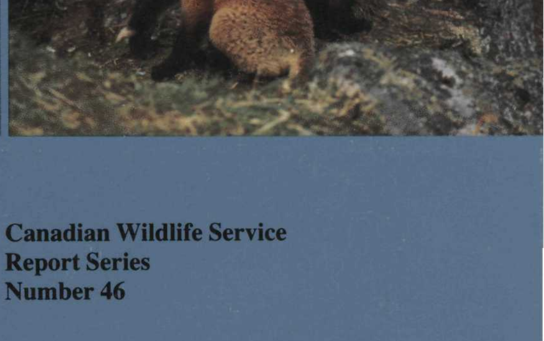
A.J. Gaston
D.K. Cairns
R.D. Elliot
D.G. Noble

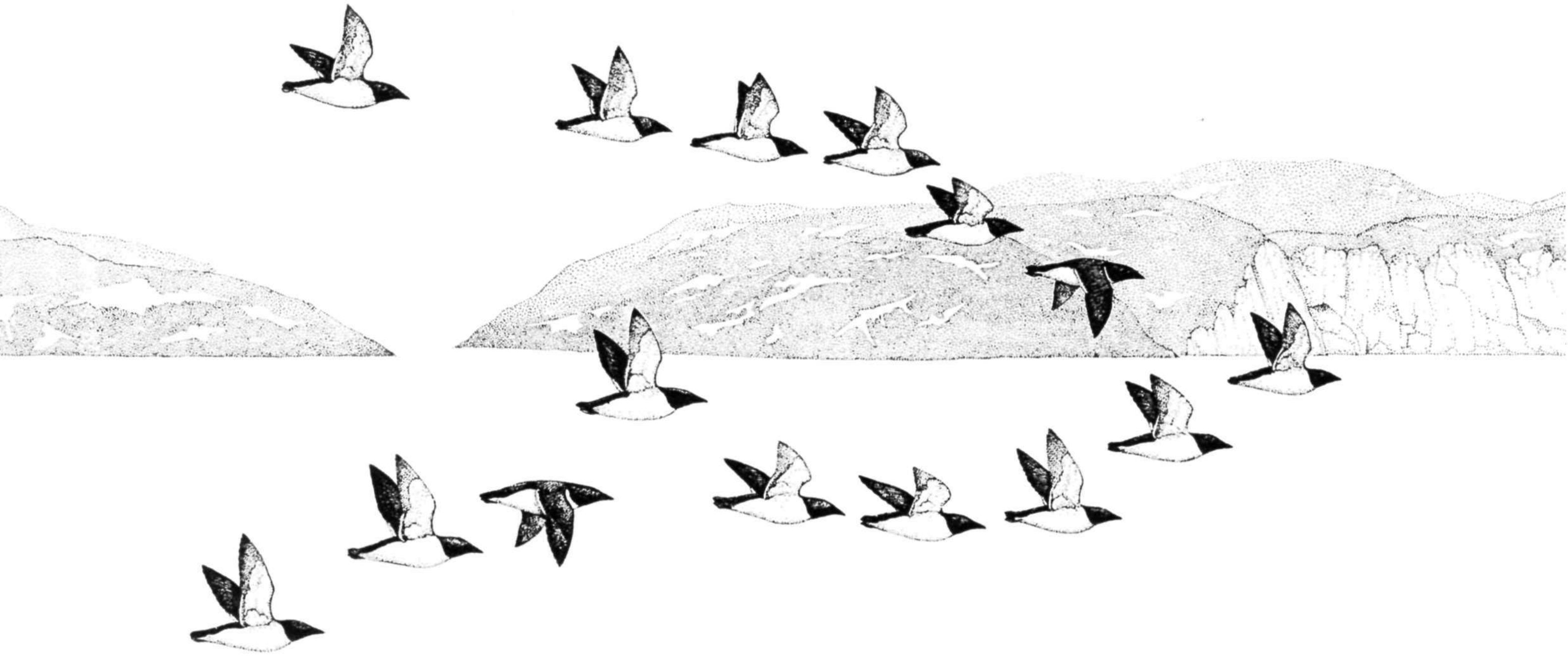
A natural history of Digges Sound



Canadian Wildlife Service
Report Series
Number 46

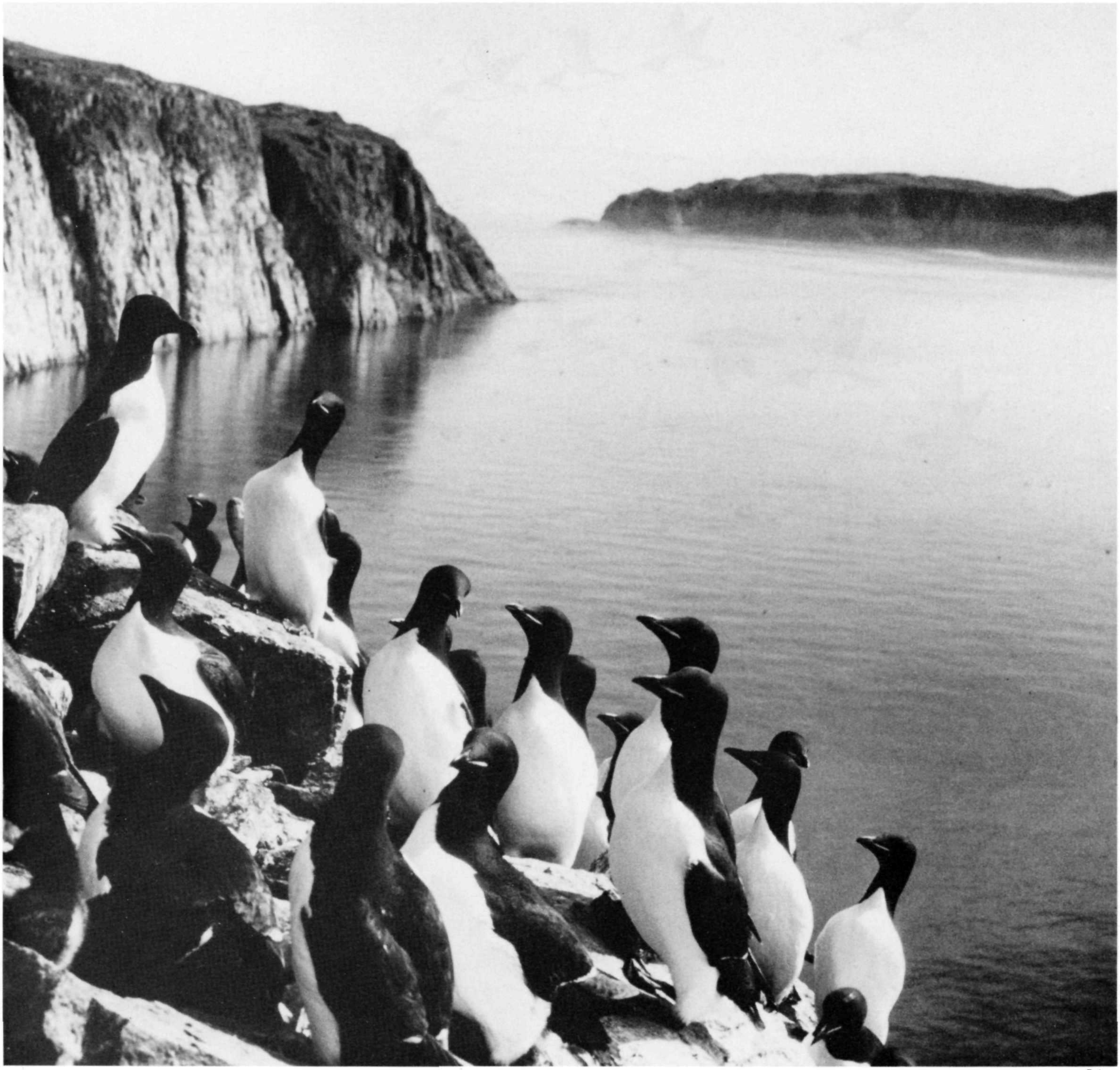
Environment Canada
Environnement Canada

Canadian Wildlife Service
Service canadien de la faune



. . . in this place is the greatest quantity of these fowle (whom we call WILLOCKS [murres]), that in few places else the like is to be seen; for if neede were we might have killed many thousands, almost incredible to those which have not seen it.

William Baffin, 1665 (in Markham 1881)



B. Lyon

A.J. Gaston*
D.K. Cairns†
R.D. Elliot‡
D.G. Noble*

A natural history of Digges Sound

Canadian Wildlife Service
Report Series Number 46

Disponible également en français

Cite as:
Gaston, A.J.; Cairns, D.K.; Elliot, R.D.; Noble, D.G. 1985. A natural history of Digges Sound. Can. Wildl. Serv. Rep. Ser. No. 46. 63 pp.

*CWS, Ottawa, Ont. K1A 0E7

†Dep. of Biology, Memorial University, St. John's, Nfld. A1B 3X9

‡CWS, P.O. Box 9158, St. John's, Nfld. A1A 2X9

Canadian Wildlife Service
Ottawa K1A 0E7

Issued under the authority of
the Minister of the Environment

Canada Wildlife Service

Available by mail from
Printing and Publishing
Supply and Services Canada
Ottawa, Canada K1A 0S9
or through your bookseller

Prices:
Canada $8.00
Other countries $9.60
Prices subject to change without notice

Catalogue No. CW65-8/46E
ISBN 0-660-11785-1
ISSN 0069-0031

Design: Rolf Harder & Assoc.
Printing: K.G. Campbell Corporation
Contract No: KN107-4-5809

Front cover
Top: East Digges Island; the waterfall, June 1981 (photo: A. Gaston)
Bottom left: Large-flowered wintergreen, East Digges Island (photo: A. Gaston)
Bottom centre: Thick-billed Murres on an ice floe, Digges Sound (photo: S. Smith)
Bottom right: Red fox kits, East Digges Island, 1981 (photo: A. Gaston)

Contents

List of tables

List of figures

List of appendices

Acknowledgements

Many people assisted with this project at one stage or another and we apologize for any omissions from the following list. For financial or logistic support or both throughout the project we thank the Baseline Studies program of Environment Canada, the OLABS program of Petro-Canada (on behalf of the Labrador Group of Companies), Polar Continental Shelf Project of Department of Energy, Mines and Resources, Bradley Air Services, the Ikaluit Laboratory of Department of Indian Affairs and Northern Development, the Asbestos Corporations of North America, and the Canadian Coast Guard. David Nettleship, Graham Cooch, Wayne Speller, and Bruce Johnston all contributed to the planning of the project, and David Nettleship also organized equipment purchases in 1980 and supervised the photo-count of the murre colonies. In Frobisher Bay we were given excellent support by Andy Thériault and by Fiona Paton and Cathy Hanson, who maintained our radio contact.

In Ivujivik we were assisted by so many people that we could probably list the whole village. We thank you all, and especially Adami Mangiuk, Passa Mangiuk, Charlie Tarqik, Paulussi Alaku, Arnaituk Mark, and Mark-André Dubé. Our sincere thanks also to the denizens of the Ivujivik nursing station: Jacques Bélanger, Chantal Renaud, Claire Rochefort, Colette Ruel, Joanne Coulombe, Raymond Valiquet, and Suzanne Dumais, who frequently provided us with a home away from home.

We are grateful to Hugh Boyd, Graham Cooch, Steve Curtis, Tony Diamond, Tony Erskine, and David Nettleship for comments on this manuscript. For the identification of specimens obtained from food material we are grateful to Dianne Laubitz, Len Marhue, Don McAllister, Mark Shih and Jane Topping of the National Museums of Canada. Thanks to the drafting department of Environment Canada for the figures and to Ian Jones for the line drawing. Lastly our sincere thanks to everyone who worked with us in the field during 1979–83: Winnifred Cairns, Jamie Campbell, Gilles Chapdelaine, George Finney, Vicki Friesen, John Geale, Colleen Hyslop, Ian Jones, Heinrich Kaiser, Bruce Lyon, Andrew Macfarlane, Michael Malone, Guy Martell, Ralph Palmer, Margaret Purdie, Steven Smith, and Joe Spears.

Abstract

Digges Sound separates East Digges Island from the northwestern tip of the Ungava Peninsula, Quebec. It has been famous for its huge colonies of Thick-billed Murres since the time of Henry Hudson. The birds and their eggs have been harvested by native peoples for hundreds, perhaps thousands, of years. During our work from 1979 to 1982 we estimated a population of 300 000 breeding pairs of murres on the cliffs flanking the sound.

Smaller numbers of other marine birds also breed there. Black Guillemots are most numerous around the Nuvuk Islands and associated small islets. We estimated about 1000 pairs of Guillemots in the area. Three species of gulls breed, although the Herring Gull is confined to the area south and west of the sound. Iceland Gulls, estimated at 350 pairs scattered in eight colonies, do not occur otherwise south of Hudson Strait. Most of the approximately 180 pairs of Glaucous Gulls breed in close association with the murres.

There is a small colony of a few dozen Atlantic Puffins on Dome Island, to the south of West Digges Island. The nearest known breeding locality is in Labrador. A few Razorbills, seen occasionally near the murre colonies, also breed. The species does not occur otherwise west of the mouth of Hudson Strait.

The murres take a wide variety of marine life, including small fish, of which the most important are arctic cod, snailfish, sandlance and capelin, and invertebrates, particularly amphipod and mysid crustacea. The chicks are fed almost entirely on fish. In comparison with Thick-billed Murres in the high arctic, those breeding at Digges Sound take a wider variety of prey species.

On East Digges Island, where we conducted most of our work, about 62% of breeding murres succeeded in rearing a chick each year. Most of the losses occurred at the egg stage, the principal cause being accidental dislodgement. During the chick-rearing period losses were small. Most of those that disappeared were probably taken by Glaucous and Iceland Gulls. Small numbers of adult murres were taken by Gyrfalcons, which nested on the colony in two years, Peregrine Falcons, and red foxes. Ravens took several thousand eggs, but the effect of these losses was probably negligible in relation to the total size of the colony. The several thousand eggs and adults removed annually by local people likewise probably have little effect on the population. However, unnecessary disturbance at the colony while eggs and chicks are present causes many losses and may have a more serious impact.

Aerial surveys carried out in July and August in northeastern Hudson Bay and western Hudson Strait showed that murres from the Digges Sound colonies often travelled over 100 km to feed. The most frequently used feeding area during most of 1981 and 1982 was to the southwest of Digges Sound, between Mansel Island and the mainland. Murres were also seen feeding in large numbers off the Nuvuk Islands, almost exclusively in water more than 40 m deep. In contrast, Black Guillemots fed mostly in shallower water, taking benthic fish, particularly blennies, which did not form an important element in the murres' diet.

The Thick-billed Murres on Digges Island laid very large eggs in comparison with those recorded elsewhere. In spite of this the chicks grew very slowly and were much lighter when they left the colony than those measured at Prince Leopold Island, in the high arctic. We found consistent differences in the sizes of eggs laid and the growth rates of the chicks between different parts of the colony. The poor growth of the chicks was presumably related to low rates of feeding by the parents, and this probably resulted from the very long distances that the adults travelled to find food.

Despite the very large concentration of Thick-billed Murres at Digges Sound and throughout Hudson Strait, the seabird community of the area has few species compared with that of Lancaster Sound, lacking Northern Fulmars and Black-legged Kittiwakes. With a greater diversity of potential prey available in Hudson Strait and an apparent abundance of suitable colony sites, it is hard to construct an ecological explanation for why there are so few species of seabirds. This paradox provides a fertile field for speculation. Our inability to solve it emphasizes the exciting opportunities for research on fundamental problems of seabird ecology in the north.

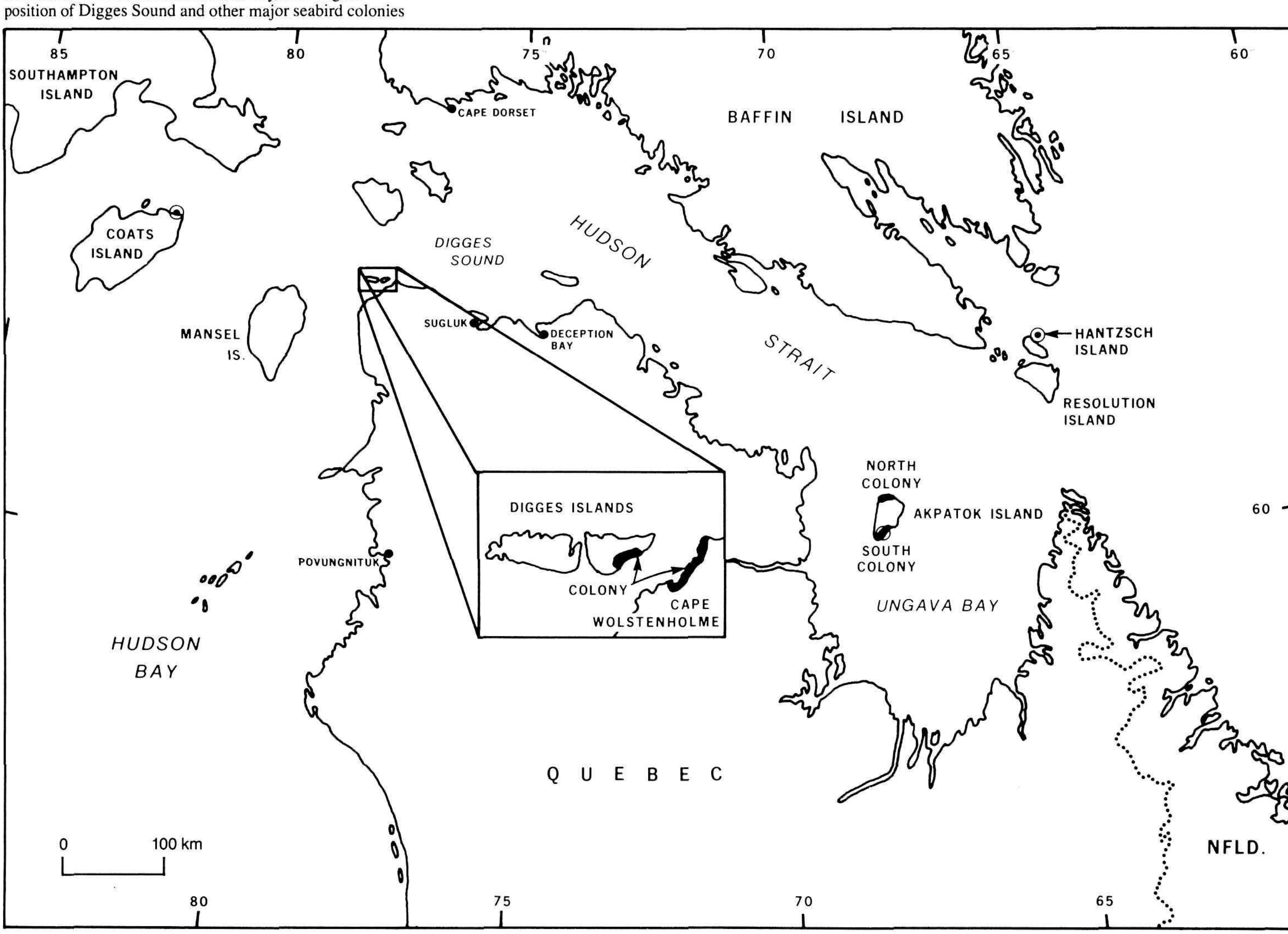
Introduction

Digges Sound, lapping at the northern tip of the Ungava Peninsula, lies at the junction of Hudson Strait and Hudson Bay (Fig. 1). It is celebrated for its huge colonies of Thick-billed Murres[1] which have attracted the attention of visitors to the area from the time of Henry Hudson (Neatby 1968). Their breeding sites line both sides of the sound, stretching unbroken along 4 km of cliffs on Digges Island and extending in slightly fragmented fashion along 8 km of the Quebec mainland south of Cape Wolstenholme (Fig. 2). Between them, they constitute the largest aggregation of Thick-billed Murres in Canada, and one of our largest concentrations of seabirds, exceeded only by the multispecies colony at Witless Bay and the gigantic assembly of Common Murres (*Uria aalge*) at Funk Island, both in Newfoundland.

The ornithology of the region is dominated by the abundance of murres, but there are other features of the area that deserve note. Digges Sound forms the southwestern limit of the breeding range of the Iceland Gull. It is the only place in Canada where this species occurs as a major scavenger on a large seabird colony,

[1]Appendix 1 gives scientific names of birds and mammals found in the study area.

Figure 1
Hudson Strait and northern Hudson Bay, showing the position of Digges Sound and other major seabird colonies



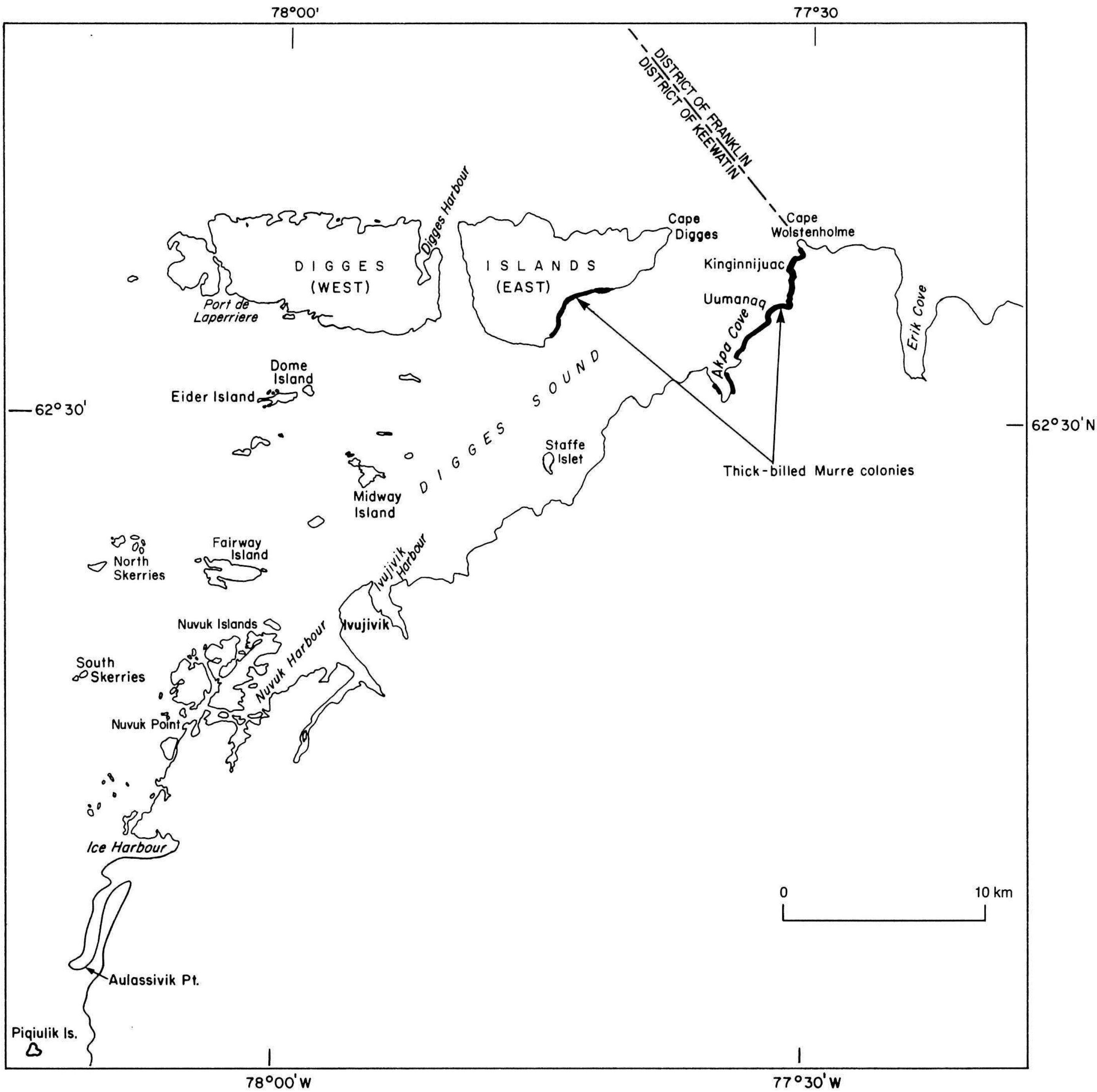
in association with the more typical Glaucous Gulls. The small breeding population of Atlantic Puffins constitutes an anomalous pocket of the species, otherwise not proved to breed in Canada north of Nain Bight, Labrador. A small number of razorbills, seen in Digges Sound in every year, although never proved to breed, also constitute an unusual outlier of a population otherwise found no further west than the Labrador coast.

We intended to study the populations and ecology of seabirds around Digges Sound. In practice, this meant concentrating on Thick-billed Murres. However, we found time to carry out research on other species, particularly those that compete with the murres for food, or that prey on the adult murres, their eggs, or chicks. The impact of the dense concentration of murres at Digges Sound on the structure of local animal communities was a constant theme of our enquiries.

Digges Sound had been visited once before by a Canadian Wildlife Service (CWS) team. In 1955 the late Leslie Tuck spent the summer there with a technician and several Inuit helpers. They performed the remarkable feat of banding 9000 Thick-billed Murres, including 3000 adults: on one day they banded 3000 murres on Digges Island. Understandably, banding took up much of Tuck's time and his notes on other aspects of the bird-life were fairly sparse (Tuck 1955), although they allow for some interesting comparisons. There have been many other visits by ornithologists, but none seem to have remained more than a few days.

In 1979 we made a pilot survey, visiting both sides of Digges Sound and some of the adjacent islands. We considered two good camp sites close to the murre colony: one at Akpa Cove at the south end of the mainland colony, and the other at the southeast corner of

Figure 2
Map of Digges Sound and adjacent waters

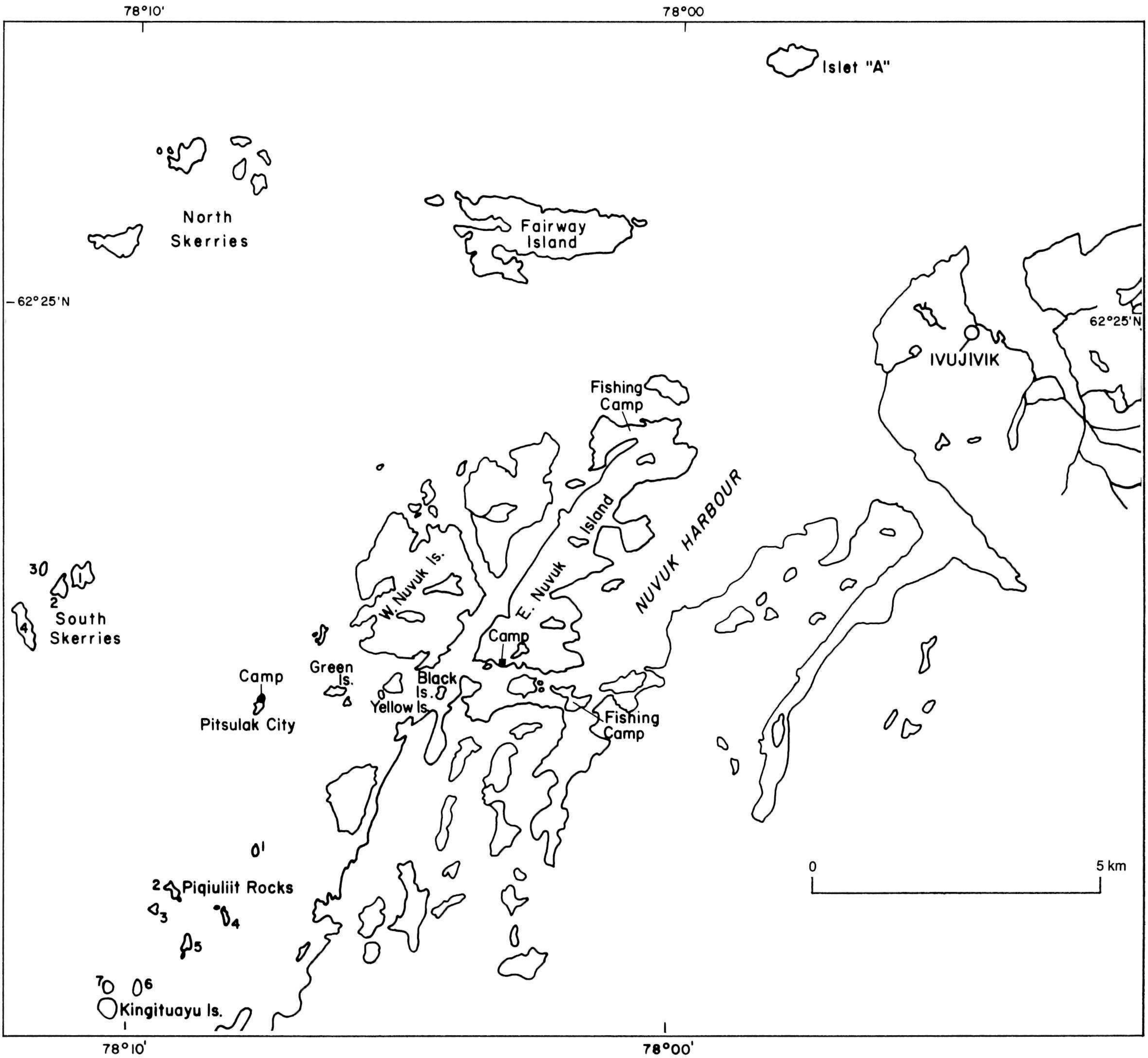


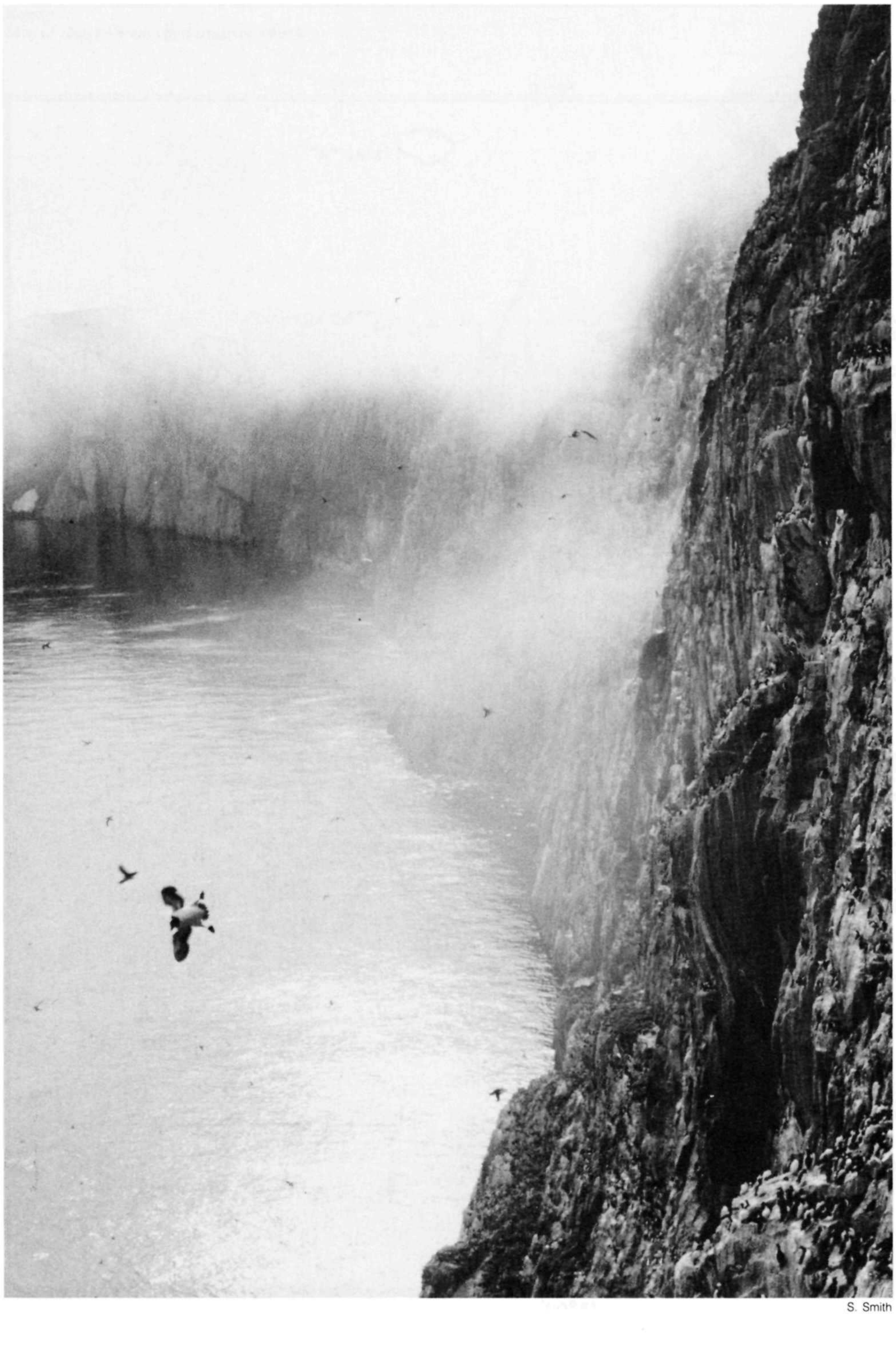
Digges Island in a small cove that we named, with regrettable lack of initiative, Camp Cove. We chose the latter for the main camp site during 1980–82 because the cliffs on East Digges Island were more suitable for observation than those on the mainland.

In 1981 a second camp was established to study Black Guillemots at the south end of East Nuvuk Island (Fig. 3). In August a fly-camp was placed on Pitsulak City, an islet 1.7 km southwest of West Nuvuk Island. In 1982 the main camp in this area was transferred to Pitsulak City and the camp on Nuvuk Island was used by John Green and assistants from Memorial University, Newfoundland, who were studying benthic fish. A similar arrangement existed in 1983, when no camp was active on Digges Island.

A large proportion of our time in all years was spent in making repetitive observations of selected study sites close to our main camps. Consequently, observations away from these camps were sporadic and concentrated in the latter half of the season when weather and ice conditions permitted us to travel easily by boat. Thus, our information on the biology of the Digges Sound area is selective. It does, nevertheless, represent a more thorough study of bird populations and their ecology than had been attempted previously for any equivalent area of Hudson Strait. We have therefore attempted to summarize our observations to link together the diverse aspects of ecology that we were able to study and demonstrate the interdependence of the many terrestrial and marine organisms that coexist at Digges Sound during summer.

Figure 3
Map of the Nuvuk Islands and surroundings




S. Smith

The ecology of Digges Sound

1. Physical environment

1.1. Topography □

The topography of the area is dominated by a gradual decline in elevation as we proceed south and west from the area immediately inland of Cape Wolstenholme. From Deception Bay westwards the south coast of Hudson Strait is precipitous and riven by deep narrow fjords. The cliffs culminate in 300 m high buttresses, which form the mainland flank in Digges Sound. The hills here are the western end of the Precambrian mountain chain that forms the backbone of the northern Ungava Peninsula. Southward and westward from Digges Sound proper, the land becomes gradually lower so that south of Ivujivik there is only modest relief.

East Digges Island is largely a plateau with an elevation of 200–300 m, sloping down to the west. The same trend continues on West Digges Island, so the western end is low lying with modest hills rising to less than 100 m. Both Digges Islands are sprinkled with lakes: we named some that we passed every day (Fig. 4). Most are deep, with steeply sloping shores and little in the way of marshes around them. This probably accounts for the paucity of breeding shorebirds.

Between the Digges Islands and Ice Harbour there is a liberal scattering of islands, mostly low lying and rocky (Fig. 2). We visited practically all of these during our studies. The largest, close inshore to the south of Ivujivik, are the Nuvuk Islands. Adjacent to this group are numerous small islets and reefs, in-

Figure 4
Map of East Digges Island

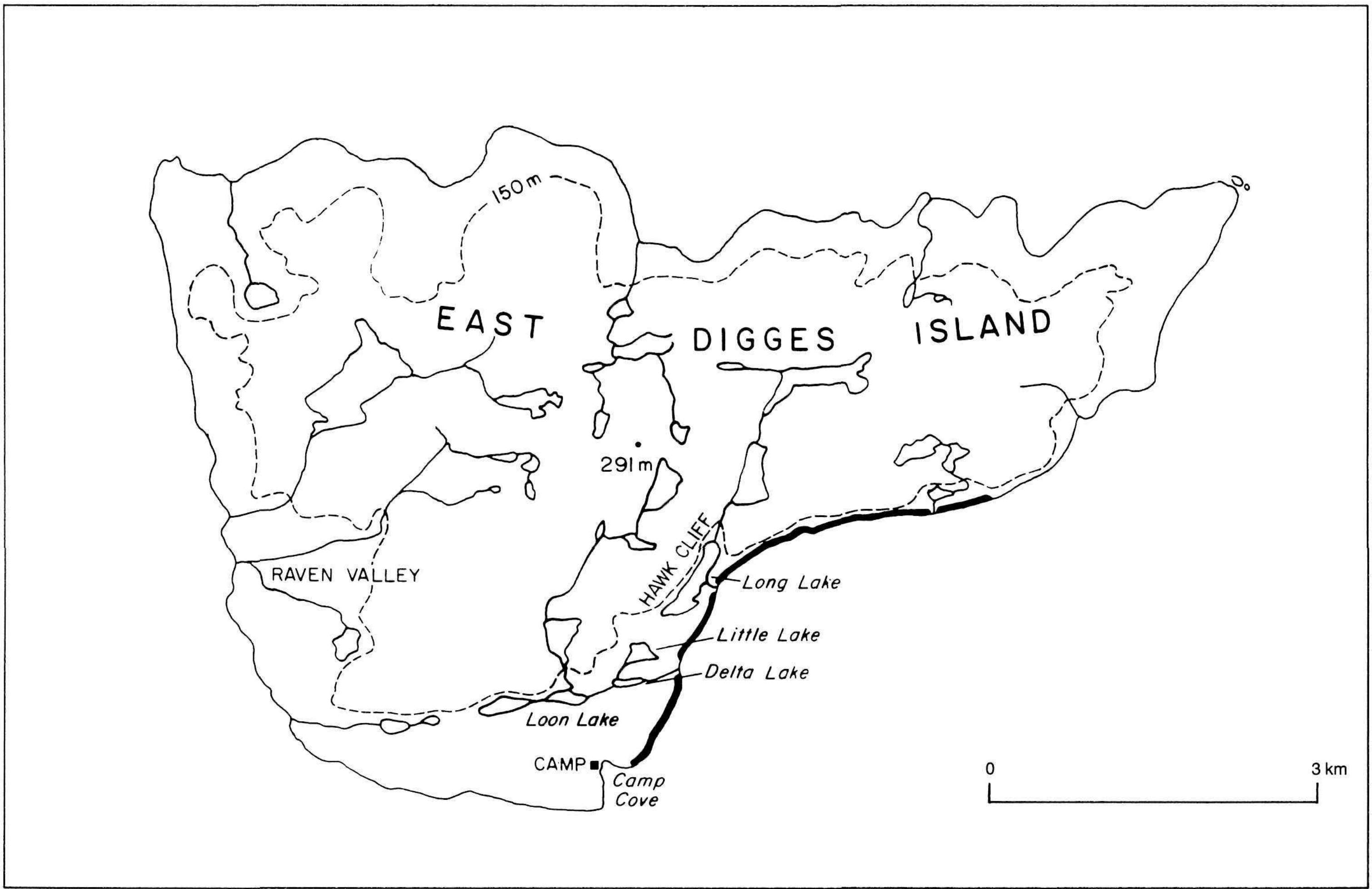
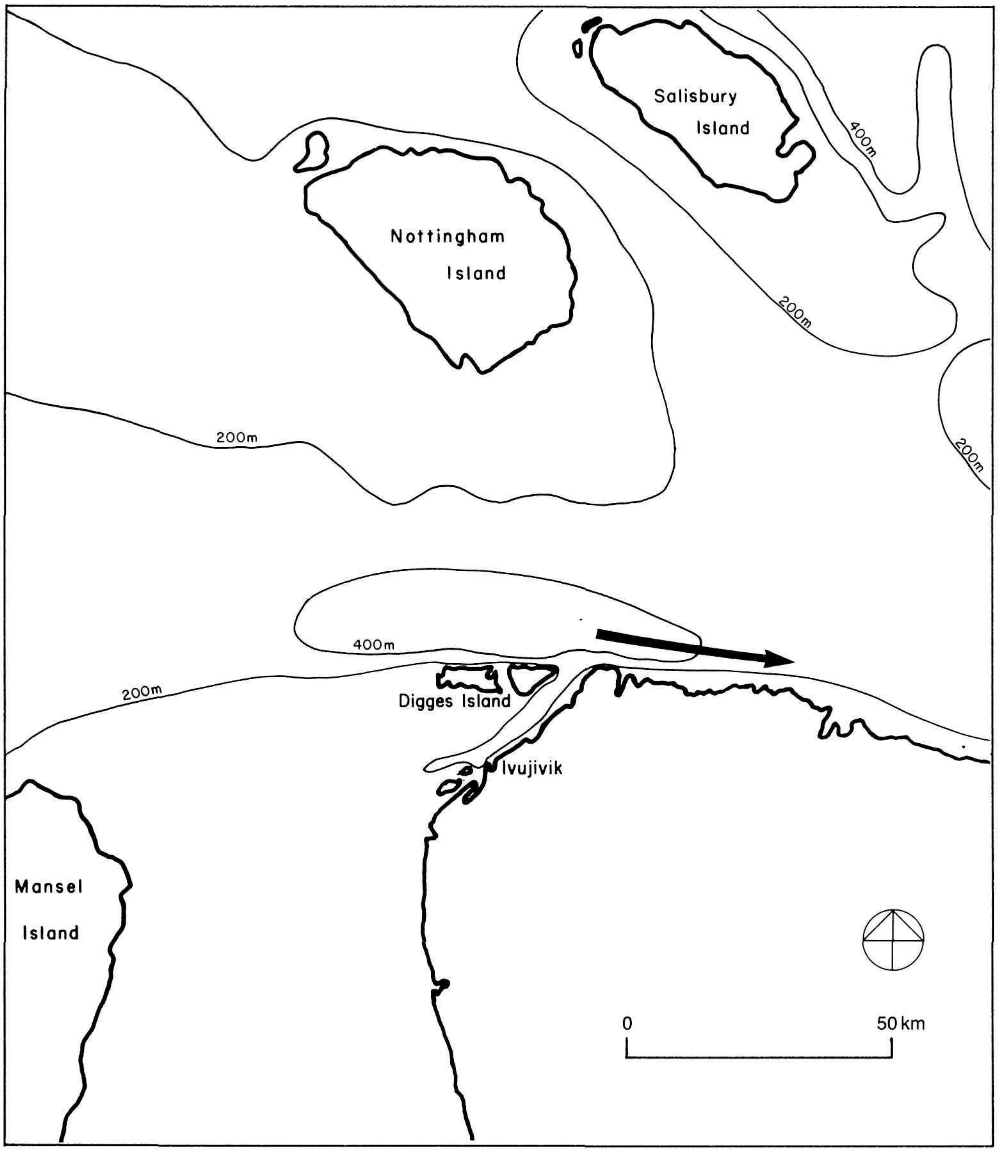


Figure 5
Bathymetry of northeast Hudson Bay and western Hudson Strait



cluding several that support sizable populations of Black Guillemots. Fairway Island, immediately to the west of Ivujivik, is next in size with a diverse topography and some low cliffs on the south side.

The Nuvuk Islands are separated from the mainland by a deep inlet, Nuvuk Harbour, running south from Ivujivik Point. At the south end, this inlet funnels down to a narrow strait dividing the south end of east Nuvuk Island from the mainland. The narrowest point of this channel is only 200 m across and the waters are shallow enough in places for kelp beds, which cover much of the bottom, to float close to the surface at low tide.

Four other islands require special mention. Staffe Islet, at the south end of Digges Sound, and only 1.5 km from the mainland, has a steep cliff about 100 m high on the west side that supports a large colony of Iceland (Kumlien's) Gulls. Dome Island, south of West Digges Island, possesses a distinctive, dome-shaped hill bounded by a cliff on the north side. Despite its northerly aspect, this is clothed in a dense turf of mosses and other vegetation and supports a small colony of Atlantic Puffins. To the west of Dome Island, Eider Island is larger and rather flat, with several small ponds used by Red-throated Loons. It supports a moderate vegetation. Piqiulik Island, on the southern margin of our survey area, differs from the other islands visited in being mainly sandy. It supports a colony of Arctic Terns.

Although much of the coast south of Ivujivik is low lying the shorelines are mainly rocky. Sandy beaches are restricted to a few coves such as Port de Laperrière on West Digges Island and a shallow inlet on East Nuvuk Island. Otherwise, where beaches occur, they are mainly composed of pebbles or boulders. The mean tidal range is 2 m (Anon. 1982).

1.2. Oceanography □

Hudson Strait forms a trough varying in depth from 300 to 500 m in the centre, and is divided into two channels at its western end by the Salisbury and Nottingham Island group (Fig. 5). The southern branch is deepest immediately north of the Digges Islands, where a basin-shaped depression descends to 500 m. A narrow tongue of deep water extends southwest from this basin through Digges Sound, cutting across the archipelago of islands off Ivujivik and passing south of Fairway Island, and north of the South Skerries.

Dunbar (1951, 1958, 1972) considers the waters of Hudson Strait to be of a low arctic type, on the grounds that Atlantic water from the West Greenland Current intermingles with arctic water from the Labrador Current in the area south of Davis Strait. It penetrates Hudson Strait with the generally westward movement of surface waters along the northern side of the strait.

Dunbar considers the waters of Hudson Bay to be essentially high arctic, but with relatively warm surface waters in summer and little vertical mixing. However, Solomonsen (1972) and Brown *et al.* (1975) classify Hudson Bay as low arctic, the division between low and high arctic being drawn through Foxe Strait, 200 km northwest of Digges Sound. Barber (1968) contrasts the active mixing of waters in Hudson Strait, through the effects of fierce tidal currents, with the comparatively unmixed waters of Hudson Bay which exhibit strong stratification of temperature, salinity, and dissolved oxygen.

Most of Hudson Bay has traditionally been regarded as a biological desert (Huntsman 1954). The lack of upwelling reduces the cycling of mineral nutrients and hence inhibits the growth of phytoplankton. Surface concentrations of chlorophyll in the centre of the bay are similar to those recorded in barren tropical oceans and are much lower that those typical of temperate shelf waters (Anderson and Roff 1980, Grainger 1982). This is not the case east of Coats Island and north of Mansel Island where biological productivity is much higher (Bursa 1961, 1968). In this area there is a general net outflow of Hudson Bay waters into Hudson Strait, causing a steep gradient in August surface temperatures from 7°C just southwest of Digges Sound to 3°C southeast of Nottingham Island (Dunbar 1958). Although current patterns around Digges Sound are dominated by tidal effects the general outflow from Hudson Bay results in a permanent eastward current along the south side of Hudson Strait to the east of Cape Wolstenholme (Anon. 1979).

Because sampling of physical and biological oceanography has been conducted on a fairly coarse scale, and because Digges Sound is close to both the high arctic/low arctic and Hudson Bay/Hudson Strait boundaries it is hard to generalize about the oceanographic characteristics of the waters surrounding the sound and its islands. It seems best to regard them as low arctic with more affinity to Hudson Strait than Hudson Bay. The abrupt changes in water depth associated with the deep water troughs and the powerful tidal currents that move in and out of Hudson Bay probably cause large-scale upwelling and mixing of waters, and this may help to increase local productivity.

Marine productivity around Digges Sound is enhanced to an unknown, but perhaps significant, degree by benthic algae. Dense thickets of kelp, with fronds 3–4 m long, cover much of the bottom to a depth of 10 m. Below this depth the large *Laminaria* becomes patchy, but the smaller *Agarum* grows in scattered clumps.

1.3. Ice □

The offshore waters of Hudson Bay and Hudson Strait are completely covered by mobile pack-ice from January to April (Larnder 1968). Land-fast ice forms a fringe around the coast and normally surrounds the Digges Islands and their associated archipelago. Local people frequently travel to the islands by snowmobile during the winter.

Heavy pack in Hudson Strait and north-east Hudson Bay begins to break up in April, usually clearing first in the area of the persistent shore-lead off Cape Dorset. By May there are large patches of open water adjacent to shore-leads in Hudson Strait and along the east coast of Hudson Bay (Fig. 6*a*): the land-fast ice begins to break up in Digges Sound and, according to people in Ivujivik, murres also begin to appear on open-water. In 1982 land-fast ice had already broken up in Digges Sound on 16 April but no murres were observed on that date.

Ice conditions in the second half of June, when Thick-billed Murres at Digges Sound begin to lay eggs, appear to be similar from year to year. Substantial areas of heavy

Figure 6
Ice conditions around Digges Sound (*a*) in May 1982, (*b*) in mid-June 1980, (*c*) in mid-June 1981, (*d*) in mid-June 1982

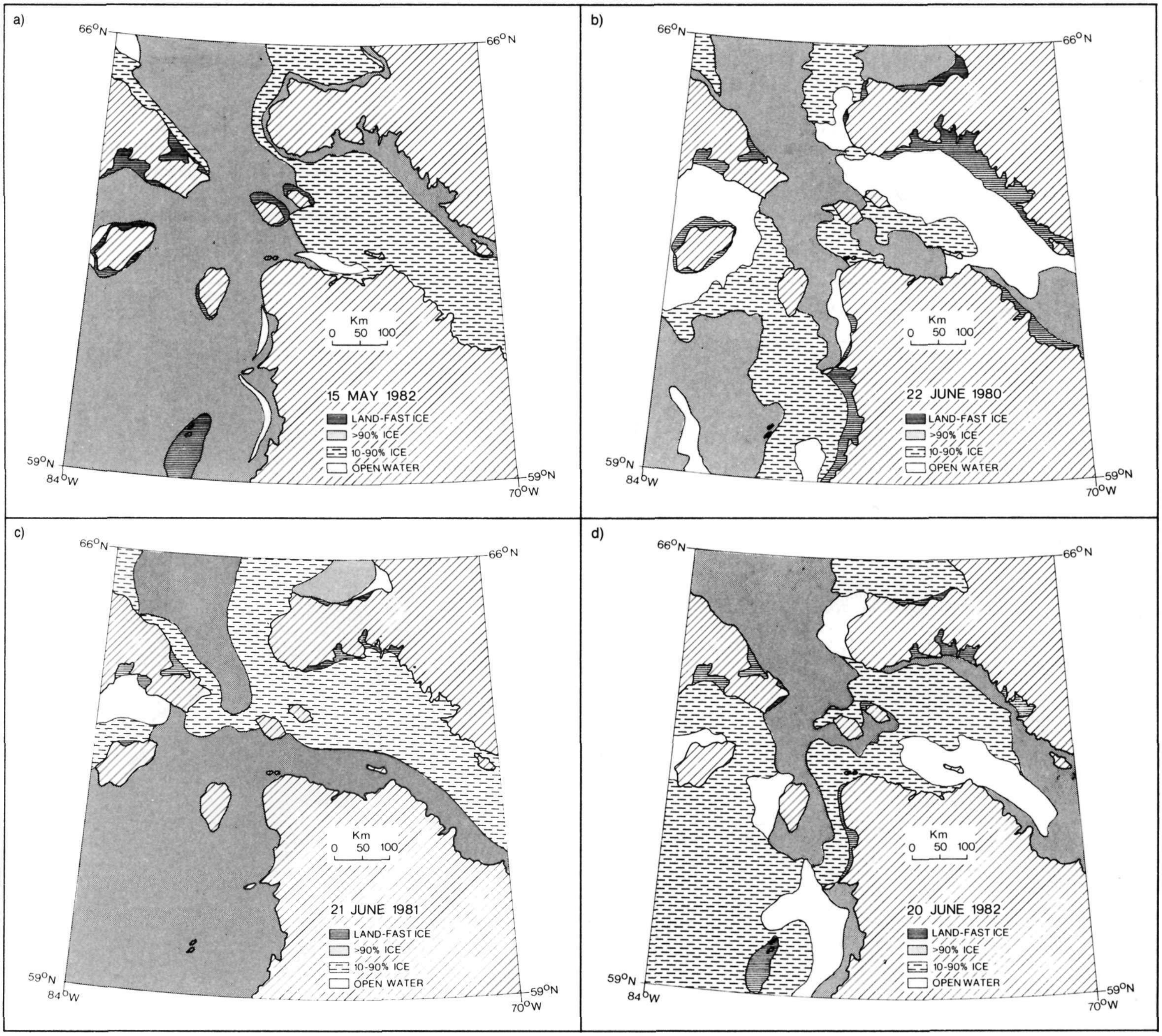


Figure 7
Position of Thick-billed Murre study plots and gull observation points on East Digges Island. Plots C, G, and H are in the area between B and S1

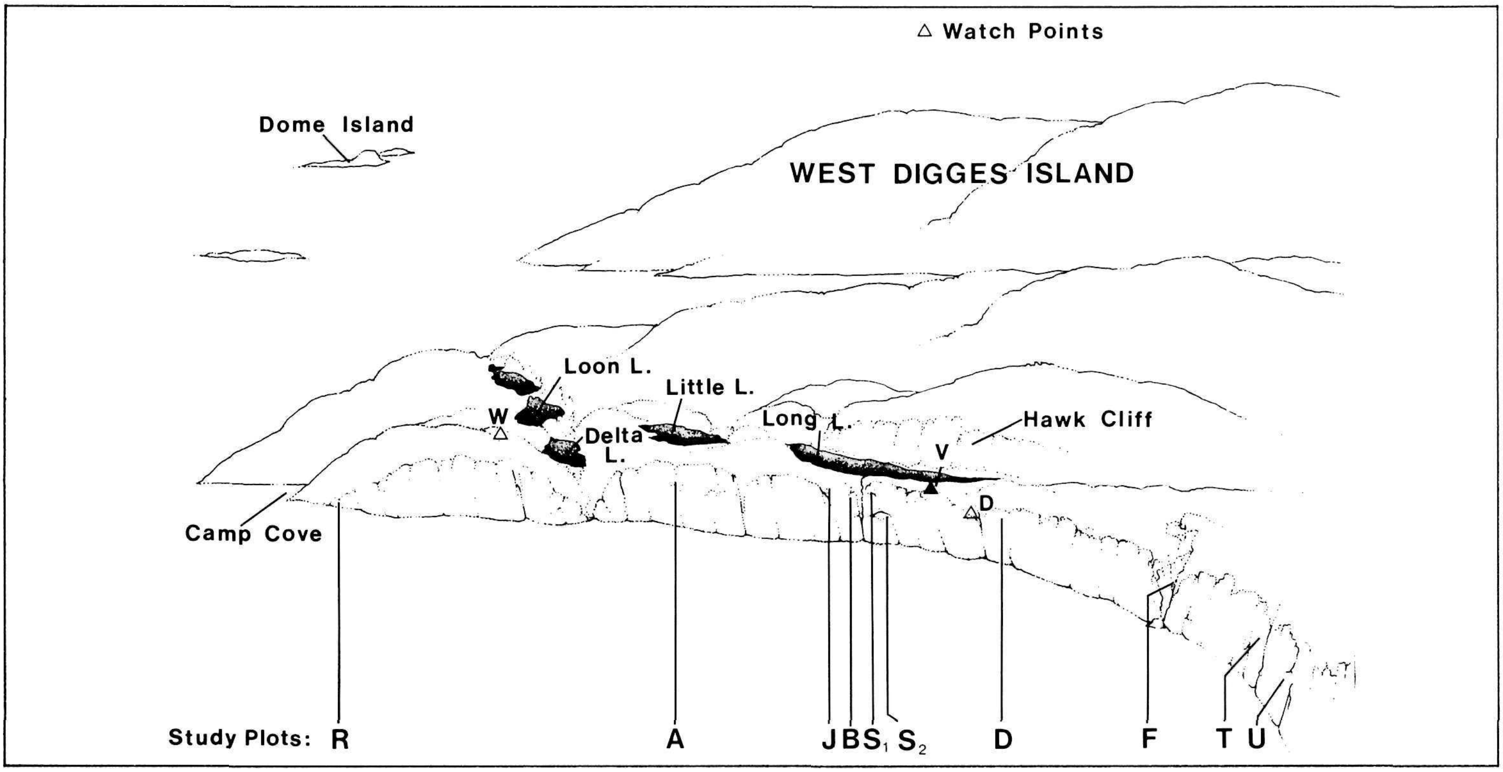
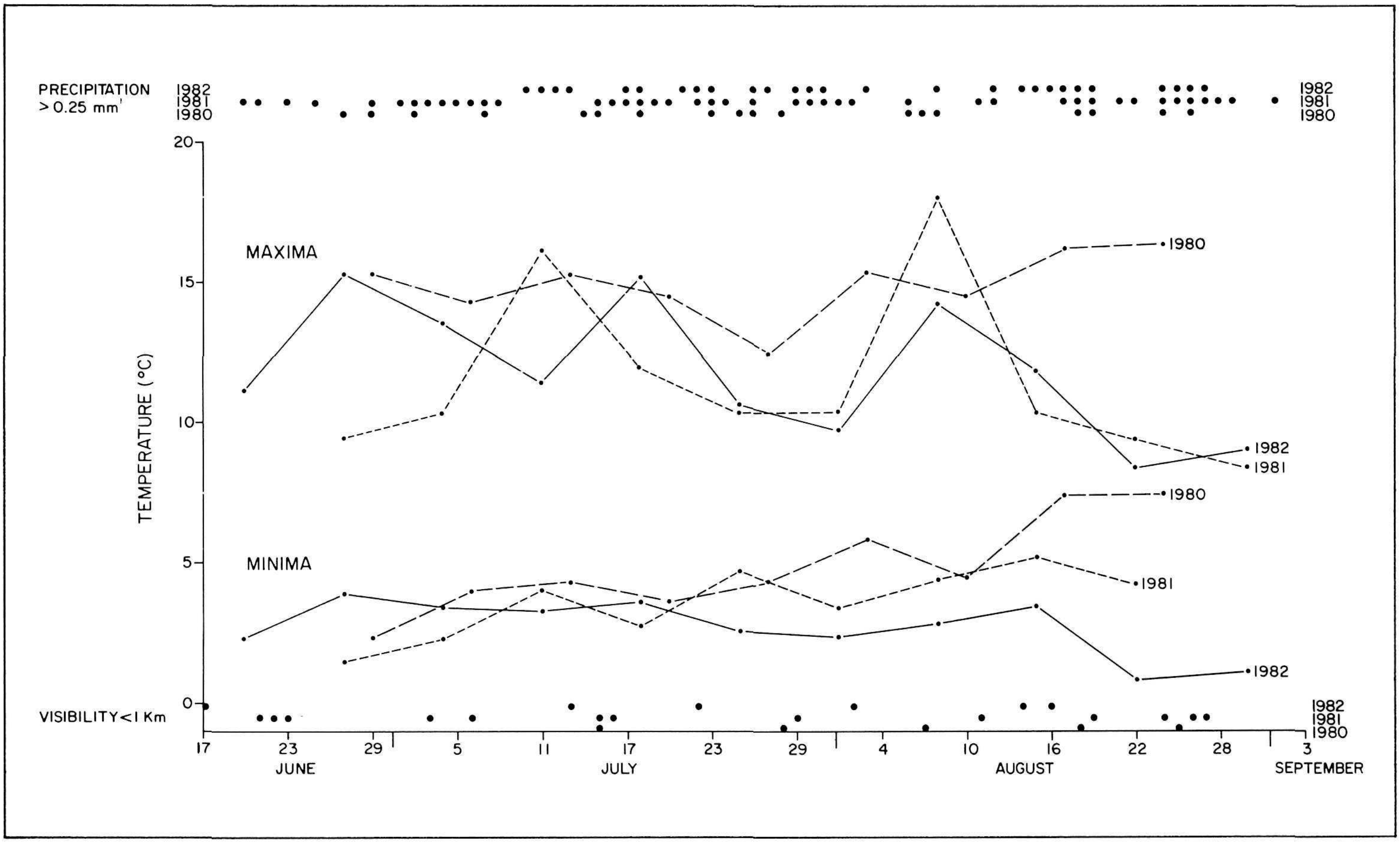


Figure 8
Weather recorded at Digges Island during summers 1980, 1981, and 1982



ice cover are present throughout Hudson Bay and Hudson Strait, but smaller areas of open water also occur, particularly in Hudson Strait, (Fig. 6*b,c,d*). In 1980 and 1981 ice pans continued to be common in Digges Sound until the second half of July. In 1982 little ice was seen after the first week of July and boating was possible from late June. Fresh ice does not begin to form in Hudson Strait until October, by which time most of the migrant seabirds have departed.

Table 1
Weather data from Nottingham Island for 1930–70 (from Anon. 1979). Figures for Digges Island during 1980–82 are given in brackets

Month	Mean temp., °C		Extreme temp., °C		Precipitation		Days with fog†	Mean wind speed (km·h⁻¹)
	Max.	Min.	Max.	Min.	Monthly total, mm	Days with rain or snow*		
May	−1.2	−7.3	8.3	−22.2	16.5	11	2	19.0
June	4.3	−1.2	18.3	−12.2	21.6	8	7	17.1
July	9.7	2.2	22.8	−3.9	31.2	9 (14)	9 (3)	16.2 (15.2)
August	9.2	2.3	20.6	−5.6	35.8	10 (12)	11 (4)	16.2 (17.9)
September	3.9	−0.9	19.4	−10.6	37.1	10	6	19.0

*>0.25 mm.
†Visibility <0.8 km.

1.4. Climate □

The Hudson Bay region has the distinction of being the coldest area on earth for its latitude and the place where the northern limit of tree growth and the southern limit of permafrost at sea level reach their most southerly point in North America (Anon. 1974). Digges Sound falls within the Hudson Strait climatic region (Maxwell 1981) which is typified by small annual temperature ranges and a high incidence of fog, compared with other areas of the Canadian eastern Arctic. The climate of Digges Sound is probably as clement as that of any major Thick-billed Murre colony. Most of those further north experience much lower summer temperatures. On some days in July and August when maximum temperatures reached 20°C incubating birds on East Digges Island situated in the sun appeared distinctly uncomfortable, panting heavily and spreading their wings.

The nearest weather station for which a long series of records is available is Nottingham Island where observations were made from 1930 to 1970. Table 1 gives weather data for May to September from this station (from Anon. 1979).

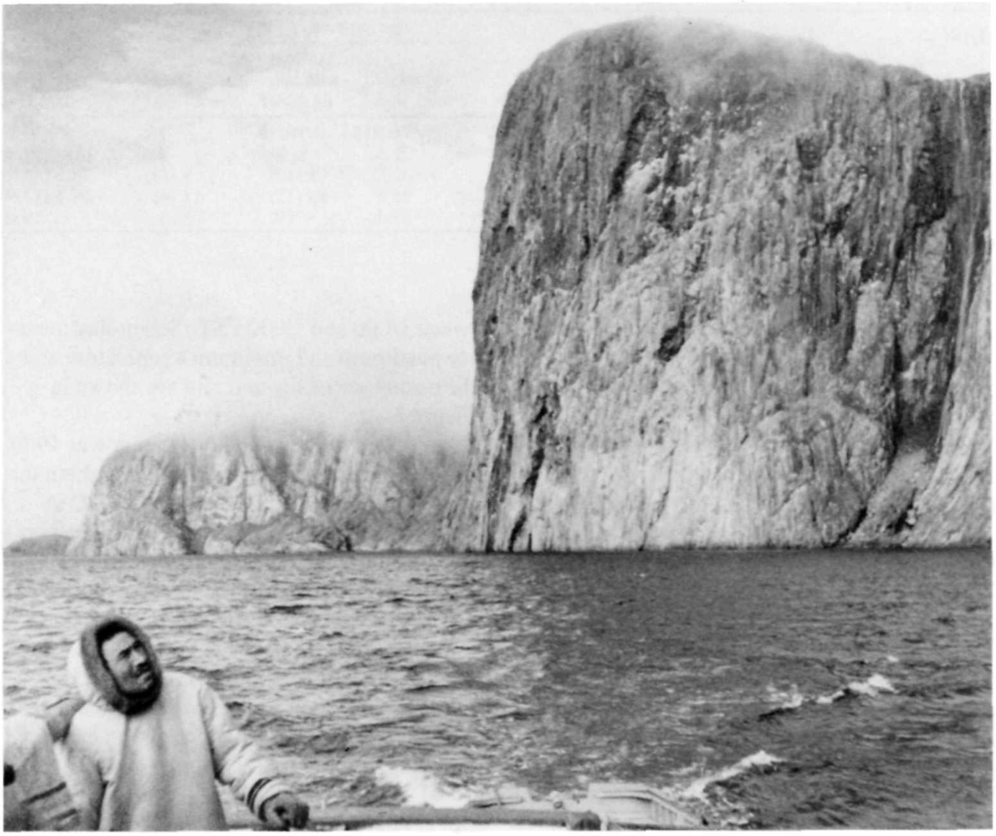
We kept weather records at Digges Island throughout our stay. Temperature (daily maximum and minimum), precipitation, and barometric pressure were measured at Camp Cove, but wind speed and direction, cloud cover, and visibility were recorded at the highest point along the colony cliffs, between plots D and F (Fig. 7). All observations were made between 18:00 and 19:00 EST. Seven-day means for maximum and minimum temperature and the occurence of fog and rain are shown in Figure 8.

The warmest and driest year was 1980, with mean maxima above 12°C throughout the season and mean minima exceeding 7°C in mid-August. By contrast, 1982, after a warm dry June, was the coldest and wettest year with minimum temperatures never rising above 4°C and falling to only 1°C in late August. The foggiest year, 1981, was still much less foggy that the average for Nottingham Island, perhaps because observations were made in late afternoon, by which time fog present early in the day had sometimes cleared away.

Digges Sound in early July 1980; East Digges Island in the foreground, Cape Wolstenholme beyond

B. Lyon

Uumanaq cliff, with Cape Wolstenholme beyond, in 1955, photographed by the late L.M. Tuck



The same cliff in 1981. Note that the distribution of 'whitewash' (murre-droppings, best compared on the upper part of the cliff) appears very similar in both pictures. Apparently little change had occurred in the location of breeding ledges over the intervening 26 years

M. Purdy

2. People

The only permanent settlement in the area is Ivujivik, a community consisting of about 30 Inuk families, and comprising about 200 people altogether. The economy of Ivujivik, like that of most Inuk settlements in the region, depends partly on traditional pursuits (hunting, fishing, trapping), partly on carving (mainly in soapstone), and partly on the apportionment of various provincially or federally sponsored jobs in the community. Hunting and fishing provide a large proportion of the food eaten, at least in summer, the mainstays being arctic char (*Salvelinus alpinus*), which are netted intensively in July and August, beluga whales, which are available mainly in June and seals, mainly ringed seals which are hunted in spring on the ice and in summer from boats.

During summer many people move out of Ivujivik to temporary camps for hunting and fishing. Particularly favoured sites are Erik Cove, mainly for hunting seals and beluga in June and July; Ice Harbour and several sites around Nuvuk Harbour for arctic char fishing; and a site near the north end of East Nuvuk Island, used for whale hunting and fishing. Although people visited Digges Island periodically to harvest murres there was no sign that a camp had been established near the colony in recent years.

Harvesting of seabirds is a traditional part of the local economy. Habakuk Prickett, Sir Dudley Digges' representative on Hudson's expedition, landed on Digges Island in 1610 and his description makes it clear that he visited the area where we situated our blinds:

> . . . we went along by the side of a great pond of water [Long Lake], which lieth under the east side of this hill [Hawk Cliff]: and there runneth out of it a stream of water as much as would drive an overshot mill; which falleth downe from a high cliffe into the sea on the south side. In this place great store of fowle breed. . . . (Prickett [1611] in Asher [1860])

Further on Prickett describes stone buildings, probably in the area above Delta Lake, which he found, ". . . full of fowles hanged by their neckes." He makes no comment about the builders but we can assume that they were the local Inuit. When Prickett returned the following summer with the rest of the mutineers who had abandoned Hudson, they found Inuit camped on Digges Island. Lured into their camp by promises of caribou meat, four of the Europeans were killed.

The seabird colonies made a deep impression on Hudson's men for as soon as spring thaw had released them from the ice of James Bay they made directly for Digges Sound without any attempt to find other food sources along the way. In 1615 William Baffin, passing the island, again noted Inuit in residence (Markham 1881).

We found the remains of at least four of the stone buildings described by Prickett: two above Delta Lake and another two, and perhaps more, in the steep valley leading from Camp Cove to the top of the island. They seem to have been about 2 m in diameter and, from Prickett's description ("like grass cockes"), presumably dome-shaped. Such buildings have been used by Inuit elsewhere for the same purpose. In northwest Greenland, Freuchen and Salomonsen (1958) mention that stone buildings were used for caching Dovekies which were further preserved by sewing them inside sealskins. However, the technique described by Prickett sounds more like the practice of the former sea-fowlers of St. Kilda in the Outer Hebrides, who used similar stone chambers ("cletts") to dry fish and birds (Fisher 1952).

The catching technique that Prickett mentions the Inuit using, a running noose on the end of a long pole, also shows remarkable convergence with similar techniques used on St. Kilda and in the Faeroe Islands. The technique is nò longer used by modern residents of Ivujivik who make no attempt to store birds on the island. They could shed no light on the people who made the stone buildings.

More evidence of the importance of the murres to Inuit in the past came from excavations near our camp. Everywhere we dug over an area of many tens of square metres we found a layer of bones and bone fragments beneath the turf, in many places resting directly on the bedrock. Most of the identifiable remains were leg and wing bones of adult murres, stained heavily by pigment leaching from the surrounding peat and very fragile. Most of the long bones were intact, suggesting that the people concerned did not have dogs with them.

It is hard to imagine that any people living in the vicinity of Digges Sound would have failed to exploit the seabird colony. Archaeological investigations at Ivujivik and the Nuvuk Islands have revealed evidence that the area was occupied by successive cultures, beginning with pre-Dorset peoples about 1500 B.C. (Taylor 1960, 1962, 1968). We can probably assume that exploitation of the birds goes back at least that far.

During the past few years the removal of eggs from the colony has been on a modest scale. In some years the presence of mobile pack in Digges Sound prevents boats from Ivujivik from reaching the colony until eggs are well set. When the water is open at laying, however, four or five visits are usually made to East Digges Island by organized teams which use buckets and ropes to lower the eggs down to waiting boats. Several hundred eggs are removed at each visit and the total for the season may be 2000–3000 eggs. The mainland cliffs are less favoured because the climbing is more difficult, but some eggs are also taken there. Egging sites are those easily accessible from the water and certain areas are harvested each year. Despite this the birds continue to use the same sites.

Throughout the season, when boating is possible, people visit the colony to shoot adult murres. Most come from Ivujivik, but boats from Sugluk and Povungnituk also stop off while passing along the coast. The majority of these visits are brief, with only a dozen or two birds killed for immediate consumption. A few are more serious ventures, with up to 300 birds taken to put in store. Moderate numbers are also shot away from the colony, particularly near Ivujivik, usually for immediate consumption.

The total number of adult birds killed probably does not exceed 2000 in a normal year. The direct effects of such a kill are unlikely to have a serious impact on the murre population. However, when shooting is carried out close to the cliffs, particularly if shotguns or .303 rifles are used, tens of thousands of birds fly off the cliffs in panic, dislodging eggs and chicks. Repeated shooting, particularly when chicks are well developed and prone to fledge prematurely, probably causes considerable losses. Chicks that fledge prematurely almost certainly perish and many thousands may be lost in this way. In 1982 many "tourists" from as far as Cape Dorset visited the colony during a festival held in Ivujivik and disturbance at Digges Island was severe.

3. Terrestrial environment

3.1. Vegetation □

Digges Sound is 500 km north of the northernmost limit of tree growth. Added to this, the elevation of the country inland from Ivujivik and the cooling influence of proximity to the icy waters of Hudson Bay combine to restrict the vegetation to truly arctic plants. In a few sheltered, south-facing spots on the mainland a low mat of willows forms the closest thing to a forest that the area can provide.

On flat ground, where soil has accumulated, a turf of grasses (holy grass, blue grass), sedges, and wood rushes is formed, sometimes associated with arctic willow. On drier areas dwarf shrubs such as bearberry, bilberry, and arctic white heather occur and in exposed places the purple saxifrage.

We made collections of whatever vascular plants we encountered. Most were obtained on East Digges Island where we found 102 out of the 109 species that we recorded (App. 2). The vegetation of the island is strongly influenced by the presence of the murre colony. Areas immediately inland of the cliffs are clothed in a dense turf of lichens, mosses, and grasses, often growing on steep slopes that would not, under any other circumstances, allow the development of soil. In some areas these slopes are treacherous to walk on because the thick carpet of wet moss slides easily on the underlying rocks and affords no secure foothold.

Along the seabird cliffs themselves broad ledges support a distinctive vegetation of coarse grasses, mountain sorrel, and scurvy grass. The vegetation at the edge of the cliffs is characterized by abundant cloudberry, cotton grass species, and the least willow. In early September people from Ivujivik visit East Digges Island specifically to collect cloudberries along the cliffs. However, a kilometre or so inland from the colony, the island is comparatively barren, supporting only lichens, *Rhacomitrium* mosses, and purple saxifrage.

At lower altitudes, particularly on south-facing slopes, vegetation is much lusher and more diverse. We investigated the vascular plants of Camp Cove thoroughly and found about 90 species, including 10 species of saxifrage and six of whitlow grass. The most distinctive flowers are large-flowered wintergreen, a large yellow daisy (*Arnica alpina*), and the showy purple heads of the broad-leaved willow-herb. Several species we recorded were at the edge of their known range, including the scurvy grasses *Draba cinerea* and *D. oblongata* and the lousewort *Pedicularis capitata* (Porsild and Cody 1980).

3.2. Herbivores □

The principal vertebrate herbivores of the region are the Labrador collared lemming and the Canada Goose. Lemmings were scarce on East Digges Island in 1980. Although large quantities of droppings and numerous runways and winter nests were exposed as the snow melted in June, hardly any animals were seen, suggesting that the population had crashed just prior to our arrival. In 1981 lemmings were seen regularly throughout the season, and in 1982 they were seen almost daily along the tops of the seabird cliffs and it was not uncommon to see two or three in a morning.

In 1980 there was much evidence of lemmings gnawing willow bark during the previous winter, perhaps an indication that food was in short supply. This must severely reduce the growth of willows when lemming populations are high and may be a factor restricting the growth of shrubby willows along the seabird cliffs where lemming densities were highest and shrubby willows were practically absent (although *Salix herbacea* was common).

Canada Geese showed an opposite trend to that of lemmings. They were common breeders in the area between Camp Cove and the east end of the murre colony in 1980, but in 1981 only two broods were seen and in 1982 none. Our activities may have discouraged nesting. Several hundred geese moulted on West Digges Island every year and their grazing clearly had some impact on grass growing around the lakes where they were concentrated. Similar numbers also grazed on well vegetated areas of the Nuvuk Islands and the adjacent mainland during spring migration in June.

Earlier visitors to the Digges Islands reported caribou. Prickett saw 16 on his visit in 1610, but we found no evidence of them on the islands except for one old set of antlers. People from Ivujivik normally have to travel far inland to hunt them now, although a small herd appeared on Cape Wolstenholme a few years ago (A. Mangiuk, pers. comm.). We found the remains of a single arctic hare on East Digges Island but the species is apparently uncommon in the area.

3.3. Carnivores □

Both the red and arctic foxes occurred on East Digges Island. In 1981 and 1982 a red fox den was situated in Camp Cove, containing at least six kits in 1981 and three in 1982. In both years the vixen shifted her den to the top of the island soon after our arrival.

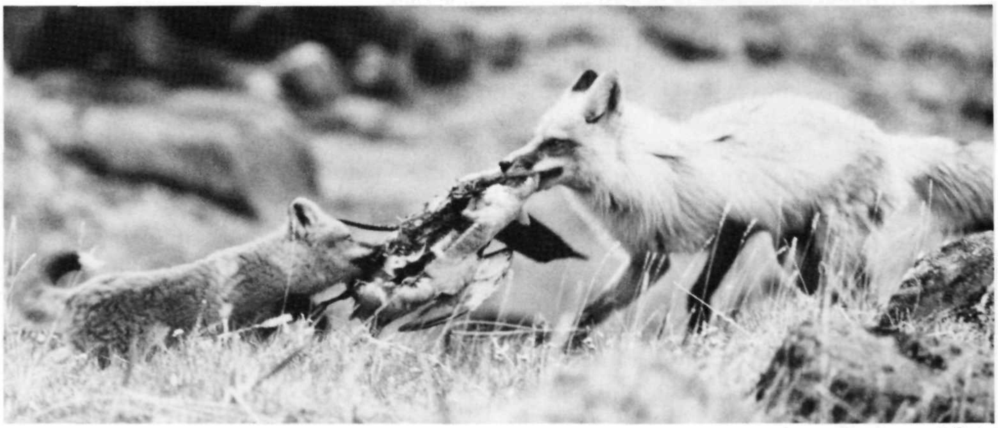
Prey remains at the den included adult murres, breeders judging from their condition, and lemmings. On the cliffs we saw foxes take murre eggs and found evidence of predation on murre chicks. In some cases dozens of chicks were killed and the headless corpses left scattered on the ledges. This was observed only in 1980, when no den was located.

We only found evidence of arctic fox on East Digges Island in 1982 in the form of the carcass of an animal which had probably died the previous winter. The species is common inland of Ivujivik and trapped in large numbers in some winters.

Avian carnivores included Northern Ravens, Rough-legged Hawks, Gyrfalcons and Peregrine Falcons. Although no nests were found on East Digges Island in 1980 ravens were very numerous; we saw up to 16 in one day along the murre cliffs. We also saw large numbers along the mainland cliffs south of Cape Wolstenholme. Two pairs of ravens bred on East Digges Island in 1981. In 1982 the same sites were occupied together with a third, definitely not used in 1981. In 1982 a pair of ravens was present on East Digges Island when we landed briefly on 16 April. Ravens were important predators of murre eggs and chicks. Analysis of pellets showed that lemmings and Snow Buntings were also taken. Ravens never showed any interest in scavenging around our camp, although they flew over almost daily.

Rough-legged Hawks were abundant in 1980, when we located seven nests: five on East Digges Island, one on West Digges Island, and one on Fairway Island. Only one nest was attempted in 1981 and this was soon abandoned, whereas in 1982 there were two nests on East and one on West Digges Island. It appears that the lemming crash in 1980 drove the hawks away. In that year only four nests produced young, rearing broods of one, two, three, and three. Three of these were on East Digges Island where murres appeared to be an important prey, as were Snow Bunting. At the other successful nest, on Fairway Island, prey remains were mainly of lemmings; the lemming population there may have been out of phase with that on East Digges Island.

Mother and cub red fox dispute possession of a Thick-billed Murre carcass, East Digges Island, June 1982



A. Gaston

Gyrfalcons nested on East Digges Island in 1980 and 1982 at the same site, near the centre of the murre colony, producing one and three young, respectively. They may also have attempted to breed in 1981 but were unsuccessful in rearing young. Their prey appeared to consist entirely of murres and we saw several captures. In each case the capture looked effortless: the falcon sailed through the throng of birds circling the cliffs and made a casual swerve to seize a passing bird which was then carried, flapping, to the cliff-top where it was rapidly subdued. Probably, the Gyrfalcons took mostly non-breeders, which spend much time flying to and fro along the cliffs throughout the season (Gaston and Nettleship 1981). Breeders generally flew directly to their breeding site on arrival and then departed rapidly to the sea.

We saw little panic among the murres when a falcon appeared. The only time a mass departure accompanied the appearance of a predator occurred when a Rough-legged Hawk attempted to take a murre from the cliff. With the daily appearance of Gyrfalcons, the murres apparently became habituated to the presence of predators.

Another Gyrfalcon nest was located in 1981 near Nuvuk Harbour, with three young, which were fledged by 1 August. The chick at East Digges Island in 1980 was not seen out of the nest until 11 August, but in 1982 two young had fledged by 23 July, suggesting that laying had taken place in early May (Cade and Digby 1982).

We saw Peregrine Falcons regularly on East Digges Island, where they hunted the murres, but we had no evidence of nesting on the island. In 1981 two nests were located elsewhere in the area, each with two young. Three young were reared at one of these sites in 1982. Prey remains that we examined included Water Pipit, Semipalmated Plover, and Black Guillemot.

3.4. Small birds □

We found only three species of small passerines nesting in the Digges Sound area: Horned Lark, Water Pipit, and Snow Bunting. We found only one nest of Horned Lark, on West Digges Island, but the other two species were common. Evidence from laying dates that we recorded helped us to compare the timing of events in the terrestrial season at Digges Sound with those elsewhere in the Artic.

On East Digges Island we found 33 Snow Bunting nests during 1980–82. Most were inaccessible, in deep crevices on cliffs or among boulders, so we could get information on timing of laying for only 25. To calculate most first egg dates we assumed that incubation lasted 12 days and eggs were laid at daily intervals (Hussell 1972). Mean clutch size was 4.64 ($\pm$0.51 SD) eggs ($N = 11$). The Snow Bunting population was extremely dense along the top of the colony cliffs, with a minimum of 14 pairs, and probably two or three more, having nests in an area of 1.8 km^2 between Camp Cove and study plot F in 1980. Densities away from the colony were much lower than this and the difference probably reflects the much greater development of vegetation in the vicinity of the colony and a consequently greater abundance of insect life.

The earliest Snow Bunting eggs were laid on 15 June and half of the clutches were initiated by 22 June (Fig. 9). This is later than any example recorded by Hussell (1972) except for that from Devon Island, 14° further north. The comparative lateness of breeding at Digges Sound may reflect the effect of the surrounding ice-covered waters in lowering the temperature.

The 19 nests of Water Pipits that we found were more readily observed than those of Snow Buntings and we could estimate dates of laying for 16, based on an incubation period, observed for two nests, of 14 days. Mean clutch size was 5.44 $\pm$ 0.62 ($N = 18$).

Water Pipits began laying on 19 June and half of the clutches had been started by 25 June. The spread of laying dates was 17 days for Snow Buntings and 15 days for Water Pipits. A full list of bird species recorded in the

Digges Sound area, with brief notes on those not otherwise mentioned in the text, is given in Appendix 1.

4. Marine biology

4.1. Plankton □

We made no attempt to sample plankton systematically and most of our observations relate to larger zooplankton that figured in the diet of murres, guillemots, and gulls. Like most areas with winter ice cover, the waters around Digges Sound probably develop a rapid bloom of phytoplankton, mainly diatoms (Bursa 1968) as soon as ice break-up occurs (Grainger 1979). This presumably feeds a corresponding surge of zooplankton production which probably peaks in July and August.

Gazing down into the clear waters of Digges Sound in June or July one could always see large comb jellies, arrow worms, copepod crustacea, and pteropod molluscs. In August surface swarms of the marine worms *Nereis pelagica* occurred and large jellyfish were often visible. None of these organisms figured prominently in the diets of any of the seabirds, although we found traces of them all. Instead the zooplankton most frequently found in the stomachs of murres that we collected were amphipod (*Gammarus, Apherusa, Onisimus*, and particularly *Parathemisto* spp.) and mysid (*Mysis, Boreomysis*) crustacea. In late August we found large numbers of *Parathemisto* sp. washed up on beaches around Ivujivik, but otherwise the larger crustacea were rarely seen.

Our total collection of marine invertebrates from all sources amounted to 43 species (Table 2), which is small compared to the total of 260 recorded for Hudson Bay by Grainger (1968). However, several records were of interest in representing species mainly confined to Atlantic waters, according to Dunbar (1964) and Dunbar and Moore (1980), including *Mysis mixta, Boreomysis nobilis*, and *Argis dentata*.

Figure 9
Laying dates of first eggs for Snow Buntings and Water Pipits at Digges Island in 1980–82

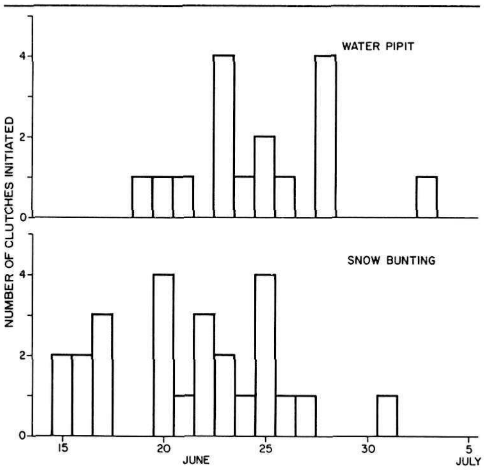


Table 2
Marine invertebrates collected in the Digges Sound area

	Source of specimen		
	Adult murre stomach	Adult guillemot stomach	Other
Class Crustacea			
Order Amphipoda			
Suborder Hyperidea			
Hyperia galba	+		
Hyperia medusarum	+		
Parathemisto libellula	+		
Parathemisto abyssorum	+		
Suborder Gammaridea			
Gammarus wilkitzkii	+	+	fish trap
Ampelisca macrocephala	+	+	
Onisimus nanseni	+		
Ischyrocerus sp.	+		
Rhachotropis sp.	+		
Monoculodes sp.	+		
Pontogeneia inermis	+		
Weyprechtia pinguis	+		
Apherusa sp.	+		
Boeckosimus edwardsii	+		
Halegonis sp.	+		
Order Mysidacea			
Boreomysis nobilis	+		
Mysis oculata	+	+	
Mysis littoralis	+		
Mysis polaris	+		
Mysis mixta		+	
Order Euphausiacea			
Thysanoessa raschii	+		
Order Decapoda			
Lebbeus polaris		+	
Eualus fabricii		+	
Eualus gaimardii		+	
Spirontocaris phippsii		+	
Sclerocrangon boreas	+		
Argis dentata	+		
Ayas coarctus			unknown
Order Copepoda			
Calanus hyperboreus	+		
Metridia longa	+		
Euchaeta norvegica	+		
Xanthocalanus sp.	+		
Cyclopina sp.	+		
Order Ostracoda			
Conchoecia spp.	+		
Other invertebrates			
Order Cephalopoda			
Gonatus fabricii	+		
Order Pteropoda			
Limacina helicina	+		plankton net arctic char
Clione limacina			plankton net
Order Pelycypoda			
Nuculana minuta	+		
Order Chaetognatha			
Sagitta spp.	+		plankton net
Order Annelida			
Nereis pelagica	+	+	fish trap
Order Ctenophora			
Beröe sp.			plankton net
Order Cnidaria			
Sarsia princeps			plankton net
Aglantha digitale			plankton net

4.2. Fish □

We set gill nets and minnow-traps for fish in 1981, mainly around Nuvuk Harbour, but also off the Digges Islands. In 1982 the Memorial University team collected benthic fish near the Nuvuk Islands with slurp guns and hand nets.

As in the case of the zooplankton, our catches of fish bore no relation to the diet of the seabirds. In gill nets we caught predominantly sculpin (*Myoxocephalus*, "crazy-fish" of the Inuit), and Greenland cod.[2] Neither of these species was recorded in the diet of the Thick-billed Murre, although the otoliths of small crazy-fish could have been confused with those of other small members of the same family. The search for benthic fish was more successful, yielding eight species, including all of those figuring in the diet of adult or nestling Black Guillemots.

Commercially, the only important fish in the waters around Nuvuk Islands was the arctic char. These were caught in gill nets in large numbers by people from Ivujivik from early July to late August. The adult fish descend the rivers soon after spring thaw and feed in the sea for a month or two before returning to spawn. Tuck (1955) recorded that the local people caught arctic char mainly off Digges Island. However, no one ever fished there while

[2] Table 3 gives scientific names of fish found in the study area.

Table 3
List of marine fish identified at Digges Sound, the means by which they were taken, and their probable occurrence in the water column

	Source of specimens					
	Thick-billed Murres		Black Guillemots			
Species	Adults	Chicks	Adults	Chicks	Captured	Occurrence
Arctic char (*Salvelinus alpinus*)					+	Pelagic (anadromus)
Capelin (*Mallotus villosus*)	+	+				Pelagic
Arctic cod (*Boreogadus saida*)	+	+	+	+		Pelagic
Greenland cod (*Gadus ogac*)					+	Benthic
Shorthorn sculpin (*Myoxocephalus scorpius*)				+	+	Benthic
Arctic sculpin (*M. scorpioides*)				+		Benthic
Bigeye sculpin (*Triglops nybelini*)*		+			+	Benthic
Moustache sculpin (*T. murrayi*)		+			+	Benthic
Ribbed sculpin (*T. pingeli*)		+				Benthic
Arctic staghorn sculpin (*Gymnocanthus tricuspis*)				+		Benthic
Daubed shanny (*Leptoclinus maculatus*)*		+				Benthic
Leatherfin lumpsucker (*Eumicrotremus derjugini*)		+				Benthic
Atlantic spiny lumpsucker (*E. spinosus*)		+				Benthic
Snailfish (*Liparis* spp.)						Pelagic
Four-lined snake blenny (*Eumesogrammus praecisus*)			+	+	+	Benthic
Arctic shanny (*Stichaeus punctatus*)			+			Benthic
Stout eelblenny (*Anisarchus medius*)			+			Benthic
Slender eelblenny (*Lumpenus fabricii*)			+			Benthic
Banded gunnel (*Pholis fasciata*)			+			Benthic
Fish doctor (*Gymnelus viridis*)		+				Benthic
Northern sandlance (*Ammodytes dubius*)		+				(Pelagic)
Stout sandlance (*A. hexapterus*)		+				(Pelagic)
Greenland halibut (*Rheinhardtius hippoglossoides*)*		+				Benthic

*Species not recorded for Hudson Bay, according to Hunter (1968).

Beluga below the cliffs on East Digges Island, June 1982

A. Gaston

we were camped on the island and we were told that there were no char in Digges Sound, although we found a few small land-locked specimens in Loon Lake and Long Lake on East Digges Island.

Arctic char, in the sea, feed on a similar size range of prey to the murres and there is some overlap in diet. We examined the contents of several char stomachs and found that they contained crustacea (mainly amphipods) and pteropod molluscs, particularly *Limacina*. Local people mentioned that *Limacina* is the main food of the char during the latter half of the season and they claim that the flesh of fish that have been feeding on *Limacina* has a distinctive flavour that they consider inferior to that of fish caught early in the season. Our observations supported the idea that *Limacina* is the main food of the char in August.

Our final list of fish from the Digges Sound area amounted to 22 species (Table 3), most of which are well-known from Ungava Bay and Hudson Strait, although three — bigeye sculpin, Daubed Shanny and Greenland halibut — were not listed by Hunter (1968) among the marine fish of Hudson Bay. The assemblage contains a number of low arctic species, such as capelin and sandlance, both schooling pelagic species, as well as species more typical of high arctic waters such as arctic cod, and ribbed and moustache sculpins. The list is much more extensive than that of six species compiled from roughly the same sources (food remains and stomach contents of Thick-billed Murres, Black Guillemots, and other seabirds) at Prince Leopold Island, Barrow Strait, in truly high arctic waters (Gaston and Nettleship 1981 and unpubl.).

4.3. Marine mammals □

The seabirds share their position at the top of the marine food chain with certain marine mammals: the toothed whales and the seals. Remarkably, the largest animal found in the area, the bowhead whale, occupies a lower rank in the food chain because it is a filter feeder depending on pelagic zooplankton, particularly copepods, rather than fish (Lowry and Burns 1980, Watson 1981).

The bowhead, in the late 19th century the centre of a thriving whaling industry in northern Hudson Bay, is now rare despite the fact that commercial whaling ended in 1915 (Mitchell and Reeves 1982). Moderate numbers, and probably a significant proportion of the remaining world population, winter in West Hudson Strait, north of Digges Sound (K.J. Finley, pers. comm.), but they seem to forsake this area in summer. We never saw them, and people in Ivujivik report that they are rare. In the past they may have had an important role in the marine ecology of the area.

The only whale seen in any numbers in Digges Sound was the beluga, which was frequent in June: we saw up to 71 in a day off East Digges Island. In some years hundreds winter in the mobile pack-ice of Hudson Strait (K.J. Finley, pers. comm.), and we saw about 60 between Digges Sound and Ivujivik on 16 April 1982. Few were recorded after the end of June. We saw only one narwhal, a female off East Digges Island in August 1980.

Three species of seal occurred in our area, of which the ringed seal was the most common. The bearded seal was an uncommon resident, and the harp seal was a rare visitor in July and August. Although seals were hard to identify at sea our assessment was supported by the frequency with which the three species were shot by members of the Ivujivik community. Although the harbour seal (*Phoca vitulina*) occurs around Hudson Bay (Mansfield 1968) we obtained no evidence of the species at Digges Sound.

All the seals seem to overlap with the seabirds in their food preferences. Both the ringed and harp seals take pelagic fish and zooplankton (Lowry *et al.* 1980, Ronald and Dougan 1982); the ringed seals in Hudson Strait feed particularly on arctic cod, amphipods, and mysids (McLaren 1958). Ringed Seal stomachs that we examined contained mainly amphipods with some arctic cod otoliths. A single bearded seal stomach obtained at Nuvuk Harbour contained exclusively hundreds of large shrimps (*Argis dentata*). Under most circumstances, the diet of bearded seals, which feed mainly on benthic animals, including shellfish, would overlap less with seabirds that would the diets of the other two seals (Smith 1981).

At the top of the marine food chain is the polar bear, which feeds mainly on ringed and bearded seals (Stirling and Archibald 1977, Smith 1980). We had only three records of bears during our stay and, although they must be more common in winter, no more than 5–10 are shot each year by Ivujivik hunters. It seems that polar bears do not exert a strong influence on the ecology of Digges Sound.

The seabirds

1. Populations and colonies

1.1. Eiders □

Common Eiders bred on most of the small islands south and west of Digges Sound. Populations were censused by nest count in the Nuvuk Islands and adjacent areas. Elsewhere populations were estimated from visual impressions of abundance of nests and adult birds. The census effort in the Nuvuk area was complicated by the widespread harvest of eggs and down by local Inuit, which removed the evidence of breeding. We wanted to census all nests that would have been active in the absence of exploitation, and we thus included well defined but empty nests in the survey. Nevertheless, our figures probably underestimate the true number of eiders that attempted to breed because we did not count nests from which the eggs and down had been removed by Inuit or, in the case of down, by the wind.

Eider nests were most abundant on the South Skerries and on Mitik Island (Table 4). Elsewhere nest densities tended to be low, particularly on the large islands and on the mainland. This distribution can be most easily explained by the pattern of human exploitation. Few people visit the South Skerries because of their distance from the regular boat route between Ivujivik and Ice Harbour. Eggs are probably not collected from Mitik Island because it is located in a freshwater pond and cannot be reached without a boat portage.

Islands closer to the mainland may have supported larger eider populations in the past. Local Inuit told us that the eiders of the Piqiuliit Rocks have been much reduced, and indeed the name of these islands ("the place to gather eggs") suggests that they have been exploited for many years. Eiders are frequently shot for food by Ivujivik Inuit, and hunting pressure along the coastal boat route probably reinforces the tendency of birds to nest on offshore islands.

King Eiders were frequently encountered in the study area, especially during early summer. No definite evidence of breeding was found, although females were seen alone occasionally. Generally, we saw groups of less than 50 birds, but in 1983 large flocks totalling several thousand birds were recorded west and southwest of the Nuvuk Islands in mid-July. Heavy snow-cover on lakes in breeding areas on Baffin Island and around Foxe Basin may have caused many birds to forgo breeding that year (FG. Cooch pers. comm.)

Table 4
Estimated numbers of Common Eiders breeding in the Digges Sound area, between Cape Wolstenholme and Piqiulik Island

Area	Population estimate (pairs)	Minimum–maximum
Nuvuk Islands and vicinity		
Pitsulak City, Green, Yellow, and Black Islands	40	30–55
West Nuvuk Island:		
mainland	40	25–60
Mitik Island	55	45–65
East Nuvuk Island	20	8–50
Kingatuayu Is. and Piqiuliit Rocks	27	25–31
Piqiulik Island	12	8–16
South Skerries	158	143–181
Other islands	6	4–16
Total	358	288–474
Islands south of Digges Islands		
North Skerries	20	10–50
Fairway Island	10	5–20
Eider Island	30	15–50
Midway Island	15	10–25
Staffe Islet	5	4–7
Small islands off West Digges Island	15	10–25
Total	95	54–177
Grand total	453	342–651

1.2. Gulls □

Three species of large gulls — Glaucous Gull, Iceland Gull and Herring Gull — bred at Digges Sound, forming loose colonies of up to 100 pairs, the Glaucous and Iceland Gulls frequently intermixed. Some Glaucous Gulls nested solitarily. Although most of the Glaucous Gulls and all of the Iceland Gulls nested on cliff ledges, the Herring Gulls and a few Glaucous Gulls used flat nesting sites on small islands either offshore or on inland lakes (Herring Gulls only).

We explored all coasts and islands as far as Sugluk to the east and Piqiulik Island to the south to locate breeding gulls. The main concentration occurred on the east side of East Digges Island and on the opposing mainland cliffs as far south as Staffe Islet, where we found six distinct colonies and many scattered pairs of Glaucous and Iceland Gulls (Fig. 10).

Herring Gulls bred only on Pitsulak City, Piqiuliit Rocks, and on lakes inland from Nuvuk Harbour. They were seen frequently around Nuvuk Harbour, and at Port de Laperrière on West Digges Island, and sometimes encountered among the islands south and west of Dome Island. On East Digges Island they were recorded only once or twice each year and there was no evidence that Herring Gulls ever scavenged around the murre colony on either side of the sound. Nor were they seen on the coast of Hudson Strait west of Sugluk Inlet.

Because we visited many of the gull colonies only once or twice, at irregular dates, we could obtain good estimates of the number of breeding pairs in only a few cases. At one colony on Digges Island (S2 or number 5 on Fig.10) we obtained extensive data on numbers of birds present at the colony in relation to time of day and date and we have used these data to estimate numbers of breeding pairs for colonies where we could make only a single visit (App. 3). Islands in the Nuvuk Islands area were subject to careful ground searches, but harvesting of eggs by local people and the poor breeding success of the gulls hampered our census. Our counts included nests without eggs only when the nest cup appeared recently maintained.

By combining information from all years, and assuming that populations remained stable, we calculated that our area held 170 pairs of Glaucous Gulls, of which about 70 were within 1 km of the murre colony; about 350 pairs of Iceland Gulls, with approximately 110 within 1 km of murres; and about 30 pairs of Herring Gulls (Table 5).

1.3. Arctic Tern □

Arctic Terns bred at two sites near the southern border of our area. We visited low, sandy, Piqiulik Island in July 1983, but were unable to conduct a proper census because vandals had collected many tern eggs and left them in a heap. On the basis of the nests we found and the number of heaped eggs, we estimated 45–90 breeding pairs.

The other Arctic Tern colony was located at Aulassivik Point and Aulassivik Island, both of which are low and rocky. Terns probably bred at both sites, but we did not land to confirm this. From the number of terns in attendance in the area, we estimate 15 breeding pairs. Large numbers of terns, presumably on passage, occurred around Nuvuk Islands in August each year.

1.4. Razorbill □

In August 1979 we saw several Razorbills flying to and from the cliffs on the west side of Akpa Cove, among the small group of Thick-billed Murres that forms the southern edge of the mainland colony. In subsequent years we visited the same area several times but saw Razorbills only once. Elsewhere, on 25 August 1980 we saw one sitting on a site among Thick-billed Murres on East Digges Island, and again on 20 August 1981; otherwise, we had eight records, mostly on the water in Digges Sound, but including one bird flying over Pitsulak City and two birds just off Staffe Islet.

The frequency of sightings, and the fact that they were spread over all 3 years, suggest that a small number of Razorbills, perhaps half-a-dozen pairs, may breed at Digges Sound. They are hard to pick out among the huge numbers of Thick-billed Murres. However, we were unable to obtain definite evidence of breeding. The nearest known breeding sites of this species otherwise are in Nain Bight, Labrador, or west Greenland.

1.5. Thick-billed Murre □

The Thick-billed Murre colonies, which form such a striking element in the biology of Digges Sound are situated on the high-

Figure 10
Position of gull colonies in the vicinity of Digges Sound

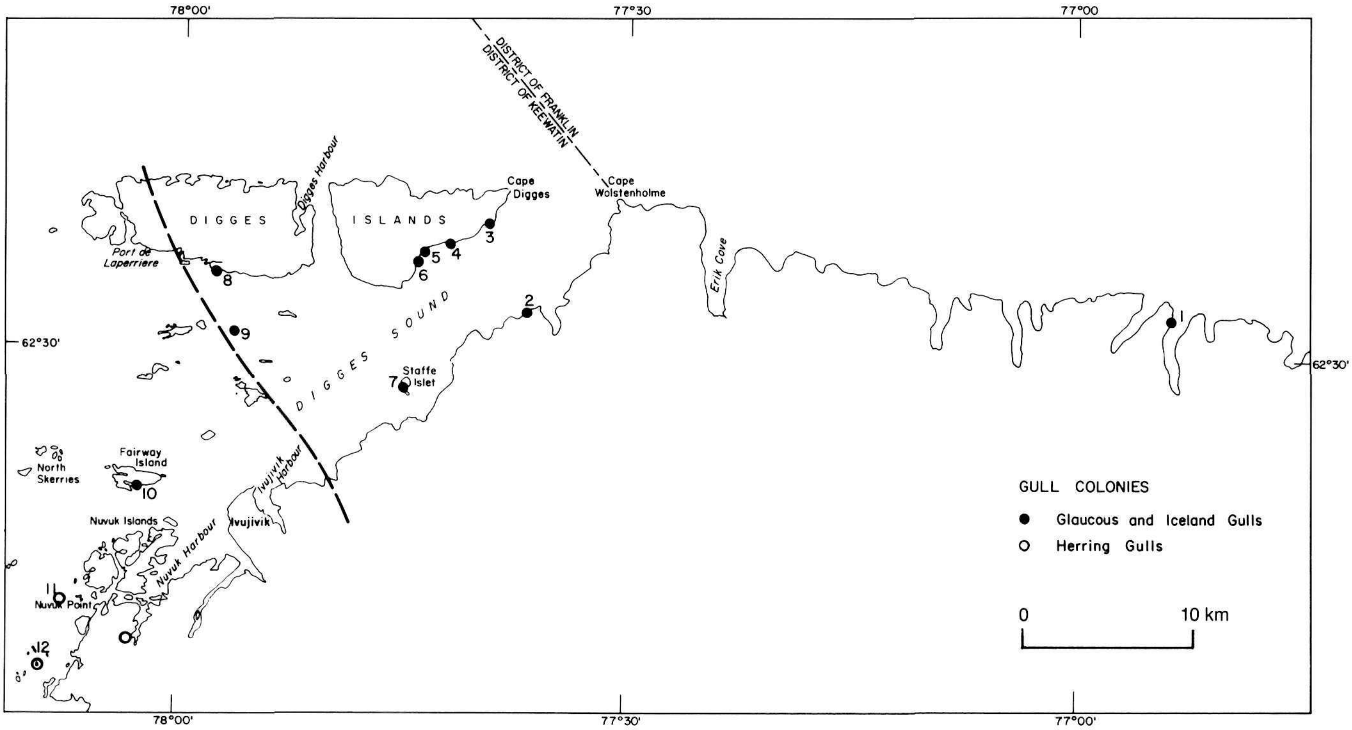
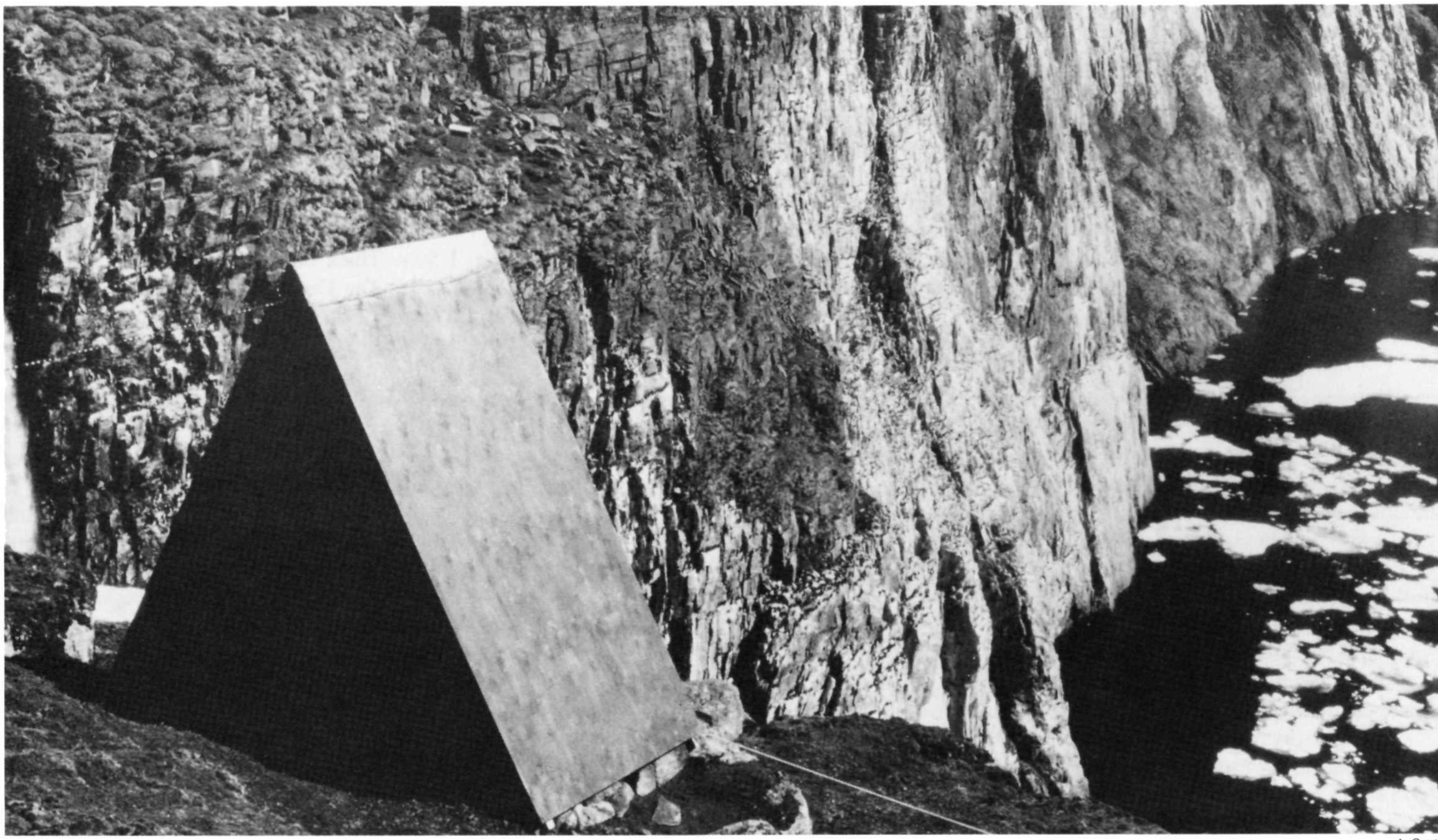


Table 5
Counts and breeding population estimates for gulls in the Digges Sound area (colony numbers refer to Fig. 10)

Colony	Date of best estimate	Glaucous Gull			Iceland Gull			Herring Gull		
		Count	Est. pairs	95% limits	Count	Est. pairs	95% limits	Count	Est. pairs	95% limits
1. Cap Révillon	19 July/80	10–15	7–11	5–18	105–120	78–89	56–146			
2. Akpa Cove	3 July/82	10	7	5–11	120	82	60–127			
3. E. Digges Is., Z	14 July/82		17*			10*				
4. E. Digges Is., U	14 July/82		8*			10*				
5. E. Digges Is., S2	1982		21*							
6. E. Digges Is., A	14 July/82		9*			12*				
7. Staffe Islet	3 July/82	15	10	7–16	185	126	92–196			
8. W. Digges Is.	14 July/82		2*		36	24	12–18			
9. Islet "B"	14 July/82		10–15*							
10. Fairway Island	8 Aug./80	35	28	21–44						
11. Pitsulak City	6 Aug./80								3*	
12. Piqiuliit Rocks	July/83		6*						7*	
13. Lake colony	2 Aug./80							30	24	18–34
Cape Wolstenholme —										
Akpa Cove (scattered pairs)			25							
Other scattered pairs			25							
Approximate totals			180			350			34	

*Estimates from counts of occupied nests.

Our blind overlooking plot S2, June 1982



A. Gaston

Green Island and Pitsulak City (furthest away) from Yellow Island, August 1981

D. Cairns

est, steepest cliffs on the entire coast of Hudson Bay and Hudson Strait. Cliffs of similar height extend along the south shore of Hudson Strait as far east as Sugluk, but none is as precipitous as those flanking the sound. Hence, for Thick-billed Murres, the coasts of Digges Sound present an area of excellent breeding habitat not matched until we reach Akpatok Island in Ungava Bay, more than 400 km distant.

Breeding murres extend over about 12 km of cliffs on both sides of Digges Sound. They lay their eggs wherever there are suitable narrow ledges, from just above the splash zone to just below the top of the cliffs, which rise, at Uumanaq and Kinginnijuac cliffs near Cape Wolstenholme, to more than 300 m above the sea. In some places, particularly on the east side of the sound, there are areas of cliff with suitable ledges that are unoccupied. The cliffs in these areas support copious orange lichen (*Caloplaca*) and the ledges are covered in grassy turf. By contrast, on East Digges Island, there are several areas where breeding murres are encroaching on turfy ledges, so that the grass is killed and the underlying peat is rapidly being eroded. A gradual shift in the centre of gravity of the population from the mainland to the island may be in progress.

Censusing huge colonies like those at Digges Sound is difficult. Tuck (1955) estimated that three million birds were present, representing a million breeding pairs, but the method he used to arrive at these figures seems to have been very approximate. We decided to rely on counts made from enlargements of black-and-white photographs because only small parts of the colony could be viewed from the ground. Counting murres from a small boat is virtually impossible because the observer is unable to keep track of which areas have been covered; something which can only be achieved by using a telescope on a tripod firmly planted on land.

To improve the accuracy of our estimate we counted some areas directly from the cliff top and used these counts to derive a correction factor to apply to the photo counts. For the correction counts we tried to select areas that faced seawards and were thus typical of most of the occupied cliffs. To compare counts made on different dates we used conversion factors (*K*-ratios) derived from daily counts at our study plots to convert each count of individuals to the equivalent number of breeding pairs (see "The seabirds" section 3.2.1.).

For Digges Island the photographs used for the census were taken on 30 July 1980. A total of 125 000 birds was counted on these, and a mean correction factor of 2.4 (SE ± 0.19) was calculated for areas counted on the ground (Nettleship and Milton, unpubl.; App. 4). The majority of areas counted from the land were near the top and hence among the hardest to count. This may have biased our estimate somewhat, so we have adopted a correction factor of 2. The *K*-ratio derived from simultaneous counts at our study plots was 0.72 and the number of breeding pairs was estimated as $125000 \times 2 \times 0.72 = 180000$ pairs. A correction factor of 1.5 (lower than all but one of those calculated) gives a corresponding estimate of 135 000 pairs, whereas a correction factor of 2.4 yields an estimate of 216 000 pairs. The true figure almost certainly lies between the two extremes.

No ground counts were possible on the mainland colony so we have used the correction factor derived for Digges Island and the *K*-ratio observed for the appropriate date. The photographs counted were taken on 3 July 1982 and yielded a count of 79 000 birds. Using the *K*-ratio of 0.68 and correction factor of 2 this yields an estimate of $79000 \times 0.68 \times 2 = 107000$ breeding pairs, with minima and maxima (correction factors 1.5 or 2.4) of 81 000 and 129 000 breeding pairs, respectively. Hence, the best population estimate for Thick-billed Murres in the whole of Digges Sound is 287 000 pairs (East Digges Island 180 000, Cape Wolstenholme 107 000) with real figures probably between 216 000 and 345 000 pairs. Considering the limitations of our methods, we prefer to round the figure off to 300 000 pairs.

1.6. Black Guillemot □

Black Guillemots occurred throughout the Digges Sound area, breeding on mainland cliffs and islands wherever there were rock crevices or boulder heaps that provided suitable nesting sites within 100 m of the sea. They were most numerous in the vicinity of the Nuvuk Islands.

It is difficult to estimate breeding populations of Black Guillemots from casual visits to breeding areas. Numbers of birds present on the water offshore and on the rocks near their nests fluctuate considerably with time of day, generally reaching a peak in the early hours of the morning and being lowest in mid-afternoon (Cairns 1979). Searching for nests is a time-consuming business and after the parents have ceased to brood their chicks, which happens about 5 days after hatching, nests cannot be found by flushing adults. However, when chicks are large, extensive "whitewash" often gives a clue to their presence. Many nest cups are situated out of sight down cracks running at right angles to the entrances or amidst jumbles of boulders. In some cases a single nest may have several openings.

We gathered information on Black Guillemot populations in two ways. On islands south and west of the Nuvuk Islands we made prolonged searches to get an accurate count of nests during the incubation period. At the same time, on Pitsulak City, we counted birds present on the colony and on the water nearby and compared these counts to numbers of breeding pairs (App. 5). We used the information obtained at Pitsulak City to correct counts made on single visits to other areas, although such estimates were crude because counts were generally not made in the optimal morning period. Table 6 shows the resulting population estimates, along with estimated minima and maxima.

Table 6
Estimated numbers of Black Guillemots breeding in the Digges Sound area between Cape Wolstenholme and Piqiulik Island

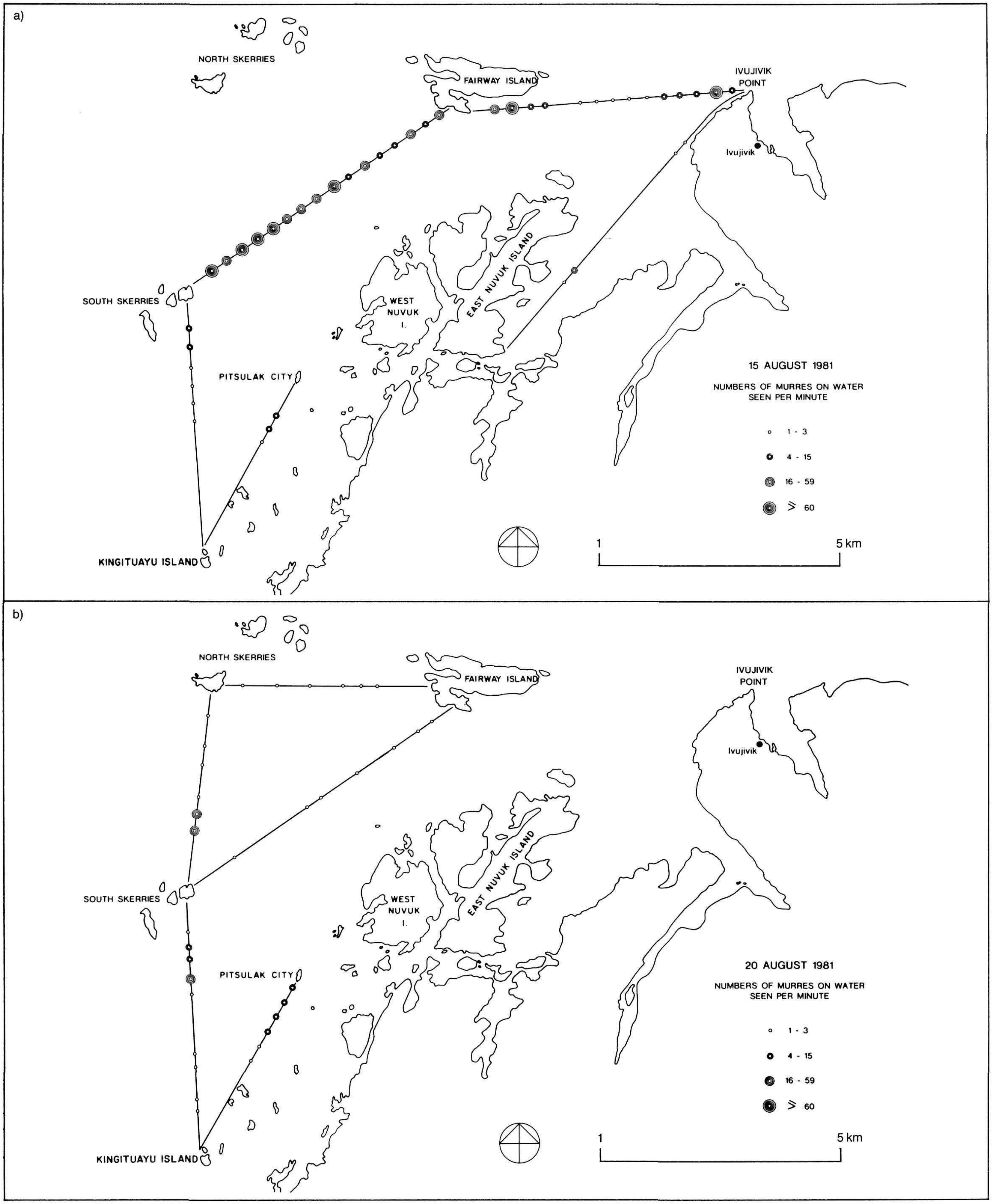
Area	Population estimate, pairs	Minimum–maximum
Nuvuk Islands		
Pitsulak City	190	-185–195
Green Island	100	85–115
Yellow Island	18	16–22
Black Island	14	12–16
West Nuvuk Island	4	0–10
East Nuvuk Island	4	0–10
Piqiuliit Rock 2	12	12–12
3	1	1–1
5	29	28–30
7	2	2–3
Kingitauyu Island	10	5–15
Qitik Is.	7	5–10
Mainland	5	0–10
South Skerries 1	8	7–9
2	5	4–6
4	48	40–60
Piqiulik Island	3	3–4
Total	460	405–528
Islands south of Digges Islands		
North Skerries	10	5–25
Fairway Island	20	15–50
Dome and Eider Islands	50	30–100
Unnamed (Islet "A")	15	10–25
Midway Island	15	10–30
Staffe Islet	100	50–250
Mainland, Ivujivik to Akpa Cove	20	10–50
Total	230	130–530
Digges Islands and Sound		
West Digges Island	80	30–200
East Digges Island	60	40–150
Mainland north of Akpa Cove	40	20–100
Total	180	90–450
Grand totals	870	625–1508

Guillemots were particularly numerous on Pitsulak City and Green Island, which together sheltered about one-third of the total population of the region. The abundance of guillemots in this area is probably due to the extensive areas of water less than 40 m in depth, which guillemots favour for feeding. Water to the north and east of the Nuvuk area is, for the most part, much deeper, and presumably less suitable for guillemot feeding. In the Nuvuk area, breeding habitat does not appear to be a limiting factor in guillemot reproduction, as apparently suitable but unused crevices were found on most islands.

1.7. Atlantic Puffin □

The presence of puffins in Digges Sound was indicated by a single sighting recorded by McLaren (in Todd 1963) in 1960. The presence of a small colony on Dome Island was evident from the preliminary survey made by Gaston and Malone (1980), but breeding was not confirmed until 1981 when we found eggs on Dome Island and Pitsulak City. All the

Figure 11
Distribution of Thick-billed Murres seen on boat transects around Pitsulak City on (*a*) 15 August 1981, and (*b*) 20 August 1981



nests found were in natural crevices, rather than burrows, making them hard to identify.

We counted up to 45 birds on and around Dome Island, but we estimated only 12 active nests on the island in 1982. Up to 18 birds were seen on the water near Pitsulak City on occasions but no more than one active nest was located. Scattered pairs may breed on other islands, such as the North Skerries, but we obtained no definite evidence. Adami Mangiuk reported seeing 150 in October 1981 near Dome Island which strongly suggests that there are more puffins breeding in the area than we detected.

2. Distribution at sea

We collected information on the feeding areas used by seabirds from Digges Sound in several ways. At Digges Island we observed the directions taken by departing murres. At Pitsulak City we watched Black Guillemots leave their nest sites and in many cases we were able to keep them in sight until they alighted on the sea. We also conducted counts from small boats (Achilles inflatables powered by 15 hp outboard motors) in the Nuvuk Islands area while following straight courses between islands. To obtain information on the foraging range of the murres from Digges Sound we conducted several aerial surveys covering waters up to 200 km from the colony using techniques previously described by Nettleship and Gaston (1978) and McLaren (1982). All surveys were flown in a DeHavilland Twin-Otter at 50 m altitude and speeds ranging from 150 to 210 km.h^{-1} using one observer on each side of the aircraft.

2.1. Boat surveys □

In 1981 and 1982 we collected information on seabird distribution between Piqiuliit Rocks, the South and North Skerries and Ivujivik.

Black Guillemot were seen in similar numbers on all surveys and were confined to shallow waters, less than 40 m deep. In contrast, the vast majority of Thick-billed Murres seen on the water, and presumably feeding, were in areas where water depths were greater than 40 m (Table 7). The distribution of murres, unlike that of guillemots, fluctuated drastically over short periods. Surveys conducted 5 days apart in August 1981 showed a considerable alteration in the numbers of murres feeding between the South Skerries and Fairway Island (Fig. 11).

During surveys carried out in 1982 we used an echo-sounder which provided a continuous trace of shoals of fish or zooplankton. The distribution of guillemots showed no correlation with the density of the sounder trace. However, in July large concentrations of feeding Thick-billed Murres were associated with a continuous trace of what was probably a dense band of zooplankton at depths down to 20 m (Fig. 12). Murres shot in the same area contained large numbers of the pelagic amphipod *Parathemisto libellula*.

Marked guillemots from Pitsulak City were seen as far as 14 km from the colony. Birds catching fish for their chicks did not range as far, usually foraging within 2 km of the colony. A favourite feeding area for the birds breeding on Pitsulak City in 1982 was the shallow water surrounding the Piqiuliit Rocks, about 2–3 km from the island.

Table 7
Mean numbers of Black Guillemots and Thick-billed Murres recorded per minute on small-boat transects carried out around Nuvuk Islands in August 1981, in relation to water depth

	Black Guillemot		Thick-billed Murre	
Water depth, m	$\bar{x}$	SE	$\bar{x}$	SE
0–11	2.3	0.63	0.4	0.34
11–18	2.5	0.71	1.0	0.66
18–37	1.1	0.25	1.9	0.46
37–92	0.1	0.05	7.8	3.00
92–183	0	0	8.0	3.30
>183	0	0	31.5	18.40

2.2. Aerial surveys □

In 1980 surveys were flown in September to trace the route of adults and young Thick-billed Murres leaving Digges Sound. They showed that most young murres passed through Hudson Strait during the first half of September in 1980 (Gaston 1982*a*). Few seabirds other than Thick-billed Murres

Figure 12
Echo-sounder trace in Nuvuk Islands area, showing the position of concentrations of murres in relation to probable zooplankton swarms

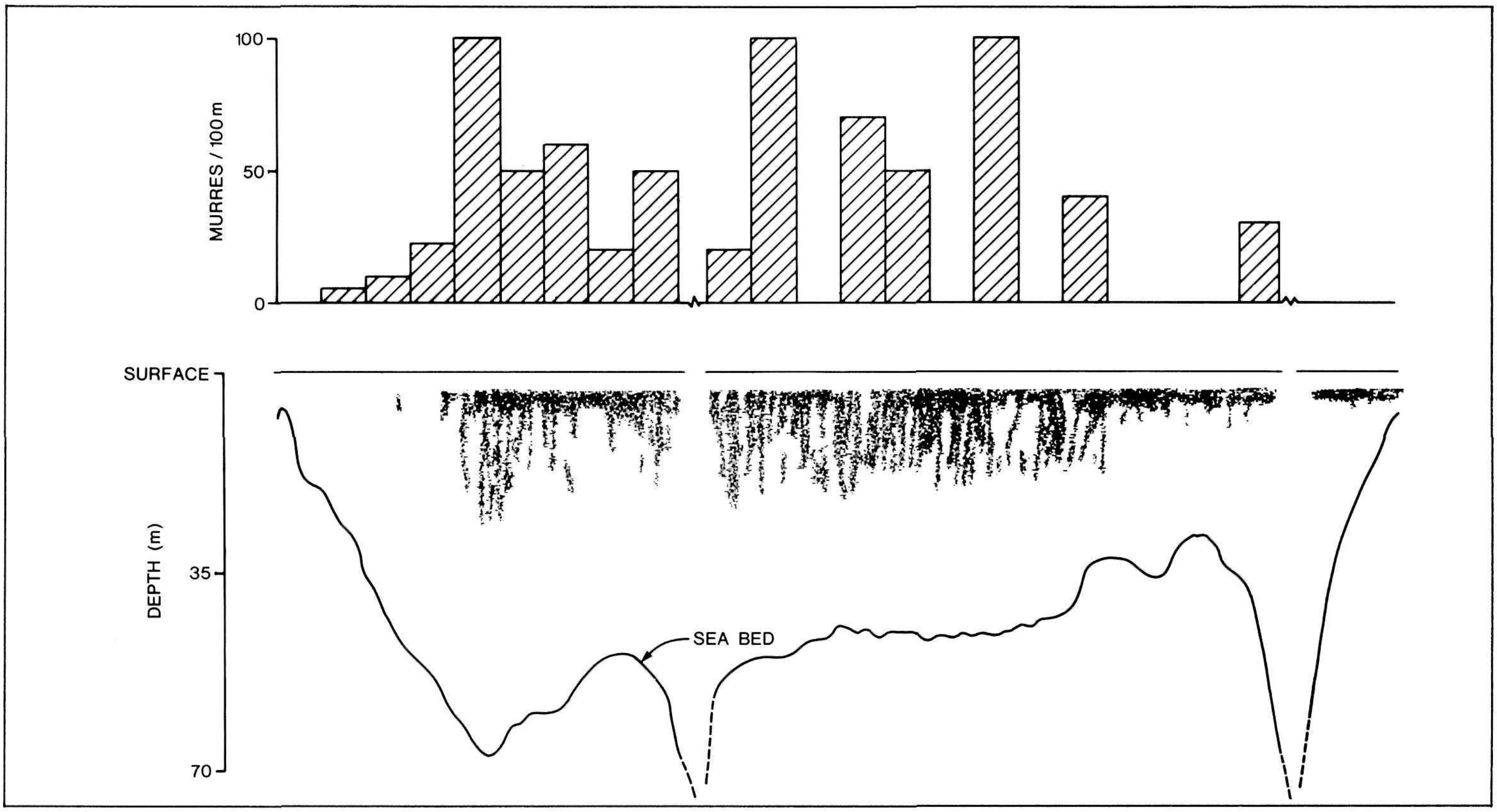


Figure 13
Flight directions and numbers of Thick-billed Murres seen on aerial surveys around Digges Sound on 9 July 1981

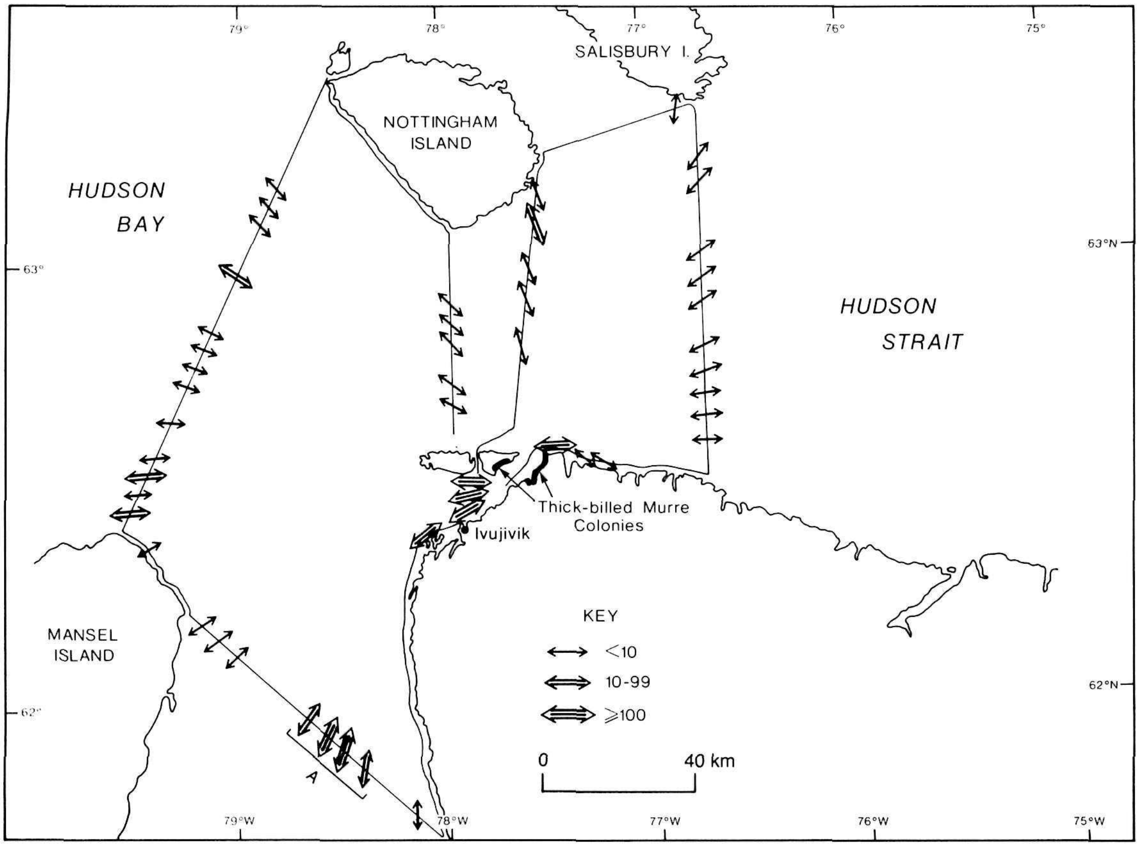
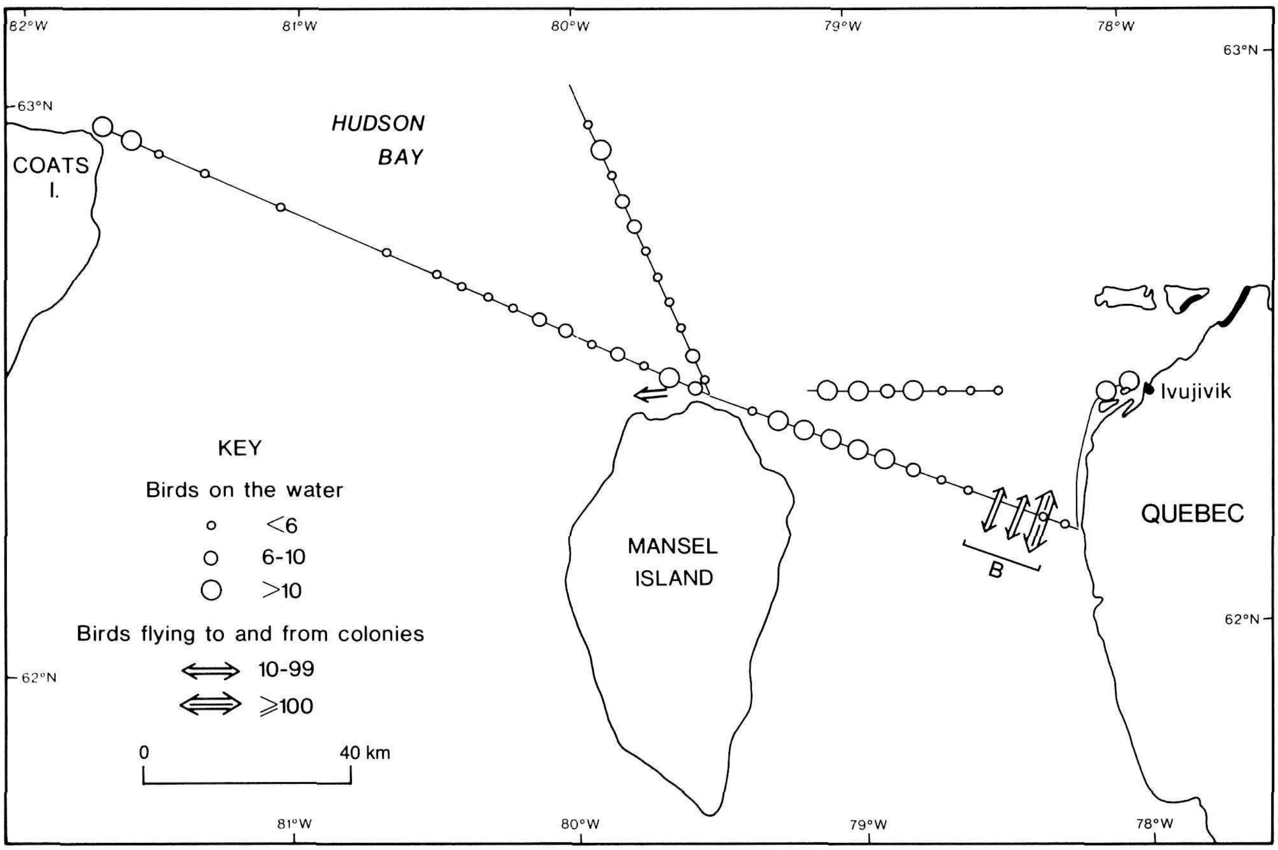


Figure 14
Densities of Thick-billed Murres seen on aerial surveys around Digges Sound on 9 August 1981



were recorded in September in western Hudson Strait.

In 1981 we flew surveys on 9 July and 9 August to obtain some idea of the foraging range of Thick-billed Murres on those dates. Weather conditions on both days were practically ideal, with calm seas and good light.

On 9 July we saw no concentrations of murres on the water, but large numbers in flight heading north and south between the mainland and Mansel Island (Fig. 13). Using a correction for the relative speeds and flight directions of birds and aircraft (Gaston and Smith 1984) we estimated the rates of movement of murres passing across sector A between the mainland and Mansel Island. Across this line, 24 km long, we estimated murres flying away from Digges Sound at a rate in excess of 500 birds every minute. The corresponding rate for birds crossing the whole of the transect between Mansel and Nottingham Islands was 70 birds per minute. Hence, the most favoured feeding area at that date was probably located more than 100 km from the colony, somewhere between Mansel Island and the mainland, and probably well offshore, as birds were not following the coast. Inuit hunters report that, for birds feeding near the shore, the southern limit is near Akulivik, about 200 km from the colony.

Observations from Pitsulak City, where large numbers of Thick-billed Murres were seen daily in July 1981 passing southwest–northeast to the west of the island, suggested that the pattern observed on 9 July was probably fairly constant throughout the incubation period in 1981. We recorded similar movements, at rates of several hundred birds per minute, in 1982. Observations from Digges Island also suggested that the main direction of departure was towards the southwest, with relatively few birds from Digges Island heading north or east in Hudson Strait.

On 9 August 1981 the heavy passage of murres between the mainland and Mansel Island still continued, with 700 birds per minute estimated to be crossing sector B (Fig. 14). Moderate numbers were also recorded on the water between Digges Sound and Mansel Island, particularly in the western half of this area. Smaller numbers were also recorded to the west of Mansel Island, but on the transect between Mansel and Coats Islands a break in the distribution of murres was encountered after about 150 km from Digges Sound. No substantial numbers were recorded from then on until we came within 30 km of the small colony at the northern tip of Coats Island.

We carried out one more survey, on 10 August 1982, covering the same transects used on 9 July 1981. Owing to some moderately rough seas and poor visibility the results of this survey were probably not comparable with those of the 1981 surveys. However, a strong movement of birds southward between Mansel Island and the mainland was recorded again and the few birds recorded on the water were mainly north of Mansel Island.

None of our surveys gave any indication that birds concentrate close to Digges Sound, except for groups engaged in social activities close the the breeding cliffs. The majority of birds from the colony apparently forage at a considerable distance. Rates of movement across sectors A and B were sufficient to account for a majority of the breeding and non-breeding birds based at Digges Sound, given the observed rate of incubation changes of breeding pairs. Thus, most birds probably travelled more than 100 km to feed during the incubation and chick-rearing periods in 1981. This may have been true in 1982 as well.

3. Breeding biology

3.1. Gulls □

3.1.1. Attendance □

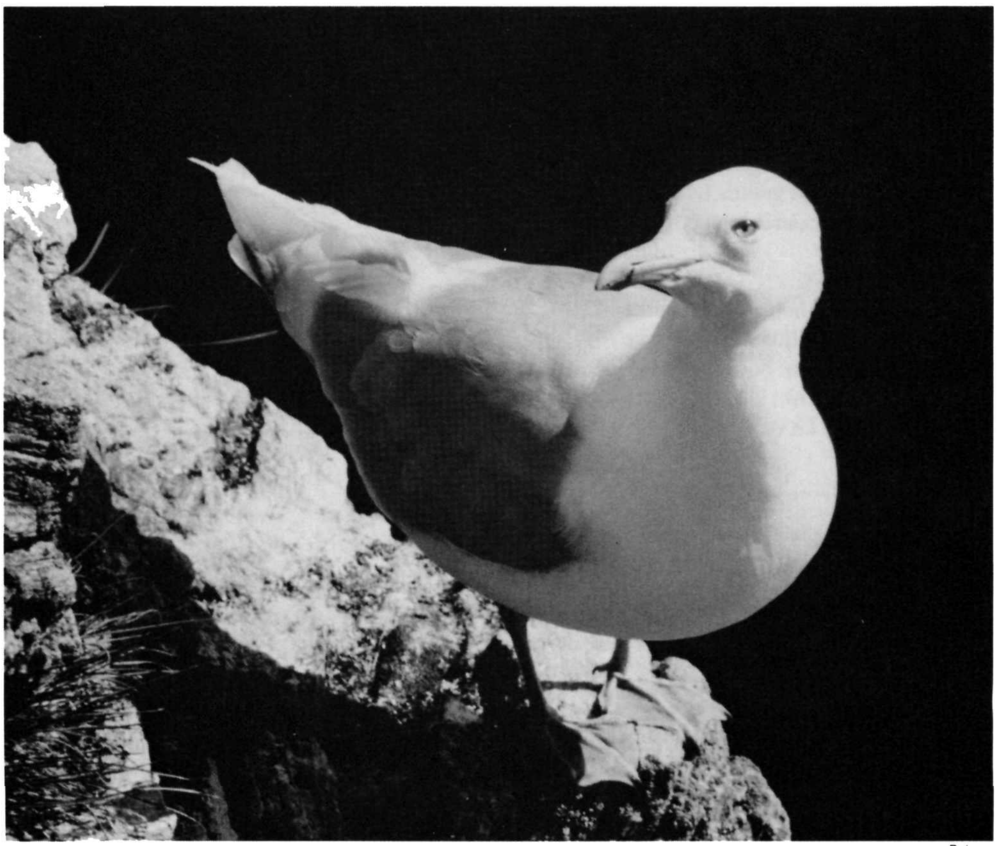
Gulls occurring in the area of the murre colony on Digges Island were concentrated along the cliffs and at a few loafing sites on the shores of lakes near the cliff edge, the most important of which was on the west shore of Long Lake. This made it easy for us to count the gulls present at any instant by spreading observers along the colony to count at prearranged times. In 1982, we used four people placed at W, V, D, and U (Fig. 7) and made simultaneous counts every 10 days. Observers also checked the loafing sites adjacent to their observation point and each count was performed at 14:00 and again half an hour later.

We were not able to cover the entire colony area in this way but we did include all the important breeding and loafing sites and gulls in flight along about 80% of the cliffs. Hence, we probably counted at leat 90% of the gulls present. Because many of the birds were counted at long range, we could not always tell Glaucous and Iceland gulls apart.

On 19 June we counted a mean of 91 gulls, but for the rest of the season numbers varied from 161–191. The highest count came on 12 July, by which time most Iceland Gulls had laid, but few nests had failed. From 23 July onwards numbers remained constant, with means of 162.5, 161, 161, and 161. The area under observation supported 70 breeding pairs (43 Glaucous and 27 Iceland) so the figures suggest a non-breeding population of about 20 birds (about 14%) in the latter part of the season. Appendix 6 gives full counts.

Observations on the Glaucous Gull colony of 21 pairs at S2 showed that there was a clear diurnal pattern of behaviour, with numbers present on the colony being highest in the middle of the night, when numbers were equivalent to the total breeding population, and lowest in the early morning (Fig. 15). On the night of 2–3 August 1982, the majority of gulls present on the colony between 22:00 and 03:00

A typical adult of Kumlien's race of the Iceland Gull, East Digges Island, July 1980



B. Lyon

Figure 15
Counts of Glaucous Gulls at colony S2 and on an adjacent loafing area on 2–3 August 1982

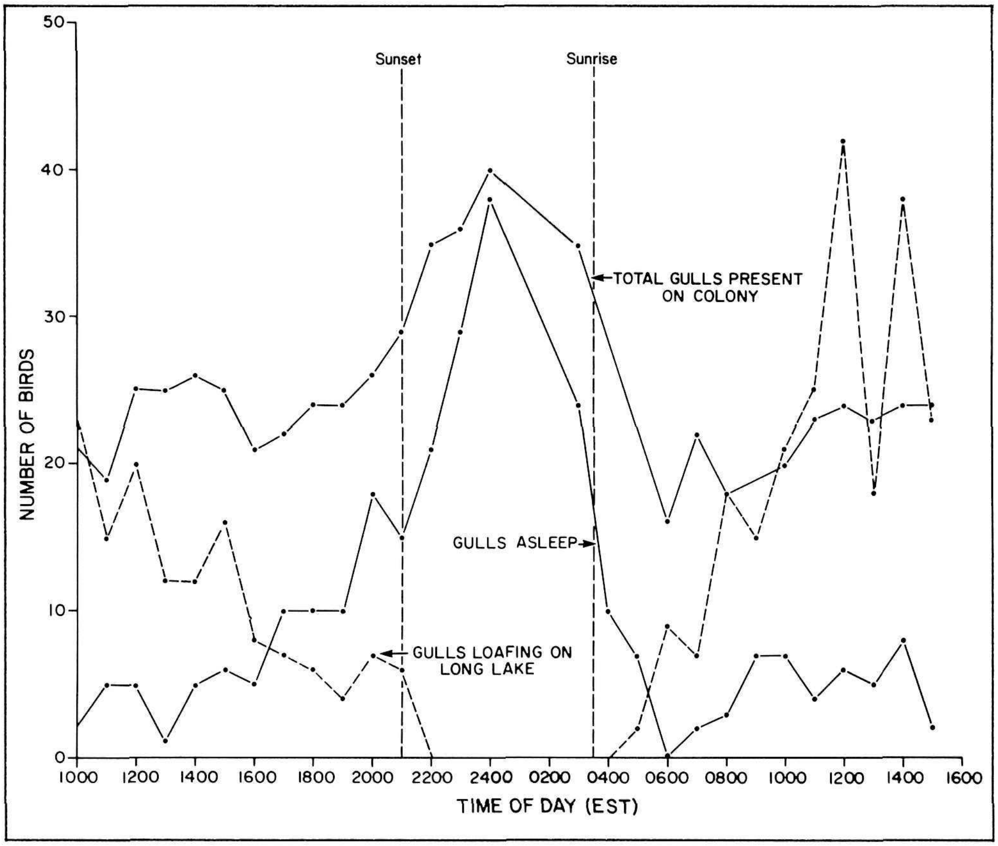
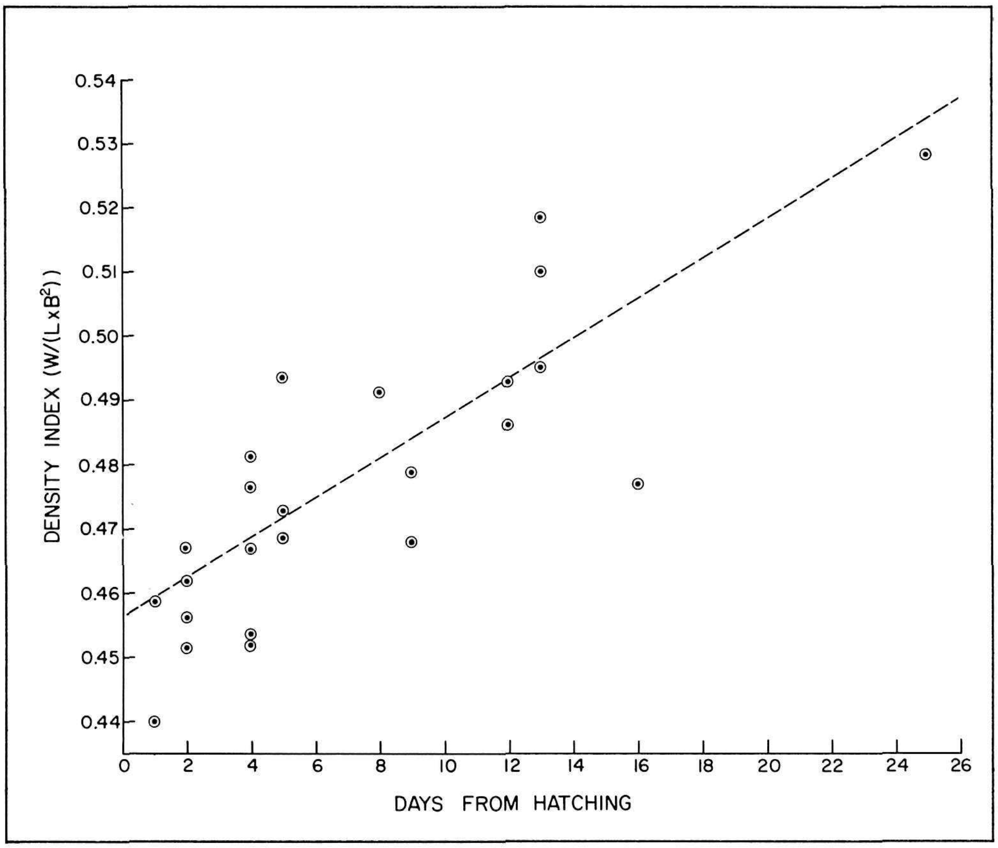


Figure 16
Density indices of Glaucous Gull eggs measured at Digges Island in relation to the length of time before hatching



were asleep. Numbers present at the adjacent loafing site on Long Lake were inversely related to numbers on the colony.

Although our counts suggested that numbers present at the colony were largely accounted for by resident breeders, we also noticed a steady passage of gulls towards and away from the colony, particularly along the south coast of East Digges Island. Most of the outbound gulls, watched through a telescope, eventually settled on the sea to the southwest of the colony, often joining other gulls. We assume that these were foraging trips, and evidence from feeding watches showed that fish and crustacea formed a portion of the food fed to chicks at S2. If a significant number of resident gulls left the colony periodically then gulls other than those breeding on East Digges Island were probably more numerous than our counts suggested.

3.1.2. Timing of breeding □

Most of our information on the timing of breeding among gulls was collected on East Digges Island and Staffe Islet. Dates of hatching were observed for Glaucous Gulls on the colony at S2 in 1981 and 1982, and were determined from egg densities for Iceland Gulls at U on Digges Island and at Staffe Islet in 1982.

Six Glaucous Gull eggs were weighed and measured within 2 days of hatching, but before pipping had occurred. The density index (weight/[length × breadth squared]) of these eggs was used as an estimate of density just prior to hatching and initial density at laying was then estimated by assuming a weight loss of 15.5% during incubation (as determined for another similar-sized gull by Morgan *et al.* [1978]). We assumed that weight decreased at a constant rate during incubation and a comparison of the predicted density index – age relationship with density indices for eggs of known hatching date (Fig. 16) suggests that this is a reasonable approximation. Estimated hatching dates for 24 Glaucous Gull eggs and 77 Iceland Gull eggs in 2- or 3-egg clutches gave mean age differences of 3.6 and 3.4 days, respectively, between eggs in the same clutch. Eggs are probably laid at 2-day intervals (Dementiev and Gladkov *in* Cramp and Simmons [1983]) and hence these differences suggest a mean error of 1–2 days in our estimates of hatching dates.

Observed dates of hatching for Glaucous Gulls on Digges Island were between 22 June and 4 July in 1981 and 18 June and 20 July in 1982, with peaks in both years between 22 and 26 June (Fig. 17). Assuming an incubation period of 27–28 days (Swenander, *in* Godfrey [1966]), this means that first eggs were laid about 24 May 1981 and 28 May 1982.

Iceland Gulls, both at Digges Island and at Staffe Islet, bred about 2 weeks later than Glaucous Gulls in 1982, with earliest hatching on 1 July and the peak between 12 and 16 July. Two incubation periods we observed were 24–26 days from the completion of the clutches, so laying probably began about 6 June. The difference between the two species agrees with the observations of Smith (1966) in southern Baffin Island, although laying appears to have been slightly earlier at Digges Sound and the difference between the two species somewhat greater.

For Glaucous Gulls, eggs laid early averaged larger in volume than those laid late in the season ($r = 0.383$, $N = 35$, $P < 0.01$) and early clutches tended to be larger, although the difference was not statistically significant (Table 8). Neither of these effects was apparent for Iceland Gulls. Appendix 7 gives details of egg dimensions.

Our observations on clutch size were probably affected by the fact that most Glaucous Gull clutches were close to hatching when counted. Some egg loss may already have occurred and may account for the large number of single egg clutches observed among Glaucous Gulls.

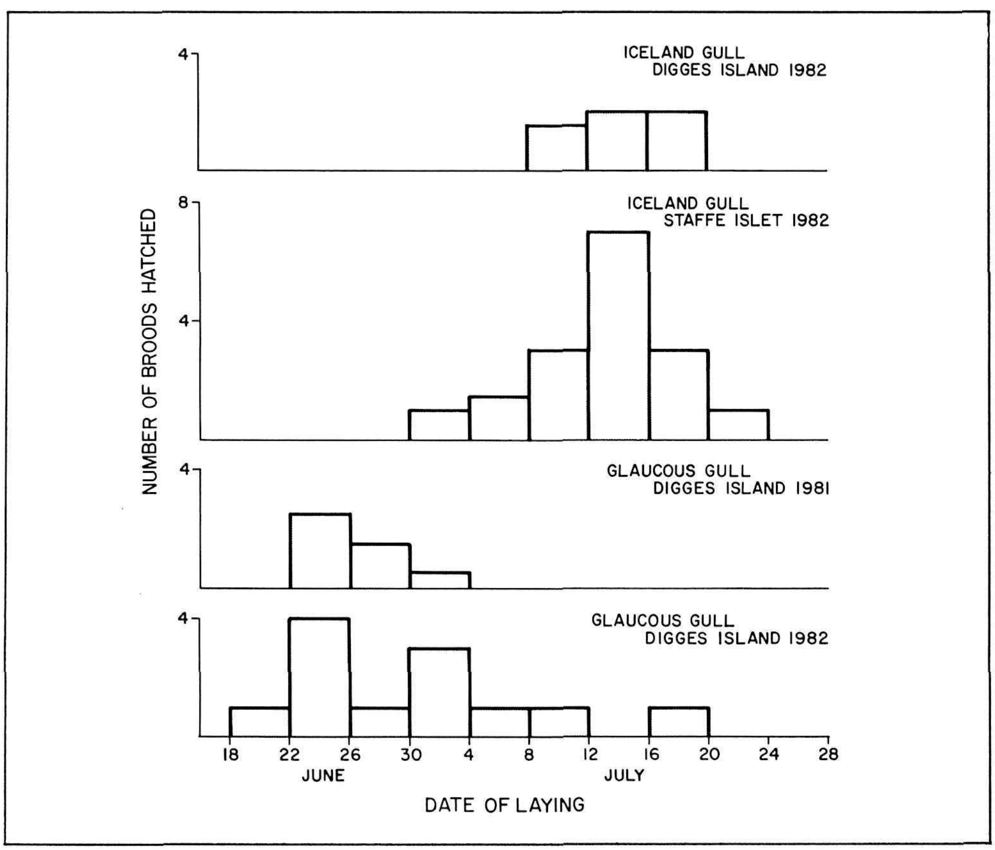
3.1.3. Breeding success □

We recorded numbers of eggs hatched and the survival of the chicks for Glaucous Gulls on colony S2 in 1981 and 1982. For Iceland Gulls our information on breeding success was dependent on counts of large young made in early August. These probably give a good indication of the mean number fledged by successful pairs but certainly overestimate success for the entire population.

Table 8
Clutch sizes of Glaucous and Iceland Gulls at Digges Sound, 1981 and 1982

Species	Date of laying	Clutch size 1	2	3	$\bar{x}$	SD
Glaucous Gull	Up to 30 June	3	2	7	2.33	0.89
	After 30 June	6	5	2	1.69	0.75
	Totals	9	7	9	2.00	0.87
Iceland Gull	Up to 14 July	1	9	10	2.45	0.60
	After 14 July	2	13	9	2.29	0.62
	Totals	3	22	19	2.36	0.61

Figure 17
Timing of hatching in the Digges Sound area for Glaucous Gulls in 1981 and 1982 and for Iceland Gulls in 1982



In 1981, observations at S2 began at the same time that the earliest clutches hatched so we have no information on egg survival. We identified 16 active nest sites on 27 June with a minimum of 29 eggs on that date. At least 27 eggs hatched and 22 chicks were present on 18 July, all of which survived until 9 August when the first was seen on the wing. Survival of chicks from hatching to fledging was therefore between 76 and 81%.

In 1982, our observations began on 15 June, and 18 nests contained a minimum of 36 eggs by 22 June. Fifteen pairs succeeded in hatching at least one chick and 11 pairs produced one or more chicks that survived to fledge (Table 9). Altogether, 21 young fledged, representing a 72% survival rate from hatching to fledging. Two eggs that disappeared during hatching may have hatched, and the chick been lost, before we had a chance to record them. In that case the chick survival rate would have been 68%. We set foot on the colony only once before the chicks were well grown, on 22 June when we measured the eggs, so our observations are unlikely to have had much effect on breeding success.

In 1982, we visited Staffe Islet on 3 July, just after the completion of egg-laying by Iceland Gulls, and again during 6–8 August when most Iceland Gull chicks were about half grown. Mean clutch size on 3 July was 2.39 ($N = 33$), whereas the mean number of young per surviving nest during 6–8 August was 1.51 ($N = 73$). This suggests a maximum breeding success of about 63%, but this takes no account of nests that failed completely. The brood size of Glaucous Gulls on the same colony was 1.93 ($N = 15$), almost identical with the size of contemporaneous broods on S2. The average size of Iceland Gull broods banded on Staffe Islet and East and West Digges Islands between 24 July and 1 August 1980 was 1.62 ($N = 26$). Taken together these figures suggest that productivity per brood among Iceland Gulls tends to be lower than that of Glaucous Gulls at Digges Sound.

3.1.4. Feeding ecology and diet □

We made incidental observations on gulls feeding and on food remains around nest sites in all years. In 1982, we made regular watches of 1–3 h at colony S2 to record the rate

Table 9
Breeding success of Glaucous Gulls at colony S2 on East Digges Island, 1982

Item	No.
Pairs occupying sites	21
Pairs known to have laid	18
Total eggs laid	36
Nests hatching 1 or more eggs	15
Eggs hatched	29
Nests fledging 1 or more chicks	11
Chicks fledged	21
Chicks reared per pair	0.87
Chicks reared per pair that laid	1.17
Chicks reared per successful pair	1.92

at which chicks were fed and the type of food brought to them. We also examined nest sites at Staffe Islet to identify food remains brought to chicks and watched birds coming to and going from the colony to find out where they were feeding.

Glaucous Gulls breeding amid the murres on Digges Island apparently obtained most of their food either by scavenging around the colony or by predation on murre eggs and chicks. Many Glaucous Gull nest sites were surrounded by large heaps of murre eggshells, and regurgitated pellets usually showed evidence of murre chicks, particularly the feet, which normally appeared almost undigested. The situation for Iceland Gulls was less clear. We saw instances of successful predation attempts by Iceland Gulls on murre eggs and chicks, but their nests did not usually contain murre remains. Even where they nested close to the murres, they did not seem to exploit them for food to the same extent as the Glaucous Gulls.

Murre eggs and chicks made up 85% of identifiable food remains delivered to Glaucous Gull chicks at S2, but this is probably misleading because, although murre eggs and chicks could be easily recognized, other things were hard to identify at the range of 100 m from which we watched. Murre remains made up 43% of all feedings ($N = 187$), with the only other clearly recognizable item, fish, making up a further 7%. During July, murre eggs made up 31% of food brought to chicks ($N = 122$), but in August the gulls switched almost entirely to chicks, which formed 60% of the diet in that month ($N = 65$, Table 10). Unidentified food may have consisted of scavenged meat, small marine organisms, or partially digested fish.

Murre eggs may have been more important in July than it appeared. Most of the eggs that we saw delivered to chicks were regurgitated whole at the nest site and then pecked open either by the adult or the chicks. In some cases, the eggs were already broken when regurgitated. If adult gulls sometimes pecked open the eggs away from the colony and swallowed the contents to regurgitate to the chicks, or if the eggshells became fragmented in transit, it would have been hard to identify the regurgitated mixture of yolk and albumen. The same would have applied to eggs that rolled off their ledge to be scavenged by the gulls after smashing on the rocks. However, 49% of regurgitations seen in July ($N = 122$) were definitely not eggs, so these made up no more than half of the chicks' diet in July.

When we visited the gull colony on 25 July we collected the shells of 372 murres eggs, of which 345 were associated with the 12 nests that still contained chicks. The number of eggshells varied widely among nests: five nests accounted for 90% of all shells. As Gaston and Nettleship (1981) have shown elsewhere, some pairs or individuals specialize in taking murres' eggs. We found a similar situation at colony U with many shells around some nests and few around others.

The rate at which broods were fed appeared to be relatively constant over the season, averaging between 6 and 10 meals daily (App. 8), but this is probably deceptive because the amount of food regurgitated at each feeding may have increased as the chicks grew. There was also no indication of any fluctuation in the rate of feeding in relation to time of day, except for high rates recorded on two out of three watches carried out after 20:00 (Fig. 18). This may reflect the arrival of adults returning to the colony to roost.

Most food deliveries, where divisible, were shared by the whole brood but each chick received the equivalent of 2.5–5 whole deliveries each day. Towards the end of the nestling period, when more than half the items being delivered were murre chicks, we can estimate the approximate food intake of each chick. Most murre chicks weigh 100–150 g while on the colony (see section 3.2.4.). If we estimate that each gull chick receives the equivalent of three murre chicks each day, then it gets about 350–400 g of meat, equivalent to about 25% of its body weight. This estimate is similar to Spaans' (1971) findings for Herring Gulls in the Netherlands, which required a similar body-weight equivalent in fish.

Iceland Gull chicks at Staffe Islet apeared to be fed less frequently than the Glaucous Gulls at Digges Island. Rates of feeding observed on 7 August were 0.05 feeds per brood per hour between 14:30 and 17:30 and 0.12 feeds per brood per hour between 19:15 and 21:15. These suggest overall daily rates of 1–2 feeds per chick. Most of the food delivered to the chicks could not be identified but it included one murre chick (ignored by the chicks involved) and several meals of small crustacea.

Examination of Iceland Gull nests at Staffe Islet revealed the remains of four more murre chicks. Some adults watched departing from the island headed northeast, towards the mainland murre colony, from which the murre chicks presumably originated. We examined nine Glaucous Gull nests on Staffe Islet but found no signs of murre eggs or chicks in any of them. It seems that the gulls breeding on Staffe Islet make little attempt to forage at the murre colonies, perhaps finding most of their food at sea. We saw Iceland Gulls sitting on the water and feeding by pecking at small organisms close to the surface after the fashion of Black-legged Kittiwakes *(Rissa tridactyla)*, on several occasions.

One remarkable feature of the gulls in the Digges Sound area was their scarcity in the vicinity of Ivujivik. Apart from the local garbage dump, there was a large amount of potential food for gulls available in and around the settlement in the form of discarded fish and parts of seals, whales, and walruses. Nevertheless, gulls were not a prominent feature of Ivujivik and no large flocks were associated with the village. Usually, only one or two gulls could be seen in the vicinity of the village. Nor was there any evidence that gulls habitually scavenged around fishing camps nearby, where there were often copious amounts of discarded fish.

Table 10
Food fed to Glaucous Gull chicks at colony S2 on East Digges Island, 1982

Date	No. of feedings				
	Eggs	Chicks	Fish	Other	Totals
7–15 July	11 (23%)		6 (13%)	30 (64%)	47
16–31 July	27 (36%)	3 (4%)	3 (4%)	42 (56%)	75
1–15 August		25 (61%)	3 (7%)	13 (32%)	41
16–31 August	1 (4%)	14 (58%)	2 (8%)	7 (30%)	24
Totals	39 (21%)	42 (22%)	14 (7%)	92 (50%)	187

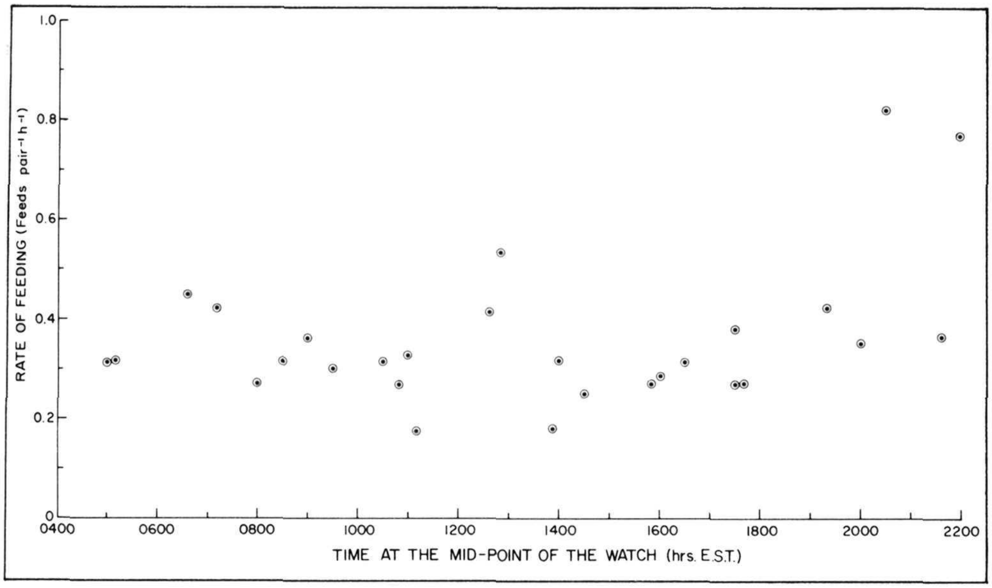
3.2. Thick-billed Murre □

The breeding biology of a large Thick-billed Murre colony and the methods of study have been thoroughly described for Prince Leopold Island by Gaston and Nettleship (1981) and we shall not attempt to repeat the same information for Digges Sound. Instead we present a basic outline of the species' biology at Digges Sound and draw comparisons with the situation observed at Prince Leopold Island. All references to Prince Leopold Island are to the study cited above. Otherwise, we concentrate on the role of the Thick-billed Murre in the marine ecosystem and its relationship with predators, competitors, and prey.

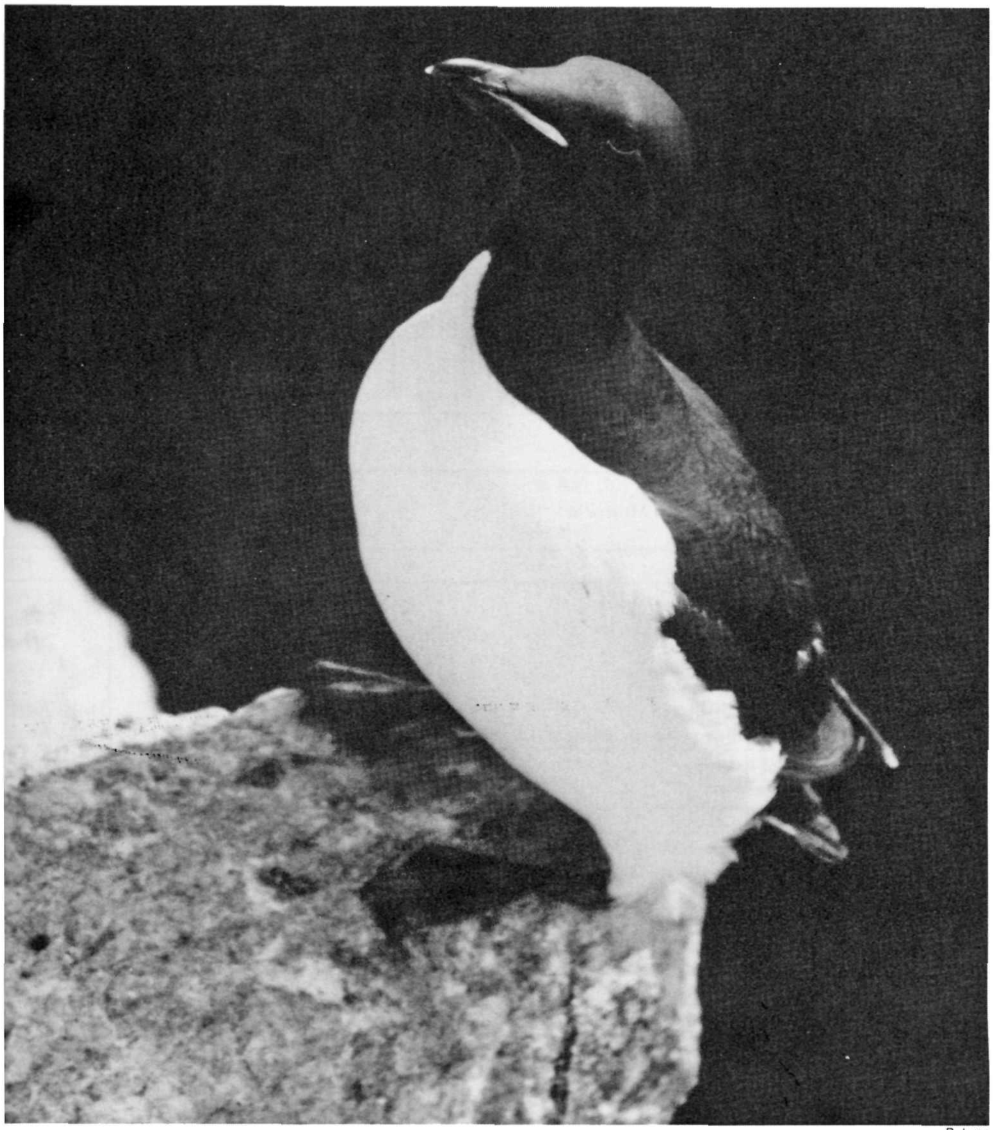
Most of our information was based on observations of a small number of study plots selected on arrival at Digges Island in 1980 (Fig. 7). These fell into four categories:

1. count plots (10; A1, A2, B, C, D, E, F1, F2, G, H on which the number of birds present was counted between 17:00 and 18:30 daily;
2. breeding plots (five; A1, B, D, F1, J; four of these also count plots) on which we estimated reproductive success by watching from a distance and recording daily those sites that had eggs or chicks (Type 1 monitoring of Birkhead and Nettleship 1980);
3. egg plots (three; R, S1, T) on which all eggs were measured and weighed; and
4. growth plots (two; R and T; both also used as egg plots) on which the growth of chicks was recorded by weighing and measuring them every 3 days from hatching onwards.

Figure 18
Rates of feeding recorded for Glaucous Gull chicks at colony S2 in relation to time of day



Adult Thick-billed Murre, East Digges Island, August 1980



To investigate the murres' diet we collected birds where they were feeding, up to 80 km from the colony, on a number of dates through the season in all years. We obtained samples of food delivered to chicks by collecting dropped or discarded fish from the breeding ledges during chick-weighing or banding operations.

3.2.1. Attendance □

According to local people, the murres generally appear at the fast-ice-edge near Ivujivik soon after the ice begins to break up on Digges Sound in April or early May. At Cape Dorset, at the northwest corner of Hudson Strait, murres also appear at the ice-edge in May. We saw none at either locality on 16 April 1982, on an aerial survey, despite the presence of open water close to the colony, nor did we see any elsewhere on transects flown across western Hudson Strait. In 1982 murres had not penetrated through Hudson Strait by mid-April. A few murres apparently winter in northern Hudson Bay in the vicinity of Southampton Island (Sutton 1932), but these are probably only a small proportion of the population and may originate from the colony at Coats Island.

The earliest that we established a camp on Digges Island was 12 June in 1982 and by this date murres were present on the cliffs in large numbers. During the period prior to egg-laying, numbers fluctuated considerably: the cliffs were almost deserted in bad weather. Once egg-laying commenced about 20 June, numbers on the cliffs remained high through to the time when most of the chicks had left at the end of August.

Highest numbers of birds were present on the colony between mid-incubation (mid-July) and the start of fledging (mid-August) (Fig. 19). Numbers were lower in 1981 than in the other 2 years for all but two 7-day periods, and in 1982 numbers were higher than in the other 2 years from 28 days before until 7 days after the median date of hatching. The proportion of breeding pairs to birds present (*K*-ratio) was not very different among years because the number of eggs laid in 1982 was also higher than in the other seasons.

The general pattern of attendance was similar to that seen at Prince Leopold Island, but peak numbers seemed to occur earlier in the season, with peaks in 1980–82 falling at the median date of hatching, or 7 days before. In contrast, at Prince Leopold Island, peak attendance occurred at or after the median date of hatching in the "normal" summers of 1975–77.

The ratio of breeding pairs to the total number of birds present was generally higher than found at Prince Leopold Island during the early part of the season, but ratios during the period between the middle of the incubation period and the middle of the chick-rearing period were quite similar (Table 11). This strengthens the idea that a *K*-ratio of about 0.67 can be used to convert counts made about the time of hatching to numbers of breeding pairs at large Thick-billed Murre colonies.

3.2.2. Timing of breeding □

We used several methods to determine the date on which Thick-billed Murres on Digges Island laid their eggs. We recorded layings on the breeding plots by direct observation in 1980 and 1981. In 1981 and 1982 we derived dates of laying from the densities of eggs weighed on the egg plots, and in all years we recorded hatching dates on the growth plots.

First eggs on the breeding plots were laid on 18 June in 1980 and 1982 and on 24 June in 1981. Other measures confirmed that breeding was slightly later in 1981 than in the other 2 years (Table 12). In addition, the average age of chicks at fledging was greater in 1981, but the date by which 90% had left the colony was similar because laying ceased earlier in 1981. The dates of laying, hatching, and fledging were similar to those recorded in 1975–77 at Prince Leopold Island, despite the fact that Digges Island is 12° farther south. Timing at Digges Island was earlier in 1955, when Tuck estimated that the earliest hatching took place on 16 July. He recorded peak fledging on 16–17 August.

3.2.3. Egg size □

The mean volume index (length times the square of the breadth) for all eggs measured on the three egg plots at Digges Island was 204.3 cm^3 ($N = 1175$). This is larger than the mean for any sample measured at Prince Leopold Island or for eggs measured at Coburg Island or Cape Hay, Bylot Island in 1979 (Birkhead and Nettleship 1981).

Eggs laid at plot R, at the southern extremity of the colony were larger, on average, than those laid on plots S1 or T, and this difference was consistent in all 3 years (Table 13). There was no significant variation in the volume of eggs laid among the 3 years of the study, despite the variation in timing of laying.

In 1981 and 1982, egg volumes at all plots decreased as the season progressed, so that early laid eggs averaged a volume index of about 210 cm^3, whereas those laid in the second half of July averaged only about 190 cm^3. In both years there was a sharp decrease in the size of eggs after about two-thirds of the eggs had been laid (Fig. 20*a*, *b*), particularly in 1982 when egg size fell dramatically between 25–29 June and 30 June – 4 July at plots S1 and T. A similar decline occurred between 30 June – 4 July and 5–9 July at plot R where the median date of laying was later.

Where we knew the date on which eggs had been laid to within 48 h, we could compare fresh weights with volume indices. These were closely correlated ($r = 0.952$, $N = 78$, $P < 0.001$) and the regression of fresh weight on volume index allows us to estimate the fresh weights of all eggs.

Figure 19
Changes in numbers of Thick-billed Murres present during daily counts and changes in the proportion of breeding pairs to birds present (*K*-ratio) at study plots on East Digges Island

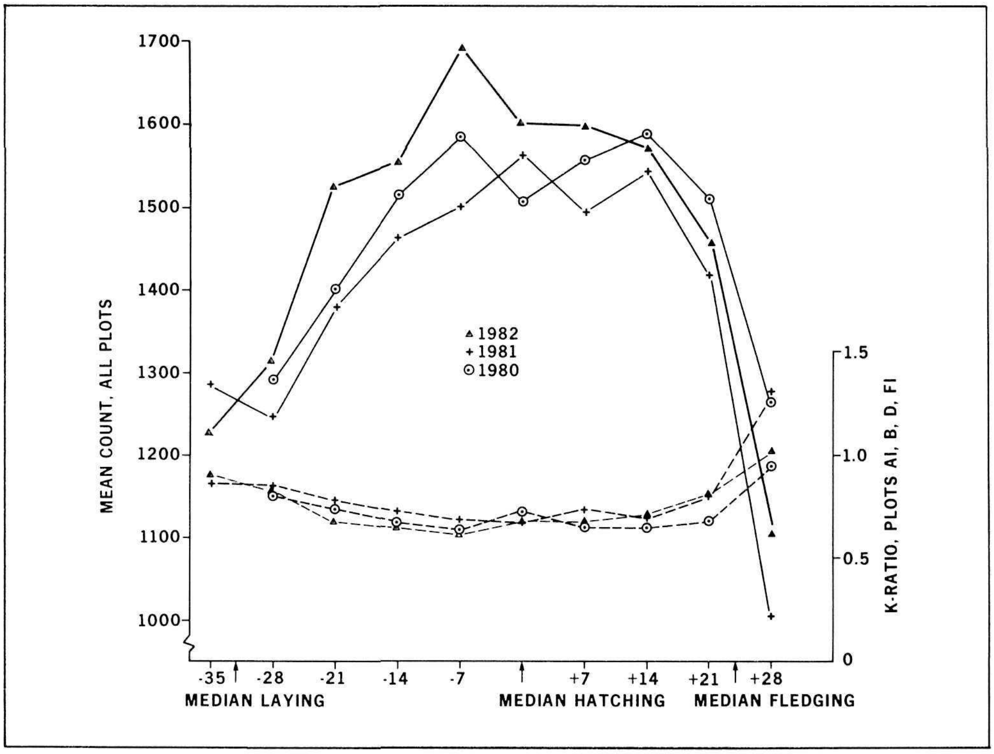


Table 11
Comparison of *K*-ratios at Prince Leopold Island and East Digges Island during 1 week at about the median date of hatching (Prince Leopold Island, 1–7 August; Digges Island, the 7-day period centred on median date of hatching)

		Prince Leopold Island		Digges Island		
		1976	1977	1980	1981	1982
Breeding pairs	(*A*)	659	650	305	306	306
Mean count	(*B*)	906.2	1032	445.3	460.5	466.6
K-ratio	(*A*/*B*)	0.73	0.63	0.71	0.68	0.67

Table 12
The timing of breeding of Thick-billed Murres at East Digges Island in 1980–82

	1980	1981	1982
First eggs laid (breeding plots)	18 June*	24 June	18 June
Median date of laying (breeding plots)	26 June	30 June	29 June
Median date of laying (egg plots)	28 June	29 June	26 June
Median date of hatching (growth plots)	28 July	31 July	4 August
Mean age at fledging, days (growth plots)	21.6	24.0	22.0
Date of peak fledging (breeding plots)	19–21 August	25 August	21–23 August
90% of chicks fledged (breeding plots, including re-lays)	29 August	31 August	31 August

*Extrapolated from date of hatching.

Table 13
Egg volume indices (length × breadth^2, cm^3) recorded on three plots on East Digges Island in 1980, 1981, and 1982

	1980			1981			1982		
Plot	$\bar{x}$	SD	*N*	$\bar{x}$	SD	*N*	$\bar{x}$	SD	*N*
R	207.45*	15.45	126	205.80	15.96	160	207.31	16.01	171
S1	202.21	17.22	103	204.03	15.87	110	203.62	16.73	127
T	200.84	19.39	128	201.83	19.96	123	203.63	15.55	127

*Two-way analysis of variance:
by plot, $F = 8.77$, df 2, $P < 0.001$;
by year, $F = 0.62$, df 2, N.S.

Fresh egg weight =
0.4917 (volume index) + 6.5327 g

An egg with a volume index of 210 cm^3, the average for early laid eggs, weighed 109.8 g at laying, whereas one of 190 cm^3, typical of later eggs, had a fresh weight of 100.0 g. Hence, the approximate decline in fresh weights during the laying period was 9.8 g or 9% of the weight of early eggs.

Incubation periods for eggs where we knew dates of laying and hatching to within 48 h averaged 32.4 ± 1.37 days ($N=28$) in 1980, 32.8 ± 1.77 ($N=69$) in 1981 and 32.8 ± 1.86 days ($N=15$) in 1982. The most common period was 32 days in 1980 and 1982 and 33 days in 1981. These incubation periods were identical with those recorded at Prince Leopold Island and give no evidence that the larger eggs laid at Digges Island take longer to hatch.

3.2.4. Chick growth

Chicks weighed within 24 h of hatching had a mean weight of 73.4 g and, not surprisingly in view of the fact that egg volumes were similar, there was no significant variation among years. The much larger samples of weights available for 2-day old chicks did show significant interyear variation, however, with those hatched in 1981 averaging 75.4 ± 7.6 g ($N=43$), compared with 78.9 ± 8.3 g ($N=38$) and 79.5 ± 8.9 g ($N=57$) for 1980 and 1982, respectively (Gaston *et al.* 1983).

Increase in weight was fairly uniform up to about 8 days old, after which the rate of increase flattened off to reach an asymptote at about 20 days (Fig. 21). Chicks attained highest weights in 1982 when those on plot R had a mean weight of 153.0 g at 14 days and 161.8 g at fledging. In 1981, the year of slowest growth rates, the corresponding figures were 134.0 g and 148.4 g. Appendix 9 gives full details of chick growth at plot R in all 3 years.

In 1981, some chicks barely increased in weight at all after hatching, three weighing less than 100 g at 14 days. Feather growth was clearly retarded in these chicks, with no growth of the primary coverts and little development of the contour feathers. The nestling down was shed, however, so that by 14 days old the chicks were practically naked.

Despite the fact that the eggs laid on Digges Island were larger than those laid on Prince Leopold Island, the chicks that emerged increased in weight more slowly (Fig. 21). Mean weights at Prince Leopold Island ranged from 174 to 200 g at 14 days old and 196 to 216 g at fledging. The corresponding weights at Digges Island were 134–153 g and 148–162 g (App. 10). A comparison with chicks weighed on Coats Island in 1981 and on Hantzsch and Akpatok Islands in 1982 showed that chicks on Digges Island also grew more slowly than those at other colonies in Hudson Strait (Gaston *et al.* 1983).

As well as being slow to put on weight, the chicks at Digges Island grew their wing feathers more slowly than those at Prince Leopold Island (Fig. 22). The mean length of the primary coverts, the longest juvenile wing feathers, at 14 days old, ranged from 53–56 mm at Prince Leopold Island, compared to 45–53 mm at Digges Island (App. 10). At fledging, the Digges Island chicks left the colony with shorter wings despite the fact that they were generally older at departure.

Figure 20
Egg volume indices for Thick-billed Murres at East Digges Island in (*a*) 1981, and (*b*) 1982, in relation to date of laying and proportion of eggs laid

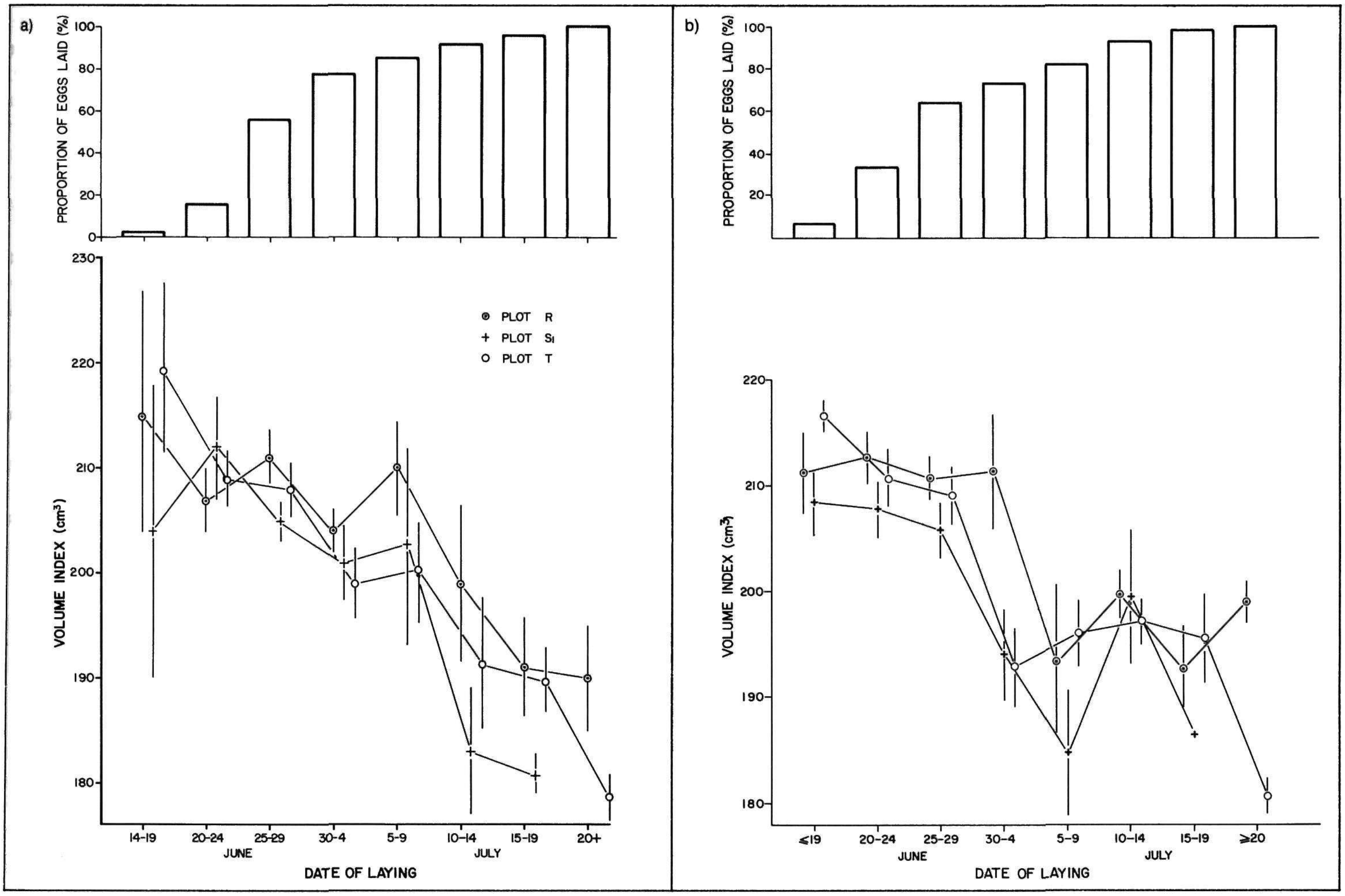


Figure 21
Weight increase in Thick-billed Murre chicks at East Digges Island in 1980–82, compared to data for 1977 from Prince Leopold Island

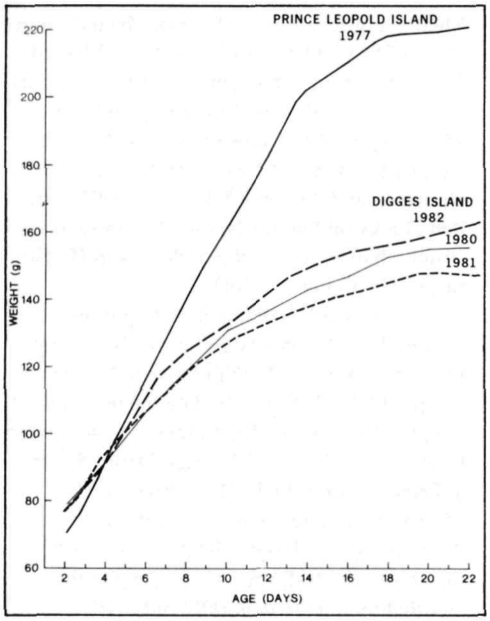
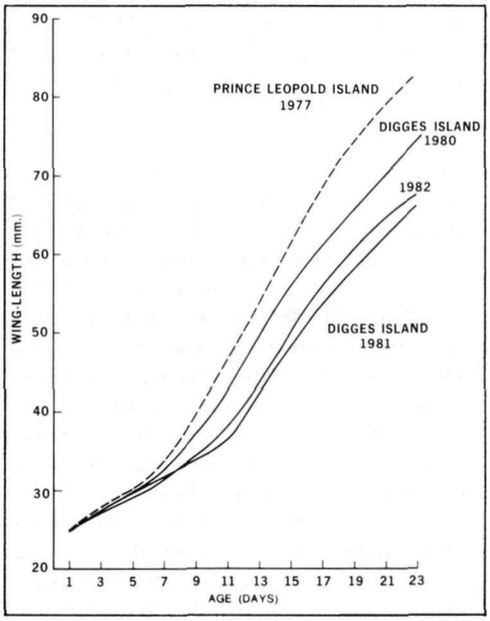
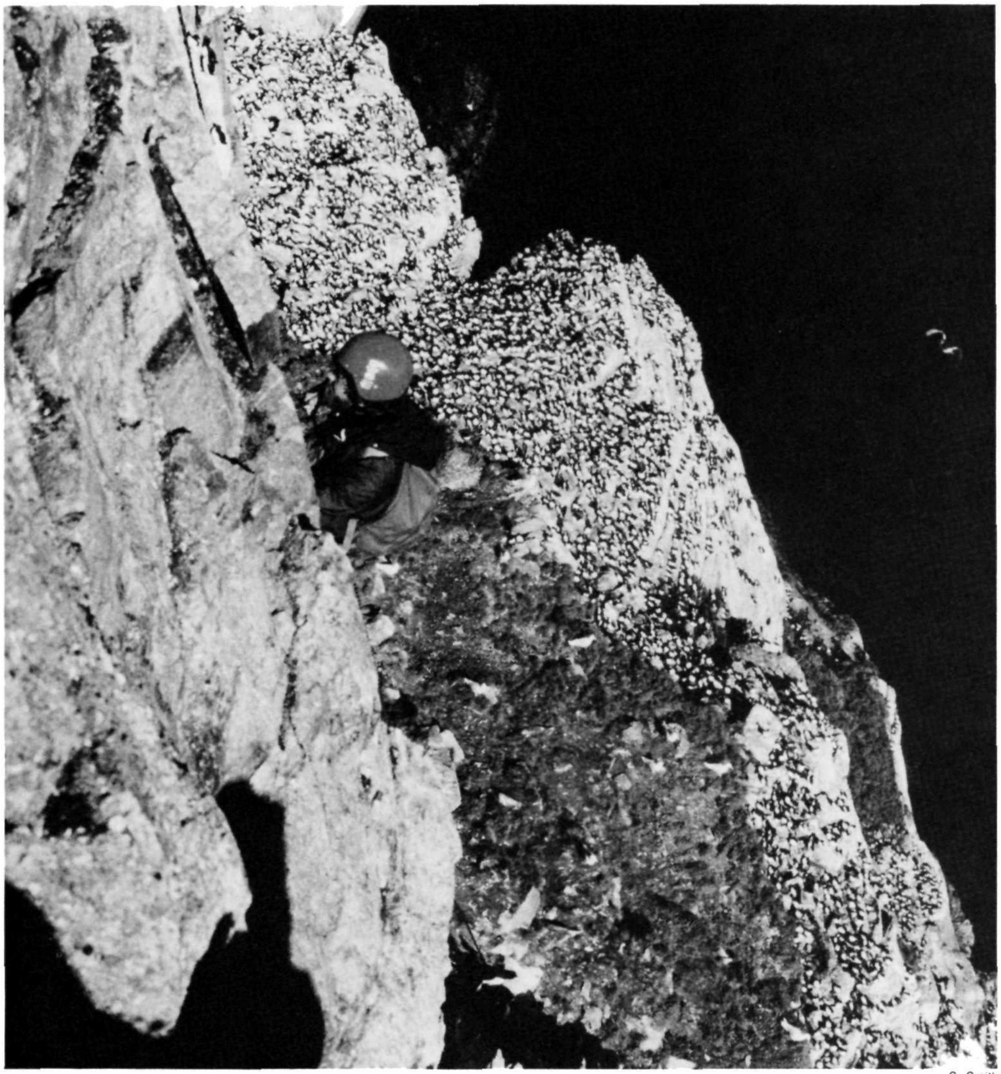


Figure 22
Increase in wing length of Thick-billed Murre chicks at East Digges Island in 1980–82, compared to data for 1977 from Prince Leopold Island



A bander on the way down to plot S2, which can be seen below the figure, July 1981



S. Smith

Some chicks were captured at sea soon after leaving the colony in 1979. Mean weights and wing lengths were similar to those recorded in 1980–82 for chicks at growth plots, when they were weighed and measured for the last time prior to leaving. Our activities on the cliff seem to have had only a small effect on the growth of the chicks we studied.

3.2.5. Breeding success □

During 1980 and 1981, we recorded reproductive success by watching each breeding plot (A1, B, D, F1 in 1980; the same and J in 1981) for several hours each day. We found that eggs were laid at practically all sites that were occupied on more than 80% of our visits between the median date of laying and the start of fledging (App. 11). In 1982, therefore, we did not make prolonged observations during the egg-laying and incubation periods at plots A1, B, D, and F1 but visited the plots only to record which sites were occupied. We began to make lengthy checks as soon as hatching began and thereafter made the same observations as in previous years. At plot J we made the normal observations throughout the season in 1982.

The proportion of breeding pairs that succeeded in rearing a chick to at least 15 days old (chicks disappearing at 15 days or older were assumed to have fledged successfully) was 64% in 1980, 60% in 1981, and 68% in 1982 (Table 14). Taking a mean of 1980 and 1981, out of every 100 eggs laid, 65 hatched successfully and 61 chicks fledged. Out of the 35 eggs lost, 6 were replaced, 2 hatched, and 1 fledged, for a total of 62 chicks fledged for every 100 breeding pairs.

3.2.6. Adult diet □

We examined the diet of adult Thick-billed Murres by collecting birds at feeding grounds away from the colony. We shot most of the specimens southwest of Digges Sound around Ivujivik and the Nuvuk Islands. We also took samples off the north coast of West Digges Island and to the east of Cape Wolstenholme along the mainland coast, as far as Sugluk. Collections were made throughout the season, as opportunity arose, so that approximately one-third of the specimens in each year were taken between first laying and first hatching (20 June–20 July), one-third between first hatching and first fledging (21 July–15 August), and one-third after the start of fledging (16–31 August).

We collected 223 birds during 1980–82 of which all but 10 contained identifiable food remains. The majority were dissected within 4 h of collection and the stomach and proventriculus removed and preserved in 70% ethyl alcohol. Food material was sorted by taxonomic group and the number of organisms represented estimated by counting whole animals and identifiable parts (e.g., otoliths for fish, telsons or heads for crustacea, beaks for squid, jaws for annelids).

Table 14
Reproductive success of Thick-billed Murres at East Digges Island in 1980–82

	Plots														Totals (A_1,B,D,F_1 only)		
	A_1			B			D			F_1			J				
	1980	1981	1982	1980	1981	1982	1980	1981	1982	1980	1981	1982	1981	1982	1980	1981	1982
First eggs	51	52	54	85	82	82	56	58	60	113	114	122	102	102	305	306	318
Hatched, %	66.7	40.4	—	60.0	69.5	—	62.5	69.0	—	75.2	63.2	—	66.7	73.5	67.2	62.1	—
Fledged, %	94.1	90.5	—	88.2	93.0	—	97.1	90.0	—	95.3	94.0	—	97.1	94.7	93.7	92.6	—
Replacements	1	10	—	6	5	—	3	2	—	3	6	—	6	9	13	23	—
Hatched, %	0	40.0	—	16.7	40.0	—	33.3	0	—	66.7	66.7	—	83.3	77.8	30.8	43.5	—
Fledged, %	0	75.0	—	100	50.0	—	0	0	—	50.0	100	—	100	100	50	80.0	—
Overall breeding success, %	62.7	42.3	50.0	54.1	65.9	65.4	60.7	62.1	71.7	72.6	63.2	77.0	69.6	76.5	63.6	60.1	68.2

The imperfections of this type of analysis are well-known (Bradstreet 1980, 1982). Identifiable remains of some organisms persist longer in the stomach than others, and these organisms are therefore over-represented when the stomach is examined. Moreover, where there are large differences in the size and nutritive value of different organisms, an analysis based only on numbers exaggerates the importance of smaller ones, although this problem can be avoided by converting numbers to weights. Biases inherent in our methods have to be borne in mind when considering our figures.

We identified otoliths by comparison with a reference collection based on otoliths removed from identified fishes collected by other means. In all 3 years, but particularly in 1982, a substantial number of fish otoliths could not be identified. The majority of those were small compared to the identifiable otoliths, and some may have been accessory otoliths of identified species. However, several were distinctive in appearance and not consistently associated with other types. These presumably belonged to fish not otherwise encountered in our study.

Among fish, the most frequently recorded were the arctic cod (which occurred in 24–45% of stomachs each year), sandlance (13–37%), and snailfish (8–63%) (Table 15). Fish doctors and sculpins, both of which were brought to the chicks in moderate numbers, made up a smaller proportion of the adult diet, and Greenland halibut, which appeared in small numbers in the chicks' diet, was never identified in stomach samples.

Among invertebrates, the most common genera found were the amphipod crustaceans *Parathemisto* and *Mysis* (49–68% and 10–19% of stomachs, respectively [Table 15]), the squid *Gonatus fabricii* (4–15%) and an annelid worm, probably *Nereis pelagica* (28–50%). The genus *Mysis* accounted for 53% of all organisms recorded in 1980, but more than 99% of the 2652 *Mysis* specimens counted came from only six stomachs, with one containing 1144. *Parathemisto* was the genus taken most consistently; it was found in 56% of all stomachs examined. It was the second most numerous organism identified in 1980 (after *Mysis*)and the most numerous in 1981 and 1982 (Table 15).

Some of the small crustacea, particularly the copepods, were probably not eaten directly, but found their way into our murres in the stomachs of fish. This was clearly demonstrated when we found identifiable copepods in the stomachs of chicks taken on the cliffs. The chicks could not have been fed anything as small as a copepod and must therefore have obtained them via the fish delivered to them.

Some striking differences were apparent between years. Sandlance, which formed 10–11% of all prey items in 1980 and 1981, declined to only 1.3% in 1982. The small, shrimp-like mysid crustacea showed a similar trend, declining from 53.6% of prey in 1980, to 14.9% in 1981, and only 3.8% in 1982. At the same time snailfish, which represented only 0.2% of prey in 1980, rose to 5.5% in 1981 and 12.7% in 1982. Surprisingly, copepods were much more common in 1982 (9.4% of prey) than in 1980 (0.3%) or 1981 (0%). If, as we suggested, they find their way into the murres via fish stomachs, then it seems odd that they should fluctutate when the proportion of murres containing fish remained more or less stable. The interyear variation may be related to differences in the feeding behaviour or species composition of the fish, rather than any preference on the part of the murres.

Without knowing the relative rate at which different organisms, or their parts, pass through a murre's stomach it is hard to assess

Table 15
The diet of adult Thick-billed Murres in the Digges Sound area based on the analysis of stomach contents

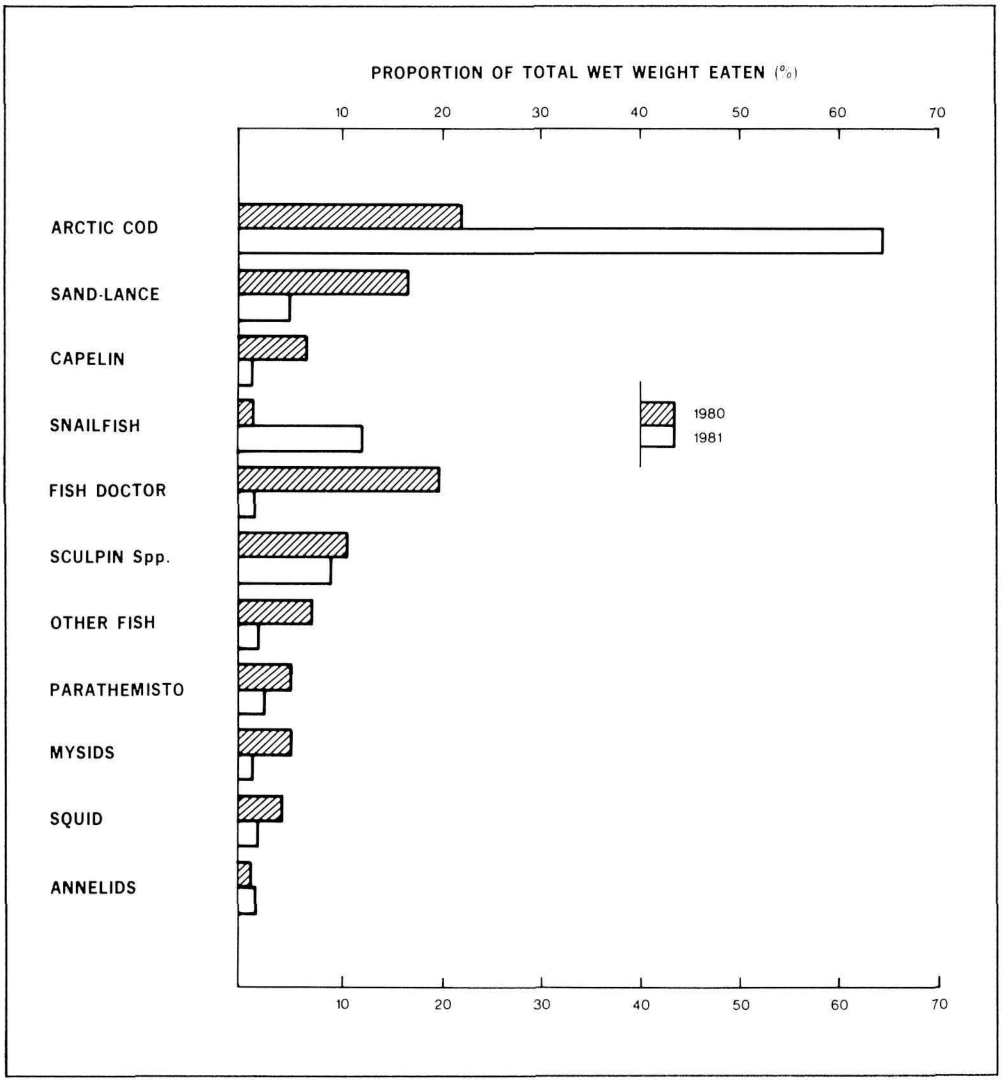
	Percentage of stomachs			Percentage of total individuals		
Prey	1980 (N = 100)	1981 (N = 44)	1982 (N = 79)	1980 (N = 5410)	1981 (N = 935)	1982 (N = 3419)
Empty	5.0	9.0	3.8			
Fish						
Arctic cod (*Boreogadus saida*)	26.0	45.0	24.1	1.5	15.1	1.0
Sandlance (*Ammodytes* spp.)	37.0	37.5	13.9	10.6	11.1	1.3
Capelin (*Mallotus villosus*)	21.0	15.0	12.7	1.2	0.7	0.5
Snailfish (*Liparis* spp.)	8.0	35.0	63.3	0.2	5.5	12.7
Fish doctor (*Gymnelus viridis*)	1.0	5.0	2.5	1.1	0.2	0.1
Sculpins (Cottidae sp.)	20.0	12.5	3.8	1.1	2.9	0.2
Unidentified	44.0	42.5	70.9	5.2	3.6	43.8
All fish	72.0	75.0	81.0	19.8	39.1	59.6
Crustacea						
Parathemisto spp.	49.0	52.5	68.4	21.3	37.9	17.9
Hyperia spp.	8.0	2.5	8.9	0.3	0.3	0.4
Mysis spp.	19.0	12.5	10.1	52.7	9.3	1.6
Boreomysis spp.	0	17.5	13.9	0	2.3	1.1
Mysidae (unident.)	9.0	20.0	16.5	0.9	3.3	1.1
Ischyrocerus sp.	7.0	5.0	6.3	1.0	0.3	0.8
Weyprechtia sp.	8.0	0	1.3	0.5	0	<0.1
Gammarus sp.	9.0	0	1.2	0.3	0	0.2
Onisimus sp.	0	2.5	2.4	0	0.1	<0.1
Ampelisca sp.	0	2.5	0	0	0.1	0
Thyssanoessa sp.	1.0	0	3.8	<0.1	0	0.1
Argis sp.	2.0	0	0	<0.1	0	0
Sclerocrangon spp.	1.0	0	0	<0.1	0	0
Calanus sp.	0	0	3.8	0	0	0.7
Euchaeta sp.	0	0	26.6	0	0	6.8
Metridia sp.	0	0	7.6	0	0	0.5
Other copepods (incl. unident.)	6.0	0	4.1	0.3	0	1.4
All copepods	6.0	0	38.0	0.3	0	9.4
Unclassified	10.0	0	21.5	0.6	0	0.8
All crustacea	78.0	70.5	91.1	78.1	53.6	33.5
Mollusca						
Gonatus fabricii	15.0	15.0	3.8	0.9	0.7	0.1
Annelida						
Nereis pelagica	28.0	42.5	50.1	1.4	6.3	6.2

the relative importance of different prey in their diet. To provide a rough approximation we have multiplied the proportion of all individuals represented by each taxa by their mean fresh weight. We have then expressed these fresh weight indices as percentages of the total fresh weight represented by all individuals over the entire season for 1980 and 1981 (Fig. 23, App. 12). For 1982 this analysis would be misleading because 44% of all remains were unidentified otoliths representing fish of unknown fresh weights.

Fish predominated in the adult diet in both years when expressed in terms of fresh weight, with arctic cod (22% in 1980, 64% in 1981), sandlance (17%, 5%), fish doctor (19%, 1%), snailfish (1%, 12%), and sculpins (11%, 9%) being the most important species. In 1982, although overall proportions cannot be estimated, arctic cod comprised a much smaller proportion of the diet than in 1981 because both the number of fish as a proportion of all fish, and their mean weight, was lower. Crustacea comprised only 10% of food in 1980 and 5% in 1981. However, if otoliths persist in murre stomachs considerably longer than crustacea remain identifiable, then these figures may be misleading. They do provide some basis for comparision with those of Bradstreet (1980) who used similar calculations (converting to dry weight) to analyse the diet of Thick-billed Murres in Barrow Strait.

It is hard to compare the total number of species found in the diet of murres at Digges Sound with those recorded in birds collected in Barrow Strait, because we collected more birds spread over a longer period. However, if we compare our samples for June and the first half of July with Bradstreet's (taken between 5 June and 4 July) we recorded five identified genera of fish in all 3 years (plus 1–3 other unidentified but characteristic otolith types) out of samples of 36, 14, and 23 stomachs. In contrast, Bradstreet found only arctic cod and sculpins among 98 stomachs. This suggests that a greater range of prey was available to the murres in the low arctic waters around Digges Sound than in the high arctic waters of Barrow Strait.

Figure 23
Diet of adult Thick-billed Murres in 1980 and 1981 estimated in terms of wet weight eaten



3.2.7. Diet of chicks □

Practically all meals that we saw being delivered to chicks consisted of a single fish, as is usually the case for murres (Tuck 1961, Gaston and Nettleship 1981). Exceptions included squid, large crustacea and, on one occasion, two small fish. For the most part, the murres made their deliveries so quickly that we were unable to identify the species of fish involved. However, most of those that could be identified were arctic cod, with small numbers of Greenland halibut and sculpins, both of the latter being distinctive and readily identifiable.

Specimens collected from the breeding ledges supported the idea that arctic cod were the main food of the chicks, comprising 45–62% of specimens collected during 1980–82 and an estimated 58–68% of the diet by weight (Table 16). The only other fish making up more than 10% of specimens in any year were capelin, sandlance, and blennies (including fish doctor), although in 1981 sculpins comprised just over 10% by weight.

To check whether the specimens collected from ledges were representative of the normal chick diet, we collected 21 chicks in August 1981 and dissected them to examine remains present in their stomachs. Arctic cod was again the most important species, comprising 53% of the 53 organisms identified. Surprisingly 28% were squid compared to only 7% squid among specimens collected on ledges in 1981. Annelid worms, not otherwise recorded as chick food, made up a further 8% of the organisms found in stomachs.

The high incidence of squid and annelid worms in the sample of remains from chick stomachs, compared with food collected on ledges, or seen being delivered, probably resulted from the persistence of their hard parts. Both animals are represented in stomachs, mainly by chitinous jaws which appear to be very resistant to digestion. They probably persist in murre stomachs longer than fish otoliths, perhaps because they do not break up and dissolve. Considering only the fish, however, the results of the stomach analysis were similar to those obtained by picking up specimens on ledges.

The mean weights of fish and squid collected and weighed while still fresh were 8.7 g, 8.6 g, and 5.7 g, respectively, in 1980–82 (Table 17). Generally speaking, arctic cod delivered to chicks weighed 5–12 g and measured 60–130 mm in length. Most other fish fell in the same weight range, although sandlance were generally smaller (1–5 g) and fish doctors larger (10–20 g). The majority of arctic cod of the size observed were probably in their second and third years, at which age they reach maturity (Craig *et al.* 1982).

Most of the fish brought to chicks were larger than those detected in the adult diet. We were unable to estimate the size of fish represented by the smallest otoliths we found in our

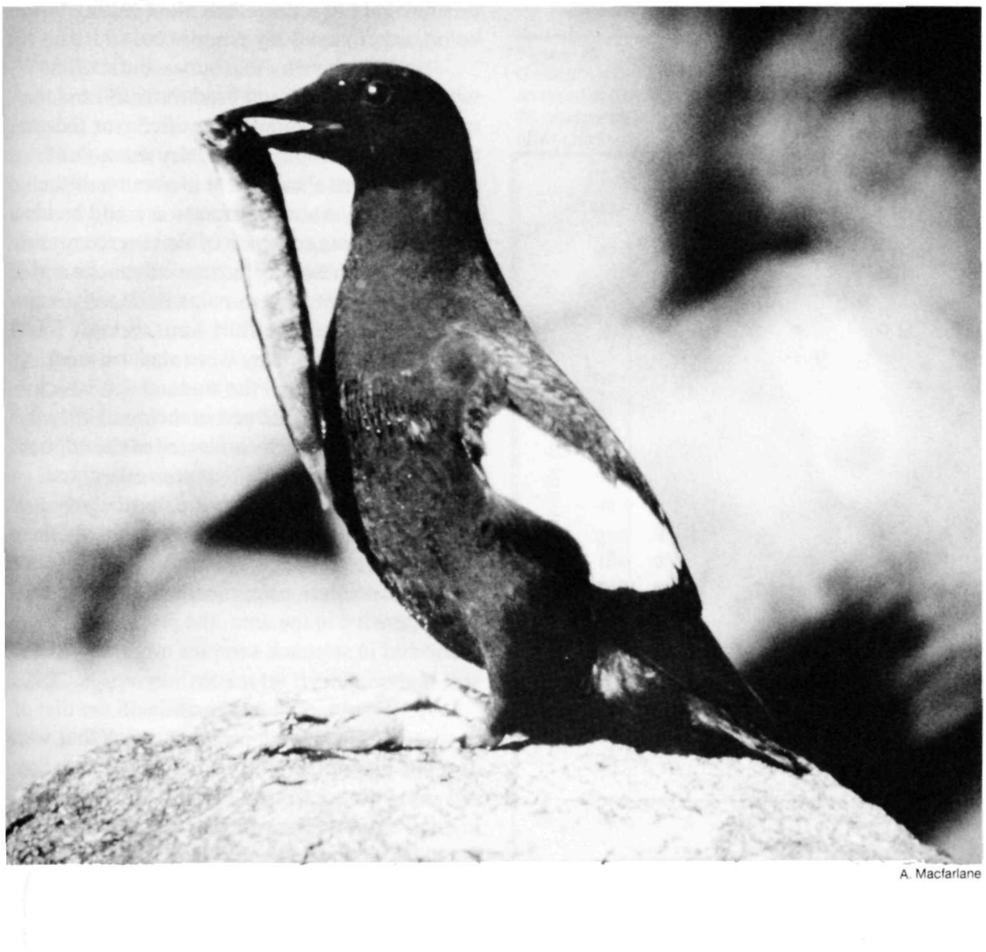
Table 16
The percentage occurrence by number and weight of nine organisms in the diet of Thick-billed Murre chicks at East Digges Island in 1980–82, based on specimens collected from the breeding ledges. There were 88 specimens in 1980, 85 in 1981, 21 in 1982

Organism	1980 ($N = 88$) No. of specimens, %	1980 Weight, %	1981 ($N = 85$) No. of specimens, %	1981 Weight, %	1982 ($N = 21$) No. of specimens, %	1982 Weight, %
Arctic cod	45.5	60.4	55.3	58.0	62.0	67.7
Capelin	9.1	4.0	3.5	6.1	10.0	7.8
Sandlance	20.5	6.2	8.2	2.4	10.0	3.3
Fish doctor	10.2	17.6	4.7	6.1	4.5	10.5
Greenland halibut	2.3	3.8	2.4	1.2	0	0
Sculpin spp.	3.3	2.6	5.9	10.6	4.5	2.8
Blenny spp.	4.5	3.1	12.9	11.9	4.5	5.6
Squid	3.4	2.3	7.1	3.5	4.5	2.4
Crustacea	1.1	0.1	0	0	0	0

Table 17
Weights of meals delivered to Thick-billed Murre chicks at East Digges Island in 1980–82

	1980			1981			1982		
	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N
Arctic cod	12.35	8.91	22	9.63	7.24	18	6.40	4.33	9
Capelin	4.09	1.64	8	16.0	—	1	4.80	0.99	2
Sandlance spp.	2.80	1.80	16	2.70	1.34	4	2.00	0.42	2
Fish doctor	15.96	10.92	7	12.00	1.41	2	12.90	—	1
Greenland halibut	15.35	7.71	2	4.75	1.06	2	—	—	—
Sculpin spp.	7.10	2.55	2	16.0	—	1	3.4	—	1
Blenny spp.	6.95	7.85	2	8.45	8.25	4	6.90	—	1
Squid	6.15	0.64	2	4.75	1.77	2	2.90	—	1
All species	8.72	8.17	61	8.63	6.66	34	5.75	4.06	17

Black Guillemot arriving with a four-lined snake blenny, Pitsulak City, August 1983



A. Macfarlane

stomach samples, but the majority of sandlance represented weighed less than 1.5 g, compared with a mean of more than 2 g for those delivered to chicks. Likewise, arctic cod from adults collected after the start of hatching were lighter in all years (8.7 g, 5.7 g, and 4.5 g) than those fed to chicks (*cf.* Table 17). The average size of arctic cod showed the same trend in both samples, being heaviest in 1980 and lightest in 1982.

The fish brought to chicks at East Digges Island seemed to be smaller than those delivered to Thick-billed Murre chicks elsewhere. At Prince Leopold Island the average meal weighed 12.5 g (Gaston and Nettleship 1981), whereas at Coats Island in 1981 the average was 11.6 g and at Hantzsch Island in 1982, 10.1 g (AJG, unpubl.). All these samples were derived in the same way, from fishes picked up on ledges. Daily feeding rates were also relatively low at East Digges Island, ranging from 2.0–2.9 feeds per chick during our study compared to rates of 3–5 feeds per chick recorded at colonies in Lancaster Sound (Birkhead and Nettleship 1981, Gaston and Nettleship 1981) and elsewhere in Hudson Strait (Gaston *et al.* 1983). Presumably, the small meals and low feeding rates combined to cause the low chick weights that we recorded.

3.3. Black Guillemot □

Our main interest in the Black Guillemots was in what they were feeding on and where they found it, but we also kept notes on their breeding biology. We made most observations around the Nuvuk Islands in 1981 and 1982, and carried out the breeding biology studies on Pitsulak City. In this area most Black Guillemots nest under large boulders on fairly flat islands so that, unlike cliff sites, there is no difficulty in getting access to the nests. Moreover, the density of nests was sufficient to allow us to observe up to 20 nests simultaneously from a blind placed on Pitsulak City.

3.3.1. Timing of breeding □

In 1981, the majority of eggs hatched between 21 July and 10 August, but there was a second small peak in late August (Fig. 24). In 1982, hatching began after 26 July and there was a single peak between 5 and 10 August. Assuming an incubation period of 31 days (Asbirk 1979, Petersen 1981), this suggests that laying extended from 20 June to 24 July in 1981 and from 25 June to 24 July in 1982, similar dates and spread to those observed for the Thick-billed Murres.

The second peak of hatching in 1981 may represent replacement clutches. Petersen (1981) mentions that 9–16% of Icelandic Black Guillemots that lose their clutches lay replacements, although this occurs only in an early season. In 1982, when breeding was later than in 1981, there may not have been sufficient time for replacements to be laid. Black Guillemot chicks fledge at 34–38 days old (Cairns

Figure 24
Timing of hatching for Black Guillemot chicks on Pitsulak City in 1981 and 1982

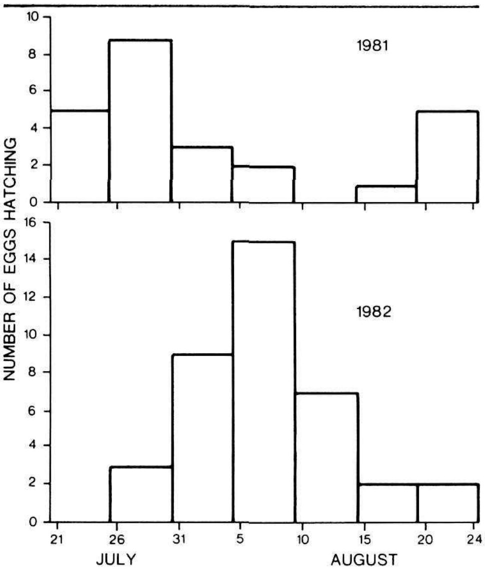


Table 18
Breeding success of Black Guillemots on Pitsulak City in 1981 and 1982

	1981	1982
Nests examined	20	52
No. eggs laid	34	100
Mean clutch size	1.70	1.92
No. chicks hatched	19	51
Eggs hatching, %	56	51
No. chicks fledged	10	47
Chicks fledging, %	53	92
No. of chicks fledged per nest	0.50	0.90

1981, Petersen 1981) so that in 1981 most chicks would have fledged about the beginning of September. In 1980, fledged juveniles were seen around the Nuvuk Islands on 2 September, suggesting that timing of breeding in that year was similar to that observed in 1981. In 1982 peak fledging would have been in mid-September, by which time we had completed our observations.

3.3.2. Breeding success □

In 1982, we checked breeding sites from early July onwards, whereas in 1981 we checked them only from late July, just before the start of hatching. This difference may account for the fact that 70% ($N = 20$) of clutches in 1981 were of two eggs, compared with 92% ($N = 52$) in 1982.

Hatching success was surprisingly low: only 56% of eggs hatched in 1981 and 51% in 1982 (Table 18). In 1981, the proportion of chicks fledging (53%) was also rather low, but was significantly higher in 1982 when 92% of chicks fledged ($Chi^2 = 11.81$, df = 1, $P < 0.01$). Breeding pairs reared an average of only 0.5 chicks each in 1981, compared to 0.90 in 1982. Actual figures for 1981 may have been even lower, for some nests may have lost their eggs before we examined them.

Black Guillemots, like many other seabirds, are susceptible to human disturbance during the breeding season, but the extent to which disturbance lowers reproductive output varies widely (Cairns 1980, Petersen 1981). Because we conducted no controlled experiments, we cannot evaluate the effects of our disturbance on guillemot breeding, and our figures on reproductive success should be treated with caution.

3.3.3. Chick growth □

We measured the wing length and weight of a sample of Black Guillemot chicks at Pitsulak City every 4–5 days until fledging in 1981 and 1982. In 1980 we made no systematic measurements, but weighed 67 chicks once only on Pitsulak City and adjacent islands between 6 and 31 August. We constructed a growth curve for this sample by using the wing length of the chicks to estimate their age (Gaston, in press).

Chicks gained weight steadily until 25 days old when weights began to level off at between 300 and 350 g (Fig. 25). Growth rates were similar in all 3 years. The rate of growth in wing length increased gradually at first, but after 12 days old the rate remained fairly constant until fledging (Fig. 26). No difference ws detectable between 1981 and 1982 in the rate of growth of wing length.

Rates of weight increase at Pitsulak City were higher than those at Prince Leopold Island (Gaston, in press), but slightly lower than those measured in the gulf and estuary of the St. Lawrence (Cairns 1981).

3.3.4. Diet □

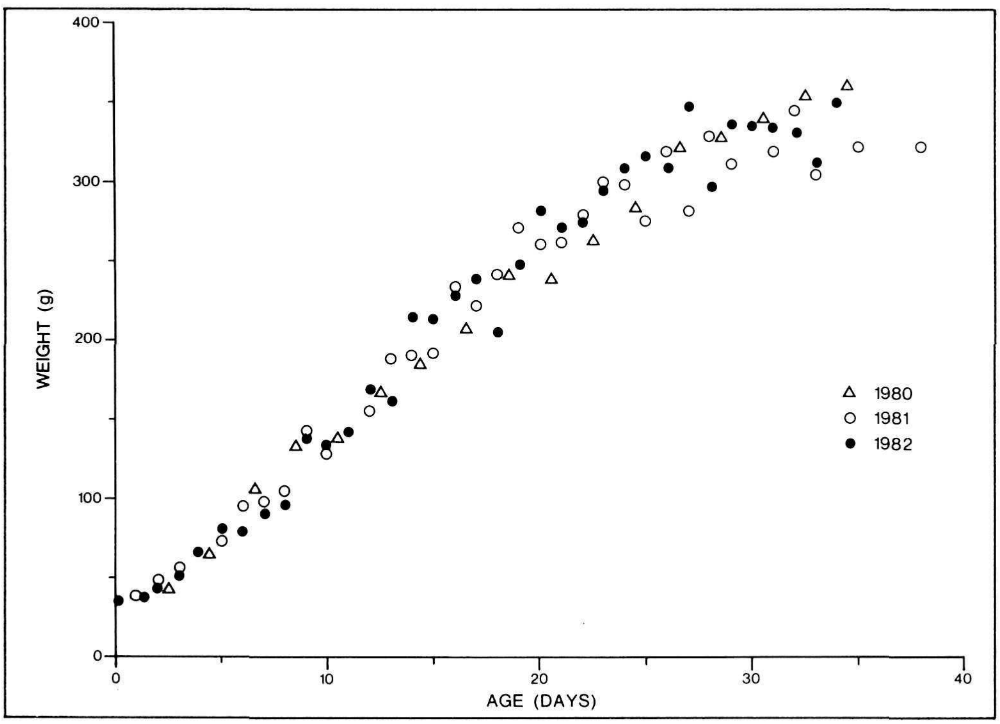
We collected 22 adult Black Guillemots in 1981 and 24 in 1982 to examine what they had been eating. All of these birds were collected well away from our study colony at Pitsulak City to reduce the risk of killing birds belonging to our study population.

In both years fish bones and otoliths were the most common food remains, and the species most commonly identified was the arctic cod (Table 19). Fragmentary remains of crustacea were also present in about half the birds but only a small proportion could be identified. The most common of these were mysids, which were numerous in some stomachs and the predominant food remains in six.

Arctic cod otoliths were not only found in many stomachs, they were also the most numerous items in all the stomachs in which they occurred in 1982 and in most in 1981. Three out of four birds collected at the edge of an ice jam on 3 July 1982 contained only remains of arctic cod, which are particularly associated with ice. We collected most of our 1981 samples in late July and August. If we had made collections earlier, when ice cover was extensive in the area, the preponderance of arctic cod in stomach samples might have been still higher.

We obtained information on the diet of nestling guillemots by picking up fish that were dropped by adults (1981) and by watching the arrival of birds carrying food (1982). Fish being delivered to chicks were held sideways in the bill, gripped just behind the head, so that

Figure 25
Weight increase of Black Guillemot chicks in the Nuvuk Islands area in 1980, 1981, and 1982. Data for 1981 based on 85 measurements of 25 chicks; for 1982, 238 measurements of 44 chicks



the whole body of the fish was visible and could usually be identified unless the bird was too quick at entering its nest site. Most of the 1981 recoveries had been dropped by birds being netted or noosed for banding in 1981, so they should represent an unbiased sample of the food delivered to chicks.

The diet of the chicks was dominated by blennies, particularly the arctic shanny and the four-lined snake blenny, which together constituted 72% ($N = 32$) of the 1981 sample and 78% ($N = 614$) of the 1982 sample. In 1981, arctic cod was also important, making up 13% of recovered items, but in 1982 this constituted only 3% of deliveries and both fish doctor (9%) and sculpins (8%) were more frequent (Table 20).

The importance of blennies in the diet was even greater when the relative weights of different prey species were considered, because the weights of arctic shannies and four-lined snake blennies that we recovered in 1981 averaged 16.7 ± 5.3 g ($N = 17$) and 19.8 ± 6.4 g ($N = 6$), respectively, compared with 5.5 ± 3.0 g ($N = 14$) for arctic cod.

In both years we found that the proportion of four-lined snake blennies in the chicks' diet increased during the course of the season, so that in 1982 almost half the food items delivered in late August were of this species. Arctic cod, on the other hand, were most important early in the season, decreasing thereafter (Fig. 27).

The predominance of blennies in the diet of guillemot chicks at Pitsulak City confirms the importance of these fish, which have been found to form the mainstay of chick diets at numerous locations in the North Atlantic (Winn 1950, Preston 1968, Bergman 1971, Asbirk 1979, Cairns 1981, Petersen 1981). The range of prey items contrasts strongly with the food being delivered at the same time to Thick-billed Murre chicks at Digges Island. The total absence of arctic shannies and four-lined snake blennies from the diet of the murres is presumably associated with their avoidance of shallow water when feeding.

In 1982 and 1983 studies of the ecology of arctic shannies, four-lined snake blennies, and fish doctors were carried out mainly in the sheltered channels between the Nuvuk Islands and the mainland. Observations by divers in this area revealed high populations of blennies, with the same order of abundance as recorded in our studies of guillemot chick feeding (i.e., arctic shannies most numerous, followed by four-lined snake blennies and fish doctors).

3.3.5. Kleptoparasitism by Parasitic Jaegers on Black Guillemots □

We saw Parasitic Jaegers, presumably postbreeding migrants, regularly at the Black Guillemot colonies of the Nuvuk area in the latter part of August 1981 and 7 August – 8 September 1982. The jaegers attempted to

Table 19
Prey remains found in the stomachs of Black Guillemots collected in the Digges Sound area in 1981 and 1982

Prey	No. of stomachs (%)		
	1981 ($N = 22$)	1982 ($N = 24$)	1981 + 1982 ($N = 46$)
Fish			
Arctic cod	13 (59)	11 (46)	24 (52)
Four-lined snake blenny	4 (18)		4 (9)
Arctic shanny	6 (27)	5 (21)	11 (24)
All fish, including unidentified	21 (95)	20 (83)	41 (89)
Crustacea			
Mysidae	5 (23)	5 (21)	10 (22)
Amphipoda	3 (14)	1 (4)	4 (9)
Decapoda	2 (9)		2 (4)
All crustaceans, including unidentified	8 (36)	16 (67)	24 (52)
Polychaeta		8 (33)	8 (17)
Pebbles, snails, plant material		5 (21)	5 (11)

Table 20
Food fed to Black Guillemot chicks at Pitsulak City in 1981 (specimens dropped by incoming adults) and 1982 (identified visually from a blind)

Species	Recoveries in 1981			Deliveries in 1982		
	No.	% total no.	% total wt.	No.	% total no.	% total wt.
Arctic cod	4	13	5	19	3.1	4.4
Sandlance				1	0.2	0.1
Fish doctor	2	6	4	58	9.4	11.2
Four-lined snake blenny	6	19	25	172	27.8	22.1
Arctic shanny	17	53	60	309	50.0	55.9
Daubed shanny	1	3	1			
Sculpins	2	6	5	48	7.8	4.0
Snailfish spp.				9	1.5	2.2
Crustacea				1	0.2	0.1
Squid				1	0.2	0.1
Total identified	32			618		

Figure 26
Growth in wing length of Black Guillemot chicks measured on Pitsulak City in 1981 and 1982. Data for 1981 based on 85 measurements of 25 chicks; for 1982, 238 measurements of 44 chicks

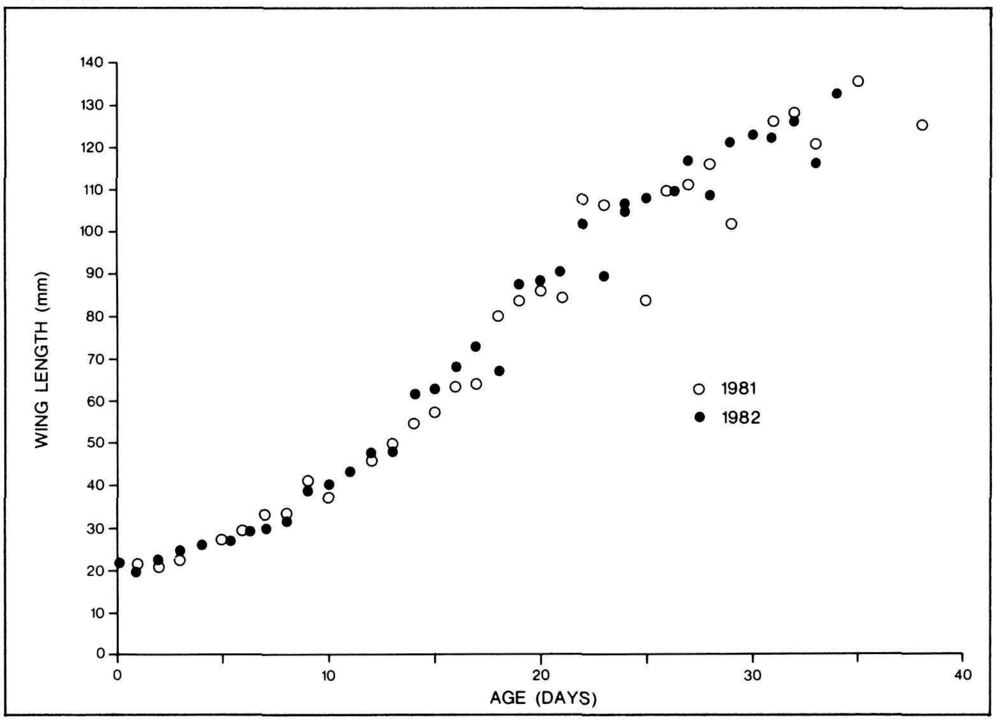
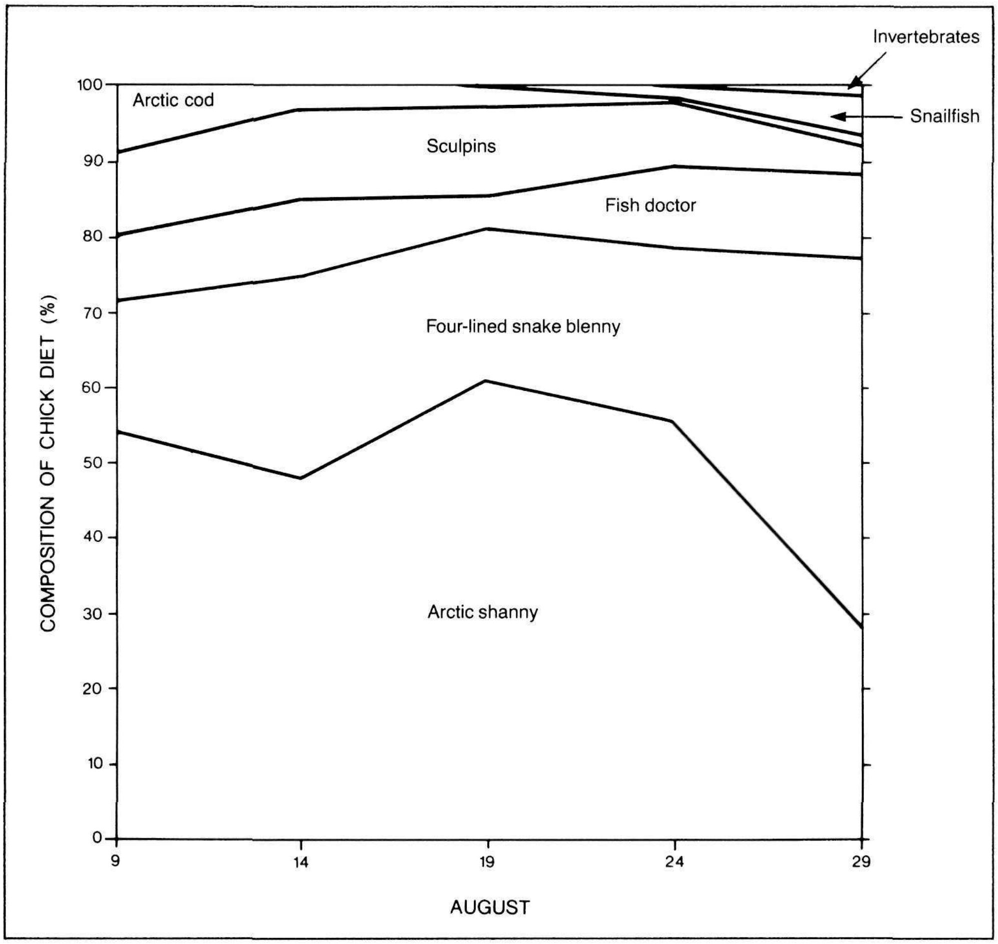


Figure 27
Changes in the proportion of different fish species in the diet of Black Guillemot chicks at Pitsulak City during August 1982 ($N = 507$)



steal fish from the guillemots by overtaking them in flight so that the victim dropped its fish to avoid harassment. The escape tactics of the guillemots were to fly as rapidly as possible or else to descend to the water and dive.

In 1982 we recorded 141 attempts by up to six jaegers to obtain fish from guillemots in 6.5 h of observation. Guillemots dropped their fish in 13 cases, giving the jaegers a success rate of 9%.

On five occasions we witnessed attacks by guillemots on Parasitic Jaegers. In two of these the guillemots lunged at a jaeger which had been sitting on the water, and in the other three the guillemot pursued a flying bird. In all cases the jaeger offered no resistance to the guillemot and rapidly flew away from the scene of the attack.

Using rough estimates of the time spent by jaegers at our observation area on Pitsulak City, we calculate that they stole about 20 fish daily from guillemots there. The area supported more than 50 active guillemot nests, and so the direct effect of jaeger kleptoparasitism was probably small. Nor did the jaegers' presence have the indirect effect of dissuading guillemots from bringing food to the colony: feeding rates rose after the jaegers arrived.

We saw the Parasitic Jaegers in attendance at Pitsulak City pursue passing Thick-billed Murres on several occasions without success, but jaeger kleptoparasitism was never recorded at the murre colonies.

The predators

Gulls and Northern Ravens were common on the murre colony throughout the season. They scavenged the remains of displaced eggs and chicks and of food dropped by murres, and preyed outright on murre eggs and chicks. In 1980 we assessed the amount of predation by ravens on murres. In 1981, and particularly 1982, we studied the importance of murres as a source of food to gulls and Northern Ravens and the probable effect of predation on the reproductive success of the murres.

The other important predators of murres and their eggs and young were Gyrfalcons and red foxes. We estimated the effect of these predators on the murres but our observations for both species were meagre and our estimates depend on several assumptions and approximations.

1. Ravens

1.1. Breeding biology □

In 1980 Northern Ravens were seen foraging along the murre colony as soon as we arrived at Digges Island. On 26 June, we counted 16 near the cliffs, some of which were newly fledged young. However, in 1981 and 1982, when nests were found, the earliest dates of fledging recorded were after 5 July (1981, two nests) and 3 July (1982, three nests). These dates indicate that laying had probably taken place between about late April and mid-May (Godfrey 1966).

The three nest sites located in 1982 we believed to be the only active nests on the island. In 1981 site 3 was not occupied and in 1980 it was used by a Rough-legged Hawk. Sites were spread well apart with 3.1 and 3.6 km separating nearest neighbours (Fig. 28). Territorial interactions were observed in 1982, between birds from nests 2 and 3, with the pair from nest 2 apparently claiming the bulk of the murre colony. After fledging, the brood from nest 2 moved to the area of Long Lake, where they roosted on Hawk Cliff. The broods from nest 1, colour-banded in 1981 and 1982, were never seen in the vicinity of the murre cliffs, although they were known to have fledged successfully. Presumably they foraged elsewhere.

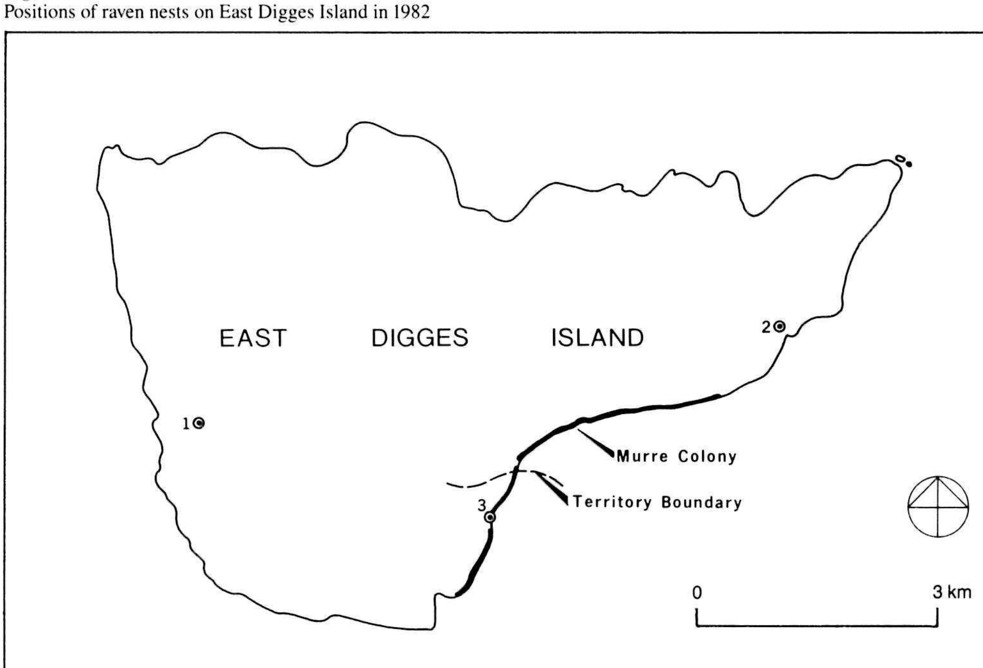
Inspection of pellets found at nest 1 in 1981 and 1982 suggested that these birds fed mainly on lemmings and small birds. Remains of an adult murre were also found nearby. This may have been scavenged, but on one occasion we saw a Northern Raven kill an injured adult murre close to the colony and at other times ravens harassed wounded murres. Several hours of watching in 1981 revealed no sign of murres' eggs being brought to the nest. However, in 1982 our observations suggested that the adult ravens may swallow the contents of the egg and then feed the young from the crop. We saw no signs of whole eggs being swallowed and hence did not expect to see eggshell fragments in the pellets.

A substantial proportion of the food fed to the young of the other two pairs, at least after fledging, consisted of murres' eggs and chicks. Young were fed for at least 3 weeks after fledging, and even more than a month after leaving the nest they appeared inept at obtaining murre eggs or chicks for themselves.

Ravens were most active during the morning in June and July 1982, with rates of predation on murres highest before midday, and practically ceasing after 18:00. In August activity was generally lower, but those predations that did occur took place between 14:00 and 18:00. We saw ravens going to roost in July at between 21:00 and 21:30. They generally left the roost between 04:30 and 05:00, soon after the sun struck their roost-sites on Hawk Cliff (nest 2) or near W (nest 3). This 7-h period of total inactivity was far longer than that of any other species on the islands at that time of year.

In both 1980 and 1982 we found that Northern Raven activity around the colony was greatest soon after the murres began to lay and declined towards the end of the season. In 1980, when all observations were made at D, ravens continued to be present along the cliffs on all watches, but the rate of predation attempts fell from more than three per hour in the first half of July to less than one in August (Fig. 29).

Figure 28
Positions of raven nests on East Digges Island in 1982



However, at least one predation attempt was seen on every watch. Rates of predation were lower in 1982, decreasing from 1.5 per hour to 0.3 per hour and the proportion of 3-h watches on which any predation attempts were seen fell from 78% in late June to only 11% in the second half of August.

During the first half of the season a large proportion of the murres' eggs taken by Northern Ravens were cached, usually by being buried in soft moss within 1 km of the cliff-edge. Out of 84 eggs and chicks taken by ravens, 69 (82%) were cached and only 10 (12%) were eaten immediately.

Some individuals took eggs rapidly when they were caching them: the record was six eggs in less than an hour on 21 June 1982. The time spent by the ravens in obtaining murre eggs was relatively small. It was quite normal to see a raven appear at the cliff-top, perhaps perch for a minute or two on some prominence, then fly to a ledge and obtain an egg within 2–3 min, circle back up the cliff holding the egg in its beak, and fly off inland to cache it. The whole process from arrival to caching frequently took less than 5 min. Although the gulls sometimes pursued the ravens, we only once saw a raven drop an egg. In most cases the ravens ignored the antics of the gulls.

Only six cached eggs were actually found *in situ* because, even when the bird was watched in the act, the spot was almost impossible to identify from a distance of more than a metre or two. Regular checks revealed that all the cached eggs that we managed to find were removed, apparently by the ravens, by 17 August. Hence, ravens probably do not keep their cached eggs for the winter.

1.2. The effect of predation by ravens on the murres □

The rate of predation of murres' eggs and chicks was highest in 1980, when the number of successful predations seen during raven watches averaged 1.2 h^{-1} over the entire season (38 h watching). The corresponding figure in 1982 was 0.8 h^{-1} (153 h watching), but all watches in 1980 were made from point D which revealed the highest rate of predation of any of the three sites used in 1982 (Table 21). Hence, the difference between the 2 years was probably smaller than the above figures suggest.

In 1981 preliminary observations suggested that the rate of predation was low, and regular watches were therefore not carried out. The impression that the predation rate was low was borne out by observations at the breeding study plots where, in 1980, four raven predations were seen, but in 1981 none was recorded despite the same amount of time spent watching. The young from nest 2 were colour-marked in 1981 but were seen only once in the vicinity of the murre cliffs, where the same family spent most of its time in 1982. Hence, presumably, the parent ravens exploited some alternative food source in 1981. A possible explanation is that the whole family crossed to the mainland murre colony soon after the young began to fly.

Because watches were made from only one spot in 1980 we could not extrapolate rates of predation to the whole colony. However, a crude extrapolation could be made on the basis of predation attempts seen on breeding study plots, assuming that these could hardly have been missed had they occurred during regular daily watches. We used only plots B, D, and F for this calculation, because at plot A observers sat very close to the plot and might have caused ravens to avoid the area.

Figure 29
Intensity of predation by ravens on Thick-billed Murre eggs and chicks at East Digges Island, in relation to date, 1980 and 1982

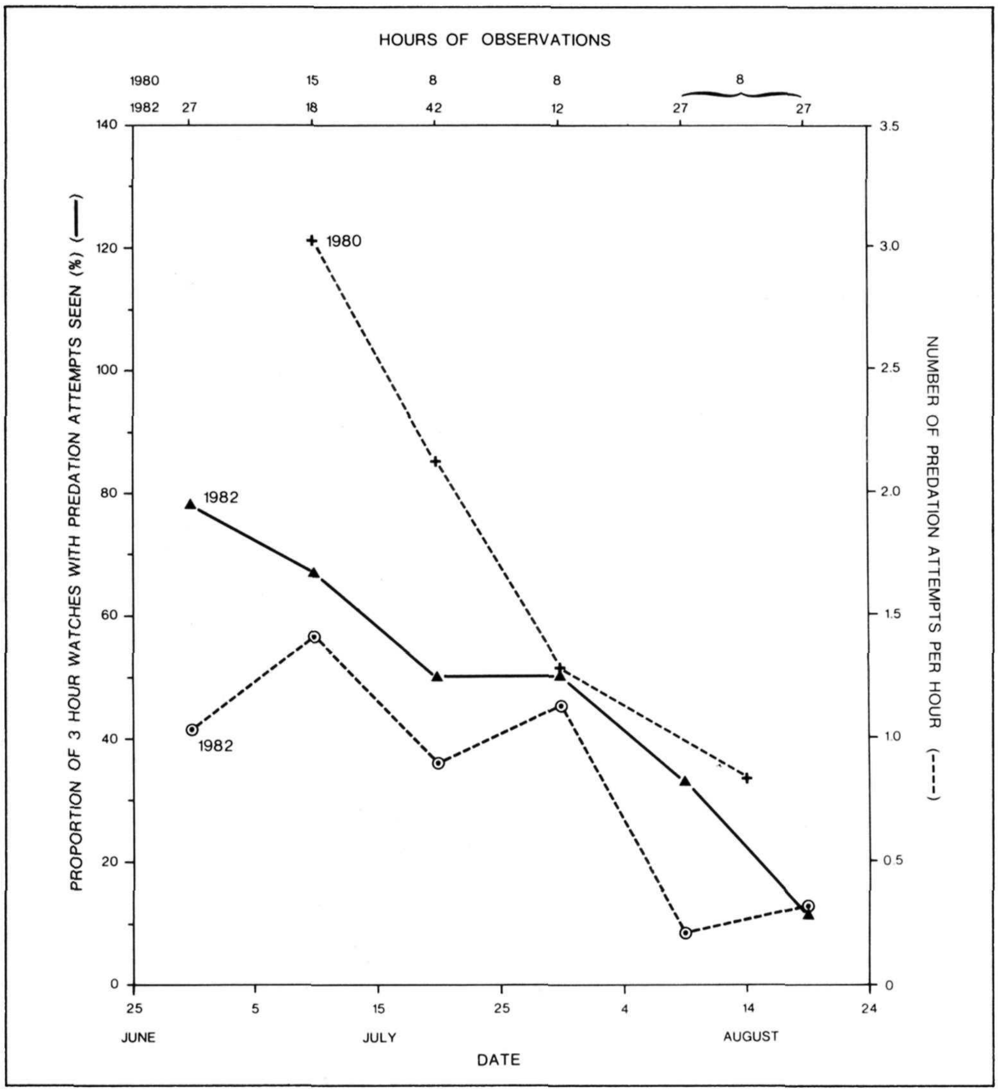
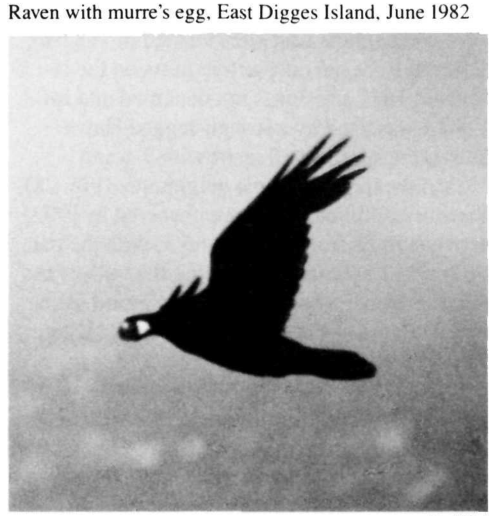


Table 21
Rates of predation by ravens on Thick-billed Murre eggs and chicks, seen from three watch points (see Fig. 7) on East Digges Island in 1982

	Watch points			
	D (pair 2)	V (pair 2)	W (pair 3)	Totals
Observation time, h	51	51	51	153
Successful predations	54	21	48	123
Predation rate (pred. h^{-1})	1.06	0.41	0.94	0.80

Raven with murre's egg, East Digges Island, June 1982



I.L. Jones

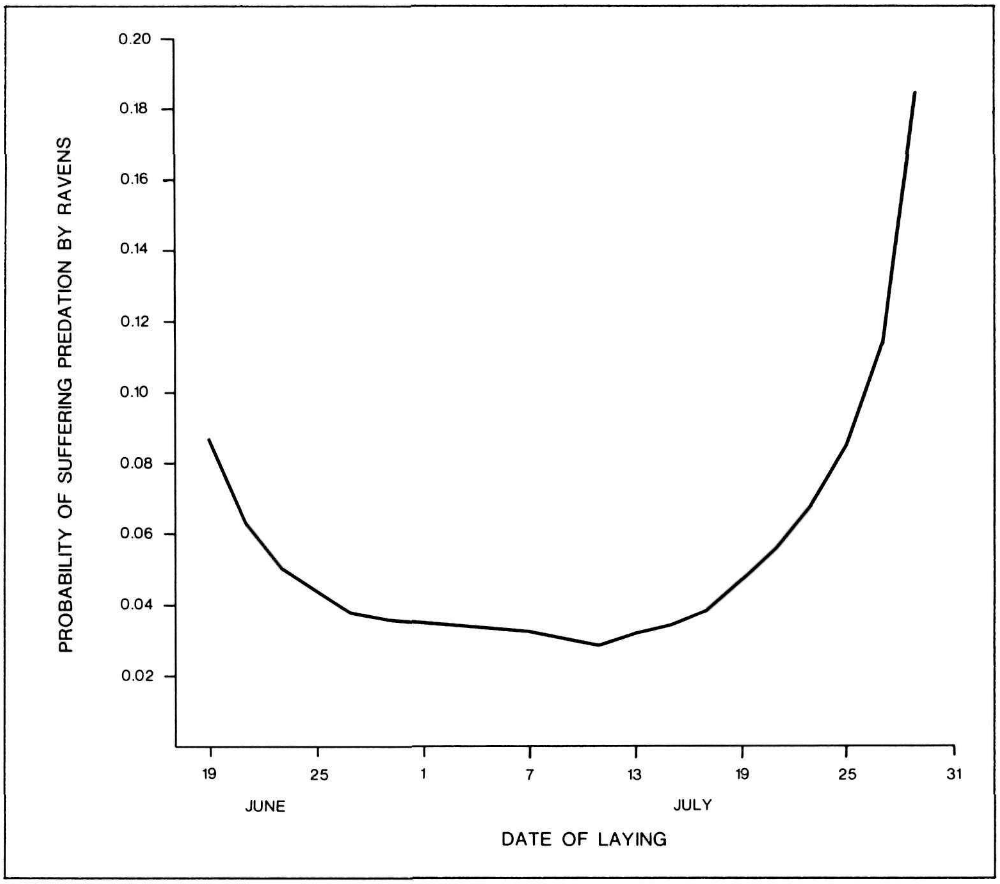
Four successful predations of eggs or chicks were seen in 148 h of watching at plots B, D, and F, where 254 pairs of murres laid eggs. Our watches probably covered about a fifth of the time in which ravens might have preyed on eggs or chicks at these plots and hence we estimate that total losses to ravens were about 20 eggs and chicks: 22% of losses from all causes.

Calculations of predations by ravens in 1982 could be made more accurately. To do this we estimated the proportion of the colony covered by watches from our three observation points by calculating the proportion that these areas represented of our total colony estimate (from the photo count, "The seabirds" section 1.5). We also estimated the proportion of breeding pairs with an egg in each 2-day period by using the known dates of laying and adjusting these by the overall rate of egg-loss calculated from observations on breeding plots (App. 13). From these figures we were able to estimate the number of eggs vulnerable to predation in each 2-day period through the season and compare this with the estimated number taken, based on observed predation rates, to give the average probability of an egg being taken in any 2-day period. We then summed these probabilities over 32-day periods to estimate the overall probability of predation by ravens for eggs laid on different dates (Fig. 30, see App. 14 for details of derivation).

According to this model, eggs laid between 27 June and 17 July had a less than 4% chance of suffering predation by ravens, but probabilities were higher for those laid earlier or later, exceeding 10% for the few eggs laid after 25 July. By 27 June, 53% of eggs had already been laid and, hence, apart from the less than 6% of eggs laid after 17 July, eggs among the earlier half of those laid suffer a higher probability of predation by ravens than those among the latter half.

Ravens preferred eggs to chicks when both were available. From 1 August onwards more chicks were on the colony than eggs, but during August ravens took 14 eggs compared to only 10 chicks. On 23 August, when chicks on the colony outnumbered eggs by 12:1, ravens took five eggs and only three chicks. Some of these late eggs may have been infertile, and birds that had incubated beyond the normal term were generally less attentive, perhaps making their eggs easier targets for ravens. If a high proportion of eggs removed by ravens at the end of the season were infertile this reduces the importance of raven predation to the reproductive success of the murres. In addition, eggs removed early in the season, when raven predation was most intense, were frequently replaced, further reducing the impact of the predation. If we assume that all eggs taken before 1 July were replaced, and 50% of those taken after 15 August were infertile, the total impact of egg predation by ravens amounts to less than 10% of breeding failures by murres.

Figure 30
The probability of predation by ravens on murre eggs during a 32-day incubation period on East Digges Island, according to date laid



2. Gulls

2.1. Predation techniques □

Both Glaucous and Iceland Gulls took murre eggs and chicks but predation by Glaucous Gulls made up the bulk of incidents in which the species was identified. During the chick-rearing period Glaucous Gulls constituted 64% ($N = 62$) of gulls judged to be hunting along the cliffs. Examination of remains at nests showed that Glaucous Gulls took more murre eggs and chicks than Iceland Gulls took.

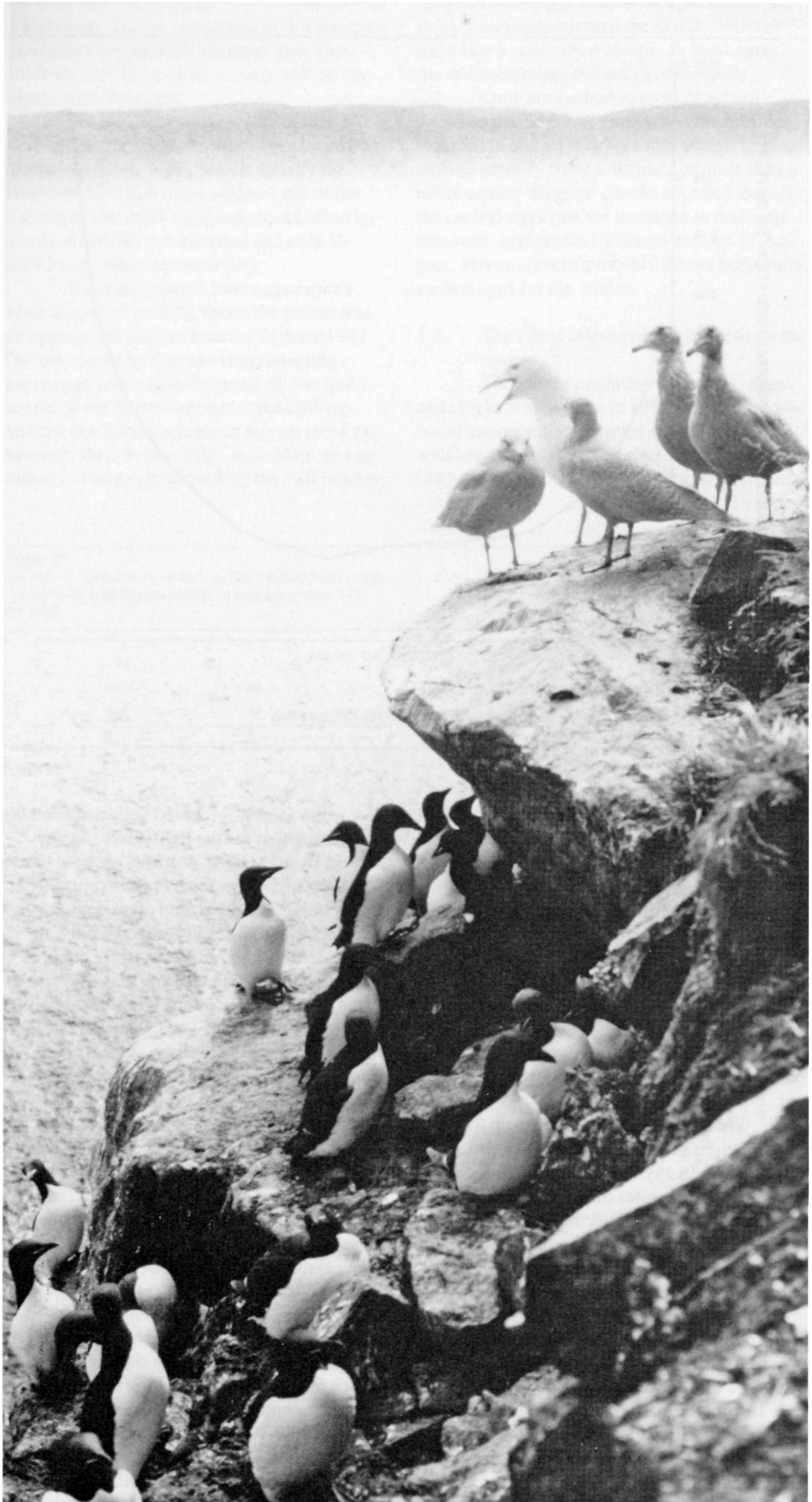
We found it impossible to keep track of the up to eight gulls that might be hunting simultaneously in any watch area and hence we could not estimate rates of predation by gulls by the method used for Northern Ravens. Observations of 29 predation attempts provided information on the techniques used by gulls. To sample typical hunting behaviour we carried out watches of individual gulls, tracking them continuously from the time that they crossed a pre-arranged boundary and entered areas D, V, or W until they landed or left the area. During this period we recorded distance from the cliff-face, height above the sea, frequency of doubling back, and attentiveness to murres (judged by head movements and responses to the distribution of murres).

An average of 25–30 gulls patrolled the cliffs throughout the daylight hours. At any moment from D, V, or W it was possible to see gulls soaring 5–20 m from the cliffs, usually gliding parallel to them, and often doubling back or circling. Gulls judged to be hunting usually flew within 5 m of the cliffs, often following occupied ledges and glancing repeatedly at the murres below. An individual gull might travel more than 1 km along the cliffs without stopping. We saw no attempts by individual gulls to defend feeding territories along the cliffs.

We tracked 600 gulls in systematic watches and estimated that 32% of these were actively looking for food. Altogether we saw 114 gulls make 187 attempts to obtain murre eggs or chicks, ranging from quick swoops to active harassment of murres. Only six resulted in successful predations (three eggs, three chicks).

Gulls were less active than ravens in harassing the murres, depending to a greater extent on eggs left unattended by murres or accidentally dislodged. They showed no preference for eggs once chicks were available and chicks outnumbered eggs by 5:2 among predations seen in August. Gulls did not cache their prey but swallowed eggs and chicks immediately, to avoid pursuit by others, regurgitating some later to their chicks.

Adult and young Glaucous Gulls close to their nest site on plot S2, East Digges Island, August 1982


B. Lyon

2.2. The effect of predation by gulls on the murres □

Because we saw relatively few predations by gulls during our systematic watches, our estimates of the numbers of eggs and chicks removed are crude approximations. However, prior to 1 August we saw four predations during an aggregate of 250 min of watching individual birds. Extrapolating this to the entire daylight period (18.5 h) for the average of 28 birds in the air at any one moment suggests a predation rate of approximately 500 eggs/chicks per day. Equivalent figures after 1 August based on two predations in 250 min, with an average of 29 birds in the air, and a day-length of 16.5 h yield approximately 230 predations per day.

These figures suggest that gulls may remove as many as 7% of murre eggs (*ca.*20% of those lost) and 8% of chicks hatched (more than observed chick losses at our study sites). Even using the maximum estimate for the breeding population (216 000 pairs) these figures represent 5% of the first eggs and 6% of chicks hatched.

We calculated the numbers of murre eggs and chicks fed to Glaucous Gull chicks at colony S2 from observations of feeding rates. We estimated that the gull chicks received 914 murre eggs and 886 chicks over the entire season (App. 15). If we assume a similar breeding success at other Glaucous Gull nests on the east side of Digges Island to that seen at S2 we can extrapolate the total losses caused by Glaucous Gulls by multiplying the figures by 55/21 (see 1982 counts, Table 5). This indicates a total consumption of 2400 eggs and 2300 chicks, which represents 1.3% of first eggs laid and 2% of chicks hatched. When we consider the murre chicks eaten by the adult gulls, non-breeders, and failed breeders, and smaller numbers eaten by Iceland Gulls, our estimate of overall predation by gulls seems about right.

Hence, gull predation is an important, probably dominant, cause of chick mortality among the Thick-billed Murres breeding on Digges Island. After the murre chicks begin to fledge in large numbers, predation of chicks remaining on the colony probably decreases because many chicks die soon after leaving the cliffs and provide an ample source of food for scavengers.

3. Falcons and foxes

3.1. Falcons □

In 1980 and 1982, when Gyrfalcons bred successfully on East Digges Island, they appeared to prey mainly, perhaps entirely, on the murres. We found no other remains in the nest when we visited it in 1980, and murres were the only prey that we saw the Gyrfalcons carrying.

We made no observations on rates of feeding, but the requirements of the adults and chicks can be inferred from their size. Adult male Gyrfalcons average about 1050 g in weight and females about 1750 g (Cade and Digby 1982). Under normal conditions they would probably not require more than one adult murre per day to feed them (Newton 1979). The nestlings would need less than this until close to fledging and hence the whole season's requirements (100 days) for the family should amount to less than 500 full-grown murres, a fraction of 1% of the total population of Digges Sound.

Casual visits by Peregrine Falcons were recorded in all years and these birds probably took murres, but the total number of days on which peregrines were seen did not exceed 12 days in any 1 year and the impact on the murre population would have been negligible.

3.2. Red fox □

Foxes not only fed on adult murres, eggs, and chicks, but also cached them for future consumption. Consequently, we could not estimate the number of murres taken by foxes from their daily energy needs. Only one predation was witnessed: at 22:00 on 30 June 1982, a fox took an incubating murre and an egg from plot S1. The fox seized the murre (a marked female) at the base of the neck and the bird ceased to struggle within a minute. Probably most hunting was done during the night, which accounts for our not seeing more predations. In 1981 four adult murres were brought to the den in Camp Cove in one night. Three murres collected untouched from the den on 1 July proved to be females with well-developed brood patches and oviducts; presumably breeders. Three others, which had been eviscerated, appeared from their bill measurements to be two females and a male.

In 1980 and 1981 a fox killed many half-grown murre chicks on growth plots S1 and T. Many of these were decapitated and left on the ledge. At least 50 were killed on plot T and about 80 on plot S1 in 1980. Following that massacre of chicks at plot S1, few adult murres returned to the plot for the rest of the season. In 1981 about 70 were killed on plot T but only small numbers on plot S1. Both of these plots are on broad ledges easily accessible from the cliff-top. In addition, our scent may have drawn the fox's attention to those areas.

Only a small portion of the area occupied by murres is readily accessible to foxes, but these spots must incur heavy losses in years when foxes are present. However, even taking into account the wasted chicks killed and not cached, and the possibility that many adults, chicks, and eggs were cached, the impact of foxes on the colony as a whole is probably small. During banding we did not encounter any areas where chicks had been killed in the fashion seen at plots S1 and T. If we assume that adults are taken at a rate of two per day during the murres' incubation and chick-rearing periods, then this amounts to about 100 murres and to this we can probably add several hundred eggs and chicks. Like the falcon predation, this is negligible in relation to the total number of murres present.

4. Conclusions

Although predation by some predators could only be measured roughly, we have tried to estimate the impact of predation from all sources on the Thick-billed Murres of East Digges Island (Table 22). If we assume a minimum breeding population of 135 000 pairs of murres this means 270 000 individuals, plus a non-breeding population amounting to about 20% of the breeding population (based on Birkhead and Hudson 1977), giving a total population of about 324 000 birds on East Digges Island. Hence, our estimate of adult mortality from all forms of predation amounts to less than 1% of the population.

Table 22
Impact of predation on the population size and reproductive success of Thick-billed Murres at East Digges Island in 1982

	Numbers taken over one breeding season		
Predator	Full-grown murres	Eggs	Chicks
Raven		6 400	[500]
Gull spp.		11 000	8700
Falcons	500		
Red fox	100	[300]	[600]
All natural predators	600	17 700	9800
Inuit	1500*	2 000†	
Totals	2100	19 700	9800

*Asssuming that 75% adult murres shot locally are from Digges Island.
†Assuming that 80% of eggs taken locally came from East Digges Island.

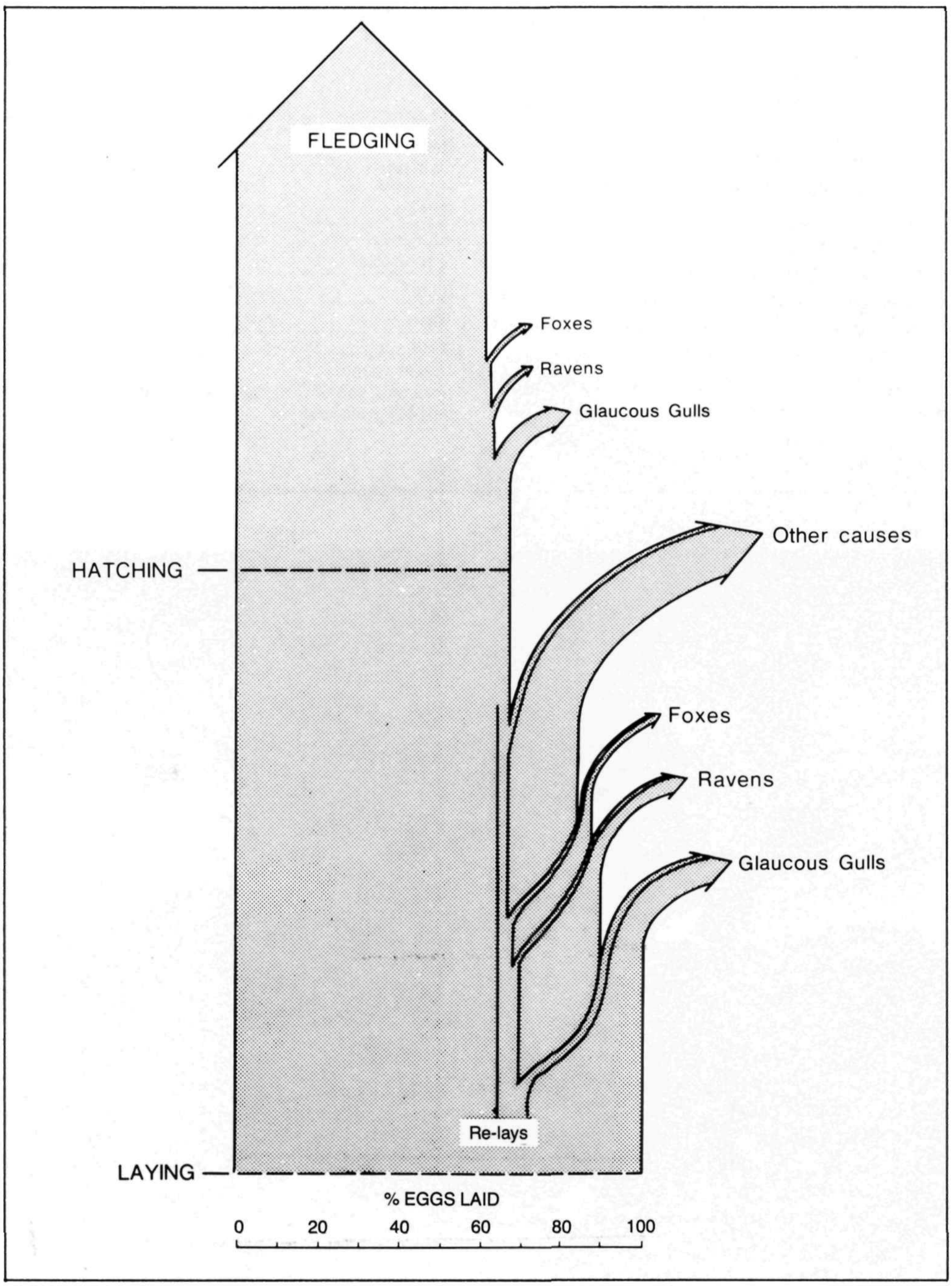
Young Gyrfalcons in the nest, East Digges Island, July 1982

D. Noble

Losses to predators represented 10% of first eggs laid, less than one-third of losses from all causes. Losses of chicks, although only 8% of chicks hatched, were equivalent to the entire losses from all causes at our study plots. Hence, the effect of predation on the reproductive success of the murres is greatest during the chick-rearing period. This may appear surprising, considering that ravens clearly select eggs, but it results from the fact that eggs are much more vulnerable to accidental loss than chicks which can actively cling onto the ledge if displaced by the movements of their parents. Figure 31 summarizes the losses of eggs to all predators except people.

The current level of harvesting by the community at Ivujivik (up to 2000 adults and 2000–3000 eggs) appears well within the limits that the population could sustain. In fact, as most of the eggs taken are replaced, the effect may be smaller than the figures suggest. Provided that harvesting is carried out sensibly, without unnecessary disturbance to the colony, and provided that the population is not subjected to undue mortality on its wintering grounds, there seems to be no reason why such a harvest should not continue indefinitely.

Figure 31
The losses of Thick-billed Murres' eggs to predators (except people) on East Digges Island as a percentage of the breeding population: average of 1980–82



The food web

Transfer of nutrients between land and sea generally proceeds in only one direction. The products of organic processes on land find their way into rivers which carry them eventually to the sea. Transport in the reverse direction is less common, but the activities of breeding seabirds constitute one of the exceptions.

Seabirds introduce organic nutrients into terrestrial ecosystems in several ways:

1. Seabird excreta is deposited on their breeding ledges. After drying out, it is transported inland by strong winds, hence fertilizing the vegetation.
2. Eggs, chicks, and adults eaten or cached by terrestrial predators such as foxes, falcons, and ravens, become incorporated into the terrestrial food web.
3. Food obtained from the sea and brought to the colony, either to feed nestlings, in courtship, or for adult consumption, may be discarded, again being incorporated into the food web of the land.

Our investigations were not sufficiently detailed to allow us to estimate the quantitative effect of these nutrient transfers, but we can describe and summarize the food web surrounding the Thick-billed Murre colony at Digges Island in qualitative terms (Fig. 32).

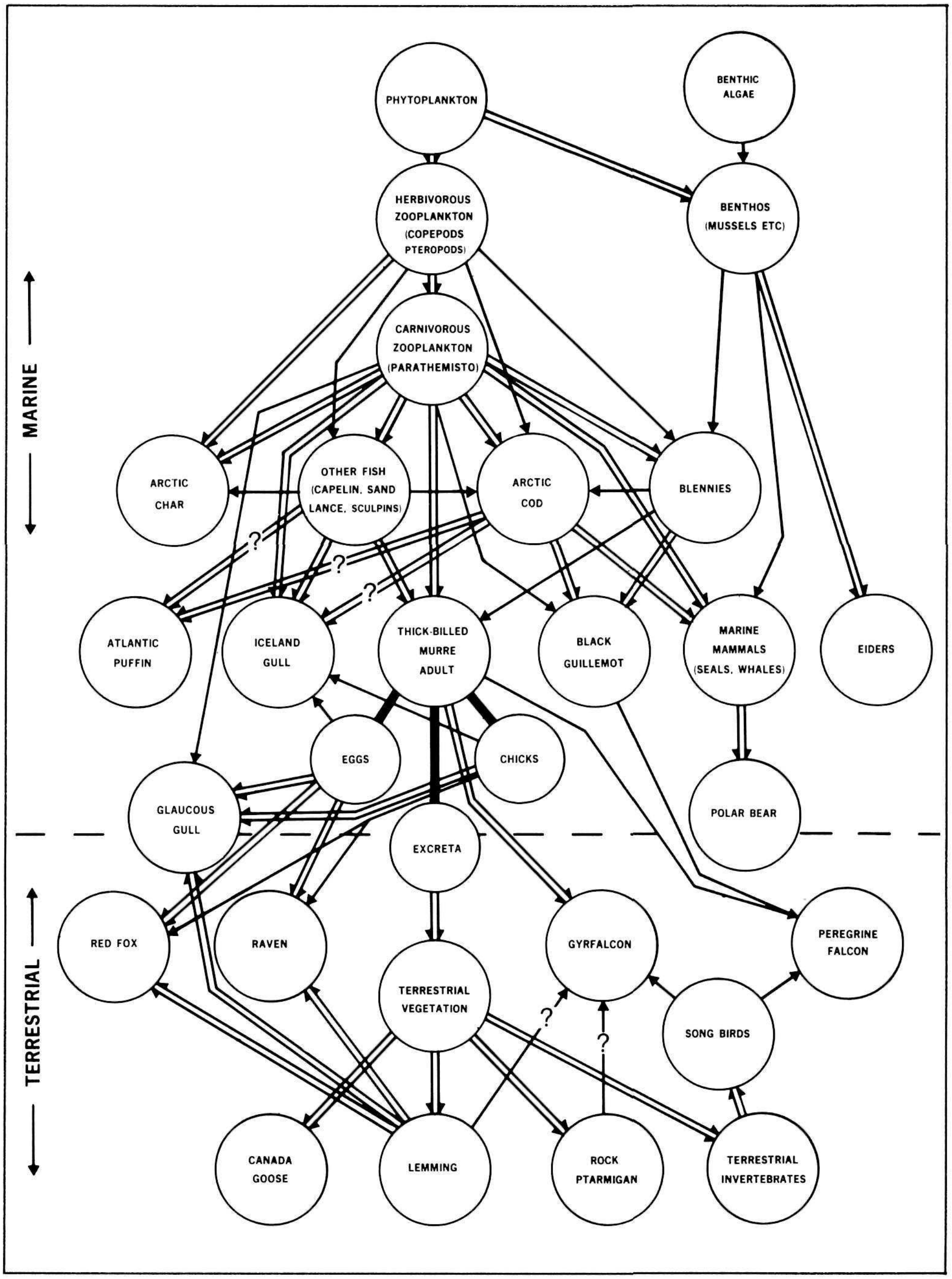
In the marine food chain we can identify six trophic levels:

1. Primary producers: the phytoplankton and large benthic algae.
2. Herbivorous zooplankton: e.g., Copepods, *Limacina*.
3. Carnivorous zooplankton: e.g., *Parathemisto libellula, Sagitta*.
4. Small fish feeding on the larger zooplankton: e.g., arctic cod, capelin, blennies, sandlance.
5. Fish-eating seabirds and marine mammals: e.g., Thick-billed Murre, ringed seal, beluga.
6. Top carnivores: polar bear, Gyrfalcon, Glaucous Gull, and red fox.

The terrestrial food chain is shorter, consisting of only three levels:

1. Primary producers: green plants.
2. Herbivores: e.g., lemmings, geese, and ptarmigan.
3. Carnivores: foxes, ravens, and falcons.

Figure 32
The food web centred on the Thick-billed Murre colony at Digges Sound, showing connections across the marine–terrestrial boundary



An alternative terrestrial chain leads from green plants to terrestrial invertebrate herbivores (Lepidoptera larvae, etc.) to songbirds and perhaps to falcons, although on Digges Island the abundance of murres probably makes songbirds relatively unattractive to falcons and the last link in this food chain may be rarely completed.

The difference in the length of the marine and terrestrial food chains is related to the size of the primary producers. In the sea the organisms comprising the phytoplankton are mainly microscopic so that the herbivores (zooplankton) are also small. These in turn are preyed upon by small carnivores (larger zooplankton and fish), leaving room for two additional layers of top carnivores. On land primary production is mainly carried out by macrophytes which support large herbivores, allowing only a single level of carnivores within the constraints of size in land organisms.

The six-stage marine food chain described above, although normal for marine food chains (Wyatt 1976), is probably not typical of the majority of pathways within the marine food web. Seabirds, for instance, feed partially on the zooplankton community and only a small proportion of seabirds later pass to top carnivores. Many more die in winter far away from Digges Sound and these individuals export nutrients from the marine food web of Digges Sound to that of more southern waters.

The food web at Digges Sound differs from the food webs described by Gaston and Nettleship (1981) and by Bradstreet and Cross (1982) for Lancaster Sound, in the High Arctic, mainly in the greater diversity of fish species and the lower diversity of seabirds and marine mammals. Comparing the fish, arctic cod dominate the food webs in both areas, but other fish such as capelin, sandlance, blennies, and snailfish all form a significant proportion of the diet of seabirds at Digges Sound, unlike the situation in the High Arctic. In contrast, four species of seabirds (Thick-billed Murre, Black Guillemot, Northern Fulmar, and Black-legged Kittiwake) form an important element in the pelagic food web of Lancaster Sound, whereas that of Digges Sound is totally dominated by the Thick-billed Murre with a small number of Black Guillemots and gulls also present.

Among marine mammals, Hudson Strait supports ringed and bearded seals, small numbers of harp seals and beluga, at least for part of the year, and small numbers of bowhead whales. In contrast, Lancaster Sound is visited by much larger numbers of harp seals in summer and the whale community is augmented by large numbers of narwhal.

This anomalous situation, with a greater species diversity at lower trophic levels being associated with a lower diversity at higher trophic levels, seems to contradict normal predictions of species diversity relationships and the pyramid of numbers (Elton 1927, Whittaker 1970, Colinvaux 1973). Whatever the cause, the same situation applies throughout Hudson Strait, with relatively few seabirds other than Thick-billed Murres being seen in the strait except at the extreme eastern end (Gaston 1982*b*).

The aggregation of Thick-billed Murres at Digges Sound and the north colony at Akpatok Island are larger than any of the colonies on Lancaster Sound, where murre foraging areas are also used by substantial numbers of Black-legged Kittiwakes and Northern Fulmars. One possible explanation of the difference in species diversity is that competition with the other seabird species in Lancaster Sound limits the population of Thick-billed Murres, whereas in Hudson Strait the murres are free to completely monopolize the available resources. Although competition from other seabird species may be affecting populations of Thick-billed Murres in Lancaster Sound, it hardly seems likely that the murres exclude their competitors from Hudson Strait. To explain the absence of Northern Fulmars and Black-legged Kittiwakes from Hudson Strait, we may have to resort to historical factors operating at the time when seabirds recolonized the eastern Canadian Arctic following the last glacial period. It is hard to believe that an area such as Digges Sound, supporting more than a quarter of a million Thick-billed Murres, could not support a single pair of Black-legged Kittiwakes, a species associated with all Thick-billed Murre colonies in the High Arctic. We are forced to the conclusion that the current seabird community in Hudson Strait is incomplete and that, given time, we can expect it to diversify. The small numbers of Atlantic Puffins and Razorbills which occur at Digges Sound, and which possibly constitute recent immigrations, may represent such incipient diversification.

Thick-billed Murres over Digges Sound

A. Gaston

Literature cited

Anderson, J.T.; Roff, J.C. 1980. Seston ecology of the surface waters of Hudson Bay. Can. J. Fish. Aquat. Sci. 37:2242–2253.

Anon. 1974. The national atlas of Canada. MacMillan (Canada) and Dep. Energy, Mines and Resour., Ottawa. 254 pp.

Anon. 1979. Sailing directions Labrador and Hudson Bay, 4th Ed. Dep. Supply and Serv. Ottawa. 423 pp.

Anon. 1982. Canadian tide and current tables 1983. Vol. 4. Arctic and Hudson Bay. Dep. Fish. and Oceans, Ottawa.

Asbirk, S. 1979. The adaptive significance of the reproductive pattern in the Black Guillemot, *Cepphus grylle*. Vidensk. Meddr. Dansk. Naturh. Foren. 141:29–80.

Barber, F. 1968. The water and ice of Hudson Bay. Part 1. The water. Pages 287–318 *in* Beals, C.S., ed. Science, history and Hudson Bay. Vol. 1. Dep. Energy, Mines and Resour., Ottawa.

Bergman, G. 1971. Gryllteisten *Cepphus grylle* in einem Randgebiet: Nahrung, Brutresultat, Tagesrhythmus und Ansiedlung. Commentat. Biol. 42:1–26.

Birkhead, T.R.; Hudson, P.J. 1977. Population parameters for the Common Guillemot, *Uria aalge*. Ornis Scand. 8:145–154.

Birkhead, T.R.; Nettleship, D.N. 1980. Census methods for murres, *Uria* spp.: a unified approach. Can. Wildl. Serv. Occas. Pap. No. 43. 25 pp.

Birkhead, T.R.; Nettleship, D. N. 1981. Reproductive biology of Thick-billed Murres (*Uria lomvia*): an inter-colony comparison. Auk 98:258–269.

Bradstreet, M.S.W. 1980. Thick-billed Murres and Black Guillemots in the Barrow Strait area, N.W.T., during spring: diets and food availability along ice edges. Can. J. Zool. 58:2120–2140.

Bradstreet, M.S.W. 1982. Occurrence, habitat use and behaviour of seabirds, marine mammals and arctic cod at the Pond Inlet ice edge. Arctic 35:28–40.

Bradstreet, M.S.W.; Cross, W.E. 1982. Trophic relationships at high arctic ice edges. Arctic 35:1–12.

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

Bursa, A.S. 1961. Phytoplankton of the "Calanus" expedition in Hudson Bay, 1953 and 1954. J. Fish. Res. Board Can. 18:51–83.

Bursa, A.S. 1968. Marine life; marine plants. Pages 343–351 *in* Beals, C. S., ed. Science, history and Hudson Bay. Dep. Energy, Mines and Resour., Ottawa.

Cade, T.J.; Digby, R.D. 1982. The falcons of the world. Cornell Univ. Press, Ithaca, NY. 188 pp.

Cairns, D.K. 1979. Censusing hole-nesting auks by visual counts. Bird-banding 50:358–364.

Cairns, D.K. 1980. Nesting density, habitat structure and human disturbance as factors in Black Guillemot reproduction. Wilson Bull. 92:352–361.

Cairns, D.K. 1981. Breeding, feeding and chick growth of the Black Guillemot (*Cepphus grylle*) in southern Quebec. Can. Field-Nat. 95:312–318.

Colinvaux, P.A. 1973. Introduction to ecology. Wiley Int., NY. 621 pp.

Craig, P.C.; Griffiths, W.B.; Haldorson, L,; McElderry, H. 1982. Ecological studies of Arctic Cod (*Boreogadus saida*) in Beaufort Sea coastal waters. Can. J. Fish. Aquat. Sci. 39:395–406.

Cramp, S.; Simmons, K.E.L. 1983. The Birds of the Western Palaearctic. Vol. 3. Oxford Univ. Press, Oxford.

Dunbar, M.J. 1951. Resources of arctic and sub-arctic seas. Trans. R. Soc. Can., 3rd Ser., Sect. V. 45:61–67.

Dunbar, M.J. 1958. Physical oceanographic results of the "Calanus" expeditions in Ungava Bay, Frobisher Bay, Cumberland Sound, Hudson Strait and northern Hudson Bay. J. Fish. Res. Board Can. 15:155–201.

Dunbar, M.J. 1964. Serial atlas of the marine environment. Folio 6. Euphausiids and pelagic amphipods: distribution in north Atlantic and Arctic waters. Am. Geogr. Soc., NY.

Dunbar, M.J. 1972. The nature and definition of the marine subarctic, with a note on the sea-life area of the Atlantic Salmon. Trans. R. Soc. Can. 4th Ser. 10:249–257.

Dunbar, M.J.; Moore, D.M. 1980. Marine life and its environment in the Canadian eastern arctic: a biogeographic study. Mar. Sci. Cent., McGill Univ. manuscr. Rep. No. 33. 119 pp.

Elton, C.S. 1927. Animal ecology. Sidgewick and Jackson, London. 209 pp.

Fisher, J. 1952. The Fulmar. Collins, London.

Freuchen P.; Salomonsen, F. 1958. The arctic year. Putnam, NY. 438 pp.

Gaston, A.J. 1982*a*. Migration of juvenile Thick-billed Murres through Hudson Strait in 1980. Can. Field-Nat. 96:30–34.

Gaston, A.J. 1982. On the seabirds of northern Hudson Bay. Nat. can. 109:895–903.

Gaston, A.J. (In press). Development of the young. *In* Birkhead, T.R.; Nettleship, D.M., eds. The Atlantic Alcidae. Academic Press, London.

Gaston, A.J.; Chapdelaine, G.; Noble, D.G. 1983*a*. The growth of Thick-billed Murre chicks at colonies in Hudson Strait: inter- and intra-colony variation. Can. J. Zool. 61:2465–2475.

Gaston, A.J.; Malone, M. 1980. Range extension of Atlantic Puffin and Razorbill in Hudson Strait. Can. Field-Nat. 94:328–329.

Gaston, A.J.; Nettleship, D.N. 1981. The Thick-billed Murres of Prince Leopold Island. Can. Wildl. Serv. Monogr. No. 6. 351 pp.

Gaston, A. J.; Noble, D.G.; Purdy, M.A.. 1983*b*. Monitoring breeding biology parameters for murres *Uria* spp.: levels of accuracy and sources of bias. J. Field Ornithol. 54:275–282.

Gaston, A. J.; Smith, G.E.J. 1984. The interpretation of aerial surveys for seabirds: some effects of behaviour. Can. Wildl. Serv. Occas. Pap. No. 53. 29 pp.

Godfrey, W.E. 1966. The birds of Canada. Natl. Mus. Can., Ottawa. 428 pp.

Grainger, E.H. 1968. Invertebrate animals. Pages 351–360 *in* Beals, C.S., ed. Science, history and Hudson Bay. Dep. Energy, Mines and Resour., Ottawa.

Grainger, E.H. 1979. Primary production in Frobisher Bay, Arctic Canada. Pages 9–30 *in* Dunbar, M.J., ed. Marine production mechanisms. Cambridge Univ. Press, Cambridge.

Grainger, E. H. 1982. Factors affecting phytoplankton stocks and primary productivity at the Belcher Islands, Hudson Bay. Nat. Can. 109:787–791.

Hunter, J.G. 1968. Fishes and fisheries. Pages 360–378 *in* Beals, C.S., ed. Science, history and Hudson Bay. Dep. Energy, Mines and Resour., Ottawa.

Huntsman, A.G. 1954. Production of life in Hudson Bay. Pages 25–29 *in* Oceanogr. Sess. Trans. R. Soc. Can. 48.

Larnder, M.M. 1968. The water and ice of Hudson Bay. Part II. The ice. Pages 318–341 *in* Beals, C.S., ed. Science, history and Hudson Bay. Dep. Energy, Mines and Resour., Ottawa.

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

Lowry, L.F.; Burns, J.J. 1980. Foods utilized by bowhead whales near Barter Island, Alaska, autumn 1979. Mar. Fish. Rev. Sept.–Oct:88–91.

Lowry, L.F.; Frost, K.J.; Burns, J.J. 1980. Variability in the diet of Ringed Seals, *Phoca hispida,* in Alaska. Can. J. Fish. Aquat. Sci. 37:2254–2261.

Mansfield, A.W. 1968. Seals and walruses. Pages 378–387 *in* Beals, C.S., ed. Science, history and Hudson Bay. Vol. 1. Dep. Energy, Mines and Resour., Ottawa.

Markham, C.R. 1881. The Voyages of William Baffin. Hakluyt Soc. London.

Maxwell, J.B. 1981. Climatic regions of the Canadian arctic islands. Arctic 34:225–240.

McLaren, I.A. 1958. The biology of the Ringed Seal (*Phoca hispida* Schreber) in the eastern Canadian arctic. Bull. Fish. Res. Board Can. 118. 97 pp.

McLaren, P. 1982. Spring migration and habitat use by seabirds in eastern Lancaster Sound and western Baffin Bay. Arctic 35:80–111.

Mitchell, E.D.; Reeves, R.R. 1982. Factors affecting abundance of bowhead whales *Balaena mysticetus* in the eastern arctic of North America, 1915–1980. Biol. Conserv. 22:59–78.

Morgan, K.R.; Paganelli, C.V.; Rahn, H. 1978. Egg weight loss and nest humidity during incubation in two Alaska gulls. Condor 80:272–275.

Neatby, L.H. 1968. History of Hudson Bay. Pages 69–125 *in* Beals, C.S., ed. Science, history and Hudson Bay. Dep. Energy, Mines and Resour., Ottawa.

Nettleship, D.N.; Gaston, A.J. 1978. Patterns of pelagic distribution of seabirds in western Lancaster Sound and Barrow Strait, Northwest Territories, in August and September 1976. Can. Wildl. Serv. Occas. Pap. No. 39. 40 pp.

Newton, I. 1979. Population ecology of raptors. T. and A.D. Poyser, Berkhamstead, UK. 399 pp.

Petersen, A. 1981. Breeding biology and feeding ecology of Black Guillemots. D. Phil. thesis, Oxford Univ.

Porsild, A.E.; Cody, W.I. 1980. Vascular plants of continental Northwest Territories, Canada. Natl. Mus. Can., Ottawa. 607 pp.

Preston, W.C. 1968. Breeding ecology and social behaviour of the Black Guillemot, *Cepphus grylle*. Ph.D. thesis, Univ. of Michigan. 138 pp.

Prickett, A. 1611. Description of Digges Island. Pages 98–135 *in* Asher, G.M., ed. Henry Hudson the Navigator. The Hakluyt Society, London, 1860.

Ronald, K.; Dougan, K.L. 1982. The ice lover: biology of the Harp Seal (*Phoca groenlandica*). Science 215:928–933.

Salomonsen, F. 1972. Zoogeographical and ecological problems in arctic birds. Proc. Int. Ornithol. Congr. 15:25–77.

Smith, N.G. 1966. Evolution of some arctic gulls (*Larus*): an experimental study of isolating mechanisms. Am. Ornithol. Union, Monogr. No. 4. 99 pp.

Smith, T.G. 1980. Polar bear predation on ringed and bearded seals in the land-fast sea ice habitat. Can. J. Zool. 58:2201–2209.

Smith, T.G. 1981. Notes on the Bearded Seal, *Erignathus barbatus,* in the Canadian arctic. Can. Tech. Rep. Fish. Aquat. Sci. No. 1042. 49 pp.

Spaans, A.L. 1971. On the feeding ecology of the Herring Gull *Larus argentatus* Pont. in the northern part of the Netherlands. Ardea 59:73–81.

Stirling, I.; Archibald, W.R. 1977. Aspects of polar bear predation. J. Fish. Res. Board Can. 34:1126–1129.

Sutton, G.M. 1932. The exploration of Southampton Island, Hudson Bay, Part II, Section 2, The Birds of Southampton Island. Mem. Carnegie Mus. No 12. 275 pp.

Taylor, W.E., Jr. 1960. Archaeological work, Ivujivik and Mansel Island, 1959. Arct. Circle 13:1–4.

Taylor, W.E., Jr. 1962. Pre-dorset occupations at Ivugivik in northwest Ungava. Arct. Inst. of N. Am., Tech. Pap. No. 11:80–91.

Taylor, W.E., Jr. 1968. Eskimos of the north and east shores. Pages 1–26 *in* Beals, C.S., ed. Science, history and Hudson Bay. Dep. Energy, Mines and Resour., Ottawa.

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

Tuck, L.M. 1955. The murre colonies of Digges Sound, Hudson Strait. Can. Wildl. Serv., manuscr. Rep. 16 pp. + 14 plates.

Tuck, L.M. 1961. The Murres. Can. Wildl. Serv., Monogr. No. 1. 260 pp.

Watson, L. 1981. Sea guide to whales of the world. Neilson, Scarborough, Ont. 302 pp.

Whittaker, R.H. 1970. Communities and ecosystems. MacMillan, NY. 162 pp.

Winn, H.E. 1950. The Black Guillemots of Kent Island, Bay of Fundy. Auk 67:477–485.

Wyatt, T. 1976. Food chains in the sea. Pages 341–358 *in* Walsh, J.J., ed. The ecology of the seas. Blackwells, Oxford.

Appendices

Appendix 1
Status and scientific names of birds and mammals recorded at Digges Sound, with notes on species not otherwise covered in the text

Birds

Common Loon, *Gavia immer*
Uncommon, a possible breeder on inland lakes. Breeding plumage adults seen on a lake south of Nuvuk Harbour, 15 August 1980 (4), and at Nuvuk Is., 31 July 1982 (1). Carcasses of adults shot by Inuit were found at Ivujivik, 19 July 1980, and Sugluk, 4 August 1980.

Yellow-billed Loon, *Gavia adamsii*
An adult in breeding plumage was observed flying by E. Digges Is., 9 August 1982 (yellow bill clearly seen). This species may breed in the Melville Pen., the nearest part of its breeding range to Digges Sound (Godfrey 1966).

Arctic Loon, *Gavia arctica*
Uncommon breeder on W. Digges and Nuvuk Is. and probably on the mainland. Adults with young were present at a pond on Nuvuk Is. in August 1981 and 1982 and a young bird, about half the size of the adults, was present on 25 August 1982. Up to six were seen around Nuvuk Is. in July and August 1982. Three adults were displaying on a lake near Digges Harbour, W. Digges Is., 14 July 1982. Few sightings on E. Digges Is.

Red-throated Loon, *Gavia stellata*
Uncommon breeder on small lakes and ponds of the Digges Is. and probably the mainland. A pair at E. Digges Is. were displaying, 13 June, occupying a pond 17 June and had two young there by 26 July 1982. An adult and 2–3-week-old juvenile were on a pond at Port de Laperrière, W. Digges Is., 28 August 1982. Fairly common around Nuvuk Harbour with daily counts of 3–4 throughout July and August 1982.

Northern Fulmar, *Fulmarus glacialis*
Rare visitor. In 1981 a light phase bird was seen on 17 and 20 August swooping near the murre cliffs of E. Digges Is. as if prospecting. Light phase birds were seen in Digges Sound on five dates in August and September 1982.

Canada Goose, *Branta canadensis*

Bar-headed Goose, *Anser indicus*
One shot by Inuit hunters on W. Digges Is. in July 1981 and examined by camp members. The bird was moulting, apparently flightless, and was with a large flock of moulting Canada Geese when killed. This bird, native to Tibet and west China, had presumably escaped from captivity somewhere in North America.

Snow Goose, *Chen caerulescens*
Recorded on passage in June and late August. In 1982 large numbers were seen during 12–18 June and the first autumn migrants appeared on 27 August. Sixty-four per cent of spring migrants in 1982 were blue phase.

Black Duck, *Anas rubripes*
A flock of 105 was seen at Port de Laperrière, W. Digges Is., 28 August 1982. This species has been collected at Cape Dorset, Baffin Is., and Todd (1963) mentions records on the east coast of Hudson Bay as far north as Povungnituk.

Pintail, *Anas acuta*
Small numbers seen in July 1980 and June and July 1982, but no evidence of breeding was found.

Oldsquaw, *Clangula hyemalis*
Frequently seen at Port de Laperrière, W. Digges Is., where a female appeared to have a nest, 17 July 1980. Small numbers were usually present in Ivujivik and Nuvuk Harbours during summer. The highest recorded count was of 50 birds on 26 June 1981, near Nuvuk Is.

Harlequin Duck, *Histrionicus histrionicus*
A male was seen near Gingi Is., 4 km south of Nuvuk Is., 28 June 1982.

Common Eider, *Somateria mollissima*

King Eider, *Somateria spectabilis*

Red-breasted Merganser, *Mergus serrator*
Two nests of this bird were found during searches of Black Guillemot nesting islands. One at Pitsulak City near Nuvuk Is. had three eggs, 24 July 1981. Individuals were often seen in the area of Nuvuk Harbour.

Rough-legged Hawk, *Buteo lagopus*

Golden Eagle, *Aquila chrysaetos*
Three sightings, probably of the same individual, were made of a subadult at E. Digges Is., 19 June, 29 June, and 26 August 1982. This bird has occurred at Sugluk, 150 km to the west of Digges Sound (Todd 1963).

Gyrfalcon, *Falco rusticolus*

Peregrine Falcon, *Falco peregrinus*

Merlin, *Falco columbarius*
One seen at Ivujivik, 1 September 1980.

Rock Ptarmigan, *Lagopus mutus*
Fairly rare on Digges Is.: we saw one all-white male, 21 June 1981; two birds, 29 June 1981; and a female with a half-grown chick, 10 August 1982. Droppings were found on W. Digges Is. and several of the small islands in Digges Sound. Probably much more common on the mainland where several were seen and heard in August 1979 inland of the seabird cliffs.

Sandhill Crane, *Grus canadensis*
One flying northward over E. Digges Is., 15 June 1982.

Sora, *Porzana carolina*
A bird killed by a child in Ivujivik was obtained on 3 July 1980.

Semipalmated Plover, *Charadrius semipalmatus*
A nest with four starred eggs was found at Sugluk, 18 July 1980. Two pairs at W. Digges Is. acted as if nests were nearby, 17 July 1980, as did a bird observed at E. Digges Is., 6 July 1981. Another individual gave distraction displays, 20 July 1982, at E. Digges Is. Frequently seen on the Nuvuk Islands where a pair with two young was seen in July 1981.

Lesser Golden Plover, *Pluvialis dominica*
Observed on 21 August 1979 at Akpa Cove, and one frequented E. Digges Is., 6–14 August 1982.

Ruddy Turnstone, *Arenaria interpres*
Small numbers of migrants were recorded in August, but no evidence of nesting was observed.

Whimbrel, *Numenius phaeopus*
One record of two individuals at Nuvuk Is., 16 July 1981.

Purple Sandpiper, *Calidris maritima*
An adult with two young was observed on an island south of W. Digges Is., 18 July 1980. Small numbers of this species were often observed on the islets between the Digges Is. and the mainland.

White-rumped Sandpiper, *Calidris fuscicollis*
A common migrant in August with a maximum of 100 being recorded at Port de Laperrière on 28 August 1982.

Semipalmated Sandpiper, *Calidris pusilla*
A nest was found on 18 July 1980 at Port de Laperrière, W. Digges Is. Small numbers were present throughout the summer around Nuvuk Harbour. The highest count was of 50 near Nuvuk Is. on 30 August 1982.

Red Phalarope, *Phalaropus fulicaria*
Most birds of this species seen at Digges Sound were migrating in June (100s on 12–13 June 1982) with almost no July sightings and just a few sightings of individuals in winter plumage in August.

Pomarine Jaeger, *Stercorarius pomarinus*
Singles seen in Digges Sound on 29 August 1980, 23–24 June, 4 July, and 5 August 1982.

Parasitic Jaeger, *Stercorarius parasiticus*

Long-tailed Jaeger, *Stercorarius longicaudus*
This species was present at sea in fair numbers in all years. They appeared to be the most common in August 1982 with 22 in view from Pitsulak City (west of Nuvuk Is.) on 1 August 1982 during onshore winds. According to Inuit nests locally on inland tundra.

Glaucous Gull, *Larus hyperboreus*
Iceland (Kumlien's) Gull, *Larus glaucoides kumlieni*

Iceland (Thayer's) Gull, *Larus glaucoides thayeri*
Several Thayer's phenotype gulls in adult summer plumage frequented the murre cliffs of E. Digges Is., 1980–82. One was paired with an adult Kumlien's Gull at a nest at E. Digges Is., 26 July 1980. A first summer individual was observed, 14 July 1982 at Cape Digges, E. Digges Is.

Great Black-backed Gull, *Larus marinus*
A first summer bird was observed at Port de Laperrière, W. Digges Is., 28 August 1982.

Lesser Black-backed Gull, *Larus fuscus*
Two sightings of a bird in first summer plumage, perhaps the same individual, were made on 26 June and 22 August 1982, at E. Digges Is.

Herring Gull, *Larus argentatus*

Sabine's Gull, *Xema sabini*
The only records were in 1982 when four adults were seen flying near Pitsulak City (off Nuvuk Is.) on 14 June, and an immature alighted briefly on the same island on 29 August.

Arctic Tern, *Sterna paradisaea*

Razorbill, *Alca torda*

Thick-billed Murre, *Uria lomvia*

Dovekie, *Alle alle*
Two records in Digges Sound, both of birds in summer plumage: 8 July 1981, 14 July 1982.

Black Guillemot, *Cepphus grylle*

Atlantic Puffin, *Fratercula arctica*

Snowy Owl, *Nyctea scandiaca*
One record on 12 June 1982, near Pitsulak City.

Black Swift, *Cypseloides niger*
One individual was observed for 30 minutes and photographed at E. Digges Is., 9 August 1980. This record of the Black Swift is remarkable because, apart from a record in Illinois, there are no others for northeastern North America.

Chimney Swift, *Chaetura pelagica*
One seen on 24–25 August 1980.

Eastern Kingbird, *Tyrannus tyrannus*
One in immature plumage (dusky throat) observed in a boggy area on E. Digges Is. on 29 June 1982.

Horned Lark, *Eremophila alpestris*
Although seen in much smaller numbers than the other two common passerines, Snow Bunting and Water Pipit, we found evidence of breeding in several localities. Adults with young were seen at Sugluk, 1 August 1980, and on E. Digges Is., 10 August 1982. A nest with four very small young was found at Port de Laperrière, W. Digges Is., 11 July 1980. This species is most often found in areas of dry tundra.

Tree Swallow, *Tachycineta bicolor*
One adult bird at E. Digges Is. on 18 July 1981.

Barn Swallow, *Hirundo rustica*
A bird was present at E. Digges Is. on 19 July 1980, and another during 18–27 July 1981. In 1982 individuals were seen at E. Digges Is. on 22 June and in Ivujivik on 4 August.

Northern Raven, *Corvus corax*

Northern Wheatear, *Oenanthe oenanthe*
A pair with young was seen, 1 August 1981, in a valley southeast of Ivujivik. One individual was observed at E. Digges Is. on 27 June 1981.

Water Pipit, *Anthus spinoletta*

Yellow-rumped (Myrtle) Warbler, *Dendroica coronata*
An adult female was observed on 22–23 June 1982, above the murre cliffs at E. Digges Is.

Common Redpoll, *Carduelis flammea*
Seen at Sugluk, 1 August 1980, and at E. Digges Is., 16 and 21 June 1982.

Pine Siskin, *Carduelis pinus*
One bird was seen at E. Digges Is. on 30 August 1980.

Savannah Sparrow, *Passerculus sandwichensis*
Although breeding was confirmed for Sugluk, where adults with young were seen, 1 August 1980, this species appears to be a non-breeding visitor to the Digges Sound region. Two individuals were observed at E. Digges Is., 23–24 August 1982.

Dark-eyed Junco, *Junco hyemalis*
As with the White-crowned Sparrow, most records of this species were at E. Digges Is. where several singing males were present in June and July of 1980, 1981, and 1982. No evidence of breeding was seen.

White-crowned Sparrow, *Zonotrichia leucophrys*
Most sightings were of singing males at E. Digges Is. In 1982, three to four males sang through June and July on the rocky tundra of E. Digges Is. Several individuals in juvenile plumage appeared, during 16–25 August. Because no nests or adults feeding young were found, breeding is not confirmed, but the presence of the juveniles does suggest breeding nearby. A singing male was observed at Sugluk, 4 August 1980.

Lapland Longspur, *Calcarius lapponicus*
A nest of this species with four eggs was found at Sugluk on 1 July 1980, and another at Ice Harbour on 4 July 1980. Although common in early June and again in late August at E. Digges Is., this species was not found to summer or nest there.

Snow Bunting, *Plectrophenax nivalis*

Mammals

Arctic hare, *Lepus arcticus*

Labrador collared lemming, *Dicrostonyx hudsonius*

Arctic fox, *Alopex lagopus*

Red fox, *Vulpes vulpes*

Polar bear, *Ursus maritimus*

Ermine, *Mustela erminea*
Several sightings in 1983, when predation by ermines was believed to have caused desertion of a number of Black Guillemot nests (Cairns, in prep.).

Walrus, *Odobenus rosmarus*
Not recorded at Digges Sound but several hundred observed off the west coast of Nottingham Is. on aerial surveys in September 1980.

Ringed seal, *Phoca hispida*

Harp seal, *Phoca groenlandica*

Bearded seal, *Erignathus barbatus*

Caribou, *Rangifer tarandus*

Beluga, *Delphinapterus leucas*

Narwhal, *Monodon monoceros*

Bowhead whale, *Balaena mysticetus*

Appendix 2
Vascular plants collected in the Digges Sound region during 1980–82. All identifications provided by J.M. Gillette of the National Museums of Canada except those marked (*) which were supplied by D.E. Swales of MacDonald College, Montreal

Polypodiaceae
Cystopteris fragilis
*Woodsia glabella**

Equisetaceae
Equisetum arvense

Lycopodiaceae
Lycopodium selago

Graminae
*Agropyron latiglume**
Alopecurus alpinus
Arctagrostis latifolia
Calamagrostis canadensis
Dupontia Fischeri
Elymus arenarius
Hierochlöe alpina
H. odorata
Poa alpina
P. arctica
Trisetum spicatum

Cyperaceae
*Carex Bigelowii**
C. membranacea
C. misandra
C. norvegica
C. Saxatilis
C. scirpoidea
C. stans
Eriophorum augustifolium
*E. callitrix**
*E. Scheuchzeri**

Juncaceae
Juncus castaneus
Luzula confusa
*L. nivalis**
L. Wahlenbergii
L. spadicea

Salicaceae
Salix arctica
S. arctophila
S. cordifolia
S. herbacea
S. reticulata

Polygonaceae
Oxyria digyna
Polygonum viviparum

Caryophyllaceae
Cerastium alpinum
C. cerastioides
Melandrium affine
M. apetalum
Minuartia biflora
M. rubella
Silene acaulis
S. uralensis
S. involucrata
Stellaria humifusa (Dome Is.)
S. longipes

Ranunculaceae
*Anemone parviflora**
*Ranunculus lapponicus**
R. nivalis
R. pedatifidus
R. pygmaeus
R. sulphureus

Papaveraceae
Papaver radicatum

Cruciferae
Arabis alpina
Cardamine pratensis
Cochlearia officinalis
Draba alpina
D. cinera Only record from Northern Ungava Pen.
D. glabella
D. lactea
D. nivalis
D. oblongata Only Quebec record
Eutrema Edwardsii

Saxifragaceae
Chrysosplenium tetrandrum
Saxifraga aizoides
S. caespitosa
S. cernua
S. foliolosa
S. hirculus
S. nivalis
S. oppositifolia
S. rivularis
S. tenuis
S. tricuspidata

Rosaceae
Dryas integrifolia
Potentilla hyparctica
P. palustris (Nuvuk Harbour)
Rubus chamaemorus

Leguminosae
Astragalus alpinus
Oxytropis Maydelliana

Empetraceae
Empetrum nigrum

Onagraceae
Epilobium angustifolium (Nuvuk Harbour)
E. latifolium

Haloragaceae
Hippuris vulgaris

Pyrolaceae
Pyrola grandiflora

Ericaceae
Arctostaphylos alpina
Cassiope tetragona (Ivujivik)
Ledum decumbens
Vaccinium uliginosum
V. vitis-idaea

Plumbaginaceae
Armeria maritima

Boraginaceae
Mertensia maritima (Nuvuk Island)

Scrophulariaceae
Euphrasia arctica
Pedicularis capitata (Only Quebec record)
P. flammea
P. hirsuta
P. lanata
*P. lapponica**

Campanulaceae
Campanula uniflora

Compositae
Antennaria angustata
A. canescens
Arnica alpina
*Chrysanthemum arcticum** (Nuvuk Harbour)
Erigeron humilis
Matricaria ambigua (W. Digges Is., Nuvuk Is.)
Taraxacum lacerum
T. lapponicum

109 species

Appendix 3
Conversion factors (K-ratios) used to convert counts of gulls at their breeding colonies to numbers of breeding pairs. Counts were carried out at colony S2 on Digges Island between 11:00 and 17:00 EST on 27 days between 27 June and 31 August 1982. Twenty-one pairs of Glaucous Gulls were believed to have laid on the colony and another three sites were attended by pairs which apparently did not attempt to lay eggs. To calculate conversion factors we have lumped daily counts by half-monthly periods

Date	Mean count	SD	*N* (counts)	95% confidence limits	*K* (pairs/count)	95% confidence limits
27–30 June	30.25	3.30	4	21.06–39.43	0.69	0.53–1.00
1–15 July	30.75	4.74	8	19.79–41.71	0.68	0.50–1.06
16–31 July	28.50	3.87	4	17.73–39.27	0.74	0.53–1.18
1–15 August	26.20	3.70	5	16.69–35.71	0.80	0.59–1.26
16–31 August	18.33	3.72	6	9.21–27.45	1.15	0.76–2.28

Appendix 4
Comparison of photo and ground counts for murres at East Digges Island. *A* and *B* are the number of breeding pairs derived from photo and ground counts, respectively. *K* is the proportion of breeding pairs to birds present

Plot	Photo count	Date	*K*	Est. (*A*)	Ground count	d Date	*K*	Est. (*B*)	*B*/*A*
R	114	3 July 1982	0.68	78	162*	—	0.68	110*	1.41
R	68	30 July 1980	0.72	49	153*	—	0.72	110*	2.25
S1	86	3 July 1982	0.68	58	147*	—	0.68	100*	1.71
S1	44	30 July 1980	0.72	32	139*	—	0.72	100*	3.16
F1	32	30 July 1980	0.72	23	164	30 July 1980†	0.72	118	5.13‡
DC 1–3	343	30 July 1980	0.72	247	723	15 July 1982	0.84	607	2.46
BC 1	23	30 July 1980	0.72	17	315	12 July 1982	0.68	214	12.60‡
BC 4	20	30 July 1980	0.72	14	93	17 July 1982	0.87	81	5.78‡
B	41	30 July 1980	0.72	30	111	30 July 1980†	0.72	80	2.67
D	22	30 July 1980	0.72	16	84	30 July 1980†	0.72	60	3.75
E	93	30 July 1980	0.72	67	157	30 July 1980†	0.72	113	1.69
G	56	30 July 1980	0.72	40	95	30 July 1980†	0.72	68	1.71
H	38	30 July 1980	0.72	27	127	30 July 1980†	0.72	91	3.37
A1, A2	77	30 July 1980	0.72	55	224	30 July 1980†	0.72	161	2.93
HC 1–3	208	30 July 1980	0.72	150	632	19 July 1982	0.62	392	2.61
DC 4,7,8	308	30 July 1980	0.72	274	930	16 July 1982	0.73	678	2.48
DC 10	72	30 July 1980	0.72	52	138	19 July 1982	0.62	86	1.65

*Breeding pairs derived from egg counts; ground count estimated from *K*-ratio.
†Count simultaneous with photo.
‡Excluded from photo count – ground count comparison because areas were poorly lit or out of focus on the photograph.

Appendix 5
Variation in hourly counts, conversion factors (*K*-ratio) for estimating breeding populations, and estimated errors of population estimates for Black Guillemots at Pitsulak City. Based on total (land + water) counts made at F Cove between 25 June and 22 August 1982. Counts made during darkness and when cove was filled with ice are not included

	Birds in attendance					*K*-	Estimated % error§			
Time	$\bar{x}$	SD	CV	n_c*	n_d†	ratio‡	$N_d=1$	$N_d=2$	$N_d=5$	$N_d=10$
24:00–02:00	101.2	70.1	0.69	6	2	0.87	298	211	133	94
03:00–05:00	88.2	62.2	0.70	9	4	1.00	196	138	88	62
06:00–08:00	103.7	40.1	0.39	19	7	0.85	91	65	41	29
09:00–11:00	75.1	54.3	0.72	17	9	1.17	161	114	72	51
12:00–14:00	20.8	26.3	1.27	17	7	4.23	299	211	134	95
15:00–17:00	13.4	11.2	0.84	19	8	6.57	193	136	86	61
18:00–20:00	57.9	39.7	0.69	20	10	1.52	153	108	68	48
21:00–23:00	103.0	43.4	0.42	15	8	0.85	97	69	43	31

*n_c = number of counts.
†n_d = number of days on which counts were made.
‡K = number of breeding pairs divided by the mean of the counts based on 88 pairs breeding in the area.
§Estimated % error (95% confidence limits) = $[(\text{SD}/N_d) / \bar{x}] \times t_{0.05(n_d)}$, where N_d = number of days on which counts will be made (after Lloyd 1975).

Appendix 6
Counts of Glaucous and Iceland Gulls on or near the Digges Island murre colony in 1982. Two counts were made on each date, at 14:00 and 14:30 EST

	Viewing point*				Loafing areas		
Date	D	V	W	U	Long L.	Delta L.	Totals
19 June	14,11	33,31	17,20	23,29	0,0	4,0	91,91
2 July	18,18	37,34	23,26	57,47	41,46	1,0	175,171
12 July	16,27	39,35	27,27	38,50	56,38	15,14	191,191
23 July	16,17	38,40	28,37	31,40	58,30	0,0	161,164
2 August	26,28	37,36	26,28	56,54	13,17	1,0	159,163
10 August	8,8	27,32	36,36	41,46	55,42	1,0	158,164
23 August	14,18	21,26	41,45	18	78,43	0,0	172,150

*Locations of viewing points are shown in Figure 7.

Appendix 7
Dimensions of eggs measured at Digges Sound

	Length, mm		Breadth, mm		
Species	$\bar{x}$	SD	$\bar{x}$	SD	N
Glaucous Gull	75.47	2.28	52.21	1.60	39
Iceland Gull	67.27	2.58	47.88	1.77	103
Black Guillemot	58.45	2.01	39.63	1.11	229

Appendix 8
Rates of feeding of Glaucous Gull broods and chicks at colony S2, East Digges Island in 1982

Date	Duration, h $(\Sigma t)^1$	Total feeds, (F)	Duration × broods $\Sigma(t \times N_b)$	Duration × chicks $\Sigma(t \times N_c)$	Daylight, h (D)	Feeds. brood^{-1}.day^{-1} $FD/\Sigma(tN_b)$	Feeds. chick^{-1}.day^{-1} $FD/\Sigma(tN_c)$
7–15 July	12.5	47	160.5	331	21	6.15	2.85
16–31 July	13.5	75	155.0	288.5	20	9.68	4.58
1–15 August	11.0	41	118.0	213	18	6.25	2.79
16–20 August	6.0	24	51.0	91	17	8.01	3.36

(cont'd next page)

Appendix 9(*a*)
Growth data for Thick-billed Murre chicks on plot R, Digges Island: weight in relation to age

Age, days	1980 $\bar{x}$, g	1980 SD	1980 N	1981 $\bar{x}$, g	1981 SD	1981 N	1982 $\bar{x}$, g	1982 SD	1982 N
1	74.77	5.93	13	71.50	7.33	4	68.50	0.71	2
2	79.74	8.70	42	74.87	7.49	39	79.53	9.11	55
3	86.00	9.87	14	87.73	10.44	11	92.56	9.92	32
4	92.13	13.51	46	94.37	11.43	16	103.00	2.83	2
5	99.12	19.80	17	98.85	16.91	27	100.97	15.28	39
6	106.72	16.78	46	107.92	16.53	12	120.00	12.08	41
7	113.80	16.33	15	111.59	14.05	22	121.33	15.76	6
8	118.74	16.80	46	115.20	19.60	25	121.93	25.28	31
9	124.27	20.88	22	127.33	22.01	6	144.67	15.01	39
10	127.65	18.25	46	123.25	16.68	32	132.20	13.77	10
11	137.90	22.06	10	127.20	10.59	15	128.80	21.89	20
12	136.70	20.18	46	138.60	15.41	10	154.53	16.24	36
13	139.60	28.95	15	129.30	20.84	27	149.72	13.96	18
14	143.13	23.48	46	131.54	14.09	13	136.50	30.45	8
15	139.81	19.01	16	149.22	22.16	9	163.45	18.37	20
16	146.52	25.59	42	136.97	23.13	29	155.90	19.95	31
17	157.80	28.05	10	137.87	15.59	8	163.85	17.72	20
18	152.15	24.02	39	145.92	15.84	13	167.50	26.67	4
19	159.12	28.46	16	150.05	17.79	20	152.04	20.46	27
20	154.45	22.51	29	144.06	14.55	16	172.00	20.42	30
21	152.12	16.98	8	144.75	8.28	12	152.60	10.78	5
22	154.89	27.43	19	142.91	12.27	11	158.26	18.73	19
23	163.33	25.95	6	148.73	14.76	15	167.85	17.22	13
24	140.50	11.09	4	145.21	17.06	15	163.50	2.12	2

Appendix 9(*b*)
Growth data for Thick-billed Murre chicks on plot R, Digges Island: wing length in relation to age

Age, days	1980 $\bar{x}$, mm	1980 SD	1980 N	1981 $\bar{x}$, mm	1981 SD	1981 N	1982 $\bar{x}$, mm	1982 SD	1982 N
1	25.81	1.11	16	24.75	0.96	4	24.50	0.71	2
2	26.45	1.00	33	26.20	0.86	39	25.27	1.22	55
3	28.33	1.37	18	27.64	1.03	11	28.18	0.92	33
4	28.86	1.21	22	29.25	1.24	16	28.50	0.71	2
5	30.79	1.55	19	29.71	1.67	28	28.69	1.49	39
6	32.07	3.10	27	30.09	2.21	11	31.36	1.53	39
7	33.24	2.31	17	31.96	1.77	23	32.17	1.83	6
8	35.43	4.55	14	32.87	2.59	24	32.32	2.69	31
9	38.00	4.72	22	36.17	5.95	6	35.82	2.81	40
10	39.31	4.29	13	36.03	3.79	31	36.50	4.53	10
11	42.30	5.25	10	36.27	4.68	15	37.38	4.53	21
12	46.21	7.26	14	41.90	3.11	10	43.47	4.33	36
13	51.40	4.90	15	42.54	4.93	26	43.22	5.26	18
14	53.17	5.91	12	43.77	6.04	13	47.25	8.21	8
15	53.56	6.21	16	50.89	4.46	9	50.84	4.30	19
16	58.00	6.18	15	50.28	5.54	29	51.31	6.04	32
17	62.64	5.28	11	49.75	9.32	8	58.20	3.85	20
18	63.45	6.17	11	55.46	4.41	13	57.25	5.31	4
19	66.87	6.75	16	58.95	7.47	21	58.11	7.19	27
20	69.33	5.41	9	61.00	3.78	15	65.87	4.99	30
21	65.50	5.53	8	60.83	4.61	12	62.20	5.93	5
22	72.30	6.45	10	62.00	6.53	11	63.10	5.80	19
23	77.83	5.56	6	68.87	4.39	16	69.92	4.01	13
24	68.00	7.00	3	68.93	4.87	14	69.00	2.83	2

Appendix 10
Comparison of Thick-billed Murre chick growth at Digges Island and Prince Leopold Island

	Digges Island (plot R)									Prince Leopold Island (plot S)*								
	1980			1981			1982			1975			1976			1977		
	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N	$\bar{x}$	SD	N
Weight at 2 days, g	78.9	8.3	38	75.4	7.6	43	79.5	8.9	57	72.1	5.7	17	75.3	7.6	27	70.8	9.0	25
Weight at 14 days, g	143.2	23.7	46	134.0	19.2	53	153.1	18.9	55	182.4	23.7	27	174.5	20.7	28	199.6	28.9	25
Wing length at 14 days, mm	52.6	5.5	46	45.1	5.0	53	47.3	5.2	75	55.1	6.0	27	52.9	4.8	28	56.1	5.7	22
Weight at fledging, g	156.9	23.0	44	148.4	16.3	53	161.8	23.7	75	195.7	16.9	27	209.0	21.8	28	215.8	26.3	25
Maximum weight, g	161.8	24.5	44	152.6	19.6	53	167.9	22.2	75	199.1	20.6	27	211.6	18.8	28	221.5	28.0	25
Wing length at fledging, mm	69.8	10.0	44	68.0	8.3	53	64.3	8.5	75	70.8	7.9	24	73.9	5.7	22	71.6	7.1	19
Age at fledging, days	21.9	3.0	44	24.6	3.0	53	21.9	3.0	75	20.5	3.0	27	22.6	2.3	28	19.2	2.7	25

*Data from Gaston and Nettleship (1981).

Appendix 11
Site occupancy in relation to laying and breeding success between the median date of laying and the start of fledging in 1980 and 1981

	Percentage of days on which site was occupied					
	≦50	51–60	61–70	71–80	81–90	>90
1980						
Egg hatched					2	198
Egg lost before date of first fledging	1	1	4	9	20	68
No egg recorded	33	9	14	15	13	6
Totals	34	10	18	24	35	272
1981						
Egg hatched					17	274
Egg lost before date of first hatching	4	3	10	12	31	56
No egg recorded	57	12	16	8	6	10
Totals	61	15	26	20	54	340

Use of 80% occupancy as a criterion for laying would, in 1980, have included 19 sites where no eggs were known to have been laid and excluded 15 where eggs were laid (error rate 34/393 = 8.7%). Corresponding figures for 1981 were 16 and 29 (error rate 45/516 = 8.7%).

Appendix 12
Calculations of total wet weight of food represented by remains in murre stomachs, 1980 and 1981

Organism	Mean length, mm	Mean weight, g A	Number, % B	A × B	Proportion by weight, %
1980					
Arctic cod	120	10.60	1.5	15.9	22.1
Sandlance	75	1.13	10.6	12.0	16.7
Capelin	100	4.00	1.2	4.8	6.7
Snailfish	?	5.00	0.2	1.0	1.4
Fish doctor	180	13.00	1.1	14.3	19.9
Sculpins	100	7.00	1.1	7.7	10.7
Other	?	[1.00]*	5.2	5.2	7.2
Parathemisto	28	0.17	21.3	3.6	5.0
Mysids	25	0.07	53.6	3.7	5.1
Ischyrocerus	[20]	[0.10]	1.0	0.1	0.1
Squid	[60]	3.00	0.9	2.7	3.7
Annelids	50	[0.50]	1.4	0.7	1.0
1981					
Arctic cod	95	6.30	15.1	143.4	64.0
Sandlance	?	[1.00]	11.1	11.1	5.0
Capelin	100	4.00	0.7	2.8	1.2
Sea snails	?	[5.00]	5.5	27.5	12.3
Fish doctor	180	13.00	0.2	2.6	1.2
Sculpins	100	7.00	2.9	20.3	9.1
Other		[1.00]	3.6	3.6	1.6
Parathemisto	28	0.17	37.9	6.4	2.9
Mysids	25	0.07	14.9	1.0	0.5
Ischyrocerus	—	[0.10]	0.3	—	0
Squid	—	[3.00]	0.7	2.1	0.9
Annelids	—	[0.50]	6.3	3.1	1.4

*Estimates in brackets were based on other similar organisms of the same size, or on rough estimates based on measurements outside the range of our reference material.

(cont'd next page)

Appendix 13

Method used in estimating the availability of Thick-billed Murre eggs and chicks at East Digges Island in 1982 and tabulated estimates

Our method of estimating the timing of laying was based on the density of 425 eggs weighed and measured between 24 June and 27 July, using the regression of egg density on time from laying derived previously (Gaston *et al.* 1983*b*). Egg losses were estimated at 30% based on observations made in 1980 and 1981 and were assumed to occur randomly with respect to date of laying and time since laying, giving a rate of 1.1% day^{-1}. The incubation period was assumed to be 32 days (Gaston and Nettleship 1983).

We assumed that the first 16.7% of eggs lost were replaced, based on observations for 1980–81, and that the interval between loss and relaying was 14 days (Gaston and Nettleship 1983). We estimated total first eggs laid as the difference between the total eggs laid and the estimated number of replacement eggs.

We estimated chick mortality prior to fledging at 6%, based on figures for 1980 and 1981, and assumed that it occurred randomly in relation to age and date of hatching. Mean age at fledging was 21 days, hence we estimated rate of loss as 0.5%·day^{-1}. We observed and recorded the proportion of chicks fledging in relation to date.

Numbers of eggs and chicks present at a given date (Table 1) were estimated by iterative calculations:

$$E_{i+1} = 0.989\ (L_{i+1} + E_i)$$

where E_i is the number of eggs present on day "i", L_{i+1} is the number of eggs laid the next day, and E_{i+1} is the number of eggs present on day i + 1. After the start of hatching

$$E_{i+1} = 0.989\ (E_i - H_{i+1})$$

where H_{i+1} is the number of eggs hatching on the next day.

Similarly, $C_{i+1} = 0.995\ (H_{i+1} + C_i)$

and $C_{i+1} = 0.995\ (C_i - F_{i+1} + H_{i+1})$

where F_{i+1} is the number of chicks fledging the next day.

Table 1

Thick-billed Murre eggs and chicks present at East Digges Island in 1982. The total first eggs was 387, the total of chicks hatched was 252

	Eggs					Chicks	
Period	First laid	Lost	Relaid	Present (*E*)	Hatched	Fledged	Total
20 June	43	1.10		41.90			
21–22 June	33	1.95		72.95			
23–24	58	3.40		127.55			
25–26	70	5.15		192.40			
27–28	43	6.11		229.29			
29–30	32	6.78		254.51			
1–2 July	18	7.07		265.44			
3–4	6.90	7.10	1.10	267.44			
5–6	9.05	7.20	1.95	273.19			
7–8	9.60	7.36	3.40	282.23			
9–10	13.85	7.64	5.15	298.74			
11–12	18.89	7.77	6.11	315.97			
13–14	11.22	8.21	6.78	325.76			
15–16	10.93	8.47	7.07	335.29			
17–18	6.65	8.72	2.35	335.57			
19–20	3.00	8.72		329.85			
21–22		8.59		321.26			
23–24		8.35		284.96	27.95		27.81
25–26		7.20		256.31	21.45		49.01
27–28		6.66		211.95	37.70		86.28
29–30		5.01		161.44	45.50		131.12
31–1 August		4.20		129.29	27.95		158.27
2–3		3.36		105.13	20.80		178.18
4–5		2.73		90.70	11.70		188.93
6–7		2.36		83.14	5.20		193.16
8–9		2.16		73.83	7.15		199.31
10–11		1.92		63.46	8.45		206.72
12–13		1.65		49.46	12.35		217.97
14–15		1.29		36.47	11.70		227.49
16–17		0.95		23.82	11.70		236.92
18–19		0.62		17.35	5.85		240.40
20–21		0.45		14	3	59.98	181.06
22–23		0.36		11	3	33.77	148.44
24–25				8	3	12.35	137.61
26–27				5	3	15.37	123.86
28–29				2	3	50.65	74.97
30–31				0	2	15.37	60.85

Appendix 14
Calculation of the probability of ravens preying on Thick-billed Murre eggs according to date laid

Input parameters
1. Eggs present, estimated by 2-day periods (*E*, from App. 13)
2. Number of hours watching (*H*) from each watch point (Table 1)
3. Number of breeding pairs (*N*) visible from each watch point (Table 1)
4. Number of eggs seen being taken (*R*) by ravens (Table 1)
5. Length of the daily activity period (*A*) for ravens (Table 1)

Table 1
Observations of ravens preying on murre eggs.
Figure 7 shows the locations of watch points D, V, and W

Dates	Hours watching (*H*) from each watch point			Breeding pairs (*N*) visible from each watch point			Eggs taken (*R*)	Activity period (*A*)
	D	V	W	D	V	W		
27–30 June	9	6	6	12 000	29 120	16 480	33	16
1–10 July	6	6	6	12 000	29 120	16 480	28	16
11–20 July	12	12	12	12 000	29 120	16 480	23	16
21 July–4 August	9	12	9	12 000	29 120	16 480	20	15
5–19 August	9	9	12	12 000	29 120	16 480	8	14
20–29 August	6	6	6	12 000	29 120	16 480	5	13

The probability of an egg being taken in any 2-day period (P_2) was then calculated from the following formula:

$$P_2 = \frac{774\,R.A}{E[(H_d N_d) + (H_v N_v) + (H_w N_w)]} \quad (1)$$

Hence, the probability of an egg being taken during the normal 32-day incubation period (P_{32}) can be estimated by summing the values of P_2 over the period concerned, starting with the date of laying as follows:

$$P_{32} = \sum_{i=1}^{16} P_2 \quad (2)$$

Appendix 15
Estimates of numbers of Thick-billed Murres' eggs and chicks fed to the chicks of Glaucous Gulls at plot S2

Period	Days (*D*)	Day-length (*L*)	Active nests (*N*)	Observation time, h (*T*)	Watch intensity ($W = \Sigma N t_i$)*	Fed to chicks: Eggs (*e*)	Fed to chicks: Chicks (*c*)	Feeding rate (Nest $^{-1}$h^{-1})†: Eggs (r_e)	Feeding rate: Chicks(r_c)	Total delivered‡: Eggs(D_e)	Total delivered‡: Chicks(D_c)
1–15 July	15	20	13	12.5	160.5	11	0	0.068	0	265	0
16–31 July	16	19	12	12.5	155.0	27	3	0.174	0.019	635	69
1–15 August	15	18	11	11.0	118.0	0	25	0	0.212	0	630
16–20 August	5	17	8	6.0	51.0	1	14	0.020	0.275	14	187

t_i = Observation time on day i ($T = \Sigma t_i$).
$r_e = e/W$; $r_c = c/W$.
$D_e = r_e DLN$; $Dc = r_c DLN$.

Other Publications in the Report Series

No. 1
Whooping Crane population dynamics on the nesting grounds, Wood Buffalo National Park, Northwest Territories, Canada by N.S. Novakowski
Cat. No. R65-8/1, Price 50¢, Publ. 1966.
No. 2
Bionomics of the Sandhill Crane by W.J.D. Stephen
Cat. No. R65-8/2, Price 75¢. Publ. 1967.
No. 3
The breeding biology of Ross' Goose in the Perry River region, Northwest Territories by J.P. Ryder
Cat. No. R65-8/3, Price 75¢. Publ. 1967.
No. 4
Behaviour and the regulation of numbers in Blue Grouse by J.F. Bendell and P.W. Elliott
Cat. No. R65-8/4, Price $1.00. Publ. 1967.
No. 5
Denning habits of the polar bear (*Ursus maritimus* Phipps) by C.R. Harington
Cat. No. R65-8/5, Price 50¢. Publ. 1968.
No. 6
Saskatoon wetlands seminar
Cat. No. R65-8/6, Price $5.25. Publ. 1969.
No. 7
Histoire naturelle du Gode, *Alca torda* L., dans le golfe Saint-Laurent, province de Québec, Canada par J. Bédard
Cat. No. R65-8/7, Price $1.25. Publ. 1969.
No. 8
The dynamics of Canadian arctic fox populations by A.H. Macpherson
Cat. No. R65-8/8, Price $1.00. Publ. 1969.
No. 9
Population estimates and distribution of barren-ground caribou in Mackenzie District, N.W.T., Saskatchewan and Alberta — March to May, 1967 by D.C. Thomas
Cat. No. R65-8/9, Price $1.00. Publ. 1969.
No. 10
The mammals of Jasper National Park, Alberta by J.D. Soper
Cat. No. R65-8/10, Price $2.50. Publ. 1970.
No. 11
Causes and implications of an observed sex differential in the survival of wapiti by D.R. Flook
Cat. No. R65-8/11, Price $1.25. Publ. 1970.
No. 12
Breeding biology of California and Ring-billed gulls: a study of ecological adaptations to the inland habitat by K. Vermeer
Cat. No. R65-8/12, Price $1.25. Publ. 1970.
No. 13
Geographical variation in the polar bear (*Ursus maritimus* Phipps) by T.H. Manning
Cat. No. R65-8/13, Price $1.00. Publ. 1971.
No. 14
Studies of bird hazards to aircraft
Cat. No. R65-8/14, Price $1.25. Publ. 1971.
No. 15
Moose and deer behaviour in snow in Fundy National Park, New Brunswick by J.P. Kelsall and W. Prescott
Cat. No. R65-8/15, Price $1.00. Publ. 1971.
No. 16
Effects of phosphamidon on forest birds in New Brunswick by C.D. Fowle
Cat. No. CW65-8/16, Price $1.00. Publ. 1972.
No. 17
Populations, movements and seasonal distribution of mergansers in northern Cape Breton Island by A.J. Erskine
Cat. No. CW65-8/17, Price $1.00. Publ. 1972.
No. 18
Waterfowl habitat trends in the aspen parkland of Manitoba by W.H. Kiel, Jr., A.S. Hawkins and N.G. Perret
Cat. No. CW65-8/18, Price $1.25, Publ. 1972.
No. 19
Vegetation of the Ngorongoro Conservation Area, Tanzania by D.J. Herlocker and H.J. Dirschl
Cat. No. CW65-8/19, Price $1.25. Publ. 1972.
No. 20
Biology of the Kaminuriak Population of barren-ground caribou.
Part 1: Total numbers, mortality, recruitment, and seasonal distribution by G.R. Parker
Cat. No. CW65-8/20, Price $1.50. Publ. 1972.
No. 21
Food habits and ecology of wolves on barren-ground caribou range in the Northwest Territories by E. Kuyt
Cat. No. CW65-8/21, Price $1.00. Publ. 1972.
No. 22
Background for managing grizzly bears in the national parks of Canada by K.R.D. Mundy and D.R. Flook
Cat. No. CW65-8/22, Price $1.00. Publ. 1973.
No. 23
The mammals of Waterton Lakes National Park, Alberta by J.D. Soper
Cat. No. CW65-8/23, Price $1.25. Publ. 1973.
No. 24
Feeding ecology of Pintail, Gadwall, American Widgeon and Lesser Scaup ducklings in southern Alberta by L.G. Sugden
Cat. No. CW65-8/24, Price $1.50. Publ. 1973.
No. 25
Home range and breeding biology of the Shoveler by H.J. Poston
Cat. No. CW65-8/25, Price $1.50. Publ. 1974.
No. 26
Calf mortality during 1970 on the calving ground of the Kaminuriak caribou by F.L. Miller and E. Broughton
Cat. No. CW65-8/26, Price $1.00. Publ. 1974.
No. 27
Bird damage to fruit crops in the Niagara Peninsula by R.G. Brown
Cat. No. CW65-8/27, Price $1.50. Publ. 1974.
No. 28
Migration of Lesser Snow and Blue Geese in spring across southern Manitoba
Part 1: Distribution, chronology, directions, numbers, heights and speeds by H. Blokpoel
Cat. No. CW65-8/28, Price $1.00. Publ. 1974.
No. 29
CWS Waterfowl studies in eastern Canada, 1969–73 edited by H. Boyd
Etude du SCF sur les oiseaux aquatiques dans l'est du Canada 1969–73 rédigé par H. Boyd
Cat. No. CW65-8/29, Price/Prix $3.00. Publ. 1974.
No. 30
Landscape classification and plant successional trends in the Peace-Athabasca Delta by H.J. Dirschl, D.L. Dabbs and G.C. Gentle
Cat. No. CW65-8/30, Price $3.00. Publ. 1974.
No. 31
Biology of the Kaminuriak Population of barren-ground caribou.
Part 2: Dentition as an indicator of age and sex: composition and socialization of the population by F.L. Miller
Cat. No. CW65-8/31, Price $3.00. Publ. 1974.
No. 32
Migration of Lesser Snow and Blue Geese in spring across southern Manitoba.
Part 2: Influence of the weather and prediction of major flights by H. Blokpoel and Maureen C. Gauthier
Cat. No. CW65-8/32, Price $1.00. Publ. 1975.
No. 33
An investigation of caribou range on Southampton Island, Northwest Territories by G.R. Parker
Cat. No. CW65-8/33, Price $2.75. Publ. 1975.
No. 34
The northern interior grizzly bear *Ursus arctos* L. by A.M. Pearson
Cat. No. CW65-8/34, Price $4.50. Publ. 1975.
No. 35
The nesting population of Lesser Snow Geese in the eastern Canadian Arctic: a photographic inventory of June 1973 by R.H. Kerbes
Cat. No. CW65-8/35, Price $3.25. Publ. 1975.
No. 36
Biology of the Kaminuriak Population of barren-ground caribou.
Part 3: Taiga winter range relationships and diet by D.R. Miller
Cat. No. CW65-8/36, Price $1.75. Publ. 1976.
No. 37
Wetland classification in western Canada: A guide to marshes and shallow open water wetlands in the grasslands and parklands of the Prairie Provinces by J.B. Miller
Cat. No. CW65-8/37, Price $2.00. Publ. 1976.
No. 38
Biology of the Kaminuriak Population of barren-ground caribou.
Part 4: Growth, reproduction and energy reserves by T.C. Dauphiné, Jr.
Cat. No. CW65-8/38, Price $3.25. Publ. 1976.
No. 39
Range ecology of Rocky Mountain bighorn sheep in Canadian national parks by John G. Stelfox
Cat. No. CW65-8/39, Price $2.25. Publ. 1977.
No. 40
Distributions, movements and numbers of Peary caribou and muskoxen on western Queen Elizabeth Islands, Northwest Territories, 1972–74 by F.L. Miller, R.H. Russell, and A. Gunn
Cat. No. CW65-8/40, Price $4.00. Publ. 1977.
No. 41
Birds in Boreal Canada: Communities, densities and adaptations by A.J. Erskine
Cat. No. CW65-8/41, Price $5.00. Publ. 1977.

No. 42
The first ten years of the co-operative Breeding Bird Survey in Canada by A.J. Erskine
Cat. No. CW65-8/42, Price $3.75. Publ. 1978.

No. 43
Migratory game bird hunters and hunting in Canada edited by H. Boyd and G.H. Finney. Aussi disponible en français
Cat. No. CW65-8/43, Price $7.50. Publ. 1979.

No. 44
The breeding birds of Long Point, Lake Erie: A study in community succession by J.D. McCracken, M.S.W. Bradstreet and G.L. Holroyd. Aussi disponible en français
Cat. No. CW65-8/44E, Price $11.75. Publ. 1982.

No. 45
Wolves in Canada and Alaska edited by Ludwig N. Carbyn. Aussi disponible en français
Cat. No. CW65-8/45E, Price $12.50. Publ. 1983.

Canadä