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ECOLOGICAL STUDIES IN THE NORTHERN BERING SEA:

STUDIES OF SEABIRDS IN THE BERING STRAIT

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Objectives: *1) To learn what species of seabirds occur, where* and in what numbers *in the Bering Strait Region; 2) to locate the* feeding areas, breeding *areas, gathering areas and other areas of great* importance; 3) to learn by trophic and other ecological studies what factors are important for reproductive success *and what* factors cause stress ; 4) to identify those human activities directly and indirectly associated with mineral development which may diminish the seabird populations of the area; 5) to prepare recommendations for stipulations for the guidance of industrial activities in order to prevent or mitigate damage.

Conclusions: 1) In the area between Cape Lisburne and Saint Lawrence Island there are 3,725,000 to 4,000,000 seabirds. 2) Little Diomede Island, the subject of this study, is a major seabird colony and the northern-most nesting colony of Parakeet, Crested and Least Auklets. 3) Drastic population reduction or steady declines are possible results of development. It has been suggested that populations be reduced at experimental colonies in order to establish the rate of recovery. *Although the evidence is not clear, there is a suggestion* that numbers of murres at Little Diomede Island have decreased since the late 1950s. If real, a decrease is consistent with the decrease of murres observed during the same period at Cape Thompson. Similarly, there is evidence that the numbers of Crested Auklets have decreased, which would be consistent with the reports to that effect by Orville Ahkinga and John Ayapana of Ignalook. 4) It is generally believed that arctic birds are subjected to stress by the extra effort required for breeding. Any further stress introduced by the impacts of development upon their food sources are likely to cause some degree of reproductive failure. It is important, therefore, to record the stresses to which the local populations are exposed and to establish their tolerance to further stress. At Little Diomede, as at other colonies in the northern Bering Sea, absence of adult kittiwakes during the incubation period in July is associated with losses of eggs, a major factor in lowered reproductive success. 5) An important aspect of OCSEAP is defining differences in biological oceanographic structures of the Bering Sea. Differences in the relative proportions of species among the several seabird colonies in the northern Bering Sea, such as an unusually high proportion of kittiwakes, Horned Puffins and Least Auklets at Little Diomede are, presumably, a response to local oceanographic conditions, but those structures are not known. 6) Seabirds have been observed to gather to feed in several rather well-defined areas north of Saint Lawrence Island and in the vicinity of the Bering Strait. These places suggest turbulence and shearing between the ocean currents which become progressively confined as they move northward.

Implications with Respect to OCS Oil and Gas Development:

1) Disturbance by the chronic effects of through traffic, by secondary effects such as helicopter operations and coastal development, by direct damage from oil spills or by indirect effects on the food of the seabirds will affect an area that is comparable to the plains of East Africa among the major natural wonders ‘of the world. The breeding seabirds of this area, numbering in the several millions, are an impressive

presence. The disturbance can take two forms at least:

a. The Bering Strait will almost undoubtedly become a major route for shipping of heavy equipment to the developing oil fields on the North Slope of Alaska.

b. The ocean current systems in the northern Bering Sea virtually guarantee that a major oil spill anywhere in the Norton Basin will find its way to the heart of the feeding and breeding areas.

2) Serious damage to the seabird populations can be expected to release a tide of public indignation which will scarcely be stemmed by cosmetic actions such as attempts to clean up the coastline and to rehabilitate the victims.

3) It behooves planners to institute strict protocols and economic punishments that will make an accident as much of a disaster for the industry that causes it as it would be biologically and politically. Political institutions designed to mitigate the negative effects might include:

a. Conditions for approval of transit of the Strait can be set, such as double shell construction of the vessels to prevent leakage of bilges or damage to inner hulls, similar to the engineering requirements of ships making their way through the ice. Passage through the Strait can be allowed only during the daylight.

b. Technical improvements alone have not prevented spills in the past, because technology works only as well as the will to do a good job. It is reported that 95% of oil spills result from human "error" and that some companies have excellent safety records while others have poor ones. Yet the only measure of qualification for, as an example, oil exploration, is the amount of money offered as the bid at a lease sale. If administrators have the will, they can establish a stepwise system by which companies with a good safety record are favored over those with bad records, and in this way make the probabilities of accident work in favor of quality instead of as measures of inevitability.

II. INTRODUCTION -- THE BERING STRAIT, TRANSPORTATION TO THE NORTH SLOPE, AND IMPLICATIONS.

A. General Nature and Scope of the Research.

The work at Little Diomede Island in 1977 is part of a larger study of seabird biology in the Bering Strait. Studies made in Cape Lisburne and Cape Thompson by Schwartz (1967) and by Roseneau & Springer (NOAA 1978) belong within this area in its broad context as well as studies made at Saint Lawrence Island by Bédard (1969), Scaly (1973), Searing (1978), Johnson (1972), Friedmann (1932), and Fay & Cade (1959). Our own studies at Sledge Island and at the cliffs at Bluff in 1975-1977 contribute to defining one of the edges of the area.

This report is written largely from hi-monthly summaries prepared in the field by the members of our field party, who were Benjamin B. Steele (26 June-12 August), Alan Watson (19 May-4 August), and Edward T. Steele (19 May-12 August).

The Bering Strait will become a major avenue of transportation of heavy equipment to the western Arctic as the oil fields of northwestern Canada and the North Slope of Alaska are developed. Furthermore, because ice conditions periodically prevent the passage of ships past Point Barrow, staging areas for ships waiting to move northward will be needed in places such as the roadsteads at Nome and Port Clarence.

A relatively dense Eskimo population and concentrations of marine mammals and birds in this area are associated with a funnel-like topography in the Chirikov Basin,. Although ice movements in the late winter are predominantly southward, during summer northward-flowing ocean currents are progressively confined as they move through the

Chirikov Basin and Bering Strait, then are released. The surveys reported in this Research Unit were planned to locate the areas critical to wildlife, to assess their vulnerability, and to consider how to prevent or mitigate damage.

The Bering Strait area should be considered both as an area which may become subject to heavy industrial development and as an area which is an ecological unit defined by ocean current, marine productivity, wildlife and the traditional economy of the natives.

Potential development and sea traffic. Heavy through traffic of ships related to North Slope development will presumably enter the area along lanes running east of Saint Lawrence Island. The traffic will pass through the Chirikov Basin and numbers of vessels will have to stop many weeks in Nome or Port Clarence; traffic that has passed through the Bering Strait may have to wait further in Kotzubue Sound as vessels did during the summer of 1975.

Local gas and oil development is predicted to be relatively light according to present estimates. Perhaps only gas wells will be involved. One can predict that extensive secondary development will occur in shore facilities for staging and transshipping in western Seward Peninsula.

Environmental Considerations. The Eskimos of the area perhaps set the scene by their unusually highly developed culture dependent primarily on sea mammals and seabirds. Native settlements in this area consisted of relatively large (100-250 people) settlements and many small mobile groups of single or several families. The large permanent settlements depended on hunting large marine mammals especially on moving sea ice.

Whaling was important at western Saint Lawrence Island and at Point Hope but according to Ray (1976) whaling was relatively unimportant in the settlements within the more narrow sense of the Bering Strait (that is, King Island, the Diomede Islands, and Wales). The people of King Island reportedly left the island in the summer, dispersing to use resources on the western coast of Seward Peninsula; but the other settlements were reportedly permanent.

Our observations of the distribution of wildlife suggest, as is only common sense, that natives gathered near dependable sources of game, and hence that critical sites for wildlife are the same as traditional native settlements. However, major feeding grounds of marine mammals and birds are not necessarily close to the nesting grounds of seabirds. We can draw some straightforward conclusions from the traditional distribution of native settlements, yet there are major features of the distribution of wildlife resources which still need to be clarified, especially those which were beyond the access of hunters before the arrival of modern transportation.

Whaling was pursued by the Eskimos at both limits of this area at Saint Lawrence Island in the south and Point Hope in the north. However, the language groups of the two are different. The people of Point Hope, Kotzebue Sound, the Diomede Islands, Wales, King Island and the west coast of Seward Peninsula as far southeast as Cape Nome speak Inupiat, the language of the Eskimo of the arctic coast of North America. The people of Saint Lawrence Island speak a Siberian form of Yupik.

It seems *probable that this separation depends* on relatively re-*cent tribal movements, for despite this difference in* language, there is an evident similarity in cultures and the food basis of the cultures.

The region of the Saint Lawrence Island waters, Chirikov Basin, Bering Strait and southern Chukchi *Sea is unified by being the site of* spring gatherings of tens of thousands of Walrus and summer gatherings of Gray and Finback Whales. Bearded, Ringed and Spotted Seals are numerous on the winter ice and formed the staples of the diet of the Bering Strait Eskimos. These concentrations of marine mammals reportedly extend into the southern Chukchi Sea. The Strait appears to form, on average, the southern limit of winter distribution of Polar Bears.

Another conspicuous wildlife element in the area is the several millions of seabirds. Murres, kittiwakes and puffins otherwise widely distributed in. all northern seas have their northern breeding limit at *Cape* Lisburne. Black Guillemots, an eastern arctic species (Schwartz 1966) and sporadically south to Saint Lawrence Island (Bédard 1966), extends south to Cape Thompson thus overlapping the northern range of the Pigeon Guillemot, a closely related member of the Pacific fauna. The Diomede Islands, King Island and Saint Lawrence Island form the most northern cluster of nesting sites of millions of Least, Crested and Parakeet Auklets. These seabirds are endemic to the region of the western Gulf of Alaska, the Bering Sea and Sea of Okhotsk.

We presume that there are ecological reasons for the marked differences in the seabirds between Norton Sound and the rest of the area. 1) The three species of auklets are present in large numbers in the Bering Strait region; however, there are no breeding colonies containing auklets in the Norton Sound area, i.e., at Sledge Island or at Bluff. 2) Presumably for ecological and habitat reasons, the proportion of kittiwakes to murres and the proportion between Common Murres and Thick-billed Murres also varies widely among the colonies over the larger Bering Strait region. For example, there are about 80,000 murres at Little Diomede, King Island, and at Bluff. However, there are about 35,000 kittiwakes at Little Diomede but only 3500-4000 at King Island and Bluff. The murres at King and Little Diomede Islands are half Common Murres and half Thick-billed, but at Bluff the population is 99% Common.

The larger marine vertebrates that provided food for natives of the Bering Strait are dependent upon the same food base. Although scattered measurements of primary productivity have been made and some samples of benthic animals reported (Alton, in Hood & Kelley 1973), little is known of the important fish or invertebrate species used as food by seabirds. It is not yet clear what is the distribution of productivity and feeding areas for the region. These feeding centers are presumably indispensible parts of the habitat of the larger vertebrates and until they are mapped we do not know the location or extent of critical parts of the system.

The currents and water masses which pass northward through the Strait have been described in general terms (Hughes et. al., in Hood & Kelley (1973) and Aagard (1975)). Evidently water enters the Chirikov Basin both from the Gulf of Anadyr and from the coastal waters dominated by the Yukon and Kuskokwim Rivers. These masses shear against each other and become progressively confined as they approach the funnel-like structure of the Bering Strait. Much of the water passes through the relatively deep channel between Cape Prince of Wales and Little Diomede Island yet the effects of mixing on primary productivity are also evident west of Big Diomede where very high levels of primary productivity have been reported (Hood & Kelley 1973).

One important implication of the northward movement of water during the ice-free seasons is that virtually any pollution which gets into the waters of the northern Bering Sea (except for the eastern end of Norton Sound) will be carried through the Bering Strait and into the southern Chukchi Sea-Kotzebue Sound. Moreover, "lenses" (a discrete volume) of Bering Sea water move past Cape Lisburne and Point Barrow into the southern Beaufort Sea.

B. Specific Objectives of This Research Unit.

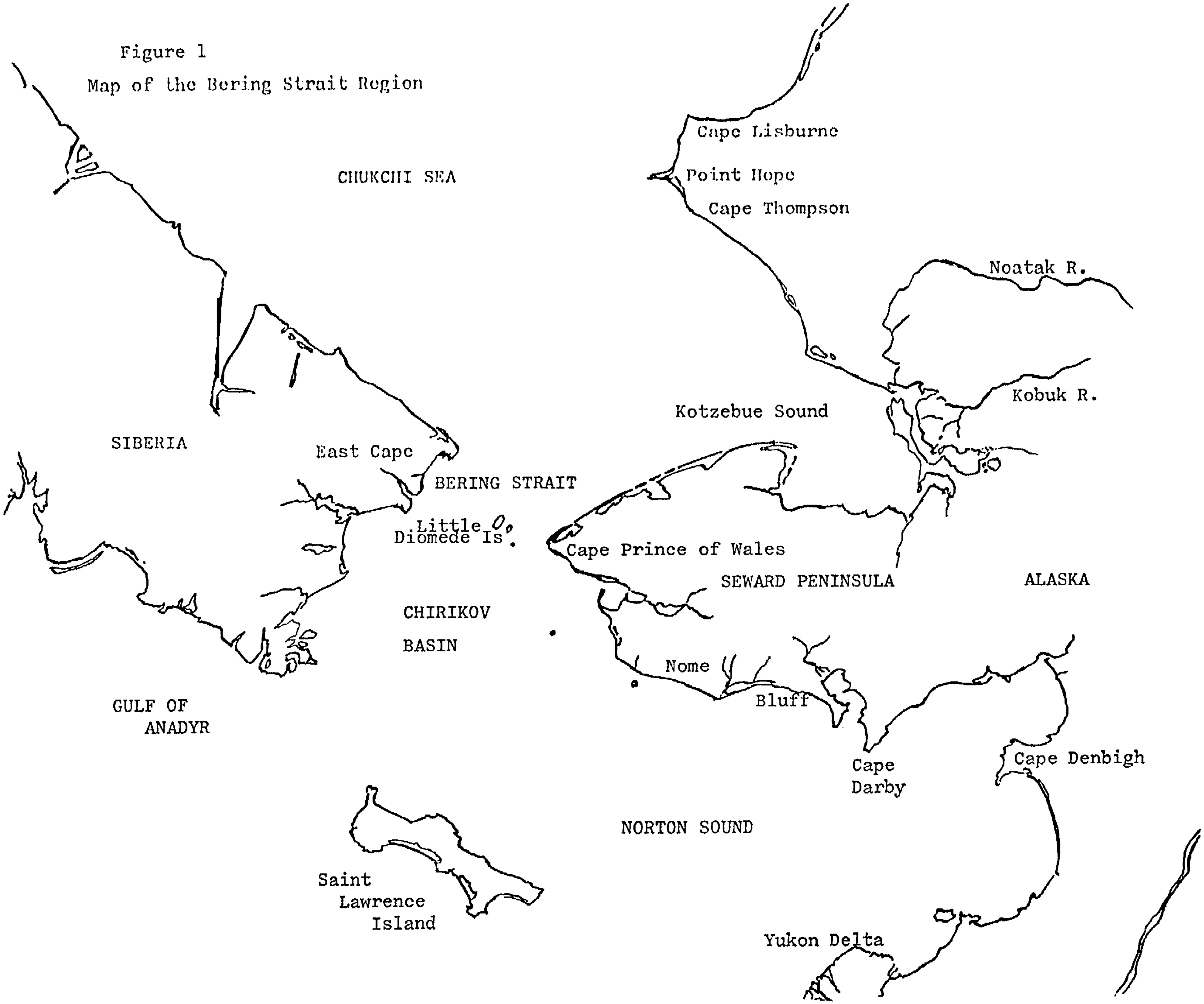
1) To learn what species of seabirds occur where and in what numbers in the Bering Strait region; 2) to locate their feeding and gathering areas and to identify other areas of great importance; 3) to learn by trophic and other ecological studies what factors are important for reproductive success and what factors cause stress on seabirds; 4) to identify those activities associated with mineral development which may diminish the seabird populations of this area; 5) to recommend stipulations to mitigate the negative effects and to maximize the positive effects of industrial development.

III. CURRENT STATE OF KNOWLEDGE.

This section was considered in detail in the report for the 1976 field season.

Figure 1

Map of the Bering Strait Region



IV. STUDY AREA -- LITTLE DIOMEDE ISLAND.

Little Diomede Island lies within the narrowest part of the Bering Strait (Figure 1). It is at 65°45′N lat., 169°W long., 20 nautical miles (37 km) west-northwest of Cape Prince of Wales, two nautical miles (3.7 km) east of Big Diomede and 23 nautical miles (45.6 km) southeast of Cape Dezhneva, Siberia.

The island (Figure 2) is characterized by steep sides, a flat top about 400 m above sea level, and a large drainage basin (area approximately 65,500 m^2) on the east side ("East Valley"). The Eskimo village of Ignalook is at the base of a boulder fan on the northwest corner. A shallow bar extends toward Big Diomede from the town and the Eskimos say this goes most of the way to Big Diomede. The north-flowing current passing over this bar results in a rip or turbulence visible in almost any weather. It is a popular feeding area for kittiwakes.

The sides of the island slope at 35°-40°(Figure 2). They consist of a mixture of 1) rock faces, 2) vegetated slopes, and 3) talus of boulders. The major areas of talus are on the west side, 1000 m to the north and south of the village, and in the East Valley. The lower 30-50 m of the sides consist of nearly vertical wave-cut cliffs. These lower cliffs are nearly" continuous around the island except for many small gullies and the areas near Ignalook and the mouth of East Valley where the talus reaches the shore. The bedrock outcrops on the east side are more friable than the 'massive face on Fairway Rock or the great slabs and arêtes on King Island. On the north end of the island some of the vegetated slopes have poor drainage and are too wet for Parakeet Auklets to nest. Near the southeastern corner there are large areas of bare soil. Otherwise the vegetated slopes are uniform.

The flat top of the island consists mainly of mat plants on large boulders. In general, the soil is too wet for burrow-nesting birds. Murres and kittiwakes nest mainly on the lower rock faces. Auklets nest under the boulders in the talus and puffins nest on the lower cliffs and higher bedrock outcrops.

Banks of unstable snow made travel on the island dangerous in May and the first half of June, but shore-fast ice provided a useful avenue of travel until the sea ice broke up at the end of June, by which time snow had disappeared from all but the deep shaded gullies. Traces of old trails were found on all parts of the island. A trail north from the town is still used and provided access to the cliffs where murres and kittiwakes nest.

Big Diomede (Siberia) appears to be generally similar to Little Diomede although much bigger, 8.5 km from north to south. Clouds of auklets can be seen over the island but Albert Ayahuk of Ignalook reported that there are many fewer Crested Auklets than on Little Diomede. The east side of the island (the only shoreline visible) is generally very steep and appears to have densities of nesting murres and kittiwakes similar to those on Little Diomede. A talus slope extends down to the water in the middle of Big Diomede's east shore. The Eskimos said that the slopes are gentle from the top to the north and northwest.

Fairway Rock is a truncated cone 534 ft (165 m) high, 8 nautical miles (15 km) southeast of Little Diomede. The top is an outcrop of massive bedrock, apparently granite. The middle slopes are thickly covered with grassy turf and the lower slopes jumbles of boulders and rock faces.

Break-up and Movement of Sea Ice.

On our arrival on 19 May the sea ice was continuous around both Diomedes and extended unbroken to the north. There was a strip of open water extending for many miles to the south, which the Eskimos told us was a product of the prevailing northerly wind. On 20 May a southerly wind closed this lead for as far as we could see. Several small leads opened off the "North Point" on 23 May, and on 26 May ice on the north side of these leads began to move north. The leads continued to widen, and much open water was present to the north and west of the Diomedes on 10 June. On 11 June there were still aprons of shore-fast ice surrounding and connecting the islands. We were able to make our last walk around the island on the shore-fast ice on 15 June, after which the ice became unsafe. On that date a lead formed between the two islands. On 17 June the pack ice on the north side of the strait between the islands broke off and moved north, and the southern pack broke and drifted north on 19 June. Bits of ice still clung to the shore of Little Diomede by this time, and either melted away or broke off in chunks.

Currents.

During the summer, northward-flowing ocean currents are confined as they pass through the Chirikov Basin and Bering Strait.

During the 1977 season there was a consistent northward flow of several knots on both sides of the island. Back eddies sometimes occurred in-shore on the slightly indented eastern shore of Little Diomede. The Eskimos say that the northward set reaches 3 knots (6 km per hour) in the main current between the island and Wales.

Figure 2

LITTLE DIOMEDE ISLAND
showing landmarks

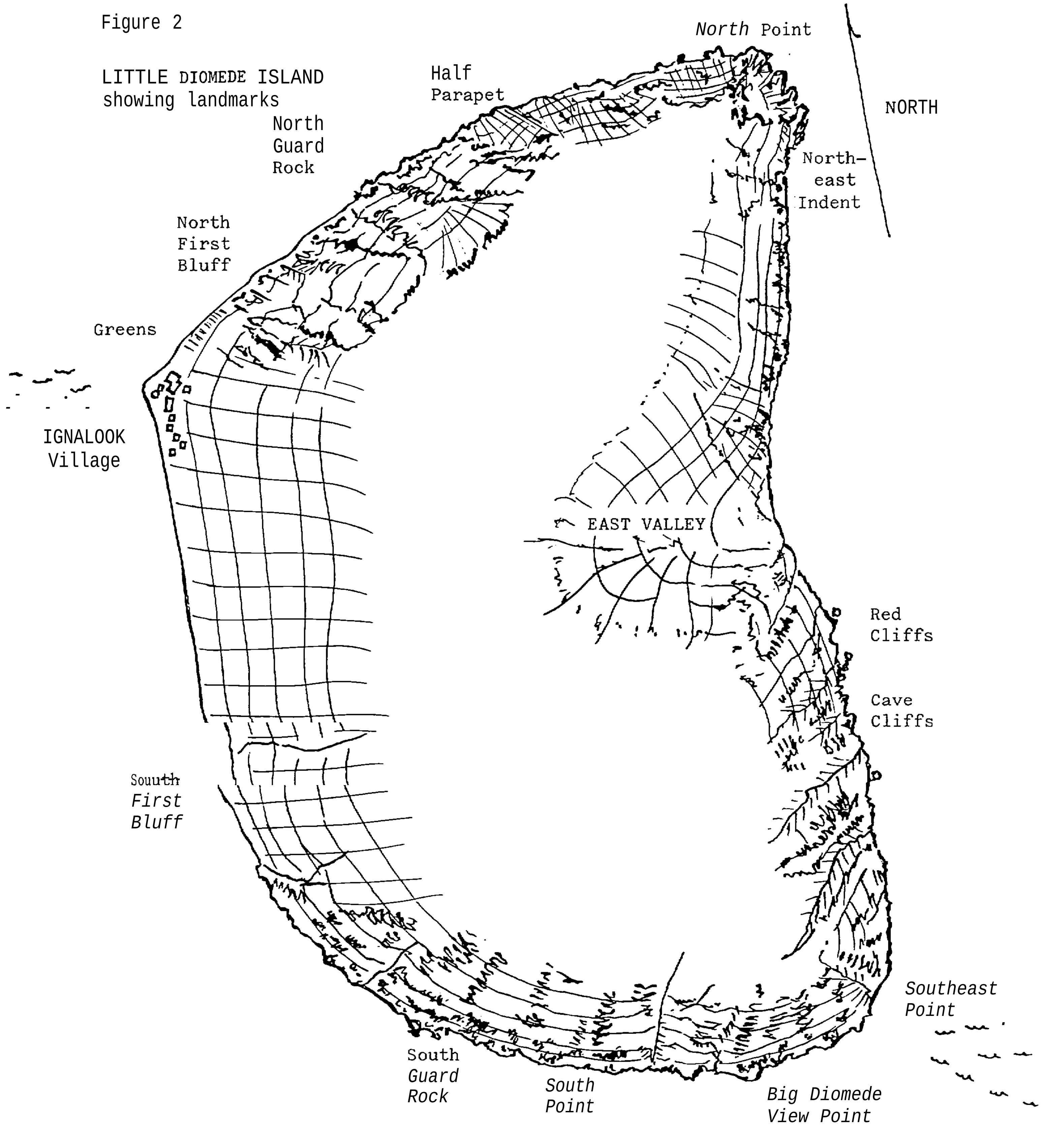
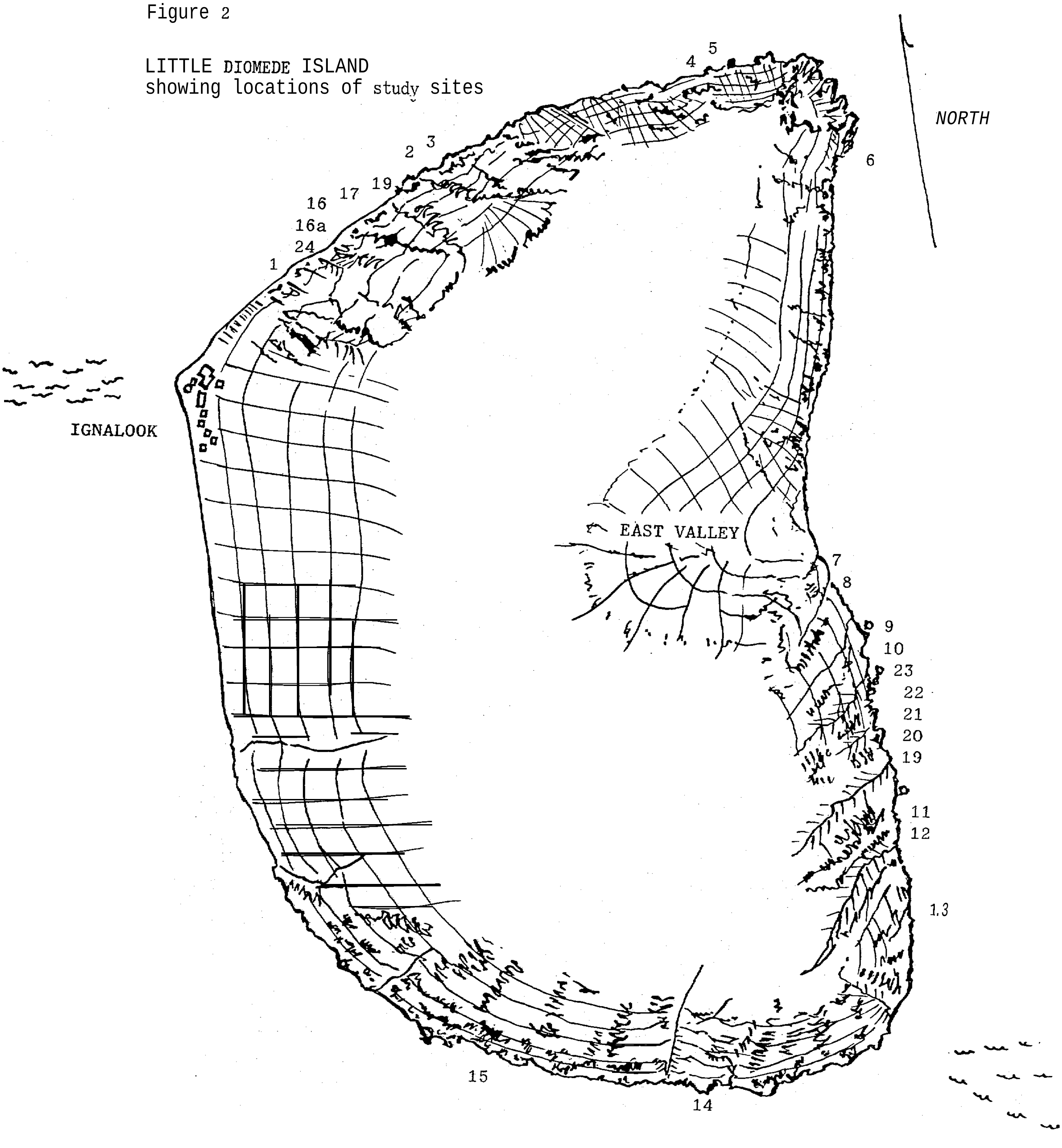


Figure 2

LITTLE DIOMEDE ISLAND
showing locations of study sites



These currents and the associated turbulence are presumably responsible in part for the very high productivity of the waters and hence rafts of feeding seabirds are to be seen on the water for tens of kilometers in all directions from Little Diomede.

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION.

Mapping the Island and Estimating Areas of Habitats.

We made a rough working map of the perimeter of Little Diomede by taking compass bearings and pacing distances along the shore-fast ice around the base of the island. In preparing this map we located and named prominent features on the island for points of reference and measured the distances between them. We have prepared a map from a BLM aerial photograph and marked on it those landmarks (Figure 2).

Because it is impossible to make direct counts of birds nesting underground in the grass or talus slopes, we sampled the number of birds per unit area of a habitat type and multiplied that figure by an estimate of the amount of each habitat type available. We defined three major habitats: green slopes, cliffs, and talus. To arrive at an estimate for the areas of habitat, we did the following:

1) We calculated the area of slope around the sides of the island. We estimated the slope of the side to average 37° except on the talus slope above the village, where it was nearer 30°, and the height of the island to be roughly 400 m between North Point and South Guard Rock and 330 m on the east side. We then calculated the distance from the bottom to the top of the slope by trigonometry and multiplied that figure by the length of each of the sections as paced between landmarks

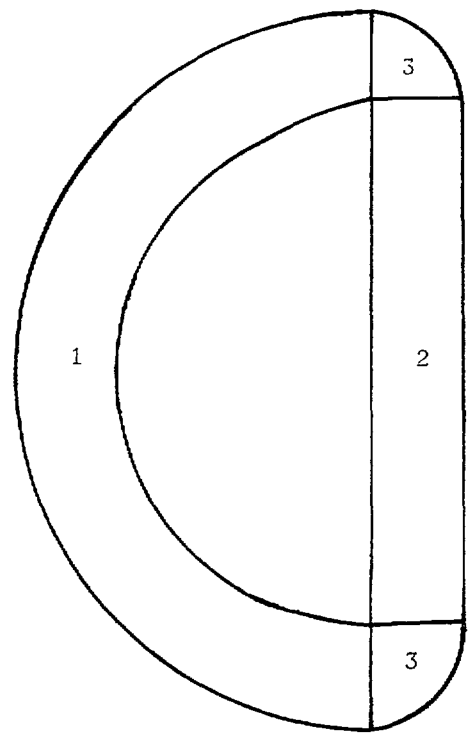
Table 1. Area of slopes and percent habitat type.

Section of Cliff	Base Length (m.)	Slope Length (m)	Total Area (m2)*	Habitat Type (% of total area) Area Talus	Area Grass	Area Rock	Area Other+
Town to 60% of distance to 1st Bluff	585	732	428,000	77	23	0	0
To 1st Bluff	390	610	238,000	55	38	7	0
To S. Guard Rock	975	610	595,000	25	42	33	0
To South Point	562	610	343,000	20	37	43	0
To Big Diomede View Point	637	610	389,000	17	37	46	0
To SE Point	487	610	149,000	17	37	46	0
To SE Corner	262	610	80,000	10	43	40	7
To Cave Cliff Corner	600	500	300,000	23	40	37	0
To Red Cliff Rock	487	500	244,000	33	33	33	0
To East Valley	637	500	239,000	25	58	17	0
To NE Indentation	1012	500	426,000	28	62	10	0
To North Point	637	500	239,000	10	28	37	25
To Half Parapet	750	610	378,000	3	10	47	40
To N. Guard Rock	600	610	366,000	7	60	17	16
To 1st Bluff North	525	610	320,000	15	50	23	12
To Greens	675	610	412,000	23	64	13	0
To Town	375	732	275,000	47	40	13	0
East Gully			65,500	50	50	0	0
Total			5,486,500	26.8	41.8	25.6	5.7

* Calculated using figures for height and degree of slope as mentioned in text, p. .

\+ Gravel and wet grass sections.

Figure 2A. Schematic diagram of Little Diomede used in alternative estimate of the area of the slope. (see text)



at the bottom of the slope. The area above each paced section was assumed to be rectangular, except for two areas more clearly trapezoidal and two triangular, which were calculated as such.

2) We estimated the percentage of each habitat type in each defined part, On 15 July we circled the island in a boat and each of three observers estimated for each section the percentage of the three major habitat types. The percentages varied generally by no more than 10 points, and frequently by as few as five.

3) We took the average of the three estimates in step (2) and multiplied it by the area in step (l). By adding up the areas so derived for each section, we arrived at a total figure for the area of each type of habitat. These results are presented in Table 1.

As an alternative method of calculating the area of the slope around the island (see (1) above) we schematized the island to appear in plane-view as in Figure 2A, tapering as a cone to an abbreviated flat top. Thus the sides of the island would be composed of: (1) a section of a cone representing the curved west side (half a large cone with base at sea level, minus half a cone with base at the top); (2) a plane on the straight east side; plus (3) two “quarter-cones” at the NE and SE corners. By estimating the height of the island as 350 m on the west and 320 m on the east, the slope as 37°, and the diameter as 3600 m, we calculated the area of the slope on the perimeter of the island as about $3.4 \times 10^6 m^2$, in contrast to the estimate of $5.5 \times 10^6 m^2$ from the method above. The difference probably lies in that this latter method makes more emphasis of the tapering quality to the sides of the island, whereas the former method assumed sections of the slope to be rectangular planes.

We have used the first, more detailed, method of calculation in making our estimates of auklet populations. Our method is only as accurate as our estimate of the consistency, suitability and amount of habitat. The data are useful for future comparisons in two ways: a) if revised calculations are made of the habitat, our figures for average bird density can be applied to them; and b) future counts of bird density can be applied to our habitat estimates. We believe the estimates are within a tolerable range of accuracy because the members of our field party were very familiar with all parts of the island.

Censuses of total populations.

Auklets. An estimate of the auklet population was obtained by sampling their density on plots of talus and multiplying by the total calculated amount of habitat. Between 16 and 24 June we made counts of Least and Crested Auklets on 20 paced sections of talus slope. Since auklets are very active, and often fly around and move in and out from under rocks, we counted the same patch repeatedly between 19:00 and 22:00, when the greatest number of auklets were present. We tried at the same time to include birds that had gone under boulders and remained there. The highest number of auklets per m^2 was used in the extrapolation.

On 10, 14, and 20 July we walked 30m-wide transects that ran up the grassy slopes to the top of the island and counted Parakeet Auklets. The transects were chosen to represent all sides of the island. Areas of talus within the grass-slope transect were subtracted. We assumed that Parakeet Auklets perched on rocks were nesting on the grassy slope. These densities multiplied by the total area of grassy slope area yield a population estimate for Parakeet Auklets and an additional number of

Least and Crested Auklets that was added to the estimate of birds on talus.

Cliff-nesting species were censused from a boat on 21 June (murres only), 15 July and 5 August. Murres and kittiwakes were counted by tens, Pelagic Cormorants, Glaucous Gulls and Pigeon Guillemots individually, and Horned and Tufted Puffins on the lower cliffs individually. Since murres and kittiwakes generally nest no more than 70 m above the water, they are visible and readily counted. Thus these numbers are directly comparable to those we have obtained by the same technique at other colonies. Horned Puffins, however, and a very few Tufteds, nest in cracks in rock outcrops all the way to the top of the slope. In order to estimate the numbers of puffins nesting on high rock faces, we made sample counts of puffins on 42 such faces, estimated the area of the face, and determined the number of birds per m^2. This figure was then multiplied by the area of rock outcrop estimated for the whole island.

On 22, 23, 31 July and 2 August we counted Thick-billed and Common Murres on 120 different areas of cliff to determine what percentage of the total population each species composed. This ratio was applied to the total census figure. The areas counted were selected to include all exposures, rock types and elevations. The number of birds counted was 30 % of the entire population, so error should be small. These counts were made at a time when birds closely tied to breeding efforts on the cliff should all be present and should be representative of the ratio of breeding birds of each species.

Fairway Rock., We visited Fairway Rock by boat on 25 June. We at first landed on the rock and climbed it to count birds on the water, then circled the rock three times in our boat, counting all species.

Breeding Phenology, Seasonal and Daily Activity Patterns, Reproductive Success.

Events over the course of the season were monitored in the following ways:

-- Between 20 May and 15 June, 25 circumnavigations of the island on the shore-fast ice were made. We established 15 count areas in sections of the cliff faces where we made day-to-day counts of murres and kittiwakes.

-- Study sites visible from the tops of the cliffs were set up after travel by foot on the island had become safe and practical. Five sites were established on the west side of the island north of the village on 19 June (16, 16B, 17, 18, 24) and were visited 20 times until 11 August, approximately every other day; six were established on the west side on 20 June (19, 19B - 23) and were visited six more times.

At these sites we followed procedures similar to those used at Bluff, described in detail in the annual report for Research Unit #237 in 1976. We made counts of adult murres, kittiwakes and puffins in defined areas; drew sketch maps on which were located individual kittiwake nests that were monitored for nest-building activity, eggs and chicks; and located murre ledges on which we could count birds in an incubating posture, and locate individuals with eggs. In addition, we irregularly monitored several nests of Pelagic Cormorants, Glaucous Gulls, and Ravens.

-- To determine the daily activity pattern of murres and kittiwakes, we made hourly counts at a study site over 26-hour periods on 1-2 July and 14-15 July. To determine the daily schedule of auklets, we made hourly counts in three defined areas of talus slope above the village for 24 hours on 5-6, 7-8, and 16-17 July.

Other Resident and Non-resident Species.

Throughout our stay on Little Diomede, *we kept miscellaneous notes on the resident non-seabird species, especially predators (Snowy Owl,* Raven), as well as on transients.

Distribution of Birds at Sea.

Methods. We used a Cessna Skymaster for our overwater transects during 1977, except for one flight in a DeHaviland Islander in middle May. Our protocol was to fly at 120 feet altitude and at 120 knots. In practice neither of these was precisely maintained. We had a different pilot for" each of our sets of flights, and until he learned of the importance of maintaining the same altitude, each was subject to lapses of attention. Also our speed over the water changed because wind directions and speed change significantly during the course of a transect: In practice our altitude varied between 90 feet and 130 feet, 80% of the *time between 100 and 120 feet. Our speed over the water varied as much* as 40 *knots, but to avoid the effects of this we divided each segment of* our transects by a sliding scale adjusted to the known positions at the start and finish of each line run.

In *practice it is unrealistic to claim any greater precision, so we must adjust our expectations of the results. The differences between* the numbers of birds seen in Norton Sound and those seen south of King Island are obvious. We have chosen increments of 5-15 birds per km^2; 25-50 birds per km^2; and 100 birds per km^2, for purposes of comparison.

During most of our flights in 1977 we used four observers. We soon learned that in order to calibrate among observers, the most important step is to ensure that times are uniformly recorded. We used a standard kitchen timer that rings a bell at the end of a given length of time. This time varies over almost a minute in practice, but at least everyone's segments are the same. We have compared the records of the observers on the same side of the airplane and find that there is good agreement. Occasionally the two observers' records are completely contradictory, but the reasons are usually easily found. Identification of the species of auklets varies enough that we believe it is best to lump all species of auklets together. On certain segments we were able to *separate Least* Auklets *from the others, but changes in altitude have an unexpectedly large effect. We believe that our separation of auklets from* murres *is reliable.* In *a small percentage of cases we can see that some murres are black and others are coffee-brown,* but we cannot separate Thick-billed from Common Murres consistently. The chief reasons for differences between observers, one forward and one aft, are 1) the forward observer has a larger field of view, being able to look forward as well as down, and 2) each observer occasionally misses a flock that the other notices. It is not possible to establish whether the differences between observers in such a case is greater than would be the differences between repeated samples taken by the same observer.

We can also compare the differences in the records of observers on opposite sides of the plane, and find that in general these numbers are also similar. They give the same indications of changes in major concentrations. Occasionally the observer on one side will see several flocks not seen on the other, which suggests that some feeding aggregations are very local. When there are major differences they reflect the effects of glare on the water and the state of the sea. We believe that it is valuable to have an observer on each side, but that it is not that much more helpful to have two observers on each side.

We believe it is necessary to make generous use of common sense in using data gathered and to draw only general conclusions, not only because of unevenness of the data but also because of irregularities in the distributions of the birds at sea.

We need next to sample the times spent on the surface and compare these with times spent under water for the several species. We believe that these differences may matter in air censuses, while surface travel is so slow that these differences do not matter.

V-I. RESULTS AND SPECIES DISCUSSIONS.

CENSUSES

1. Little Diomede

Data for our censuses of cliff-nesting species are shown for each species by section of the island and are totaled in Table 2. Since the number of birds counted is affected by the time of day, we have shown in Table 2 the extrapolated numbers that may have been on the cliff, based on the data on daily attendance patterns of murres and kittiwakes obtained in the previous day's 24-hour count.

The extrapolated total for puffins on rock outcrops and the total for the entire population are shown in Table 3. The results of our sample counts for the percent composition of the murre population is summarized by area of the island in Table 4.

The average densities of each species of auklet and the extrapolated figures for their total population are shown in Table 5.

Table 2. Census figures from 15 July island count.

Area	Murres	Kittiwakes	Horned Puffins	Tufted Puffins	Pelagic Cormorants	Glaucous Gulls	Pigeon Guillemot
Village to South Guard Rock	1745	1310	1142	47	3	7	14
South Guard Rock to Big Diomede View Pt.	2925	3030	1031	92	7	6	19
Big Diomede View Pt. to Southeast Point	2800	1350	520	55	0	4	3
Southeast Point to Cave Cliff Corner	6075	1230	1100	91	26	14	30
Cave Cliff Corner to Red Cliff Corner	6035	1670	200	33	9	14	19
Red Cliff Corner to East Gully	8275	1430	160	19	48	29	15
East Gully to Northeast Indentation	4380	450	1120	43	29	11	51
Northeast Indentation to North Point	3975	620	805	114	16	13	31
North Point to North Guard Rock	8195	4110	1521	118	21	33	58
North Guard Rock to Village	2070	2190	475	53	0	5	35
Totals	46,075	17,390	8074	665	159	136	275

Extrapolations of Total Murre and Kittiwake Numbers (from 7/15 Island Count and 7/14-7/15 24 Hour Count).

Murres - Island Count total : 46,000
24 Hour Count 1700-1900 Average Count : 400
Highest Count : 600
Ratio : 2/3
Extrapolation : 46,000 + 15,000 = 61,000

Kittiwakes - Island Count total : 17,400
24 Hour Count 1900-2100 Average : 300
Highest Count : 600
Ratio : 1/2
Extrapolation : 17,400 + 17,400 = 35,000

Table 2 continued. Census figures from 5 August island count.

Area	Murres	Kittiwakes	Horned Puffins	Tufted Puffins
Village to South Guard Rock	2410	710	1290	94
South Guard Rock to Big Diomede View Pt.	5390	2770	720	41
Big Diomede View Pt. to Southeast Point	4700	1320		
Southeast Point to Cave Cliff Corner	6310	1100	1450	79
Cave Cliff Corner to Red Cliff Corner	15420	4630		
Red Cliff Corner to East Gully			290	18
East Gully to Northeast Indentation	4880	610	2190	126
Northeast Indentation to North Point	2990	1000		
North Point to North Guard Rock	9160	4650	1680	97
North Guard Rock to Village	3160	3400	865	66
TOTALS	54420	20190 '	8485	521

Table 3. Estimate of puffin populations on Little Diomede.

Total area of rock outcrop = 1.407×10^6 m^2
Sampled area of rock outcrop = 20,540 m^2 (1.5% of total)

	Horned Puffin	Tufted Puffin
Number counted on rock outcrops	253	3
Average density on rock outcrops birds/m^2	.012	.0003
Extrapolated total birds on rock outcrops	16,884	422
Total birds on cliffs 15 July census	4,749	349
Total birds flying 15 July census	3,325	316
TOTAL POPULATION	24,958	1,087
rounded estimate	25,000	1,100

Table 4. percent composition of Murre species (by area of the island).

	Thick-billed Murre	Common Murre
Northwest Side (From 1st Bluff North to North Point)	41%	59%
Northeast Side (From Northeast Indentation to East Valley)	52%	48%
Southeast Side (From Cave Cliffs to , Southeast Point)	35%	65%
Southwest Side" (From South Guard Rock to First Bluff South)	35%	65%

Total Birds Counted – 16,380 (30% of total murre population)

Thick-billed Murres – 40% (6552]

Common Murres - 60% (9828)

Table 5. Estimates of auklet populations on Little Diomede.

Area of grassy slope = 2.294×10^6 m^2
Sampled area of grassy slope = 69,825 m^2 for Least and Crested Auklets
139,215 m^2 for Parakeet Auklets

Area of talus slope = 1.470×10^6 m^2
Sampled area of talus slope = 38,000 m^2 ±

	Least Auklet	Crested Auklet	Parakeet* Auklet
Sampled density on talus slopes birds/m^2	.645	.079	
Extrapolated number birds on talus	948,150	116,130	
Sampled density on grass slopes birds/m^2	.014	.008	west. side: .0052 east side:. 011
Extrapolated number birds on grass	32,116	18,352	west side: 6,567 east side:11,341
TOTAL POPULATION ESTIMATE	980,226	134,482	17,908
Rounded estimate	980,000	135,000	18,000

* We have separated our samples of Parakeet Auklets on the east and west sides of the island, using North Point and South Guard Rock as dividing boundaries.

Table 6 . Census and estimates of birds at Fairway Rock, 25 June 1977.

	Number Counted	Estimate of Total Population
Pelagic Cormorant	8 8 nests	20
Glaucous Gull	51 29 nests	125 - 150
Black-legged Kittiwake	640	500-1000
Common and Thick-billed Murres	130	4000 on cliffs* 20,000 on water*
Pigeon Guillemot	86	
Horned Puffin	12 (lower slopes)	
Tufted Puffin	62	100-500
Least Auklet		.15,000
Crested Auklet		10,000
Parakeet Auklet		500
Common Raven	2	
Peregrine Falcon	2	

* estimate made from airplane 22 June

2. Fairway Rock

The data from the census of Fairway Rock are shown in Table 6. At the time we visited Fairway on 25 June, the numbers of murres were at a low point on Little Diomede; thus we believe the figure for Fairway Rock on that date does not reflect the true size of the population. For other species on the table, we have also distinguished the actual number counted from our estimate of the probable number of birds represented by our counts.

SPECIES ACCOUNTS

In these accounts, the English name of the species is followed by a phonetic spelling of the name used by the Eskimos of Ignalook.

General Breeding Phenology

The reproductive phenology of the seabirds breeding at Little Diomede is shown in Figure 4. The egg dates for auklets and puffins were obtained mostly by noting the days Eskimo children brought back eggs they had found. Thus they are accurate only within a range of about a week or so. We have limited information on Pelagic Cormorants and Glaucous Gulls because of the irregularity with which these nests were checked, but we have extrapolated from estimates of the ages of chicks to identify laying and hatching dates. Dates for the kittiwakes and murres are based on observations at the study sites. Our field party left Little Diomede on 12 August before any murre eggs were seen to hatch, and before all kittiwakes had hatched. Thus, we have no fledging or departure dates.

Kenyon & Brooks (1960) noted different arrival dates for seabirds during the two seasons -- 1953 and 1958 -- when they were on the island.

Figure 4. Approximate breeding phenology of seabirds at Little Diomede Island, 1977.

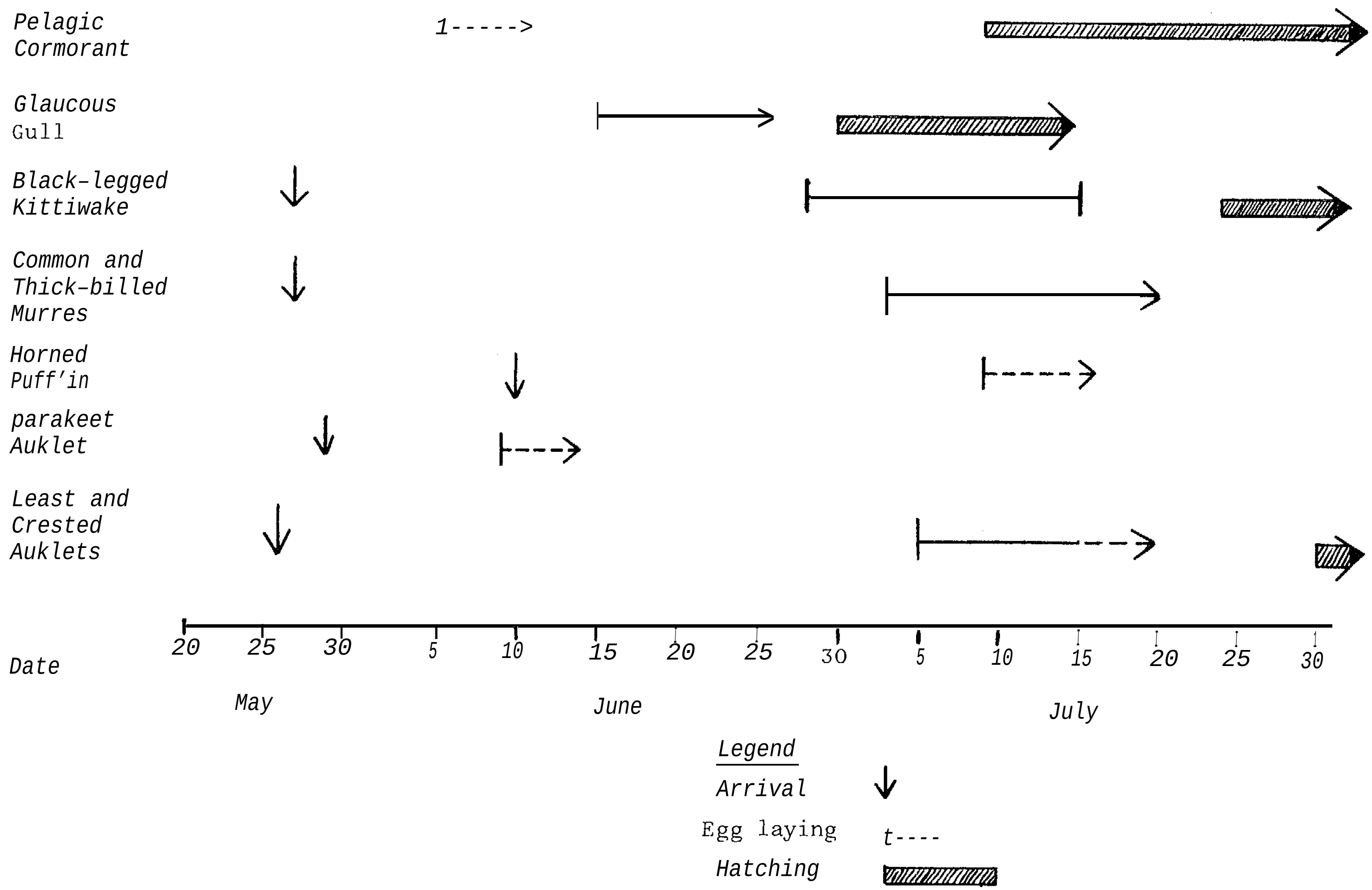


Table 7. Arrival dates of birds at Little Diomede.

Species	1953*	1958*	1977	Remarks
Kittiwakes	May 15	May 14	May 27	First sighted
	May 21	May 20	May 29	First on cliffs
Murres	April 27	May 16		First seen
	May 3	May 20	May 27	First on cliffs
Parakeet Auklet	May 29	May 26	May 30	First on rocks
Crested Auklet	May 22	May 20	May 26	First seen
Least Auklet	May 18	May 23	May 20+	First seen
	May 25	May 27	June 1	First on rocks
Horned Puffin	June 2	June 2	June 10	First seen
Tufted Puffin	June 2	May, 26	June 15	First seen

+ by Eskimos

* Kenyon and Brooks, 1960.

Arrival is apparently associated with how soon leads open near the island. However, they noted that "breeding activities commenced at about the same time" both years, regardless of when the birds were first seen. We found 1977 to be similar to 1958 when Kenyon observed few large areas free of ice until the latter half of May (Table 7).

Pelagic Cormorant (PAH-ma-sluk)

We first saw cormorants on the cliffs on 20 May, and we found one nest (empty) on 28 May. They nest on large ledges on the murre-kittiwake cliffs and on rock stacks.

On 23 June we found a nest on the Half Parapet (Figure 2) with three eggs in it. The nest contained three naked chicks on 10 July. All three had nearly fledged by 2 August.

In a sample taken at the end of July and beginning of August, four nests contained a total of 11 chicks, and one nest contained one chick and two eggs. There were three other nests which were all empty.

We often saw cormorants feeding on either side of the bar which extends west from the village.

Glaucous Gull (KAY-pok)

Glaucous Gulls were already present when we got to Little Diomede on 19 May. In addition to the breeding birds on the island, there appears to be a large number of transient non-breeding birds, including some subadults. The gulls often collect in groups of up to 50 around the piles of garbage thrown from the village onto sea ice, and around the discarded walrus and seal remains. In one such aggregation in early June, we saw 9 subadults in a group of 48 gulls.

They nest on top of rock stacks, high outcrops, and flat grassy ledges. We found a nest with one egg on 18 June, and we saw two nests each with three eggs on 23 June.

We saw an all-downy chick in a nest on 1 July. Eleven chicks were produced from the seven nests we followed. At least one three-egg clutch was lost, and another produced one chick.

Glaucous Gull pellets that we found contained songbird feathers and small bones. We saw some murre eggshells and a few Pelagic Cormorant eggshells in the vicinity of gull nests. Although we have seen the gulls feeding on Crested Auklet carcasses, we found many dead puffins and auklets that were untouched. Although the gulls clearly are predators, we could detect no serious impact of their predation on the seabirds.

Black-legged Kittiwake (KAY-po-suk)

Seasonal and daily changes in numbers --

We saw kittiwakes first on 27 May. They settled on the cliffs on 29 May. The number present from day to day fluctuated widely until 15 June (Figure 5). On 31 May we counted roughly 12,000 on a trip around the perimeter of the island.

Although we had the impression of a more stable population present after mid-June, the numbers we counted at study sites (shown in raw form in Figure 6) varied widely. Counts *at study sites were made mostly at the same time of day (mid-to-late afternoon) so should be comparable between proximate* dates. The number of birds present rises to a peak just after the peak of laying, but then drops by 25% two days later. Although subsequent peaks are all around 700 birds, there are conspicuous drops which we are unable to correlate with environmental events. The

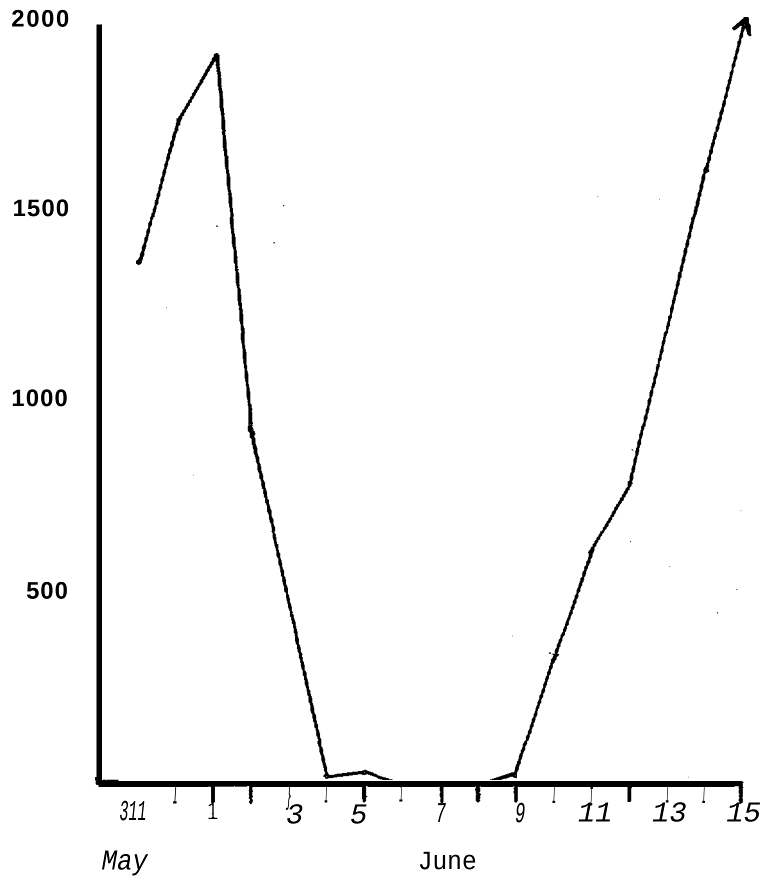


Figure 5. Number of kittiwakes counted at study sites 1 through 15, 30 May – 15 June.

Figure 6. Number of kittiwakes counted at study sites 16–18 in *raw form.*

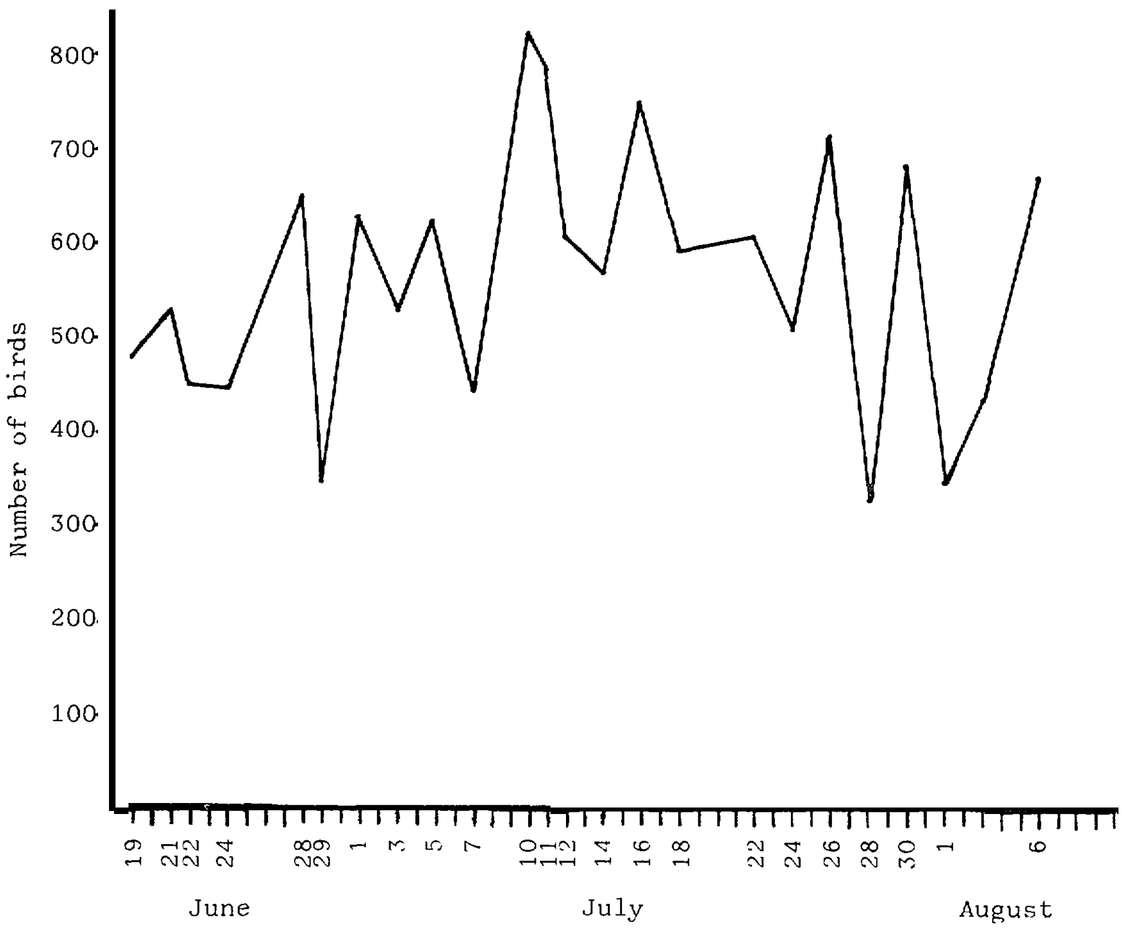
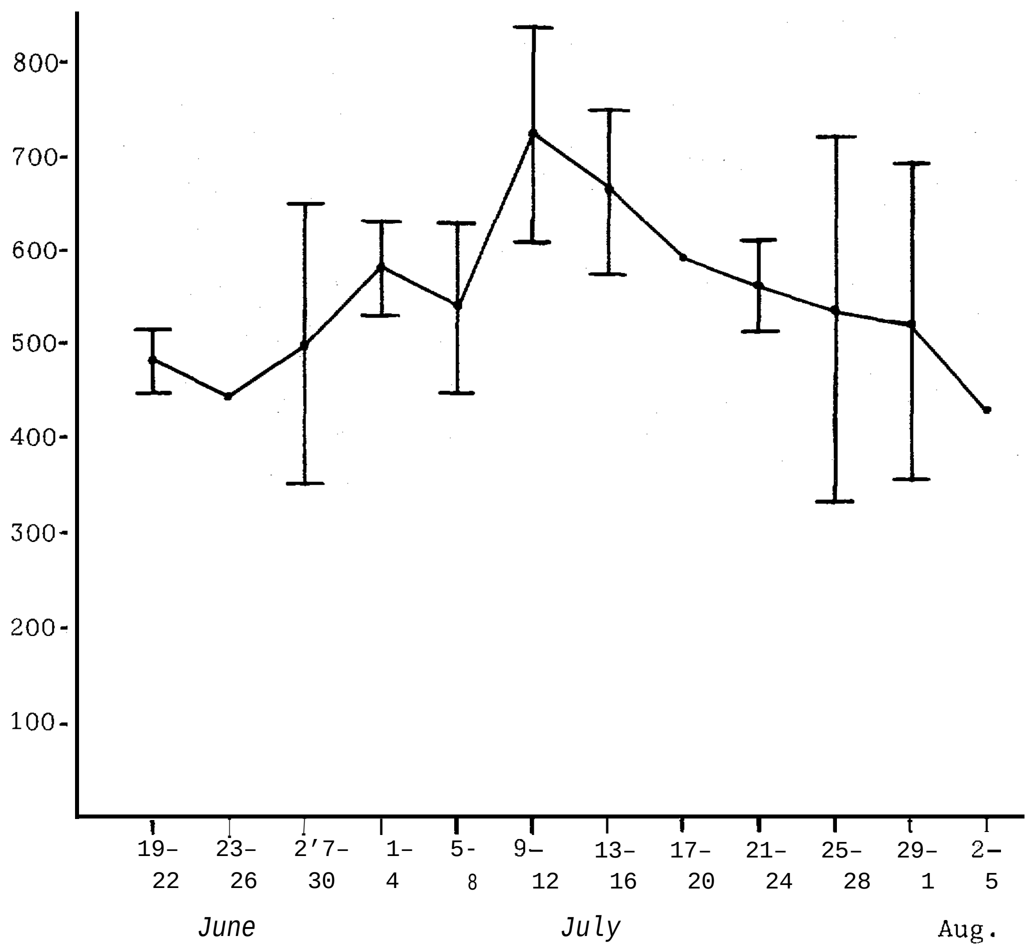


Figure 7. Four-day ranges and means of numbers of kittiwakes *counted at study sites 16-18.*



ranges and means of these numbers over four-day (usually two-visit) periods are shown in Figure 7.

The results of our two long counts to determine the kittiwakes' daily schedule are shown in Figure 8. The graphs show that the pattern changed between early and mid-July, which is consistent with our observations at Bluff in 1977. This means that censuses, if they are to be corrected to the daily activity pattern, should be made in close proximity to the daily activity count.

Nesting Habitat --

Kittiwakes are found on the lower cliffs; almost none are above 50 m over the water. Although larger numbers are present on the south end of the island, they appear to be more densely packed on the north and northwest sides, where there are many large, sloping ledges that are built up with pads of old nest material. Some of these pads are as much as one foot high.

Breeding Schedule --

We observed pairs of kittiwakes "choking" on nest sites the first day they landed on the cliffs. Nest building did not begin until after 15 June. We saw copulations first on 21 June. We found the first egg 28 June, and by 1 July several nests had two eggs. *The first hatching was on 24 July. It appears that the breeding chronology of kittiwakes at Little Diomede was similar to that at Bluff in* 1977. *However, the large percentage of eggs still unhatched on 11 August suggests that the season on Little Diomede was later than Bluff for a large number of birds. Figure 9 shows the number of new eggs and chicks seen on each visit to the study sites. We evidently missed seeing some eggs when they first*

Figure 8. Daily attendance pattern of Black-legged Kittiwakes at Little Diomede *Island. (Study sites 17 and 18.)*

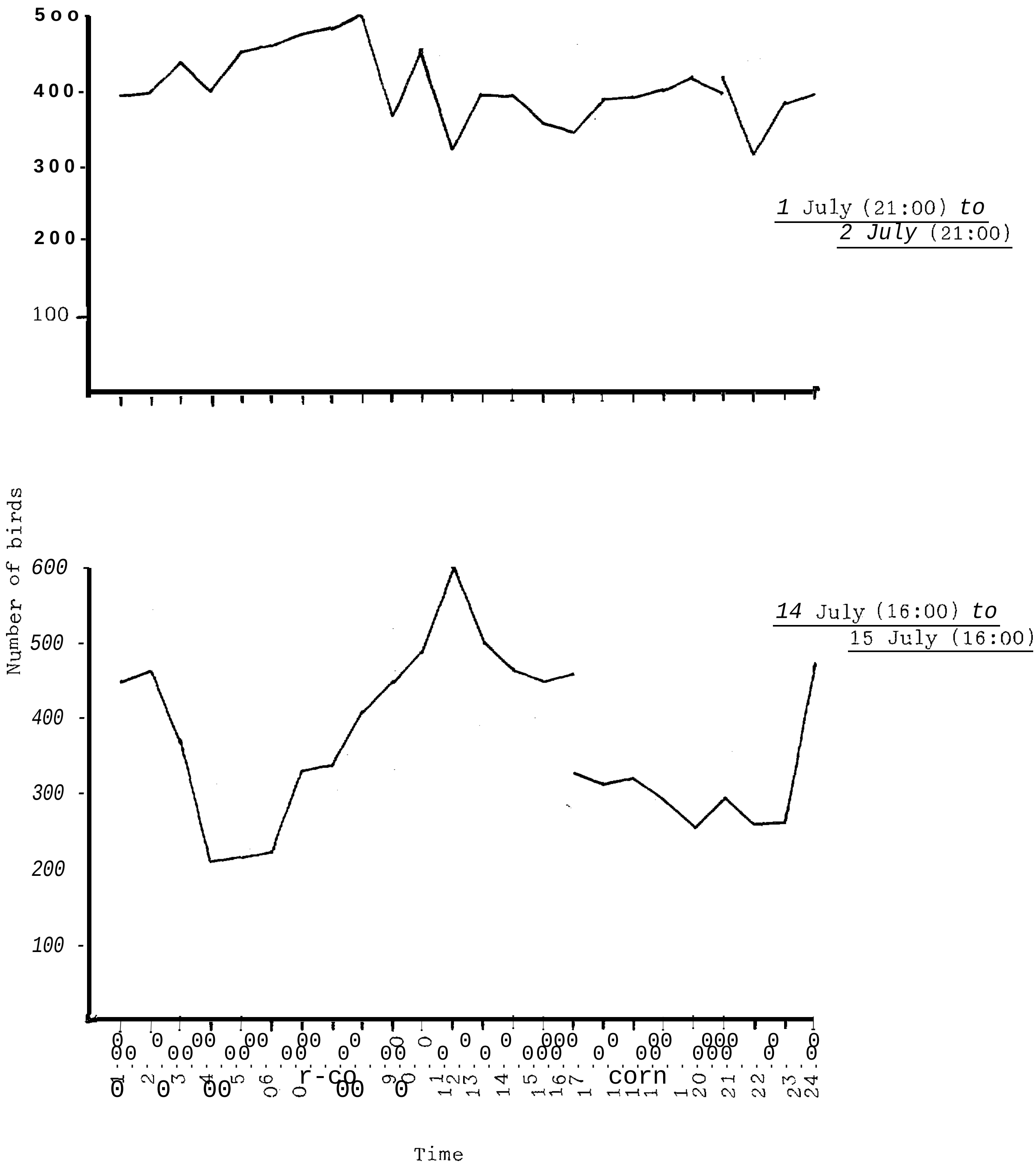
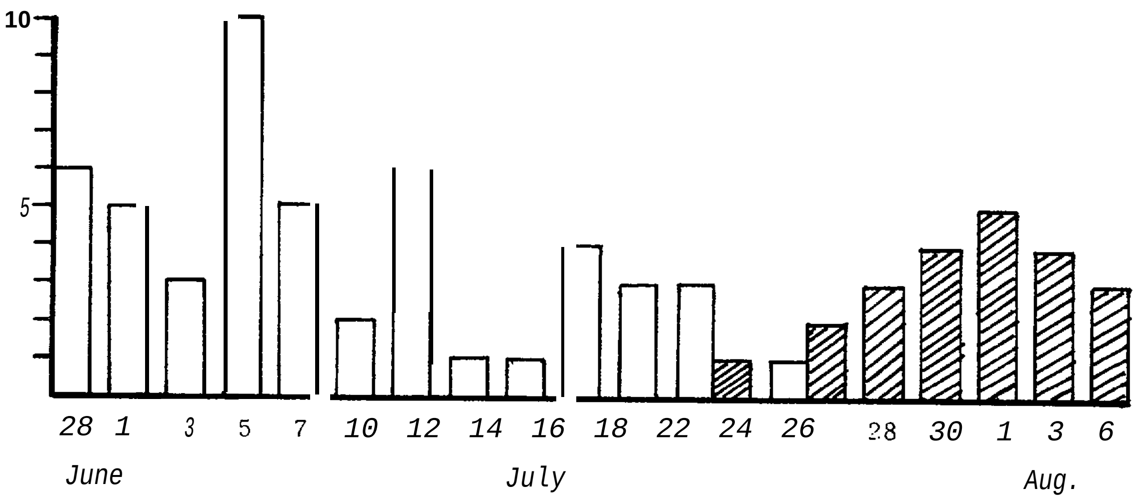


Figure 9. Laying and hatching of Black-legged Kittiwakes, Little Diomede, 1977.

Number of new eggs and chicks seen on each visit to study sites 16-18. Clear bars represent eggs; cross-hatched represent chicks.



appeared, so Figure 9 does not show complete laying or hatching curves.

Also as at Bluff, the Diomede kittiwakes had a second pulse of nest-building activity, occurring in late July. Many sites that previously had not been developed received new material, and many old sites had additional material added to them. We saw groups of 10 to 15 kittiwakes pulling grass off the slopes above the cliffs in this period. Orville Ahkinga of Ignalook told us that this second building peak occurs every year.

Reproductive Success --

Table 8 summarizes kittiwake reproduction at Little Diomede in 1977 as determined at study sites. Note that the sites on the east side of the island were visited only seven times over the season, because of their relative inaccessibility. Thus it is possible we missed recording eggs that were laid and disappeared before we saw them. The data from the east side may show higher success for that reason, and have been kept separate in the table. In the following discussions, we will refer to our more thorough data from the west side.

We have data only up to 11 August, which was before all kittiwake eggs had hatched, and before any chicks had yet fledged'. It seems that reproduction to that point was better than it was at Bluff in 1977, and certainly better than the near total reproductive failure throughout the northern Bering Sea in 1976 (Searing; Springer & Roseneau; NOAA 1978).

The main cause of low reproduction in the kittiwake colonies of the northern Bering Sea during 1976 and 1977 has been poor egg production; i.e., far fewer sites receive eggs than are occupied. At Bluff in 1977, 26% of nests that were at some time built upon received eggs; at Square at Bluff in 1977 was similar, and took a sharp rise after 24 July, peaking in early August at a number higher than the earlier peak. We do not know the shape of the graph after we left Diomede, and whether the numbers increased in August. There may in fact have been a period of stress through July during which the number of birds at the cliffs was depressed. However, poor weather does not seem to have occurred on the days when attendance dropped, and food (see below) seems to have been abundant close to the island.

Feeding and Food Sources --

We seldom saw feeding behavior close to the island until the end of June when large aggregations of feeding kittiwakes began to form over the bar that juts out west of the village. On 4 Julywe counted 4200 kittiwakes feeding there; on 15 July we counted 8000 at once. Occasionally in the first half of July we saw Gray Whales also apparently feeding in the vicinity of the bar. We assume that the current upwelling over the shallow bar makes it a convenient place to catch small crustacea. When feeding at the bar, kittiwakes landed in the water to the south of it and allowed the current to carry them over it. They repeatedly dipped their bills shallowly into the water as they drifted. When they were down-current of the bar, they flew to the south of it again and repeated the process. We interpreted the presence of red guano under many kittiwake nests to be evidence of crustacea in their diet.

Murres -- Common and Thick-billed (AHK-puk)

The arrival of murres, according to the Eskimos, occurs as soon as leads open near the island. Kenyon and Brooks (1960) sawmurres moving north past the island before any birds settled onto the cliffs. This year none landed on the cliffs until 27 May, although they flew near the cliffs on 26 May. The first birds on the cliffs were Thick-billed. We did not see any Common Murres until 31 May.

The number of murres present from day to day was erratic, fluctuating between counts of zero and 2000 until 24 June, after which there were birds present continuously and the overall population appeared to increase. Figure 10 shows the variability in numbers of murres counted at sites visible from the ice before mid-June; Figure 11 shows the number of murres counted at cliff-top study sites near the village from mid-June until early August. The peak numbers get larger as the season progresses. We found this to be the case at Bluff as well in 1977.

We made two day-long counts of murres, one in early July and one in mid-July (Figure 12). The erratic nature of the murres' daily schedule, *seen* as a 30% fluctuation in Common Murre numbers between hours, makes it difficult to predict a preferred time for censusing. However, the census of 15 July was made just after the conclusion of a daily activity count, so we feel confident in using that count to extrapolate to the maximum and minimum number of murres from the number we counted.

Nesting Habitat --

Most murres on Little Diomede nest on the lower half of the cliffs; few (except for some on the north end of the island) are higher than 70 m from the water. Thick-billed Murres are seen on small, narrow ledges, whereas Commons are found on broad, densely-packed ledges. Thick-billed Murres are most numerous where the cliffs are composed of broken rock ledges. The predominance of such cliffs on the east side may account for the relatively higher proportion of Thick-bills there. Similarly, the

Table 8. Reproduction of Black-legged Kittiwakes on Little Diomede Island. 1977.

	West Side (Study sites 16, 16B, 17, 18)	East Side (Study sites 19B, 20)
nests	116	46
eggs	57	27
clutches	45	23
chicks known hatched	23	3
broods	20	3
As of 11 August:		
eggs remaining	20	20
clutches	20	19
chicks remaining	19	3
broods	18	3
eggs per nest	.49	.59
clutches per nest	.39	.50
avg. clutch	1.27	1.17
chicks hatched per nest	.20	.07
broods per nest	.17	.07
surviving chicks per nest	.16	.07
surviving broods per nest	.16	.07
surviving chicks per egg	.33	.11
surviving chicks per clutch	.42	.13
As of 11 August: surviving eggs and chicks per nest	.34	.50

Rock near Bluff, the figure was 48%. Square Rock exhibited reproductive success four times higher than at Bluff Cliffs. At Little Diomede, about 40% of nests received eggs -- a figure closer to the one at Square Rock -- so we presume success to have been higher.

Egg mortality has also been shown to be a major cause of lowered reproductive success in Alaskan kittiwake colonies. We have evidence at Bluff in 1976 and 1977 that a period of stress during incubation forced adults to leave their nests. At Little Diomede in 1977, 33% of the eggs that were laid had hatched and 35% had not hatched and were still in their nests on 11 August, while at Bluff on 11 August, 28% of eggs had hatched, and 14% had not hatched and were still in their nests. It could be that some eggs at Diomede proved to be infertile after 11 August, and some may have been lost after hatching. If this was the case, productivity was at a maximum twice as high as that at Bluff (68% vs. 33% surviving) and at a minimum identical. It is probable, however, that the best explanation of these differences is that the breeding season on Little Diomede was later than at Bluff.

Despite the comparatively low rate of egg mortality at Little Diomede, we do have indirect evidence of some period of stress occurring in mid-July. We saw several. nests with eggs left unattended for periods of 10 to 15 minutes during visits to our study sites between 10 and 15 July. This was the time when the number of kittiwakes counted at study sites dropped sharply before rising again. Nevertheless, almost no egg mortality occurred in this period.

The mean number of kittiwakes counted at study sites (Figure 7) shows a general decrease following the peak of laying. The data obtained

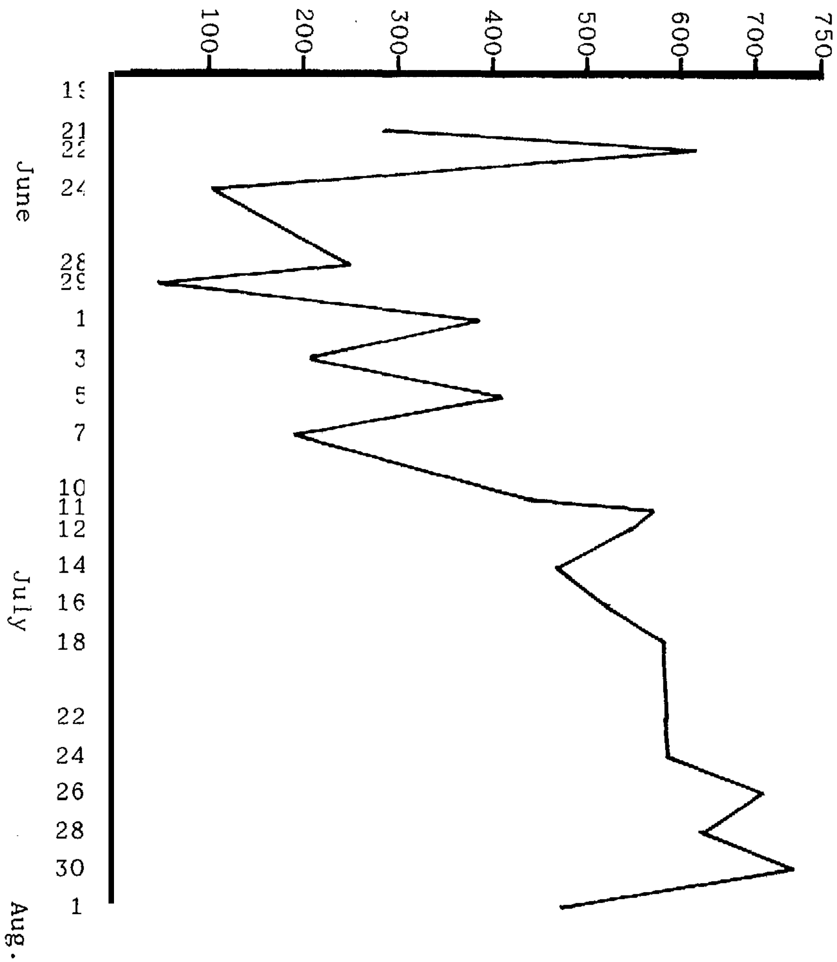


Figure 11. Number of murres counted at study sites 16-18.

Figure 10. Number of murres counted at study sites 1-15 to 15 June.

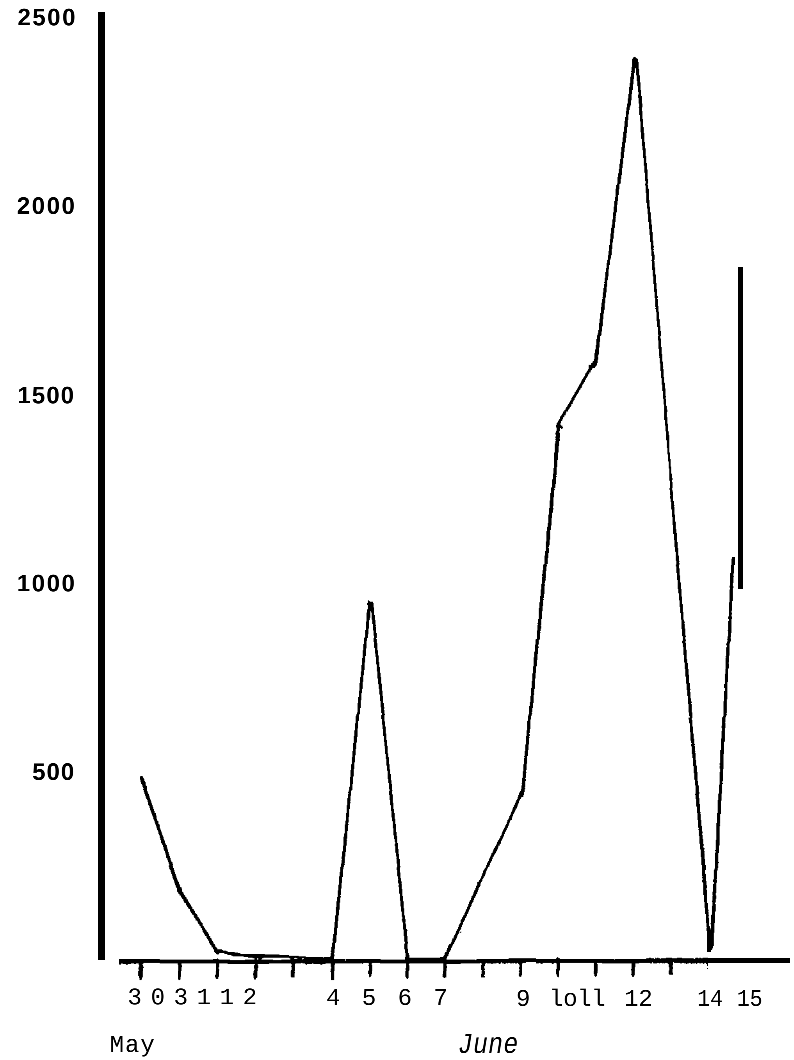
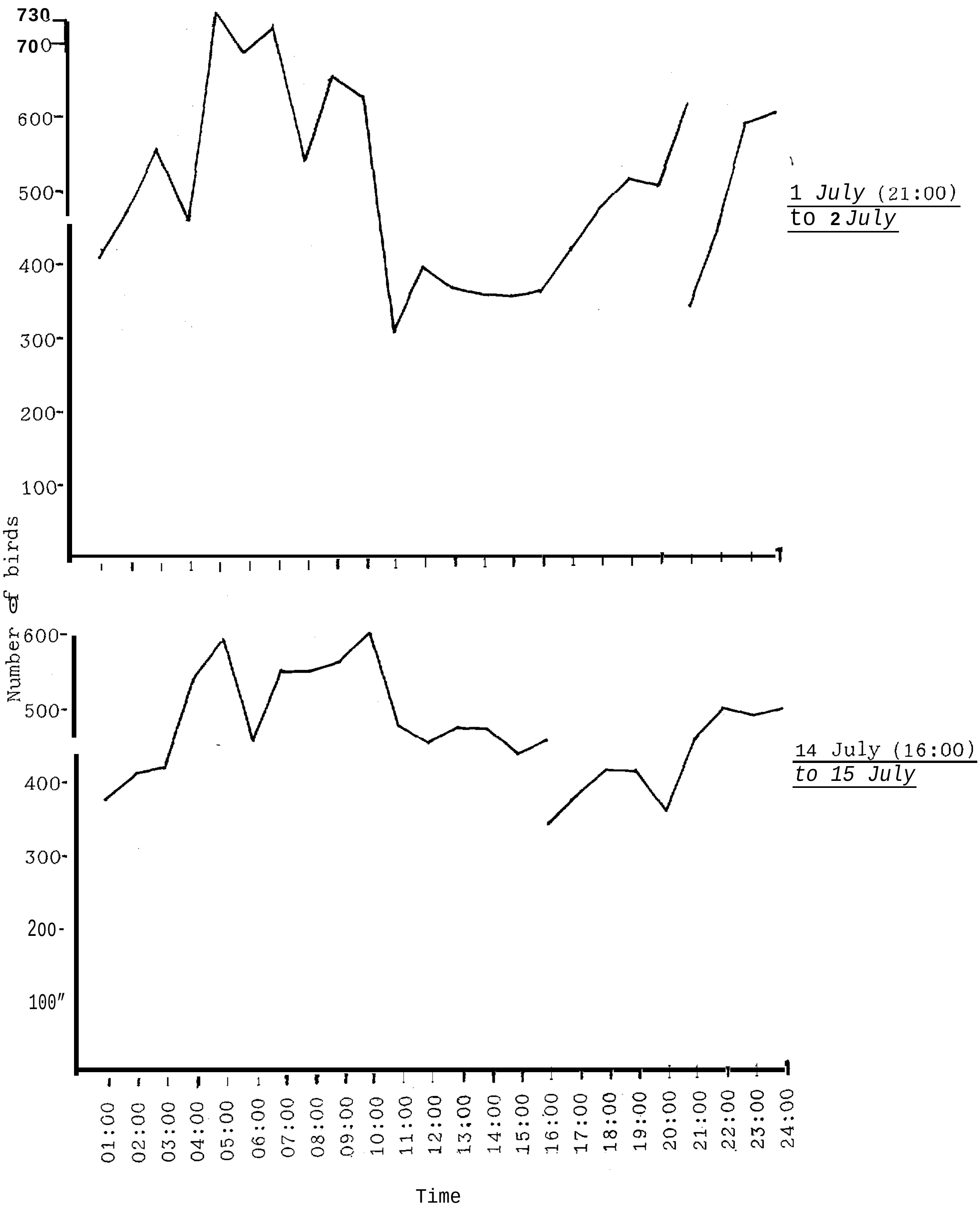


Figure 12. *Daily attendance pattern of Common and Thick-billed Murres at Little Diomede Island. (study sites 17 and 18.)*



structure of the ledges on Fairway Rock may account for the overwhelming numerical superiority of Thick-bills there.

Reproductive Success --

We have no criterion on reproductive success as our field party left the island on 11 August, by which time no murre eggs had yet hatched. According to these data, hatching was at least two weeks later than at *Bluff, and roughly the same as at the Cape Thompson* area to the north, *where Springer & Roseneau (1978) report 50% hatched* by 20 August 1976.

Breeding Schedule --

The first copulations were observed on 21 June. By 24 June, murres were harder to flush off the cliffs, which led us to believe it was close to egg-laying time. On 28 June, an Arctic Fox was seen carrying what may have been a murre egg, but the first Thick-billed Murres in an incubating posture were not seen until 3 July, and Common Murres on 5 July. We definitely saw Thick-bills with eggs on 3 July, and Commons with eggs on 10 July. By 15 July there were many eggs; some of those collected by Eskimos had developing embryos.

Feeding and Food Sources --

We have commented elsewhere on the relative abundance of Thick-billed Murres in the Bering Strait as compared to Norton Sound. At Cape Thompson, Springer & Roseneau (1978) reported that Thick-billed Murres had more diverse food sources in 1976 than did Commons, including a high percentage of invertebrates, especially shrimp, in their stomachs. We saw few fish brought to the ledges by murres at Little Diomede, and were unable to identify those that we did see, but Thick-billed Murres' droppings were primarily red in color, as distinct from the greenish-yellow of Common droppings, probably indicating a higher concentration of crustacea in the Thick-bills' diet. Several authors (Tuck 1960, Uspenski 1956, Belopolski 1957) have observed that Thick-billed Murres include more crustacea in their diet than do Common Murres.

Birds visible in the leads early in the season seem not to spend much time feeding, and later in the season most feeding seemed to be done away *from the island.*

Pigeon Guillemot (SIK-vuk)

Guillemots were first seen on the water on 26 May, and perched on rocks on 27 May. We found they were usually in pairs, and nested among the boulders at the base of the island. We saw a copulation on 20 June. In a search among low boulders at the southeast corner we found much guano but 'no nests.

Horned Puffin (KLANG-uk)

Seasonal and Daily Numbers --

Horned Puffins arrived on 10 June, when we saw both species in the water and on the island. Throughout the season, the largest numbers were on the island in the evening, arriving after 15:00 and leaving the next morning by 11:00. From day to day, as has been our observation at other colonies, their numbers were extremely erratic. In general, more seemed to be present on foggy days.

Nesting Habitat --

Horned Puffins nest in crevices at the top of the kittiwake/murre cliffs, and in rock outcrops all the way from the beach to the top of the island.

Breeding Schedule --

We first discovered eggs in burrows on 9 July, and found more in the same area on 27 July. None of these eggs had hatched, and several had been lost, by 11 August.

Reproductive Success --

Of 12 occupied nest holes into which we could see, two definitely lost eggs, and four others that were consistently occupied produced nothing. The remaining six eggs had not hatched by 11 August. It is not apparent to us how a puffin loses its egg.

We found that frequently there were no suitable burrows near where Horned Puffins perched on outcrops, and that apparently suitable crevices were unoccupied. In many areas of outcrop where we made thorough searches after flushing puffins, we could find no nest holes. We conclude from this that a large percentage of the puffins perching on the island were non-breeding birds. The same has been reported to be the case by OCSEAP workers in other colonies, and should account for the wide fluctuations in the number of puffins seen from day to day.

Tufted Puffin

We have little information on Tufted Puffins because of their relative scarcity. They were first seen on 15 June, and by 23 June were occupying some of the same areas as Horned, as well as the grassy slopes. Tufted Puffins occur mostly on the lower part of the island, and are seldom found above 100 m. Their low numbers on Diomede suggests that their numbers are limited by Arctic Foxes, since the proportion of Tufted Puffins is so much greater on Fairway Rock, where there are no over-summering foxes.

Least Auklet (AH-po-lik) and Crested Auklet (TAY-ak)

Seasonal and Daily Changes in Numbers --

We first saw Crested Auklets in small groups on the water on 26 May. The Eskimos reported first seeing Least Auklets flying over the water on 20 May; we first saw Least and Crested Auklets in a massive flight to the talus slope above the village on the evening of 1 June. During this flight, the sky became darkened with uncountable numbers of birds circling in a gyre that swept past the slope. As the flocks passed, some would break off and land, until most were sitting on the slope. These flights to the island in droves, which continued throughout June, started about 18:00 and peaked at 21:00 or 22:00. The auklets would start to leave in mid-morning, and would mostly be gone by 11:00. On days of inclement weather in the first half of June, either small flights or no flights at all occurred.

During the early part of the season, the auklets were very active and vociferous after they had landed, exploring under rocks and displaying, and were easily provoked into mass fly-offs. This makes them difficult to count, but in early June we made a rough maximum estimate of three Least Auklets per m^2 on the talus above the village. The number of auklets appeared to decrease after the first week of June and the proportion-of Crested Auklets rose. If the departing birds were those who for some reason would not breed that summer, then our density counts which were made in late June, should be close to the density of birds that were breeding.

Throughout the season, the auklets were most numerous on the island at night, generally arriving after 19:00 and departing before 12:00.

Figure 13 shows their daily schedule as determined during daily activity counts made in July.

Nesting Habitat --

Least and Crested Auklets appear most dense on talus slopes with no surface soil. Cresteds tend to nest in deeper, denser talus (children are able to get few eggs compared to the number of Least eggs they find) and a few nest among broken rocks in the grassy slopes. Virtually none nest on the flat plateaus on top of the island, probably because of the poor draimge under rocks there.

Reproductive Success -- no information

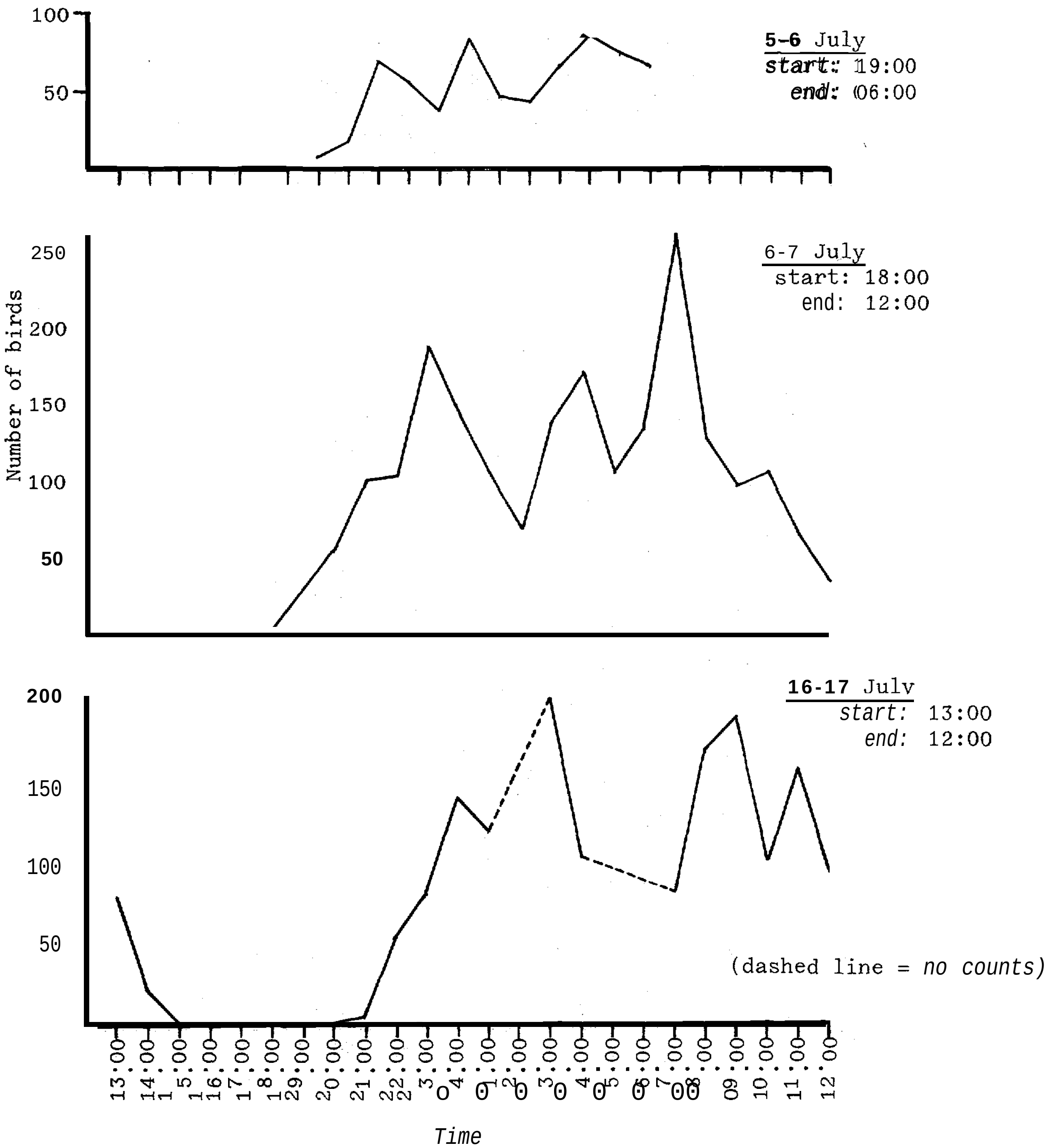
Breeding Schedule --

We saw Crested Auklets engaging in fights and mutual preening from 15 June to 6 July. We first heard auklets under the rocks during daytime hours on 17 June, so it is possible egg-laying began close to that date. Eskimo children collected their first Least and Crested Auklet eggs on 5 July and continued taking some until 15 July, when they said “eyes” (embryos) were developing. Orville Ahkinga reported hearing chicks under the rocks on 30 July. We found three downy Least Auklet chicks of about three inches in length on 4 August.

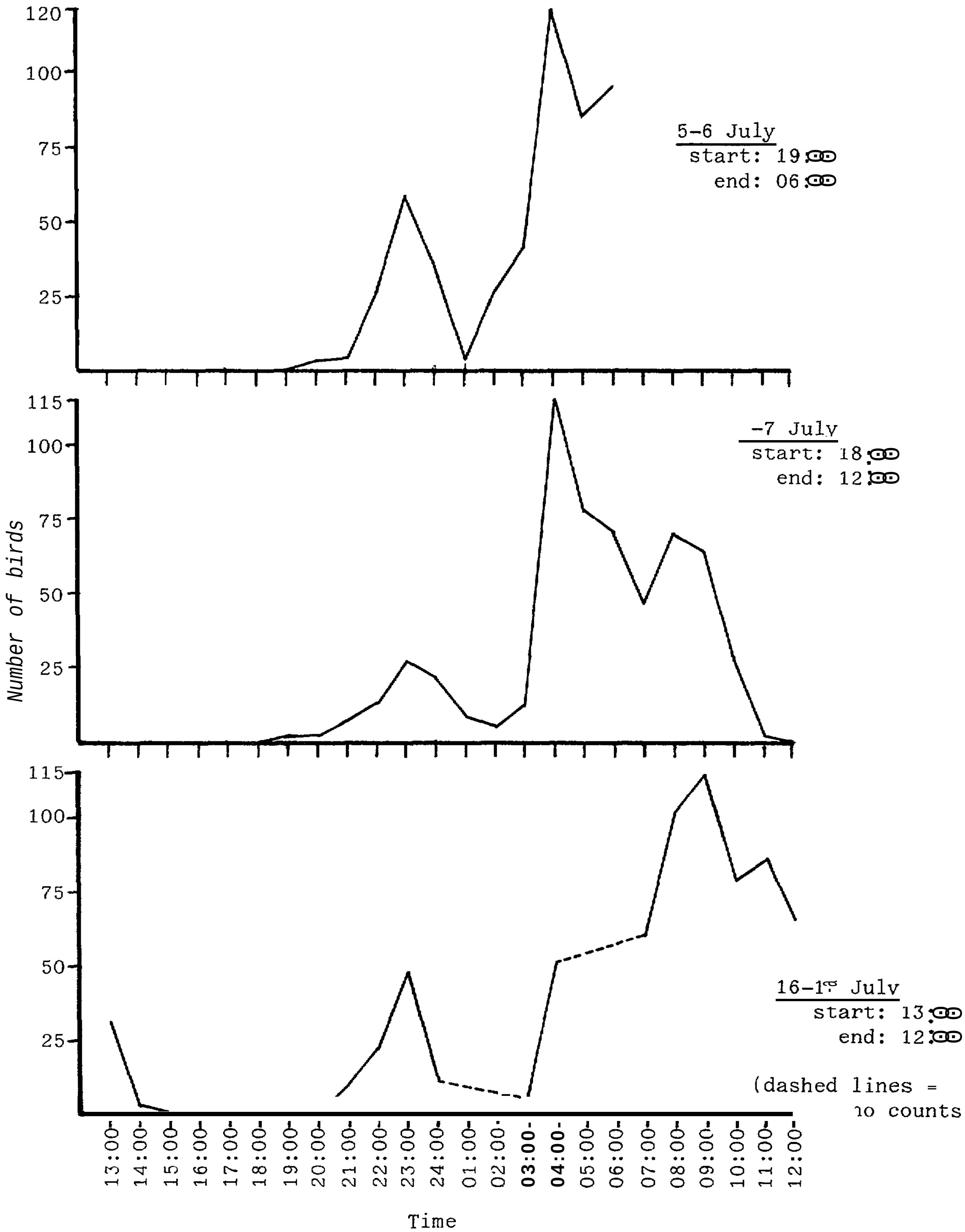
Feeding and Food Sources --

All three auklet species seemed to feed far from the island; we seldom saw feeding nearby. In early July we saw a group of 80 Crested Auklets in the water near NE Cliffs. They repeatedly dove in unison and stayed submerged for about 60 seconds.

Figure 13A. Daily *attendance pattern of Least* Auklets *at Little Diomede.*
(On talus slope above *the village.)*



F gure 13B. Daily attendance pattern of Crested Auklets at Little Diomede. (On ta us slope above the cillage.)



Parakeet Auklet (SAH-gi-uk)

Seasonal and Daily Numbers --

We first saw Parakeet Auklets on 29 May on the water; 30 May on the cliffs. They were not numerous until 9 June. Compared to Least and Crested Auklets, the Parakeet population is small. On their arrival at the beginning of June, the grassy slopes on which they nest were still snow covered; thus the auklets spent their evening hours on the edges of the murre and kittiwake cliffs and the daytime hours scattered among murres in the leads. They arrived on the cliffs about 23:00 to 01:00 and were gone by 11:00. By the first half of July, the amount of time they were evident on the island increased, with the peak between 03:00 and 09:00. Some remained around until after 12:00. By late July, they were numerous on the island until 15:00 and after.

Nesting Habitat --

Parakeets nest in burrows dug under rocks on the soft, grassy slopes. They are concentrated on the lower third of the slope, with some at the top, except at the south end of the island where they are distributed evenly along the entire height.

Breeding Schedule --

We have scant information about their reproduction. We discovered a few eggs on 9 July, but have no laying or hatching data.

Feeding and Food Sources --

They apparently feed away from the island.

Common Raven

Several were present at the time we arrived. The maximum we saw at once in early June was five, but it was difficult to census the birds because they were active in foraging.

We found one nest on the Half Parapet; there may have been another nest at the south end of the island. On 26 May there was an adult sitting tightly on the Half Parapet nest; on 23 June we saw four small downy young; on 14 July there was one fledged young perched below the nest, and two nearly fledged ones in it. On 10 August, we saw two adults and three immatures on top of the island, so we suspect one nest on the island fledged three young. Other predators on Little Diomede are Snowy Owls (possibly two pairs) and Pergrine Falcon.

OBSERVATIONS ON THE DISTRIBUTION OF BIRDS AT SEA

Our major observations are the same as those of 1976, that there is a lack of birds in Norton Sound and a concentration of birds in the Chirikov Basin. East of a line drawn from the east end of Saint Lawrence Island to Cape Spencer (Figure 14) most periods of observations have no birds. West of that line onc may see as many as 200 birds in a five-minute period. Very few periods have no birds at all. Five-minute periods at 120 knots, using our angle of sight, represents 1 square kilometer of ocean surface. The dataare presented of Figures 15A-D.

There is an oval area with gaps that extends 100 km to the south of King Island, to the International Date Line and beyond to the west, barely 25 km to the east of King Island and north to the Bering Strait, in which one can expect to see 10 to 50 birds per square kilometer. Inside that limit there is a smaller area, perhaps 75 kilometers from King Island to the south in which one can expect to see densities of up to 100 birds per square kilometer.

A similar area of high concentrations, 50-100 birds per square kilometer, exists extending 50 kilometers north of Gambell with a zone of moderate density, 10-50 birds per square kilometer, extending out 90 kilometers from Gambell and 50 kilometers from Savoonga.

Another area of high density is found from 25 kilometers south of Fairway Rock to 25 kilometers north of Little Diomede, up to 200 birds per square kilometer; and an area of lesser density, 10-50 birds per square kilometer, extends another 50 kilometers to the north of Little Diomede Island.

We have speculated elsewhere (Annual Reports and Proposals) on the general reasons for the spectacular differences in the concentrations of birds at sea in the Chirikov Basin as contrasted to Norton Sound. The flights in 1977 have let us outline the eastern edge of the zone of concentration more carefully, as mentioned previously, as a line extending from the east end of Saint Lawrence Island to Cape Spencer. East of this line, one must be within 10 kilometers of the cliffs at Sledge Island or 20 kilometers of the cliffs at Bluff to find concentrations as high as one finds 100 kilometers offshore to the west.

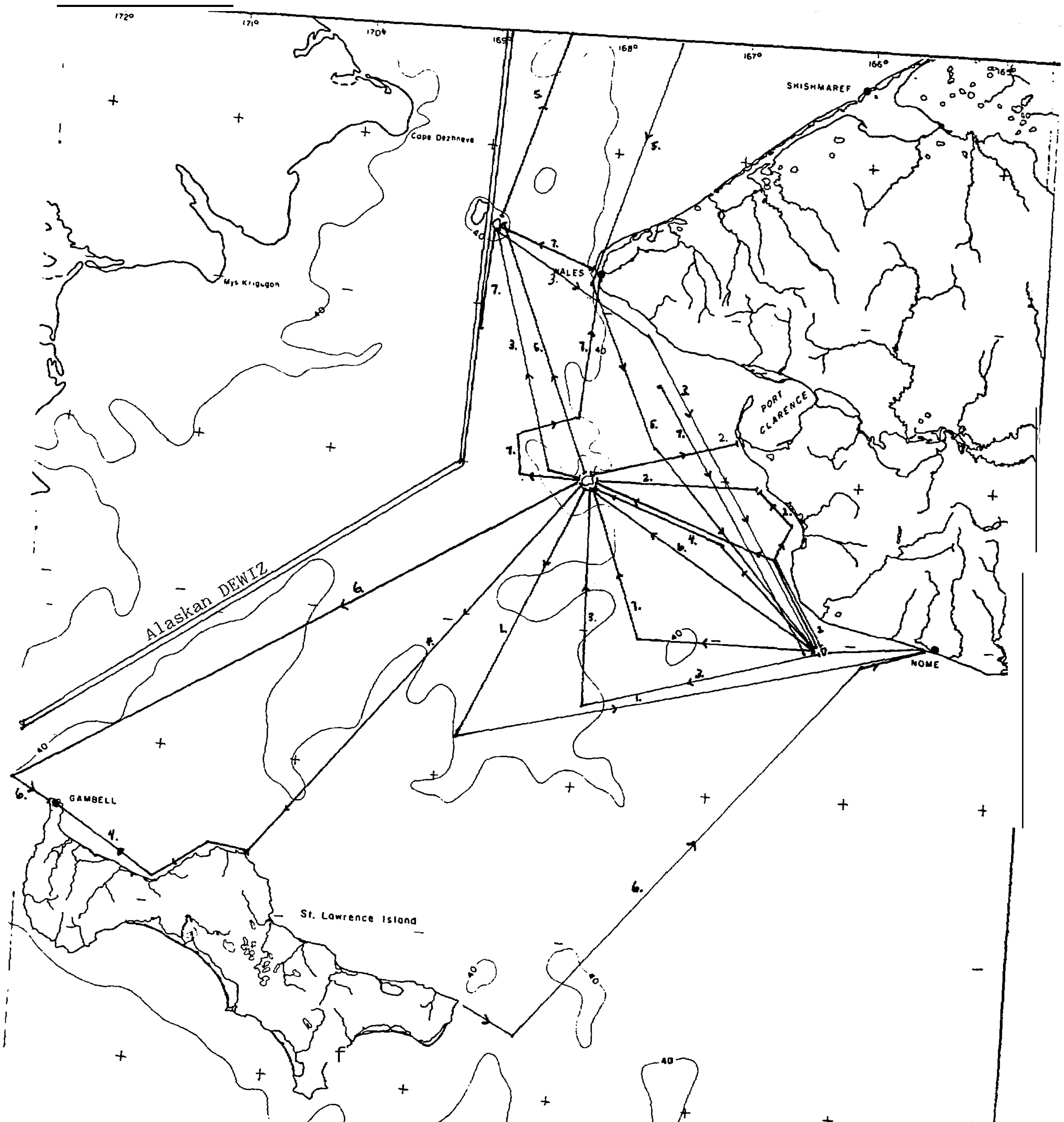


Figure 14. Routes of *Offshore Transects, 1977.*

1. 20 May
2. 2 *June*
3. 22 *June*
4. 23 *June*
5. 24 *June*
6. 21 *August*
7. 22 *August*

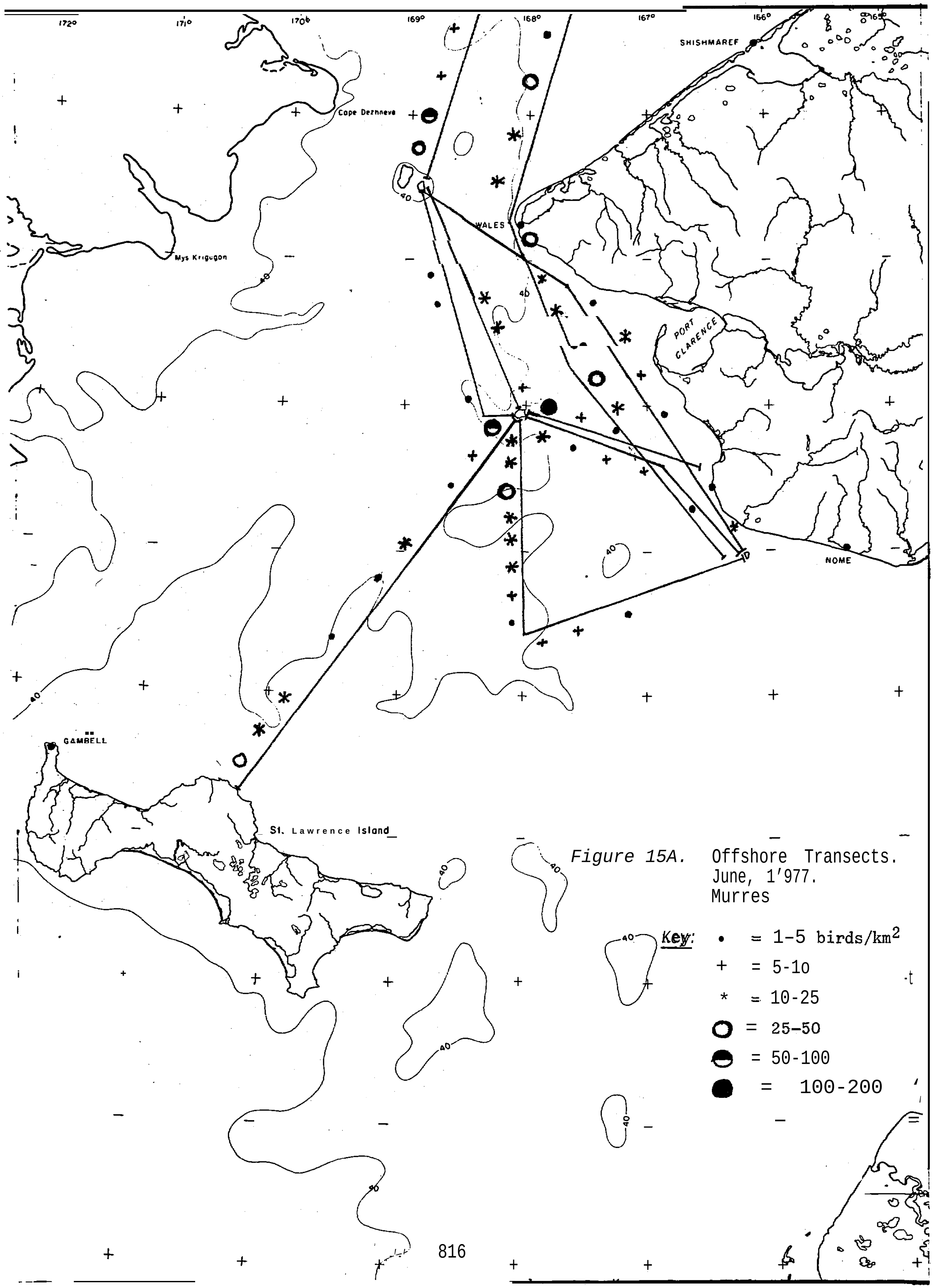


Figure 15A. Offshore Transects.
June, 1977.
Murres

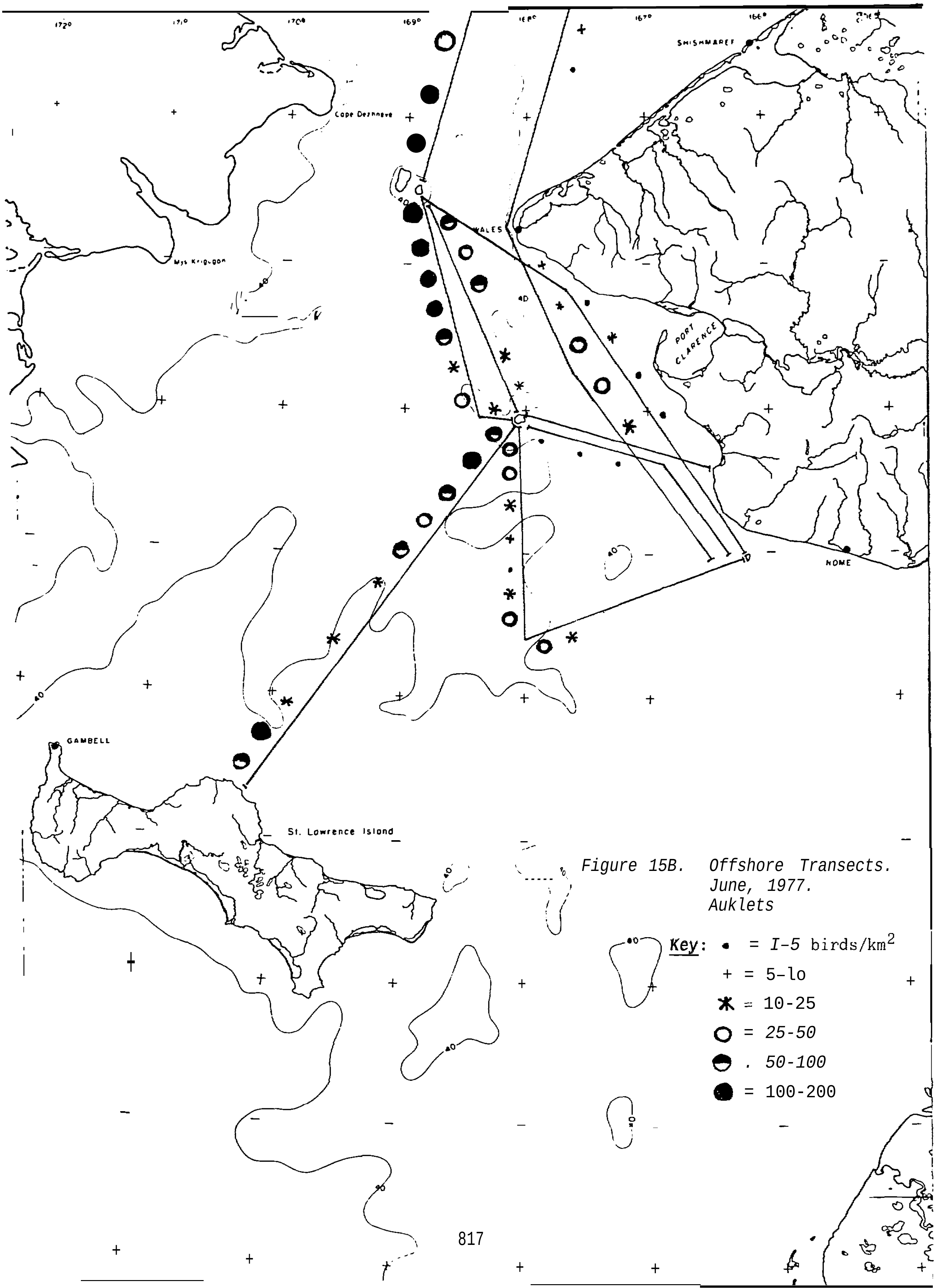


Figure 15B. Offshore Transects.
June, 1977.
Auklets

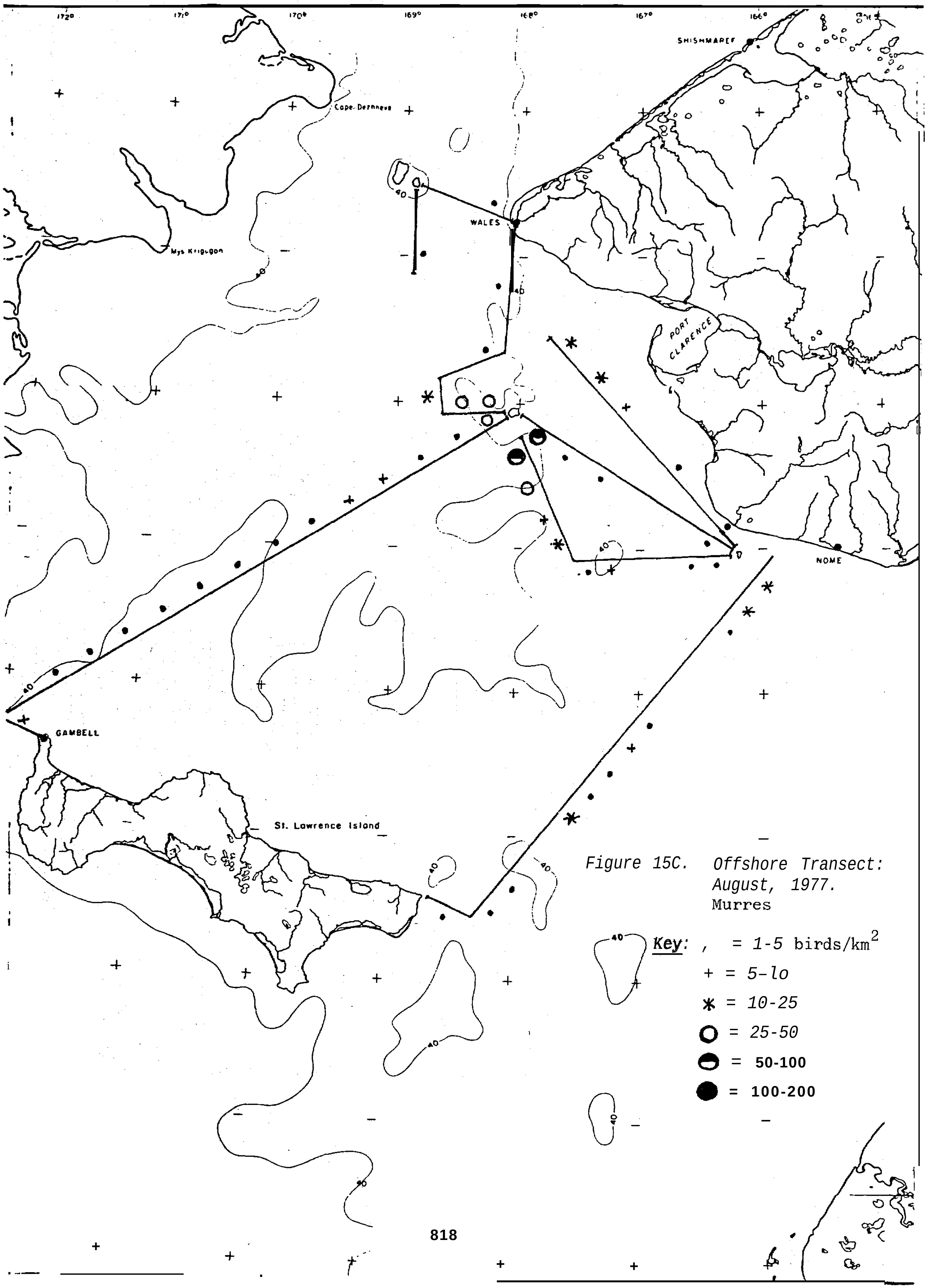


Figure 15C. Offshore Transect: August, 1977. Murres

Key: , = 1-5 birds/km^2
+ = 5-lo
✱ = 10-25
○ = 25-50
◓ = 50-100
● = 100-200

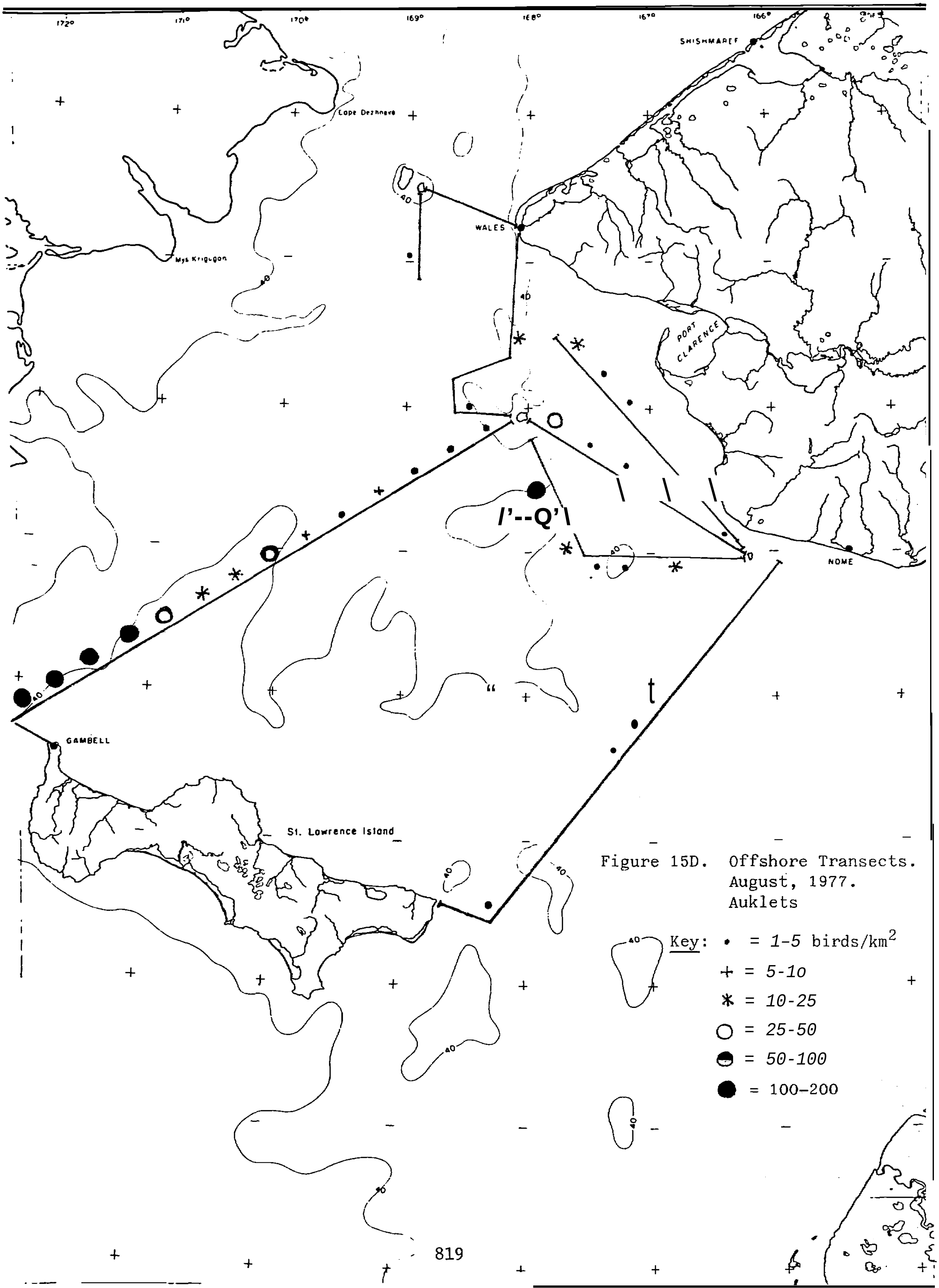


Figure 15D. Offshore Transects.
August, 1977.
Auklets

Key: • = 1-5 birds/km^2
+ = 5-10
* = 10-25
○ = 25-50
◓ = 50-100
● = 100-200

VII & VIII. DISCUSSION AND CONCLUSIONS

Importance of the bird populations at Little Diomede.

The marine birds of Little Diomede are notable for the following:

1) The island supports the major kittiwake colony in the northern Bering Sea Region (pending a more thorough estimate of the numbers at the Southwest Capes of Saint Lawrence Island), and has a relatively high proportion of kittiwakes to murres on the cliffs;

2) There is a tremendous number of Least Auklets on the island; numbers of Crested Auklets is four times and of Parakeet Auklets is half the numbers of the respective species on King Island;

3) The number of murres is relatively small compared to the 200,000 at Cape Thompson and Cape Lisburne, but is comparable to the numbers at King Island and at Bluff, i.e., 50,000 to 75,000. The proportion of Thick-billed Murres to Common Murres is about equal, as is the case at King Island.

4) The numbers of Tufted Puffins, Pigeon Guillemots and Pelagic Cormorants are small. The number of Horned Puffins is relatively large.

5) Although the breeding population of Glaucous Gulls is about what one would expect, the number of non-resident birds is large, presumably a partial result of the supply of human wastes and garbage.

Comparisons with Kenyon and Brooks estimates from the 1950s.

There are familiar difficulties in making comparisons of numbers of seabirds estimated by our party with those estimated by Kenyon and Brooks twenty years earlier.

We asked Kenyon directly how he had made his estimates and learned that his system was very similar to ours, i.e., walking around *the* island on the ice and climbing over the island counting and estimating numbers on each section of cliff and slope. He told us that he reported the totals which he got by this method as the minima in his paper and that he gave the maxima as an indication of the difficulty of getting precise figures.

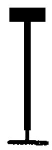
We agree with Kenyon that getting rigorous results and even estimating error is very difficult when numbers are so large, but we must develop some way to compare between years if these data are to be useful. We believe that one way to treat this difficulty is to represent numbers of birds on a logarithmic scale (Figure 16).

We know that the numbers of some species vary widely, some more than others. For example, Glaucous Gulls will aggregate in numbers tens of times the figure for the local breeding population. Horned Puffins appear around the breeding cliffs in August in numbers several times those found in June. The numbers of murres also increase as the season progresses until about mid-August. The numbers of kittiwakes, however, are more stable, but even their numbers may vary over 30% to 50% during the course of one 24-hour period.

We have recorded the variation among counts of the murres on the cliffs at Bluff (Table 9). These counts indicate the magnitude of variation and we have confidence in each of these counts because of the convenience of the study area. The figures in Table 9 are untreated for variation during the 24-hour period and for birds flying off the cliffs. The majority of our counts at Bluff fall between 30,000 and 45,000 murres.

We presume, for comparative purposes, that Kenyon and Brooks' lower figures for Little Diomede are analagous to our counts of 27,000-

Figure 16. (next page) Comparison of numbers of seabirds at Little Diomede Island in the 1950's (Kenyon and Brooks) and 1977, with counts and estimates represented on a logarithmic scale.



Range given by Kenyon & Brooks (1960) for 1953 and 1958.

Range determined in 1977. For kittiwakes, puffins and murres, the lower end is the raw count of 15 July, and the upper end is the extrapolated estimate. For auklets, the upper end is the figure derived from the larger estimate of the total area of the island's slope (5,5 x 10^6 m^2), while the lower end is the figure derived from the smaller estimate of the slope (3.3 x 10^6 m^2) as discussed under "Methods."

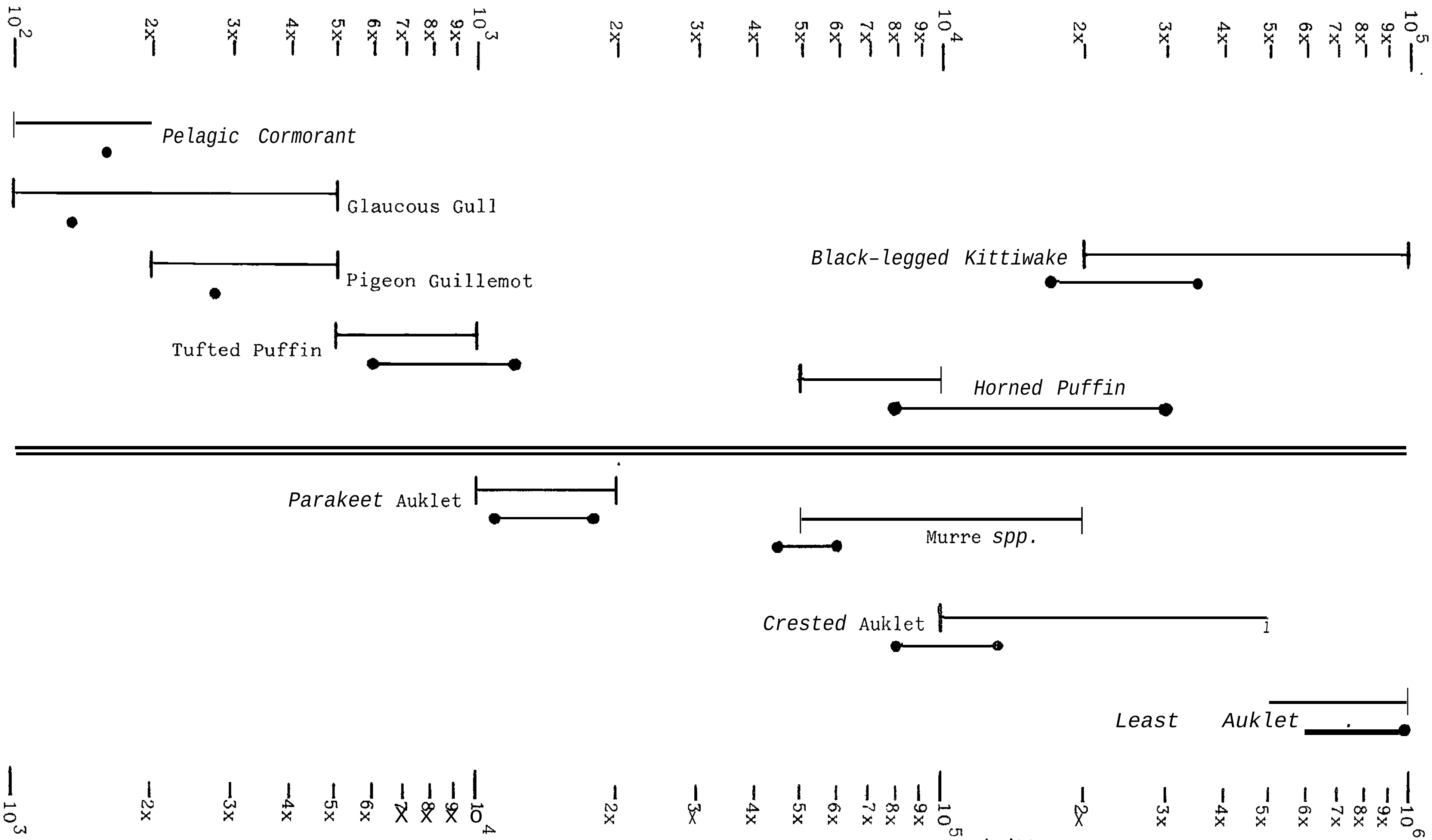


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Figure 16.

Table 9. Ranges of Murre counts at the Bluff cliffs.

	Low Extreme	Normal Range	High Extreme
1975		27,000-57,000	90,000
1976	9,040	32,000-56,000	
1977		28,000-60,000	

Table 10. Comparison of seabird numbers at Little Diomede in 1958 and 1977.

	1958*		1977		
	Minimum	Maximum	Min.	Direct Count	Max.
Pelagic Cormorant	100	200		160	
Glaucous Gull	100	500		135	
Black-legged Kittiwake	20,000	100,000	20,000		35,000
Murres	50,000	200,000	45,000		60,000
Pigeon Guillemot	200	500		275	
Parakeet Auklet	10,000	20,000	11,000		18,000
Crested Auklet	100,000	500,000	80,000		135,000
Least Auklet	500,000	1,000,000	588,000		980,000
Horned Puffin	5,000	10,000	15,000		25,000
Tufted Puffin	500	1,000	600		1,000

* Kenyon and Brooks, 1960.

35,000 at Bluff, and that their upper limits are equivalent to our count of 90,000 or, potentially, an even higher number representing all the birds which may come to the cliffs (including some over-estimation).

Making comparisons using Table 10, we would say that there is no evidence of change in numbers of Pelagic Cormorants, Glaucous Gulls, Pigeon Guillemots and Tufted Puffins. We believe that we can make no comparisons between our high counts of Horned Puffins made in August and those of Kenyon and Brooks's because theirs were made in June before the major influx of Horned Puffins takes place in August. However, our party's count of 8000 birds made on 15 July is within the spread they suggested. (See also Figure 16.)

Differences seem to be suggested in the larger numbers: kittiwakes, murres, and Parakeet and Crested Auklets. The numbers of Parakeet Auklets estimated in 1977 are suggestively close to Kenyon and Brooks's upper limit, while the numbers estimated for Crested Auklets and murres in 1977 are suggestively close to his lower limit. Least Auklets, whose swarms boggle the observer's mind, appear in 1977 to be at the uppermost limit of Kenyon and Brooks's numbers. Kenyon himself doubted that we could draw any conclusions that species numbers have changed in this period.

<u>Historical trends in numbers</u>.

The number of Least Auklets on Little Diomede is so vast that it would require exceptionally detailed efforts to improve on the accuracy or confidence limits of the present data. However, we can draw a few conclusions about murres and Crested Auklets, even though our estimates fall within the same range as those of Kenyon and Brooks.

There was a major decrease in the number of murres at Cape Thompson between the early 1960s (400,000 fide Schwartz 1966) and the last few years (200,000 fide Springer & Roseneau 1978). The fact that our estimate of murres is at the minimum of what Kenyon and Brooks estimated, makes it reasonable to expect that there has been an historical decrease.

Albert Ayahuk and Orville Ahkinga said Crested Auklets have decreased in the last several decades and commented that 1977 was a particularly low year. It is likely that natives have noticed changes among the Crested Auklets because they were an important part of the traditional diet and are still involved in a notable community hunting effort in *which the* auklets *are frightened from their* burrows and caught in hand *nets. The Diomeders say that their hunting* effort has declined over the *years, and our observation of their hunting* techniques suggests that the *impact of natives is minimal.*

In 1976 there were repeated helicopter trips to the island during the summer while a new school was being built, and in 1977 a helicopter was making trips to the island between 25 July and 5 August for installation of a telephone antenna on the top of the island. We have observed at both King Island and Little Diomede that helicopters cause particularly severe disturbances at the colony, scaring most of the birds off the island. We saw also at Bluff in 1977 that helicopters passing even at considerable distance from the colony would cause a massive fly-off greater than that caused by a close-flying fixed-wing aircraft. The Eskimos' observation of low Crested Auklet numbers at Little Diomede in 1977 may in part be a result of the repeated helicopter disturbance in 1976. Our discovery of several rotten eggs in apparently abandoned burrows from the previous season suggests the same.

Furthermore, our estimate for Crested Auklets falls at the low end of the range given by Kenyon and Brooks, whereas the number for Least Auklets is near the top of the range. The latter seems to be explainable in terms of the differences in techniques, because the process of extrapolating the average density of birds on their habitat to the total amount of habitat should yield an estimate higher than would pure visual impression. Other investigators have noted historical decreases in the number of Crested Auklets on Saint Lawrence Island, the Pribilofs, and the Outer Aleutians. Thus the evidence is that the number of Crested Auklets has probably declined.

The 1977 Reproductive Season.

Although the breakup of the sea ice was late in 1977 and so was the arrival of nesting birds, breeding schedule and success did not seem to have been affected by the late start.

Kittiwakes at Little Diomede appear to have had a good reproductive year as compared to the performance of kittiwakes in other areas in the northern Bering Sea region, although our data at Little Diomede do not tell us how many young fledged. From what we can tell, the murres did at least better than the general failure we observed during 1976. Horned Puffins at the island during 1977 appear to have done no worse than puffins appeared to do at other seabird colonies (Reports at the workshop on puffins, Pacific Seabird Group Meeting, January, 1978).

Feeding ecology as it applies to Bering Sea seabirds.

Observations in Alaska and-in northern Siberia emphasize the point that the food items of seabirds conform to categories of (a) form,

(b) *abundance , and presumably (c) behavior. The food species used in different areas in the same year vary, and those used in the same area between* years vary as well. Moreover, in 1976 murres and kittiwakes experienced poor reproductive success from Norton Sound to Cape Thompson which we suggested may have resulted from a shortage of a critical food resource. These facts illustrate that the distribution and reproductive success of seabirds are linked closely to their feeding ecology. In the following discussion, we will try to show how theory about feeding strategies applies to our studies, and to point the direction for future work.

A. Theoretical Framework

The theory developed from observations of rigid patterns of courtship behavior, from the work of students of simple predatory behavior among shrews (Helling 1968) and raptors (L. Tinbergen 1943) and from 'Game Theory', is that stereotyped actions and search patterns are combined through individual experience into a pattern of feeding behavior which will maximize the ratio of the food used to the energy expended (Royama 1966).

In the first case, Luuk Tinbergen's study of the interactions between European Sparrow Hawk (Accipiter nisus) and House Sparrows (Passer domestics), Chaffinches (Fringilla coelebs), Great Tits (Parus major) and Coal Tits (Parus ater) indicate that the predator species has species-specific hunting techniques and each individual develops routes along which it hunts. The behavior of certain potential prey species makes them more (House Sparrows) or less (Coal Tits) vulnerable to the hunting techniques and routes used.

Therefore, we doubt that there are many deterministic interspecific interactions between species *on different* trophic *'levels'. But we can* predict certain types of probabilistic interactions which"integrate" the *"specific search image" with abundance and with a factor that.represents cost/benefit ratio of energy expended to energy gained. There are also generalizations based on the observations that predators are prudent (whether sea gulls or Wall Street financiers) to keep a 'mixed* portfolio'. *Predators can be expected to use several species as prey, to search over several different habitats (habitats defined by the habitats used by the prey species) and to move among several geographic regions. One can expect these patterns* to *be expressed over both space and time.*

In order to investigate the feeding techniques of seabirds in our area, we need to observe how far and in what directions seabirds go to feed, how long they spend and what they do while they are feeding.

In the second case, T. Royama's study of changes in prey of. *Great Tits (1966) showed that* efficiency of effort plays an important *part in the feeding 'strategies' of birds.* Royama *observed that parent Great* Tits feeding themselves and their young used strategies that 'integrated' abundance and size of the prey items taken. They might feed themselves or take to their nest small caterpillars when their young were small, but as the young grew the parents fed on the small items themselves and carried only larger items back to feed their nestlings. When the young fledged, the parents used smaller, more abundant, prey again, 'because' the young accompanied them on feeding forays.

One presumes that the early departure of murre chicks, at about *18 days, facilitates the* murre parents' problems by shortening the *distance* that *food must be carried. Our observations that parent* murres *bringing food* to *the cliffs, when they cannot* find *their young often drop the prey instead of eating it, suggests that the parent had fed to satiation before bringing the food item in.*

In *order to investigate this aspect of feeding, which must have an important impact on breeding success when large prey items are rare, we need to observe what foods seabirds feed on themselves at sea and how* these items compare with what they bring to their young.

In the third case, pearson (196S) described spatial segregation of seabirds feeding off the Fame Islands, Northumberland, England, suggesting that distances flown before the birds began to feed provided an important mechanism for avoiding competition for food despite the fact that several species were feeding on the same prey (Ammodytes). Cody (1972) expanded similar ideas suggesting that spatial segregation was a general rule for the seabirds off the coast of California in the United States. Lack (1966) described spatial segregation and distances flown as parts *of* a balanced set of social and ecological adaptations by which seabirds partition available resources. Ashmole (1963) described sets of similar feeding techniques among coexisting seabirds in tropical Pacific waters as means of avoiding competition.

The assumptions underlying all these models are attributable to *Gauss's deterministic models based on* closed laboratory cultures of *Paramecium. The conclusions which he* drew and described mathematically *have, of course, become virtual ecological dogma (as wryly observed by* Slobodkin *(1960)). Reports of the feeding techniques and prey items used by northern seabirds present a* less *clear picture than the models might* predict. Lack suggested that this blurring of the rules might result from the birds using superabundant resources because their numbers are regulated by factors in operation in other parts of their ranges or at other times of year.

B. Significance to Studies of Alaskan Seabirds.

Specifically, published and unpublished reports show that murres, kittiwakes and puffins use markedly different foods in different parts of their geographic ranges (Table 11). In some cases the total list of species is the same but a species that is a major food item in one place is *virtually unused in another, (Table 12 compares the Murman Coast with* Novaya Zemlaya). *In another case, Black-legged Kittiwakes in Alaska, while several species* seem to be used as general maintenance, the abundance of one single species, Ammodytes hexapterus, was necessary for *outstanding breeding success. In the* Pribilof *Islands, where Sand Launce does not seem to have 'epidemics' and there is a rich variety of other* prey species, the kittiwakes do moderately well every year, but do not *seem to have boom years and have* not *been reported as raising more than a single chick. In the northern Bering Sea and southern* Chukchi *Sea, though in some years* 95% *of parents fail , in other years a significant percentage of parents raise two young.*

In order to investigate this phenomenon we should study the food at *different places, such as Cape Lisburne/Cape Thompson, Little Diomede Island/King Island, Saint Lawrence Island, Saint George/Saint* Paul, *Cape Newenham region, Kodiak Island region. The studies* should *include 'good' and 'bad'years and just different years in the same place.*

Table 11. Food of murres and kittiwakes in the Bering Sea and Chukchi Sea, showing variation among regions and between years.

Food of Murres (after Searing, NOAA 1978)

Locality	% occurrence of: fish	crustacea
Bristol Bay[1]	44	40
Pribilof Is.[2]	49	51
Saint Lawrence Is.[3]	33	72
Cape Thompson[4]	74	25

Food of Murres and Kittiwakes, Cape Thompson

Percent occurrence in stomachs with any contents:

	1960[4] invertebrate	1960[4] % fish	1976[5] invertebrate	1976[5] % fish
Thick-billed Murre	34	64	78	76
Common Murre	6	96	33	92
Black-legged Kittiwake	25	91	53	67

Sources:

1. Ogi & Tsujita (1973)
2. Preble & McAtee (1923)
3. Searing (NOAA 1978)
4. Schwartz (1960)
5. Springer & Roseneau (NOAA 1978)

Table 12. Food of Murres, Puffins and Kittiwakes on the north Siberian coast showing variation in species of fish used among regions (percent occurence).*

Thick-billed Murre	Kharlov Island to East Murman Coast[1]	Bezymyannaya Inlet, Novaya Zemlya[2]
(fish species)		
Ammodytes tobyanus (Sand Launce)	23.1	0.9
Mallotus villosus (Capelin)	17.9	1.7
Clupea harengus (Common Herring)	38.5	0.6
Gadus morrhua (Common Cod)	20.5	44.3
Boreogadus saida (Arctic Cod)	--	51.3
Gymnelis viridis (Ocean Pout)	--	0.9
Myoxcephalus scorpius (Sculpin)	--	0.3

Atlantic Puffin	Seven Islands East Murman Coast[3]	Ainovy Islands West Murman Coast[4]
Ammodytes tobyanus	56.8	6.3
Mallotus villosus	21.0	43.7
Clupea harengus	19.7	50.0
Gadus morrhua	2.5	--

Black-legged Kittiwake		
Fish	70.9	59.0
Mollusks	12.1	9.8
Crustacea	7.8	31.2

* Data from Belopol'skii (1957), and Uspenski (1956).

Data from: [1] 111 stomachs
[2] 314 stomachs
[3] 100 stomachs
[4] 39 stomachs

In the last two cases there must be some selective response or 'perceived availability' on the part of the predator. (The foods are observed to be different although the same prey species are all recorded as present.) The fishes brought by the birds are often different from those recorded in samples of fish taken by fishermen. For example, in Norton Sound, Barton (NOAA 1978) reported the common fish taken in gill nets, and beach seines. Sand Launce was the most numerous fish in the beach seine hauls and is a major food item of kittiwakes and puffins. The other abundant fishes in the gill net and beach seine hauls, however, Saffron Cod, Eleginus gracilis, Bering Cisco, Coregonus laurettae, Least Cisco, Coregonus sardinella, Rainbow Smelt, Osmerus mordax, were very rarely included in the samples of fish which we have from the bird cliffs. The fishes that were most numerous in the ground surveys, Arctic Char Salvelinus alpinus, six other species of salmon and whitefish, Starry Flounder, Platichthyes stellatus, were also seldom represented except for minor but regular representation of juvenile salmon. In contrast, the most important food fish brought by the most abundant bird species -- Common Murres -- was Prickle-back, Lumpenus fabricii, a species not represented in nets and seines although it was reported by 'scuba' *divers* as being among the common fish which they saw (Cottids, *Stichaeids, Gadids,* and Agonids).

It is evident that there are major differences between the food species used in different parts of the same species range. There also appears to be an important and consistent, though more subtle, set of differences in food species and abundances even within a relatively unified geographic unit such as the Bering Strait in the broad sense (from

Table 13. Comparison of seabird numbers at colonies in the Bering Strait region.

	Kittiwakes	Murres	Percent Thick-billed Murres	Parakeet Auklets	Crested Auklets	Least Auklets	Horned Puffins	Tufted Puffins
Cape Lisburne	15,000-25,000	200,000	70				1500-2000	
Cape Thompson	10,500-20,000	200,000	50				2000	
Cape Lewis . .	3500	25,000	50				300	
Little Diomede Is.	35,000	60,000	60	15,000	135,000	1,000,000	10,000-25,000	1000
King Island	4000-6000	75,000	50	35,000	35,000	85,000	10,000	1000
Sledge Island	1000	2000-3000	15	100			200	6
Bluff Cliffs	6000-7000	50,000	<1	50			2000	25
Square Rock	1000	6000					400	6
Cape Denbigh	1800	10,000-15,000	.1	5			150	
Egg Island	500	2000	<1	5			150	
Saint Lawrence Is.[1]								
Savoonga area East	10,000	75,000		35,000	225,000	150,000	3000	
West	15,000	120,000		15,000	40,000	65,000	3000	
Gambell area				2000	75,000	110,000	1500	500
Southwest Capes	15,000	120,000		12,000-18,000	190,000	350,000	1500	750
Totals	125,000-150,000	985,000-1,200,000		85,000-100,000	700,000	1,760,000	50,000	3250

Total Birds - 3,725,000 (excluding Big Diomede Is. and the coast of Siberia)

1. data from Bedard (1969) and Searing (NOAA 1978).

Cape Lisburne to Saint Lawrence Islands). This more subtle effect is reflected in differences in proportions among the species of seabirds (Table 13). There is, first, the change in proportion of Thick-billed Murres to Common Murres from 75% Thick-billed at Cape Lisburne to 60% at Little Diomede, and 50% at King Island to 15% at Sledge Island and less than 1% at Bluff Cliffs and Cape Denbigh. There is, second, a change in the number of kittiwakes as a percentage of the number of murres from 60% at Little Diomede and 40% at Sledge Island, to 6% at King Island, 10% at Capes Lisburne and Thompson, 13% at Bluff Cliffs, 16% at Square Rock, 15% at Cape Denbigh and 25% at Egg Island, suggesting a relatively uniform relation of about 10%-20% except for the sharp contrast between Little Diomede and Sledge as compared to King Island. There is, third, approximately the same number of Least and Crested Auklets on Saint Lawrence Island, but the Least Auklets become many times more numerous at King Island and especially at Little Diomede.

Needs for Further Study

A. Little Diomede Island.

There is a limited number of study sites for murres and kittiwakes which are accessible to us but are not disturbed by Eskimo food gathering. Thus it appears that the island does not have much to recommend it *per se* as a site for detailed, continuing studies. Yet the island is a critically important seabird colony and lies on the major route for heavy ship traffic between industrial development on the North Slope and "Outside". It will therefore be exposed to maximum hazards from transportation, and should have future work done on it for that reason.

This *further work on the island should be undertaken to specify* annual and seasonal variations in the numbers of kittiwakes, murres, *puffins and the annual variation in reproductive success of kittiwakes and* murres.

There is general need to develop techniques for estimating the breeding populations of the three species of auklets and methods for *measuring their reproductive success. But because their numbers are so large and that even a small percentage error means a difference of a* large *number of birds, it is unlikely* that the auklets will be really *useful for quantitative measures of environmental impacts. On the other* hand, auklets are conspicuous species *and endemic species and as such* deserve reasonable care in monitoring *their populations because of public interest in them.*

B. The Bering Strait region in general.

The most important next steps in the study of the area involve work at sea, first to define more precisely those areas of the Chirikov Basin and southern Chukchi Sea which are used by the birds for feeding grounds; second, to establish what foods are used and how do the foods used vary seasonally and regionally, i.e., what are the primary resources, secondary resources and resources of last resort.

For an adequate understanding of the populations, biogeography or trophic structure of the Bering Strait region, we need at least a survey *(second hand if necessary) of 1) the seabird colonies on the Siberian Coast between the north* limit *of the Gulf of Anadyr and the coast north of Mys* Dezhneva; *and 2) the feeding areas between the International Date* Line and the Siberian mainland.