduite dans la vallée du bas Fraser (VBF) vers la fin des années 1960 et au début des années 1970 afin d'y apporter une population reproductrice à des fins récréatives. Ces oiseaux provenaient du Minnesota, de l'Ontario, de la Saskatchewan, de l'Alberta et du Centre-Sud de la Colombie-Britannique et comprenaient des oiseaux de la sous-espèce *B. c. moffitti* et des hybrides de *B. c. interior* et de *B. c. maxima*. L'urbanisation accrue dans la VBF a suscité des fermetures de saisons de chasse locale dans certaines zones et les taux de prise n'ont pas limité la croissance de la population qui atteignait plus de 12 600 individus à l'automne 1995. Une surabondance de bernaches dans les régions urbaines a causé des problèmes quand il commença à y avoir compétition entre les bernaches et les humains pour les mêmes habitats. Les grandes densités de bernaches produisent trop de bruit, sont une menace aux territoires, contaminent les endroits publics et endommagent les terres agricoles. Les troupeaux nicheurs et en mue présentent aussi des problèmes quand ils se retrouvent dans des endroits non appropriés. Les prescriptions de gestion actuelles prévoient le pourrissement d'œufs — pour réduire le recrutement; le déplacement de troupeaux — pour enlever la pression causée par un trop grand nombre de bernaches dans les aires urbaines et pour exposer les bernaches aux pressions de la chasse en les transférant dans des zones de chasse; la modification des saisons de chasse et des limites de prises — pour augmenter les prises des chasseurs. Dans la VBF, on a fait pourrir plus de 8 200 œufs dans les aires urbaines depuis 1988, plus de 12 000 bernaches ont été prises des milieux urbains et déplacées dans des zones de chasse, les limites de prises ont été augmentées à cinq oiseaux par jour et une saison de chasse en trois temps a été instaurée dans une partie de la vallée. Des données obtenues grâce à la récupération d'oiseaux bagués ont indiqué que la majorité des bernaches prises dans la VBF en provenaient et que les bernaches déplacées faisaient preuve d'une grande fidélité à leur site original de capture. Les pratiques de gestion actuelles, en grande partie, sont acceptées par le grand public et permettent un suivi des activités de contrôle grâce à la disposition du permis qui exige que le détenteur rapporte ses prises. Les objectifs gestionnels sont de maintenir des nombres appropriés de bernaches pour l'observation et pour la chasse tout en minimisant les plaintes dues à la nuisance

Figure 1
Christmas Bird Counts (CBC), November blitz counts (Blitz), and estimated harvest of Canada Geese in the Lower Fraser Valley, British Columbia



des oiseaux. Pour atteindre ces objectifs, il faudra peut-être avoir recours à d'autres moyens tels que l'assouplissement des restrictions locales sur l'utilisation des armes à feu, des changements aux pratiques traditionnelles de gestion des habitats et l'élimination sélective des troupeaux. La gestion de la Bernache du Canada dans la VBF requiert un engagement à long terme de la part de multiples niveaux de gouvernements et de gestionnaires de propriétés afin de déterminer et de maintenir les niveaux acceptables de populations de Bernaches du Canada.

1. Introduction

The purposes of this report are to document the history of introductions of Canada Geese (*Branta canadensis*) in the Lower Fraser Valley (LFV), the present population status, the problems associated with an overabundance of geese, and the current management activities and their effectiveness, and to offer suggestions for future management strategies.

1.1 History

In the late 1960s and early 1970s, Canada Geese were introduced into the Lower Fraser Valley to provide a breeding population that would allow a harvestable excess (CWS/BCMOE 1988). These birds originated from Minnesota, Ontario, Saskatchewan, Alberta, and south-central British Columbia. They included the subspecies *B. c. moffitti* and hybrids of *B. c. interior* and *B. c. maxima*. These birds have since interbred, resulting in a multi-hybrid race now occupying the valley. They adapted well to the increasing urban environment, and the goose population continues to grow.

Prior to the introduction of breeding stock, Canada Geese were considered a migrant and infrequent winter visitor in the Lower Fraser Valley. In the early 1930s, Cummings (1932) noted them only as a winter migrant, and Munro and McTaggart-Cowan (1947) list no nesting records for the species in the Vancouver area. A "few" Canada Geese were reported in Stanley Park in 1945, and only two additional pairs were added there over the next seven years. The first introduction at the George C. Reifel Migratory Bird Sanctuary consisted of 24 pinioned geese (20 from Stanley Park) and occurred in June 1967. An additional 41 pinioned geese were introduced as breeding stock over the next five years. By 1970, the species was considered a frequent resident in the Vancouver area (Campbell et al. 1972), and the goose population in Stanley Park grew to 210 birds by 1975 (Dawe and Davies 1975). The resident goose population of the Lower Fraser Valley built up largely from these breeding populations at Stanley Park and the George C. Reifel Migratory Bird Sanctuary.

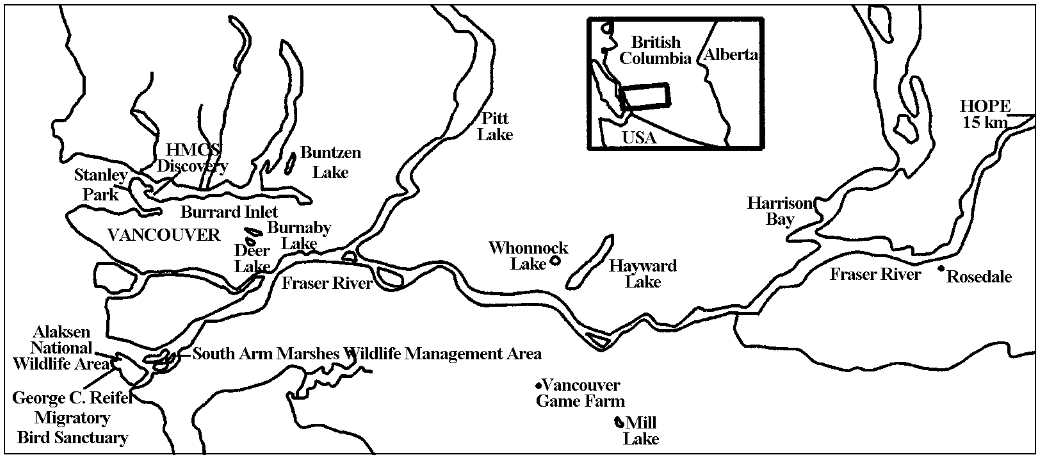
In 1973, 290 goslings were translocated from the areas listed above to many locations throughout the Lower Fraser Valley (BCMOE 1980). Eggs were removed from the first clutches of nesting geese early enough to allow the geese to lay replacement eggs. Eggs were incubator-hatched, and the goslings were released. This technique effectively doubled goose production. From 1973 to 1978, over 3300 goslings were translocated using this method (BCMOE 1980).

1.2 Population growth and harvest rates

An analysis of Christmas Bird Count and November valley-wide census ("blitz" counts) data indicated a continued increase in the Canada Goose population in the Lower Fraser Valley over the last two decades (Fig. 1). By 1978, numbers reached a level where a Canada Goose hunting season was implemented, with a bag limit of two birds per day. Estimated harvest increased to about 2000 birds per season by 1980 and showed little change from 1980 to 1990 (BCMOE 1978–94).

The rapidly increasing goose population allowed an increase in the bag limit to five birds in 1991. Harvest increased to about 3000 birds per season under the new regulation, but goose numbers continued to grow. In 1994, an experimental triple-split hunting season was implemented in part of the Fraser Valley to further increase hunter harvest. Initial results indicated an increase in the harvest of geese in the area of the triple-split season. The Canada Goose

Figure 2
The Lower Fraser Valley (LFV) in southwestern British Columbia



population of the valley in November 1995 was estimated at almost 14 000 birds (Smith and Klassen 1995).

Areas where geese can be hunted are decreasing in the LFV, and the sales of Fraser Valley Special Area Permits are decreasing (A. Gibbons, BCMOE, Victoria, unpubl. data), dropping from 4113 in 1989 to 2813 in 1994. If this trend continues, hunting may eventually disappear in the LFV, removing it as a tool for goose population reduction.

Several hundred geese are shot each year under the authority of crop depredation permits, offering a temporary solution at a very local scale. Most areas that were previously open to hunting are being closed under municipal by-laws prohibiting the discharge of firearms. This is a result of a perceived threat to human safety and pressure from the antihunting lobby in an expanding urban environment. The combination of fewer hunters and fewer areas to hunt decreases harvest rates; thus, hunting will have less effect on the goose population in future.

1.3 Problems

The increasing human population in the LVF is resulting in urbanization of agricultural lands (Moore 1990). In the urban setting, Canada Geese prefer open grassy areas, particularly those near water. These are habitats typical of urban parks, golf courses, cemeteries, and other public lands. Between 1980 and 1986, the LFV lost 2167 ha of agricultural grasslands to urbanization (Moore 1990). Habitat loss continues, forcing the shrinking habitat remaining to accommodate increasing numbers of Canada Geese. Problems arise when geese and people compete for the same habitats. In urban settings of the LFV, most complaints are from Stanley Park, Burnaby Lake, and Deer Lake. These areas have the highest densities of geese within the city. Buntzen, Hayward, Whonnock, and Mill lakes are located in more remote areas, but still have problem Canada Goose populations. Agricultural conflicts arise when large flocks of geese move to feed on farmland in the cultivated areas of the LFV.

Canada Geese cause a number of problems. The general public is concerned for the welfare of geese, yet local residents complain about noise, territorial threats, and the mess nesting and feeding activities create. High densities of geese foul grassy public areas, contribute to crop damage and soil compaction on agricultural lands, transmit diseases and parasites to humans (swimmer's itch), and increase coliform contamination of water at recreational swimming beaches, causing their closure for fear that they may be unsafe for human use (Breault and McKelvey 1991). When members of the public choose to feed geese on public property, goose numbers further concentrate, and these problems are exacerbated (Smith 1995).

The LFV population of Canada Geese now meets or exceeds the current demands for both consumptive and nonconsumptive uses. In order to control the increasing goose population, a number of management techniques are available. Smith (1995) described a variety of these techniques in detail, and Breault and McKelvey (1991) examined public acceptance on the application of these techniques.

2. Study area

The LFV is located in the southwestern corner of mainland British Columbia. The Fraser Lowland includes the LFV and the northwestern part of Washington State. It is roughly triangular in shape, with its apex near Hope in the east, where the Fraser River exits from the Coast Mountain Range, and its base at the Strait of Georgia to the west. The base of the triangle extends from Bellingham Bay northward to Burrard Inlet. The Canadian portion of the lowland (Fig. 2) measures 3092 km^2 and makes up about two-thirds of the total lowland area (Ward et al. 1992). The Fraser River flows through this floodplain to form the largest estuary on the Pacific coast of Canada. The extensive wetlands and mild climate of the lowland and delta areas are ideal habitat for Canada Geese and attract the highest densities of waterbirds, shorebirds, and raptors in Canada in winter (Butler and Campbell 1987).

3. Management practices

Population numbers can be influenced in only two ways — by affecting recruitment or mortality. The primary techniques for managing Canada Geese in the LFV are egg addling and relocating moulting flocks from problem areas to areas where the birds are more vulnerable to hunting pressure. Egg addling reduces recruitment into the present population but will not result in any short-term decrease in local populations due to the longevity of adults. Relocating moulting flocks to areas where they can later be hunted, in conjunction with increasing bag limits and modifying hunting seasons, is an attempt to increase mortality of adult birds. Traditionally, hunting is regulated to control hunter-caused mortality of wildfowl populations; however, in the LFV, hunting opportunities no longer exist in many areas due to expanding local restrictions on the discharge of firearms in a growing urban environment. Consequently, sanctuary conditions exist in many of these areas, allowing the goose population to avoid hunters.

3.1 Egg addling

In areas where nesting Canada Geese pose problems, recruitment of young birds can be limited by addling their eggs. This involves intensive searching for nests and, once these are found, shaking the eggs until the internal membranes rupture, preventing further development of the egg. The addled eggs are returned to the nest to prevent the goose from laying a replacement clutch. Two visits are recommended within the nesting period (mid and late April for the LFV) to ensure that eggs laid after the first procedure are subsequently treated. Appropriate timing of the treatment varies with latitude and local conditions.

The addling program began at Burnaby Lake in 1988 and has continued there every spring since. Other communities and organizations have adopted this type of program under permits issued by the Canadian Wildlife Service. One of the conditions of the permit requires the permittee to submit data on the number of nests and eggs treated. These data are used to track progress toward the objective and to measure effectiveness.

3.2 Flock relocation

Canada Geese moult their flight feathers in early summer and congregate in areas perceived by them to be relatively safe from predators. Geese are flightless for up to six weeks in mid to late June, and are reluctant or unable to leave the area they have chosen for moulting. These groups of flightless geese are rounded up, banded, and transported in poultry trucks to other areas of the valley, where they are exposed to higher levels of natural predation and can eventually be hunted once the season opens later in the year. To reduce further genetic mixing with other Canada Goose populations and races, recently geese have not been moved to areas outside of the LFV.

The first Canada Goose round-up took place in 1978, when 120 birds were removed from Stanley Park and relocated farther up the Fraser Valley. The purpose of these early relocations was not only to relieve the pressures that too many geese imposed on the park, but also to increase the numbers of Canada Geese elsewhere in the valley to establish recreational resources for hunters and wildlife-viewing opportunities for nonhunters. Later relocations were intended to alleviate problems associated with high concentrations of geese in the urban setting by reducing local goose numbers. Detailed data collection began in 1987 for geese gathered, banded, and relocated from areas within the Greater Vancouver Regional District.

3.3 Banding

Banding data have been collected at annual round-up/relocations since 1987. The origin of banding for recaptured birds was determined to demonstrate fidelity of geese to capture sites. Derivation of harvest for geese banded and released within the LFV and the origin of banding of harvested geese recovered within the LFV were also determined.

4. Effectiveness of management practices

4.1 Egg addling

The egg-addling program treated over 8200 Canada Goose eggs up to 1995 in the LFV (Table 1). A simple model, designed to show the potential productivity from addled eggs, indicated that, using very conservative population parameters, the numbers of geese in the valley could be double or triple the present levels if no addling program had existed (McKelvey, unpubl.). The majority of eggs and nests treated were at Burnaby Lake, which holds the largest numbers of nesting geese within the urban LFV.

4.2 Flock relocation

Moulting flocks of Canada Geese collected from Stanley Park and Deer Lake since 1987 and from Burnaby Lake since 1988 were banded and relocated elsewhere in the LFV. BC-Hydro has performed similar round-ups at Hayward and Buntzen lakes (Table 2).

Removing and relocating geese from urban areas can reduce the numbers of birds in problematic areas and can keep their numbers lowered for some time thereafter. Daily counts showed a large drop in the number of geese seen around Stanley Park after the 1995 round-up and relocation (Fig. 3). The number of geese was reduced to about half that present before the round-up and remained at that level for nearly two months. Counts were discontinued after 23 August 1995.

4.3 Recaptures

A large proportion of birds captured in relocation operations were previously banded (Table 2). The majority of these birds were banded in previous relocation operations and show strong fidelity to their original capture site (Table 3). For all years combined, Burnaby Lake and Stanley Park recaptured geese made up 93% and 98%, respectively, of the total banded recaptures. The composition of recaptured birds at Deer Lake was more mixed, with 33% coming from Stanley Park, 20% from Burnaby Lake, and 47% from the original capture site of Deer Lake. This mixing was expected, with Burnaby and Deer lakes being in such close proximity.

Geese from round-up/relocation operations were released at various locations within the LFV but removed from the urban setting. These locations included Pitt Wildlife Management Area (WMA), Addington Marsh, Pitt River, Harrison Bay, Rosedale, the South Arm Marshes WMA, and the Alaksen National Wildlife Area. Historically, these areas have shown high rates of band returns for geese, and geese in

Table 1
Numbers of eggs and nests addled in the Lower Mainland, 1988–95

Area	1988	1989	1990	1991	1992	1993	1994	1995	Total
Burnaby Lake									
Eggs	734	529	589	844	692	615	655	405	5063
Nests	140	96	99	139	123	107	115	69	888
Avg. clutch size	5.24	5.51	5.95	6.07	5.63	5.70	5.70	5.87	5.70
Vancouver Game Farm									
Eggs				866	316	127	174	0	1483
Nests				174	57	27	34	0	292
Avg. clutch size				4.98	5.54	4.70	5.12	0	5.08
HMCS Discovery									
Eggs	189	204	131	95	71	56	80	63	889
Nests	40	42	28	29	30	21	19	20	229
Avg. clutch size	4.73	4.86	4.68	3.28	2.37	2.67	4.21	3.15	3.88
Whonnock Lake									
Eggs					26	18	30	3	77
Nests					5	3	5	1	14
Avg. clutch size					5.20	6.00	6.00	3.00	5.50
Mill Lake									
Eggs					66	57	50	35	208
Nests					12	11	10	9	42
Avg. clutch size					5.50	5.18	5.00	3.89	4.95
Other areas									
Eggs						64	87	332	426
Nests						13	20	76	99
Avg. clutch size						4.92	4.35	4.37	4.20
Total									
Eggs	923	733	720	1805	1171	937	1076	838	8203
Nests	180	138	127	342	227	182	203	175	1574
Avg. clutch size	5.13	5.31	5.67	5.28	5.15	5.15	5.30	4.79	5.21

these areas when the season begins should face relatively high hunting pressure.

4.4 Recoveries of bands from hunter-killed birds

The majority of Canada Goose band returns from the LFV were from birds moved from urban areas within the LFV. From the 867 reported band returns of geese banded within the LFV, 756 (87.2%) were shot within the LFV. Of the 782 banded Canada Geese reported recovered from within the LFV, 759 (97.1%) were from geese banded within the LFV. The remaining 2.9% of recoveries were from geese banded farther north within British Columbia.

5. Discussion

Egg addling is one of the most publicly acceptable management tools being used to limit recruitment for Canada Geese (Breault and McKelvey 1991). Over 28 municipalities, cities, golf courses, parks and recreation departments, and other property managers in the LFV have adopted this technique in an attempt to control goose numbers within their boundaries. Reduction of recruitment in a closed population will eventually allow a decrease in total numbers as adults are removed by mortality or emigration. Band-return information indicates that urban geese can live for more than a decade. This longevity prevents an immediate reduction in the local goose population in response to egg addling alone. If sufficient effort is employed in an addling program, the population should stabilize and then begin to decrease after several years. Egg addling is a long-term program that must receive diligent annual effort to be effective.

Flock relocation, although shown to reduce the local numbers of Canada Geese for a short time, is not recommended as a practical long-term management tool. The costs are high, and relief is only temporary. Relocated birds may also cause problems at the release sites similar to those caused at their capture sites. This procedure was discontinued in Burnaby Lake in 1993 due to difficult logistical problems caused by shallow water and overgrown submergent vegetation, which affected boat operation and resulted in fewer birds being captured than in previous operations. Egg addling has continued there, and late spring counts indicated that the local population has not increased. Round-up/relocations still continue in some areas, but other more practical goose population management techniques will be considered for the future. These include habitat modification to make areas less attractive to geese, hazing programs to frighten geese away from target areas, local by-laws and signs prohibiting public feeding of geese, and culling geese.

The majority of geese recaptured in translocation operations had been previously banded in prior round-ups. The geese show a strong fidelity to their original capture site, and some birds were recaptured as many as eight times in successive operations. Most of the geese captured in the urban environment are LFV residents that return to the relative safety of city parks year after year. Band-return data indicated that only about 3% of birds shot by hunters in the LFV originated outside the LFV. These birds were banded in

Table 2
Numbers of Canada Geese rounded up from various problem areas on the Lower Mainland. HY refers to hatch-year birds, AHY refers to after hatching-year birds, and nr+ indicates that no round-up was conducted.

Area	1987	1988	1989	1990	1991	1992	1993	1994	1995	Total
Stanley Park										
HY	70	73	38	53	82	83	77	73	29	578
AHY	938	643	463	736	622	484	429	397	365	5 077
Previously banded	0	299	356	388	385	285	349	329	306	2 697
Total	1008	1015	857	1177	1089	852	855	799	700	8 352
% previously banded	0	29.5	41.5	33.0	35.4	33.5	40.8	41.2	43.7	32.3
Deer Lake										
HY	27	30	14	48	5	66	28	37	48	303
AHY	135	27	32	25	6	27	29	32	18	331
Previously banded	0	88	94	83	93	80	78	84	91	691
Total	162	145	140	156	104	173	135	153	157	1 325
% previously banded	0	60.7	67.1	53.2	89.4	46.2	57.8	54.9	58.0	52.2
Burnaby Lake										
HY	nr+	43	34	9	33	79	nr+	nr+	nr+	198
AHY		437	168	77	86	40				808
Previously banded		29	215	118	191	36				589
Total		509	417	204	310	155				1 595
% previously banded		5.7	51.6	57.8	61.6	23.2				36.9
Buntzen Lake										
HY	nr+	nr+	22	15	21	22	25	9	9	123
AHY			71	20	20	17	12	10	35	185
Previously banded			6	32	25	49	55	17	57	241
Total			99	67	66	88	92	36	101	549
% previously banded			6.1	47.8	37.9	55.7	59.8	47.2	56.4	43.9
Hayward Lake										
HY	nr+	nr+	20	0	0	22	4	22	22	71
AHY			19	7	5	17	12	6	2	101
Previously banded			1	10	2	49	6	4	9	38
Total			40	17	7	88	22	32	32	210
% previously banded			2.5	58.8	28.6	55.7	27.3	12.5	28.1	18.1
Fraser River										
HY	nr+	nr+	nr+	nr+	nr+	0	nr+	nr+	nr+	0
AHY						53				53
Previously banded						3				3
Total						56				56
% previously banded						5.4				5.4
Total										
HY	97	146	128	125	141	253	134	141	108	1 273
AHY	1073	1107	753	865	739	671	482	445	420	6 555
Previously banded	0	416	672	631	696	459	488	434	463	4 259
Total	1170	1669	1553	1621	1576	1383	1104	1020	991	12 087
% previously banded	0	24.9	43.3	38.9	44.2	33.2	44.2	42.6	46.7	35.2

the Pemberton and Cariboo regions of the province. Over 1700 geese were banded in those regions in the mid to late 1980s, with few since. Many hunter-shot geese in the LFV may have originated outside the valley; as recent banding efforts in other areas are low, their numbers cannot be estimated reliably. More banding in the Cariboo and other regions may be useful in determining the true proportion of resident birds present in the LFV during the hunting season. Relocated urban birds may not be targeted by hunting in the release areas as much as expected.

6. Recommendations

It is recommended that egg addling be promoted and expanded to further limit recruitment of local Canada Geese in areas where there is an overabundance of nesting birds. This method is currently the most acceptable to the general public, can be done by property management agencies with a minimum of training, and can be monitored through permit-issuance and data-reporting procedures.

Moulting geese pose problems in certain areas where harassment techniques cannot be applied for logistical or other reasons. Some round-up, banding, and relocation will continue in these traditional areas. Prevention of the formation of flocks of moulting geese will be encouraged in other areas where scare and habitat-modification techniques can be utilized.

Agricultural land is important habitat for wildlife; however, farmers can protect their investments from damage from Canada Geese under the authority of crop-depredation permits. Crop-protection programs, such as “Greenfields,” are designed to provide cooperators with compensation through cost-sharing for the planting of cover crops in fall. Programs such as these should be encouraged, as they support soil conservation and enhance wildlife habitat.

Figure 3
Number of Canada Geese in 1995 in Stanley Park before and after the July relocation efforts

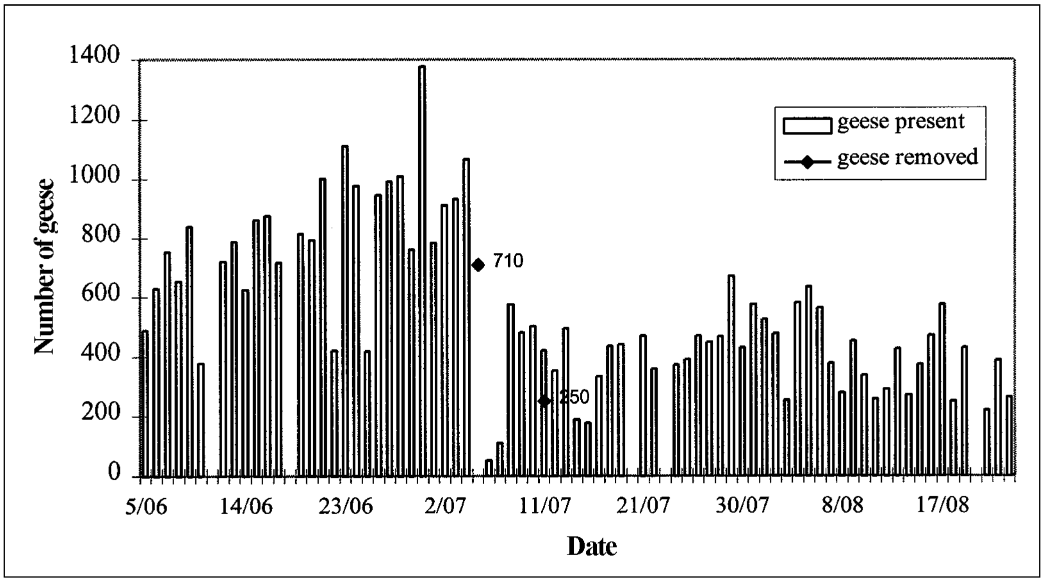


Table 3
Origins of previously banded Canada Geese recaptured during relocation operations

		Round-up/relocation year																				
		1988			1989			1990[b]			1991			1992			1993		1994		1995	
Band year	Loc. code[a]	SP	DL	BL	SP	DL	BL	SP	DL	BL	SP	DL	BL	SP	DL	BL	SP	DL	SP	DL	SP	DL
1987	SP	258	0	–	166	2	8	122	37	4	122	39	5	46	31	1	41	24	34	21	22	17
	DL	4	68	–	1	49	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	BL	4	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1988	SP		–		161	5	1	113	3	1	54	2	1	34	2	0	34	1	23	1	15	1
	DL		–		2	18	2	0	15	0	1	13	1	0	17	0	0	5	0	3	0	2
	BL		–		1	9	163	4	8	68	3	9	99	0	10	13	2	12	1	13	1	12
1989	SP		–			–		117	0	0	67	0	2	27	0	0	32	0	17	0	15	0
	DL		–			–		0	8	0	0	3	1	0	2	0	0	1	0	2	0	2
	BL		–			–		2	3	38	0	2	51	0	1	8	0	1	0	5	1	8
1990	SP		–			–			–		133	0	1	43	0	0	34	2	36	0	36	0
	DL		–			–			–		6	9	2	0	9	0	1	4	0	4	0	3
	BL		–			–			–		3	3	20	0	4	7	0	4	0	5	0	6
1991	SP		–			–			–			–		84	1	0	68	1	47	2	30	2
	DL		–			–			–			–		1	2	0	0	1	0	0	0	1
	BL		–			–			–			–		0	1	3	1	1	0	1	0	2
1992	SP		–			–			–			–			–		108	0	51	0	29	0
	DL		–			–			–			–			–		1	11	0	11	0	8
	BL		–			–			–			–			–		1	0	0	0	0	1
1993	SP		–			–			–			–			–			–	109	5	64	3
	DL		–			–			–			–			–			–	0	3	0	1
1994	SP		–			–			–			–			–			–		–	75	1
	DL		–			–			–			–			–			–		–	7	13

[a] Location codes: SP = Stanley Park, DL = Deer Lake, BL = Burnaby Lake.
[b] Example: for the 1990 Stanley Park round-up, of the 388 recaptured previously banded birds (Table 2), 122 were originally captured at Stanley Park in the 1987 round-up.

A detailed analysis of band-return information is recommended to give more insight into population composition, derivation of harvest, and origin of banding. All data collected to date should be used to construct a model for calculation of the number of geese that could be removed to bring the valley population to a predetermined level. Scientific reason tempered with public input must be used to determine what the acceptable level would be. Further manipulation of the hunting seasons and regulations is anticipated in an attempt to increase Canada Goose harvest within the LFV.

Management objectives for the LFV are to maintain appropriate numbers of geese for viewing and hunting while minimizing nuisance complaints. Strategies at present are to reduce recruitment, increase mortality, and increase emigration and distribution. These goals are being addressed through egg-addling programs, relocation operations, modifications to hunting seasons and regulations, issuance of crop-depredation permits, and education of property managers with information on the application of acceptable techniques to control Canada Geese and modify their habitats. To achieve these goals, other means may need to be employed, such as liberalization of local firearm restrictions, flock culling, and modification of habitats of urban parks to less traditional landscapes.

Monitoring of the Canada Goose population within the LFV should be continued with annual counts. The trend in the population can be used to measure the effectiveness of management techniques now being applied and will influence decisions about future management practices. Canada Goose management in the LFV requires cooperation among multiple levels of government and property managers to determine and maintain acceptable goose population levels.

7. Acknowledgements

I wish to thank all those who contributed data through participation in the cooperative management of Canada Geese within the Lower Fraser Valley. These include staff of the British Columbia Institute of Technology's Fish and Wildlife Program; staff of many district, municipal, and city governments; and other volunteers too numerous to mention here. Round-up and relocation operations were staffed by members of the Canadian Wildlife Service, B.C. Ministry of Environment, Lands and Parks (BCMOELP) — Wildlife Branch, Ducks Unlimited Canada, City of Vancouver and Burnaby, and many volunteers. Unpublished data on hunting permit sales were provided by Annette Gibbons of BCMOELP — Wildlife Branch, Victoria. Daily counts of Canada Geese in Stanley Park were conducted by staff of Vancouver City under the direction of Mike MackIntosh. I thank Kathleen Moore, who produced the map of the Lower Fraser Valley. I also appreciate the critical reviews of the document by André Breault, Jack Evans, and Rick McKelvey, whose constructive suggestions were most helpful.

8. Literature cited

BCMOE (B.C. Ministry of the Environment). 1978–94. Fraser Valley Canada Goose harvest questionnaire. Unpublished reports. Victoria, British Columbia.

BCMOE (B.C. Ministry of the Environment). 1980. Species statement. Unpublished report. Canada Goose management file. Victoria, British Columbia.

Breault, A.M. and R. McKelvey. 1991. Canada Geese in the Fraser Valley: a problem analysis. Can. Wildl. Serv. Tech. Rep. Ser. No. 133, Delta, British Columbia.

Butler, R.W. and R.W. Campbell. 1987. The birds of the Fraser River delta: populations, ecology and international significance. Can. Wildl. Serv. Occas. Pap. No. 65.

Campbell, R.W., M.G. Shepard and R.H. Drent. 1972. Status of birds in the Vancouver area in 1970. Syesis 5:137–167.

Cummings, R.A. 1932. Birds of the Vancouver District, British Columbia. Murrelet 13:3–15.

CWS/BCMOE. 1988. Draft management plan for Fraser Valley Canada Geese. Environment Canada, Canadian Wildlife Service, Delta, and British Columbia Ministry of Environment, Victoria, British Columbia.

Dawe, N.K. and B.D. Davies. 1975. A nesting study of Canada Geese on the George C. Reifel Migratory Bird Sanctuary, British Columbia. Syesis 8:1–7.

Moore, K.E. 1990. Urbanization in the Lower Fraser Valley, 1980–1987. Can. Wildl. Serv. Tech. Rep. Ser. No. 120, Delta, British Columbia.

Munro, J.A. and I. McTaggart-Cowan. 1947. A review of the bird fauna of British Columbia. B.C. Prov. Mus. Spec. Publ. 2:55–57.

Smith, D.W. 1995. A handbook for the control of problem Canada Geese. Canadian Wildlife Service, Pacific and Yukon Region.

Smith, D.W. and D. Klassen. 1995. Canada Goose survey of the Fraser Lowland, November, 1995. Canadian Wildlife Service, Pacific and Yukon Region, unpublished.

Ward, P., K. Moore and R. Kistritz. 1992. Wetlands of the Fraser Lowland, 1989: an inventory. Can. Wildl. Serv. Tech. Rep. Ser. No. 146, Delta, British Columbia.

Range expansion and population growth of Giant Canada Geese in southern Ontario: benefits, drawbacks, and management techniques

Darrell G. Dennis, Norman R. North, and Harry G. Lumsden

Summary

Giant Canada Geese (*Branta canadensis maxima*) were part of the original fauna of southern Ontario. As a result of a management program begun in the late 1960s, the population of Giant Canada Geese has grown to more than 350 000 in early August 1998. The geographic range of the breeding population now includes most of southern Ontario. The introduction program, benefits and drawbacks of the growing population, as well as management techniques used in southern Ontario, an area of dense human population, are described.

Résumé

Les Bernaches du Canada géantes (*Branta canadensis maxima*) faisaient partie de la faune originelle du Sud de l'Ontario. Suite au programme de gestion amorcé vers la fin des années 1960, la population de Bernaches du Canada géantes s'est accrue à plus de 350 000 individus au début du mois d'août 1998. La distribution géographique de la population reproductrice comprend maintenant la plus grande partie du Sud de l'Ontario. Le programme d'introduction, les avantages et les inconvénients de la population croissante, de même que les techniques de gestion employées dans le Sud de l'Ontario, une zone à forte densité démographique, sont décrits.

1. Reestablishment of the Giant Canada Goose breeding population

The Giant Canada Goose (*Branta canadensis maxima*) as a breeding species was essentially extirpated from southern Ontario during the 19th century. Archeological remains as well as reports of explorers and missionaries indicate that Canada Geese were present and breeding in southern Ontario in the 17th century (Lumsden 1981).

McIlwraith (1891) discussed the bird as only a migrant in southern Ontario and did not identify it as breeding. Subsequently, Fleming (1913), writing of the Toronto area, noted the Canada Goose to be a regular migrant, formerly common, and Saunders and Dale (1933) wrote that geese pass through Middlesex County in goodly numbers spring and fall. There is no mention of breeding in these areas. Perhaps a small number of the original stock still nested in the 1920s in the Lake St. Clair area.

In the late 1920s and 1930s, a number of private citizens allowed progeny of their captive Canada Geese to fly free (Lumsden 1981). By the 1950s, these stocks probably numbered about 1000–1200 birds. Baillie and Harrington (1936) noted "The several instances of this bird nesting in southern and central Ontario almost undoubtedly concern injured or semidomesticated individuals...," referring to the new feral flocks as semidomesticated.

By the 1950s, Ontario's Department of Lands and Forests (now called the Ministry of Natural Resources) began programs to introduce Canada Geese to selected locations, usually at the initiation of staff biologists, often assisted by private citizens or local fish and game clubs. Efforts by the Department of Lands and Forests and other agencies to reintroduce Giant Canada Geese to Ontario were sporadic until 1967.

In that year, a cooperative venture was started by the Ontario Waterfowl Research Foundation, Kortright Waterfowl Park, and the Ontario Ministry of Natural Resources. Kortright Park, near Guelph, was used as the production area, and young geese as well as some adults were released by cooperators in various locations. Release techniques ranged from abrupt releases on local ponds to gentle releases that involved artificial feeding and holding wing-clipped birds in a semicaptive state for several years. A number of areas, usually townships, were closed to hunting in association with the releases in the late 1960s.

The racial stocks in the restoration projects were mixed, including *B. c. maxima*, *B. c. interior*, and possibly *B. c. canadensis*. In addition, Horace Mack at Niska game farm (later called Kortright Park) brought geese of unknown race from western Canada, and there were birds of local origin that probably came from duck hunting clubs near Lake St. Clair. These latter birds were likely the original southern Ontario stock. Reintroductions after 1978 were associated that Canada Goose control along the Toronto waterfront. Geese captured on the waterfront were often transferred to areas in central and northern Ontario (Table 1).

A number of circumstances contributed to the success of Giant Canada Geese in southern Ontario. Areas were closed to goose hunting, but these closures were confined to counties and townships where the initial releases were made. Hunting seasons were not closed in most of the agricultural

Table 1
Destinations of geese and eggs shipped from the Toronto area waterfront (Frenchman's Bay in 1987–89, Bluffers Park in 1989–92, Toronto Island in 1993–95, and Mississauga in 1997 and 1998)

	Adults		Goslings		Eggs		
Year	No.	Destination	No.	Destination	No.	Destination	Total
1978	500	Ohio	200	Aylmer MNR	0		700
1979	1 000	Ohio	100	Pembroke MNR	0		1 100
1980	1 608	Tennessee	150	Aylmer MNR	500	Nova Scotia	2 767
	276	Iowa			233	Manitoba	
1981	1 717	Iowa	160	Tiny Marsh	346	Florida	2 569
			200	Rankin WMA	146	Nova Scotia	
1982	800	Arkansas	50	Tiny Marsh	242	Nova Scotia	2 255
	767	Ohio	60	Rankin WMA	276	Fort Frances MNR	
					60	Pembroke MNR	
1983	895	Oklahoma	20	Tiny Marsh	60	Nova Scotia	1 705
	350	North Carolina			290	Fort Frances MNR	
					90	Pembroke MNR	
1984	1 318	Arkansas	30	Huronia	465	Fort Frances MNR	1 907
			54	Thunder Bay	40	Huronia	
1985	1 365	Oklahoma	324	Thunder Bay	101	Fort Frances MNR	1 790
				Atikokan			
				Pembroke			
				Sudbury			
1986	1 160	North Carolina	121	Thunder Bay	0		1 281
				Atikokan			
1987	987	Mississippi	300	Sudbury	0		1 287
				Blind River			
1988	1 115	Oklahoma	100	Sudbury	0		1 397
			75	Sioux Lookout			
			75	Thunder Bay			
			32	Oklahoma			
1989	1 073	Mississippi	85	Blind River	0		1 368
			45	Espanola			
			100	Sudbury			
			65	Nipigon			
1990	1 126	Oklahoma	73	Sudbury	0		1 199
1991	*No relocations*						
1992	315	New Brunswick	35	New Brunswick	0		350
1993	700	New Brunswick	0		0		700
1994	700	New Brunswick	0		0		700
1995	*No relocations*						
1996	700	New Brunswick	0		0		700
1997	1 800	New Brunswick	0		0		1 800
1998	500	SW Ontario	0		0		1 300
	800	NW Ontario					
Total	21 572		2454		2849		26 875

parts of the province. Rural people were remarkably sensitive to the needs of Canada Geese, and poaching during the closed season was rare. The area closures began to be reopened in the mid 1970s and were essentially discontinued by 1981. However, refuge during hunting seasons was always available on a patchwork of private lands posted against trespass. The *Trespass to Property Act* of 1980 further prohibited entry onto agricultural land, whether posted or not, without the consent of the owner. Hunting regulations were liberalized through the subsequent years, and special early and late seasons were added. The bag limits were increased to eight birds each day (with a total of 16 birds in possession) during the special seasons. In addition, the maximum number of hunting days allowed under the Migratory Birds Convention was reached (107 days), providing the most hunting opportunity possible.

2. Breeding population growth and range expansion

The Canadian Wildlife Service conducted four telephone surveys for Ministry of Natural Resources districts in southern Ontario from 1977 to 1986 to estimate the number of resident Canada Geese (Table 2). The surveys requested the District Fish and Wildlife supervisor to canvas field staff and provide an estimate of the number of resident Canada Geese (not held under avicultural permit) that were in the district on 1 August. For several districts, the best estimates were based on the knowledge of the surveyor. The project ended in 1986 when numbers in some districts, such as Cambridge and Maple, became too large to estimate with accuracy.

We estimate that in the late 1960s, several thousand local Canada Geese were present in southern Ontario. In 1988, the Canadian Wildlife Service participated in a Mississippi Flyway-wide survey of resident Canada Geese, surveying 270 randomly distributed plots in the part of

Table 2
Estimates of numbers of resident Canada Geese in Ontario Ministry of Natural Resources districts, in August 1977, 1980, 1984, and 1986

District	1977	1980	1984	1986
Aylmer	600	1 750	2 650	3 000
Bracebridge	100	25	25	25
Brockville	200	100	200	100
Cambridge	4 040	7 000	15 000	>20 000
Chatham	450	450	600	600
Cornwall	3 600	3 600	3 600	5 000
Huronia	700	1 000	1 300	3 000
Lindsay	300	300	300	1 050
Maple	3 765	5 226	10 000	15 000
Napanee	225	350	600	800
Niagara	350	350	400	430
Ottawa (Carleton Place)	150	100	200	225
Owen Sound	2 000	3 500	4 000	5 200
Simcoe	1 800	1 800	2 000	2 160
Tweed	5	1	20	20
Wingham	1 000	1 500	2 000	5 000
Total	19 285	27 052	42 895	61 610+

Figure 1
Number of indicated breeding pairs of Canada Geese on plots in southern Ontario, 1971–98

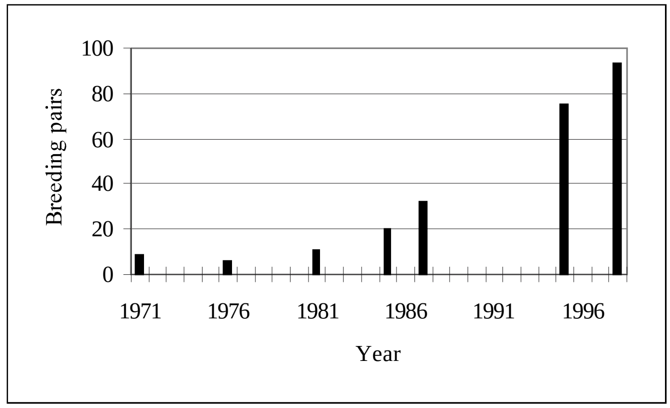
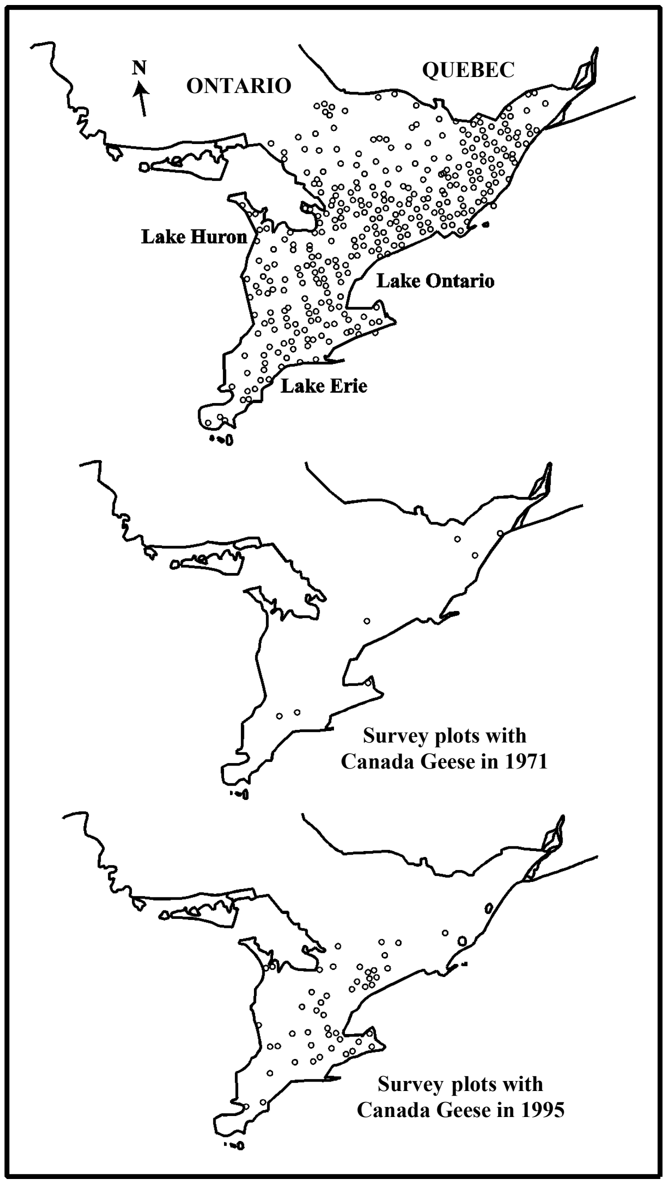


Figure 2
Range expansion of the Giant Canada Goose in southern Ontario. The top map shows the location of the survey plots. The middle map identifies the plots where Canada Geese were found as pairs in 1971. The bottom map shows where Canada Geese were found as pairs in 1995.



southern Ontario (mainly the southwest) that was determined to have breeding geese. The results indicated a breeding population of approximately 15 400 pairs. The survey was repeated in 1993, and the number of breeding pairs had increased to 27 800. This survey was discontinued because the range of breeding Canada Geese had outgrown the survey area. However, other information derived from a general survey of breeding waterfowl in southern Ontario revealed that the number of indicated breeding pairs on survey plots increased from 7 in 1971 (Dennis 1974) to 93 by 1998 (Fig. 1). These numbers indicate an increase in the size of the breeding population, in southern Ontario, from 2500 pairs in 1971 to 58 000 pairs by 1998. The extent of the range expansion between 1971 and 1995 is shown in Figure 2.

3. Winter population growth

There were traditionally some Canada Geese (*B. c. interior*) that wintered in Ontario. These birds, part of the Mississippi Flyway population, were usually from the Hudson Bay lowlands and southern James Bay area. They were generally confined to the vicinity of the Jack Miner Sanctuary near Kingsville in southwestern Ontario.

With the reestablishment of the Giant Canada Goose population in the late 1960s, an increasing number have remained to winter in the province (Table 3). In the early years, there was a substantial decline in the number of geese in Ontario prior to early January. Since 1986, there appear to be more geese in Ontario during January than in mid December. We believe that as goose numbers continued to increase, the accuracy of the December inventory decreased because recently established goose flocks were often overlooked. By January, these birds are confined to a smaller number of locations that usually remain ice-free and thus are easier to count.

Table 3
Goose inventories and estimates in Ontario, August through January, 1977–98. ND = no data.

Year	August population estimates for *B. c. maxima*	Mid-December inventory *B. c. maxima*[a]	Mid-December inventory *B. c. interior*[a]	January inventory of all geese (next calendar year)
1977	19 285	ND	ND	ND
1978	ND	6 180	11 200	5 794
1979	ND	5 690	25 850	11 247
1980	27 052	6 057	13 430	4 949
1981	ND	9 085	11 575	5 037
1982	ND	6 226	25 794	9 795
1983	ND	9 457	15 775	7 635
1984	42 895	11 760	16 281	22 692
1985	ND	13 692	16 457	21 821
1986	61 610	17 660	19 802	48 431
1987	ND	17 310	22 424	59 987
1988	ND	16 637	28 202	50 885
1989	100 000 +	12 339	16 771	30 225
1990	ND	18 884	18 804	43 401
1991	ND	8 932	14 170	42 198
1992	ND	13 178	11 377	43 022
1993	ND	10 600	9 275	44 080
1994	200 000	16 168	9 600	40 923
1995	250 000	ND	ND	36 817
1996	250 000	16 361	6 500	51 140
1997	ND	ND	ND	46 229
1998	350 000	ND	ND	—

[a] Proportions of the two subspecies are estimated by using historical information, plumage characteristics, and the percentage of neck collars observed.

4. Benefits and drawbacks of the growing population

Canada Geese are an aesthetic asset in heavily settled parts of the continent where clean farming and development have stripped the countryside of many other desirable wildlife species. Canada Geese are the only large birds to be seen in many areas. An early 1980s survey in Toronto (Fetterolf 1983) showed the extent to which the public enjoy the presence of geese in parks, despite their droppings. A large majority (83%) of those questioned felt that the number of geese should not be reduced. Fifty-four percent stated that the geese made their visit more enjoyable, and 33% felt that the geese did not affect their visit. Only 13% said that the geese made their visit less enjoyable. Comparable data 15 years later are not available, but because of the continuously increasing goose population, it is possible that the number of geese has surpassed the number desired by a larger portion of people. For example, an Environics survey conducted in the last week of March 1998 in the City of Mississauga showed that most citizens polled agreed that the effect of Canada Geese on city parks and private property is a “serious” to “somewhat serious” problem (64%). Eighty percent of those who said the problem was very serious supported a cull to resolve goose problems, and 57% of those who said the problem was somewhat serious also supported a cull (B. Carr, City of Mississauga, pers. commun.).

Canada Geese produced in Ontario make a substantial contribution to the recreational harvest in Ontario and in U.S. states in both the Atlantic and the Mississippi flyways. The distribution of hunting season recoveries of Canada Geese banded during summer as locally produced birds in Ontario south of 45°30'N latitude since 1978 are shown in Figure 3. Each point on the map represents a block of 10' latitude × 10' longitude wherein at least one Canada Goose meeting the above criteria was shot during the hunting season.

Figure 4 shows the Canada Goose harvest for the three hunting zones of Ontario for the period 1972–97 (Cooch 1974; Cooch and Newell 1977; Wendt et al. 1978, 1979; Wendt and Hyslop 1980; Métras 1984, 1985; Boersma 1990; H. Lévèsque, Canadian Wildlife Service, pers. commun.). Zone 1 is the southwestern part of the province, zone 2 is the central part, and zone 3 is the part of Ontario north of North Bay (see map in Lévèsque et al. 1993). The Canada Goose harvest has increased in all three zones, and Giant Canada Geese have contributed an unknown portion to the increase. Zone 1 and the southern portions of zone 2 are the areas in Ontario where most Giant Canada Geese are produced and harvested. These two zones also show the greatest increase in the goose kill. A portion of the kill in zone 3 is made up of subadult Giant Canada Geese that have flown north to moult and are harvested there during the hunting season. Migratory Game Bird Hunting Permit purchasers in Ontario numbered 139 182 in 1968, peaked at 159 698 in 1978 (Boersma 1990), and declined to approximately 72 500 in 1997 (H. Lévèsque, Canadian Wildlife service, pers. commun.), indicating that the general harvest increase is related to increasing numbers of geese, and not to increased hunter numbers.

In addition to the benefits of public enjoyment and recreational hunting, the present abundance of geese in southern Ontario has created problems. The mowed and fertilized grass of parks and golf courses is highly attractive to geese when rivers, lakes, or ponds are present. However, some human users of the same areas object to goose droppings. A survey of municipalities in the greater Toronto area showed the areas of their concern with urban geese (Gartner Lee Ltd. 1997). The five problems of most concern in order of importance were fouling of lawns by goose feces, aesthetic deterioration, damage to lawns, water quality deterioration, and potential human health hazards. In 1996, the cost of goose control measures undertaken by 25 muncipalities in the Toronto area totalled approximately $400 000 (Gartner Lee Ltd. 1997). The city of Mississauga alone spent more than $250 000 over two years on various measures to deal with the overabundant population (news release, City of Mississauga, 25 June 1997).

Agricultural damage occurs over a surprising range of crops. Based on crop-depredation complaints, geese will graze and destroy sprouting corn, beets, carrots, soybeans, wheat, rye, oats, barley, and alfalfa. They will also consume market garden crops such as tomatoes and cucumbers, especially where alternative foods are in short supply. Adult southern geese are unable to fly for several weeks in June and July when they moult their flight feathers. Much of the damage to crops occurs during the moulting period when the birds are flightless and cannot be scared from the area. Reliable information about the magnitude of crop damage by Giant Canada Geese is not currently available. In 1988, damage was especially extensive, because the drought caused geese to switch from feeding on grass, which dried out, to eating green agricultural crops such as soybeans. At present, no mechanism exists in Ontario to compensate landowners for crops damaged by waterfowl.

Figure 3
Ten-minute blocks in which Canada Geese banded since 1978 as local birds in Ontario south of 45°30'N latitude have been recovered during the hunting season. The points are not weighted by the number of recoveries.

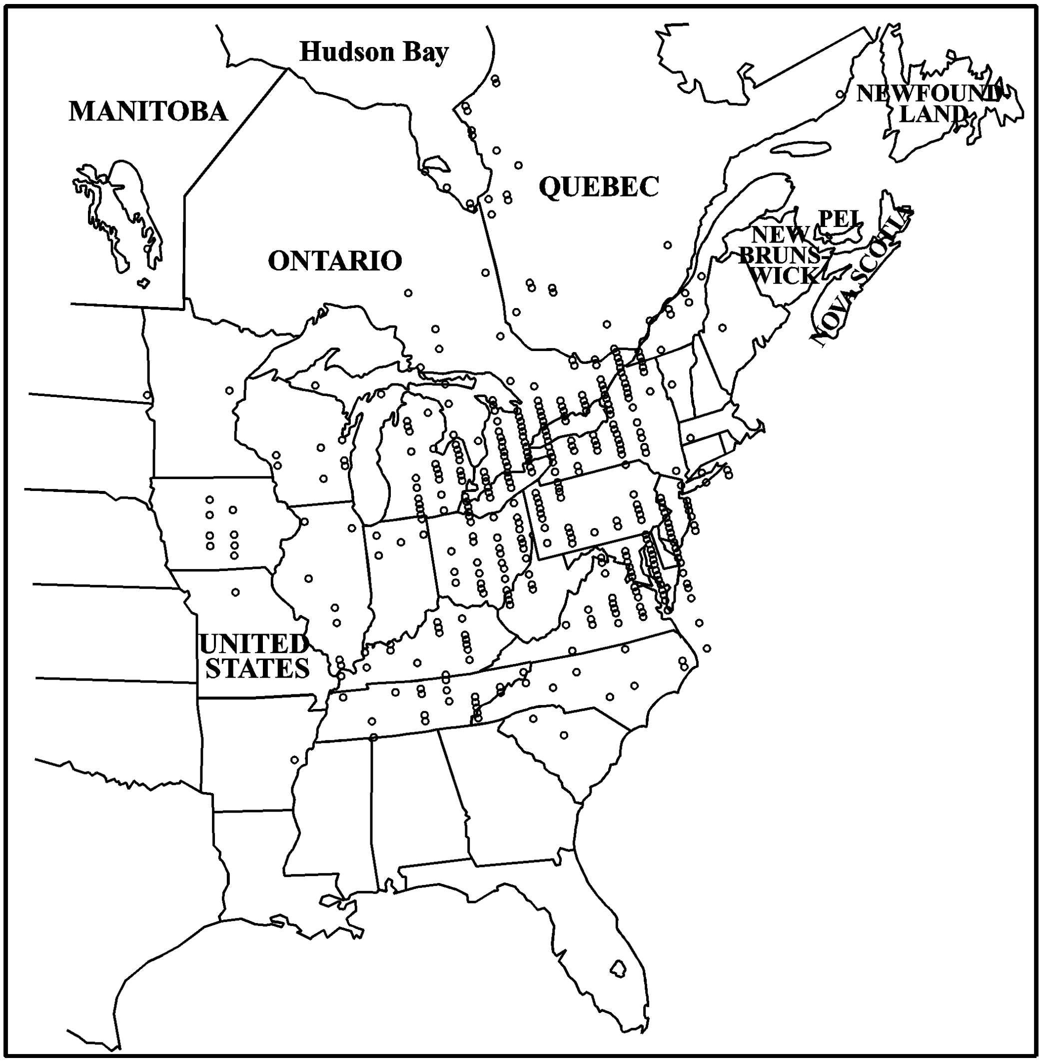
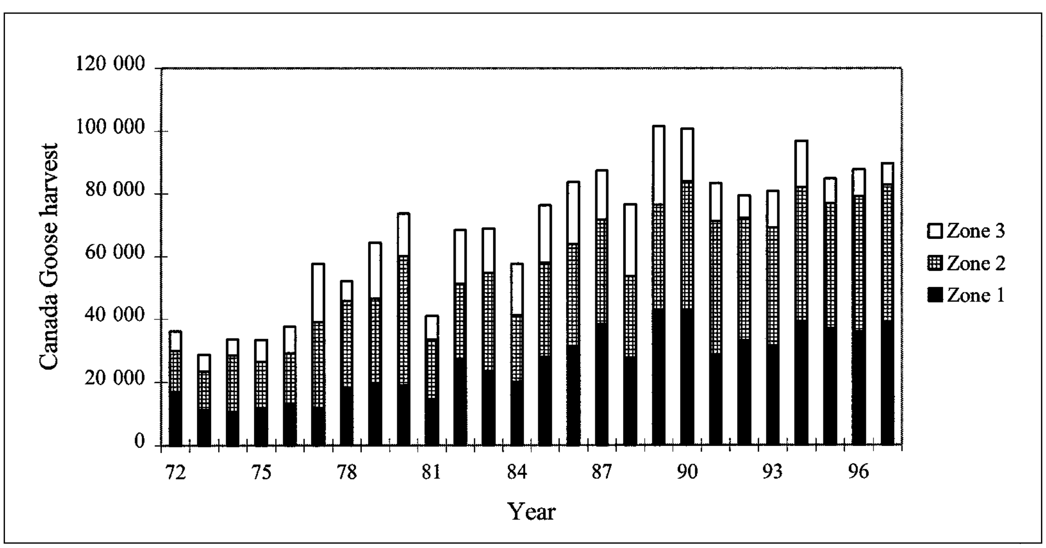


Figure 4
Harvest of Canada Geese, by zone, in Ontario, 1972–97. Zone 1 is southwestern Ontario, zone 2 is central Ontario, and zone 3 is the part of Ontario north of North Bay.



Large numbers of Giant Canada Geese are moving to Akimiski Island, Northwest Territories (now Nunavut), and adjacent areas of mainland James Bay and eastern Hudson Bay for the moulting period. In the range of the Southern James Bay Population (SJBP) Canada Geese, moult migrants compete for food resources with local goslings, contributing to their high mortality and the decline of the SJBP population (Leafloor et al. 1996).

5. Control of nuisance and problem geese

Under the Migratory Birds Regulations, permits to scare or kill Canada Geese with firearms are available from the Canadian Wildlife Service to assist farmers in protecting crops. A permit is not required to scare geese using techniques that do not involve firearms or aircraft.

Remedies for depredation or nuisance problems depend on correct diagnosis of the causes. If breeding geese are the problem, it is unlikely that tactics to scare geese from established territories will work. Destroying eggs may cause a pair to move the next year, but if populations are dense, a new pair is likely to take over the abandoned territory. Egg destruction through addling or oiling, however, may help to slow the growth of the population and may alleviate crop damage if, following egg destruction, the pair leaves the nesting area to moult. Pairs may have to be killed where densities of breeding geese are high. Kill permits do not necessarily result in the destruction of geese, because many landowners are reluctant to actually kill birds; however, complaints are often halted once a legal remedy is available.

Local, acute problems are caused by the influx of moult-migrants to safe areas where high-quality food is available. In Ontario, geese start to move into moulting areas in mid May, and movement is typically completed by mid June. The moult is well under way by 20 June. By 25 June, most of the geese are flightless.

Problems caused by moult-migrants may not be solved by opening areas to hunting in the autumn, because nuisance geese may come from a considerable distance and leave prior to the opening of the goose hunting season in Ontario. For example, recaptures of previously banded birds during banding operations showed that some geese from adjacent Great Lakes states such as Ohio, New York, and Pennsylvania come to moult in southern Ontario (North, unpubl.). Many of these birds do return to the nearby jurisdictions and are harvested during the hunting seasons there. Special early hunting seasons will help when the problem involves destruction of crops by breeding geese and their young, because early September seasons, which may have increased bag limits, tend to reduce the local population of geese. To be successful, a remedy must be applied to nuisance geese at the right time and place.

Scaring with a single shot launcher and screamer cartridges has proven effective in some circumstances. Based on our observations, scaring should be started as soon as the vanguard of geese arrive in May and should be continued until mid June. If done at every appearance of the birds, this technique appears to be effective. The use of dogs to scare geese is also an effective technique providing the dog is a fast runner and nearly catches the birds. Springer spaniels and border collies are most satisfactory for scaring geese, approaching the task with enthusiasm unmatched by most other breeds. In southern Ontario, the average number of scare or kill permits issued per year was 34 for the period 1984–89. During 1990–96, the average number of permits issued was 97 (J. Sullivan, Canadian Wildlife Service, pers. commun.).

As a result of the potential for goose collisions with aircraft, a large number of geese and eggs have been removed from the Toronto waterfront near the Toronto Island airport. Based on shipment records from 1978 to 1998, a total of 21 072 adults and 2574 eggs were relocated to various areas, including Ohio, Tennessee, Iowa, Arkansas, Oklahoma, North Carolina, Mississippi, Florida, Manitoba, Nova Scotia, and New Brunswick (Table 1). Some of these eggs and an additional 2539 goslings were relocated within Ontario. Relocation has also had the effect of relieving pressures on park lawns and beaches.

When round-ups on the Toronto waterfront began in 1978, the June population exceeded 3000 birds in the vicinity of the Toronto Island parks, and the southern Ontario resident goose population was slightly in excess of 20 000 birds. By 1990, the June population of the Toronto Island parks was 500 birds, and the Ontario population was in excess of 100 000. Thus, removal programs can be effective but are extremely costly. Approximately 1300 person-days were spent on the waterfront goose round-ups up to 1990, this total not including the effort spent by staff in the jurisdictions that received translocated geese. The city of Mississauga spent nearly $18 000 in 1997, rounding up 1800 geese and shipping them to New Brunswick. In subsequent years, the cost would be reduced by half because fewer consultants would be needed (B. Carr, City of Mississauga, pers. commun.).

6. Discussion

The highly successful Giant Canada Goose restoration program in southern Ontario resulted in a number of benefits. Human contact with an attractive wild species has been increased in a part of the world where wildlife contacts have become increasingly rare. The expanded population has also augmented goose hunting opportunities.

The expanding population has also resulted in several major problems, including competition for resources between increasing numbers of moult-migrants and decreasing northern Canada Geese, crop depredation, soiling of parks, and hazards at airports. Problems will become more significant as the goose population continues to expand.

The potential to control populations by increasing recreational-hunting opportunities is limited. Relocating birds from problem areas is not a long-term solution for population control because most suitable areas have or will have more than adequate numbers of local geese. Scaring birds from one area moves them to another where they may cause more problems. Some modification of the physiography of local problem areas by the installation of low barriers to control movement of flightless geese from water to grazing areas has potential in a few locations. There is a possibility that an acceptable ground cover for parks will be found that is not palatable for geese. Another mechanism with potential to alleviate goose damage includes the establishment and enhancement of management areas to attract geese away from problem sites. In the future, management efforts to minimize problems and stabilize the goose population will include an increased number of kill permits in problem areas, expanded egg destruction, and encouraging the harvest of Giant Canada Geese by increasing the accessibility of these birds to hunters.

7. Acknowledgements

The authors would like to thank Kathryn Dickson for support and help in producing this paper.

8. Literature cited

Baillie, J.L. and P. Harrington. 1936. The distribution of breeding birds in Ontario. Part 1. Contrib. No. 8. R. Ont. Mus. Zool. 50 pp.

Boersma, D.C. 1990. Migratory game birds harvested in Canada during the 1988 hunting season. Can. Wildl. Serv. Prog. Note No. 190. 40 pp.

Cooch, F.G. 1974. Species of waterfowl and age and sex ratios of ducks harvested in Canada during the 1973 season. Can. Wildl. Serv. Prog. Note No. 42. 47 pp.

Cooch, F.G. and K.L. Newell. 1977. Species of waterfowl and age and sex ratios of ducks and geese harvested in Canada during the 1975 season. Can. Wildl. Serv. Prog. Note No. 71. 43 pp.

Dennis, D.G. 1974. Breeding pair surveys of waterfowl in southern Ontario. Pages 45–52 *in* Boyd, H. (ed.), Canadian Wildlife Service waterfowl studies in eastern Canada, 1969–1973. Can. Wildl. Serv. Rep. Ser. No. 29. 105 pp.

Fetterolf, P.M. 1983. Canada Goose/gull management plan for the Toronto waterfront. Metro Toronto Region Conservation Authority Report, Toronto, Ontario. 82 pp.

Fleming, J.H. 1913. Pages 206–237 *in* Faull, J.H. (ed.), The natural history of the Toronto region. Canadian Institute, Toronto, Ontario. 419 pp.

Gartner Lee Ltd. 1997. A strategy for the management of the Canada Goose in the greater Toronto bioregion. Prepared by Gartner Lee Ltd in association with Brian Henshaw. Prepared for The Waterfront Regeneration Trust, Toronto, Ontario. 44 pp. plus appendices.

Leafloor, J.O., K.F. Abraham, D.H. Rusch, R.K. Ross and M.R.J. Hill. 1996. Status of the Southern James Bay Population of Canada Geese. Pages 103–108 *in* Ratti, J.T. (ed.), Proceedings of the 7th International Waterfowl Symposium, Memphis, Tennessee.

Lévèsque, H., B. Collins and A. Legris. 1993. Migratory game birds harvested in Canada during the 1991 hunting season. Can. Wildl. Serv. Prog. Note No. 204.

Lumsden, H.G. 1981. History of breeding Canada Geese (*Branta canadensis*) in southwestern Ontario. Ont. Field Biol. 35:49–55.

McIlwraith, H.G. 1891. Birds of Ontario. 2nd edition. William Briggs, Toronto. 426 pp.

Métras, L. 1984. Migratory birds killed in Canada during the 1982 season. Can. Wildl. Serv. Prog. Note No. 143. 39 pp.

Métras, L. 1985. Migratory birds killed in Canada during the 1983 season. Can. Wildl. Serv. Prog. Note No. 154. 39 pp.

Saunders, W.E. and E.M.S. Dale. 1933. History and list of birds of Middlesex County Ontario. Univ. of Toronto Press, Toronto. 251 pp.

Wendt, J.S., F.G. Cooch and K.L. Newell. 1978. Species of waterfowl killed in Canada during the 1976 and 1977 seasons. Can. Wildl. Serv. Prog. Note No. 92. 27 pp.

Wendt, J.S. and C. Hyslop. 1980. Migratory birds killed in Canada during the 1979 season. Can. Wildl. Serv. Prog. Note No. 115. 42 pp.

Wendt, J.S., W. Mortimer and F.G. Cooch. 1979. Migratory birds killed in Canada during the 1978 season. Can. Wildl. Serv. Prog. Note No. 101. 45 pp.

Recent publications in the Occasional Papers series

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, by A.J. Erskine, ed. 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, ed.
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 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. 99
Breeding ecology of the Horned Grebe *Podiceps auritus* in subarctic wetlands, by Michael A. Fournier and James E. Hines.
Cat. No. CW69-1/99E. 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