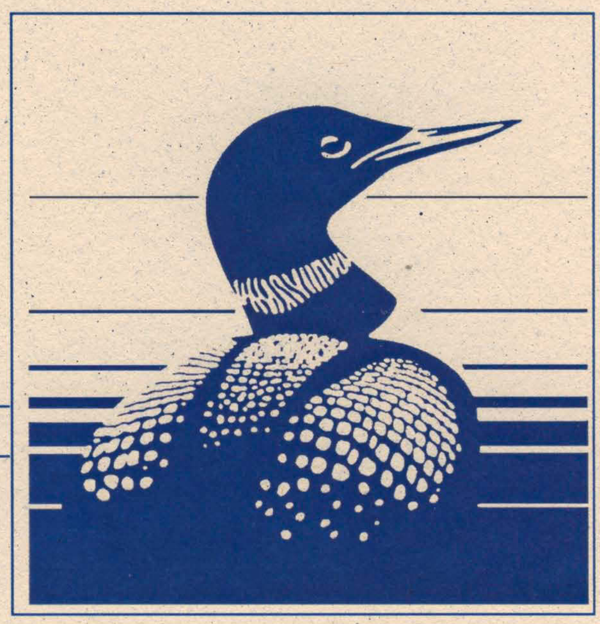
Population size and trends of seabirds breeding in the Gannet Islands, Labrador

Gregory J. Robertson and Richard D. Elliot

Atlantic Region 2002
Canadian Wildlife Service
Environment Conservation Branch



Technical Report Series Number 393

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

Canada

POPULATION SIZE AND TRENDS OF SEABIRDS BREEDING IN THE GANNET ISLANDS, LABRADOR

Gregory J. Robertson[1] and Richard D. Elliot[2]

[1]*Canadian Wildlife Service, 6 Bruce Street, Mount Pearl NF A1N 4T3*

[2]*Canadian Wildlife Service, 17 Waterfowl Lane, P.O. Box 6227, Sackville NB E4L 1G6*

Canadian Wildlife Service Technical Report Series No. 393

This report may be cited as:

Robertson, G. J., and R. D. Elliot. 2002. Population size and trends of seabirds breeding in the Gannet Islands, Labrador. Canadian Wildlife Service Technical Report Series No. 393. Atlantic Region. v + 36 pp.

Published by the authority of the
Minister of Environment
Canadian Wildlife Service

Catalogue No.: CW69-5/393E
ISBN: 0-662-32958-9

Copies may be obtained from:

Gregory J. Robertson
Canadian Wildlife Service
6 Bruce Street
Mount Pearl NF A1N 4T3
Canada

Tel: 709-772-2778
Fax: 709-772-5097
e-mail: greg.robertson@ec.gc.ca

Summary

The Gannet Islands, off the southeastern coast of Labrador, supports the largest and most diverse seabird breeding colony in Labrador. Surveys were conducted in 1998-2000 to update population size estimates and compared with earlier estimates to assess recent population trends.

Total population sizes of breeding Razorbills (*Alca torda*) were estimated from boat counts of individuals occupying suitable breeding habitat, and correction factors relating the number of nest sites to the number of adults present on a plot. Population size estimates were 6497 pairs (3644 – 9349; 95% CI) in 1978, 6070 pairs (4133 – 8571), in 1983, 10 300 pairs (7490 – 13 852) in 1998 and 9808 pairs (5830 – 15 503) in 1999. Differences between 1978 and 1998, and 1983 and 1998 were significant. Permanent study plots were established in 1983 and overall the number of nest sites in these plots was not significantly different between 1983-84 and 1998-99. On one island, which was known to harbour arctic foxes in the early 1990s, the number of active nests was significantly lower by 1998-99. In spite of the large confidence intervals around our estimates of population size, these surveys confirm the importance of the Gannet Islands as the largest colony of Razorbills in North America with about 10 000 breeding pairs.

All adult Common Murres (*Uria aalge*) and Thick-billed Murres (*U. lomvia*) in breeding areas were counted, and an estimate of the number of breeding pairs was derived using a correction factor obtained from detailed study plots. Common Murre breeding populations were estimated at 37 155 pairs (31 300 – 43 011; 95% CI) in the Gannet Clusters and 23 734 pairs (19 970 – 27 498) on Outer Gannet Island in 1983. In 1998, the Gannet Clusters had an estimated 19 360 pairs (18 419 – 20 302), and Outer Gannet Island 17 342 pairs (16 499 – 18 185) of breeding Common Murres; corresponding to declines of 47.9% and 26.9%. For Thick-billed Murres, we estimated that 946 pairs (899 – 992) bred in the Gannet Clusters and 471 pairs (448 – 495) bred on Outer Gannet Island in 1983. In 1998, 1337 pairs (1291 – 1384) bred on the Gannet Clusters and 560 pairs (541 – 580) bred on Outer Gannet; corresponding to increases of 41.3% and 18.9%. Apparent declines in Common Murre, and increases in Thick-billed Murre populations, may reflect a period of colder water and a corresponding shift in prey distribution that occurred in the 1990s in the marine ecosystem in the Northwest Atlantic. Arctic fox predation, other sources of mortality, a low breeding effort and/or variation among surveys may explain the apparent reduction in numbers of breeding Common Murres.

Surveys to estimate the breeding population of Atlantic Puffins (*Fratercula arctica*) were conducted in the summers of 1978, 1983, 1984, 1999 and 2000. Surveys methods involved counting every hole that could lead to a burrow, and assessing puffin occupancy rates of holes from randomly located 30 m^2 plots (25 m^2 in 1978). The number of breeding pairs of Atlantic Puffins in the Gannet Clusters was estimated at 33 005 pairs (27 976 – 38 034; 95 % CI) in 1978, 42 252 pairs (37 328 – 47 176) in 1983, 39 573 pairs (34 194 – 44 952) in 1984 and 34 612 pairs (28 874 – 40 350) in 1999. On Outer Gannet Island, the estimated number of breeders was 6342 pairs (2839 – 9845) in 1978, 8399 pairs (7545 – 8798) in 1983 and 4054 pairs (2204 – 5904) in 2000. Even though the number of puffin holes increased in the last 20 years, more of these were connected to other entrances or lead to unsuitable burrows by 1999. Occupancy rates of

burrows suitable for breeding have declined slightly since the 1980s. The puffin breeding population appears to have peaked in the 1980s on the Gannet Clusters; but has remained relatively stable over the last 20 years at 33 000 – 42 000 pairs, and remains the second largest breeding colony in eastern North America.

The other less common species have shown a variety of patterns. Black Guillemots (*Cepphus grylle*) have never been a common nesting species, and, if anything, their breeding population was reduced from the early 1980s to 1999. Black-legged Kittiwake (*Rissa tridactyla*) numbers have not changed much since the early 1980s, despite impressive increases through the 1970s. A similar trend was seen for Northern Fulmar (*Fulmaris glacialis*). Great Black-backed Gull (*Larus marinus*) numbers are lower than during the 1980s. Leach's Storm-petrel (*Oceanodroma leucorhoa*) were a confirmed as a nesting species in the 1980s, and although they were heard calling at night, breeding was not re-confirmed in the late 1990s.

To summarize, Razorbill and Thick-billed Murre populations appear to have shown a real increase through the last two decades; while Common Murre populations may be somewhat reduced. Puffins and the other less common species have not shown any substantial changes, with the possibly exception of the local extirpation of the small (< 15 pairs) Leach's Storm-petrel population.

Résumé

Les îles Gannet, au large du sud-est du Labrador, hébergent la colonie de nidification d'oiseaux marins la plus grande et la plus plurispécifique du Labrador. En 1998-2000, on a recensé les effectifs, pour les actualiser et, après comparaison avec des estimations antérieures, en dégager les tendances récentes.

On a estimé l'effectif total de petits pingouins reproducteurs (*Alca torda*) à partir de dénombrements en bateau des nicheurs occupant un habitat approprié et de facteurs de correction reliant le nombre de nids au nombre d'adultes présents sur une parcelle de terrain. Ainsi, le nombre estimé de couples était de 6 497 (3 644 – 9 349, intervalle de confiance [IC] de 95 %) en 1978; de 6 070 (4 133 – 8 571) en 1983; de 10 300 (7 490 – 13 852, IC = 95 %) en 1998; de 9 808 (5 830 – 15 503) en 1999. Les différences entre 1978 et 1998 ainsi que 1983 et 1998 étaient significatives. En 1983, on a créé des parcelles permanentes, et, globalement, le nombre de nids n'a pas sensiblement différé entre 1983-1984 et 1998-1999. Sur une île connue pour héberger des renards arctiques au début des années 1990, le nombre de nids occupés était sensiblement inférieur en 1998-1999. Malgré les grands intervalles de confiance recouvrant nos évaluations des effectifs, ces recensements confirment le premier rang qu'occupent les îles Gannet comme colonie la plus nombreuse de petits pingouins en Amérique du Nord, avec ses 10 000 couples.

On a compté tous les guillemots marmettes (*Uria aalge*) et tous les guillemots de Brünnich (*U. lomvia*) dans les zones de nidification et on a estimé le nombre de couples au moyen d'un facteur de correction obtenu grâce aux parcelles d'étude détaillée. En 1983, on avait estimé les effectifs des couples reproducteurs du guillemot marmette à 37 155 (31 300 – 43 011, IC = 95 %) dans les Gannet Clusters et à 23 734 (19 970 – 27 498) dans l'île Outer Gannet. En 1998, on les a estimés respectivement à 19 360 (18 419 – 20 302) et à 17 342 (16 499 – 18 185), ce qui correspond à un déclin de

47,9 % et de 26,9 %, respectivement. En 1983, on a estimé les effectifs de couples reproducteurs du guillemot de Brünnich à respectivement 946 (899 – 992) et à 471 (448 – 495), puis, en 1998, à 1 337 (1 291 – 1 384) et à 560 (541 – 580), ce qui correspond à une augmentation de 41,3 % et de 18,9 %, respectivement. Ces déclins apparents du guillemot marmette et ces augmentations apparentes du guillemot de Brünnich peuvent coïncider avec une période de refroidissement de l'eau et une variation correspondante de la répartition des proies survenue dans les années 1990 dans l'écosystème marin du nord-ouest de l'Atlantique. La prédation due au renard arctique, d'autres causes de mortalité, un faible effort de reproduction, ou des écarts dans le déroulement des recensements peuvent expliquer la baisse apparente des effectifs du guillemot marmette.

Au cours des étés 1978, 1983, 1984, 1999 et 2000, on a recensé les macareux moines (*Fratercula arctica*) afin d'en estimer les effectifs des reproducteurs. Les méthodes employées ont compris le dénombrement de tous les orifices d'entrée d'éventuels terriers et l'évaluation des taux d'occupation des orifices se trouvant dans des parcelles de 30 m^2 (25 m^2 en 1978) situées au hasard. On a estimé le nombre de couples reproducteurs dans les Gannet Clusters à 33 005 (27 976 – 38 034, IC = 95 %) en 1978, à 42 252 (37 328 – 47 176) en 1983, à 39 573 (34 194 – 44 952) en 1984 et à 34 612 (28 874 – 40 350) en 1999. Dans l'île Outer Gannet, le nombre estimé de couples reproducteurs a été de 6 342 (2 839 – 9 845) en 1978, de 8 399 (7 545 – 8 798) en 1983 et de 4 054 (2 204 – 5 904) en 2000. Quoique le nombre d'orifices ait augmenté au cours des 20 dernières années, une plus forte proportion d'entre eux menait, en 1999, à d'autres entrées ou à des terriers inutilisables. Le taux d'occupation des terriers convenables a légèrement diminué depuis les années 1980. Les effectifs du macareux semblent avoir culminé dans les années 1980 dans les Gannet Clusters; ils sont restés relativement stables au cours des 20 dernières années, à 33 000 – 42 000 couples, et la colonie de nidification reste la deuxième de l'est de l'Amérique du Nord.

Les effectifs des autres espèces moins communes se sont diversement comportés. Le guillemot à miroir (*Cepphus grylle*) n'a jamais été abondant. Le nombre de ses reproducteurs était plutôt légèrement moindre en 1999 qu'au début des années 1980. Le nombre de mouettes tridactyles (*Rissa tridactyla*) n'a pas beaucoup changé depuis le début des années 1980, en dépit d'augmentations frappantes au cours des années 1970. On pose un constat semblable pour le fulmar boréal (*Fulmaris glacialis*). Les effectifs du goéland marin (*Larus marinus*) sont inférieurs à ceux des années 1980. Dans les années 1980, on a confirmé le statut d'espèce nidificatrice de l'océanite cul-blanc (*Oceanodroma leucorhoa*), et bien que l'on ait entendu ses cris nocturnes, on ne l'a pas confirmé de nouveau à la fin des années 1990.

Bref, les effectifs du petit pingouin et du guillemot de Brünnich semblent avoir véritablement augmenté au cours des deux dernières décennies, tandis que ceux du guillemot marmette peuvent être quelque peu réduits. Les effectifs du macareux moine et des autres espèces moins communes n'ont pas présenté de changement sensible, à l'exception, peut-être, de la disparition locale de la petite population (moins de 15 couples) d'océanites culs-blancs.

1. Introduction

1.1 The Gannet Islands

The Gannet Islands is an important seabird colony in eastern North America. It harbours, by far, the largest seabird colony in Labrador and has a rich breeding species composition of 8 (possibly 9) different seabirds. Others have described the Gannet Islands in detail (Tuck 1961, Birkhead and Nettleship 1987a, Birkhead 1993), so a lengthy description is not provided here. Briefly, the Gannet Clusters consists of 6 (referred to GC1-GC6) relatively low-lying islands, about 40 km northeast of Cartwright (53° 56'N, 56° 32'W; Figure 1.1). There are 4 small inner islands (GC1-GC4) and two larger islands at the southern (GC5) and western (GC6 or Western Gannet) edge of the cluster (Birkhead and Nettleship 1995). The main islands range in size from 4.4 - 125 ha and there are a few exposed rocks and sunkers within the island cluster. In addition, there is another island 7 km north of the cluster referred to Outer Gannet (54° 00'N, 56° 32'W), which is about 1 km x 300 m at its widest point. Most islands have an outer ring of exposed rocky habitat, surrounding a ring of suitable breeding habitat for Atlantic Puffins (*Fratercula arctica*). The interiors of the larger islands have a more typical tundra-dominated community of sedges, low-lying heathers and shrubby plants (*Salix* spp. and *Betula*. spp.), where only Great Black-backed Gulls (*Larus marinus*) and possibly Leach's Storm-petrel (*Oceanodroma leucorhoa*) breed. The rocky coasts of these islands are a mixture of cliff, rock slab and boulder scree, and is where the bulk of the seabirds nest.

For the purposes of this paper, the Gannet Clusters refer to the six inner islands, GC1 to GC6, while the Gannet Islands includes GC1 to GC6 and Outer Gannet.

1.2 History of research and protection

Historical visits and accounts of the seabirds of coastal Labrador and the Gannet Islands are well summarized in other sources (Tuck 1961, Todd 1963, Birkhead 1993). Tuck (1961) visited the Gannet Islands in 1952, and provided the first estimates of the size of the murre (*Uria aalge* and *U. lomvia*) breeding populations. In 1972, the Gannet Islands were visited by A. R. Lock and estimates of the number of murres, Razorbills (*Alca torda*) and Atlantic Puffins were made, and notes about the presence of other seabirds were recorded (Nettleship and Lock 1973a, Nettleship and Lock 1974). In 1978, R. D. Elliot and R. Odense undertook the first complete survey of all nesting seabirds of the Gannet Islands. Beginning in 1981, a major research effort was launched, which lasted until 1985. A cabin was constructed on GC2 in 1981 and a smaller satellite cabin was built on GC4 in 1982. A number of blinds overlooking murre plots were also built on GC2 and GC4. Both cabins and several blinds still stand today. During this period, most research focused on murres nesting on GC4 examining their ecology and populations (Birkhead and Netleship 1984,1987abc, 1988, Birkhead and del Nevo 1987) and their mating systems (Birkhead et al. 1985,1986). Additional studies of food habits and breeding success of Razorbills and Atlantic Puffins were also conducted. Within this period, another complete survey was undertaken in 1983 to estimate the population sizes of all breeding seabirds in the Gannet Islands. These surveys were meant to be comprehensive and establish long-term monitoring plots. A summary of these surveys is presented in Birkhead and Nettleship (1987a). Some further survey work was conducted in 1984 and 1985.

In 1992, the Gannet Islands were again revisited, when significant changes in the seabird populations were noticed. Birkhead (1993) and Birkhead and Nettleship (1995) describe these changes, which were largely due to the presence of Arctic foxes (*Alopex lagopus*).

In 1996, a research program was re-initiated on the Gannet Islands by I. L. Jones and the ACWERN (Atlantic Cooperative Wildlife Ecology Research Network) node of Memorial University of Newfoundland. The focus of these studies has varied from assessing productivity, diet and competition among murres and puffins (Bryant et al. 1999, Bryant and Jones 1999, Hipfner and Bryant 1999, Baillie 2001), parasitology (Muzzafar 2001), examining Razorbill nest site selection (Rowe and Jones 2000) and investigating patterns of life history evolution in auks (Hipfner and Gaston 1999, Hipfner 2000, Hipfner et al. 1999, 2000ab, 2001, Hipfner and Dussureault 2002,). Work was also conducted on behaviour of the large population of Harlequin Ducks (*Histrionicus histrionicus*) that moults on the Gannet Islands (Adams et al. 2000).

In 1998 and 1999, a survey was again undertaken to assess the breeding populations. In 1998, the focus was to count murres and Razorbills, while in 1999 the focus was to assess Atlantic Puffin populations and the other less common species. The survey was completed in 2000. The purpose of this report is to present the results of these recent seabird surveys. We also gathered as much historical data together for comparisons with earlier estimates. Overall results of 1983 survey are summarized in Birkhead and Nettleship (1987a), but in certain instances, raw data available from CWS files were reanalyzed in a manner consistent with recent surveys to allow for direct statistical comparisons. The details of the 1978 survey are published for the first time in this paper. Results from 1984 and 1985 are presented where data could be extracted from field notes, and certain data from 1992 were extracted from Birkhead and Nettleship (1995). Counts of moulting Harlequin Ducks were also conducted and are reported in Gilliland et al. (2002).

The Gannet Islands and surrounding marine waters have been protected as a *Seabird Ecological Reserve* under the provincial legislation of Newfoundland and Labrador *Wilderness and Ecological Reserves Act (1980)* since 1983. This colony was first designated as a *Wildlife Reserve* in 1967 under the provincial *Wildlife Act*. Under current policy and legislation, access is only allowed under permit, and a committee reviews all proposed research activities. Annual reports are required that document all permitted activities. There are no current provisions for access by the public, including tourists. The cabins and blinds on the islands are owned and maintained by the Canadian Wildlife Service.

2. Razorbills

2.1 Introduction

Of the six species of auks (Alcidae) breeding in the North Atlantic, the Razorbill has the smallest population size, estimated at 500 000 - 700 000 breeding pairs (Nettleship and Evans 1985, Lloyd et al. 1991, Gaston and Jones 1998). Most Razorbills breed in Iceland (70%), the rest in the British Isles (20%), and the remaining 10% divided between eastern and western Atlantic (Gaston and Jones 1998).

Population estimates for the North America have varied between 15 000 and 21 100 pairs (Bédard 1969, Brown et al. 1975, Nettleship and Evans 1985); the most recent estimate is 38 000 pairs (Chapdelaine et al. 2001). In the 1960s and early 1970s, declines of Razorbills were noted at colonies along the north shore of Québec (Moisan and Fyfe 1967, Nettleship and Lock 1973b, Chapdelaine and Laporte 1982, Chapdelaine and Brousseau 1984). Recently, there is evidence that these populations are recovering (Chapdelaine and Brousseau 1991, Chapdelaine 1995, Chapdelaine et al. 2001).

The largest colony of breeding Razorbills in eastern North America is in the Gannet Islands. Here, we present the results of two techniques to estimate the population size and population trends of breeding Razorbills in the Gannet Islands. The first are the results of egg counts in permanent study plots established in 1983 (with some information from 1978). The second are the results from boat surveys in 1978, 1983, 1998 and 1999 of total colony counts of Razorbills to estimate the total number of breeding pairs.

2.2 Methods

2.2.1 Permanent study plots

In 1983, nine permanent study plots were established on five islands to monitor numbers of breeding Razorbills. Each plot was selected in an area of suitable Razorbill breeding habitat (ledges and crevices), and encompassed between 500 - 2500 m^2. Once the limits of the plot were established, sketch maps, written descriptions and photographs were taken to accurately describe the limits of the plot. Further, features (such as uniquely shaped boulders) were incorporated as corners of the plot, and permanent markers were installed (tent pegs or spikes) to mark the corners of the plots. In subsequent years, the plots were re-established using the maps, descriptions and photos. Ropes were placed on the ground to accurately define the limits of the plot. Researchers then searched the entire plot for Razorbill eggs, chicks and incubating adults. Plots were generally surveyed late in the incubation period. The total number of eggs, chicks and incubation adults was recorded. One large plot on GC2 (plot GC2-c) consisted of two distinct sections which where are treated separately in some comparisons. Three of the study plots on GC2 (GC2a-GC2c) were the same as ones used in 1978, so earlier data was available for these three plots.

2.2.2 Boat survey

Colony counts of all six islands were made in 1978, 1983, 1998 and 1999. Two counts were made in 1978 (5 and 16 July), one in 1983 (22 July), one in 1998 (12 July) and one in 1999 (18 July). Researchers in inflatable boats slowly surveyed each island from 100-250 m from shore. All Razorbills seen on the islands were counted and recorded, and it was noted whether individuals were seen in suitable breeding habitat or on large exposed boulders close to shore. The latter we assumed to be loafers not associated with a nesting site. In addition, the number of individuals that could be seen on each of the permanent study plots was recorded during the survey. This information was used to calculate a correction factor (k), which is the total number of breeding sites divided the total number of birds counted in breeding areas. This correction was necessary to determine the relationship between the number of Razorbills seen on islands and the true number of nesting pairs (Nettleship 1976).

2.2.3 Analyses

Plot counts were compared between 1983-84 and 1998-99 using paired t-tests. We calculated correction factors (*k*) to estimate the true number of breeding pairs from the number of birds counted from the boat which were standing in suitable breeding habitat (Nettleship 1976). Correction factors are notoriously variable for many auks, especially Razorbills (Lloyd 1975, Cairns 1979). To eliminate some of the variability, correction factors were calculated from data collected at the same time as the survey. In 1978, correction factors were based on three study plots, in 1983, eight plots, in 1998, nine plots and in 1999, 11 study plots. We log transformed *k* values as they tended to show distributions skewed right. Mean correction factors for the survey were calculated from the log *k* for each plot, with each plot weighted by the total number of breeding sites. This weighting increased the contribution of large plots to the calculation of *k*, as we assumed that larger plots produce more robust estimates of *k*. After calculating the mean of log *k*, *k* was extracted with a back transformation. Standard errors in *k* were also calculated and these were used to calculate error in the estimates of total population size. The population size estimates for the two 1978 surveys were averaged, along with their standard errors. Population size estimates were compared with t-tests. Variances and pooled variances necessary to perform for t-tests were calculated using the standard error of the population size estimate. Degrees of freedom of tests were based on the number of *k* factors used to calculate the standard error of the population size estimate (6 for 1978, 8 for 1983, 9 for 1998 and 11 for 1999). We did not assume equal variances between samples and used the appropriate reduced degrees of freedom (Zar 1974).

GC5 and GC6 were surveyed on a different date (3 July) in 1978. We used the lower *k*, obtained on 16 July 1978, to estimate the population size on these two islands. We used this lower value because we believe our ability to see breeding Razorbills on these two islands was quite high (compared to GC1-GC4) based on the structure of the breeding habitat (mainly cliffs rather than boulder scree).

2.3 Results

2.3.1 Plot counts

Overall, there was no detectable change in the number of Razorbills nesting in the 11 plots between 1983-84 and 1998-99 (paired t-test, t = 1.23, P = 0.25). The number of nesting Razorbill pairs increased on the two plots on GC1 and decreased on the 6 plots on GC2 (Table 2.1). The increase on GC1 was not significant (paired t-test, t = 2.02, P = 0.29), the decrease on GC2 was significant (paired t-test, t= 3.08, P = 0.028). Sample sizes and magnitudes of change are too small to detect any changes either way on the other three islands (Table 2.1). Since 1992, when foxes were present (Birkhead and Nettleship 1995), breeding populations in the Gannet Islands appear to be recovering, at least partially, in the case of GC2 (Table 2.1).

2.3.2 *Boat surveys*

The correction factors (*k*) calculated within each survey (range 0.82 – 13.00) and between surveys (range 1.845 – 3.491) were quite variable (Table 2.2). The overall estimate for 1978, pooling the two surveys, is 6497 (3644 – 9349; 95% CI) breeding pairs of Razorbills; for 1983 the estimate is 6070 (4133 – 8571), for 1998, 10 300 (7490 – 13 852) and 1999, 9808 (5830 – 15 503) breeding pairs (Table 2.3). The estimates for 1978 and 1998, and 1983 and 1998 were significantly different ($t = 2.28$, d.f. = 14.1, $P = 0.038$; $t = 2.82$, d.f. = 15.3, $P = 0.013$), all are other yearly comparisons were not detectably different from each other ($P > 0.05$).

2.4 Discussion

2.4.1 *Interpretation of survey results*

It is important to assess whether there are biases in our estimates of population sizes and trends for Razorbills breeding in the Gannet Islands. Plot counts have the advantage of being easily replicated year after year (Nettleship 1976). The disadvantage of plot counts is that trends apparent in the plots may not reflect trends in the colony as a whole. Further, placement of plots is very important. Plots in high density nesting areas may be useful in detecting population declines, however, population increases may not be detected if new recruits settle in unused peripheral areas of the colony (G. Chapdelaine, pers. comm.). As Razorbills also nest on cliffs (Hudson 1982, Rowe and Jones 2000), plots that do not encompass cliffs will not effectively track trends in this habitat. Finally, plot counts do not allow estimation of total breeding population size, unless the total area of suitable breeding habitat is known, and the density in the plots is assumed to be constant over the entire breeding area. On the other hand, total colony counts do provide an estimate of the total breeding population size. However, total bird counts are very difficult to interpret. Colony attendance patterns are highly variable in Razorbills (Lloyd 1975, Cairns 1979) and other auk species (Jones 1992). Birds counted during surveys may be non-breeding floaters, off-duty birds from other plots, or breeding birds. The proportion of breeding birds actually at the colony compared to those at sea also varies considerably (Cairns 1979). In some colonies, Razorbills will move to the water when disturbed (as during a survey) and colony counts of birds remaining on the islands may be difficult to interpret (G. Chapdelaine, pers. comm.).

Given the limitations of these two techniques, is it possible to make inferences from our results? Our first approach was to combine them, utilizing the strengths of both methods. If the results of both lead to similar conclusions, then we have some assurance that our techniques are effective. For boat surveys, we attempted to control for as much variation in colony attendance as possible by calculating correction factors from data collected at the same time as the survey. Thus, we only assume that the correction factors calculated at study plots accurately represent what is occurring in the entire colony at the same time. Further, we recognize the variation in correction factors among plots, and use this variation to apply confidence limits on population size estimates. Indeed, we found considerable variation in correction factors among plots on the same day.

2.4.2 *Population size estimates and trends*

In the Gannet Islands, we estimated that there were 6497 pairs of breeding Razorbills in 1978, 6070 in 1983, 10 300 in 1998 and 9808 in 1999. The higher estimate for 1998 and 1999 are largely due to the higher correction factor calculated for these years (3.26 and 2.90 versus 1.77, 2.74 and 2.40) and greater counts from the peripheral islands GC5 and GC6. We used a higher number of plots in 1998-99 (9 and 11) to estimate our correction factor and do not believe that the 1998-99 correction factor is biased high. The results from the two surveys in 1978 are encouraging, as correction factors for two different dates differed substantially (1.77 and 2.74), but resulted in population size estimates that were very similar (5633 and 5519).

In contrast to the boat survey results, which strongly suggest that the Razorbill population has increased, no apparent trends were indicated by the egg plot counts. This discrepancy is likely explained by the predominance of study plots on one island, GC-2 (6 of 11 plots). The number of Razorbills breeding on GC2 in the late 1999s was lower than in the early 1980s. This is not surprising as Arctic foxes were found on this, and other, islands in the Gannet Clusters in the early 1990s (Birkhead and Nettleship 1995, Appendix 1). In 1992, no evidence of successful breeding was found on any plot on GC2, and several dead adults were found (Birkhead and Nettleship 1995). The population now appears to be recovering on GC2, although it has yet to reach its former numbers. The results of the boat survey also suggest that numbers may be lower on GC2 in 1998-99 compared to the early 1980s. It is not known whether the population decline on GC2 represents a real numerical decline of the breeding population due to fox predation, reduced recruitment, or redistribution to other islands (such as GC1).

Our results confirm that the Gannet Islands is the most important Razorbill colony in North America with close to 10 000 breeding pairs. There are two colonies along the North Shore of Québec, that support 1000s of Razorbills, but probably not 10 000 pairs. Although the Baie des Loups migratory bird sanctuary may have had close to these numbers in the past (Moisan and Fyfe 1967, Bédard 1969), this colony suffered a severe decline in the 1960s and has yet to recover (Chapelaine 1995).

Although we detected a possible increase in the Razorbill population at the Gannet Islands, and there is evidence that Razorbill populations are increasing dramatically in North America and elsewhere throughout their range (Stowe 1982, Chapdelaine and Brousseau 1991, Chapdelaine 1995, Chapdelaine and Brousseau 1996, Chapdelaine et al. 2001, Robertson and Elliot 2002, Robertson et al. 2002a, Hipfner and Chapdelaine 2002), there are a number of reasons to continue to closely monitor Razorbill populations. Razorbill populations have declined dramatically in the past (Moisan and Fyfe 1967, Nettleship and Lock 1973b, Chapdelaine and Laporte 1982, Chapdelaine and Brousseau 1984), and there is no reason to believe that declines could not occur again. The presence of predators, even natural ones such as foxes and polar bears *(Ursus maritamus*), can have devastating effects on seabird colonies. Specific to the Gannet Islands, it appears that breeding numbers have not recovered on GC2, where Arctic foxes denned in 1992 (Birkhead and Nettleship 1995). In North America, Razorbills are shot illegally (presumably mistakenly) during the legal Newfoundland murre hunt (Elliot 1991, Chapdelaine 1997). Like most auks, Razorbills, are susceptible to getting caught in gill nets. Although there have been major reductions in cod (*Gadus morhua*) and other groundfish fishing in Newfoundland and the Gulf of St.

Lawrence, gill net by-catch of seabirds still occurs in some fisheries. If these fisheries are revitalized in the future, seabird by-catch will probably become an important source of mortality (Takekawa et al. 1990, Falk and Durink 1991). Fisheries for forage fish, such as sandlance (*Ammodytes* spp.) and capelin (*Mallotus villosus*) can result in depletion of prey for Razorbills and consequent breeding failure (Furness and Ainley 1984, Cairns 1987, Monaghan 1992). There is recent evidence that a large portion of the North American Razorbill population winters at the mouth of the Bay of Fundy (Chapdelaine et al. 2001, F. Hüttmann and A.W. Diamond, unpubl. data), making it vulnerable to a single catastrophic event, such as an oil spill (Bourne 1976, Piatt et al. 1991). Razorbills exhibit high annual survival rates, with estimates varying between 89-92% (Lloyd and Perrins 1977, Hudson 1985, Harris and Wanless 1989, Chapdelaine 1997, Harris et al. 2000), indicating that populations are very sensitive to reductions in adult survival. A conservative approach to minimize Razorbills mortality and careful monitoring of Razorbills are needed to ensure populations are sustained, and current increases in the population continue.

3. Murres

3.1 Introduction

Populations of both Common and Thick-billed murres have undergone substantial changes across their ranges. Some Common Murre populations in Europe and western North America have experienced serious declines caused by a variety of sources such as over-fishing of bait fish stocks, direct harvest and egging, gill-net mortality, oil pollution, and climatic and marine ecosystem changes (Ainley and Lewis 1974, Piatt and Nettleship 1987, Piatt et al. 1990, Vader et al. 1990, Takekawa et al. 1990, Harris 1991, Byrd et al. 1993). Common Murres in the northwest Atlantic were heavily prosecuted in the early part of the 1900s, but populations are recovering (Tuck 1961, Nettleship and Evans 1985, Chapdelaine 1995). Worldwide, Thick-billed Murre populations appear stable (Gaston and Hipfner 2000), although some populations have shown serious declines. In many cases these declines were attributable to direct harvest of adults and eggs, although other factors probably played a role (Evans and Kampp 1991, Byrd et al. 1993, Gaston and Hipfner 2000). Most of these large-scale harvests have been reduced or have ceased, and populations in the eastern Canadian Arctic appear to be stable or increasing (Gaston 1999, 2002, Gaston and Hipfner 2000).

3.2 Methods

From 30 June to 28 July 1983 and from 10 July to 22 July 1998, total counts of all murres in appropriate breeding habitat were conducted on GC1-GC4 and Outer Gannet Island. Suitable observation points were chosen on each island that allowed a good view of a distinct sub-section of the colony, while also providing sufficient cover that murres were only minimally disturbed by researchers. In some cases, it was possible to survey portions of one island from another. From one to three observers made counts, and all counts were either conducted by R. D. Elliot, or by observers trained by RDE. Counts were made during mid-day (0900h-1600h) as murre attendance patterns are most stable at this time (Birkhead and Nettleship 1980).

To relate the numbers of murres in breeding habitat with the actual number of breeding pairs, a correction factor (*k*) was calculated following Nettleship (1976, see

Section 2.2.2). Seven study plots (2 for Common Murres and 5 (only 3 in 1983) for Thick-billed Murres) were monitored every day on GC4 from 30 June - 28 July 1983 and every second day from 11 - 23 July 1998, roughly coinciding with the incubation period. Observations were conducted from mid-morning (after 0900h) to early afternoon (1400h). The number of breeding sites was counted by careful observation and by mapping known breeding sites on to detailed maps and photographs. These well-described study plots have been monitored intermittently since the early 1980s (Birkhead 1987abc, Bryant et al. 1999, Hipfner and Bryant 1999). One or two counts of the total number of murres on the study plot were made each day. Correction factors and associated 95% confidence intervals were calculated for each species. The bounds of 95 % confidence intervals (CI) were extracted from a *t* distribution with the degrees of freedom calculated as the number of plots monitored less 1. Breeding population size estimates for 1983 and 1998 were compared with t-tests, using the number of plots monitored as the sample size.

3.3 Results

3.3.1 1983

In 1983, 79 928 Common Murres and 1756 Thick-billed Murres were counted in breeding areas (Table 3.1). The correction factor (*k*) for Common Murres was calculated at 0.7611 ± 0.0095 (0.6404 – 0.8818; 95% CI, n = 2 plots) and for Thick-billed Murres at 0.8045 ± 0.0094 (0.7640 – 0.8450, n = 3 plots). Using these correction factors we estimate that in the Gannet Cluster 37 155 pairs (31 300 – 43 011; 95% CI) of Common Murres bred in 1983, and on Outer Gannet 23 734 pairs (19 970 – 27 498), for a total of 60 889 (51 270 – 70 510) breeding pairs. For Thick-billed Murres, we estimate that 946 pairs (899 – 992) bred in the Gannet Cluster and 471 pairs (448 – 495) bred on Outer Gannet for a total of 1417 (1347 – 1488) breeding pairs (Table 3.1).

3.3.2 1998

In all we counted 41 053 Common Murres and 2 705 Thick-billed Murres in 1998 (Table 3.1). The correction factor for Common Murres was calculated at 0.8940 ± 0.0101 (0.8505 – 0.9375, n = 2 plots), and for Thick-billed Murres 0.7012 (0.6768 – 0.7256, n = 5 plots). Using these correction factors, we estimate that in the Gannet Cluster 19 360 pairs (18 419 – 20 302; 95% CI) of Common Murres bred in 1998, and on Outer Gannet 17 342 pairs (16 499 – 18 185), for a total of 36 702 (34 918 – 38 486) breeding pairs. For Thick-billed Murres, we estimate that 1337 pairs (1291 – 1384) bred in the Gannet Cluster and 560 pairs (541 – 580) bred on Outer Gannet for a total of 1897 (1831 – 1964) breeding pairs.

3.3.3 Comparisons between 1983 and 1998

The number of Common Murres breeding in the Gannet Clusters declined significantly by 47.9% (t = 44.1, d.f. = 1, P < 0.001) and by 26.9% on Outer Gannet (t = 22.4, d.f. =1, P = 0.002), from 1983 to 1998. In contrast, the numbers of Thick-billed Murres increased significantly in the Gannet Clusters by 41.3% (t= 26.5, d.f. = 6, P < 0.001) and by 18.9% on Outer Gannet (t = 13.4, d.f. = 6, P < 0.0001) between 1983 and 1998.

Changes also occurred in the distribution of breeding murres. In 1983, 49% of Common Murres in the cluster bred on GC1; this ratio increased to 61% by 1998 (Table 3.1). Conversely, the proportion of murres on GC3 was 39% of the breeding population in 1983, but only 22% by 1998 (Table 3.1). Most Thick-billed Murres bred on GC-4 (74% in 1983 and 71% in 1998). No murres were found breeding on GC-2 in 1998.

3.4 Discussion

3.4.1 Common Murres

Our most recent estimate for the total population size of Common Murres breeding in the Gannet Islands is about 37 000 pairs. Common Murre populations in the Northwest Atlantic were greatly reduced by the turn of the century, mostly due to overhunting and egg collection (Tuck 1961, Nettleship and Evans 1985). Since then, populations have begun to recover in some locations. Populations in insular Newfoundland have enjoyed spectacular increases, with some colonies showing increases in orders of magnitude within 10-20 years (Tuck 1961, Nettleship and Evans 1985). Populations in the Gulf of St. Lawrence have also increased (Chapdelaine 1995), but at slower rates and to only relatively small levels compared with populations thought to be present in the 1800s (Nettleship and Evans 1985). Common Murres in Labrador, and specifically the Gannet Islands, have increased in the first part of the twentieth century (Austin 1932, Tuck 1961, Birkhead and Nettleship 1987a), peaking at 61 000 pairs by 1983 (Table 3.2). Subsequently, it appears that breeding population of Common Murres on the Gannet Islands has declined to 37 000 pairs by 1998. This apparent decline may be caused by a number of factors. Although we corrected for attendance rates, we only collected correction factors from a few plots on one of the five islands surveyed. Plots that are close together may show the same patterns, while plots further away may show different attendance patterns (Piatt and McLagan 1987). If our estimate of the correction factor is not representative of the colony, it is possible that our 1998 population size estimate could be biased low. However, our estimate of the correction factor for 1998 was 0.89, appreciably higher than the value for 1983 (0.76). Older prospecting Common Murres (3+ years) are also present in breeding areas (Halley et al. 1995). Most of the variation in attendance patterns is driven by numbers of pre-breeding and prospecting birds, not attendance patterns by breeding adults (Gaston and Nettleship 1982, Hatch and Hatch 1989). Gaston and Nettleship (1982) showed that fewer prospectors attend the colony in years with poor food availability. Therefore, the high correction factors (i.e. low number of prospectors) in 1998 may reflect a year of poor food availability or a low absolute number of prospecting birds. Bryant et al. (1999) documented that the amount of time adults spent at the colony between foraging trips in 1997 was relatively low compared to other studies, suggesting that Common Murres were foraging at a relatively high intensity and food abundance may have been low. However, all other aspects of their reproductive ecology suggested that murres were not food-stressed in 1997 (Bryant et al. 1999). Therefore, if numbers of prospecting birds were low, this could reflect poor foraging years in the late 1990s or a real numerical absence of this prospecting cohort. Hipfner and Bryant (1999) also documented low numbers of pre-breeding and prospecting Common Murres at the Gannet Islands, suggesting that recruitment may have been low for Common Murres in the mid-1990s.

Arctic foxes were present on the Gannet Islands through most of the 1990s (Birkhead and Nettleship 1995, Appendix 1), apparently causing widespread reproductive failure of murres and likely lowering the number of recruits available. Further, water temperatures in the Northwest Atlantic were colder than average through the early 1990s, and prey distributions changed (Bryant et al. 1999). In the early 1980s, Common Murre chicks were fed mostly capelin, while in 1996-1997 chicks were fed mostly daubed shanny (*Lumpenus maculatus*) (Birkhead and Nettleship 1987c, Bryant et al. 1999). In spite of the differences in chick diet, no differences in breeding success, chick growth or adult mass were found (Bryant et al. 1999). Therefore, it does not appear that production to the fledging stage in the late 1990s has been low in recent years at the Gannet Islands. Little is known about post-fledging survival rates, which may have been has been reduced by unknown factors. Changes have also occurred in the winter diet of murres in Newfoundland waters from 1984-1986 to 1996-1998 (Elliot et al. 1990, Rowe et al. 2000). Murres consumed similar proportions of fish, but less Arctic cod (*Boreogadus saida*) and capelin were in the diet. Among the crustaceans, euphasiids replaced hyperiid amphipods in the diet (Rowe et al. 2000).

Overall, it is not possible to definitively explain the apparent reduction in the breeding population of Common Murres on the Gannet Islands. In contrast to our surveys, for the one long-term plot on GC4 that had been monitored in 1981 and 1996, Common Murre numbers increased in from 101 to 121 (Bryant et al. 1999). Additionally, some areas occupied by Common Murres in the late 1990s were not used in the early 1980s (M. Hipfner, pers. comm.). Future surveys will assist in resolving whether the breeding population is truly reduced or if other factors created low apparent breeding numbers in 1998.

During surveys of other species on GC5, we discovered at least one site that contained nesting Common Murres. Most were nesting under very larger boulders and in crevices, which were difficult to see unless examined from the ground. We guess that no more than 500 Common Murres bred on GC5 in 1998, so our overall estimate for the population should not be biased too low. However, future surveys should include counts on GC5, as any expansion in the breeding population may occur at this peripheral site.

On colonies in Groswater Bay, 75 km northwest of the Gannet Islands, Common Murre populations have modestly increased between 1978 and 2002 (Robertson et al. 2002a). The large Common Murre colony on Funk Island, Newfoundland has stabilized at 300 000 - 400 000 breeding pairs in the last 40 years (Tuck 1961, Birkhead and Nettleship 1980, G. J. Robertson, J. W. Chardine and P. C. Ryan, unpubl. data), while the large colony on Green Island in Witless Bay appears to continue to increase, J. W. Chardine, unpubl. data, J. O'Brien pers. comm.). Overall, population trends for Common Murres in the Northwest Atlantic appear mixed.

3.4.2 Thick-billed Murres

Although the number of breeding Thick-billed Murres on the Gannet Islands is very small compared to other colonies (1 300 versus 10s to 100s of thousands; Nettleship and Evans 1985, Gaston and Hipfner 2000), their numbers appear to be increasing since the 1950s (Birkhead and Nettleship 1987a, Table 3.2). Even though this a southerly colony for this species, small pockets of Thick-billed Murres breed still further south in insular Newfoundland and in the Gulf of St. Lawrence (Cairns et al. 1989, Gaston and Hipfner 2000), so this colony probably lies within the normal range for this Arctic species. The cold water events in the North Atlantic may have had the opposite impact on Thick-billed Murres than on Common Murres. In terms of chick feeding, Thick-billed Murres responded in a similar way to Common Murres, and fed their chicks more daubed shanny in the 1990s (Bryant et al. 1999). In contrast, *k*-values for Thick-billed were low, and large numbers of pre-breeding murres were seen on the colonies later in the breeding season, suggesting an increasing colony with high recruitment (Hipfner and Bryant 1999). Interestingly, of Common and Thick-billed Murres, and Razorbills, Thick-billed Murres showed the lowest breeding success in 1997 (Hipfner and Bryant 1999). Low breeding success is expected in colonies with high recruitment rates (de Forest and Gaston 1996) due to the large numbers of inexperienced breeders which may chose poor breeding sites (Gilchrist et al. 1994). High survival of post-fledging young and adults may offset this lower breeding success.

Other Thick-billed Murre populations appear to be stable or increasing in Labrador (Robertson et al. 2002a) and the eastern Canadian Arctic (Gaston et al. 1993, Gaston 1999, 2002). A significant hunt of Thick-billed Murres occurs in Newfoundland and Labrador (Elliot et al. 1991) and chronic mortality caused by oil pollution is a persistent problem (Wiese and Ryan 1999). Hunting mortality was reduced in the 1990s and is now on the order of 250 000 to 300 000 birds taken annually (Chardine et al. 1999), while chronic oil pollution is estimated to have killed between 160 735 and 274 877 Thick-billed Murres annually in the winters of 1998 to 2000 in southern Newfoundland (Wiese 2002). In spite of these impacts, Thick-billed Murre populations are increasing in the Gannet Islands.

3.4.3 *Conclusion*

Murres are internationally recognized as an important species among circumpolar countries. International (Anon. 1996) and national plans (Chardine and Elliot 2000) have been completed and a variety of activities are ongoing to aid in worldwide murre conservation.

Murres have long played important roles in the history of Newfoundland and Labrador (Tuck 1961). Traditionally used as a food source in winter months, murre hunting is still an important recreational activity in Newfoundland waters (Elliot 1991, Chardine et al. 1999). Recently, significant tour boat operations have developed around some sea bird colonies in Newfoundland, providing substantial income to coastal communities. With the continuous changes occurring in the Northwestern Atlantic marine ecosystem, and the ecological and socio-economical importance of murres, their populations need to be monitored closely.

4. Atlantic Puffins

4.1 Introduction

The Atlantic Puffin is a common seabird nesting throughout the north Atlantic. Recent estimates place the world population at 5 - 10 million breeding pairs, with over half breeding in Iceland (Gaston and Jones 1998). Populations in Norway have shown dramatic declines due to low recruitment caused by collapse in herring (*Clupea harengus*) stocks (Anker-Nilssen and Røstad 1993), while populations in Scotland have remained stable or have increased in recent years (Harris and Rothery 1988, Harris et al. 1997). In North America, there are about 375 000 breeding pairs (Chardine 1999) and over half of these breed in Witless Bay, Newfoundland (Rodway et al. 1996). After suffering serious declines in the late 1800s, puffin numbers in North America appear to be stable or increasing in recent years (Nettleship and Evans 1985, Chapdelaine 1995, Rodway et al. 1996).

The Gannet Islands is the largest colony in Labrador. It was surveyed in 1978, 1983 and 1984 but the methods and detailed results have yet to be published. Preliminary analyses of these data suggest the colony to be in the neighbourhood of 33 000 to 42 000 breeding pairs (Birkhead and Nettleship 1987a, Lock et al. 1994). Here we provide a recent (1999-2000) estimate for the breeding population of Atlantic Puffins in the Gannet Islands and to compare these estimates with those from the 1970s and early 1980s.

4.2 Methods

Surveys to estimate the number of breeding puffins were conducted in the summers of 1978, 1983, 1984, 1999 and 2000. Methodologies were slightly different in the first year (1978), however, the basic method used throughout involved counting the number of puffin holes on all islands and estimating the occupancy rates of these holes (Nettleship 1976). For this paper, we define a hole as any suitable entrance that could lead to a puffin burrow, when assessed by an observer standing up (i.e. not kneeling down to look in the hole). A burrow is defined as a suitable tunnel that could house a pair of breeding puffins, and does not include unsuitably short holes, or additional entrances to a burrow.

Total hole counts of the Gannet Islands were conducted in 1978, 1983 and 1999-2000. Using total hole counts, rather than estimating densities of occupied burrows and extrapolating to the area of the colony, removes biases associated with uneven burrow densities across the breeding colony. Unlike other colonies, total hole counts were feasible on the Gannet Islands, as the nesting islands are not too large, and the topography not too steep. Each island was divided into manageable sections, usually using prominent landmarks, and the number of holes in each was counted. Ropes were used to delimit the extent of the section being counted. Survey teams walked in parallel formation, about 5 - 20 m apart, and counted holes to one side of them. Another rope was laid out at the edge of each transect and the team member at the edge of the transect counted up to the rope. Once a transect was complete, team members moved to the other side of the rope, laid out another rope at the upper edge of the transect, and proceeded to count all holes in this transect. This was repeated until all holes were counted in a section. In rare cases, holes were counted visually, especially in areas that were too steep to safely walk or where habitat was severely degraded and burrows would inevitably collapse. Fortunately, counting holes in these cases is relatively easy, as vegetation is sparse.

Hole occupancy rates were assessed by grubbing (reaching into the hole as far as possible, using a 30-40 cm stick or spoon to extend reach if necessary) in randomly placed plots. In 1978, 5 m by 5 m square plots were placed in suitable breeding habitat (Nettleship 1976). In 1983 and onward, plot locations were chosen by constructing a grid on a map of each island and by selecting locations based on randomly generated pairs of numbers. Only locations that fell in suitable habitat were selected and extra locations were selected beyond the number needed. All locations were marked on maps and taken to the field. In some cases a chosen plot location was either on a slope too steep to safely grub or too close to breeding murres. In these cases it was replaced with one of the extra random locations. A 1 m long PVC pole, with the plot number inscribed, was placed at the center of the plot. A 30 m^2 circular plot was drawn on the ground by using a can of spray paint attached to a rope 3.09 m long. Our intention was to set up systematically monitored plots rather than randomly selected plots (Savard and Smith 1985), but as most survey stakes laid out in 1983 had been removed by 1999, we randomly selected another set of plots.

For all five survey years, each hole in all plots was assessed for puffin occupancy, with holes on the edge of the plot alternately included and excluded. The contents of each occupied hole were recorded as *definitely occupied* (containing an egg or chick and/or an adult puffin), or *most likely occupied* (nest material, nest down and/or chick feces present). Other categories included; holes *too short* to support a breeding pair (under 30 cm), holes that were *additional entrances* to another burrow, and burrows that were *empty*. The final category was *unknown*, these were usually very long burrows, although every attempt was made to determine the contents of long burrows. Plot were grubbed between 2 - 17 July in 1978, 2 - 27 September in 1983, 2 - 11 July in 1984, 20 July - 1 August in 1999 and 23 July 2000, corresponding to the incubation stage in all years but 1983, which was grubbed during chick-rearing.

Burrow occupancy rates were calculated as the number of *occupied* burrows (*definitely* and *likely* combined) divided by the number of *occupied* burrows plus the number of *empty* burrows. Hole occupancy rates were calculated as the number of *occupied* burrows divided by the sum of the number of *occupied* burrows, the number of *empty* burrows, the number of *additional entrances* and the number of burrows *too short* to support a breeding pair. To calculate island-wide occupancy rates each plot was weighted by the number of holes grubbed in the plot, therefore plots with greater number of holes contributed more to the calculation of mean rates. Standard errors were based on the number of plots grubbed (not the number of holes) on an island. Comparisons among rates were done with ANOVA, once again weighted by the number of holes in each plot. 95% confidence intervals were calculated based on the *t* distribution with degrees of freedom based on the number of plots grubbed less 1.

4.3 Results

4.3.1 Occupancy rates

Within the Gannet Clusters (GC1-GC6), there was a significant difference among burrow occupancy rates across years, after controlling for within-island differences ($F = 6.24$, d.f. = 2, 195, $P = 0.0024$). Student-Newman-Keuls post-hoc means tests showed that 1983 (0.833 ± 0.015) and 1984 (0.862 ± 0.015) were different from 1999 (0.791 ± 0.017). Burrow occupancy rates declined by 1999-2000 on all islands except for GC3 (Figure 4.1). The burrow occupancy rate for Outer Gannet Island was very low in 2000 (Figure 4.1).

Within the Gannet Clusters, there were also significant declines in hole occupancy rates across years, after controlling for within-island differences ($F = 16.3$, d.f. = 3, 214, $P = 0.0001$). All years differed from 1999, and there was no difference among 1978, 1983 and 1984 (Student-Newman-Keuls post hoc means test). GC1, GC2 and GC5 showed an increase in hole occupancy rates from 1978 to the mid-1980s, and then declined by 1999 (Figure 4.1). On the other hand, hole occupancy rates declined steadily on GC3 and GC4 from 1978 through 1999 (Figure 4.1). Once again, Outer Gannet had a very low hole occupancy rate in 2000.

4.3.2 *Holes and number of breeding pairs*

On most islands more holes were counted as time progressed (Figure 4.2), the exception being GC2, where the number of holes counted has declined (Figure 4.2, Table 4.1). In terms of estimated number of breeding pairs, each island seems to follow a different pattern (Figure 4.2). Islands GC1, GC5 and Outer Gannet showed an increase between 1978 and 1983-84, and then declined by 1999-2000, although the estimates for GC5 for 1983 and 1984 are very different and the 1999 population estimate for GC5 is slightly higher than the 1984 estimate (Figure 4.2). Estimated numbers on GC4 have steadily decreased. Estimated numbers for GC2 suggest little change between 1978 and 1983-84 and then a reduction by 1999. The estimates for GC3 and GC6 are relatively unchanged, with a slight increase in 1999 (Figure 4.2).

Overall, the number of Atlantic Puffins pairs breeding in the Gannet Clusters was estimated at 33 005 (27 976 – 38 034; 95 % CI) in 1978, 42 252 (37 328 – 47 176) in 1983, 39 573 (34 194 – 44 952) in 1984 and 34 612 (28 874 – 40 350) in 1999. On Outer Gannet, the number of Atlantic Puffins pairs breeding was estimated at 6342 (2839 - 9845; 95% CI) in 1978, 8399 (7545 – 8798) in 1983 and 4054 (2204 – 5904) in 2000.

4.4 Discussion

The number of breeding pairs of Atlantic Puffins on the Gannet Clusters has varied between 33 000 and 42 000 over the last 20 years, and 4000 – 8000 on Outer Gannet Island. Occupancy rates of holes and burrows have declined over time, in spite of the increase in the number of holes.

Populations of puffins along the coast of eastern North America were much reduced by the end of the 19th century (Nettleship and Evans 1985), but have increased steadily since. Information for recent trends is sparse for North America. In Groswater Bay, six colonies showed a mix of patterns, but overall a decline between 1978 and 2002 (Robertson et al. 2002a). Along the north shore of the Gulf of St. Lawrence, Québec, puffin numbers decreased from the 1930s to the 1970s (Chapdelaine 1980). Numbers have been increasing recently, but they have yet to return to previous levels (Chapdelaine 1995). It is difficult to ascertain trends at the colonies in Witless Bay, where survey methodologies have not been consistent (Nettleship 1972, Rodway et al. 1996). However, it does appear that these large colonies have not shown any reductions in the last 25 years and may be increasing (Rodway et al. 1996, Calvert and Robertson 2002).

Within the Gannet Islands, the breeding population appeared to have increased from 1978 to 1983-84 and then declined by 1999-2000. Most of this apparent decline comes from a reduction in the number of holes occupied, in spite in an increase in the number of hole entrances available. The reduction in hole occupancy rate is most likely related to increased numbers of entrances that do not lead to suitable burrows. Puffins substantially modify their habitat when building burrows, and breeding habitat can become very degraded. Colonies may be abandoned once the habitat has been degraded to the point where burrows are no longer stable (Harris 1984). The Gannet Islands has been supporting a substantial colony of breeding puffins for well over 25 years and probably the last 50 years (Nettleship and Evans 1985). Although the increased number of hole entrances suggests a decline in overall habitat quality as the dense breeding areas become honeycombed, there is still plenty of available habitat in the Gannet Islands. For example, GC6, the largest island, has extensive apparently suitable habitat that is not used (G. J. Robertson, pers. obs). Additionally, estimated numbers have increased on GC3, where burrow occupancy rates are the highest of all islands. This suggests that GC3 may be the most recently colonized, as the breeding habitat on GC3 does not appear as degraded as the other islands.

The sporadic appearance of terrestrial predators, notably Arctic foxes, may limit puffin numbers on the larger islands (Birkhead and Nettleship 1995). Further, the lower numbers of puffins estimated for 1999 may be a function of the poor breeding effort showed by puffins in the early 1990s when Arctic foxes were present (Birkhead and Nettlehship 1995, Appendix 1). The very low burrow and occupancy rates on Outer Gannet were probably due high rainfall in July 2000, as many burrows were found to be flooded while grubbing. Puffin eggs appeared consistently in the diet of Great Black-backed Gulls that month (B. G. Veitch, unpubl. data), and gulls can only regularly obtain puffin eggs if they have been washed out of burrows. Therefore, the breeding population estimate for Outer Gannet in 2000 is likely to be an underestimate as many puffins would have lost their eggs.

Baillie (2001) showed that puffins shifted to feeding chicks predominately capelin in the early 1980s to mostly sandlance in the late 1990s. In spite of this diet shift, reproductive success remained at similar levels, suggesting that puffins were able to adjust to changing prey distributions (Baillie 2001). Therefore, the change in population numbers between the early 1980s and the late 1990s is probably not related to shift in prey distributions as puffins were able to maintain reproductive output.

In 1983, occupancy rates were assessed in September during the late stages of chick rearing, rather than during incubation in July. Rodway et al. (1996) suggested that comparatively low population estimates for puffins in Witless Bay in 1979 were due to surveys assessing occupancy rates too late in the chick-rearing period. Breeders who failed to rear chicks would have abandoned their burrows, thus reducing the estimate of occupancy rate. However, as occupancy rates in 1983 were still high, it appears that the breeding population was high, and that 1983 was a good year for puffins attempting to breed. Regardless, the breeding puffin population on the Gannet Islands has remained relatively constant for the last 20 years at 33 000 to 42 000 pairs on the clusters and 4 000 to 8 000 on Outer Gannet. Monitoring of this important colony should continue to determine if the population is indeed declining, or whether shifts are occurring in distribution. Surveys of other nearby puffin colonies may show increases as the habitat on Gannet Islands changes and puffins shift to new islands.

5. Other species

5.1 Black Guillemot

Black Guillemots (*Cepphus grylle*) are not a common nesting species on the Gannet Islands, and it is difficult to accurately assess their breeding numbers. In 1983 permanent plots were established on GC2, one at the north end of the island, and one just northeast of the cabin. In 1983, 6 nests were in the northern plot, while 3 pairs nested near the cabin. In 1984, 4 pairs nested in northern plot, and by 1998 and 1999 only 2 pairs were nesting there. No pairs nested in the plot near the cabin in 1998 or 1999.

Nesting has been confirmed on GC5 (1983) and GC6 (1978). The large number of guillemots seen around GC6 is apparently not related to nesting birds (Table 5.1). Various unsystematic searches of this island have only revealed a handful of nests (2 in 1978, 0 in 1999). This may be a non-breeding or failed breeding population that attends GC6 in early summer, or a concentration of nesting sites has yet to be discovered. Black Guillemots are regularly sighted around Outer Gannet; a maximum of 13 in 1983, but nesting has yet to be confirmed.

5.2 Black-legged Kittiwake

In 1999, Black-legged Kittiwake (*Rissa tridactyla*) nests were counted from 18 - 21 July on the Gannet Clusters and on 4 August on Outer Gannet. Nest were counted if they were in good condition, and an adult, egg or chick were present on the nest. Nests were counted from a boat for GC1, GC3 and Outer Gannet, and from the ground on GC4.

The first documentation of kittiwakes breeding in Labrador was 16 nests on Outer Gannet in 1972 (Nettleship and Lock 1974). Kittiwake numbers then increased through the 1970s and early 1980s to 52-63 pairs in the clusters and 40-57 pairs on Outer Gannet (Birkhead and Nettleship 1988, Table 5.2). By 1999, numbers did not change greatly on either the clusters or Outer Gannet. However, the distribution of kittiwake nests has changed within the clusters. Prior to 1982, all nests in the clusters were on GC4. Three nests were built on GC1 in 1983 and five in 1984 (Birkhead and Nettleship 1988). By 1999, 16 nests were built on GC1 and 4 pairs nested on GC3.

Kittiwake numbers appear to have been low and stable from the mid-1980s to 1999. Although kittiwakes suffered low breeding success in 1984-1985 and 1996-1998 (Birkhead and Nettleship 1988, Hipfner et al. 2000), the population on the Gannet Islands appears able to maintain itself. However, the increases seen through the 1970s have ceased.

5.3 Great Black-backed Gull

Great Black-backed Gull nests were counted from 18 to 28 July 1999 on the Gannet Clusters and on 4 August 1999 on Outer Gannet Island. In most cases, nests were counted during other survey work. In some cases nests were not accessible, but if a pair of birds were consistently seen in an area, or chicks were subsequently sighted, we assumed they were a breeding pair. For Outer Gannet, where we could only count birds from a boat survey, we attempted to identify individuals or pairs defending a specific portion of the island.

In all, 25 nests were identified in the cluster, 10 pairs on GC1, 1 on GC2, 7 on GC3, 5 on GC4, 1 on GC5 and 1 on GC6. On the 4 August 1999 boat survey, we counted 10 individual birds on Outer Gannet, all appeared to be paired, so we estimate 5 Great Black-backed Gulls nested. Similar observations suggest that 10 pairs nested on Outer Gannet in 1983 (Birkhead and Nettleship 1987a).

Great Black-backed Gulls have not been closely monitored at the Gannet Islands in previous surveys. Estimates of about 100 breeding pairs exist for 1978 and 1983. In the early 1980s, some gulls were shot and poisoned to reduce predation on other seabirds, so part of the apparent decline may be due to culling. However, as no year-to-year decreases were detected then, longer-term trends may reflect the effects of Arctic fox predation in the early 1990s. Unlike Herring Gull (*Larus argentatus*) populations, which are declining in many jurisdictions (Chapdelaine and Rail 1997, Robertson et al. 2001), Great Black-Gull populations appear to be stable in Atlantic Canada (Robertson et al. 2001). Great Black-backed Gulls are also expanding their range, eastwards (Ewins et al. 1992) and northwards (S. G. Gilliland, unpublished data). Therefore, declines at the Gannet Islands appear to be a local effect.

5.4 Leach's Storm-petrel

Leach's Storm-Petrel were a rare breeding species in the Gannet Islands. Breeding was first confirmed in 1978 in the central part of GC2, where 9 occupied burrows were found and 12-15 breeding pairs were estimated. In 1983, this area was still used by breeding petrels. However, repeated checks of this region in 1998 and 1999 did not reveal any occupied burrows. Petrels were still heard calling in 1998 and 1999 at night, so they were present, but if breeding, it is in very low numbers. No petrels were found in any puffin burrow assessed in 1983 or 1999. In 1983, petrels were not heard on overnight stays on GC4 nor Outer Gannet, nor were they heard on east side of GC5 in 1999. Breeding was confirmed on GC6 in 1979 (E. Verspoor, unpubl. data).

Petrels are near the northern limit of their breeding range at the Gannet Islands, and this may represent marginal marine habitat for them. Petrel populations appear to be stable at major colonies in Newfoundland (Stenhouse et al. 2000, Robertson et al. 2002b), but smaller colonies, especially in the Maritimes, are suffering declines (Drury 1973,1974, Huntington et al. 1996, Robertson and Elliot 2002).

5.5 Northern Fulmar

Stenhouse and Montevecchi (1999) recently summarized information regarding Northern Fulmar (*Fulmaris glacialis*) populations in the northwest Atlantic, including the Gannet Islands. Breeding was first confirmed on Outer Gannet in 1972 (Nettleship and Lock 1973a). A correction to the information provided to Stenhouse and Montevecchi (1999) is that they list no breeding pairs in 1978 in the Gannet Clusters. In fact, 17 sites were occupied on GC2 (of which 2 were confirmed to contain eggs) and 2 sites were occupied on GC4.

The distribution of Northern Fulmars nesting in the Gannet Islands had shifted by 1998 and 1999. Instead of most of them nesting on GC2, most birds were found nesting on GC5, and in 1997 and 1999, fulmars were seen at sites on GC1 (Table 5.3). No nesting was seen on GC4 in 1998 or 1999. Overall, the numbers of occupied sites has apparently stabilized, or possibly decreased, from the mid-1980s to the late 1990s on the Gannet Islands.

5.6 Common Eider

There are no mentions of Common Eiders (*Somateria mollissima*) breeding on the Gannet Islands in 1978 or 1983 field notes. However, Birkhead (1993) mentions that in 1981 "GC3 was the major breeding area for several hundred pairs of Common Eiders." In 1998, breeding eiders were noted on several islands, and systematic searches were conducted in 1999, from 18 - 26 July. Seven nests were found on GC1, 2 nests on GC2, 24 nests on GC3, 3 nests on GC4. On 26 July 1999, GC6 was searched and no nests were found, however the island is large and nests could have been missed. GC5 was not systematically searched for nests, although like GC6, this large island would be difficult to survey. Overall 36 nests were found in 1999, and this certainly represents a minimum. Interestingly, field crews in 2000 noted large numbers of eiders nesting on the Gannet Islands (about 60 pairs), and they speculated that heavy ice in nearby Table Bay, a large eider colony, may have forced the birds to breed elsewhere.

Large numbers of moulting eiders were seen around GC6 on 18 July 1999, 517 eiders were counted, along with a brood. These birds could still fly, but many had begun the pre-basic moult. On 12 July 1998, 116 adult and 18 young eiders were counted around GC6.

5.7 Other breeding birds

Various other nesting species have been documented on the Gannet Islands. In 1978, nests of a White-crowned Sparrow (*Zonotrichia albicollis*), a Spotted Sandpiper (*Actitis macularia*) and a Water Pipit (*Anthus spinoletta*) were found on GC2. A pair of Common Ravens (*Corvus corax*) nested on GC2 and probably GC6 in 1978. Ravens were still nesting on GC2 on 1998 (but not 1999), and 1-2 pairs were seen on GC6. A Savannah Sparrow (*Passerculus sandwichensis*) nest was found on GC5 in 1999. Another commonly seen species is the Horned Lark (*Eremophila alpestris*), which was confirmed to nest in 1981 (Birkhead 1993).

6. Summary

The Gannet Islands remain a diverse seabird breeding colony with important concentrations of many species (Table 6.1). Most changes that have occurred in the breeding population of seabirds at the Gannet Islands since 1983 have not been dramatic. Increases in Razorbills and Thick-billed Murres contrast with declining or stable populations of puffins and Common Murres. If there is a single factor that may explain these trends, it is the reduction in numbers of capelin available to breeding birds in Labrador through the 1990s, caused by oceanographic changes. In general, populations of the traditional capelin-feeders (puffins, Common Murre and Black-legged Kittiwakes) are stable or possibly declining, while species that commonly feed on other species, such as Razorbills (feeding on sandlance) and Thick-billed Murres (feeding on shannies or Arctic cod) appear to be doing particularly well. Black Guillemots do not fit this pattern, as their numbers are stable or possibly lower, and they feed on nearshore benthic fishes. However, the guillemot population is so small, demographic stochasticity may play a large role. The absence of any major declines, in spite of a number of mortality factors known to impact these species is encouraging. Chronic oiling, hunting and bycatch appear not to have had major impacts on these populations in recent years. Additionally, the numbers of seabirds present suggest that the populations responded well after the major disruptions in nesting in 1992, and probably other years, caused by Arctic foxes.

These trends are only based on 3-5 data points in most cases, and only span intervals of about 20 years. Continued monitoring, coupled with ecological studies, will greatly assist us in understanding how seabirds respond to changes in their environment in Labrador, and across their range.

7. Acknowledgments

For assistance in the field we thank R. Odense and T. R. Birkhead in 1978, A. MacFarlane in 1983, and P. Adams, S. Bin Muzzafar, M. Button, J. Cotter, J. Dussureault, S. Rowe and B. Veitch in 1998-2000. This study was funded by the Canadian Wildlife Service and we received considerable logistical support from D. N. Nettleship and Petro-Canada in 1983 and I. L. Jones, ACWERN (Atlantic Cooperative Wildlife Ecology Research Network) and the Memorial University of Newfoundland for the 1998-2000 surveys. H. Carter (Government of Newfoundland and Labrador) and R. Cahill of Labsea Logistics provided logistical support and organized charters from Cartwright. J. Hancock provided information on the legislative status of the Gannet Islands Seabird Ecological Reserve. We thank the Parks and Natural Areas Division, Department of Tourism, Culture and Recreation of the Government of Newfoundland and Labrador for permission to work on the Gannet Islands Seabird Ecological Reserve. Finally, we thank M. Hipfner for providing helpful comments on an earlier draft of this manuscript.

8. Literature Cited

Adams, P. A., G. J. Robertson and I. L. Jones. 2000. Time-activity budgets of Harlequin Ducks molting in the Gannet Islands, Labrador. Condor 102: 703-708.

Ainley, D. G., and J. T. Lewis. 1974. The history of Farallon Island marine bird populations, 1854-1972. Condor 76: 432-446.

Anker-Nilssen, T., and O. W. Røstad. 1993. Census and monitoring of puffins *Fratercula arctica* on Røst, N. Norway. Ornis Scand. 24: 1-9.

Anonymous. 1996. CAFF international murre conservation strategy and action plan. Conservation of Arctic Flora and Fauna, Akureyri, Iceland.

Austin, O. L., Jr. 1932. The birds of Newfoundland-Labrador. Memoirs of the Nuttall Ornithological Club 7: 1-229.

Baillie, S. M. 2001. Atlantic Puffin response to changes in capelin abundance in Newfoundland and Labrador: an inter-colony and inter-decade comparison. M. Sc. thesis. Memorial Univ. Newfoundland. St. John's, NF.

Bédard. J. 1969. Histoire naturelle du Gode *Alca torda* dans le Golfe St. Laurent, province de Québec, Canada. Can. Wildl. Serv. Rep. Ser. No. 7. Ottawa, ON.

Birkhead, T. R. 1993. Great Auk Islands. T & AD Poyser, London.
Birkhead, T. R., and D. N. Nettleship. 1980. Census methods for murres, *Uria* species: a unified approach. Can. Wildl. Serv. Occas. Pap. No. 43. Ottawa, ON.
Birkhead, T. R., and D. N. Nettleship. 1984. Egg size, composition and offspring quality in some Alcidae (Aves: Charadriiformes). J. Zool. (Lond.). 202: 177-194.
Birkhead, T. R., and D. N. Nettleship. 1987a. Ecological relationships between Common Murres, *Uria aalge*, and Thick-billed Murres, *Uria lomvia*, at the Gannet Islands, Labrador. I. Morphometrics and timing of breeding. Can. J. Zool. 65: 1621-1629.
Birkhead, T. R., and D. N. Nettleship. 1987b. Ecological relationships between Common Murres, *Uria aalge*, and Thick-billed Murres, *Uria lomvia*, at the Gannet Islands, Labrador. II. Breeding success and site characteristics. Can. J. Zool. 65: 1630-1637.
Birkhead, T. R., and D. N. Nettleship. 1987c. Ecological relationships between Common Murres, *Uria aalge*, and Thick-billed Murres, *Uria lomvia*, at the Gannet Islands, Labrador. III. Feeding ecology of the young. Can. J. Zool. 65: 1638-1649.
Birkhead, T. R., and A. J. del Nevo. 1987. Egg formation and the pre-laying period of the Common Guillemot *Uria aalge*. J. Zool. (Lond.). 211: 83-88.
Birkhead, T. R., and D. N. Nettleship. 1988. Breeding performance of Black-legged Kittiwakes, *Rissa tridactyla*, at a small, expanding colony in Labrador. Can Field-Nat. 102: 20-24.
Birkhead, T. R., and D. N. Nettleship. 1995. Arctic fox influence on a seabird community in Labrador: a natural experiment. Wilson Bull. 107: 397-412.
Birkhead, T. R., S. D. Johnson and D. N. Nettleship. 1985. Extra-pair matings and mate guarding in the common murre *Uria aalge*. Anim. Behav. 33: 608-619.
Birkhead, T. R., S. D. Johnson and D. N. Nettleship. 1986. Field observations of a possible hybrid murre *Uria aalge* X *Uria lomvia*. Can Field-Nat. 100: 115-117.
Bourne, W. R. P. 1976. Seabirds and oil pollution. Pages 403-502 *in* R. Johnston (ed.), Marine pollution. Academic Press, London.
Brown, R. G. B., D. N. Nettleship, P. Germain, C. E. Tull and T. Davis. 1975. Atlas of eastern Canadian seabirds. Can. Wild. Serv., Ottawa, ON.
Bryant, R., and I. L. Jones. 1999. Food resource use and diet overlap of Common and Thick-billed Murres at the Gannet Islands, Labrador. Waterbirds 22: 392-400.
Bryant, R., I. L. Jones and J. M. Hipfner. 1999. Responses to changes in prey availability by Common Murres and Thick-billed Murres at the Gannet Islands, Labrador. Can. J. Zool. 77: 1278-1287.
Byrd, G. V., E. C. Murphy, G. W. Kaiser, A. Y. Kondratyev and Y. V. Shibaev. 1993. Status and ecology of offshore fish-feeding alcids (murres and puffins) in the North Pacific. Pages 176-186 *in* K. Vermeer, K.T. Briggs, K.H. Morgan and D. Siegel-Causey (eds.), The status, ecology and conservation of marine birds of the North Pacific. Can. Wildl. Serv. Spec. Publ. Ottawa, ON.
Cairns, D. 1979. Censusing hole-nesting auks by visual counts. Bird-Banding 50: 358-364.
Cairns, D. 1987. Seabirds as monitors of marine food supplies. Biol. Oceanogr. 5: 261-271.
Cairns D. K., W. A. Montevecchi and W. Threlfall. 1989. Researcher's guide to Newfoundland seabird colonies. 2nd Edition. Memorial Univ. Newfoundland Occasional Papers in Biology, No 14. St. John's, NF.
Calvert, A. M., and G. J. Robertson. 2002. Using multiple abundance estimators to infer population trends in Atlantic puffins. Can. J. Zool. 80: 1014-1021.

Chapdelaine, G. 1980. Onzième inventaire et analyse des flucuations des populations d'oiseaux marin dans les refuges de la Côte Nord du Golfe Saint-Laurent. Can. Field-Nat. 94: 34-42.

Chapdelaine, G. 1995. Fourteenth census of seabird populations in the sanctuaries of the north shore of the Gulf of St. Lawrence, 1993. Can. Field-Nat. 109: 220-226.

Chapdelaine, G. 1997. Pattern of recoveries of banded Razorblls (*Alca torda*) in the western Atlantic and survival rates of adults and immatures. Colon. Waterbirds 20: 47-54.

Chapdelaine, G., and P. Laporte. 1982. Population, reproductive success, and analysis of contaminants in Razorbills (*Alca torda*) in the estuary and Gulf of St. Lawrence, Québec. Can. Wildl. Serv. Prog. Notes No. 129. Ottawa, ON.

Chapdelaine, G., and P. Brousseau. 1984. Douzième inventaire des population d'oiseaux marins dans les refuges de la Côte-Nord du golfe du Saint-Laurent. Can. Field-Nat. 98: 178-183.

Chapdelaine, G., and P. Brousseau. 1991. Thirteenth census of seabird populations in the sanctuaries of the north shore of the Gulf of St. Lawrence, 1982-1988. Can. Field-Nat. 105: 60-66.

Chapdelaine, G., and P. Brousseau. 1996. Diet of Razorbill *Alca torda* chicks and breeding success in the St. Mary's Islands, Gulf of St. Lawrence, Québec, Canada, 1990-1992. Pages 27-37 *in* W.A. Montevecchi (ed.), Studies of high latitude seabirds. 4. Trophic relationships and energetics of endotherms in cold ocean systems. Can. Wildl. Serv. Occ. Pap. Ser. No. 91. Ottawa, ON.

Chapdelaine, G., and J.-F. Rail. 1997. Relationship between cod fishery activity and the population of herring gulls on the North Shore of the Gulf of St. Lawrence, Québec, Canada. ICES J. Mar. Sci. 54: 708-713.

Chapdelaine, G., A. W. Diamond, R. D. Elliot and G. J. Robertson. 2001. Status and population trends of the Razorbill in eastern North America. Can. Wildl. Serv. Occ. Pap. No. 105. Ottawa, ON.

Chardine, J. W. 1999. Population status and trends of the Atlantic Puffin in North America. Bird Trends 7: 15-17.

Chardine, J. W., and R. D. Elliot. 2000. Canadian murre conservation plan: 2000-2005. Can. Wildl. Serv. Seabird Tech. Ctee. Rep. No. 2. Atlantic Region, Sackville, NB.

Chardine, J. W., B. T. Collins, R. D. Elliot, H. Lévesque and P. C. Ryan. 1999. Trends in the annual harvest of murres in Newfoundland and Labrador. Bird Trends 7: 11-14.

de Forest, L. H., and A. J. Gaston. 1996. The effect of age in timing of breeding and reproductive success in the Thick-billed Murre. Ecology 77: 1501-1511.

Drury, W. H. 1973. Population changes in New England seabirds. Bird-banding 44: 267-313.

Drury, W. H. 1974. Population changes in New England seabirds. Bird-banding 45: 1-15.

Elliot, R. D. 1991. The management of the Newfoundland turr hunt. Pages 29-35 *in* A.J. Gaston and R.D. Elliot (eds.), Studies of high-latitude seabirds. 2. Conservation of Thick-billed Murres in the Northwest Atlantic Can. Wildl. Serv. Occ. Pap. No. 69. Ottawa, ON.

Elliot, R. D., P. C. Ryan and W. W. Lidster. 1990. The winter diet of Thick-billed Murres in coastal Newfoundland waters. Stud. Avian Biol. 14: 125-138.

Elliot, R. D., B. T. Collins, E. G. Hayakawa and L. Métras. 1991. The harvest of murres in Newfoundland from 1977-1978 to 1987-88. Pages 36-44 *in* A.J. Gaston and R.D. Elliot (eds.), Studies of high-latitude seabirds. 2. Conservation of Thick-billed Murres in the Northwest Atlantic Can. Wildl. Serv. Occ. Pap. No. 69. Ottawa, ON.

Evans, P. G. H., and K. Kampp. 1991. Recent changes in Thick-billed Murre populations in West Greenland. Pages 7-14 *in* A.J. Gaston and R.D. Elliot (eds.), Studies of high-latitude seabirds. 2. Conservation of Thick-billed Murres in the Northwest Atlantic Can. Wildl. Serv. Occ. Pap. No. 69. Ottawa, ON.

Ewins, P. J., H. Blokpoel and J. P. Ludwig. 1992. Recent extensions of the range of Great Black-backed Gulls, *Larus marinus*, in the Great Lakes of North America. Ont. Birds 10: 64-71.

Falk, K., and J. Durinck. 1991. The by-catch of Thick-billed Murres in salmon drift nets off West Greenland in 1988. Pages 23-28 *in* A.J. Gaston and R.D. Elliot (eds.), Studies of high-latitude seabirds. 2. Conservation of Thick-billed Murres in the Northwest Atlantic Can. Wildl. Serv. Occ. Pap. No. 69. Ottawa, ON.

Furness, R. W., and D. G. Ainley. 1984. Threats to seabird populations presented by commercial fisheries. Pages 701-708 *in* J.P. Croxall, P.G.H. Evans and R. W. Schreiber (eds.), Status and conservation of the world's seabirds. ICBP Tech. Publ. No. 2. Cambridge, UK.

Gaston, A. J. 1999. Trends in Thick-billed Murre populations in the eastern Canadian Arctic. Bird Trends 7: 7-11.

Gaston, A. J. 2002. Studies of high-latitude seabirds. 5. Monitoring Thick-billed Murres in the eastern Canadian Arctic, 1976-2000. Can. Wildl. Serv. Occ. Pap. No. 106. Ottawa, ON.

Gaston, A. J., and D. N. Nettleship. 1982. Factors determining seasonal changes in attendance at colonies of the Thick-billed Murre *Uria lomvia*. Auk 99: 468-473.

Gaston, A. J., and I. L. Jones. 1998. The Auks. Oxford University Press, Oxford, UK.

Gaston, A. J., and J. M. Hipfner. 2000. Thick-billed Murre *Uria lomvia*. Pages 1-32 *in* A. Poole and F. Gill (eds.), The Birds of North America, No. 497. The Birds of North America, Inc. Philadelphia, PA.

Gaston, A. J., L. N. de Forest, G. Gilchrist and D. N. Nettleship. 1993. Monitoring Thick-billed Murre populations at colonies in northern Hudson Bay. Can. Wildl. Serv. Occ. Pap. No. 80, Ottawa, ON.

Gilchrist, H. G., L. N. de Forest and A. J. Gaston. 1994. Age and breeding site selection in Thick-billed Murres: effects of vulnerability to predation by Glaucous Gulls. J. Ornithol. 135: 382.

Gilliland, S. G., G. J. Robertson, M. Robert, D. Amirault, J.-P. L. Savard, P. Laporte and P. Lamothe. 2002. Abundance and distribution of Harlequin Ducks molting in eastern Canada. Waterbirds 25: 333-339.

Halley, D. J., M. P. Harris and S. Wanless. 1995. Colony attendance patterns and recruitment in immature Common Murres (*Uria aalge*). Auk 112: 947-957.

Harris, M. P. 1984. The Puffin. T & A.D. Poyser. London, UK.

Harris, M. P. 1991. Population changes in British Common Murres and Atlantic Puffins, 1969-88. Pages 52-58 *in* A.J. Gaston and R.D. Elliot (eds.), Studies of high-latitude seabirds. 2. Conservation of Thick-billed Murres in the Northwest Atlantic Can. Wildl. Serv. Occ. Pap. No. 69. Ottawa, ON.

Harris, M. P., and P. Rothery. 1988. Monitoring of puffin burrows on Dun, St Kilda, 1977-1987. Bird Study 35: 97-99.

Harris, M. P., and S. Wanless. 1989. The breeding biology of Razorbills *Alca torda* on the Isle of May. Bird Study 36: 105-114.

Harris, M. P., S. N. Freeman, S. Wanless, B. J. T. Morgan and C. V. Wernham. 1997. Factors influencing the survival of Puffins *Fratercula arctica* at a North Sea colony over a 20-year period. J. Avian Biol. 28: 287-295.

Harris, M. P., S. Wanless and P. Rothery. 2000. Adult survival rates of Shag *Phalacrocorax aristotelis*, Common Guillemot *Uria aalge*, Razorbill *Alca torda*, Puffin *Fratercula arctica*, and Kittiwake *Rissa tridactyla* on the Isle of May 1986-1997. Atlantic Seabirds 2: 133-150.

Hatch, S. A., and M. A. Hatch. 1989. Attendance patterns of murres at breeding sites: implications for monitoring. J. Wildl. Manage. 53: 483-493.

Hipfner, J. M. 2000. The effect of egg size on post-hatching development in the Razorbill: an experimental study. J. Avian Biol. 31: 112-118.

Hipfner, J. M., and R. Bryant. 1999. Comparative breeding biology of guillemots *Uria* spp. and Razorbills *Alca torda* at a colony in the Northwest Atlantic. Atlantic Seabirds 1: 121-134.

Hipfner, J. M., and A. J. Gaston. 1999. Timing of nest departure in the Thick-billed Murre and Razorbill: tests of Ydenberg's model. Ecology 80: 587-596.

Hipfner, J. M., and J. Dussureault. 2002. The occurrence, size and composition of Razorbill nest structures. Wilson Bull. 445-448.

Hipfner, J. M., and G. Chapdelaine. 2002. Razorbill *Alca torda*. Pages 1-36 *in* A. Poole and F. Gill (eds.), The Birds of North America, No. 635. The Birds of North America, Inc. Philadelphia, PA.

Hipfner, J. M., A. J. Gaston, D. Martin and I. L. Jones. 1999. Seasonal declines in replacement egg-laying in a long-lived, Arctic seabird: costs of late breeding or seasonal variation in female quality? J. Anim. Ecol. 68: 988-998.

Hipfner, J. M., A. J. Gaston, D. L. Martin and I. L. Jones. 2000. Seasonal declines in incubation periods of Brünnich's Guillemots *Uria lomvia*: testing proximate causes. Ibis 142: 92-98.

Hipfner, J. M., P. A. Adams and R. Bryant. 2000. Breeding success of Black-legged Kittiwakes, *Rissa tridactyla*, at a colony in Labrador during a period of low capelin, *Mallotus villosus*, availability. Can. Field-Nat. 114: 413-416.

Hipfner, J. M., A. J. Gaston and A. E. Storey. 2001. Nest-site safety predicts the relative investment made in first and replacement eggs by two long-lived seabirds. Oecologia 129: 234-242.

Hudson, P. J. 1985. Population parameters for the Atlantic Alcidae. Pages 233-261 *in* D.N. Nettleship and T.R. Birkhead (eds.), The Atlantic Alcidae. Academic Press, London, UK.

Huntington, C. E., R. G. Butler and R. A. Mauck. 1996. Leach's Storm-petrel, *Oceanodroma leucorhoa*. Pages 1-32 *in* A. Poole and F. Gill (eds.), The Birds of North America, No. 233. The Birds of North America, Inc., Philadelphia, PA.

Jones, I. L. 1992. Colony attendance of Least Auklets at St. Paul Island, Alaska: implications for population monitoring. Condor 94: 93-100.

Lloyd, C. S. 1975. Timing and frequency of census counts of cliff-nesting auks. British Birds 68: 507-513.

Lloyd, C. S., and C. M. Perrins. 1977. Survival and age at first breeding in the Razorbill (*Alca torda*). Bird-banding 48: 239-252.

Lloyd, C. S., M. L. Tasker and K. Partridge. 1991. The status of seabirds in Britain and Ireland. T and AD Poyser, London, UK.

Lock, A. R., R.G.B. Brown and S. H. Gerriets. 1994. Gazetteer of marine birds in Atlantic Canada. Canadian Wildlife Service, Sackville, NB.

Muzzafar, S. B. 2001. Ectoparasites of auks (Alcidae) at the Gannet Islands, Labador: diversity, ecology and host-parasite interactions. M. Sc. thesis, Memorial University of Newfoundland. St John's, NF.

Moisan, G., and R. W. Fyfe. 1967. Ninth census of non-passerine birds in the sanctuaries of the north shore of the Gulf of St. Lawrence. Can. Field-Nat. 81: 67-70.

Monaghan, P. 1992. Seabirds and sandeels: the conflict between exploitation and conservation in the northern North Sea. Biodiversity Conserv. 1: 98-111.

Nettleship, D. N. 1972. Breeding success of the Common Puffin (*Fratercula arctica* L.) on different habitats at Great Island, Newfoundland. Ecol. Monogr. 42: 239-268.

Nettleship, D. N. 1976. Census techniques for seabirds of Arctic and eastern Canada. Can. Wildl. Serv. Occ. Pap. Ser. No 25. Ottawa, ON.

Nettleship, D. N., and A. R. Lock. 1973a. Observations of Fulmars on ledges in Labrador. Can. Field-Nat. 87: 314.

Nettleship, D. N., and A. R. Lock. 1973b. Tenth census of seabirds in the sanctuaries of the north shore of the Gulf of St. Lawrence. Can. Field-Nat. 87: 395-402.

Nettleship, D. N., and A. R. Lock. 1974. Black-legged Kittiwakes breeding in Labrador. Auk 91: 173-174

Nettleship, D. N., and P. G. H. Evans. 1985. Distribution and status of the Atlantic Alcidae. Pages 53-154 *in* D.N. Nettleship and T.R. Birkhead (eds.), The Atlantic Alcidae. Academic Press. London, UK.

Piatt, J. F., and R. F. McLagan. 1987. Common Murre (*Uria aalge*) attendance patterns at Cape St. Mary's, Newfoundland. Can. J. Zool. 65: 1530-1534.

Piatt, J. F., and D. N. Nettleship. 1987. Incidental catch of marine birds and mammals in fishing nets off Newfoundland, Canada. Mar. Poll. Bull. 68: 344-349.

Piatt, J. F., C. J. Lensink, W. Butler, M. Kendziorek and D. R. Nysewander. 1990. Immediate impact of the '*Exxon Valdez*' oil spill on marine birds. Auk 107: 387-397.

Piatt, J. F., H. R. Carter and D. N. Nettleship. 1991. Effects of oil pollution on marine bird populations. Pages 125-141 *in* J. White, L. Frink, T.M. Williams, and R.W. Davis (eds.), The effects of oil on wildlife. Sheridan Press. Hanover, PA.

Robertson, G. J., D. Fifield, M. Massaro and J. W. Chardine. 2001. Changes in nesting-habitat use of large gulls breeding in Witless Bay, Newfoundland. Can. J. Zool. 79: 2159-2167.

Robertson, G. J., R. D. Elliot, and K. Chaulk. 2002a. Breeding seabird populations in Groswater Bay, Labrador, 1978 and 2002. Canadian Wildlife Service Technical Report Series No. 394. Atlantic Region. Mount Pearl, NF.

Robertson, G. J., J. Russell and D. Fifield. 2002b. Breeding population estimates for three Leach's Storm-petrel colonies in southeastern Newfoundland, 2001. Can. Wildl. Serv. Tech. Rep. Ser. No. 380. Atlantic Region, Mount Pearl, NF.

Robertson, G. J., and R. D. Elliot. 2002. Changes in seabird populations breeding on Small Island, Wadham Islands, Newfoundland. Can. Wildl. Serv. Tech. Rep. Ser. No. 381. Atlantic Region. Mount Pearl, NF.

Rodway, M. S., H. R. Regehr, and J. W. Chardine. 1996. Population census of breeding Atlantic Puffins at Great Island, Newfoundland in 1993-1994. Can. Wildl. Serv. Tech. Rep. Ser. No. 263. Atlantic Region. Sackville, NB.

Rowe, S., I. L. Jones, J. W. Chardine, R. D. Elliot, B. G. Veitch. 2000. Recent changes in the winter diet of murres (*Uria* spp.) in coastal Newfoundland. Can. J. Zool. 78: 495-500.

Rowe, S., and I. L. Jones. 2000. The enigma of Razorbill *Alca torda* breeding site selection: adaptation to a variable environment? Ibis 142: 324-327.

Savard, J.-P. L., and G. E. J. Smith. 1985. Comparison of survey techniques for burrow-nesting seabirds. Can. Wildl. Serv. Prog. Notes No. 151, Ottawa, ON.

Stenhouse, I. J, and W. A. Montevecchi. 1999. Increasing and expanding populations of breeding Northern Fulmars in Atlantic Canada. Waterbirds 22: 382-391.

Stenhouse, I. J., G. J. Robertson and W. A. Montevecchi. 2000. Herring Gull *Larus argentatus* predation on Leach's Storm-petrels *Oceanodroma leucorhoa* breeding on Great Island, Newfoundland. Atlantic Seabirds 2: 35-44.

Stowe, T. J. 1982. Recent population trends in cliff-breeding seabirds in Britain and Ireland. Ibis 124: 502-510.

Takekawa, J. E., H. R. Carter and T. E. Harvey. 1990. Decline of the Common Murre in central California, 1980-1986. Stud. Avian Biol. 14: 149-163.

Todd, W. E. C. 1963. The birds of the Labrador Peninsula. Univ. Toronto Press. Toronto, ON.

Tuck, L. M. 1961. The murres: their distribution, populations and biology - a study of the genus *Uria.* Canadian Wildlife Service Monograph No. 1 Ottawa, ON.

Vader, W., R. T. Barrett, K. E. Erikstad and K.-B. Strann. 1990. Differential responses of Common Murres and Thick-billed Murres to a crash in the capelin stock in the southern Barents Sea. Stud. Avian Biol. 14: 175-180.

Wiese, F. K. 2002. Estimation and impacts of seabird mortality from chronic marine oil pollution off the coast of Newfoundland. Ph. D. thesis. Memorial Univ. Newfoundland. St. John's, NF.

Wiese, F., and P. C. Ryan. 1999. Trends of chronic oil pollution in southeast Newfoundland assessed through beached-bird surveys 1984-1997. Bird Trends 7: 36-40.

Zar, J. H. 1974. Biostatistical analysis. 2nd edition. Prentice-Hall Inc. Englewood Cliffs, New Jersey.

Table 2.1. Numbers of occupied breeding sites in permanent Razorbill study plots in the Gannet Clusters, Labrador. The mean value for 1983 and 1984 was used when both are available in comparisons with 1998/1999.

Plot	1978[a]	1978[a]	1983	1984	1992[b]	1998	1999	% change 1983-84 to 1998-99
GC1-a	-	-	120	134	-	153	124	+9%
GC1-b	-	-	110	113	121	165	126	+30%
GC2-a	128	125	118	123	0	37	55	-62%
GC2-b	22	23	32	30	0	13	21	-45%
GC2-c[c]	80	92	35/58	51/57	0/0	22/33	25/45	-45%/-32%
GC2-d	-	-	46	50	0	23	25	-50%
GC2-e	-	-	52	53	0	26	37	-40%
GC3-a	-	-	56	43	22	55	44	0%
GC4-a	-	-	45	32	7	36	46	+6%
GC5-a	-	-	-	27	0	21	54	+39%
Totals				706		584	602	-16%

[a] two counts were conducted in 1978, 5 and 16 July
[b] from Birkhead and Nettleship 1995
[c] distinct sections of GC2-c treated separately after 1978

Table 2.2. Estimates of correction factors (*k*) for Razorbills in the Gannet Islands, Labrador.

Plot	5 July 1978			16 July 1978			22 July 1983			12 July 1998			18 July 1999		
	Eggs	Boat count	*k*	Eggs	Boat count	*k*	Eggs	Boat count	*k*	Eggs	Boat count	*k*	Eggs	Boat count	*k*
GC1-a							120	70	1.71	153	47	3.25	124	113	1.10
GC1-b										165	44	3.75	126	56	2.25
GC2-a	128	62	2.01	125	86.5[a]	1.45	118	46	2.56	37	9	4.11	55	8	6.88
GC2-b	22	7	3.14	23	26[a]	0.86	32	9	3.56	13	1	13.00	21	5	4.20
GC2-c	80	20	4.00	92	35[a]	2.63	93	22	3.88	55	16	3.44	70	14	5.00
GC2-d							46	35	1.28	23	11	2.10	25	13	1.92
GC2-e							52	42	1.24	26	11	2.36	37	4	9.25
GC3-a							56	16	3.50	55	17	3.24	44	5	8.80
GC4-a							32	16	2.00	36	39	0.92	46	34	1.35
GC5-a[b]													97	25	3.88
GC5-c													109	66	1.65
corrected *k*			2.740 ± 0.436			1.774 ± 0.319			2.401 ± 0.332			3.258 ± 0.393			2.903 ± 0.535

[a] based on average of two boat counts
[b] larger plot than encompassed by egg plot GC5-a

Table 2.3. Numbers of Razorbills counted from boat surveys and estimates of population size (pairs) in the Gannet Clusters, Labrador, 1978-1999. See Table 2.2 for calculation of *k* values.

	5 July 1978	16 July 1978	22 July 1983	12 July 1998	18 July 1999	corrected 5 July 78	corrected 16 July 78	corrected mean 1978	Corrected 1983	corrected 1998	corrected 1999
GC1	638	893	511	808	1225	1748 ± 278	1585 ± 285	1666 ± 282	1227 ± 170	2633 ± 318	3556 ± 655
GC2	630	734	272	399	213	1726 ± 275	1302 ± 234	1514 ± 254	653 ± 90	1300 ± 157	618 ± 114
GC3	432	737	415	654	574	1184 ± 188	1308 ± 235	1246 ± 1150	996 ± 138	2131 ± 257	1666 ± 307
GC4	356	746	697	499	589	975 ± 155	1324 ± 238	1150 ± 197	1674 ± 232	1626 ± 196	1710 ± 315
GC5	449[a]	-	566	605	553	-	-	797 ± 143[b]	1359 ± 188	1971 ± 238	1605 ± 296
GC6	70[a]	-	67	196	225	-	-	124 ± 22[b]	161 ± 22	639 ± 77	653 ± 120
Total GC1-GC4	2056	3110	1895	2360	2601	5633 ± 897	5519 ± 992	5576 ± 944	4550 ± 630	7690 ± 928	7549 ± 1391
Total GC1-GC6	2575	-	2528	3161	3379		-	6497 ± 1110	6070 ± 840	10 300 ± 1242	9808 ± 1807

[a] counts were made on 3 July 1978
[b] $k = 1.774 \pm 0.319$ from 16 July 1978 used

Table 3.1. Counts and breeding population estimates of Common and Thick-billed Murres at the Gannet Islands, Labrador.

Island	Common Murres Count	Common Murres Breeding pairs	Thick-billed Murres Count	Thick-billed Murres Breeding pairs
1983				
GC-1	23 816[a]	18 162 (15 305 – 21 019)	258	208 (197 – 218)
GC-2	50[a]	50	19[b]	19
GC-3	18 939	14 414 (12 128 – 16 701)	27	22 (21 – 23)
GC-4	5939[a]	4529 (3816 – 5241)	866	697 (662 – 732)
Outer Gannet	31 184	23 734 (19 970 – 27 498)	586	471 (448 – 495)
Total	79 928	60 889 (51 270 – 70 510)	1756	1417 (1347 – 1488)
1998				
GC-1	13 726	12 271 (11 675 – 12 868)	445	312 (301 – 323)
GC-2	0	0	0	0
GC-3	4734	4232 (4026 – 4438)	120	84 (81 – 87)
GC-4	3195	2856 (2717 – 2995)	1341	940 (908 – 973)
Outer Gannet	19 398	17 342 (16 499 – 18 185)	799	560 (541 – 580)
Total	41 053	19 360 (18 419 – 20 302)	2705	1897 (1831 – 1964)

[a] Includes 148 eggs counted directly on GC-1, 50 on GC-2 and 35 on GC-4. These direct counts were not multiplied by the *k* ratio
[b] directly counted

Table 3.2. Summary of breeding population size estimates of Common and Thick-billed Murres in the Gannet Islands, Labrador.

Year	Common Murres Gannet Cluster	Common Murres Outer Gannet	Thick-billed Murres Gannet Cluster	Thick-billed Murres Outer Gannet	Source
1952	2750[a]	8900[a]	15[a]	300[a]	Tuck 1961
1972	17 500	17 700	0	475	Brown et al. (1975)
1978	20 616[a]	26 144[a]	942[a]	320[a]	R. D. Elliot and T. M. Birkhead, unpublished data
1983	37 155	23 734	946	471	this study, reanalysis of Birkhead and Nettleship (1987a)
1992	-	-	2025[a]		Birkhead (1993)
1998	19 360	17 342	1337	560	this study

[a] uncorrected raw counts (data to obtain *k* ratio not collected in these years)

Table 4.1. Number of holes, occupancy rates and estimated number of pairs of breeding Atlantic Puffins in the Gannet Islands. Total population estimates and their standard errors are based on the sum of the island estimates for each year, not the product of the overall hole occupancy rate and total hole count.

Island	Number of holes	n[a]	Hole occupancy rate	Number of breeding pairs
1978				
GC-1	9412	4	0.607 ± 0.019	5713 ± 179
GC-2	16 796	8	0.385 ± 0.050	6466 ± 840
GC-3	9091	5	0.646 ± 0.038	5873 ± 345
GC-4	15 602	5	0.657 ± 0.068	10 251 ± 1061
GC-5	7464	1	0.630	4702
GC-6	-		-	-
Total Clusters	58 365	23	0.567 ± 0.033	33 005 ± 2425[b]
Outer Gannet	14 317	5	0.443 ± 0.088	6342 ± 1260
1983				
GC-1	15 650	10	0.733 ± 0.032	11471 ± 501
GC-2	14 072	18	0.449 ± 0.029	6318 ± 408
GC-3	9111	10	0.625 ± 0.051	5694 ± 465
GC-4	15 611	16	0.602 ± 0.035	9398 ± 546
GC-5	12 426	8	0.690 ± 0.040	8574 ± 497
GC-6[c]	1155	-	0.690 ± 0.040[c]	797 ± 46
Total Clusters	68 025	62	0.604 ± 0.020	42 252 ± 2463
Outer Gannet	12 085	15	0.695 ± 0.033	8399 ± 399
1984				
GC-1	15 650[d]	11	0.670 ± 0.049	10 486 ± 767
GC-2	14 072[d]	25	0.491 ± 0.027	6909 ± 380
GC-3	9111[d]	10	0.619 ± 0.044	5640 ± 401
GC-4	15 611[d]	18	0.600 ± 0.032	9367 ± 500
GC-5	12 426[d]	11	0.528 ± 0.048	6561 ± 596
GC-6[c]	1155[d]	-	0.528 ± 0.048[c]	610 ± 55
Total Clusters	68 025[d]	75	0.572 ± 0.017	39 573 ± 2699
1999				
GC-1	15 029	16	0.520 ± 0.045	7815 ± 676
GC-2	14 251	18	0.343 ± 0.028	4888 ± 399
GC-3	12 011	12	0.543 ± 0.041	6522 ± 492
GC-4	16 736	16	0.441 ± 0.031	7381 ± 519
GC-5	15 336	12	0.454 ± 0.045	6963 ± 690
GC-6[c]	2298	-	0.454 ± 0.045[c]	1043 ± 103
Total Clusters	75 661	74	0.464 ± 0.018	34 612 ± 2879
2000				
Outer Gannet	13 789	12	0.294 ± 0.061	4054 ± 841

[a] number of plots grubbed
[b] GC-6 was not surveyed in 1978, so overall estimate is lower than other years
[c] Grubbing plots were not established on GC-6 so values for GC-5 used
[d] Hole counts were not made in 1984, so 1983 hole counts used

Table 4.2. Summary of breeding population size estimates of Atlantic Puffins in the Gannet Islands, Labrador.

Year	Gannet Clusters	Outer Gannet	Source
1972	37 425	4950	Brown et al. (1975)
1978	33 005	6342	this study
1983	42 252	8399	this study, reanalysis of Birkhead and Nettleship (1987a)
1984	39 573	-	this study
1999	34 612	-	this study
2000	-	4054	this study

Table 5.1. Number of adult Black Guillemots counted from boat surveys in the Gannet Clusters, Labrador.

	1978	1983	1998	1999
Date	5 July	26 June	12 July	18 July
GC1	0	1	0	0
GC2	12	15	10	3
GC3	0	1	5	0
GC4	0	0	0	0
GC5	9	4	7	3
GC6	191	286	66	183

Table 5.2. Number of Black-legged Kittiwake pairs breeding in the Gannet Islands, Labrador.

Year	Gannet Clusters	Outer Gannet	Source
1972	0	16	Nettleship and Lock (1974)
1978	3	48	Birkhead and Nettleship (1988)
1979	10	40	Birkhead and Nettleship (1988)
1981	26	-	Birkhead and Nettleship (1988)
1982	37	-	Birkhead and Nettleship (1988)
1983	52	57	Birkhead and Nettleship (1988)
1984	63	56	Birkhead and Nettleship (1988)
1985	58	40	Birkhead and Nettleship (1988)
1999	54	49	this study

Table 5.3. Number of site holding Northern Fulmars counted from boat surveys in the Gannet Islands, Labrador. Nests where breeding confirmed in brackets. Much of the information up to 1998 is summarized in Stenhouse and Montevecchi (1999).

	1978	1983	1984	1985	1997	1998	1999
GC1	0	0	-	-	4	4	2
GC2	17 (2)	14 (8)	14	19 (4)	5	3	4
GC3	0	0	-	-	0	0	0
GC4	2 (0)	3 (0)	-	-	1	0	0
GC5	0	0	-	-	11 (5)	5	13 (3)
GC6	0	0	-	-	0	0	0
Outer Gannet	8 (1)	3 (1)	24 (7)	31 (10)	5	7	5

Table 6.1. Summary of recent breeding population size estimates (in pairs) for seabirds nesting in the Gannet Islands, Labrador.

Species	Most recent survey	Gannet Clusters	Outer Gannet	Gannet Islands
Razorbill	1999	9808	-	-
Common Murre	1998	19 360	17 342	36 702
Thick-billed Murre	1998	1337	560	1897
Atlantic Puffin	1999/2000	34 612	4054	38 666
Black Guillemot	1999	2[a]	-	-
Black-legged Kittiwake	1999	54	49	103
Great Black-backed Gull	1999	25	5	30
Leach's Storm-petrel	1999	0[a]	0[a]	0[a]
Northern Fulmar	1999	19	5	24
Common Eider	1999	36[a]	-	-

Note: dash (-) denotes not surveyed
[a] numbers represent minimums, as some nests likely missed due to difficulty in finding or late timing of survey

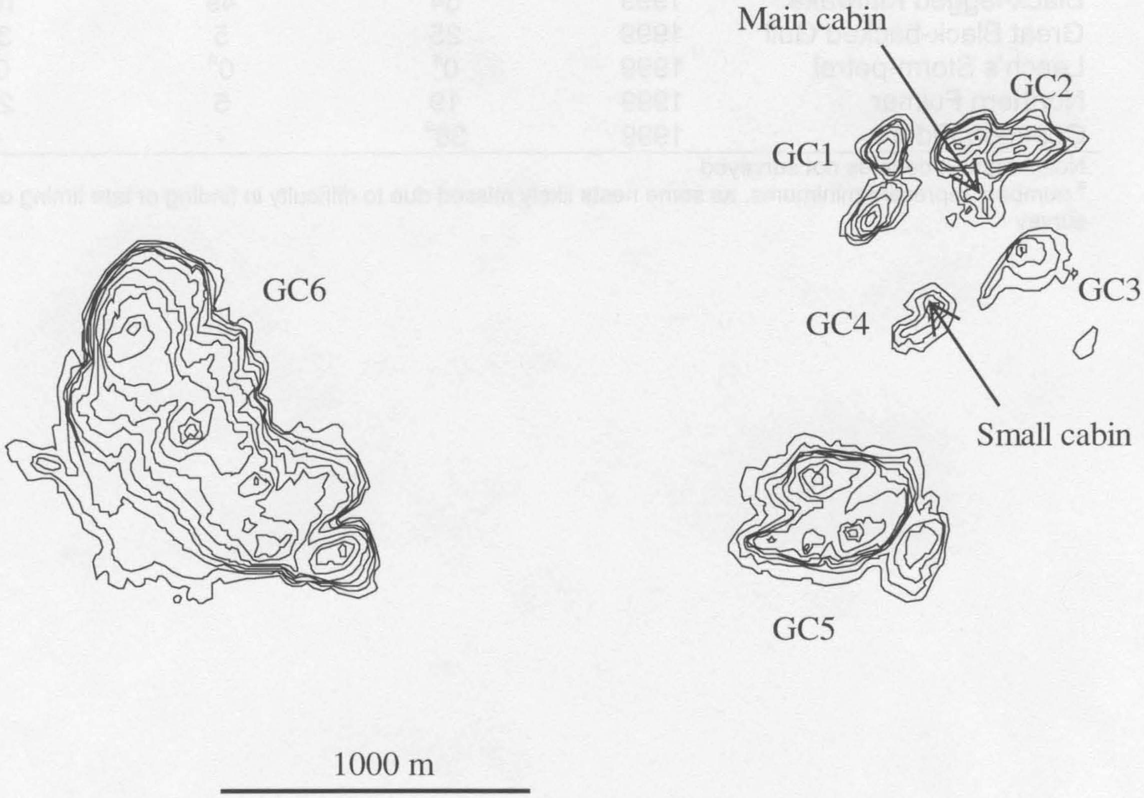


Figure 1.1. The Gannet Islands Seabird Ecological Reserve, Labrador. Outer Gannet Island lies 7 km to the North of the Gannet Clusters shown here. 20 m contour lines are shown.

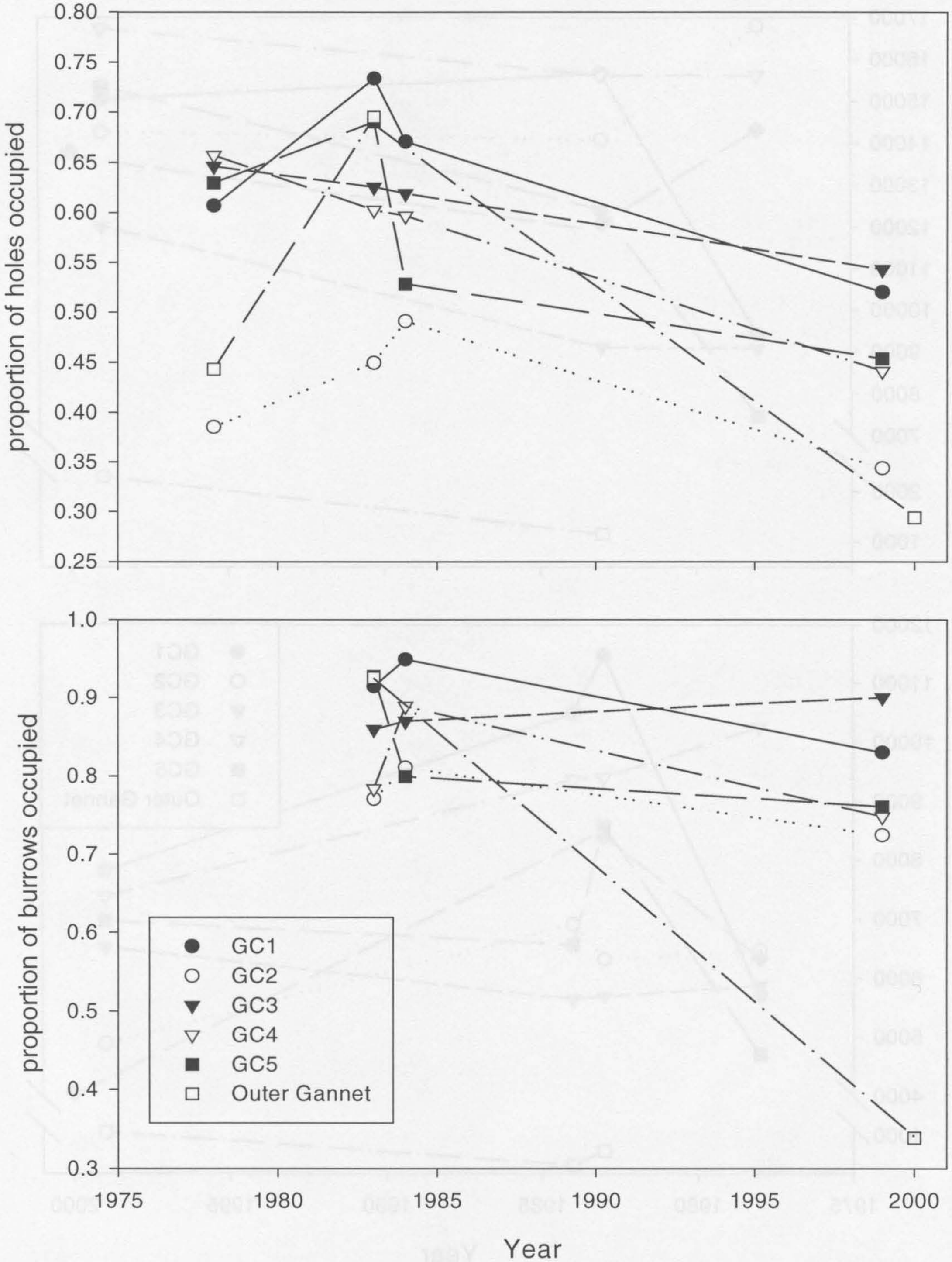


Figure 4.1. Hole and burrow occupancy rates of Atlantic Puffins on the Gannet Islands, Labrador.

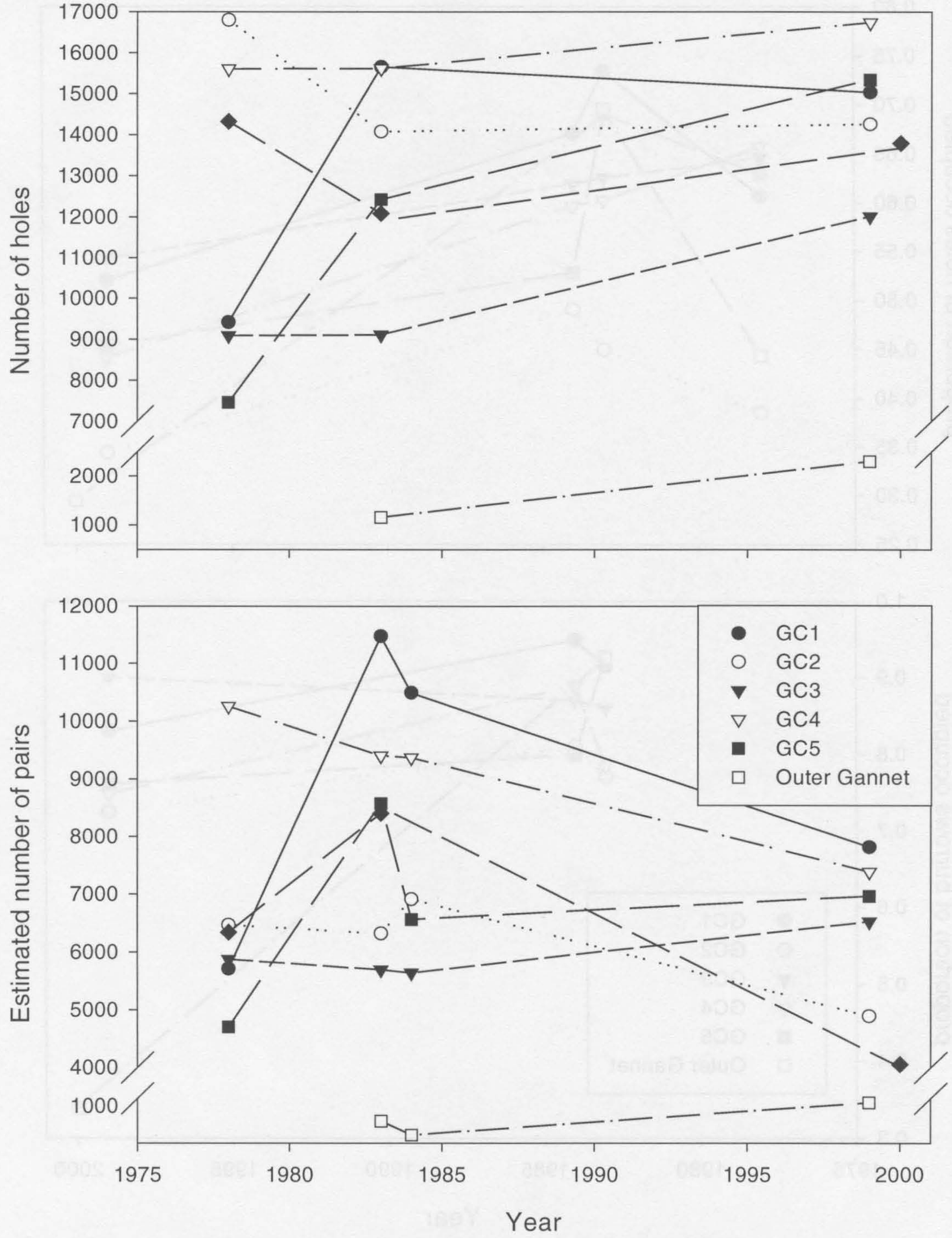


Figure 4.2. Hole counts and estimated breeding population size of Atlantic Puffins on the Gannet Islands, Labrador

Appendix 1. Records of Arctic fox and polar bear on the Gannet Clusters 1978-1999. The following summary is based on published reports (Birkhead and Nettleship 1995), and personal recollections (primarily Ian L. Jones and Richard D. Elliot).

Year		
1978	–	no evidence of recent or current fox presence on any of GC1 to GC6 or Outer Gannet during 2 visits in July (RDE)
1981-83	–	no indication from CWS crews present throughout three summers that foxes had been, or were present, on GC1 to GC6 or Outer Gannet (RDE, Birkhead and Nettleship 1995)
1992	–	Arctic fox(es) were present on GC2 (1 pair and 2 pups) and GC5 (2 adults)
	–	there was "clear evidence" that they had recently been on GC4 (scats, cached Common Murre and puffin eggs and adult puffins) and "circumstantial evidence" they had been on GC3 (1800 abandoned Common Murre sites, fewer Razorbill eggs)
	–	David N. Nettleship surmises foxes had been there for several years by 1992, perhaps since southern influx of foxes in winter of 1987-88
	–	1 female and 2 pups removed from GC2 and 1 adult from GC5 by Harry Martin, the local Provincial Conservation Officer
1993	–	none thought to be on the Gannet Clusters, checked by Harry Martin in May (DNN, Harry Martin)
1995	–	1+ Arctic fox(es) seen on GC2 (RDE, ILJ, John W. Chardine)
	–	Note: team only landed on GC2, GC4
1996	–	1 fox on GC2, moved to GC1 over pack ice in June where it remained all summer (ILJ)
	–	this individual appeared to eat primarily puffins
1997	–	one Arctic fox seen on GC3 in late June (Brian G. Veitch)
	–	recent scats were seen on GC4
	–	one fox was present part or all of summer in Cluster (Sherrylynn Rowe)
1998	–	Arctic fox sign on GC5 (RDE, Mark E. Button, Gregory J. Robertson) on 13 July, including smell in cracks just southeast of Razorbill plot GC5-a, possible den site on west end near top, and fur hooked on growing vegetation confirming presence
	–	no fox found by BGV, Peter Adams and Sabir Bin Muzzafar when they visited GC5 on 13-14 July and searched the whole island, presume fox had left or died by then
1999	–	no foxes noted on Gannet Clusters or Outer Gannet
	–	a polar bear was seen on GC1, GC3 and East Gannet Rock in first week of August; was eating puffins, gull chicks and murre eggs and chicks. In mid-August driven by Zodiac from GC1 to GC6 by BGV and Johanne Dussureault, continued to swim to Outer Gannet, where Harry Martin drove it further north towards shore. Not seen again.

ENVIRONMENTAL CHOICE · CHOIX ENVIRONNEMENTAL

Over 50% recycled paper including 10% post-consumer fiber.