Progress Notes

Aussi disponible en français

No. 73, April 1977

Studies of seabirds at Prince Leopold Island and vicinity, Northwest Territories[1]
Preliminary report of biological investigations in 1975

by David N. Nettleship[2]

Abstract

This interim report gives provisional findings and views of the biological team based on field work at Prince Leopold Island, NWT, May to September 1975.

The status (breeding population size), use of habitat (distribution), phenology of breeding, breeding performance and food preferences were studied for five species of seabirds (Northern Fulmar *Fulmarus glacialis*, Glaucous Gull *Larus hyperboreus*, Black-legged Kittiwake *Rissa tridactyla*, Thick-billed Murre *Uria lomvia* and Black Guillemot *Cepphus grylle*) on the cliffs and adjacent waters of Prince Leopold Island during the 1975 breeding season. The purpose of the study, current state of knowledge of seabird populations in the region, description of the study area, and methods and approach are outlined briefly.

Provisional findings are summarized and discussed in order to show the types of population parameters measured at Prince Leopold Island and permit input regarding possible approaches of investigations there and elsewhere in the future. After completion of the analysis of the 1975 summer's records, the data will show population performance of four species breeding at Prince Leopold Island (studies of Black Guillemots were limited to breeding distribution and population size) and determine the importance of Barrow Strait and associated waters for successful breeding. Preliminary results indicate that Barrow Strait has a relatively high density of fish food which is critical to the nutritional requirements of a large proportion of the total seabird population, especially Thick-billed Murres, during the chick-rearing period when the demand for food is greatest.

At least two additional seasons of similar observations are necessary to determine the average performance and variation between years of accurately measurable population parameters such as population sizes, timing of breeding, hatching and fledging success, food types and feeding frequencies, fledging periods and growth rates of chicks, which can then be used to assess the impact of industrial developments on the marine environment. Much more work needs to be done on the identification of precise feeding areas and general water habitat usage by birds in Barrow Strait (most of which breed at Prince Leopold Island) both geographically and chronologically. The pelagic distribution of seabirds can only be investigated by systematic coverage by aircraft of permanent marine transects over the open water areas of Barrow Strait at intervals through the breeding season, which will require a considerable increase in funding.

The analysis so far of the data makes clear that a thorough understanding of population performance at the major breeding site, by a monitoring system sensitive enough to measure changes in levels of important population parameters and of the distribution of birds in associated open water areas, is required if we are to determine the ecological requirements of seabirds in the region and be able to assess the impact of industrial expansion.

Introduction

Several seabird species reproduce and summer in the waters of Lancaster Sound and associated channels (Barrow Strait, Wellington Channel and northern Prince Regent Inlet). They include Northern Fulmar, Glaucous Gull, Black-legged Kittiwake, Thick-billed Murre and Black Guillemot. Most of these species are colonial and concentrate during the breeding season at locations where there are oceanographic conditions which provide a suitable food supply, i.e. areas of upwelling waters and high nutrient cycling, and suitable breeding sites, i.e. rocky coasts or offshore islands, within range of this food supply. Sites having both these properties are rare in the Canadian arctic.

The general area of Barrow Strait – Prince Regent Inlet – Lancaster Sound is most critical to the reproduction and survival of a large proportion of the total seabird population in the Canadian high arctic. Strong currents from Barrow Strait and Lancaster Sound converge on Prince Leopold Island and produce considerable upwelling and enriching of the sea, resulting in unusually high biological productivity at all trophic levels. Although the chief breeding site is at Prince Leopold Island, the critical feeding areas during reproduction for birds at this colony (and at smaller sites located in eastern Barrow Strait) are in Peel Sound, Barrow Strait, Prince Regent Inlet and western Lancaster Sound. This clumped distribution pattern exposes seabird populations to high risk from changes in the environment caused by industrial development, e.g. gas pipeline construction and operation (Polar Gas), lead–zinc mining (Cominco), and deep-water oil drilling (Norlands Petroleums).

The study is a contribution to a comprehensive multi-species study of the status and reproductive ecology of seabirds in the eastern Canadian arctic, with special emphasis on the Northern Fulmar and Thick-billed Murre. It is intended to provide a data base from which estimates and predictions of population density flux, biomass changes and bioenergetic demands of seabird populations, especially with reference to

[1] An investigation associated with the program "Studies on northern seabirds", Can. Wildl. Serv., Dept. of Fisheries and the Environment (Report No. 40)

[2] CWS, Bedford Institute of Oceanography, Dartmouth, N.S. B2Y 4A2.

the breeding season, can be made. These data are essential to resource management questions concerning the effects of industrial expansion in the high arctic on seabird populations and their invertebrate–vertebrate foods. More specifically, the investigation will identify the relationships between the distribution patterns of seabirds utilizing the marine waters in Barrow Strait near the gas pipeline crossing areas proposed by Polar Gas and the importance of this usage to environmental and nutritional requirements for successful reproduction. It is also intended to reveal specific differences in the way that species selectively use the waters and food resources.

State of knowledge to 1975[3]

Breeding distributions and requirements of breeding seabird populations

The distributions of seabird colonies in the Barrow Strait – Lancaster Sound region are now well known (e.g. Nettleship 1974*a*, Nettleship 1974*b*, Nettleship and Smith 1975; Brown *et al.* 1975), but precise estimates of the sizes of the breeding populations and food habits of the major species are lacking. A knowledge of feeding ecology (food types, quantity, foraging patterns, feeding areas, etc.) is essential in understanding a species' environmental and nutritional requirements, and also the degree of competition for a food resource among species that are part of the same ecosystem. Except for one summer's study (1956) of Thick-billed Murres at Cape Hay, Bylot Island (Tuck 1960), we know *nothing* of the food and energy requirements of seabirds breeding in the Canadian high arctic. For example, until this past summer, information on food habits of the Northern Fulmar was limited to a small number of specimens taken in West Greenland and Davis Strait waters, most of which were collected in the late 1800's and early 1900's. Few data exist for other species and *nothing* is known of patterns of marine water usage among the different species or of factors related to food prey availability and abundance anywhere in the Canadian arctic. Furthermore, information basic to the evaluation and monitoring of the effects of industrial development, such as reproductive phenology, breeding performance and mortality rates of bird populations, or to the availability and location of food supplies in limiting population sizes is largely unknown.

Pelagic distributions of seabirds

Few quantitative data exist on the distributions of seabirds at sea in the area associated with the proposed pipeline or eastwards in Lancaster Sound. The available information has been summarized by Brown *et al.* 1975. Studies associated with the Polar Gas Project have attempted to reduce this gap. However, the distribution pattern of birds at sea, both geographically and chronologically through the key portion of the annual cycle (April to October inclusive), in Barrow Strait and Lancaster Sound has yet to be described by systematic coverage of permanent transect lines to identify zones most critical to bird reproduction and survival.

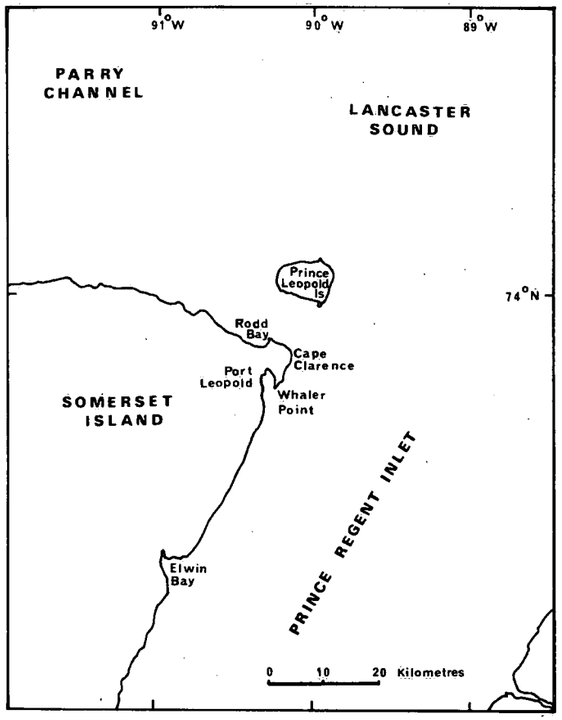
[3]Note: Significant studies of pelagic distributions and food habits of seabirds in Lancaster Sound were made in 1976 and are reported in Bradstreet (1976), Johnson *et al.* (1976) and Nettleship and Gaston (1977).

Study area

Location

The study was done at Prince Leopold Island, located off the northeast coast of Somerset Island (Fig. 1) at 74°02′N, 90°00′W, approximately 13 km from Cape Clarence, the northeastern corner of Somerset Island.

Figure 1
Prince Leopold Island and vicinity



Prince Leopold Island is flat-topped and surrounded by vertical sandstone-limestone cliffs about 245–265 m high, with a prominent gravel spit running out from the southeast corner and extensive talus slopes on the south and west sides (Fig. 2). It is oblong in shape and measures about 11 km long and 8 km wide. The island has a rocky coastline of precipitous cliffs with numerous escarpments and pinnacles. Except for the east side of the island, there are extensive scree slopes at the base of the cliffs, often extending upwards to 100 m or more.

Figure 2
Sketch map of Prince Leopold Island showing physiographic features, location of study plots and the general breeding distribution of Northern Fulmars and Thick-billed Murres

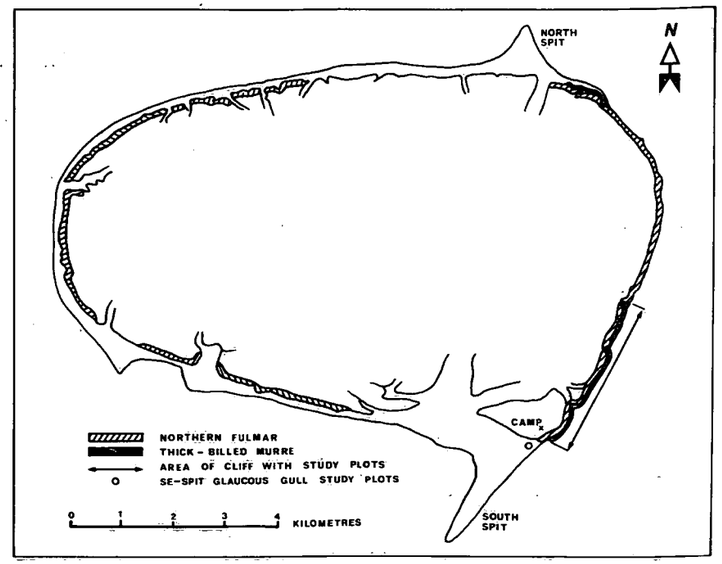
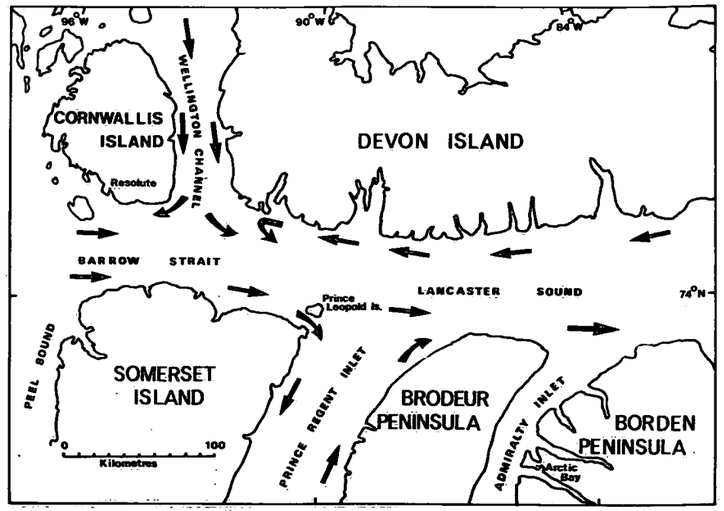


Figure 3
General pattern of sea currents in the Barrow Strait – Lancaster Sound region (after Bailey 1957 and Collin 1962)



Strong currents flow south through Wellington Channel and east through Barrow Strait from Viscount Melville Sound into Lancaster Sound where they converge and meet a distinct current flowing westward along the south coast of Devon Island (Fig. 3). There is also a significant southward water transfer from Barrow Strait through Prince Regent Inlet. These interactions of major water masses in the vicinity of Prince Leopold Island and northern Somerset Island appear to cause a local enrichment of nitrates, phosphates and other nutrients which promote the production of phytoplankton. This abundance of plankton in the vicinity of the study area is reflected higher up the food web in the unique structure of the seabird community at Prince Leopold Island, principally its high species diversity. The oceanographic features of the Barrow Strait – Lancaster Sound region have been described in detail by Bailey (1957) and Collin (1962).

Seabird fauna

The community of breeding seabirds on Prince Leopold Island was estimated by Barry (1961) in 1958 to comprise about 150 000 Northern Fulmars nesting continuously around the upper portions of the cliffs, more than 350 000 Thick-billed Murres and 100 000 Black-legged Kittiwakes on the east and north cliffs, 4 000 Black Guillemots among the talus and rock crevices on the cliffs, 2 000 Glaucous Gulls scattered above the murre and kittiwake colonies, and small numbers of Parasitic Jaegers *Stercorarius parasiticus*. Population figures derived from preliminary surveys made in 1972 and 1973 by Nettleship (see Brown et al. 1975) were similar to those reported by Barry (1961), though the estimates of murres and kittiwakes indicated a substantial reduction in bird numbers since 1958. Provisional estimates for 1975 are presented below (see Table 2).

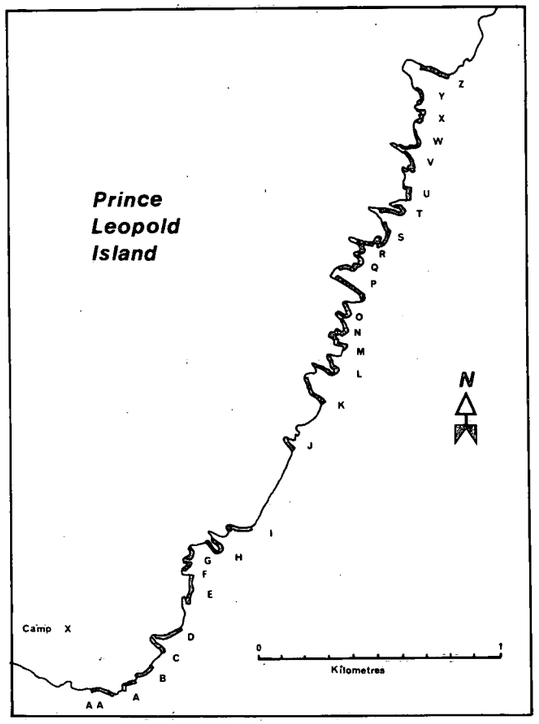
Methods

Biologists and technicians worked in the field from 18 May to 24 September 1975. Observations were made on land at representative study plots (see below) and from the sea in inflatable boats, except for a short series of transects by Bell 206 helicopter early in the season (9–10 June). A small party remained to observe the exodus of Northern Fulmars after the breakup of the colonies of the other species.

The investigations at Prince Leopold Island during the summer of 1975 were in three parts: measurements of population distribution and abundance, measurements of breeding performance, and measurements of food habits. Measurements in all three categories were gathered for four of the five abundant species; only the population distribution and abundance of the Black Guillemot were studied.

The data gathering and analysis of breeding distributions and the determination of breeding population sizes were conducted according to methods outlined by Nettleship (1976). The census programs were aimed at determining total populations and establishing a system by which population changes could be assessed in future years. A survey of the cliffs on Prince Leopold Island utilized by seabirds was carried out by helicopter. These data combined with ground and boat surveys permitted the identification and mapping of the general distribution pattern and main concentrations of cliff-nesting birds around the island. Following an analysis of the breeding habitats (nest-site density and habitat characteristics), representative study areas, i.e. colonies or sub-colonies, were set up to give as complete coverage as possible of the range of habitats used by each of the species (Fig. 4). From within these primary areas, smaller study plots were selected for the examination of nest densities, habitat characteristics, productivity and variations in attendance at the colony. These studies extended from prelaying and establishment to fledging of young and the breakup of the colony.

Figure 4
Distribution of study areas (colonies and sub-colonies) along the east cliffs in 1975



Data on reproductive phenology (timing of breeding), breeding success, fledging condition and factors of mortality were also obtained in the study plots. The plots were marked off on 8 × 10 in. photographs using natural topographic features as plot boundaries. Nest sites within the study plots were identified, numbered on photos, and checked at regular intervals (1–2 days) through the complete breeding cycle. Thus phenological stages and input variables for reproduction studies were determined by following the result of the reproductive effort (production, timing, fate of eggs and chicks, breeding success) of nest-site holders distributed on the mapped study plots. The number of study plots and total sample sizes varied according to species abundance, habitat usage and

importance, i.e. whether the species is at risk to industrial developments; details are given in Table 1. Some Northern Fulmar and Thick-billed Murre chicks at nests studied for breeding success were weighed with a Pesola spring balance, and their feather development and wing lengths were recorded. Data used for fledging condition, i.e. body weight and wing-length just prior to fledging, are in most cases those taken from the chicks 1 or 2 days before actual fledging.

Quantitative observations of behaviour such as colony attendance, intra- and interspecific competition, and chick feeding rates, were made at selected study plots, in most cases from permanent wood blinds or temporary shelters (see Gaston and Nettleship 1976, Nettleship and Taylor 1976).

Assay of the food habits of Northern Fulmars and Thick-billed Murres was accomplished by collecting birds from the ledges and from the air both as they flew by the nesting cliffs and as they returned to the cliffs from foraging at sea. Food samples were collected throughout the breeding cycle to determine the composition, seasonal variation and size of meal. These data were augmented by observations of food samples delivered by parents to the young during the chick-rearing period.

Variables measured during the study

Features and variables measured for the four species populations at the Prince Leopold site during the 1975 breeding season include:

(1) *Late winter and early spring activities* – time of arrival of adults in late winter and spring and the distribution pattern and buildup in numbers in open-water areas in the vicinity of Prince Leopold Island.

(2) *Pre-nesting period of cliff occupation* – sequence of events in the occupation of cliffs including: first arrival, first landing, first mass occupation of ledges, patterns of visitation – attendance on the cliffs during the full pre-nesting period, i.e. presence and absence at the cliffs, and daily activity patterns.

(3) *Egg-laying, incubation and hatching* – the characteristics of the egg-laying and incubation regimes of birds on mapped study plots representative of the full range of nesting habitats including:
   a. onset of egg-laying of first egg
   b. pattern of egg-laying, i.e. new eggs laid per day, on study plots through the egg-laying period
   c. completion of egg-laying of first egg
   d. pattern of incubation activity
   e. incubation period
   f. pattern of egg-laying of replacement clutches, i.e. number and rate of second clutches produced by pairs that have lost their first clutch
   g. pattern of hatching of eggs at nest sites on study plots.

(4) *Nestling period* – the length of time between the hatching of a clutch and the normal fledging of the young from that clutch.

(5) *Fledging period* – the length of time between leaving the nest site and attainment of juvenile status, i.e. time at which the fledgling attains adult body weight or becomes independent of its parents, whichever occurs later. (Note: it is not possible to quantify this parameter at Prince Leopold Island as it is normally completed after the birds have left the vicinity of the island, but qualitative observations of the behaviour of adult and young immediately after fledging have been made.)

(6) *Breeding performance* – the determination of breeding success, i.e. the production of offspring surviving to fledging, by following the fate of eggs distributed at various study plots through the colonies and determining:
   a. hatching success – the fraction of the first eggs laid which actually hatch

Table 1
Numbers and locations of study plots and nest sites examined at Prince Leopold Island in 1975

Species	No. of study plots	Location and no. of study plots within the study areas	No. of nest sites monitored through the breeding season
Northern Fulmar	14	AA(1), A(1), C(1), D(1), G(1), H(1), J(1), L(2), M(1), N(1), O(1), P(1), T(1)	771
Glaucous Gull	24*	AA(1), E(1), F(1), I(1), L(2), M(1), N(1), P(1), Q(1), R(1), S(2), T(1), U(1), X(3), Y(3), Z(2), SE-Spit†	37
Black-legged Kittiwake	8	G(1), M(1), Q(3), R(1), S(1), T(1)	455
Thick-billed Murre	11	G(2), M(1), N(1), Q(3), S(3), U(1)	885

*23 study plots along the east cliff tops each contained one solitary nesting pair; the SE-Spit plot contained a small colony of 14 pairs.
†The SE-Spit study area is not shown on Fig. 4; see Fig. 2.

b. fledging success – the fraction of nestlings hatched from first eggs which successfully fledge
c. breeding success – the fraction of the eggs laid of first clutches which produced fledglings
d. annual productivity – the fraction of the eggs laid for first and replacement clutches which produced fledglings
e. post-fledging survival – the fraction of fledged individuals which survive to become juveniles. (Note: it is not possible to measure this parameter accurately, but some data were derived.)

(7) *Development of young* – the growth of chicks on separate study plots (not those plots studied for breeding performance input variables) including measurements for: hatching weights, growth curves and fledging weights.

(8) *Departure of chicks from the cliffs* – the documentation of the pattern of departure of chicks from nesting areas, i.e. sequence of events through the full departure period and daily departure pattern, and chick mortality.

(9) *Timing of population emigration* – the termination of the annual reproductive cycle including:
a. adult and juvenile emigration onset – the dates at which emigration begins, determining both time and rate
b. adult and juvenile emigration termination – the dates at which emigration is completed, determining both time and rate.

(10) *Breeding season adult mortality* – the determination of the rate of adult mortality during the breeding season and of associated causal factors.

(11) *Food habits* – the collection of food samples from adults through the breeding season to show frequency and occurrence of prey items and seasonal variations in food habits, including the examination of food loads (type, composition, weight) delivered by parents to the young through the nestling period, and feeding rates and patterns.

Preliminary results

Breeding distributions and numbers

The sea cliffs at Leopold Island probably support close to 1/2 million seabirds (breeders and non-breeders). Estimates of population levels and general breeding distribution patterns observed in 1975 of the five regular breeders at the site are given in Table 2. Numbers given are provisional estimates for breeders only; the sizes of the non-breeding group for each species have not yet been determined, though initial studies suggest that they are large. For example, counts of non-breeding birds on the fulmar colonies indicate that non-breeders comprise about 40% of the entire population. The general distribution of Northern Fulmars and Thick-billed Murres is shown in Figure 2.

Reproductive phenology

The phenologies of Northern Fulmar and Thick-billed Murre populations are summarized in Table 3 and Figure 5. In general, the colonies at Prince Leopold Island are active from late April through September. Northern Fulmars may arrive as early as mid-April and vary in numbers at the island in a quasi-cyclical fashion during spring occupation and settlement; late breeders may remain at the cliffs into the first half of October, although weather and ice conditions probably modify this pattern from year to year. It is also possible that a segment of the Black Guillemot population overwinters in open-water areas close to Barrow Strait, as has been observed elsewhere in high arctic regions. Provisional estimates of the phenological stages of Glaucous Gull, Black-legged Kittiwake and Black Guillemot populations are also presented in Figure 5.

Table 2
Populations and general breeding distributions of seabirds at Prince Leopold Island in 1975

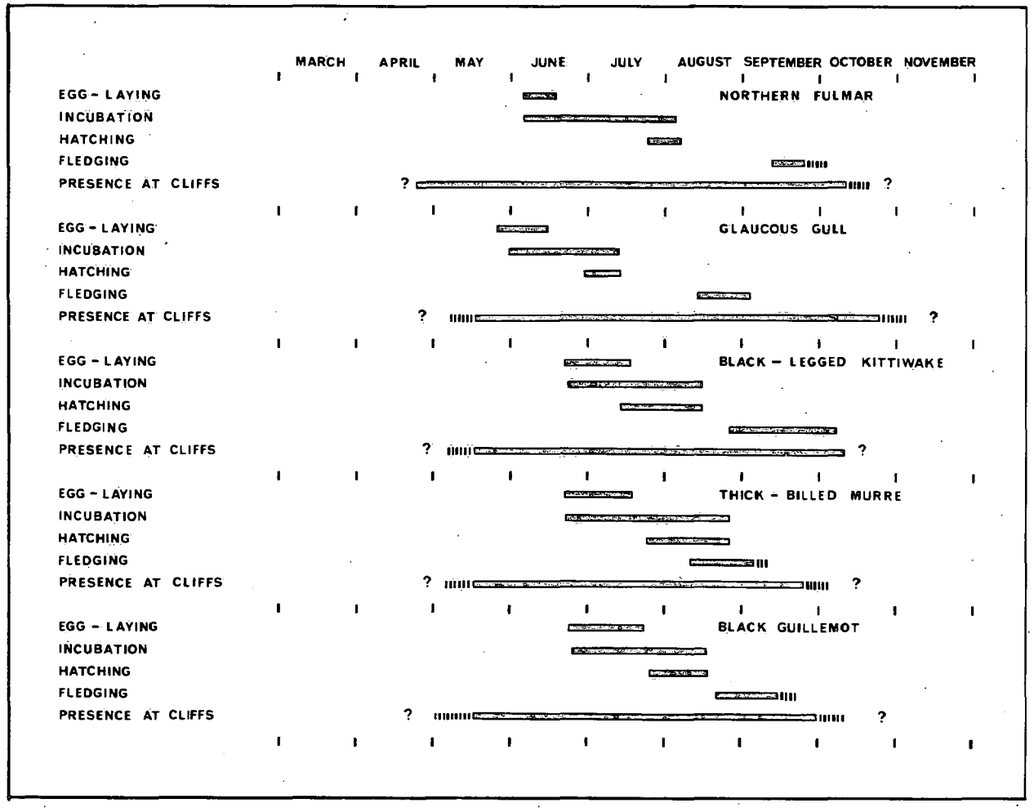
Species	No. of breeding pairs	Breeding distribution
Northern Fulmar	30 000	Almost continuously around the cliffs
Thick-billed Murre	70 000	NE and SE cliffs
Black-legged Kittiwake	29 000	NE and SE cliffs
Black Guillemot	3 000	Scattered continuously around the cliffs; largest concentrations along NW and W cliffs
Glaucous Gull	200	Scattered continuously around cliffs
Total	132 200 pairs	

Table 3
Reproductive phenology of Northern Fulmar and Thick-billed Murre populations in 1975

Stage	Northern Fulmar	Thick-billed Murre
Arrival	Present 18 May	Present 18 May
Egg-laying	4–17 June	20 June – 16 July (1st eggs only)
Hatching	23 July – 5 Aug.	22 July – 27 Aug. (1st eggs and replacement clutches)
Fledging	9–24+ Sept.*	12 Aug. – 3+ Sept.†
Departure	95% total population by 24 Sept.	98% total population by 3 Sept.

*95% of young fledged by 24 September.
†98% of young fledged by 3 September.

Figure 5
Provisional summary of the reproductive phenology of seabird populations breeding at Prince Leopold Island



Summary of food habits

Crustacea (amphipods and copepods) were present in regurgitations and stomachs of Northern Fulmars (both adults and nestlings) throughout the breeding cycle (May–September). Fish food first appeared in the samples in late July (at time of hatching of young) and constituted a high percentage of the foods examined until mid-September, after which crustaceans once again predominated.

None of the Thick-billed Murres collected prior to egg-laying had any visible food remains. Stomachs examined during egg-laying and incubation contained mostly fish material, although about 30% also had crustaceans (amphiphods and copepods). Food observed being fed to chicks consisted almost entirely of fish (preliminary analysis includes Polar Cod *Boreogadus saida* and Sculpin *Triglops* sp). Only two instances of other food items (invertebrates) being brought to chicks were recorded. These results suggest that timing of breeding of fulmars and murres may be related to the availability of fish food in the region. However, analysis of samples from fulmars and murres has not been completed.

Breeding performance

Table 4 summarizes the breeding performance of Northern Fulmars and Thick-billed Murres at study plots monitored throughout the breeding season. More detailed data are presented elsewhere (Gaston and Nettleship 1976, Nettleship and Taylor 1976).

Table 4
Breeding success and annual productivity of Northern Fulmars and Thick-billed Murres at Prince Leopold Island in 1975

Variable*	Northern Fulmar†			Thick-billed Murre		
	Total no.	No. of successes	%	Total no.	No. of successes	%
First clutches:						
Hatching success	229	167	72.9	885	742	84
Fledging success	167	111	66.5	742	696	94
Breeding success	229	111	48.5	885	696	78.6
Replacement clutches:						
Hatching success	No evidence of replacement clutches			30	23	77
Fledging success				23	12	52
Annual productivity	229	111	48.5	885	708	80

*For definitions see section headed 'Variables measured during study'.
†Data presented for study plots only.

Pelagic distributions and feeding areas
Helicopter transects were made on 10 June during the pre-breeding period from Prince Leopold Island east across Prince Regent Inlet to the northwest corner of Baffin Island (Cape York), north across Lancaster Sound to Cape Hurd, Devon Island, and south across the east coast of Somerset Island to Elwin Bay. The results of these 'test' transects are given in Table 5.

In general, the density of seabirds observed along all transects was low. Fulmars were distributed in small numbers

Table 5
Pelagic distributions of seabirds over five transects in the vicinity of Prince Leopold Island on 10 June 1975

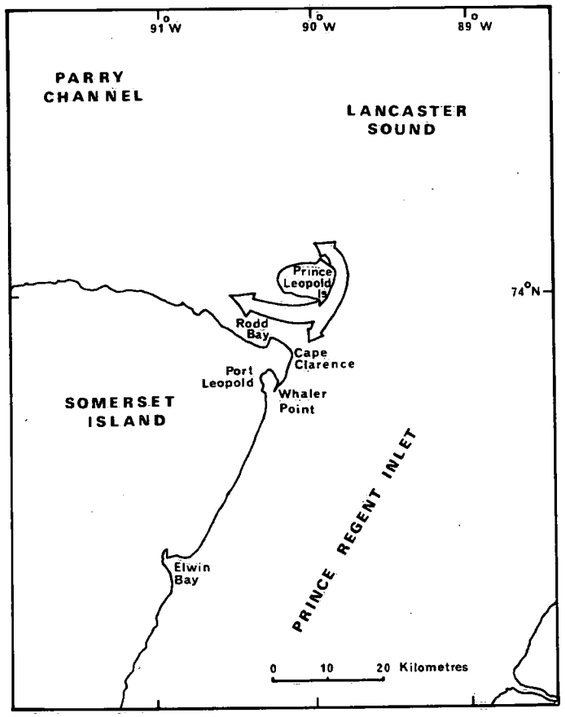
Transect no.* and location	Transect length (km)	Start time†	End time†	Northern Fulmar Total no.	Northern Fulmar Density (no./km^2)	Black-legged Kittiwake Total no.	Black-legged Kittiwake Density (no./km^2)	Thick-billed Murre Total no.	Thick-billed Murre Density (no./km^2)
1. Cape Clarence, Somerset I. to Cape York, Baffin I.	103	14:16	14:51	32	0.30	13	0.13	19	0.19
2. Cape York, Baffin I. to Cape Hurd, Devon I.	89	14:52	15:43	58	0.71	35	0.35	96	1.22
3. Cape Hurd, Devon I. to Prince Leopold I.	53	17:20	17:40	44	0.70	17	0.30	31	0.58
4. Cape Clarence, Somerset I. to Jackson Inlet, Baffin I.	76	18:15	18:50	27	0.30	121	0.14	87	1.05
5. Midway between Jackson Inlet, Baffin I./Elwin Bay, Somerset I. to Cape Clarence, Somerset I.	64	19:05	19:38	27	0.38	37	0.41	397	5.05
Mean density for all transects					0.48		0.27		1.62

*Transects made from Bell 206 helicopter at 100 m above sea level in a straight line with observers on both sides of the aircraft counting all birds estimated to be within 500 m of the line directly below the helicopter.
†Times are given in local time (GMT minus 5 hours).

rather uniformly over the sea, with the highest densities on the Lancaster Sound transects; slight concentrations of birds occurred along the margins of landfast ice. A concentration of murres was found along the edge of the sea-ice about 56 km southeast of Prince Leopold Island in Prince Regent Inlet, midway between Somerset and Baffin islands. Kittiwakes were seen in consistently lower numbers than the other two species. Details of foraging patterns in space and time cannot be derived from data for a single day over a small geographic area. Systematic coverage of a set of permanent transect lines across Parry Channel and Barrow Strait through the breeding season would permit a precise measurement of water usage by seabirds, especially for feeding.

Very little factual information was obtained on the feeding distributions of birds from the colony. The best data are for Thick-billed Murres. On average, murres seen through a telescope departing from the cliffs continued flying until lost from sight at a distance of about 8 km. The bearings of departing birds through the season ranged from north to south, but most of those seen flying south veered west towards the north coast of Somerset Island once they were out beyond the tip of the south spit (Fig. 6). During the period of incubation a large proportion of birds observed disappeared southwestward towards Cape Clarence and Rodd Bay (Somerset Island), but final destinations and the distances involved are not known. Birds appeared to be utilizing Barrow Strait waters along the north coast of Somerset Island, the majority travelling further than 16 km from the colony.

Figure 6
General flight directions of Thick-billed Murres departing from Prince Leopold Island in 1975



The best evidence obtained to support the view that Barrow Strait waters are critical to birds breeding at Prince Leopold Island is from Thick-billed Murres during the peak period of chick feeding. The number of murres returning to the colony at this time from the direction of waters along north Somerset Island was too large to count but was estimated to be 150–200 birds per minute on 11 August 1975. Of these birds, about 25% were visibly carrying fish. On 11 August, with about 50 000 chicks in the murre colony, a rate of 140 birds per minute would have accounted for all the feeding visits at the entire colony (based on a known feeding rate for that time of four food deliveries per chick per day). Because the proportion of incoming birds which were actually bringing food could not be determined, there is no way of knowing what proportion of the colony, i.e. birds with chicks, was using this route at the time, but it could not have been less than one-third. This means that a minimum of 33% of murres with chicks at Prince Leopold Island on 11 August must have been feeding off the north coast of Somerset Island. If figures for birds carrying fish that went unnoticed, failed breeders, and the non-breeding birds are added to this, it seems clear that waters in Barrow Strait and Parry Channel are critical to the Thick-billed Murre population at Prince Leopold due to a relatively high food density, especially during the period of greatest food demand by the population, (at time of hatching and chick growth at the breeding site).

Conclusions and recommendations
The major shortcoming of the results of the study is the lack of data for the identification of precise feeding areas and distances and how these parameters change through the breeding season, especially in Barrow Strait waters immediately north of Somerset Island.

In an environment as unpredictable as the arctic, a single season's work is not adequate to assess the real and potential variability of any of the parameters measured. Two, or if possible three, further seasons of similar observations are necessary to provide some information on the variation between years of accurately measurable phenomena such as breeding population sizes (in equilibrium or not), timing of breeding, hatching and fledging success, food types and feeding frequencies, fledging periods and growth rates of chicks. All of these population parameters could usefully be re-measured on Prince Leopold Island. Failure to do so would substantially reduce the value of observations made in 1975.

The main areas of investigation which were not covered satisfactorily, or at all, in 1975 were:
(1) the food habits of birds through the season;
(2) changes in foraging strategies (feeding areas, distances, proportion of total bird numbers) in space and time;

(3) relationship between changes in foraging patterns and food availability (food distributions and density); and
(4) precise identification of critical feeding areas.

Information on (1) is relatively easy to obtain. Further collecting of adults flying in to the colony during all phases of the reproductive cycle can be undertaken, as can the collection of a much larger sample of fish brought to chicks during the hatching and chick growth periods. However, information on items (2), (3) and (4) is extremely difficult to obtain because of practical work considerations and cost. Some quantitative measurements can be made to determine the significance of Barrow Strait waters to the nutritional requirements of bird populations (especially murres and fulmars) during the period of chick growth from additional studies of chick feeding rates and flight headings of adults to and from the colony at observation sites on land at Prince Leopold Island and perhaps northeast Somerset Island. Less quantitative measurements could also be taken in a similar manner at other times of the season. These data would be of value to item (2), and could also be of importance to item (4) if these data were to be augmented by detailed aerial transects of distributions of birds at sea over Barrow Strait and contiguous marine regions through the season. Information for item (3) could be derived by systematic sampling of marine phytoplankton and zooplankton at certain locations in Barrow Strait and in waters close to Prince Leopold Island. This would provide an insight into seasonal changes in the marine environment, and could be done by Fisheries and Marine Service and/or CWS.

In summary, the identification of precise feeding areas and general water habitat usage by seabirds in Barrow Strait (most of which breed at Prince Leopold Island) can only be investigated by marine transects by aircraft covering open water areas from the floe-edge in Barrow Strait east to the northwest coast of Brodeur Peninsula, Baffin Island. Systematic coverage of permanent transect lines over this marine area should be carried out at least twice during each period of the breeding cycle (pre-laying, incubation, chick-rearing, fledging) of fulmars and murres and possibly three or four times during September to document the direction of dispersal of birds from the colony during and after fledging. The September transects are of special importance to our knowledge of Thick-billed Murre post-fledging movements as these birds must accompany their flightless young and swim east to west Greenland where they spend the winter (see Brown *et al.* 1975). It is also important to remember that the distribution of murres during the pre-laying period (based on the preliminary helicopter transects) was significantly non-random, which suggests that birds were concentrated on localized food sources. To what extent, and in which areas, this might be true later in the season is not well known, although observations of preliminary flight headings of birds, and of bird numbers, suggest that food density is relatively high in Barrow Strait. However, the possible impact of industrial development in the marine environment at different distances from the colony cannot be assessed without both a thorough understanding of population performance at the major breeding site and of the distribution of birds in associated open water areas.

Acknowledgements

I am grateful to the biological team for their excellent field work at Prince Leopold Island in 1975: R. Forbes, A.J. Gaston, P.S. Taylor, M. Taylor and E. Verspoor. Special thanks to A.J. Gaston and P.S. Taylor for their contribution to comprehensive studies on Thick-billed Murres and Northern Fulmars respectively, both in the field and in the analysis and preparation of data during the winter. The team is indebted to F. Brazeau, D. Fillman, P. Madore and M. Channing for assistance in various ways through the season. I am also very appreciative of the outstanding logistic support provided to the project by the Polar Continental Shelf Project and staff, especially F. Alt and G. Hobson. My grateful thanks, as always, to Hugh Boyd for his critical and constructive review of the manuscript.

This work was financed principally by the CWS Program "Studies on northern seabirds" with additional support from the Environmental-Social Program Northern Pipelines and the Polar Continental Shelf Project.

References

Bailey, W.B. 1957. Oceanographic features of the Canadian Archipelago. J. Fish Res. Bd. Canada 14(5):731–769.

Barry, T.W. 1961. Seabird colonies of Prince Leopold Island and vicinity. Can. Field-Nat. 75(2):72–73.

Bradstreet, M.S.W. 1976. Summer feeding ecology of seabirds in eastern Lancaster Sound, 1976. LGL Ltd., Environmental Research Associates. Report for Norlands Petroleums Ltd., Calgary, Alberta. 187 pp.

Brown, R.G.B., D.N. Nettleship, P. Germain, C.E. Tull and T. Davis. 1975. Atlas of eastern Canadian seabirds. Can. Wildl. Serv., Ottawa. 220 pp.

Collin, A.E. 1962. The oceanography of Lancaster Sound. Unpub. Ph.D. Thesis, McGill University, Montreal. 204 pp.

Gaston, A.J. and D.N. Nettleship. 1976. Studies of seabirds at Prince Leopold Island, N.W.T. Biological investigation of Thick-billed Murres (*Uria lomvia*) in 1975. Studies on northern seabirds. No. 46. Can. Wildl. Serv. Rep. Unpubl. 105 pp.

Johnson, S.R., W.E. Renard, W.J. Richardson, R.A. Davis, C. Holdsworth and P.D. Hollingdale. 1976. Aerial surveys of birds in eastern Lancaster Sound, 1976. LGL Ltd., Environmental Research Associates. Report for Norlands Petroleums Ltd., Calgary, Alberta. 365 pp.

Nettleship, D.N. 1974*a*. Seabird colonies and distributions around Devon Island and vicinity. Arctic 27:95–103.

Nettleship, D.N. 1974*b*. Northern Fulmar colonies on the south coast of Devon Island, N.W.T., Canada. Auk 91(2):412.

Nettleship, D.N. 1976. Census techniques for seabirds of arctic and eastern Canada. Can. Wildl. Serv. Occ. Pap. No. 25. 33 pp.

Nettleship, D.N. and A.J. Gaston. 1977. Identity, abundance and patterns of distribution of populations of seabirds in western Lancaster Sound and Barrow Strait, Northwest Territories. Studies on northern seabirds. No. 50. Can. Wildl. Serv. Rep. Unpubl. 76 pp.

Nettleship, D.N. and P.A. Smith (Eds.). 1975. Ecological sites in northern Canada. CCIBP-CT Panel 9, Ottawa. 330 pp.

Nettleship, D.N. and P.S. Taylor. 1976. Studies of seabirds at Prince Leopold Island, N.W.T. Biological investigation of Northern Fulmars (*Fulmarus glacialis*) in 1975. Studies on northern seabirds. No. 47. Can. Wildl. Serv. Rep. Unpubl. 70 pp.

Tuck, L.M. 1960. The murres. Can. Wildl. Serv. Monogr. Ser.: 1. 260 pp.