Environmental Assessment of the Alaskan Continental Shelf

Annual Reports of Principal Investigators for the year ending March 1979

Volume II. Receptors — Birds

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF INTERIOR
Bureau of Land Management

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	BIRDS
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Outer Continental Shelf Environmental Assessment Program
Boulder, Colorado

October 1979

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

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DISCLAIMER

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RECEPTORS -- BIRDS

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ANNUAL REPORT
APRIL 1978 - MARCH 1979
RESEARCH UNIT 337

SEASONAL DISTRIBUTION AND ABUNDANCE OF MARINE BIRDS IN ALASKA

PRINCIPAL INVESTIGATOR

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Anchorage, Alaska

1 April 1979

I. SUMMARY

The overall objective of RU 337 in FY 79 was to prepare and analyze all shipboard and aerial data collected from 1975-1977 and to unite this information into a comprehensive report to the Outer Continental Shelf Environmental Assessment Program (OCSEAP). When completed, this project would privide information on the seasonal distribution and abundance of birds in Alaska's marine habitats.

II. INTRODUCTION

Over 10,000 transects have been completed since the inception of RU 337. This equates to over 100,000 computer cards or over 1,000,000 pieces of information. This data base contains information derived from shipboard and aerial surveys of birds in all of Alaska's marine habitats. The greatest bulk of data is from the Gulf of Alaska, particularly in the Kodiak region. A substantial amount of data from the Bering Sea and a small amount from the Chukchi and Beaufort Seas is also present.

The specific objectives in FY 79 were the processing, editing, reduction and analysis of data and the preparation of a final report. This included such tasks as conversion of data from old to new formats (Hal Petersen, RU 527), verification and correction of digital data, development of data storage files, and the development of software programs for data analysis.

Information on the distribution and abundance of marine birds over the outer continental shelf of Alaska is critical for the establishment of methods for preventing or mitigating impacts associated with the development of petroleum reserves.

III. CURRENT STAGE OF KNOWLEDGE

Information relating to the distributian and abundance of marine birds in Alaskan waters is scattered in a wide and unwieldy variety of publications, unpublished reports and private as well as institutional data bases. Important bibliographic sources relevant to this subject can be found in Gabrielson and Lincoln (1959), Kessel and Gibson (1978), Bartonek and Lensink (1978) and Sowls et al. (1979).

Files of the USFWS, Biological Services Program-Coastal Ecosystems of Anchorage, Alaska, contain extensive data and reports on marine birds in Alaskan waters. These data and reports have, for the most part, been collected and written under Research Unit (RU) 337 of the OCSEAP, and have been summarized in annual reports by Lensink and Bartonek (1975, 1976), Lensink et al. (1976), Gould (1977), Harrison

(1977) and Gould et al. (1978). Studies of the distribution and abundance of marine birds in Alaskan waters have also been conducted by other OCSEAP investigators including Hunt (RU 083), Wiens (RU 108), Divoky (RU 196) and Myres (RU 239). Data from these investigations have been summarized in annual or final reports by Divoky (1976, 1977), Guzman (1976), Hunt (1976, 1977), Myres and Guzman (1977), Wiens (1976, 1977) and Wiens et al. (1978).

IV. STUDY AREA

Information from RU 337 will be analyzed on the basis of three major geographic areas: Gulf of Alaska, Bering Sea and Arctic Seas. Data from the Gulf of Alaska will also be divided into subsets for specific lease sale areas including the Northeast Gulf of Alaska, Cook Inlet and Kodiak Basin.

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

New data were not collected under RU 337 during FY79, but relevant information from studies conducted under RU 341 and the integrated food web studies in Kodiak Basin were incorporated into the data base.

VI-VII. RESULTS-DISCUSSION

Hal Petersen (RU 527) completed the format conversion and editing of RU 337 digital data during FY79. Magnetic tapes of this data were prepared by Dr. Petersen and one copy of each was given to NODC and to our Anchorage Office. FY79 data obtained under RU 341 studies were digitized and corrected at our Anchorage office and will soon be sent to the Bering Sea-Gulf of Alaska Project Office in Juneau. A small number of digital errors (not detectable under Dr. Petersens program) and one major formatting error were found in the data tapes supplied to us. These were corrected, but they delayed the creation of a working data file which we need for final data analysis.

Software programs for the analysis of RU 337 data have almost been completed by Alaska Information Management Services (AIMS) which is part of the USFWS Biological Services Program. All that remains is the inclusion of digital map data which are now being obtained from the NOAA computer lab in Boulder, Colorado.

Introductory sections for the final report were completed during FY79.

VIII. CONCLUSIONS

We still anticipate a completion date of 1 July 1979 for the final report. The delays caused by errors in format conversion, however, may create an overrun of up to three weeks.

IX. NEEDS FOR FURTHER STUDY

The final report will contain a discussion of data gaps and suggestions for further studies. At present we anticipate a need for the following:

1. More intensive winter studies in most Alaskan regions,

2. Low level monitoring of areas identified as important in future lease sale areas,

3. An integration of data from all relevant Research Units, especially RU's 337, 083, 108, 196 and 239.

X. SUMMARY OF JANUARY-MARCH QUARTER

Data collection and analysis were not conducted. Introductory sections of the final report were completed and preparations were made for the final analysis of data.

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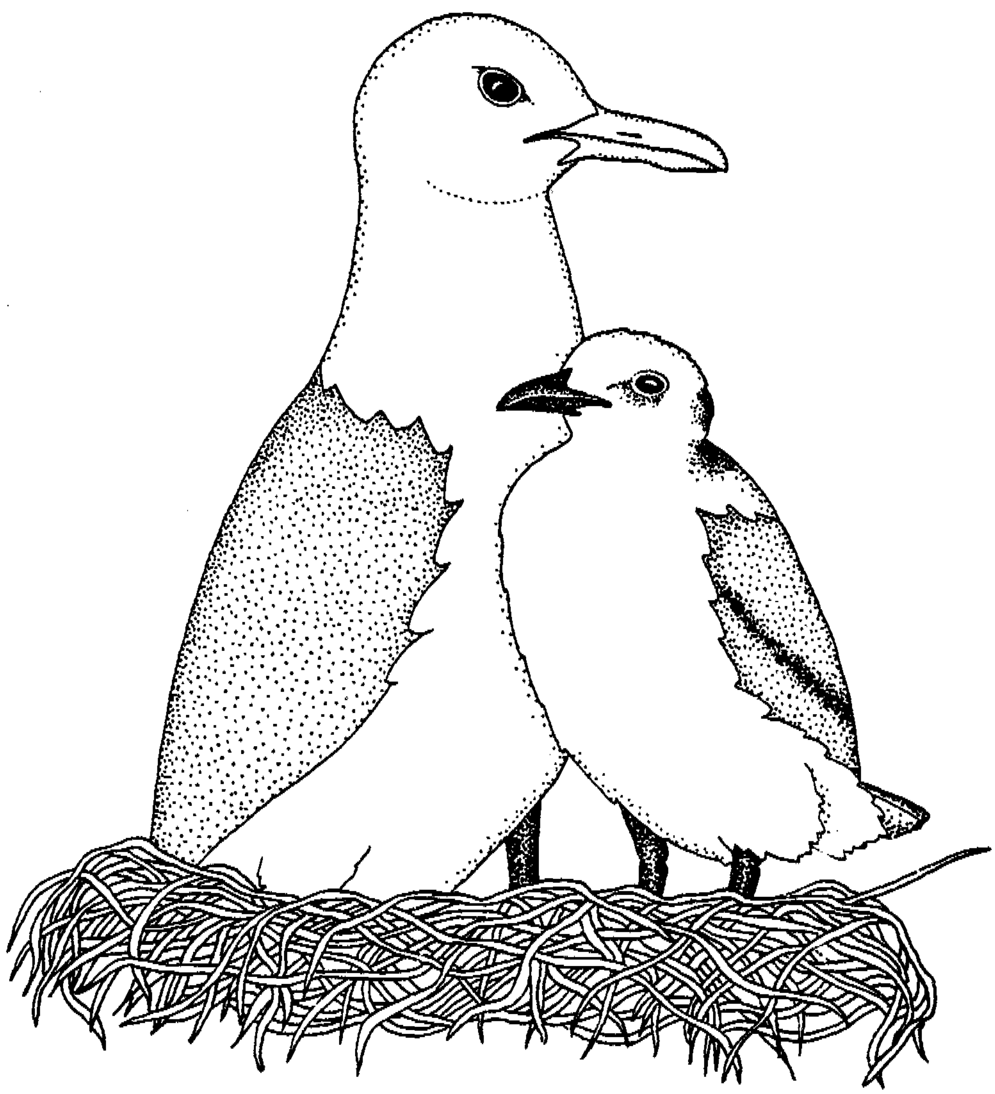
POPULATION DYNAMICS AND TROPHIC RELATIONSHIPS OF MARINE BIRDS IN THE GULF OF ALASKA



U.S. Fish and Wildlife Service
Biological Services Program-Coastal Ecosystems
Anchorage, Alaska

ANNUAL REPORT
APRIL 1978 - MARCH 1979
RESEARCH UNIT 341

POPULATION DYNAMICS AND TROPHIC RELATIONSHIPS OF MARINE BIRDS IN THE GULF OF ALASKA

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1 April 1979

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I. SUMMARY 1

Studies of the breeding biology of selected seabirds were conducted in 1978 at Middleton Island, Chisik Island, Chiniak Bay and Sitkalidak Strait. Comparable information is presented in this report on pelagic cormorants (*Phalacrocorax pelagicus*), glaucous-winged gulls (*Larus glaucescens*), black-legged kittiwakes (*Rissa tridactyla*), and tufted puffins (*Lunda cirrhata*). Information from individual sites, in varying degrees of detail, is also presented for red-faced cormorants (*Phalacrocorax urile*), mew gulls (*Larus canus*), arctic terns (*Sterna arctica*), Aleutian terns (*Sterna aleutica*), common murres (*Uria aalge*), thick-billed murres (*Uria lomvia*), horned puffins (*Fratercula corniculata*), common eiders (*Somateria mollisima*), and black oystercatchers (*Haematopus bachmani*).

Trophic studies in the Kodiak area during spring and summer, 1978, concentrated on sooty shearwaters (*Puffinus griseus*), black-legged kittiwakes, common murres, pigeon guillemots (*Cepphus grylle*), marbled murrelets (*Brachyramphus marmoratus*), and tufted puffins. White-winged scoters (*Melanitta fusca*), oldsquaw (*Clangula hyemalis*), common murres and marbled murrelets were emphasized in feeding studies conducted at Kachemak Bay during the winter of 1977-1978.

COLONY STUDIES

Pelagic cormorants were studied at Chiniak Bay in 1977 and 1978 and at Middleton Island in 1978. The population of pelagic cormorants at Chiniak Bay has remained relatively stable since 1975 but, from year to year, birds have frequently shifted colony sites. At Middleton Island, numbers of pelagic cormorants have increased several fold since the mid 1950's. In 1978, egg laying by pelagic cormorants at Middleton Island preceeded this species breeding schedule in Chiniak Bay by 27 days with the onset of egg-laying being 3 May and 30 May respectively. At Middleton Island, reproductive success for an intensively studied plot was 0.64 chicks per nest attempt, but considerable spatial variability in productivity was evident within this colony. Productivity was apparently as high as 1.0 to 1.5 chicks per nest attempt in less intensively studied areas. Six small colonies were studied at Chiniak Bay and reproductive success varied from 0.00 to 1.58 chicks per nest attempt in 1978 and 0.00 to 2.14 chicks in 1977. Overall production in Chiniak Bay decreased from 1.36 chicks fledged per nest attempt in 1977 to 0.54 chicks in 1978.

Glaucous-winged gulls were studied at Chiniak Bay, Sitkalidak Strait and Middleton Island in 1978. The breeding schedules of gulls at Chiniak Bay and Sitkalidak Strait were similar, with egg-laying from late May to early June, hatching in late June, and fledging in mid to late August. The population of gulls at Middleton Island, which has increased from a few nonbreeders in 1956 to 1,400 breeding birds in 1978, initiated egg laying on 28 April, a full month before birds at the other study sites.

Fledging of glaucous-winged gulls at Middleton Island also occurred one month before other sites. Overall reproduction of this species at Chiniak Bay decreased from 1.15 fledglings per nest attempt in 1977 to 0.74 fledglings in 1978. Similarly, production of glaucous-winged gulls at Sitkalidak Strait decreased from 1.07 fledglings per attempted nest in 1977 to 0.38 fledglings in 1978.

Black-legged kittiwakes were the principal species studied at all four locations. The number of kittiwakes at Middleton Island has increased spectacularly from approximately 15,000 in 1956 to an estimated 150,000 birds in 1978. Egg laying at Middleton Island began on 23 April, but not until 4 June to 17 June at the other sites. Similarly, kittiwake chicks began fledging on Middleton Island on 2 July and was all but completed by 21 August, while at Chiniak Bay, Sitkalidak Strait and Chisik Island fledging did not begin until mid-August. Again, fledging lasted much longer at Middleton Island than elsewhere. The reproduction of black-legged kittiwakes at most sites was poor. The highest success was at Chiniak Bay where 0.77 chicks fledged per attempted nest, a decrease from a high of 1.23 chicks per nest attempt in 1977. At Sitkalidak Strait, production dropped from 0.74 fledglings per attempted nest in 1977 to 0.17 in 1978. Breeding success was also low at Chisik Island where only 0.02 chicks fledged per nest attempt. A shortage of forage fish was considered the primary factor resulting in low production at these sites. At Middleton Island the overall reproductive success of kittiwakes in 1978 was 0.156 chicks fledged per attempted nest, but considerable variation in both reproductive success and the timing of breeding was observed among birds occupying different nesting habitats. Evidence suggests that this variability may reflect characteristics of population structure resulting from the recent expansion of this colony.

Tufted puffins were studied at Middleton Island, Sitkalidak Strait and Chiniak Bay in 1978. Eggs were layed on Middleton Island from 12 May to 13 June, and at Sitkalidak from 27 May to 4 July. Fledging started on 12 August at Middleton Island, 16 August at Chiniak Bay and 21 August at Sitkalidak Strait. It continued through early September at all sites. Reproductive success at both Sitkalidak Strait and Chiniak Bay was about the same in 1977 and 1978. In 1978, tufted puffins fledged 0.31 chicks per attempted nest at Sitkalidak and 0.69 chicks per nest attempt at Chiniak Bay.

Red-faced cormorants, mew gulls, arctic terns, Aleutian terns, common eiders, and black oystercatchers were also studied at Chiniak Bay in 1978. Red-faced cormorants showed a decrease in production from 1.91 chicks fledged per nest attempt in 1977 to 1.33 chicks per nest attempt in 1978. Mammalian predators were suspected to limit production at tern colonies on mainland Kodiak, and hatching success was near zero at tern colonies visited by a weasel (<u>Mustela erminea</u>). In Chiniak Bay, the breeding phenology of Aleutian terns was about six days behind that of arctic terns. One colony of mew gulls was studied on Mary Island in Chiniak Bay. The reproductive success of this colony decreased from 1.00 chicks per nest built in 1977 to 0.46 chicks in 1978. Information on horned puffins in 1978 was available only from Chisik Island where they are an abundant breeder. Egg laying occurred between 5 and 29 June, hatching between 18 July and 27 August, and fledging between 28 August and 19 September. In contrast with black-legged kittiwakes at Chisik Island, horned puffins had relatively high production with 0.60 chicks fledging per breeding pair. Like the other species, populations of murres at Middleton Island have grown substantially over the past 22 years, increasing from about 400 to 11,000 birds. Of this population, common murres comprise over 96%.

Forage fish, notably capelin (Mallotus villosus) and Pacific sand lance (Ammodytes hexapterus), were the most important prey brought to young during the 1978 breeding season. At Chisik Island, horned puffins relied exclusively on sand lance as food for nestlings. Similarly more than 60% of the volume of regurgitations from nestling kittiwakes were sand lance, while only 10% were capelin and 4% were walleye pollock (Theragra chalcogramma). Euphausiids made up a negligible portion of the food of kittiwake nestlings at Chisik Island, whereas on Middleton Island, kittiwakes brought considerable quantities of euphausiids to their chicks. Although the seabirds of Sitkalidak Strait and Chiniak Bay were highly dependent on fish in 1977 and 1978, substantial differences in the relative importance of the two principal prey species occurred between the two years. At Sitkalidak Strait in 1977, glaucous-winged gulls, kittiwakes and tufted puffins brought large quantities of capelin to their chicks. In 1978, however, capelin were apparently not as readily available, and birds took relatively more sand lance. A similar situation existed in Chiniak Bay in 1978 where beach runs of Capelin did not materialize. This decreased availability of capelin was probably the principal factor resulting in the lower productivity of many species of seabirds at Sitkalidak Strait and Chiniak Bay in 1978. At Middleton Island, capelin were absent in the diet of nestling seabirds. Bill loads of rhinoceros auklets (Cerorhinca monocerata) were composed mostly of sand lance, and smaller amounts of other fish and cephalopods. Cephalopods were important as food for nestling tufted puffins at Middleton Island.

Several features stand out when comparisons are made among the four colony sites. Most notable, is the early initiation of breeding by the seabirds of Middleton Island in 1978. The seven species studied began breeding two to seven weeks earlier than the same species at the other colonies, and showed a protracted breeding chronology. This phenomenon is probably related to an earlier availability of food, but no data directly support this conclusion. Secondly, black-legged kittiwakes in 1978 had almost universally low reproductive success among the four sites. Productivity of all major species studied at Chiniak Bay and Sitkalidak Strait, except the tufted puffin, decreased from 1977 to 1978. The decrease in productivity may be related to a decreased availability of sufficient quantities of capelin. Capelin, however, was the major prey found in stomachs of adults of several species of seabirds in the Kodiak area during the summer of 1978.

These results once again emphasize the variability in the reproductive success of seabirds in the Gulf of Alaska. At many sites, such extreme variability from year to year may be the norm rather than the exception. Because of this, discussion of the average reproductive success of a species is impossible because of the few seasons of data amassed thus far. Many factors can account for low reproductive success, but food availability, predation, and weather are the most obvious and important factors emerging from our studies. Although some marine birds, such as white-winged scoters and oldsquaw wintering in Kachemak Bay are generalists in their food habits, most species studied in the Gulf of Alaska are dependent on few prey species, the most important being capelin, sand lance, and euphausiids of the genus Thysanoessa. Destruction of these food resources from oil pollution would have a highly deleterious effect on those birds not directly affected by the oil.

TROPHIC STUDIES

Studies of food habits and trophic dynamics of marine birds were concentrated in waters of Kodiak and in Kachemak Bay, with studies in the latter area limited to the winter season. Although regurgitation and bill load studies at colonies suggest that capelin were not as available to birds in the Kodiak area in 1978 as in 1977, they were still the principal food item found in the stomachs of seabirds collected at sea. Capelin comprised almost 50% or more of the food, by volume, in stomachs of 270 black-legged kittiwakes, tufted puffins, common murres and sooty shearwaters collected in Izhut and Kiluda Bays in 1978.

The diet of black-legged kittiwakes, which feed at or near the surface, was restricted primarily to capelin, sand lance, and euphausiids. On the other hand, diving seabirds such as shearwaters, common murres, tufted puffins and pigeon guillemots, which have the entire water column available to them, took a wider variety of prey, including walleye pollock, Pacific sandfish (Trichodon trichodon), amphipods, shrimp and squid. Pigeon guillemots also fed on crabs, indicating that they sometimes feed on the bottom. Euphausiids occurred in five species of diving and surface feeding seabirds but were not found in stomachs after late June, suggesting a seasonal availability of these crustaceans.

During the winter of 1977-1978, oldsquaw collected in Katchemak Bay were found to be extreme generalists, taking a minimum of 56 species of prey. Eighteen of these species made up 74% of the prey volume. Sand lance were the most important individual prey item, comprising 23% of the volume but as a group, gastropods, pelecepods and crustaceans were more important. The diet of white-winged scoters was not as broad as oldsquaw and they relied heavily on the clam Prototheca and the mussel Mytilus edulis. Summer and winter studies have shown the common murre in the Kodiak area to be reliant on fish. In contrast, common murres in Kachemak Bay during the winter fed heavily on pandalid shrimp and mysids. Herring (Clupea harengus), capelin, pollock and sand lance were taken in smaller quantities. Winter studies of the feeding ecology of marbled murrelets in Kachemak Bay in 1977-1978 have shown this species to feed heavily on small capelin. A similar study, undertaken in Chiniak Bay during the same winter showed that mysids were the most important prey. During the summer of 1978, sand lance were the most important prey of marbled murrelets in the Kodiak area.

II. INTRODUCTION

Since 1975, the U.S. Fish and Wildlife Service, Biological Services Program, Alaska, has conducted OCSEAP-funded studies of seabirds inhabiting the outer continental shelf of Alaska. Work performed under Research Unit 341 identifies areas of importance for breeding and foraging of seabirds and describes the population dynamics, life histories and trophic relationships of key species at selected locations in the Gulf of Alaska. The specific objectives of this research unit are:

- To determine the location, size and species composition of nesting colonies of seabirds and summarize the information in a catalog of Alaska seabird colonies.

- To determine the reproductive success and breeding phenology for key species at selected colonies.

- To establish sampling areas which may be used in subsequent years for monitoring the status of populations.

- To determine the amount, kinds, and trophic levels of prey used by key seabird species, primarily in the Kodiak region and in Kachemak Bay.

- To deleineate important foraging areas for seabirds in the Kodiak and Cook Inlet regions.

A recent estimate put the population of Alaskan seabirds at more than 40 million (Sowls et al., 1979). This population is swelled substantially each spring with the arrival of an even larger number of shearwaters from the southern hemisphere. This large population, in conjunction with the known vulnerability of seabirds to contamination by oil gives cause for concern (Bourne 1968, 1976b; Clark, 1969). The death of seabirds as a result of either large or chronic oil spills will probably be the most visible biological impact from OCS development in Alaska. In addition to the direct effects of contamination by oil, increased disturbance to seabirds near nesting or foraging areas, or contamination and reduction of food resources, may result in lower survival and reproductive rates and may have long term effects on populations and reduce or preclude recovery of populations subjected to direct losses from oil spills. Because of the large population of birds using Alaskan waters, losses of seabirds from oil contamination may be larger than ever before experienced.

III. CURRENT STATE OF KNOWLEDGE

Probably the most important publication on Alaskan birds is Gabrielson and Lincoln's (1959) THE BIRDS OF ALASKA which provided a comprehensive review of all literature, including unpublished reports which preceeded its publication. Information on the distribution and population status of many species have been updated by Kessel and Gibson (1978). The publication of the CATALOG OF ALASKAN SEABIRD COLONIES (Sowls et al., 1979) has filled major gaps in our knowledge of nesting colonies of Alaskan seabirds.

Prior to the OCSEA Program, work on seabirds in Alaska had provided only general information on life history and distribution. The OCSEA Program has resulted in a wealth of new information, most of which is yet to appear in standard scientific journals. The most extensive collection of citations on marine and coastal birds of Alaska is Bartonek and Lensink's REVIEW OF THE LITERATURE (1978, RU-339). The list contains over 900 references and provides a cursory review on a geographic basis for some of this information. A review of th literature pertaining to our individual studies is cited in the individual reports which make up the results section of this paper.

Several papers dealing with the conservation of marine birds have appeared in the literature including those by Sowl and Bartonek (1974), Bartonek et al. (1971), King (1973), King et al. (1979), Bourne (1970, 1976a) and nisbet (1979). The effects of oil contamination on marine birds have been the subject of numerous reviews including those by Bourne (1968, 1976b), Clark (1969), Croxall (1975), Clark and Kennedy (1968), Aldrich (1970) and Tanis and Morzer-Bruijns (1969). Vermeer and Vermeer (1974) reviewed the literature appearing between 1922 and 1973 on the effects of oil on birds. Assessment of the impact of OCS oil and gas development on marine birds in Alaska is discussed in reports by the USDI (1976a, 1976b, 1977).

IV. STUDY AREAS

During 1978, studies of the breeding biology of seabirds were conducted at three locations in the Gulf of Alaska (Middleton Island, Sitkalidak Strait, and Chiniak Bay), and one location in Cook Inlet (Chisik Island). Studies on the trophic relationships of seabirds were conducted in the Kodiak area, primarily in Izhut and Kiliuda Bays, during the summer of 1978, and in Kachemak Bay during the winter of 1977-1978. The feeding habits of birds directly pertinent to breeding biology were studied at Sitkalidak, Chisik and Middleton. The selection of study sites was based on several factors, including their location in relation to OCS lease areas, the diversity of habitats, the species of seabirds present, the information available for each site, and the accessibility of each site. Each study site is briefly characterized below. Detailed descriptions are provided in the individual reports which make up the bulk of the results section of this paper.

CHINIAK BAY, KODIAK ISLAND

Surveys of colonies were initiated in 1975 and continued through 1976. Intensive studies of several colonies in Chiniak Bay were begun in 1977 and terminated following the 1978 season. Chiniak Bay contains several small, accessible colonies possessing similar avifaunas. The mainland surrounding the bay has an extensive road system and abundant support facilities. The presence of other OCSEAP-funded studies, primarily those concerning invertebrates and fish in nearby Izhut Bay, make this area attractive for study.

SITKALIDAK STRAIT, KODIAK ISLAND

OCSEAP-funded studies were inititated in 1977 and terminated following the 1978 field season. Sitkalidak Strait contains several colonies of seabirds of small to moderate size and is most likely to be affected by oil and gas development from the Kodiak lease area. Old Harbor, in Sitkalidak Strait, is a potential site for a deep water oil tanker resupply base. The population of Old harbor is expected to swell to 3,000 people following development and its inclusion as a stop on the Alaska ferry system. These colonies may be an excellent site to monitor the effects of increased disturbance from humans. As in Chiniak Bay, other interdisciplinary studies in the area, e.g., Kiliuda Bay, increase the attractiveness of this site for the study of seabirds.

MIDDLETON ISLAND

Studies on Middleton Island were initiated in 1976 and, following a hiatus in 1977, were resumed with OCSEAP funds in 1978. Middleton Island is the site of one of the largest black-legged kittiwake colonies in the Gulf of Alska. It is susceptable to oil spills from the Northeast Gulf of Alaska lease area and from oil tankers entering and leaving Prince William Sound.

CHISIK ISLAND, COOK INLET

Studies of seabirds on Chisik Island were initiated in 1978 and will continue through the 1979 field season. This site was selected for study because it is the largest seabird colony in Cook Inlet, an area which is presently experiencing a high level of oil related activity. Commercial wells are presently active in Upper Cook Inlet and exploratory drilling is occurring on tracts southeast of Chisik Island. Another lease sale on tracts north, south and east of Chisik Island will soon take place.

IZHUT BAY, AFOGNAK ISLAND

Brief collections were made in Izhut Bay in 1977 but work in 1978 represents the first of intensive repetitive collections. The bay is representative of deep water bay systems in the northern part of the Kodiak study area. The feeding ecology of seabirds was studied aboard the R/V COMMANDO which also participated in OCSEAP studies of other biota.

KILIUDA BAY, KODIAK ISLAND

Intensive collections of seabirds were made in Kiliuda Bay during both 1977 and 1978. This bay is located in the Sitkalidak Strait region of southeastern Kodiak Island. The area supports tens of thousands of breeding seabirds. Areas immediately offshore support large numbers of shearwaters from the southern hemisphere. The feeding habits of all of these seabirds were studied intensively in Kiliuda Bay from the R/V COMMANDO which also participated in OCSEAP studies of other biota.

KACHEMAK BAY, COOK INLET

The feeding ecology of seabirds was studied from November, 1977, through April, 1978. Kachemak Bay is noted for its high productivity and its important fisheries. In winter, the bay supports large numbers of seaducks and alcids, notably oldsquaw, white-winged scoters, common murres and marbled murrelets. The importance and accessibility of the bay from Anchorage makes it an ideal location for study.

V. METHODS

Techniques were similar to those described in previous years as well as those described by other OCSEAP investigators. However, in some cases methodologies differ from site to site depending on colony size, species studied and characteristics of the habitat. A detailed description of methods used at each site is provided in the individual reports for each area.

VI. RESULTS

Six individual reports are included in this section. They are presented in the following order:

A. The breeding biology of seabirds associated with Chiniak Bay, Kodiak Island, 1975-1978. By David R. Nysewander and D. Bruce Barbcur.

B. Breeding biology and feeding habits of seabirds of Sitkalidak Strait, 1977-1978. By Patricia A. Baird and Martha A. Hatch.

C. Reproductive ecology of seabirds at Middleton Island, Alaska. By Scott A. Hatch, Tom W. Pearson, and Patrick J. Gould.

D. The pelagic birds of Tuxedni Wilderness. By Robert D. Jones, Jr., and Margaret R. Petersen.

E. The winter feeding habits of selected species of marine birds in Kachemak Bay, Alaska. By Gerald A. Sanger, Robert D. Jones, Jr., and David W. Wiswar.

F. The feeding ecology of marine birds in two bays on the southeast coast of Kodiak Island, Alaska, 1978. By Lynne D. Krasnow, Gerald A. Sanger, and David W. Wiswar.

VII. LITERATURE CITED

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THE BREEDING BIOLOGY OF MARINE BIRDS ASSOCIATED WITH CHINIAK BAY, KODIAK ISLAND, 1975-1978

by

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1 April 1979

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Abstract

Eighteen island breeding colonies of seabirds were censused and studied in Chiniak Bay between 1975 and 1978. In addition, two tern colonies on mainland Kodiak were monitored intensively 1977-78.

Nesting attempts and numbers of cliff nesting birds in Chiniak Bay in 1978 were similar to those found in 1975 and 1977. Between 1975 and 1978 cormorants showed the most annual variation in colony site selection, species composition, and numbers. Pelagic Cormorants nested more in the inner bays in 1978 than in 1975 while Red-faced Cormorants moved their nesting effort more towards the outer parts of Chiniak Bay during the same period.

A colony of approximately 80-100 pairs of Rhinoceros Auklets was located on the outer cliffs of Long Island.

Breeding phenology and productivity were recorded in 1977 and 1978 for twelve species with emphasis directed at the following six: Black-legged Kittiwake, Tufted Puffin, Pelagic Cormorant, Red-faced Cormorant, Mew Gull, and Glaucous-winged Gull.

Breeding phenologies were essentially the same in 1977 and 1978 for all species except Pelagic Cormorants. Pelagic Cormorants began laying eggs the same time in 1978 as in 1977, but heavy egg loss eliminated these nests. Renesting occurred 15 to 20 days later giving the hatching phenology in 1978 a two to three week delay.

Productivity decreased in 1978 for all the major study species except Tufted Puffin. Productivity was most affected in the incubation phase for Black-legged Kittiwakes and Glaucous-winged Gulls. Most Mew Gull loss occurred during the chick stage while the Pelagic Cormorant loss was considerable in both stages.

Beach spawning runs of capelin did not appear for that sport fishery in Kodiak in 1978. This change in availability of capelin appears to be one of the more probable causes, at least indirectly, behind the increased egg/chick predation by the large gulls and the decreased productivity of many bird populations in Chiniak Bay in 1978.

All three kittiwake colonies studied had lower reproductive success in 1978, but the degree of success varied considerably. The larger colony of 996 pairs on Viesoki Island failed completely while two smaller

colonies of 254 and 218 pairs on Gibson Cove and Kulichkof Island had 0.17 and 0.77 chicks fledged per nest attempt respectively.

Data on growth were gathered on 53 Black-legged Kittiwake chicks and 37 Tufted Puffin chicks.

Five food watches of kittiwakes and puffins at colony sites suggested that puffins bring food to the colony throughout the day while kittiwakes tended to feed their chicks during the early morning.

Six sea mammal and eleven bird carcasses were found in the 74.5 kilometers of beach walked from May to September 1978. Sixty-four percent of all bird carcasses were found either in May or September with September being the peak month.

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I. INTRODUCTION

Intensive studies of the breeding biology of marine birds were conducted at Chiniak Bay, Kodiak Island, in 1978 for the second consecutive year (Figure 1). This enabled us to evaluate the rate and annual variation of reproductive success for Black-legged Kittiwake *(Rissa tridactyla)*, Tufted Puffin *(Lunda cirrhata)*, Glaucous-winged Gull *(Larus glaucescens)*, Mew Gull *(Larus canus)*, Pelagic Cormorant *(Phalacrocorax pelagicus)*, and Red-faced Cormorant *(Phalacrocorax urile)*. Objectives of the 1978 summer field work were:

1. To census the entire Chiniak Bay complex of breeding colonies and compare populations with those of 1975.

2. To monitor sample plots established in previous years for evaluation of reproductive success.

3. To describe the local breeding phenology of the Black-legged Kittiwake, Tufted Puffin, Glaucous-winged Gull, Mew Gull, Pelagic Cormorant, Red-faced Cormorant, Arctic Tern *(Sterna paradisaea)*, and Aleutian Tern *(Sterna aleutica)*.

4. To gather data on growth of chicks of Black-legged Kittiwakes and Tufted Puffins.

5. To study the feeding schedule and time-energy budgets of breeding pairs of Black-legged Kittiwakes and Tufted Puffins.

6. To continue the beached bird and mammal surveys.

The authors arrived in Kodiak on 17 May. Field work on colonies began on 20 May and continued until 2 September. Eighteen island-breeding colonies containing sixteen species of marine birds and two mainland colonies of terns were censused and monitored during the summer. Four of the island colonies were used for intensive study sites.

II. CURRENT STATE OF KNOWLEDGE

A detailed account of the current states of knowledge for Chiniak Bay marine birds is contained in the 1977 annual field report (Nysewander and Hoberg, 1978).

III. STUDY AREAS

The aforementioned 1977 annual report contains a detailed description of the study sites (Figure 1).

Although Kodiak is characterized by moderately heavy precipitation and cool temperatures, the summer months (June to August) usually have the least rainfall averaging 3.54 - 4.30 inches per month with an average three month total of 11.96 inches. The summer of 1978 was comparatively dry with a three month total of 8.27 inches compared to 21.24 inches recorded for the same period in 1977.

IV. SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION

The methods used in 1978 were generally the same as those used in 1977 and are described by Nysewander and Hoberg (1978). The following discussion will concern only changes or additions in methodologies used in 1978.

1. Censuses

The only new census procedures used this year involved crepuscular censuses of nocturnal breeding seabirds at island sites where they were suspected to breed.

2. Nesting Habitat, Breeding Phenology, and Productivity

The major effort was devoted to the eight species of colonial seabirds breeding at accessible sites in Chiniak Bay. Incidental notes were gathered on the scattered nests of Black Oystercatcher *(Haematopus bachmani)*, Common Eider *(Somateria mollissima)*, Pintail *(Anas acuta)*, and Red-breasted Merganser *(Mergus serrator)*.

Black-legged Kittiwake

As in 1977, all nests in the Kulichkof Island colony were checked every four to five days. Sixty-one nests that could be reached were marked and used to derive nesting phenology and growth of chicks.

The colonies at Gibson Cove (254 pairs) and Viesoki Island (996 pairs) were used only for estimates of productivity. Two to four visits to each colony ascertained the number of attempted nests and number of chicks fledged.

Tufted Puffin

The plot used for intensive study of Tufted Puffins on Cliff Island in 1977 was checked every four or five days in 1978 from just prior to hatching up to near fledging. An additional 24 eggs or chicks outside the intensive plot were used to supplement sample size in the analysis of growth rates.

The density of active burrows in the sample plot was derived by a three step process: 1) All burrows had a row of toothpicks (15-20) placed in the entrance of the burrow resembling a picket fence. These were then checked several times within 24 to 48 hours of the initial set up. 2) All burrows indicated as active were then searched by hand and categorized as either having an egg, having no egg with burrow end reached, or having no egg with the burrow end not reached. 3) The percentage of eggs found in those burrows completely explored was extrapolated to those active burrows in which the egg chamber was too deep to reach thereby giving an estimated density for the whole sample plot.

Pelagic and Red-faced Cormorant

The intensive studies of phenology and productivity of Pelagic Cormorants were conducted on Kulichkof Island as they were in 1977 with visits every four to five days. Other cormorant used only for estimating productivity came from the following colony sites or islands: Kulichkof, Puffin, Cliff, Gibson Cove, Blodgett, and Mary. Red-faced Cormorant nests were monitored only on Cliff and Puffin Islands.

Glaucous-winged Gull

A shoreline plot on the southwest side of Zaimka Island was used to determine phenology and productivity of Glaucous-winged Gulls as in 1977. All nests were marked and chicks banded in this plot. The other nine sample plots used in previous years on Cliff and Zaimka Islands (Nysewander and Hoberg, 1978) were checked only once in 1978 to determine the nesting density.

Mew Gull

Eleven quadrats in the south colony on Mary Island were studied in 1978. Except for a more intensive color banding effort of chicks in 1978, all other procedures remained the same.

Arctic and Aleutian Tern

Three colonies were monitored for phenology: 1) a mixed species colony on Mary Island; 2) a scattered Aleutian Tern colony at the head of Middle Bay; and 3) a large mixed species colony on a deltaic island at the head of Kalsin Bay. Nesting densities were compared in various habitats found on Mary Island and Kalsin Bay.

3. Growth

Rates of growth for chicks of Black-legged Kittiwakes and Tufted Puffins were determined from measurements obtained every four to five days. Pesola scales used for weighing chicks were calibrated and checked for accuracy throughout the field season.

4. Trophic Relationships

Certain parts of the kittiwake colony on Kulichkof Island and the puffin colony on Cliff Island were observed during all hours of available daylight on several different days to determine the timing and frequency of food brought to chicks of varied ages. For kittiwake food watches we observed several nests and considered it a successful feeding when the adults regurgitated food and the chicks made swallowing or feeding motions. For puffin food watches the number of puffins bringing food to the entire cliff slope was recorded and correlated with the time of day. In addition, the number of times fish were taken into two burrows by puffins was recorded during each period of observation.

5. Mortality

Beached bird surveys were run monthly on the seven strips established in 1976 and 1977. Bird banding efforts were similar in 1978 to those recorded in 1977 (Nysewander and Hoberg, 1978).

V. RESULTS AND DISCUSSION

1. Censuses

Chiniak Bay has nineteen island breeding colonies of seabirds and three to four mainland colonies of terns. Ten of the island colonies were censused in 1975, 1977, and 1978 while eight others were censused only in 1975 and 1978 (Figure 2). The Cape Chiniak colony was censused in detail only in 1975.

The number of active nests of Pelagic Cormorants in Chiniak Bay, 503 in 1975 and 594 in 1978, showed considerable annual variation at any one site (Table 1). In 1975 40 percent of all nesting efforts by this species in Chiniak Bay occurred in inner Chiniak Bay whereas in 1978 the inner bay contained 63 percent of the total nesting effort. This increase may be the results of 1) recruitment/loss, 2) better or worse breeding conditions affecting the number of pairs which attempt to breed, or 3) a shift in population from the outer to inner portions of the bay. We favor the last explanation because of the following: 1) The overall bay totals of nesting efforts are not that different between years. 2) No sizeable population of non-breeding adults was ever associated with the bay or its colonies. 3) The annual nesting variations peculiar to cormorants, where old colony sites are often completely abandoned even if new colonies occur on the same island, seem to indicate a moving population.

Red-faced Cormorants also showed much annual variation in numbers of nests at any one site (Table 2). Unlike the Pelagic Cormorants, the Red-faced Cormorants increased the percentage of nesting efforts in the outer portions of Chiniak Bay in 1978 compared with that found in 1975. Despite these variations, this species had essentially the same total of nesting attempts occur in Chiniak Bay in 1978 (322) as was found in 1975 (318).

The overall nesting population of about 3445 pairs in 1975 and 3071 pairs in 1978 of Black-legged Kittiwakes was quite similar even though the numbers of active nests varied at certain colonies (Table 3). The trend was for the number of nests at large colonies to decrease and those at small colonies to increase. This trend was also noted when comparing the number of adults attending several colonies (Table 4). Annual variations in nesting attempts of kittiwakes differ from those discussed for cormorants. Kittiwake nesting sites, are rarely, if ever, completely abandoned and occupy the same ledges each year even though numbers of birds or nests vary annually.

The presence of Rhinoceros Auklets and Ancient Murrelets along the outer edge of Chiniak Bay and in the adjacent waters of the continental shelf suggested the presence of local breeding colonies of these nocturnal birds. In 1978 one Rhinoceros Auklet was seen on Cliff Island and another near Queer Island. The only colony positively identified was on the southeast side of Long Island. On 28 June and 12 July Rhinoceros Auklets were observed from a small boat between 2000 and 2100 hours flying into the middle third of the outer cliffs of Long Island. The number of birds observed indicated that the colony contained a minimum of 80 pairs. Daytime examination of the cliffs revealed that the auklets were probably nesting on steep vegetated slopes sandwiched between sheer upper and lower cliffs. Tufted Puffins were also nesting in this habitat.

Ancient Murrelets were thought to breed on Ugak Island, but weather and other commitments prevented an intensive survey of this island. However, during the first week of July A. R. DeGange (pers. comm.) observed two adults and two chicks within ten kilometers south-southwest of Ugak Island. These chicks were one-half to two-thirds grown. Hence, the possibility still remains that a small breeding colony exists either on Ugak Island or somewhere else along the southeast side of Kodiak or Afognak Island.

2. Nesting Habitat, Breeding Phenology, and Productivity

Black-legged Kittiwake

In 1975 Dick (1976a) found 7,261 pairs of kittiwakes breeding on twelve sites in Chiniak Bay. The majority of these colonies were on small vegetated islands and groups of stacks.

Dick (1976b) reported egg laying commencing during the third week of June in 1975. The low number of completed nests at colonies, the small clutch size found as late as 28 June, and the lack of pipping or hatching activity on 21 July seem to imply a late phenology and/or considerable egg loss due to predation or some related cause. It is difficult to interpret this data because the individual colonies were not visited intensively and recent studies (Baird and Moe, 1977; Nysewander and Knudtson, 1976) have shown that kittiwake colonies may lose most of their eggs very quickly during some years.

During 1977 and 1978 phenologies were much more intensively monitored at Kulichkof Island. In both years the phenologies were essentially identical (Figures 3-4). Egg laying started 4 June and peaked 12-15 June with the mode (middle two-thirds) occurring between 10 and 24 June. Hatching began 2-4 July and peaked 10-14 July with the mode ranging from 7-22 July. Defining fledging as the first flight of the chick, we found fledging to start between 7 and 15 August. In 1978 renesting occurred 22-28 June with these few nests hatching 19-27 July.

The mean number of eggs per completed clutch for the Kulichkof Island colony was 1.91 (n = 177, S.E. = 0.03) in 1977 and 1.72 (n = 171, S.E. = 0.04) in 1978 (Table 5). Productivity decreased from 1.23

chicks fledged per nest attempt in 1977 to 0.77 chicks in 1978 (X^2 = 17.95, df = 1, $P < 0.01$). This decrease resulted from two factors: 1) a smaller clutch size and 2) more egg loss during incubation.

Reproductive success varied considerably between individual colonies (Table 6). Even though similar in size, the Gibson Cove colony had lower productivity (0.30 in 1977 and 0.17 in 1978) than the one on Kulichkof Island (1.23 in 1977 and 0.77 in 1978), and the probable causes are its location on mainland Kodiak near a cannery and river system where predators like eagles, crows, magpies, and gulls were quite common. The larger colonies in eastern Kodiak Island were not monitored regularly, but four failures were reported between 1975 and 1978 for larger colonies while none were recorded for the smaller colonies. The Whale Island colony of approximately 10,000 pairs had no young reported during the late chick stage in either August 1975 (Dick, et al. 1976b) or July-August 1977 (Forsell, pers. comm.). In 1978 the Viesoki Island colony only had three chicks produced out of 996 nest attempts. The Boulder Bay colony of 10-20,000 pairs appeared to produce almost no fledglings in 1978 (Forsell, pers. comm.). It thus appears that the large colonies (900 + nests) may have breeding failures while smaller colonies (< 900 nests) continue to produce young.

If a lack of food was the sole factor behind these failures, then the smaller colonies close to the larger ones should have failed completely also. The fact that some of these colonies still produced fledglings suggests that some other variable is in operation. Food shortages may force kittiwakes to spend more time away from nests for foraging thus increasing their vulnerability to predators. Larger colonies could possibly be more attractive to predators than the small colonies resulting in increased loss of eggs and chicks.

Table 7 compares the reproductive success at Kulichkof Island of kittiwakes nesting in the center and on the edge of the colony. The larger mean clutch size, higher hatching success, and more young fledged per pair found in the colony center (X^2 = 4.29, df = 1, $P < 0.05$) corroborates the findings of Coulson (1968). He found that older, heavier male kittiwakes occupy the nesting sites in the center of colonies and that these nests have the highest reproductive success in a colony. This points out how important it is to study representative samples of birds when measuring mortality rates of colonial birds or estimating mean reproductive success of a species.

Tufted Puffin

The Tufted Puffin was found by Dick et al. (1976a) to be the most abundant and widely distributed breeding species in both Chiniak and southern Marmot Bays. In Chiniak Bay alone in 1975, over 8300 breeding pairs were recorded for 21 island colonies. The optimal nesting habitat was on steep slopes which usually extended around an island periphery in a band one to ten meters wide. A 100 square meter quadrat on a steep slope on Cliff Island had mean densities of 0.49 and 0.66 active burrows per square meter in 1977 and 1978 respectively. In contrast, active burrow density within a ten square meter plot on the island top was only 0.1 per square meter in 1977.

Phenology was found to be almost identical on Cliff Island during 1977 and 1978 (Figure 5). In 1977 hatching began 10 July and peaked 19 July with the mode occurring between 14 and 25 July. In 1978 hatching began 3 July and peaked 17 July with the mode occurring between 11 and 25 July. The last known hatching was 8 August in 1977 and 2 August in 1978. By using a 45 day incubation period (Sealy, 1973; Lensink et al., (1978) and backdating from hatching dates, egg laying was calculated to have begun the last two weeks of May and peak the first week in June. Fledging would then have peaked the end of August or the first week of September. The estimated average duration of the nestling period in 1978 was between 40 and 45 days (Table 8).

Unlike the kittiwake, the Tufted Puffin showed very little variation in reproductive success between 1977 and 1978 (Table 9). Hatching success of known eggs was 88.0% (n = 25) in 1977 and 84.8% (n = 46) in 1978. Fledging success of known chicks was 90.9% (n = 22) in 1977 and 89.7% (n = 39) in 1978. The mean number of chicks fledged per nest attempt was similar also: 0.67 in 1977 and 0.69 in 1978 (X^2 = 0.0080, df = 1, P = 0.93).

In 1977 at Cliff Island 18% of 74 burrows never had birds associated with them. Of the remaining burrows entered at least once during the season, 17% were not used for breeding. Thus, 66% of all burrows under observation were used by breeding birds at this site. In 1978 no data are available on number of burrows that never had birds associated with them, but 10% of the 51 burrows entered by birds were not used for breeding.

The Tufted Puffin was the only species of the six seabird species studied intensively that did not have its reproductive success decrease in 1978 from that recorded in 1977. Two factors seem most likely as causes: 1) The puffin, being a diver, has a larger water column available for pursuit of forage fish than do the surface or near-surface feeders.

2) The use of burrows protects the eggs from predation by hungry surface feeding seabirds like the Glaucous-winged Gull and food shortages would not cause increased predation.

Pelagic and Red-faced Cormorants

Cormorants are not highly philopatric and nest sites, even whole colonies, are often moved from year to year (Tables 1-2). Despite this, the breeding populations have remained similar for four years in Chiniak Bay.

Dick (1976b) noted that Pelagic Cormorants in 1975 commenced laying around 12 June with a peak on 20 June at Zaimka Island. Intensive monitoring of Pelagic Cormorants on Kulichkof Island in 1977 and 1978 found this species to be ten (1977) to thirteen (1978) days ahead of the phenology noted in 1975. In 1977 egg laying extended from 3 to 24 June, peaking on 10 June. In 1978 egg laying occurred between 30 May and 14 June, peaking on 7 June. However, many nests were lost and renesting occurred between 21 and 30 June with a peak of renesting on 26 June. The overall mode in 1978 was 7-28 June (Figure 6).

Hatching peaked on 11 July in 1977 and on 26 July in 1978. Overall mode was 9-14 July in 1977 and 21-29 July in 1978 (Figure 7). In 1977 when there was essentially no renesting, hatching ranged between 4 and 18 July. In 1978 hatching of first nest attempts occurred between 14 and 24 July while the hatching of renests occurred between 21 and 30 July. Fledging began around 15 August in 1977 and 1 September in 1978.

The phenology of Red-faced Cormorants is not well known in Chiniak Bay. Some evidence in 1977 suggested that it was earlier than that of Pelagic Cormorants that year. In 1978 only two Red-faced Cormorant colonies were accessible for study. One on Cliff Island was used to estimate productivity. The other colony on Puffin Island nested close to gull colonies in 1978 and quickly lost all of its eggs. However, on 26 May 1978 seven of these nests had one egg each while Pelagic Cormorants did not even begin laying until 30 May 1978 anywhere in Chiniak Bay. This suggestion of a slightly advanced phenology for Red-faced Cormorants could help explain why, in mixed colonies, Red-faced Cormorants tend to nest in definite subgroups more or less excluding Pelagic Cormorants.

The mean clutch size of Pelagic Cormorants dropped from 3.52 (n = 25, S.E. = 0.14) in 1977 to 2.17 (n = 23, S.E. = 0.26) in 1978. Table 10 compares the reproductive data recorded in 1977 and 1978 for this species for both the intensive plots (Kulichkof Island) and production plots (six islands). The production plots showed a significant decrease from 1.35 chicks fledged per nest attempt (n = 127) in 1977 to

0.60 chicks (n = 135) in 1978 (X^2 = 38.09, df = 1, $P < 0.01$). On the intensive study plots a similar decrease in 1978 (X^2 = 22.81, df = 1, $P < 0.01$) was found to be due to increased loss in both the egg and chick stages.

Red-faced Cormorants also showed a production decrease from 1.91 chicks fledged per nest attempt (n = 57) in 1977 to 1.33 chicks (n = 30) in 1978 (X^2 = 3.61, df = 1, P = 0.0575).

Success varied tremendously from island to island for both species (Table 11). This variation as well as the overall decrease in reproductive success in 1978 was related to five factors listed in decreasing order of importance: 1) egg and chick predation by large gulls; 2) more islands visited by River Otters driving cormorants from nests even if eggs could not be reached; 3) predation by crows and eagles on certain colonies; 4) human disturbance forcing cormorants frequently from their nests thereby leaving eggs unprotected; and 5) egg and chick loss due to storms.

The two study plots on Kulichkof Island in both years demonstrated that human disturbance, association with kittiwake nests, and cormorant nest density affects the reproductive success of Pelagic Cormorants. The cormorants associated with the kittiwakes in our intensive study area produced 1.42 young per nest attempt (n = 26) in 1977 and 0.25 (n = 28) in 1978 while the more dense, less disturbed, and single species colony of cormorants on the rest of the island produced 2.14 young per nest attempt (n = 45) in 1977 and 0.89 young (n = 35) in 1978 (X^2 = 53.57, df = 3, $P < 0.001$).

The increased egg loss of cormorants on Kulichkof Island in 1978 seemed attributable to visits by a River Otter (Lutra canadensis) in early June. No otter was known to visit this island during the breeding season in 1977. In 1978 the otter could not usually reach the cormorant nests as it could the gull nests found on the island top, but its trails were close to nest sites and the cormorants probably left their nests when the otter was present. This disturbance probably caused the loss of the nests to gulls since egg predation by Glaucous-winged Gulls generally increased throughout Chiniak Bay in 1978 over that observed in 1977.

Glaucous-winged Gull

Dick (1976a) found 1,072 pairs of Glaucous-winged Gulls breeding on sixteen islands in Chiniak Bay in 1975. There are several indications that the population is growing. In 1975, Dick reported 165 pairs on Puffin Island and no breeding pairs on Kulichkof Island. A 3 June 1977 survey of Puffin Island revealed a minimum of 250 pairs on that island while, in 1978, 28 pairs were nesting on Kulichkof Island. These two colonies are close to the town of Kodiak and birds nesting there probably feed on offal from the canneries, fishing boats, and the dump.

Mr. Terry Wahl of Bellingham, Washington, helped Dick band gulls in 1975 on Zaimka Island. Mr. Wahl has had considerable experience banding Glaucous-winged Gulls in Washington and his following observations support the idea of growing or new colonies in Chiniak Bay: 1) Gulls in the dense and numerous Washington colonies were much more aggressive than those found in Chiniak Bay. The former dived at and struck banders, inflicting wounds unless protection was worn, whereas the latter merely circled or landed some distance away. 2) The non-attacking behavior of the gulls on Zaimka Island was similar to that of new, relatively recently formed colonies in Washington.

Dick (1977) pointed out another factor affecting numbers of gulls in Chiniak Bay. Crew members on some of the fishing boats involved in the winter fishery around Kodiak Island told him that at least fifteen of the boats under 80 feet in the Kodiak Tanner Crab fleet use gulls extensively for hanging bait and that 11,000 to 15,000 birds were estimated to be shot annually. This type of mortality in the past has resulted in small, continually growing colonies found in Kodiak.

Dick (1976b) found that Glaucous-winged Gulls preferred to nest in the *Elymus* zone on low, well vegetated islands. Typically, nests were found around the periphery of islands and up to 50 meters inland. Our observations in 1977-78 support these observations but indicate that Glaucous-winged Gulls also utilize inland mixed meadow (*Calamagrostis* - umbel) habitat considerably, especially on Puffin Island.

In 1976 Dick set up nine 100 square meter plots containing low density nesting habitat on Cliff and Zaimka Islands and one high density plot of 766 square meters on Zaimka Island (Figure 8). The mean density for the low density plots did not differ significantly between years: 2.6 nests per square dekameter in 1977 and 2.3 nests in 1978 (X^2 = 0.0011, df = 1, P = 0.97). The mean density of nests in the high density plot was also similar between years: 5.2 nests per square dekameter in 1977 and 5.0 nests in 1978 (X^2 = 0.0004, df = 1, P = 0.98). In 1977, the mean distance to nearest nest of the same species was not significantly different between low and high density plots (T = 1.56, df = 59, P > 0.10). Behavioral needs apparently require a certain amount of clumping even in less desirable habitat.

The breeding phenologies of Glaucous-winged Gulls were similar in 1977 and 1978 at Zaimka Island (Figures 9-10). Egg laying began 28 May and peaked 6 June in 1978 with the mode occurring between 1 and 10 June. Relaying occurred between 25 and 29 June. Hatching started 25 June in 1977 and 26 June in 1978 with the peak on 2 July in 1977 and 3 July in 1978. The modes were 28 June to 4 July in 1977 and 27 June to 7 July in 1978. The renests hatched 15-25 July in 1977 and 20-24 July in 1978. Fledging began between 26 July and 1 August. Dick (1976b) reported hatching to start 18-19 June peaking around 30 June on Zaimka Island in 1975, slightly earlier than observed in either 1977 or 1978.

The mean number of eggs per completed clutch for the high density intensive plot on Zaimka Island was 2.64 (n = 33, S.E. = 0.13) in 1977 and 2.49 (n = 35, S.E. = 0.12) in 1978. Productivity declined from 1.15 chicks fledged per nest attempt in 1977 to 0.74 chicks in 1978 (Table 12; X^2 = 4.42, df = 1, P = 0.035). Like the kittiwakes, the decrease resulted from two factors: 1) a smaller clutch size and 2) more egg loss during incubation. Gulls were apparently preying on each other's eggs as well as those of other species. Some loss of eggs is also due to egg collection by residents of Kodiak.

Banding of hatching year Glaucous-winged Gulls from 1975 through 1978 has already given some idea of the movements of juvenile birds. One chick banded on Zaimka Island in 1975 was recovered in Astoria, Oregon while another banded on the same island in 1975 appeared at the Tsakawis River mouth in British Columbia. A chick banded near Nelson Lagoon on the Alaska Peninsula in July 1976 was recovered in the Geese Island area of southwest Kodiak Island in January 1977. Evidence indicates a general southward and eastward movement of gulls to and from the Kodiak area. However, several thousand gulls winter in the Chiniak Bay region (Dick, 1977) and evidence indicates that some young birds stay in the Kodiak area. For example, a chick banded in August 1977 at Zaimka Island turned up at the Coast Guard dump at Kodiak in November 1978. Another chick banded July 1978 at Zaimka Island was seen November 1978 at the Kodiak dump.

Mew Gull

Up to 2,000 Mew Gulls have been noted wintering in Chiniak Bay (Dick, 1977). During the breeding season, this species disperses inland and along the coast using occasional bay or lake islands, shorelines of coastal lakes and streams, or upland habitats near coastal regions for nesting. The breeding colonies in the Kodiak Island region are usually small (25 - 50 breeding pairs), but both larger colonies and single scattered nests exist. Single isolated nests were found in Kalsin Bay and Rose Tead Lake in 1977 and 1978 while MacIntosh (pers. comm.) found Mew Gulls nesting on Tugidak Island in June 1978 to be scattered over a wide area of crowberry tundra. In Chiniak Bay, Mary Island has two colonies totaling 200 breeding pairs and all birds nested in a wet meadow dominated by Calamagrostis. The mean distance of the nearest nest of the same species was 3.31 meters (n = 60, S.E. = 0.22) in 1977. The mean number of nests per square dekameter on the nine 100 square meter intensive study plots was 4.44 (range = 1-7) in both 1977 and 1978 (Figure 11).

The breeding phenologies were very similar for both 1977 and 1978 on Mary Island (Figures 12-13). Egg laying began 24 May peaking on 31 May in 1978 with the mode occurring between 27 May and 3 June. Relaying took place between 7 and 26 June. Hatching started 15 June in 1977 and 21 June in 1978, but the peaks of hatching were more similar, being 24 June in 1977 and 26 June in 1978. The hatching modes (middle two thirds) were 19-29 June in 1977 and 23-28 June in 1978. The renests hatched 10-14 July in 1977 and 5 July in 1978. Initiation of fledging varied from 27 July (1978) to 5 August (1977). Using the assumption that incubation begins on the laying of the last egg and that hatching usually occurs one day after pipping, we found a mean of 24.6 days (n = 32, S.E. = 0.21) for incubation. This differs some from the 26 days reported by Barth (1955) and Bianki (1967).

The mean number of eggs per completed clutch for the Mary Island plots was 2.66 (n = 38, S.E. = 0.11) in 1977 and 2.51 (n = 39, S.E. = 0.12) in 1978. Reproductive success declined between 1977 and 1978 on the intensive study plots in the south colony on Mary Island (X^2 = 8.14, df = 1, P = 0.004) (Table 13). Hatching success was identical both years, but the overall reduced success was caused by two factors: 1) lower clutch size caused by egg predation early in incubation before the grass was tall enough to conceal nests; and 2) a decrease in fledging success. In both 1977 and 1978 fledging success was low, but the mortality occurred in two different ways. In 1977 in the last week before fledging, the mean brood size was over two chicks per nest attempt. A three week period of severe storms and rains brought on much mortality and the final productivity was reduced to a maximum of 1.00 chicks fledged per nest attempt. In 1978 the chick mortality was not concentrated at the end of the chick stage, but occurred throughout the nestling period with the final productivity being 0.46 chicks fledged per nest attempt. A three week period of severe storms and rains brought on much mortality and the final productivity was reduced to a maximum of 1.00 chicks fledged per nest attempt. In 1978 the chick mortality was not concentrated at the end of the chick stage, but occurred throughout the nestling period with the final productivity being 0.46 chicks fledged per nest attempt. This species has been noted to have relatively high fleding mortality at times, but as a rule Bianki (1967) found Mew Gulls to average 1.5 fledglings per pair.

The relatively low reproductive success in both 1977 and 1978 seemed linked with food supply although predation by other gulls and a River Otter did occur. In both years chicks were often found dead, untouched by predators. The severe storms in 1977 may have driven the forage fish out of the shallow or surface waters where Mew Gulls feed. In 1978 food found on the colony or regurgitated by chicks tended to be more from intertidal and estuarine sources than noted the previous years. The presence of species like small clams (Macoma baltica), rock louse (Idotea wosnesenskii), and threespine stickleback (Gasterosteus aculeatus) suggest that a decrease in availability of forage fish like capelin over the entire chick stage may have forced Mew Gulls to look for other food sources.

Arctic and Aleutian Terns

The total number of breeding pairs of Arctic Terns found on four sites in Chiniak Bay ranged from 214 (1977) to 133 (1978). Breeding pairs of Aleutian Terns varied at seven sites in Chiniak Bay from approximately 200 (1977) to 270 (1978). The numbers of active nests at any one site differed considerably from year to year for both species (Table 14, **Figure 14). Nesting densities in different habitats varied** between years for both species (Table 15). The colonies that varied most were either small colonies or those that experienced mammal predation the preceding year. Our observations indicate that Arctic Terns can nest in a variety of habitats while Aleutian Terns are usually restricted to a heavy grass habitat (Calamagrostis). Nesting densities of both species are higher on small islands than on mainland Kodiak.

Arrival times for terns in Kodiak are not well known. Aleutian Terns are usually seen by mid-May while Arctic Terns arrive earlier, usually during late April and early May (MacIntosh, pers. comm.). Departure of terns is sometimes spectacular as Chiniak Bay appears to serve as a staging area during late July and early August. Several thousand terns were seen 5 August 1975 off of Long Island by Juan Guzman (Field notes, 1975). On 26 July 1977 approximately a thousand terns were flying through the Women's Bay area. Most of the terns depart Chiniak Bay by mid-August although some Aleutian Terns were still present in Middle Bay during the third week of August 1978.

Although egg laying dates were not obtained in 1977, our data suggests that the breeding phenology for each tern species was similar in 1977 and 1978. At any one site in both 1977 and 1978, the breeding phenology of Aleutian Terns was two to six days behind that of Arctic Terns (Figure 15). In addition, the phenology of both species of terns nesting on mainland Kodiak was seven to ten days earlier than that found for the same species on the island colonies (Figure 15).

In 1978 the peak of egg laying for Arctic Terns was 28 May on the mainland (n = 45) and 5 June on the islands (n = 47). The peak of egg laying for Aleutian Terns was 30 May on the mainland (n = 93) and 10 June on the islands (n = 11).

Hatching of Arctic Terns began 18 June in 1977 and 19 June in 1978 with the peak being 26 June in both years (Figure 16). Hatching of Aleutian Terns began 22 June in 1977 and 28 June in 1978 with the peak being 1 July in 1977 and 3 July 1978 (Figure 16).

The mean number of eggs per completed clutch of Arctic Terns in different colonies varied from 1.91 to 2.19 while that of Aleutian Terns varied from 1.73 to 2.00 (Table 16). Hatching success varied considerably between different sites 1977-78 (Table 16). A comparison of the reproductive success data for both tern species in 1977 and 1978 generally indicated that hatching success in 1977, which was similar to that reported by Bianki (1967) and Hawksley (1957), was greater than the hatching success in 1978. Hatching success at several tern colonies was essentially zero in 1978 due to predation by mammals. Our data also indicate that, at any one site where both species bred, Arctic Terns usually had larger clutch sizes while Aleutian Terns tended to have better hatching success.

In 1977, most mortality occurred during the chick stages in the form of predation by a River Otter and exposure/starvation due to intense storm activity. In 1978, weasels destroyed almost all eggs of both tern species as well as those in several nests of Pintails and Mew Gulls at the head of Kalsin Bay. It is uncertain what caused losses at Middle Bay and Mary Island, but more loss occurred during the egg stages in 1978 than in the previous year. Previous studies of terns by this author in Prince William Sound and Kodiak using the same procedures found much higher hatching success than that found in 1978 at Kodiak. Hence, factors such as reduced availability of food of terns and increased predation may have together caused the increased egg loss in 1978.

Common Eider

Several hundred Common Eiders winter in Chiniak Bay (Dick, 1977). By late March males and females began to pair while still in flocks. Approximately 35-40 pairs nested on seven or eight islands in the inner portions of Chiniak Bay in both 1977 and 1978. The total population for all of Chiniak Bay is estimated at about 80 breeding pairs. Most small islands in inner Chiniak Bay had two or three nests with Mary Island having the most with 11 nests in 1977 and 20 nests in 1978. From May to July flocks, composed predominantly of males and raning in size up to 50-60 birds, loitered on various island spits and reefs in Chiniak Bay. Nests were usually located in dense stands of tall grass near water, but were also found in building ruins, under trees or brush, in the umbel-grass associations on island tops, and in beach driftwood.

Egg laying on Mary Island started on 23 May and peaked on 3 June in 1978 (n = 20). The mode was between 30 May and 17 June (Figure 17). Hatching started on 22 June in 1977 and 20 June in 1978 with the peak being 6 July in 1977 and 2 July in 1978. The hatching modes both years were similar in time, but different in extent. In 1977 the hatching mode was 1-8 July while it was 24 June - 12 July in 1978.

The mean clutch size was 4.55 in both years (Table 17). The number of nests hatching one or more young declined from 63.2% in 1977 to 45.0% in 1978. Brood size at hatching ranged from 4.2 in 1977 to 3.7 in 1978. The females leave the nesting islands with their broods soon after hatching and are rarely, if ever, seen thereafter.

In 1977 three nests were preyed upon, two were abandoned, one was washed away by a high tide, and one nest loss was unexplained. In 1978 three nests were lost to predation, five were abandoned, and three nest losses were unexplained. The higher abandonment rate in 1978 possibly stems from two sources: 1) increased disturbance of nesting pairs by hydrographic field parties and picnicking by residents of Kodiak; and 2) disturbance caused by our studies which started earlier in 1978 and disturbed the females before full clutches were laid, a period when nest fidelity is not as strong as later in incubation.

Black Oystercatcher

Dick (1977) estimated that 100-150 Black Oystercatchers wintered in Chiniak Bay in 1976 with flock sizes ranging up to 70 birds. Island censuses from 1975 to 1978 indicate that 30-32 pairs breed in Chiniak Bay itself (Table 18) with an additional six pairs found on or nearby Spruce Island in southern Marmot Bay. These latter birds may also winter in Chiniak Bay.

Some hatching dates were obtained in 1977, but only in 1978 were study sites visited early enough to record most nesting attempts. In 1978 egg laying began on 3 May reaching a peak on 19 May with the mode being between 8 May and 2 June (Figure 18). Relaying occurred on 9 and 20 June. Hatching in 1978 started on 31 May and peaked on 8 June with the mode being 4-30 June. One renest hatched on 7 July.

The mean size of completed clutches was 2.08 (n = 12) in 1978 while it was 2.40 (n = 5) in 1977. In 1977 studies did not begin sufficiently early to identify all nesting attempts. Using behavior as a criterion, we estimated that we found only five nests of the ten probably attempted in our study areas in 1977. In 1978 an earlier and continued effort recorded twelve nests out of the fourteen possibly attempted. Hence the 1978 data on Table 19 is probably closer to normal reproductive success than that of 1977. This conclusion is also supported by comparisons with five years of studies conducted in British Columbia and Washington (Hartwick, 1974; Nysewander, 1977). These studies found that hatching success never exceeded 76.7% and was usually well below this level. The hatching success for 1978 in Chiniak Bay of 52% compares most favorably with these studies. Although the indicated decrease in hatching success between 1977 and 1978 may not have been as large as our data suggests, the decrease was likely real in view of the mortality and egg predation to which other species were subjected in 1978.

3. Growth

Growth rate data on weight and flattened wing length were obtained on 53 Black-legged Kittiwake chicks and 37 Tufted Puffin chicks (Appendix II and III). The wing length will be useful for aging chicks in future work when hatching dates are not precisely known (Figures 19-20).

Weight was displayed in two ways: 1) the plotting of the mean, standard, error. and range of weights against a three day interval of time (Figures 21 and 23); 2) the plotting of individual measurements on a time axis using a polynomial regression (Figures 22 and 24).

The growth curve for chicks of Black-legged Kittiwake (Figure 22) has a r square value of 0.96 with the curve equation being $y = 1.80 X^3 + 5.39 X^2 + 1.18 X + 2.40$. The growth curve of Tufted Puffin chicks (Figure 24) has a r square value of 0.89 with the curve equation being $y = 3.88 X^3 + 9.96 X^2 + 1.50 X + 3.13$.

The weight at time of fledging may be a good gauge of how reproductive success is faring any one year. A comparison of polynomial regression lines of kittiwake chick growth at two sites in Kodiak and one site in lower Cook Inlet in 1978 (Figure 25) shows that rates may differ at times, but that asymptote or peak weights also differ. In 1978 at Chiniak Bay the Tufted Puffin chicks left their burrows at a mean weight of 561 grams (n = 16, S.E. = 12.7 g.) with a range between 470 and 665 grams.

4. Trophic Relationships

In 1977 one hundred and twelve birds were collected for food and parasite analysis. Capelin *(Mallotus villosus)* was the one species found in almost all species of birds. Sand lance *(Ammodytes hexapterus)* was also important as food for Tufted Puffins and Black-legged Kittiwakes (Nysewander and Hoberg, 1978).

In 1978, rather than collect seabirds, we conducted food watches at Tufted Puffin and Black-legged Kittiwake colonies and studied the timing and frequency of parental trips to the nest with food. These food watches were not combined with food collections. Collections of food at the one colony studied disrupted colony attendance to such a degree that food watch data would have been meaningless. As we had little chick regurgitation and bill load data from 1977 with which to compare 1978 data, we felt it more important to concentrate on colony attendance and feeding cycles.

Nine kittiwake nests on Kulichkof Island were monitored on 1, 4, and 14-15 August each covering three complete cycles of available daylight (0330 - 2200 hours). Over two thirds (68%) of all feedings observed (n = 233) occurred during morning hours (Figure 26). Generally, it appeared that one member of a pair left the nest at or prior to dawn while the other departed later in the morning. In the afternoon, both adults were often present at or near the nest and chicks were seen more often unsuccessfully begging for food.

Harris and Hartt (1977) found that capelin was the primary pelagic fish species in three bays on the east and south coasts of Kodiak Island and that they were found in all depth strata with density increasing towards the bottom (61-100 m) during daylight hours. At night the schools of fish break up and individuals disperse to the surface waters (0 - 20 m.). Beach spawning capelin have been found to prefer water temperatures of 5.5 - 8.5°C (Jangaard, 1974). It was found in parts of Newfoundland that water temperatures rise so fast that beach spawning becomes sporadic and is usually replaced by deepwater spawning. In 1978 at Chiniak Bay, Kodiak Island, the beach spawning runs of capelin usually sought by a local sport fishery did not appear. These variations in habits of capelin not only relate to the variations in bird reproductive success mentioned earlier, but also to the feeding cycles of kittiwake adults noted in Figure 26. With capelin spawning in deeper water, the kittiwakes are even more dependent on feeding when capelin are near the surface at or near darkness.

One face of the puffin colony on Cliff Island was monitored over a 24-hour cycle 16-17 August (Figure 27). The small sample size limits any conclusions, but it appears that puffins might be feeding more during daylight hours as Amaral (1977) found Tufted Puffins doing in the Barren Islands.

5. Mortality

Six sea mammal and eleven bird carcasses were found in the 74.5 kilometers of beach walked from May to September 1978. Sixty-four percent of all bird carcasses were found either in May or September with September being the peak month during this period. For further detail, refer to the beached bird survey report consolidated overall for the Gulf of Alaska by Kent Wohl (U.S.F.W.S., BSP-CE, Anchorage).

Banding of young with U.S. Fish and Wildlife leg bands was done on Puffin, Zaimka, and Mary Island between 4 and 8 August 1977. A total of 267 Glaucous-winged Gulls, 75 Mew Gulls, and 7 Arctic Terns was banded. In 1978 U.S. Fish and Wildlife bands were put on 27 Glaucous-winged Gulls 1 August and 21 Mew Gulls 28 July. Numbered green color bands were used on study plots between 26 June and 1 August 1978 when a total of 53 chicks of Glaucous-winged Gulls and 133 of Mew Gull was banded. Only chicks surviving to near fledging were banded with metal bands later. The five returns of Glaucous-winged Gulls associated with Kodiak Island are discussed earlier in the section dealing with this species and its breeding biology in Chiniak Bay.

VI. NEEDS FOR FURTHER STUDY

Chiniak Bay contains a diversity of breeding seabirds and the studies undertaken from 1975 through 1978 provide a basis for future monitoring of trends in the population. Additional work is needed on the feeding relationships of the major species during the breeding season. Even less work has been done on the trophic ecology of the large wintering populations of marine birds found in Chiniak Bay at times (Dick, 1977).

The area needing the most attention, in light of imminent lease sales and the large number of auklets and ducks found wintering there, is the Shelikof Straits side of Kodiak Island. Up to 15,000 Crested Auklets and 4,000 King Eiders have been observed wintering in the straits while they rarely or briefly use Chiniak Bay. Atwell (U.S.F.W.S., 1973 and 1975) censused 54-56,000 birds wintering near Kodiak Island with 31,000 sea ducks, 15,000 auklets, 15,000 murres, and 4,500 dabbling ducks being the most numerous species groups. This wintering population is probably typical of that found along the southern coast of the Alaska Peninsula and little is known of the dynamics of these wintering concentrations.

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Table 1. Variations in Pelagic Cormorant nesting in Chiniak Bay, 1975-1978.

Islands	Number of Nests		
	1975	1977	1978
Inner Chiniak Bay			
Bird	56	100	121
Blodgett	0	47	3
Cliff	0	5	24
Gibson Cove	0	50	63
Holiday	43	58	10
Kulichkof	25	71	63
Mary	0	0	14
Puffin	39	31	36
Viesoki	22	4	8
Zaimka	17	25	30
Subtotal of inner bay	202	391	372
Outer Chiniak Bay (excluding Cape Chiniak)			
Jug	6	-	4
Kalsin	36	-	39
Kekur	25	-	0
Long	177	-	131
Middle	2	-	48
Queer	8	-	0
Svitlak	46	-	0
Utesistoi	1	-	0
Subtotal of outer bay	301	-	222
Chiniak Bay total	503	-	594

Table 2. Variations in Red-faced Cormorant nesting in Chiniak Bay, 1975-1978.

Islands	Number of Nests		
	1975	1977	1978
Inner Chiniak Bay			
Bird	3	31	17
Blodgett	0	7	0
Cliff	2	2	23
Gibson Cove	0	10	24
Holiday	0	23	0
Kulichkof	5	0	0
Mary	0	0	0
Puffin	17	33	20
Viesoki	103	14	26
Zaimka	22	21	31
Subtotal of inner bay	152	141	141
Outer Chiniak Bay (excluding Cape Chiniak)			
Jug	4	-	3
Kalsin	58	-	52
Kekur	45	-	0
Long	55	-	65
Middle	0	-	30
Queer	2	-	0
Switlak	1	-	26
Utesistoi	1	-	5
Subtotal of outer bay	166	-	181
Chiniak Bay total	318	-	322

Table 3. Variations in Black-legged Kittiwake Nesting in Chiniak Bay[1], 1975-78

Islands	Number of Nests 1975[2]	1977	1978
Inner Chiniak Bay			
Gibson Cove	114	199	254
Holiday	5	5	33
Kulichkof	104	218	259
Viesoki	1306	1096	996
Zaimka	20	0	0
Inner bay subtotal	1549	1518	1542
Outer Chiniak Bay			
Kekur	585	-	332
Long	142	-	385
Middle	0	-	20
Svitlak	14	-	8
Utesistoi	1155	-	784
Outer bay subtotal	1896	-	1529
Chiniak Bay total[1]	3445	-	3071

1/Cape Chiniak kittiwake colonies (10,000 nests) not included.

2/Data provided by Matt Dick.

Table 4. Comparisons of numbers of birds attending selected kittiwake colonies in Chiniak Bay between 1975 and 1978.

Islands	Number of Birds 1975	1978
Gibson Cove	250	391
Kekur	1200	1045
Kulichkof	228	393
Long	300	613
Viesoki	2857	2014
Total	4835	4456

Table 5. Reproductive data on Black-legged Kittiwakes on Kulichkof Island in Chiniak Bay, 1977-78

	1977	1978
Number of nests built	210	259
Nests with eggs/nests built	.84	.66
Mean clutch size	1.91	1.72
Sample size	177	171
Standard error	.03	.04
Chicks hatched/egg laid	.84	.72
Mean brood size at hatching	1.67	1.50
Sample size	172	138
Standard error	.04	.04
Mean brood size at fledging	1.60	1.45
Sample size	161	108
Standard error	.04	.05
Chicks fledged/chicks hatched	.90	.93
Chicks fledged/eggs laid	.77	.68
Chicks fledged/nest with eggs	1.46	1.16
Chicks fledged/nest built	1.23	.77

Table 6. Productivity of Black-legged Kittiwakes in Chiniak Bay, 1977-78.

Colony Site	Number of Nests Built		Chicks Fledged Per Nests Built	
	1977	1978	1977	1978
Kulichkof Island	218	259	1.23	0.77
Gibson Cove	199	254	0.30	0.17
Viesoki Island	-	996	-	0.003

Table 7. Comparison of breeding biology of kittiwakes breeding on the edge and in the center of a colony on Kulichkof Island, 1978.

	Colony Center	Colony Periphery
Nests with eggs	110	61
Mean clutch size	1.77	1.62
Standard error	.05	.06
Chicks hatched/eggs laid	.77	.64
Chicks fledged/chicks hatched	.95	.91
Chicks fledged/nest with eggs	1.29	.93

Table 8. Age of Tufted Puffin chicks at fledging in 1978 at Chiniak Bay.

Age (days)	Disappeared or Fledged	Close to Fledging	Not Ready to Fledge
30 - 35			3
35 - 40	2	3	
40 - 45	7	9	
45 - 50	2		

Note: The last day burrows were checked was 27 August. Half of the age classifications of chicks above came from interpolations based on weights and wing lengths.

Table 9. Reproductive data on Tufted Puffins on Cliff Island in Chiniak Bay, 1977-78.

	1977	1978
Nest attempts	30	51
Nests with eggs	25	46
Chicks hatched/eggs laid	.88	.85
Chicks fledged/chicks hatched	.91	.90
Chicks fledged/nest attempt	.67	.69
Chicks fledged/nest with eggs	.80	.76

Table 10. Reproductive data on Pelagic Cormorants in Chiniak Bay, 1977-78.

	Intensive Plot*		Other Plots*	
	1977	1978	1977	1978
Number of nests built	26	28	127	135
Nests with eggs/nest built	.96	.75	-	-
Mean clutch size	3.52	2.17	-	-
Sample size	25	23	-	-
Standard error	.14	.26	-	-
Chicks hatched/eggs laid	.69	.32	-	-
Mean brood size at hatching	2.81	2.09	-	-
Sample size	21	11	-	-
Standard error	.19	.21	-	-
Mean brood size at fledging	2.18	1.40	-	-
Sample size	17	5	-	-
Standard error	.18	.25	-	-
Chicks fledged/chicks hatched	.62	.44	-	-
Chicks fledged/eggs laid	.42	.14	-	-
Chicks fledged/nest with eggs	1.48	.33	-	-
Chicks fledged/nest built	1.42	.25	1.35	.60

*Note: The intensive plot is on one island while the other plots were on six islands and were visited only twice.

Table 11. Comparison by island of differing productivities of two cormorant species, Chiniak Bay 1977-78.

	Island or Colony Site							
	Kulichkof Intensive	Kulichkof Production	Bird	Puffin	Gibson Cove	Cliff	Zaimka	Mary
Red-faced Cormorant								
1977								
Sample size	0	0	17	33	2	2	3	0
Chicks fledged per nest built	-	-	1.82	2.15	2.50	1.00	0.00	-
1978								
Sample size	0	0	-	12	-	18	-	0
Chicks fledged per nest built	-	-	-	0.00	-	2.22	-	-
Pelagic Cormorant								
1977								
Sample size	26	42	16	25	16	5	23	0
Chicks fledged per nest built	1.48	2.14	1.94	0.65	1.50	1.20	0.13	0
1978								
Sample size	28	35	-	36	25	24	-	14
Chicks fledged per nest built	0.25	0.89	-	0.19	0.20	1.58	-	0.00

Table 12. Reproductive data on Glaucous-winged Gulls on Zaimka Island in Chiniak Bay, 1977-78.

	1977	1978
Number of nests built	40	38
Nest with eggs/nest built	.83	.92
Mean clutch size	2.64	2.49
Sample size	33	35
Standard error	.13	.12
Chicks hatched/eggs laid	.86	.54
Mean brood size at hatching	2.45	2.08
Sample size	31	25
Standard error	.13	.16
Chicks fledged/chicks hatched	.61	.60
Chicks fledged/eggs laid	.53	.32
Chicks fledged/nest with eggs	1.39	.80
Chicks fledged/nest built	1.15	.74

Table 13. Reproductive data on Mew Gulls on Mary Island in Chiniak Bay, 1977-78.

	1977	1978
Number of nests built	42	40
Nest with eggs/nest built	.93	1.00
Mean clutch size	2.66	2.51
Sample size	38	39
Standard error	.11	.12
Chicks hatched/eggs laid	.87	.86
Mean brood size at hatching	2.31	2.49
Sample size	36	35
Standard error	.13	.11
Chicks fledged/chicks hatched	.42 1/	.32 1/
Chicks fledged/nest with eggs	-	-
Chicks fledged/nest built	1.00 2/	.46 2/

1/Fledging success was determined by the following formula: total number of chicks fledged or on island perimeter near colony just before fledging/number of colony nest attempts times clutch size average times hatching success.

2/Based on colony estimate of 200 nests since colony attendance ranged between 365 and 422 birds.

Table 14. Variations in Arctic and Aleutian Tern nesting in Chiniak Bay, 1975 - 78.

Colony Sites	Number of Nests 1975	1977	1978
Arctic Tern			
Blodgett Is.	15	0	0
Mary Is.	45	130	85
Head of Kalsin Bay	present	80	46
Head of Middle Bay	?	4	2+
Aleutian Tern			
Blodgett Is.	30	0	0
Mary Is.	25	27	20
Head of Women's Bay	10	0	20+
Head of Middle Bay	present	25	30
Head of Kalsin Bay	present	120	160
Olds River	?	8	0
Narrow Cape	20-30[1/]	?	30-40[2/]

1/Located where Loran station is now.
2/Located just to the southwest of Burton Ranch.

Table 15. Nesting densities per square dekameter of Arctic and Aleutian Terns, Chiniak Bay 1977-78.

Habitat	Arctic Tern 1977	Arctic Tern 1978	Aleutian Tern 1977	Aleutian Tern 1978
Mary Island				
Island hillside	8	1	0	0
Low wet meadows	13	4	13	9
Beach perimeter vegetation	10	0	0	0
Beach gravel	0	32.5 1/	0	0
Mew Gull colony (wet meadow)	9	4	0	0
Head of Kalsin Bay				
Beach gravel	?	3.1 2/	0	0
Low meadows	0	0	?	1.4 3/

Notes: 1/ The colony on the beach occupied 80 m^2 in which there were 26 nests and 17 possible renests. The above density came from extrapolation whereas all other densities on Mary Island came from 10 x 10 meter plots in each habitat.

2/ Total area sampled was 1500 m^2.

3/ Total area sampled was 6600 m^2.

Table 16. Reproductive success of Arctic and Aleutian Terns at three sites in Chiniak Bay, 1977-78.

Site	Arctic Tern 1977	Arctic Tern 1978	Aleutian Tern 1977	Aleutian Tern 1978
Mary Island				
Nests with eggs	96	67	22	12
Chicks hatched/eggs laid	.85	.53	.91	.52
Mean clutch size (± S.E.)	2.21 (.06)	1.91 (.08)	2.00 (.07)	1.92 (.15)
Mean brood size at hatching	2.01	1.89	1.82	1.63
Percent of clutches hatching one or more	92.8	53.7	100.0	66.7
Middle Bay				
Nests with eggs	-	-	15	16
Chicks hatched/eggs laid	-	-	.85	.19
Mean clutch size (± S.E.)	-	-	1.80 (.11)	2.00 (.00)
Mean brood size at hatching	-	-	1.77	-
Percent of clutches hatching one or more	-	-	86.7	18.8
Kalsin Bay				
Nests with eggs	-	46	8	93
Chicks hatched/eggs laid	-	.03	.86	.10
Mean clutch size (± S.E.)	-	2.07 (.12)	1.75 (.16)	1.73 (.05)
Mean brood size at hatching	-	3.00	1.50	1.78
Percent of clutches hatching one or more	-	2.2	100.0	9.6

1/Maximum possible at last observation.

Table 17. Reproductive data of Common Eiders in Chiniak Bay, 1977-78.

	1977	1978
Nests with eggs	19	20
Mean clutch size	4.55	4.55
Sample size	18	20
Range	2-7	1-6
Standard error	.35	.38
Chicks hatched/eggs laid	.68	.36
Mean brood size at hatching	4.30	3.67
Sample size	13	9
Standard error	.43	.47
Chicks hatched/nest with eggs	2.63	1.74
Percent of clutches hatching one or more	63.2	45.0

Table 18. The distribution of breeding pairs of Black Oyster catchers in Chiniak Bay 1974-78.

	Number of Pairs (* = nest found)		
Island	1975	1977	1978
<u>Inner Chiniak Bay</u>			
Mary	3	1+*	4*
Blodgett	0	1*	1*
Zaimka	2*	3*	3*
Cliff	-	1*	1*
Puffin	2	1	1
Kulichkof	0	1	1*
Holiday	1	1	1
Bird	0	1	1
<u>Outer Chiniak Bay</u>			
Long	2	2	2
Queer	3	-	1-3
Kalsin	1	-	4+
Jug	0	-	1?
Middle	2	-	1-2
Utesistoi	1	-	1
Switlak	1*	-	2-3
Cape Chiniak	2-3	-	present

Note: In 1978 the innter Chiniak Bay site were visited many times. The Kalsin Bay sites were estimated in terms of numbers of birds, their distribution, and behavior. The above counts do not include any of the non-breeding flocks. Data from 1975 comes from Dick (Field notes, 1975)

Table 19. Reproductive data of Black Oystercatchers in Chiniak Bay, 1977-78.

	1977	1978
Number of nests built	10-12?	14
Number of nests found	5	12
Mean clutch size	2.40	2.08
Standard error	.24	.23
Chicks hatched/eggs	.85	.52
Mean brood size at hatching	2.20	2.17
Sample size	5	6
Standard error	.20	.40
Chicks hatched/nest attempts	1.3 ?	.93
Percent of clutches hatching one or more	.60	.43

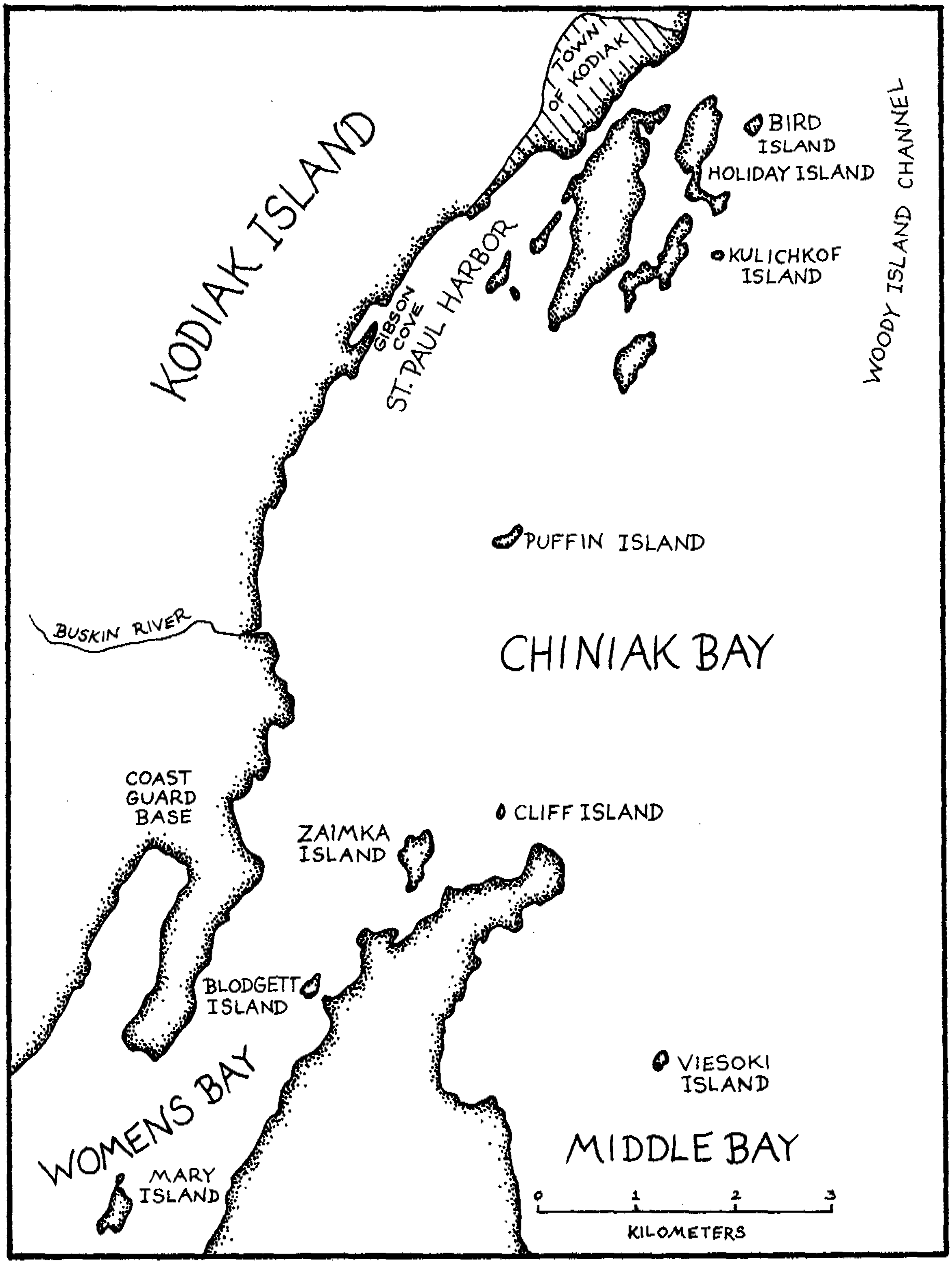

Figure 1. Study sites in inner Chiniak Bay.

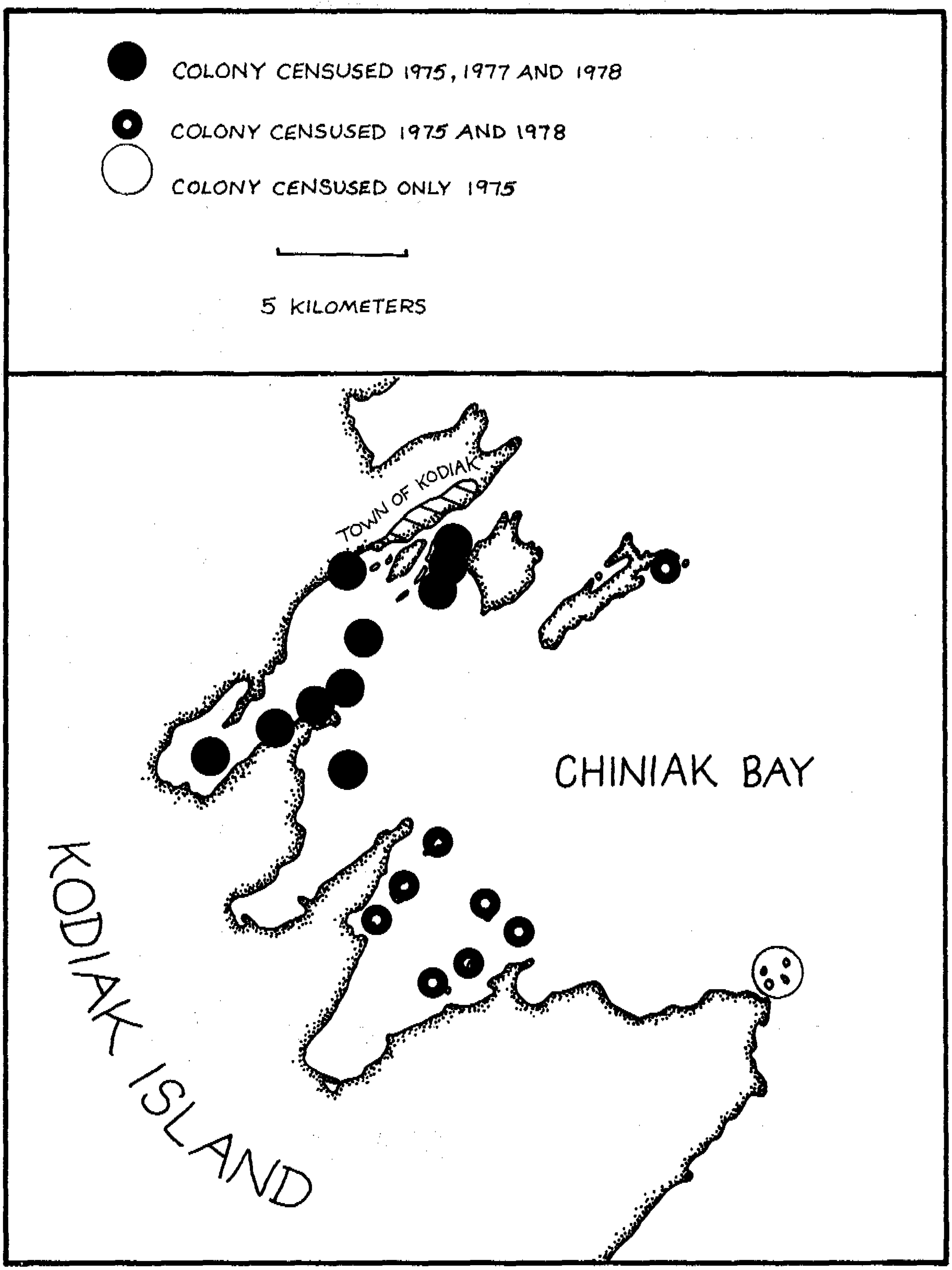

Figure 2. Colonies censused in Chiniak Bay, 1975-78.

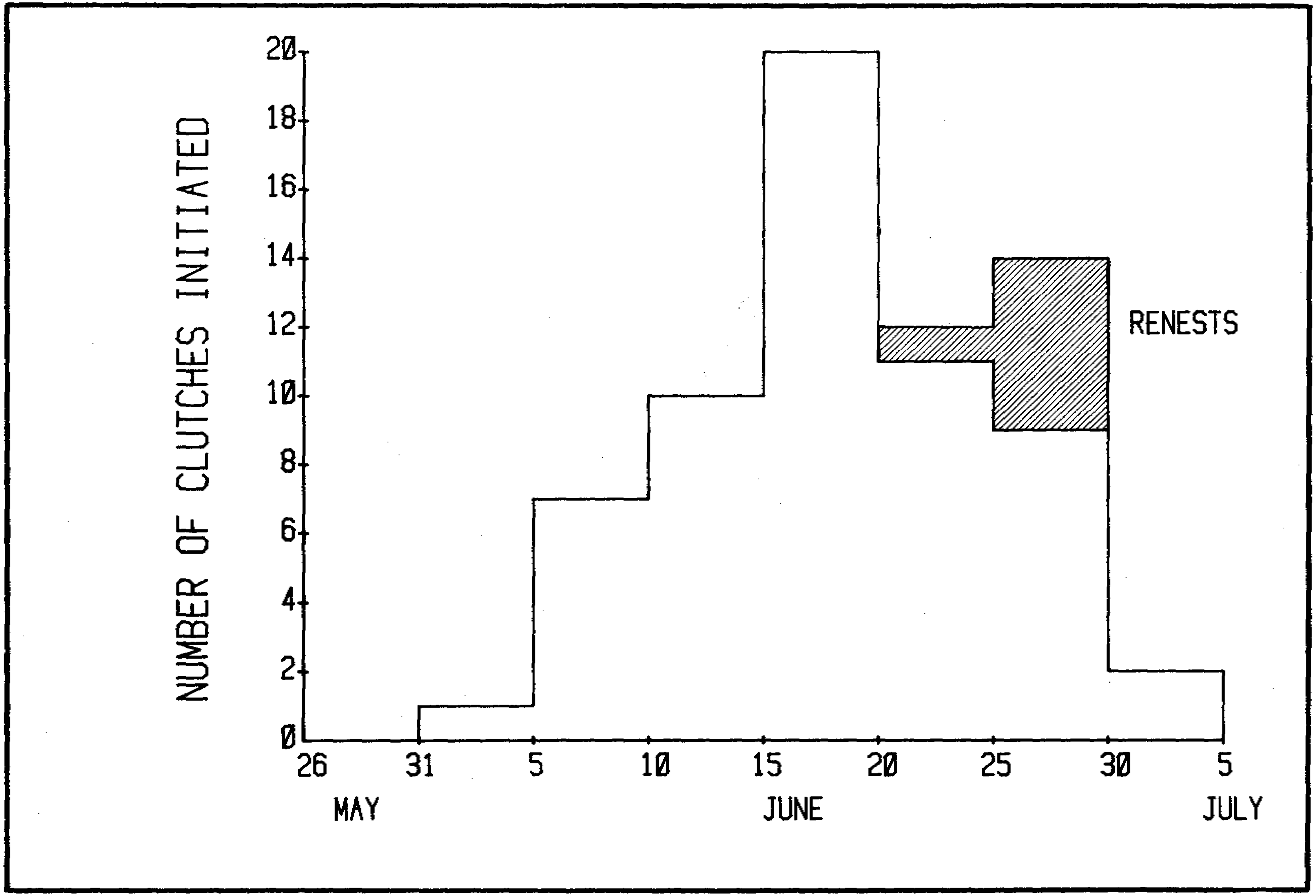

Figure 3. Laying phenology of Black-legged Kittiwakes on Kulichkof Island in Chiniak Bay, 1978.

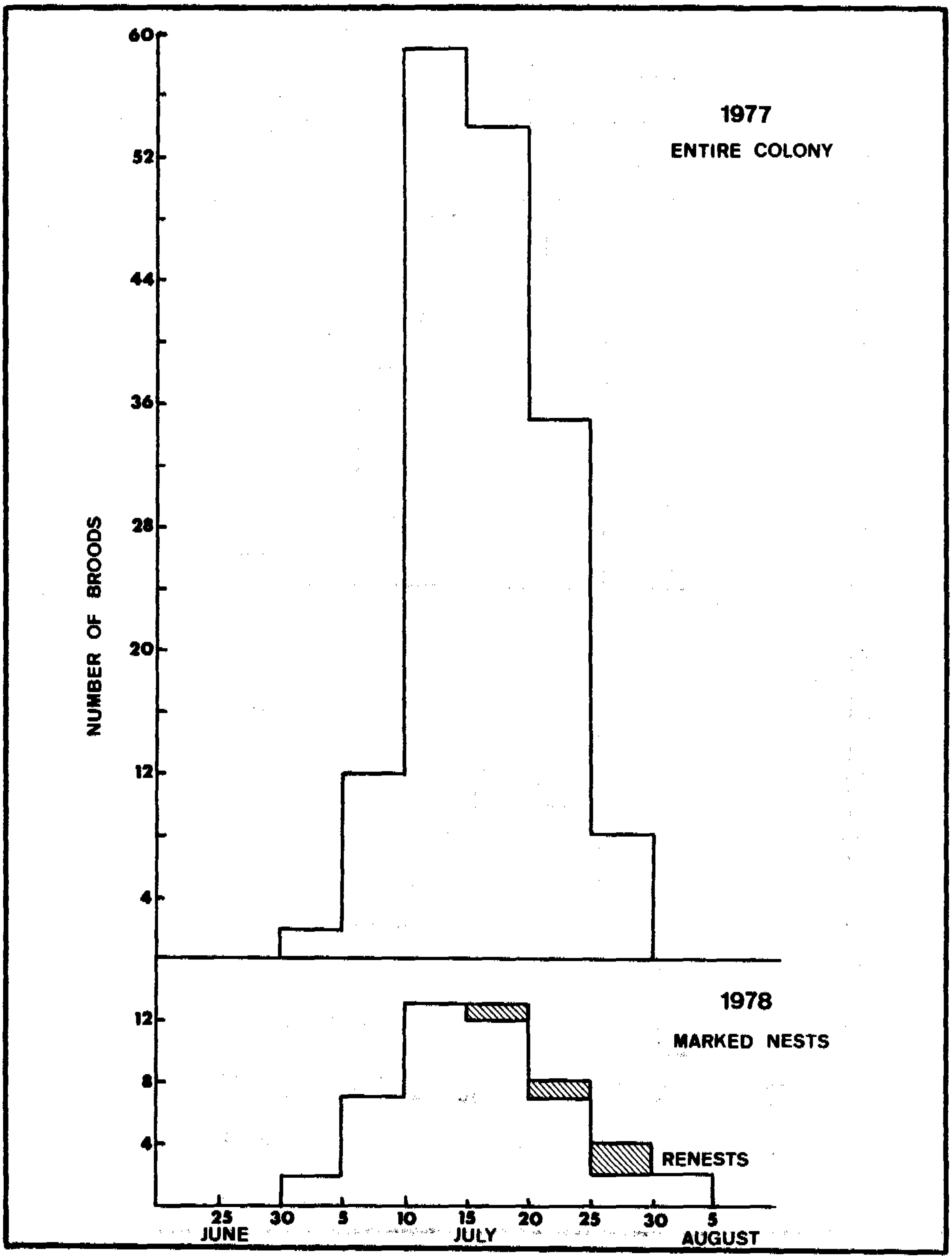

Figure 4. Hatching phenology of Black-legged Kittiwakes on Kulichkof Island, Chiniak Bay, 1977-78.

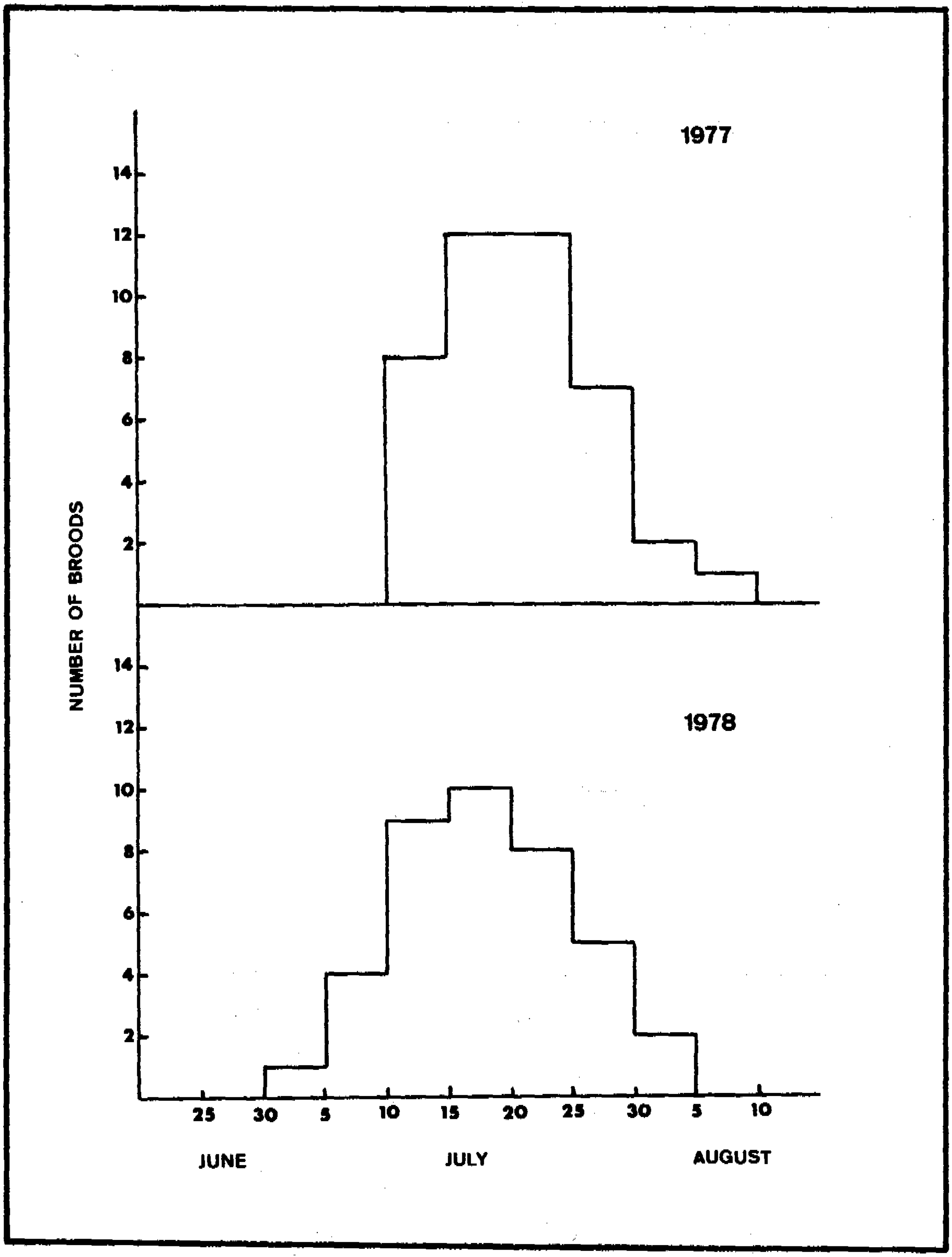

Figure 5. Hatching phenology of Tufted Puffin on Cliff Island in Chiniak Bay, 1977-78.

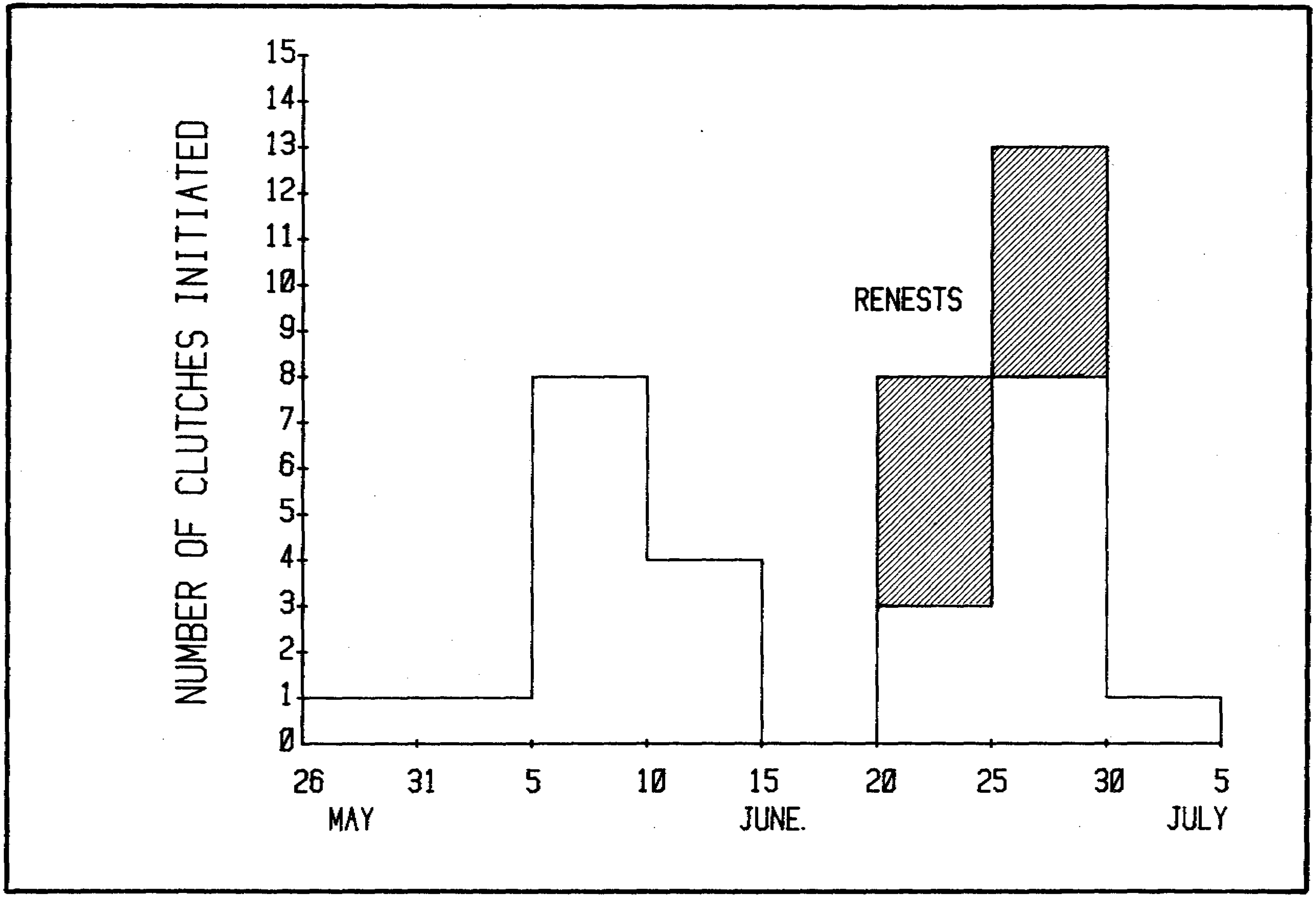

Figure 6. Laying phenology of Pelagic Cormorant on Kulichkof Island in Chiniak Bay, 1978.

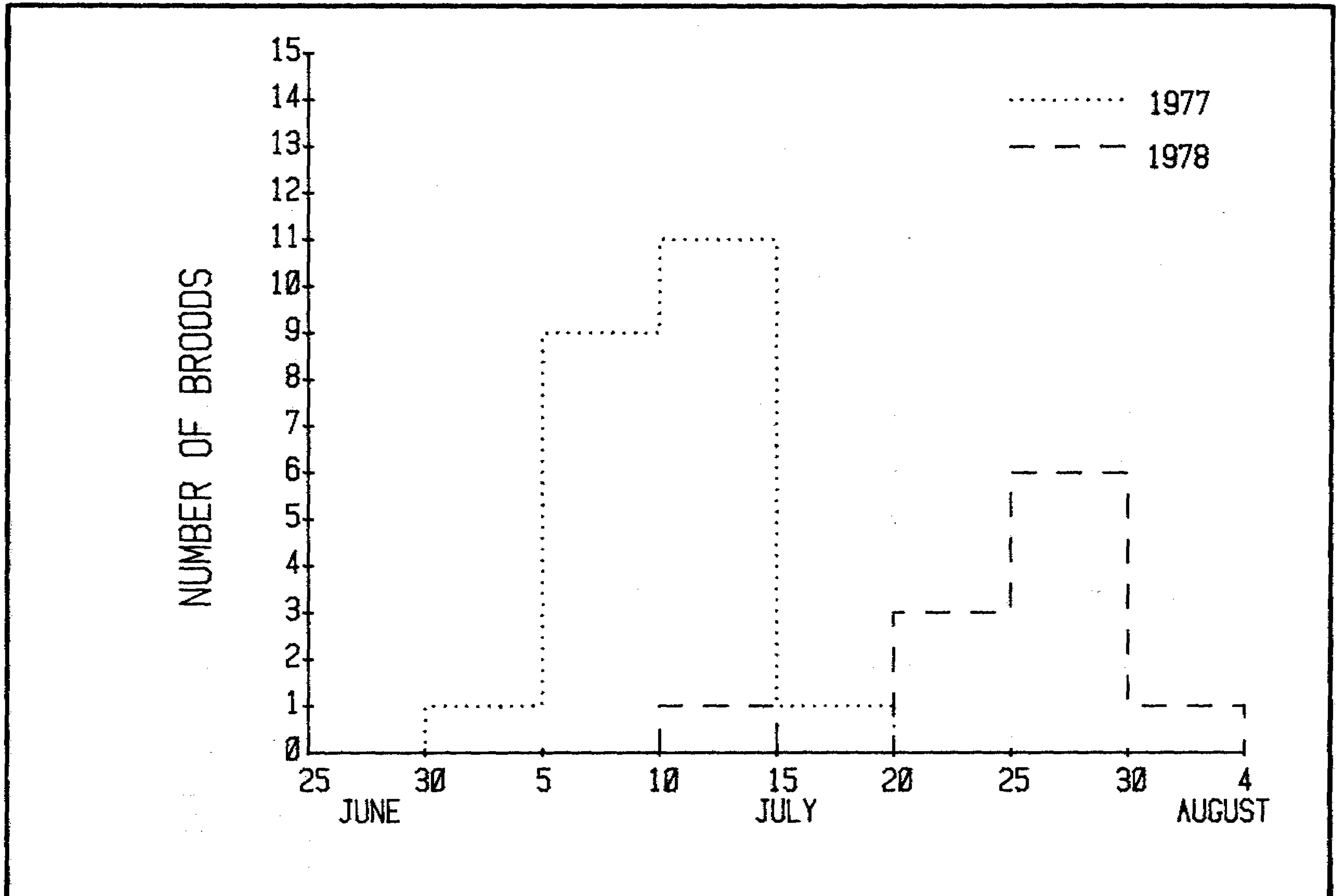

Figure 7. Hatching phenology of Pelagic Cormorant on Kulichkof Island in Chiniak Bay, 1977-78.

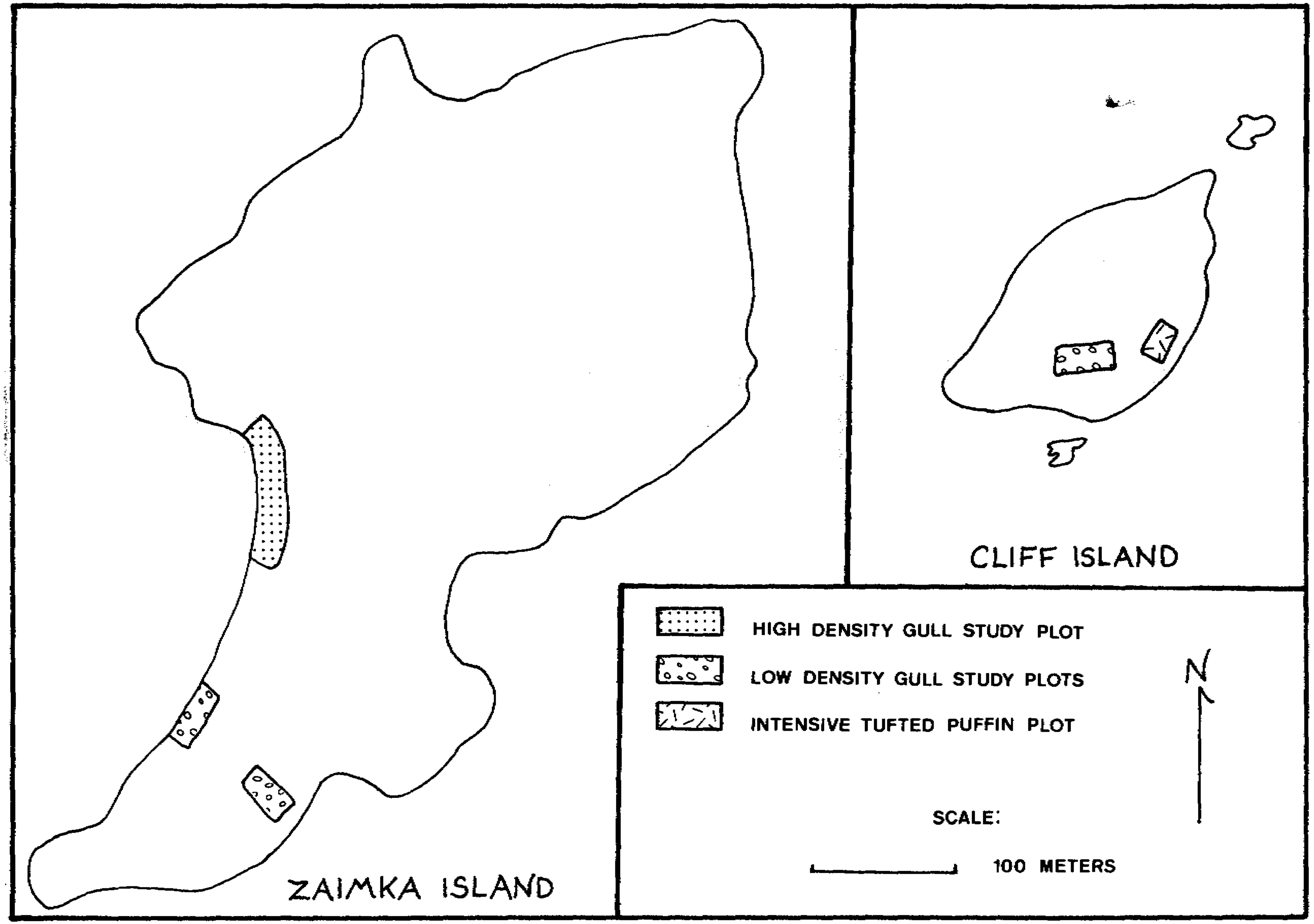

Figure 8. Study plots of Glaucous-winged Gull and Tufted Puffin nesting on Cliff and Zaimka Islands, 1977-78.

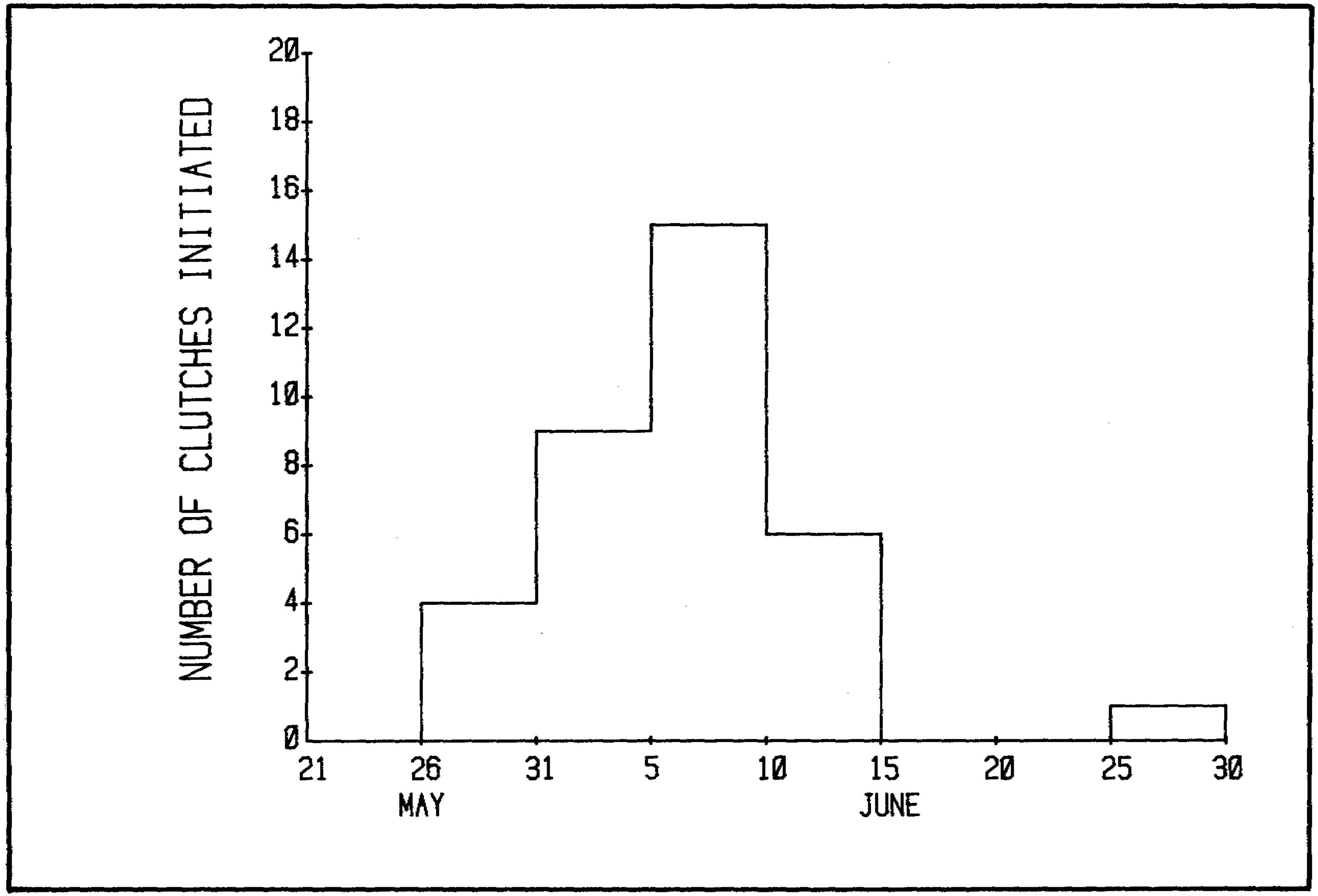

Figure 9. Laying phenology of Glaucous-winged Gulls on Zaimka Island in Chiniak Bay, 1978.

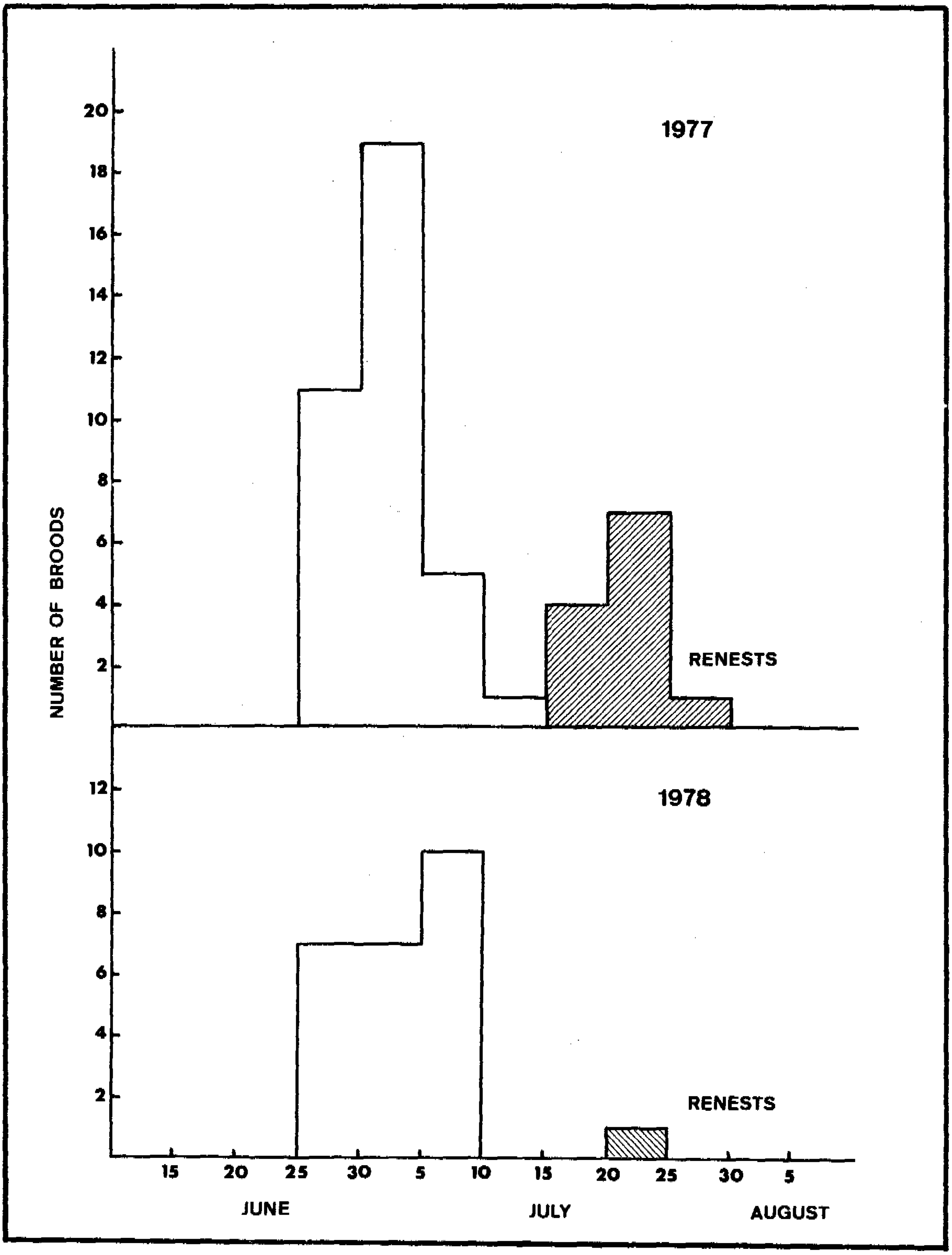

Figure 10. Hatching phenology of Glaucous-winged Gull on Zaimka Island in Chiniak Bay, 1977-78.

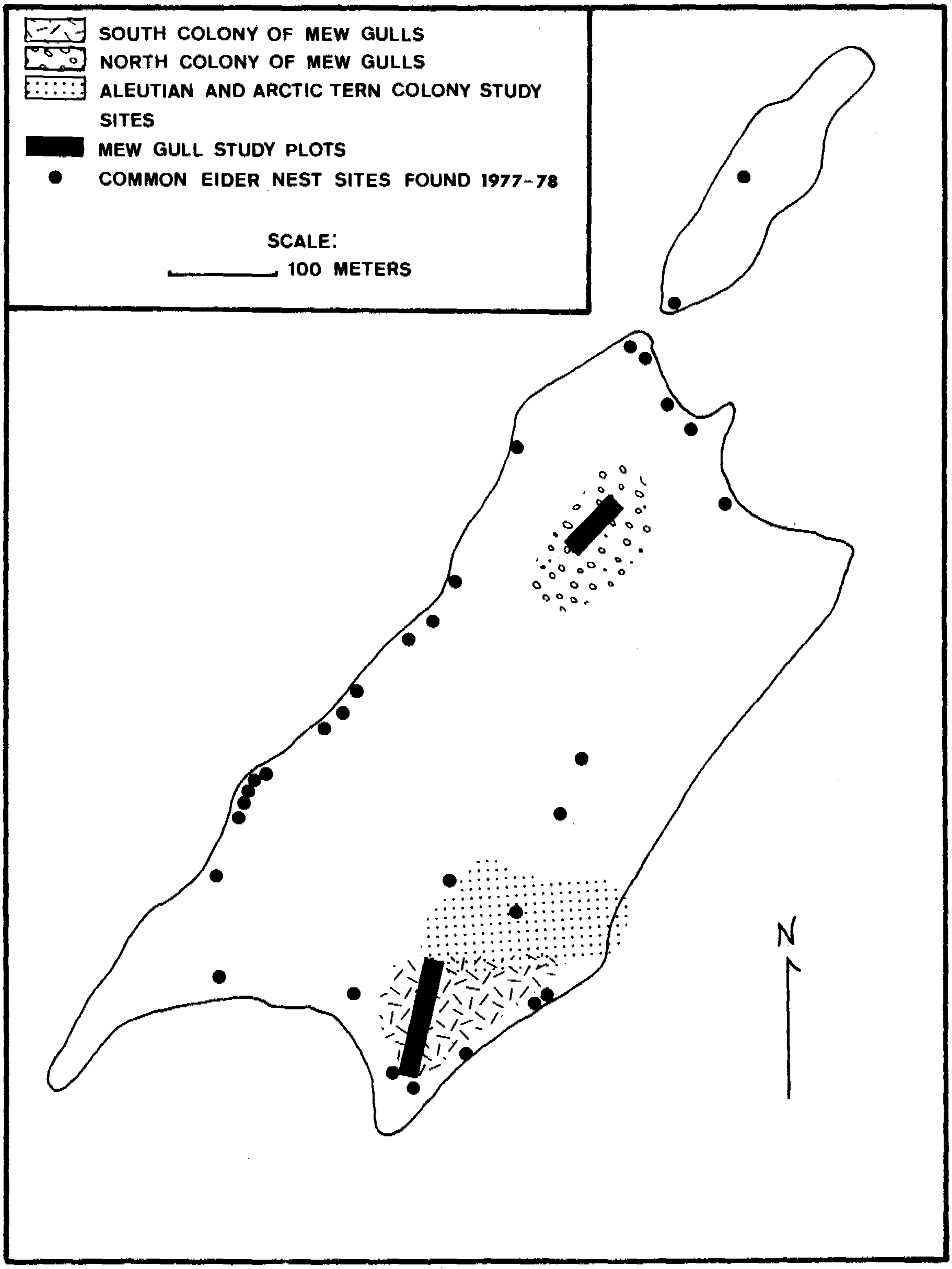

Figure 11. Study sites/plots of four species at Mary Island, Chiniak Bay, 1977-78.

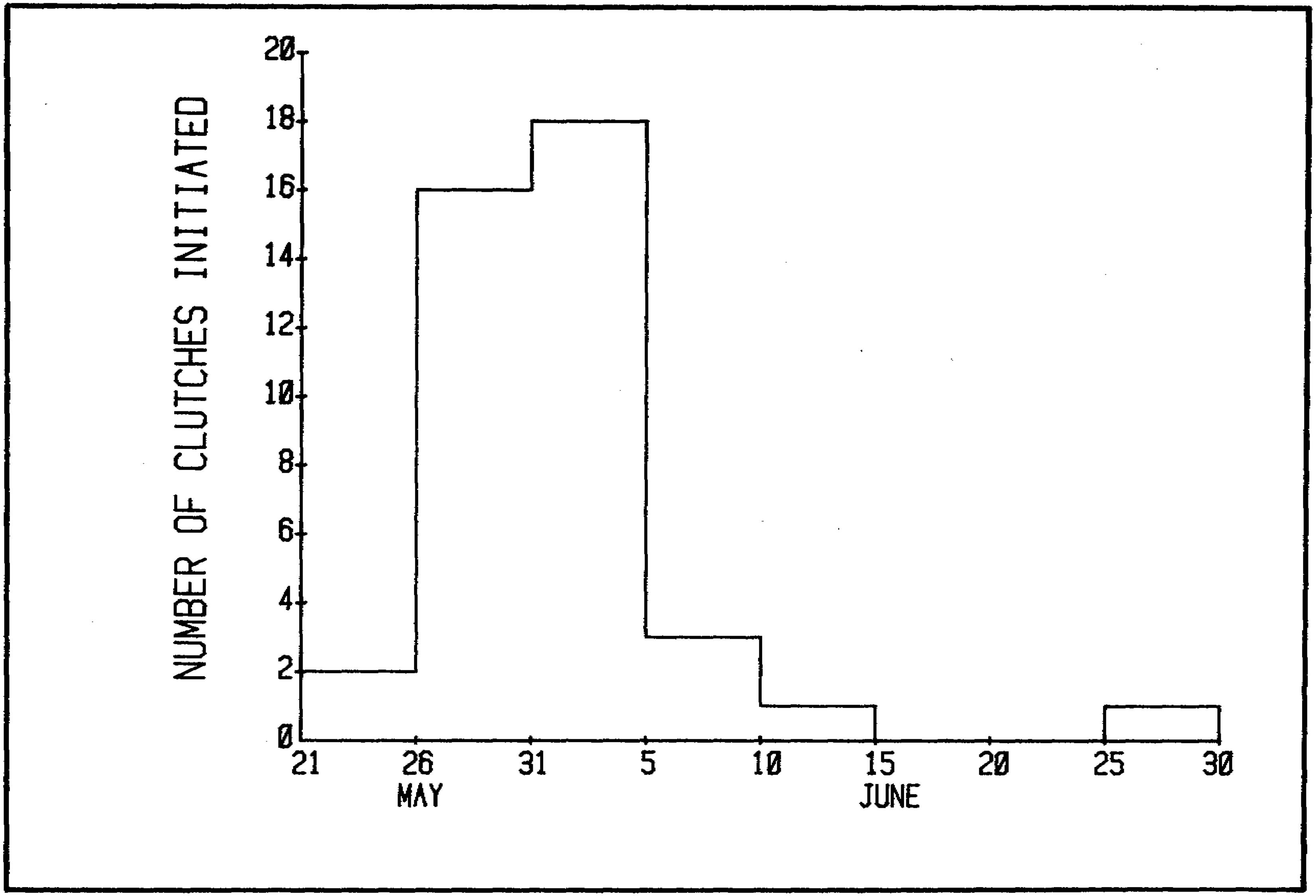

Figure 12. Laying phenology of Mew Gulls on south colony of Mary Island in Chiniak Bay, 1978.

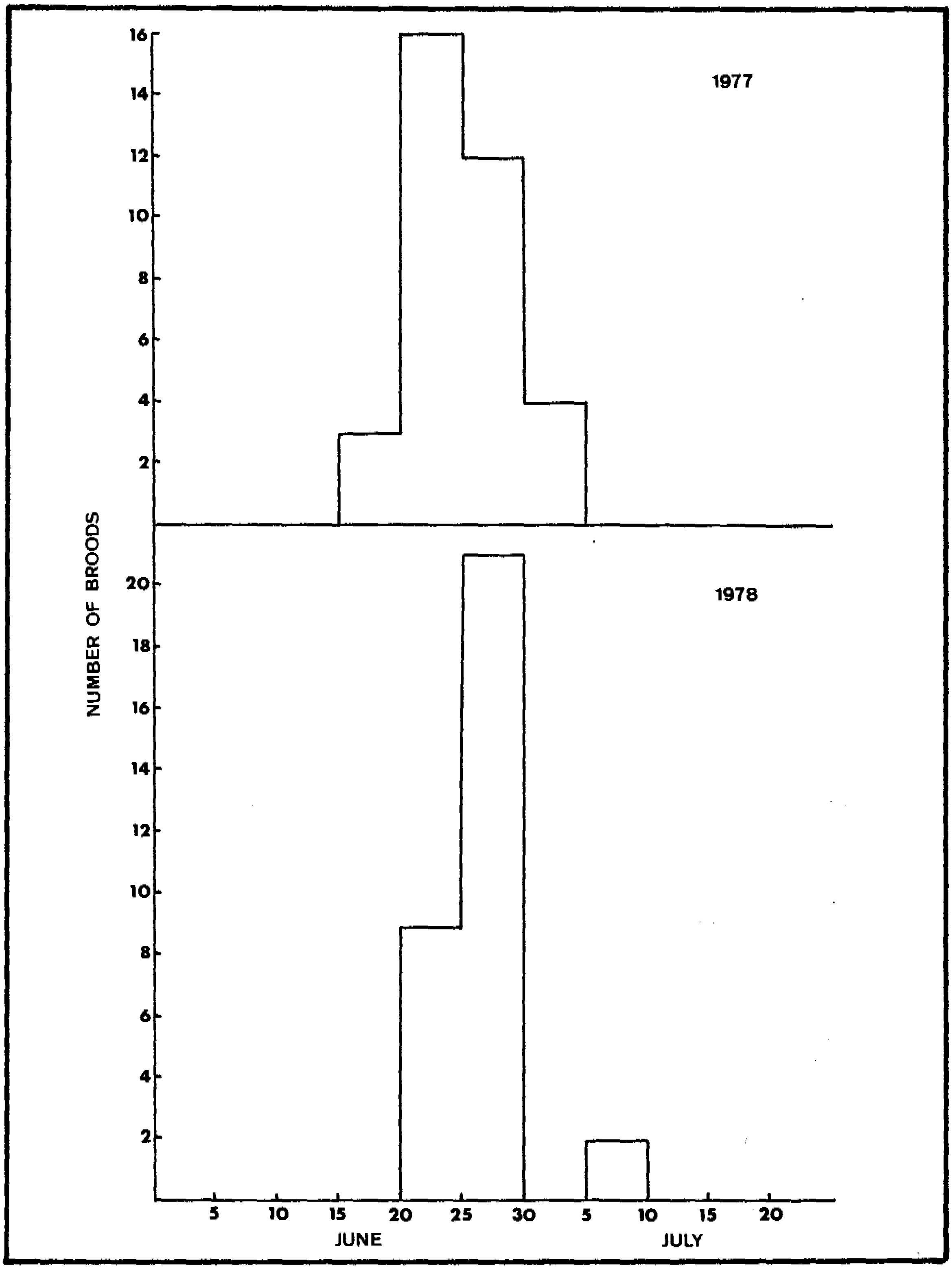

Figure 13. Hatching phenology of Mew Gulls on south colony of Mary Island, 1977-78.

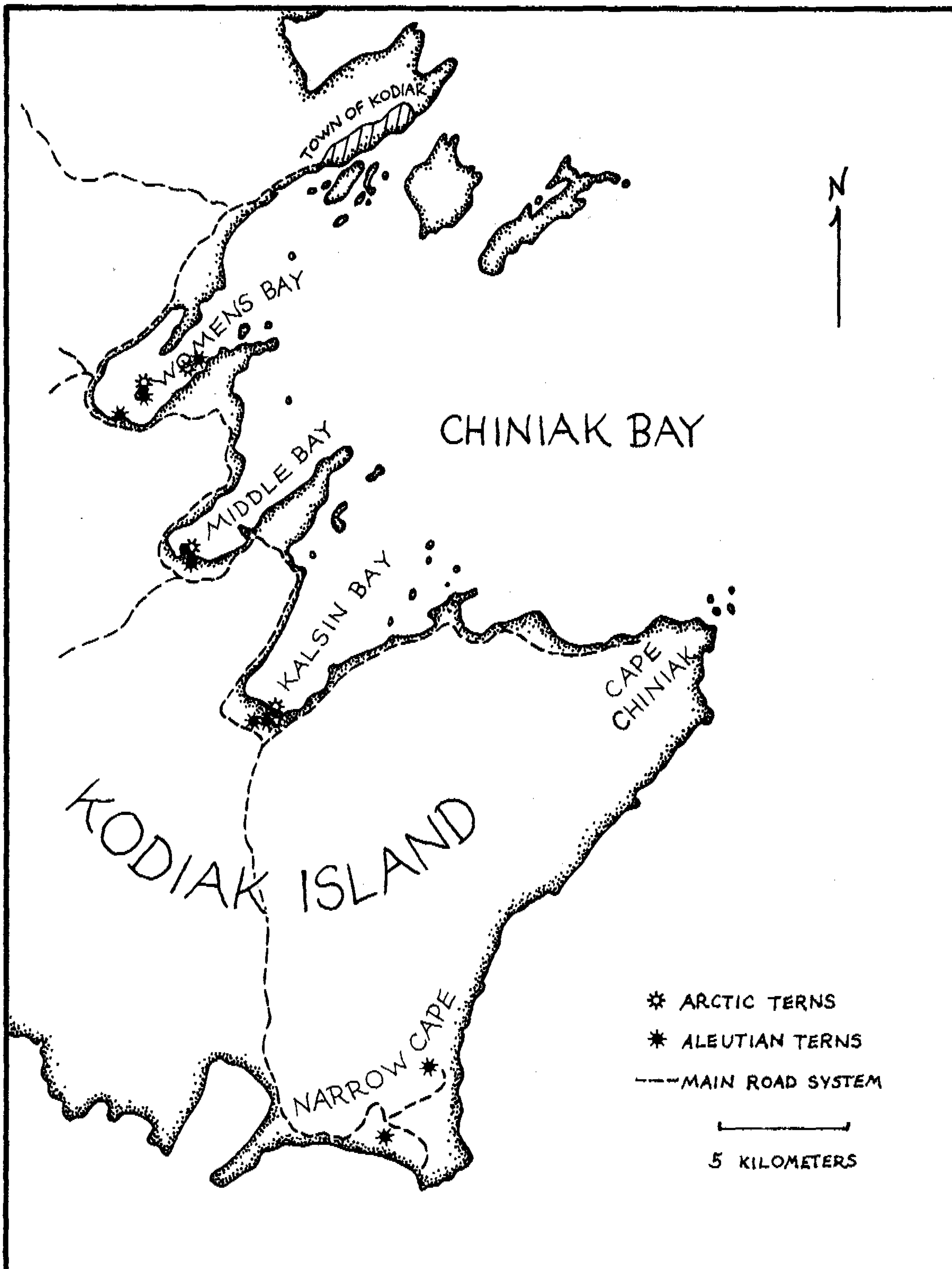

Figure 14. Arctic and Aleutian Tern colonies found in Chiniak Bay 1975-78.

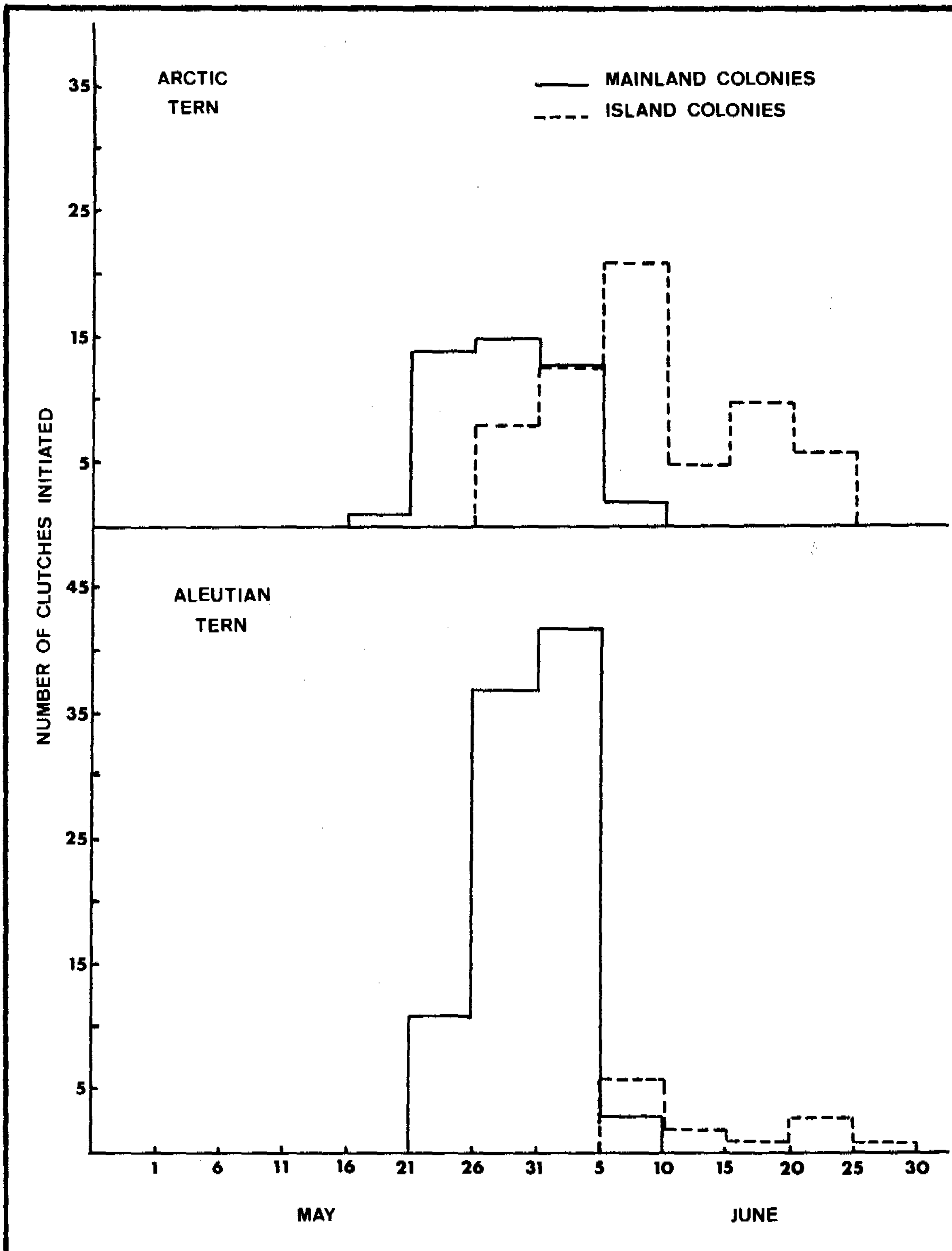

Figure 15. Comparison of laying phenologies of Arctic and Aleutian Tern colonies in Chiniak Bay, 1978.

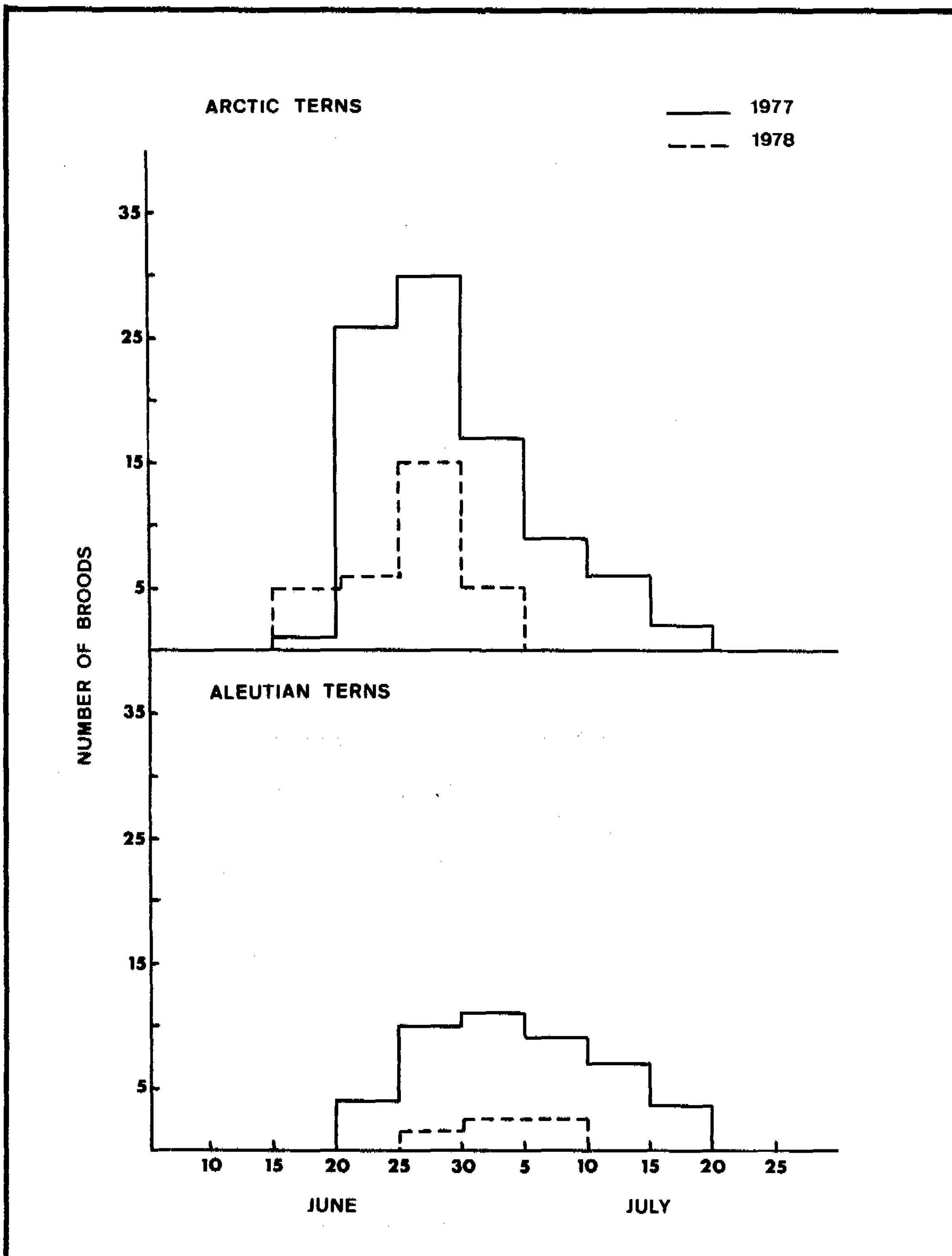

Figure 16. Hatching phenologies of Arctic and Aleutian Terns in Chiniak Bay, 1977-78.

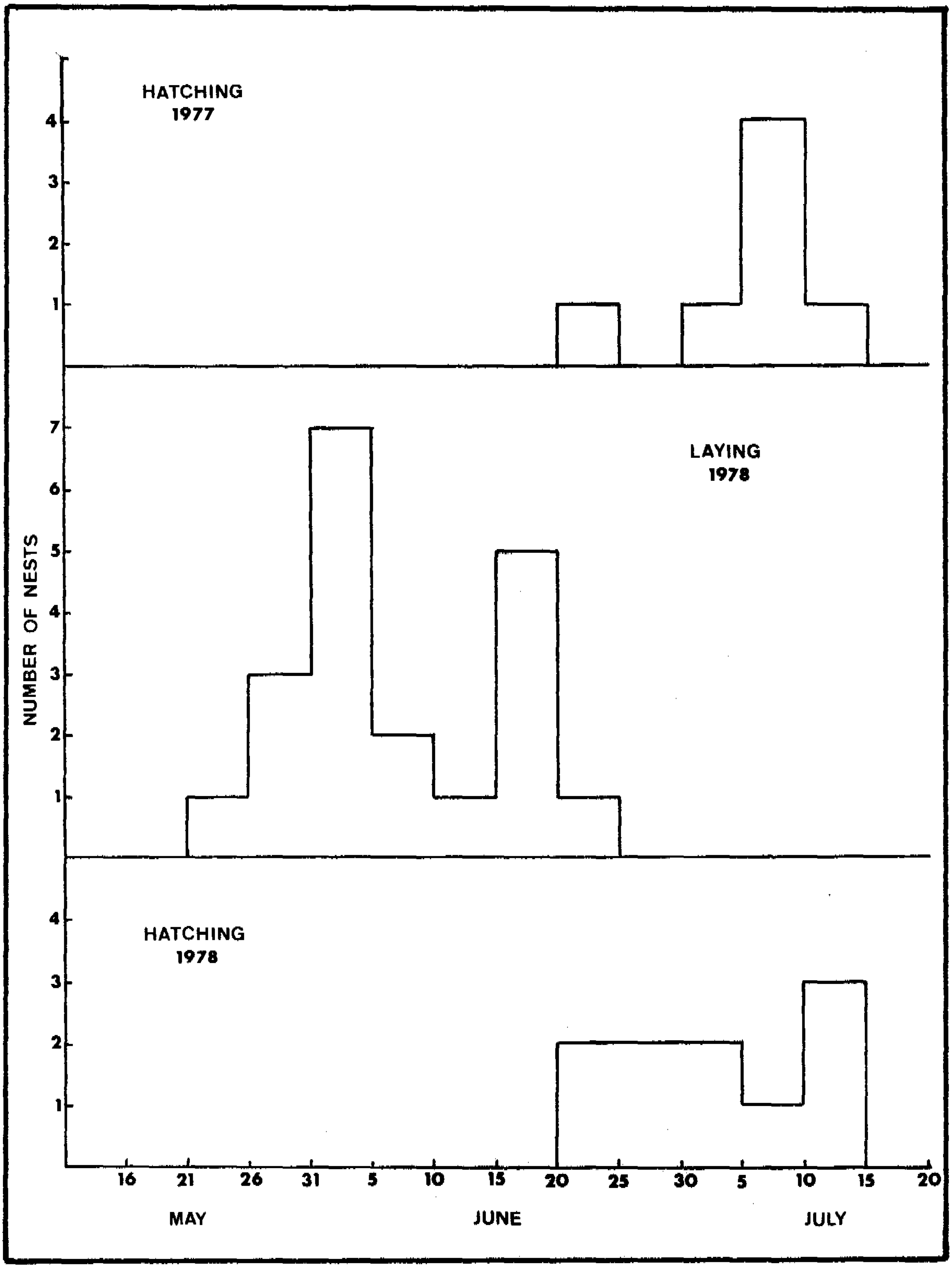

Figure 17. Laying and hatching phenologies of Common Eider in Chiniak Bay, 1977-78.

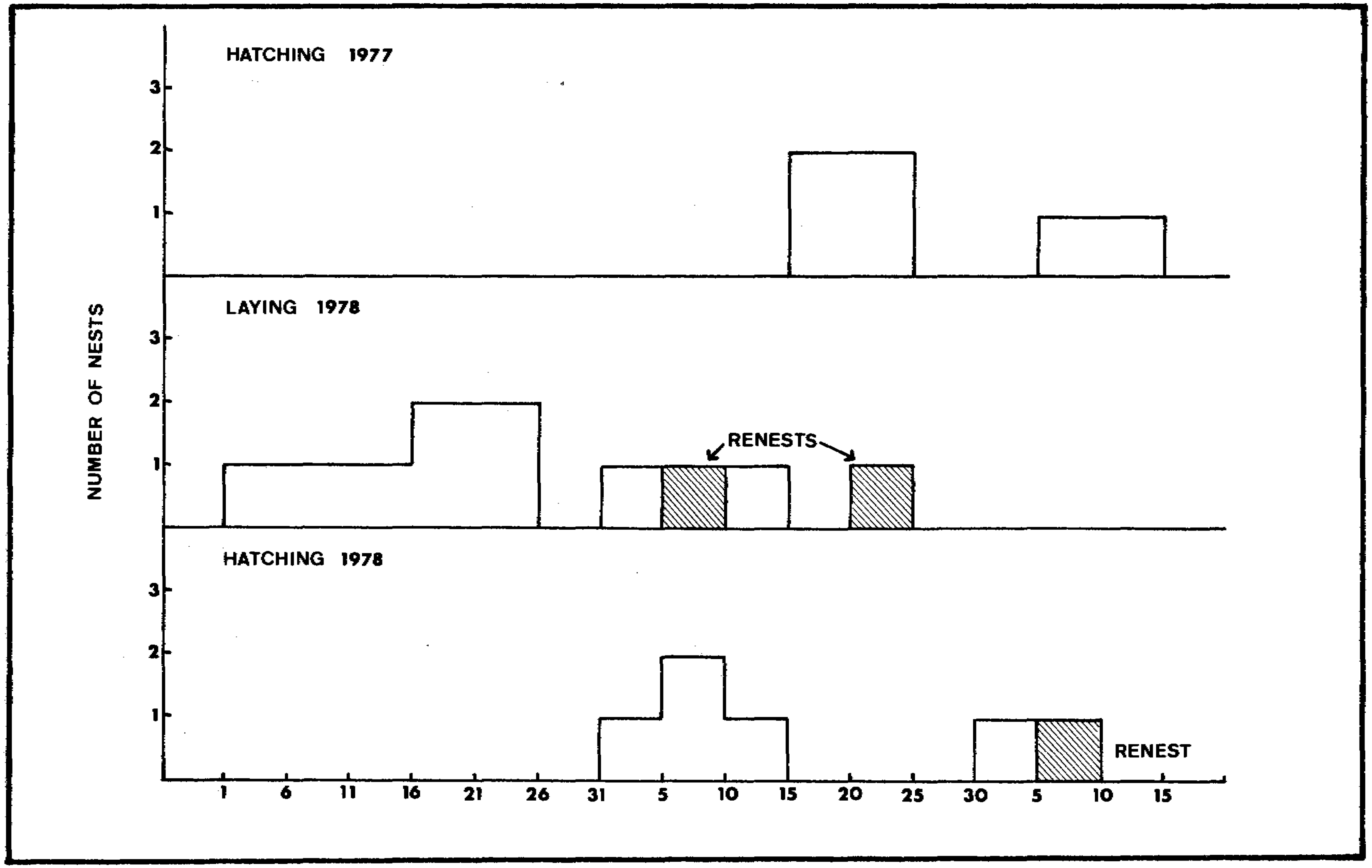

Figure 18. Laying and hatching phenologies of Black Oystercatchers in Chiniak Bay, 1977-78.

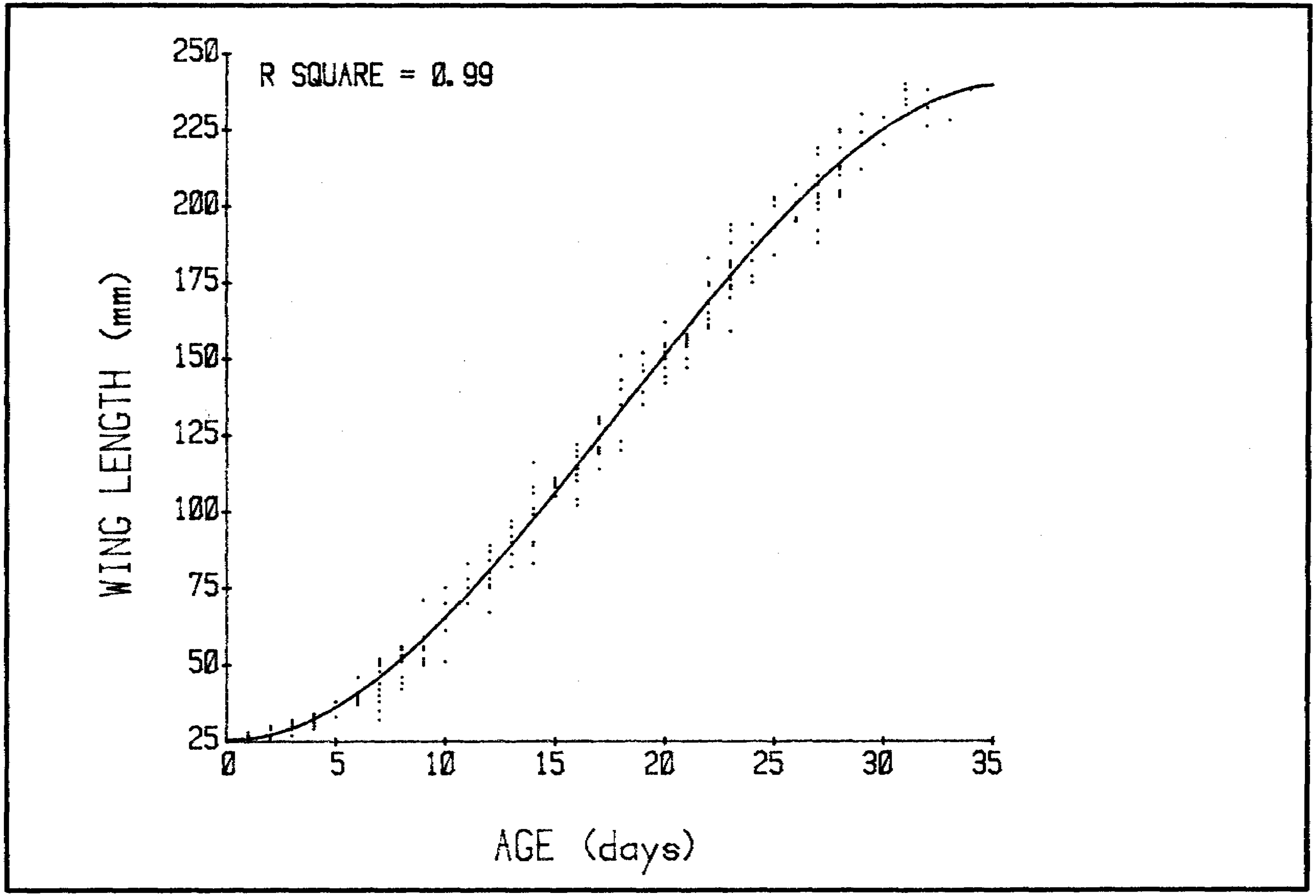

Figure 19. Relationship between age and flattened wing length of Black-legged Kittiwake chicks in Chiniak Bay, 1978.

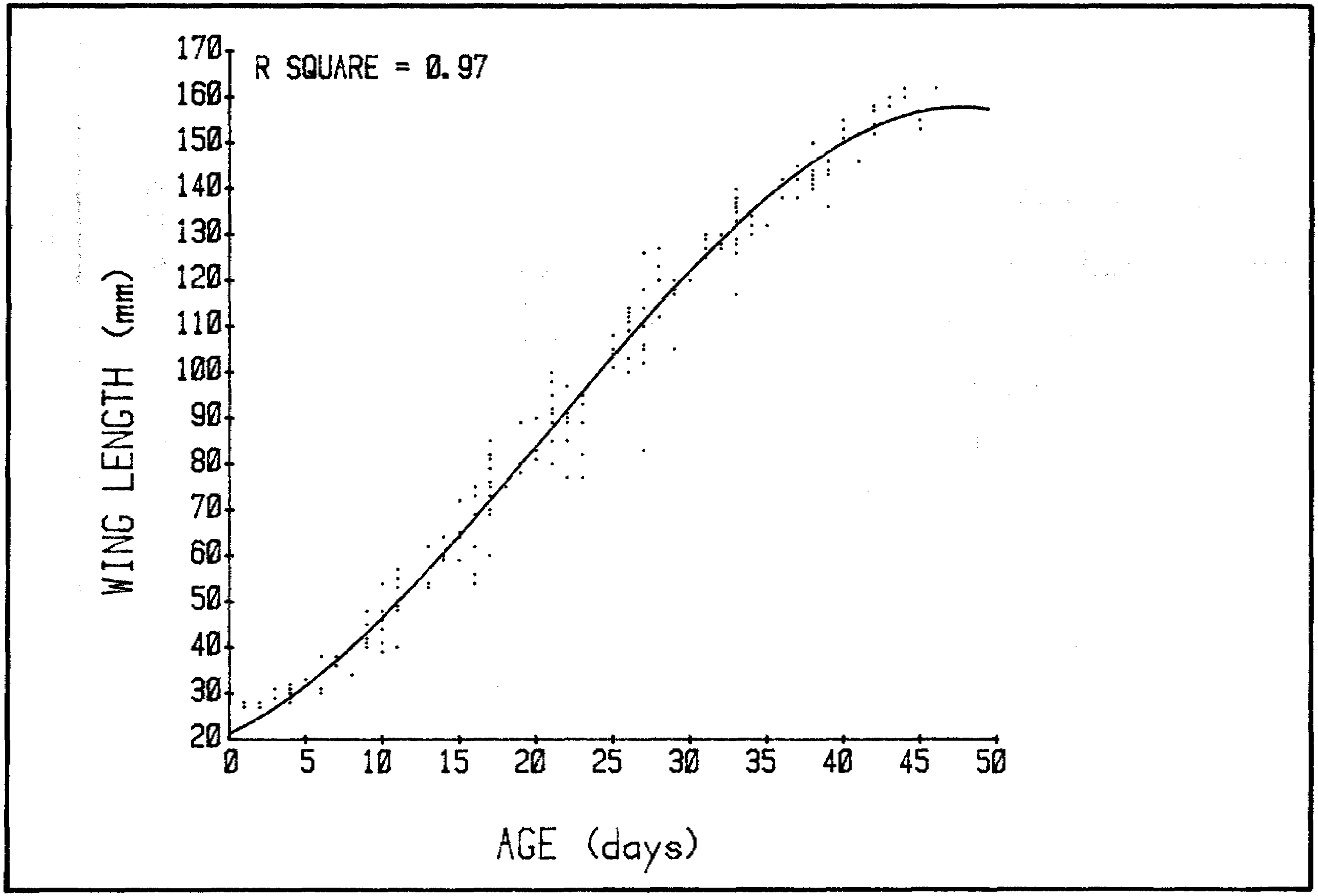

Figure 20. Relationship between age and flattened wing length of Tufted Puffin chicks in Chiniak Bay, 1978.

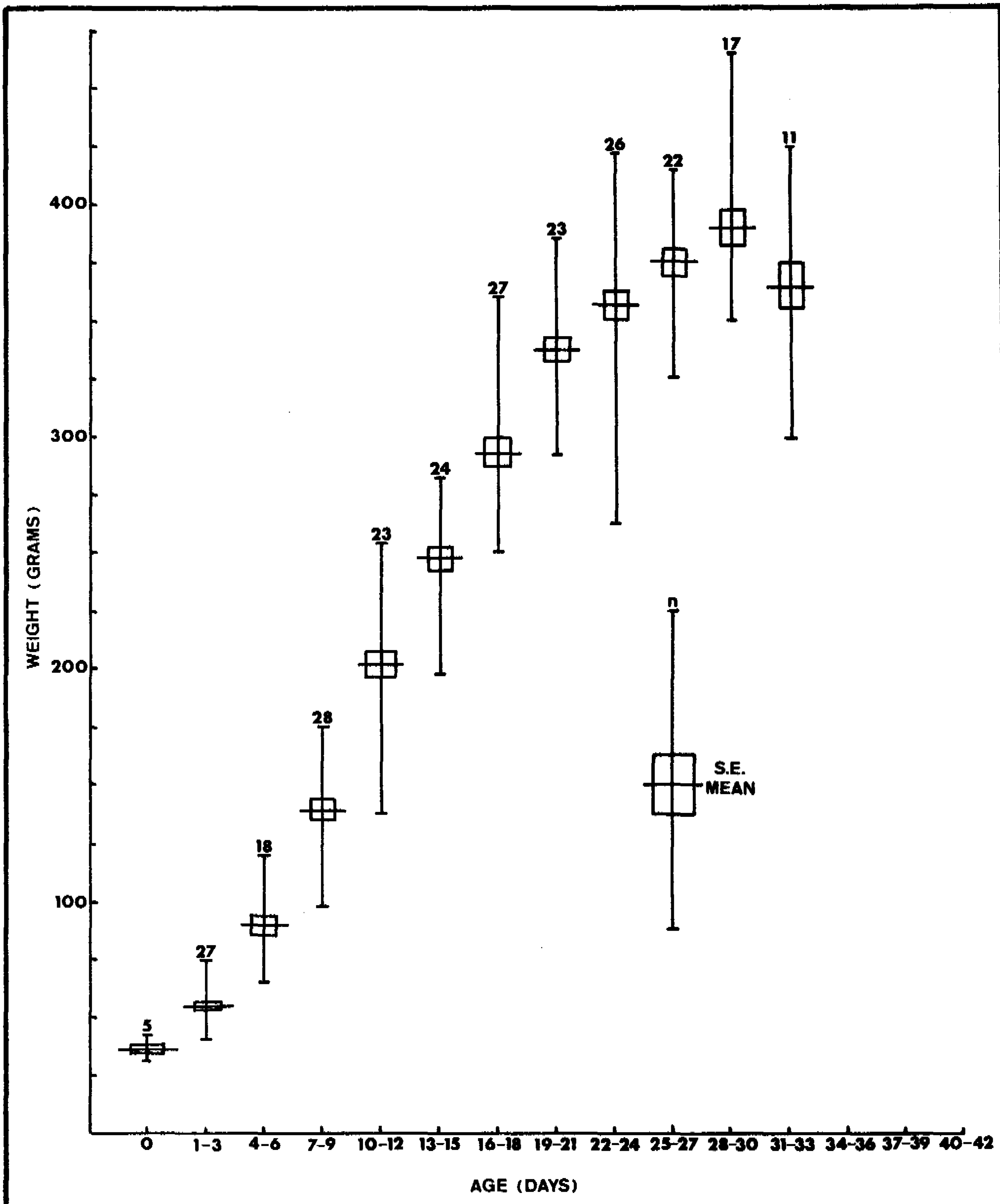

Figure 21. Growth rates of Black-legged Kittiwake chicks, Chiniak Bay, 1978.

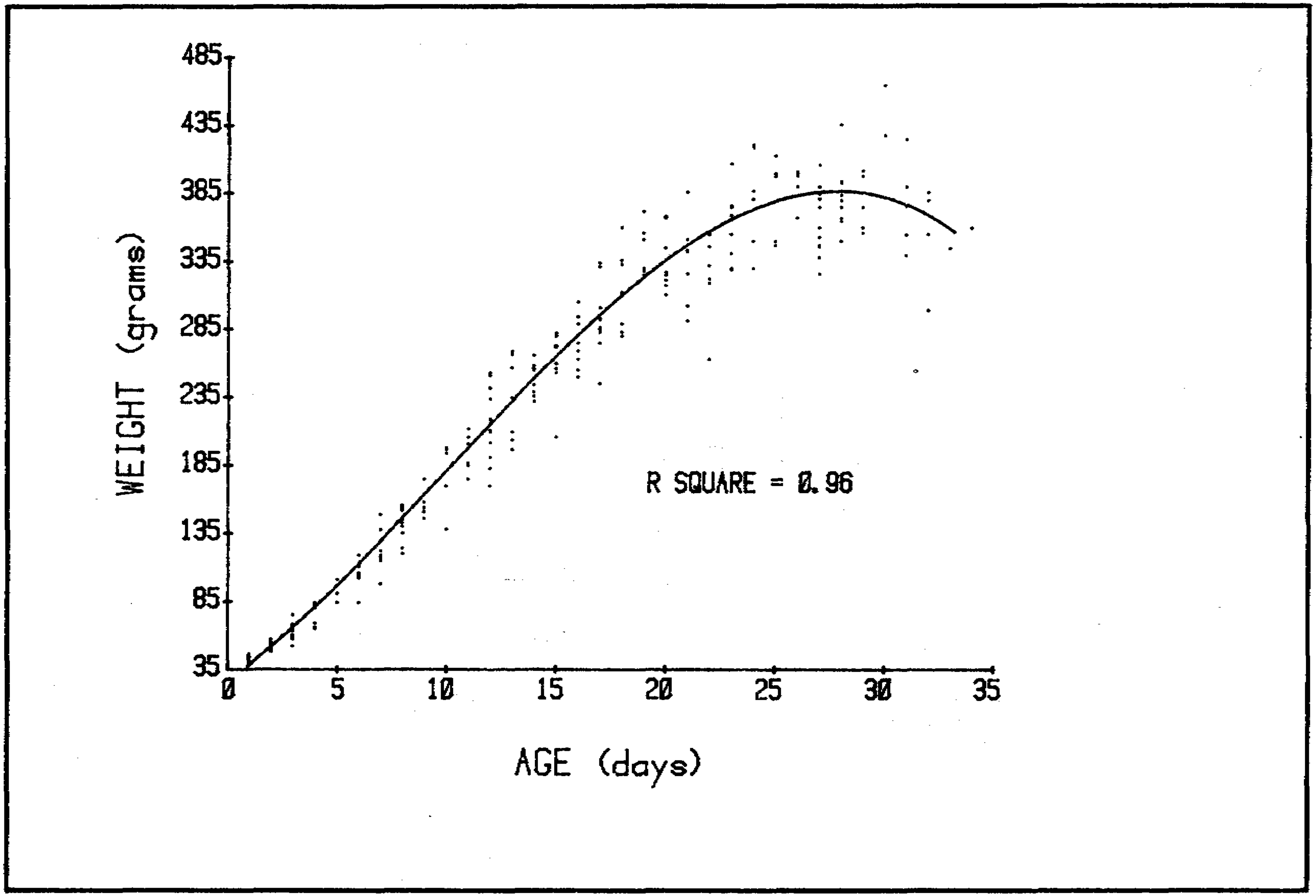

Figure 22. Polynomial regression of age and weight of Black-legged Kittiwake chicks in Chiniak Bay, 1978.

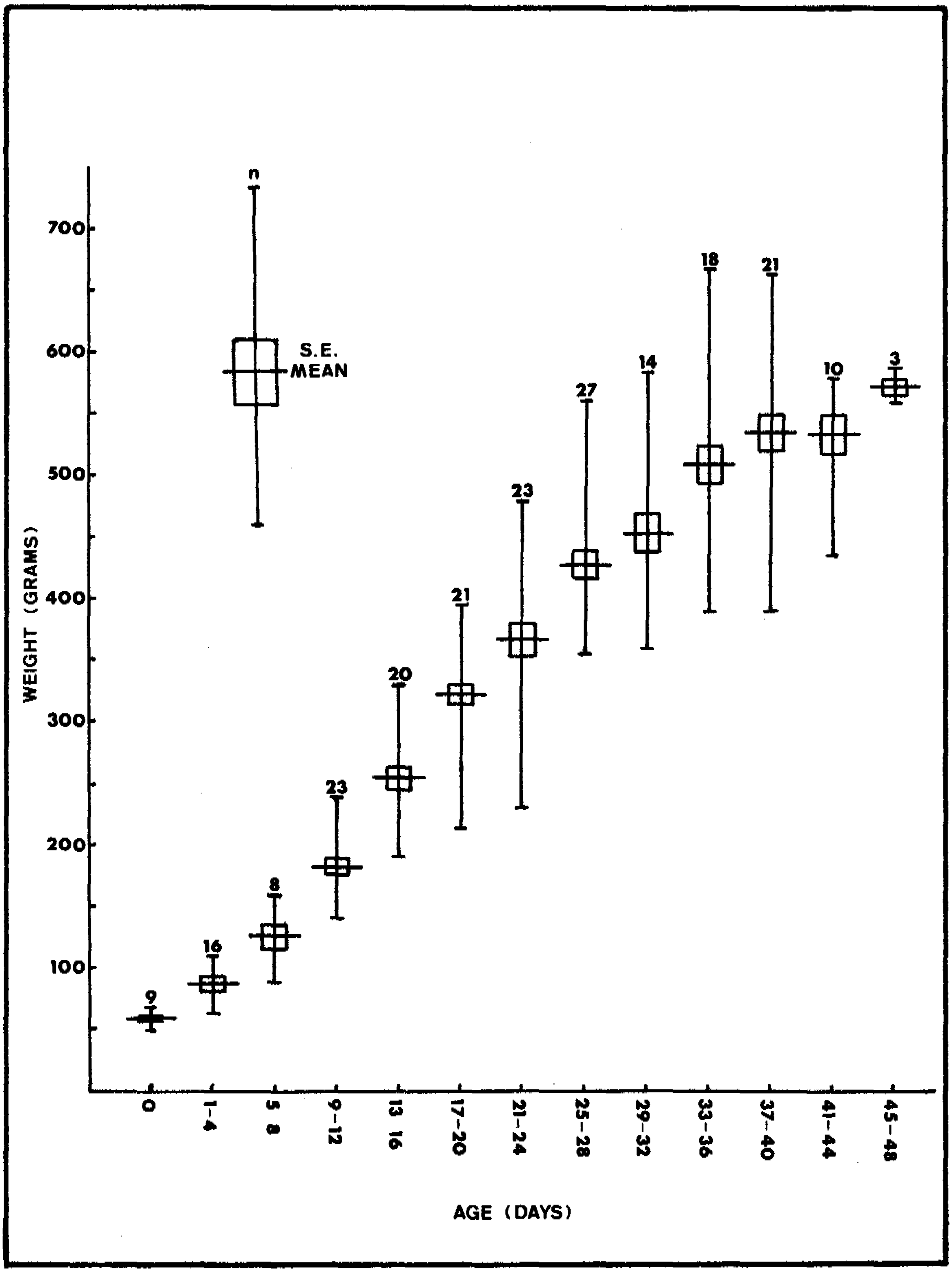

Figure 23. Growth rates of Tufted Puffin chicks, Chiniak Bay, 1978.

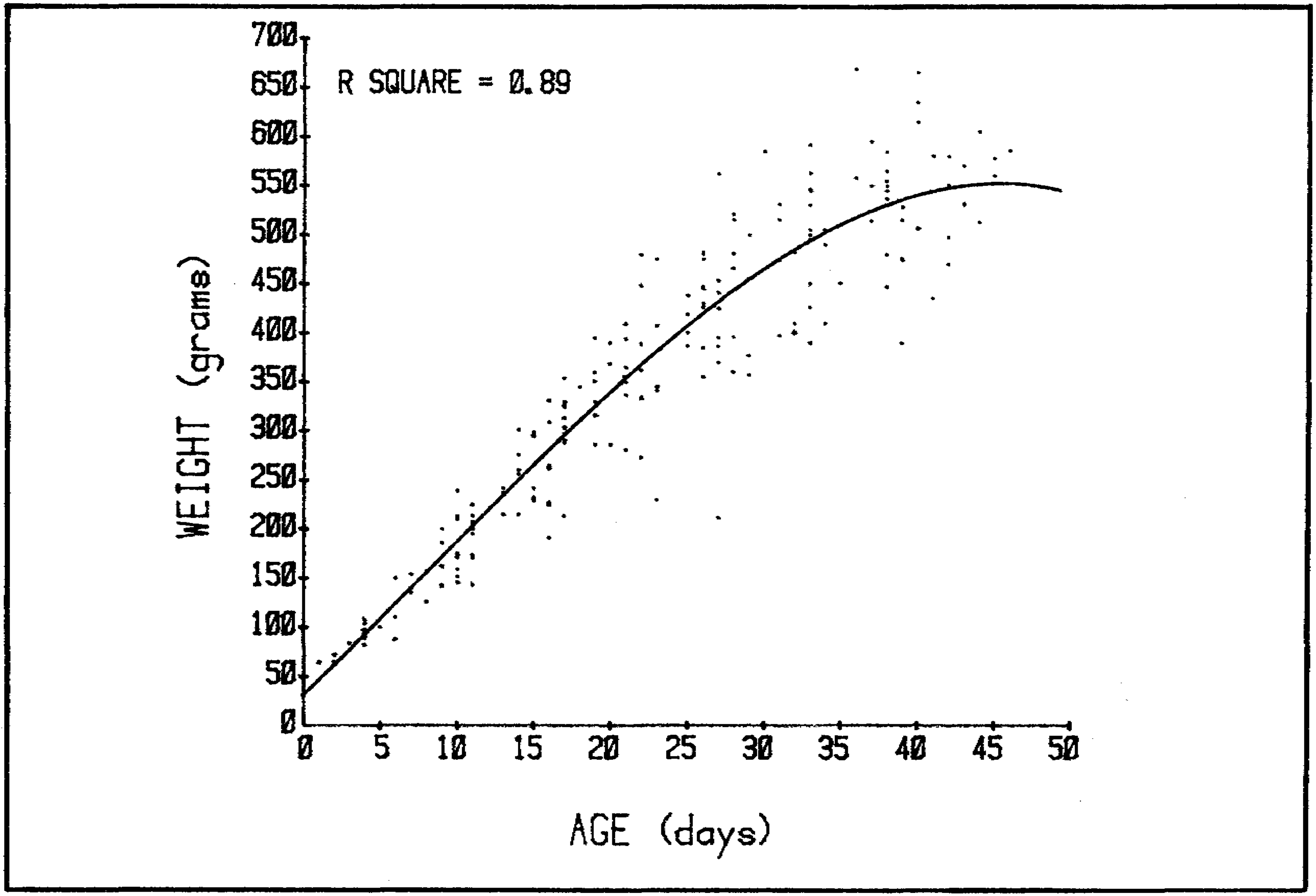

Figure 24. Polynomial regression of age and weight of Tufted Puffin chicks in Chiniak Bay, 1978.

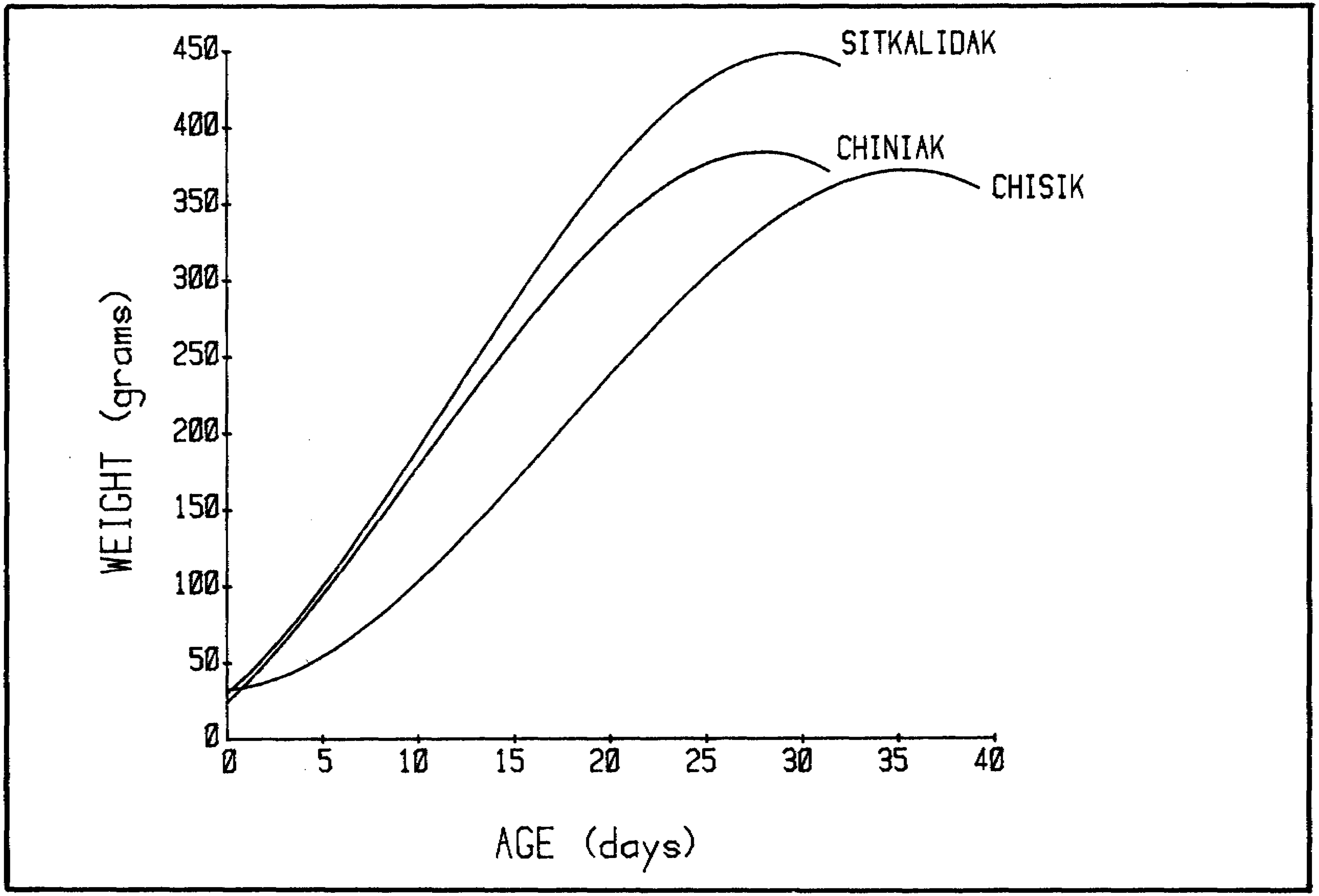

Figure 25. Comparison of regression curves of kittiwake chick growth in the northern Gulf of Alaska at three sites, 1978.

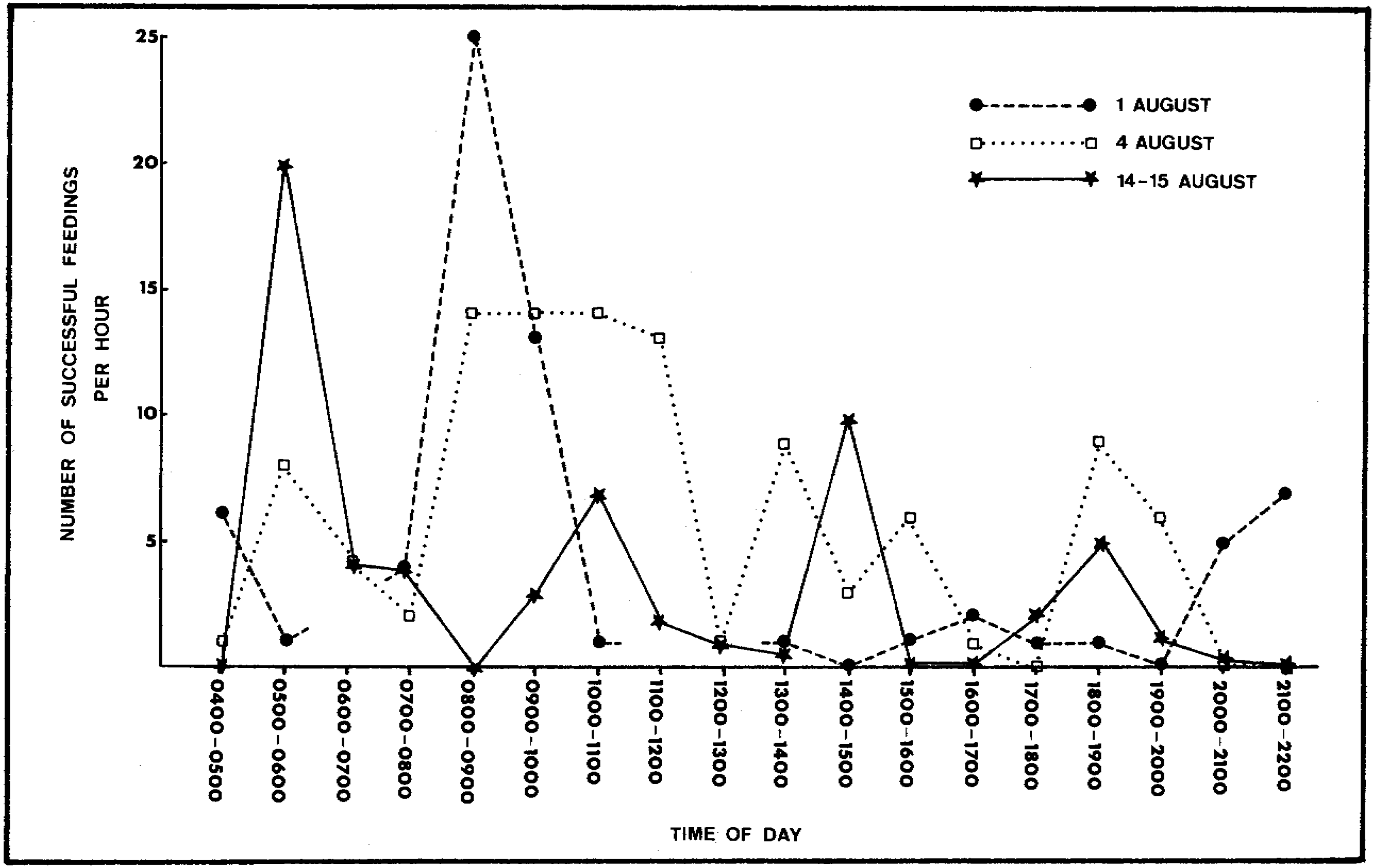

Figure 26. Feeding occurrence for Black-legged Kittiwake chicks in Chiniak Bay, 1978.

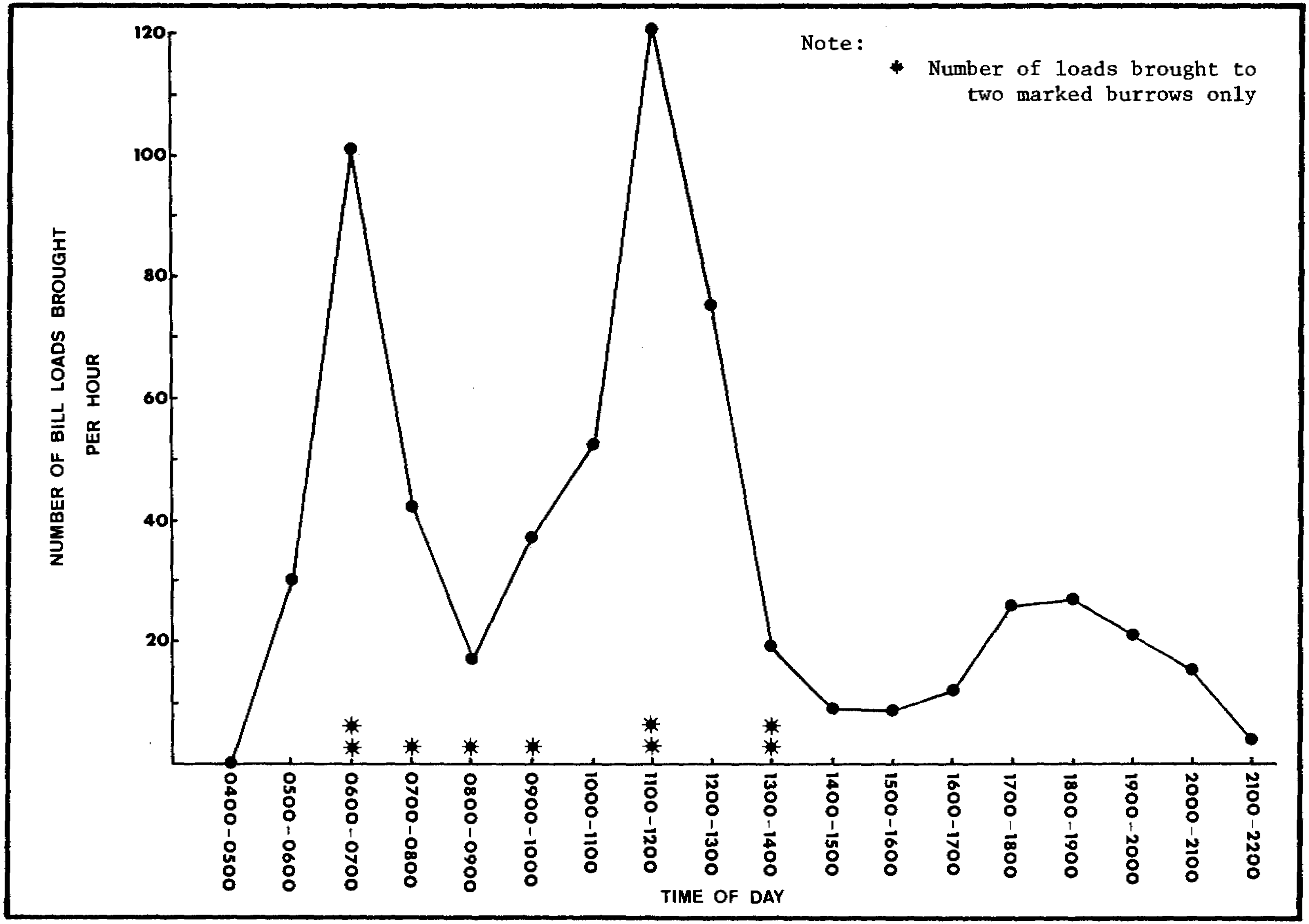

Figure 27. Occurrence of bill loads brought to Tufted Puffin plot, Chiniak Bay, 1978.

Appendix I. Annotated species list, 1978:

In conjunction with breeding studies of certain seabirds in the Chiniak Bay area of Kodiak Island, observers kept notes concerning the abundance, distribution, and general items of interest of other bird species observed primarily on the islands, shorelines, and adjacent waters of Chiniak Bay in 1978. With some exceptions, the passerines and other birds of mainland Kodiak are not covered in much detail. These observations range from 17 May to 2 September 1978. Dick (1977) gives a good idea of bird distribution and abundance in Chiniak Bay through the fall, winter, and spring.

SPECIES

Common Loon *(Gavia immer):* One individual in winter plumage was seen on 24 May.

Red-throated Loon (*G. stellata*): Five adults and one immature (HY) were seen on 26 July at the head of Kalsin Bay and on the estuarine ponds nearby. It was believed that at least one pair nested in this vicinity.

Fulmar *(Fulmarus glacialis):* None were seen in or near Chiniak Bay while occasional individuals were seen in Shelikof Straits on 21 July.

Shearwater *(Puffinus* spp.): On 23 July large numbers (thousands) of shearwaters moved by Spruce Cape within five kilometers of land. On 27 July feeding flocks were clustered just off of Spruce Cape engaged in the feeding behavior where the birds walk on the water for a few steps and then suddenly dive. We felt that many of these birds were Short-tailed Shearwaters *(P. tenuirostris).* Both this species and Sooty Shearwater *(P. griseus)* carcasses were picked up on beached bird surveys run on 1 and 2 September.

Fork-tailed Petrel *(Oceanodroma furcata):* This species did not appear in numbers near Chiniak Bay in 1978 as it did during the last week of July in 1977.

Brant *(Branta bernicula):* Thirty-five birds were seen in Kalsin Bay on 24 May while fifteen, including two immature birds, were noted in Middle Bay on 25 May. The last sighting was eight individuals on 2 June near Mary Island.

White-fronted Goose *(Anser albifrons):* One family group of seven to ten individuals was seen flying away from Rose Tead Lake on 1 September.

The same day two more family groups were seen at the head of Kalsin Bay. One family group contained two adults and four young while the second had two adults and six young.

Mallard *(Anas platyrhynchos):* This species was the third or fourth most common and abundant duck found in the heads of bays on 5 June. A brood of seven about three weeks old was seen on 7 July. A flock of 20 birds was seen on 8 August in Kalsin Bay. Mallards were still present on 2 September when we left the study area.

Pintail *(A. acuta):* This was the most common duck found at heads of bays on 5 June. One nest was found at Rose Tead Lake, three at Kalsin Bay in the tern colony, and four on Mary Island. Clutch sizes were 5, 6, 7, 8, 9, 9, and 10. Four of the eight nests were destroyed by mammals. The three nests at Kalsin Bay were found on a tern plot involving 6600 square meters of a deltaic island. Laying ranged approximately between 20 May and mid-June while hatching occurred mainly between 26 June and 10 July for the surviving nests. One brood of six about three weeks old was seen on Mary Island on 10 July. The largest single flock was 46 birds seen in Kalsin Bay on 8 August.

Green-winged Teal *(A. crecca):* This species was found in the heads of bays when we first checked them on 24 May. This was the fifth most numerous duck found in these same areas on 5 June. Flocks began to accumulate in mid-August and were still there on 2 September when observations ceased.

American Widgeon *(A. americanus):* This species was present on the bays on 24 May. One brood of four was seen on 26 July at the "loon pond" found on the south side of Kalsin Bay.

Northern Shoveler *(A. clypeata):* Shovelers were seen once on 22 May near Mary Island.

Greater Scaup *(Aythya marila):* Forty individuals were seen in Women's Bay on 25 May. Small numbers of this species were seen through June and early July with the largest flock size being 10 on 20 June.

Common Goldeneye *(Bucephala clangula):* Three individuals were seen on 7 June near Mary Island.

Harlequin Duck *(Histrionicus histrionicus):* This is a common species throughout the year on Kodiak Island. A flock of 61 was seen on Mary Island 2 June while somewhere between 200 and 300 males were found on 28 June in the northern half of Kalsin Bay. Flocks noticed on 11 July on

Long Island were molting. On 26 July one brood of eight and one of six were seen on the Karluk River in western Kodiak Island. The phenology is probably quite similar in the Chiniak Bay region. Another flock of 43 birds was seen near Narrow Cape on 1 September. It appears that most of flocks of males move out of inner Chiniak Bay during the summer and concentrate mostly along the more remote, outer islands and capes of the coastline.

Steller's Eider *(Polysticta stelleri):* One male in breeding plumage was seen near Blodgett Island on 22 May and its damaged wing prevented it from flying. On 2 June two males in breeding plumage were noted in Women's Bay. On 28 July a male in eclipse plumage was seen near Mary Island and it was presumably the same male with the damaged wing we observed earlier.

Common Eider *(Somateria mollissima):* On 22 May a flock of 53 contained 26 males in breeding plumage. Between 7 and 15 June it became apparent that pairs were separating and towards the end of June the larger flocks of males began leaving the breeding islands. Molting was occurring and a flock of 36 on Mary Island on 26 June were all in eclipse plumage. Four broods containing a total of fifteen ducklings were seen on 10 July in Women's Bay. One brood of eight and one of four were seen on 26 July in Women's Bay.

Oldsquaw *(Clangula hyemalis):* One male in winter plumage was seen in Women's Bay on 22 May.

White-winged Scoter *(Melanitta fusca):* This species was seen at Narrow Cape on 24 May and at Long Island on 11 July. On 1 September a flock of approximately 300 was observed just offshore from Narrow Cape. It is possible that flocks of this species molt in some of these more remote islands and capes and may be present part of the summer.

Surf Scoter *(M. perspicillata):* This species was observed only on 2 June at Mary Island.

Common Merganser *(Mergus merganser):* This species was present in Kodiak when we checked the bays on 24 May. It was the third or fourth most common duck found at heads of bays on 5 June. The largest flock size at any one spot was twelve birds at Middle Bay on 5 June.

Red-breasted Merganser *(M. serrator):* This merganser was more abundant than the Common Merganser and it was the second most common duck found in heads of bays on 5 June. One nest containing fifteen eggs was found on 7 June on Mary Island while another nest of 7 eggs was found on Mary Island on 20 June. Males completed most of their postnuptial molt by 23 June. The nest with fifteen eggs had ten hatch by 10 July. Three of the remaining five eggs died while pipping. One brood of five was seen at Long Island on 11 July. Three broods (4,9,9) were seen at the head of Kalsin Bay on 26 July. This species was quite common on 1 September with a concentration of 40-50 birds observed on Rose Tead Lake.

Bald Eagle *(Haliaeetus leucocephalus):* Eagles were seen throughout the summer. Three nests were noticed, all up in large Black Cottonwood trees *(Populus balsamifers)*. One nest was located on Buskin Lake near a stream leading into the lake. Another nest was at the head of Kalsin Bay just behind the Kalsin Bay Inn. The third nest was located about 4-5 kilometers west of the Burton ranch on Narrow Cape between the road to the loran station and the mountains.

Pigeon Hawk *(Falco columbarius):* A female was seen on 2 September in Women's Bay area.

Black Oystercatcher *(Haematopus bachmani):* A flock of 24 nonbreeding oystercatchers was observed on 26 July at the mouth of a stream in Kalsin Bay near Mayflower Creek.

Semipalmated Plover *(Charadrius semipalmatus):* This bird is quite abundant along heads of bays and other locations where suitable gravel beaches are found. One nest with four eggs was found at Middle Bay on 25 May, but more intensive searches could have turned up at ten to twenty nests at Middle and Kalsin Bay beaches.

Surfbird *(Aphriza virgata):* Three birds were observed at Kalsin Bay on 8 August.

Black Turnstone *(Arenaria melanocephala):* The first bird was seen on 26 June at Mary Island and its molt from breeding plumage was already beginning. Two turnstones were seen on 30 June at Mary Island. Flocks increased in size up to nineteen birds by 7 July and small flocks were seen throughout the rest of July. Few were noticed in inner Chiniak Bay in August, but one bird was seen there on 1 September.

Ruddy Turnstone *(Arenaria interpres):* One bird was observed the first week of July mixed in with the first wave of Black Turnstone flocks to arrive in Chiniak Bay.

Common Snipe *(Capella gallinago):* This species was present by 24 May and courship flights were heard at Kalsin Bay on 5 June. These flights and subsequent nesting occurred at many places with Narrow Cape, Kalsin Bay, and Middle Bay wetlands being the primary nesting sites we recorded.

Bristle-thighed Curlew *(Numenius tahitiensis):* One bird was seen several times on 1 September frequenting the east side of Narrow Cape. Whimbrels *(N. phaeopus)* were seen in July and August 1977 and are more likely to occur, but this was the only curlew type recorded in the summer of 1978.

Spotted Sandpiper *(Actitis mocularia):* Two birds were observed on 5 June frequenting the south shore of Middle Bay as well as some watershed or drainage to the south. Two birds in winter plumage were spotted in the same general area on 9 August. Four birds were seen on Narrow Cape for the first time on 2 September.

Wandering Tattler *(Heteroscelus incanus):* This is one of the last shorebird migrants to come through Kodiak and one of the earliest to return in the summer. One bird was seen on 26 May at Puffin Island while two were recorded at Mary Island on 2 June. By 23 July this species had returned and was the most common rock-oriented shorebird in the Kodiak area. A flock of eighteen was seen on Middle Bay 26 July and a flock of twenty was seen on Mary Island on 28 July. Six tattlers were seen 1 September on Narrow Cape.

Greater Yellowlegs *(Tringa melanoleucus):* We saw one bird on 5 June in Kalsin Bay. Although we did not locate the nest, we felt sure on 22 June that a pair was nesting in the Twin Lake area of Narrow Cape near the Burton ranch. Some areas of the head of Kalsin Bay also seemed like probable nesting areas. Birds began being present on bays conspicuously by 26 July and were present until we left on 2 September.

Rock Sandpiper *(Calidris ptilocnemis):* A few were seen on 21 July near the western end of Kodiak Island (Alitak Bay). In 1977 small flocks began to appear in Chiniak Bay 15-20 August. We noticed none in 1978 by 2 September.

Baird's Sandpiper *(C. bairdii):* Twelve birds were seen on 24 July in Kalsin Bay and one was seen in the same area on 8 August. Two more birds were seen at Narrow Cape on 1 September.

Least Sandpiper *(C. minutilla):* This species was the most consistently common small shorebird found in Chiniak Bay throughout the entire summer. Courtship flights were noted on Narrow Cape and near Rose Tead Lake on 24 May. Three chicks about two days old were found on 13 June at the head of Middle Bay. Courtship flights were still being seen on Narrow Cape on 22 June. The flights alternated with periods where the sandpiper would perch in the top of an alder bush. Birds began to appear in flocks in mid-July. We observed a flock of 50 to 100 birds on 26 July in Kalsin Bay. Birds were still present 8 August and 1 September, but the numbers had decreased from the peaks that occurred in July.

Short-billed Dowitcher *(Limnodromus griseus):* Seven dowitchers were seen on 5 June in Kalsin Bay. Some were also present on 26 July in Kalsin Bay.

Western Sandpiper *(Calidris mauri):* Fifteen were seen on 22 June at Narrow Cape. Flocks started returning in number to Chiniak Bay in mid-June. On 23 June over 200 birds were observed at Kalsin Bay. On 26 July a flock containing between 400 and 600 birds was seen at Kalsin Bay. Numbers diminished in August, but small numbers were still seen up through 2 September when field operations ceased.

Sanderling *(C. alba):* This species is not common in Kodiak, but one was seen on 24 July and two on 26 July in Kalsin Bay.

Northern Phalarope *(Lobipes lobatus):* Several small flocks were seen in Kalsin Bay on 24 May. Two birds were present in Kalsin Bay on 5 June. During the third and fourth week of July this species became very common in offshore waters.

Pomarine Jaeger *(Stercorarius pomarinus):* One light phase adult perched on a Narrow Cape beach during a period of severe high winds on 22 June. Several birds were seen mixed in with shearwater feeding flocks observed on 27 July near Spruce Cape.

Parasitic Jaeger *(S. parasiticus):* One dark phase adult was seen in Kalsin Bay near the tern colonies on 25 May. One immature and two adult dark phase birds were seen resting on Narrow Cape on 22 June during high winds. This species was also mixed in with the feeding flocks of shearwaters seen on 27 July. One other bird was seen 8 August in Middle bay.

Long-tailed Jaeger *(S. longicaudus):* This species was seen only on 27 July when the birds were associated with large feeding flocks of shearwaters.

Mew Gull *(Larus canus):* R. MacIntosh found on 7 July a colony of 50 to 100 breeding pairs on an island in Afognak Lake on Afognak Island.

Bonaparte's Gull *(L. philadelphia):* An immature bird was observed on Narrow Cape on 22 June during the same period of high winds that brought many other birds to that Cape.

Sabine's Gull *(Xema sabini):* In 1977 numerous adults and immatures were seen just offshore from Long Island during the last half of July. No birds were noticed in 1978 when the migration of shearwaters and jaegers occurred.

Common Murre *(Uria aalge):* Up to 284 murres were censused on 10 June in the vicinity of Viesoki Island and the breeding colony estimate would be 125 to 150 pairs. On 23 June murres were seen in the vicinity of Kekur Island, but eagles sitting on the island disrupted the small colony so much that no estimate of breeding pairs is possible. Another colony of murres exists at Cape Chiniak, but it was not censused this year.

Pigeon Guillemot *(Cepphus columba):* This is a common species in Chiniak Bay. One bird was still in winter plumage on 20 May, but most were in breeding plumage by this time. Although this species was found breeding on many islands, only Mary and Blodgett Island were censused early. On 22 May there were 30 adults around Mary Island while Blodgett Island had a similar number.

Marbled Murrelet *(Brachyramphus marmoratum):* Certain parts of Chiniak Bay like Long and Woody Islands had this species associated with them. On 29 May one bird was noted in transitional plumage. This species was not observed often in inner Chiniak Bay, but many birds were seen mixed in with the shearwater feeding flocks near Spruce Cape on 27 July.

Ancient Murrelet *(Synthliboramphus antiquum):* Two adults and two chicks were seen within ten kilometers of Ugak Island on 7 July. Two birds in winter plumage on 27 July were associated with the large shearwater feeding flocks.

Parakeet Auklet *(Cyclorrhynchus psittacula):* Fifteen pair were breeding on Eider Island near Spruce Island on 10 July 1977, but none were noticed in 1978 on 30 July.

Horned Puffin *(Fratercula corniculata):* This species is a low density, ubiquitous breeder in Chiniak Bay.

Short-eared Owl *(Asio flammeus):* One bird was seen on Ladder Island in Kiliuda Bay on 22 July. Another was observed on 8 August in Middle Bay.

Downy Woodpecker *(Picoides pubescens):* One was seen on 26 July near Rose Tead Lake.

Tree Swallow *(Iridoprocne bicolor):* These were first seen on 24 May and were one of two most common swallows seen all summer.

Bank Swallow *(Riparia riparia):* This was the second most common swallow seen in Chiniak Bay. One colony was located in roadside banks east of the Buskin River and a second was new this year on cliffs on the east side of Narrow Cape near the Burton ranch. This last colony was established during the first three weeks of June.

Black-billed Magpie *(Pica pica):* This is an abundant resident of mainland Kodiak. It was not seen on the smaller islands very often in the summer.

Common Raven *(Corvus corax):* A nest with three to four chicks was found on 26 May on the east end of Puffin Island. This same area had a raven nest in 1977 also.

Northwestern Crow *(C. caurinus):* Zaimka Island had the largest colony and a flock of 36 was seen near there at Cliff Point on 9 June.

Black-capped Chickadee *(Parus atricapillus):* This common resident was seen in winter flocks on 2 August.

Red-breasted Nuthatch *(Sitta canadensis):* One bird was seen 3 August in town of Kodiak.

Winter Wren *(Troglodytes troglodytes):* This was one of the passerine species frequenting the smaller islands.

Varied Thrush *(Ixoreus maevius):* This thrush was heard and seen mostly in the more heavily wooded islands like Long Island.

Hermit Thrush *(Catharus guttata):* This very common thrush frequented the bush and thickets on the islands.

Golden-crowned Kinglet *(Regulus satrapa):* This species was seen and heard on Long Island as well as the town of Kodiak.

Water Pipit *(Anthus spinoletta):* This species became common on the mud-flats of Middle Bay (probably other bays also) on 2 September.

Wilson Warbler *(Wilsonia pusilla):* This appeared to be the most common and noticeable warbler seen on the islands of Chiniak Bay.

Pine Grosbeak *(Pinicola enucleator):* These were seen near Gibson Cove in June as well as on Long Island on 11 July.

Common Redpoll *(Carduelis flammea):* Flocks were most common on Long Island on 11 July.

Pine Suskin *(Spinus pinus):* This was another species noted on Long Island on 11 July during our overnight trips there.

Savannah Sparrow *(Passerculus sandwichensis):* This sparrow is extremely common both on islands and mainland Kodiak.

Golden-crowned Sparrow *(Zonotrichia atricapilla):* Birds were calling on 24 May when we first arrived and this sparrow seemed the most abundant sparrow at different times.

Fox Sparrow *(Passerella iliaca):* This is another of the common passerines found on the smaller islands in Chiniak Bay.

Lapland Longspur *(Calcarius lapponicus):* Breeding plumage males were abundant on Narrow Cape in May. By 22 June the pairs were bunching back into flocks of 20-30 birds and only two males retained much of the breeding plumage. This species was still present on Narrow Cape on 2 September.

Appendix II. Growth of Black-legged Kittiwake Chicks, Chiniak Bay, 1978

Age (days)	n	Weight (g) Mean	S.D.	Range	Flattened Wing (mm) Mean	S.D.	Range
0	5	35.6	2.70	33-39	25.5	1.73	24-27
1-3	27	54.0	9.15	40-75	28.2	2.11	25-32
4-6	18	90.1	16.30	65-119	35.6	4.33	29-46
7-9	28	139.7	18.30	98-175	49.7	8.15	32-71
10-12	23	202.0	27.26	138-253	75.9	9.37	51-89
13-15	24	248.2	24.18	197-282	99.6	9.61	82-111
16-18	27	292.3	27.74	250-360	123.3	11.86	102-151
19-21	23	338.1	24.13	291-386	150.6	6.27	135-162
22-24	26	356.5	33.47	263-421	176.5	10.13	159-194
25-27	22	375.3	25.50	326-413	201.2	8.55	184-219
28-30	17	389.1	30.42	350-465	217.6	8.76	203-229
31-33	11	364.6	32.58	299-425	234.4	4.57	226-240

Appendix III. Growth of Tufted Puffin Chicks, Chiniak Bay, 1978

		Weight (g)			Flattened Wing (mm)		
Age (days)	n	Mean	S.D.	Range	Mean	S.D.	Range
0	9	58.4	4.28	51-66	27.1	1.05	25-28
1-3	5	70.0	8.46	64-84	28.3	1.51	27-31
4-6	15	98.9	16.10	88-150	30.9	2.40	28-38
7-9	9	156.1	23.93	126-200	40.4	4.30	34-48
10-12	18	187.3	28.44	143-239	46.9	5.88	39-57
13-15	13	253.8	30.50	215-299	61.8	5.71	53-72
16-18	19	290.61	47.61	191-354	70.9	9.54	54-85
19-21	19	355.30	41.59	281-410	87.9	6.31	78-100
22-24	13	366.3	73.37	230-480	92.3	17.21	77-143
25-27	21	419.67	66.51	212-562	107.8	8.36	83-126
28-30	11	455.7	74.74	357-585	118.4	5.75	105-127
31-33	21	485.3	62.70	390-592	130.6	5.41	117-140
34-36	6	513.8	91.00	410-669	134.7	4.50	130-142
37-39	16	519.2	53.99	390-595	143.8	4.09	136-150
40-42	11	549.1	72.58	435-665	152.8	3.31	146-158
43-45	6	559.5	33.16	513-605	158.6	3.46	153-162

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BREEDING BIOLOGY AND FEEDING HABITS OF SEABIRDS OF SITKALIDAK STRAIT, 1977-1978

by

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Abstract

We studied the breeding biology and food habits of tufted puffins, black-legged kittiwakes, glaucous-winged gulls, arctic and Aleutian terns during the 1977 and 1978 breeding seasons at inner east Sitkalidak Strait. We censused the entire area, including Kiliuda Bay both years.

Breeding chronology for all bird species was essentially the same for 1977 and 1978. The number of breeding kittiwakes, gulls and terns of both species declined in 1978 whereas the number of breeding tufted puffins remained rather constant. Likewise productivity at all stages of breeding: number of eggs laid, number of chicks hatched, number of chicks fledged and chicks fledged per nest attempt declined for all of the above surface and cliff nesters, but not for the tufted puffins. The decline in reproductive output in 1978 was due to a number of factors: fewer breeding birds, fewer eggs laid to begin with, increased predation of eggs and chicks by mew and glaucous-winged gulls, ravens, northwest crows and bald eagles, and perhaps a change in the prey base.

The prey base for all of the species we studied changed radically from 1977 to 1978. In 1977, capelin, *Mallotus villosus*, was by far the most important prey with respect to numbers and frequency of occurrence. In 1978 capelin was replaced by sandlance, *Ammodytes hexapterus* as the most important prey and was found in significantly fewer numbers and in significantly fewer of the regurgitations and bill loads of the birds than it was in 1977. This decline of capelin in 1978 may have somehow influenced the decrease in numbers of breeding birds and also their lowered reproductive success.

INTRODUCTION

The purpose of the OCSEAP studies was to define the role of seabirds in the Alaskan marine environment and to identify and evaluate potential impacts to the seabirds from the development of the petroleum reserves on the Alaska Outer Continental Shelf.

The studies in and around Kodiak Island are part of an integrated program to assess the entire ecosystem in the area in anticipation of drilling in lease areas. The program is interdisciplinary and involves biology, geology, chemistry and physical oceanography. These integrated studies were first initiated in 1978 in order to fill in data gaps in our knowledge about the ecosystem in the Kodiak area.

The USFWS has identified 251 seabird colonies in and around Kodiak Island (Bartonek et al., RU 337) and about 130 bird species that are present in the coastal areas of Kodiak. The USFWS has information on the abundance and distribution of seabirds from the pelagic studies we have been conducting off Kodiak from 1976-1978 (RU 337). Sitkalidak Strait with its important colonies on Cathedral Island and the adjacent Boulder Bay was identified as a key site to study.

STUDY AREA

Sitkalidak Strait separates Kodiak and Sitkalidak Islands in the western Gulf of Alaska (Figures 1, 2). It varies in width from about 0.5 km at its center, Sitkalidak Passage, to about 5 km at its eastern and western midpoints and 14.5 km at its eastern and western entrances. The inner part of the strait is fairly shallow (2.5-18.5 m) but near Cathedral Island and Barling Bay the depth increases to about 130 m. Surface water temperatures range from about 6^{o}C in May to near 12^{o}C in August. Summer weather is generally wet and mild. Air temperatures during our 1978 studies ranged from a minimum of 0^{o}C to a maximum of 28^{o}C with highest temperatures occuring in August (Figure 26). Over 711 mm of rain fell between 13 May and 7 August, 1978 averaging about 6.4 mm per day with only about 28 percent of the days being rain free (Figure 27). The biggest storm occurred on 23-24 May when 79 mm of rain fell in a 48 hour period. Winds, generally between 8 and 32 km/hr, were usually from the southeast, northwest and southwest with the former predominating in early summer and the latter occurring mostly in late summer (Figure 28). Numerous bays, fjords and small islands occur within this area and 1,500 mountains surround the strait. These mountains provide shelter from the open ocean to the south. The dominant breeding seabird species in the strait are tufted puffin, black-legged kittiwake, glaucous-winged gull and arctic and Aleutian terns.

Our base camp was located at Cozy Cove (Figure 3) and we concentrated our 1977 and 1978 studies in the inner two-thirds of the eastern arm of Sitkalidak Strait. The islands where our 1977-78 studies were conducted ranged from flat, grassy Sheep Island to the fairly steep, mixed meadow-umbel covered Cathedral Island. All of the islands in this area are easily accessible and the colonies are quite workable. There is some interference by the natives of Old Harbor, 6 mm east of our base camp, not only with their traditional egging of tern and gull nests but also with their use of the islands as recreation areas. The villagers, however, are very interested in the wildlife around Old Harbor, and have a progressive outlook of preserving the area and keeping development at a minimum.

MATERIALS AND METHODS

In 1978 we adhered to most of the methods we used in 1977, culling those which we found to-be less important or meaningful, and adding some new ones to answer questions formulated as a result of last year's analysis.

The main thrusts of our investigations in 1978 were to determine: 1) chronology, 2) reproductive success and 3) growth of chicks for black-legged kittiwakes, tufted puffins, and gluacous-winged gulls, and to compare these results with those we found in 1977. We also conducted censuses of all colonies in the immediate study area with less extensive surveys of colonies in adjacent bays and fjords. These latter surveys helped us determine the abundance and distribution of breeding birds in the entire Sitkalidak Strait area. Before our intensive surveys in 1977 and 1978, the only other information we had were brief flyovers by Lensink and Berns (Lensink 1957, Berns 1972) and a survey by boat in 1976 (Sanger et al., 1976).

In conjuntion with our colony-based studies we investigated habitat preferences of all major species for possible correlation of selected habitat parameters with reporductive success. We also gathered feeding data concurrently with our growth studies of the chicks by collecting their regurgitations or their parents' bill loads.

Monthly we conducted a beached-bird survey at Ocean Bay on the ocean side of Sitkalidak Island and at the landing beach on Amee Island (Figure 4).

We also made monthly seawatches at Lagoon Point in Sitkalidak Strait (Figure 3). The purpose of these was to detect possible regular diurnal movements of birds away from and to nearby colony. These data have not yet been analyzed but will be presented in our final report.

We took daily measurements of maximum and minimum tempreatures, precipitation and wind. Incidentally we noted the abundance and distribution of marine mammals and other birds. These notes appear in the species account.

TUFTED PUFFINS

We studied mainly the puffins on Cathedral Island which was by far the most important tufted puffin colony in the inner east Sitkalidak Strait area. We also studied two plots on Amee Island which were chosen as a comparison for reproductive success in less preferred habitat.

We chose all study plots to give equal representation to the different kinds of tufted puffin habitat on Cathedral and Amee Islands, including different slopes, exposures and burrow densities. Table 1 explains the way in which we set up our study plots. In 1978 we studied seven of the nine total puffin plots from 1977. We also set up four new plots (Figure 5). Of the eleven plots studied, three were used for monitoring chick growth, seven were used for habitat analysis, two were used as controls for disturbance during the egg stage and five were used for monitoring reproductive success without disturbance from measuring the chicks. All nests were used for information about chronology. The plots that we did not disturb during the egg stage we called "undisturbed plots" and the burrows in them we only dug up near time of fledging to discover the number of chicks produced per plot. All other burrows we excavated by making window-holes with tufted grass and earth plugs over the nest chamber in order to check for presence of eggs and chicks. It was through these windows that we removed the chicks for the growth studies.

We checked the burrows on "disturbed plots" every three days prior to egg laying. As soon as we discovered an egg in a nest chamber, we did not disturb that burrow again until forty days later--a few days less than the incubation period of tufted puffins. If we found a chick at this point in time, unless the plot was a growth plot, we did not disturb the burrow again until approximately forty days from that date--a time period just less than the normal fledging period. The first time we discovered a chick in the productivity or growth plots we weighed and measured it. We monitored the growth plots every three days, taking the following measurements on all chicks present: weight, lengths of diagonal tarsus, exposed culmen, and wing cord. We weighed the chicks in plastic bags hung from Pesola scales. Near fledging we banded the chicks with green color bands and Fish and Wildlife bands.

At the outset of the study we attempted to use a method others have used in the past to check for burrow occupancy (Wehle 1977, Nysewander 1977). In this method, a fence of toothpicks is placed across the burrow entrance and then checked 24 hours later to see if the toothpicks have been knocked down. Supposedly, the burrows with eggs (or chicks), the nesting burrows, will have the toothpicks knocked down, while those that are inactive will have the toothpicks up. However we found that this method is not valid for determining nesting burrows because many burrows (22%) that had no eggs or chicks in them would have adult puffins using them and they would knock down the toothpicks. The interpretation of the results of the toothpick method is critical. The method should be used to estimate the ratio between burrows entered and burrows with nests, not for estimating the breeding population solely in the number of burrows with toothpicks knocked down.

We took habitat measurements on five of the disturbed plots and both of the undisturbed control plots. Parameters measured were nearest neighbor distance, slope, exposure, burrow depth, and burrow length and slope. The summary of these measurements is in the Addendum.

We collected bill loads that adult tufted puffins were bringing in for the chicks by our method of bill taping (Baird and Moe 1977). We preserved the samples in 10% formalin within an hour after they were collected, and analyzed the specimens months later in the lab, recording species, length, numbers weight, and volume of the prey. For data analysis we used species length, numbers, and frequency of occurrence of prey.

BLACK-LEGGED KITTIWAKES

This year we studied four of the five kittiwake plots that we had set up in 1977 and added one new plot (Figure 6). Three we chose as chronology and growth plots and two were chronology and productivity plots. We used five of the plots for habitat analysis, which will appear in the Addendum.

We chose the plots to obtain a good representation of sizes of colonies, their height above water, exposures, and slopes. We disturbed the productivity plots as little as possible , checking them every three days for number of nests, number of eggs and number of chicks. To check the plots with as little disturbance as possible we had to climb above the colony and look down over the cliff to determine presence of nests, eggs, and chicks. We initially marked individual nests with numbered tongue depressors so that we could relocate them. We reached the growth plots by climbing ropes and checked these plots once every three days. We obtained the habitat parameters for all nests on five of the six plots during the first week in September when most of the chicks had fledged. These observations were taken with the aid again of climbing ropes.

In mid-July we conducted a kittwake census of the entire inner Sitkalidak Strait area, counting every occupied nest and every chick. Two counts by two people were always made for each area censused and these counts usually yielded the same number or were within 5% of each other. If the numbers differed we used the avarage of the two after a second count was made.

On the growth plots we numbered the eggs with red or blue china marker and as soon as the chicks hatched we fitted them with numbered plastic color bands. We weighed chicks every three days using Pesola scales and measured their exposed culmen, diagonal tarsus, and wing cord. On all plots, when the chicks neared fledging, we weighed, measured, and banded them with Fish and Wildlife bands and color bands if they had not previously been banded.

The parameters of the habitat that we measured the first week of September were: height above water, nearest neighbor distance, exposure, slope, ledge width, presence and amount of overhang, presence of adjacent ledge and overhang of adjacent ledge. A summary of these is in the Addendum.

Concurrently with the growth measurements we collected feeding data opportunistically. In our disturbance of the kittwake chicks for growth they would often regurgitate their stomach contents. Immediately we would place this regurgitation in a plastic bag and label it and within four hours we added 10% formalin. We performed the analysis of these regurgitations months later in the lab and recorded the same information on these food samples as we did for the tufted puffins: species, number, weight, length and volume. For analysis, we used length, frequency of occurrence, and percent numbers of prey. Volume is an inadequate measure for soft prey such as fish because of rapid digestion of the tissue. Two birds could eat exactly the same number and kind and length of a certain fish species but due to different amounts of time that the prey remained in the stomach, the volumes could be radically different from each other, depending on when that regurgitation was collected. Thus volume measurements tend to give meaningless if not erroneous results and we did not use this measurement and do not recommend it for food analysis of piscivorous species.

GLAUCOUS-WINGED GULLS

We repeated the same sampling scheme for glaucous-winged gulls that we used last year. We constructed our plots to sample colony types (solitary and grouped). We further divided the solitary-type plots into vertical plots relatively inaccessible to humans and horizontal easily accessible plots in order to test for human disturbance of the nesting gulls. Both of the colonial plots were rather inaccessible, one being on a precipitous sea rock, Lesser Kittiwake Rock, and the other on a sea stack, Amee Rock, reachable only by climbing ropes (figure 7). All plots were the same ones as last year, plus we had six "opportunistic" nests that were at the tops of the kittiwake plots, and we also monitored these.

We used all plots for chronology, habitat analysis, growth and reproductive success. Human disturbance does not seem to be a problem with gulls once the chicks are hatched, so we combined growth and productivity plots due to the low sample sizes.

One of the questions we wanted to answer was if there was a noticeable difference in chronology between the two main kinds of gull colonies: truly colonial and solitary. If there were a difference then it would perhaps indicate a preference in type of nesting situation. In order to determine if there were differences in habitat we measured slope, exposure of, and vegetation height and cover around the nest, and also the nearest neighbor distance.

The plots we chose represented a variety of slopes, exposures and habitat types, and we feel that they were a good sample of the available habitat occupied by the breeding gulls.

We checked the solitary plots and one colonial plot once every three days, and the colonial plot on Amee Rock approximately once every week, depending on weather. We had to ascend this sea stack with a rope and at times the weather was too stormy for a safe ascent.

We numbered every egg with a china marker and when chicks hatched we banded them with numbered color bands. We used the same techniques for weighing and measuring gull chicks as we did for the other species. We also collected regurgitations opportunistically. Just before fledging we banded the chicks with U.S. Fish and Wildlife bands.

We conducted a census of the gulls during their late incubation stage. At this time they are conspicuous and easy to count at the nest site, so we feel our count is fairly accurate. If only one member of the pair were present we counted it as two birds to derive our estimates. Because the count was during incubation we assumed that at least one of the pair of all breeding adults would be on the nest at this time.

RESULTS

TUFTED PUFFINS

Distribution and Abundance

In the entire Sitkalidak Strait area, there are two major tufted puffin colonies, Puffin and Cathedral Islands, with minor colonies on the three islands in Kiliuda Bay and on Amee Island.

We censused the inner east Sitkalidak Strait area by boat on 12 July 1978 and Kiliuda Bay on 22 May 1978, counting birds and also estimating numbers of "nesting burrows" by extrapolation from the densities of our flagged plots (Tables 2,3). We detected no new colonies in this census or in any of our trips in and around the Sitkalidak Strait area.

The tufted puffin population of inner-east Sitkaldiak Strait remained stable from 1977 to 1978, and the tufted puffins occupied the same geographical areas in 1978 as they had in 1977 (Figure 8). The numbers of birds seen during our boat survey, as in 1977, was approximately half that of the estimated number of nesting burrows, probably because one of each pair was at the burrow during our count.

Phenology

When we arrived at Sitkalidak Strait on 8 May the tufted puffins had already established territories and were occupying burrows. They were also in the midst of their pre-egg laying attendance cycles with approximately two days of absence and one day of colony occupation. The first eggs were laid on 27 May, with 59% being laid by 5 June (Figure 9). This is slightly ahead of 1977 when 23% were laid by this date. The four eggs laid between 22 June and 4 July may represent second clutches.

Chicks began to hatch on 8 July, peaking 16-18 July, indicating an incubation period of about 42 days which is similar to what others have found (Baird and Moe 1977, Nysewander 1977, Wehle 1976, 1977). The last chicks hatched on 1 August. Fledging began on 21 August and peaked the 25th of August, yielding a nesting period of about 44 days, corresponding to nesting periods from other studies (Ibid.). Of 32 chicks studied, only two had not fledged by the time we left on 7 September.

Productivity

The productivity of tufted puffins in 1978 was similar to that in 1977 (Table 4). In 1977, for the disturbed plots, 72.0% of all the burrows entered at least once had eggs and in 1978, 67.0% had eggs ($p>0.4$*) The hatching success, or chicks hatched per egg laid, was 61.2% in 1977 and 52.2% in 1978 ($p>0.1$). Fledging success, or chicks fledged per chick hatched was 87.8% and 88.9% in 1977 and 1978 respectively ($p>0.5$). The chicks fledged per burrow with eggs was 0.537 and 0.464 ($p>0.2$) and the number of chicks fledged for all burrows entered at least once was 0.38 and 0.31 ($p>0.1$) respectively. Thus, for each stage in the reproductive cycle, the percent success was very similar between years.

The undisturbed plots also were similar in their productivity between years, in the number of chicks fledged per burrow entered at least once (Table 5). There was a radical difference in number of chicks fledging from disturbed and undisturbed plots (Table 6). Significantly more chicks fledged from the undisturbed plots than from the disturbed. This does not, however, invalidate our estimate of productivity because they must be disturbed in order to study them and this disturbance probably affects them in the same ways from year to year.

* Statistical analysis is based on the equality of two percentages or t-tests with a $p<0.05$ showing a significant difference between years.

Mortality

The proportion of eggs and chicks lost in 1977 and 1978 was similar: 46.7% in 1977 and 49.3% in 1978. Likewise the proportions of mortality in the egg and chick stages were similar (Table 7). However the kinds of mortality differed somewhat between the two years. The greatest mortality in 1977 was simply disappearence of the egg, 19.4% while in 1978 it was abandonment of the egg, 27.5%. Disappearance of the egg in 1977 however may simply reflect abandonment. Few of the eggs (1.5%) in 1978 were infertile, while in 1977 there were many, (9.0%). Total chick mortality was similar for both years: 42.0% in 1978 and 37.3% in 1977. All the chick mortality in 1978 is probably related to inattentiveness by the adult. The disappearance of a chick is most likely due to the parent's not bringing food to the burrow. A hungry chick of any age will, at some level of hunger, leave the burrow. The fate of the chicks that disappeared is unknown but we assume they all died once they left the burrow, unless they were almost ready to fledge.

Because the number of chicks fledged from undisturbed plots was significantly greater than from disturbed, we assumed that human disturbance in the areas where puffins nest is very detrimental to their reproductive success. However, in the disturbed plots, the actual touching of an adult in the burrow while we were checking for eggs did not seem to effect abandonment of the egg. In the disturbed plots we chose three categories to compare the effect of physical contact with a tufted puffin adult or checking of the burrow with the adult still inside it (we call this "disturbed"): burrows disturbed and subsequently abandoned, burrows abandoned but not disturbed, and burrows disturbed but not subsequently abandoned. A chi-square test among these categories revealed no difference, so we can say that the disturbance of a particular burrow does not always result in abandonment--that it probably depends on the individual puffin and also on the stage of incubation (Table 8). However more important, with respect to development of this area, the constant disturbance or perhaps simply presence of humans at the breeding colonies of tufted puffins drastically reduces their reproductive success.

Trophics

Table 9 shows the prey types that tufted puffins took in 1977 and 1978 and includes the percent numbers, frequency of occurrence, and lengths. At this time we do not have prey lengths for the prey that tufted puffins brought their chicks in 1977. The types of prey items taken in both years differed somewhat qualitatively and the frequency in which they were taken was similar except for the two major fish species, capelin and sandlance. Chi-square tests between years respect to percent numbers of prey taken and also to frequency of occurrence of all prey yielded no significant differences between all of the species. However a percentage test between capelin and between sandlance of both years did yield a significant difference in percent numbers for both species and for frequency of occurrence for capelin (Tables 11 and 12). Capelin (Mallotus villosus) and sandlance (Ammodytes hexapterus), the two most important food items for all seabirds in the Kodiak area, occurred in different proportions for 1977 and 1978. In 1977 capelin and sandlance made up 64.9% and 25.8% of the total numbers and occurred in 75.0% and 37.5% of the bill loads respectively. In 1978, capelin and sandlance made up 36.9% and 49.6% of the total numbers and occurred in 34.6% and 46.2% of the bill loads. Thus, if all species are compared together, the similarity of species other than sandlance and capelin override any differences between these two species in the two years. Yet there does seem to be a real difference in numbers and frequency of occurrence. The mean lengths of all food taken by tufted puffins was 94.79 ± 1.97 mm in 1978.

Likewise, diversity, H', of the prey base was similar and the species evenness, J', or the frequency in which they took each prey species was approximately the same for both years (Table 10).

We aged chicks from known dates of hatching and then constructed the growth curves of the chicks using these actual ages and their corresponding weights. The purpose of constructing growth curves is to find the average growth of the chicks in a supposedly stable environment against which other years may be compared. Growth therefore for these purposes is typically defined as weight gained and no wing growth over a certain time period because wing growth is less influenced by environmental changes than is weight.

Figure 10 shows the data points of all the chicks we studied with the best fitting polynomial regression curve drawn through them. Growth is typically sigmoid with a thrid order polynomial best describing the growth pattern (r^2=0.9487 in 1977 and r^2=0.9086 in 1978). Figure 11 compares the ploynomial regression curves between 1977 and 1978. The slopes are almost identical, and the absolute values of the curves are very similar. From this we can say that the growth of tufted puffin chicks was similar in 1977 and 1978.

BLACK-LEGGED KITTIWAKES

Distribution and Abundance

We censused all the kittiwake colonies in east inner Sitkalidak Strait in August, when presence of chicks would be obvious. The number of pairs of kittiwakes found on this census was similar to that of 1977 (Tables 2,3, and Figure 12), except for an increase of about 124 breeding pairs on Ghost Rocks in 1978. Likewise the kittiwakes occupied the same colonies in 1978 as they did in 1977, with the exception of the marginal colony on Amee Rock which they did not use in 1978. We censused the colonies in Kiliuda Bay in May and found similar numbers as Douglas Forsell had found there in 1977 (personal communication).

We also censused the large colony of kittwakes in Boulder Bay, once in June and once in August. The difference in numbers of breeding pairs present in June between years at the Boulder Bay colony was great, with 25,000 pairs in 1977 and 3,500 pairs in 1978. By August 1978 there were only 1,500 pairs remaining at the Boulder Bay colony. The reasons for this drastic decrease in numbers in 1978 are not apparent at this time, but the decrease reflects the overall poor productivity that kittiwakes had in 1978.

Phenology

Upon our arrival the first week in May, we found the kittiwakes already occupying nest sites on the cliffs. The total number of occupied nests reached a peak around the 12th of June and then declined drastically between 1-20 July (Figure 13). The greatest loss of nests occurred the first 2 weeks in July. We defined nest loss as complete disappearance of the nest from the cliff and also disappearance of a major portion of the nest due to non-maintenance and repair. Thus, kittiwakes could still be occupying a nest site but not be considered a breeding pair due to an inadequate nest.

Kittiwakes initiated most of their clutches from 12 June - 17 July with one started 3 August. The commencement of clutch initiation was similar to that of 1977 when the first eggs were laid on 14-17 June. The peak of laying occurred between 22 June and 3 July with the greatest number of eggs present on the colonies on 30 June (Figures 14, 15). There was a peak of egg mortality immediately after the first eggs were laid between 20 June and 7 July. After this, second clutches were initiated by 42.3% of the kittiwakes (Figure 16).

The first chicks hatched between 14 and 19 July, yielding an incubation period of about 27-31 days which agrees with what others have found (Nysewander 1977, Jones and Peterson 1978). The first chicks fledged on 18 August with the peak occurring the first week in September. This gives a brooding period of approximately 30 days which is similar to the brooding times found by others (Ibid).

Of all chicks still living by the time we left on 7 September, 19.0% had not yet fledged. These chicks were all from one plot and they were all from second clutches. The rapid decline in number of chicks present on the colonies (Figure 13) was due mainly to predation by gulls, not to fledging.

Productivity

The productivity of black-legged kittiwakes in 1978 was minimal and drastically reduced from that of 1977 (Table 14). Clutch size ($\bar{x}$ = 1.26) was significantly decreased from last year ($\bar{x}$ = 1.68) with only 14.1% of the nests with 2-egg clutches this year, compared with 55.2% in 1977 ($p<0.05$) (Table 13). The number of nests with eggs per all nests built was also lower in 1978: 53.7% versus 83.8% in 1977 ($p<0.001$). The number of chicks hatched per egg laid was likewise significantly lower in 1978 than in 1977: 35.9% and 74.2% ($p<0.001$), with the mean brood size at hatching also lower: 1.25 and 1.57 respectively ($p<0.0001$). The similarity of clutch size and brood size at hatching indicates that the one and two-egg clutches were preyed on equally. Clutch size thus may have no effect on egg loss. The number of chicks fledged per chick hatched (fledging success) was also low compared to 1977: 52.6% versus 76.5 ($p<0.05$). The mean brood size at fledging was significantly different between the two years: 1.15 and 1.34. The young fledged per nest with eggs differed radically between the two years with 0.89 fledging in 1977 and only 0.31 in 1978 ($p<0.05$), as did the young fledged per nest attempt 0.74 in 1977 and 0.17 in 1978), (both $p<0.001$).

Mortality

The combined mortality of eggs and chicks of black-legged kittiwakes was significantly higher in 1978 than in 1977 (Table 13, $p<0.05$) but of this the percentage of chicks dying was approximately the same for both years while the number of eggs dying was much higher in 1978 (62.7%) than in 1977 (30.9%). The majority of the egg deaths (88.5%), and all chick deaths in 1978 were presumably from predation. We assumed that disappearance of an egg or chick was due to predation.

Most of the predation was by glaucous-winged gulls with additional predation by crows and ravens. The chicks they ate were sometimes quite old--over four weeks, almost ready to fledge. In 1977, predation of eggs and chicks accounted for only 58.9% of all mortality while in 1978 it accounted for 90.6%.

* a p value less than 0.05 means there was no significant difference between years, and is derived from either a t-test or a difference in percentages test.

In 1978 the greatest mortality (64.1%) took place the last two weeks of June (Figure 16). This was immediately after the first eggs were laid. The time of the next highest peak of mortality was the week before and the week of the first fledglings when there was 17.6% mortality.

Trophics

The differences between the food base for kittiwakes in 1977 and 1978 is evident in Table 16. In 1977, sandlance, Ammodytes hexapterus and capelin, Mallotus villosus occurred in 50.0% and 59.3% respectively of the regurgitations and together made up 85.5% of the total numbers of all food items ingested. In 1978, Ammodytes and Mallotus respectively were in 75.9% and 6.9% of all the regurgitations. Together they made up 79.3% of the total number of food items ingested and of these numbers, Ammodytes comprised 90.5%. Contingency chi-square tests between the two years with respect to percent numbers and frequency of occurrence yielded significant differences ($p<0.0001$. $X^2 = 22.4332$ and $p<0.0180$, $X^2 = 10.0691$ respectively Tables 11 and 12). The mean lengths of the food items kittiwakes preyed on in 1978 was 103.19 ± 2.79. We do not yet have this information for kittiwakes in 1977.

If 1977 and 1978 are compared with respect to diversity, the kittiwakes were eating a more diverse diet in 1977 (H' = 0.5509) than in 1978 (H' 0.3402) and the species eveness was also different, with the kittiwakes in 1977 taking more even proportions of all food items (J' = 0.7080) than they did in the inbalanced situation in 1978 (J' = 0.5651, Table 17).

In summary, 1978 was a very different year, food-wise for kittiwakes than was 1977. The kinds of food taken changed both qualitatively and quantitavely. The food base was somewhat more diverse in 1977 and the frequency of occurrence and percent numbers of food items taken differed greatly. Kittiwakes relied heavily on Mallotus villosus in 1977, and in 1978 they did not. In fact, this species was almost nonexistent in the regurgitations of the chicks in 1978.

Chick Growth

We aged chicks from known dates of hatching and then constructed the growth curves of the chicks using these actual ages and their corresponding weights (Figure 17), as we had with tufted puffins. The growth of kittiwakes followed the typical sigmoid pattern. When growth from hatching to fledging is compared for both years (Figure 18) it is apparent that there is no difference in growth between the two years. The curves themselves are very similar and are the best fit of polynomials through the paired values of age and weight. The polynomials best describing the growth for both years are third order polynomials with r^2s of 0.936 and 0.954 for 1977 and 1978 respectively.

GLAUCOUS-WINGED GULLS

Distribution and Abundance

The population of breeding adult glaucous winged gulls declined by 49.0% in 1978 (Table 2). In 1977 there were 940 gulls breeding in the area and in 1978 there were 480. Even with the decrease in numbers, they used the same areas as last year in which to nest (Figure 19), but these areas were not as heavily populated as in 1977. The populations around Kiliuda Bay increased somewhat from 1977 (Table 3) but not enough to account for the decline in the gull population in the inner part of Sitkalidak Strait. There were always quite a few non-breeders especially later on in the season when many second and third year gulls were roosting on the beaches and rocks adjacent to the colonies.

Phenology

When we arrived in the Sitkalidak Strait area the 8th of May, the glaucous-winged gulls had already established territories. They were constructing nests but had not yet laid eggs. They initiated the first clutches on 5 June and continued egg laying until 19 July (Figure 20). The peak of total nests was the first week in June as was the peak of total eggs (Figure 21). There was much egg mortality the first two weeks after laying and there were a few renestings but most of the adults whose eggs were preyed on, or whose eggs were otherwise lost, abandoned the nest site. The bimodal graph in Figure 21 reflects the second clutches that some gulls started due to loss of their first clutch.

The first chicks hatched on 3 July with the peak of hatching on 11 July. The greatest number of chicks present on the colony was on 17 July (Figure 22), and the last chicks hatched 4 August. This gives an incubation time of 28 days. Fledging took place from 12 August to 5 September, with two chicks not having fledged by the time we left on 7 September. This yields a brood period of approximately 40 days.

Productivity

At all stages, the productivity was less in 1978 than it was in 1977. There were fewer nests with eggs per nest built, 45.3% (1978) and 64.3% (1977, p 0.001*), fewer chicks hatched per egg laid, 48.0% and 75.4% ($p<0.001$) and fewer chicks fledged per chicks hatched, 74.6% and 89.1% ($p<0.001$), (Table 18).

The mean clutch size of glaucous-winged gulls was 2.2 (Table 18) and only 45.3% of all nests had clutches. The initial and final brood sizes likewise were fairly high 2.1 and 1.9, yet there was only a 48.0% hatching success (chicks hatched/egg laid) and a 74.6% fledging success (chicks fledged/chicks hatched).

We found no difference between colonial and solitary nesting gulls with respect to clutch size ($p>0.16$) brood size ($p>0.07$), or number of fledglings ($p>0.47$). Likewise we found no differneces between the inaccessible and the accessible plots with respect to all phases of productivity, ($p>0.05$.) as we had found in 1977. This may reflect less egging. Perhaps the similarities between these inaccessible and accessible plots this year were in part due to egging not being a mortality factor for eggs.

Mortality

Avian predation at the egg stage was the major cause of reporductive failure in glaucous-winged gulls at Sitkalidak in 1978 (Table 19). Egg and chick mortality were 40.7% and 9.8% respectively. The next highest and only other cause of mortality at the egg stage was exposure 9.8%. In 1977 the number % eggs lost was approximately three times the number of chicks lost while in 1978 that number is approximately 4. Predation by other birds was not very important in 1977 (3.0%).

Most of the mortality, 56.7% occurred from 15-21 June during the peak of the egg stage (Figure 23). Many chicks died while pipping, apparently a very vulnerable time. The next peak of mortailty was 16 between 6 and 12 July.

Trophics

The glaucous-winged gulls, like the black-legged kittiwakes, had a significant change in diet from 1977 to 1978, both qualitatively and quantitatively. In comparing individual prey species in the regurgitations of the chicks, we found a significant difference (p 0.003, $X^2 = 29.5841$, Table 20) in the frequency of occurrence between 1977 and 1978. The same difference was true for changes in percent numbers ($p=0.0005$, $X^2=40.0354$, Table 8).

The diversity in both years was fairly high, ($H' = 0.8877$ for 1977 and $H' = 0.9166$ for 1978, Table 21) which is common for a generalist species like a gull. Species eveness was also fairly high for both years, $J' = .7372$ in 1977 and 0.7997 in 1978.

From Table 20 it is apparent that in 1978, _Ammodytes hexapterus_ was the most important food item for glaucous-winged gulls with respect to numbers and frequency of occurrence in the regurgitations, 46.4% and 24.0% respectively, with _Mallotus villosus_ being the next important; 16.4% and 16.0%. The rest of the species are of minor importance in the gulls diet although together they occur in 47.0% of the chicks' regurgitations unlike in other species that are not so much generalists. In 1977, _M. villosus_ was the most important with respect to numbers and frequency of occurrence (56.8% and 48.5%), followed by _A. hexapterus_ (20.3% and 20.0%) with again, the other species having little importance in the diet. It therefore seems that these two species of fish are the most heavily used food item of glaucous-winged gulls and that if one of them is not taken in great quantities one year, the other will be. These data of course are based only on two years but we believe they reflect an interesting trend in feeding strategies which should be pursued.

Chick Growth

We compared growth rates of chicks by fitting a ploynomial regression line through a set of points of age and weight of chicks as in the tufted puffin and black-legged kittwake data. Again, we found that a sigmoid curve yielded the best fit (r^2 = 0.9569, 1978 and r^2 = 0.9749, 1977, Figure 24). We then compared the growth curves of 1977 and 1978 with respect to slope and shape and found great similarity between the two (r^2 = 0.9749, 1977 Figure 25).

ARTCIC+ALEUTIAN TERNS

Data from 1978 have yet to be analyzed for these two species. However, we feel that their failure on one major breeding colony should be addressed here. In April, shortly before the terns arrived, natives from Old Harbor burned an island which constituted one of the terns' major colonies, Amee Island. The vegetation was 70-80% destroyed on this island. The terns however attempted to nest there, but due to the lack of vegetation, their nests were very conspicuous. Egging of the nests was quite heavy and about 80% of the nests on our plots were abandoned. The ckicks that hatched on our plots were all from second clutches. Their hatching coincided with a series of violent storms in early July and these storms were responsible for killing 82% of the chicks. At this time also there was increased avian predation of the terns. On our plots, 18% of the hatchlings were taken by mew gulls, and there were 0% of fledglings.

Where humans interfere as they did with terns in 1978 on Amee Island, it can mean the failure of an entire colony. If terns are indicative of the true situation caused by human disturbance, and, if this disturbance were to continue for many years, major shifts in the abundance and distribution of seabirds could occur.

DISCUSSION

The breeding season of 1978 at Sitkalidak Strait was quite different from that of 1977. The breeding populations of tufted puffins and black-legged kittiwakes in inner east Sitkalidak Strait did not change in numbers between the 1977 and 1978 seasons, but there was a 49% decrease in glaucous-winged gull breeding populations and a 75.0% decrease in the large kittiwake population at Boulder Bay. The same nesting areas were used by all species except cormorants in both years. Perhaps with an increase in population, other habitats that may be marginal would be used. The breeding chronology seemed to be rather fixed, varying only a few days between years for all species.

The most outstanding differences between the two breeding seasons of 1977 and 1978 were those of reproductive success and those of the prey items taken by all species. Both the kittiwakes and glaucous-winged gulls had drastically reduced reproductive success in 1978 from what they had in 1977 while the reproductive success of tufted puffins was similar for the two years. Another major difference was the proportions in which the frequences and numbers of the two major prey species, capelin and sandlance, changed between 1977 and 1978.

For glaucous-winged gulls and kittiwakes in 1978, the percent of nests with eggs decreased and the clutch sizes were smaller. The number of chicks fledged per breeding pair was much less for both species in 1978 than in 1977, and the number of fledglings per nest attempt was drastically reduced. This compares with no differences between years for tufted puffin productivity. The percent of nesting burrows in 1977 and 1978 was similar as was the number of chicks fledging per breeding pair and per nest attempt.

For kittiwakes and gulls, the decrease in number of eggs hatching and in number of chicks fledging was accentuated by increased avian predation in 1978. This predation was much greater than in 1977, yet predation was not a mortality factor for tufted puffins. Many more adult glaucous--winged gulls and black-legged kittiwakes abandoned their nests and more eggs and chicks were preyed on this year than were last year. Glaucous-winged gulls were the most conspicuous predator, but ravens, northwest crows, mew gulls and immature bald eagles were more highly abundant around the colonies this year and we observed them preying on eggs and chicks. We observed mew gulls taking tern chicks, ravens taking eggs, and we saw signs of eagle predation on adult puffins, glaucous-winged gulls, black-legged kittiwakes and both species of terns. The avain predators are all generalists and opportunists and probably take the easiest and most available prey which is often eggs and chicks of other or their own species. This increased predation pressure may be augmented by decreased nest attentiveness by the prey species in inferior food years. These two factors probably act synergistically in increasing the mortality of the eggs and chicks and together with decreased numbers of nests with eggs and smaller clutch sizes they severely depress the reproductive success.

A great amount of predation of the kittiwakes and gulls took place shortly after or during peak laying between 15 and 28 June, and again, at hatching and shortly thereafter, from 6-26 July. At this time 15.6% of the kittiwake and 30.0% of the gull chicks died. This is mainly due to predation but some of it is from the high winds accompanied by temperatures that plunged into the 30's and low 40's. Instead of directly affecting the chicks, the elements may have affected the amount of food brought to them perhaps either by cooling down the water and thereby suppressing the upward magration of some prey, or by disturbing the water surface so much that the adults had a hard time locating prey. Likewise increased avian predation may in part be due to pressure from lack of an adequate food base.

This year, the arctic and aleutian tern populations were also down from those of 1977. The terns were probably affected in the same ways as were the gulls and kittiwakes with the human disturbance they experienced adding to the decrease in numbers of breeders and in the number of eggs hatched. The burning of one of their nesting islands so soon before their arrival altered the habitat so completely that a nesting failure was almost a foregone conclusion. Even if the nests had not been egged so readily, due to low vegetation cover, we believe that avian predation or exposure would have decimated the chick and egg population just as much. Predation by humans simply speeded up the process which had already been set in motion by the general "failure phenonmenon" that was happening throughout the Sitkalidak Strait area.

Accompanying this reduction in productivity and probably related to it was a radical shift in food habits of the seabirds both qualitatively and quantitatively. The proportions of the frequencies and number of the major prey s species, capelin and sandlance, changed from 1977 to 1978. The most important food item in 1977 was the capelin, Mallotus villosus and the second was the sandlance, Ammodytes hexapterus. In 1978 this order of importance changed. Sandlance and capelin still comprised the majority of the total numbers of prey and occurred in more of the regurgitations than any other food items. However, sandlance became the most important food item with capelin taken in significantly fewer numbers and occurring in significantly fewer regurgitation or bill loads. The shift from capelin to sandlance was much more radical for the glaucous-winged gulls and kittiwakes than for the puffins. Tufted puffins were still able to obtain capelin 36% of the time while gulls and kittiwakes only obtained capelin 16% and 5.3% of the time respectively. Capelin likewise comprised 36.0% of the total food items for puffins and only 16.4% and 6.4% for glaucous-winged gulls and kittiwakes. So despite an overall decrease in available capelin, puffins still managed to obtain a rather large proportion even though it was less than in 1977.

We may speculate on this difference in food between the two years. Capelin have a circadian migration to the surface at night and may also stratify themselves in the water column in part with respect to temperature. However, if the conditions are not right, they may remain at greater depths. Kittiwakes and gulls are surface feeders while puffins are divers. Carscadden (personnal communication) states that the capelin in the nearshore waters are the fish most important to marine birds and in the northwest Atlantic they may be the most important fish fodder in that ecosystem. He continues that in daylight, the schools are stratified from the bottom to midwater but at night the schools break up with individuals dispersing to surface waters (0-40m). Light seems to be the environmental trigger for diurnal migration. Perhaps the difference in light was such this year that the capelin did not make their migration upward or if they did, they may have remained mainly at depths unavailable to the surface-feeders. It is interesting to note that, perhaps following this upward migration of capelin, the kittiwakes did feed at night, while the puffins, who were able to procure capelin at greater depths during the day when the capelin were deep, did not feed at night. This then may be one of the reasons that the percent numbers and frequency of occurrence of capelin were greater for tufted puffins in 1978 than they were for kittiwakes and gulls. Puffins may have been able to reach the depths at which the capelin were schooled whereas the kittiwakes and glaucous-winged gulls could not.

Lack of adequate food or nutrients at the outset of the breeding season may cause reproductive failure in many birds. The causes for this failure either may be due to a lack of food during the pre-laying period which predicts trends in the low abundance of food later on in the season when the chicks are hatched, or else may be due to simply a lack of the right nutrients or amounts thereof in the diet to provide the ingredients necessary for egg formation. Either or both of these factors may be operating on the birds when they first arrive on the breeding grounds and will begin to have effects immediately.

The decrease in the breeding population of glaucous-winged gulls in inner east Sitkalidak Strait and of black-legged kittiwakes at Boulder Bay in 1978, and the general reproductive failure of both species may be a response to this decrease in abundance or availability of capelin. The behavior of the prey may be important with respect to catchability. Perhaps one species is harder to catch than another and the birds would have to spend more time searching and catching this prey. Capelin may be a more nutritious fish than sandlance and because they were not attainable in great numbers in 1978, even though sandlance may have been, the surface surface feeders, gulls and kittiwakes, may have responded to this with a decrease in productivity, while puffins which could reach the available capelin did not respond in this way. This decrease was reflected in all stages of the breeding cycle from reduced adult breeding populations to fewer nests with eggs, smaller clutch sizes, and fewer fledglings per nest attempt and per breeding pair, as well as increased predation by other avian species as the season progressed. The lack must still have been present during the egg and chick stages because other birds, especially gulls, ravens and crows chose to utilize one of the more easily available food sources at that time: eggs and chicks of surface nesters. Thus the lack of food that precipitated smaller clutches and fewer nests with eggs continued throughout the breeding season affecting the populations at all stages of the cycle and further decreasing the final overall productivity.

Chick growth is intended to be a measure of the environmental influence on the chick population. The assumption is that if the food base is inadequate the chicks will no grow as rapidly as in a good food year. However, during 1978, it was apparent that the food base was different and probably not as good as in 1977, but that the the chicks were growing as rapidly as they did in 1977. It therefore seems that the response to an inadequate food supply is not to deliver less or worse quality food to chicks, thus depressing their growth rate, but rather to depress the productivity rate. There were less chicks produced per nest but of those that made it grew equally as well as chicks produced in a bad year.

CONCLUSIONS

Reproductive success of seabirds is not constant from year to year but varies perhaps in accordance with fluctuations in the ecosystem. We believe that one of the variables in the ecosystem which may influence reproductive success is food availability. In the food base, the factor that changed the most drastically between the 1977 and 1978 breeding season was the availability of capelin. Capelin seems to be one of the critical components in the prey base for all seabirds in the Sitkalidak Strait area, such that a decrease in their supply or their availability to seabirds may be reflected in drastic reduction in reproductive success of the seabirds. It seems that reduction in prey below a certain level with respect to numbers or frequency of occurrence of the prey may decrease reproductive output in the birds. Even though the numbers and frequency of occurrence of capelin were significantly reduced from 1977 for tufted puffins, the reductions weren't as much as those for black-legged kittiwakes and glaucous-winged gulls. Correspondingly, the tufted puffins had as good reproductive success in 1978 as in 1977 whereas the other two species did not. Perhaps the level to which the capelin were reduced for puffins was above the critical level so that it did not affect puffin productivity, while the low levels of capelin for kittiwakes and gulls were below this level and their productivity reflected this.

Growth of chicks seems to be rather constant from year to year and independent of the reproductive success. The chicks of glaucous-winged gulls, tufted puffins and black-legged kittiwakes in 1978 grew at similar rates and reached similar asymptotes at fledging as did the chicks in 1977 even though the productivity for gulls and kittiwakes was below that of 1977.

Tufted puffins and arctic and Aleutian terns seemed to be most sensitive to human disturbance. Comparisons of disturbed and undisturbed plots of tufted puffins yielded higher reproductive success in plots where puffins were not disturbed during the egg or early chick stage.

Disturbance of the habitat for Arctic and Aleutian terns combined with egging produced very little reproductive output in the colony where this disturbance occurred. Presence of humans and their pets and any major habitat disturbance or destruction at the time before egg laying, and during the egg and chick stages tend to be detrimental to the productivity of the seabirds.

In 1977 heavy egging on accessible glaucous-winged gull plots severely decreased the reproductive output of the birds on these plots versus the output of birds on plots relatively inaccessible to humans. In 1978 however the glaucous-winged gulls were not egged as heavily as they were in 1977 and this showed up in equal productivity between plots accessible and inaccessible to humans.

NEEDS FOR FURTHER STUDY

If capelin are indeed important for high reproductive success it would be interesting to identify what the critical numbers and frequency of occurrence of capelin in the environment are. The identification then of these levels would help pinpoint potentially bad food years which tend to produce low reproductive success for some or all the seabird species. In conjunction with this it would be good to be able to predict low food years based on some physical parameter which might somehow influence the abundance or distribution of capelin.

It would be wise to test the theory of the relationship of food availability and reproductive success by monitoring the colonies yet another year. Two years have produced opposite outcomes and a third year should give credence to a testing of the theory of this relationship.

Table 1. Kinds of Studies Conducted on the Different Puffin Plots, 1978

	Cathedral Island									Amee Island	
	2	3	4	5	6	7	8	9	10	1	2
Chronology	X	X	X	X	X	X	X	X	X	X	X
Productivity											
Disturbed					X		X	X	X		X
Undisturbed	X			X							
Chick Growth		X				X				X	
Habitat Measurements	X	X	X	X	X	X				X	

Table 2. Number of Breeding Birds in the Sitkalidak Strait Area, 1977-1978.

Species	Numbers 1977	Numbers 1978
Tufted Puffin	13,584	10,714
Black-legged Kittiwake	4,766	5,032
Glaucous-winged Gull	940	482
Arctic Tern	1,275	544
Aleutian Tern	1,065	
Pelagic Cormorant	252	226
Red-faced Cormorant	137	262
Horned Puffin	184	104
Pigeon Guillemot	520	232
Mew Gull	20	24
Northwest Crow	8	12
Bald Eagle	4	4

Table 3. Census of the Kiliuda Bay Area.[1]

Species	Boulder Bay 1977[3]	Boulder Bay 1978[5]	Duck Is. 1977[2]	Duck Is. 1978[4]	Nest Is. 1977[2]	Nest Is. 1978[4]	Ladder Is. 1978[4]
Tufted Puffin			1,500	400[6]	400	1,400	300[7]
Black-legged Kittiwake	40,000	7,000	828	1,400	380	360	250
Glaucous-winged Gull			50	200		180	350
Pigeon buillemot						20	25
Pelafic Cormorant							10

1. Blank means no census taken

2. Census by D. Forsell

3. Census by P. Baird, D. Forsell, A. Moe

4. Census by P. Baird, V. Hironaka

5. Census by P. Baird, M. Hatch, D. Nysewander

6. Density = $2.0/m^2$

7. Density = $2.2/m^2$

Table 4. Reproductive Success of Tufted Puffins at Sitkalidak Strait in 1977 and 1978.

	1977	1978	P*
Number of nests built	93	103	
Number of nests with eggs	67	69	
Mean clutch size	1.0	1.0	
Number of eggs laid	67	69	
Number of chicks hatched	41	36	
Mean brood size at hatching	1.0	1.0	
Number of chicks fledged	35	32	
Laying success (Nests with eggs/nest built)	72.0%	67.0%	> 0.4
Hatching success (Chicks hatched/egg laid)	61.2%	52.2%	> 0.1
Fledging success	87.8%	88.9%	> 0.5
Chicks fledged/nest w eggs	0.537	0.464	> 0.2
Chicks fledged/nest attempt	0.38	0.31	> 0.1
Percent nests hatching one or more eggs	61.2%	52.2%	

* Statistical analysis is based on the equality of two percentages test with a $p < 0.05$ reflecting a significant difference between years.

Table 5. Productivity of burrows in undisturbed plots of tufted puffins, 1977, 1978.

	1977	1978
Fledglings	23	16
Burrows entered at least once [(a)]	54	33
Eggs [(b)] (extrapolated from disturbed plots)	39 (72.0%)	22 (67.0%)
Fledglings per eggs laid	0.59	0.73
Fledglings per nest attempt	0.43	0.49

(a). evidenced from toothpicking the entrances

(b). percents applied to all burrows to find # of eggs, are obtained from disturbed plots.

Table 6. Comparison of Productivity in the Disturbed and Undisturbed Tufted Puffin Plots, 1978.

	Disturbed (N = 103)		Undisturbed (N = 33)	
	N	% of Total	N	% of Total
# Chicks fledged	32	31.1	16	48.5
# eggs laid	69	67.0	22 (67%x33)	assume 67.0
# chicks fledged per # eggs laid	46.4		-	72.4

Table 7. Mortality of Tufted Puffins

Egg Stage	(N = 67) 1977 N	%	(N = 69) 1978 N	%
Eggs rolled out of nest	0	0	6	8.7
Eggs abandoned	6	9.0	19	27.5
Eggs infertile	6	9.0	1	1.5
Fate unknown (eggs disappeared)	13	19.4	3	4.4
Total egg	25	37.3	29	42.0
Chick Stage				
Chicks starved	3	4.5	3	4.4
Chicks flooded out	1	1.5	0	0
Fate unknown (chick disappeared)	2	3.0	2	2.9
Total chick	6	9.0	5	7.3
Total mortality	31	46.7	34	49.3

Table 8. Chi-square analysis of disturbance on tufted puffins: egg stage only.

Disturbed and abandoned........12
Disturbed, not abandoned.......16
Not disturbed but abandoned....15

$X^2 = 0.31818$ $p > 0.10$

Table 9. Prey items of tufted puffin chicks. Sitkalidak Strait 1977 and 1978

Species	1977 % Frequency of occurrence	1977 % Total Numbers	1978 % Frequency* of occurrence	1978 % Total* Numbers	$\bar{X}$ Length ± SE
Mallotus villosus	75.0	64.9	31.0 (34.6)	36.0 (36.9)	94.87 ±3.64
Ammodytes hexapterus	37.5	25.8	41.4 (96.2)	48.3 (49.6)	97.02 ±2.19
Trichodon trichodon	14.2	3.1	--	--	--
Onchorhyncos nerka	8.9	1.6	--	--	--
Theragra chalcogramma and Gadidae	14.3	3.7	10.3 (11.5)	10.5 (10.8)	71.0 ±2.53
Salmonida and Osmeridae	--	--	3.5 (3.9)	1.8 (1.8)	137.0 ±5.5
Unidentified fish	--	--	10.3	2.6	--
Cephalopoda	1.8	0.3	--	--	
Octopoda	1.8	0.6	3.5 (3.9)	0.9 (0.9)	

* parentheses are percentages not including unidentified fish.

Table 10. Prey species diversity and evenness, tufted puffins, 1977 and 1978.

	1977	1978
Species diversity H'	0.6509	0.5316
Species evenness J'	0.7702	0.7605

Table 11. Changes in percent numbers of food items between 1977 and 1978.

	Black-legged Kittitwake	Tufted Puffin	Glaucous-winged Gull
Contingency x^2	$X^2 = 22.4332$	$X^2 = 5.3516$	$X^2 = 40.0359$
	p = 0.0001	p = 0.1478	p = 0.00001

Table 12. Changes in percent frequency occurrence of food items between 1977 and 1978.

	Black-legged Kittiwake	Tufted Puffin	Glaucous-winged Gull
Contingency X^2	$X^2 = 10.0641$	$X^2 = 8.1170$	$X^2 = 29.5841$
	p = 0.0180	p = 0.0874	p = 0.0003

Table 13. Distribution of frequencies for clutches, nestlings, and fledglings: black-legged kittiwakes, 1977 and 1978.

Clutch Size	Number of eggs		Number of chicks		Number of fledglings	
	1977	1978	1977	1978	1977	1978
1	38	49	36	21	51	17
2	75	17	48	7	26	3
3	1	--	--	--	--	--

Table 14. Reproductive Success of black-legged kittiwakes at Sitkalidak Strait in 1977 and 1978.

	1977	1978	p
Number of nests built	136	121	
Number of nests with eggs	114	65	
Mean clutch size	1.68	1.26	
Number of eggs laid	178 (83.8%)	78 (53.7%)	
Number of chicks hatched	132 (74.2%)	28 (35.9%)	
Mean brood size at hatching	1.57	1.25	
Mean brood size at fledgling	1.34	1.15	
Number of chicks fledged	101	20	
Laying success (nests with eggs/nest built)	83.8%	53.7%	< 0.001
Hatching success (chicks hatched/egg laid)	74.2%	35.9%	< 0.001
Fledging success (chicks fledged/chick hatched)	76.5%	52.6%	< 0.05
Chicks fledged/nest w eggs	0.886	0.308	< 0.001
Chicks fledged/nest attempt	0.743	0.165	< 0.001
Percent nests hatching one or more eggs	56.6%	43.1%	

Table 15. Mortality of black-legged kittiwakes

Egg stage	(N = 191) 1977 N	%	(N = 83) 1978 N	%
Egg rolled out			2	2.41
Egg abandoned			4	4.82
Egg disappeared probably predation	39	20.42	46	55.42
Egg infertile	11	5.76		
Exposure	9	4.71		
Total egg	59	30.89	52	62.65
Chick stage				
Predation	1	0.52	12	14.46
Starved	2	1.05		
Exposure	15	7.85		
Chick disappeared	13	6.81		
Total chick	31	16.23	12	14.46
Total all mortality	90	47.12	64	77.11

Table 16. Prey items of black-legged kittiwake chicks, Sitkalidak Strait, 1977 and 1978.

Species	1977 % Frequency of occurrence	1977 % Total Numbers	1978 % Frequency* of occurrence	1978 % Total* Numbers	X̄ Length ± SE
Mallotus villosus	59.3	42.2	5.3 (6.9)	6.4 (7.6)	94.87 ±3.64
Ammodytes hexapteres	50.0	43.6	57.9 (75.9)	60.3 (71.7)	104.04 ±2.36
Trichodon trichodon	2.8	1.0	10.5 (13.8)	12.7 (15.1)	112.43 ±4.20
Onchorhynlos nerka	7.4	4.3	--	--	
Theragra chalcogramma	4.6	3.8	--	--	
Unidentified fish	--	--	21.1	14.3	
Pandalopsis (shrimp)	6.5	5.2	--	--	
Katharina tunicata	--	--	2.6 (3.5)	4.7 (5.7)	

* parentheses are percentages not including unidentified fish.

Table 17. Prey species diversity and evenness, black-legged kittiwakes, 1977 and 1978, Sitkalidak Strait.

	1977	1978
Species Diversity H'	0.5509	0.3402
Species Evenness J'	0.7080	0.5651

Table 18. Reproductive success of glaucous-winged gulls at Sitkalidak Strait in 1977 and 1978.

	1977	1978	p
Number of nests built	84	117	
Number of nests with eggs	54	53	
Mean clutch size	2.48	2.28	
Number of eggs laid	134	123	
Number of chicks hatched	101	59	
Mean brood size at hatching	1.87	2.10	
Mean brood size at fledging	1.67	1.91	
Number of chicks fledged	90	44	
Laying success (Nests with eggs/nest built) = Breeding pairs/nest built	64.3%	45.3%	< 0.001
Hatching success (Chicks hatched/egg laid)	75.4%	48.0%	< 0.001
Feldging success (Chicks fledged/chicks hatched)	89.1%	74.6%	< 0.001
Chicks fledged/ness w eggs	1.67	0.83	< 0.001
Chicks fledged/nest attempt	1.07	0.376	< 0.001
Percent nests hatching one or more eggs	NA	54.7	

Table 19. Mortality of glaucous-winged gulls at Sitkalidak, 1977 and 1978.

	1977 N = 134		1978 N = 123	
Egg stage	N	%	N	%
Exposure	1	0.7	12	9.8
Predation	4	3.0	38	30.9
Infertile	5	3.7		
Shell damage	2	1.5		
Rolled out	2	1.5		
Disappeared	3	2.2		
Total Egg	17	12.7	50	40.7
Chick Stage				
Exposure			2.	1.6
Predation			10	8.1
Starved	1	0.7		
Died pipping	3	2.2		
Disappeared	2	1.5		
Total chick	6	4.5	12	9.8
Total	23	17.2%	62	50.4

Table 20. Prey items of glaucous-winged gull chicks, Sitkalidak Strait, 1977 and 1978.

Species	1977 % frequency of occurrence	1977 % total[a] numbers	1977 $\bar{X}$ length ± SE	1978 % frequency of occurrence	1978 % total numbers	1978 $\bar{X}$ length ± SE
Mallotus villosus	31.5(39.5)	$56.8_b(63.8_b)$	89.86 ±1.24	16.0(22.2)	$16.4_b(19.4_b)$	107.0 ±15.5
Ammodytes hexapterus	14.8(18.6)	$20.3_b(22.8_b)$	101.75 ±2.37	24.0(33.3)	$46.4_b(54.8_b)$	118.33 ±7.27
Theragra chalcogramma	0.9(1.2)	$0.6_b(0.7_b)$		2.0(2.8)	$0.9_b(1.1_b)$	83.0 ±0
Trichodon trichodon	0.9(1.2)	$0.3_b(0.4_b)$		6.0(8.3)	$11.8_b(14.0_b)$	121.33 ±4.61
Hemilepidotus hemilepidotus	---	---	---	2.0(2.8)	$0.9_b(1.1_b)$	167.0 ±0
Osmeridae	2.8(3.5)	$3.0_b(3.6_b)$	64.67 ±0.27	---	---	
Cottidae	0.9(1.2)	$0.3_b(0.36_b)$	274.0 ±0	---	---	
Pholididae	---	---		2.0(2.8)	$0.9_b(1.1_b)$	
Ophiidae	---	---		2.0(2.8)	$0.9_b(1.1_b)$	
Unidentified fish	20.4 (--)	11.0_b --		28.0	15.5_b --	
Diptera adults and larvae	0.9(1.2)	$1.9_b(2.2_b)$		2.0(2.8)	33.5(34.5)	1.0

Table 20. Prey items of glaucous-winged gull chicks, Sitkalidak Strait, 1977 and 1978. (cont'd)

Species	1977 % frequency of occurrence	1977 % total[a] numbers	1977 $\bar{X}$ length ± SE	1978 % frequency of occurrence	1978 % total numbers	1978 $\bar{X}$ length ± SE
Isopoda (*Siduria entoma*)	---	---		2.0(2.8)	0.9[b](1.1[b])	
Brachy & *Telmessus* crabs	0.9(1.2)	0.3[b](0.4[b])		2.0(2.8)	0.9[b](1.1[b])	77.0
Lepasterius hexactus	0.9(1.2)	0.6[b](0.7[b])	52.5 ±8.84	---	---	
Stronglescentratis sp.	3.7(4.7)	1.3[b](1.5[b])		2.0(2.8)	0.9[b](1.1[b])	
Mytilus edulis	5.6(7.0)	1.9[b](2.2[b])		6.0(8.3)	2.7[b](3.2[b])	46.0
Tube worm	5.6(7.0)	---		---	---	
Fish eggs	4.6(5.8)	55.3(58.1)	0.2	2.0(2.8)	48.6(50.0)	0.2
Pelecypoda	0.9(1.2)	0.3[b](0.4[b])		2.0(2.8)	0.9[b](1.1[b])	
Katharina tunicata	2.8(3.5)	1.0[b](1.1[b])		---	---	
Plant material	1.9(2.3)	---		---	---	

a parentheses are percentages not including unidentified fish

b percent does not include fish eggs and insect larvae

Table 21. Prey species diversity and evenness, glaucous-winged gulls, Sitkalidak Strait, 1977 and 1978.

	1977	1978
Species Diversity	0.8877	0.9166
Species Evenness	0.7372	0.7997

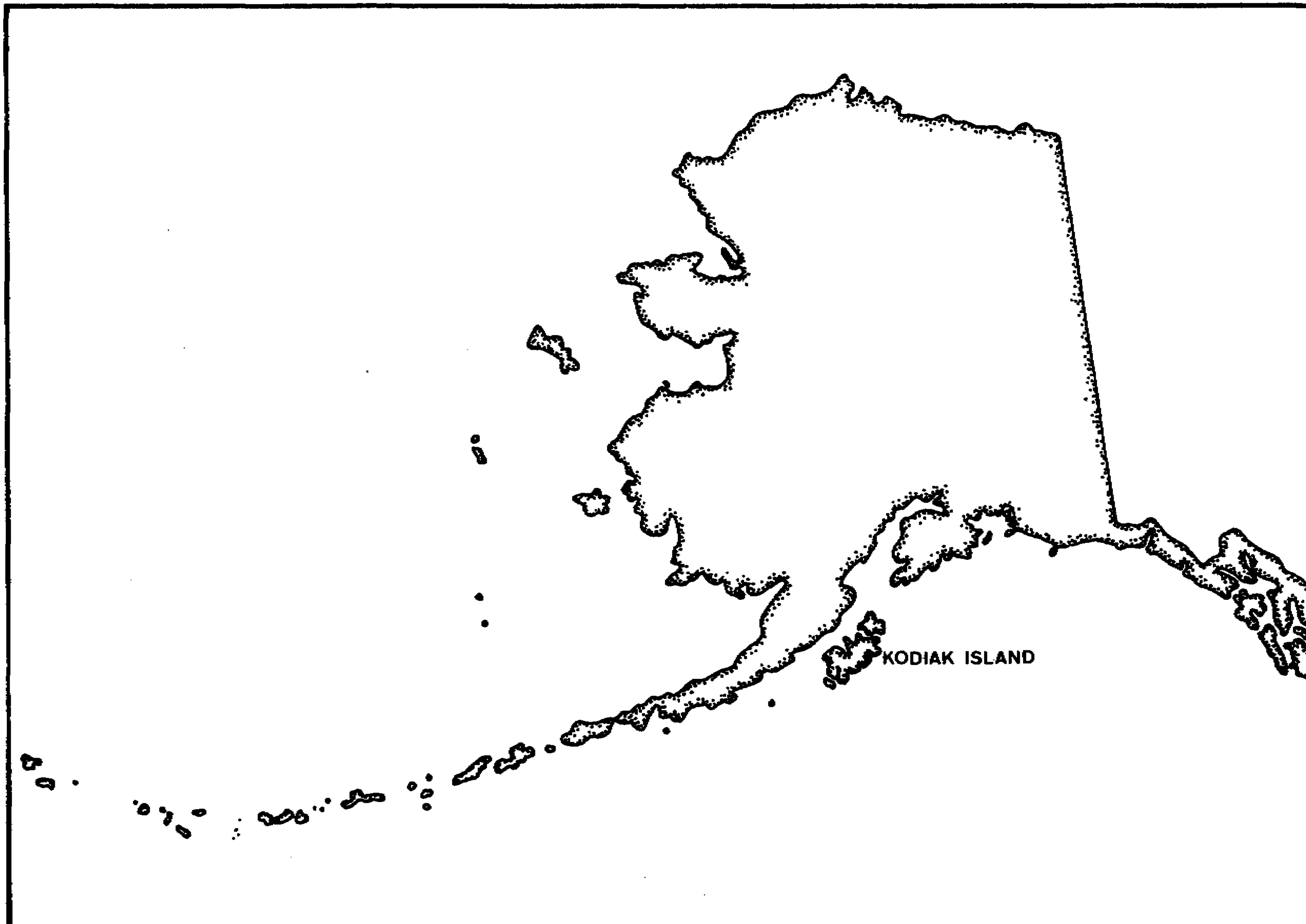

Figure 1. Alaska and Kodiak Island.

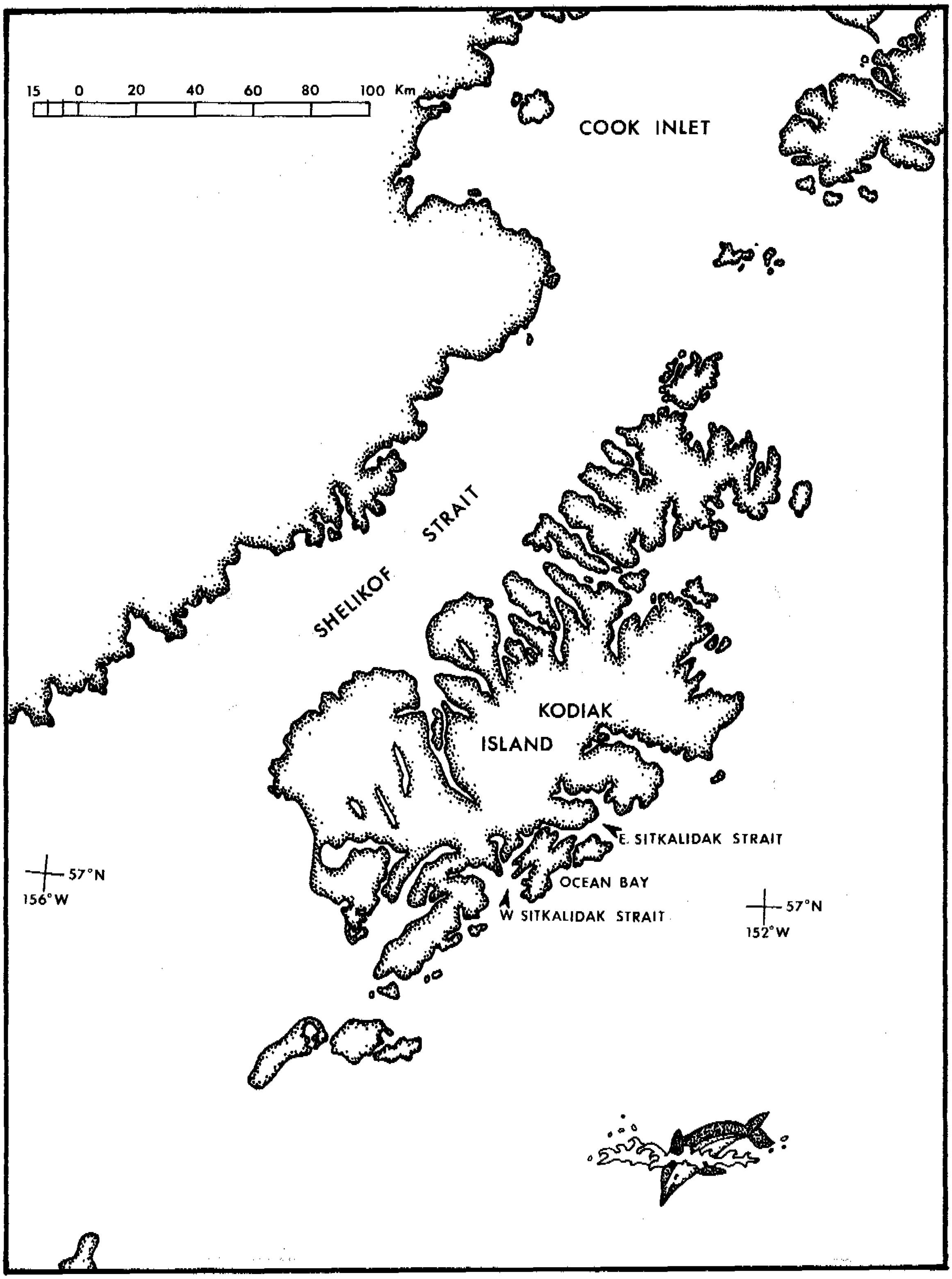

Figure 2. Kodiak Island and Sitkalidak Strait.

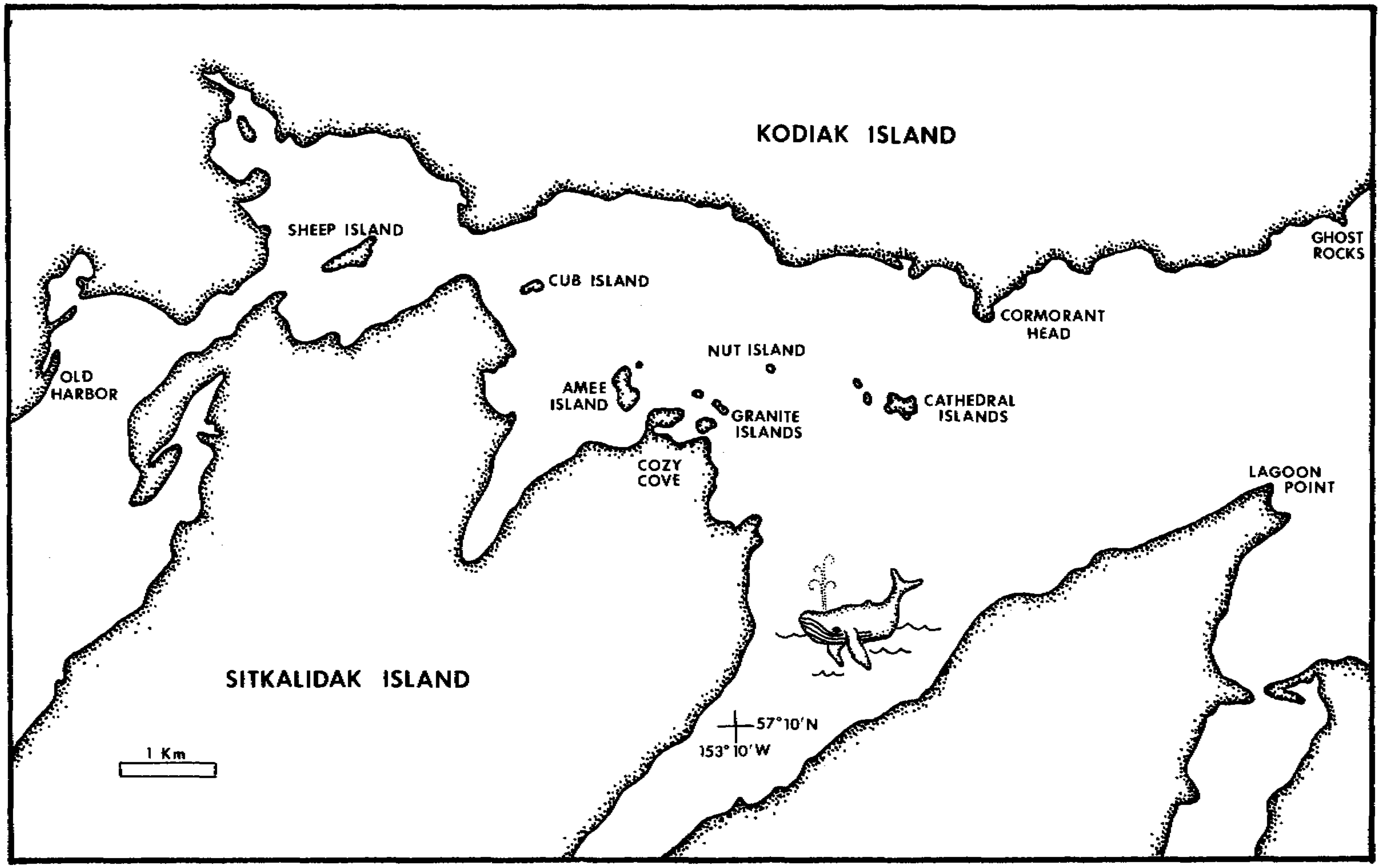

Figure 3. Inner east Sitkalidak Strait.

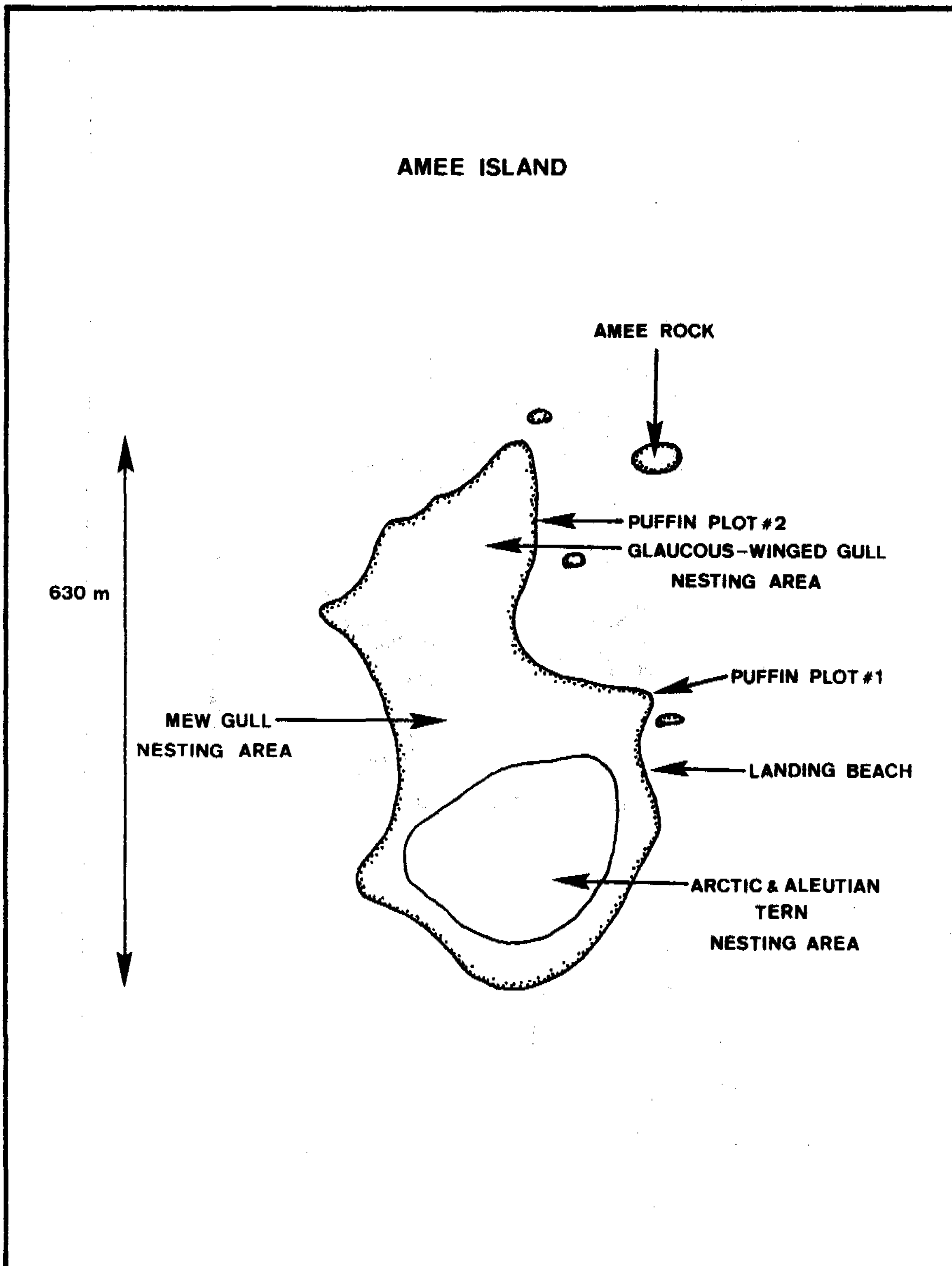

Figure 4. Amee Island:tufted puffin plots and landing beach.

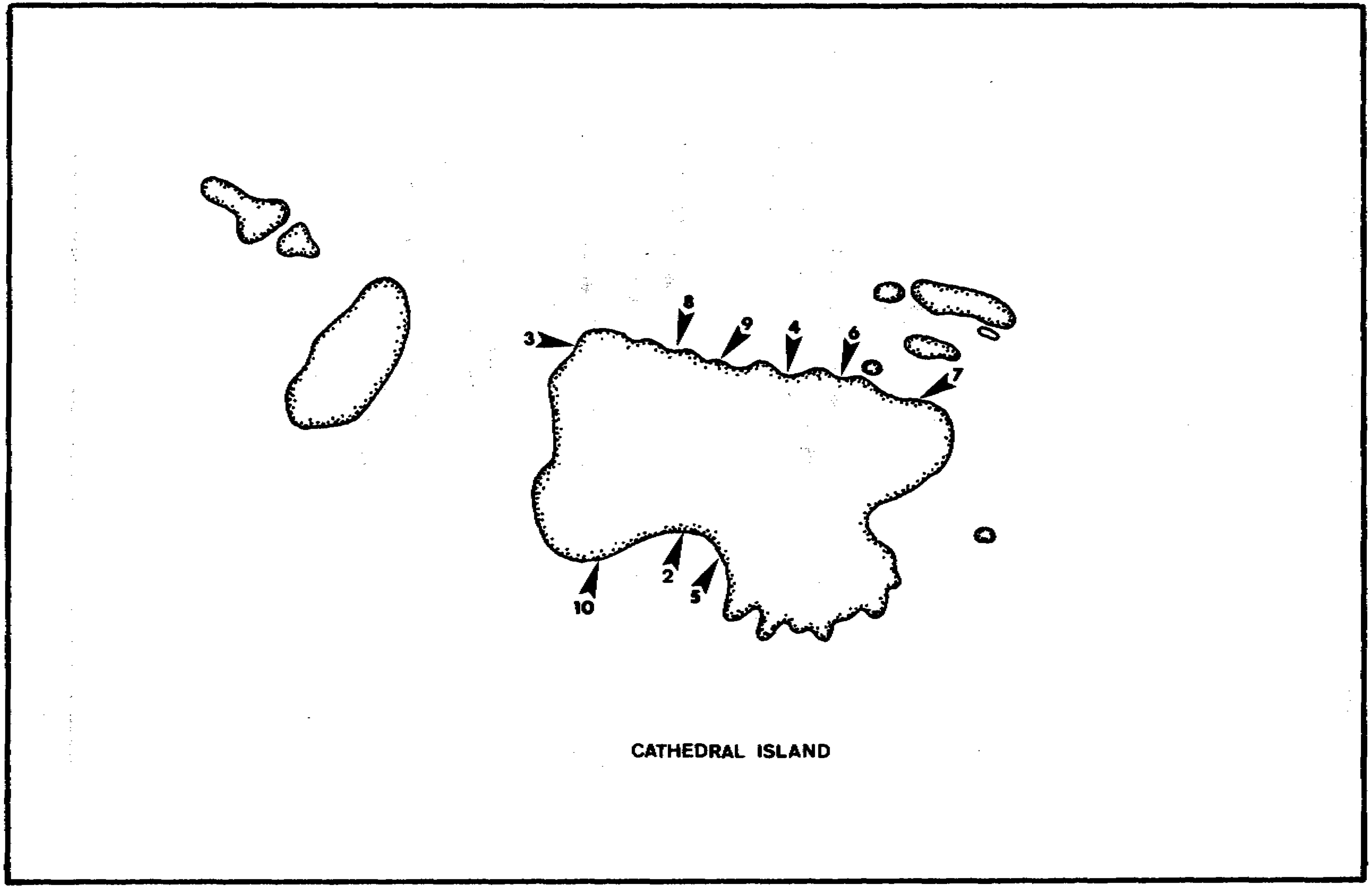

Figure 5. Cathedral Island:tufted puffin plots.

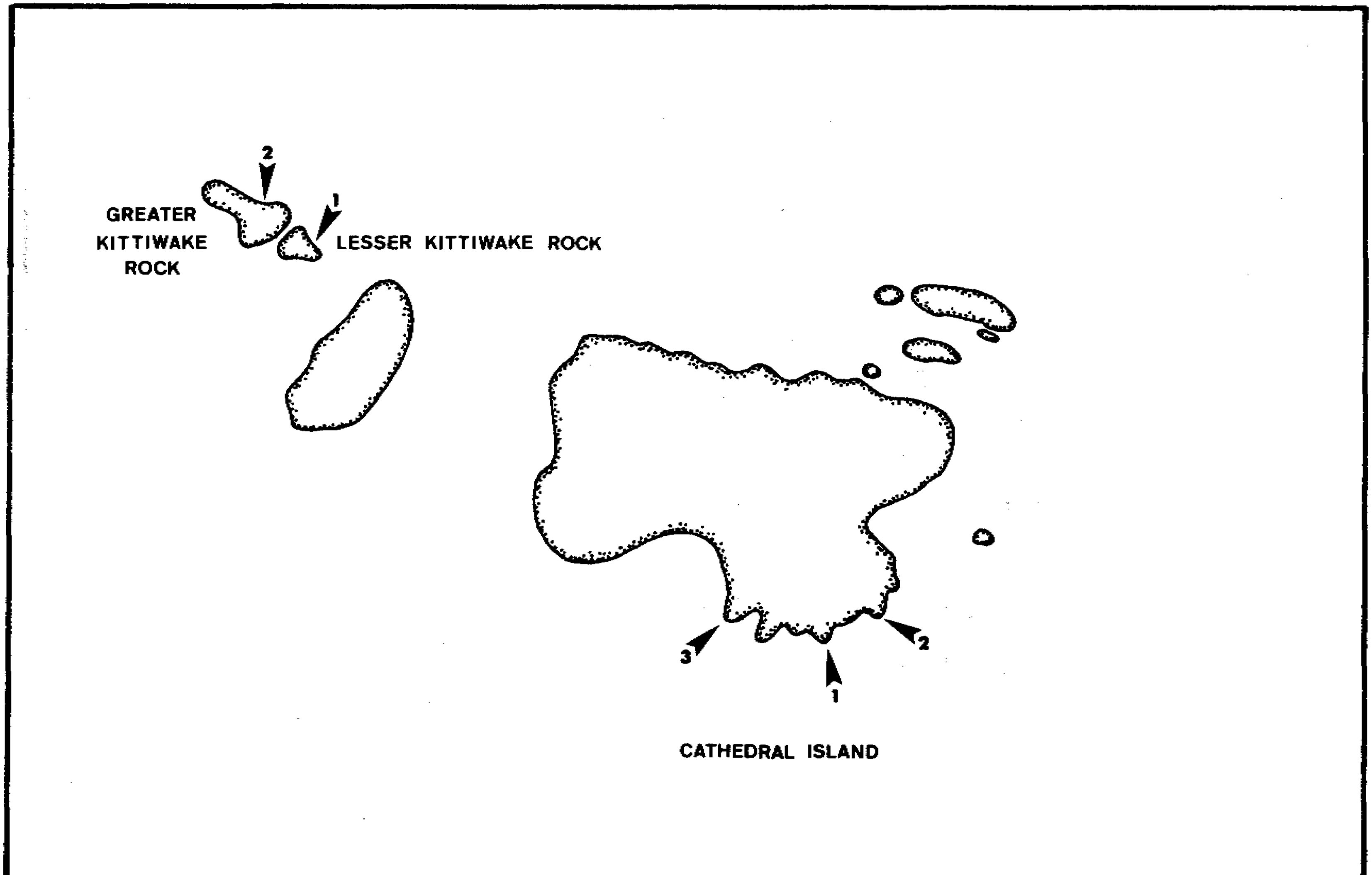

Figure 6. Cathedral Island: black-legged kittiwake plots.

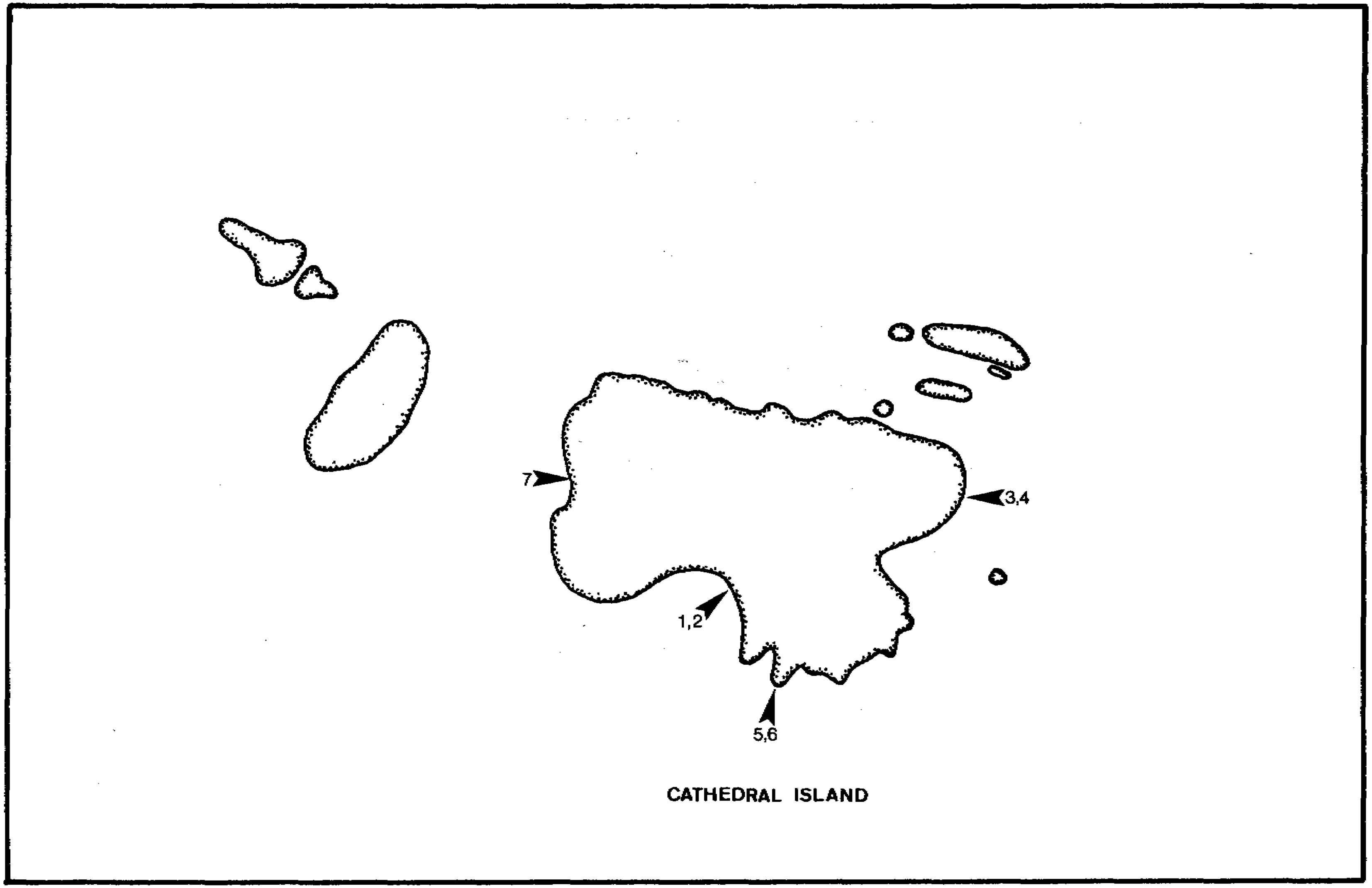

Figure 7. Cathedral Island: glaucous-winged gull plots.

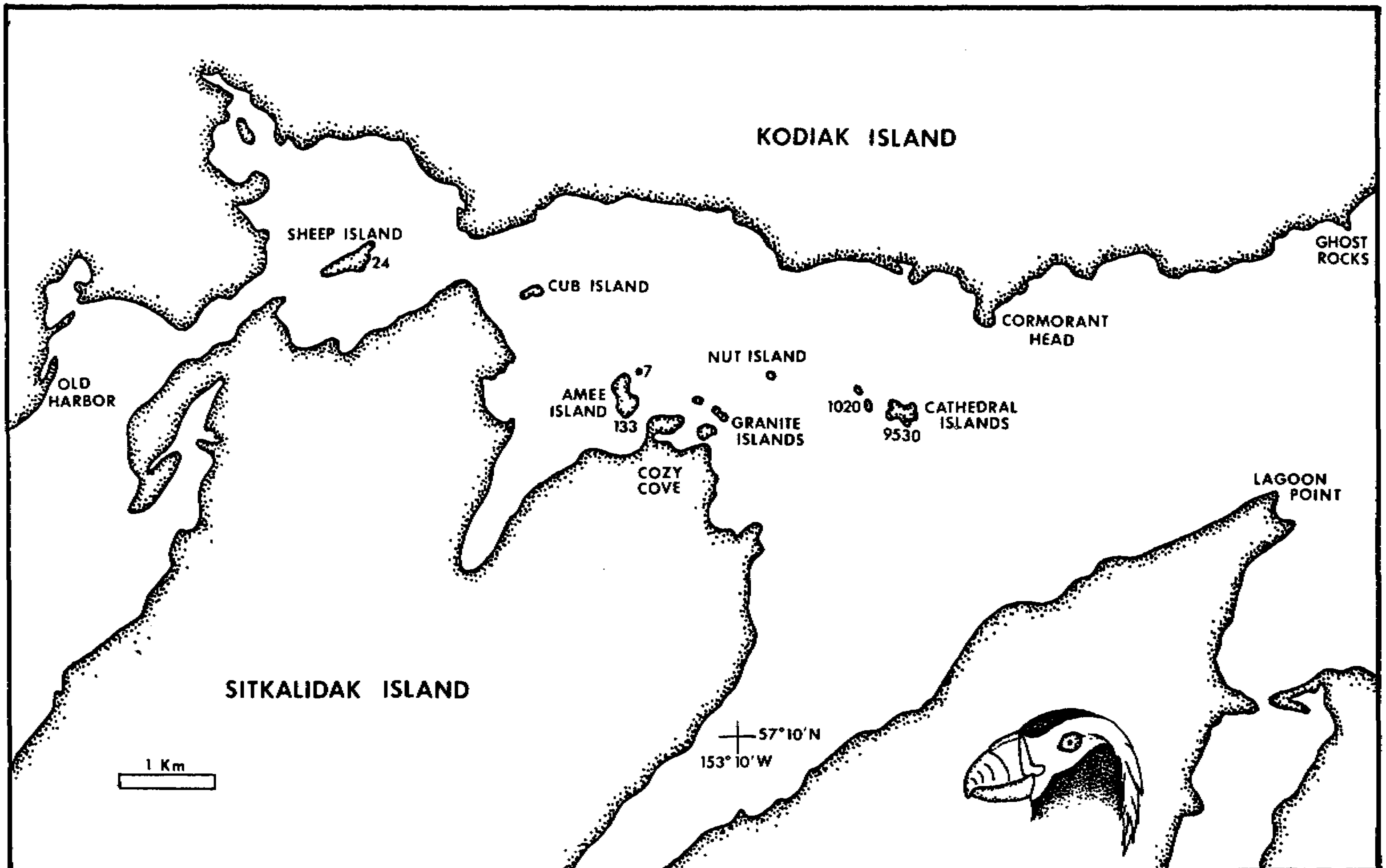

Figure 8. Distribution of tufted puffins.

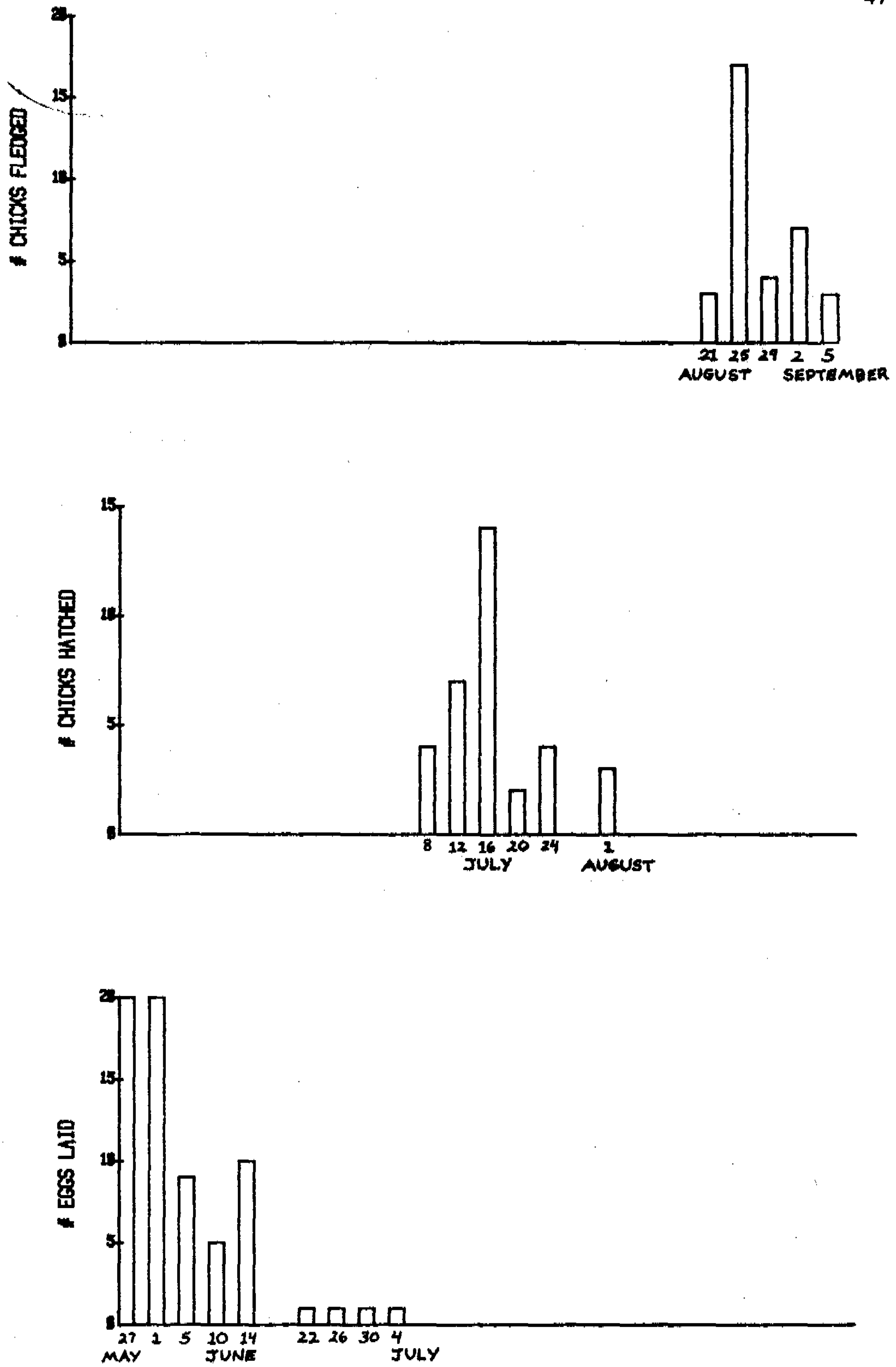

Figure 9. Chronology of tufted puffins.

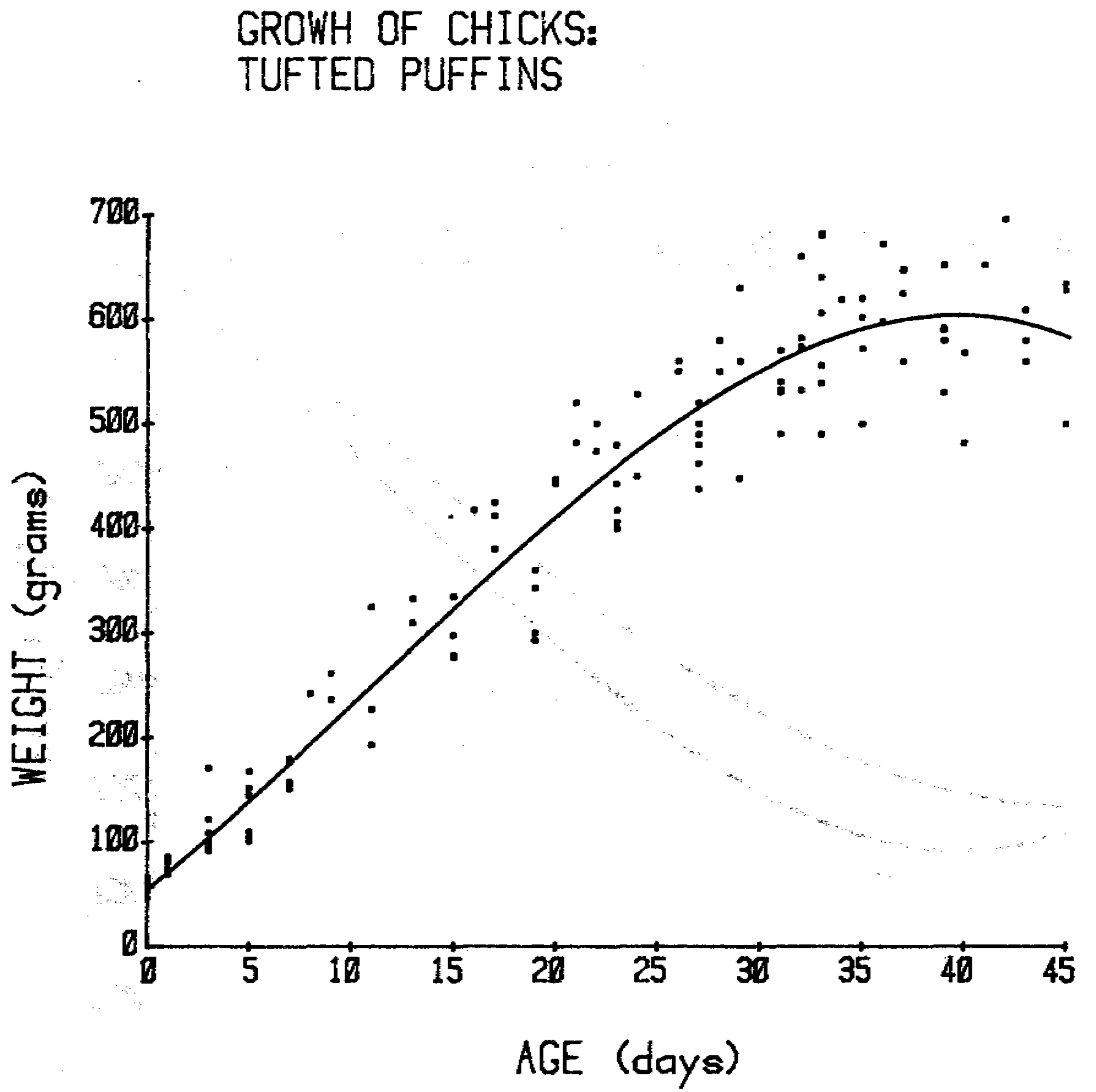

Figure 10. Growth of tufted puffin chicks, 1978.

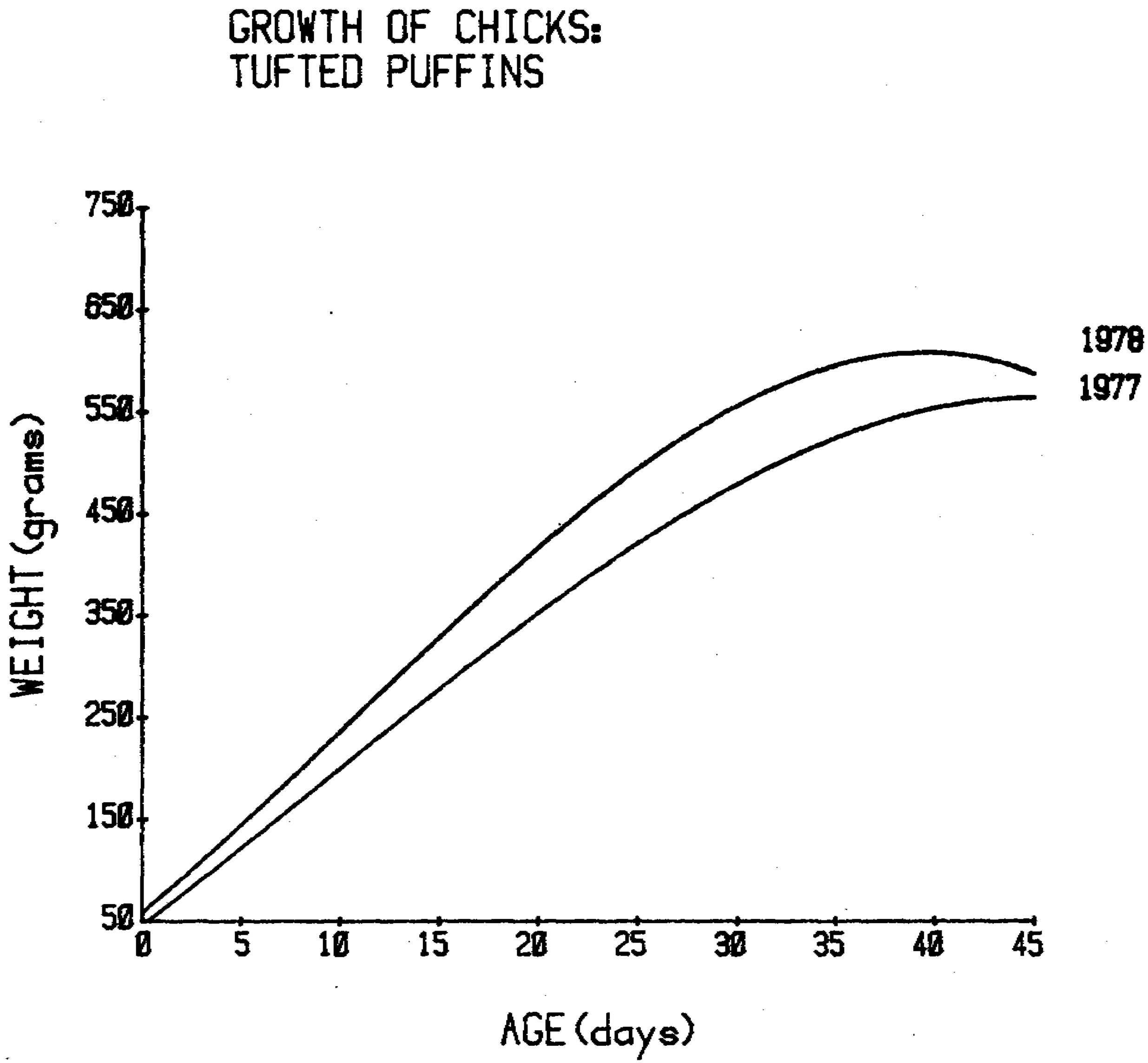

Figure 11. Growth of tufted puffin chicks, 1977 and 1978.

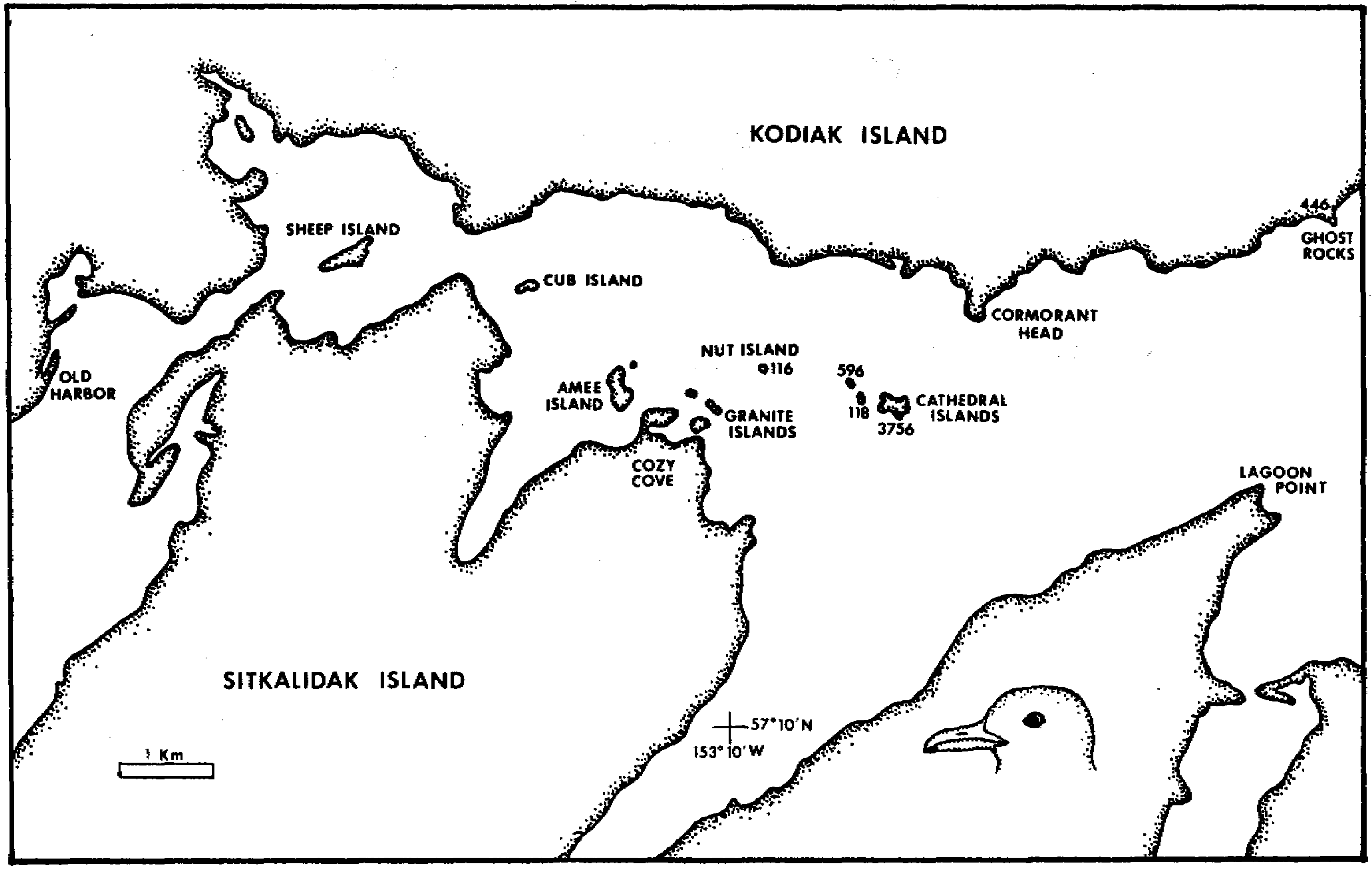

Figure 12. Distribution of black-legged kittiwakes.

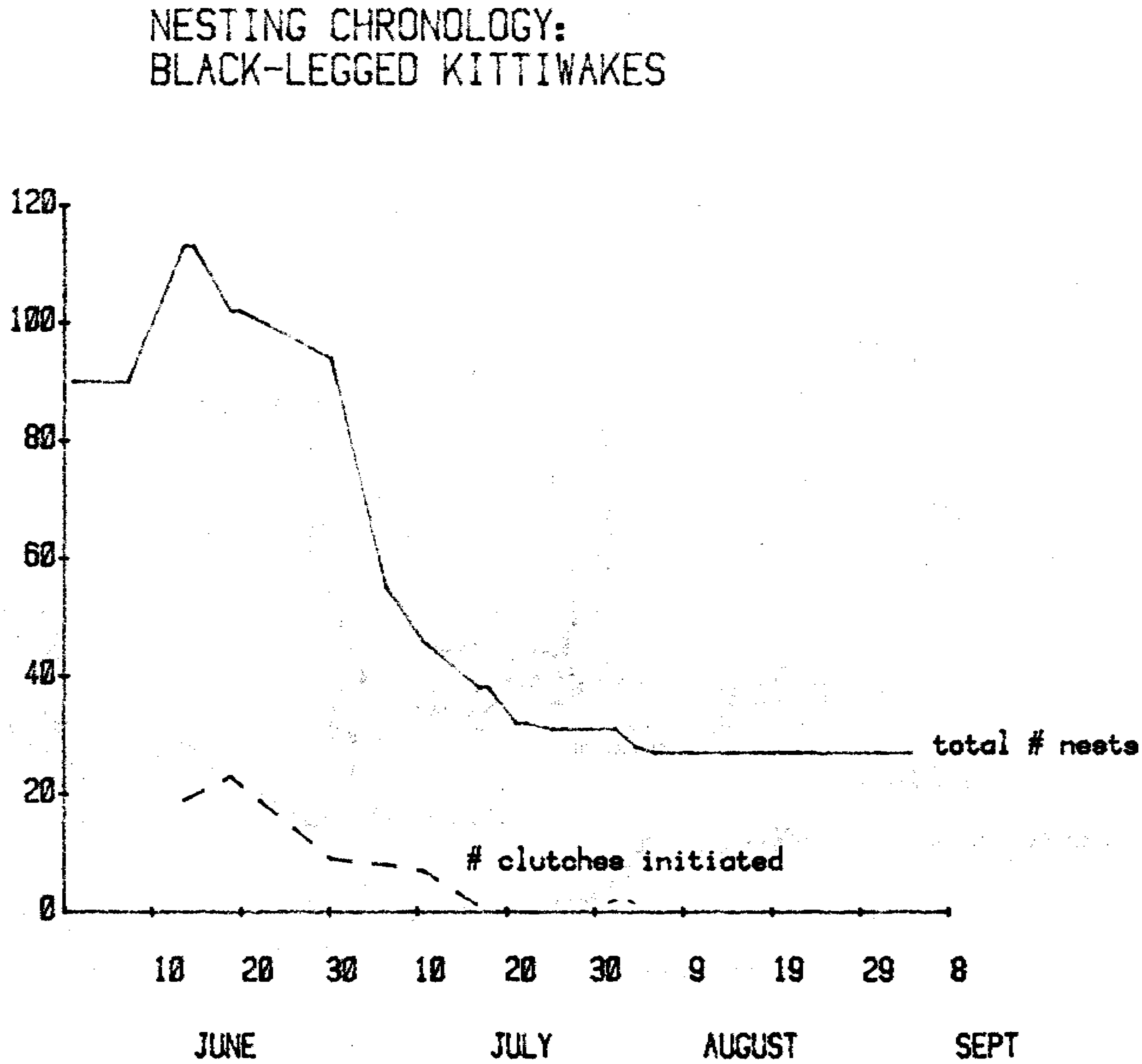

Figure 13. Nesting chronology of black-legged kittiwakes.

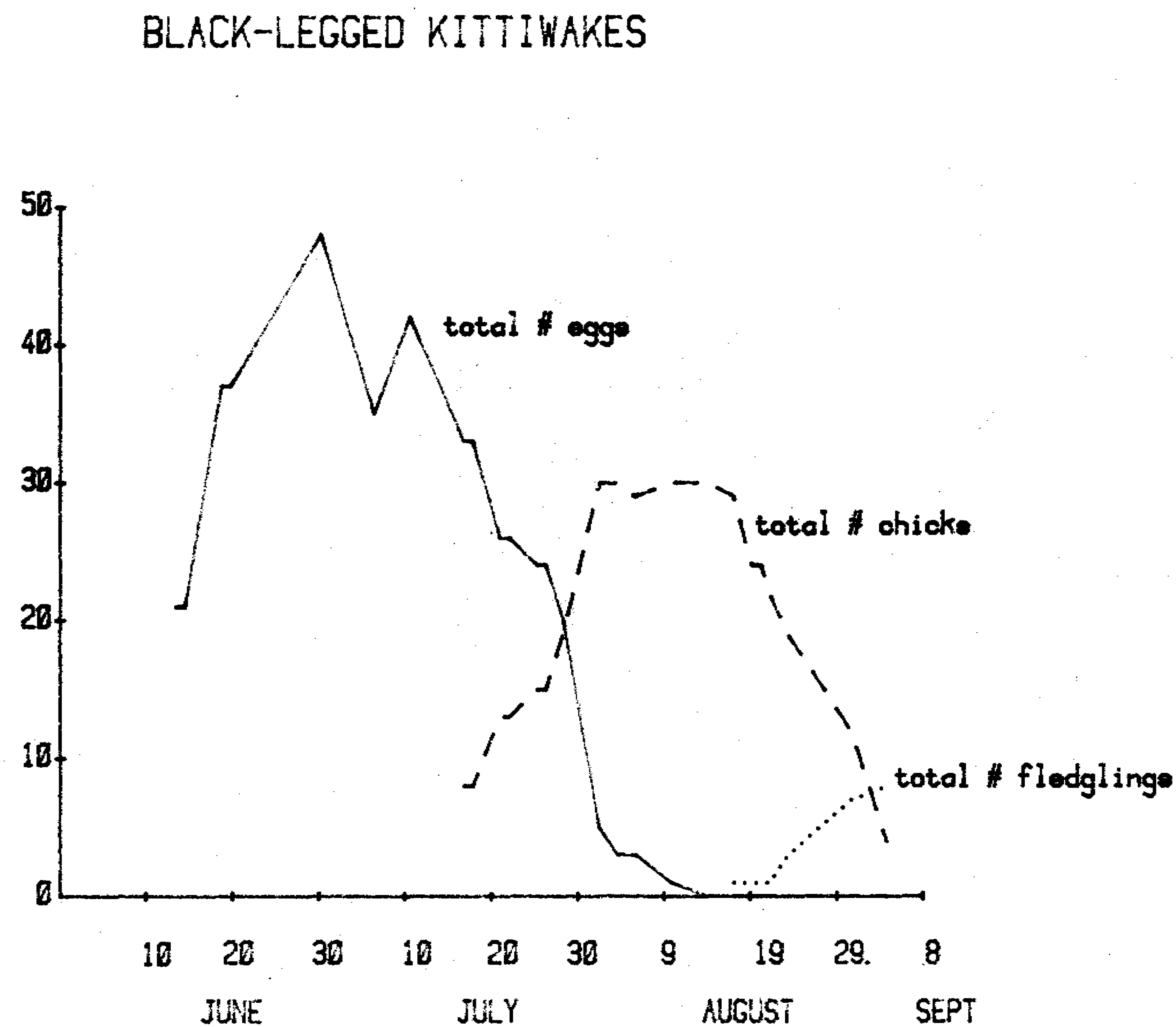

Figure 14. Numbers of eggs, chicks, and fledglings, black-legged kittiwakes.

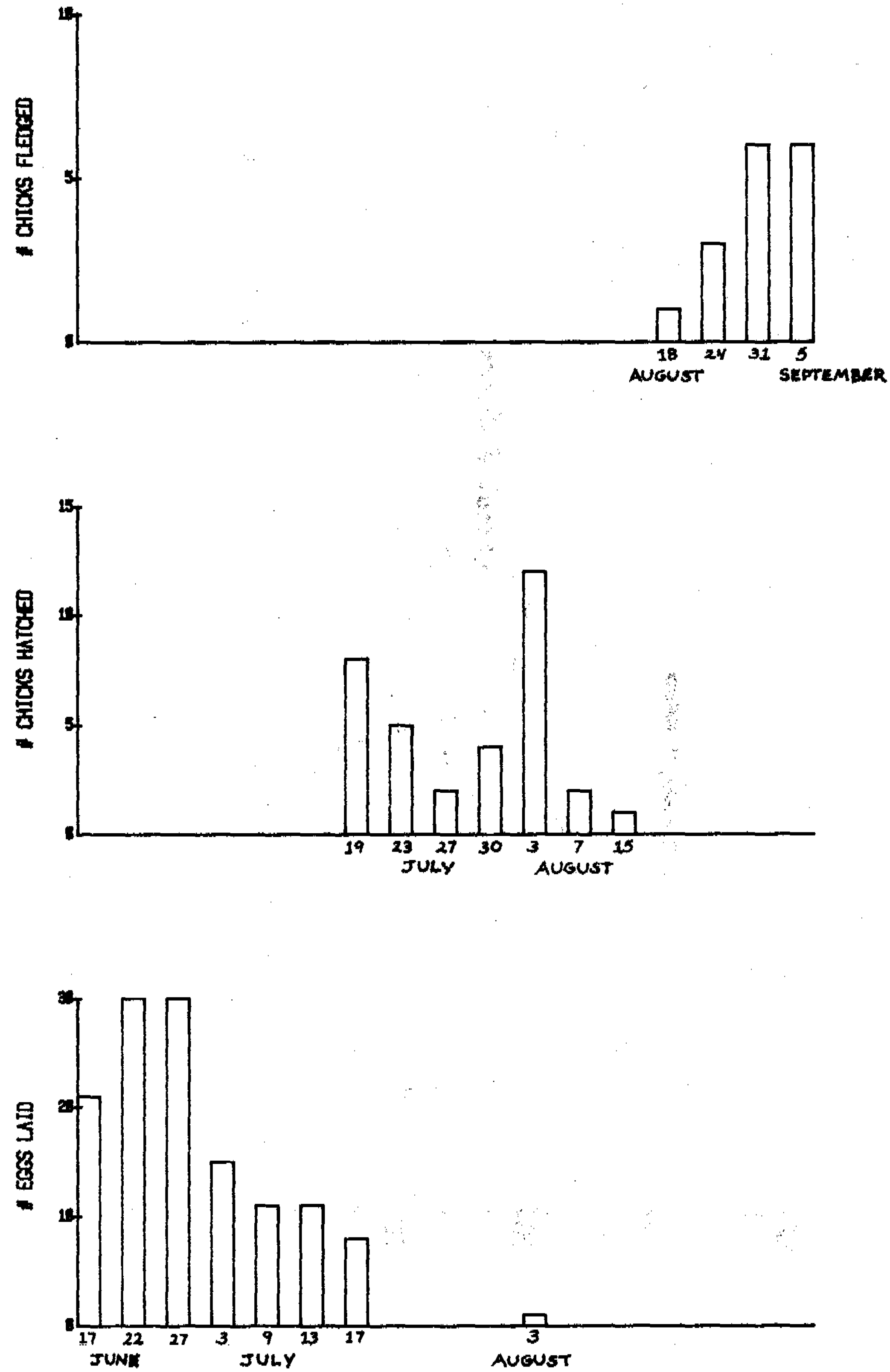

Figure 15. Chronology of black-legged kittiwakes, 1978.

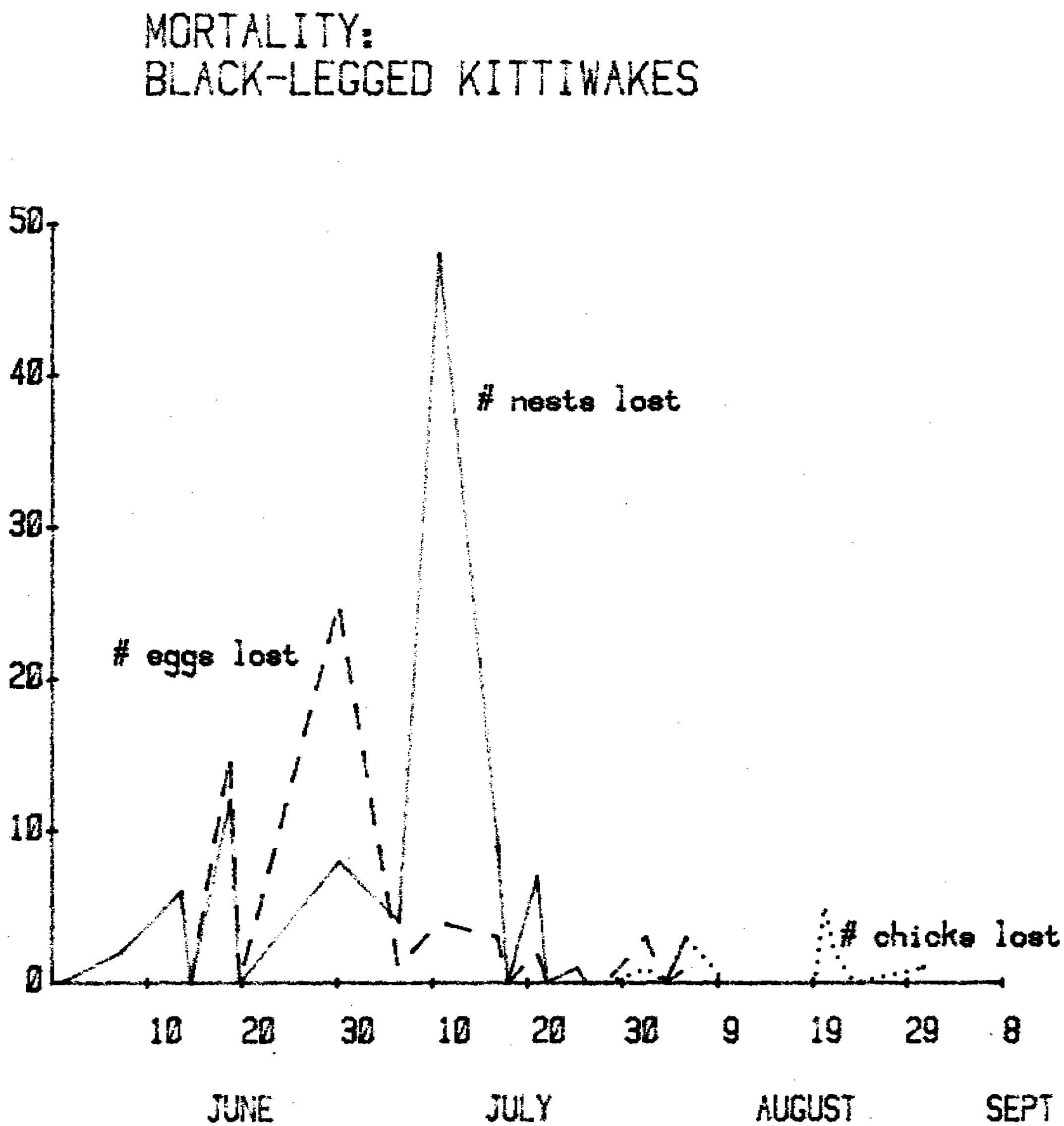

Figure 16. Mortality of black-legged kittiwakes.

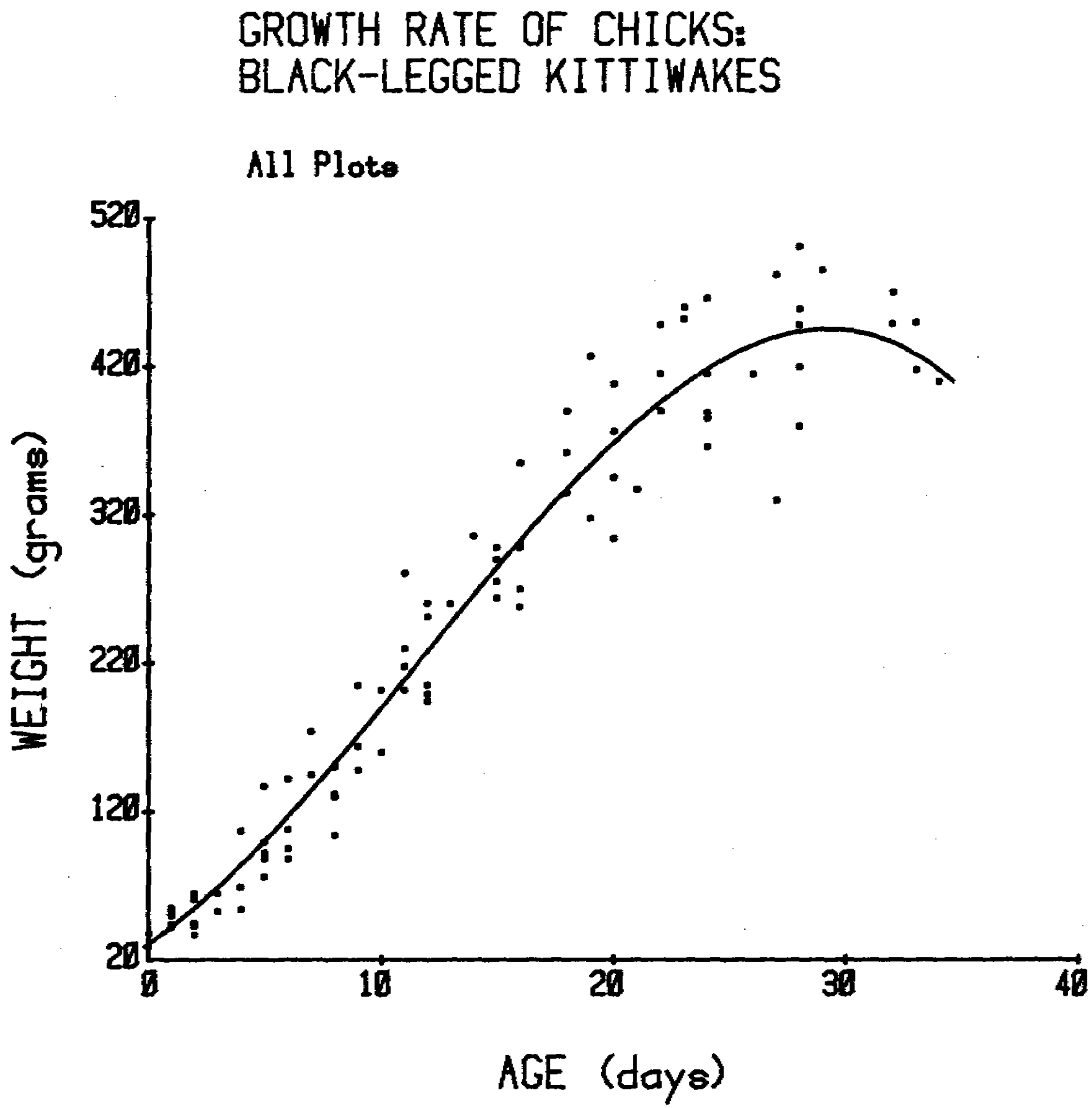

Figure 17. Growth of black-legged kittiwake chicks, 1978.

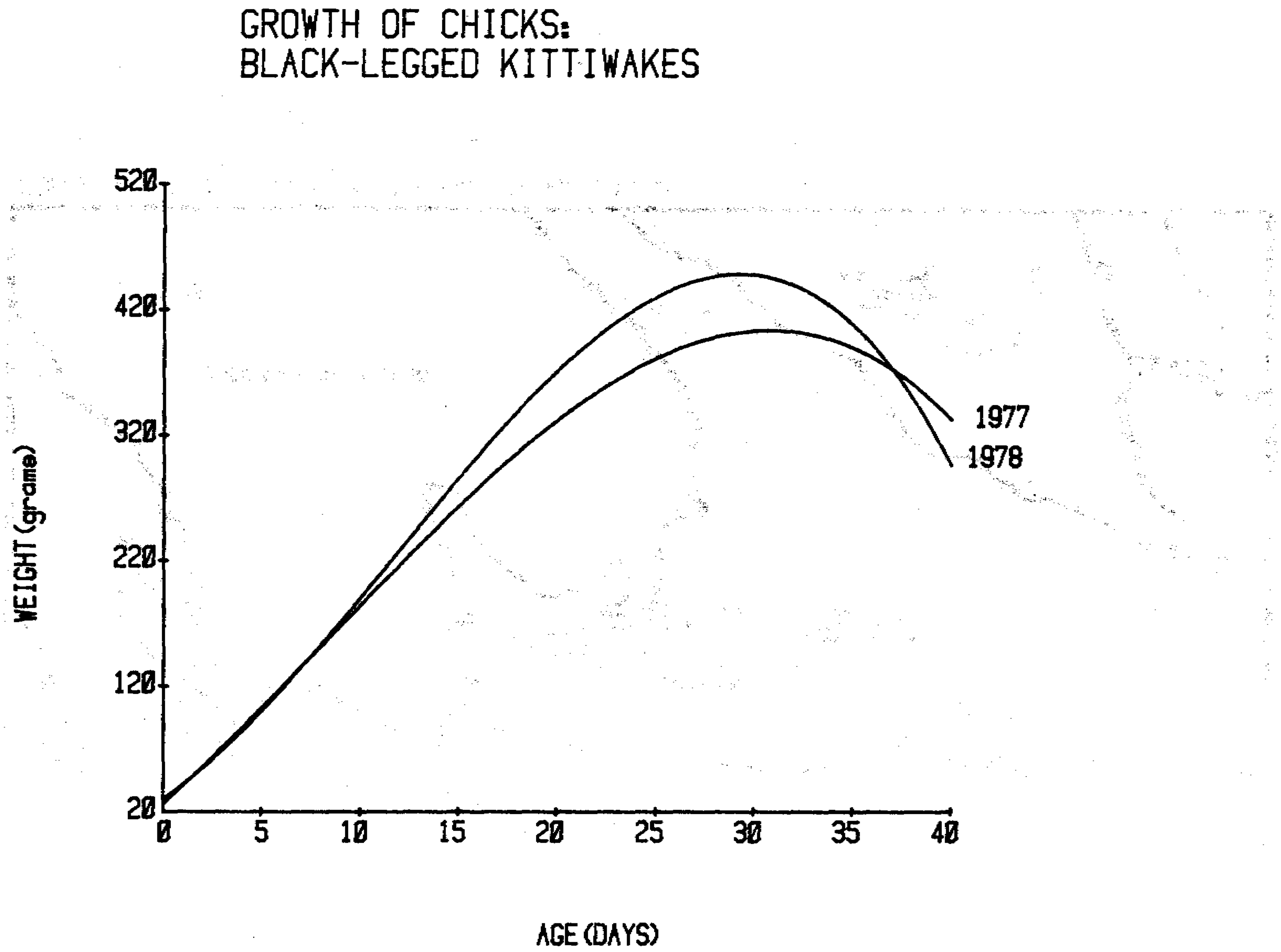

Figure 18. Growth of black-legged kittiwake chicks, 1977 and 1978.

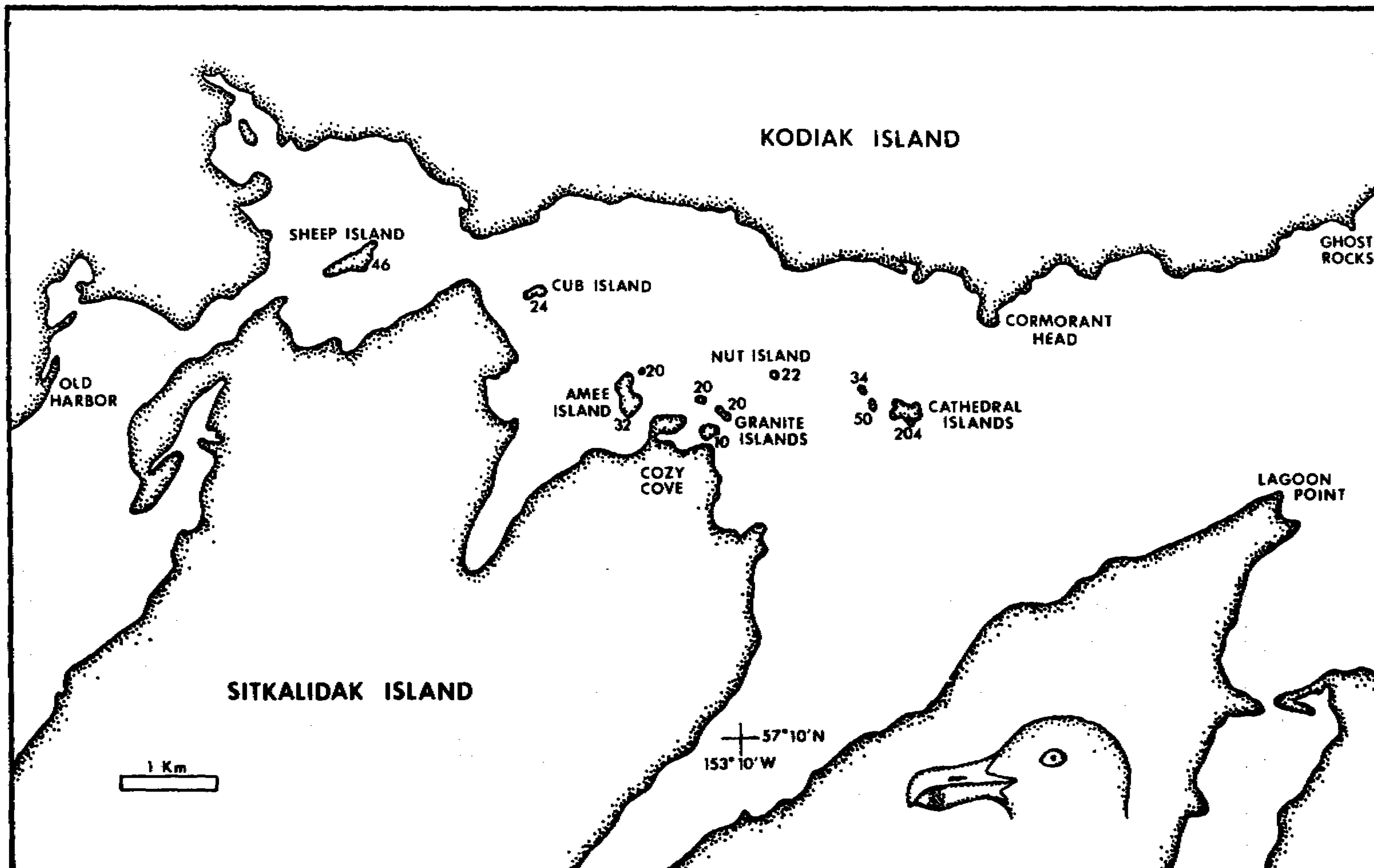

Figure 19. Distribution of glaucous-winged gulls.

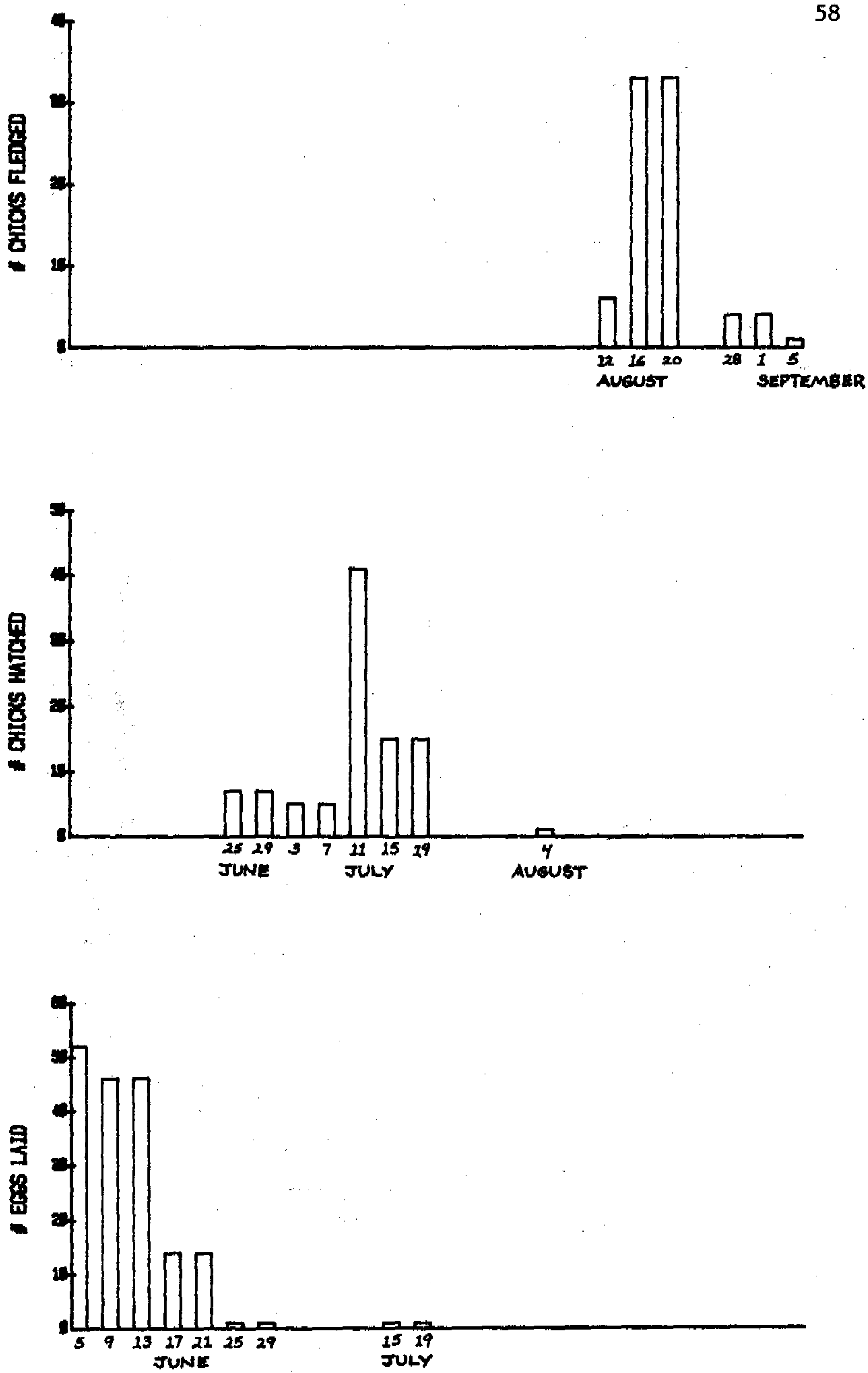

Figure 20. Chronology of glaucous-winged gulls.

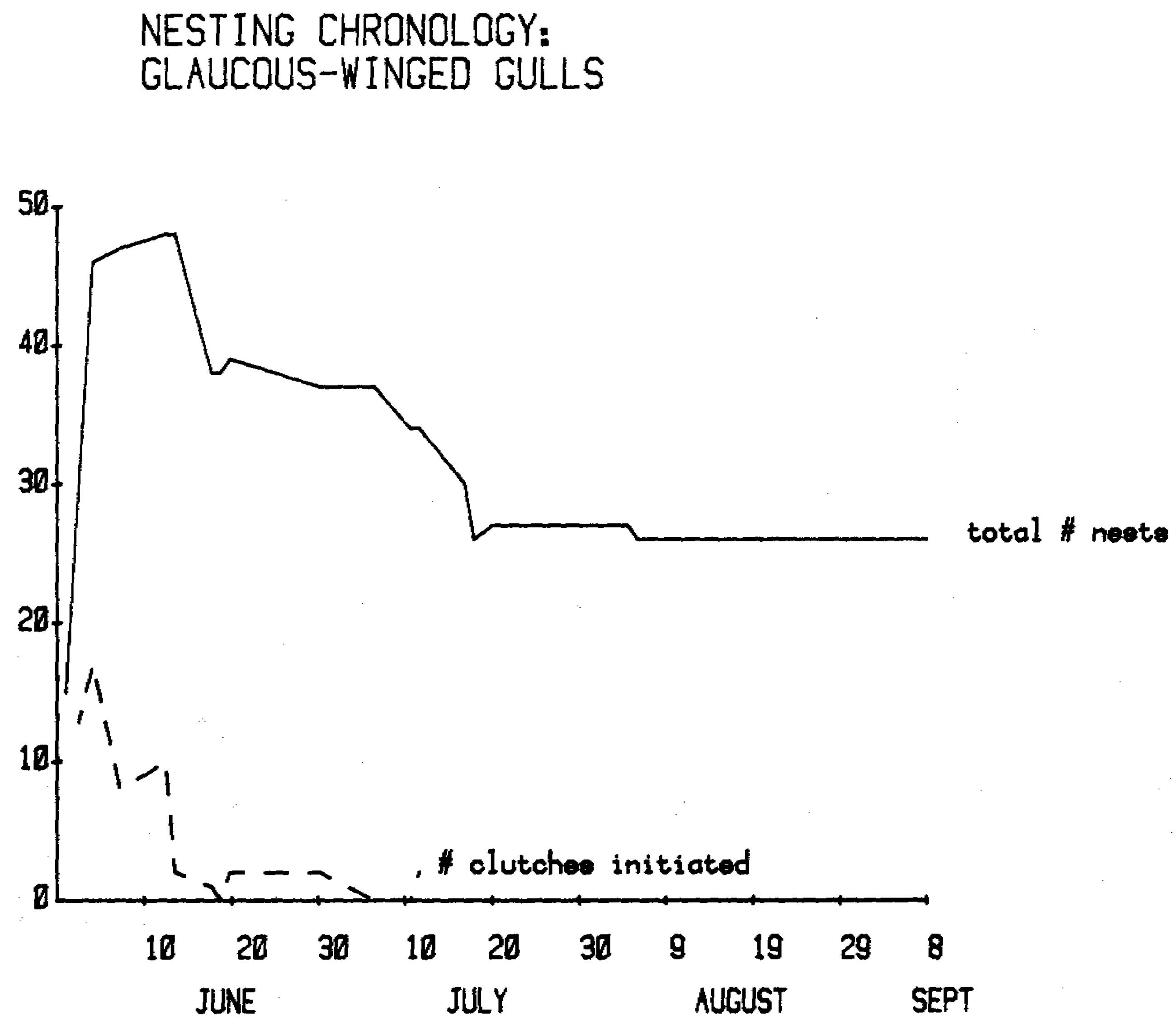

Figure 21. Nesting chronology of glaucous-winged gulls.

GLAUCOUS-WINGED GULLS

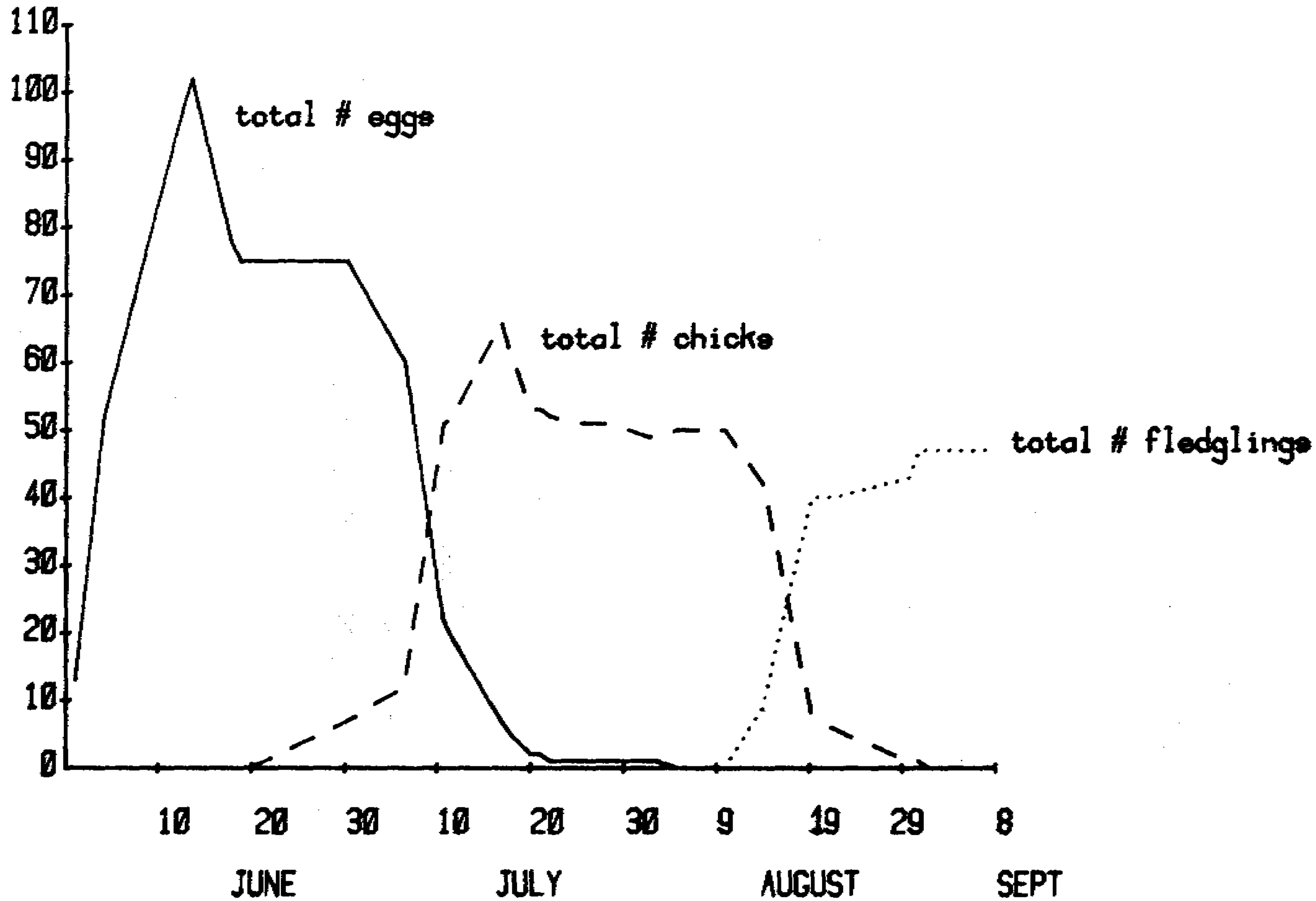

Figure 22. Numbers of glaucous-winged gull eggs, chicks and fledglings.

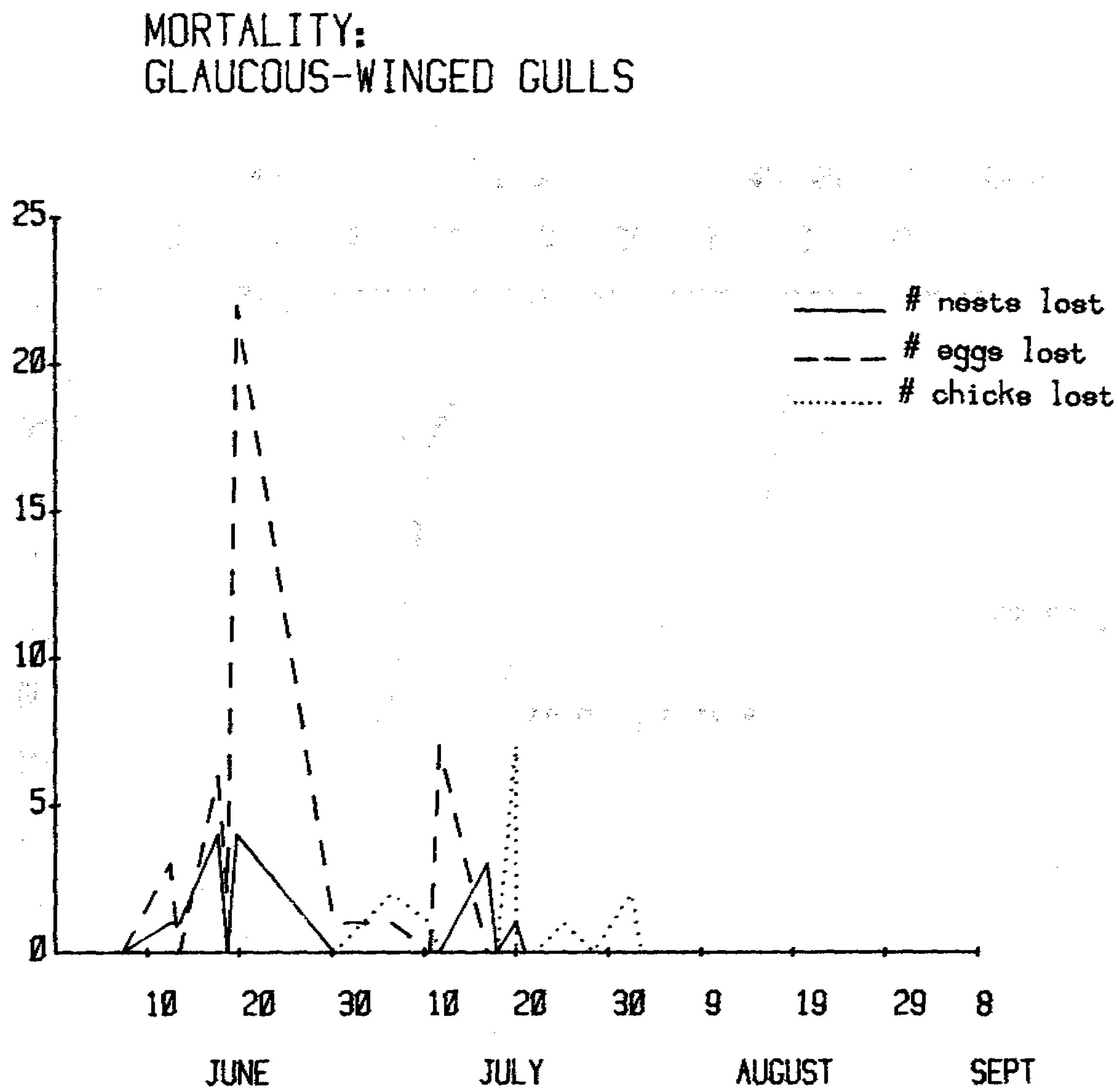

Figure 23. Mortality of glaucous-winged gulls.

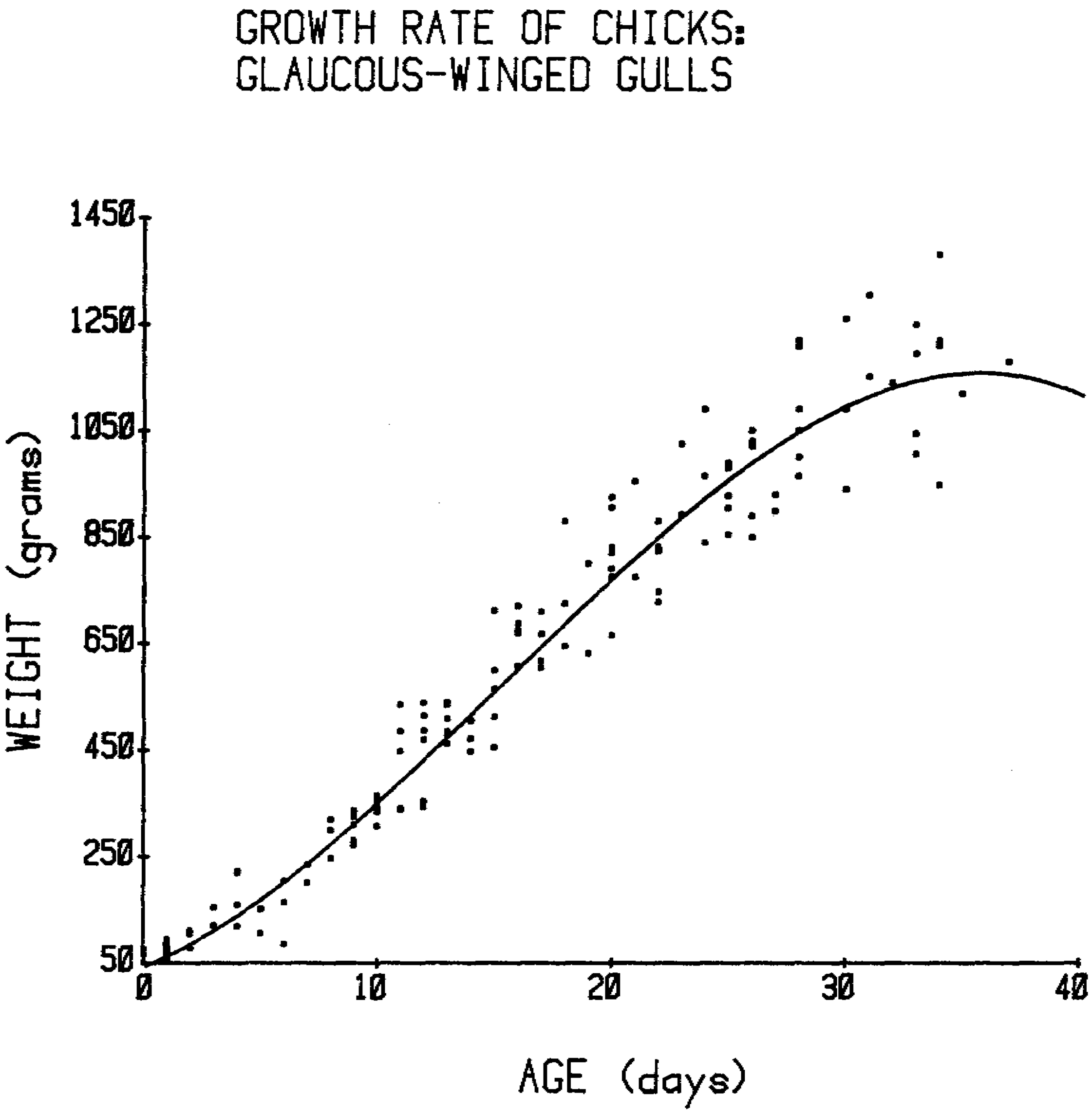

Figure 24. Growth rate of glaucous-winged gull chicks, 1978.

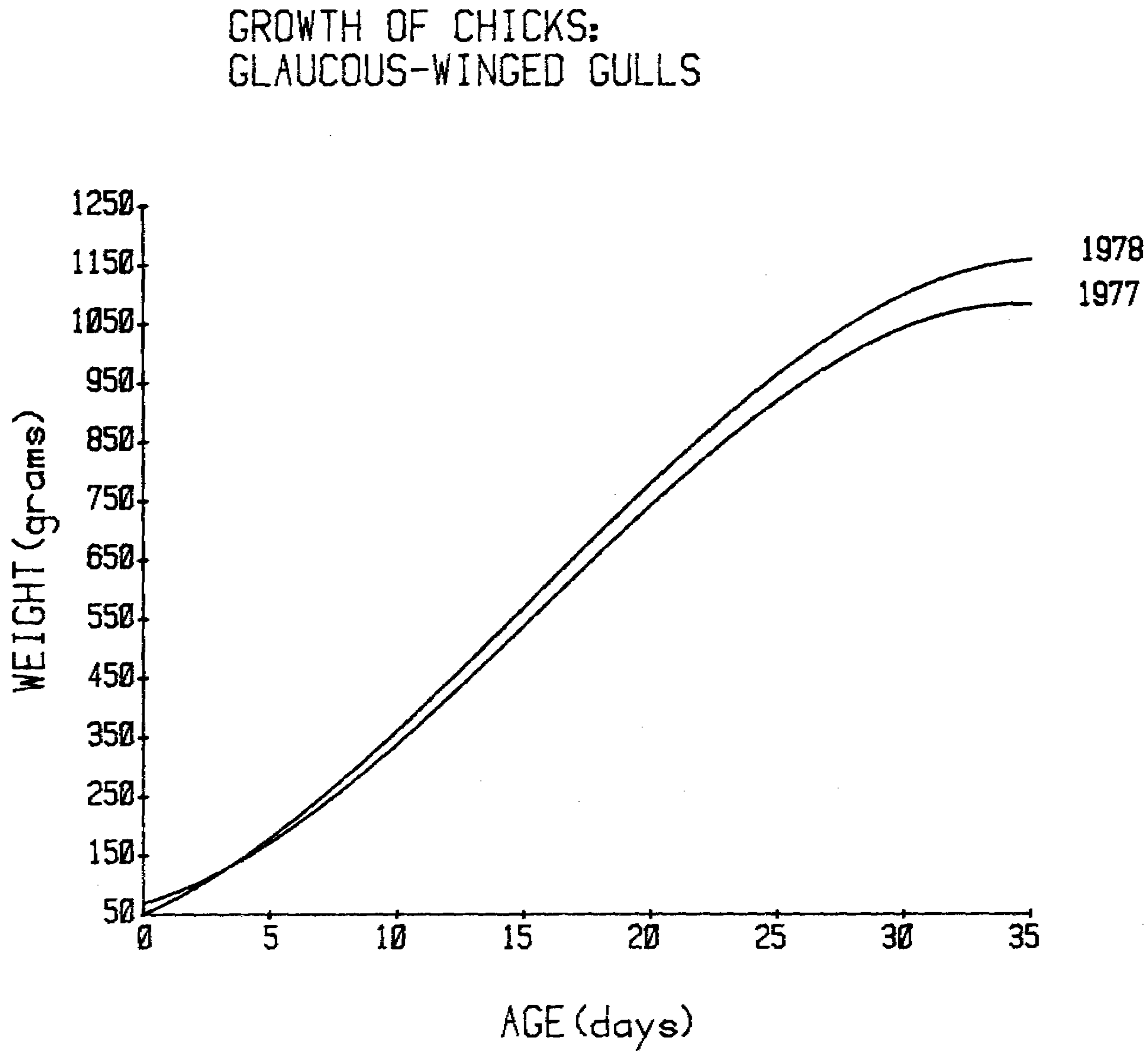

Figure 25. Growth rates of glaucous-winged gull chicks, 1977 and 1978.

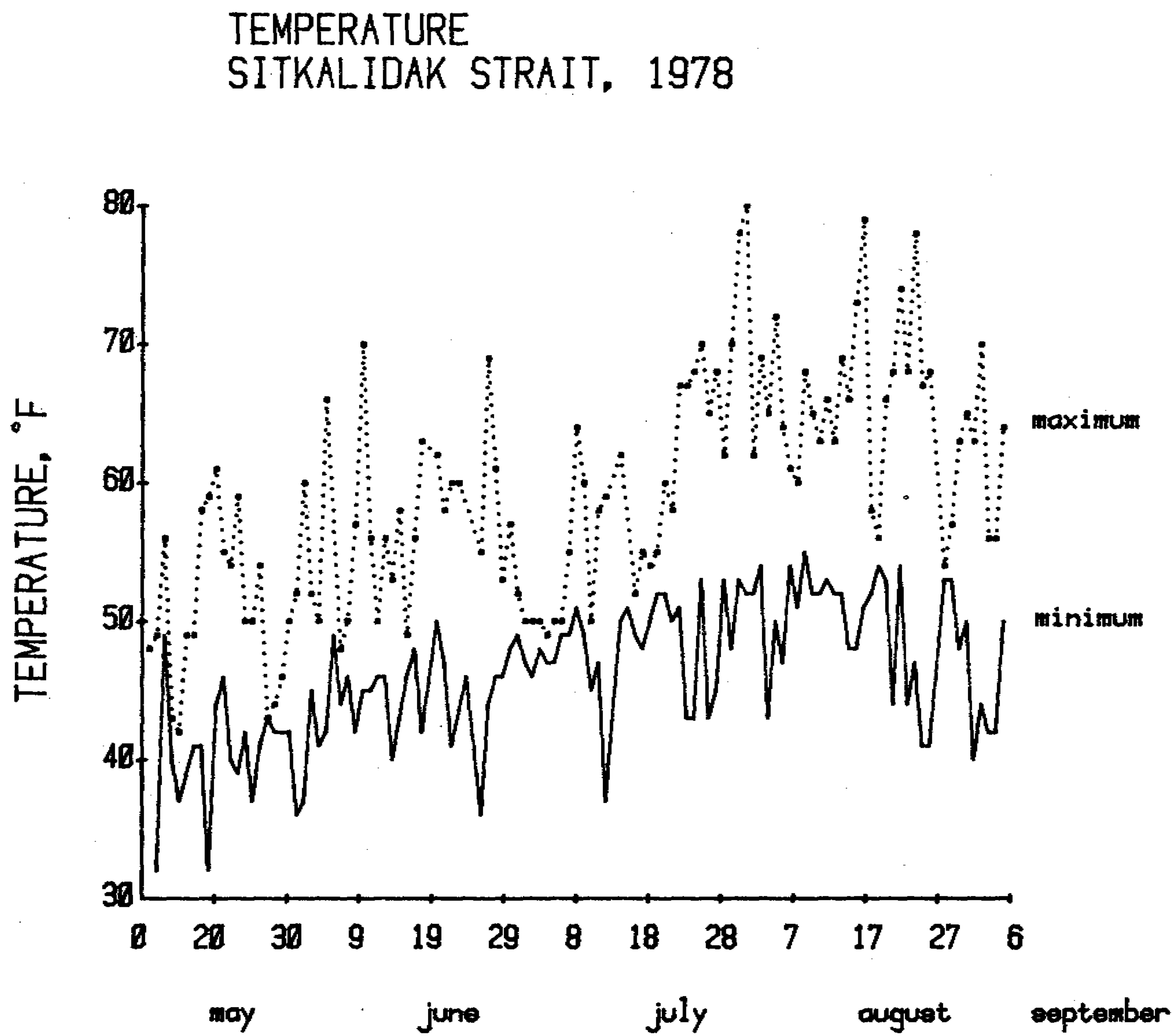

Figure 26. Temperature at Sitkalidak Strait, 1978.

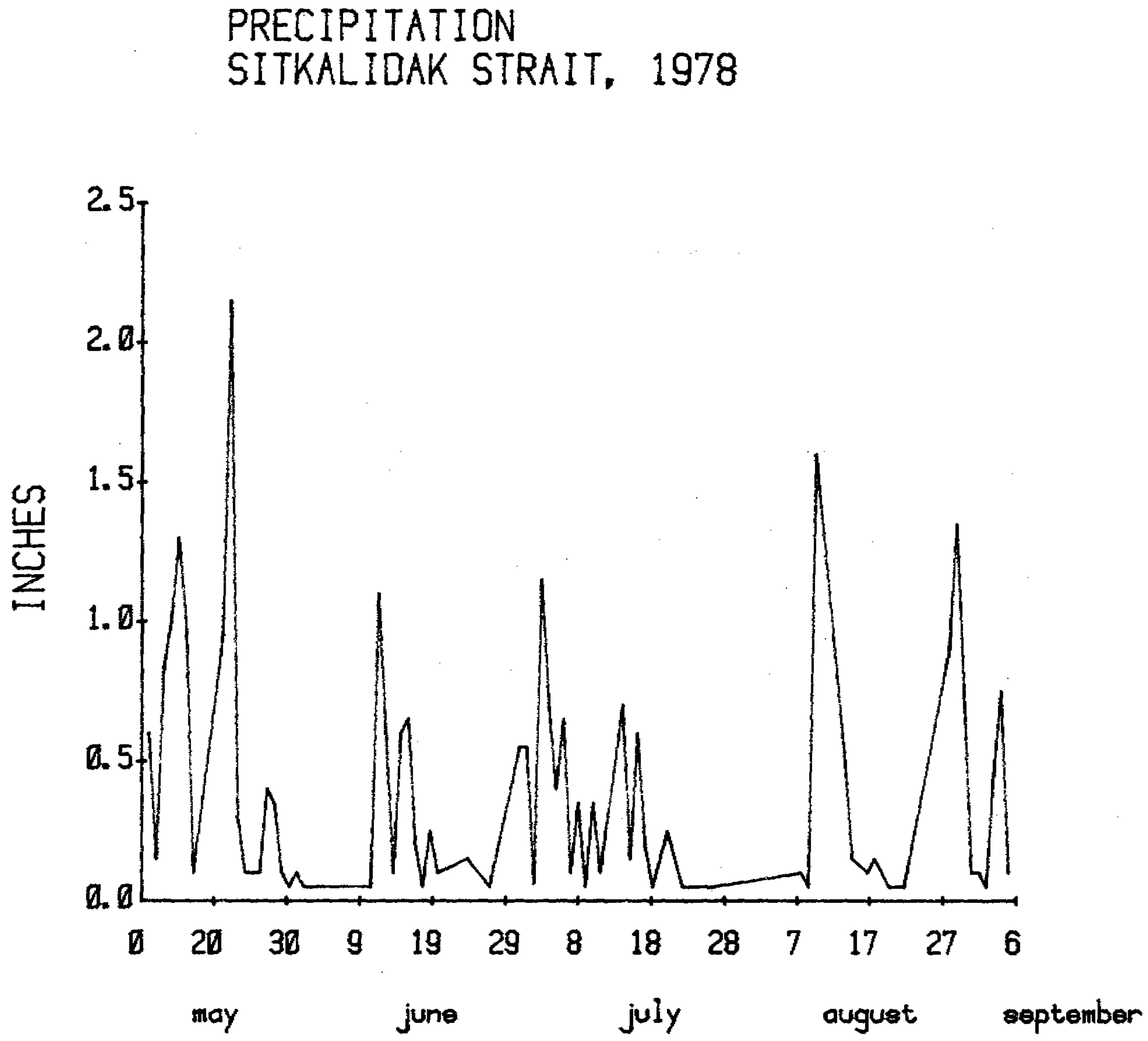

Figure 27. Precipitation at Sitkalidak Strait, 1978.

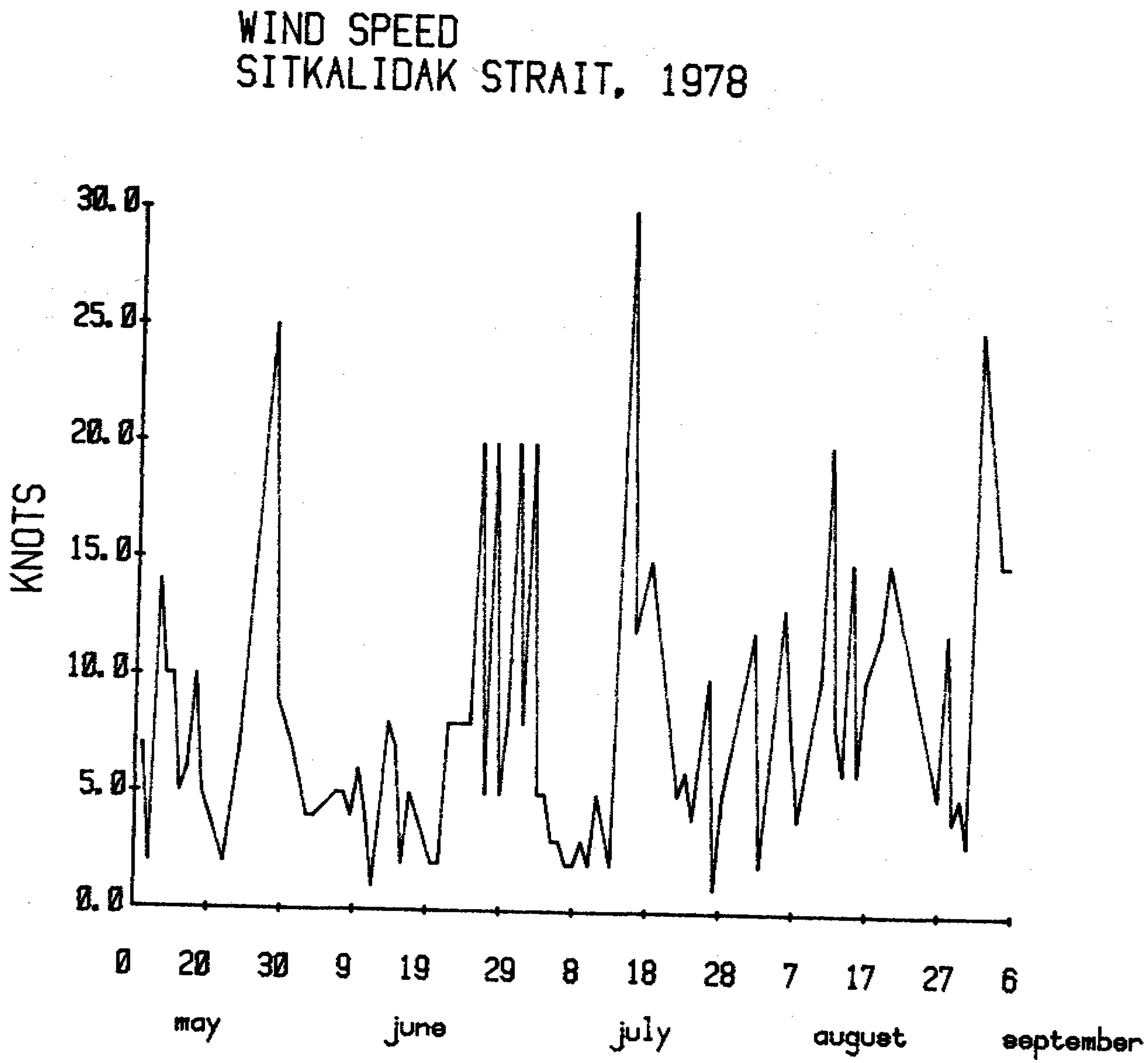

Figure 28. Wind speed at Sitkalidak Strait, 1978.

ADDENDUM

Species Account

Aves

Red-throated loon (Gavia stellata) One was seen in May off our camp beach.

Eared grebe (Podiceps caspicus) On 22 August two were near the Outer Granite islands.

Fulmar (Fulmarus glacialis) On 17 July and 9 August, during storms we saw one near Cathedral Island.

Shearwater (Puffinus spp.) During a storm on 17 July shearwaters were off Lagoon Point and on 9 August one was in a mixed feeding flock off Inner Granite Island.

Trumpeter Swan (Olor buccinator) A pair was in the lakes along the road to Ocean Bay on 24 August.

Mallard (Anas platyrhynchos) Mallards nested in small numbers on Sheep Island.

Pintail (Anas acuta) Thirty pintails were in the lakes along the road to Ocean Bay on 25 August. On 24 August at the head of Amee Bay there were 76 and on 3 September a flock of 10 was seen heading South.

Green-winged teal (Anas carolinensus) On 25 August there were 26 teal on the lakes near the road to Ocean Bay.

American widgeon (Mareca americana) Two females were on the lakes on the way to Ocean Bay on 20 June.

Scaup (Aythya spp.) On 20 June there were 20 scaup on the lakes along the road to Ocean Bay.

Harlequin duck (Histrionicus histrionicus) Harlequin ducks were common throughout the breeding season and were found in flocks of 6 - 30 from Sheep Island to Lagoon Point.

Red-breasted merganser (Mergus serrator) Red-breasted mergansers nested on Sheep, Cub, Amee, and Cathedral islands. They were not present in large numbers, but we saw them almost every day. The average clutch size of the four nests we found was 10.0 eggs. The first merganser chick fledged 14 July. Mergansers were also present on the lakes on the way to Ocean Bay.

Bald eagle (Haliaeetus leucocephalus) Bald eagles, both adult and immature were present throughout the breeding season. They stayed around the colonies during the early laying period of the seabirds and preyed on the adults. There were three aeries from Kiliuda Bay to Ocean Bay to Sheep Island.

Ptarmigan (Lajopies spp.) We found a dead ptarmigan chick on Dusk Island in Kiliuda Bay on 20 July.

Black oystercatcher (Haematopus bachmani) Black oystercatchers nested in small numbers on Sheep, Cub, and Amee islands.

Semipalmated plover (Charadrius semipalmatus) Semipalmated plovers nested on Sitkalidak Island. We saw a pair on the road to Ocean Bay on 20 June, and another pair with a one-to-two-day old chick at Port Hobron on 27 June.

Ruddy turnstone (Arenaria interpres) We saw one in breeding plumage in Amee Bay on 24 July.

Black turnstone (Arenaria melanocephala) We saw black turnstones off Cathedral Island 7-11 August and on Sitkalidak Island on 19 August.

Wandering tattler (Heteroscelus incanum) Wandering tattlers were observed occasionally throughout the breeding season - on 8 and 20 July on the Cub Island spit and on 20 July along the coast near Boulder Bay. On 28 August we saw one in winter plumage off the camp beach.

Lesser yellowlegs (Totanus flavipes) On 24 July in Amee Bay we saw one lesser yellowlegs and on 25 August we saw two on the Ocean Bay beach.

Western sandpiper (Ereuneks mauri) We observed 60 at Ocean Bay on 7 July and ten in Amee Bay on 24 July.

Mew gull (Larus canus). Mew gulls rested on Amee Island this year as they had in 1977, but in fewer numbers. The first chick fledged on 18 July.

Pigeon guillemot (Cepphus columba) Pigeon guillemots were nowhere abundant but were observed every day throughout the breeding season. They nested in low numbers on Sheep, Amee, Cub, Cathedral and the Granite islands.

Marbled murrelet (Brachyramphus marmoratum). Marbled murrelets were seen more often this year than in 1977, possibly indicating that they are increasing in numbers in the Sitkalidak Strait area. We saw the first fledglings on 25 August.

Ancient murrelet (Synthilbor amphus antiquum) An ancient murrelet was observed off Lagoon Point on 17 July during a severe storm.

Horned puffin (Fratercula corniculata) Horned puffins were not observed until 14 May. About 25 pairs nested on Cathedral Island and perhaps another 10 pairs were scattered among Sheep, Cub, and Amee islands.

Short-eared owl (Asio flammus) One flew over camp on 1 September at 2100 - approximately the same date we saw one last year.

Belted kingfisher (Megaceryle alcyon) On 12 July we found a pair of belted kingfishers nesting near our camp above Cozy Cave. A pair had nested nearby there in 1977.

Violet-green swallow (Tachycireta thalassina) Violet-green swallows were observed over a marsh on mainland Kodiak near upper Kiliuda Bay/ Shearwater Cove on 22 May.

Black-billed Magpie (Pica pica) Magpies nested on Amee and Sitkalidak Island and were seen constantly throughout the breeding season.

Common raven (Corvus corax) Ravens were present throughout the breeding season but were observed most commonly in May and early June.

Northwestern crow (Corvus caurinus) Northwestern crows nested on small islands throughout the Sitkalidak Strait area and were much more abundant this year than last.

Winter wren (Troglodytes troglodytes) Winter wrens nested on Sitkalidak Island.

Golden crowned sparrow (Zonotrichia atricapilla) Golden crowned sparrows nested on Sitkalidak Island.

Fox sparrow (Passerella iliaca) Fox sparrows nested on Sitkalidak, Sheep, Caub, Amee, and Cathedral islands.

Song sparrow (Melospiza melodia) Song sparrows nested on Sitkalidak and Cathedral Islands.

Mammalia

Brown bear (Ursus arctus) Kodiak brown bears were present on Sitkalidak Island and Kodiak Island but we never observed them. In the spring and early summer they remained near a cattle ranch on Sitkalidak and later on they were at the salmon streams.

Shorttail weasel (Mustela erminea) As in 1977, shorttail weasels raised a litter near our camp on Cozy Cove.

River/land otter (Lutra canadensis) We observed otter sign on Dusk Island on 20 July and we saw an adult with two pups near our camp in early August.

Red Fox (Vulpes fulva) Red foxes were occasionally observed on the beaches of Sitkalidak Island and they always ran from us, unlike some of the foxes on the Aleutians.

Northern sea lion (Eumetopias jubatus) We observed a female sea lion in late August. Her bevavior was aberrant and we believe she was injured or sick.

Harbor seal (Phoca vibilium) We saw harbor seals throughout the season, usually basking on the rocks from Cub to Cathedral Islands.

Beaver (Castor Canadensis) On 7 June one beaver swarm past our camp - about the same date one swam by in 1977. On 22 August we saw four in a lake near our camp.

Tundra redback vole (Clethrnonomys rutilus) Voles were present on all the islands in the area.

Sitka white-tailed deer (Odocoileus virginianus) Sitka deer, an introduced species, were observed near camp on 3 and 7 June and 11 and 21 July. All were females. The deer on 21 July was being chased by people in an outboard motor boat.

Killer whale (Orcinus orca) We saw a pod of killer whales once on 23 July when we observed eight off Cathedral Island in Port Hobron Straits.

Harbor porpose (Phocoena phocoena) Harbor porpoises were sighted almost daily and often joined the seabird feeding flocks in Inner East Sitkalidak Strait. We saw them May through September.

Dall porpoise (Phocoenoides dalli) We often saw dall porpoises on the seaward side of Cathedral Island off the Lagoon Point seawatch site.

Minke or Piked whale (Balaenoptera acutorostrata) We observed minke whales from May through September and they were often seen in mixed feeding flocks of seabirds.

HABITAT PARAMETERS : BLACK-LEGGED KITTIWAKES

Plot #	Nest #	Nest Width (cm)	Dist. to water (cm)	Nest overhang presence *	Nest overhang %	Adjacent ledge presence *	Adjacent ledge % ovrhg.	Exposure	Dist. from top(cm)	Slope	Nearest Neighbor Distance
1	1	27	1151	0	0	1	0	170	70	70	20(#2)
1	2	22	1151	1	25	0	0	170	70	70	20(#1)
1	3	32	1001	1	25	1	0	173	100	40	60(#13)
1	4	20	891	1	25	1	75	145	210	75	45(#13)
1	5	25	841	0	0	1	0	145	260	90	30(#6)
1	6	20	841	0	0	1	0	145	260	90	30(#5)
1	7	17	791	0	0	1	0	155	310	85	30(#8)
1	8	22	794	0	0	1	0	155	307	85	30(#7)
1	9	23	751	0	0	1	0	205	350	65	71(#14)
1	10	18	491	0	0	1	0	191	610	65	15(#11)
1	11	21	421	0	0	1	0	195	680	85	60(#12)
1	12	23	446	0	0	1	0	195	655	85	60(#11)
1	13	16	882	1	75	1	25	173	219	90	45(#4)
1	14	20	491	0	0	1	0	205	310	60	55(#8)
2	1	20	395	0	0	0	0	185	140	50	80(#2)
2	2	21	445	0	0	1	0	185	90	55	80(#1)
2	3	20	530	0	0	1	0	180	5	60	90(#4)
2	4	25	395	0	0	0	0	130	140	90	40(#5)
2	5	20	438	0	0	0	0	130	97	90	40(#4)
2	6	31	310	0	0	0	0	155	225	90	33(#14)
2	7	25	325	1	25	1	0	120	210	85	28(#14)
2	8	25	286	0	0	0	0	145	244	80	26(#6)
2	9	23	226	0	0	0	0	195	309	75	25(#10)
2	10	28	271	0	0	0	0	195	264	85	25(#9)
2	11	22	335	0	0	1	0	175	200	65	53(#15)
2	12	20	325	0	0	0	0	175	210	75	55(#11)
2	13	20	415	0	0	0	0	175	120	75	27(#15)
2	14	20	325	0	0	0	0	120	210	85	28(#7)
2	15	21	410	1	25	1	0	175	125	80	37(#13)

* 0=no, 1=yes

HABITAT PARAMETERS : BLACK-LEGGED KITTIWAKES

Plot #	Nest #	Nest Width (cm)	Dist. to water (cm)	Nest overhang presence *	%	Adjacent presence *	ledge % ovrhg.	Exposure	Dist. from top(cm)	Slope	Nearest Neighbor Distance
3	1	37	355	1	100	0	0	164	222	55	155(#12)
3	2	23	265	1	25	1	0	186	312	80	45(#13)
3	3	20	225	0	0	1	0	181	352	75	20(#13)
3	4	16	335	0	0	0	0	215	242	70	135(#15)
3	5	23	265	1	25	1	0	216	312	85	110(#3)
3	6	28	235	1	50	0	0	220	320	75	30(#9)
3	8	22	242	0	0	0	0	220	313	70	62(#6)
3	9	25	290	1	25	1	0	220	265	85	30(#6)
3	10	26	175	1	25	1	75	213	380	80	30(#11)
3	11	26	235	0	25	1	0	213	320	80	30(#10)
3	12	19	250	0	0	0	0	223	305	85	70(#9)
3	13	20	225	0	0	1	0	186	352	75	20(#3)
3	14	27	336	0	0	0	0	220	219	80	67(#5)
LKWR	1	16	1459	0	0	1	0	45	145	80	26(#41)
LKWR	2	25	1454	0	0	1	0	45	150	80	27(#14)
LKWR	3	23	1404	1	75	1	0	0	200	80	38(#46)
LKWR	4	20	720	0	0	1	0	40	780	90	100
LKWR	5	18	1275	1	75	0	0	40	225	90	178(#6)
LKWR	6	22	1453	0	0	0	0	40	47	90	55(#46)
LKWR	7	22	830	0	0	1	0	63	70	90	32(#9)
LKWR	8	20	805	0	0	1	25	62	95	90	88(#65)
LKWR	9	20	782	0	0	1	0	63	118	90	32(#7)
LKWR	10	17	813	1	50	1	50	62	87	90	66(#11)
LKWR	11	21	820	1	50	1	50	62	80	90	30(#48)
LKWR	12	27	850	1	50	1	25	30	50	90	46(#48)
LKWR	14	24	750	1	25	1	0	350	150	30	62(#52)
LKWR	15	20	855	1	25	1	0	15	45	80	31(#16)

* 0=no, 1=yes

HABITAT PARAMETERS : BLACK-LEGGED KITTIWAKES

Plot #	Nest #	Nest Width (cm)	Dist. to Water (cm)	Nest overhang presence *	Nest overhang %	Adjacent ledge presence *	Adjacent ledge % ovrhg.	Exposure	Dist. from top(cm)	Slope	Nearest Neighbor Distance
LKWR	16	25	853	0	0	1	0	15	47	80	31(#15)
LKWR	17	25	865	1	25	0	0	80	35	90	55(#51)
LKWR	18	20	870	0	0	1	0	345	30	85	54(#16)
LKWR	19	28	735	0	0	0	0	50	110	90	35(#20)
LKWR	20	26	771	0	0	1	0	48	74	90	35(#19)
LKWR	21	26	784	0	0	1	0	48	70	90	38(#22)
LKWR	22	--	799	0	0	0	0	48	46	90	38(#21)
LKWR	23	20	772	0	0	1	0	48	73	90	30(#24)
LKWR	24	17	666	0	0	1	**	55	44	85	30(#23)
LKWR	25	24	592	0	0	1	0	55	118	90	35(#23)
LKWR	26	18	680	0	0	1	**	100	30	90	55(#25)
LKWR	27	--	245	0	0	0	0	40	465	80	15
LKWR	28	22	465	0	0	0	0	40	245	80	128
LKWR	29	20	585	0	0	0	0	55	125	80	70(#32)
LKWR	30	26	678	0	0	1	0	55	32	80	60(#25)
LKWR	31	38	490	0	0	1	50	40	220	90	43(#32)
LKWR	32	23	490	1	50	1	0	40	220	90	43(#31)
LKWR	33	18	302	0	0	1	0	55	38	85	42(#30)
LKWR	34	36	235	0	0	0	0	80	105	85	105(#36)
LKWR	35	18	350	0	0	0	0	40	360	80	15(#27)
LKWR	36	--	628	1	50	1	25	118	--	90	105(#34)
LKWR	37	20	1060	0	0	0	0	62	440	90	345(#8)
LKWR	38	21	1415	0	0	1	0	63	85	90	34(#7)
LKWR	40	30	655	0	0	1	0	50	90	90	35(#19)
LKWR	41	24	1404	0	0	1	0	45	200	80	26(#1)
LKWR	42	21	1434	0	0	1	0	45	170	80	33(#43)
LKWR	43	35	1399	0	0	1	0	45	205	80	33(#42)
LKWR	44	20	1480	0	0	1	0	45	124	80	27(#2)

* 0=no,1=yes
** nest at top of cliff

HABITAT PARAMETERS : BLACK-LEGGED KITTIWAKES

Plot #	Nest #	Nest Width (cm)	Dist. to Water (cm)	Nest overhang presence *	%	Adjacent ledge presence *	% ovrhg.	Exposure	Dist. from top(cm)	Slope	Nearest Neighbor Distance (cm)
LKWR	45	15	1434	1	50	0	0	45	170	80	36(#3)
LKWR	46	15	1109	1	50	0	0	45	150	80	38(#3)
LKWR	47	17	1534	1	75	1	0	10	70	90	34(#38)
LKWR	48	32	715	1	25	0	0	62	100	85	30(#11)
LKWR	49	30	725	0	0	0	0	30	90	85	50(#13)
LKWR	50	26	803	1	25	1	0	40	97	80	35(#51)
LKWR	51	20	803	0	0	1	25	40	97	80	35(#50)
LKWR	52	26	680	0	0	1	25	350	220	70	62(#14)
LKWR	65	20	820	1	75	1	50	62	80	85	35(#11)

* o=no, 1=yes

HABITAT PARAMETERS : TUFTED PUFFINS

Plot #	Nest #	Dist. along transect (m)	Dist. from transect (cm)	Nearest Neighbor Distance (cm)	Slope	Soil Depth (cm)	Window Location (cm)
Cathedral Island							
2	1	8.45	L 125	130(#2)	22	26	R 90
2	2	7.55	L 106	* (#6)		in rock(connected #6)	
2	3	7.25	R 56	70	28	8	U 35,R 22
2	4	6.65	R 115	75	38	19	U 45
2	5	7.06	R 128	false burrow			
2	6	6.77	L 103	100	25	in rock	U 58 L 40
2	7	5.30	R 167	105	22	68	no chamber(conn. #10)
2	8	5.95	L 10	70(#3)	38	45	U 51,L 35
2	9	4.65	0	103(#7)	17	61	U 48
2	10	5.35	R 90	82	20	47	no chamber(conn.#7)
2	11	4.34	R 131	103(#8)	29	31	U40,L 60
2	12	0.50	1 90	70(#22)	40	18	U 56,R 20
2	13	2.05	L 10	60(#27)	28	35	U 60,R 23(conn.#27)
2	14	3.35	L 70	63(#13)	24	39	L 72
2	15	2.37	L 60	63(#14)	27	32	U 60 R 23
2	16	3.50	L 136	90(#14)	30	19	U 20,L 90
2	17	2.04	R 26	55	18	42	U 60
2	18	1.30	R 8	45(#20)	26	15	U 20(conn.#21)
2	19	1.85	L 94	60	22	41	U 30,R 20
2	20	1.00	L 63	45(#18)	28	40	U 48,L 15
2	21	0.95	R 34	68(#20)	27	20	U 20(conn.#18)
2	22	0.80	L 160	45	34	32	U 55, L 24
2	23	1.60	L 190	56	22	43	U 10,R 38
2	24	2.65	L 177	70(#23)	25	32	U 45,L 42
2	25	5.95	L 10	70(#3)	38	45	(conn.#8 at entrance)
2	26	8.44	R 35	92(#3)			
2	27	2.85	R50	60(#13)	23	40	U 53,R 25(conn.#13)
3	1	0.70	L 35	90	24	20	U 32
3	2	4.69	R 90	65	29	75	R 36
3	3	5.00	L 18	43	28	24	U 55,R 63
3	4	5.65	L86	60	29	28	U 43,R 53
3	5	6.85	0	106	25	36	R 65
3	6	6.70	R 39	100	26	23	U 55 L 59
3	7	8.85	R 40	65	28	25	U 45, L 24
3	8	9.50	L 5	65	27	32	R 44
3	9	10.02	R 100	175	26	18	L 63
3	10	14.35	R 15	93	25	17	U 26,R 26

* connected (no nearest neighbor distance)

HABITAT PARAMETERS : TUFTED PUFFINS

Plot #	Nest #	Dist. along transect (m)	Dist. from transect (cm)	Nearest Neighbor Distance (cm)	Slope	Soil Depth (cm)	Window Location (cm)
4	1	0	R 24	92(*2)	41	23	U 61,L 22
4	2	1.43	L 19	66	41	39	U 40,L 55
4	3	1.30	L 100	80	18	56	R 82
4	4	1.55	R 100	80	33	70	U 88
4	5	3.40	L 14	80	23	81	L 38
4	6	7.07	L 24	160	32	66	U 65
4	7	12.34	R 23	74	38	23	U 26,L 49
4	8	12.08	L 70	90(#9)	18	35	U 36,L 20
4	9	14.94	L 86	90(#8)	18	42	U 36,L 20
5	1	3.23	L 63	130(#2)	19	35	U 75,R 63
5	2	2.09	L 33	92(#5)	14	18	U 50,L 36 & D 42,R 20
5	3	2.09	R 47	50(#6)	18	46	no chamber
5	4	2.84	R 89	103(#9)	9	12	U 80,R 43
5	5	1.39	L 94	45(#8)	17	12	U 44,R 25
5	6	1.51	R 40	50(#3)	22	23	reachable
5	7	1.43	L 176	76(#8)	14	33	U 77
5	8	1.39	L 133	45(#5)	19	24	U 55,L 25
5	9	1.77	R 114	69(#6)	90	0	in #6
5	10	0.87	L 65	60(#11)	27	30	U 56
5	11	0.50	L 35	50(#8)	31	33	U 52
5	12	0.90	R 160	110	35	33	reachable
5	13	0.25	R 15	65(#10)	36	14	in #10
5	14	0	L 35	62(#15)	31	0	reachable: in rocks
6	1	1.9	L 7	60(#2)	18	40	U 45, R 20
6	2	2.8	R 25	60(#1)	18	20	U 60,R 36
6	3	3.75	L 30	56(#4)	30	51	U 70,L 33
6	4	3.75	L 70	56(#3)	26	51	U30,R 5
6	5	4.10	L 106	80(#4)	10	53	U 55,R 34
6	7	4.65	R 43	61	30	54	U 52,R 25
6	8	6.90	R 10	148(#9)	14	63	U 60,R 40
6	9	7.05	L 32	148(#8)	12	52	R 75 & U 60,R 75
7	1	0	R 34	66(#2)	24	19	U 83 (*#3)
7	2	0.9	L 13	66(#1)	24	22	U 58,L15(in#3)
7	3	1.41	0	60(#2)	24	46	U 83 (* #1)
7	4	2.00	L 43	46	24	10	a)L 63 b) U 69
7	5	1.92	R 78	53	24	40	reachable
7	6	2.75	R 58	70	30	42	U 90
7	7	2.99	L 42	80(#4)	30	33	U 53
7	8	4.17	R 47	50	22	12	U 45
7	9	4.00	R 95	78	22	57	U 50
7	10	3.95	L 82	50(#11)	48	22	U 48 (*#7)

* connected to

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THE PELAGIC BIRDS OF TUXEDNI WILDERNESS, ALASKA

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ABSTRACT

We report herein a study of seabird colonies on Chisik and Duck Islands comprising the Tuxedni Wilderness in lower Cook Inlet. We compiled productivity statistics concerning black-legged kittiwakes and horned puffins through their incubation and nestling stages to fledging with major elements as follows.

Productivity of black-legged kittiwakes

Nests with eggs/nest built	.748
Mean clutch size	1.56
Clutches with one or more eggs hatching	25.5%
Mean brood size at hatching	1.15%
Broods with young fledging	7.7%
Mean brood size at fledging	1.0%
Young fledged from eggs laid	1.1%
Mean number of young raised per pair	0.015

Productivity of horned puffins

Pairs laying eggs on sample plots	96.7%
Mean clutch size	1.0
Clutches with eggs hatching	72.7%
Broods with young fledging	92.3%
Mean number of young raised per pair on sample plots	0.6

We recorded observations of common murres and glaucous-winged gulls on a more incidental basis. The gulls emerged as an important predator of kittiwakes and murres. The kittiwakes (a surface feeder) failed in the reproductive effort, while the puffins (a diver) achieved success. Both of these species fed on Pacific sand lance, puffins exclusively and kittiwakes nearly so. We believe kittiwakes failed because this fish did not enter surface waters in substantial numbers, but puffins found them in deeper layers. The kittiwakes have failed in three of four known breeding attmepts, which argues a need to continue these studies and to study the fish. Airplanes, particularly helicopters on OCS related activities, create disturbances that expose kittiwake eggs and nestlings to predation by overabundant glaucous-winged gulls.

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THE PELAGIC BIRDS OF TUXEDNI WILDERNESS, ALASKA

INTRODUCTION

On the evening of 16 May 1978 the authors of this report arrived on Chisik Island within the Tuxedni Wilderness to study its seabirds. The Wilderness, situated on the west side of lower Cook Inlet (Figure 1) provides nesting sites for about 28,000 black-legged kittiwakes *Rissa tridactyla*, 10,000 common murres *Uria aalge*, 6,000 horned puffins *Fratercula corniculata* and smaller numbers of other sea and land birds, making it the largest seabird colony in Cook Inlet. Kittiwakes had been studied there earlier (Snarski 1970, 1971, and Unpubl. Ms.), but the others were unknown except for enumeration. In the weeks ahead we studied the three primary species with a view to their reproductive performance and those factors influencing it, and to their foods and feeding habits. We remained on the Wilderness 110 days studying kittiwakes and puffins intensively, and murres to a limited extent. We closed camp 4 September.

THE STUDY AREA

Captain James Cook in 1778 anchored off Anchor Point as he worked his ships down what later became known as Cook's Inlet (Cook 1785). On that occasion the skies were clear and the two volcanoes now named Mt. Redoubt and Mt. Iliamna were observed and the fact recorded in the ship's log. Though these two landmarks bracket a view of Chisik Island from Anchor Pt., its presence is not noted in the log. The island's native name *Khazik* appears in Tebenkov's Atlas of the northwest coast of America (1852), and *Chasik* in Eichwald's (1871) German text. The name *Chisik* appears in Baker (1906) and Orth (1967) and on modern charts. In February 1909 President Theodore Roosevelt signed Executive Order 1039 proclaiming Chisik and Egg (now Duck) Islands a bird reserve to be known as the Tuxedni Reservation. The name Tuxedni Bay originated as a native name published by Tebenkov (1852) as Zaliv Tukuzit, and by Dall (1896) as Tuk-sed-ni. The Reservation later became the Tuxedni National Wildlife Refuge, and in 1970, the additional classification as a wilderness (Figure 2) (23 Oct. 1970, Public Law 91-504).

The rationale behind issuance of Executive Order 1039 does not appear in the order, though its wording implies knowledge of the seabird colonies. We have not discovered how this information came to the attention of the Chief Executive, but the relevant literature makes clear that the region was hardly isolated from human activity. The presence of oil and gas seeps about 40 miles southwest of the island had encouraged exploratory drilling as early as 1898, and a number of geologists explored the area about the turn of the century. One such was Dr. William Healey Dall, who visited Tuxedni Bay in 1895. Though numerous "shows" of oil and gas have been reported from exploratory wells in the region, no commercial production has occurred (Cobb et al. 1967).

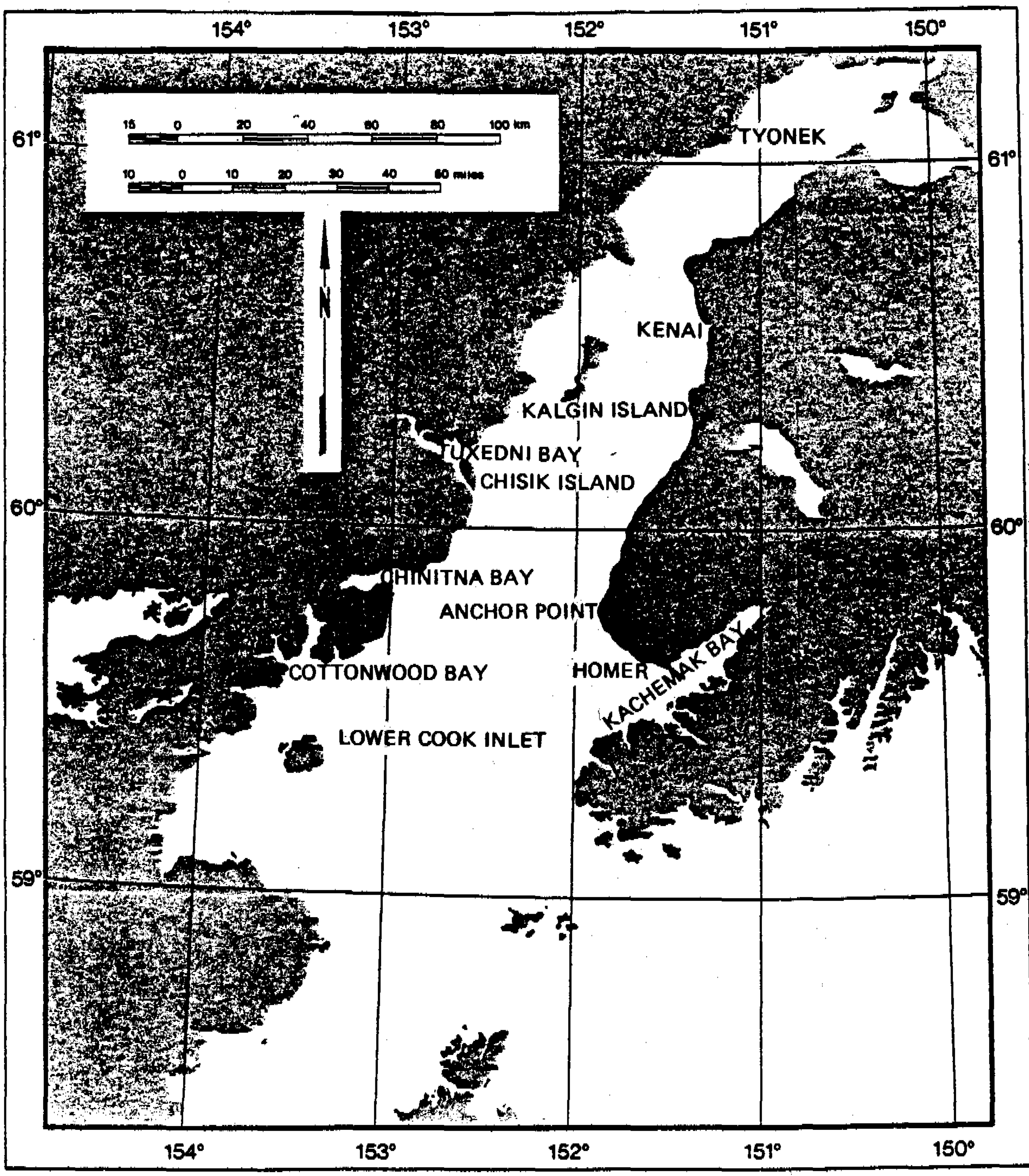

Figure 1. Map of the lower Cook Inlet area.

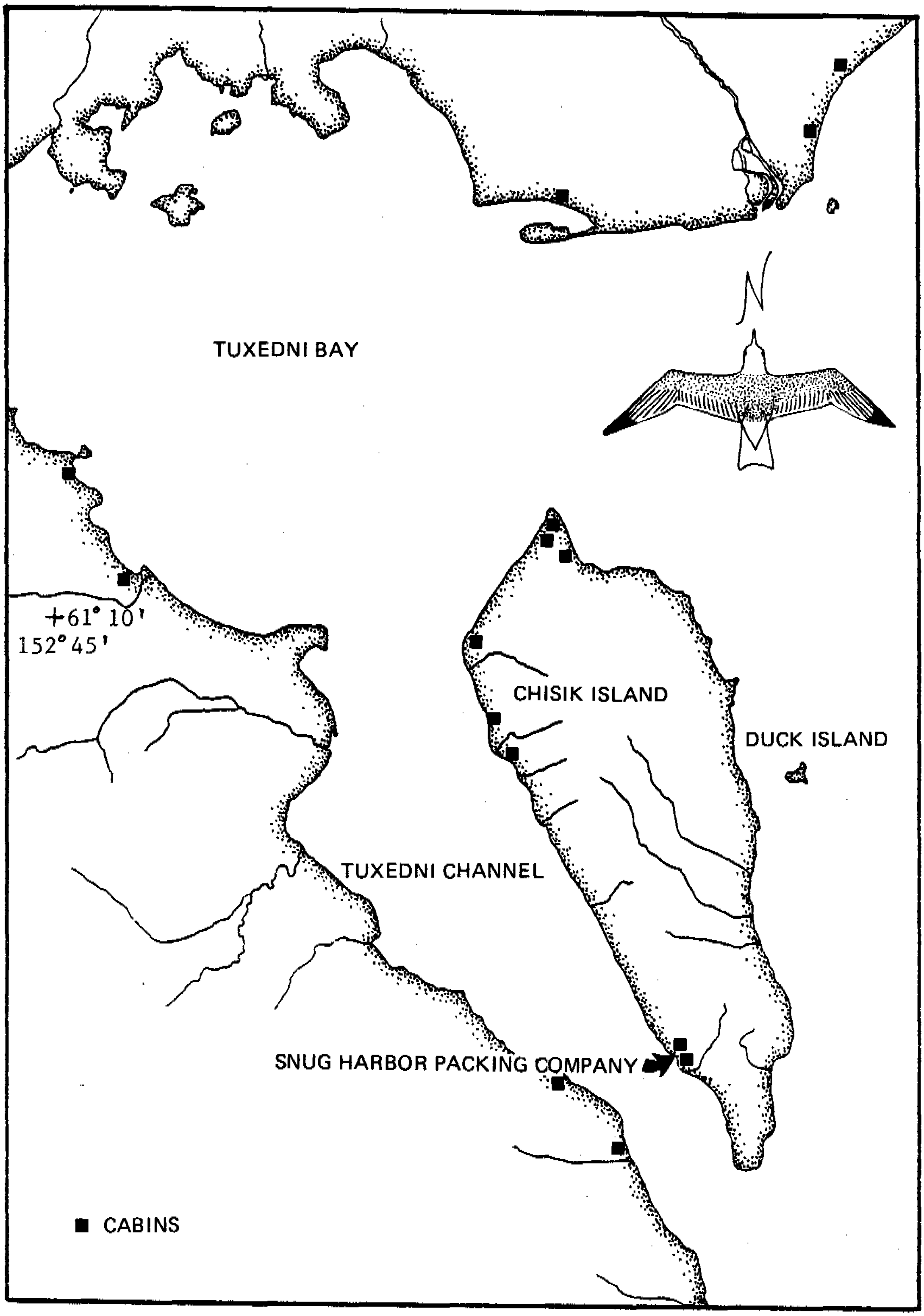

Figure 2. Tuxedni Wilderness study area.

Chisik Island (2606 ha, 6439 acres) lies in the mouth of Tuxedni Bay where it is separated from the mainland by Tuxedni Channel, a stretch of water 0.8 km (0.5 miles) wide at its southern end and about 3.2 km (2.0 miles) at its northern end. Chisik is 10.5 km (6.5 miles) long and about 3.6 km (2.25 miles) wide at the northern end, but narrows to less than 0.4 km (0.25 mile) at its southernmost point. It is 815 meters (2,674 feet) in altitude at its highest point in the north end of the island. From this point the land dips southward gradually along a narrow ridge to the south end of the island. On the east and west side of Chisik the slopes are steep and rise abruptly from the tide flats to the crest of the ridge. All streams are short, and flow in precipitous courses. Waterfalls furnish a conspicuous feature of the landscape. A heavy tangle of alder *Alnus crispa* dominates the slopes and the ridge on all but the highest parts of the island. A few Sitka spruce *Picea sitkensis* occupy scattered areas on the island, and cottonwood *Populus balsamifera* occur on the lower slopes of the west side. Some of these are quite handsome, large trees, perhaps two or three hundred years old. The dominant grass on the island is *Calamagrostis canadensis*.

Duck Island (2.4 ha, 6 acres) about 0.4 km (0.25 miles) off the midpoint of Chisik's east side, is a steep-sided rock outcrop reaching an elevation of 49 m (160 feet). There is no water on Duck Island. Like Chisik, alders dominate the heavy vegetative cover. Both islands produce an understory including devil's club *Echinopanax horridum*, salmonberry *Rubus spectabilis*, nettles *Urtica Lyallii*, *Calamagrostis canadensis*, elderberry *Sambucus recemosa*, and several genera of the family Umbelliferae. The cliffs constitute a showcase rock garden of colorful flowers including forget-me-not *Myosotis alpestris*, roseroot *Sedum rosea*, Jacob's ladder *Polemonium boreale*, and particularly monkey flower *Mimulus guttatus*. The latter flourish on the high steep cliffs of Chisik.

The rocks on Chisik range from middle to late Jurassic in age (Detterman 1963), and today present a physically instable formation. Active and continuous erosion results in a steady fall of small, angular stones, and frequent falls or slides of rocks weighing tens, hundreds or thousands of pounds. These rocks shatter on the beach at the foot of the cliffs, and accumulate in loose slides at the bottom of declivities. Thus the beaches protected from wave action consist of angular, shattered rocks. On the exposed beaches, i.e., the southern and eastern sides of Chisik and all of Duck Island, wave action grinds the rocks together, obliterating the angularity. Except for a few locations on the west side and a spit of marine origin at the north end, the beaches of Chisik lie directly at the feet of the cliffs. At many points the water at high tide covers the beaches and stands well up the base of the cliffs. At others, especially on the east side of the island, the cliffs rise directly from the water. Thus it is not possible to travel far afoot on the beaches at high tide, and in some parts of the island not at all. Overland travel is prevented by sheer cliffs and the heavy tangle of vegetation. Boat travel is the only means of access to study areas.

The island shelters Tuxedni Channel from the storms of Cook Inlet, thereby furnishing the only deep water harbor on the west side of the Inlet. This has become known as Snug Harbor. About 1.6 km (1 mile) north of the southern point of Chisik on its west side within Snug Harbor, lies one of the few locations where the cliffs of Chisik do not rise directly from the beach. On this site stand the structures of the Snug Harbor Packing Company. Originally razor clams *Siliqua patula patula,* and later salmon *Oncorhynchus* spp were processed, but since the season of 1970 no processing has occurred here. Nevertheless, the packing company remains the focus of all activities normal to such an establishment, including the purchase of fish. Processing occurs at a plant on the east side of the Inlet. North of this site about 0.8 km (0.5 miles) is another location where the cliffs do not rise directly from the beach. At this location the packing company formerly stored piling used for fish trap construction, now forbidden by State law. We established our camp at this location. About 4.8 km (3.0 miles) farther north three similar sites are occupied by wooden structures housing fishermen and their families. Several shacks and tents occupy the flat, triangular spit at the north end. No structures exist on the east side of the island, and none on Duck Island. With the exception of a watchman at the packing company these structures are not normally occupied in winter.

In the season of salmon fishing, numerous locations around Chisik Island and one on Duck Island are occupied by fixed gill nets. These are floating nets set perpendicular to the beach where they are attached at one end and to a buoyed anchor at the other. On the east side of Chisik three such nets were set in the open water about a mile south of Duck Island. State fisheries regulations prescribe the dates and hours when salmon fishing may be conducted. In 1978 this was usually Mondays and Fridays between 0600 and 1800 hours. During the early part of the season, late June and early July, numerous fishing boats anchored in Snug Harbor on non-fishing days and at night. Their idle crews came ashore and walked the beaches during those periods when tide levels permitted.

The tide range at Snug Harbor is 7.65 m (25.1 ft.), semi-diurnal in character with considerable difference in the levels of successive lows and highs. Which is to say that higher highs are substantially higher than lower highs, and the same is true for the higher and lower lows. Such extreme tides create strong currents in the Inlet, and in many locations a tide rip. One such rip exists just outside the southern end of Chisik in certain conditions, and one known as the "middle rip" lies approximately half way between Chisik Island and Anchor Point on the east side of the Inlet. Rips can be expected in Cook Inlet associated with any abrupt change in depth.

Climatalogical data for the west side of Cook Inlet are unavailable for points south of Tyonek (Evans et al. 1972), but certain comparisons with the east side can be instructional. H.W. Searby, Chief Climatologist for the National Weather Service in Anchorage (Evans et al. 1972) expressed his opinion that for comparable latitudes precipitation on the west side of the Inlet is about 50 percent higher than on the east. Thus an estimate for Snug Harbor, based on converting the record for Homer [58.6 cm (23.08 inches) total precipitation, 140.7 cm (55.4 inches) snow] becomes 87.8 cm (34.6 inches) including 211.0 cm (83.1 inches) snow.

Local residents indicated that summer precipitation varies from year to year. Our record of 45 days of rain in 110 days for a total of 48.89 cm (19.25 inches) was regarded by the residents as a wet summer (see Table 1). However, Detterman and Hartsock (1966) reported a storm 11 August 1958 in which 18.54 cm (7.3 inches) of rain fell in eight hours. The total rainfall for the 24 hour period of that storm was 28.47 cm (11.21 inches) accompanied by high winds. Winter snowfall is reported to be about three meters (ten feet). Snarski (1971) reported Chisik Island under a heavy mantle of snow when he arrived 14 May 1971, and that most of the island remained under snow for several weeks. His record of only ten precipitation-free days between 14 May and 21 June was rather wetter than our twenty-one for the same period in 1978.

Table 1. Summary of the weather record 18 May - Sept. 1978 at Snug Harbor, Alaska.

	Temperature in C. (F)		Precip. in cm (inches)	Days of rain
	Mean low	Mean high		
18-31 May	4.2 (39.6)	13.2 (55.7)	0.55 (2.18)	6
June	6.5 (43.7)	15.9 (60.6)	1.25 (4.92)	10
July	8.0 (46.4)	17.6 (63.7)	1.98 (7.8)	19
August	8.2 (46.7)	16.9 (62.5)	0.98 (3.85)	11
1-4 Sept.	5.0 (41.0)	21.1 (70.0)	0.13 (0.5)	1

METHODS

Jones and Petersen spent 207 days in the field between 16 May and 4 September: Petersen 108, Jones 99. In addition Dr. Patrick Gould and Mr. Gerald Sanger each participated three days.

We marked with painted numbers 91 kittiwake nests in the colony on the south end of Chisik Island, and examined these nests every three days. Rain, which rendered the cliffs and beaches too slippery for safe working conditions sometimes necessitated changes in the schedule. From Duck Island we observed 64 kittiwake nests located on a sea stack adjacent to the Island. These we observed on a five day rotation schedule when weather and tide conditions permitted. We recorded productivity on the sea stack; and productivity, growth and feeding habits in the marked nests. We weighed and measured twelve chicks (all that became available in the 91 marked nests) at three day intervals until they disappeared from the nests. When chicks regurgitated food samples we collected these.

The horned puffin colony is situated on Duck Island. There we measured and marked with paint and flags ten plots, each five meters square, and located all the active puffin burrows in each. We marked 35 burrows (not all within the ten plots) on the Island and examined them at five day intervals for chronology, productivity and growth rates.

We recorded chronological events relating to common murres and glaucous-winged gulls *Larus glaucescens* on Duck Island. The murres nested in fair numbers, the gulls as scattered pairs. In addition, a gull colony occupied the cliff at our campsite. Thus we were afforded ample opportunity for incidental observations of these species. Others were noted as they came to our attention.

Nine transects across lower Cook Inlet provided information concerning distribution and abundance of foraging birds. In four transects we employed a 5.2 m (17 ft) MonArk work boat between the harbor at Homer and Anchor Pt., thence across the Inlet to the southern end of Chisik Island, or return. The dates for these were 16 May, 3 and 4 August, and 4 September. In the most favorable conditions the boat can run at 25 knots, but such conditions prevailed only on the crossing of 4 August. On the other three we accomodated to fog and rough water generated by a combination of wind and syzyganous tides. We counted birds continuously and referred the counts to successive short time intervals. On five other occasions we crossed the Inlet as a passenger in a light aircraft, noting concentrations or the lack thereof en route. Three of these flights followed the same general route of the boat transects between Chisik Island and Anchor Pt., thence over land to Homer. The other two followed a course via Kalgin Island north to Kenai.

RESULTS

BLACK-LEGGED KITTIWAKE

Nesting distribution and abundance

Kittiwakes nest primarily on the south end of Chisik Island with smaller groups nesting on the mainland portion of Tuxedni Channel, the eastern portion of Chisik Island and on Duck Island (Figure 3). Estimates of the number of birds present on the Tuxedni Wilderness indicate about 28,000 birds, although counts of birds on photographs exposed during the 1978 nesting season may yield a more current estimate of numbers.

Breeding phenology

The first kittiwakes arrived on the nesting area 13 March 1978. (Richard Baldwin pers. comm.), slightly earlier than reported for Chisik Island in previous years (Table 2). We found birds on the colony when we arrived 16 May 1978, and they occupied the cliff areas continuously during the breeding season. All birds did not appear to be on the nesting area at all times, although continuous observations of individual nests was impossible.

Kittiwakes began building nests on 22 May, gathering nest material from the grassy slopes of Chisik Island and exposed tidal mud flats. Nest building activity continued throughout the breeding season, although most of this activity was observed during the egg-laying period.

Eggs were first observed in nests on 10 June, and continued to appear in nests until 30 June. Most clutches (66%) were initiated 12 to 24 June. No second clutches were observed or suspected, although adult females were not marked and may have laid replacement clutches in other nests.

As eggs hatched in few clutches, data are insufficient to determine a modal hatching period. The first egg hatched 6 July, and the last hatched 25 July, but eggs would have been hatching to 28 July if all eggs had survived to hatching.

The fledging time of black-legged kittiwake chicks is difficult to determine without continuous observations of marked nests (Coulson and White 1958), but two chicks apparently fledged by 23 August at 42 and 45 days of age respectively.

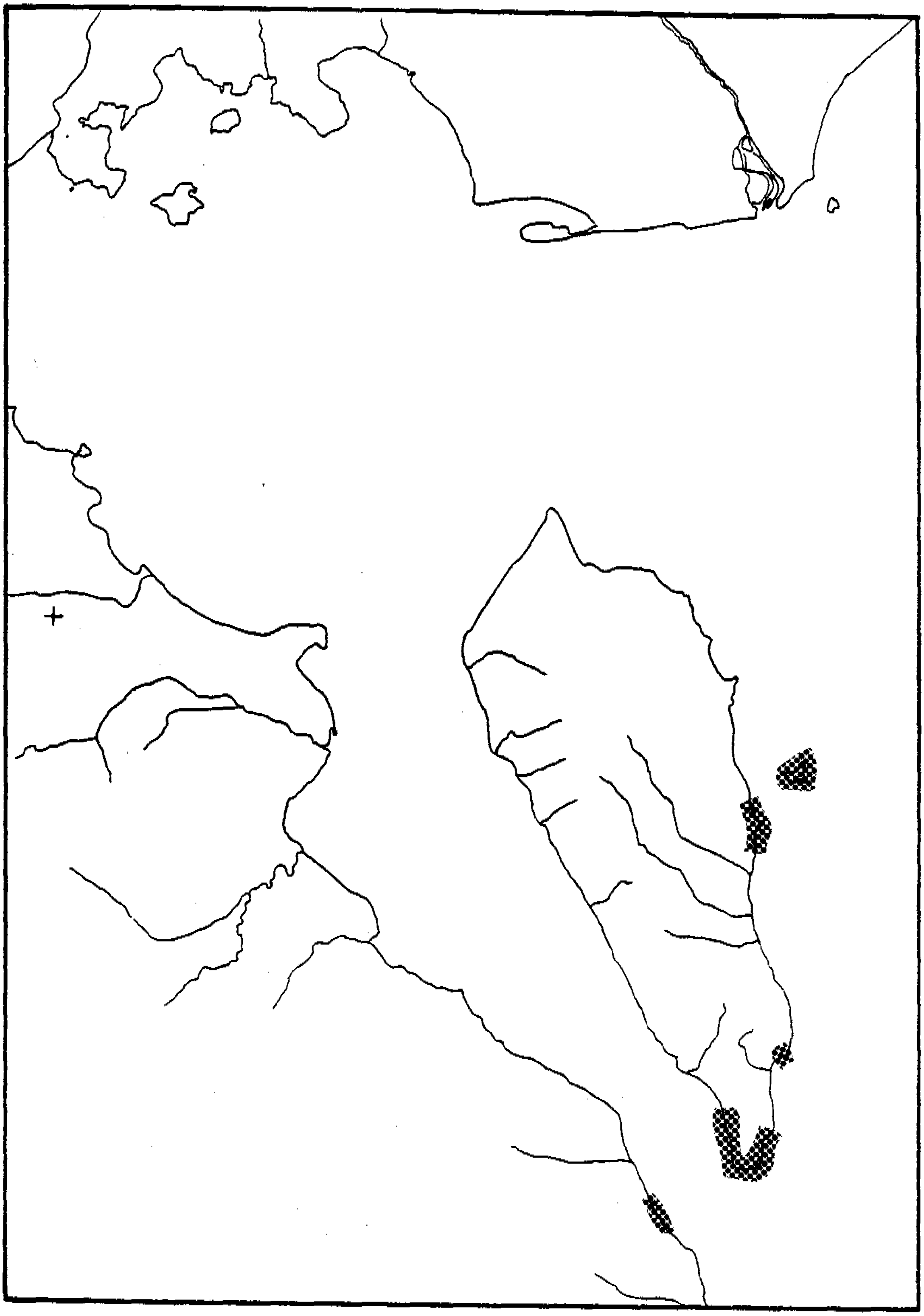

Figure 3. Nesting distribution of black-legged kittiwakes - 1978.

Table 2. Breeding phenology of black-legged kittiwakes.

	Date			
Event	1970[1]	1971[1]	1973[1]	1978
Arrival	17 Mar	27 Mar		13 Mar
Nest building initiated	1 Jun	17 Jun		22 May
Egg laying	19 Jun- 5 Jul	27 Jun- 10 Jul	<30 May>	10-30 Jun (N=110)
Modal egg laying (2/3 pop.)				12-24 Jun
Hatching	18 Jul-?	26-29 Jul	<27Jun>	6-25 Jul (N=16)
Fledging	none	none	<7 Aug>	23 Aug

[1]D.J. Snarski 1970, 1971 and Unpubl. Ms.

Productivity

Productivity of black-legged kittiwakes at Chisik Island in 1978 was poor; only 0.015 young were raised per pair on the colony. This was similar to that for 1970 and 1971 when no young survived (Table 3). The year 1973 remains our only record of "normal" or good productivity.

The rate of nest loss in 1978 was the same for the incubation stage and the nestling stage ($\chi^2 = 2.251$, 1 *df*, $P > 0.05$) (Table 4). We chose Mayfield's (1975) method for calculating nest success, not because of difficulty in finding kittiwake nests, but because of difficulty maintaining continuous observations. According to this method the probability of a kittiwake pair laying eggs and successfully raising one or more young to fledging date in 1978 was estimated at 0.081. We estimated that only 74.8% of the pairs present on the colony laid eggs, hence the probability of any pair on the colony producing fledged young was low.

A larger percentage of pairs laid eggs in 1978 than in 1971, and on average, more eggs were laid in each nest in 1978 than in 1971. But in none of the years studied has the average clutch size reached what Coulson and White (1958) showed to be "normal" for kittiwakes in similar latitudes in British waters.

Table 3. Reproductive success of black-legged kittiwakes.

	Date			
Event	1970[1]	1971[1]	1973[1]	1978
Nests with eggs/nest built		.50		.748 (N=147)
Mean clutch size	1.71 ±0.066 (N=49)	1.27 ±0.052 (N=24)		1.56 ±0.048 (N=115)
Clutches with one or more eggs hatching				25.5% (N=102)
Mean brood size at hatching				1.15 ±0.074 (N=26)
Broods with young fledging	0.0%	0.0%		7.7% (N=2)
Mean brood size at fledging	0.0	0.0	1.5	1.0 (N=2)
Young fledged from eggs laid	0.0% (N=83)	0.0% (N=94)		1.1% (N=179)
Mean number of young raised per pair	0.0	0.0 (N=148)		0.015 (N=137)

[1]D.J. Snarski 1970, 1971 and Unpubl. Ms.

± = standard error

Table 4. Mortality rates of black-legged kittiwake eggs and young - 1978.

	Avg. mortality rate for period[1]	Calculated no. of nests lost[2]	Calculated no. of nests surviving[2]
Incubation	0.743	42.3	14.6
Brood raising	0.919	14.7	1.3

[1]Calculated according to Mayfield (1975).

[2]Calculated according to Dow (1978).

Food habits

Adult kittiwakes fed their chicks almost exclusively fish, with only a trace of Crustacea identified in the regurgitation samples (Table 5). Pacific sand lance *Ammodytes hexapterus* is by far the single most common fish fed to chicks as expressed in both aggregate percent volume and percent frequency of occurrence. Similarly adult kittiwakes collected in 1971 ate predominantly sand lance (Snarski Unpubl. Ms.).

Blackburn (1978) suggests that Pacific sand lance are the most common small fish in lower Cook Inlet, with 0, 1 and 2 the predominant age classes captured in sampling gear. Of the samples collected as regurgitations from kittiwake chicks, 21 sand lance were sufficiently intact to permit estimates of length. Of these, 20 were in age 1 class (83 to 116 mm) and one in age 2 (127 mm).

Feeding flocks were rarely observed at or near Chisik Island and were not observed on any of four transects conducted in a small boat between Chisik Island and Anchor Point. Further observations are necessary to determine the feeding areas used by kittiwakes.

Table 5. Foods delivered to black-legged kittiwake young - 1978.

Species	Aggregate % volume	% Frequency of occurrence
Pisces	99.85	100.0
Ammodytes hexapterus	62.15	69.23
Mallotus villosus	10.00	15.38
Theragra cahalcogramma	3.85	7.69
Unidentified pisces	23.85	30.77
Crustacea	0.15	15.38
Thysanoessa inermis	0.08	7.69
Unidentified crustacea	0.08	7.69

N = 13 samples

Growth

The sample size is insufficient to justify many conclusions regarding the growth rates of black-legged kittiwake young. Apparently the young kittiwakes on Chisik Island grew slowly the first week, grew at a more normal rate thereafter, and probably reached fledging date later than "normal" chicks (Figure 4).

The growth rates of the successful and unsuccessful chicks appear different (Figure 5), but again, data are insufficient to make meaningful statistical comparisons. Possibly the slow overall growth rate reflects the retarded rate of those chicks receiving insufficient food to survive.

HORNED PUFFIN

Nest distribution and abundance

Horned puffins nest in a colony along the rubble slopes of Duck Island, and as scattered individuals along the cliffs of Chisik Island (Figure 6). No puffins nested on the alder covered slopes of Duck Island, nor on the active rubble slopes of Chisik Island.

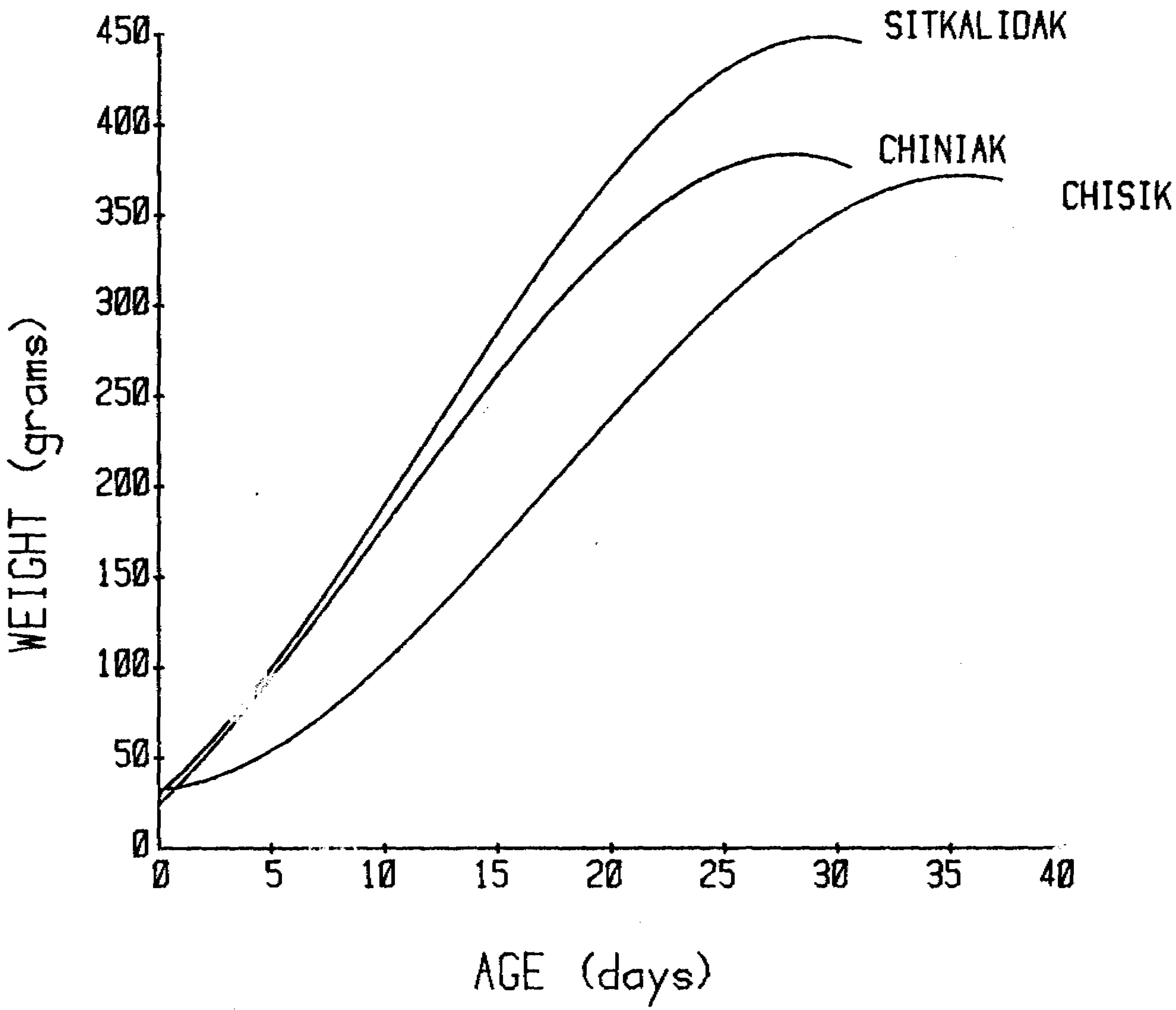

Figure 4. Growth curves of black-legged kittiwake chicks at Chiniak Bay, Sitkalidak Straits, and Chisik Island - 1978.

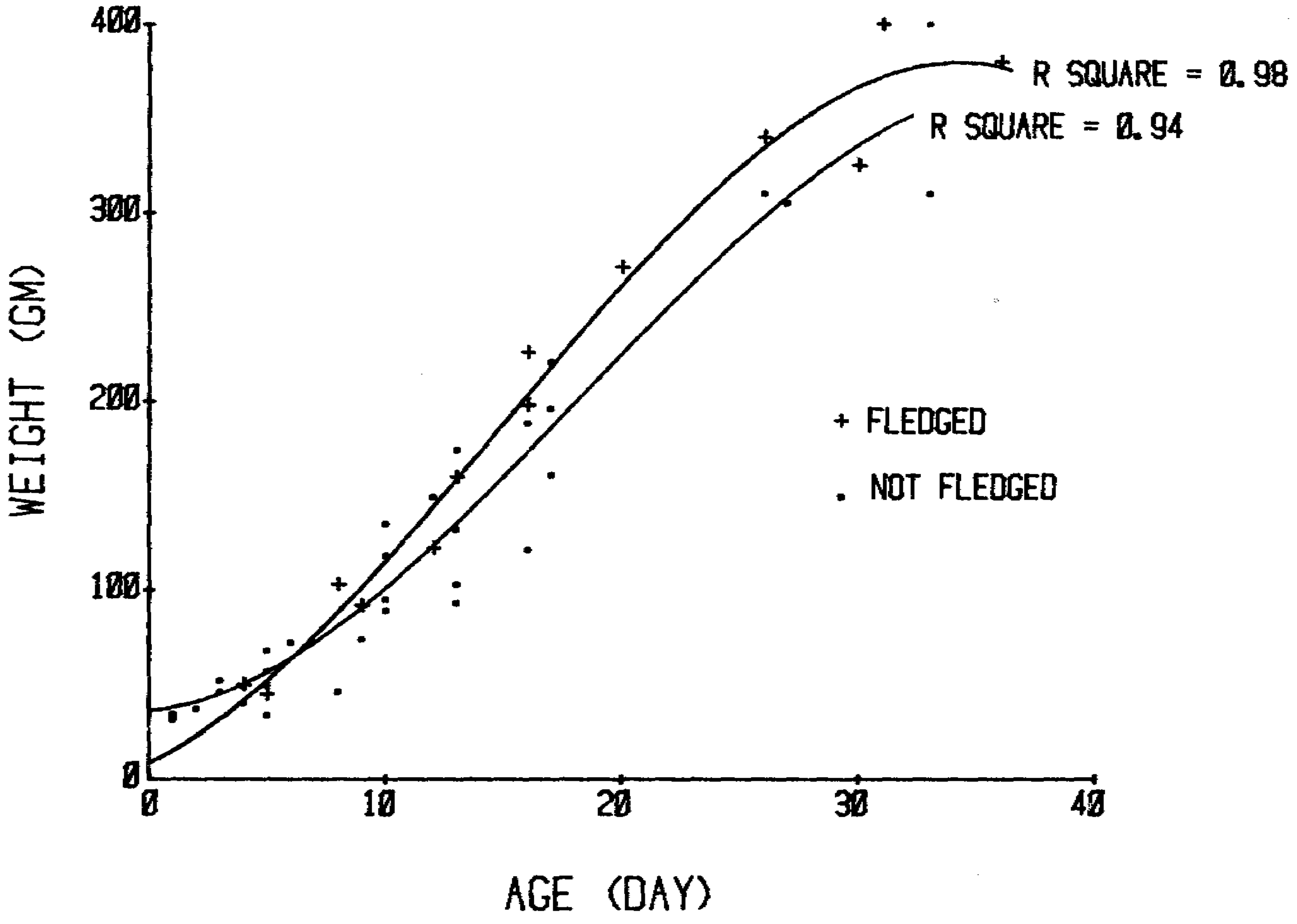

Figure 5. Growth curves of successful and unsuccessful black-legged kittiwake chicks at Chisik Island - 1978.

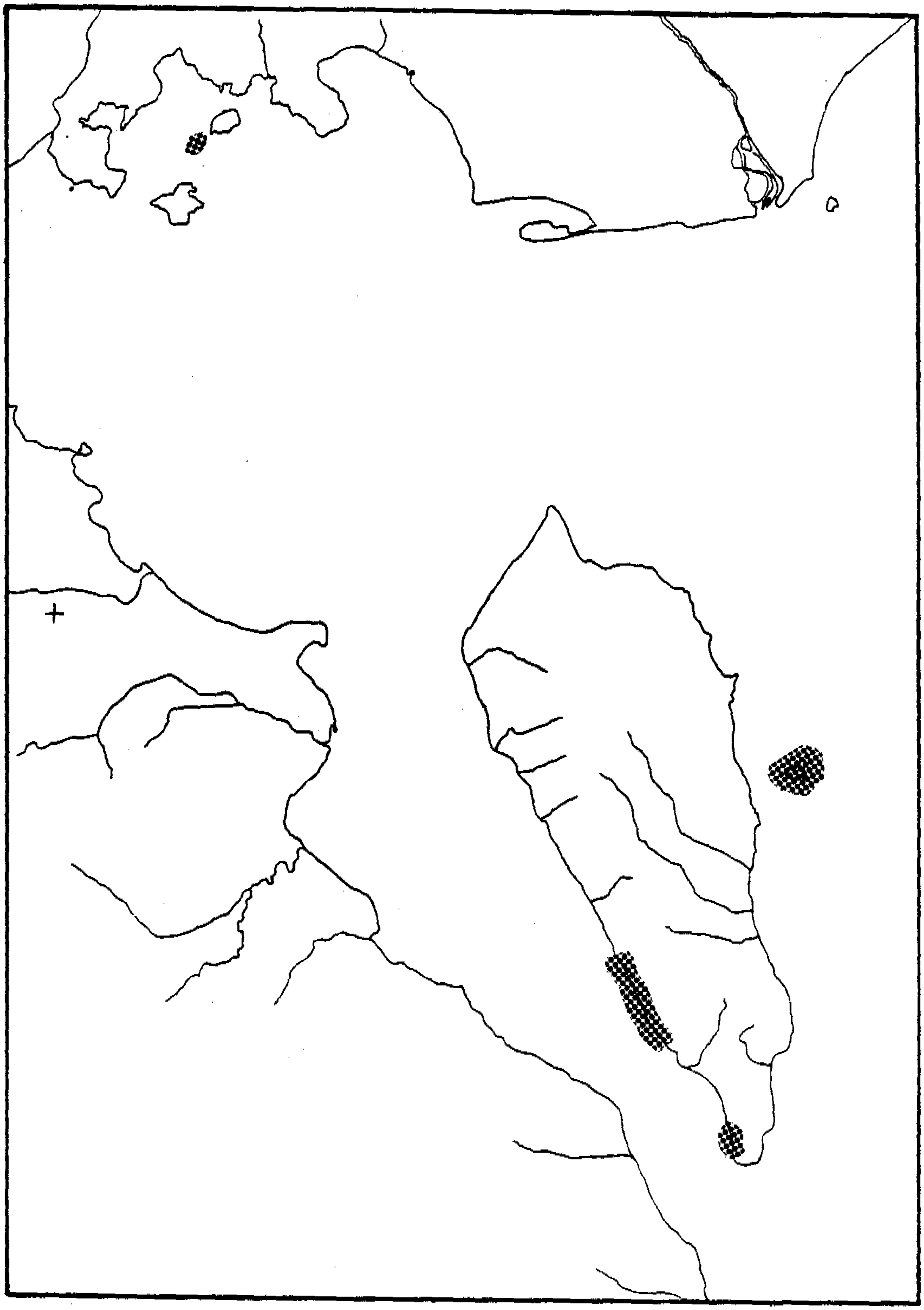

Figure 6. Nesting distribution of horned puffins - 1978.

Burrows in 10 plots averaged 0.18±0.04 per square meter (range 0.04 to 0.44 burrows/m^2). We believe the plots represent the most common puffin densities and habitat, although the sample size is insufficient to project a population estimate for the entire colony on Duck Island.

Phenology

Horned puffins began laying eggs 5 June and continued until 29 June, with 66% of the females laying eggs 10 to 23 June (Table 6). Hatching occurred over a 40 day period beginning 18 July, with 66% of the eggs hatching over a 7 day period 19-26 July.

Four young left their burrows 28 August to 2 September at 37 to 44 days of age, and nine young (38 to 46 days of age) were still in burrows 2 September. Seven of those nine young completed primary growth by 2 September, and probably left their burrows soon thereafter. Two young, ages 25 and 33 days on 2 September should have reached fledging 11 and 19 September. Thus fledging probably extended from 28 August to 19 September.

Table 6. Nesting phenology of horned puffins - 1978.

Event	Sample size	Date
Egg laying	29	5 - 29 June
Modal egg laying (2/3 pop.)		10 - 23 June
Hatching	23	18 July - 27 Aug
Modal hatching		19 - 26 July
Fledging	20	28 Aug - 19 Sept

Productivity

Most puffins (96.7%) establishing burrows on the study plots in the spring laid eggs with an average clutch size of 1.00 egg (Table 7). Slight egg loss occurred on the study plots; one egg apparently rolled out of its burrow very early in incubation, two eggs were either infertile or the embryo died while very young, one egg disappeared from the burrow, and embryos in two eggs died one to two days before hatching. Later examination of these two revealed the yolk sac to be almost completely absorbed. Eighteen of the 24 eggs (75.0%) on the study plots hatched.

In a sample of 26 young, three (11.5%) did not survive to fledging. These three disappeared from their burrows at about 3.5, 4 and 24 days of age (± two days). Fate of these young could not be determined, although we suspected that the older one may have moved into an unreachable arm of the burrow system.

Again we chose Mayfield's (1975) method for calculating nest success, this time because not all burrows were discovered at inception. We calculated the probability of the nestling surviving to fledging as 0.845, hence an overall probability of success from newly laid egg to fledged young as 0.578. Eggs and nestlings survived equally well, there being no significant difference between calculations of survival and losses of both eggs and young ($\chi^2 = 1.708$, 1 *df*, $P > 0.05$) (Table 8).

Food habits and feeding areas

The single most important food item brought to the chicks as expressed in occurrence (100%) and volume (100%) was the Pacific sand lance. Of the hundreds of fish observed in the bills of adults and found at burrows, all were sand lance.

Adult puffins did not forage for food near Chisik Island, although they frequently occurred in rafts on the water near the colony. They seemed to be distributed as scattered individuals or in groups of up to four individuals offshore. This was the pattern we observed across lower Cook Inlet during all four transects conducted in a boat. Recently fledged young (nine individuals) were only found offshore in the Inlet as scattered individuals. Presumably both adults and young forage primarily offshore in waters 50 to 100 meters in depth.

Growth

Horned puffin chicks grew at what is probably a normal rate for the species. The growth curve suggests an early period of rapid weight gain followed by one of slightly depressed gain (Figure 7) corresponding with the period of primary feather development at day 16.

Table 7. Reproductive success of horned puffins - 1978.

		Sample size
Pairs laying eggs on sample plots	96.7%	25
Mean clutch size	1.00	29
Clutches with eggs hatching	72.7%	29
Broods with young fledging	92.3%	26
Mean number of young raised per pair on sample plots	0.60	25

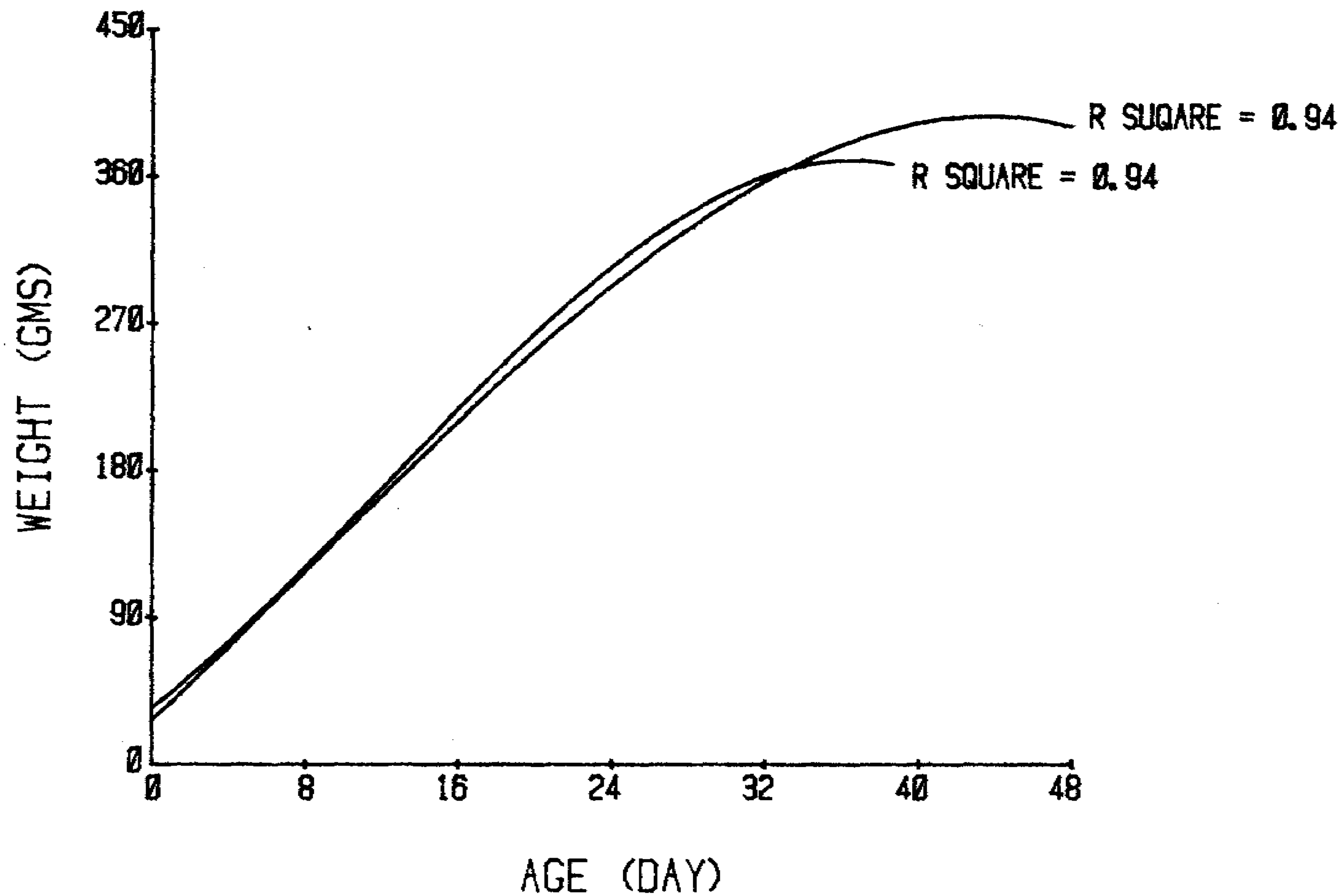

Figure 7. Growth curves of horned puffin chicks at Chisik Island in 1978 and at Ugaiushak Island in 1976 (Wehle 1977).

Table 8. Mortality rates of horned puffin eggs and young - 1978.

	Avg. mortality rate for period[1]	Calculated no. of nests lost[2]	Calculated no. of nests surviving[2]
Incubation	0.316	7.9	17.1
Brood raising	0.155	3.6	19.4

[1] Calculated according to Mayfield (1975).

[2] Calculated according to Dow (1978).

COMMON MURRE

Nesting distribution and abundance

Murres nested on the cliffs of Chisik Island and the slopes and cliffs of Duck Island (Figure 8). Lack of continuous observations of sample plots precluded any reliable estimates of density and abundance of common murres. Possibly 10^4 murres were present on the Tuxedni Wilderness in 1978.

Phenology

Common murres were present in the waters adjacent to Duck and Chisik Islands when we arrived 16 May, and intermittently on the colonies until 29 June when the first egg was observed. The first chicks hatched 10 August and left the cliffs by 2 September at 18 to 23 days of age.

Production

Production of murres could not be estimated with any degree of accuracy. Eggs laid early appeared to have experienced a high loss rate, as glaucous-winged gulls were occasionally seen carrying murre eggs.

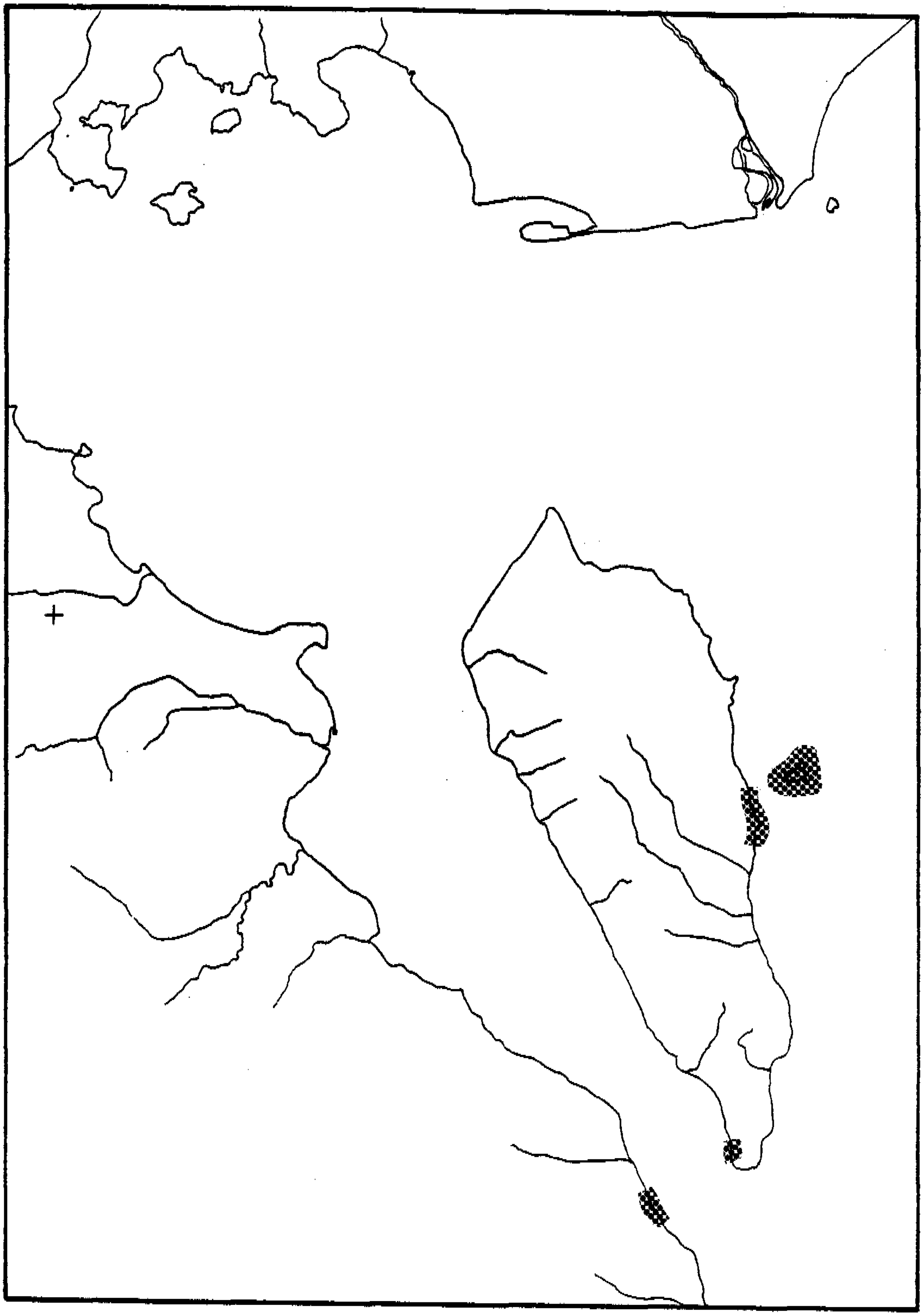

Figure 8. Nesting distribution of common murres - 1978.

Feeding areas

Murres were never observed feeding near the colonies. Birds were frequently seen on the water in dense flocks near the colonies but were never observed feeding. Murres in groups of up to seven individuals were frequently seen on the water in the course of the small boat transects across Cook Inlet. On 4 September seven groups of one adult and one chick were encountered in the open Inlet. Murres encountered at sea are presumed to have been feeding, but more observations of feeding birds are needed.

GLAUCOUS-WINGED GULL

Nesting distribution

Glaucous-winged gulls nested on the cliff faces of Chisik Island, the grassy slopes of Duck Island, and on small, mammal free islands in Tuxedni Bay (Figure 9). Most nests were inaccessible to human observers, and densities could not be accurately estimated. Possibly 2,000 gulls were present in Tuxedni Bay in 1978.

Nesting phenology

Glaucous-winged gulls were on nesting territories when we arrived 16 May, and the first eggs were laid 18 May. Most birds were incubating eggs by 27 May, and the last nests were probably initiated around 1 June, as no new nests were observed thereafter on the cliff face at our camp. The first young fledged 28 July, and the last left the cliffs 27 August. All of the adult birds and almost all of the young had left the Tuxedni Wilderness by 29 August 1978.

DISCUSSION

FACTORS AFFECTING PRODUCTION

Food

Snarski (1970, 1971) reported two reproductive failures of Chisik Island kittiwake colonies, and we report herein a third. He suggested poor food availability as a possible underlying cause, and the evidence we gathered favors the same conclusion. Dement'ev and Gladkov (1969) observed diminished fertility in kittiwakes as a function of reduced food availability. This took the form of reduced clutch size: a mean of 1.6 in a year of low food availability contrasted with 2.3 in a good year. Egg production of the Chisik colonies in 1970, 1971 and 1978 yielded mean clutch sizes of 1.71, 1.27 and 1.56 respectively, and of these, few hatched. Drury (1977) observed poor egg production in a Norton Sound colony of kittiwakes and ascribed this to inadequate food resources in near-shore waters.

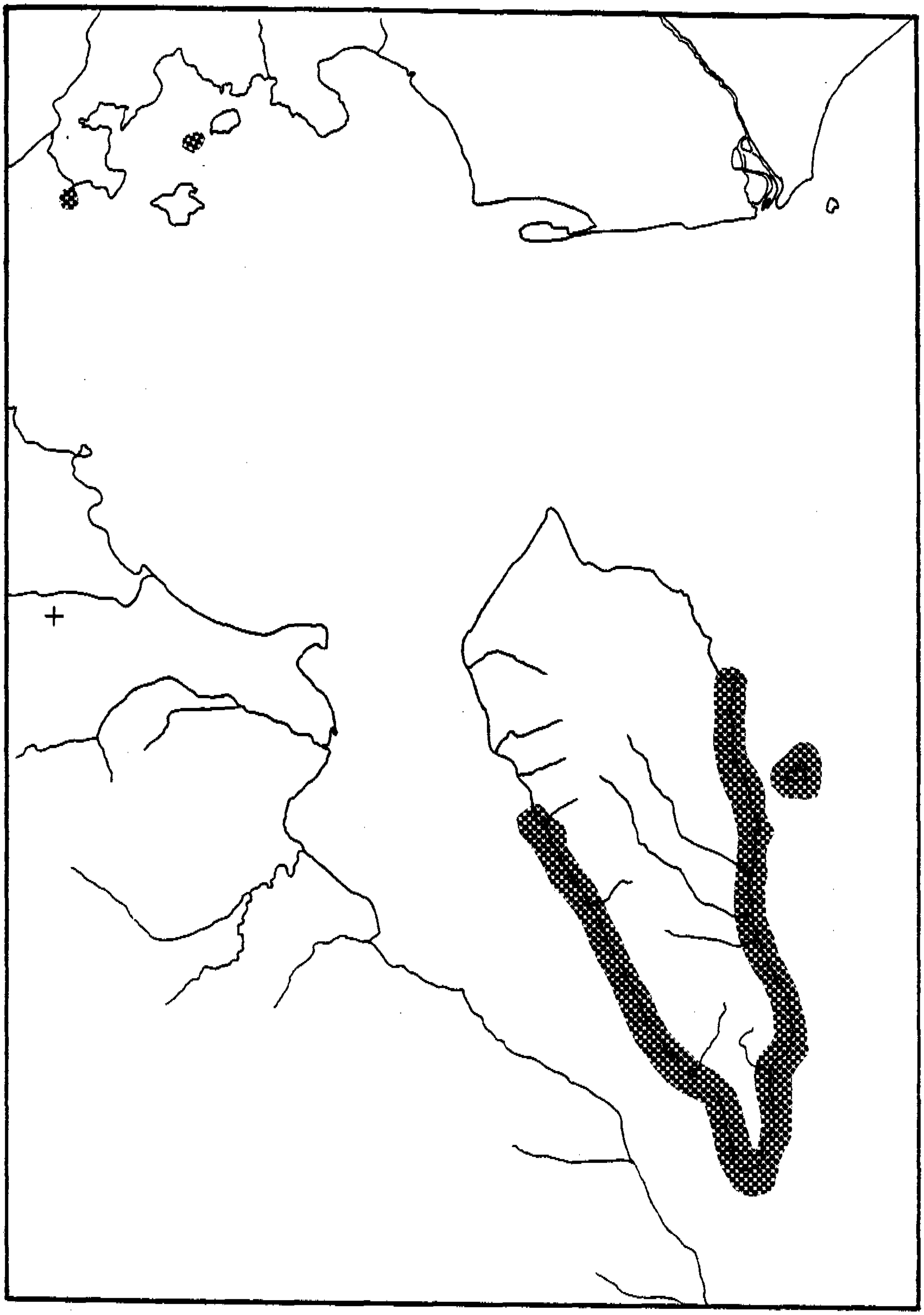

Figure 9. Nesting distribution of glaucous-winged gulls - 1978.

Twenty five and a half percent (see Table 3) of the kittiwake eggs hatched in 1978, a hatching rate much below colonies undergoing expansion (Coulson and White 1958), and the subsequent survival and growth rates of these few nestlings seemed below average. We felt intuitively that they were undernourished. Later, when data from other colonies could be compared on the basis of growth curves it became apparent that the Chisik chicks developed slowly, and reached the point of fledging at a lighter weight (Figure 4).

Drury (1977) describes kittiwake feeding as typically in melees or "feeding frenzies" at no great distance from the colony. No such melee occurred within our view in 1978, either near the colony or in our several crossings of the Inlet by boat and light aircraft. We did observe kittiwakes far from the Chisik colony on all these crossings, and on the most favorable (distinguished by calm winds and an absence of fog) observed them feeding as individuals. But there is no assurance these were Chisik birds.

The Pacific sand lance constituted the major food item for the Tuxedni Wilderness kittiwakes and the sole food for its horned puffins in 1978 (see discussion under RESULTS). Little is known of this small fish, but Blackburn (1978) studied its distribution in lower Cook Inlet. He found it the numerically predominant fish species caught in beach seine and tow net hauls in all major areas sampled in the Inlet, but that the species "displayed a complex pattern of abundance by location and time, . . . and an unusually great variability." He expressed his view that the sand lance always appears in schools and that there are areas in which the species is absent. In a personal communication he suggested that, on the basis of his collections in 1976 and summer 1978, the nearshore areas on the west side of lower Cook Inlet do not constitute good sand lance habitat, but then added that the birds could probably shed more light on sand lance distribution than could scientific collecting.

More is known of the Atlantic species of *Ammodytes* than *A. hexapterus*, the Pacific form. McIntosh and Masterman *in* Pearson (1968) found *A. lanceolatus* and *A. tobianus* performing migrations in British waters from the middle layers, where they spend the winter, to the surface layers and inshore in late April and May. Sealy (1975) suggested that an onshore migration of *A. hexapterus* had occurred in British Columbian waters in early June when mixed assemblages of seabirds began taking them.

We regard the success of the horned puffins in capturing *A. hexapterus* as evidence of their presence near Tuxedni Wilderness in at least fair abundance. We do not know how far the puffins go to find them, but we found sand lance buried in the sandy substrate of an extensive tide flat that begins four miles north of the colony and continues several miles farther north. This tide flat is occupied by a very large stock of razor clams which indicates the existence of large lower trophic level food resources in the water column. We regard the absence of knowledge concerning the behavior of this fish a major failure in the effort to understand the ecology of lower Cook Inlet. Indeed, this may be said of all OCS areas in Alaska.

Predation and disturbance

In mixed seabird colonies such as those on Duck and Chisik Islands, glaucous-winged gulls exhibit marked predatory behavior (Gabrielson and Lincoln 1959). We estimate the population of these gulls in Tuxedni Bay to number about 2,000 birds. They choose nesting sites among those of the kittiwakes on Chisik and Duck Islands in addition to other areas on Chisik and other islands in the Bay. During the years in which the Snug Harbor Packing Company processed clams or salmon the gull population received a subsidy of offal from the cannery. Personnel of the company report "glaucous gluttony" and Snarski (1970) notes the same. Both cannery personnel and Snarski agree that there was no comparable utilization of the offal by kittiwakes. It appears that the gull population expanded in these circumstances, but has not declined since withdrawal of the subsidy in 1971. This agrees with the behavior of large-gull populations in the Atlantic Ocean off the New England States and Atlantic Provinces. There, according to William Drury (OCS Vertebrate Ecology Workshop, 17-19 Oct., 1978 Fairbanks, AK), though waste management has been brought under control in the last two decades, the large-gull populations have merely stopped growing but not returned to "natural" levels.

Disturbances which cause the attending kittiwake adult to leave its nest create the circumstances in which gulls may take eggs or chicks. The colonies on the Tuxedni Wilderness are exposed to disturbance by several activities. Natural ones include the activities of bald eagles *Haliaeetus leucocephalus*, common ravens *Corvus corax*, and occasional other Falconiformes. Of these a family of peregrine falcons *Falco peregrinus* with an eyrie across Tuxedni Channel from our campsite proved the most disturbing. Eagles rarely appeared at the colonies, and only twice appeared to be in active pursuit of kittiwakes. Cannery personnel reported mobbing of eagles by kittiwakes, but we did not observe this. The falcons made daily forays to the colony south of the cannery, and though we did not compile records of their take, it seems likely to have been at least one kittiwake daily. Their arrival at the south face of the cliff, the center of the colony, invariably provoked a massed flight of kittiwakes. The falcons actively pursued the latter while the glaucous-winged gulls continued flying along the cliff face in full view of the now exposed nest contents. Unfortunately, the sheer cliff at this point rises to 500 feet and most of the action takes place near the top. The nearly vertical angle of observation from the beach prevented us from seeing the actions of the gulls. Ravens also soared along the cliffs in these circumstances, and occasionally the falcons pursued them but without success. This appears to be a form of recreation on the part of both ravens and falcons, but meanwhile the nests of the kittiwakes lay exposed to the gulls.

Our appearance on the colony beaches elicited a similar response from kittiwakes nesting on the lower cliff levels. Our presence did not produce the sustained disturbance of the falcon, and did not affect the higher levels, but for a time numerous nests were exposed. Some of the set-net fishing sites mentioned earlier lie under the colonies, and during salmon fishing days the fishermen appear at these sites frequently, creating the same kind of disturbance. A few birds, most commonly the divers, were caught in the set-nets.

Early in the summer supersonic aircraft passed over the Wilderness, producing two sharp, loud booms each time. The effect was startling, and had it continued into the kittiwake incubation period might have caused exposure of their eggs to predation. The most consistently disturbing activity on the Tuxedni Wilderness arises from its location on the flight path for all aircraft flying up or down the west side of the Inlet. Most disturbing of these are helicopters which, perhaps because of the pulsing sound produced by the flying machine, are extremely disturbing to birds. Several operated in the vicinity of Snug Harbor, while numerous others travelled up and down the coast all summer. One, Evergreen N59440, landed on a beach in the center of the colony at 1835 hours on 13 August. Five persons wielded geologists hammers on the rocks of the cliff for a time, and then the machine proceeded south after thoroughly disturbing the entire colony.

Numerous light aircraft pass back and forth over the Tuxedni Wilderness, but unless they are close to the colonies do not appear to disturb the kittiwakes. Fixed-wing, especially light, aircraft can approach the colonies much more closely without disturbance than can helicopters. Generally, experienced pilots prefer to give such masses of birds a wide berth.

We did not study these factors in detail. Indeed, the significance of disturbance in relation to the large numbers of glaucous-winged gulls present among the nesting kittiwakes only became clear when the nesting season was well advanced. We noted that fledging kittiwake chicks were very vulnerable to gull predation. This was true for newly fledged glaucous-winged gull chicks as well, though they were more successful in evading the attack of an adult gull than the kittiwake fledglings. It appears that a lone kittiwake chick in its early flight experience is doomed to gull predation if it alights on the water.

Horned puffins proved less responsive to disturbance factors than the kittiwakes, though a sudden departure of puffins signalized our arrival by boat on the Duck Island beach. Normalcy, or at least what we perceived as normalcy, returned to their activities much more promptly than in the case of the kittiwakes. Moreover, since the puffin chicks lie hidden in a burrow they are not exposed by the adult's absence to gull predation. The feeding strategy of puffins no doubt springs from this choice of nest sites, allowing both adults to forage simultaneously. The unescorted departure of the chick at its time of fledging, however, would make it vulnerable to predation but for the fact that the gulls' chicks have fledged and the gulls have departed the colony (Figure 10).

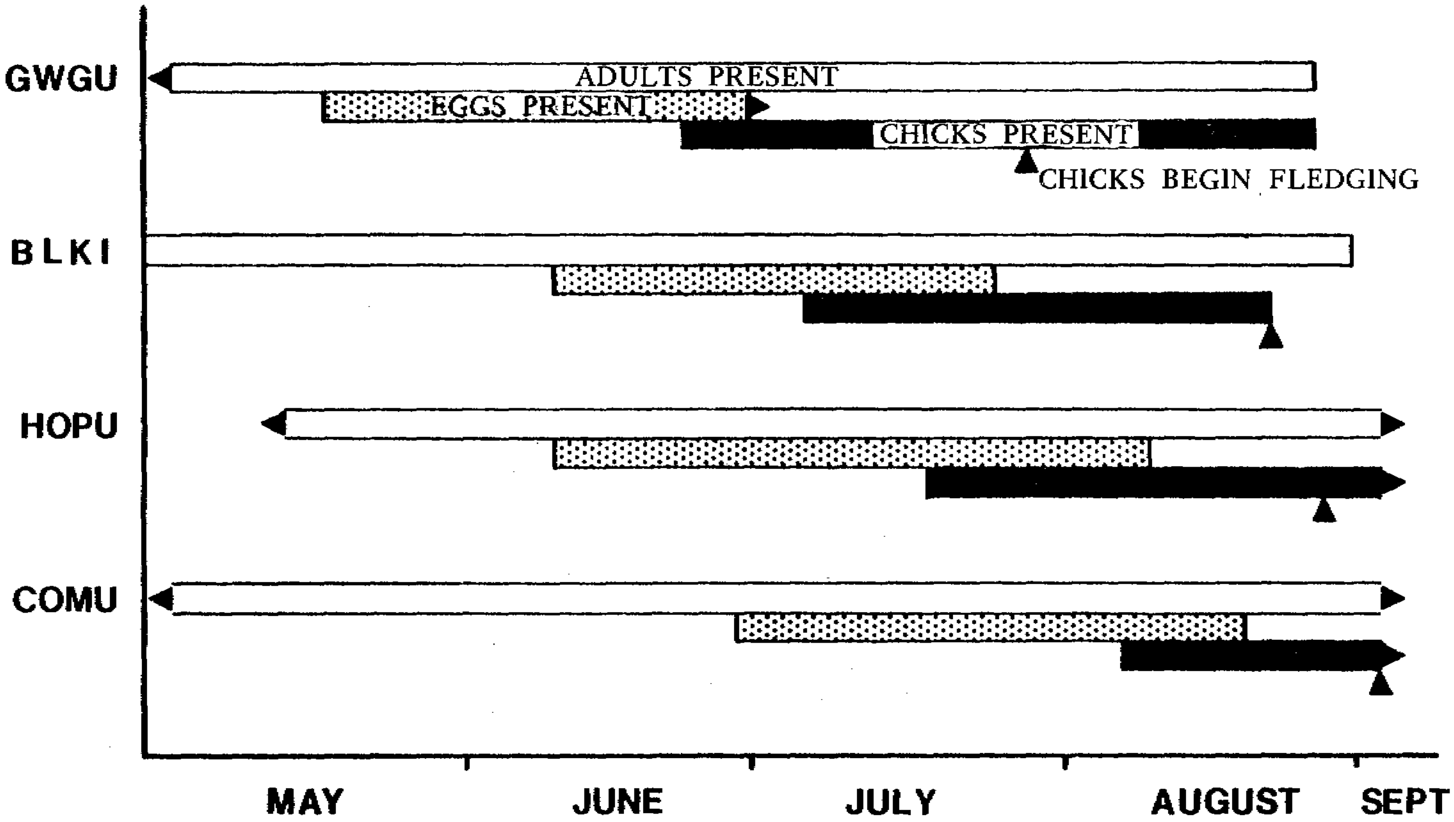

Figure 10. Nesting chronology of seabirds at Chisik Island - 1978.

Figure 10 illustrates the adaptive strategy of common murres to gull predation on the Tuxedni Wilderness. Egg laying commenced in late June and continued desultorily until in mid-July as if by prior agreement; the entire breeding population laid eggs and immediately undertook close incubation. By this time the glaucous-winged gull chicks were approaching the point of fledging. When the murre eggs began to hatch and chicks appeared in the colony, the gulls were essentially gone.

Ectoparasites

Ticks of the genus *Ixodes* appeared on horned puffin chicks, usually on the head. Their effect seemed negligible, but we made no quantitative determination.

In the major kittiwake colony at the south end of Chisik Island we encountered fleas of the genus *Ceratophyllus*, probably *C. niger*. Dr. Glenn Haas of the Alaska Dept. of Health and Social Services is preparing specimens we collected for identification.

Our experience with these insects was personally unpleasant since they jumped to our clothing and attacked us. As the pest is quite small and rather mobile, we carried them around on our clothes for a day or more before we identified the source of multiple irritating bites. After that we examined our clothes carefully after each contact with a kittiwake nest, and destroyed the parasites that had transferred from the nest to us. We were not completely successful in preventing further annoyance because of the pests' ability to hide in seams, hems and folds of clothing. We are at pains to relate our own experience as an indicator of what may be a substantial problem to the nest-bound chick. We are aware of no work to measure the consequences of such parasitism, but we suggest the potential exists for considerable impact. As an example, Petersen laid her gloves beside a kittiwake nest while weighing and measuring its occupant. After returning to the beach she collected fourteen fleas from the gloves.

Distribution of these insects proved quite uneven. We found none on Duck Island, either in kittiwake or horned puffin nests, while in the main kittiwake colony at the south end of Chisik, most nests produced them, but in variable numbers.

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APPENDIX I. Annotated species list: Aves.

In conjunction with studies of seabirds on the Tuxedni Wilderness observers have kept notes concerning the distribution, abundance and general items of interest on all birds inhabiting the Wilderness and adjacent areas. Observations reported here are restricted to those birds seen in nearshore waters of Chisik Island, Duck Island, Tuxedni Bay and Channel, and adjacent lands and islets.

Observers were present 25 May to 9 August 1970 and 14 May to 8 September 1971 (Snarski 1970, 1971), and 16 May to 4 September 1978 (R.D. Jones, Jr. and M.R. Petersen). As none of the observers have been in the area during the early spring, late fall and winter, notes on birds present in those periods are from persons living at the Snug Harbor Packing Company buildings.

SPECIES

Common loon *(Gavia immer)* - This species has been observed occasionally in Tuxedni Channel (2 and 22 June, and 22 July 1971 and 21 August 1978) and near the east side of Chisik Island 28 August and 2 September 1978).

Arctic loon *(G. arctica)* - Arctic loons were observed only once in 1978 (10 June), once in 1970 (25 June), and on four occasions in 1971 (3 and 22 June, 2 and 25 July). All observations were on the east side of Chisik Island or in Tuxedni Channel.

Red-throated loon *(G. stellata)* - Loons were observed on six occasions in Tuxedni Bay (18, 22, 29 June, 10, 27 July, and 15 August 1978). Loons have also been observed near the Johnson River in July 1970 and August 1971.

Red-necked grebe *(Podiceps grisegena)* - This grebe was observed in Tuxedni Channel only in 1971 (18 May, 22 June and 2 July), and not observed in 1970 or 1978.

Horned grebe *(P. auritus)* - A bird was occasionally seen diving in Tuxedni Channel (18-20 July, and 10 August 1978), and noted present on 20, 21 and 30 May 1971.

Shearwater *(Puffinus* sp.*)* - A common bird in the Inlet and occasionally seen in Tuxedni Channel (25 May and 30 July 1978).

Double-crested cormorant *(Phalacrocorax auritus)* - A common nesting species on the cliffs of Chisik Island, and locally on the slopes of Duck Island. Young were produced in all years except 1971. In 1978 eggs were laid about 21 May, and the first volent young were observed on the shores of Chisik Island on 27 July.

Pelagic cormorant *(P. pelagicus)* - This species is variable in abundance in the Tuxedni area from year to year. A fairly common nesting species in 1970; one nest was found in 1971; two nests were found in 1973 and no nests were found in 1978. Only seven birds were observed in 1978.

Swan *(Olor* sp.*)* - Swans were apparently a fairly common breeder in the marsh-pond area near Tuxedni Bay in 1971. No swans were observed in 1978.

Canada goose *(Branta canadensis)* - Canada geese were observed in small flocks over Tuxedni Channel and in Tuxedni Bay in 1970, 1971 and 1978.

Brant *(Branta bernicla)* - A flock of black brant *(B. b. nigricans)* was seen near Duck Island 6 June 1971 and one bird was present on Duck Island on 12 and 13 August 1971.

White-fronted goose *(Anser albifrons)* - One flock was observed 15 May 1971 near Chisik Island.

Mallard *(Anas platyrhynchos)* - A commonly encountered duck on the mud flats of Chisik Island and Tuxedni Bay. A flock of 109 birds was observed 18 June 1978 on the mud flats in Tuxedni Bay, and 12 flightless birds were encountered on 27 July 1978 in Tuxedni Bay.

Pintail *(A. acuta)* - A common duck found on the mud flats of Chisik Island and Tuxedni Bay in all years. A flock of 133 birds (more than 75% male) was observed in Tuxedni Bay on 18 June 1978.

American widgeon *(A. americanas)* - A common duck found in Tuxedni Bay during all years May to August.

Northern shoveler *(A. clypeata)* - Shovelers were seen only once (August 1971) along Tuxedni Channel.

Green-winged teal *(A. crecca)* - Teal were observed several times May to August in 1970, 1971 and 1978 in Tuxedni Bay.

Greater scaup *(Aythya marila)* - A common bird found in Tuxedni Bay in all years. A flock of 200 to 300 birds (more than 90% male) was observed in Tuxedni Bay on 18 June 1978.

Common goldeneye *(Bucephala clangula)* - Goldeneyes were occasionally seen in Tuxedni Channel May and August 1971.

Harlequin duck *(Histrionicus histrionicus)* - Harlequin probably nest along the streams flowing into Tuxedni Bay. Birds were regularly encountered in Tuxedni Bay during 1970, 1971 and 1978.

Common eider *(Somateria mollissima)* - A common nesting bird on *Elymus* covered beaches and beneath the alder along the beaches of Chisik and Duck Islands. An estimated 100 - 150 pair nested in 1971, and an estimated 30 pair nested on Chisik Island in 1978. Young were commonly observed in 1970, 1971 and 1973, but not in 1978. In 1978 egg loss was heavy as few females incubated longer than a week before the eggs disappeared from the nests. Marten *(Martes americana)* are believed to be the primary predator of the eggs. Some birds apparently attempted to renest, but none was successful.

.ldsquaw *(Clangula hyemalis)* - A common sea duck in Tuxedni Bay 1-6 June 1971, but not observed in 1970 nor 1978.

Black scoter *(Melanitta nigra)* - The most common scoter observed in Tuxedni Bay (est. 300) during May 1978, and the least common scoter thereafter (only 25 to 50 birds seen).

White-winged scoter *(M. fusca)* A common scoter seen in Tuxedni Bay (est. 200 - 250 males) in June 1978. It was frequently encountered at the mouth of Tuxedni Bay near the Polly Creek clam beds, and on the east side of Chisik Island in 1978.

Surf scoter *(M. perspicillata)* - The most frequently observed scoter in 1970 and 1971, and the most common scoter observed in Tuxedni Bay (est. 1500 males) during June through August 1978. Probably most of the birds molted their primaries in Tuxedni Bay as 80% of the birds were flightless on 27 July and 18 August 1978.

Common merganser *(Mergus merganser)* - This ergานser was observed only once on 2 July 1971 near Snug Harbor in Tuxedni Channel.

Red-breasted merganser *(M. serrator)* Red-breasted mergansers were occasionally seen in Tuxedni Channel in 1970 and May 1971. Flocks of 12 and 25 birds were observed in Tuxedni Bay on 27 July and 18 August 1978, respectively.

Goshawk *(Accipiter gentilis)* - A single goshawk was observed once on Chisik Island on 2 and 3 September 1978, respectively.

Sharp-shinned hawk *(A. striatus)* - Two sharp-shinned hawks were seen on Chisik Island in August 1971.

Rough-legged hawk *(Buteo lagopus)* - This hawk was seen infrequently near the cliffs of Chisik Island in May and July 1978.

Red-tailed hawk *(B. jamaicensis)* - A Harlan's hawk *(B. j. harlani)* was observed 23 May 1971 over Chisik Island.

Bald eagle *(Haliaeetus leucocephalus)* - A common species observed throughout the seasons of 1970, 1971, and 1978. Two active nests were found on the mainland near Chisik Island in 1970 and 1971, and two nests were found on the mainland portion of Tuxedni Channel in 1978.

Osprey *(Pandion haliaetus)* - A single bird was observed over Tuxedni Channel on 6 June 1971.

Gyrfalcon *(Falco rusticolus)* - Single gyrfalcons were seen occasionally in the vicinity of the gull and kittiwake colonies on Chisik Island in 1970 and 1971, and on 25 July and 17 August 1978.

Peregrine falcon *(F. peregrinus)* - Peregrine falcons were occasionally observed near the cliffs of Chisik Island in 1970 and 1971, and frequently seen in 1978. A pair may have nested in previous years on the cliff on the northwest side of Chisik Island (Joe Munger pers. comm.), and did nest on the mainland side of Tuxedni Channel in 1978. One young was produced in 1978. Birds were observed stooping on ravens, gulls and kittiwakes, and seen carrying kittiwakes and a magpie.

Merlin *(F. columbarius)* - Two individuals were observed at Chisik Island on 4 September 1971, and several individuals were seen at the mainland during July 1970 and August 1971.

Spruce grouse *(Canachites canadensis)* - One grouse was seen at the north end of Chisik Island in a spruce tree on 27 May 1970.

Willow ptarmigan *(Lagopus lagopus)* - Ptarmigan were commonly found atop Chisik Island in 1970 and 1971. The area was not visited during the nesting season in 1978 and no birds were observed.

White-tailed ptarmigan *(L. leucurus)* - Birds were seen on 15 and 16 May 1971 atop Chisik Island.

Sandhill crane *(Grus canadensis)* - A single crane was seen flying over Tuxedni Channel on 29 May 1971.

Black oystercatcher *(Haematopus bachmani)* - Oystercatchers were common breeding birds on the rocky beaches of Chisik and Duck Islands in 1970, 1971 and 1978. One nest with two young and one egg was found 16 June 1978 on Duck Island. One pair raised three young at the southeast tip of Chisik Island in 1971. Possibly four to eight pairs nest on the Tuxedni Wilderness.

Semipalmated plover *(Charadrius semipalmatus)* - Plovers were commonly seen during spring migration in 1970 and 1971, and commonly encountered along the sand-gravel beaches of Chisik Island in 1970 and 1971. Only one bird was observed 11 August 1978 at Chisik Island.

Whimbrel *(Numenius phaeopus)* - This species was observed on three occasions in 1971 along the mainland portion of the beach of Tuxedni Channel.

Spotted sandpiper *(Actitis mocularia)* - A common bird observed on the beaches of Chisik and Duck Islands during all years. It may nest on Chisik Island.

Wandering tattler *(Heteroscelus incanum)* - A shorebird frequently encountered along the beach on the western portion of Chisik Island (1970, 1971 and 1978), and on the beaches of Duck Island (1970 and 1971). It may nest on Chisik Island.

Greater yellowlegs *(Tringa melanoleucus)* - Yellowlegs were seen 3-18 July 1970 and 15-18 May 1971 on Chisik Island. None was observed in 1978.

Lesser yellowlegs *(T. flavipes)* - Krohn (1966) reported lesser yellowlegs feeding near Snug Harbor. None was observed in 1970, 1971 or 1978.

Short-billed dowitcher *(Limnodromus griseus)* - Dowitchers were seen on the mud flats of Chisik Island 18-25 May 1971.

Surfbird *(Aphriza virgata)* - This species was occasionally observed along the beaches of Chisik Island in 1971. Only one bird was seen in 1970 (24 July), and none in 1978.

Black turnstone *(Arenaria melanocephala)* - A flock of twenty-five turnstones was seen on the beaches of Chisik Island on 25-28 August 1971. None was seen in 1970, and only one on 13 July 1978.

Dunlin *(Calidris alpina)* - One dunlin was observed on Chisik Island on May 1971.

Baird's sandpiper *(C. bairdii)* - Baird's sandpiper was a common species seen during spring migration 14-22 May 1971.

Least sandpiper *(C. minutilla)* - This sandpiper was a common shore-bird seen on spring migration 15-24 May 1971.

Semipalmated sandpiper *(C. pusillus)* - Semipalmated sandpipers were an occasional spring migrant in 1971.

Western sandpiper *(C. mauri)* - A common sandpiper seen during spring migration 14-30 May 1971, and an occasional summer visitant on the mud flats of Chisik Island in mid-July 1970 and 1971.

Northern phalarope *(Lobipes lobatus)* - Phalaropes were occasionally seen in Tuxedni Channel May - August 1970, 1971 and 1978. Concentrations of these birds were frequently encountered in all years during the fall migration.

Common snipe *(Capella gallinago)* - Snipe were observed at a wet area on Chisik Island in 1970 and 1971.

Parasitic jaeger *(Stercorarius parasiticus)* - Two birds were seen once in Tuxedni Bay (25 May 1978), and one bird was seen in Cook Inlet during two of four small boat surveys (3 August and 4 September 1978).

Pomarine jaeger *(S. pomarinus)* - This species was not seen in the Tuxedni Wilderness, although it may occasionally occur there as birds were seen in Cook Inlet.

Glaucous gull *(Larus hyperboreus)* - A sub-adult was seen in the vicinity of the cannery on June 1970 and 8 August 1978.

Glaucous-winged gull *(L. glaucescens)* - This gull was a common breeding bird on the cliffs of Chisik Island, and on the top of Duck Island and other small islands in Tuxedni Bay. Nesting success is variable as almost no young were produced in 1971, contrasted to many in 1978.

Mew gull *(L. canus)* - This gull probably nests in the marsh areas adjacent to Tuxedni Bay, and was frequently seen throughout the summer in Tuxedni Bay and Tuxedni Channel during all years. Volent young were seen on 22 July 1978.

Franklin's gull *(L. pipixcan)* - An adult Franklin's gull was observed and photographed 14-18 May 1971 at Snug Harbor.

Bonaparte's gull *(L. philadelphia)* - This species was seen only in 1970 and 1971 along the west side of Chisik Island and near Fossil Point.

Black-legged kittiwake *(Rissa tridactyla)* - The kittiwake is the most abundant species of bird on the Tuxedni Wilderness. The primary nesting area is on the cliffs of the south and east portions of Chisik Island, and on the cliffs of Duck Island and along Tuxedni Channel.

Arctic tern *(Sterna paradisaea)* - Terns were observed along Tuxedni Channel 18 May to 3 June 1971, and in Tuxedni Bay 22 June and 6 July 1978.

Aleutian tern *(S. aleutica)* - One adult Aleutian tern was seen in Cook Inlet on 16 May 1978.

Common murre *(Uria aalge)* - Murres are a common nesting alcid on the south and east cliffs of Chisik Island, on Duck Island, and on the cliffs near the mouth of Tuxedni Channel.

Pigeon guillemot *(Cepphus columba)* - Pigeon guillemots may be declining in numbers on the Tuxedni Wilderness. Krohn (1966) reported guillemots as "very abundant" in 1966, and Snarski similarly reports them as "common" in 1970. Guillemots were less common in 1971, and only one pair was noted on the southeast part of Chisik Island in 1978. Only about a dozen pairs were found in Tuxedni Bay in 1978.

Horned puffin *(Fratercula corniculata)* - A very common puffin nesting in a dense colony on Duck Island, and scattered along the cliffs of Chisik Island and small islands in Tuxedni Bay.

Rhinoceros auklet *(Cerorhinca monocerata)* - One pair of birds was reported at Duck Island by Tom Diaz and Robert Bright in 1970. Bright reported seeing one bird enter a burrow. No rhinoceros auklets were seen in 1971 and 1978.

Marbled murrelet *(Brachyramphus marmoratum)* - Murrelets were seen in 1970 by Tom Diaz, and found in 1971 and 1978 in Tuxedni Channel and Tuxedni Bay. Birds were observed primarily July and August 1971 and May to September 1978. The first volent young was observed 14 August 1978.

Kittlitz's murrelet *(B. brevirostre)* - Kittlitz's murrelets were seen in Tuxedni Bay during August 1971.

Parakeet auklet *(Cyclorrhynchus psittacula)* - Four, six, and 25 birds were seen at Duck Island in 1970, 1971 and 1978 respectively. One bird incubating an egg was found on 12 August 1971, and one fledged 16 to 22 August 1978.

Rock dove *(Columba livia)* - The domestic pigeon arrived at Snug Harbor in June 1978. Survival was very poor, with most birds killed by falcons within a week of the pigeons arrival. All injured and dead birds had been banded with pigeon fanciers' bands and identifying codes. The origin of the pigeons is still being traced, but it is suspected that they were released by fishermen living in the area during the fishing season (June through August).

Great horned owl *(Bubo virginianus)* - This species was never observed during 1970, 1971 or 1978, although it may occur in the spruce stands on the north end of Chisik Island (Joe Munger pers. comm.).

Short-eared owl *(Asio flammeus)* - Owls were commonly seen 14-28 May 1971 atop Chisik Island.

Rufous hummingbird *(Selasphorus rufus)* - Joe Munger reported seeing hummingbirds in previous years.

Belted kingfisher *(Meyaceryle alcyon)* - One kingfisher flew by our camp on 27 August 1978.

Downy woodpecker *(Picoides pubescens)* - This species is apparently common in the spruce stands and alder covered slopes of Chisik Island. One nest with young was found July 1971 in a spruce stub.

Northern three-toed woodpecker *(P. tridactylus)* - One bird was found in a spruce stand on Chisik Island on 27 May 1970.

Say's phoebe *(Sayornis saya)* - This bird was seen at Chisik Island on 4 September 1971.

Traill's flycatcher *(Empidonax traillii)* - Flycatchers were common in the alders on Chisik Island in 1970 and 1971, but none was observed in 1978.

Cliff swallow *(Petrochelidon pyrrhonota)* - Cliff swallows were occasionally seen foraging near Chisik Island, and were a common breeding bird on the cliffs over the water in Tuxedni Bay.

Violet-green swallow *(Talchycineta thalassina)* - This bird was fairly common on Chisik Island in 1970 and 1971, but was not observed in 1978.

Tree swallow *(Iridoprocne bicolor)* - A common nesting bird in the cannery buildings and in nest boxes set up by local fishermen.

Bank swallow *(Riparia riparia)* - This species was occasionally observed on Chisik Island in 1970 and 1971. It was not seen in 1978.

Black-billed magpie *(Pica pica)* - Magpies were occasionally seen near Snug Harbor (1970 and 1971), and along the cliffs on the west side of Chisik Island (1978). One bird was captured by a peregrine falcon on 3 September 1978.

Common raven *(Corvus corax)* - Ravens were commonly observed along the cliffs of Chisik Island, Duck Island and in Tuxedni Bay. Two nesting localities were found on Chisik Island in 1971.

Black-capped chickadee *(Parus atricapillus)* - Chickadees were occasionally seen at Chisik Island during August 1971.

Dipper *(Cinclus mexicanus)* - Dippers were found along streams and waterfalls on Chisik Island. They were common in 1970, found along two streams in 1971, and seen only once near a waterfall in 1978.

Brown creeper *(Certhia familiaris)* - Five brown creepers were seen in a spruce tree on the north end of Chisik Island on 5 August and 4 September 1971.

American robin *(Turdus migratorius)* - Robins were found nesting near Snug Harbor in 1970, and were seen occasionally 15 May to 5 June and August 1971. Dick Baldwin reported the first robin of 1978 on 10 May.

Varied thrush *(Ixoreus naevius)* - This thrush was seen and heard in the cottonwood stands on Chisik Island in 1970 and 1971, but not in 1978.

Hermit thrush *(Catharus guttata)* - A common breeding thrush in the alder thickets of Chisik Island. Volent young appeared 1-19 June and 13-29 July 1978 on the beaches of Chisik Island. Thrushes were commonly observed 16 May to 29 July 1978.

Swainson's thrush *(C. ustulata)* - This thrush was commonly observed along the cliffs and beaches of Chisik Island 29 May to 5 June, and 22 July to 21 August 1978.

Gray-cheeked thrush *(C. minima)* - This uncommon thrush was observed along the cliffs on the west side of Chisik Island 19 May, 8 June and 13-31 July 1978.

Golden-crowned kinglet *(Regulus satrapa)* - An uncommon species seen 2-7 September 1971.

Ruby-crowned kinglet *(R. calendula)* - This kinglet was found in the spruce stands on Chisik Island in 1970 and 1971.

Water pipit *(Anthus spinoletta)* - This bird was commonly found in the revegetated slide areas along the slopes of Chisik Island in 1970, 1971 and 19 May to 18 July 1978.

Bohemian waxwing *(Bombycilla garrulus)* - Waxwings were found on Chisik Island 25 May 1970 and 19-20 June 1971.

Northern shrike *(Lanius excubitor)* - Shrikes were never observed in 1970, 1971 or 1978, but were reported to occur in some years on the island (Joe Munger pers. comm.).

Orange-crowned warbler *(Vermivora celata)* - A common warbler found in the alder thickets atop Chisik Island in 1970 and 1971.

Yellow warbler *(Dendroica petechia)* - Yellow warblers were common in the alder thickets 24 May to 31 August 1978 and 1970 and 1971.

Yellow-rumped warbler *(D. coronata)* - The myrtle warbler *(D. c. coronata)* was commonly seen near Snug Harbor in 1970 and 1971.

Blackpoll warbler *(D. striata)* - A single bird was seen on 28 June 1978 in a cottonwood thicket on the west side of Chisik Island.

Northern waterthrush *(Seiurus noveboracensis)* - Waterthrushes were occasionally observed along a creek above Snug Harbor in 1970.

Wilson's warbler *(Wilsonia pusilla)* - A common warbler found in the alder thickets of Chisik Island May through August 1978 and in 1970 and 1971.

Rusty blackbird *(Euphagus carolinus)* - A common bird found on the mainland August through September, and occasionally seen on Chisik Island in 1971.

Pine grosbeak *(Pinicola enucleator)* - Pine grosbeaks were observed occasionally in 1970, a few times in 1971 (16-19 May and 2 September), and once in 1978 (17 July).

Gray-crowned rosy finch *(Leucosticte tephrocotis)* - This species occurs irregularly at Chisik Island. It was not observed in 1970, nested in 1971 and not observed in 1978.

Common redpoll *(Carduelis flammea)* - Redpolls were very common on Chisik Island in all years. In 1978 they were present in flocks 22 June to 24 August.

White-winged crossbill *(Loxia leucoptera)* - This bird was seen only once in July 1971 in a spruce stand on Chisik Island. Possibly this species is more common in the extensive spruce stands on the mainland portion of Tuxedni Bay.

Savannah sparrow *(Passerculus sandwichensis)* - The common sparrow found in the grassy areas of Chisik Island during the summers of 1970, 1971 and 1978.

Dark-eyed junco *(Junco hyemalis)* - The slate-colored junco *(J. h. hyemalis)* was encountered infrequently at Chisik Island on 27 May 1970, 29 June to 5 July and 2-3 September 1971 and 1 June and 10 July 1978.

White-crowned sparrow *(Zonotrichia leucophrys)* - This sparrow was uncommon in all years, and was found along the north and west shores of Chisik Island.

Golden-crowned sparrow *(Z. atricapilla)* - A very abundant bird at the edge of the alder on Chisik Island throughout the summer in all years.

Fox sparrow *(Passerella iliaca)* - A commonly encountered bird in the alder on Chisik Island in 1970 and 1971, but rarely seen in 1978.

Song sparrow *(Melospizia melodia)* - The most conspicuous small bird on Duck Island, and frequently found in the alders of Chisik Island in all years.

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REPRODUCTIVE ECOLOGY OF SEABIRDS AT MIDDLETON ISLAND, ALASKA

by

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Abstract

Studies of population, breeding phenology, productivity, and food habits of seabirds were conducted on Middleton Island from 22 April to 18 August, 1978. Particular emphasis was placed on the breeding phenology of seven species, on the productivity of Black-legged Kittiwakes and Pelagic Cormorants, and on the foods brought to nestling Kittiwakes, Rhinoceros Auklets and Tufted Puffins. Recent increases in the populations of several species may be responsible for the widespread use of unusual nesting habitat and for wide variation within the colony in both breeding phenology and reproductive performance. On the whole, breeding phenology of seabirds at Middleton Island was extraordinarily early and protracted relative to other colonies in the Gulf of Alaska. Likewise, contrasts were found between the food habits of Puffins and Kittiwakes at Middleton Island and the diets of these species elsewhere in the Gulf of Alaska.

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I. INTRODUCTION

Middleton Island lies about 50 miles southeast of Montague Island and 70 miles from the Alaskan mainland (Figure 1). The island harbors the largest colonies of several species of seabirds in the north-central Gulf of Alaska. It is situated almost directly in the path of the main Alaska Current and directly downstream from potential oil drilling or pumping operations. For these reasons, Middleton Island is deemed to be a site of key importance for baseline environmental study in the region.

Seven species of seabirds are known to breed on Middleton Island. In order of abundance these are: Black-legged Kittiwake (*Rissa tridactyla*), Common Murre *(Uria aalge)*, Pelagic Cormorant (*Phalacrocorax pelagicus*), Tufted Puffin (*Lunda cirrhata)*, Rhinoceros Auklet (*Cerohinca monocerata)*, Glaucous-winged Gull *(Larus glaucescens*), and Thick-billed Murre *(Uria lomvia)*. One additional species, the Red-faced Cormorant *(Phalacrocorax urile*), is a possible breeder. During our work, one bird was observed standing on a partially constructed nest, but breeding remains unconfirmed.

The main purpose of the work reported here was to obtain data on populations, breeding phenology, productivity, and food habits of breeding seabirds, with particular emphasis on the Black-legged Kittiwake. The writer (SAH) was on the island from 22 April until 18 May and from 6 July until 18 August. During his absence the observations were continued by Gould (19 May - 6 June) and by Pearson (7 June - 5 July), who also assisted until the completion of the field work on 18 August. Dr. Sam Patten conducted studies on the island from 19 May to 13 July, and the success of our work was enhanced by cooperation with him.

We are grateful to personnel of the Federal Aviation Administration (FAA) for providing our field party with comfortable living quarters on the island. We especially thank Messrs. Carl Bergstedt, Jim Leslie, Fred Sam, and Kevin Weaver for many favors and for helping to make our stay on the island an enjoyable one. Martha Wiley and Rena Wenkart performed the laboratory analysis of the food samples collected.

II. STUDY AREA

The geology of Middleton Island has been studied by Miller (1953), the vascular flora by Thomas (1957). Information on the avifauna is available in Rausch (1958), O'Farrell and Sheets (1962), and Frazer and Howe (1977). There are no land mammals indigenous to Middleton Island (O'Farrell 1965), but rabbits (*Oryctolagus cuniculus*) have populated the island since their introduction in 1954. Observations on weather from May to August 1978 are presented in Table 1.

The island is generally flat, the only relief being several steplike terraces ascending from east to west along its long axis. It reaches a maximum elevation of only about 130 feet on its southwest side. The Alaska earthquake of 1964 raised the island about 15 feet and exposed large areas of flat land previously under water. On the eastern, southern, and southwestern stretches of the coast, the distance between the sea cliffs and the present shoreline averages about a third of a mile. It is probably safe to say that most biologists viewing the island for the first time in winter would scarcely imagine that it supports large populations of cliff-nesting birds.

Presumably, the attractiveness of Middleton Island to seabirds lies in the oceanography of its surrounding waters. Two features may be particularly significant. First, the earthquake conceivably increased primary and secondary productivity in the immediate vicinity of Middleton Island by bringing a large area of submerged land close to the surface. Probably more important, however, is the fact that the island is located only 12 miles from the edge of the continental shelf. Deep water foraging areas and the productive zone associated with the continental slope are thus within easy range of birds breeding on Middleton Island. This is not the case at most other colonies in the Gulf of Alaska.

The habitats used by nesting seabirds on Middleton Island are portrayed in Figure 2. Habitat A consists of flat, marshy ground exposed during the 1964 earthquake. Scattered boulders, many of which are occupied by nesting kittiwakes, protrude above this surface. Numerous shallow ponds of fresh or brackish water are another important feature of habitat A.

Habitat B is a slope of soil or rubble at the base of the cliffs. The lower margin of this slope approximates the pre-earthquake shoreline around much of the southern end of the island.

Habitat C is a steep cliff surrounding the southern third of the island. Nowhere does this cliff exceed about 120 feet in height. It is composed of poorly consolidated marine sediments and is subject to relatively rapid erosion in many places.

Differing rates of erosion have resulted in a narrow ledge (habitat D) near the top of the cliff at the interface between sedimentary rock and an overlying layer of soil. Much of this ledge is constantly wet due to seepage.

Habitat E is the exposed margin of a layer of peaty soil which averages about four feet in thickness.

Habitat F comprises hummocky, grass-covered upland which, in the south-central portion of the island, is dotted with numerous mounds up to 20 feet in height.

In addition to the habitats provided by these physiographic features, birds also occupy the decks and rigging of the wrecked S. S. Coldbrook which grounded off the southwestern shore of Middleton Island in 1944.

The FAA supports a station on Middleton Island to maintain and operate an air navigation installation (VORTAC). Six people resided there during this study. The facility includes an airstrip, living quarters, and road system (Figure 3). The island is also the site of an abandoned air force base which was occupied from 1956 to 1965.

III. METHODS

1. Population Census

Frazer and Howe (1977) recognized five colonies of birds on Middleton Island and divided the entire breeding grounds into ten census areas with easily identifiable boundaries (Figure 4). Their scheme is followed here except that the whole population is regarded as one colony composed of five subcolonies.

Pelagic Cormorant and Black-legged Kittiwake

Censuses of these species were carried out concurrently on 7 days from 10 July to 20 July. Counts of all nests in each census area were made from the flats below the cliffs using 20-45x spotting scopes. The numbers of active and inactive nests were recorded separately. Active nests are defined as those containing eggs or chicks at the time of observation. Inactive nests were empty but may still have been attended by one or both adults.

Common and Thick-billed Murres

A count of all birds was made from the flats on 26 July. All nesting areas were delineated in photographs. The proportions of the two species in the population were estimated from the ratio of Common to Thick-billed Murres in the population of chicks leaving the cliffs in August.

Tufted Puffin

On Middleton Island, a count of puffin burrows is hampered by their scattered distribution and by the presence of rabbit burrows which are similar in appearance. A direct count of birds standing outside their burrows is the best alternative. Maximum numbers of birds are observed during the week or two just preceding egg-laying. Complete or partial counts of all birds were made from the flats on six days from 1 May to 15 May. There was considerable replication in these counts; only the largest count in a given segment of the colony was retained. The data give an indication of the minimum size of the population on Middleton Island and an impression of actual size.

Glaucous-winged Gull and Rhinoceros Auklet

No systematic censuses of these species were carried out. Data given by Frazer and Howe (1977) were supplemented or revised by partial counts of burrows or nests.

2. Breeding Phenology and Productivity

Pelagic Cormorant

A large proportion of the nests of Pelagic Cormorants on Middleton Island are easily accessible for study using a "hands-on" approach. There are, however, few vantage points from which nests can be observed from the tops of the cliffs without causing undue disturbance. Furthermore, only the odd nest here and there is located far enough below eye level to afford an easy view of its contents from above. Most observations of undisturbed study plots must therefore be made from the flats below the cliffs. From here the status of nests is not readily discerned until late in the nestling period.

Anticipating heavy predation by gulls on disturbed study plots, separate plots were used to gather information on breeding phenology, clutch sizes, and nesting success. A plot of 68 nests was established on 6 May and checked at 4-day intervals thereafter until the completion of egg-laying (plot A, Figure 4). Nests were identified with numbered stakes, and new eggs were marked with pencil as they appeared. Because of the level of disturbance on this plot, it provided data only on the dates of clutch initiation. To determine mean clutch size, 50 previously undisturbed nests were visited on 23 June, and the number of eggs or recently hatched chicks in each was noted (plot B, Figure 4). This date was chosen because most cormorants had completed their clutches, while few nests had reached the hatching stage

A third study plot of 102 active nests was established on 20 June and observed at intervals of 3 to 7 days until 15 August (plot C, Figure 4). These nests were observed from the flats using a spotting scope and care was taken never to flush the birds off their nests. The presence and number of adults, eggs, and chicks was noted on each visit insofar as this information could be determined.

Glaucous-winged Gull

All data on breeding phenology, clutch sizes, and hatching success of gulls were gathered in upland habitat south of the VORTAC site (Figure 4). Ninety nest scrapes were marked with numbered flags on 30 April and visited at 4-day intervals thereafter until hatching. Eggs were laid in only about a third of these nests, but additional nests with eggs were added as they were discovered while walking along a prescribed route. Egg-laying phenology was determined from observed laying dates or estimated from hatching dates.

Black-legged Kittiwake

Information on breeding phenology and nesting success of kittiwakes was obtained for 180 nests in three study plots (plots A, B, and C, Figure 4). Photographs were taken prior to egg-laying and the locations of 60 nests were marked on a black and white enlargement of each plot. Nests were checked every other day from 30 April to 16 August using a spotting scope from the top of the cliff. This procedure ensured that the breeding performance of kittiwakes was unaffected by human disturbance. Some additional information on phenology was obtained from a disturbed study plot at the south end of the island (plot D, Figure 4).

Common Murre and Thick-billed Murre

Data on the phenology of murres on Middleton Island is obtained most effectively during the fledging period under rather odd circumstances. Having left the ledges in a flightless condition, the chicks of these species must traverse about a third of a mile of flat, marshy ground before reaching the sea. This journey usually begins under cover of darkness, but many chicks do not reach the sea by morning. Those that do not spend the following day (or days) in any of several ponds dotting the flats below the cliffs. During this time, they are vocal, gregarious, and usually accompanied by an equal or greater number of adults.

About 400 such fledglings were easily captured, measured and banded during daily searches of the ponds from 26 July to 16 August. The numbers of new chicks arriving in the ponds each day provided some information on their survival after leaving the cliffs.

Observations of murres were attempted earlier in the season from a blind at the top of the cliff in census area 2, but did not prove to be worthwhile. There is probably no satisfactory way to observe directly the breeding habits of murres on Middleton Island without resorting to disturbance on the nesting ledges. Data on productivity obtained by such activity are all but meaningless.

Rhinoceros Auklet and Tufted Puffin

Breeding phenology of these species was determined by digging out burrows during the nestling stage and estimating the ages of the chicks encountered. Ages of auklets were estimated using the wing length-age relationship given by Leschner (1976). A similar relationship was derived for puffins using data collected at Middleton Island and in Sitkalidak Strait, Kodiak Island (P. A. Baird, pers. comm.).

No observations were made on the productivity of auklets or puffins. Although a thorough breeding study of Tufted Puffins would be possible on Middleton Island, the circumstances are such that an inordinate amount of disturbance and loss of production in other species, especially Pelagic Cormorants, would be unavoidable.

3. Growth

Black-legged Kittiwake and Tufted Puffin

Measurements of weight, wing, tarsus, and culmen were made at 3-day intervals using Pesola scales and vernier calipers. Nests used for this purpose were located in puffin study plots A and B and kittiwake study plot E (Figure 4). All puffins and some of the kittiwakes were measured from the time of hatching. Because of a high rate of loss among kittiwakes, however, new individuals of unknown age were continually added to the sample. Ages were assigned to these chicks in the manner described by Ricklets and White (1975) which is based on increments in wing growth between visits.

4. Food Habits

Black-legged Kittiwake and Pelagic Cormorant

Regurgitations were collected from kittiwake chicks as they were handled for growth measurements. All samples were fixed in a 10 percent formaldehyde solution for two days then permanently preserved in a 50 percent solution of isopropyl alcohol.

A few food samples were also obtained from Pelagic Cormorants in this manner, but the intensity of predation by Glaucous-winged gulls rendered the collection of food samples from cormorants a destructive and inefficient process.

Rhinoceros Auklet and Tufted Puffin

Foods fed to young auklets and puffins were sampled by applying muzzles to the chicks in the manner described by Baird and Moe (1977). Briefly, the method consists of taping the bill shut so that the food deposited in the burrow by adults cannot be eaten. Muzzles were applied for a 48-hour period, but collections were made after each 24-hour interval. Each sample so obtained is referred to as a burrowload and represents the quantity of food delivered to a chick in a 24-hour period. The chicks involved were weighed at each visit during their period of enforced fasting.

IV. RESULTS AND DISCUSSION

1. Pelagic Cormorant

Nesting Habitat

Pelagic Cormorants usually nested in linear formation just below the top of the cliff (habitat D, Figure 2). A few built nests farther downslope (habitat C), and at least 35 pairs occupied ledges on the shipwreck.

Population

The census of Pelagic Cormorants indicated that Middleton Island, with about 2,300 pairs (Table 2), harbors one of the largest breeding concentrations of this species in Alaska. All substantial nest platforms were counted, whether active or failed and abandoned, and this probably accounts for the discrepancy between 1976 and 1978 population figures. The earlier observers apparently counted only those nests which were still active in July.

Rausch (1958) reported that Pelagic Cormorants were largely restricted to the lower west side and south side of the island in 1956. Cormorants were found in all ten census areas in 1978 and have probably increased severalfold in the past 22 years (see also the communication from Rausch appended to this report).

Breeding Phenology

Cormorants were apparently in full attendance at Middleton Island when field work began on 22 April. The distribution of dates of clutch initiation in 63 nests is shown in Figure 5. Eggs were never laid in 5 of 68 nests under observation. The data are probably not entirely representative of breeding phenology everywhere on the island since eggs were noted in cormorant nests as early as 3 May in other parts of the colony. In particular, pairs breeding on the higher cliffs near the south end of the island appeared to be somewhat advanced in comparison with data from the study plot. Altogether, egg-laying spanned a period of at least 46 days from 3 May to 18 June (Table 3).

Only first clutches are included in Figure 5. Losses to Glaucous-winged Gulls resulted in near total hatching failure in these nests, and the few chicks which hatched survived less than a week. About 25 percent of the females thus affected produced replacement eggs beginning 8 to 24 days after loss of their first clutches. The latest replacement eggs were laid on or about 27 June. Egg loss in undisturbed areas appeared to be minimal, however, and replacement laying probably did not occur to any significant degree elsewhere on the island.

The best representation of hatching and fledging dates is obtained by extrapolation from known egg-laying dates (Figures 6 and 7). An incubation period of 31 days and a fledging period of 48 days are assumed (Drent et al. 1964). In reality, hatching and fledging span a somewhat longer interval than egg-laying due to deviations from the average values from the incubation and fledging periods. Also, depending on the timing of mortality of eggs and chicks, the curves for hatching and fledging may have had somewhat different shapes than are portrayed using this method.

Frazer and Howe (1977) were unable to furnish the details of breeding phenology in Pelagic Cormorants in 1976 but estimated that egg-laying commenced on or about 17 May in that year. This suggests that phenology may have been one to two weeks earlier in 1978, depending on which nesting areas Frazer and Howe observed.

The departure of adult cormorants from the colony was monitored on another plot containing about 100 nests. Between 20 June and 15 August the percentage of nest sites occupied by adults diminished from 100 percent to 18 percent (Figure 8).

Productivity

Of 50 previously undisturbed nests visited on 23 June, 1 nest contained 1 egg, 8 contained 2 eggs, 39 contained 3 eggs, and 2 contained 4 eggs. Thus, the average clutch size just prior to hatching was 2.84 eggs (SD = 0.510). Significant losses from these nests resulting from this disturbance precluded their use in further observations on productivity.

Nesting success was measured on a third study plot of 102 nests observed from the flats. Due to the upward angle of the line of sight it was not possible to determine the contents of nests until the chicks were well grown and no longer closely brooded by the adults. The mobility of older chicks along the ledges further hampered attempts to detect changes in brood size at individual nests. It was determined, however, that approximately 65 chicks ($\pm$ 5 chicks) were ultimately fledged from these 102 nests. Assuming an average clutch of 2.84 eggs, reproductive success (young fledged/egg laid) on this plot was about 22 percent (65 young/290 eggs laid). An average of 0.64 young were fledged per breeding pair.

Just as breeding phenology appeared to be later on the east side of the island, the production of young appeared to be lower there than in other portions of the breeding grounds. At the time of the census in mid-July the proportion of nests which were still active ranged from 84 percent on the high cliffs at the southern tip of the island to about 53 percent in subcolony C, where all other data on phenology and productivity were gathered (Figure 9). Later, it looked as though many pairs in census areas one through six had reared broods of two or three chicks to fledging. Roughly 70 percent of the breeding pairs in census areas one to six, which contain nearly 75 percent of the population of Middleton Island, probably raised at least one chick. Mean brood size at fledging was probably closer to two chicks among these more successful birds. Except for the area where more detailed observations were made, then, productivity of Pelagic Cormorants was probably between 1.0 and 1.5 young fledged per breeding pair. Future observations at Middleton Island should take due account of spatial variability in productivity by including observations of study plots at the south end of the island.

Food

On 20 July, regurgitations were collected from four or five chicks, all judged to be within two weeks of fledging. The samples, totaling about 300 grams of food, were composed almost entirely of a Hexagrammid, probably kelp greenling (*Hexagrammos decagrammos*). The remains of about five fish were represented. The whole fish probably ranged in length from about 150 to 250 mm. One other unidentified species of fish, probably also greater than 150 mm in length, was present in the sample.

2. Glaucous-winged Gull

Nesting Habitat

Glaucous-winged Gulls nested primarily in two types of habitat on Middleton Island. The majority of the population nested in several loose colonies amongst driftwood and boulders on the flats below census areas 2, 5, 6, and 8 (habitat A, Figure 2). Considerable numbers also nested in upland areas of hummocky ground in the south-central portion of the island (habitat F). Favored nest sites were the tops of the mounds dotting this terrain, most of which were occupied by one or two pairs of Glaucous-winged Gulls.

Population

Frazer and Howe (1977) estimated the breeding population of Glaucous-winged Gulls at Middleton Island to be 570 pairs. No earnest attempt was made to refine their estimate this year. There were at least 150 nests in upland habitat, however, instead of fewer than 50 as indicated by Frazer and Howe. Thus, the population this year was probably about 700 breeding pairs plus undetermined numbers of immature gulls. Birds in subadult plumage outnumbered adult birds during the latter part of April and early May. Apparently, most immature birds then left Middleton Island, for they were far less common during the rest of the summer.

According to Rausch (1958 and Appendix) the Glaucous-winged Gull was a nonbreeding species at Middleton Island in 1956, or else was breeding in very low numbers. While the present population is neither large nor approaching full use of the available nesting habitat, it is clear that substantial changes have occurred in the status of Glaucous-winged Gulls in the last two decades.

Breeding Phenology

The dates of clutch initiation in 68 nests are shown in Figure 5. Egg-laying began on 27 April which is probably the earliest record of nesting for this species in Alaska. Egg-laying continued for at least 45 days (Table 3). There were no known cases of replacement laying; the data presented here refer only to first nesting attempts.

The distributions of hatching and fledging have been closely approximated in Figures 6 and 7 by extrapolation from known egg-laying dates. An incubation period of 27 days and a fledging period (hatching to first sustained flight) of 40 days are assumed (Drent et al. 1964).

Egg-laying was estimated to have begun on about 17 May in 1976 (Frazer and Howe 1977). In view of the exceptional spread of breeding exhibited by gulls on Middleton Island and the small sample of nests observed in 1976, it is unlikely that the actual difference in phenology between years was this pronounced.

Productivity

Clutch sizes were determined with certainty since the history of egg-laying and egg-loss, if any, was known in each case. Females laid an average of 2.89 eggs (SD = 0.320, n = 70). One supernormal clutch of five eggs was discovered, undoubtedly the product of two females. Eighteen nests were used by Dr. Sam Patten in his experiments on the effects of petroleum exposure on hatching success. Hatching success was 82 percent (123 of 150 eggs) in 52 control nests, with 90 percent (47/52) of the pairs hatching at least one egg. Thus, the average brood size at hatching was 2.62 chicks (SD = 0.573, n = 47). No attempt was made to follow the fate of chicks after hatching.

3. Black-legged Kittiwake

Nesting Habitat

Kittiwakes nested in all types of habitats illustrated in Figure 2 except uplands. On the flats (habitat A), nests were crowded on boulders up to about eight feet in height. This habit reached its extreme expression in several pairs which nested solitarily on small rocks in shallow ponds.

None of the habitats used by kittiwakes on Middleton Island could be considered "typical" for the species. Habitat C, cliff faces composed of a clay-conglomerate, comes the closest to the norm but differs in the smoothness of its surface which occasionally results in the sloughing away of ill-constructed nests. Many nests are located on flat ground at the upper edge of the cliffs (habitat E) and on vegetated slopes below the cliffs (habitat B). The use of the shipwreck by nesting kittiwakes and other birds is one of Middleton Island's more notable aesthetic assets.

Population

Slightly more than 75,000 nests were counted during the census (Table 2), indicating a population of about 150,000 adult kittiwakes. This figure agrees closely with the results of a census by M.E. Isleib and others in 1974 (unpublished data) but not with the results obtained in 1976 by Frazer and Howe (1977). The explanation for this may lie partly in differing definitions of the nest site. Frazer and Howe chose not to include in their count those platforms lacking a conspicuous nest depression when viewed from above. They noted that 20 to 30 percent of all nest platforms were of this type and believed these to be roosting sites used by birds from active nests. But observations made early in the 1978 season suggest this view was mistaken. Virtually every site showing any improvements in the form of added mud or plant materials was regularly occupied by a pair during the pre-laying period. While the data furnished by Frazer and Howe may come closer to the actual population of breeding birds, the present data represent the population of paired birds in possession of nest sites at some time during the season. This measure of population is more capable of being repeated in the future. In determining the proportion of breeders in the population, there is no substitute for detailed and prolonged observations of a representative sample of occupied sites.

A dramatic increase in the population of Black-legged Kittiwakes using Middleton Island has occurred in the last two decades. Rausch (1958 and Appendix) found a population of some 10,000 to 15,000 birds in 1956, indicating at least a tenfold increase since that time. New habitat was created, and has since been occupied, as a result of the 1964 Alaska earthquake. But this would appear to be an insufficient explanation for the increase. Habitat which was available but unoccupied in 1956 has since been colonized, and nests are evidently much more densely spaced on the cliffs now than in 1956.

It is unclear to what degree this increase is intrinsic or due to immigration of birds reared at other colonies. In either case, one result of such rapid expansion would be a population structure unusually strong in the younger age classes. An appreciation of this fact will be important for understanding certain aspects of breeding biology discussed below.

Breeding Phenology

The first adult kittiwakes probably returned to Middleton Island during the first week of March in 1978. Several hundred birds were noted on 11 March loafing on the tidal flats near the shipwreck (K. Wohl, pers. comm.), but none had yet occupied their nest sites. On flights to and from the island, FAA personnel noticed that "relatively few" were present around the island on 22 March and that the colony appeared to be fully occupied by 3 April.

Adult kittiwakes apparently began leaving the island in mid-June. By mid-August the proportion of nests on the study plots still occupied by adults had decreased to zero or to about 50 percent, depending on the level of production (Figures 10 and 11). Although field work was discontinued before the final departure of kittiwakes, FAA employees kindly made the following notes. Adult birds continued to abandon the cliffs in late August at a rate of about 5 to 10 percent per day until, on 4 September, only a few remained. On 6 September no nest sites were occupied. Kittiwakes were last noted on 9 and 10 September when a couple thousand birds were seen loafing on the beaches at the south end of the island.

When this study began on 22 April, most pairs had already built serviceable nests. Some new nests were started after this date, however, and most birds continued to add material to their nests at a slow but steady rate through the month of May.

The distribution of dates of clutch initiation in the combined sample of 180 nests (study plots A, B, and C) is shown in Figure 5. Hatching and fledging are represented in Figures 6 and 7 by extrapolation from known dates of egg-laying. An incubation period of 27 days and a fledging period of 43 days are assumed (Coulson and White 1958b).

A survey on 23 April disclosed that a small number of kittiwakes at the south end of the island (study plot D, Figure 2) had started laying eggs. None of the several nests involved contained more than one egg. To our knowledge, this is the earliest breeding record for kittiwakes in Alaska. It precedes, by several weeks to more than a month, the onset of egg-laying at all other colonies that have been studied in the Gulf of Alaska.

Egg-laying continued through 11 June, giving a spread of first breeding attempts of at least 50 days (Table 3). There were only three instances of replacement laying following egg-loss on the study plots. The second clutch was completed before 11 June in each case. Hatching was noted as late as 21 July elsewhere on the island, however, indicating that a few breeding attempts were initiated as late as 24 June. Thus, the entire period over which eggs were laid was about 62 days.

Data on breeding phenology of kittiwakes in 1976 (Frazer and Howe 1977) and 1978 are compared in Figure 12. Although there is an apparent difference of about three weeks in the onset of egg-laying, this can be largely explained by the location of study plots. Frazer and Howe confined their observations to subcolony C where breeding was known to have been comparatively late in 1978, and this was presumably true in 1976 also.

The three plots used in this study were selected on the basis of easily recognized differences in nesting habitat. Plots A and C occupied steep, rocky cliffs devoid of vegetation (habitat C, Figure 2). Plot C was located at lower elevation than plot A, however, and may well have been within the splash zone prior to the 1964 earthquake. Plot B was located on a more gradual, soil-covered slope (habitat B, Figure 2). Dense vegetation had grown up around the margins of plot B by mid-summer. The nesting habitat on plot B and the breeding performance exhibited by the birds on the plot were representative of a third to half of the Middleton Island colony. Most of subcolony C, for example, would fall in this category.

The phenology of egg-laying on study plots A, B, and C is shown individually in Figure 13. Birds on plot A bred about one week earlier, on the average, than birds on plot C, which in turn bred about a week earlier than birds on plot B. All paired differences between mean laying dates on these plots were significant ($P < 0.001$).

Studies on populations of kittiwakes in Great Britain have focused on a number of interacting factors affecting the timing of breeding. These factors include age (Coulson and White 1956, 1958a, 1960, 1966), density of nest sites (Coulson and White 1960), duration of the pair bond (Coulson 1966), and the location of nests with respect to the "center" and "edges" of a colony (Coulson 1968). The effects of these factors can only be demonstrated directly through long-term study of birds individually color-marked from the year of first breeding. Such was the approach taken by Coulson and White, and their findings suggest the following interpretation of the data from Middleton Island. Birds on study plot B were probably younger, on the average, than those on the other plots and/or were of poorer physical quality. Annual observations of marked birds on these plots would probably show a more rapid rate of turnover on plot B, reflecting both a higher rate of adult mortality and more frequent changes of mate or nest site.

Further evidence suggests that the breeding phenology on these plots may be correlated with the order in which they were colonized. Note that the spread of breeding decreased as the onset of breeding was progressively delayed. In fact, egg-laying was completed on the same day on all three study plots, so the differences between means arise from differences in the onset and synchrony of breeding. These results are consistent with the suggestions of Coulson and White (1956) that:

1. new terrain is colonized by young birds,
2. older birds breed earlier in the season than young birds,
3. older colonies (or portions of colonies in this case) would be expected to have more age classes present and to show a greater spread of breeding, and
4. all colonies would have the youngest age classes present and would therefore be expected to finish egg-laying at about the same time.

In contrast to the finding of Coulson and White (1960) that the density of nest sites is positively correlated with earlier breeding, the reverse was true on Middleton Island (compare nest spacing in Figures 14, 15, and 16). In this instance the density of nest sites may have been largely dictated by the nature of the substrate and less related to the "desirability" of the habitat and competition.

Productivity

Data on productivity on the three study plots are summarized in Table 4. Several important differences in breeding performance are clearly evident. More than 90 percent of the pairs on plots A and C produced eggs, compared with only 55 percent on plot B. Moreover, the mean clutch size was significantly smaller on plot B than on plots A and C ($P < 0.001$). Nine of 26 completed clutches on plot B contained only 1 egg; the rest contained 2 eggs. All but 1 of 55 clutches on plot A contained either 2 eggs (51 clutches) or 3 eggs (2 clutches). Every clutch on plot C contained 2 eggs. Coulson and White (1958) found that clutches of one egg are usually laid by kittiwakes breeding for the first time.

More than 90 percent of the pairs on plots A and C succeeded in hatching at least one egg, while those on plot B experienced total hatching failure. Egg-losses to Glaucous-winged Gulls usually occurred during the first two days of incubation. All birds had difficulty in raising chicks, however, and only about 0.25 young were fledged per breeding pair among even the most successful birds.

The smaller mean clutch size and larger proportion of nonbreeding birds on plot B are consistent with the explanation already advanced for differences in phenology. The plot apparently contained a large proportion of young birds with little or no breeding experience (Coulson and White 1958 a, 1960). Alternatively, or in addition, these birds may have been of poorer physical quality than their more productive neighbors (Coulson 1968).

In opposition to the foregoing ideas it could be argued that breeding success was directly governed by differences in nesting habitat. Admittedly, plot B and similar nesting areas were more susceptible to disturbance by rabbits than steeper, unvegetated terrain, and this was in fact observed on one occasion. By all appearances, however, hatching failure on plot B was primarily due to a general lack of assiduousness and coordination between members of a pair. Variations in productivity as well as breeding phenology were almost certainly related to differences inherent in the birds themselves.

In Table 5 the breeding success of birds on study plot A is considered with reference to the timing of breeding. Plot A showed an overall spread of breeding of 42 days which has been broken into three two-week periods for this analysis. Hatching success was depressed in late breeders who also failed to rear any chicks to fledging. Though based on small samples, these data tend to reinforce the ideas that earlier breeding involved older, more experienced pairs and that a greater range of age classes was represented on plot A than on plot B.

In mid-July the percentage of nests with chicks or eggs varied in a consistent manner, being highest on the southwest side of the island and decreasing steadily from census area 2 through area 8 (Figure 9). This phenomenon is probably a legacy of temporal and spatial patterns in the recent expansion of the colony. Curiously, the highest percentage of active nests at the time of the census was found on the shipwreck. The ship is known with certainty to have been colonized since Rausch's observations in 1956. At that time the cliffs on the southwest side of the island contained most of the population (Rausch 1958 and Appendix). The latter area may therefore be considered the "core" of the Middleton Island colony. The shipwreck, offering high quality nesting habitat and being located directly adjacent to the original concentration of birds, was presumably the first new area to be colonized by an expanding population. This subcolony may therefore include a relatively large proportion of older, more experienced birds. However, the higher apparent nesting success of birds on the ship is also partly due to the way in which the data were collected. The ship was thoroughly searched from on board, and few chicks present during the count could have escaped notice. Elsewhere, nesting success was no doubt consistently underestimated by a small amount since the counts were made using spotting scopes from a distance.

As we have seen, some elements of the breeding population exhibited poor hatching success, while others achieved high hatching success followed by failure during the chick stage. The reasons for poor fledging success can only be surmised. They presumably related to food supply since weather conditions were not severe. No pairs nesting on any of the study plots successfully reared two chicks to fledging, although a small number of pairs off the plots did so. One member of a brood of two chicks usually disappeared shortly after hatching. The remaining chick frequently survived several weeks, only to disappear prematurely, probably taken by gulls.

As the season progressed, the flats below the cliffs became strewn with the remains of young kittiwakes which had been killed and eaten by gulls. Usually, the only remains were the wings and sternum. The distribution of wing lengths in a random sample of 113 carcasses is shown in Figure 17. The data indicate that a majority of the kills took place after the young had left their nests, fully capable of flight. Fledglings often mingled with Glaucous-winged Gulls for a few days in the larger ponds. On one occasion a gull was observed as it attacked and killed a kittiwake, suggesting that this was in fact the manner in which most of the young birds died. The cohort of fledglings produced on Middleton Island this year, was thus reduced still further before the birds ever left the island.

Growth

Data on nestling weight gain and growth in wing, tarsus, and culmen are summarized in Figure 18 and Table 6. Chicks reached a mean maximum weight of 410 grams about 35 days after hatching then lost weight before leaving the nest at a little less than 400 grams.

Chicks gained an average of 15.0 grams per day between the ages of 5 and 20 days. The corresponding figures from studies by Coulson and White (1958b) and Maunder and Threlfall (1972) are 15.6 grams per day and 16.0 grams per day, respectively. Such slight differences in growth during the first half of the nestling period are probably neither statistically nor biologically significant. Differences are apparent in the latter half of the nestling period, however, with chicks reaching a maximum weight of about 410 grams at age 35 days at Middleton Island, 420 grams at age 29 days in Newfoundland (Maunder and Threlfall 1972), and 350 grams at age 28 days in Great Britain (Coulson and White 1958b). Subsequent weight loss before fledging was greatest in the birds from Newfoundland (fledging weight 300 to 350 grams, or 77 percent of peak weight) and least in Great Britain (estimated fledging weight 330 grams, or 94 percent of peak weight). The different patterns of growth in the late nestling stage may be partly related to morphological differences among adults in the populations studied. Average adult weight was 437 grams in the birds from the western Atlantic and 354 grams in the population from Great Britain. No data on adult body weight are available from Middleton Island.

Food

Forty regurgitations were collected from chicks of various ages. Fish, mostly Pacific sand lance (*Ammodytes hexapterus*), constituted nearly 80 percent of the diet by weight, while the euphausiid *Thysanoessa* *spinifera* comprised most of the remainder (Table 7, Figure 19). Other crustacea, cephalopods, and salmonid eggs were present, but only in insignificant amounts.

The lengths of euphausiids in the samples ranged from 20 to 32 mm and averaged 26.5 mm (SD = 2.77). The gammarid amphipod *Paracallisoma alberti* ranged from 13 to 20 mm in length.

4. Common Murre and Thick-billed Murre

Nesting Habitat

About half of the murres on Middleton Island occupied ledges just below the top of the cliff in census areas 1, 2, 3 and 8 (habitat D, Figure 2). Here they were distributed in numerous groups of a few dozen to several hundred birds. But the largest concentration of murres on the island (at least 3,000 birds) occupied a broad, gently sloping ledge in census area 2. This group consisted entirely of Common Murres. The breeding ledge they used was probably formed by a large slump during the 1964 earthquake and represents a modification of habitat D (Figure 2).

Population

The results of the 1976 and 1978 censuses of murres are in fairly close agreement (Table 2). Apparent changes in the apportionment of birds between census areas 1 and 2 are probably due to diurnal or seasonal fluctuations in colony attendance.

The proportions of Thick-billed and Common Murres were difficult to determine accurately by direct observation. However, it was apparent that few, if any, Thick-billed Murres nested outside of census area 1 in which they comprised an estimated 7.4 percent of the population. This ratio was determined from the number of Thick-billed Murre chicks among 311 chicks captured in census area 1 during fledging. It is assumed that the two species had similar nesting success. The assessment of the population of Thick-billed Murres by this method is in agreement with a general impression gained from observation of birds on the ledges.

Southern et al. (1965) have shown that the proportion of murres present on the ledges at any instant during incubation and brooding is about 60 percent of total population. Thus, the census total of 6,803 murres suggests a total for Middleton Island of about 11,000 birds, of which perhaps 350 are Thick-billed Murres.

Rausch (1958) found a population of only about 400 murres, mostly Thick-billed Murres, present on Middleton Island in 1956. The increase in population during the last 22 years is all the more remarkable in light of physical changes brought about by the 1964 earthquake which might have been expected to discourage murres altogether from nesting on Middleton Island.

Breeding Phenology

On 27 May, several hundred murres were flushed from ledges in census area 1, and only 3 eggs were present. This date probably marked the commencement of egg-laying. The remainder of information on phenology was gained from the banding project in late July and August. Egg-laying is estimated to have ended on June 23, giving a spread of 27 days (Table 3, Figure 5). The distribution of hatching is shown in Figure 6. In back-calculating dates of laying and hatching from known fledging dates, an incubation period of 33 days and a nestling period of 21 days are assumed (Tuck 1961).

The limited observations by Frazer and Howe (1977) suggest that murres may have bred up to three weeks earlier in 1978 than in 1976. The comparison hinges on whether the 1976 data refer only to the small group of murres in subcolony C, where breeding was probably late in both years.

The numbers of new chicks found in or near the ponds on each day from 26 July to 16 August are shown in Figure 20. The distribution is approximately a normal one, except for a conspicuous decline in the number of chicks leaving the cliffs on 31 August and 1 July. The lull occurred during an unusual spell of foggy weather, although such conditions might have been expected to have the opposite effect. Peak numbers of birds left the cliffs as soon as the fog lifted.

Fledging Condition and Survival

Upon leaving the cliffs (an event here loosely referred to as "fledging"), 374 Common Murre chicks ranged in weight from 128 to 310 grams and averaged 204 grams (Table 8). Twenty-three Thick-billed Murres averaged 201 grams and ranged from 125 to 292 grams. The average values observed on Middleton Island, are within the ranges given by Tuck (1961) in pointing out the considerable geographic variation in age at departure and weight among murre chicks. Annual variation in fledging condition has been little studied but may be of major importance in the survival of chicks during their first few days at sea.

Measurements of Common Murre chicks from census areas 1 and 2 are compared in Table 9. Census area 2 included the main concentration of Common Murres on the island. This group was well isolated from birds in census area 1, and there was no crossing over of chicks between areas as they made their way to sea. Chicks in area 2 began fledging a few days later than in area 1 and were significantly smaller in both weight and wing length. This suggests that breeding phenology was somewhat later in this group and that chicks were leaving at a younger age, possibly to compensate for their later start. There were no differences, however, in the measurements of chicks leaving during the early, peak, or late portions of the fledging period in census area 1.

Many chicks spent more than one day in the ponds before making the final trek to sea. Twenty-one percent of Common Murre chicks banded before 13 August were recaptured at least once. Thick-billed Murres, with a recapture rate of about 70 percent, showed an even greater tendency to linger in the ponds (Figure 21).

Most chicks received no food during the time they spent in the ponds. They lost an average of 17.7 grams and faced an increasing probability of death each day. Of a cohort of 374 chicks banded on or before 12 August, 82 percent apparently made it to sea, while 18 percent were later recovered dead (Table 10). The mean weight of 68 casualties was 199.4 grams upon leaving the cliffs and 174.2 grams on the day before death.

Surprisingly, predation by gulls was not an important cause of mortality. In fact, gulls displayed general indifference toward murre chicks under all circumstances observed. Only two carcasses were encountered which appeared to have been partially eaten by gulls, and these birds may have been scavenged after dying from other causes. Observed mortality of murre chicks apparently resulted from exposure and the depletion of energy reserves. Chicks were often found in a lethargic and probably hypothermic condition hours or minutes before they died. Some adverse effects, possibly an increase in mortality, may have resulted from the temporary disruption of adult-chick bonds caused by daily banding activities.

A small number of chicks were fed while in the ponds and managed to spend a week or more in fresh water, either maintaining body weight or exhibiting limited growth (Figure 22). In one instance an adult was observed delivering a meal to such a chick. This was apparently a learned behavioral pattern acquired by only a few adults. At our last visit on 16 August several chicks which had spent more than a week in one particular pond were still alive and healthy, apparently having postponed for awhile the last leg of the journey to sea.

In addition to 68 banded chicks, another 16 unbanded chicks were found dead in daily searches of all ponds. A total of 397 chicks were banded. Since 81 percent of all dead chicks were banded, a mark-recapture estimate of the number of chicks that left the cliffs is 490. This estimate is known to be greatly in error, however, because a large proportion of chicks undoubtedly proceeded directly to sea without stopping in the ponds. Thus, these data do not imply that only 81 percent of all chicks made it to sea, only that 81 percent of those which stayed in the ponds long enough to be banded eventually reached the sea.

5. Rhinoceros Auklet

Nesting Habitat

Rhinoceros Auklets were found primarily in four discrete nesting areas on Middleton Island (Figure 4). In addition, one occupied burrow was found among puffin burrows on the east side of the island, indicating that a few auklets may have been scattered throughout subcolony C.

The four concentrations of birds were found on moderate soil-covered slopes. With one exception, they were not really a part of the system illustrated in Figure 2, since they were located in places where there were no cliffs.

Auklets tended to nest only where other species were scarce or absent. This preference seemed to override other factors such as soil and vegetation which varied widely. Much of area 1 was characterized by a loamy soil and a cover of cow parsnip (*Heracleum lanatum*) and other forbs. Area 2 was located in a dense thicket of salmonberry (*Rubus spectabilis*), also on loamy soil. Many burrows in area 3 were excavated in a hard, sticky soil composed largely of clay, while birds in area 4 occupied a dunelike bank of sand and gravel. The vegetation in both areas 3 and 4 was predominantly beach rye (*Elymus arenarius*).

Population

Frazer and Howe (1977) estimated the population of auklets in three of the four nesting areas (areas 1, 3, and 4) to be 1,368 birds.

Their figures for area 1 (1,260 birds) and 4 (100 birds) are probably fairly good, but they noted only 8 birds in area 3 where 80 burrows were counted this year. Nesting area 2, newly discovered this year, contained at least 100 burrows. The estimate of total population may be safely revised upward to 1,800 birds.

Breeding Phenology

The hatching dates of 30 auklet chicks were estimated from wing measurements (Figure 6). The distributions of egg-laying (Figure 5) and fledging (Figure 7) have been calculated assuming a mean incubation period of 46 days and a mean fledging period of 51 days (Leschner 1976). Auklets began laying eggs about 22 April and continued until about 3 June, a span of 43 days (Table 3).

Diet and Food Consumption Rate of Chicks

The diet of auklet chicks consisted almost entirely of Pacific sand lance but included small quantities of four other species of fish as well as squid and octopus (Table 11).

Data on the lengths of all prey species are summarized in Table 12. Length frequency profiles for sand lance show that two age classes were well represented in the food samples (Figure 23). The smaller fish (age 0) were hatched within the year, probably in January or February, while the larger fish (age 1) were hatched one year previously (Blackburn 1978). The two or three largest fish may have been members of age class 2. Age 0 fish considerably outnumbered older sand lance in the food samples, but the latter comprised a larger porportion of the diet by weight (Figure 24).

Sampling was conducted in four two-day bouts spaced at four- or five-day intervals. Mean body length in the younger cohort of sand lance increased at the rate of about 16 mm per month over the three-week sampling period (Figure 23). Blackburn (1978) suggests that growth in sand lance is very sensitive to local and seasonal variations in their food supply. He found a fairly constant growth rate of 8 to 9 mm per month (May to September) among age 0 fish in Kachemak Bay.

The age of each auklet chick from which food samples were collected was estimated from wing measurements. Ages ranged from 11 to 50 days at the time of sampling. No relationships were detected between either the sampling date or age of the chick and the quantity or quality of food delivered.

The average quantity of food per load in 72 samples was 39.6 grams, but no food was delivered on about 1 night in 10 (Table 13). Chicks thus received food at an average rate of 35.6 grams or 13.4 percent of body weight per day (mean weight was 265 grams at the time of sampling). They lost weight at the rate of 22.9 grams per day or 8.6 percent of initial body weight during the first 24 hours of enforced fasting.

The quantity of food delivered to an auklet chick over its entire nestling period may be calculated. Chicks spend an average of 51 days in the nest (Leschner 1976). From day 11 until departure they receive an average of 35.6 grams per day, or 1,460 grams. To this must be added the amount of food received during the first 10 days of life which, if delivered at a similar rate, would bring the total to 1,816 grams. Depending on the level of breeding success, between one and two metric tons of food may be consumed annually by auklet chicks on Middleton Island.

6. Tufted Puffin

Nesting Habitat

Tufted puffins nested in the thin mantle of soil at the tops of cliffs (habitat E, Figure 2), on more extensive slopes either above or below the cliffs (habitat B), and on the shipwreck. Those nesting in burrows probably experienced occasional interference from rabbits or competition with these burrowing mammals for space. Puffins nesting on the ship did not dig burrows but laid their eggs in such novel places as closets, storage bins, shower stalls, under bunks, etc.

Population

The results of the census indicate a minimum population of 2,640 puffins with concentrations in census areas 1, 2, and 8 (Table 2). About 50 pairs nested on the ship where none were present in 1956 (Rausch 1958 and Appendix). It does not appear, however, that the population of this species has undergone the radical changes in the last 20 years which have occurred in the cliff-nesting species. The population of puffins on Middleton Island today is probably not less than 3,000 or more than 5,000 birds.

Breeding Phenology

Hatching dates of 57 chicks were estimated from wing measurements (Figure 6). Approximate dates of egg-laying and fledging have been calculated from the mean duration of the incubation and fledging periods. Wehle (1978) found that both of these intervals average 46 days in the Tufted Puffin. Egg-laying spanned about a month from 12 May to 13 June (Figure 5). Puffins were among the last seabirds to leave the island, with some young probably remaining through the second week of September (Table 3, Figure 7).

Data collected by Frazer and Howe (1977) suggest that the breeding phenology of puffins may have been about a week earlier this year than in 1976.

Growth

Data obtained on the growth of Tufted Puffin nestlings are summarized in Table 14. From age 5 to 21 days chicks showed an average weight increase of 15.3 grams per day. Growth measurements were interrupted in August, but the available data and general observations indicated that adult puffins were having no difficulty in providing their young with sufficient food for normal, rapid growth.

Food

In light of the circumstances just mentioned, the results of the food sampling scheme were a little perplexing. Whereas the technique of taping the bill shut did not appear to affect in any way the behavior or feeding schedule of Rhinoceros Auklets, an examination of the results shown in Table 13 suggests that problems of this sort did enter in the case of Tufted Puffins.

Taken at face value, the data would indicate that puffin chicks were receiving food on only 1 day out of 3 at the same time that auklets were fed on 9 nights out of 10. Furthermore, the samples collected from puffins averaged only one third the size of auklet burrow loads, both in weight and in number of items. The muzzle may have interferred with the chicks' normal behavior, causing adults to suspend food-gathering activity, or parents may have consumed food left untouched by the young. We suspect that both influences were operating.

These problems notwithstanding, the series of samples obtained is adequate to show one striking difference between the food habits of Tufted Puffins and Rhinoceros Auklets. Whereas auklets took only insignificant numbers of squid and octopus, these prey constituted about 36 percent (by weight) of the diet of puffin chicks (Table 15, Figure 24). This contrast suggests a difference in foraging range between these two species, since the cephalopods were probably obtained in deep water foraging areas beyond the continental slope some 10 to 15 miles to the south of Middleton Island.

One prey species of Tufted Puffins which did not appear in any of the burrow-loads is worth mentioning. A bill-load was collected which consisted of one young pink salmon *(Oncorhynchus gorbuscha)*. The fish measured 154 mm in length and weighed 24.6 grams.

V. FURTHER DISCUSSION AND CONCLUSIONS

Middleton Island is one of the few sites in Alaska for which we have sufficient historical information to make a sound statement about changes in seabird populations spanning several generations. As we have seen, the populations of cliff-nesting species have increased remarkably in the last 22 years.

Possibly related to this increase is the widespread use of unusual nesting habitat by kittiwakes, murres, cormorants, and puffins. The Alaska earthquake of 1964 created new habitat, but this is believed to have been only fortuitously associated with the increase in population rather than its cause.

The biology of seabirds at Middleton Island is exceptional in important respects beyond the outward appearance of the nesting habitat. Breeding phenology of all species is both earlier and more protracted than at other colonies studied in the Gulf of Alaska. In Black-legged Kittiwakes the difference amounts to anywhere from four to seven weeks in the onset of breeding and two to four weeks in the spread of breeding. The difference is only slightly less marked in Pelagic Cormorants, Glaucous-winged Gulls, and Rhinoceros Auklets.

While the birds of Middleton Island are no doubt consistently early breeders, the contrast may be less pronounced in some years than it was in 1978. Judging from the observations of Frazer and Howe (1977), breeding phenology at Middleton Island may have been up to two or three weeks earlier in 1978 than in 1976. The extent of annual variation in phenology at Middleton Island will remain uncertain, however, until variation within the colony is duly accounted for in several years of study.

The exceptional patterns of phenology observed on Middleton Island could be partly inherent in the age structures of recently expanded populations. But it seems necessary that the differences also have a strong environmental basis. In this connection, it may be significant that the food brought to chicks by kittiwakes and puffins, for example, differed qualitatively from that observed at other colonies in the Gulf of Alaska (see for example Amaral 1977, Baird and Moe 1978, Nysewander and Hoberg 1978, Wehle 1978). The diets of these birds at most colonies are composed almost entirely of either or both of two species of fish, Capelin (*Mallotus villosus*) and Pacific sand lance. At Middleton Island, however, the birds supplemented their intake of fish (mostly sand lance) with considerable quantities of invertebrates - squid and octopus in the case of puffins and the euphausiid *Thysanoessa spinifera* in the case of kittiwakes. Capelin were entirely lacking in the samples from Middleton Island.

The colony of kittiwakes at Middleton Island exemplified many of the demographic features which have been so profitably researched in Atlantic studies of this species. The site provides a promising opportunity for further study of breeding performance in relation to population structure. Such studies may shed light on the origin of local variability in productivity which is frequently observed elsewhere in Alaska but otherwise hard to explain.

V. SUMMARY

1. The Black-legged Kittiwake, with a population of about 150,000 birds, is the most abundant seabird species on Middleton Island. The combined population of seven species is about 172,000 birds.

2. Populations of several species have increased greatly in the last 22 years. Kittiwakes have increased in number from 10 or 15,000 birds to 150,000 birds, murres from 400 to at least 7,000 birds. A change of similar magnitude has probably occurred in the population of Pelagic Cormorants. The population of Glaucous-winged Gulls has changed from a few non-breeders to about 1,400 breeding birds.

3. Large numbers of cliff-nesting birds use highly unusual nesting habitats on Middleton Island.

4. The seven species studied began breeding two to seven weeks earlier at Middleton Island than at other colonies in the Gulf of Alaska and showed a greater spread of breeding. Black-legged Kittiwakes occupied

Middleton Island for six and a half months from early March to mid-September in 1978.

5. Productivity of Pelagic Cormorants was 0.64 young per breeding pair in the subcolony observed intensively but may have been up to twice as high elsewhere on the island.

6. Distinct and recognizable sub-groups of kittiwakes exhibited marked differences in breeding performance. These differences were believed to be related to the age and/or physical quality of the birds. The syndrome observed in the less productive elements of the population included later breeding phenology, a higher proportion of non-breeding birds, smaller clutches, and lower hatching success. Overall, production of kittiwakes at Middleton Island was poor in 1978 with only 0.172 young fledged per breeding pair.

7. The diet of Rhinoceros Auklet chicks was composed mostly of two age classes of sand lance but included small amounts of other fish and cephalopods. By contrast, cephalopods composed one-third (by weight) of the food brought to young Tufted Puffins. The diet of kittiwakes nestlings included considerable quantities of the euphausiid *Thysanoessa spinifera*.

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Table 1. Middleton Island weather summary, 1 May - 17 August, 1978.

Month	Temperature (°C) Extremes Max.	Extremes Min.	Ave. Daily Max.	Ave. Daily Min.	Mean	Precipitation % Days	Precipitation Total (mm)	Wind Direction (No. Days) NE	SE	SW	NW	Calm
May	15.6	3.3	9.5	5.0	7.5	61	115	5	18	1	6	1
June	17.8	5.0	12.9	7.1	10.0	63	93	1	12	12	1	4
July	18.9	6.7	14.1	9.9	12.0	74	128	11	10	2	0	6
August	19.4	5.0	15.6	10.1	12.9	65	61	0	10	2	0	5

Table 2. Populations of seabirds censused in 1978 on Middleton Island.

	CENSUS AREA (Number of Nests)											
Species	1	2	3	4	5	6	7	8	9	10	Total Nests	Total Birds
Pelagic Cormorant												
1976	646	343	85	41	302	97	13	322	14	56	1,919	3,838
1978	778	279	125	41	439	84	100	407	53	35	2,341	4,682
Black-legged Kittiwake												
1976	8,500	5,040	1,880	470	8,750	4,461	60	12,490	14	794	42,458	84,916
1978	19,851	12,202	6,666	1,101	15,354	6,773	310	11,469	20	1,501	75,247	150,494
Common Murre												
1978	2,591	3,370	275	0	0	0	0	360	0	0	6,596[1/]	10,993*
Thick-billed Murres												
1978	207	0	0	0	0	0	0	0	0	0	207	345*
Total Murres												
1976	1,149	4,333	149	0	0	0	0	220	0	0	5,851	9,752*
1978	2,798	3,370	275	0	0	0	0	360	0	0	6,803	11,338*
Tufted Puffin												
1976	180	190	4	20	290	40	6	110	30	15	885	1,770
1978	280	180	0	15	110	60	100	470	55	50	1,320	2,640

1/Values for murres in this column represent total number of birds counted during the census. These values are divided by 0.6 (see text) to obtain estimated populations in right-hand column.

*Estimate

Table 3. Summary of breeding phenology of seabirds on Middleton Island in 1978.

	Laying			Hatching		Fledging	
	First	Last	Spread (Days)	First	Last	First	Last
Pelagic Cormorant	3 May	18 Jun	46	3 Jun	19 Jul	21 Jul	5 Sep
Glaucous-winged Gull	28 Apr	12 Jun	45	24 May	8 Jul	3 Jul	17 Aug
Black-legged Kittiwake	23 Apr	11 Jun	50	20 May	9 Jul	2 Jul	21 Aug
Common & Thick-billed Murres	28 May	23 Jun	27	30 Jun	26 Jul	21 Jul	16 Aug
Rhinoceros Auklet	22 Apr	3 Jun	43	7 Jun	19 Jul	28 Jul	9 Sep
Tufted Puffin	12 May	13 Jun	33	27 Jun	29 Jul	12 Aug	14 Sep

Table 4. Productivity of Black-legged Kittiwakes, Middleton Island, 1978.

	Study Plot			
	A	C	B	Total
No. Nests Built	60	60	60	180
No. Nests with Eggs	55	57	33	145
Nests with Eggs/Nests Built	0.917	0.950	0.550	0.806
Egg-laying Dates				
Mean	21 May	27 May	3 Jun	27 May
S. Dev. (days)	9.36	5.32	5.43	8.81
Clutch Size				
No. Clutches	55	57	26	138
Mean	2.02	2.00	1.65	1.94
SE	0.032	0	0.095	0.025
% Pairs Hatching $\geq$ 1 Egg	90.9	91.2	0	70.3
Brood Size at Hatching				
No. Broods	50	52	0	102
Mean	1.76	1.67	-	1.72
SE	0.061	0.066	-	0.045
Chicks Hatched/Egg Laid	0.779	0.763	0	0.625
% Pairs Fledging $\geq$ 1 chick[1/]	22.0	26.9	-	24.5
Brood Size at Fledging				
No. Broods	11	14	0	25
Mean	1	1	-	1
SE	0	0	-	0
Chicks Fledged/Chicks Hatched	0.125	0.161	0	0.143
Chicks Fledged/Egg Laid	0.097	0.123	0	0.089
Chicks Fledged/Nest with Eggs	0.200	0.246	0	0.172
Chicks Fledged/Nest Built	0.183	0.233	0	0.156

1/Percentage of pairs with hatching success which also fledged at least one chick.

Table 5. Nesting success in relation to breeding phenology of Black-legged Kittiwakes on study plot A, Middleton Island, 1978.

	Early (30 Apr-14 May)	Middle (15 May-28 May)	Late (29 May-11 June)
No. Clutches Initiated	14	32	9
% Pairs Hatching ≥ 1 Egg	92.9	96.9	66.7
Chicks Hatched/Egg Laid	0.821	0.844	0.526
Chicks Fledged/Chicks Hatched	0.174	0.130	0
Chicks Fledged/Breeding Pair	0.286	0.219	0

Table 6. Growth of Black-legged Kittiwake chicks, Middleton Island, 1978.

Age(days)	n	Weight (g) Mean	S.D.	Range	Wing (mm) Mean	S.D.	Range	Tarsus (mm) Mean	S.D.	Range	Culmen (mm) Mean	S.D.	Range
0	14	34	2.00	30-37	19	0.77	18-20	18.3	0.55	17.3-19.0	14.1	0.37	13.6-14.7
1-3	25	47	6.87	38-61	21	1.43	18-24	19.8	0.97	17.6-21.8	15.0	0.81	13.8-17.5
4-6	25	74	14.13	50-98	26	2.25	21-30	22.7	1.29	20.3-25.0	16.5	0.81	15.2-18.0
7-9	25	117	21.76	77-166	33	3.88	23-41	26.2	1.43	23.0-29.2	18.5	0.96	15.9-20.2
10-12	27	178	27.03	136-234	50	6.38	39-65	29.1	1.20	26.7-32.0	20.5	1.06	18.4-22.2
13-15	27	235	27.98	176-285	72	7.23	57-90	30.8	1.17	28.9-33.3	21.8	1.33	18.4-23.9
16-18	36	270	33.59	165-320	95	9.56	75-119	31.9	1.40	29.6-34.6	23.2	1.37	19.4-25.6
19-21	33	299	38.31	240-410	120	8.62	106-142	32.7	1.19	30.3-34.7	24.4	1.49	20.7-26.9
22-24	36	330	33.84	270-395	141	9.45	121-165	33.3	1.21	30.4-35.6	25.4	1.57	21.8-28.7
25-27	25	372	30.55	320-425	166	7.03	153-179	34.1	0.85	32.4-36.3	27.1	1.32	24.2-29.7
28-30	25	380	44.65	275-430	185	8.71	162-200	34.3	1.36	31.2-37.2	28.1	1.72	24.0-31.2
31-33	28	400	30.09	315-440	207	6.75	194-221	34.5	1.09	37.4-32.8	29.6	1.31	26.8-31.5
34-36	14	411	24.87	365-455	228	6.70	214-236	34.8	0.98	37.2-33.4	31.2	1.02	28.8-32.8
37-39	11	401	28.18	355-435	241	5.19	230-249	34.7	0.72	35.7-33.6	31.8	1.27	29.7-33.6
40-42	6	390	27.39	350-420	258	7.24	249-265	34.9	0.49	35.6-34.3	31.6	1.13	33.1-30.3

Table 7. Composition of food samples from Black-legged Kittiwake chicks, Middleton Island, 1978. (Sample size=40 regurgitations)

Prey	Weight (g)		Occurrence	
	Total	%	No. Samples	%
Pacific sandlance *(Ammodytes hexapterus)*	186.2	29.8	7	17.5
Pacific sandfish *(Trichodon trichodon)*	20.0	3.2	1	2.5
Unid. fish	282.5	45.2	21	52.5
Octopus	5.2	0.8	2	5.0
Squid	3.4	0.5	2	5.0
Thysanoessa spinifera	115.1	18.4	18	20.0
Paracallisoma alberti	2.1	0.3	4	10.0
Decapoda (unid.)	0.2	0.03	1	2.5
Salmonid eggs	10.0	1.6	1	2.5
Total	624.7	100		

Table 8. Mensural data for Common and Thick-billed Murre chicks at the time of departure from the cliffs, Middleton Island, 1978.

	Weight (g)	Wing (mm)	Tarsus (mm)	Culmen (mm)
Common Murre (n = 374)				
Mean	203.8	72.9	35.1	21.3
SE	1.37	0.42	0.085	0.076
Range	128-310	54-104	31.0-39.9	17.7-25.8
Thick-billed Murre (n = 23)				
Mean	200.7	80.5	34.7	22.8
SE	7.41	1.63	0.305	0.400
Range	125-292	62-101	32.2-36.9	20.0-28.6

Table 9. Comparison of fledging condition of Common Murres in census areas 1 and 2, Middleton Island, 1978.

	Weight (g)	Wing (mm)	Tarsus (mm)	Culmen (mm)
Census Area 1 (n = 288)				
Mean	207.8	74.3	35.4	21.5
SE	1.63	0.47	0.096	0.085
Range	128-310	54-104	31.0-39.9	17.9-25.8
Census Area 2 (n = 86)				
Mean	190.7	68.4	34.1	20.6
SE	2.11	0.74	0.142	0.144
Range	141-231	50-91	31.5-36.9	17.7-24.8

Table 10. Fate of a cohort of 374 Common and Thick-billed Murre chicks in the first five days after leaving the cliffs, Middleton Island, 1978.

No. Days Elapsed	No. Alive in Ponds	No. Gone to Sea	No. Died in Ponds	Daily Percentage Mortality[1/]
0	374	-	-	-
1	92	264	18	4.8
2	41	29	22	23.9
3	14	7	20	48.8
4	5	2	7	50.0
5	4	0	1	20.0
Total		302	68	

1/Figures indicate the percentage of chicks alive in ponds on day *i* which died by day *i* + 1.

Table 11. Composition of food samples from Rhinoceros Auklet chicks, Middleton Island, 1978. (Sample size = 72 burrow loads.)

Prey	Number Total	Number %	Weight (g) Total	Weight (g) %	Occurrence No. Samples	Occurrence %
Pacific sandlance *(Ammodytes hexapterus)*						
Age 0	517	58.8	922.0	34.0	65	90.3
Age 1	313	35.6	1668.1	61.6	65	90.3
All	830	94.4	2590.1	95.6	72	100
Pacific sandfish *(Trichodon trichodon)*	17	1.9	38.9	1.4	8	11.1
Kelp Greenling *(Hexagrammos decagrammus)*	8	0.9	25.1	0.9	7	9.7
Sablefish *(Anoplopoma fimbria)*	4	0.5	11.9	0.4	3	4.2
Rockfish *(Sebastes* sp.)	7	0.8	10.6	0.4	5	6.9
Squid	7	0.8	18.0	0.7	5	6.9
Octopus	6	0.7	12.7	0.5	5	6.9
Total	879	100	2707.3	100		

Table 12. Lengths of fish and cephalopods in the diets of Rhinoceros Auklets and Tufted Puffins, Middleton Island, 1978.

	Rhinoceros Auklet			Tufted Puffin		
	n	Mean Length(mm)	range	n	Mean Length(mm)	range
Pacific sand lance (*Ammodytes hexapterus*)						
Age 0	481	87.5	55-102	42	85.7	74-104
Age 1	304	127.2	108-146	10	131.2	127-135
Age 2	3	158.3	151-168	2	161.0	154-168
Pacific sand fish (*Trichodon trichodon*)	17	69.6	61-84	1	78.0	-
Kelp Greenling (*Hexagrammos decagrammus*)	7	74.1	53-115	-	-	-
Rockfish (*Sebastes* sp.)	7	58.9	57-60	-	-	-
Prowfish (*Zaprora silenus*)	-	-	-	2	106.5	95-118
Sablefish (*Anoplopoma fimbria*)	4	89.3	82-87	-	-	-
Pink Salmon (*Oncorhynchus gorbuscha*)	-	-	-	1	154	-
Squid1/	4	56.3	45-73	8	56.6	31-72
Octopus2/	5	70.8	40-100	14	71.9	51-90

1/Dorsal mantle length.

2/Total length from anterior end of mantle to tip of longest tentacle.

Table 13. Results of the food sampling scheme for Rhinoceros Auklets and Tufted Puffins, Middleton Island, 1978.

	Rhinoceros Auklet	Tufted Puffin
No. Chick-days of Effort	101	68
No. Burrow-loads Obtained[1/]	72 (71.2%)	16 (23.5%)
Weight per Load (g)		
Mean	39.6	13.4
SE	1.94	3.80
No. Items per Load		
All Prey Species		
Mean	12.2	4.2
SE	0.72	1.06
Range	1-29	1-17
Sand lance only		
Mean	11.5	2.4
SE	0.69	0.68
Range	1-27	0-10
No. Days No Food Collected[1/]	9 (11.1%)	33 (67.3%)
No. Deaths or Disppearance	11 (10.9%)	8 (11.8%)
No. Days Chick Removed Muzzle	9 (8.9%)	11 (16.2%)

1/Percentages given exclude the days when the technique failed because the chick died or removed its muzzle.

Table 14. Growth of Tufted Puffin chicks, Middleton Island, 1978.

Age(days)	n	Weight (g)			Wing (mm)			Tarsus (mm)			Culmen (mm)		
		Mean	S.D.	Range	Mean	S.D.	Range	Mean	S.D.	Range	Mean	S.D.	Range
0	5	61	4.88	54-67	21	1.41	20-23	20.3	0.85	19.4-23.5	22.6	0.62	21.8-23.4
1-4	12	93	19.04	64-122	26	1.87	23-29	23.7	1.26	21.8-26.0	24.3	1.18	22.3-26.0
5-8	12	131	16.11	102-153	31	2.02	27-35	25.4	0.95	23.8-26.9	26.4	1.08	24.8-28.2
9-12	13	186	32.47	138-262	39	3.90	34-47	27.3	1.05	25.8-29.3	28.6	1.52	25.9-31.2
13-16	14	276	37.83	221-340	57	6.78	45-66	29.7	1.40	26.7-32.3	31.4	1.37	29.5-33.8
17-20	8	339	48.88	245-390	71	2.62	66-74	31.6	1.63	28.2-33.4	33.7	1.18	31.8-35.3
21-24	7	375	41.27	292-410	89	6.79	80-102	32.0	1.47	29.2-34.0	34.7	1.37	32.6-36.3
25-28	5	443	23.30	410-475	103	6.54	96-113	33.7	1.14	31.9-34.8	36.5	0.75	35.4-37.4
29-32	1	512	-	-	97	-	-	32.8	-	-	35.4	-	-
33-36	2	595	7.07	590-600	129	3.54	126-131	34.5	1.27	33.6-35.4	39.4	1.98	38.0-40.8
37-40	2	565	31.82	542-587	140	0.71	139-140	33.5	0.14	33.4-33.6	39.6	0.21	39.4-39.7
41-44	3	609	20.03	590-630	150	1.53	149-152	34.5	1.02	34.3-35.6	43.3	0.31	43.0-43.6

Table 15. Composition of food samples from Tufted Puffin chicks, Middleton Island, 1978. (Sample size = 16 burrow loads.)

Prey	Number		Weight (g)		Occurrence	
	Total	%	Total	%	No. Samples	%
Pacific sand lance *(Ammodytes hexapterus)*						
Age 0	28	43.1	47.0	21.9	12	75.0
Age 1	11	16.9	64.1	29.8	6	37.5
All	39	60.0	111.1	51.7	13	81.3
Prowfish *(Zaprora silenus)*	2	3.1	22.2	10.3	2	12.5
Pacific sand fish *(Trichodon trichodon)*	1	1.5	3.6	1.7	1	6.3
Squid	10	15.4	46.0	21.4	7	43.8
Octopus	13	20.0	31.9	14.9	7	43.8
Total	65	100	214.8	100		

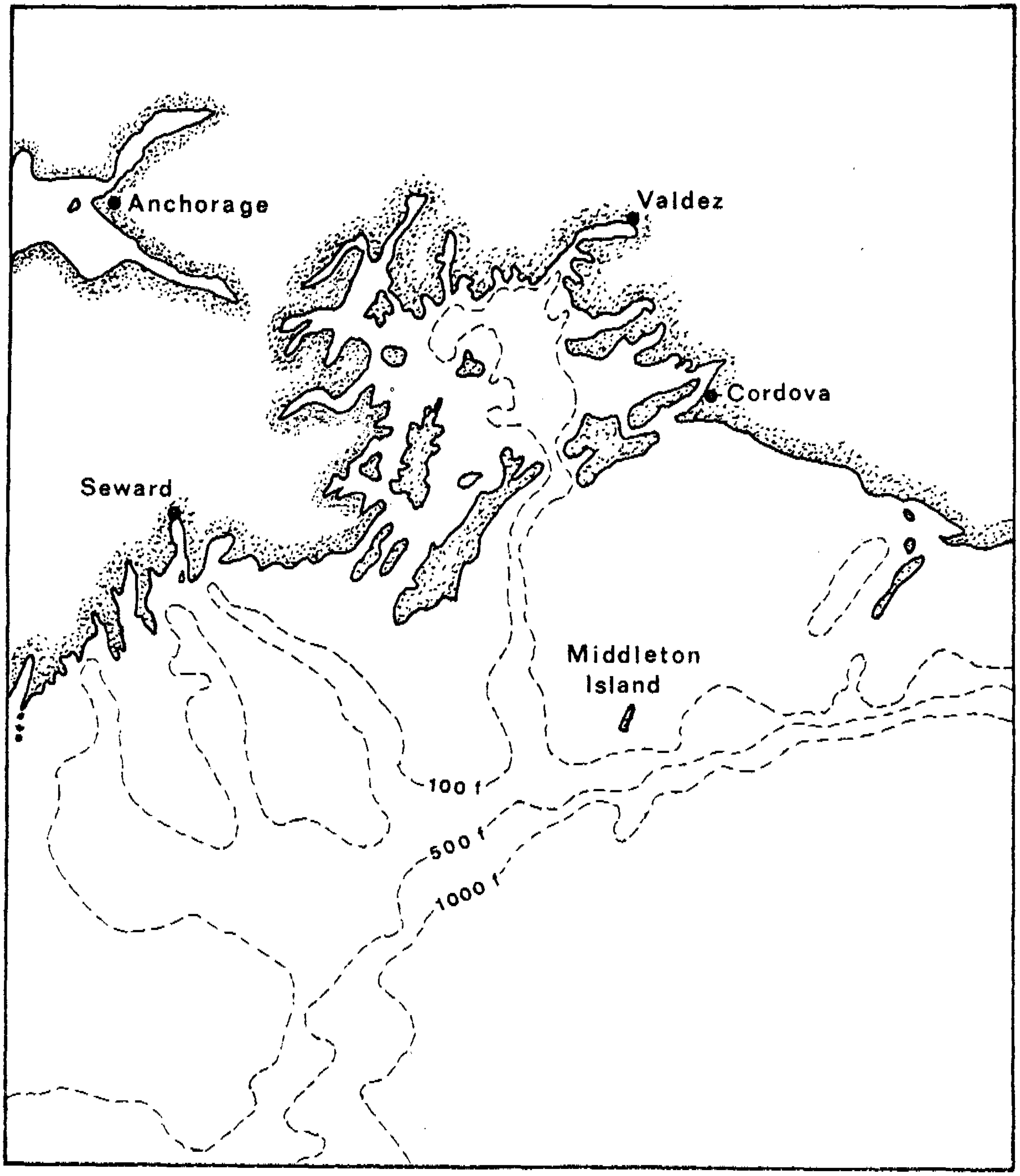

Figure 1. Location of Middleton Island in the north-central Gulf of Alaska.

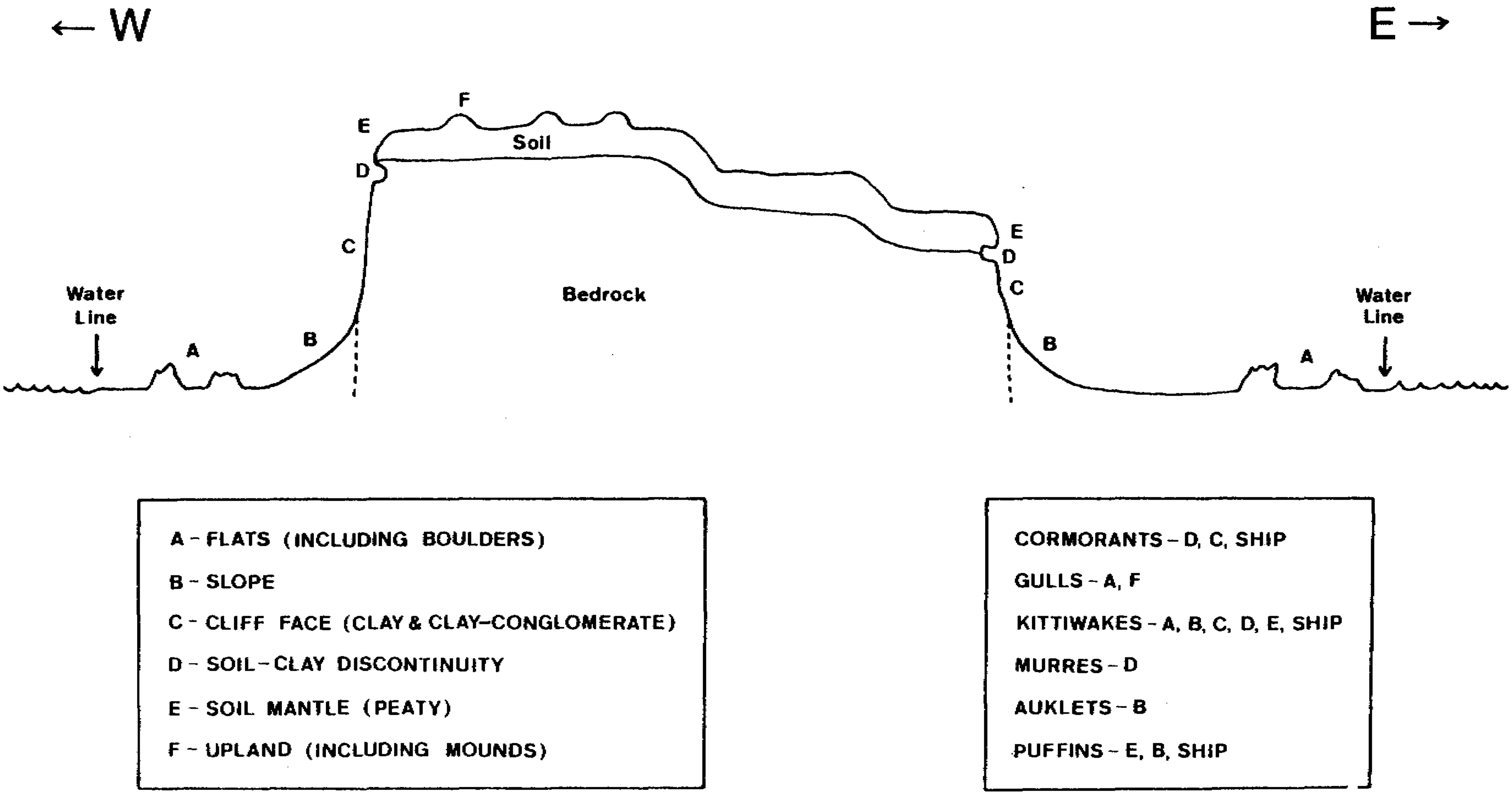

Figure 2. Profile of Middleton Island showing nesting habitats used by seabirds (cross-section at point A, Figure 3).

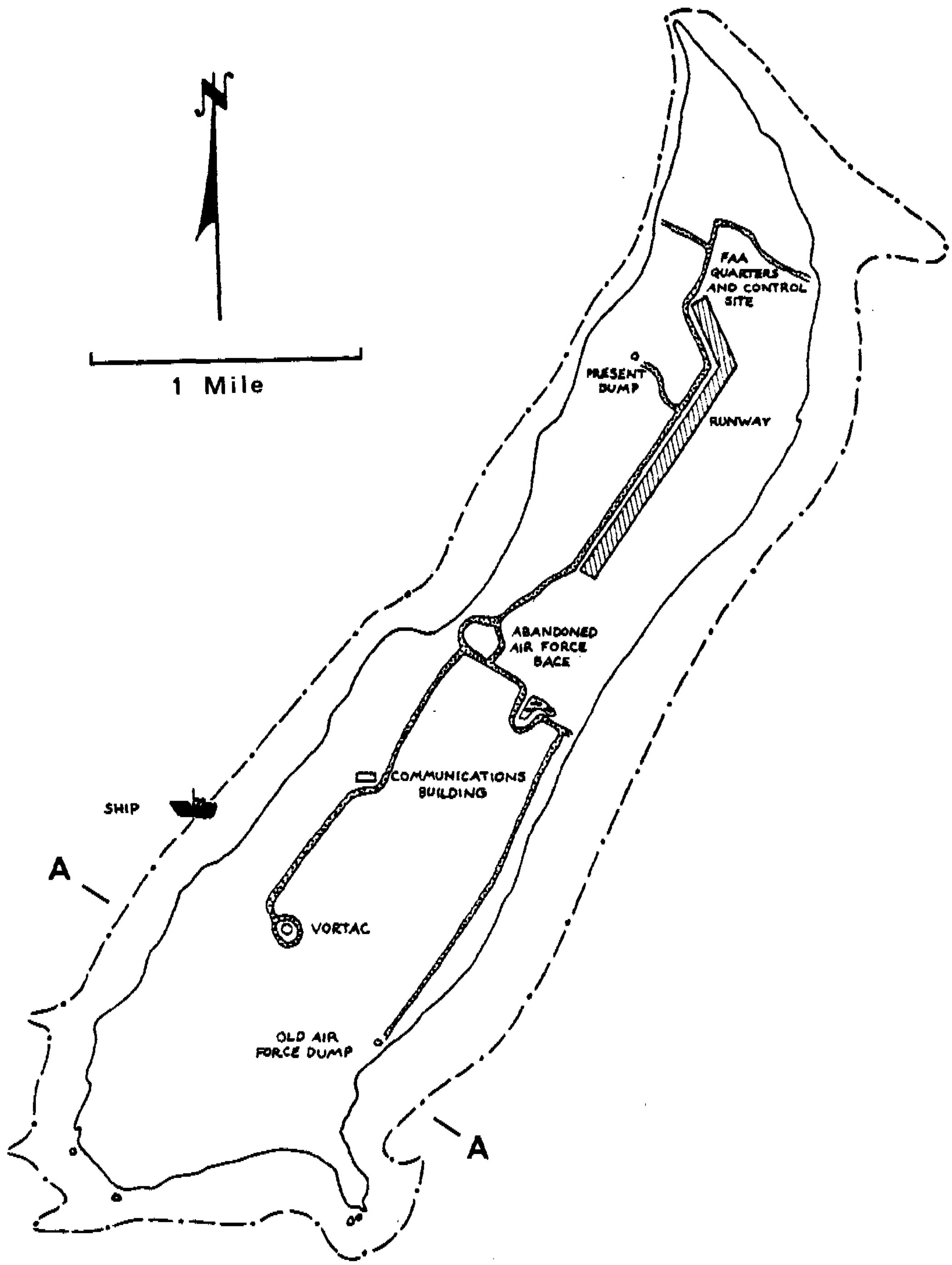

Figure 3. Human constructions on Middleton Island. (Redrawn from Frazer and Howe 1977). Dashed line indicates present shoreline.

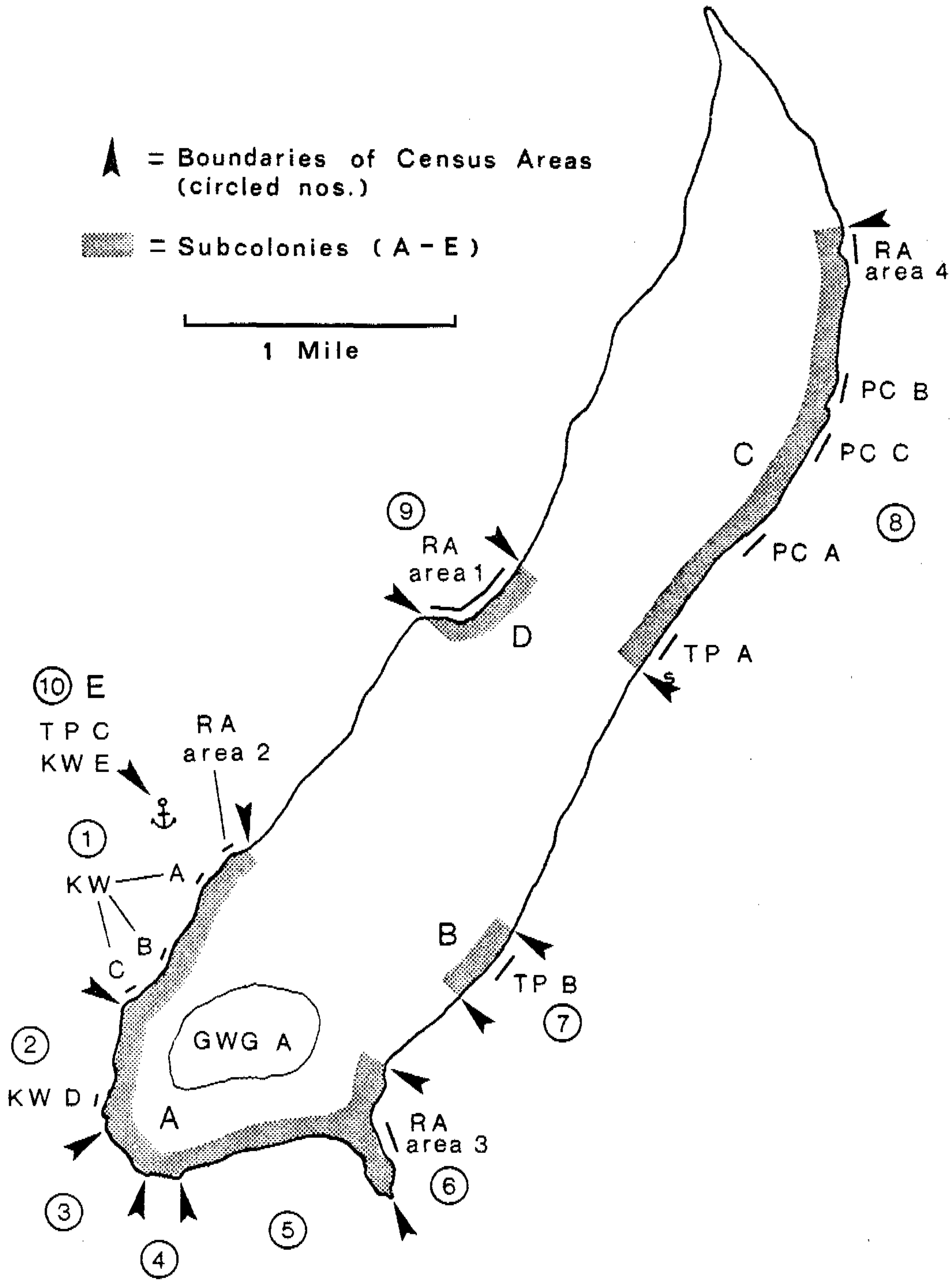

Figure 4. Boundaries of census areas and subcolonies and locations of study plots on Middleton Island, 1978. (GWG = Glaucous-winged Gull, KW = Black-legged Kittiwake, PC = Pelagic Cormorant, TP = Tufted Puffin, RA = Rhinoceros Auklet.)

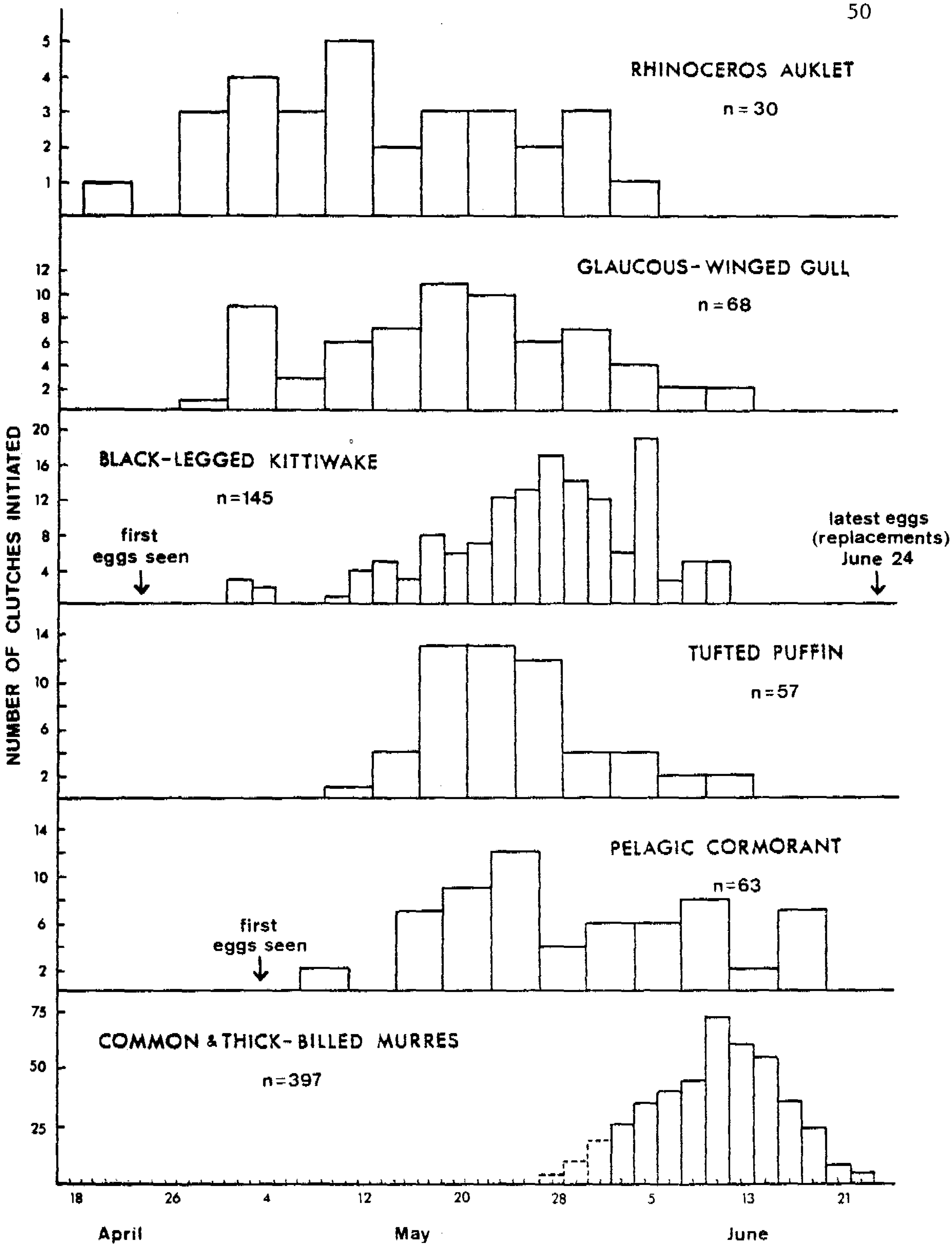

Figure 5. Egg-laying phenology of seabirds, Middleton Island, 1978.

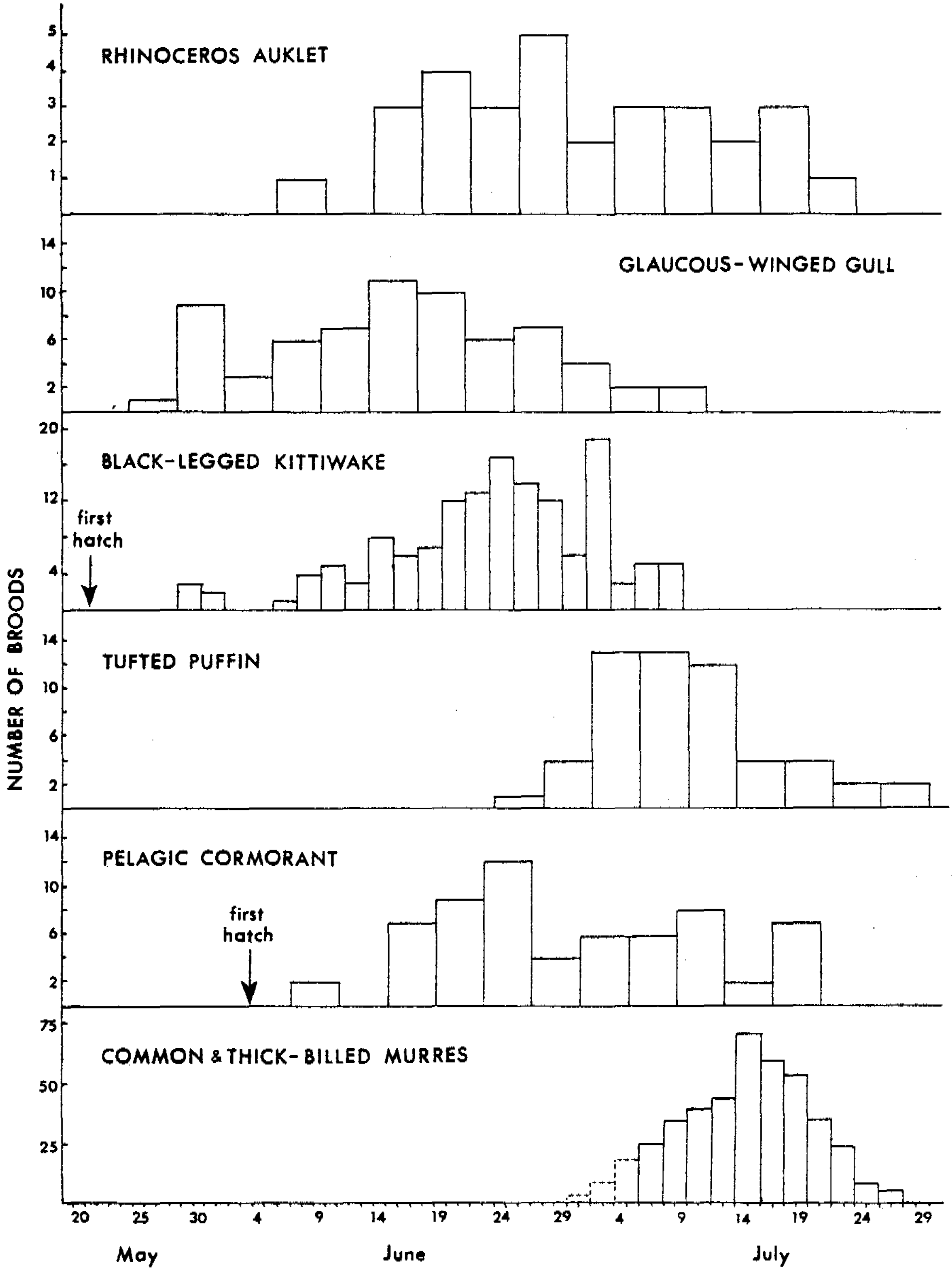

Figure 6. Hatching phenology of seabirds, Middleton Island, 1978.

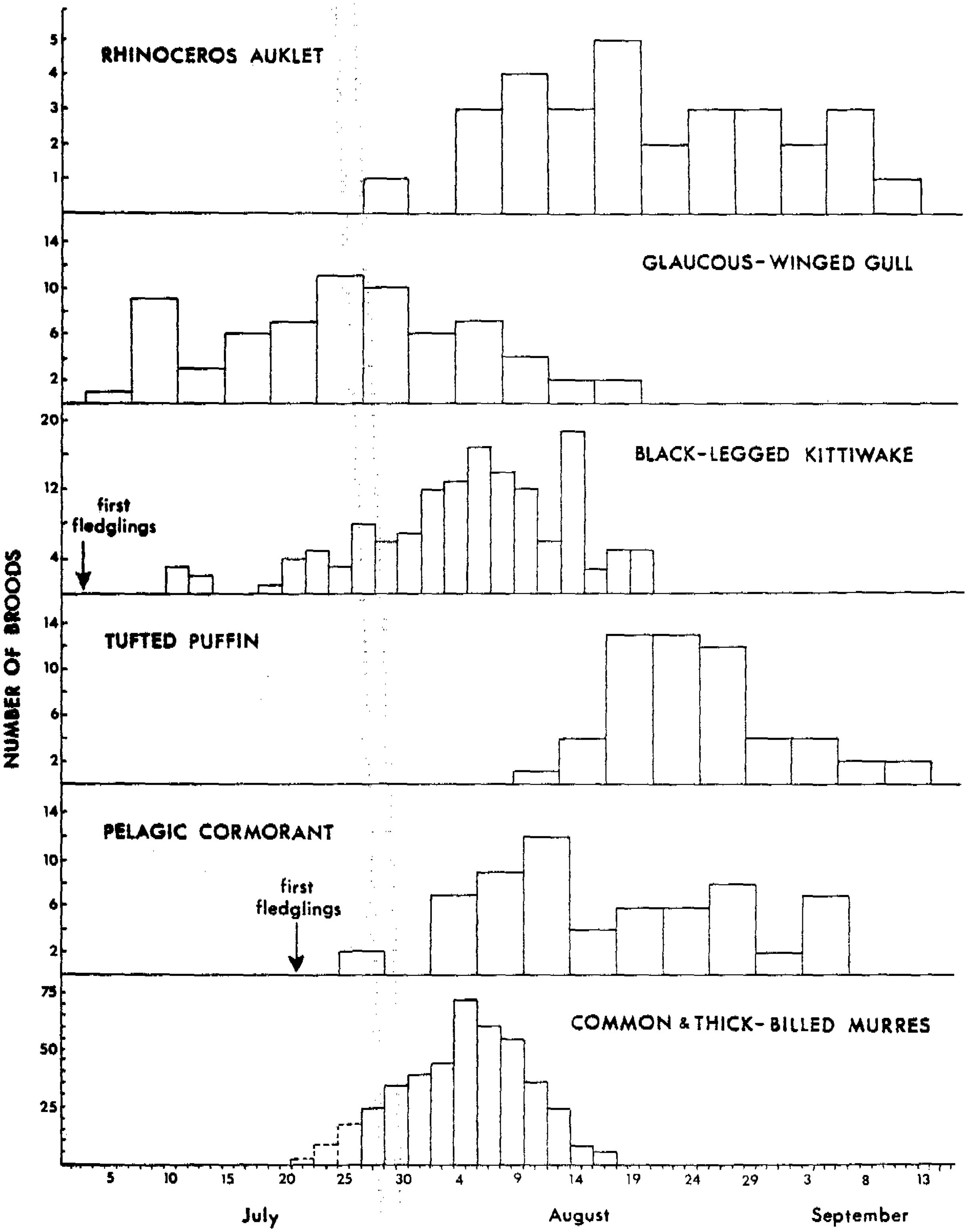

Figure 7. Fledging phenology of seabirds, Middleton Island, 1978.

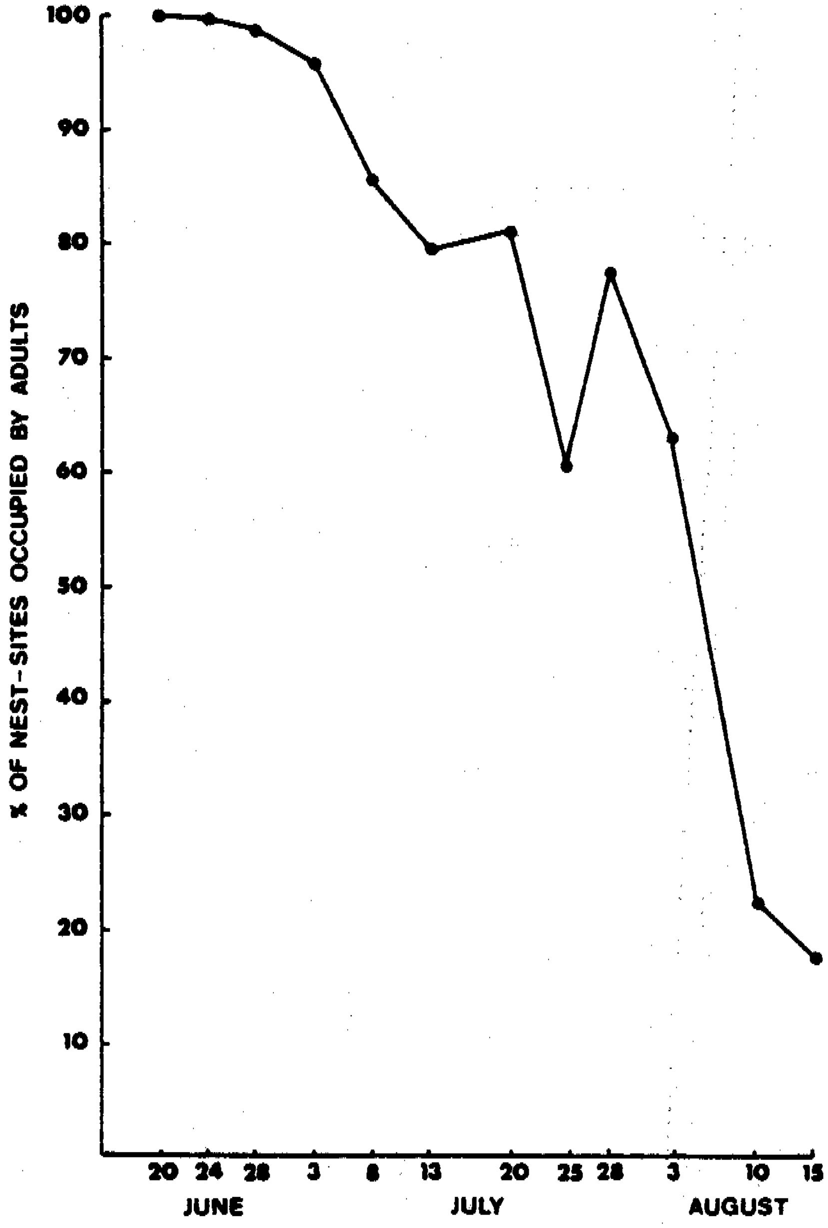

Figure 8. Nest site attendance of adult Pelagic Cormorants, Middleton Island, 1978.

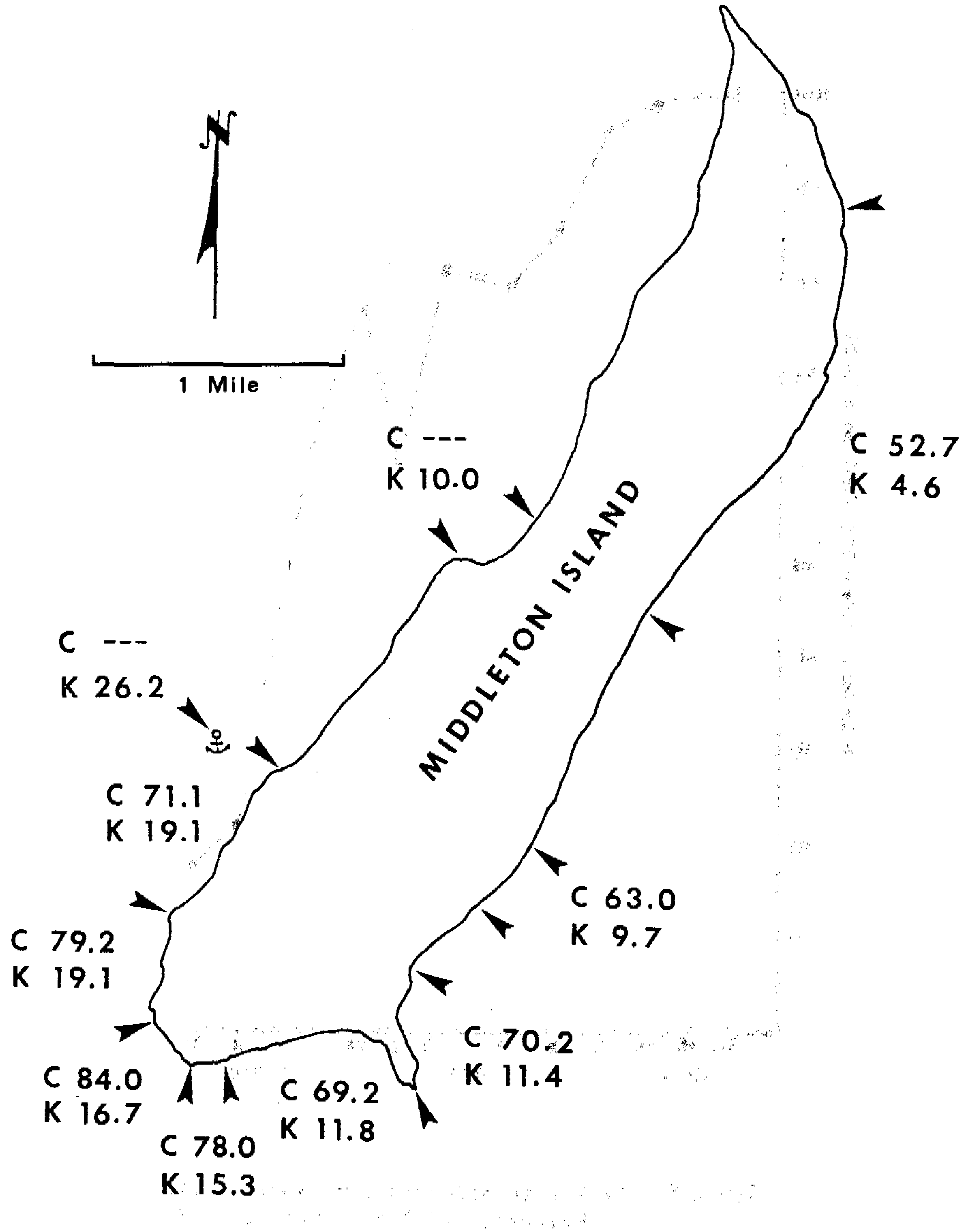

Figure 9. Approximate percent nesting success of Black-legged Kittiwakes (K) and Pelagic Cormorants (C) by census area, Middleton Island, 1978.

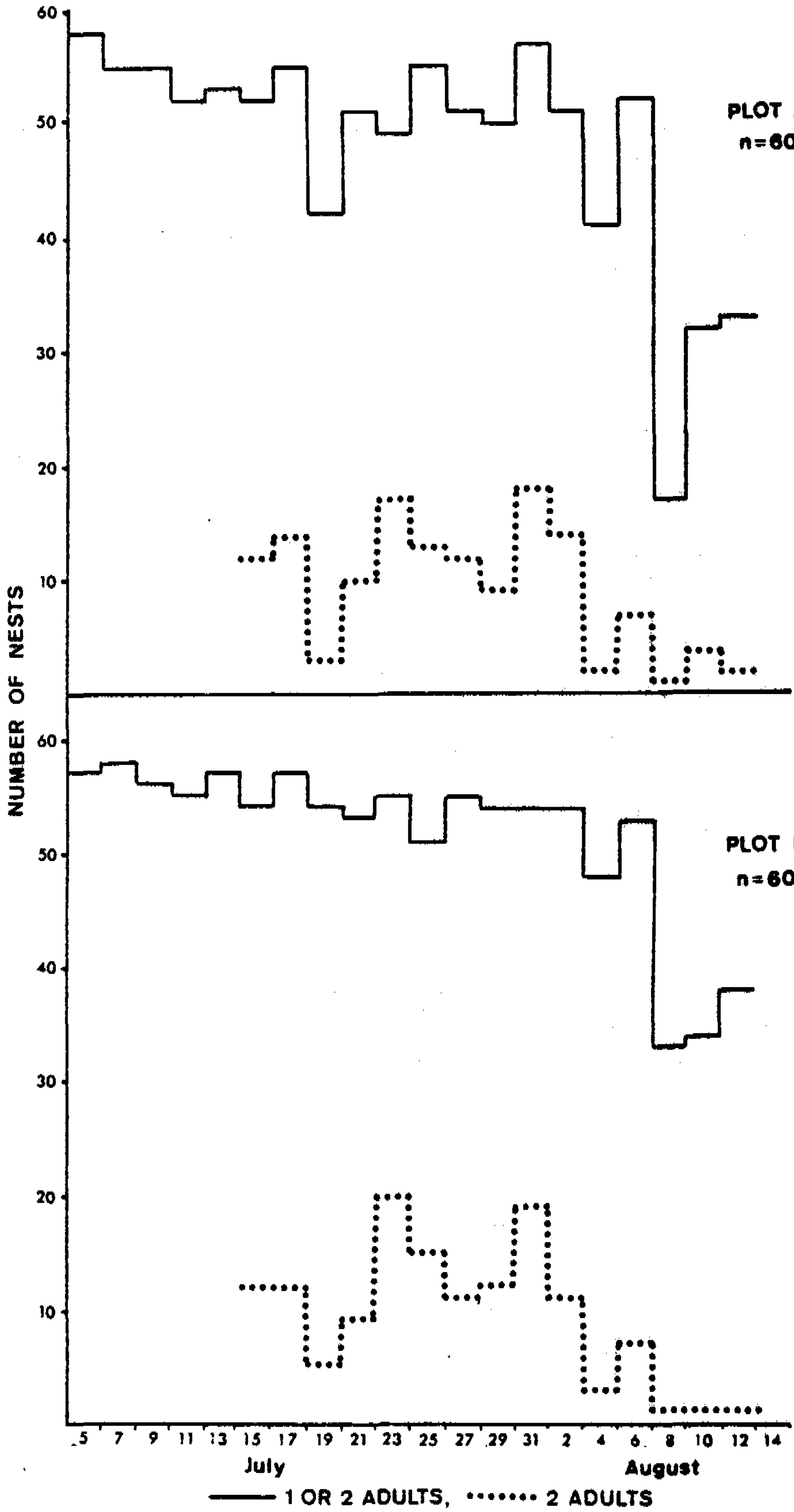

Figure 10. Nest site attendance of Black-legged Kittiwakes on plots A and C, Middleton Island, 1978.

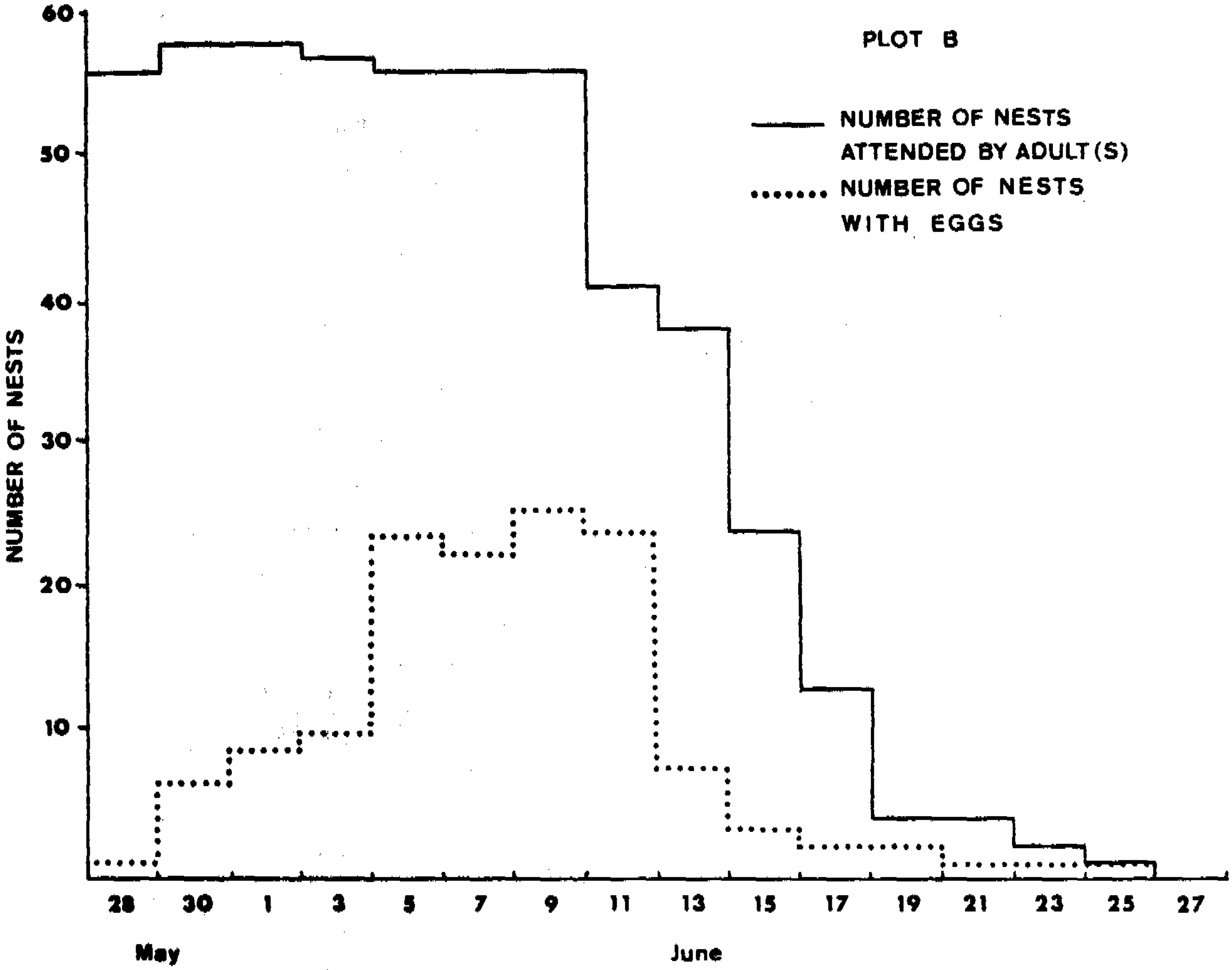

Figure 11. Nest site attendance of Black-legged Kittiwakes on study plot B, Middleton Island, 1978.

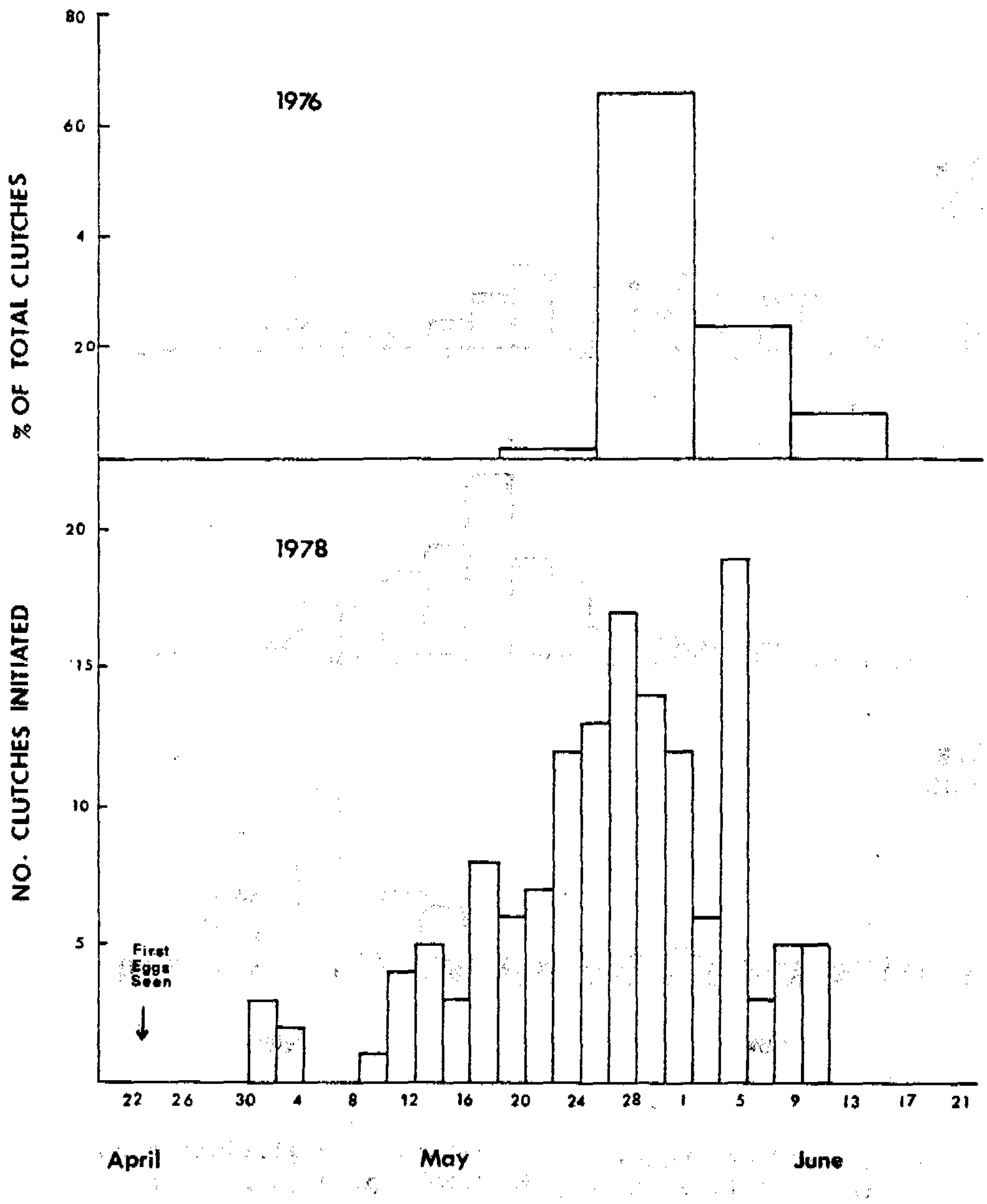

Figure 12. Egg-laying phenology of Black-legged Kittiwakes on Middleton Island in 1976 (Frazer and Howe 1977) and 1978.

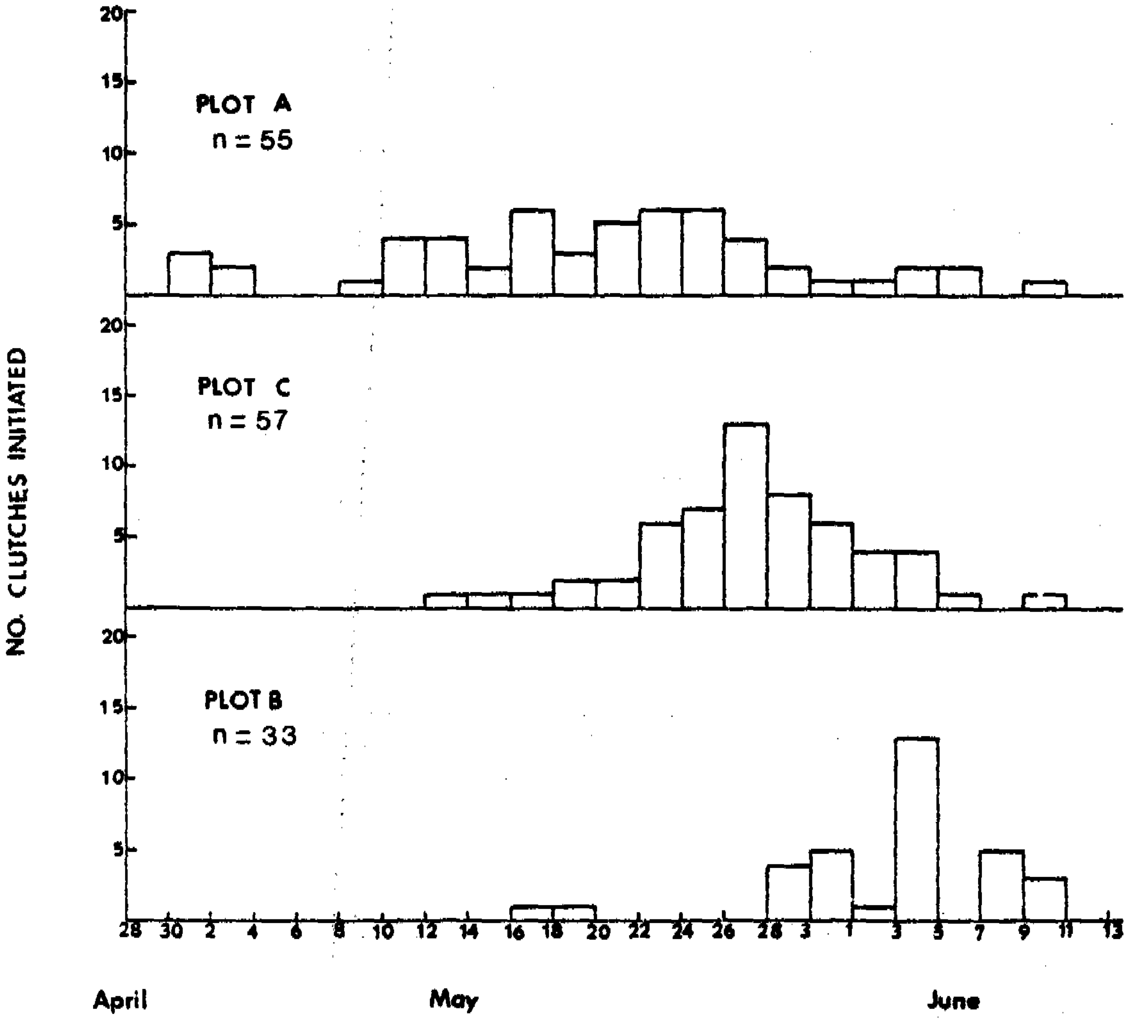

Figure 13. Egg-laying phenology of Black-legged Kittiwakes on study plots A, B, and C, Middleton Island, 1978.

Figure 14. Photograph of kittiwake study plot A showing density of nest sites, Middleton Island, 1978.

Figure 15. Photograph of kittiwake study plot B (upper right) and similar habitat (upper left) showing density of nest sites, Middleton Island, 1978.

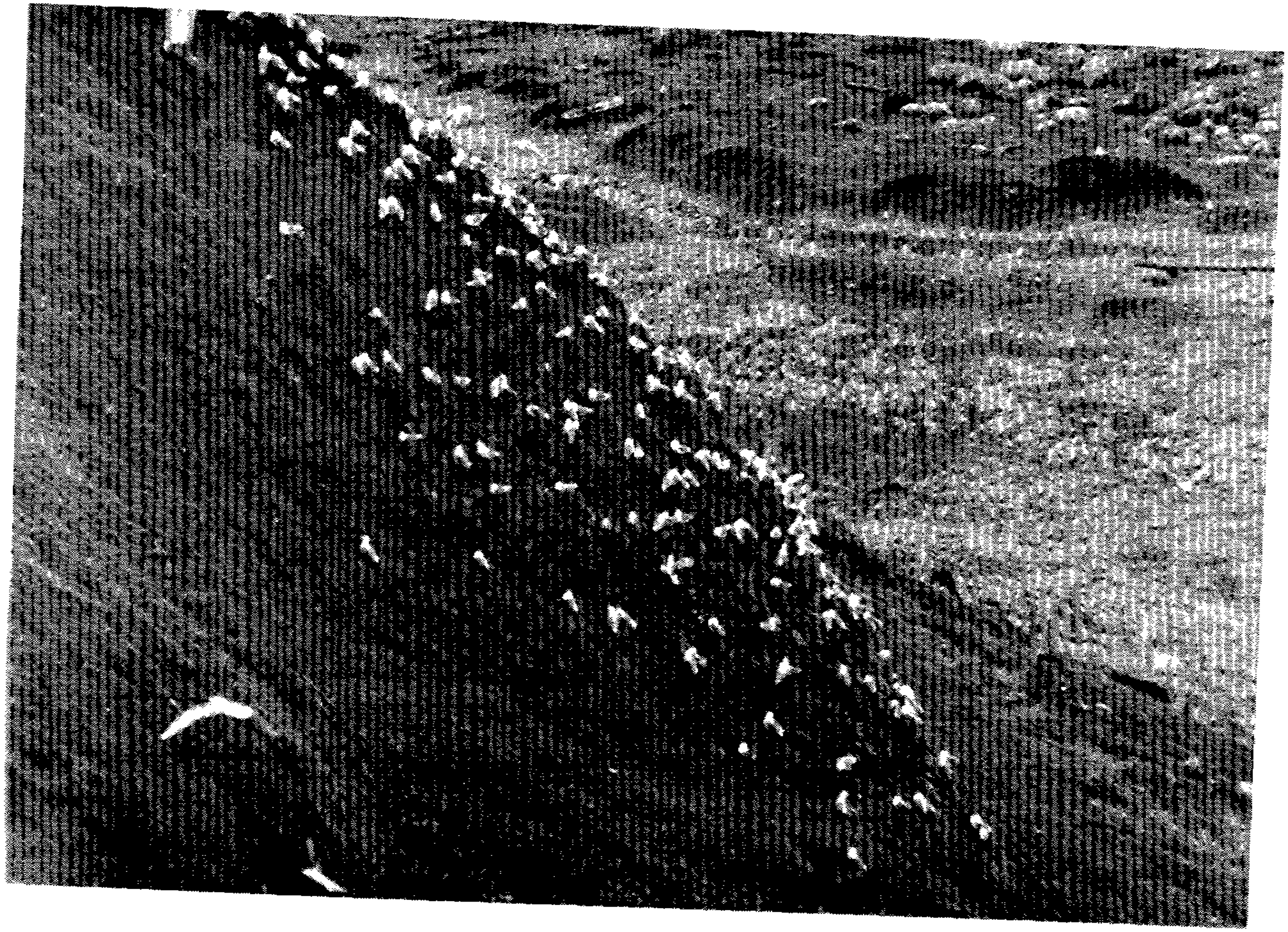

Figure 16. Photograph of kittiwake study plot C showing density of nest sites, Middleton Island, 1978.

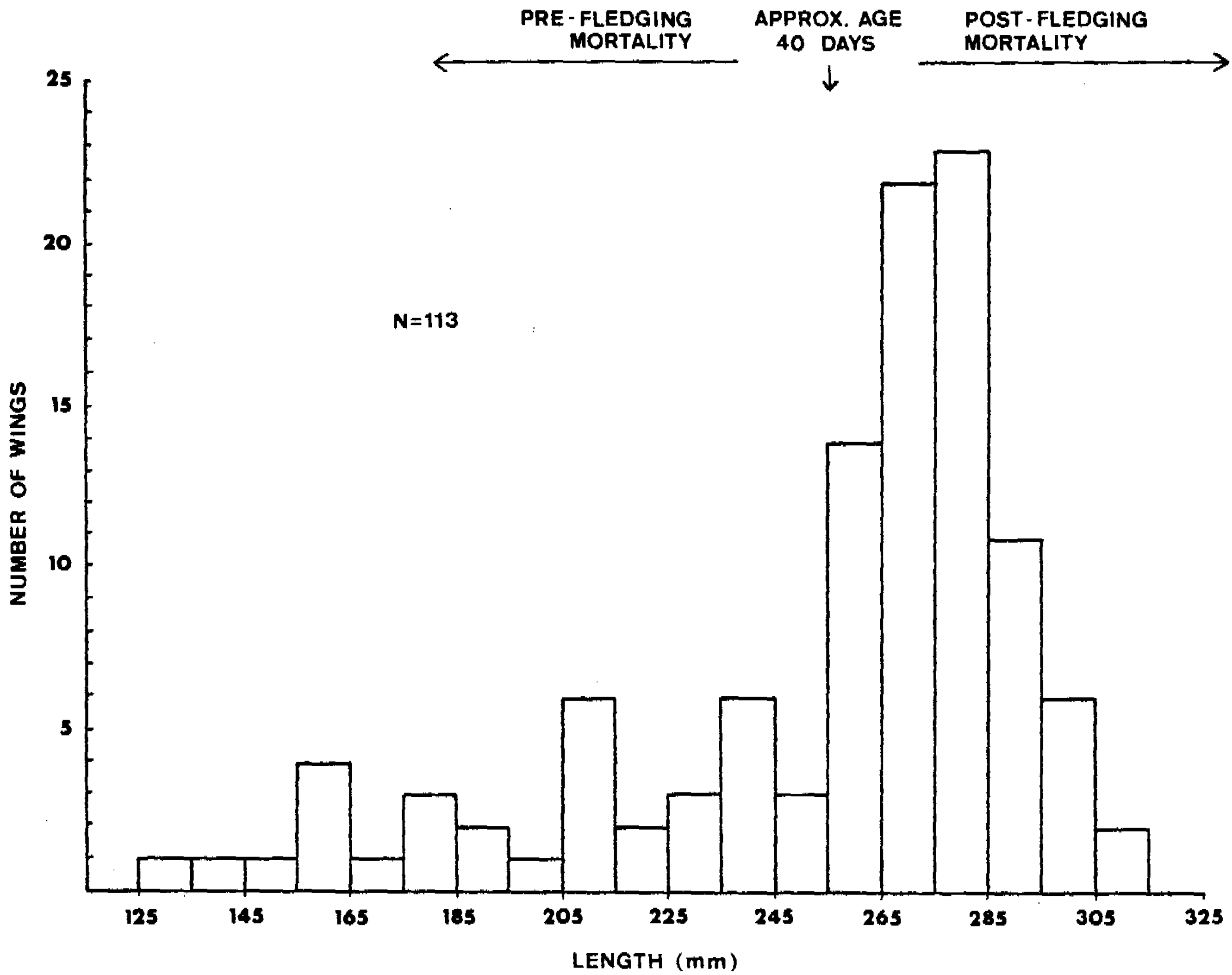

Figure 17. Distribution of wing lengths of young kittiwakes killed by gulls, Middleton Island, 1978.

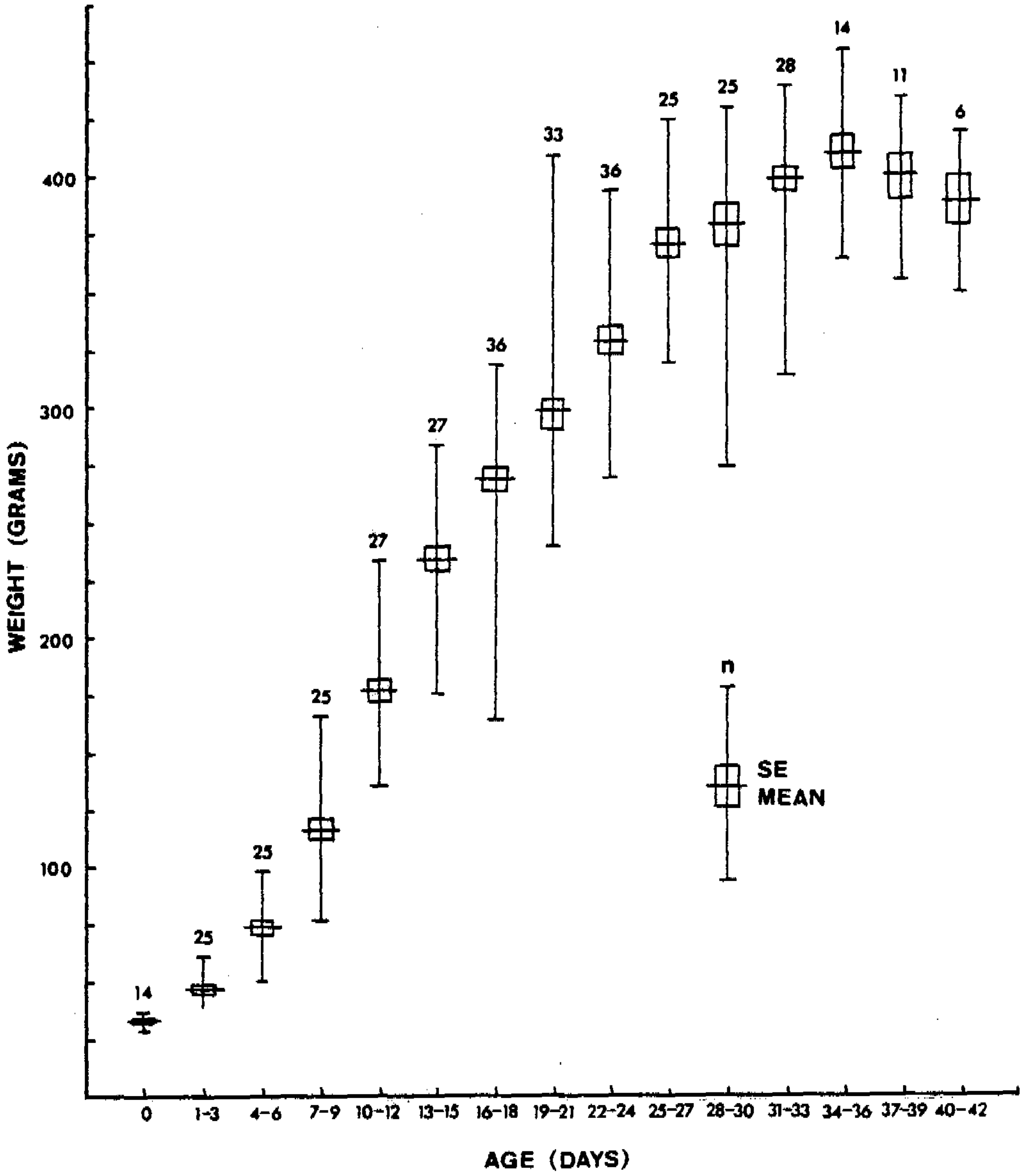

Figure 18. Weight gain of Black-legged Kittiwake nestlings, Middleton Island, 1978.

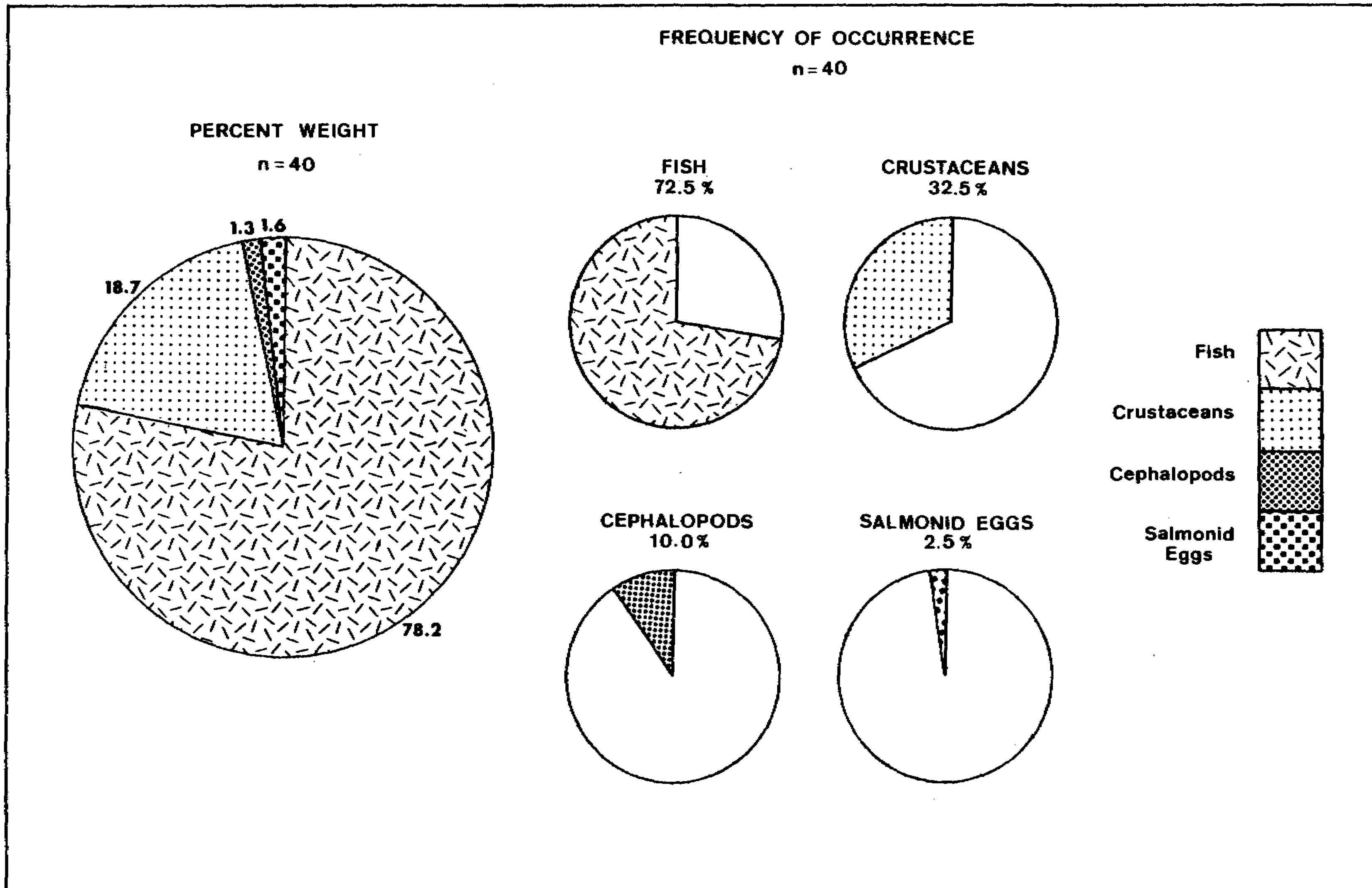

Figure 19. Composition of food samples from Black-legged Kittiwake nestlings, Middleton Island, 1978.

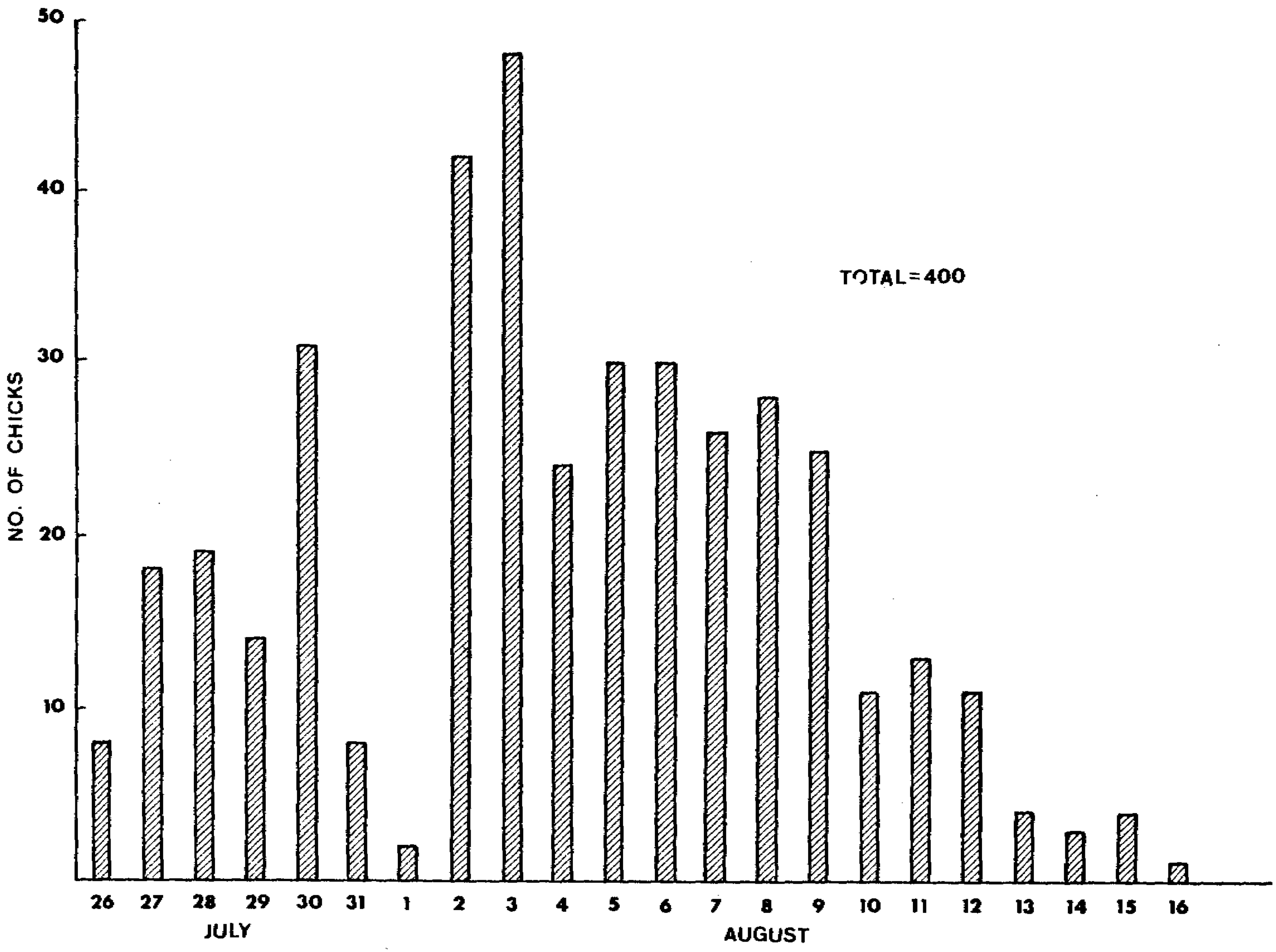

Figure 20. Number of new Common and Thick-billed Murre chicks captured daily in ponds below cliffs, Middleton Island, 1978.

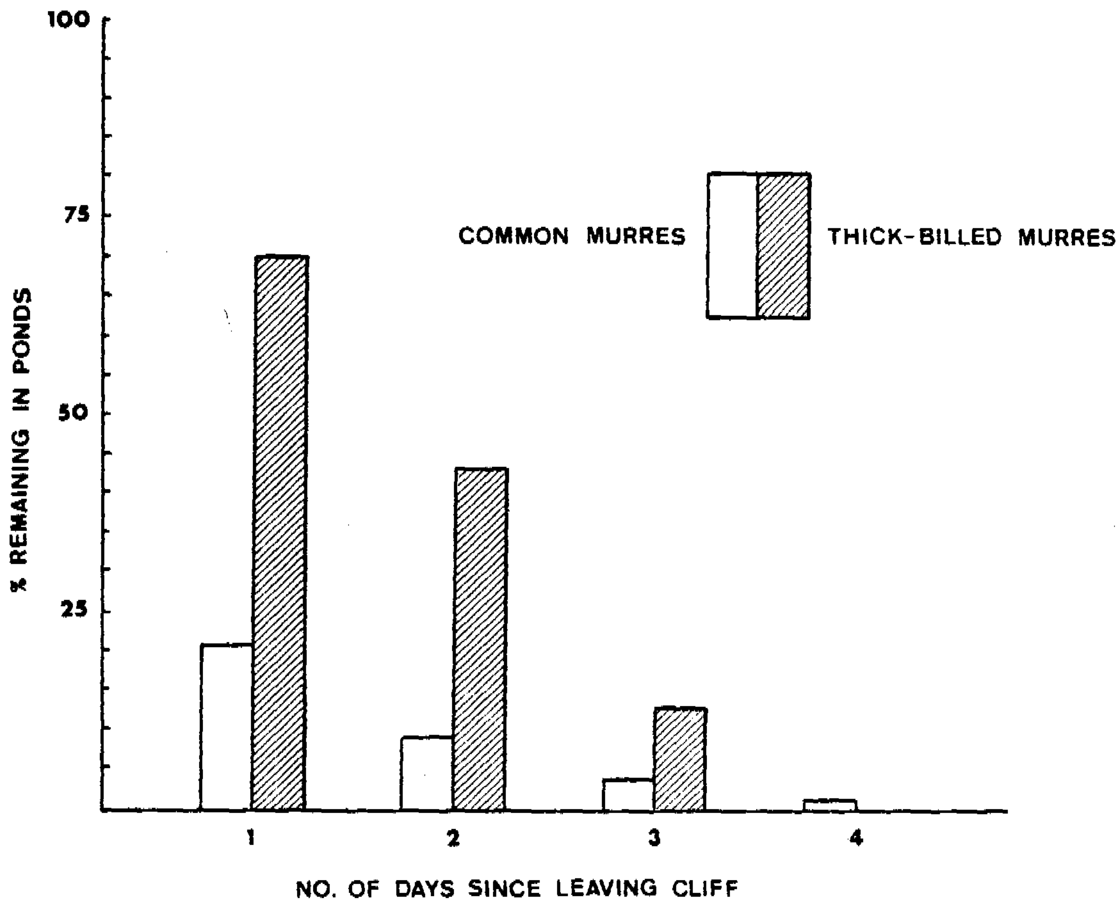

Figure 21. Percentages of Common and Thick-billed Murre chicks remaining in ponds on succeeding days after initial capture, Middleton Island, 1978.

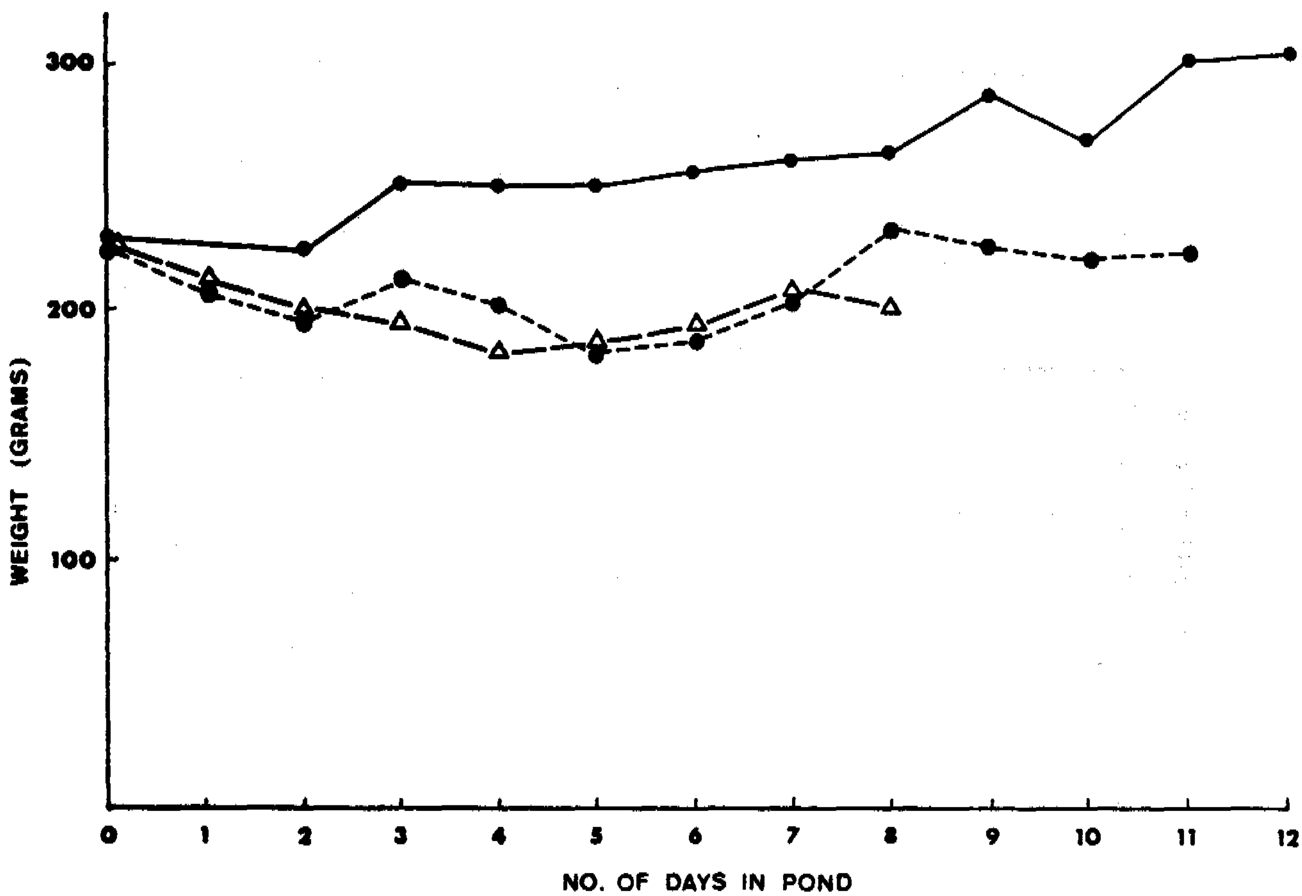

Figure 22. Weight changes in three Common Murre chicks which stayed in fresh water ponds more than a week, Middleton Island, 1978.

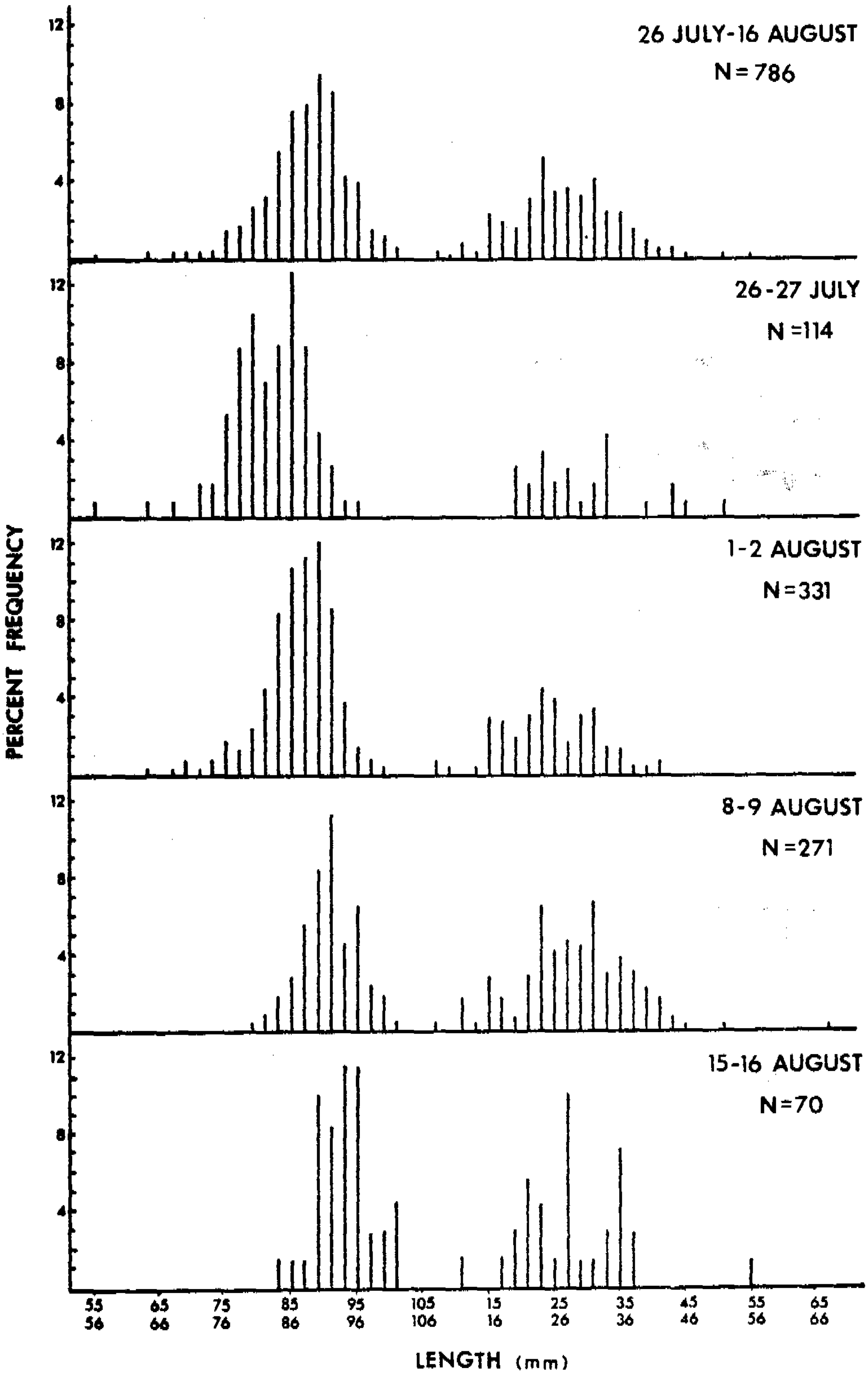

Figure 23. Length frequency profiles of Pacific sand lance in food samples from Rhinoceros Auklets, Middleton Island, 1978.

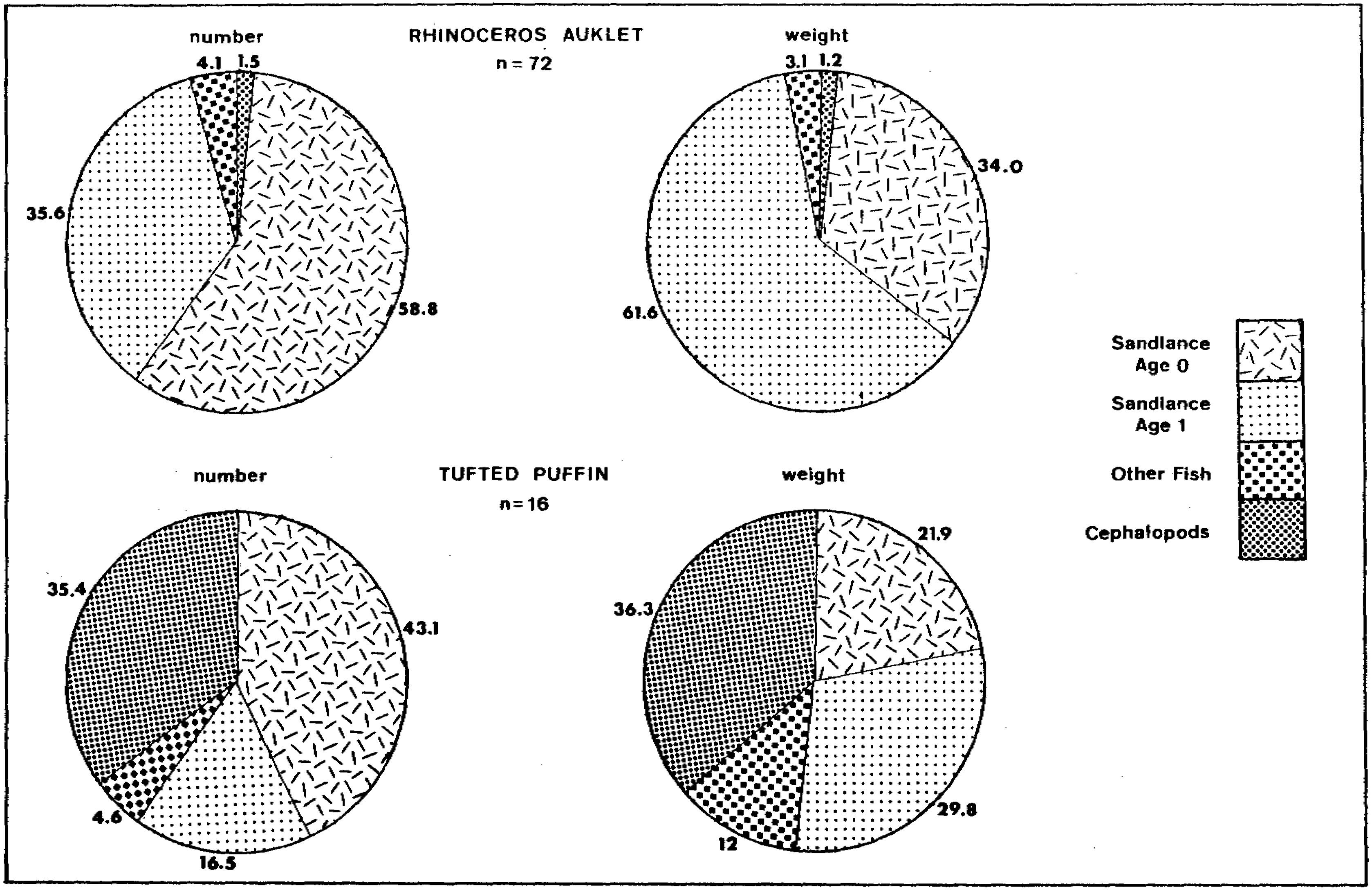

Figure 24. Composition of food samples from Rhinoceros Auklets and Tufted Puffins, Middleton Island, 1978.

APPENDIX

Communication From R. L. Rausch Concerning the Changing Population Status of Seabirds on Middleton Island

UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON 98195

15 XI 78

School of Medicine
Division of Animal Medicine SB-42

Mr. Scott Hatch, Wildlife Biologist
Fish and Wildlife Service
1011 E. Tudor Road
Anchorage, Alaska 99503

Dear Mr. Hatch:

Thank you for your letter of 10 October, concerning the situation on Middleton Island. I am sorry for the delayed response, but mail from Saskatoon is sent on at intervals by one of my students (E. P. Hoberg, whom you probably know), and I also have been out of the state for a meeting. We have been at this address since early April.

The situation on Middleton Island seems to me to have changed remarkably since the time of my work there. As you realize, it has been quite a long time, but I think that I recall the details rather well.

It is my impression from your data and from the photographs that kittiwakes have indeed increased greatly in numbers. The only large concentration in 1956 was that on the cliffs and adjacent soil on the west side of the island, where the largest colony of murres was observed (see my fig. 6). This would be the area marked "B" just below the middle of the west side of the Island on the smaller of the two maps on page 230. This area is perhaps your photograph no. 6. In any case, I saw nothing like the conditions shown in your photographs 10 and 11. My estimate of "several thousands" would be more in the range of 10-15,000.

At that time, kittiwakes were not along the tops of the cliffs, nor did any nest on boulders or other objects. The ship then was far offshore, but I saw no indication that anything was nesting on it. There was only the one area where kittiwakes nested on level ground above the cliffs or slopes and there the number of nests was estimated only as "more than 100," but I think not many more than that. There was really only the one relatively large concentration of nests.

Murres were uncommon, and the largest number was that on the west side (my fig. 6). I can only support your conclusion that there must have been a 16-fold increase. I walked around the entire island, and plotted all of the nesting-areas for the various cliff-nesting species on outline-maps. I could not have missed any concentrations that were not mentioned.

Cormorants were not numerous, and the largest concentration was that on the cliffs near the large colony of kittiwakes. Again, it is my impression that there has been a very considerable increase in their numbers.

APPENDIX (cont.)

Mr. Hatch-2

I have nothing really to add concerning glaucous-winged gulls. They were few, and I don't think that I would have missed finding nests, except for those on pinnacles offshore. Nothing was seen there with glasses, and it appeared that the birds were only resting on the pinnacles.

As I recall, we were near the shipwreck by dory, but I do not recall having seen any birds on the ship. I also looked at it with glasses from the shore. Any signs of nesting there certainly would have been at least mentioned in my paper.

The changes with regard to the shoreline are quite remarkable. Near the SW end of the island, the beach might have been 30-40 m wide, but it was not much. I remember that I could look almost directly down on it to observe seals that were there much of the time. I captured one or two pups at the edge of the water. A sandspit extended fairly far out at the north end of the beach, and beyond that, on rodks, there were sometimes sea lions.

As I recall, I had quite a good map of the island, so the relative width of beaches as shown on the larger map on page 230 is accurate. Even at low tide, there was very little beach exposed; I recall this specifically, since I was attempting to collect marine invertebrates and the zone exposed at low tide was quite limited. I am quite amazed to see conditions shown in your photographs (e.g., 8 and 15).

Unless you prefer otherwise, I shall keep your maps and phootographs for a time, in case you might want to correspond further. I probably could find my old notes and field maps, if this seems essential. If you wish to have the materials returned at once, please let me know.

I should much like to have a copy of your report and any subsequent publications. The appearance of the island is not at all familiar now; I had not realized that uplift had been so great.

With regards,

Sincerely,

Robert Rausch

Robert L. Rausch
Professor of Pathobiology

NOAA-OCSEAP Contract: 01-5-022-2538
Research Unit: 341
Principal Investigators: C. J. Lensink
P. J. Gould
G. A. Sanger
Reporting Period: April 1, 1978 to
March 31, 1979

Annual Report

THE WINTER FEEDING HABITS OF SELECTED SPECIES OF MARINE BIRDS IN KACHEMAK BAY, ALASKA

By

Gerald A. Sanger, Robert D. Jones, Jr., and David W. Wiswar

U. S. Fish and Wildlife Service
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1011 E. Tudor Road
Anchorage, Alaska 99503

April 1, 1979

I. ABSTRACT

From November 1977 to April 1978, marine birds were studied on Kachemak Bay, Alaska to determine their feeding habits and trophic relationships. Studies concentrated on oldsquaw, white-winged scoters, common murres and marbled murrelets. The birds ate 74 prey species in 11 major taxonomic groups. Oldsquaw were extreme generalists (56 prey species) on benthic fauna, with clams being the most important type of prey. White-winged scoters tended to be generalists (19 prey species) on benthic fauna, feeding mostly on clams. Common murres ate 11 species of crustaceans, fish and polychaetes, with pandalid shrimp and mysids being the most important. Fish were relatively unimportant to murres in Kachemak Bay, compared to their known feeding habits elsewhere. Marbled murrelets specialized on juvenile capelin, and ate lesser numbers of mysids and euphausiids. The birds in Kachemak Bay in winter appear to be largely dependent on a food web which has a detrital base. Additional analyses of the present data are needed for the final report, but it is evident that additional field work is needed to adequately describe the feeding ecology of marine birds on Kachemak Bay and elsewhere in lower Cook Inlet.

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II. INTRODUCTION

Kachemak Bay, located at the southwest end of the Kenai Peninsula, Alaska, is a major geographic feature of lower Cook Inlet (Figure 1). It has long been recognized for its high biological productivity. Important fisheries for species such as pandalid shrimp exist in the bay, which is also a critical nursery area for the larvae and juveniles of these and other commercial species (SAI 1977). Although marine birds have not been studied as intensively nor for as long as the commercially important populations, Arneson (1977) showed that Kachemak Bay has large year-round populations of birds. He felt that the bay is especially important as a primary wintering area for marine birds.

The lack of information on winter feeding habits and ecology of marine birds in lower Cook Inlet was recognized as a major gap in our knowledge at the first OCSEAP data synthesis meeting in November 1976 (SAI 1977). The idea of including birds in the integrated ecological processes study (P-210) for lower Cook Inlet was first suggested by OCSEAP Lease Area Coordinator Paul Becker in September 1977. Planning discussions ensued, and a study of the winter feeding habits of the birds in Kachemak Bay was added as an integral part of Research Unit 341.

Monthly field operations commenced in November 1977 and ended in April 1978. As originally conceived, the study was to continue for at least two winter field seasons, but dwindling funds in the OCSEA Program forced a termination of field work after one season.

This report provides a preliminary analysis of results. Data are presented on the feeding habits of four species of marine birds, the oldsquaw *(Clangula hyemalis)*, white-winged scoter *(Melanitta deglandi)*, common murre *(Uria aalge)* and marbled murrelet *(Brachyramphus marmoratum)*. The first three species probably comprise most of the numbers and biomass of the birds wintering on the bay, while marbled murrelets occur in unpredictable, localized concentrations. Being considerably smaller than the first three species, the murrelets further provide a wider perspective on the winter feeding habits of the entire bird community. Limited information on surf scoters *(M. perspicillata)*, black scoters *(Oidemia nigra)* and pigeon guillemots *(Cepphus columba)* will be discussed in the final report.

The specific objective of this report is to present data on the aggregate percent numbers, volume and frequency of occurrence of prey species in aggregate samples of the birds for the entire study period.

These three parameters are used to calculate the Index of Relative Importance (Pinkas *et al.* 1971) for the prey of the birds. Most of the analyses and interpretation of the data is being deferred until the final report, particularly the seasonal aspects.

Because changes in distribution or abundance of food may be critical to survival of birds, changes in the structure of their food web(s) caused by development of petroleum resources may have major significance. This study, by determining types and importance of prey, will improve predictions of the consequences of environmental changes from petroleum activities.

III. CURRENT STATE OF KNOWLEDGE

This section will be considered more fully in the final report. There have been virtually no systematic studies of the winter feeding ecology of marine birds in Kachemak Bay or anywhere in Alaska. Studies such as Cottam's (1939) for North America in general, and Nilsson's (1972) for Sweden in winter provide a general background on the feeding ecology of marine watefowl. However, they have limited application to the specific aspects of the winter feeding ecology of birds in Kachemak Bay.

IV. STUDY AREA

Description of Kachemak Bay

William Healey Dall (1896) wrote a description of Kachemak Bay: "Two days later we entered Kachekmak *(sic)* Bay, on the eastern shore of the inlet. This locality is interesting on account of the presence of extensive deposits of brown coal, and because it is the finest harbor in the inlet, never obstructed by ice, and one of the finest on the whole Pacific coast. The native name of the bay is Kachekmak, in allusion to the high bluffs of the northern shore; the natives of Chugach Bay (Prince William Sound) in coming to the inlet made a portage from the Pacific to the head of this bay, and so reached the Russian trading post at Port Graham, so the traders called it the bay of the Chugachi, or Chugachik. The native name was misspelled on an obscure map without the central 'k', and although the Coast Survey in the first and only special chart of the bay gave the correct spelling, the Board of Geographic names adopted the incorrect form, which thus becomes obligatory in all Government publications.

"This harbor separates the comparatively level plateau of the Kenai Peninsula west of its axial mountain range from a spur of that range which comes down to the sea at Pt. Bede, with several indentations affording anchorage.

"These mountains are not very high, but from them descend several attractive glaciers not difficult to reach. . . . The harbor is protected by a long, low spit of gravel, within which is good anchorage close to the shore, but the beach in front of the bluffs makes off shoal for two, or toward the head of the bay, fully three miles. We observed the range of tide in the upper bay to be 22 feet at springs the extreme range is said to be thirty in the upper part of the bay and somewhat less toward the entrance."

The Study Area

The spit mentioned by Dall, now known as Homer Spit, divides Kachemak Bay into inner and outer parts (Figure 1). The town of Homer, Alaska, is located at the head of the spit. At roughly right angles to the spit the 20 fathom curve divides both parts of the bay into nearly equal halves, with all the deep water in the southern half. The diurnal tide range at Homer is 5.5 m, and tidal currents occur everywhere in the bay, especially where land forms constrict flow.

Birds were collected where they were concentrated, but this varied somewhat depending on month and bird species. Generally, most were observed and collected within two km of shore between Anchor Point and Bluff Point in the outer bay, and in the inner bay between Homer Spit and a line from Fritz Creek to Glacier Spit. Some collecting was done in China Poot Bay in January.

Environmental Conditions

The weather at Homer is maritime in temperature, but not in precipitation. Homer lies in a rain shadow from mountains both east and west, which reduce precipitation reaching the town by 50%. We consistently encountered northeast winds, and pan and brash ice was common in the inner bay. The latter made it difficult to tow vehicles while launching and retrieving the work boat in Homer Harbor, and created obstacles to the floating boat. The ice forms at low tide from runoff from the Fox River at the head of the bay. High tides float the ice, which drifts toward Homer Spit with ebbing tides and the northeast wind; there it accumulates and drifts into the harbor.

Except for April, air temperatures were generally below freezing throughout the study. They ranged from a low of nearly -13°C in December to about 4°C in April. Sporadic snow and sleet was common, and freezing spray on ourselves, the boat, and other gear was a constant problem. Surface water temperatures were generally in the 4-5°C range, despite the frequent presence of drifting ice in the inner bay.

V. METHODS

Field Methods

Field trips of three to five days duration were conducted each month, from November 1977 through April 1978 (Table 1). The work boat was a 6.7 m MonArk, with a welded aluminum, cathedral hull. The main power was a 75 hp outboard engine, with a 10 hp engine always carried as a spare. The boat was launched and retrieved each trip in Homer Harbor, and stored in the interim at the Alaska Department of Fish and Game office in Homer.

Conducting field work where sleet, snow, drifting ice, wind and freezing spray are constantly present requires a certain determination to even contemplate, let alone perform. Jones was directly in charge of the field work, and his years of experience in handling small boats in Alaskan waters in all seasons was the key to the successful, safe completion of this project. He was assisted on each trip by a different BSP-CE staff member (see Acknowledgements).

The main objective on each trip was to collect samples of at least five specimens of each species studied. General observations on the distribution, abundance and behavior of the birds were made when possible. However, with prohibitive weather and sea conditions a constant threat, the general approach was to collect the birds as fast as possible. The short daylight in mid-winter limited the work to four to six hours each day, and it usually took two to three days to complete the collections. The remainder of each trip (Table 1) was spent in launching and retrieving the boat, and in travel between Homer and Anchorage.

A 12-guage, double-barreled shotgun was used for collecting. Early attempts to use a pump-action shotgun failed because freezing spray soon rendered the sliding action of the gun useless. After collection, the digestive tract of each specimen was immediately injected with 10% buffered formalin. The formalin was injected with a syringe, through tygon tubing inserted through the bird's esophagus to the gizzard, until the formalin ran out the bill. This assured maximum penetration of the formalin into the digestive tract, to stop digestion which otherwise continues after death (van Koersveld 1950). In cold weather, the specimens soon froze in the open air, within a couple of hours, thus further preserving the stomach contents.

Laboratory Methods

After each trip, the frozen birds were stored in a laboratory freezer until processed. For initial processing, each bird was thawed, and standard ornithological measurements were made and recorded (NODC File Type 031). Measurements particularly pertinent to studies of feeding ecology are body weight, bill width (gape) and fat index. The fat index is a numerical but subjective indication of the amount of body fat on a scale of 1 to 5, with a "1" being little or no fat and "5" being very fat. Finally, the age and sex of the specimen was determined, and the upper digestive tract (esophagus, proventriculus and gizzard) removed and placed in a labeled jar with 50% isopropal alcohol.

For analysis of food contents, the digestive tract was carefully cut lengthwise with scissors, and non-food items such as rocks and gravel were removed and set aside. The contents were drained of excess moisture, weighed to the nearest 0.1 g. on a laboratory balance, and their volume was determined to the nearest ml. by water displacement in a calibrated container. The contents were then separated into taxonomic groups, and each identified to the lowest possible taxon and counted. The volume of each kind of prey was visually estimated as a percent of the total. Whenever an identification was uncertain, the material was sent to a taxonomic specialist for confirmation or identification. Voucher specimens of each new species encountered in the stomachs were labeled and preserved in 50% isopropal alcohol. All non-food items were counted and their greatest length measured to the nearest mm.

Data Analysis Methods

For this report, the aggregate percent volume, numbers and frequency of occurrence of each prey species and each major prey group was determined by lumping the data for each bird species for the entire six-month study period.

It should be noted that the aggregate percent volume is derived differently than the average percent volume. The former is the percent of the combined volume of the prey in all birds in a sample, while the latter is the mean percent volume of the prey among all the birds in the sample. The relative merits of both methods are discussed by Swanson *et al.* (1974).

The three parameters noted above were used to calculate the index of relative importance (IRI) of each prey to each of the four bird species (Pinkas *et al.* 1971). The IRI is defined as:

IRI = %FO (%V + %N), where

%FO = aggregate percent frequency of occurrence of prey among all birds in sample;

%V = aggregate percent volume of prey in total volume of stomach contents of all birds in sample; and,

%N = aggregate percent number of prey in total number of prey items in all birds in sample.

The composition of prey in stomach samples is often expressed as percent volume, whether aggregate percent volume (such as used here) or mean percent volume. It is often implied that such volumes are a reflection of the volumes of prey ingested. Such assumptions may be incorrect, since they ignore the fact that various prey are digested at different, although unknown rates; e.g., soft bodied forms such as squid and polychaetes probably are digested the fastest. Fish are probably digested nearly as fast as squid and polychaetes, while crustaceans are probably digested relatively slowly, depending on the thickness of their exoskeletons. Hard-bodied forms such as clams and gastropods no doubt have the slowest rates, at least until their shells are crushed in the bird's gizzard.

A way of determining the relative volumes of prey at the time of their ingestion, and a means of measuring or estimating their ingestion rates is needed. This is at the crux of determining trophic relationships. Lacking this information, it is desirable to somehow weight the measured volumes so they will more accurately reflect their volumes when ingested. Pinkas *et al.* (1971) recognized this problem, since most of their fish stomach samples were in advanced states of digestion. They attempted to overcome this problem by developing the index of relative importance.

To avoid possible confusion about the IRI, we emphasize that it is an <u>index</u> and not an actual measure. While it may indicate the "importance" of the prey better than their measured volumes, we do not intend it to substitute for the elusive ingested volume. The IRI is useful for examining the feeding habits of the birds, particularly when presented graphically (Pinkas *et al.* 1971), such as we do in this report.

The area of the rectangles representing each prey item in the IRI graphs are directly proportional to the IRI values presented in the tables. However, as seen on the graphs, the three component parameters are still individually discernible.

VI. RESULTS

A total of 123 specimens of six species of marine birds was collected in this study (Table 1). Of this total, 117 were of the four species which are the focus of this report. One-hundred-thirteen (96.6%) of these had food in their stomachs. Only two of the 30 common murres and one of the 21 marbled murrelets had empty stomachs. This contrasts to the lower proportions of specimens with food in their stomachs in spring-summer in the Kodiak area, which was 87% in 1977 (Sanger *et al.* 1978), and 91% in 1978 (Krasnow *et al.* 1979).

In each field operation, specimens of each species were generally collected at about the same time and place, although the locations of the collections often varied from month to month (Figures 2, 4, 6, and 8). Certain details of these variations are noted below.

Data on the aggregate percent volume, numbers and frequency of occurrence, and the IRI values are listed in Tables 2 - 5 and in Figures 3, 5, 7, and 9. The figures allow a simultaneous comparison of the data among the major prey groups and the most important prey species.

The species accounts summarize the feeding habits of the four bird species, and these are followed by a discussion of the most important prey species and groups of species to the bird community as a whole.

Species Accounts

Oldsquaw *(Clangula hymaelis)*.--Most oldsquaws were collected in the inner bay (Figure 2). Depending on the final identification of gammarid amphipods (there were at least four species), at least 56 prey species in nine major prey groups were identified from the stomachs of the 28 birds collected (Table 2). Pelecypods (clams) were considerably more important than other prey groups; their IRI was 7,570 compared to 2,092 for the crustaceans, the next highest group. However, fish, polychaetes and gastropods were also important.

Figure 3 shows data for the 16 most important prey species or closely related groups of species (73.7% of the total volume). The clams *Glycemeria subobsoleta, Mytilus edulis* and *Spisula polynema,* as well as Pacific sand lance *(Ammodytes hexapterus)*, were the four most important prey species. It should be mentioned, however, that the sand lance occurred only once (February) in the oldsquaw.

White-winged Scoter *(Melanitta deglandi)*.--Most of the scoters were collected in the area between Anchor and Bluff Points (Figure 4). A total of 19 prey species in six major prey groups was found in the 36 white-winged scoters collected (Tables 3, Figure 5). With an IRI value of 10,686, clams were overwhelmingly the most important major prey group of the scoters. Gastropods were important too (IRI = 1,812). Crustacea and polychaetes were less common in the stomachs, and echinoderms and sipunculid worms were present only in trace amounts. The clams *Prototheca staminea* and *Mytilus edulis* were the two most important species of prey, with IRI values of 2,313 and 1,150, respectively. Together they comprised 63.3% of the total volume (Figure 5).

Common Murre *(Uria aalge)*.--The 28 common murres were all collected in the inner bay (Figure 6). A total of 11 prey species in three major prey groups was found in the stomachs (Table 4). Crustaceans were overwhelmingly the most important prey, showing up in 93% of the birds, and comprising 94% of the numbers and 84% of the volume of all samples (Table 4, Figure 7). Pandalid shrimp in the aggregate and the mysid crustacean *Neomysis rayii,* were the most important prey. Total fish had an IRI value of 1,100, but no one species was outstanding. Herring, *(Clupea harengus)*, capelin *(Mallotus villosus)*, walleye pollock *(Theragra chalcogramma)*, and Pacific sand lance *(Ammodytes hexapterus)*, all occurred in this species' diet, but in small numbers, volumes and frequencies (Figure 7).

These results are unexpected, considering the nearly exclusive piscivorous feeding habits of this species in the Kodiak area (Sanger *et al.* 1978; Krasnow *et al.* 1979) and in the Bering Sea in summer (Hunt 1976; Ogi and Tsujita 1973).

Marbled Murrelet *(Brachyramphus marmoratum)*.--The murrelets were collected in the same general area as the murres (Figure 8). The murrelets had the least diverse diet of the four birds, consuming about eight species of prey (the number of gammarid amphipod species is uncertain) in only two major taxonomic groups (Table 5, Figure 9). Fish, predominately juvenile capelin, was present in all stomachs containing food.

The euphausiid *Thysanoessa rashii* and unidentified mysids were also important to the murrelets (Figure 9).

No murrelets were present in areas we collected in during early winter, but concentration areas were located in January, and the species was well represented in the collections from then on (Table 1).

The Prey of the Four-Species Bird "Community"

An examination of the data from the standpoint of the four-species "community" is useful. Is there any overlap in the diets of the four species? Are any prey species shared by all four birds? Can anything be learned by direct comparison of the IRI's? Simple comparisons of the data are instructive, and suggest that a calculation of indices of diversity of the prey will be worthwhile for the final report.

A total of 74 individual species in 11 higher taxonomic groups occurred in the birds (Table 6). This included six species of fish, 19 species of crustaceans (minimum), 11 species of polychaete worms, 18 species of gastropods, 12 species of clams, four species of echinoderms, and four kinds of "other" invertebrates.

Table 7 lists the numbers and percentage of prey species and major groups of species (as noted in Tables 2-5) found in each of the four birds, as proportions of the total numbers of species and groups of species eaten by all of the birds. Oldsquaws consumed 76% of the total number of prey species, followed by white-winged scoters (26%), common murres (15%) and marbled murrelets (11%).

Crustaceans were eaten by all four species of birds; they were least important to the white-winged scoters (IRI = 91) and most important to the common murres (IRI = 16,490). Fish were eaten by all species except the scoters. All the other major prey groups were eaten only by the oldsquaws and scoters, both benthic feeders.

Looking at the overall importance of individual prey species, however, it appears that one which was particularly important to one species of birds, was of minor, if any, importance to the others. For example, while sand lance were eaten by all species except the scoters, the IRI of this prey was 825 for oldsquaw, but only 26 and 78, respectively, for murres and murrelets. Similarly, the clam *Protothaca staminea* had an IRI of 2,313 in the scoters, but only 75 in the oldsquaw. The only exception to this trend is for the blue mussel, *Mytilus edulis*, which had an IRI of 1,150 in the scoters and 532 in the oldsquaw, still relatively high.

An evaluation of food selection from the standpoint of the prey rather than the predators was attempted by listing the 26 prey species or major groups whose IRI is 100 or greater in descending order of magnitude (Table 8). This allows a simultaneous comparison of the IRI data on both major groups and individual species. As expected, the major groups had higher IRI values than the individual species, and the IRI's of the prey of murres and murrelets tended to be greater than those of the oldsquaw and scoters, which ate greater numbers of prey species.

Further, a major prey group can be more important to a bird than an individual prey species in another group. For example, while no one species of crustacean stood out in importance to oldsquaw (Table 2, Figure 3), crustaceans as a whole had a higher IRI (2,092) than that of the most important prey species (909 for the clam *Spisula*). Similarly, gastropods as a whole were most important to white-winged scoters (IRI = 1,812) than was *Mytilus*, the most important prey species (IRI = 1,150).

VII. DISCUSSION

While we have not yet attempted to determine the trophic levels of the birds' prey, it appears that the birds are largely first- and second-order carnivores in a food web which is largely detrital based. Most prey species are largely filter- and deposit-feeders on organic detritus, and filter feeders on microplankton (Lees 1978). Primary production is undoubtedly very low in lower Cook Inlet in winter, and secondary production is thus largely dependent upon organic detritus (Lees 1978). The relative contributions of terrestrial and marine detritus are unknown, but the extensive beds of kelp (*Nereocystis* and *Alaria*) on the east side of lower Cook Inlet, particularly around the southern end of the Kenai Peninsula, probably contribute largely to the productivity of the ecosystem in Kachemak Bay in winter (Lees 1978).

For the final report we will analyze the data for its seasonal and geographical variations, and we will calculate inter- and intraspecific indices of prey diversity. We will review and integrate the pertinent literature. We will attempt to determine the trophic levels of the prey, and estimate their consumption rates by the birds. To accomplish this, we will use assumed daily consumption rates based on published studies, and base the consumption rates of individual prey species on their volumes in the bird stomachs, possibly weighting the data to account for amount of digestion. Finally, we will describe the food webs of the four bird species in a manner which takes into account the estimated trophic levels of the prey and their estimated consumption rates.

VIII. CONCLUSIONS

The following conclusions are tentative, and subject to modification in the final report:

1. Oldsquaw ducks were extreme generalists on benthic fauna, consuming 56 prey species in 11 major prey groups. Clams were the most important prey group, but fish, crustaceans, polychaetes were important too.

2. White-winged scoters were also benthic generalists, eating 19 species in 6 major prey groups. Clams were the favored prey group, and the scoters ate no fish.

3. Common murres consumed 11 prey species in three major groups. Mysids and pandalid shrimp were the most important prey. In marked contrast to their feeding habits in other locations, fish were relatively unimportant.

4. Marbled murrelets specialized on juvenile capelin, and ate lesser numbers of mysids and euphausiids.

5. The four-species bird "community" ate 74 prey species in 11 higher taxonomic groups.

6. Crustaceans were eaten by all four species, fish were eaten by all species except the scoters, and all other prey forms were eaten only by the benthic-feeding oldsquaws and/or white-winged scoters.

7. Major prey groups containing no single species of outstanding importance were often more important to a bird species than an outstanding individual prey species in a different major prey group.

8. The bird "community" appears to be dependent on a food web with a largely detrital base.

9. Additional analyses of the data base are needed before all implications will be known.

IX. NEEDS FOR FURTHER STUDY

Needs for further study will be addressed in the final report, "when all the facts are in."

X. SUMMARY OF 4th QUARTER ACTIVITIES

Work during the quarter focused on the preparation of annual reports and verification of data entered in NODC File Type 031.

XI. ACKNOWLEDGEMENTS

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Table 1. Summary of birds collected in Kachemak Bay, Alaska, November 1977 to April 1978 for feeding ecology studies.

	Number of Birds Collected						
	1977		1978				
Species	Nov. 9-13	Dec. 6-10	Jan. 9-12	Feb. 8-12	Mar. 6-9	Apr. 3-5	TOTALS
Oldsquaw	5	5	5	5	6	2	28
White-winged scoter	1	2	14	10	5[a]	5	37
Black scoter	1					1	2
Surf scoter		1			1	2	4
Common murre		6	9	5[b]	6	5	31
Marbled murrelet			6	5[c]	5[d]	5	21
Totals	7	14	34	25	23	20	123

[a]No prey volume data on 1 bird
[b]2 empty stomachs
[c]1 empty stomach
[d]No prey volume on 2 birds

Table 2. Percent aggregate numbers and volume, and the percent frequency of occurrence and Index of Relative Importance (IRI) of the prey of 28 oldsquaw collected in Kachemak Bay, Alaska, November 1977 - April 1978.

Prey Form	Percent No.	Percent Vol.	Percent F.O.	IRI
Fish				
Total	2.3	26.0	39.2	1,109
Cottidae, Un.[1]	<.1	2.2	3.6	8
Ammodytes hexapterus	2.2	23.5	32.1	825
Crustacea				
Total	7.2	20.7	75.0	2,092
Cirripedia, Un.	0.1	0.8	7.1	6
Mysidacea, Un.	<.1	0.1	3.6	<1
Cumacea, Un.	0.2	0.2	10.7	4
Gnorimosphaeroma oregonensis (Isopod)	<.1	0.1	3.6	<1
Amphipods, Gammaridea	2.1	5.6	42.9	330
Shrimp, Un.	0.2	0.3	7.1	4
Spirontocaris spina	0.1	0.8	7.1	6
Pandalidae, Un.	0.7	1.3	3.6	7
Pandalus goniurus	0.8	3.5	7.1	31
Crangon septemspinosa	<.1	0.3	3.6	1
Crabs, Un.	0.3	1.4	7.1	12
Hyas lyratus	1.6	2.3	14.3	56
Cancer magister	0.8	3.2	17.9	72
C. sp.	<.1	<.1	3.6	<1
Polychaeta				
Total	4.3	10.4	46.4	682
Unidentified	0.5	2.6	25.0	76
Harmothoe extenuata	<.1	0.2	3.6	1
Pholoe minuta	2.0	2.8	3.6	17
Phyllodocidae, Un.	<.1	<.1	3.6	<1
Phyllodoce mucosa	<.1	0.2	3.6	1
Eteone sp.	<.1	0.3	3.6	1
Nereidae, Un.	<.1	0.1	3.6	1
Glycinde sp.	<.1	0.2	3.6	1
Lumbrinereis sp.	<.1	<.1	3.6	<1
Pectinaria granulata	0.4	1.8	14.3	31
Amphaeretidae, Un.	1.1	2.2	3.6	12

Table 2. (cont'd.)

Prey Form	No.	Vol.	F.O.	IRI
Gastropoda				
Total	11.7	8.3	60.7	1,214
Unidentified	3.4	0.9	10.7	46
Limpet sp.	<.1	0.2	3.6	1
Lacuna varigata	0.9	0.2	17.9	20
Alvina compacta	0.8	0.3	25.0	28
Cerithiopsis sp.	<.1	0.1	3.6	<1
Natica clausa	0.2	0.2	3.6	1
Boreotrophon pacificus	<.1	<.1	3.6	<1
Mitrella tuberosa	1.3	1.3	3.6	9
Neptunea sp.	<.1	0.1	3.6	<1
Admete couthouyi	0.2	0.1	3.6	1
Turridae, Un.	0.2	0.3	7.1	4
Oenopota sp.	3.8	2.4	14.3	89
Odostomia sp.	0.4	0.2	21.4	14
Cephalaspidea, Un.	<.1	<.1	3.6	<1
Aglaja diomedeum	0.1	<.1	3.6	<1
Onchidoris bilamellata	0.2	1.2	7.1	10
Pelecypoda				
Total	72.3	19.9	82.1	7,570
Unidentified	0.2	1.5	17.9	30
Nucula tenuis	2.6	<.1	35.7	93
Nuculana cf. *fossa*	2.3	1.4	28.6	106
Glycemeria subobsoleta	15.2	3.1	28.6	523
Mytilus edulis	14.8	3.8	28.6	532
Spisula polynyma	27.4	4.4	28.6	909
Clinocardium sp.	<.1	<.1	3.6	1
Orobitella compressa	<.1	<.1	3.6	<1
Macoma sp.	9.9	2.9	10.7	137
Saxidomus gigantea	<.1	<.1	3.6	<1
Psephidia lordi	0.2	0.1	3.6	1
Prototheca staminea	1.5	1.1	28.6	74
Mya sp.	0.8	0.4	21.4	26
Echinodermata				
Ophiuroidea, Un.	0.3	8.2	7.1	60
Ophiopholis aculeata	1.4	2.2	3.6	13
Amphipholis pugetana	0.2	0.4	3.6	2
Echnoidea, Un.	<.1	0.1	3.6	1
Other Invertebrates				
Foraminifera, Un.	<.1	<.1	3.6	<1
Echiurus echiurus alaskensis	<.1	0.8	3.6	3
Microporina borealis (Ectoprocta)	<.1	0.2	3.6	1

[1]Un. = Unidentified

Table 3. Percent aggregate numbers and volume, and the percent frequency of occurrence and Index of Relative Importance (IRI) of the prey of 36 white-winged scoters collected in Kachemak Bay, Alaska, November 1977 - April 1978.

	Percent			
Prey Form	No.	Vol.	F.O.	IRI
Crustacea				
Total	3.4	1.3	19.4	91
Cirripedia	0.4	0.4	2.8	2
Shrimp, Un.	0.8	0.4	5.6	7
Crabs, Un.	1.9	0.4	13.9	32
Cancer magister	0.4	<.1	2.8	1
Polychaeta				
Total	1.9	1.0	11.1	32
Unidentified	1.1	0.5	5.6	9
Halosydna brevisetosa	0.4	0.3	2.8	2
Nephtys sp.	0.4	0.2	2.8	2
Gastropoda				
Total	40.6	13.8	33.2	1,812
Unidentified	5.6	2.3	22.2	175
Margarites cf. *pupillus*	17.3	0.9	8.3	151
M. sp.	4.5	0.5	2.8	14
Lacuna sp.	1.1	2.4	5.6	20
Trichotropis cancellata	0.4	0.3	2.8	2
Natica clausa	1.5	3.4	2.8	14
Neptunea lyrata	4.1	3.6	8.3	64
N. sp.	5.6	0.3	2.8	17
Admete couthouyi	5.3	0.5	5.6	32
Pelecypoda				
Total	41.0	79.2	88.9	10,686
Unidentified	7.1	14.3	38.9	832
Mytilus edulis	21.8	30.0	22.2	1,150
Macoma sp.	1.1	1.5	8.3	22
Prototheca staminea	10.5	33.3	52.8	2,313
Mya sp.	0.4	0.1	2.8	1
Echinodermata				
Ophiuroidea, Un.	0.8	<.1	2.8	2
Strongylocentrotus drobachiensis	0.4	0.1	2.8	1
S. sp.	0.4	0.4	2.8	2
Holothuroidea, Un.	0.4	0.4	2.8	2
Other Invertebrates				
Sipunculidea, Un.	0.4	0.4	2.8	2

Table 4. Percent aggregate numbers and volume, and the percent frequency of occurrence and Index of Relative Importance (IRI) of the prey of 28 common murres collected in Kachemak Bay, Alaska, November 1977 - April 1978.

	Percent			
Prey Form	No.	Vol.	F.O.	IRI
Fish				
Total	4.8	12.3	64.3	1,100
Unidentified	1.6	1.4	21.4	64
Larvae	0.3	0.4	3.6	2
Clypea harengus (Herring)	0.3	4.4	3.6	17
Mallotus villosus (Capelin)	2.2	3.1	21.4	113
Theragra chalcogramma (Pollock)	1.1	2.2	14.3	47
Lumpenus maculata	0.3	1.3	3.6	6
Ammodytes hexapterus (Sand lance)	0.5	3.1	7.1	26
Crustacea				
Total	93.6	83.9	92.9	16,490
Unidentified	0.5	1.4	7.1	13
Neomysis rayii (Mysid)	83.6	49.0	14.3	1,894
Shrimp, Un.	70.7	1.1	3.9	280
Eualus cf. *stimsoni*	0.3	0.6	3.6	3
Pandalidae, Un.	1.3	6.6	17.9	141
Pandalus borealis	5.6	17.0	17.9	404
P. goniurus	0.3	0.4	3.6	2
Pandalidae, Total	7.2	24.0	40.0	1,248
Crangon franciscorum	1.1	5.0	14.3	87
Polychaeta				
Nereidae, Un.	0.3	<.1	3.6	1

Table 5. Percent aggregate numbers and volume, and the percent frequency of occurrence and Index of Relative Importance (IRI) of the prey of 18 marbled murrelets collected in Kachemak Bay, Alaska, November 1977 - April 1978.

	Percent			
Prey Form	No.	Vol.	F.O.	IRI
Fish				
Unidentified	1.2	4.2	15.0	81
Mallotus villosus (Capelin)	21.3	66.7	65.0	5,720
Theragra chalcogramma (Pollock)	0.3	0.7	10.0	10
Ammodytes hexapterus (Sand lance)	0.3	7.5	10.0	78
Crustacea				
Mysidacea, Un.	33.7	6.5	10.0	402
Gammaridea	1.2	1.4	10.0	26
Thysanoessa inermis (Euphausiid)	0.4	1.2	5.0	8
T. rashii	41.3	9.5	30.0	1,524
T. spinifera	0.2	1.0	5.0	6

Table 6. - Indices of Relative Importance (IRI) of the prey in aggregate samples of Oldsquaw, White-winged Scoters and Common Murres in Kachemak Bay, Alaska November 1977 to April 1978.

	Bird Species & IRI of their Prey			
Prey Form	Oldsquaw n=28	White-winged Scoter n=36	Common Murre n=28	Marbled Murrelet n=18
Fish (Osteichthys)	1,112		1,096	10,230
Unidentified sp.	3		63	81
Unidentified sp. (larvae)			2	
Clupeidae				
Clupea harengus			16	
Osmeridae				
Mallotus villosus			56	5,720
Gadidae				
Theragra chalcogramma			46	10
Cottidae				
Unidentified sp.	8			
Lumpenidae				
Lumpenus maculata			5	
Ammodytidae				
Ammodytes hexapterus	825		26	78
Crustacea	2,094	90	16,487	5,820
Unidentified sp.			14	
Cirripedia (Barnacles)				
Unidentified sp.	6	3		
Mysidacea ("Opossum Shrimp")				
Neomysis rayii			5,208	
Unidentified sp.	<1			402
Cumacea				
Unidentified sp.	4			
Isopoda ("Pill Bugs")				
Gnorimosphaeroma oregonensis	<1			
Amphipoda ("Scud Shrimp")				
≥ 4 species	327			26
Euphausiacea ("Krill")				
Thysancessa inermis				8
T. raschii				1,524
T. spinifera				6
T. sp.				

Table 6. (cont'd.)

Prey Form	Bird Species & IRI of their Prey: Oldsquaw n=28	White-winged Scoter n=36	Common Murre n=28	Marbled Murrlet n=18
Natantian Decapods (Shrimp)				
Unidentified sp.	4	6	70	
Spirontocaris spina	6			
Eualus cf. *stimsoni*			3	
Pandalidae, Unidentified	5		141	
Pandalus borealis			403	
P. goniurus	31		2	
Crangon septemspinosa	1			
C. franciscorum			87	
Reptantian Decapods (Crabs)				
Unidentified sp.	12	32		
Hyas lyratus	55			
Cancer magister	72	1		
C. sp.	<1			
Polychaeta (Annelid Worms)	686	32		
Unidentified sp.		9		
Halosydna brevisetosa		2		
Harmothoe extenuata	78			
Pholoe minuta	17			
Phyllodocidae, Unidentified	<1			
Phyllodoce mucosa	1			
Eteone sp.	1			
Nereidae, Unidentified	1		1	
Nephtys sp.		2		
Glycinde sp.	1			
Lumbrinereis sp.	<1			
Pectinaria granulata	30			
Ampharetidae, Unidentified	12			
Gastropoda (Snails, etc.)	1,216	1,813		
Unidentified sp.	46	177		
Limpet sp.	1			
Margarites cf. *pupillus*		152		
M. sp.		14		
Lacuna varigata	19			
L. sp.		20		
Littorina sp.		1		
Alvina compacta	28	1		

Table 6. (cont'd.)

Prey Form	Oldsquaw n=28	White-winged Scoter n=36	Common Murre n-28	Marbled Murrelet n=18
	Bird Species & IRI of their Prey			
Cerithiopsis sp.	<1			
Trichotropis cancellata		2		
Natica clausa	2	14		
Boreotrophon pacificus	<1			
Mitrella tuberosa	9			
Neptunea lyrata		64		
N. sp.	<1	17		
Admete couthouyi	1	32		
Turridae, Unidentified	4			
Oenopota sp.	89			
Odostomia sp.	14			
Cephalaspidea	<1			
Aglaja diomedeum	<1			
Onchidoris bilamellata	10			
Pelecypoda (Clams)	7,572	10,683		
Unidentified sp.	32	833		
Nucula tenuis	92			
Nuculana cf. *fossa*	105			
Glycymeris subobsoleta	524			
Mytilus edulis	532	1,150		
Spisula polynyma	907			
Clinocardium sp.	<1			
Orobitella compressa	<1			
Macoma sp.	138	22		
Saxidomus gigantea	<1			
Psephidia lordi	1			
Prototheca staminea	75	2,310		
Mya sp.	26	1		
Echinodermata				
Ophiuroidea (Brittle Stars)				
Unidentified sp.	61	2		
Ophiopholis aculeata	13			
Amphipholis pugetana	2			
Echnoidea (Sea Urchins)				
Unidentified sp.	1			
Strongylocentrotus droebachiensis		1		
S. sp.		2		
Holothuroidea (Sea Cucumbers)				
Unidentified sp.		2		

Table 6. (cont'd.)

Prey Form	Bird Species & IRI of their Prey Oldsquaw n=28	White-winged Scoter n-36	Common Murre n-28	Marbled Murrelet n=18
Other Invertebrates				
Foraminifera, Unidentified	3			
Sipunculid, Unidentified		2		
Echiurus echiurus alaskensis	3			
Microporina borealis (Ectoprocta)	1			

Table 7. Numbers of prey species and major prey groups eaten by four species of marine birds in Kachemak Bay, Alaska, November 1977 to April 1978.

	Prey Spp. (n = 74)		Prey Groups (n = 11)	
Bird Species	N	%	N	%
Oldsquaw	56	75.7	9	81.8
White-winged Scoter	19	25.7	6	54.5
Common Murre	11	14.9	3	27.3
Marbled Murrelet	8	10.8	2	18.2

Table 8. The most important prey species and/or groups of species to marine birds in Kachemak Bay, Alaska, in winter, based on their IRI values.

IRI	Prey Form	Bird Species
16,487	Crustacea, total	Common Murre
10,686	Clams, total	White-winged Scoter
10,230	Fish, total	Marbled Murrelet
7,750	Clams, total	Oldsquaw
5,820	Crustaceans, total	Marbled Murrelet
5,720	Capelin (fish)	Marbled Murrelet
2,313	*Prototheca* (clam)	White-winged Scoter
2,092	Crustacea, total	Oldsquaw
1,894	*Neomysis* (Mysid "shrimp")	Common Murre
1,812	Gastropods (snails, etc.), total	White-winged Scoter
1,524	*Thysanoessa rashii* (Euphausiid)	Marbled Murrelet
1,214	Gastropods, total	Oldsquaw
1,150	*Mytilis* (clam)	White-winged Scoter
1,109	Fish, total	Oldsquaw
1,096	Fish, total	Common Murre
909	*Spisula* (clam)	Oldsquaw
825	Sand lance (fish)	Oldsquaw
682	Polychaete worms	Oldsquaw
532	*Mytilus* (clam)	Oldsquaw
524	*Glycymeris* (clam)	Oldsquaw
404	Pandalid shrimp	Common Murre
402	Mysids	Marbled Murrelet
330	Amphipods ($\geq$ 4 gammarid spp.)	Oldsquaw
280	Shrimp, unidentified	Common Murre
151	*Margarites* (snail)	White-winged Scoter
137	*Macoma* (clam)	Oldsquaw
106	*Nuculana* (clam)	Oldsquaw

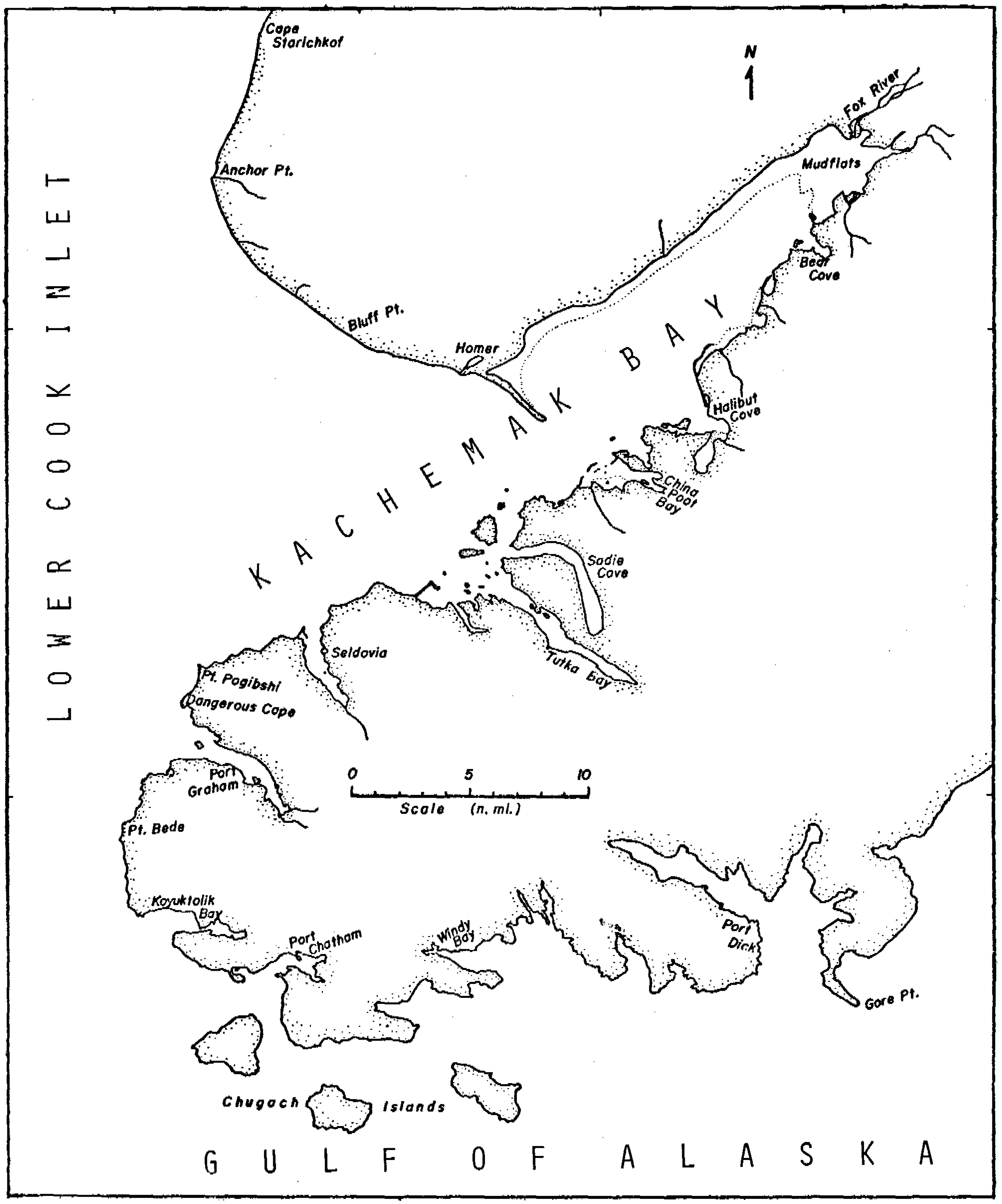

Figure 1. Perspective view of Kachemak Bay and the southern Kenai Peninsula, Alaska.

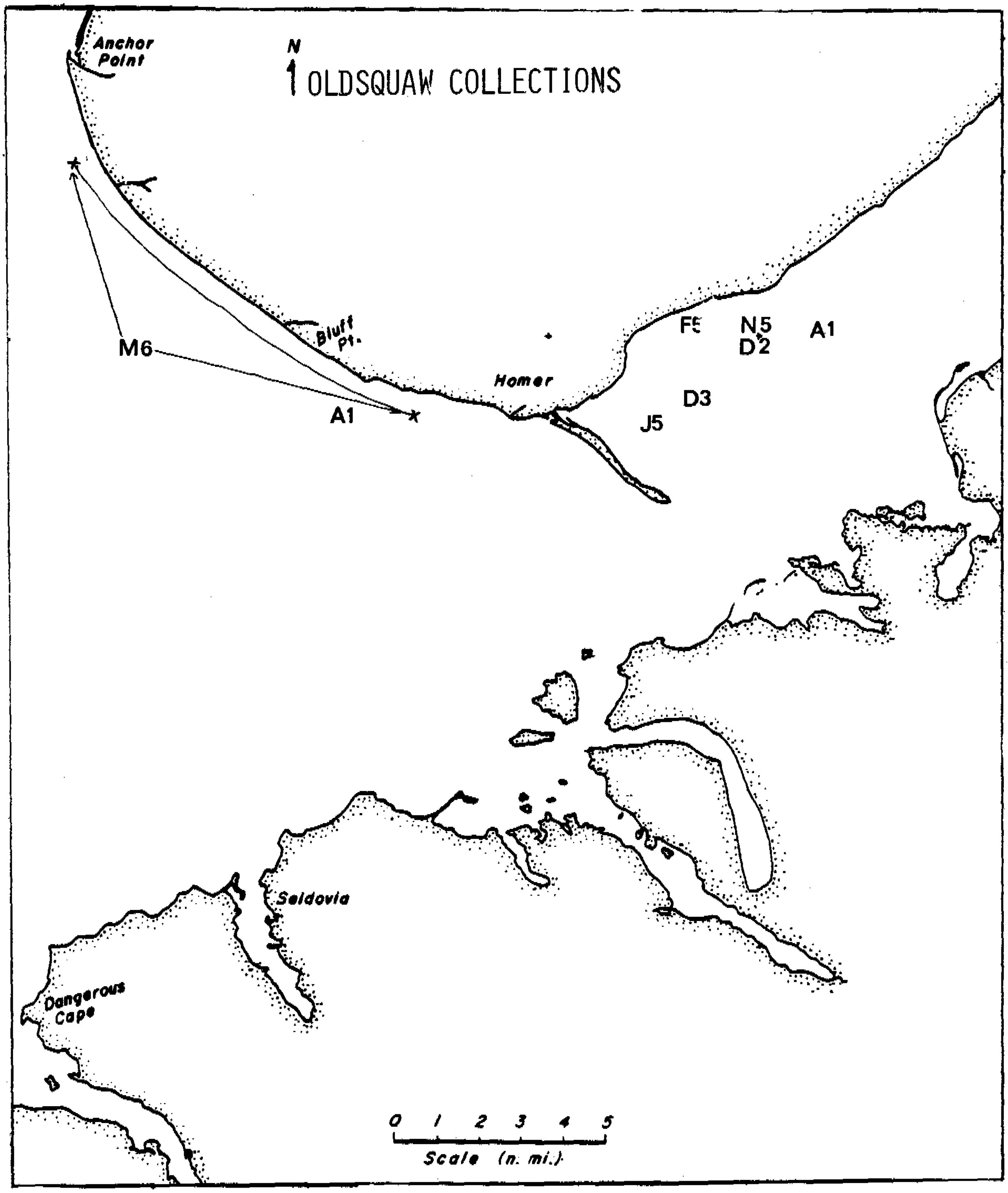

Figure 2. Locations of oldsquaw collections in Kachemak Bay, November 1977 to April 1978. Letters and numbers indicate months and numbers of specimens.

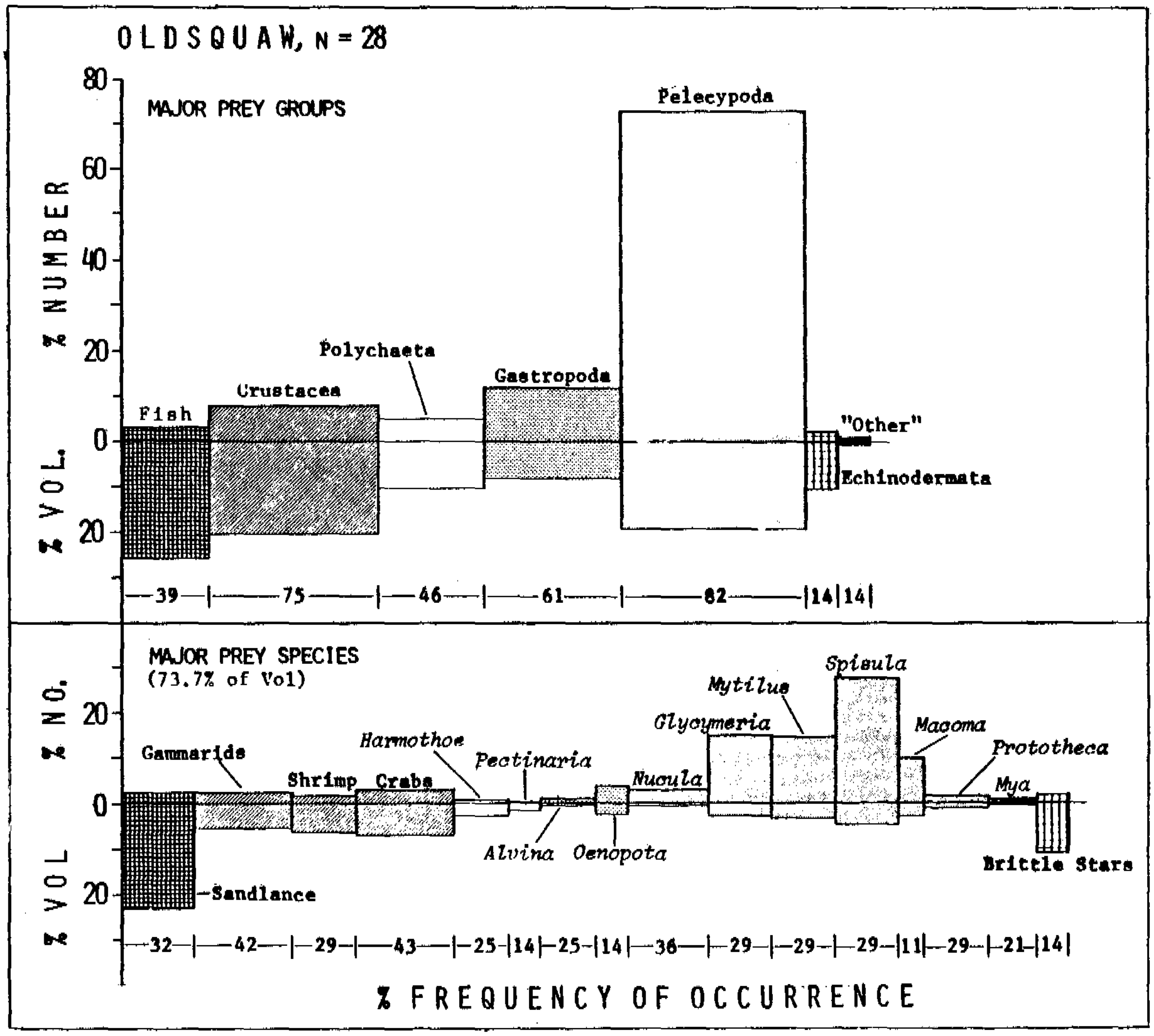

Figure 3. The aggregate percent numbers, volume and frequency of occurrence of prey in the stomachs of 28 oldsquaw collected on Kachemak Bay, November 1977 to April 1978.

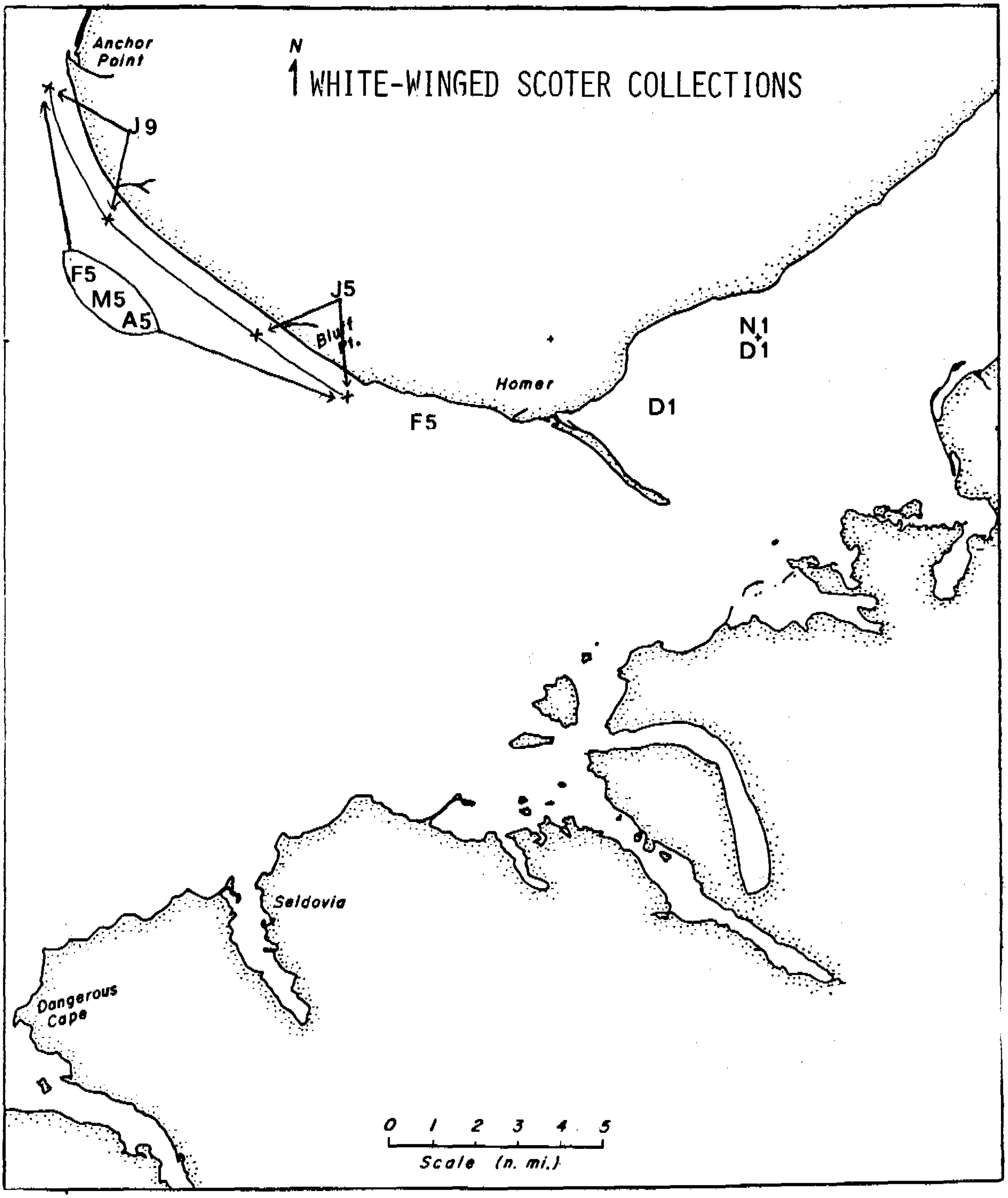

Figure 4. Locations of white-winged scoter collections in Kachemak Bay, November 1977 to April 1978. Letters and numbers indicate months and numbers of specimens.

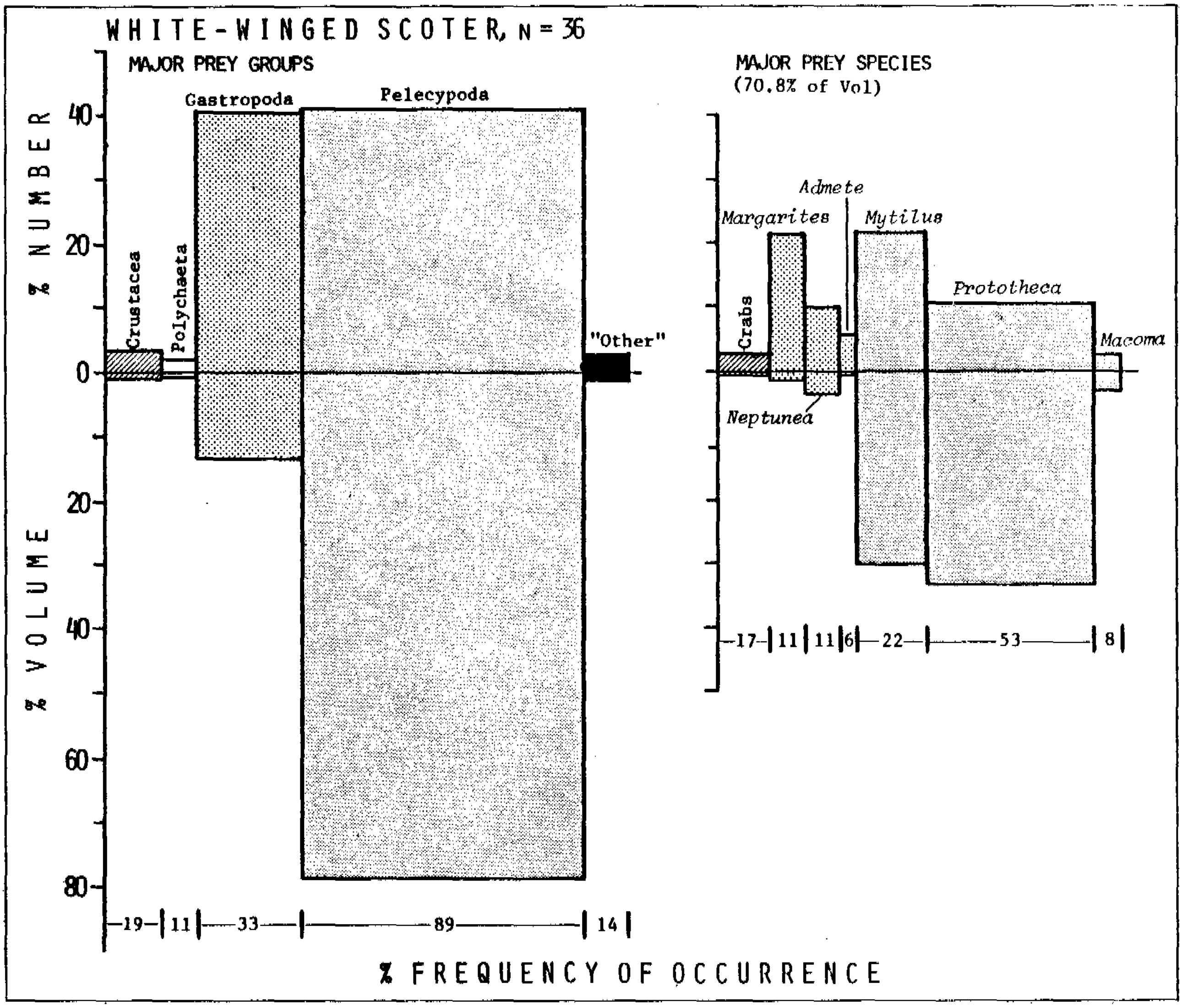

Figure 5. The aggregate percent numbers, volume and frequency of occurrence of prey in the stomachs of 36 white-winged scoters collected on Kachemak Bay, November 1977 to April 1978.

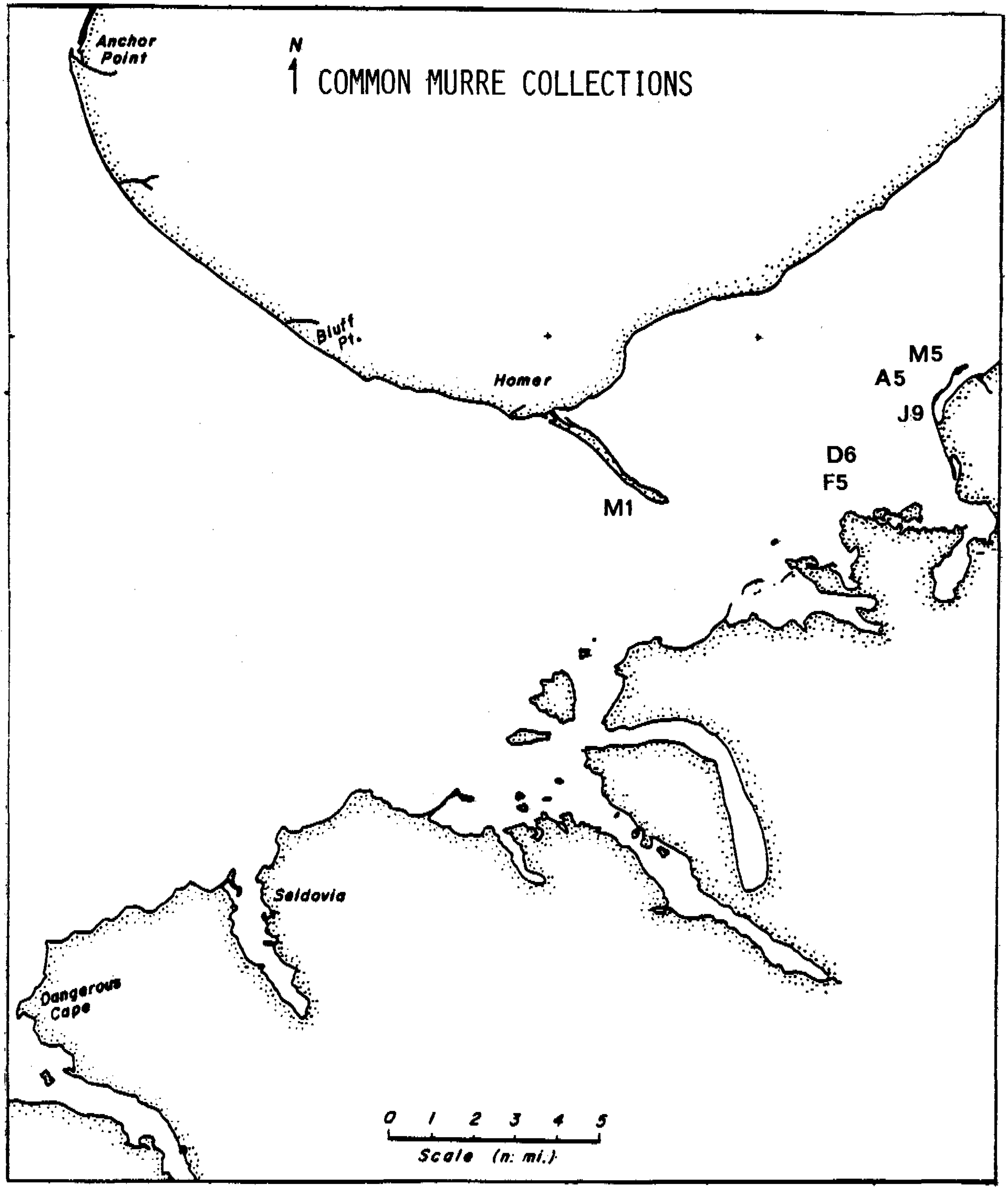

Figure 6. Locations of common murre collections in Kachemak Bay, November 1977 to April 1978. Letters and numbers indicate months and numbers of specimens.

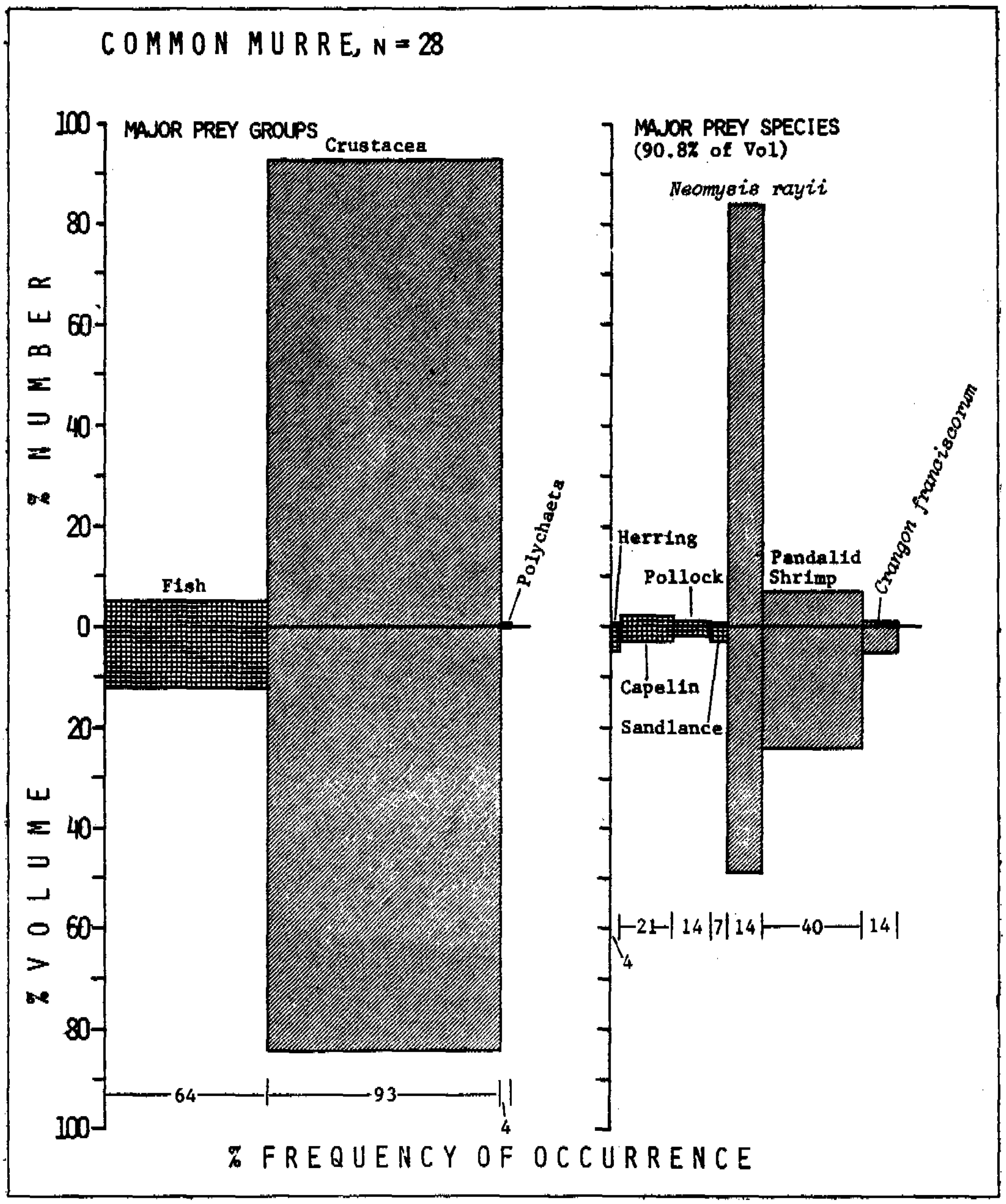

Figure 7. The aggregate percent numbers, volume and frequency of occurrence of prey in the stomachs of 28 common murres collected on Kachemak Bay, November 1977 to April 1978.

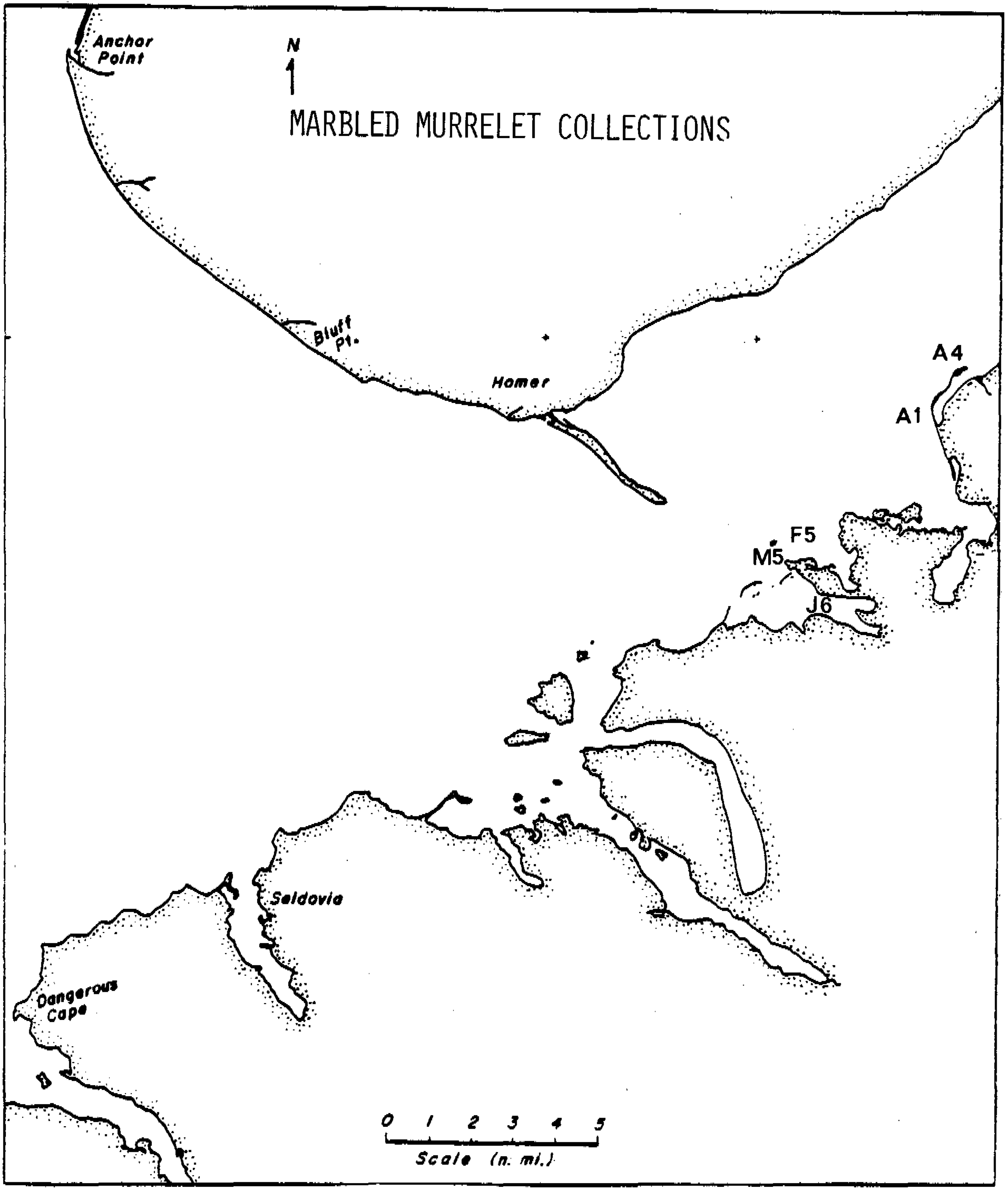

Figure 8. Locations of marbled murrelet collections in Kachemak Bay, January - April 1978. Letters and numbers indicate months and numbers of specimens.

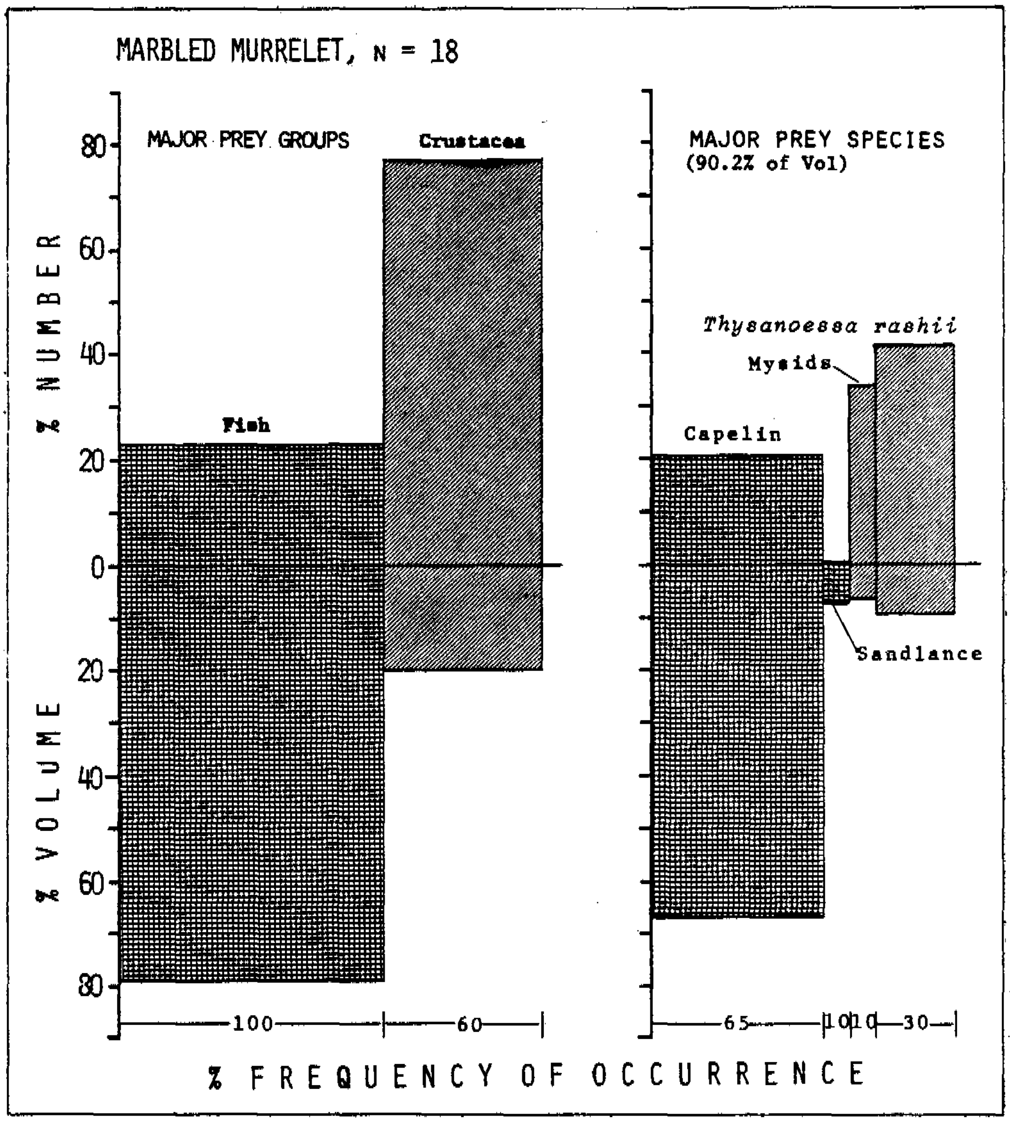

Figure 9. The aggregate percent numbers, volume and frequency of occurrence of prey in the stomachs of 18 marbled murrelets collected on Kachemak Bay, November 1977 to April 1978.

ANNUAL REPORT

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NEARSHORE FEEDING ECOLOGY OF MARINE BIRDS IN THE KODIAK AREA, 1978

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SUMMARY

A study of the feeding habits of marine birds in the nearshore waters of the Kodiak Island area was undertaken in order to evaluate the possible impact of OCS activities on their feeding ecology. A total of 58 oldsquaw *(Clangula hyemalis)*, black scoters *(Melanitta nigra)*, common murres *(Uria aalge)* and marbled murrelets *(Brachyramphus marmoratum)* were collected in Chiniak Bay between 23 and 26 February 1978. Their stomachs were examined and aggregate percent volume was calculated for each type of prey. Thirty-nine (67%) of the stomachs contained digestible prey tissue. Oldsquaw (n=21) were generalized benthic feeders, consuming unidentified foraminifera, nemertea and bryozoa and at least six species of polychaetes, 22 species of mollusks, 8 species of crustacea, 3 species of echinoderms, and 1 family of fish. Black scoters (n=4) subsisted almost exclusively on blue mussels *(Mytilus edulis)*, common murres (n=4) ate walleye pollock *(Theragra chalcogramma)*, and marbled murrelets (n=14) ate mysid crustacea.

Seabird collections were made between 3 April and 30 August 1978 as part of a cooperative, multi-disciplinary study of marine food webs in the Kodiak area. A total of 555 black-legged kittiwakes *(Rissa tridactyla)*, tufted puffins *(Lunda cirrhata)*, common murres, sooty and short-tailed shearwaters *(Puffinus griseus* and *P. tenuirostris)*, marbled murrelets and pigeon guillemots *(Cepphus columba)* was collected in Izhut Bay on Afognak Island and Kiliuda Bay on Kodiak Island. Of these, 323 (58%) had digestible prey tissue in their stomachs. Volumetrically, euphausiids *(Thysanoessa inermis, T. raschii,* and *T. spinifera)* and capelin *(Mallotus villosus)* were important prey in spring and early summer. Pacific sand lance *(Ammodytes hexapterus)* became increasingly important in July and August.

Offshore Continental Shelf activities which endanger the productivity of benthic invertebrate or epipelagic euphausiid and fish populations could have a significant negative impact on the feeding ecology of marine birds. Most of the seabirds studied are primarily piscivorous, consuming almost entirely capelin, sand lance, pollock and Pacific sandfish *(Trichodon trichodon)* during the breeding season. Those which have more diverse diets (pigeon guillemots and wintering oldsquaw and black scoters) are dependent on sessile or slowly moving benthic forms which may be unable to avoid contact with contaminated water.

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INTRODUCTION

Nature and Objectives of Study

This study is part of the Outer Continental Shelf Environmental Assessment Program (OCSEAP), designed to evaluate the potential risk of petroleum development. Marine birds, the most visible of marine resources, may be affected by OCS development directly by contact with water-borne contaminants, or indirectly, by contamination or a decrease in availability of their prey. The present study, by identifying the seasonal importance of prey consumed by birds, provides a basis for evaluating the second type of impact.

This research is part of the Kodiak Integrated Food Web Study. Objectives of this study include the determination of the taxonomic and seasonal compositions, distributions and abundances of selected planktonic, pelagic and demersal crustacea and fishes, foods and foraging habits of nearshore fish, birds and mammals and the relationships between seasonal variation in oceanographic conditions and the timing of the occurrence, distribution and food habits of selected marine organisms.

Winter studies focused on the feeding ecology of two species of seaducks in Chiniak Bay, oldsquaw *(Clangula hyemalis)* and black scoters *(Melanitta nigra)*. Oldsquaw, which breed on tundra lakes, were the most abundant duck on Chiniak Bay during the winter of 1976-1977 (3,000 to 5,000 birds, Dick 1977). An estimated 1,000 to 1,500 black scoters were also present at this time.

Both the winter and summer feeding habits of common murres *(Uria aalge)* and marbled murrelets *(Brachyramphus marmoratum)* were examined. The breeding population of common murres on Kodiak Island is small (less than 2,000 birds), although large populations occur on the Barren Islands to the north and Semidi Islands to the south (Sowls, Hatch and Lensink 1979). Murres from these or other colonies may contribute to the population wintering in the Kodiak area.

The marbled murrelet is a non-colonial species that probably nests throughout the Kodiak region. Little is known of its life history. We have observed adults and young foraging in shallow water around Kodiak and Afognak Islands during spring and summer, as did Dick (1977) in winter.

Other species studied are abundant in waters surrounding Kodiak Island in summer. Black-legged kittiwakes *(Rissa tridactlya)*, tufted puffins *(Lunda cirrhata)* and pigeon guillemots *(Cepphus columba)* nest on more than 200 colonies located on inaccessible cliffs and offshore islands. Sooty and short-tailed shearwaters *(Puffinus griseus* and *P. tenuirostris)* breed in the southern hemisphere, but are abundant in the Gulf of Alaska during the boreal summer (Palmer 1972; P. Gould, USFWS, unpubl. data).

Current State of Knowledge

Sanger, Hironaka and Fukuyama (1978) discussed the feeding habits of five major species of seabirds in the Kodiak area (black-legged kittiwakes, tufted puffins, common murres, sooty and short-tailed shearwaters) during the spring and summer of 1977. Little else is known of the food web relationships of marine birds and other biota. This report and those of other OCSEAP investigators will permit a better understanding of the relationship of marine bird feeding habits to the availability of prey.

A review of the pertinent literature on feeding habits of marine birds will be presented in the final report.

Needs for Further Study

Needs for further study will be evaluated in a final report, after analyses of all available data are completed.

Study Area

The coastline of Kodiak Island is highly irregular, dissected by inlets and estuaries formed by glacial and tectonic processes (Redburn 1976). The continental shelf extends 240 km southeast from the island and is marked by a series of four shallow shoals (<90 m) separated by troughs (Schumacher, Sillcox, Drevis and Muench 1978).

Circulation along the southeast coast of Kodiak is dominated by the Alaska Current, a northern extension of the Alaska Gyre. Flow is counterclockwise, intensified by winds associated with the Aleutian low pressure system. This effect, associated with an upward divergence of water in the central Gulf and low runoff resulting from freezing, causes water to pile up along the coast.

During summer, conditions reverse; anti-cyclonic winds produced by the Central Pacific high pressure systems exert a braking effect on the counterclockwise flow of Gulf waters. At the same time, the vertical upward flow of water in the central Fulf is relaxed and freshwater runoff from local snowsheds begins. During this period, there is an offshore component of dilute water at the surface (Favorite, Ingraham and Fisk 1975).

This short-term surface effect doesn't significantly change the composition of the deep water mass. Steady state conditions exist below 200-300 m.

The four shallow banks located off the southeastern coast of Kodiak have supported an extensive commercial fishery since the late 1800's and are probably important feeding areas for seabirds nesting on Kodiak and its associated islands. Redburn (1976) describes other general types of coastal ecosystems which make this area one of the most productive in the northern Pacific (Harris and Hartt 1977). Kitoi Bay, an eastern extension of Izhut Bay on Afognak Island, is an example of an exposed, medium salinity estuary (Figure 1). Due to high water clarity and nutrient input and summer sater column stratification, primary production in Kitoi Bay is substantial. Herring, shrimp and dungeness crab larvae, fast growing organisms which depend on the availability of rich zooplankton stocks, are abundant. Approximately 3,000 cormorants, oystercatchers, gulls, guillemots and puffins nest in Izhut Bay, including a small colony of guillemots and puffins on Midarm Island in Kitoi Bay (Sowls, Hatch and Lensink 1979).

Redburn (1976) describes Shearwater Bay, an arm of Kiliuda Bay on Kodiak Island, as a sheltered and stratified estuarine ecosystem (Figure 1). The mouth of Shearwater Bay is restricted, protecting the waters within from direct exposure tp oceanic processes. Spring and summer snowmelt runoff creates a low salinity layer over a more saline, denser layer. Warm summer temperatures create a distinct thermocline whick adds to the stability of the water column, maintaining photosynthetic organisms in the light-rich upper layer. This effect is not as marked in estuaries whick are directly exposed to turbulent oceanic wave and tidal influences, keeping the water column mixed. Approximately 63,000 seabirds nest on cliffs and small islands in the vicinity of Shearwater and Kiliuda Bays (Sowls et al. 1979).

Eelgrass communities provide food for waterfowl and nurseries for invertebrate and fish populations. A large eelgrass bed is located at Port Hobron on Sitkalidak Island (Figure 1). The mudflats characteristic of this ecosystem support a rich community of intertidal polychaetes, crustacea and bivalves (Redburn 1976). Approximately 25,000 seabirds nest in the vicinity of northern Sitkalidak Strait (Sowls et al. 1979).

Currently, the waters surrounding Kodiak Island support some of the most important commercial fisheries in the North Pacific (Harris and Hartt 1977). In 1974 the economic value of the salmon, herring, groundfish, crab, shrimp, scallop and razor clam fisheries in this area was $34 million (Alaska Dept. of Fish and Game 1977).

METHODS AND MATERIALS

Collections were made in Chiniak Bay, Kodiak Island, between 23 and 26 February, 1978. During this visit, 25 oldsquaw, 4 black scoters, 9 common murres, and 19 marbled murrelets were collected by shotgun from a 24 foot dory. Stomachs were injected with 10% buffered formalin via plastic tubing inserted through the esophagus. Upon returning to Kodiak, specimens were wrapped in plastic bags and frozen. Subsequent morphometric measurements were made and prey were identified in the Fish and Wildlife Service (FWS) lab in Anchorage. Prey tissue was found in the stomachs (esophagi, proventriculi and gizzards) of 39 (67%) of these birds (Table 1).

Spring and summer collections were made in conjunction with OCSEAP plankton and fisheries investigations aboard the R/V *Commando*. Two FWS biologists accompanied nine of ten cruises of the *Commando* between 3 April and 30 August 1978. Weekly trips were made between Izhut Bay on Afognak Island and Kiliuda Bay on Kodiak Island. During these cruises, seabirds were collected from a 13 foot Boston Whaler deployed from the research vessel.

Whenever possible, five specimens of each abundant species (oldsquaw, black-legged kittiwake, tufted puffin, common murre, sooty and short-tailed shearwater) were collected on each cruise in both bays. Up to three specimens of the less abundant species (marbled murrelets and pigeon guillemots) were collected. In addition, general observations were made of the locations, sizes and species composition of feeding flocks encountered.

Immediately after each specimen was collected, the date, time, body weight (to the nearest 5g) and bill gape (to the nearest 1mm) were recorded. Stomachs were injected with 10% buffered formalin. Upon returning to the *Commando*, standard morphometric measurements were taken (Table 2). Stomachs were removed and preserved in 10% buffered formalin.

In the laboratory, stomachs were opened longitudinally and a general description of the type of prey found in each section (esophagus, proventriculus, stomach) was recorded. The drained, wet weight of the contents (to the nearest 0.1g) and the displacement volume (to the nearest 1ml) were measured.

Each prey item was identified to the lowest possible taxon. J. Blackburn (Alaska Dept. of Fish and Game, Kodiak) helped identify the juvenile fish and personnel at the University of Alaska Institute of Marine Science (Fairbanks) assisted in the identification of invertebrates.

The lengths of whole prey and parasphenoid bones were measured. The parasphenoid bone lies longitudinally in the roof of the mouth of bony fishes and may be used to estimate the total length of fishes which are too digested to measure directly (Sanger, Hironaka and Fukuyama 1978).

Data from stomach samples were grouped by bird species, collection location (bay) and field operation number (Table 1). Aggregate percent volume (the total volume of all items of each type of food expressed as a percentage of the total volume of all types of food, Ashmole 1967) was calculated for each group. This is equivalent to "aggregate volume", described by Swanson, Krapu, Bartonek, Serie and Johnson (1974). Only digestible prey tissue was included in this analysis in order to minimize bias due to the underestimation of the amount of prey consumed when only hard parts such as otoliths, vertebrae and shell fragments remain in the stomach.

RESULTS

Chiniak Bay, Winter Study

Oldsquaw consumed a larger variety of bottom dwelling organisms than any other species studied (at least 40 species). Foraminifera, nemerteans, polychaetes (6 species), gastropods (14), bivalves (8), copepods, mysids, cumacea, amphipods, shrimp, crabs, bryozoa, ophiuroids, echinoids, and stichaeids were identified in oldsquaw stomachs collected in Chiniak Bay (Table 3). Bivalves and amphipods each comprised approximately one quarter of the volume of food consumed (Figure 2).

Black scoters also fed on bottom dwelling organisms. Although the information derived from the digestive tracts of only four birds is inconclusive, their almost exclusive consumption of the blue mussel, *Mytelis edulis*, suggests the importance of this prey item.

Similarly, although the winter diet of common murres was not adequately sampled in this study (n=4), a high degree of dependence on fish in indicated. Walleye pollock comprised 93% of the total volume and daubed shanny *(Lumpenus maculatus)*, capelin and sand lance were consumed in small amounts. The euphausiid *Thysanoesa inermis*, and the shrimp *Pandalus borealis*, each comprised less than 1% of the total volume.

Marbled murrelets preyed heavily on crustacea (5 species). Mysids, *Acanthomysis* sp. and *Neomysis* sp. contributed 62% and 22% of the total volume of prey consumed, respectively. Small amounts of amphipods, euphausiids *(T. raschii)* and shrimp *(P. goniurus)* were present. The remaining 10% of the diet was comprised of capelin, unidentified osmerids and other unidentified fish.

Izhut and Kiliuda Bays, Summer Study

Black-legged kittiwakes consumed primarily three species of prey: a euphausiid crustacean *(T. inermis)*, capelin and sand lance (Table 4, Figure 4). Euphausiids were eaten only in late May and early June. During this period, they comprised 52% of the diet (by volume) in Izhut Bay and 91% of the diet in Kiliuda Bay (Figure 5a & 5b). One bird collected in Kiliuda Bay in early April contained a specimen of the gammarid amphipod, *Paracallisoma alberti* (Figure 5b). Although the numbers of kittiwakes collected in the two bays on each cruise were small and unequal, it appears that in Izhut Bay, capelin comprised a larger proportion of the diet by volume, than did sand lance (Figure 5a). The reverse appears to have been true in Kiliuda Bay (Figure 5b).

Fish comprised 77% of the diet of tufted puffins; capelin and sand lance contributed 24% and 41% respectively (Table 4, Figure 4). Two species of euphausiids *(T. inermis* and *T. spinifera)* were consumed in both bays in late April and early May (Figures 6a & b). By late May, puffins took only *T. inermis*. Squid were present in small amounts in the stomachs of puffins in Kiluida Bay in July and in both bays in early August.

As in winter, common murres were found to be primarily piscivorous. Fish comprised 98% of the overall prey volume (Figure 4). Squid, euphausiids *(T. inermis)*, walleye pollock, capelin, sand lance and sandfish were taken in Kiluida Bay (Figure 7b). Murres collected in Izhut Bay contained only capelin, sand lance and sandfish (Figure 7a). The discrepancy between the diets of murres collected in the two bays could be an artifact of small sample sizes.

Sooty shearwaters were also piscivorous. Fish, including capelin, sand lance, sandfish and tom cod *(Microgadus proximus)* (Table 4, Figure 4) comprised almost 100% of the overall prey volume. Capelin were generally more important in Izhut Bay and sand lance were more important in Kiliuda Bay (Figures 8a & 8b). Euphausiids *(T. inermis* and *T. spinifera)* were taken in early June (Figures 8a & 8b). Squid contributed a small proportion (0.1%) of the volume of food consumed in June in Kiliuda Bay (Table 4).

Short-tailed shearwaters were observed only sporadically in the study area. Five of seven specimens collected contained digestible tissue. *Thysanoessa inermis* comprised 100% of the volume of prey in the three short-tailed shearwaters collected in late May. Two short-tails collected in July contained sand lance and unidentified fish (Figure 9).

Five species of fish comprised 90% of the diet of marbled murrelets (5 species, Table 4, Figure 4). Sand lance alone contributed 62% of the total prey volume. In Kiliuda Bay, the only prey consumed by four murrelets collected in late April and early May was *T. inermis* (Figure 10b). A single murrelet collected during the same time period in Izhut Bay contained sand lance (Figure 10a).

The diet of pigeon guillemots was the most diverse of any alcid species studied (Table 2, Figure 4). Shrimp *(Heptacarpus tridens, P. jordani)* and crab *(Cancer oregonensis, Hyas lyratus)* together comprised 19% of the total prey volume. Seven families of fish were represented.

DISCUSSION

The prey consumed by oldsquaw and black scoters in Chiniak Bay were similar to those reported by other investigators. In the present study, oldsquaw were generalists, consuming a variety of benthic organisms. Cottam (1939) analyzed the digestive tracts of 227 oldsquaws collected in 14 states and in eight Canadian provinces in winter. On a percent volume basis, crustacea were the most important prey, followed by mollusks, insects, fishes and plant material.

Stott and Olson (1973) observed that the diet of oldsquaws collected along the New Hampshire coastline "contained a wide variety of food items", including mollusks, shrimp and isopods. They related this generalized feeding strategy to the generalized distribution of oldsquaws along the New Hampshire coast, along both sandy and rocky beaches and within two of three harbors censused.

The predominance of *Mytilus edulis* in the diet of four black scoters collected in Chiniak Bay also coincides with reports by other investigators. Cottam (1939) observed that black scoters from around the United States (including Alaska) and Canada subsisted primarily on bivalve mollusks. *Mytilus edulis* comprised 24% of the diet (aggregate percent method, Swanson et al. 1974). McGilvrey (1967) found blue mussels in the gizzards of nearly one-half of 17 usable digestive tracts of black scoters collected in New England; comprising over half of the total volume. The diet of black scoters collected along the southern coast of Sweden was also dominated by *Mytilus edulis* (Nilsson 1972).

Due to differences in the methods of calculating "percent aggregate volume", data for seabirds collected off Kodiak Island during the 1977 and 1978 field seasons are not directly comparable. In 1977, the percent volume of each type of prey in each stomach was calculated and then averaged over all stomachs collected ("aggregate percentage" method, Swanson, et al. 1974). This method potentially overestimates the importance of a small volume of prey in a stomach which is not full, compared to an equal volume of prey in a stomach which is very full. In 1978, aggregate volume was calculated (Swanson et al. 1974, "aggregate percent volume"; Ashmole and Ashmole 1967). With these differences in mind, only tentative comparisons of data collected in the two years are presented. Percent aggregate volume will be recalculated for the 1977 data so that a direct comparison may be presented in the final report.

Black-legged kittiwakes consumed a limited number of prey types in both years (Figures 12 and 4). Except for euphausiids, which were taken in May and June in both years, and gadids, which were important only in September 1977, kittiwakes fed exclusively on capelin and sand lance (Figures 5a, 5b and 13).

The availability of an important prey species during a critical portion of the breeding cycle may have a significant impact on seabird productivity. Productivity was poor for kittiwakes breeding in Chiniak Bay and northern Sitkalidak Strait in 1978 (Baird and Hatch, 1979 and Nysewander and Barbour 1979). These authors suggest that predation on kittiwake chicks by glaucous-winged gulls was precipitated by an absence of beach spawning capelin, a normal forage species for nesting gulls in 1977 (Baird et al. 1978). Glaucous-winged gulls were not collected for stomach contents analysis in either year, however, black-legged kittiwakes, which are also surface feeders, preyed heavily on capelin in each, indicating no change in availability.

Utilization of capelin by tufted puffins decreased in May and June 1978, compared to 1977 (Figures 6a, 6b, and 14). Sand lance, which was of minor importance in 1977, was taken in large amounts in July and August 1978. Euphausiids were eaten in August 1977 and in the early part of summer 1978.

In contrast, utilization of capelin by common murres increased in May and June 1978 (Figures 7a, 7b, and 15). An increase in sand lance consumption was also apparent. Four murres collected in Chiniak Bay during February 1978 contained almost exclusively walleye pollock, suggesting a seasonal shift in dependence on this species.

Sand lance utilization by sooty shearwaters increased in 1978 as capelin and squid utilization decreased (Figure 8a, 8b, and 16). Shearwaters were the most abundant bird in the waters surrounding Kodiak Island in June, July and August 1978 (Gould and Forsell, unpublished data), when they were likely to have exerted a significant impact on the energy flow of the nearshore ecosystem (Wiens and Scott 1975, Hameedi, Petersen and Wolf 1976, and Krasnow 1978).

Marbled murrelets collected in Chiniak Bay in February consumed mysids and small amounts of capelin, pandalid shrimp and amphipods (Figure 2). Dick (1977) collected 19 marbled murrelets in 1976; these birds contained mysids (37% frequency of occurrence) and larval osmerids (84% FO). In the present study, marbled murrelets had switched from mysids and fish to a diet of euphausiids and capelin by spring. Beginning in June, sand lance increased in importance (Figure 10a and 10b).

A seasonal change in availability of major marine bird prey species is indicated by this study. Two seabird species collected in February contained primarily pollock and mysids. Euphausiids were consumed from late April until mid-June. Capelin were taken in May through August but in July, sand lance became important (volumetrically).

CONCLUSIONS

Oldsquaw wintering in Chiniak Bay consumed a variety of benthic invertebrates (at least 40 species), while black scoters preyed heavily on blue mussels. Murrelets ate primarily crustacea in winter (at least 4 species), switching to fish by summer. Walleye pollock was the major prey of four common murres collected in winter.

In summer, seabirds in Izhut and Kiliuda Bays shifted in utilization between three major prey species: *Thysanoessa* euphausiids, capelin and sand lance. Euphausiids were taken only in April, May and June, indicating that they were only available at this time. Capelin generally comprised a greater proportion of the volume of prey consumed in the early part of summer, while sand lance were more important in July and August. The extent to which this pattern is determined by seasonal migrations of these prey is unknown, but it is hoped that this problem will be illuminated by examining data collected by other investigators in the Kodiak Integrated Food Web Study.

A tentative comparison of seabird feeding habits between the two summers indicates an increased utilization of sand lance in 1978. The percent of the total volume of prey comprised by capelin was approximately equal in the two years.

It is apparent that OCS development activities which endanger the productivity of benthic invertebrates or pelagic euphausiid and fish populations could have a significant negative impact on these food resources of marine birds. Most of the seabirds studied are primarily piscivorous, relying on capelin, sand lance, pollock and sandfish during the breeding season. Those which have more diverse diets (pigeon guillemots and wintering oldsquaws and black scoters) are dependent on sessile or slowly moving benthic forms which may be unable to avoid or escape contact with polluted water.

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Table 1. Number of seabirds collected for stomach contents analysis and number of stomachs containing prey tissue in the Kodiak area, 1978. (CHIN = Chiniak Bay, KIL = Kiliuda Bay, IZ = Izhut Bay)

Dates & Field Operation	Location	Oldsquaw		Black Scoter		Common Murres		Marbled Murrelets	
		No.	No. w/ food	No.	No. w/ food	No.	No. w/ food	No.	No. w/ food
2/23-26/78 FW 8003	CHIN	25	21	4	4	9	4	19	14

Dates & Field Operation	Location	Black-Legged Kittiwakes		Tufted Puffin		Common Murres		Sooty Shearwater		Short-Tailed Shearwater		Marbled Murrelet		Pigeon Guillemot	
		No.	No. w/ food	No.	No. w/ food	No.	No. w/ food	No.	No. w/food	No.	No. w/food	No.	No. w/food	No.	No. w/ food
4/3-8/78 FW 8006	KIL	1	1			7	2								
4/20-27/78 FW 8007	IZ	1	0			4	1					3	3	7	2
	KIL	1	0	2	0	1	1							6	2
4/28-5/18/78 FW 8008	IZ			12	8							3	1	5	3
	KIL			6	6	7	1					5	4		
5/23-6/10/78 FW 8014	IZ	7	7	6	3	7	3	12	7			7	0	3	3
	KIL	12	7	17	9	14	5	5	4	5	3	7	2		
6/13-30/78 FW 8015	IZ	25	18	18	16	8	3	27	23	1	0	6	2	4	3
	KIL	9	5	11	7	5	3	8	3			5	0	1	0
7/11-31/78 FW 8017	IZ	3	1	8	8	3	0	11	4			4	3	6	4
	KIL	17	7	26	17	11	4	16	10	3	2	6	3	3	3
8/1-15/78 FW 8018	IZ	10	8	10	8	1	1	4	4			5	3	2	2
	KIL	8	2	11	9	3	1	11	7			1	0		
8/14-30/78 FW 8019	IZ			14	10	4	1	16	11			4	4	4	0
	KIL	5	4	11	7	3	2	5	1					3	1

Table 2. Definitions of standard morphometric measurements taken on marine bird specimens collected for stomach contents analysis.

Exposed Culmen - [a] The distance from the tip of the upper mandible in a straight line to the base of the feathers on the forehead; to the nearest 0.1mm.

Total Length - [a] The distance from the tip of the bill to the tip of the longest rectrix to the nearest 0.1cm.

Right Wing Length - [a] The distance from the bend of the right wing to the tip of the longest primary. The curvature is not straightened and the measurement is made with dividers from the bend directly to the tip; to the nearest 0.1cm.

Right Tarsus Length - [a] The distance from the point of the joint between the right tibia and metatarsus (in back) to the point of the joint at the base of the middle toe (in front); to the nearest 0.1mm.

Length of Largest Gonad - [b] The length of the largest testis or diameter of the largest ovum; to the nearest 0.1mm.

Bursa (of Fabricius) Length - [b] The length of the outpocketing of the dorsal wall of the lower intestine which is located just above the cloaca; to the nearest 0.1mm.

Fat Index - [b]

1 - Very little visceral and neck fat, none on skin. Feather papillae very evident on breast. Little fascia and grey-orange fat at humerus and femur junctions with body.

2 - Some visceral and neck fat. Feather papillae still evident on breast. Slight streak of yellow on back portion of breast muscle (posterior end of sternum). Streak along trachea before it enters clavicles. Slight streak along femur between femur and tibial muscles.

3 - Moderate visceral fat. Fat on skin but papillae still visible in dorsal half of belly tracts. Fat between tracts on belly and breast. Fat on bifurcation of clavicles, femur and humeral regions.

4 - Considerable visceral fat. Feather papillae not visible through skin.

5 - Consolidated masses of visceral fat. Skin fat 1/8-1/4 inches thick. Heavy fat in bifurcation of clavicles and along posterior edge of breast muscles. Fat on neck regions and over lower belly on skin.

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[a] - Pettingill (1970)

[b] - From "Description of Format, File Type 031" circulated by OCSEAP to feeding ecology investigators.

Table 3. Aggregate percent volume of prey consumed in Chiniak Bay, February 1978.

	Marbled Murrelets	Common Murres	Black Scoters	Oldsquaw
	n = 14	4	4	21
Protozoa				
Foraminifera				0.2
Nemertea				0.8
Annelids				
Polychaetes				8.2[a]
Polynoids				
Harmanthoe sp.				0.2
Siglionids				
Pholoe minuta				0.1
Syllids				0.2
Cirratulids				0.2
Flabelligerids				0.2
Ophellids				
Travisia sp.				0.9
Oweniids				
Owenia sp.				1.3
Pectinarids				
Pectinaria granulata				0.1
Glycerids				
Hemipodus borealis				0.9
Mollusks				
Gastropods				16.8[a]
Acmaeids				
Collisella sp.				1.2
Trochiids				
Margarites pupillas			1.0	0.3
Lacunids				
Lacuna variegata				7.9
Littorinids				
Littorea sitkana				0.4
Rissoids				
Alvinia compacta				1.8
Cingula katherina				0.4

[a] Identified and unidentified individuals combined

	MAMU	COMU	BLSC	OLSQ
Eulimids				
Melanella sp.				0.4
Trichotrophids				
Trichotropis cancellata				0.4
Muricids				
Nucella lima				0.4
Cancellarids				
Admete couthouyi				0.1
Turrids				
Oenopota sp.				1.1
Pyramidellids				
Odostomia sp.				0.5
Philinids				
Philine sp.				0.1
Onchydorids				
Onchidoris bilamellata				0.1
Bivalves				
Glycymerids				27.7[a]
Glycymerus subobsoleta				0.3
Mytilids				
Mytilus edulis			99.0	19.0
Musculus vernicosus				0.4
Tellinids				
Macoma sp.				0.5
Venerids				
Saxidomus gigantea				0.3
Psephidia lordi				0.4
Prototheca staminea				6.2
Mysids				
Mya sp.				0.2
Arthropods				
Crustacea	89.7[a]	0.7[a]		30.9[a]
Copepods				
Harpactacus sp.				0.1
Malacostraca				
Mysids				
Acanthomysis sp.	62.3			0.2
Neomysis spp.	21.9			
Cumacea				0.2
Amphipods	1.4			24.1
Eualus pusiolus				0.1
Euphausiids				
Thysanoessa inermis		0.2		
Thysanoessa raschii	0.1			
Decapods				
Caridea	1.0			

Hymenodora frontalis			2.6
Pandalus borealis		0.4	
Pandalus goniurus	0.7		
Crangon septemspinosa			0.4
Anomura			
Pagurus sp.			0.3
Paralithodes camtschatica			1.7
Brachyura			
Cancer oregonensis			0.1
Bryozoa			
Microporina borealis			0.4
Echinoderms			13.2[a]
Ophiuroids			
Ophiolis aculeata			5.5
Amphiolis pugetana			4.8
Echinoids			
Strongylocentrotus droebachiensis			2.4
Vertebrates			
Fish	10.3[a]	99.3[a]	
Osmerids			
Mallotus villosus	3.0	1.9	
Gadids			
Theragra chalcogramma		93.2	
Stichaeids			1.8
Lumpenus maculatus		2.4	
Ammodytids			
Ammodytes hexapterus		1.7	

Table 4. Aggregate percent volume of prey consumed by seabirds in Izhut and Kiliuda Bays 1978.

	Black-legged Kittiwake	Tufted Puffin	Common Murre	Sooty Shearwater	Short-tailed Shearwater	Marbled Murrelet	Pigeon Guillemot
N =	60	108	28	74	5	25	23
Mollusks							
Cephalopods		1.3	1.0	0.1			
Arthropods							
Crustacea	16.1[a]	21.2	0.7	0.6	81.4	9.8	18.7
Amphipods							
Paracallisoma alberti	2.3						
Euphausiids							
Thysanoessa inermis	13.8	19.2	0.7	0.5	81.4	8.1	
Thysanoessa raschii						1.7	
Thysanoessa spinifera		0.7		0.1			
Decapods							
Caridea							
Heptacarpus tridens							0.1
Pandalus jordani							4.6
Brachyura							
Cancer oregonensis							6.5
Hyas lyratus							3.4
Vertebrata							
Fish	83.9[a]	77.5	98.3	99.3	18.6	90.2	81.3
Osmerids							
Mallotus villosus	54.8	41.1	53.5	68.8		12.5	35.4
Gadids							
Gadus macrocaphalus		0.2					
Microgadus proximus		0.2	3.3	0.5			
Theragra chalcogramma		4.8	17.7			2.9	
Cottids							
Hemilepidotus jordani		1.5					
Myoxocephalus polyacanthoephalus							3.7

	BLKI	TUPU	COMU	SOSH	STSH	MAMU	PIGU
Trichodontids							
Trichodon trichodon		2.3	3.8	0.5			17.4
Fish							
Stichaeids							
Lumpenus sp.							2.3
Pholids							
Pholis laeta							2.1
Ammodytids							
Ammodytes hexapterus	20.4	24.2	18.7	25.3	12.8	62.3	
Pleuronectids							2.3

[a] Identified and unidentified individuals combined.

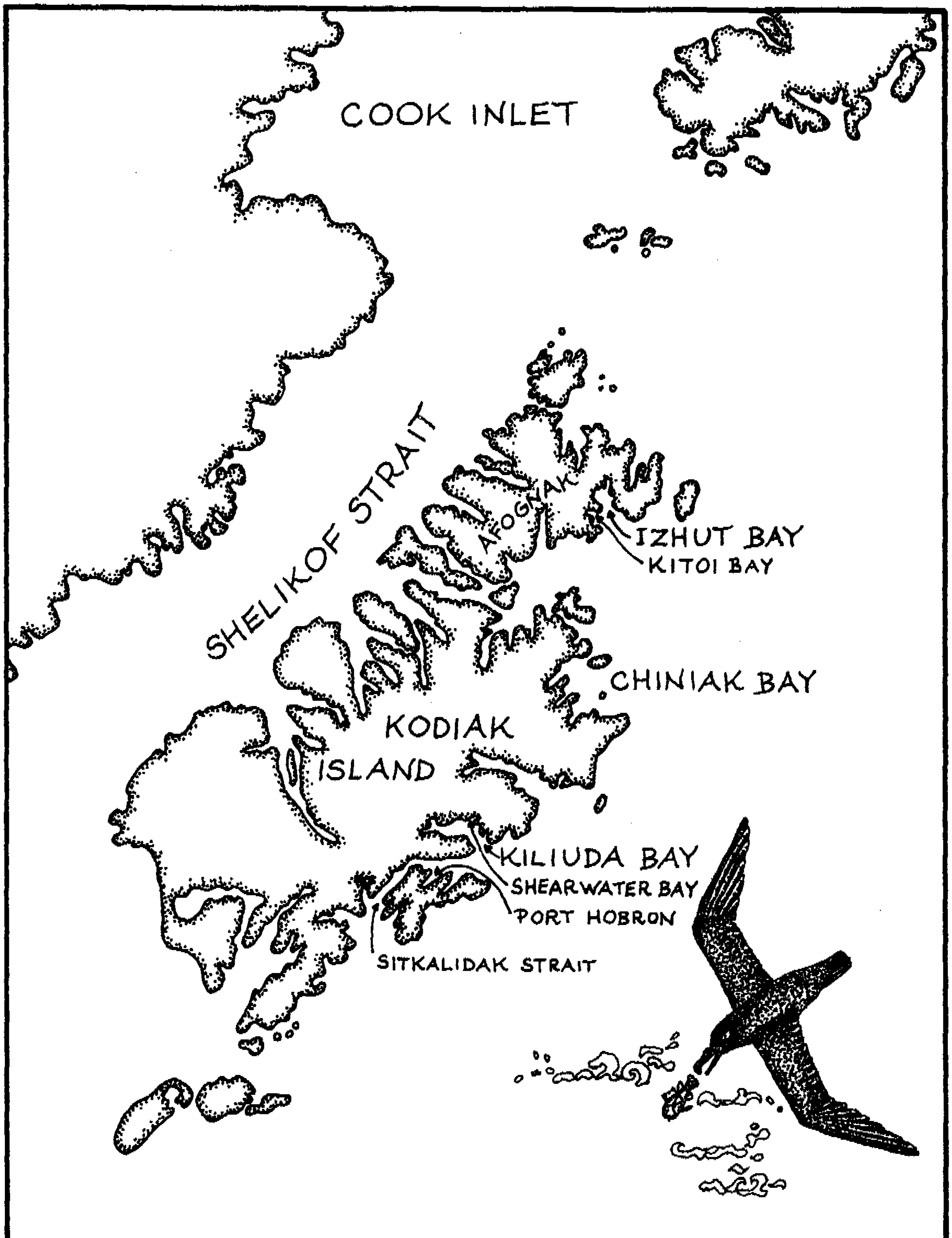


Figure 1. Location of study area in the northcentral Gulf of Alaska.

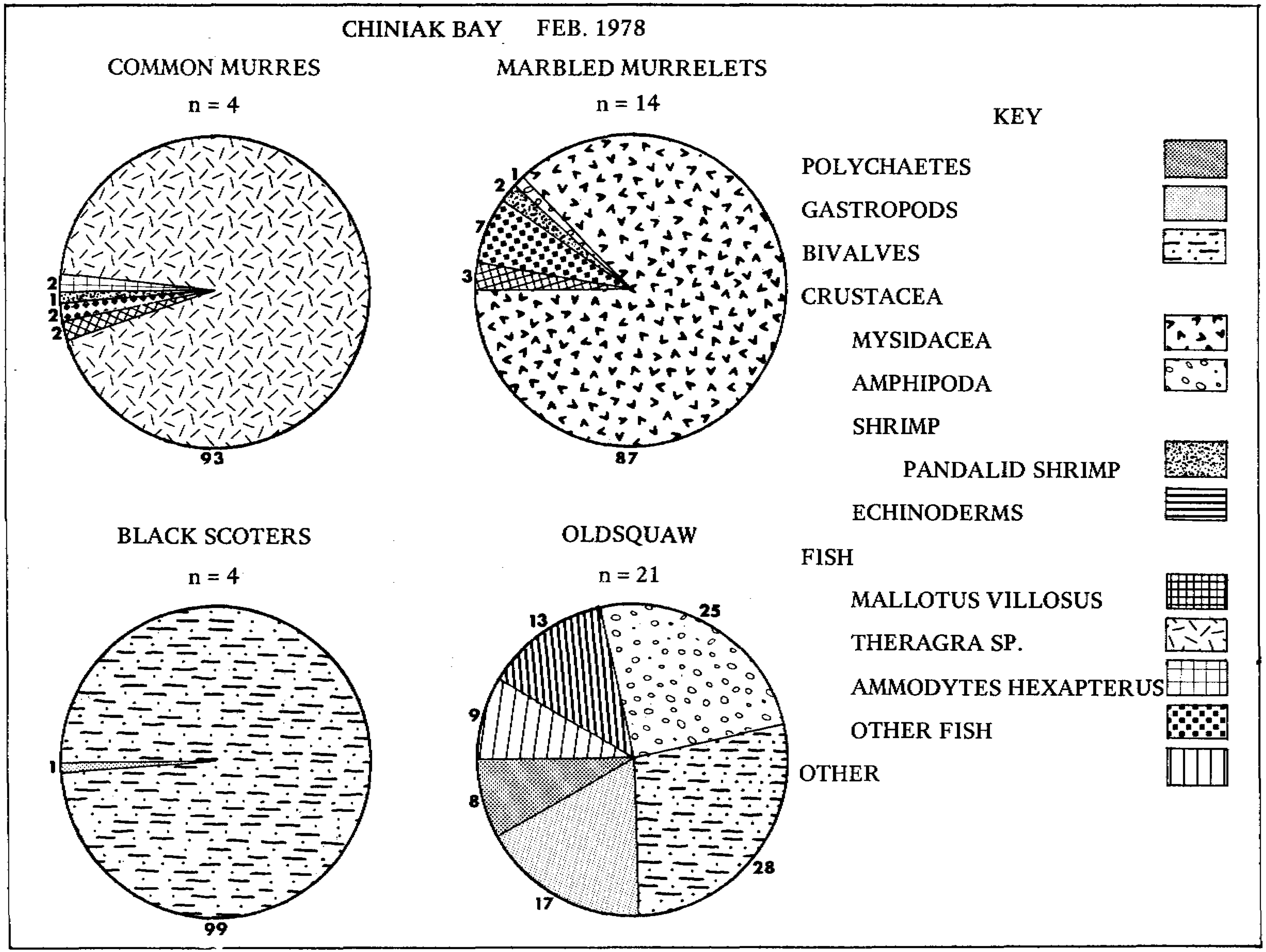


Figure 2. Aggregate percent volume of prey consumed in Chiniak Bay, February 1978.

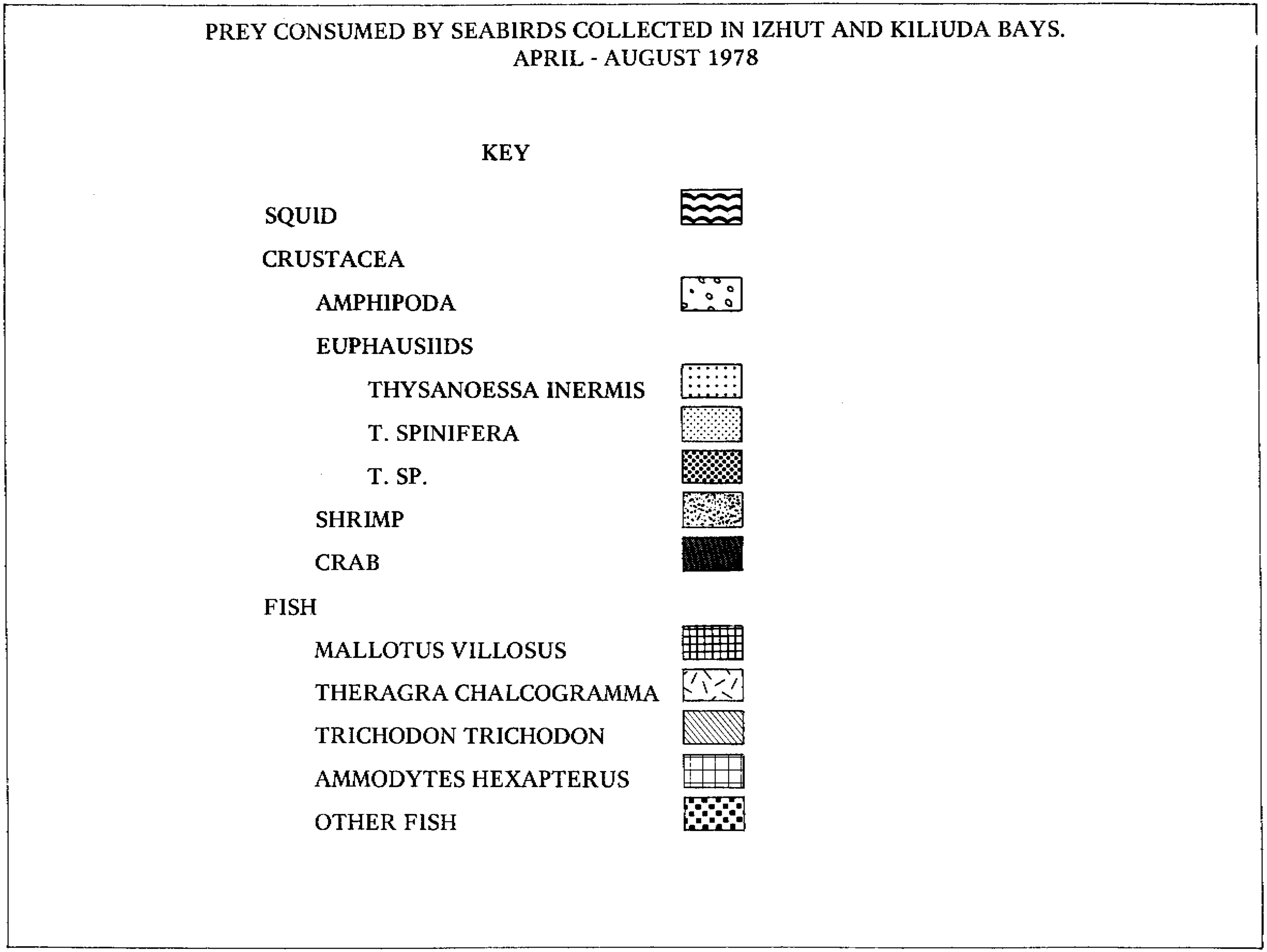


Figure 3. Key to prey consumed by seabirds in Izhut and Kiliuda Bays, 1978, Figures 4-11.

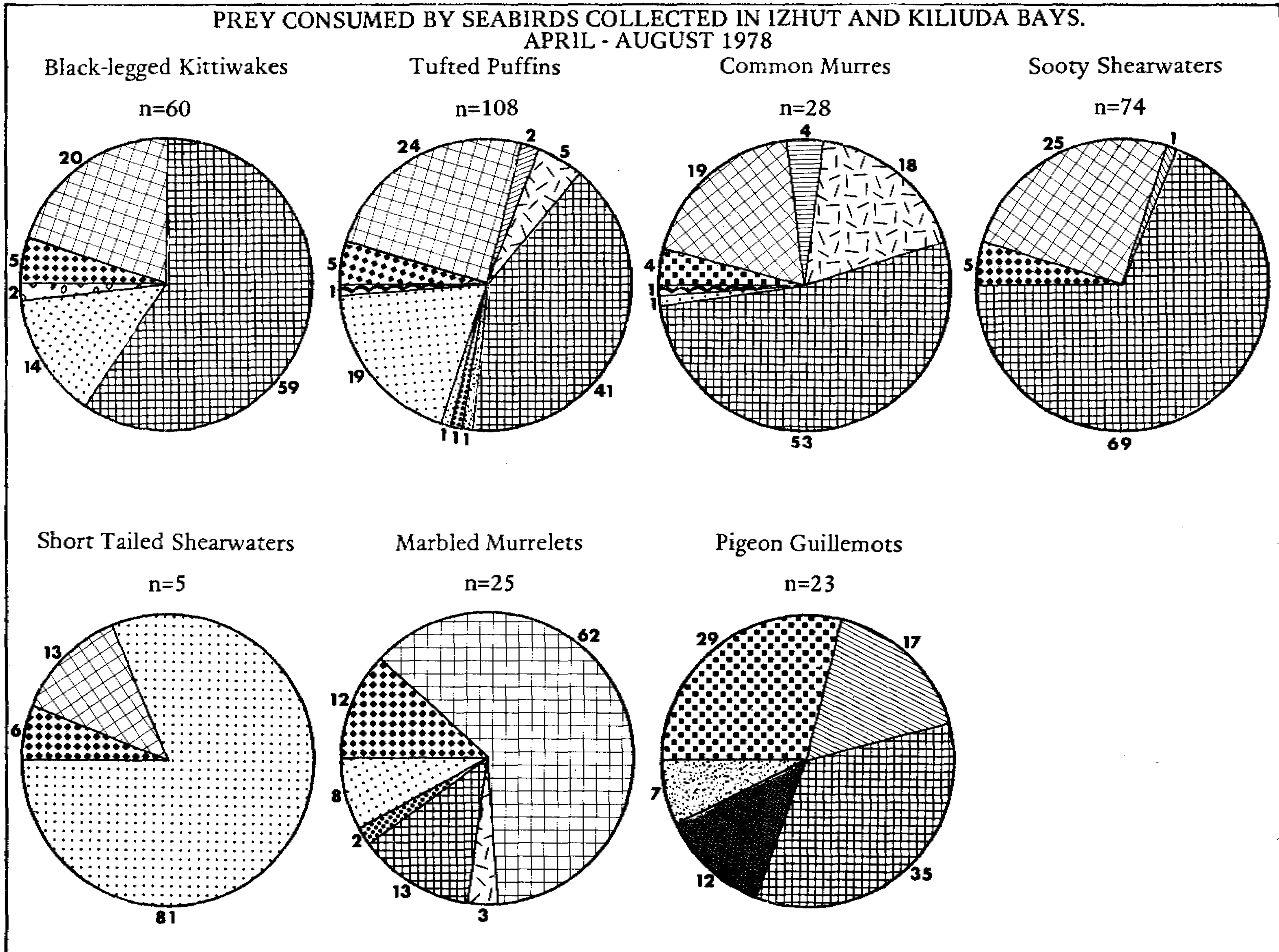


Figure 4. Aggregate percent volume of prey consumed by seabirds in Izhut and Kiliuda Bays, April through August 1978. (See Key, Figure 3)

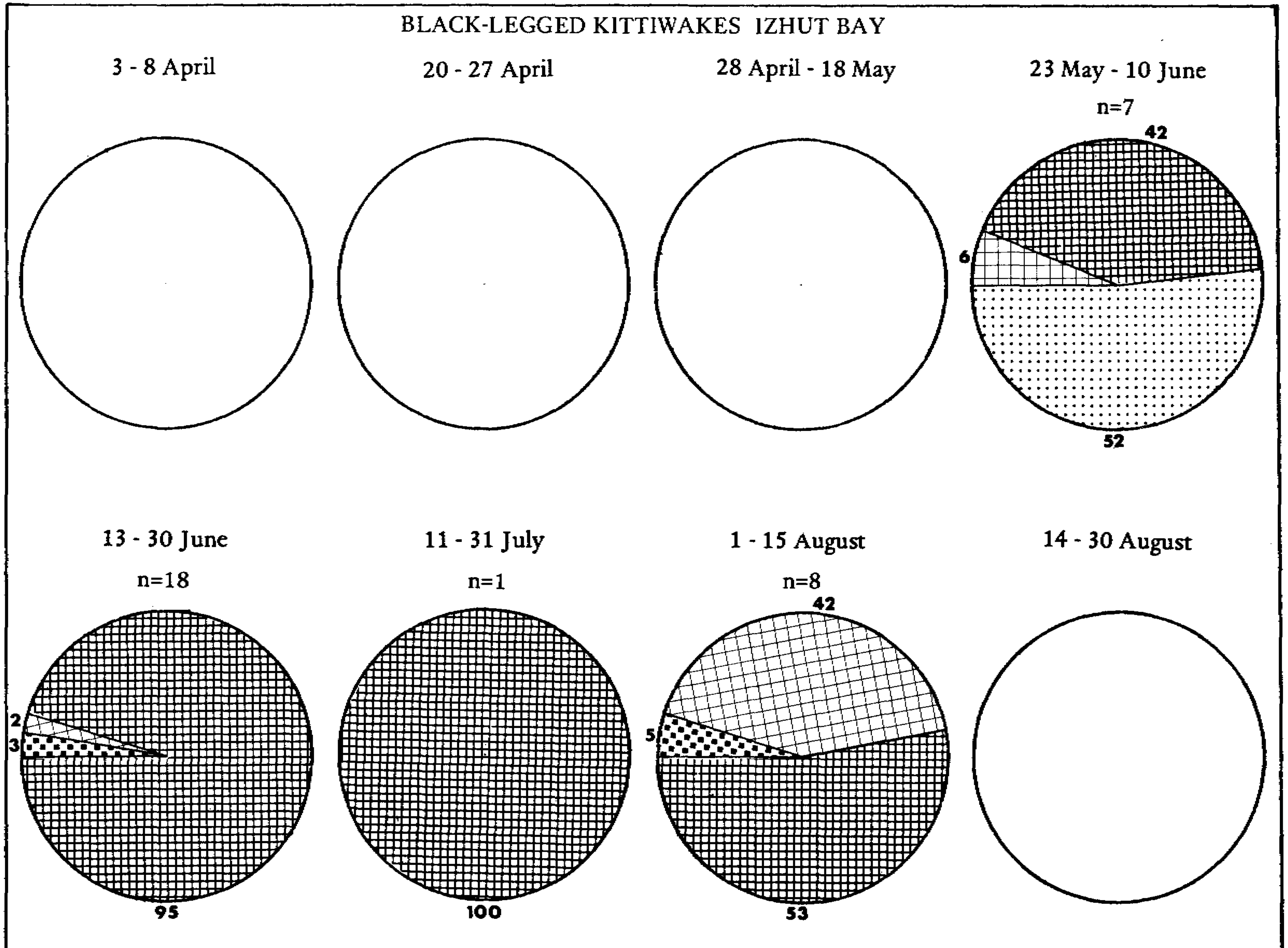


Figure 5a. Aggregate percent volume of prey consumed by black-legged kittiwakes in Izhut Bay, April through August 1978. (See Key, Figure 3)

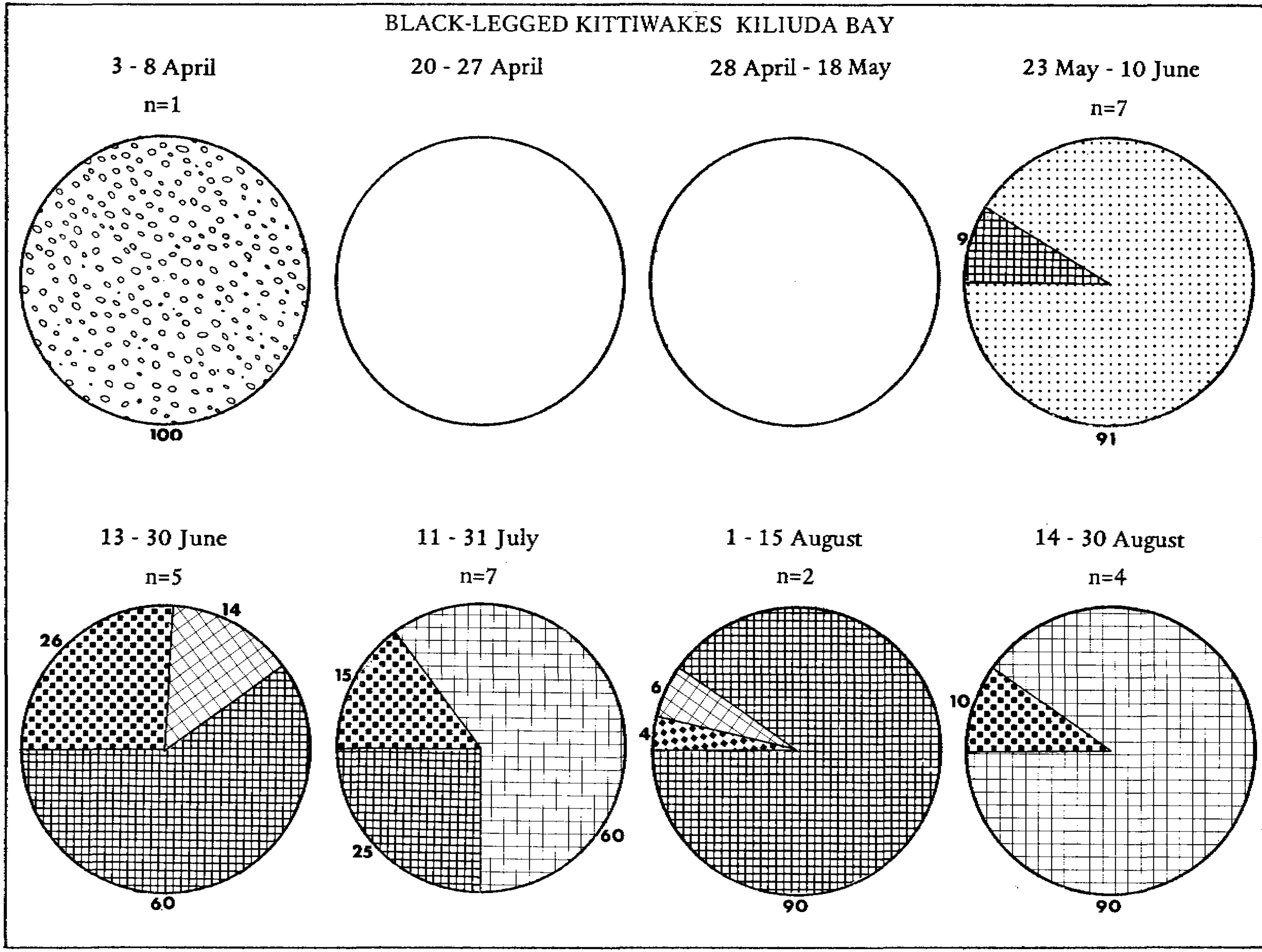


Figure 5b. Aggregate percent volume of prey consumed by black-legged kittiwakes in Kiliuda Bay, April through August 1978. (See Key, Figure 3)

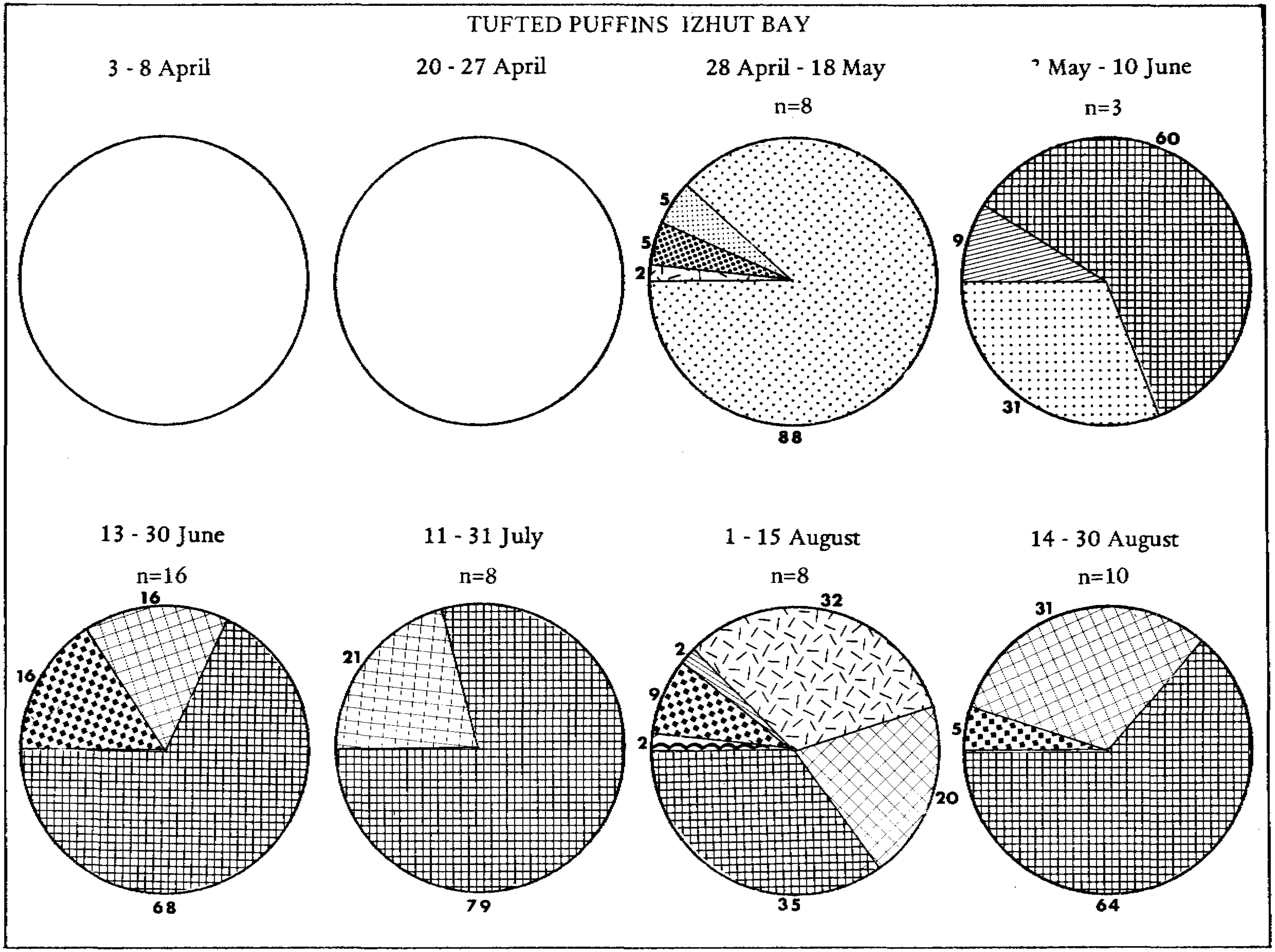
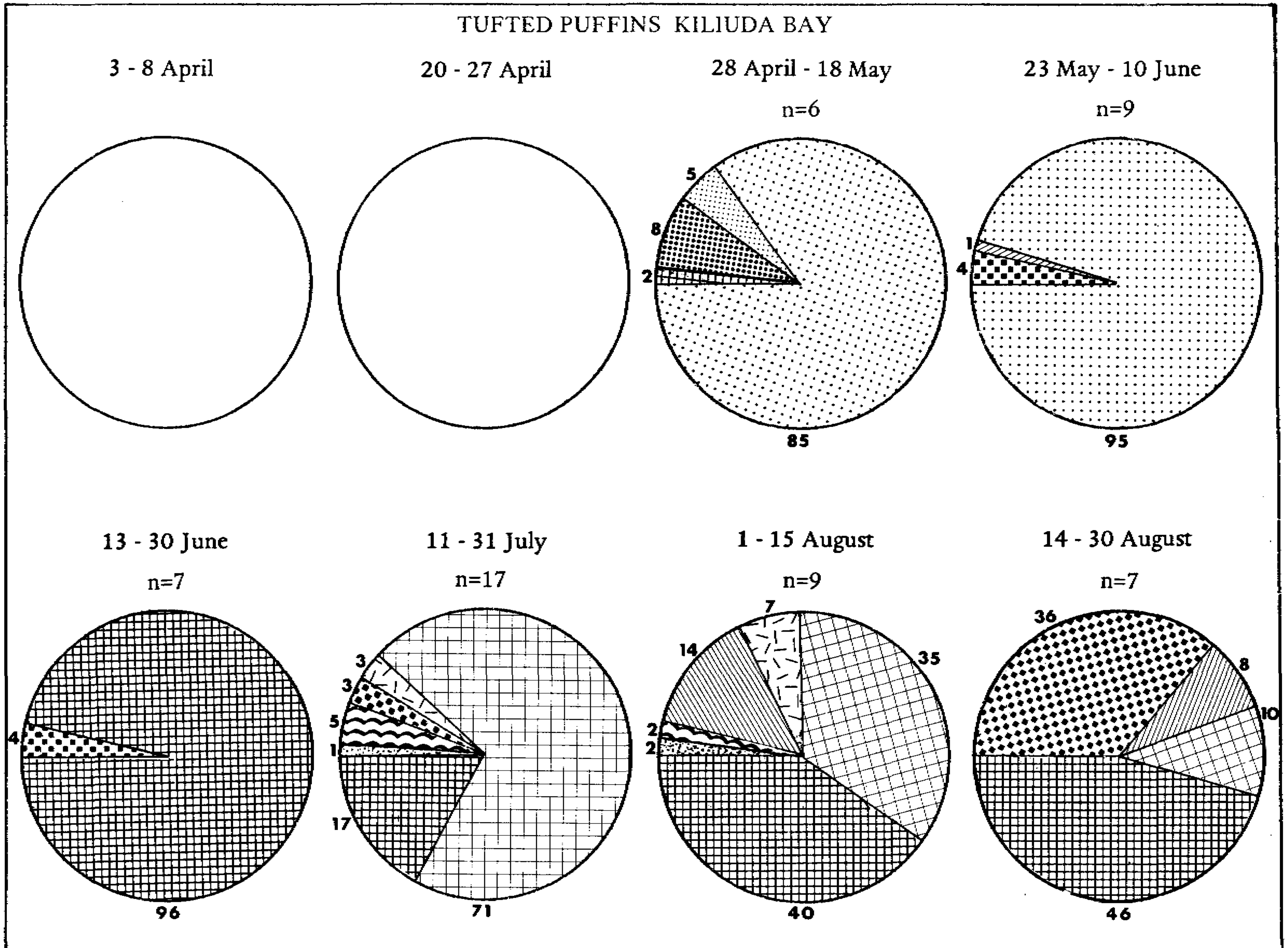


Figure 6a. Aggregate percent volume of prey consumed by tufted puffins in Izhut Bay, April through August 1978. (See Key, Figure 3)



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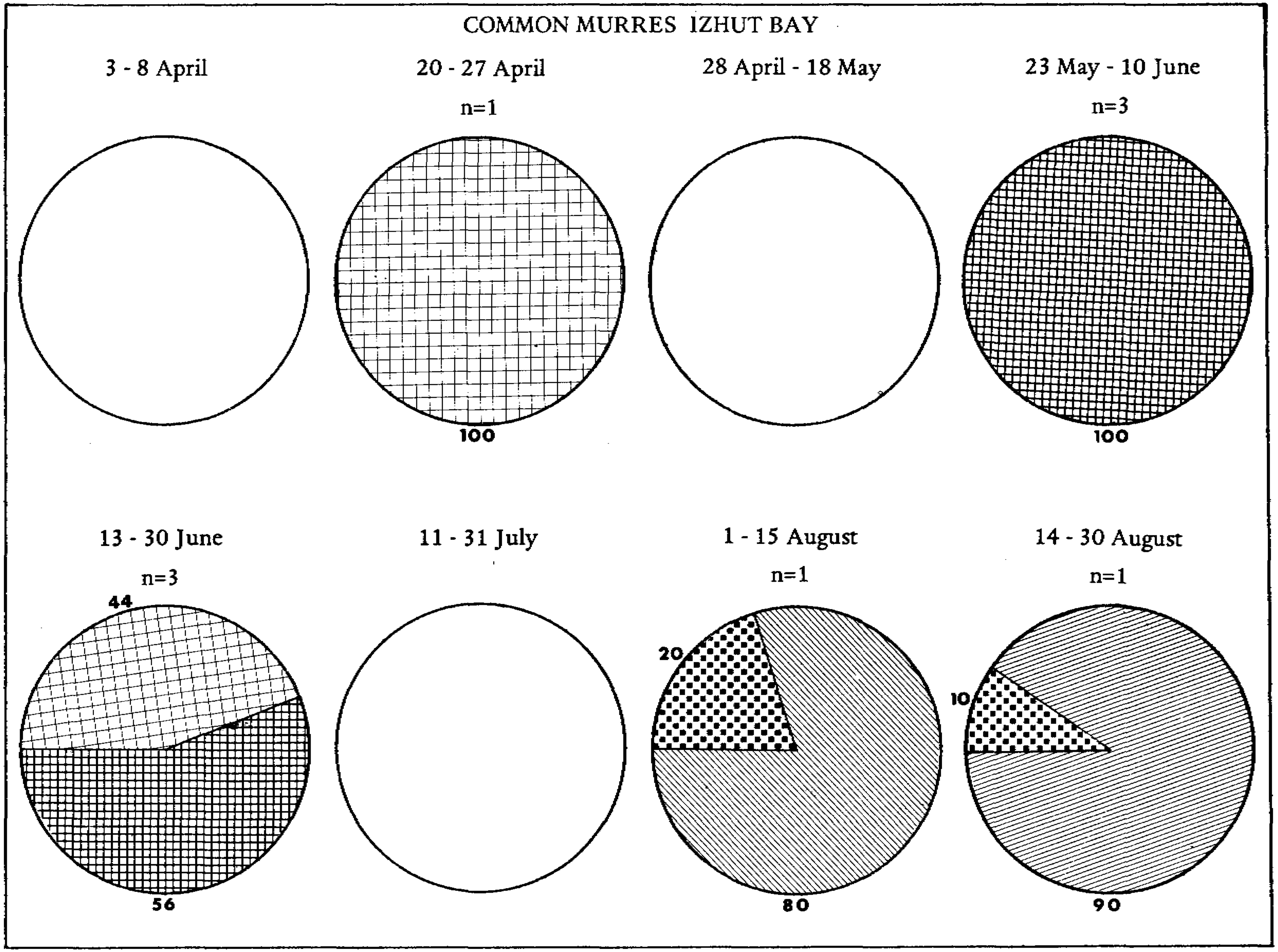

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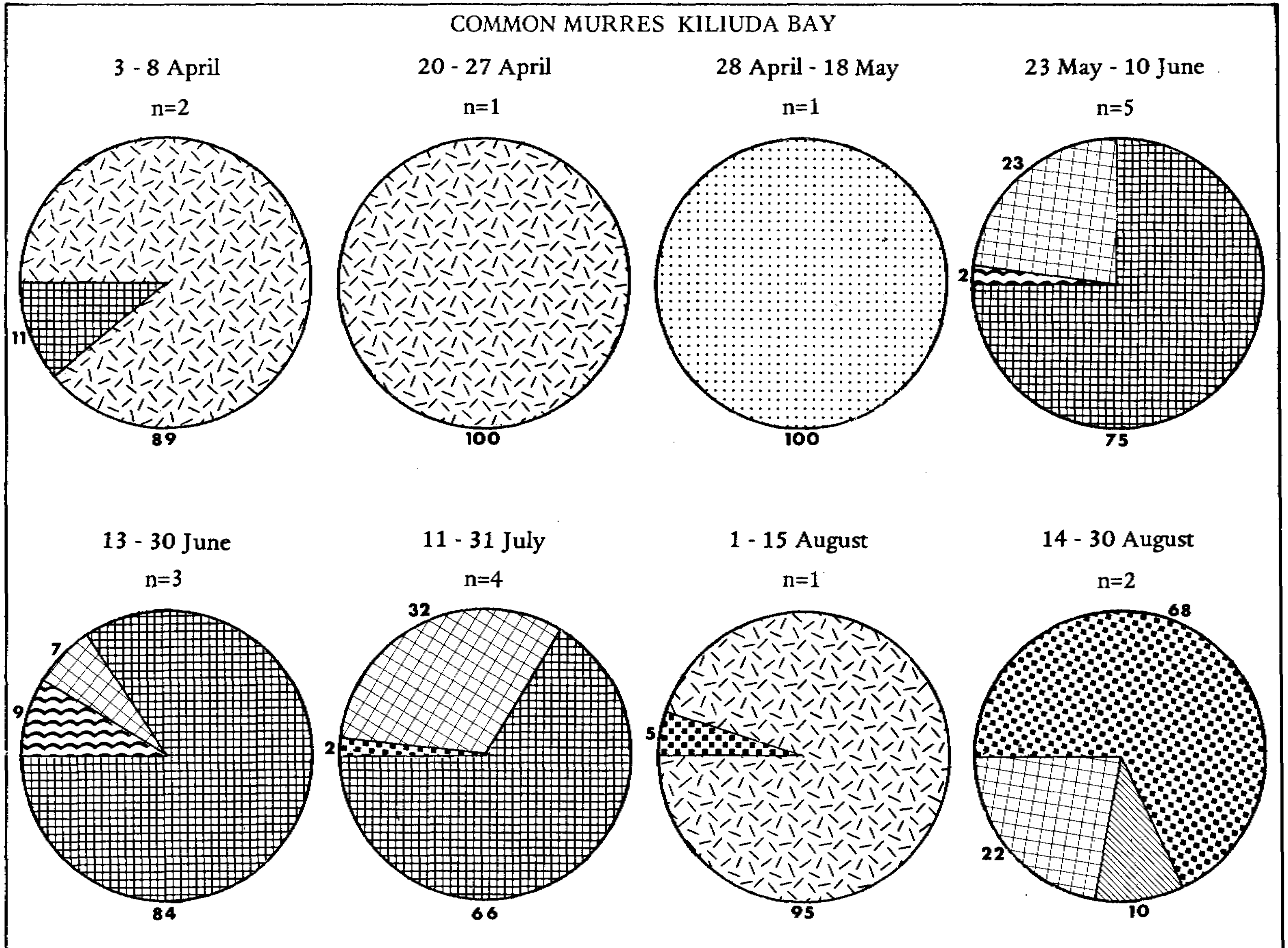

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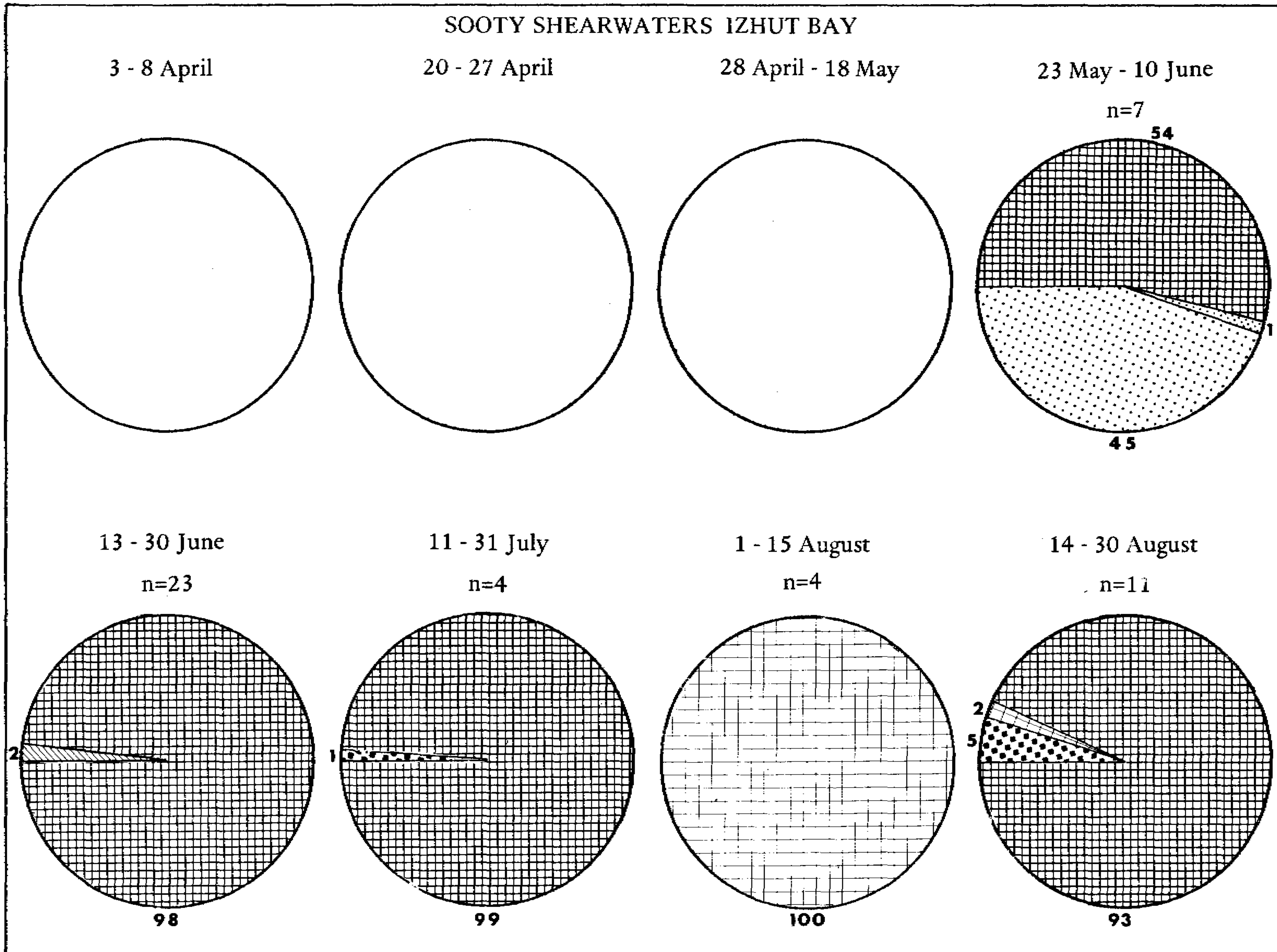

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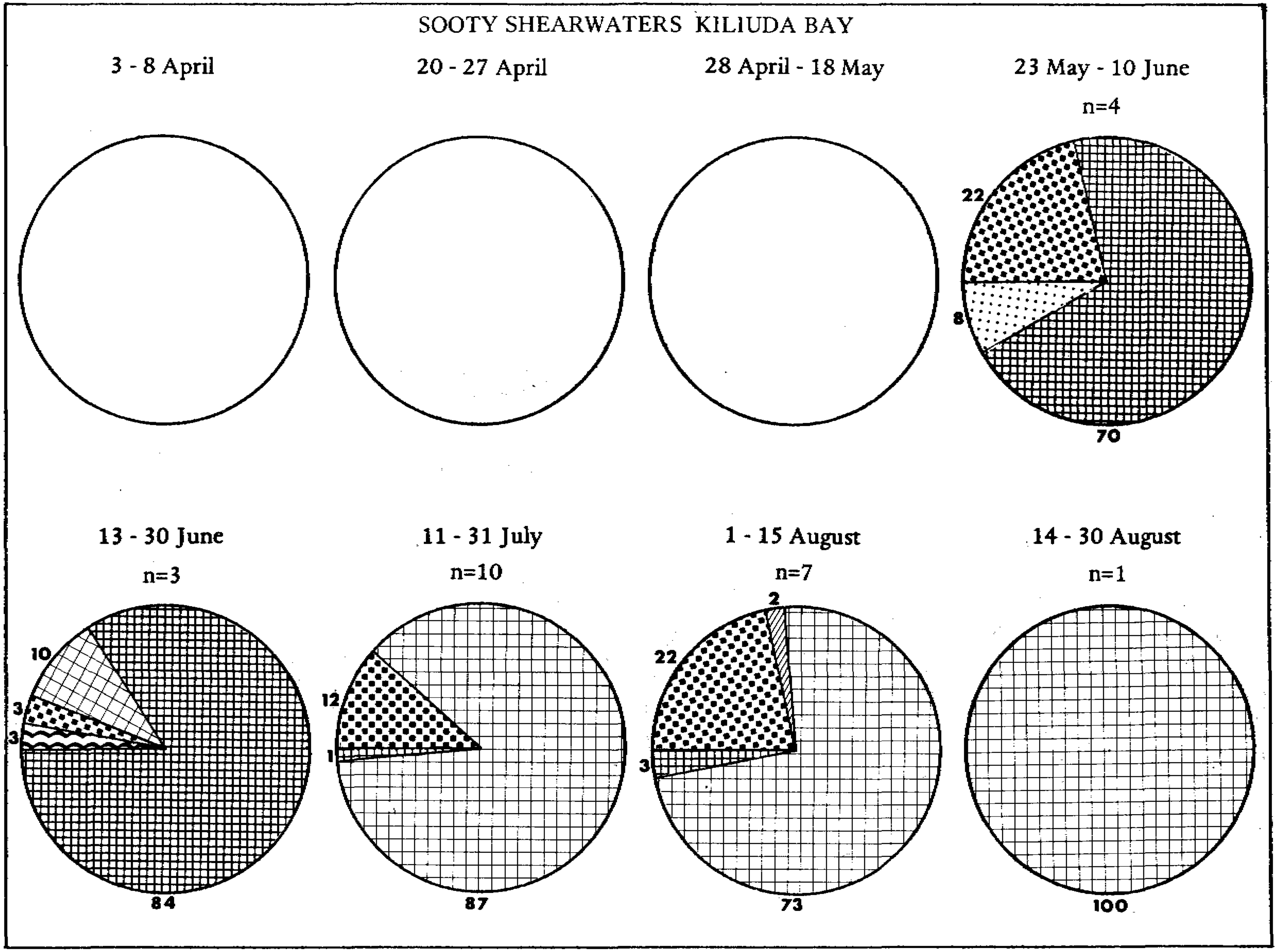

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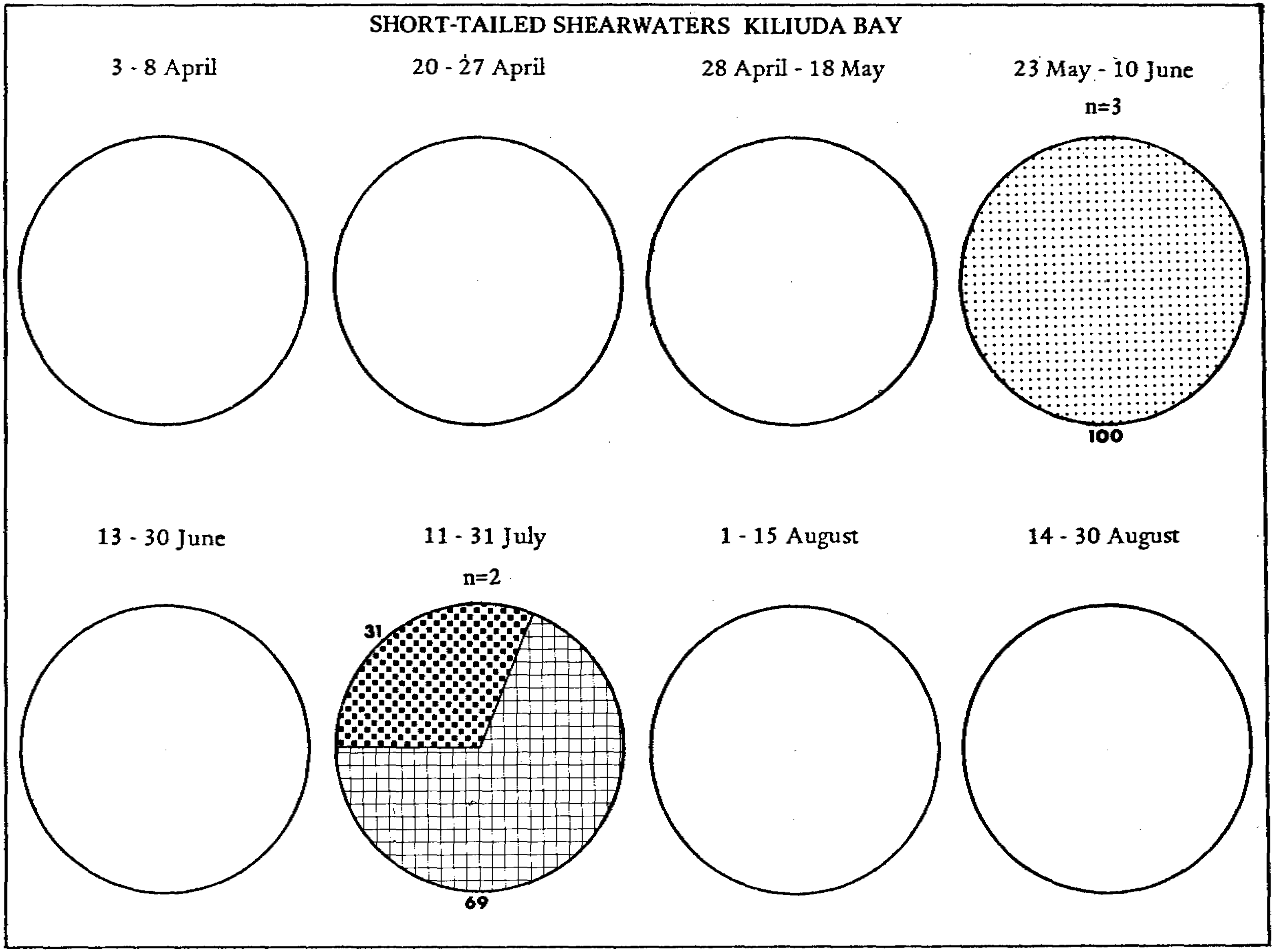

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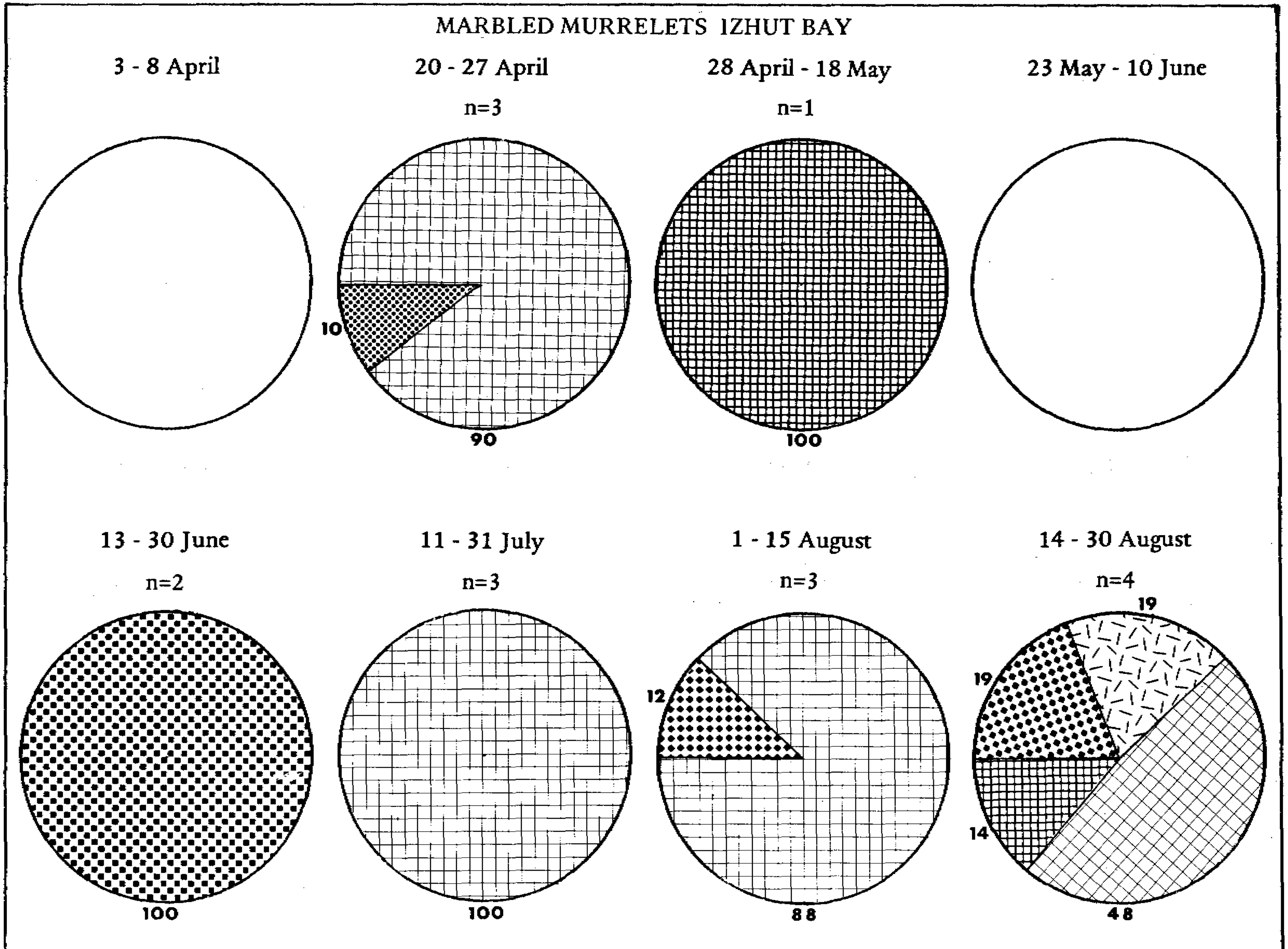

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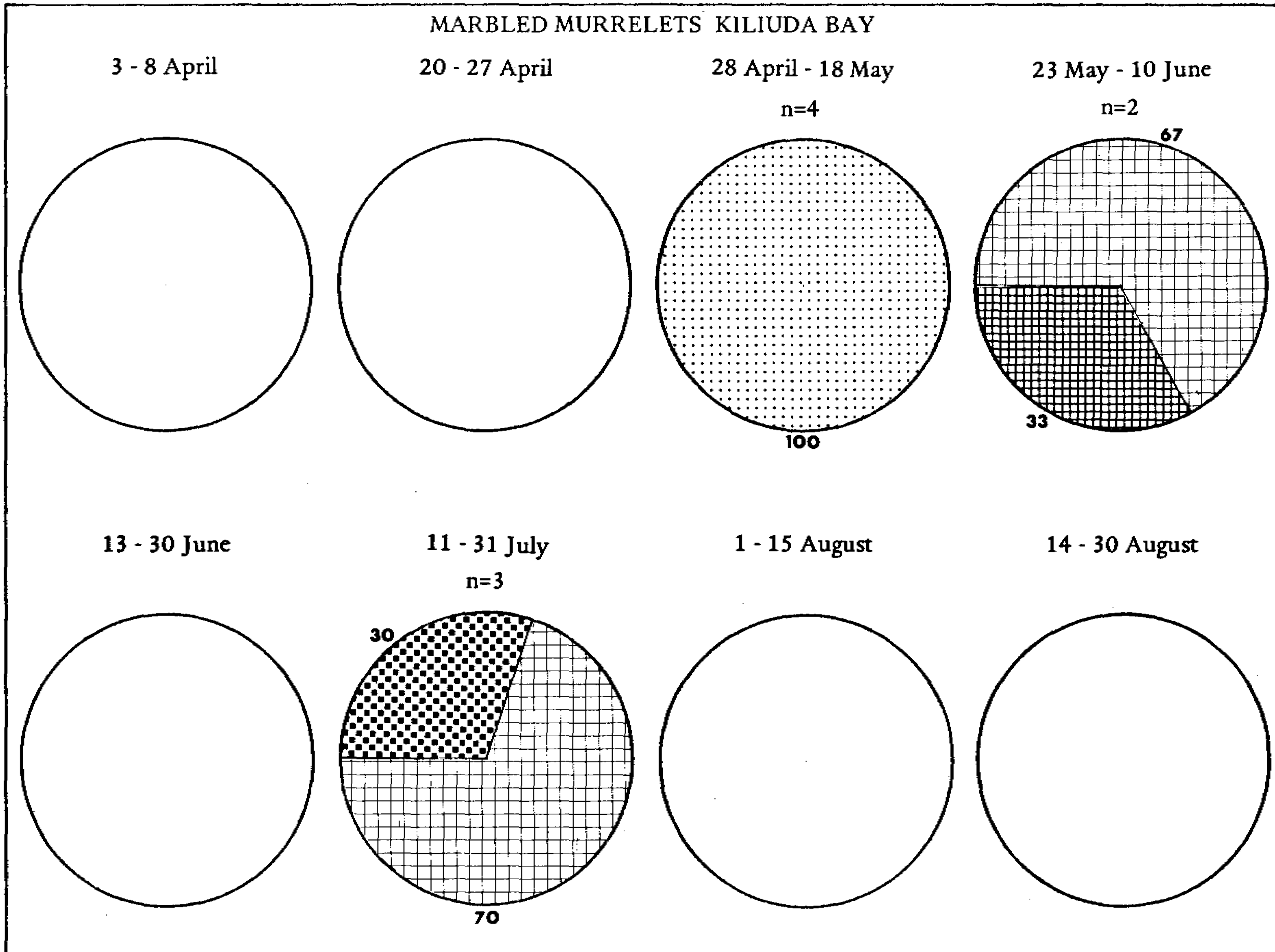

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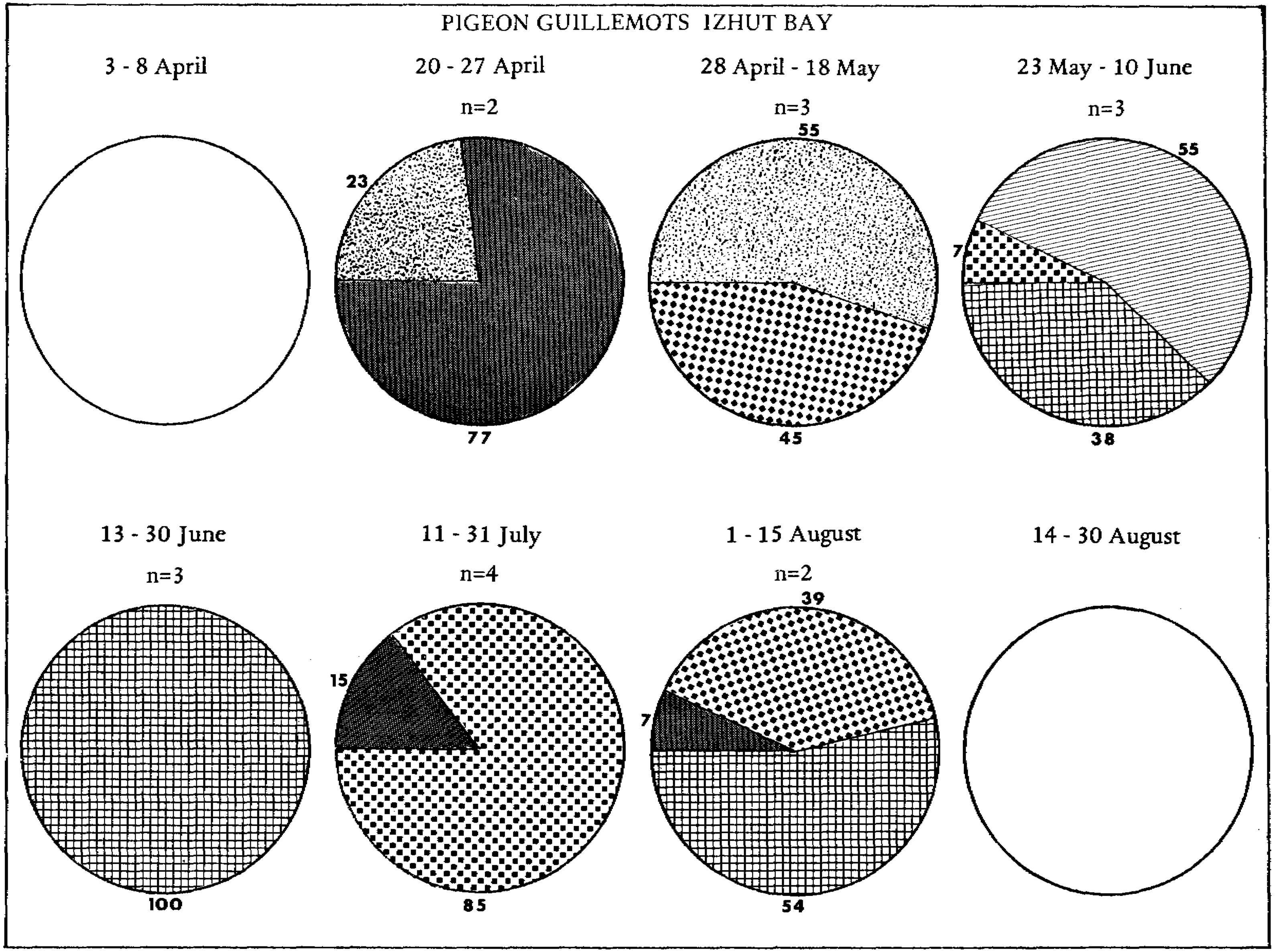

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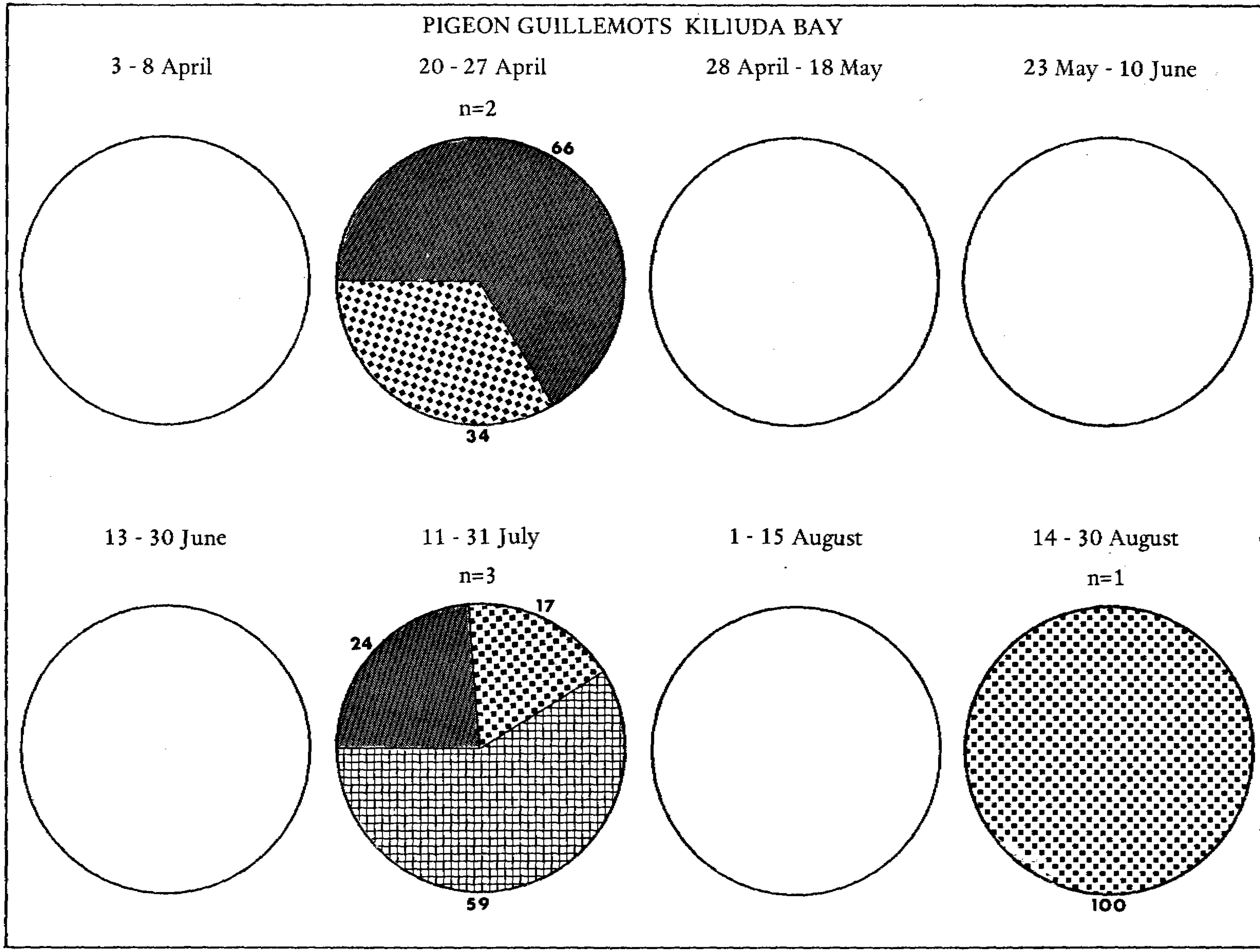

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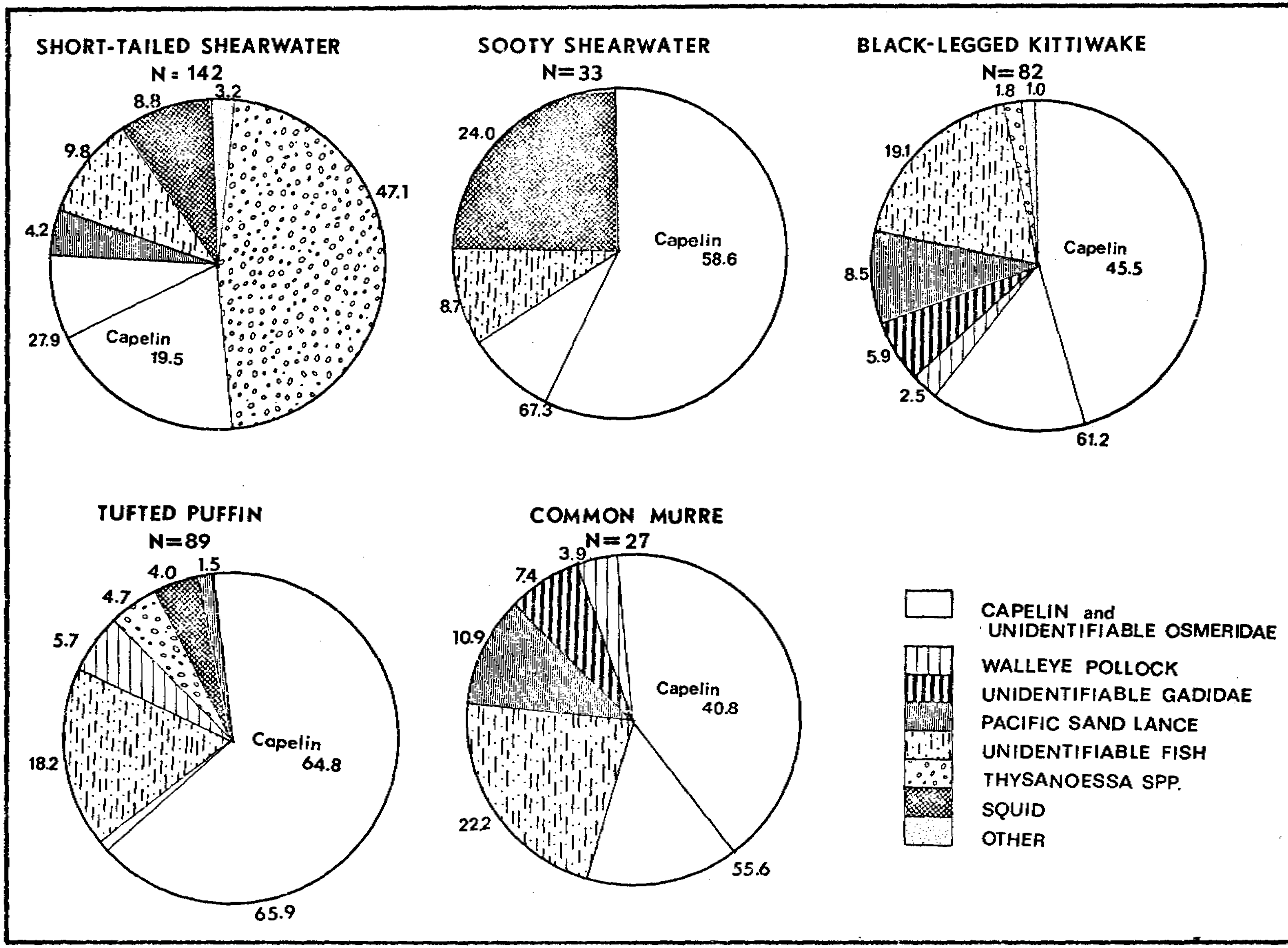

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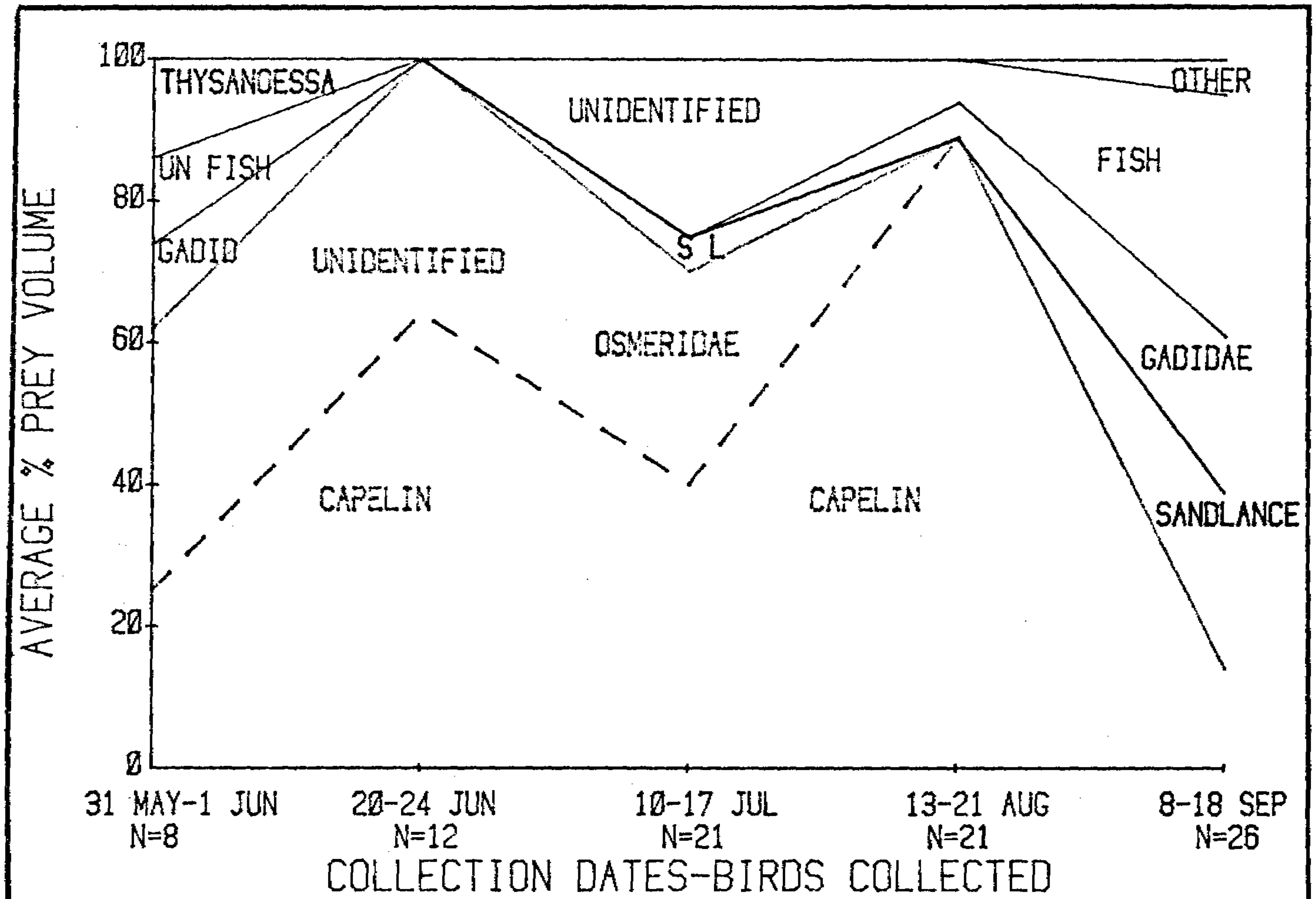

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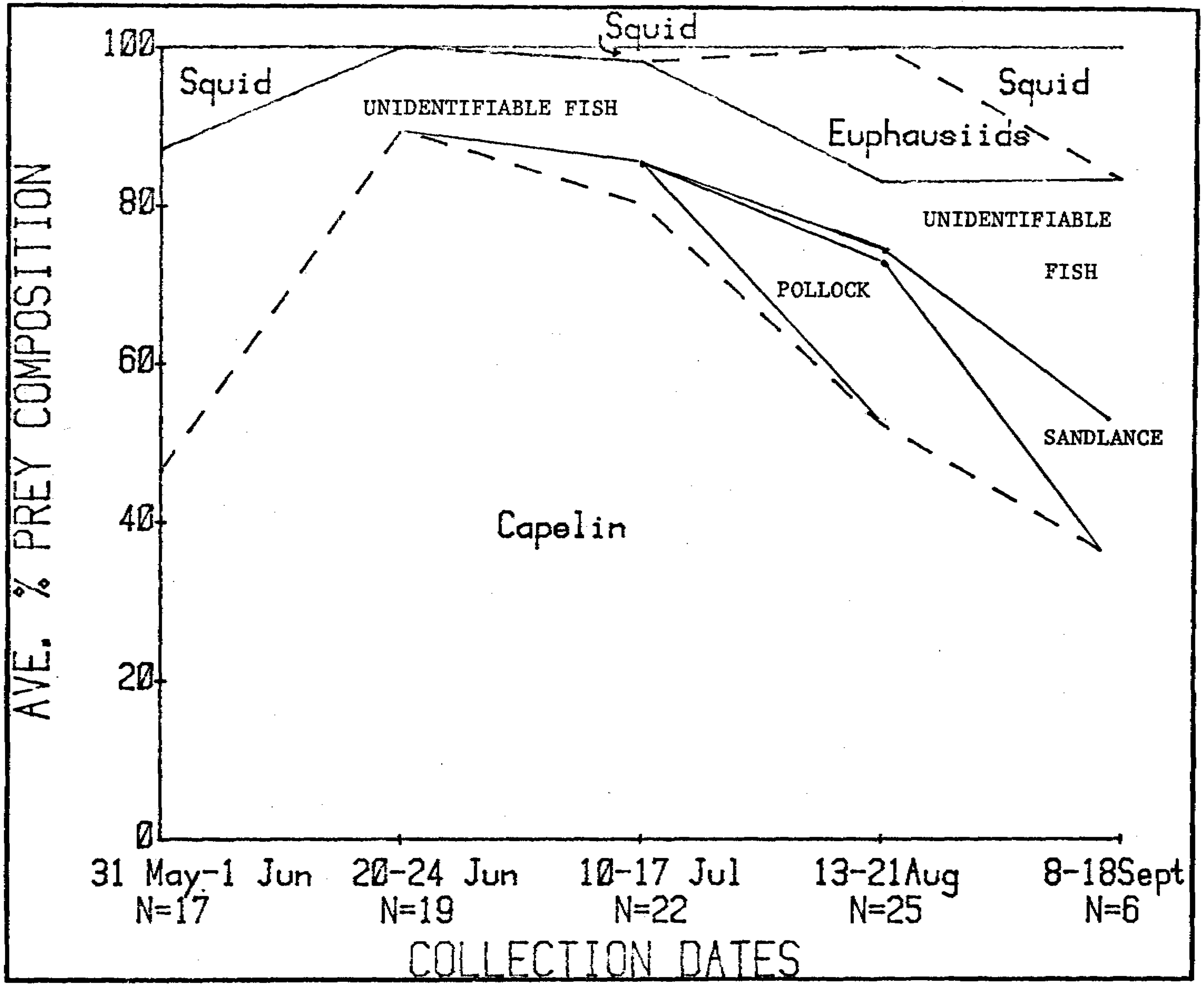

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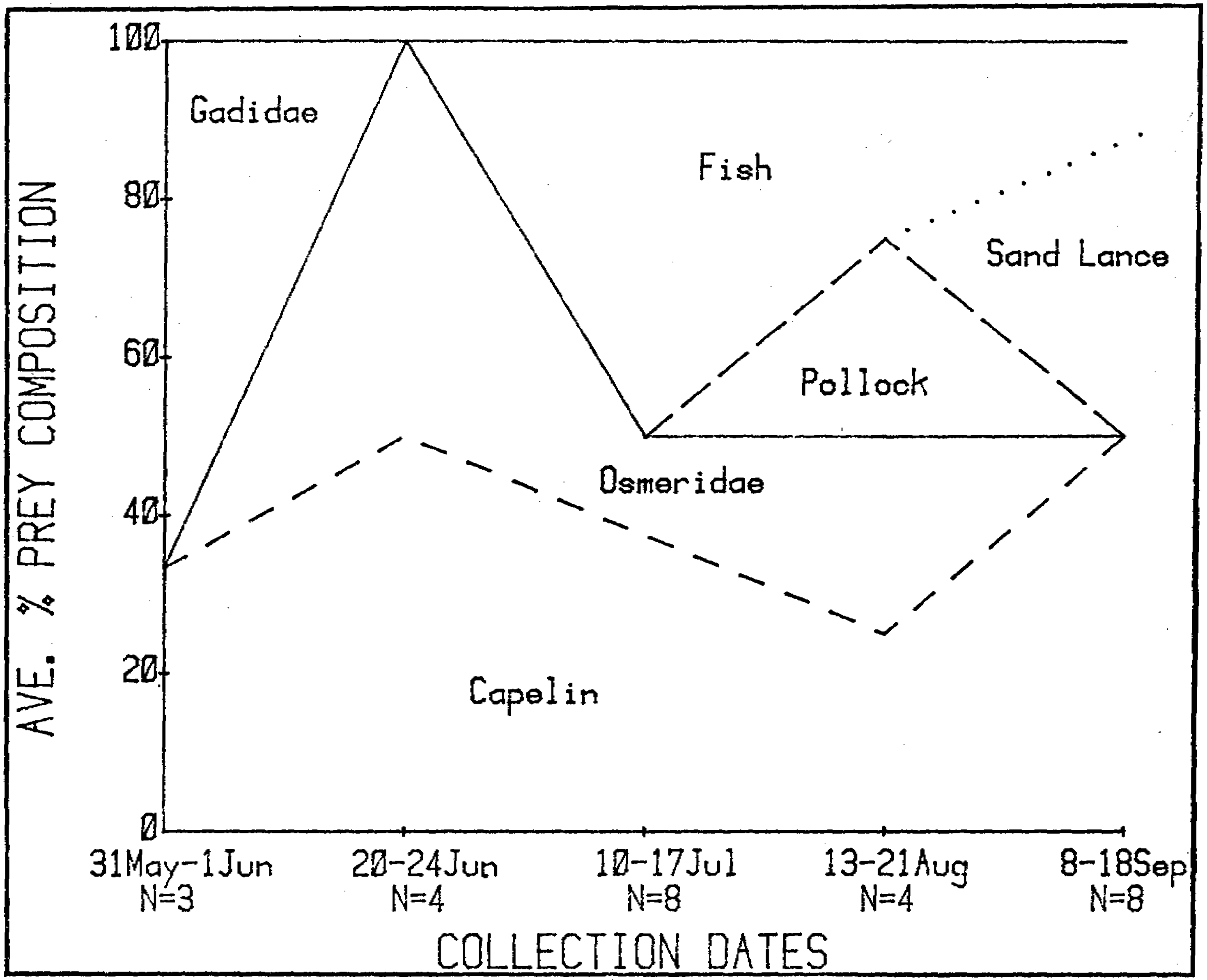

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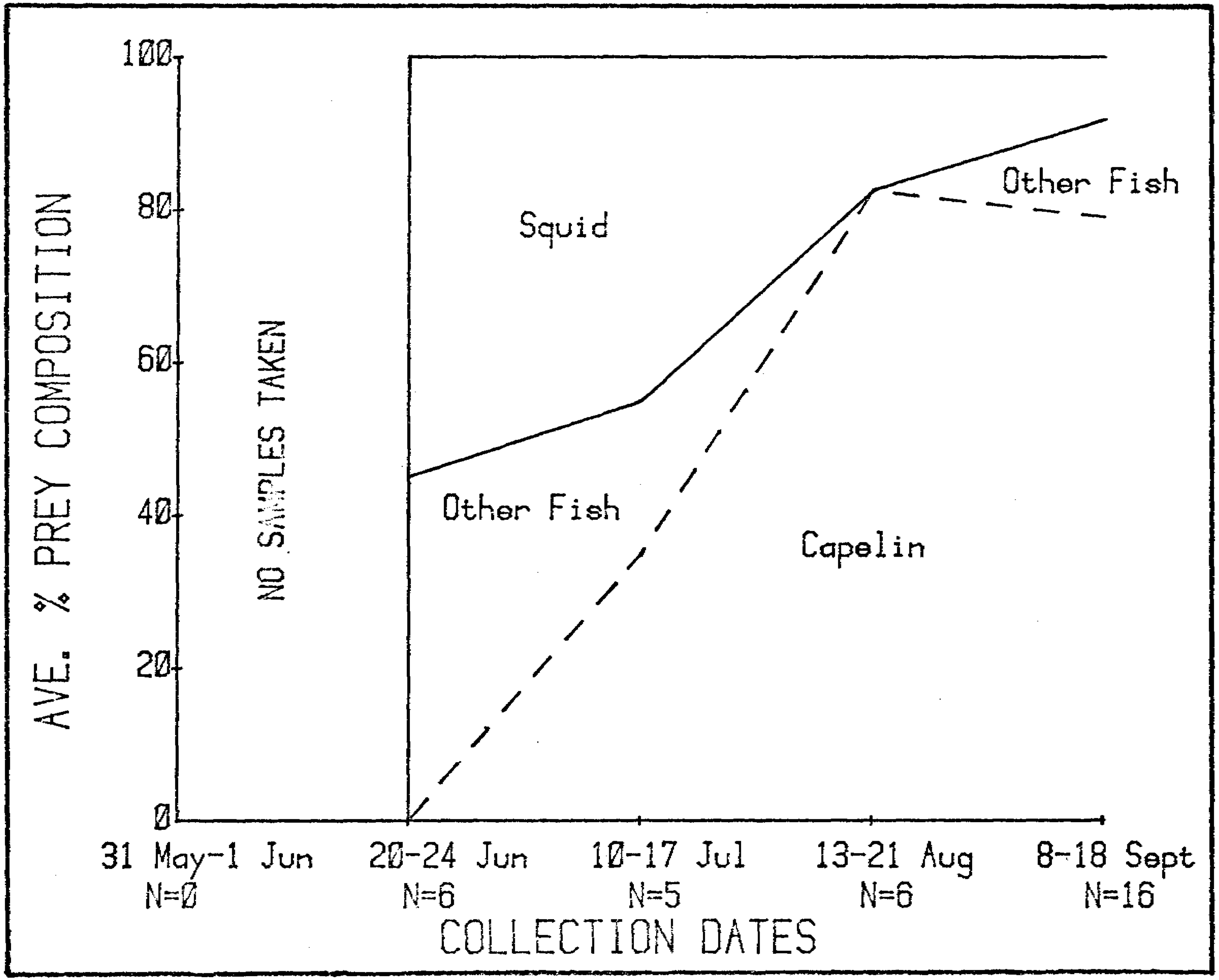

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ANNUAL REPORT

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POPULATIONS AND ECOLOGY OF SEABIRDS OF THE KONIUJI GROUP, SHUMAGIN ISLANDS, ALASKA

by

R.A. Moe and R.H. Day

PART VI

of

POPULATION DYNAMICS AND TROPHIC RELATIONSHIPS OF MARINE BIRDS IN THE GULF OF ALASKA AND SOUTHERN BERING SEA

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Anchorage, Alaska

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INTRODUCTION AND OBJECTIVES

This study of marine birds in the Shumagin Islands was one of several site specific studies of birds conducted under the BLM/NOAA program for environmental assessment of the outer continental shelf. The general purpose of the studies was to obtain information on birds necessary to evaluate the potential impacts of the proposed development of petroleum resources of the outer continental shelf and to provide baseline data for monitoring the effects of the development program. The specific objectives of this study included:

1. to identify all nesting colonies within the study area,
2. to determine the approximate population and the habitat require ments of individual species occupying the colony site,
3. to determine productivity of individual species and the factors influencing reproductive success,
4. to determine food requirements and foraging areas of principal species.

The Shumagin Islands were chosen as a study site because of the presence of large, diverse populations of marine birds that could be adversely affected by development in the Kodiak Basin or by tanker traffic from development areas in the Bering, Chukchi, or Beaufort Seas. In addition, the presence of large populations of small alcids was of interest because species in this group are highly vulnerable to marine pollution and were not adequately represented at other study areas.

Field work was initiated on 25 May 1976, and continued to 3 September 1976. R. Allen Moe and Robert H. Day participated in the project for the entire period while Ted Schad continued only to 24 July. In addition to the objectives stated above, Moe conducted an intensive study of predators and Day evaluated the presence of plastic particles which occur in the stomachs of many seabirds, in particular the Parakeet Auklet, and all participants maintained records of the distribution and abundance of all birds and mammals observed during the field season. This data will be discussed in separate reports.

STUDY AREA

The continental shelf extends seaward approximately 130 km from the south shore of the Alaska Peninsula and is dominated by several island groups. The largest of these is the Shumagin Group, which consists of fifteen sizeable islands and many smaller islets and rocks. The easternmost of these islands, Big and Little Koniuji Islands and the smaller surrounding islets, are here considered as the Koniuji Group and are the focus of the present study (Figure 1). This group of islands has a total land mass of roughly 72 square miles and lies between latitudes 54°55' and 55°17' north and longitudes 159°19' and 159°41' west. Our field camp was maintained at Yukon Harbor, on the southeast end of Big Koniuji Island.

Geology

Islands of the Koniuji Group are underlain by a thick layer of interbedded sandstone and mudstone, called the Shumagin Formation, which is intruded by a granitic batholith (Moore, 1974). The structural trend is northeasterly, parallel with the outer margin of the continental shelf, and the contact between the two formations is often very distinct. The Shumagin Formation is confined to the western arms of Big Koniuji and to Peninsula Island while the remainder of the land mass is made up of the intrusive granodiorite (Figure 2). A few more recent alluvial deposits are present but only on a very limited scale.

The mountainous character of the area is illustrated by the fact that Big Koniuji alone contains over 30 peaks more than 1000 feet in elevation, seven of which are over 1500 feet, yet there is not a single point on the island that lies more than one mile from the ocean. The slopes are very rugged with abundant talus, and traveling overland is uncommon.

Vegetation

Low summer temperatures, exposure to wind, and little soil development have limited vegetation generally to low growing life forms. No trees are present except for three large Sitka Spruce planted near an old fox farm cabin located on the west side of Little Koniuji Island.

Vegetation can be grouped into four major categories.

1. The beach or dune association is characterized by *Elymus arenarius* and *Honckenya peploides*
2. The mixed meadow association of grasses (*Calamagrostis canadensis*) and umbels (*Heracleum lanatum* and *Angelica lucida*) is found on sites with the most soil development.
3. The alder-willow thickets (*Alnus crispa*, *Salix glanca* and *Rubus spectabilis*) occurs on protected slopes and gullies.
4. Alpine tundra is present in two forms on areas with poor soil development. Dry tundra is the most common and is composed of lichens, mosses and heath (*Phyllodoce aleutica* and *Cassiope* spp.). Moist tundra dominated by crowberry (*Empetrum nigrum*) is found only in some of the flatter, poorly drained ridges.

A list of plant species collected in the Big Koniuji area of the Shumagin Islands is presented in Addendum I of this report.

Weather and Climate

The Shumagin Islands are south of the severely low winter temperatures of interior and northern Alaska, and the surrounding waters are free of sea ice. Spring comes late, with vegetative growth beginning in late May - early June. Although on Big Koniuji Island in 1976 most of the snow was gone from the low areas and was broken into patches on the North-facing slopes by 7 May, the slopes did not turn noticeable green until the first part of July.

Precipitation and temperature were measured at Yukon Harbor with a standard rain gauge and a Taylor maximum-minimum thermometer. These observations were recorded daily at 0900 between 1 June and 24 August (Table 1). Precipation was greatest in July, with a total 7.75 inches. Although the thermometer was on the north side of a 4-in. post, it may have been influenced by direct sunlight at times and thus the maximum temperatures may run a bit high.

The nearest permanent weather station is at Cold Bay, and although the climate there is basically maritime, it received considerably less rainfall than Big Koniuji. Big Koniuji also received considerably more rainfall in June than did either the station at Sitkanak, just south of Kodiak Island in an apparently similar maritime locality, or Adak in the Aleutians (Table 2). The mountainous terrain near the Koniuji station may contribute to the excessive rainfall there.

Wind speed was not recorded at Yukon Harbor during the summer of 1976, but high winds, at times exceeding 40 knots, occurred about 25% of the time throughout the summer. In June, these winds were predominately from the northwest; in July they were quite variable, but north winds were uncommon; and in August they came mainly from the southwest with a few strong winds from the north in the latter part of the month.

DISTRIBUTION AND ABUNDANCE OF THE SEABIRDS

Methods

Colonies were defined as any concentration of nesting birds with well-defined boundaries. Most of these were small off-shore islets containing a mixture of species. The six areas designated as colonies on Big Koniuji were, for the most part, concentrations on very limited sections of cliff face or talus (Figure 4).

During the course of the summer the entire coastline of Big Koniuji Island and much of the coastline of Little Koniuji Island were surveyed by two observers in a 12-foot Zodiac running approximately 30 meters offshore. Castle Rock, Peninsula, Atkins and Herendeen Islands were also censused in this way. Because of the large area to be censused, and the unreliable weather, the surveys were carried out in segments during a 2 1/2-month period (Figure 3). Such a procedure limits the accuracy of the population estimates, especially in the alcids, because the number of birds present at a colony at any given time may be greatly influenced by the phase of the breeding cycle, time of day and weather conditions (Nettleship, 1976). In an attempt to obtain some measure of colony attendance, an hourly count of the birds on the water and rocks within 300 meters of the southeast side of Hall Island was made on 2 July.

Census techniques were modified for each species or species group depending on nesting strategy and colony location.

1. Cliff nesters (Black-legged Kittiwake, cormorants, and murres)

The breeding populations of these birds were determined by direct counts of nests, or in the case of murres, by counting birds on cliff ledges. Black-legged Kittiwakes were censused during the middle of the incubation period except those at Castle Rock which were censused during the middle of the nestling period. Thus, the Castle Rock counts may not include those pairs whose nests were destroyed during incubation and first half of the nestling period. Cormorants nesting on the western side of Big Koniuji were censused during the mid-nesting period, while those on the eastern side were censused during early incubation.

2. Surface nesters (Glaucous-winged Gull)

Early in the season, before vegetation obscured the nests on Hall Island, direct counts were mdde of Glaucous-winged Gull nests in a selected area and the mean distance between them was calculated for a measure of average density. This estimate was then applied to the remainder of the area used by the gulls to determine the total breeding population. At other locations, counts of birds at presumed nest sites were made from a distance without actually counting the nests themselves, while on Peninsula Island, where gulls were nesting on flat areas behind beaches and out of sight from offshore observers, the estimation of breeding pairs was based on a count of birds in the area correlated with the extent of available nesting habitat.

3. Nocturnal burrowers (Cassin's Auklet, Ancient Murrelet, and Storm Petrels)

No burrows of either Leach's or Fork-tailed Storm Petrels were found on Hall Island, and here their populations were determined by flight activity and flight-call rates during three successive nights. However, as pointed out by Nettleship (1976:13), this technique has the serious drawback of large changes in the daily and seasonal activity patterns of the birds and so is of rather limited value.

On Castle Rock, burrows of all four of these species were very much in evidence, but our visits to this colony were limited to only two hours on 24 July and five hours on 9 August. The value of the second visit was severely diminished as all chicks of Ancient Murrelets and many chicks of other species had fledged by that time. Breeding populations were estimated here by counting the burrows in sample areas and projecting these counts to areas of similar habitat. No permanent sample plots were established because of limited time.

On Peninsula and Hall Islands, Ancient Murrelet populations were estimated by counting feeding and rafting groups offshore either coinciding with the arrival at the colony for egg-laying (Hall Island) or just before dark during late incubation (Peninsula Island).

4. Diurnal burrowers and/or crevice nesters (Pigeon Guillemot, Parakeet Auklet, Crested Auklet, Horned and Tufted Puffins)

Generally, these alcids were censused by counting the birds seen during the Zodiac surveys, either on the colonies, on adjacent waters or both. The accuracy of such a technique is questionable for correction factors to compensate for the varying activity patterns of these birds must be applied to arrive at a reasonable population estimate. The specific techniques applied to each of these species are discussed in the following section.

Results and Discussion

Except for the Horned Puffin and Crested Auklet concentrations at its southern end and the Black-legged Kittiwakes in the Cape Thompson region, neither Big Koniuji nor Little Koniuji Islands harbored extensive seabird populations. Red fox were present on both of these islands and are presumed to be a major factor limiting the breeding populations of seabirds there. Those birds that were present nested either deep in talus or on cliff faces inaccessible to the foxes. The fox-free offshore islets, on the other hand, were considerably more important to nesting seabirds.

At Koniuji Head, the island's southeastern tip, large populations of Crested Auklets and Horned Puffins nested in the talus. The Koniuji Strait colony is composed exclusively of Horned Puffins, the Yukon Harbor colony exclusively of Crested Auklets*, and the Granite Cove colony of both species. Staging areas for Crested Auklets in these two colonies are spatially very distinct, each population staging in the body of water for which the colony is named, and there appears to be no mixing of the Crested Auklets overland from one colony to another. Therefore, although these groups are nearly contiguous, they are treated herein as three separate colonies (Figure 5). Population estimates are presented in Tables 3 and 4. Table 5 outlines the habitat at each colony.

Pigeon Guillemot: The most evenly distributed seabird throughout the Koniuji Group was the Pigeon Guillemot. Hardly a section of coastline existed that did not provide the broken cliffs or beach rubble that this bird prefers for its nest sites, and birds were consistently seen roosting on coastal rocks or rafting in small groups just offshore even in sections devoid of other seabirds.

Pigeon Guillemots are best censused early in the morning before egg-laying, when pairs are displaying on the sea (Manuwal et al., 1975) Unfortunately, this procedure was not always possible and population estimates had to be based on numbers of individuals observed on the rocks and waters adjacent to the nesting areas at other times of the day and during other phases of the breeding cycle. The results of hourly counts made off Hall Island on 2 July, during the incubation period, reveal a maximum number present in the morning and early afternoon, dropping off sharply by mid-afternoon (Figure 6). No information was obtained on diurnal cycles prevailing during the nestling period, which was when Little Koniuji and the western coastline of Big Koniuji were surveyed.

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* The Yukon Harbor Colony is considered mono-specific even though there are Horned Puffins nesting in moderate numbers in the cliffs above the talus. These puffins are considered part of the Koniuji Strait colony because their access to these cliffs is via Koniuji Strait, not Yukon Harbor.

Murie (1959) noted an evenly distributed nesting pattern for guillemots along the Alaska Peninsula and the Aleutian Islands and usually found them in small groups. The largest aggregation he observed was a loose band of 40 west of Atka. Our observations in the Koniuji Group found small groups to be the rule, although several large flocks were seen in the vicinity of Yukon Harbor (Table 6) At least two of these aggregations were feeding flocks; on 2 July the birds were feeding along with 59 Horned Puffins, 54 Tufted Puffins, four cormorants, 7000 Crested Auklets, and one Minke Whale; and on 7 May they were feeding with 5000 Crested Auklets. No large groupings of Pigeon Guillemots were observed after the eggs hatched.

Parakeet Auklet: Like the Pigeon Guillemot, the Parakeet Auklet was quite uniformly distributed throughout the Koniuji Group, although it was sometimes found in high concentrations (such as on Castle Rock) and pairs would frequently nest side by side in suitable beach talus.

Estimating the breeding population of Parakeet Auklets was complicated by the large number of non-breeders immediately offshore from the nesting areas. Of 38 birds collected between 10 July and 15 August, 44.7% were non-breeders. In addition, we observed a marked daily cycle in number of birds present in the vicinity of the colonies. Counts on 02 July, during late incubation, were highest during mid-day (Figure 7). Counts at other times would substantially underestimate the size of the population.

Crested Auklet: Highly colonial, the Crested Auklet was observed nesting only in four localities; Castle Rock, Cape Thompson, Yukon Harbor and Granite Cove (Figure 4). These birds were never seen singly and would gather in immense tight rafts on staging areas adjacent to the colonies in the mornings and evenings. Estimates of the number of birds in these colonies are based on the maximum number of birds counted in staging aggregations.

Cassin's Auklet: Only one Cassin's Auklet was seen during the entire 1976 field season. This bird was 20 m from shore in Northwest Harbor, Little Koniuji Island, on 31 July. However, the strongly nocturnal breeding behavior and pelagic foraging habits of this species enable it to be very abundant yet remain undetected in the locality of a nesting colony in the daytime. Such was very much the case at Castle Rock. There was no evidence whatsoever of Cassin's Auklets during our coastal survey on 26 June and it was not until we actually went ashore on 24 July that evidence of this bird was found. During this visit and a subsequent visit on 09 August, the density of Cassin's Auklet burrows were estimated to be as high as $4/m^2$ in some areas indicating a total population of 23,000 pairs.

Cassin's Auklets probably nested on Hall Island as well, but in much lower numbers. Although no burrows were ever found, on two occasions Glaucous-winged Gull pellets were found containing remains of this species.

Least Auklet: This auklet is believed to be present in the area in very low numbers. Bob Day reported seeing one off Castle Rock on 26 June, and the wing of a freshly-killed Least Auklet was found in an eagle aerie on 30 August near Koniuji Strait.

Ancient Murrelet: Ancient Murrelets were present at only three locations, but in each locality the numbers of breeding birds were quite high. They were frequently encountered in feeding groups of 5-15 birds in Yukon Straits and between Murre Rocks and Hall Island during June and the first half of July. A large raft of about 2000 birds was seen off Hall Island at 1220 on 07 June, and another of about 1000 birds was seen on 24 July between Peninsula Island and Big Koniuji at 1700 hours. This raft grew to 2500 birds by 2055 hours.

Tufted Puffin: All of the outer islets had moderate to large populations of Tufted Puffins, but the species was distributed somewhat sporadically and in low numbers along the coasts of Big and Little Koniuji Islands. Tufted Puffins are quite vulnerable to predation by red foxes, thus, they are confined to places where their burrows are inaccessible to such predators.

Wehle (1976) in his work with Tufted Puffins on Buldir Island found these birds to have considerable variance in their attendance at the colony, with peak numbers occurring during the hour preceeding sunset for all phases of the breeding cycle. He also found the activity to be cyclic, with peaks occurring every four to five days. However, our hourly counts of Tufted Puffins rafting within 300 m of the Hall Island colony during late incubation, indicated that highest numbers were present from about 1700 hours until mid-afternoon, at which time numbers steadily declined (Figure 8). Wehle was measuring activity at the colony itself while this study was measuring fluctuations in the numbers of birds adjacent to the colony. Both factors must be taken into account when censusing this species.

Horned Puffin: Like the Tufted Puffin, Horned Puffins were scattered throughout Big and Little Koniuji Islands. However, Horned Puffins, being crevice nesters, were inaccessible to foxes and thus were able to maintain a very large colony in talus on the southeastern tip of Big Koniuji. At colonies on the surrounding islets where the two puffin species occurred together, the Tufted Puffin generally outnumbered the Horned Puffin three to one. But when the total populations of the two species in the Koniuji Group are considered, the Horned Puffin is 29% more abundant.

Sealy (1973a) found the peak attendance of Horned Puffins at the colony to be in the afternoon whereas Wehle (1976) found colony attendance to peak in the mid-morning with a lesser peak in the afternoon. The hourly counts off Hall Island during the latter part of egg-laying revealed a peak in numbers at mid-day (Figure 9). Because these birds are inshore feeders (see Feeding Ecology), such a count is probabaly of feeding birds and may not be correlated with the breeding activities of the adjacent colony. Nevertheless, it must be taken into consideration when doing offshore census work.

Estimating the numbers of Horned Puffins at the Koniuji Strait colony was very difficult, even though the colony was visited several times on foot. The birds here are nesting deep within large talus and many birds may use the same entrance to gain access to the labrynth beneath, so a count of nests in sample plots was not possible. Population estimates were made by counting the number of birds present on discrete sections of talus during periods of peak activity and extrapolating this count to the entire colony. The estimate could well be low for I was never present during the mornings, when Wehle found colony attendance to be at its highest.

Thick-billed and Common Murres: Murres were found only in a mixed colony on the south side of Castle Rock where Common Murres out-numbered Thick-bills by about ten to one. No Thick-billed Murres were distinguished on our first visit on 26 June, but on 09 August, with a total count of 706 birds on the ledges, 38% of these were Thick-billed. This species tended to be closer to the inside of the ledges than Common Murres, so they may have been obscured by the more abundant Common Murres in the earlier count. In colonies studied by Tuck (1960) on the Atlantic coast, Thick-billed Murres arrived later and nested later than did Common Murres which would explain a higher proportion of Thick-billed Murres at the end of a breeding season. Swartz (1966) however, did not find any difference between the nesting chronologies of the two species at Cape Thompson. The actual proportions of the Thick-billed to Common Murres on Castle Rock as well as their relative chronologies must be verified by further investigations.

Leach's and Fork-tailed Storm Petrels: Neither storm petrel was abundant in the Koniuji Group except on Castle Rock. No burrows were found on Hall Island, but their presence was verified by remains in gull pellets and by birds coming ashore and calling in moderate numbers at night. A single Leach's Petrel was heard at Yukon Harbor base camp at 2400 hours on 05 August. It is quite possible that both species nest in moderate to low numbers on offshore islets although no evidence of this was found.

Black-legged Kittiwake: Black-legged Kittiwakes were concentrated at the northern end of Big Koniuji Island in the Cape Thompson and Castle Rock colonies, which together had 13,700 nesting pairs. The only other colony in the area was one of 155 pairs on the north side of Hall Island. Loafing and feeding birds were seen in low numbers throughout the Koniuji Group.

Glaucous-winged Gull: The largest colony of Glaucous-winged Gulls in the Koniuji Group, was 775 nesting pairs on Hall Island. Birds were often seen roosting on offshore rocks throughout the area (Figure 10).

Red-faced, Pelagic and Double-crested Cormorants: Cormorant numbers were estimated from direct counts of roosting individuals and nests. Red-faced and Pelagic Cormorants were about equally abundant and together were about seven times as abundant as the Double-crested Cormorant. The main roosting areas are shown in Figure 10.

Black Oystercatcher: Oystercatchers were often encountered in groups of two to nine individuals on the intertidal rocks. The largest group observed was one of 19 birds on 30 August in Koniuji Straits.

Bald Eagle and Peregrine Falcon: In the areas censused, there were 12 known and 7 suspected aeries of Bald Eagles (Figure 11). At each known aerie there were two adults with one or two immatures, indicating the total population could be in excess of 70 birds.

Three Peregrine Falcon aeries were probably active although we located only one.

BREEDING BIOLOGY

Methods

Data on nest site selection, breeding chronology, and productivity of marine birds were collected in conjunction with censuses of the breeding population. Variations in nesting habitat were examined by measuring the slope, substrate, and relationships of the nest's location to predators and to vegetative cover. The breeding chronology of each species was determined in the outlying areas by examining nests for eggs or chicks and noting their stage of development.

The most intensive studies were conducted on Hall Island and at the Koniuji Strait Colony (Figure 12). Hall Island had a mixed assemblage of breeding birds, and here Tufted and Horned Puffins, Pigeon Guillemots, Parakeet Auklets, Black Oystercatchers, Glaucous-winged Gulls, and Black-legged Kittiwakes were studied while only Horned Puffins were studied at the Koniuji Strait Colony.

Most nests had eggs when they were first located, so most of the egg-laying dates are extrapolations using incubation periods observed elsewhere by other workers. Once an egg was discovered, its length and width (Table 7) were measured with calipers and its weight taken using a plastic bag and 100g Pesola scale (Figure 7). Nests were not examined again until the expected hatching time approached. Then, when possible, they were checked daily to determine exact hatching date(s).

The growth of chicks was monitored at intervals averaging three days, but this period varied with the weather; severe stroms often making it impossible to travel to the island. Chick weights were taken using a 100g Pesola scale followed in succession by 500g and 1,000g scales whenever necessary. Exposed culmen, diagonal tarsus, and wing cord measurements were taken with dividers and a ruler (Figure 13). The problem of differentiation between Pigeon Guillemot siblings was overcome by placing a piece of masking tape around the tarsus of one of the chicks. The tape was removed prior to fledging.

The small colony of kittiwakes on Hall Island was inaccessible, although an observer could reach a good vantage point overlooking the colony. Because our time was limited, and incubating or breeding birds concealed their eggs and young, we attempted to obtain counts of clutch or brood size by flushing adults from their nests and then photographing the nesting area. Because of the lack of clarity in the photographs and because not all of the kittiwakes left their nests at the same time, precise data were not obtained.

Results and Discussion

A chronology of breeding events was obtained for 15 species (Figure 14). Details for each species are discussed in the following accounts.

Horned Puffin

Nest site selection and the pre-egg stage: Both Tufted and Horned Puffins are reported to arrive at the vicinity of the nesting colonies at approximately the same time (Swartz, 1966; Sealy, 1973a; Wehle, 1976). This was not found to be the case at Big Koniuji. When the Yukon Harbor area was visited by the field camp construction crew on 6-7 May, no Horned Puffins were present, although Tufted Puffins were seen in low numbers near Hall Island. However, by the time the field team arrived on 26 May, Horned Puffins were present in moderate rafts (20-60 birds) in the waters off Hall Island, and by 02 June, they were seen flying to the rock ledges on Hall Island. The first copulation was observed on 07 June.

The Koniuji Strait colony was surveyed by foot on 31 May, by Zodiac on 02 June, and again by foot on 16 June*, and at none of these times were any Horned Puffin observed in the waters of Koniuji Strait or at the colony. The area was not visited again until 04 July, and at this time 5000 Horned Puffins were on the waters of Koniuji Strait and many more on the talus of the colony. Although the exact arrival date to the Koniuji Strait colony was not determined, I believe at least some of them arrived in the general area on 15 June, for on this day a marked increase in the numbers of Horned Puffins in Yukon Harbor was observed.

Nest site selection throughout the Koniuji Group was almost exclusively associated with vertical or horizontal crevices in sea cliffs, beach, boulders, or inland talus. At the Koniuji Strait colony, talus that was completely devoid of vegetation seemed to be preferred. All habitat of this type above 500 feet elevation was occupied by large numbers of birds. They nested to a lesser degree in adjacent vegetated talus and in a few cases dug through a thin surface layer of sod and vegetation to reach the talus beneath.

Little exposed talus was available on Castle Rock and Horned Puffins there nested in heavily-vegetated talus. On the north side, a basin of large boulders provided openings which permitted puffins to enter the talus without burrowing. On the south side, rock talus was smaller and uniformly covered with a surface layer of sod through which the birds burrowed. As the slope lessened near the top and soil became thicker, Tufted Puffin burrows began to appear along with the Horned Puffin. Further up where it flattened even more, puffins were replaced by Cassin's Auklets (Figure 15). Horned Puffins on Castle Rock were also found nesting in burrows where talus did not occur. Only on Kodiak Island and Chamisso Island (Bretherton, 1896 and Grinnell, 1900 in Sealy, 1973a) has the Horned Puffin been found to dig its own burrow, and on both of these islands breeding Tufted Puffins were scarce.

In the Granite Cove colony, Horned Puffins shared the talus with Crested Auklets. They are probably dividing up this talus according to size, the Horned Puffin being larger and thus requiring larger spaces between the rocks (see the discussion on Crested Auklets).

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* The actual colony itself was not covered by foot on this date but a vantage point was reached from which the nesting talus could be seen.

The egg stage: No nests were found prior to egg-laying in either the Hall Island or the Koniuji Strait colonies of Horned Puffins. However, the hatching dates are known for nine chicks on Hall Island and ten chicks on Koniuji Strait to within two days. Taking these hatching dates and subtracting the 41-day incubation period for Horned Puffin (Sealy 1973a:112), the laying dates for these two colonies can be estimated (Table 8). On 11 July a bird from an unknown nesting locality was collected in Yukon Harbor with a fully-shelled egg in the oviduct which would extend the estimated laying period for Koniuji Strait another week, and that for Hall Island nearly two weeks.

The laying dates coincided (peaking 23 and 25 June respectively) for both the Hall Island and the Koniuji Straits colonies even though the apparent arrival at each colony varied by nearly two weeks. Although birds were not seen on the Koniuji Strait colony until after 16 June and not even observed on the water before 15 June, egglaying began by 18 June. Swartz (1966) found the Horned Puffins at Cape Thompson to arrive about 20 days before the first eggs appeared in 1960, and also that they appeared to occupy the ledges soon after arrival. Sealy (1973a) found the Horned Puffins on St. Lawrence Island to arrive 26 days before the egg-laying began in 1967. Wehle (1976) found Horned Puffins to reach their maximum numbers at the colonies on Buldir Island at about the same time that egg-laying began. He also found colony attendance before that date to undergo considerable fluctuation and Swartz (1966:652) reports that "In England occupation of the nesting area by Common Puffins, Fratercula arctica (Linnaeus), is frequently preceeded by alternate periods of presence and absence of the birds on the water near the nesting site." Although Swartz did not observe a similar pattern with the Horned Puffins at Cape Thompson, such a pattern may well have occurred infrequently and birds could have landed at the colony and departed without being detected.

The chick stage: Hatching took place in both colonies between 28 July and 14 August (Figure 16). Only two hatching dates are known exactly. The others were estimated from the state of development of the chicks when found.

A fairly constant rate of growth was shown by the nine chicks monitored in both colonies (Figure 17).

None of the chicks we were monitoring had fledged by the time we left on 03 September. Using the nestling period of 38 days given by Sealy (1973), the fledging period probably extended from 04-27 September. Comparison of the body weights and measurements of chicks at hatching and at 29 days with those obtained by Sealy on St. Lawrence Island in 1967 suggest that growth of chicks in the two study areas is quite similar, although the small sample sizes limit the accuracy of the comparison (Table 9).

Occurrence of immatures: On only three occasions were immature birds seen anywhere in the vicinity of either colony. On 03 August two immature birds were seen flying from a cliff containing nesting puffins on Hall Island, and on 23 August one was seen flying above the Koniuji Strait talus.

Production: The fates of the nests of the Hall Island and Koniuji Strait colonies are considered seperately (Table 10) because the differences between the two colonies may have some effect on their production. The Hall Island birds were in cliff face crevices in close proximity to other nesting seabirds and free from mammalian predators except for an occasional river otter. Those on Koniuji Strait were in a single species colony in talus at 600-1000 feet elevation and subject to predation by red foxes.

Assuming those chicks that were still being monitored by September to have later fledged and assuming the observed chick mortality rates to apply to the chicks that were unable to be reached, the following production estimates for the two colonies can be determined:

Hall Island Colony	-83.4%
Koniuji Strait Colony	-72.0%

The Koniuji Strait colony, as judged by this production estimate, is doing quite well in spite of the predation by foxes, especially when it is taken into consideration that many of the nests that were monitored, being accessible to man, were also accessible to foxes; while the majority of the nests in the colony were not accessible to either.

Tufted Puffin

Nest site selection and the pre-egg stage: Tufted Puffins were present in the vicinity of Hall Island on 07 May, but in low numbers. By the time the field team arrived on 26 May, birds were present in their full numbers and landing on the slopes and ledges of their breeding areas. Copulation was first observed on 31 May.

Almost all burrows were of two types: those right on the cliff edge and those in steep vegetated slopes (Figure 18). As with Common Puffins (Nettleship, 1972) it appeared to be important for the Tufted Puffins to be able to enter and depart from the burrow with a minimum amount of time on land where they are vulnerable to predation and klepto-parasitism. Less time was necessary for entering burrows on steepest slopes and slopes of less than 20° were not used for nesting.

The desertion rate for birds nesting in the two types of habitat was markedly different. On Hall Island 40 cliff-edge nests and 12 slope nests were located during the egg stage. When these burrows were examined again near hatching, 66% of the slope nesters but only 20% of the cliff-edge nesters had deserted. A possible explantation of this difference is that the cliff-edge birds had better warning of our approach and would almost always be absent from the burrows when they were examined, whereas the slope nesters were often found in their burrows.

The egg stage: Although no burrows were located prior to egg-laying, hatching dates were obtained to within a day for eleven chicks and to within two days for eight chicks. Using Sealy's estimation of a 45-day incubation period for Tufted Puffin (Sealy, 1972), the laying dates were calculated to range from 25 May to 13 June with 50% laid by 03 June.

The chick stage: Hatching took place on Hall Island between 09 and 26 July, with 50% of the chicks hatched by 15 July (Figure 19). When not actually observed, hatching dates were estimated by the developmental stage of the chicks when first found. Hatching dates were later on Peninsula Island. Of eight burrows examined on 24 July half contained eggs still unhatched, only one of which was pipped.

The growth of 15 chicks monitored throughout the nestling period is illustrated in Figure 20. A mean fledgling period of 45 days was derived from the known fledgling periods of four chicks. The weights, wing, and culmen lengths of these four birds, just prior to departure from the nest show them to have been between 63-78% of the size of the adult except for the tarsus which appeared to be fully grown (Table 11). The chick mortality rate (No. of chicks died/total no. of chicks) was 16%. One of the chicks was found trampled in its runway when it was one day old. The other two left the nest early, one for unknown reasons and the other apparently escaping a burrow subject to standing water (See Table 12).

Production: Assuming the chicks surviving to 02 September eventually fledged (which is quite likely as all five of the remaining chicks were very close to fledging) and assuming the 16.7% chick mortality in our sample applied to other chicks, the fledging success of this population is estimated to be 52.4% (No. chicks fledged/no. eggs laid).

Parakeet Auklet

Nest site selection: No Parakeet Auklets were seen in the area on 06-07 May when the camp was set up in Yukon Harbor, but by the arrival of the field team on 29 May the birds were commonly seen in rafts just offshore and landing on the ledges and boulders of the colonies. The first observed copulation was on 05 June, but nests proved difficult to locate and no laying dates were obtained.

By far the most frequently chosen nest sites were in the cobbled beaches, and on Hall Island the garbled chattering of these birds could be heard deep within the beach boulders and talus at the head of every small cove. They were most abundant where larger boulders protruded from the smaller cobbles; probably this arrangement permitted the birds to enter deeper into the cobbles. In one place where the birds seemed particularly close to the surface, I dug down .7 m into the talus to a single cold egg, which proved to be infertile.

Some cliff-face cracks were used as well, and on Castle Rock these auklets nested in dirt burrows on rather heavily-vegetated slopes along with Cassin's Auklets and Tufted Puffins. To what extent they nested in burrows is uncertain, but probably many did, for the beach talus on Castle Rock was not sufficiently extensive to accommodate the large numbers of birds seen offshore.

Breeding chronology and the chick stage: Hatching dates of chicks were determined indirectly on Hall Island from a variety of observations. On 10 July, a 76 g chick was found in beach talus and on 16 July a 113 g chick was found in talus between two large boulders. On 16 July chicks were first heard in the talus. Thus the hatching period probably extended from about 01 to 15 July. Assuming an incubation period of 35 days (Sealy, 1973b), egg-laying probably took place between 28 May and 14 June and fledging between 06 and 20 August. These estimates may be a bit late for on 06 August one of the chicks being monitored had only a slight trace of down along its flanks and was very close to fledging. Another chick had probably fledged by that date as it had only a trace of down when last visited on 03 August, and had already begun some of the weight loss (Figure 21) characteristic of alcids just prior to fledging (Sealy, 1976). During a census around Hall Island at 1100 hours on 15 August, only 12 birds were seen; and most, if not all, of these were still attending chicks (verified by the full sub-lingual pouches of all six birds collected at this time). After that date only an occasional Parakeet Auklet was seen.

Crested Auklet

Nest site selection and the pre-egg stage: Crested Auklets had arrived in moderate numbers at Yukon Harbor by 06 May, when 4000 birds were seen displaying on the water; however, they did not fly up to the nesting talus. By the time the field team arrived on 26 May, the birds were in full numbers and were landing at the colony.

Talus was the universal choice of Crested Auklets nesting in the Koniuji Group. The only major difference between the four localities was the distance either horizontally or vertically from water. Birds at Cape Thompson used cavities between large beach boulders just above high tide line and extended their activities up the steep talus gullies no more than 130 feet. The birds on Castle Rock used a similar area of steep talus on the rock's Northeast side but this colony was never investigated on foot. The Yukon Harbor colony faces north, is backed by 500 foot cliffs, and is one of the last areas on Big Koniuji to lose its snow. Birds are concentrated here in the more exposed talus, but a few use the marginal vegetated talus.

The Granite Cove colony nested in isolated patches of exposed talus beginning at 150 feet and extending up to 700 feet. They seem to prefer the lower talus at the bases of cliffs, while Horned Puffins tended to be more abundant in the upper gully talus. Horned Puffins nested near to the surface of the talus while Crested Auklets nested deeper within it. As the Horned Puffin averages 31% longer and 111% heavier than the Crested Auklet, segregation of the talus between the two different-sized species is probably accomplished by each species seeking different-sized crevices within the talus. Bedard found segregation by boulder size for Least and Crested Auklets on St. Lawrence Island (in Sealy, 1974).

Breeding chronology: One aspect common to all colonies was the inaccessibility of auklet nests. This situation was caused in part by the presence of red foxes on Big Koniuji which force the auklets to nest out of reach. The result of many hours' searching throughout the summer yielded only one nest, on 05 August, located two feet below the surface of the talus containing a nearly-fledged chick. Consquently, no eggs were found and the chronology of the breeding cycle was obtained by indirect means.

A bird was collected on Yukon Harbor on 06 June with a post-ovulatory follicle 12.5mm in diameter, indicating that an egg had been laid within the last day. On the following day many copulations among the birds rafting on Yukon Harbor were observed. These observations place the egg-laying around 06-10 June. Applying 36-38 day incubation and 34-day fledgling periods for this species (Sealy, 1968), hatching must have occurred between 12-17 July and fledging between 15-20 August. In fact, the first fledglings were seen on Yukon Harbor on 15 August. Their numbers steadily increased while the numbers of adults decreased so that by 29 August most of the 400-500 Crested Auklets on Yukon Harbor were fledglings. Their behavior was very much like that of the adults with tight flocks flying closely above the water and swarming into the air in spirals. There were less than 100 birds on Yukon Harbor when we left on 03 September. Two fledglings were collected, and their body measurements indicate that chicks of this species fledge at nearly the size of adults in measurements other than weight (Table 13).

Cassin's Auklet

Nest site selection: On Castle Rock, Cassin's Auklets nested along the rock's more level crest, and on its west end nesting extended down the 50¼ gullies heavily vegetated with Elymus, Angelica, and Rumex. Nesting also occurred along the edges and slopes above the cliffs. The vegetation was almost completely trampled down in the areas of high burrow density. Burrows were in dirt, usually extending back about 1-2 m, and had entrances 10-15 cm wide. In areas of high density, a burrow often had several entrances and different burrows often were inter-connected, forming a maze. This observation differs with that of Chase-Littlejohn on Sanak Island (Bendire, 1895) where burrows never intersected.

Drainage seemed to be an important consideration in nest site selection. From my field notes 09 August:

> "The entire western slope was also trampled down by auklets between the steep cliffs and the level umbel-covered plateau. There were a few burrows in the heavily-vegetated level area but not many and only along its margin. One such burrow (with a chick) had 1.5 cm of filthy standing water in it which may explain why they don't use this area. The shallower burrows being less-vulnerable to poor drainage."

Manuwal (1974) found 51% of the Cassin's Auklets on the Farallons nesting in rock crevices, but no nests of this type were found on Castle Rock.

Breeding chronology: The breeding season of the Cassin's Auklet on Castle Rock appears to be very spread out. On 24 July, eight inhabitated burrows were examined and contained young in all stages of development from an egg to a nearly fledged chick (205g). On 09 August all but one of the eight chicks found were very close to fledging and up to 75% of the burrows were empty, indicating that young had already fledged. Using the incubation period of 37.8 days and the nestling period of 41 days found by Manuwal (1974), the egg-laying period was estimated to extend from 08 May to 18 June, the hatching period from 14 June to 26 July, and the fledging period from 24 July to 05 September.

Ancient Murrelet

Breeding chronology: The first observation of Ancient Murrelets was that of a single bird in Yukon Harbor on 03 June. On 07 June a flock of more than 2000 birds was seen rafting between Hall Island and Murre Rocks, and thereafter they were seen in moderate numbers until the second week of July, after which they almost disappeared from the area.

On Hall Island seven nests were located on 17 June. All of these nests had two eggs by this time which meant, because of the sevenday interval between the laying of the first and second eggs (Sealy, 1975), that the egg-laying began in these nests no later than 10 June - only three days after the first sighting of large numbers of birds in the area. By 10 July three dead downy young were found in the Glaucous-winged Gull colony. The 35-day incubation period for this species (Sealy, 1972) would place the laying of the first egg in these nests no later than 28 May, six days before any birds were seen in the area. Sealy (1975) found this species to leave the colony during the period between the laying of the first and second egg so it is very probable that the "arrival" of Ancient Murrelets observed during the first week of June was actually their second one.

The chronology on Castle Rock may have been similar to that found on Hall Island for on 24 July all the burrows found on Castle Rock contained only egg-shell fragments. The schedule on Peninsula Island, however, was considerably later, for on the same day (24 July) two Ancient Murrelets were found incubating two eggs each, one set of which was starred. Three other burrows yielded fresh egg fragments. Also, at 2100 hours a raft of 2500 birds accumulated off of Peninsula Island, apparently waiting for darkness so they could approach the colony.

Nest site selection: All seven of the nests located on Hall Island were in dirt burrows. Some of these seemed unnecessarily large and probably were old Tufted Puffin burrows, but the rest were apparently excavated by the murrelets themselves. Both the vegetated 30-40¼ north slope of the island as well as the cliff-edge turf were utilized for nesting. On Castle Rock and Peninsula Island all of the nests found were shallow burrows in slopes of *Calmagrostis*. Approach runways often extended several feet through thickly-matted dead grass.

Production: All seven of the nests on Hall Island produced two eggs, and the outcome of these 14 eggs is shown in Table 14. It was not possible to obtain an estimate of chicks that successfully made it to sea, but the occurrence of dead chicks in the Glaucous-winged Gull colony attests to gull predation playing a role in the productivity of Ancient Murrelets on Hall Island. The entire population of Ancient Murrelets was vulnerable to predation during its residence at the Hall Island colony, adults appearing in 19.4% of the gull pellets analyzed (n=36). Bald Eagles on Hall Island and Murre Rocks were also preying heavily on the murrelets.

Pigeon Guillemot

Nest site selection and the pre-egg stage: On 07 May, Pigeon Guillemots were seen in Yukon Harbor but not on the rocks themselves, but by 27 May they were active on the cliff ledges and the offshore rocks. The first copulation was observed on 02 June.

During June and the first part of July, 17 nests were located on Hall Island and adjacent Murre Rocks. Nests were found in natural cavities in mixed dirt and rock often with heavy vegetation near the entrance, and exposed cracks protected by overhangs more than two meters above them but otherwise quite open. A single surface nest was a clump of Elymus and was already abandoned when found on 16 July. Nests probably also occured deep and unreachable in beach talus.

The egg stage: No nests were located prior to egg-laying, but the hatching dates of 13 chicks were obtained. Applying the incubation period of 32.0 days for the first egg and 29.8 days for the second egg (Drent, 1965), the egg-laying period is calculated to range between 02-18 June, with 50% of the eggs laid by 13 June. On 19 June, a nest was found with a single egg; on 08 July, it contained two eggs. Assuming a 3-day interval between the laying of the first and second egg (Drent 1965) the laying period is extended to 19-21 June. These eggs failed to hatch due to predation of one of the adults by a Bald Eagle

Two eggs were found in 93% of the nests on Hall Island and Murre Rocks. This compares to 57% on Mandarte Island (Drent, 1965), and 79.9% in Skagit County, Washington (Thorenson and Booth, 1958).

Of the 27 eggs laid, 55.6% hatched, which is in close agreement with the 53.9% hatching success found by Thorenson and Booth (1958). The causes of hatching failure are outlined in Table 15. The three eggs that rolled from the nests may be a result of experimental disturbance. Each of them had been handled by the observer and replaced in the nest only to be found one or two feet from the nest on the next visit. The substrate of the two nests involved was rough gravel and the surface was level, so it is unlikely that the eggs rolled out on their own accord. Thorenson and Booth (1958) suggested the possiblity of the birds' being able to distinguish a dead egg and ejecting it from the nest. Perhaps the birds can distinguish an egg that had been held by the field worker or that had not been placed back exactly as it had been found, and react to it as they would to an infertile egg.

The chick stage: The first chick was found on 10 July and by 15 July 50% of the eggs had hatched. The last egg hatched on 20 July. The chicks, once they were two or three days old, became quite adept at hiding in the recesses of their nest chambers, and for this reason only six chicks were monitored for their entire residence at the nest. The growth measured by weight (Figure 22) is quite comparable to that found by Drent (1965:141) on Mandarte Island in 1959-60 and by Thorenson and Booth (1958:20) in Washington in 1957, although the small sample from Hall Island indicates considerable irregularity during the later stages of growth.

Table 16 outlines the fate of the 15 chicks that hatched. The two chicks that died from exposure were in a cliff-face crevice exposed by a crack above. A particularly heavy storm (leaving 1.02 inches of rain) came when the chicks were one and three days old respectively, and they were found dead the following day, although still being incubated. A chick eaten by an avian predator was in an exposed cliff-face crack. It's nest mate was unharmed, and later fledged.

The first fledgling was seen on 10 August in a cove 1 mile north of Yukon Harbor and the first monitored chick to fledge did so by 12 August. The exact date of fledging for this bird could not be determined because six days had elapsed since the nest was last visited. Another chick fledged between 15-18 August. Apart from these two nests, which were in cliff-faced cracks and in which the presence or absence of a chick could readily be determined, no other fledging dates were obtained. However, the newly-fledged birds tended to remain in inshore waters and the frequency that these birds were observed in Yukon Harbor provided a general view of the fledging period. They were first seen on 15 August and peaked in numbers on 18 August, which would put the nestling period at about 34 days. This agrees with the 35-day nestling period (range 29-40 days) observed by Drent (1965). Extrapolating from the hatching dates using the 35-day nestling period places fledging from 02-28 August on Hall Island. One of the chicks was still present in the nest on 29 August, and a few adults were still seen carrying fish on 30 August which indicates that the nestling period for some of the birds extended into the beginning of September.

Occurrence of immatures: On only two occasions were first-year birds seen. The first was seen on 07 June flying in Yukon Straits, and the second was observed 17 June in the breeding colony on Hall Island.

Production: The number of chicks fledged was obtained by taking the known mortality rate (37.3%) and applying it to the seven chicks not located once they hatched (Table 17). As pointed out, Thorenson and Booth (1958) observed a hatching success in close agreement with that found in this study, but their observation of a 14% chick mortality is considerably lower than the 37.3% mortality observed here. I suspect that the mortality rate found here is higher than the true chick mortality rate because it is based only on the nests most accessible to predation and environmental hazards as well as to the observer.

Leach's and Fork-tailed Storm Petrels

Nest site selection: Both species of storm petrels were nesting in shallow burrows in the grassy slopes and flat areas of Castle Rock where Cassin's Auklets were not nesting. On the slopes they were associated with Ancient Murrelets. In a flat heavily-vegetated plateau on the island's west end, Cassin's Auklets were nesting along the edges, but apparently the threat of standing water in their burrows limited their distribution inward where storm petrels predominated. From the field notes of 09 August:

> "The more surface burrows of Leach's and Fork-tailed Petrels were in considerable abundance and were reached via wide tunnels through the umbel-*Elymus* cover with burrow entrances every two feet or so. Much like doors along hallways. The storm petrel burrows ran par allel to the main tunnel for 1-3 feet before terminating in a nest chamber, and none of them penetrated the surface humus layer."

Breeding chronology: Most authors agree that the Fork-tailed Petrel nests 4-8 weeks earlier than the Leach's Petrel (Willet in Bent, 1919: 140; Dement'ev, 1951:387; Harris, 1974:256). Cody (1973) suggests that asynchronous breeding season for the two species is a mechanism reducing interspecific competition. Our observations during the two visits to the Castle Rock island (24 July and 09 August) however, indicated that nesting occurred at about the same time for both (Table 18). Using our meagre data and the incubation and nestling periods determined by Harris (1974) the laying dates, hatching dates, and fledging dates of both species can be estimated. Because of the advanced season and the fact that most of the chicks of both species found on 09 August were very near fledging, the eggs found on 24 July were considered to be very near hatching. The two-month variation in the estimates of breeding chronologies of both storm petrels here indicates a very flexible breeding schedule.

Black-legged Kittiwake

Nest site selection: Granodiorite cliffs broken up into blocks and ledges were the basic component of all three colonies of Black-legged Kittiwakes in the Koniuji Group. Birds began nesting about three meters above high tide line, extended up the cliffs, usually to no more than 30 m. The upper terminus of the area used for nesting was usually, but not always, determined by the leveling off of the cliff. Another feature of the nesting areas was a very broken coastline with narrow cavelike fjords, the walls of which were used for nesting. Large offshore rocks, were also used for nesting as well as roosting.

The Hall Island colony was in a narrow cleft on the island's north side, and although some of the nests were less than two meters above high tide line, the colony was not severely damaged by high seas and storms. On 26 July, the day after a particularly violent storm with winds up to 50 knots from the north, and accompanied by 3-5 foot waves, only one nest was found to have fallen into the water, the main force of the storm apparently having been taken by the rock projecting in front of the colony.

Breeding chronology: Birds were present on the Hall Island colony when it was first discovered on 02 June although the first egg was not found until 16 June. Egg-laying continued until around 08 July, although for various reasons it was not possible to get exact dates for egg-laying or hatching. The principal obstacle was the extreme tenacity of the birds to their nests, for never were we able to get every bird off its nest and never were the birds gone for more than a few seconds.

On 27 June I was able to reach and examine individual nests at Cape Thompson. Nests on an adjacent but inaccessible cliff were examined by scaring the birds as best we could. The very different estimates obtained by the two methods (Table 19) indicate that birds with completed clutches are much more nest-tenacious than birds with no eggs or birds with only one egg. This conclusion is assuming that the actual distribution of clutch sizes at locations were in fact similar. Such equality is quite likely because these two nesting areas were not only segments of the same colony, but also of the same sub-colony.

Further complications in determining laying and hatching dates in the Hall Island colony were predation (presumably by Common Ravens) that peaked at hatching, the irregularity of the visits to the colony because of unstable weather, and the difficulty of distinguishing between an egg and a chick in a photograph. A general outline of the chronology of the Cape Thompson and Hall Island colonies could be determined however, using the nestling and incubation periods of 44 days and 28 days respectively, (Swartz, 1967:644-5). The chronology of the Cape Thompson colony is based on observations of chicks on 10 August. No chronology is presented for the Castle Rock colony. The apparent absence of chicks could mean one of three things: 1) that the chicks were still very young and could not be seen from the water; 2) that the Castle Rock colony succumbed to a natural disaster as did the Hall Island colony; or 3) that the chicks had already fledged, which was not unlikely because several fledglings were seen in the area.

Production: The Hall Island colony did not fledge any birds. Predation by Common Ravens was the apparent cause of this failure, most loss occuring at the time of hatching. A total of 134 eggs were laid in 109 nests, and of these only 9% were gone by 16 July when the eggs were beginning to hatch. During the period between 16-26 July, 56% of the eggs/chicks disappeared. There was still no indication of the cause of these losses and no evidence of any actual destruction of the colony; but on 28 July, fifteen nests were floating below the colony and five Common Ravens were seen in the immediate vicinity. All but five of the nests remaining on the cliff were empty and most of them were very near the bottom of the colony on ledges with low overhangs that would be difficult for a raven to approach. Even these gradually disappeared so that by 18 August there were no young or eggs remaining. The adults remained on the nests even after 03 September, although they slowly grew less tenacious.

The Cape Thompson colony appeared to have fared much better. When visited on 10 August, out of 150 nests; 75 (50%) were empty, 40 (26.7%) had one chick, and 35 (23.3%) had two chicks. Assuming these chicks to have fledged, which is reasonable as most of them were within 7-12 days of fledging at the time, we estimate that at least one chick fledged from 50% of the nests built on the colony and from Table 19 we can assume that over 85% of these nests originally contained eggs. Thus, 0.37 chicks were produced per nest built by adults.

Glaucous-winged Gull

Nest site selection and the pre-egg stage: No Glaucous-winged Gulls were observed on Hall Island by the crew setting up the field camp on 06 May, although a few were seen in the neighboring bays and on offshore rocks. When the island was visited on 02 June, most of the breeding population had arrived and apparently had established territories for the birds were scattered singly and in pairs throughout the nesting area. Although most of the nests at this time were little more than scrapes, by 09 June, many were quite developed and some already contained eggs.

On Hall and Herendeen Islands the areas chosen for nesting were the flatter sections, usually heavily-vegetated with mixed meadow species which provided 100% cover to the nest by the time the chicks hatched in early July. The nesting density of the Hall Island colony is estimated at $0.20/m^2$, but varied considerably. The most preferred area was in heavy vegetation just south of the island's crest, and the least preferred area was a patch of Elymus near the island's west end. There were no birds nesting in the low heath, presumably because it provided no cover. This was an important nesting requirement, for predation was a factor affecting the success of the gulls there. Bald Eagles, whose aerie was just at the colony's edge, and up to five Common Ravens were often seen cruising over the colony.

The small number of birds nesting on Castle Rock (30 pairs) was concentrated right on the rock's summit in an area of narrow vegetated terraces, while the 140 pairs on Peninsula Island apparently were confining their nesting activities to beach rubble just above the high tide line.

The egg stage: The first egg was laid on 04 June and 50% of the eggs on Hall Island had been laid by 11 June. The last egg was laid there around 20 June. The average clutch size was 2.4 (n=100).

As indicated by Table 20, the Hall Island colony had quite a high hatching success. Punctured eggs and egg fragments were often found at the gull roosting spots throughout the colony so many of the unexplained egg losses probably can be attributed to avian predation, much of which was by the gulls themselves; although direct evidence of this was observed in only four cases.

The chick stage and production: The first chicks were found on 07 July, some of which were over a day old by that time, and 50% of the eggs had hatched by 09 July. The last chick hatched on 18 July. Because the colony was not visited daily and every nest was not located each visit, the exact incubation period was determined for only one egg: 28 days.

Once hatched, the chicks proved incredibly adept at hiding themselves in the dense vegetation, and after a few unsuccessful days no further attempt was made to monitor chick growth. Consequently, there are no estimates of overall production because: 1) very few fledglings were seen either in the colony itself or in the surrounding area; and 2) while banding what chicks we could locate on 06 August, the bodies of 12 chicks were found. It is unknown what caused their death for all of them were quite intact, although some had been pecked at.

The first observation of fledglings was on 12 August when three were seen on loafing rocks with adults.

Red-faced, Pelagic, and Double-crested Cormorants

Nest site selection, breeding chronology and production: All three species of cormorants nested together on the same cliff, and although there appears to be considerable overlap in choice of habitat between Red-faced and Pelagic Cormorants. The Double-crested Cormorant, being a larger bird, showed a definite preference for wider platforms on the tops of rock columns, with space sufficient for only a single nest. In fact, the Double-crested Cormorant was never found in the immediate vicinity of other members of the same species, although they nested on ledges with Black-legged Kittiwakes. Red-faced and Pelagic Cormorants, on the other hand, were nearly always nesting on ledges in close proximity to other members of the same species. They too were occasionally found nesting amid kittiwakes. The Pelagic Cormorant seemed to have a preference for more inaccessible nest sites such as small caves, or the farthest in on a ledge. This preference may be a reflection of the slightly smaller size of the Pelagic Cormorant relative to that of the Red-faced Cormorant.

All three cormorants were seen in the Yukon Harbor area by the field camp construction crew on 06 May and by 28 May they were in the process of building nests on Yukon Head. No eggs were laid before 05 June, and after that date observation of the cormorant nests there (seven Red-faced, one Pelagic and one Double-crested) was cancelled because of the disturbance to the Peregrine Falcons nesting on an adjacent cliff. On 23 June, all nests but one of Red-faced and one of Double-crested were deserted. Each of the remaining nests had two eggs. Chicks of Double-crested Cormorants hatched about 03 July and of the Red-faced between 13-15 July. No other information was obtained, for by 02 August all of the chicks were found dead in their nests. This damage may have been caused by the Peregrine Falcons for it coincided with the fledging of the falcon chicks.

A similar fate was met by a colony containing 21 nests of Red-faced Cormorants, eight of Pelagic Cormorants and nine of Double-crested Cormorants, that was located on a cliff 1/2 mile south of Flying Eagle Harbor. Last visited on 25 June, this colony was completely vacated when visited again on 10 August.

Black Oystercatcher

Nest site selection: The nests of three pairs of Black Oystercatchers were located (Table 21). All three nest sites were devoid of vegetation and were in the immediate vicinity of extensive rocky intertidal areas. Two of the nests were directly below aeries of Bald Eagles.

Breeding chronology: All the nests had chicks when found so no direct observations of laying or hatching dates were made. The dates could be approximated by estimating the ages of the chicks from their coloration, plumage development, and body measurements (David Nysewander, pers. comm.), and then using the 27-28 day incubation period found for this species in Washington (Nysewander, 1977). Considerable variation is evident in the chronology of the three nests (Table 22), which may be a reflection of their seasonally-independent food source of intertidal mollusks (see Feeding Ecology).

Chick stage: Although two of the nests were only visited once, the nest on Hall Island was reasonably accessible and the growth of the chicks was measured on intervals of 1-3 days during the first part of July. Unfortunately, this nest was almost directly below the eagle aerie and all of the chicks were killed by these birds so growth data are imcomplete. It might be noted here that when the nest was first found on 16 July with three chicks, the fresh foot of another chick of approximately the same age was found in a talus gully 15 meters away leading to the eagle aerie. It is possible that this was from a fourth chick, although the occurrence of four chicks is very uncommon (Nysewander, pers. comm.).

Production: Only an approximate estimate of production by the three nests can be made as the available data are quite limited. Assuming each of the single chicks found at the Oystercatcher Rock and Castle Rock nests to have later fledged, which is not unlikely since they were already three weeks old when found, and assuming each of these clutches to have originally been three eggs, the production for the three nests found in the Koniuji Group is calculated to be 22.2% of eggs laid.

Bald Eagle

Seven aeries of Bald Eagles along the southeastern part of Big Koniuji were studied, mainly for evaluation of food habits, but some breeding information was also obtained as outlined in Table 23. The first aerie was found on 31 May and already had a chick, although it was less than one week old. Only one aerie was found during incubation. This was a single egg which failed to hatch and was abandoned by 14 June. Using the incubation period of 34-35 days (Bent, 1937), egg-laying for these Bald Eagles is estimated to have taken place between 20 April and 05 May.

Peregrine Falcon

A pair of Peregrine Falcons was active off the cliffs in the vicinity of the Yukon Head aerie on 06 May and when the nest was discovered on 01 June it contained four eggs. Because of the extreme sensitivity of the brooding parent this nest was not visited again until 13 June when three pink young were present, probably less than one week old. On 04 July, they were covered with a white down but no contour feathers had erupted. On 13 July, contour feathers were developing and the chicks were dark grey. By 02 August all three chicks had fledged.

FEEDING ECOLOGY

Methods

Birds were collected from the water between 6 June and 23 August 1976, with a shotgun. Most of the birds were collected in Yukon Harbor and the waters around Hall Island, although some Parakeet and Crested Auklets were collected off Castle Rock on 24 July. The stomachs and proventriculi, when containing any remains of food, were preserved in 60% alcohol. This method is not recommended because of the incomplete preservation of even small items and the build-up of a residue that is sometimes difficult to distinguish from some of the stomach contents. Body measurements from each collected bird were taken using the method employed on chicks (see Table 24).

Food items were sorted and identified in the laboratory using a low-powered microscope. Whenever possible, weights and lengths of the food items were recorded, but because of the poor preservation of the samples this was often impossible. However, total weight of the entire sample was almost always obtained, except when the stomach remains consisted only of such digestion-resistant items as squid beaks or fish otoliths, which are useful only in identification of food items; their weight having little to do with the food volume actually consumed. From the otoliths alone it was possible to approximate the lengths of the Ammodytes by referring to a collection of otoliths taken from fish of known size (J. Hall, pers. comm.). The overall length for crustaceans was taken from the tip of the rostrum to the tip of the telson, and for fish from the tip of the snout to the fork in the tail.

Food brought back to the chicks was collected whenever it was found in or near the nests and identified, weighed, and measured in the laboratory. Such a method does not supply information about the total weight of each bill load, but it does indicate the types of food brought back. Even this value may be subject to some bias because all of the samples obtained in this way were those that were unsuccessfully delivered to the chicks or undesirable to them for reasons unknown. Complete, presumably random, bill loads were obtained from the Horned Puffins by hiding in the nesting talus and grabbing at a bird when it landed. If timed accurately, this procedure would cause the homecoming bird to drop its entire bill load in the scramble to escape. These loads were then collected, preserved in 60% alcohol, and subjected to the laboratory analysis outlined earlier.

As pointed out by Ashmole and Ashmole (1967), to provide an adequate portrayal of the importance a particular prey species plays in the diet of a bird the following must be considered: 1) the numbers of the prey species for an indication of its abundance and the bird's ability in catching it; 2) the total weight of the prey species consumed for an estimation of the energy provided by that species; and 3) the frequency with which the prey species appears in the diet for information as to whether or not that species is a reliable food source. Therefore, whenever possible all three of these measurements are considered in the analysis of the food habits of the various seabirds.

All the estimates of foraging distance of the different species are based on: 1) a single pelagic transect made aboard the Nordic Prince by Dr. Pat Gould and myself on 24 July; 2) two aerial transects made on 16 July 1975, by Dave Cline, Nate Johnson, and Kent Wohl; and 3) general observations throughout the summer of 1976 made incidental to other activities.

Results and Discussion

Horned Puffin

Food Sources: The stomach contents of six adult Horned Puffins collected in the outer Yukon Harbor area and along Hall Island indicate a diet high in fish and moderate in invertebrates (Table 25). The two birds collected off Hall Island from compact feeding flocks of mixed species on 23 August contained the euphasiid Thysanoessa inermis, in their proventriculi, but three of the five present were in the esophagi of the fish and the remaining two are suspected of being disgorged by the fish as they were eaten by the puffins. These euphasuiids are not considered as food items of either bird.

The importance of fish in the diets of these Horned Puffins as based on the presence of otoliths may be biased, these food remains being much more resistant to decomposition than, say, a euphausiid carapace. The percent frequency of occurrence (number of stomachs containing a particular food) of fish and invertebrates found in this study is compared, in Table 26, with that found by other workers. Squid account for most of the invertebrates found in the stomachs at Buldir Island. This food source was not available to the Horned Puffins (or not utilized by them) at either Big Koniuji or Cape Thompson.

Between 11 and 28 August, bill loads were collected from 32 birds returning to feed their chicks at the Koniuji Strait colony (Table 27). Eighteen of these were complete loads with a mean weight of 13.8 grams and a range from 7 to 25.4 grams. No invertebrates were present in any of these loads, but on 11 August a regurgitation was found on a rock in the Koniuji Strait talus containing 39 T. inermis and one hyperiidea amphipod. It is unknown if this was meant for a chick, so it is not considered in the analysis.

The total numbers, total weight, and the percent frequency of occurrence of each species of fish in the bill loads are given in Table 28. The importance of A. hexapterus in the diet of chicks from the Koniuji Strait colony is obvious by all three methods of analysis. The relative importance of the two major prey species, A. hexapterus and M. villosus, appears to change considerably during the two and one-half week period in August that the food samples were taken (Figure 23). Sealy (1975) found that Ancient Murrelets of Langara Island also undergo a diet change (from plankton to fish) in the middle of their breeding season, and he believes that this switch reflects a change in the prey available to the birds. A similar mechanism may be acting on the Horned Puffins in the present study but the sample sizes are too small and irregular for any conclusive statements. Our data suggests the desirability of much further research.

The mean lengths and the ranges of lengths for each fish species brought in by the puffins indicate a selection for fish between 5.6 and 7.4 mm. There was no apparent increase in the size of the fish as the chicks grew older.

Foraging Distance: Most literature indicates prevalence of inshore feeding by Horned Puffins during the breeding season. At Forrester Island, Willett (in Sealy, 1973a) found Horned Puffins feeding closer to shore than the Tufted Puffins, and frequently saw them in small flocks inside the kelp patches. Sealy (1973a) found Horned Puffins to concentrate their feeding within one or two km from the colony at St. Lawrence Island; Wehle (1976) found that numbers of Horned Puffins observed within two km of the shore at Buldir were often much greater than those observed during most of the offshore transects.

Because the sightings of either Horned or Tufted Puffins during the aerial transects made on 16 June, 1975, were so low, these transects provide little statistical data for the offshore distribution of either bird. But it is interesting to note that only two Horned Puffins were seen in the waters more than five km south of the large Koniuji Strait colony in mid-afternoon, a time when many of the birds should have been away from the colony (Wehle, 1976:34). The transect made on 24 July aboard the Nordic Prince provided more substantial results and showed the Horned Puffin to be highly concentrated within two km of the nesting colony. The Tufted Puffin, although also present in higher numbers in the immediate vicinity of the colony, did not drop off in numbers so rapidly and its abundance relative to that of the Horned Puffin increased with the distance from shore (Figure 24). However, as pointed out by Wehle (1976:46): "Caution must be taken in interpreting these data due to many variables involved. Times of observation, weather, tides, stage of breeding period, and age and breeding status of individual birds all probably exert effects, to varying degrees, on the distributional pattern." And certainly one must be even more cautious in making interpretations from a single transect.

Other observations of Horned Puffins were made during the course of everyday work in nearshore waters of Koniuji Straits, Herendeen Straits, and to some extent, Yukon Straits (Figure 25). They were frequently seen, along with the less abundant Tufted Puffins in tight, mixed feeding flocks as well as in loose rafts and scattered groups.

Tufted Puffin

Food Source: A diet consisting mainly of euphausiids, shrimp, squid, and fish is indicated by our analysis of nine stomachs (Tables 29 and 30). Wehle (1976) points out the difficulty of determining just when fish and squid were ingested, when these prey are represented merely by squid beaks and otoliths, because the length of time such matter is retained in the stomach is unknown. It is possible that these items, especially the squid beaks which are particularly resistant to digestion and the muscular action of the stomach, were ingested during the preceeding winter. No fresh squid were ever found in the stomach or brought as food to the chicks.

The feeding of the chicks was not studied in depth, but on 28 and 30 July unidentified immature octopi (1.4 and 1.5g) were found in two different burrows. Another burrow yielded an .8g, 35mm fish, *Hemilepidotus hemilepidotus* on 15 July.

Foraging Distance: Observations made during the 24 July Nordic Prince transect indicated that Tufted Puffins foraged farther offshore than Horned Puffins (see the previous discussion under Horned Puffins). Wehle (1976:51) suggests that the Tufted Puffin at Buldir may have been concentrating their feeding efforts in deep oceanic waters off the island, and such may have been the case at Big Koniuji although it was not investigated.

Tufted Puffins were observed to be feeding in tight mixed feeding flocks with Horned Puffins in inshore waters, but usually in lower numbers. Further, there appears to be a difference of food items selected by the two different puffin species in these flocks. In one such feeding flock 300m south of Hall Island on 23 August, three Tufted Puffins and two Horned Puffins with fresh food samples in their proventriculi were collected. All three Tufted Puffins had been eating T. inermis immediately prior to being collected while both of the Horned Puffins had been eating only M. villosus. Two of the three Tufted Puffins had been eating fish earlier, but not immediately before being collected as the fish remains were in the stomachs, not the proventriculi, and were more digested than the euphausiids.

Parakeet Auklet

Food Source: Of the 43 Parakeet Auklets collected, only seven had any food in their stomachs. Euphausiids were prominent, mostly of the species T. inermis, although some samples were too decomposed for positive identification (Table 31). The importance of the polychaetes in the summer diet of these auklets is somewhat questionable as they are represented by the hard perignaths which were imbedded in the folds of the gizzard and could have been from polychaetes eaten long before. Bent (1919:18) reports the diet of Parakeet Auklets to consist "mainly of amphipods and other small crustaceans", and Dement'ev (1957) felt that planktonic copepods were the most important food. He also reports polychaetes to have been found in stomachs of Parakeet Auklets collected off the Chukot Peninsula.

The nine sub-lingual pouch samples showed a heavy reliance on T. inermis, but a small fish (about 10mm wide) was also found in one pouch along with euphausiids, which accounted for more than 75% of the contents (Table 32).

Foraging Distance: Although these auklets were frequently seen in small groups within one km of shore, most birds were probably not feeding there because only 16.3% of the birds collected had any food in their stomachs. Also, Nelson (in Bent, (1919:118) found Parakeet Auklets to be "invariably feeding some distance offshore and rarely in water less than 10 to 20 fathoms deep," and Dement'ev (1957:245) reports that the bird "feeds at sea." However, it should be pointed out that at least some of the Parakeet Auklets in the Koniuji area were feeding in more inshore situations for there were many observations of this species participating in the mixed flocks of seabirds foraging within 400m of shore.

Crested Auklets

Food Sources: The stomachs of only five of the Crested Auklets collected contained food. Contents were exclusively of euphausiids. Most, if not all, of these euphausiids were T. inermis, but what little food remained was always in the gizzard and often too decomposed for species identification. Five sub-lingual pouch samples were obtained, four in Yukon Harbor and one off Castle Rock, which were exclusively T. inermis.

Foraging Distance: The lack of freshly-consumed euphausiids in the stomachs or sub-lingual pouches of the birds collected in the inshore waters of Yukon Harbor or Castle Rock suggests that these birds were not feeding there but rather farther out. Observations were frequently made of small flocks of 20-40 birds feeding in the waters south and east of Hall Island and in Herendeen and Koniuji Straits. These flocks were often associated with other seabirds and occasionally Minke whales. Flocks of the same size were also seen on the waters to the south of Big Koniuji (Figure 26).

Crested Auklets, probably from the Cape Thompson colony, were seen in feeding flocks 3.5-7km out from the colony during the 24 July Nordic Prince transect.

Cassin's Auklet

Food sources: No food samples either as stomach contents or as food brought for the young were obtained from any Cassin's Auklets on Castle Rock. However, the nesting areas did have the pinkish fecal smears and the heavy odor suggestive of crustaceans. On the Farallon Islands, Manuwal (1974) found T. spinifera to play an important role in the diet of the chicks there. It is quite likely then that T. inermis, so prevalent in the diet of most of the other seabirds in the Koniuji area, is a principal component of the diet of the Cassin's Auklet on Castle Rock.

Foraging distance: Except for the single bird seen in inshore waters of Little Koniuji Island on 31 July, no Cassin's Auklets were observed. Little, then, can be said about their feeding areas except that they apparently are not in inshore waters. Cody (1973) found Cassin's Auklets to be feeding farther out than any of the other five species of alcids on the Olympic Peninsula and suggests that his estimate of a mean foraging distance of 12.4km for this species is an underestimate.

The aerial transects of 16 July, 1975, recorded a rather large concentration of "unidentified small alcids" 6 km north of Castle Rock and small to moderate numbers between 45-55 km to the southeast (Figure 27). It is quite possible that at least the outlying records were of Cassin's Auklets and possibly even the sighting 6 km away, although Cody reported no Cassin's Auklets feeding in this close to shore.

Ancient Murrelet

Food sources: Analysis of the stomachs and proventriculi of the seven Ancient Murrelets collected during the incubation period in the Hall Island vicinity revealed a diet almost exclusively of euphausiids (Table 33). Bones from an unidentified fish were found on only one occasion. All of the euphausiids were probably T. inermis, but some were too decomposed for positive identification.

Sealy (1975) noted a marked change in the diets of Ancient Murrelets during the breeding season at Langara Island with a shift in emphasis from T. spinifera earlier in the season to Ammodytes hexapterus as the season progressed. Such a dietary transition was not apparent in the birds examined at Big Koniuji for the euphausiid remained the dominant food species of the Ancient Murrelets there. However, as no birds were collected during the first half of the breeding season, i.e. until 21 June, our data are somewhat incomplete.

Foraging distance: Large feeding aggregations of Ancient Murrelets broken down into small units of 5-15 birds were frequently seen in the waters between Hall Island and Murre Rocks, in Yukon Straits, and occasionally between Hall Island and Koniuji Head (Figure 28 and Table 34). Sealy (1975:426) also noted small flocks (4-12 birds) within large aggregations in British Columbia and he found feeding to be concentrated from about 0600 hours to 1200 hours which corresponds to the times feeding flocks were observed in the vicinity of Hall Island.

However, Sealy found the Ancient Murrelet to be an offshore feeder, feeding at distances of up to 20 km from the nesting colonies in water greater than 50 km deep. He never found them feeding at the staging areas adjacent to the colonies. This is not the case with the birds nesting at Hass Island, as shown by observations of feeding flocks in inshore waters 60m deep at the very most, and by collections of feeding birds from these waters. Offshore transects were not conducted during the 1976 breeding season, so it is not known if murrelets also utilized waters farther offshore.

Pigeon Guillemot

Food sources: Three birds were collected on 08 June, during egg laying, and examination of their stomachs revealed a mixed diet of crustaceans, mollusks, and fish.

During four visits to a nest in an exposed crack, fish were found below the nest indicating unsuccessful deliveries. The identity, size and weight of these fish is given in Table 35. Because of the limited sample size and the fact that these fish came from the same nest, any general evaluation of foods used by guillemots remains for further study.

Foraging distance: Pigeon Guillemots were rarely seen more than 1 km from shore and they were the only bird, other than an occasional Horned Puffin, to consistently feed in the inner waters of Yukon Harbor. Further, they were rarely seen in any groups greater than one or two birds, although their occurrence in probable feeding groups of up to 663 birds prior to the hatching of the eggs was discussed earlier. Although Drent (1965) found the Pigeon Guillemots at Mandarte Island obtaining food for the young in shoal waters 4-5km from the colony, the birds at Hall Island foraged immediately offshore from the nests. Birds were very seldom seen traveling with fish in their bills more than a few hundred meters from the colony.

Leach's and Fork-tailed Storm Petrels

Food sources: On 09 August a food sample consisting of *Thysanoessa inermis* was collected at the entrance to a Leach's Petrel burrow in Castle Rock. Dement'ev (1957) states the food of both Leach's and Fork-tailed Petrels to consist of shrimp and other small crustaceans, and Bent (1919:134) supports this statement for Leach's Petrel, while he limits the food of the Fork-tailed Petrel to "soft, oily substances with perhaps a few minute particles of animal food."

Foraging distance: In a study of Leach's Petrel on the Atlantic, Wilbur (1969) determined the incubation shift to average three days. Such a long incubation shift is typical of birds feeding a considerable distance from the colony (Sealy, 1973a) as is nocturnal attendance at the breeding colony (Cody, 1973). No Leach's or Fork-tailed Petrels were ever seen on inshore waters nor were they seen on the offshore transect of the *Nordic Prince* on 24 July, but Fork-tailed Petrels were seen in large numbers 55-60km southeast of Castle Rock during the aerial transect on 16 July 1975, and it is quite possible that these birds were members of the Castle Rock colony (Figure 29).

Black-legged Kittiwakes

Food sources: Only one food sample from Black-legged Kittiwakes was obtained, that being a regurgitation consisting entirely of *T. inermis* collected from the base of the colony on Hall Island on 10 July. This may not be indicative of the feeding of this species for at Cape Thompson, Swartz (1966:669) found that fish dominated the diet of the Black-legged Kittiwake. He found no euphausiids among the invertebrates taken and only a very low number of decapods. Gabrielson and Lincoln (1959:457) also report fish as being a major part of their diet and describe Black-legged Kittiwakes as feeding by "congregating about schools of small fish which they take on the wing by expert flying and diving." Such feeding aggregations of up to 70 birds were frequently seen in the waters off Hall Island, in Koniuji Straits and in the bays throughout the Koniuji Group. Often these flocks would be mixed with puffins, cormorants, Parakeet Auklets, Glaucous-winged Gulls, and sometimes Minke whales, but the Black-legged Kittiwake or the Glaucous-winged Gull usually predominated.

Foraging distance: It is not known where the members of the large Cape Thompson or Castle Rock colonies foraged, for Kittiwakes were not observed in large numbers in either of the aerial transects. During the offshore transect on 24 July aboard the *Nordic Prince* however, 25 kittiwakes were encountered 3-6km from the Cape Thompson colony and most of these birds were flying in a direct path southeast towards Atkins Island, which suggests that the Cape Thompson kittiwakes could be feeding, in part, in the inshore waters of the northern part of Little Koniuji Island, 20km from the colony.

Glaucous-winged Gull

Food sources: Food pellets regurgitated by Glaucous-winged Gulls were collected at the Hall Island colony (Table 36). Birds or their eggs, and marine invertebrates (mainly intertidal) dominated pellet contents, each of the two groups being represented in 61.1% of the 36 pellets examined. The low value for fish (13.9%) probably does not accurately represent the proportion of fish consumed because small fish, being more digestible, may not be cast in pellets. All of the bird species eaten were probable residents of the Hall Island colony and all of them were nocturnal on the breeding colonies. During the nights that were spent on the island (18 June, 03 July, 15-20 July) the Glaucous-winged Gulls continued to have spurts of activity throughout the night, although much reduced from their daylight activity. They were active coincident to the arrival of the storm petrels and the Ancient Murrelets after dark and were probably preying on these nocturnal seabirds.

Fish occurred in a much higher proportion in food brought in and regurgitated for the chicks (Table 37), although three downy young Ancient Murrelets and one Glaucous-winged Gull chick from another nest were found on four occasions at gull nests and probably were brought there as food.

Foraging distance: Gulls were occasionally seen in tight, mixed-species, feeding flocks off Hall Island where they were probably feeding on swarms of small fish which in turn were feeding on localized blooms of euphausiids. They also frequented the intertidal areas, as verified by observation and the occurrence of intertidal organisms in their pellets, and occasionally were seen scavenging on the beaches. Very seldom were any gulls seen more than a few kilometers from shore.

Black Oystercatcher

Food sources: Food remains were noted at all three nest sites of Black Oystercatchers and collected at two of them. The results are outlined in Table 38 and show *Acmaea digitalis* to play by far the dominant role at two of the sites, and to share this dominance with *Katharina tunicata* at the third.

Foraging distance: As evidenced by its prey species and by the observations made of these birds, the Black Oystercatcher feeds exclusively in the intertidal zone.

Minke Whale

Because of the close association between the plankton-feeding Minke whale and the mixed feeding flocks of seabirds, some discussion of this whale is pertinent to a review of the feeding ecology of seabirds at Big Koniuji.

Minke whales were frequently seen feeding in the waters of Hall Island throughout the summer (Figure 30). The first one was observed on 09 June and the last on 18 August, with the peak of activity concentrated in the first two-thirds of July (Figure 31). They fed often in the vicinity of feeding flocks of seabirds. In fact, such feeding flocks may have used Minke whales as an indicator of food location, as groups of birds would sometimes land in the immediate area of a feeding whale. Only once was a Minke whale seen outside of the Hall Island area: on 16 August one was seen 200m off the southwest tip of Big Koniuji.

SUMMARY AND CONCLUSION

The objective of the colony census work was first, to determine the exact location of the colonies in the Koniuji Group, and second, to arrive at a reliable estimate of the numbers of birds at each location. The first part was accomplished to some extent, although about half of Little Koniuji remains to be surveyed. The second part however, was met only generally. Certainly in the case of the kittiwakes and cormorants, whose breeding populations were determined by actual counts of every nest, a reliable quantitative estimate was reached that could be used in identifying numerical changes and geographical shifts in these birds in later years.

With the other birds whose breeding populations had to be estimated by indirect methods, the reliability of the census results diminishes greatly. Although these results are of questionable value for comparative population studies done in future years, they do provide some measure of the general abundance of these birds, their distribution, and the relative importance of the different geographical areas of the Koniuji Group to each species of seabird.

Investigation of the breeding colonies revealed a wide variety of habitats being used, which extended from the beach cobbles just above high tide line to cliffs and talus more than 1000 feet above sea level. Between these extremes, the sea cliffs, vegetated slopes and more inland areas were used by the seabird for nesting in varying degrees.

The time span which these nesting habitats are used varies with the species and ranges from at least early April to mid-October, but is most concentrated between mid-May and early September, during which 85.5% of the breeding birds in the Koniuji Group complete their residence on land. The use of the waters immediately offshore of the colonies for staging and feeding areas by pre-breeding birds lengthens the most critical time into at least late-April, although further studies will have to be undertaken at the margins of the breeding season before the exact range of this use can be determined. Because of their tendency to gather in large aggregations during this pre-breeding stage, birds would be extremely vulnerable to oil pollution occurring at this time. The Pigeon Guillemot, which before had been considered a fairly solitary alcid and therefore not a species critically affected by oil pollution, was found by this study to congregate in large flocks during this pre-breeding stage as well as during incubation.

The principal causes of chick and egg mortality during 1976 can be attributed to environmental influences and predation, but it must be stressed that the estimates of mortality rates and the production estimates derived from them are probably in excess of the situation that actually existed. The nests that were the most exposed, and hence the most vulnerable to predation and environmental influences, were the nests available for study; the majority of the nests of the various populations being beyond the reach of predators, environmental hazards, and the investigator. However, for comparative purposes these production estimates are quite useful.

The euphausiid, Thysanoessa inermis, was found to be the principal dietary component of all the plankton-feeding seabirds considered in this study and probably is the base of the food chain for those species feeding on fish. The distribution of this euphausiid in the Koniuji Group is unknown, but because it was taken by birds feeding well offshore as well as those feeding in inshore waters, it appears to be quite varied in its distribution.

A notable feature of the colony distribution in the Koniuji Group is the concentration of breeding seabirds at the northern end of Big Koniuji and in the Koniuji Strait - Yukon Harbor area at the island's southeastern end. At each of these localities strong winds and tidal rips are prevalent, which are important mechanisms of nutrient-mixing in this greater availability of nutrients, support a large standing crop of euphasiids, which in turn support large seabird populations.

Before parameters can be put on the critical feeding habitat of these seabirds while at the breeding colonies of the Koniuji Group, the distribution and abundance of this euphausiid must be determined along with its relationship to local oceanographic factors as well as those of the Gulf of Alaska.

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TABLE 1. Climatological data recorded at Yukon Harbor, Big Koniuji Island, Alaska, 1976.

MONTH	AVG. MAX.	AVG. MIN.	MAX.	MIN.	DATE	TOTAL	GREAT. DAY	NO. OF DAYS		
								.10 or more	.50 or more	1.0 or more
June	54.7	39.9	69	31	08 June	3.66	1.65	9	2	1
July	61.0	43.6	88	38	11 July	7.75	1.98	14	5	3
Aug.*	62.1	45.7	78	38	15 Aug.	4.78	.88	12	4	0

*only 01-24 August recorded

TABLE 2. Precipitation for June, 1976, at three weather stations compared with that recorded at Big Koniuji during the same period. (data from NOAA, 1976)

STATION	TOTAL	NO. OF DAYS		
		.10 or more	.50 or more	1.0 or more
Sitkanak	1.00	4	0	0
Cold Bay	2.69	3	1	1
Adak	1.55	6	1	0
Big Koniuji	3.66	9	2	1

TABLE 3. Results of the colony censusing work done in the Koniuji Group during the summer of 1976. See Figure 4 for colony locations.

SPECIES	BREEDING BIRDS IN NUMBERS OF PAIRS										
	Atkin's Island	Heren-deen Is.	Hall Is.	East-Central Koniuji	Cape Thompson	Castle Rock	Peninsula Island	West-Central Koniuji	Granite Cove	Yukon Harbor	Koniuji Straits
Fork-tailed Storm Petrel			150			3000					
Leach's Storm Petrel			750			6000					
Double-crested Cormorant				9	4			1			
Pelagic Cormorant				8	14			65			
Red-faced Cormorant				21	27			34			
Glaucous-winged Gull	40	200	775			30	140				
Black-legged Kittiwake			155		7904	5805					
Common Murre						3600					
Thick-billed Murre						400					
Pigeon Guillemot	1000	300	600		20	25	30				
Ancient Murrelet			1300			15000	1500				
Cassin's Auklet			present			23000					
Pauakeet Auklet	2000	800	1750		1000	7000			20		
Crested Auklet					2000	1750			2500	15000	
Least Auklet						present					
Horned Puffin	3000	500	1200		1500	30000	700		1500		30000
Tufted Puffin	6000	1500	2600		1000	40000	2000				
Steller's Sea Lion	4000					150					

TABLE 4. Total number of breeding pairs of seabirds in the Koniuji Group.

SPECIES	NUMBERS OF BREEDING PAIRS Designated colonies	Big Koniuji	Northern half Little Koniuji	TOTAL
Pigeon Guillemot	1975	652	191	2818
Parakeet Auklet	12570	2446	620	15636
Crested Auklet	21250	0	0	21250
Cassin's Auklet	23000	0	0	23000
Ancient Murrelet	18000	0	0	18000
Thick-billed Murre	400	0	0	400
Common Murre	3600	0	0	3600
Tufted Puffin	53100	1141	0	54241
Horned Puffin	68400	3775	100	72275
Leach's Petrel	6750	0	0	6750
Fork-tailed Petrel	3150	0	0	3150
Glaucous-winged Gull	1185	0	0	1185
Black-legged Kittiwake	13864	0	0	13864
Pelagic Cormorant	87	2	0	89
Red-faced Cormorant	82	14	0	96
Double-crested Cormorant	14	5	0	19

TABLE 5. Habitat utilized at the seabird colonies of the Koniuji Group

COLONY	HABITAT TYPE
Atkins Island	Steep vegetated slopes with some cliffs
Herendeen Island	Steep vegetated slopes with some cliffs
Hall Island	Moderate to steep vegetated slopes with some cliffs
East-central Koniuji	Cliff face
Cape Thompson	Beach boulders and cliffs surmounted by vegetated slopes
Castle Rock	Moderate to steep vegetated slopes with some cliffs
Peninsula Island	Steep vegetated slopes
West-central Koniuji	20-30m cliffs
Granite Cove	Talus
Koniuji Straits	Talus
Yukon Harbor	Talus

TABLE 6. Occurrence of large flocks of Pigeon Guillemots in the Yukon Harbor area, Big Koniuji Island, 1976.

DATE	TIME	LOCATION	NO. SEEN	TYPE OF FLOCK
07 May	1700	1 mi. E. Hall Is.	300	mixed feeding
02 June	1600	Yukon Straits	400	dense raft
03 June	1640	Yukon Straits	600	dense raft
07 June	1220	Yukon Straits	200	dense raft
15 June	1600	off Yukon Head	500	mixed with Horned Puffins
02 July	1900	off SE tip Hall Is.	663	mixed feeding
07 July	1930	Yukon Straits	320	feeding groups of up to 15 birds

TABLE 7. Egg measurements from five species of alcids, Big Koniuji, 1976.

SPECIES	SAMPLE SIZE	DIMENSION	MAXIMUM (mm)	MINIMUM (mm)	MEAN (mm)
Tufted Puffin	56	length	80.7	68.5	73.4
		width	51.9	46.0	48.7
Horned Puffin	23	length	70.1	61.0	66.1
		width	47.9	43.0	45.2
Parakeet Auklet	3	length	56.3	50.3	53.5
		width	35.5	34.2	34.8
Ancient Murrelet	19	length	66.1	60.2	63.4
		width	40.3	37.0	38.6
Pigeon Guillemot	23	length	67.1	56.2	61.6
		width	43.9	39.4	41.9

TABLE 8. Egg-laying periods for two colonies of Horned Puffins, 1976.

COLONY	RANGE OF LAYING DATES	DATE 50% OF THE EGGS LAID
Hall Island	18-28 June	23 June
Koniuji Strait	18 June-4 July	25 June

TABLE 9. Body weights and measurements of Horned Puffin chicks at hatching and at 29 days.

AGE IN DAYS	BODY WEIGHT (g)	CULMEN (mm)	TARSUS (mm)	SOURCE
1(5)*	50.6	17.7	18.8	This study
29(1)	392.0	29.2	30.3	
1(2)	58.6	17.2	19.3	Sealy
29(2)	420.9	28.5	30.0	(1973)

*sample size in parenthesis

TABLE 10. Nest fates at two Horned Puffin colonies, 1976.

	Hall Island Colony	Koniuji Strait Colony
Total no. eggs laid	12(100)	20(100)
Egg deserted	1(8.3)	2(10.0)
Egg eaten by avian predator	1(8.3)	0
Egg eaten by fox	0	2(10.0)
Total egg mortality	2(16.6)	4(20.0)
Unable to reach chick	7(58.3)	9(45.0)
Chick eaten by fox	0	1(5.0)
Chick monitored	3(25.0)	6(30.0)

*percent of total eggs laid

TABLE 11. Measurements from four Tufted Puffin fledglings, Hall Island, 1976.

FLEDGLING PERIOD (days)	WING LENGTH (mm)	TARSUS LENGTH (mm)	CULMEN LENGTH (mm)	WEIGHT (g)
48	158 (80)*	36.1 (100)	39.6 (66)	530 (64)
45	149 (76)	36.1 (100)	39.1 (65)	467 (56)
44	151 (77)	34.9 (100)	38.8 (64)	479 (58)
46	154 (79)	38.1 (100)	41.2 (68)	607 (73)

*percent of adult measurement

TABLE 12. Nest fates for the Hall Island Tufted Puffin colony, 1976.

	NUMBER	PERCENT OF TOTAL NO. OF EGGS LAID
Eggs laid	51	100.0
Eggs deserted	14	27.5
Egg damage	4	7.8
Nest destroyed	1	2.0
Total egg mortality	19	37.3
Chick died	3	5.9
Unable to reach chick	14	27.5
Not fledged by 02 Sept.	5	9.8
Fledged	10	19.6

TABLE 13. Mean body measurements taken from two Crested Auklet fledglings collected on Yukon Harbor, 15 August, 1976.

CULMEN (mm)	TARSUS (mm)	RT. WING (mm)	WEIGHT (g)	TOTAL LENGTH (mm)
11.6 (96.7)*	29.4 (100)	128.5 (92.8)	231.5 (89.0)	244.5 (92.3)

*percent of adult mean

TABLE 14. Success of 14 Ancient Murrelet eggs on Hall Island, 1976.

HATCHED	DESERTED-HUMAN DISTURBANCE	DESERTED WHEN FOUND
8 (57.1%)	4 (28.6%)	2 (14.3%)

TABLE 15. Egg mortality for Pigeon Guillemots nesting on Hall Island and Murre Rocks, 1976.

MORTALITY FACTOR	NO. OF EGGS
Hatched	15 (55.6%)
Deserted when found	4 (14.8%)
Rolled from nest	3 (11.1%)
Parent killed	2 (7.4%)
Deserted (human disturbance)	2 (7.4%)
Died pipping	1 (3.7%)

TABLE 16. Fate of the Pigeon Guillemot chicks on Hall Island, 1976.

MORTALITY FACTOR	NO. OF CHICKS
Fledged	5 (33.3%)
Not located	7 (46.7%)
Exposure	2 (13.3%)
Predation (avian)	1 (6.7%)

TABLE 17. Pigeon Guillemot production on Hall Island and Murre Rocks, 1976.

Total number of nests	14 (100%)
Nests fledging two chicks	1 (7%)
Nests fledging one chick	2 (14%)
Nests with unknown fate	4 (29%)
Eggs laid	27 (100%)
Eggs hatched	15 (55.6%)
Chicks fledged	9.4 (35%)

TABLE 18. Developmental stage of young storm petrels found on Castle Rock 24 July and 09 August and the estimated breeding chronology.

DATE	OCCUPANT	STAGE	LAYING DATE	HATCHING DATE	FLEDGING DATE
			LEACH'S PETREL		
24 July	egg	near hatching	16 June	27 July	08 Oct.
24 July	egg	near hatching	16 June	27 July	08 Oct.
09 Aug.	chick	near fledging	21 April	01 June	12 Aug.
09 Aug.	chick	near fledging	21 April	01 June	12 Aug.
09 Aug.	chick	near fledging	21 April	01 June	12 Aug.
09 Aug.	chick	newly hatched	26 June	06 Aug.	18 Oct.
			FORK-TAILED PETREL		
24 July	egg	near hatching	16 June	27 July	08 Oct.
09 Aug.	chick	near fledging	21 April	01 June	12 Aug.

TABLE 19. Comparison of nest contents obtained by two methods of investigating Black-legged Kittiwake nests.

METHOD	NESTS WITH TWO EGGS	NESTS WITH ONE EGG	NESTS WITH NO EGGS
Counting from a distance(n=98)*	12(12%)	30(31%)	56(57%)
Counting 100% up close (n=182)	111(61%)	45(24%)	26(15%)

*the birds of an additional 98 nests did not leave, and these nests are not considered in this analysis.

TABLE 20. Hatching success of 100 Glaucous-winged Gull nests on Hall Island, 1976.

Nests hatching young	88 (88%)
Nests unsuccessful	12 (12%)
Egg disappeared	31 (12.7%)
Egg eaten by avian pred	4 (1.6%)
Egg infertile	9 (3.7%)
Shell damage	2 (0.8%)
Eggs hatched	196 (80.3%)

TABLE 21. Habitat of three Black Oystercatcher nests in the Koniuji Group, 1976.

LOCATION	SUBSTRATE	DISTANCE FROM WATER	
		HORIZONTAL	VERTICAL
Oystercatcher Rock (South Big Koniuji)	rock platform	3m	6m
Hall Island	rock platform	3m	4m
Castle Rock	beach cobbles	7m	2m

TABLE 22. Chronology of the Black Oystercatcher nests in the Koniuji Group, 1976.

LOCATION	DATE FOUND	ESTIMATED AGE OF CHICKS	DATE LAID	DATE HATCHED
Oystercatcher Rock	04 July	3 weeks	16 May	13 June
Hall Island	16 July	1 week	12 June	10 July
Castle Rock	09 Aug.	2-3 weeks	24 June	22 July

TABLE 23. Chronological and production data from seven Bald Eagle aeries in the south part of Big Koniuji Island, 1976.

AERIE	FLEDGING DATE	NO. CHICKS FLEDGED
1	20-29 August	2
2	15-29 August	2
3	----	0
4	20-23 August	1
5	25-30 August	3
6	10-15 August	2
7	01-16 August	2

TABLE 24. Mean body measurements taken from collected birds, Big Koniuji Island, 1976.

SPECIES	SEX	SAMPLE SIZE	WEIGHT (g)	LENGTH (mm)	CULMEN (mm)	TARSUS (mm)	WING (mm)
Tufted Puffin	M	9	829.8	388.0	60.3	35.8	169.9
	F	1	823.0	393.0	58.0	34.0	208.0
Horned Puffin	M	4	562.0	347.8	49.9	30.9	181.3
	F	4	536.3	350.8	48.5	30.2	182.3
Crested Auklet	M	15	266.0	269.5	12.6	28.4	141.4
	F	17	253.9	261.3	11.4	27.5	136.1
Parakeet Auklet	M	28	260.9	275.2	15.2	30.3	150.3
	F	14	249.9	267.2	14.8	29.4	146.4
Ancient Murrelet	M	4	233.8		13.5	27.1	
	F	3	225.0		13.0	27.7	

TABLE 25. Stomach contents of six Horned Puffins collected in the Yukon Harbor area, 1976.

STOMACH NUMBER	DATE COLLECTED	PREY ITEM IDENTITY	LENGTH	QUANTITY
022	11 July	unidentified euphausiids	fragments	
098	23 Aug.*	*Mallotus villosus*	82 mm	1
		" "	70-90 mm	1
099	23 Aug.*	*Mallotus villosus*	73 mm	1
100	23 Aug.	*Ammodytes hexapterus*	120 mm	1
		unidentified fish bones		
106	23 Aug.	unidentified shrimp		1
		unidentified fish bones		
107	23 Aug.	*M. villosus*	--	2
		A. hexapterus	120 mm	3
		" "	90 mm	1
		" "	70 mm	1
		unidentified decopod (*Pandalus montagui*?)	35 mm	2
		unidentified euphausiid larvae	1.5 mm	1
		unidentified fish bones		

*collected from a mixed feeding flock

TABLE 26. Frequency of occurrence of fish and invertebrates in Horned Puffins from three different localities.

% FREQUENCY OF OCCURRENCE		SOURCE
FISH	INVERTEBRATES	
83.3	50.0	Big Koniuji Island this study n=6
75.8	62.5	Cape Thompson Swartz (1966:671) n=17
27.0	95.0	Buldir Island Wehle (1976:58) n=41

TABLE 27. Bill loads brought to Horned Puffin chicks at the Koniuji Strait colony, 1976.

DATE COLLECTED	TIME	SPECIES	NO. OF INDIVS.	WEIGHT (g)	TOTAL WT. (g)	COMPLETE LOAD
11 August	1700	Mallotus villosus	2	2.9	4.0	no
		unid. eel	1	.5		
		unid. flatfish	1	.6		
11 August	1730	M. villosus	4	6.9	7.5	no
		Ammodotes hexapterus	1	.6		
11 August	1745	M. villosus	2	5.3	5.3	no
11 August	1800	M. villosus	1	1.8	1.8	no
11 August	1830	A. hexapterus	2	2.5	2.5	no
14 August	1700	M. villosus	8	15.3	15.3	yes
14 August	1715	A. hexapterus	1	7.4	7.4	yes
14 August	1745	A. hexapterus	3	1.8	1.8	no
14 August	1810	A. hexapterus	4	14.0	14.0	yes
14 August	1830	A. hexapterus	1	13.9	13.9	yes
19 August	1400	Gadus macrocephalus	8	10.6	10.6	no
19 August	1430	A. hexapterus	1	12.8	12.8	yes
19 August	1500	M. villosus	5	10.3	10.3	no
19 August	1530	M. villosus	8	13.6	13.6	yes
19 August	1540	A. hexapterus	11	8.1	8.1	no
19 August	1600	Trichodon trichodon	1	.9	.9	no
19 August	1630	A. hexapterus	1	10.3	10.3	yes
19 August	1700	M. villosus	1	1.5	1.5	no
19 August	1700	M. villosus	1	1.7	1.7	no

TABLE 27. CONTINUED

DATE COLLECTED	TIME	SPECIES	NO. OF INDIVS.	WEIGHT (g)	TOTAL WT. (g)	COMPLETE LOAD
23 August	1630	G. macrocephalus	9	14.3	14.3	yes
28 August	1100	A. hexapterus	10	10.6	10.6	yes
28 August	1130	A. hexapterus M. villosus	4 1	3.8 1.7	5.5	no
28 August	1140	A. hexapterus	13	16.3	16.3	yes
28 August	1200	A. hexapterus M. villosus	12 1	14.2 1.1	15.3	yes
28 August	1210	A. hexapterus	4	16.1	16.1	yes
28 August	1240	A. hexapterus	4	14.6	14.6	yes
28 August	1310	A. hexapterus	3	13.0	13.0	yes
28 August	1330	A. hexapterus	16	25.4	25.4	yes
28 August	1340	A. hexapterus	1	9.6	9.6	yes
28 August	1400	A. hexapterus	4	9.7	9.7	yes

TABLE 28. Importance of the various species of fish in the bill loads of Horned Puffins, 1976.

SPECIES	NUMBER CAUGHT	TOTAL WEIGHT (g)	% FREQUENCY OF OCCURRENCE (n=32)
Ammodytes hexapterus	107 (66.5%)	211.4 (70.3%)	68.8
Mallotusvillosus	34 (21.1%)	62.1 (20.7%)	34.4
Gadus macrocephalus	17 (10.6%)	24.9 (08.3%)	6.3
Trichodon trichodon	1 (0.6%)	.9 (0.3%)	3.1
unid. flatfish	1 (0.6%)	.6 (0.2%)	3.1
unid. larval fish	1 (0.6%)	.5 (0.2%)	3.1

TABLE 29. Stomach contents of nine Tufted Puffins collected in the Yukon Harbor area, 1976.

DATE COLLECTED	PREY ITEM IDENTITY	LENGTH	QUANTITY
11 July	*Thysanoessa inermis*	fragments	6
11 July	unid. squid beaks	1.0-2.3mm	6
11 July	unid. squid beaks	.8mm	1
	unid. otoliths	1.0mm	14
23 August*	*T. inermis*	24.0mm	31
	unid. euphausiid	11.0mm	1
	unid. fish	50-80mm	3
	Mallotus villosus	57.0mm	1
	Ammodytes otoliths	3.0mm	5
23 August*	*T. inermis*	24.0mm	31
	unid. imm. euphaus.	10.0mm	4
	unid. fish	50-80mm	2
23 August*	*T. inermis*	25.0mm	6
	unid. megapod larv.		1
	Ammodytes otoliths	2.0-3.1mm	18
	unid. zooplankton	2.0mm	3
23 August	*Ammodytes* otoliths	2.0-3.5mm	11
23 August	*T. inermis*	23-29mm	40
	unid. imm. euphaus.	5.0mm	3
	unid. fish	50.0mm	1
	unid. fish	---	2

*collected from a mixed feeding flock

TABLE 30. Percent frequency of occurrence of food classes in the stomachs of Tufted Puffins collected at Big Koniuji, summer 1976, compared with that found by other investigators.

PERCENT FREQUENCY OF OCCURRENCE		
FISH	INVERTEBRATES	SOURCE
77.8	88.9	Big Koniuji this study n=9
18	72	Buldir Island Wehle (1976:58) n=73
100	50	Cape Thompson Swartz (1966:672) n=2

TABLE 31. Stomach contents of Parakeet Auklets.

PERCENT FREQUENCY OF OCCURRENCE n=7	
Euphausiids	Polychaetes
71.4	28.6

TABLE 32. Contents of sublingual pouch samples taken from Parakeet Auklets.

% FREQUENCY OF OCCURRENCE n=9	
T. inermis	fish
100.0	11.0

TABLE 33. Percent frequency of occurrence of the major food types in the Ancient Murrelets collected in the Hall Island vicinity, 1976.

% FREQUENCY OF OCCURRENCE n=7	
Euphausiids	Fish
100.0	14.2

TABLE 34. Observations of Ancient Murrelets in the Yukon Harbor area of Big Koniuji Island, 1976.

DATE	TIME	NUMBERS OF BIRDS	TYPE OF FLOCK	LOCATION
07 June	1220	2000	large raft	between Hall I. and Murre Rocks
10 June	0730	100	rafts of 5-15 birds	"
19 June	1020	950	"	Yukon Straits
"	1700	500	single raft	between Hall I. and Murre Rocks
25 June	1045	500	rafts of 5-15 birds	off Murre Rocks
01 July	1110	700	"	"

TABLE 35. Fish found at a Pigeon Guillemot nest on Hall Island, 1976.

DATE FOUND	SPECIES	LENGTH	WEIGHT
30 July	*Hemilepidotus*	91mm	8.2g
03 Aug.	*Pholis laeta*	158mm	7.3g
03 Aug.	*P. laeta*	155mm	8.7g
06 Aug.	*Trigolops pingeli*	156mm	22.4g
12 Aug.	*P. laeta*	170mm	9.6g

TABLE 36. Occurrence of the food items in 36 Glaucous-winged Gull pellets collected on Hall Island, 1976.

FOOD ITEM	FREQUENCY OF OCCURRENCE	% FREQUENCY OF OCCURRENCE (n=36)
unidentified mammal	2	5.6
total mammal	2	5.6
Ancient Murrelet adults	7	19.4
Ancient Murrelet young	3	8.3
Cassin's Auklet	3	8.3
Storm petrel	4	11.1
unidentified bird	1	2.8
GW Gull egg	3	8.3
Pigeon Guillemot egg	1	2.8
total birds & eggs	22	61.1
unidentified fish	5	13.9
total fish	5	13.9
Chiton	10	27.8
Limpet (*Acmaea* sp.)	3	8.3
Sea urchin	2	5.6
Mussel	3	8.3
unidentified mollusk	2	5.6
unidentified crab	1	2.8
unidentified shrimp	1	2.8
total marine invertebrates	22	61.1
unidentified seaweed	3	8.3
total plant	3	8.3

TABLE 37. Frequency of food items in regurgitations for Glaucous-winged Gull chicks on Hall Island, 1976.

FOOD ITEM	% FREQUENCY OF OCCURRENCE (n=16)
Mallotus villosus	6.3
Ammodytes hexapterus	12.5
unidentified fish	56.3
total fish	75.0
Acmaea sp.	12.5
unidentified crab	12.5
total invertebrates	25.0

TABLE 38. Food remains collected at three Black Oystercatcher nest sites, 1976.

NEST LOCATION	DATE COLLECTED	FOOD ITEM	NUMBER	% OF TOTAL
Oystercatcher Rock	04 July	*Acmaea digitalis*	many	----
		Katharina tunicata	many	----
		Mytlus *edulus*	some	----
		Thais emarginata	few	----
Hall Island	18 and	*A. digitalis*	257	78.3
n=328	28 July	*A. scutum*	31	9.4
		M. edulus	18	5.5
		K. tunicata	13	4.0
		T. emarginata	6	1.8
		Littorina sitkana	2	.6
		unid. starfish	1	.3
Castle Rock	09 Aug.	*A. digitalis*	207	94.5
n=219		unid. gastropod	18	8.2
		A. scutum	4	1.8

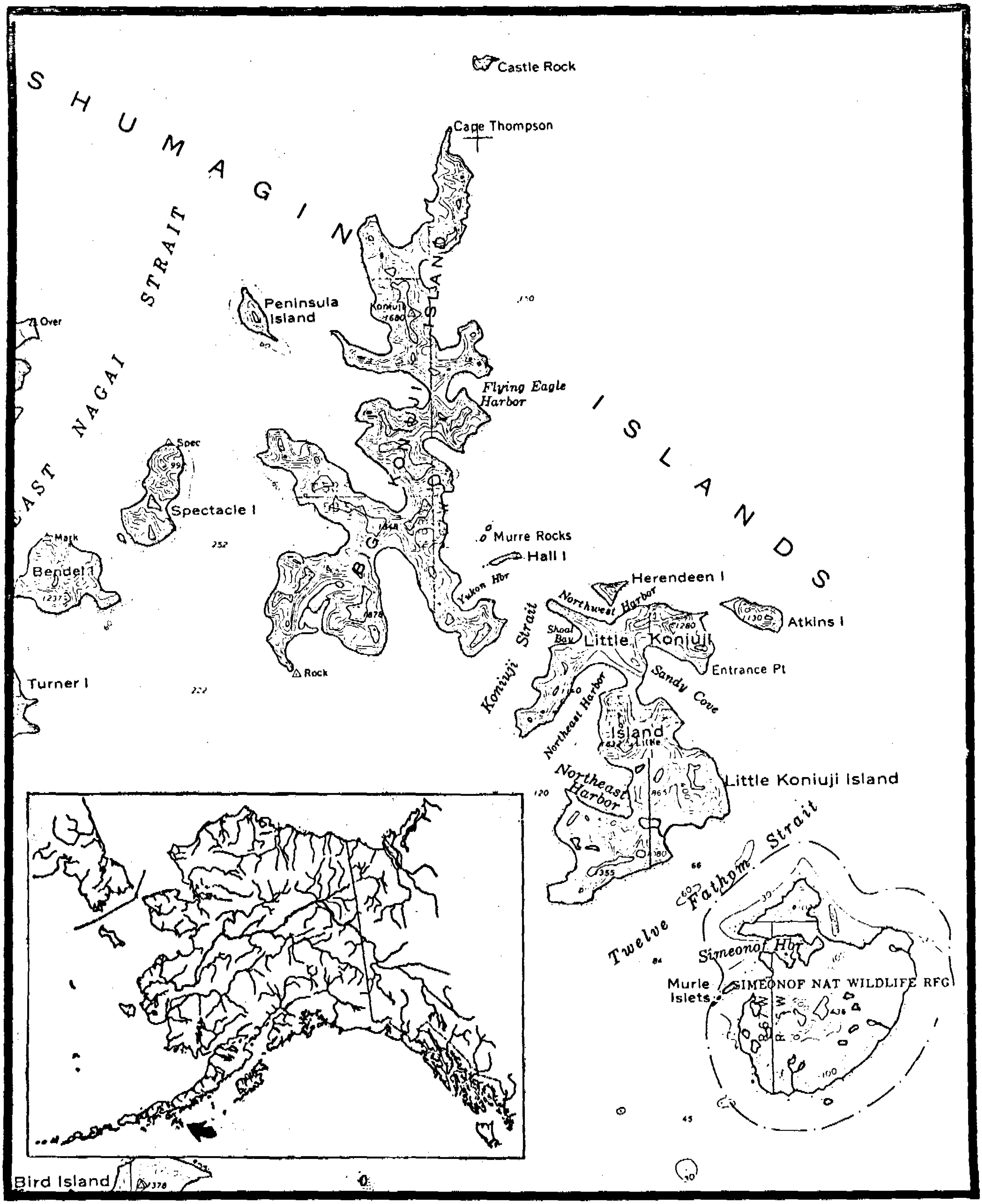

Figure 1. The Koniuji study area and its location off the Alaskan Peninsula.

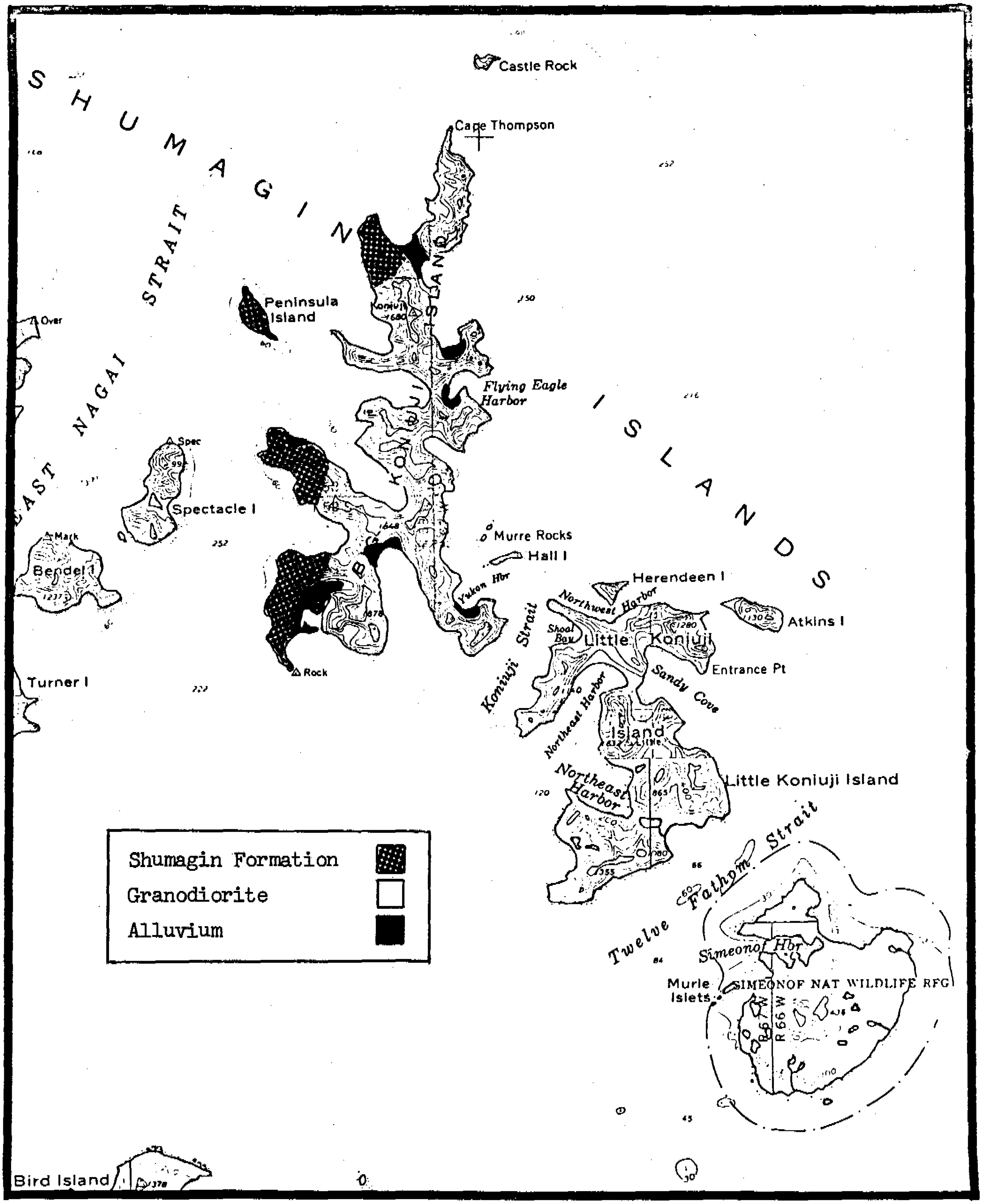

Figure 2. Geology of Big Koniuji Island (Moore 1974).

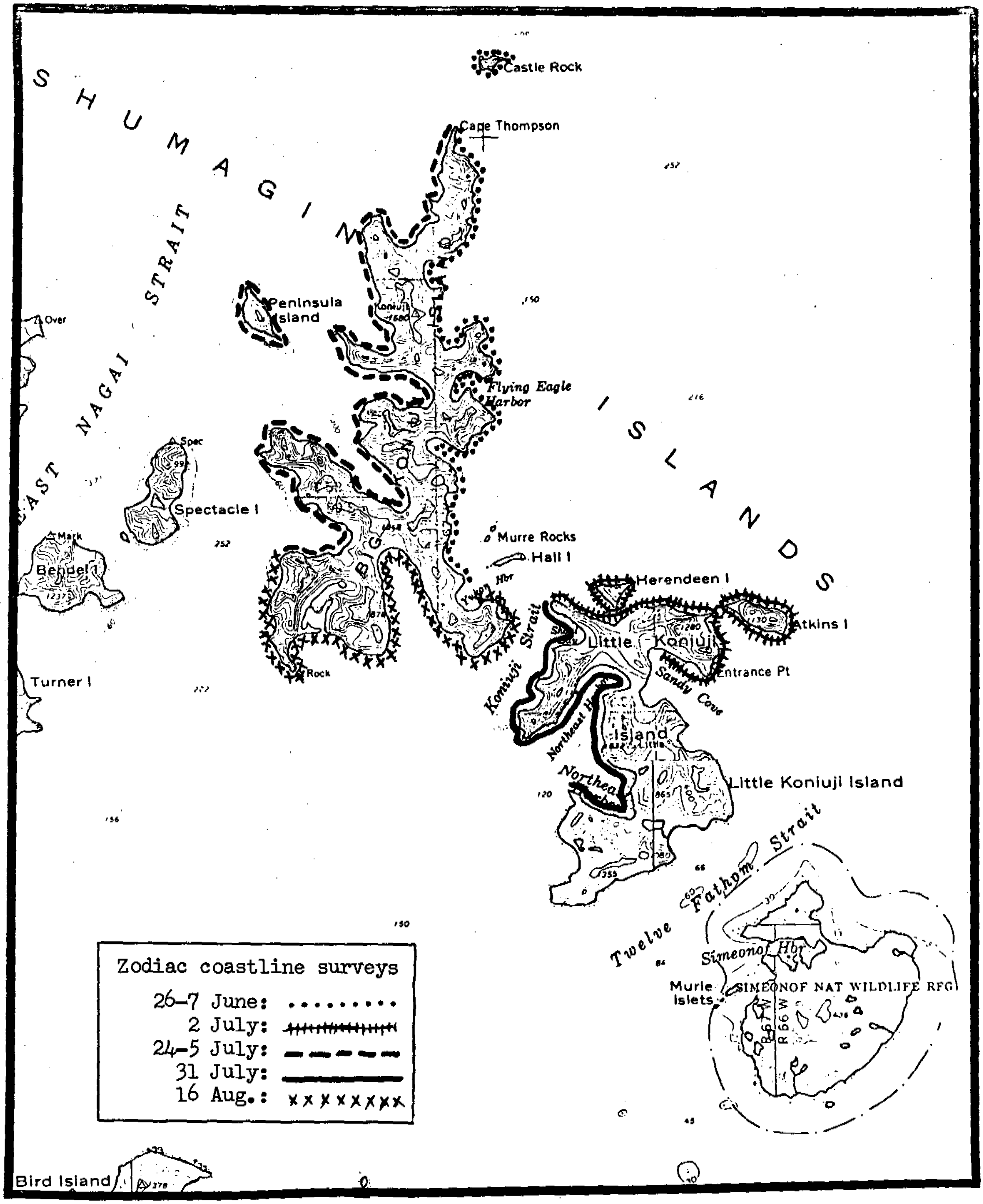

Figure 3. Colony censusing schedule - Big Koniuji, Summer 1976.

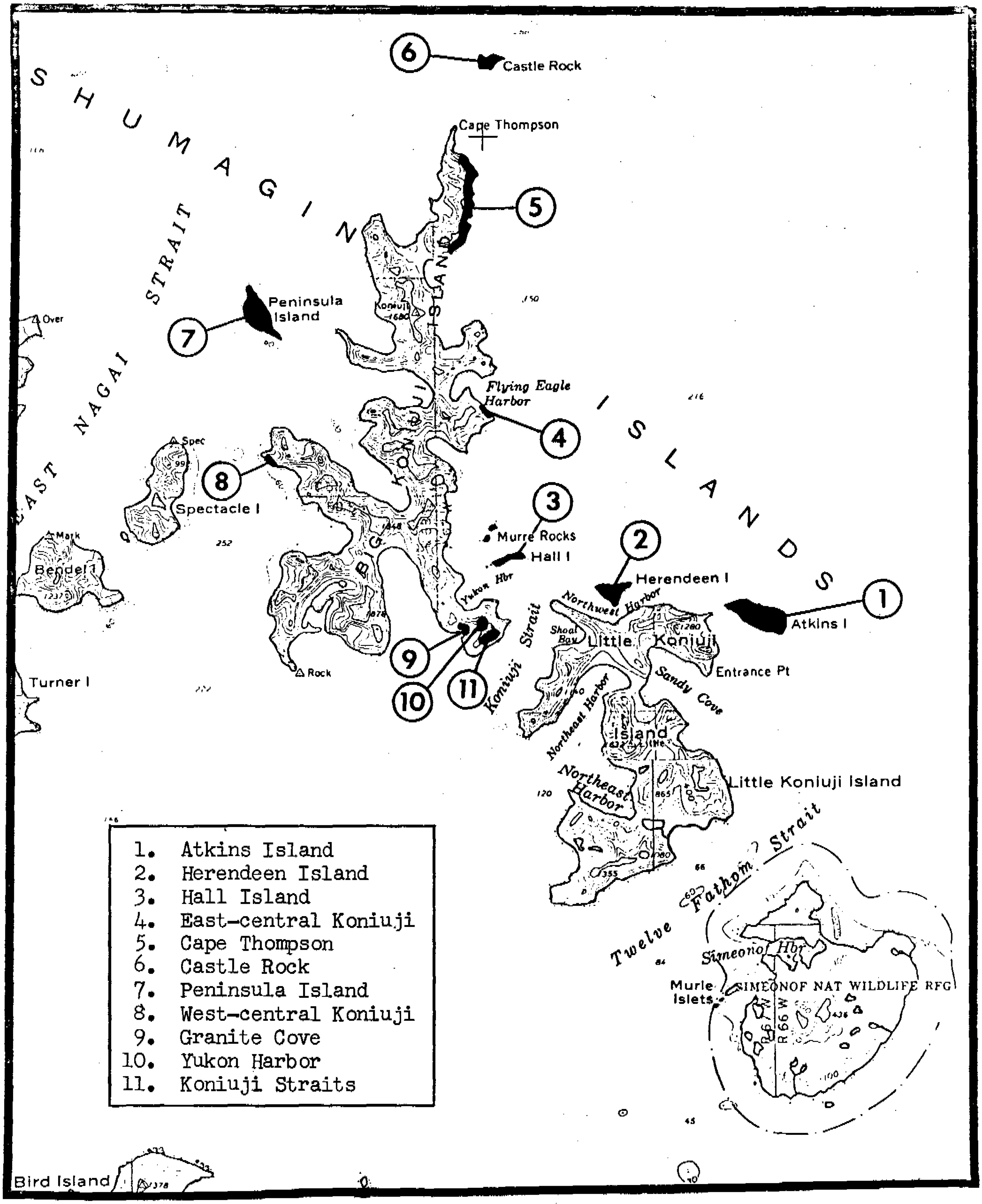

Figure 4. Colony locations in the Koniuji Group. See table 3 for censusing results.

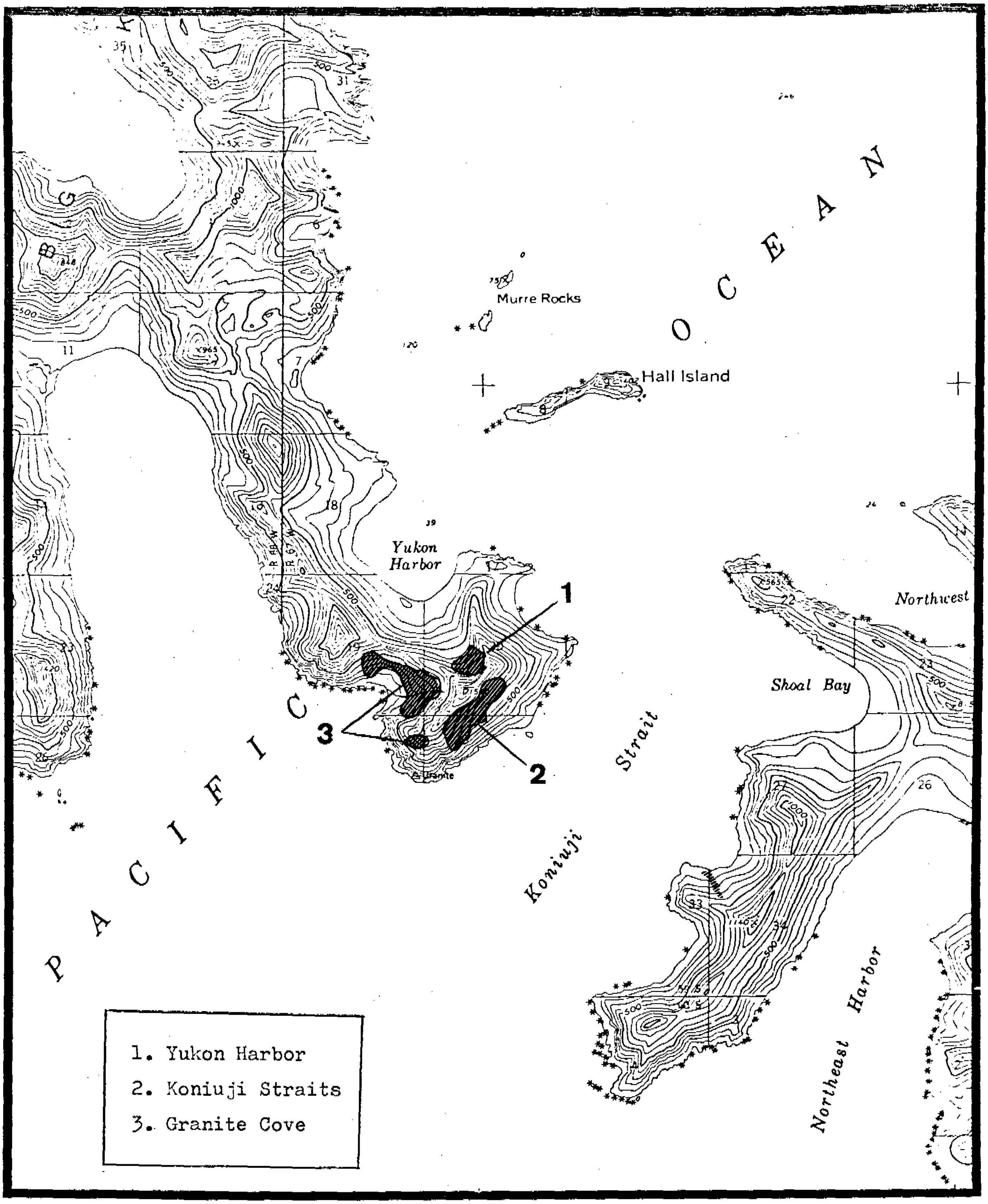

Figure 5. The three colonies of Koniuji Head.

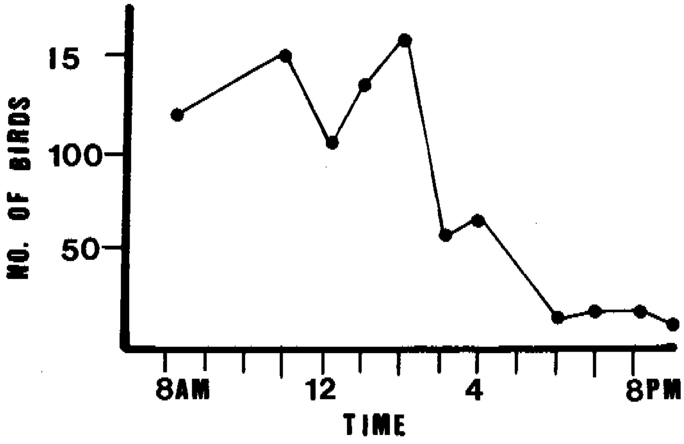

Figure 6. Hourly counts of Pigeon Guillemots off Hall Island, 02 July, 1976.

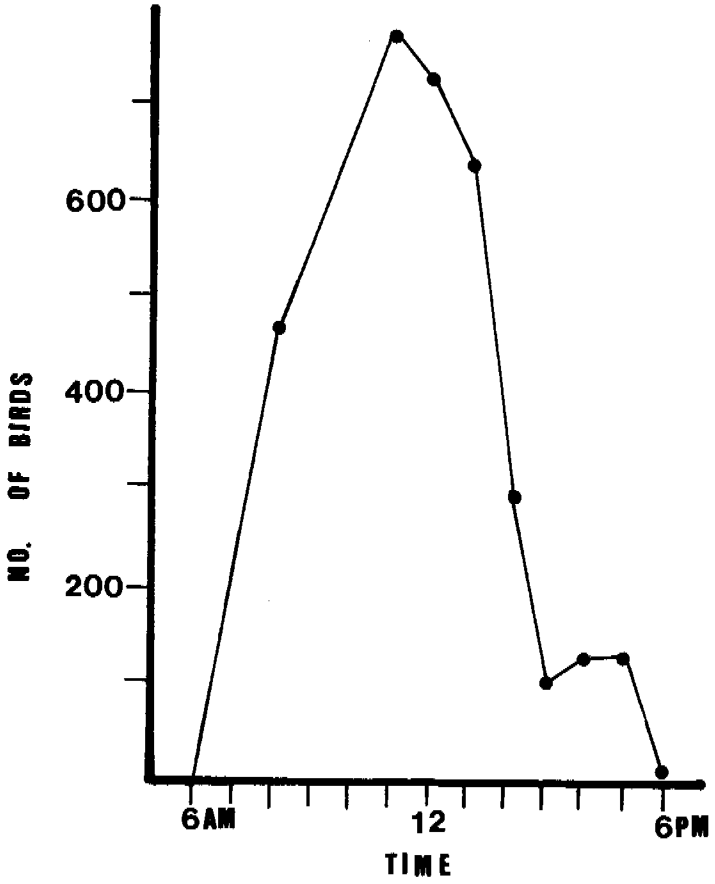

Figure 7. Hourly counts of Parakeet Auklets off Hall Island, 02 July, 1976.

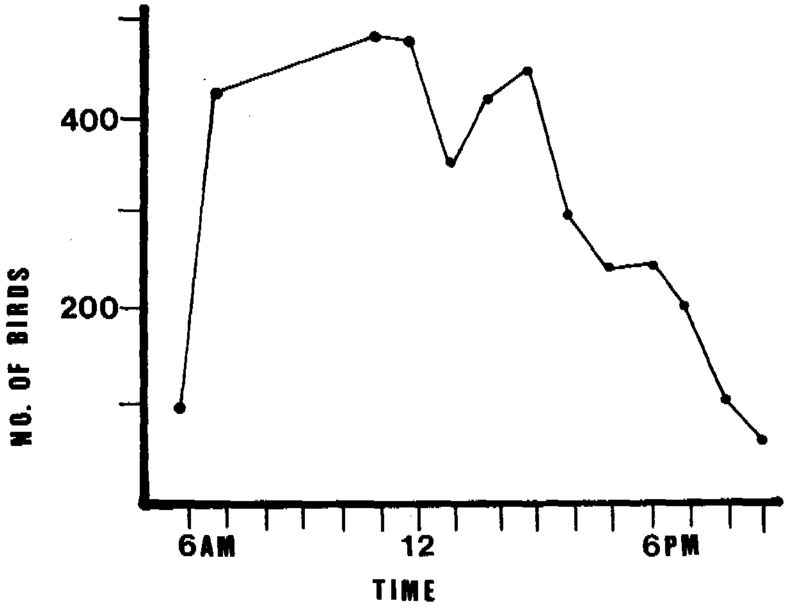

Figure 8. Hourly counts of Tufted Puffins off Hall Island, 02 July, 1976.

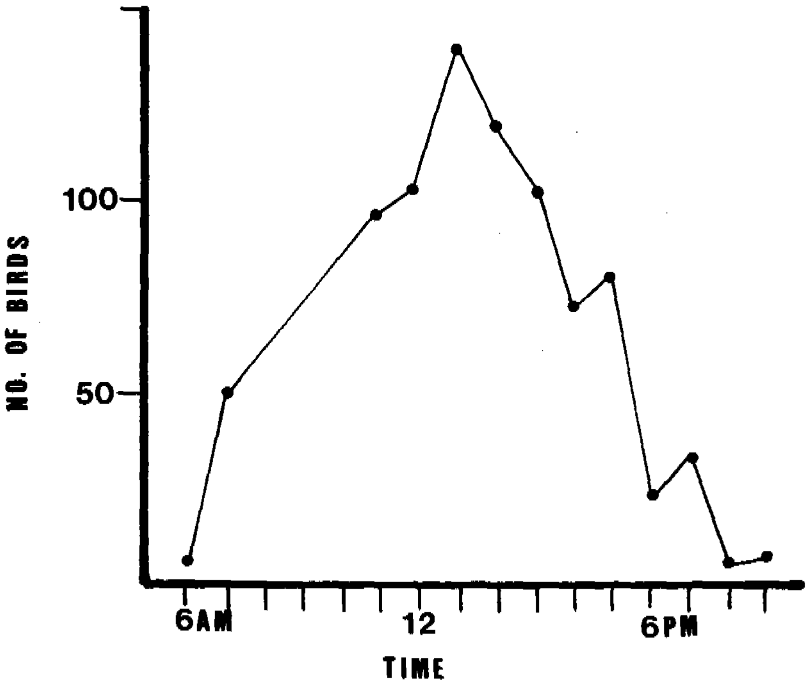

Figure 9. Hourly counts of Horned Puffins off Hall Island, 02 July, 1976.

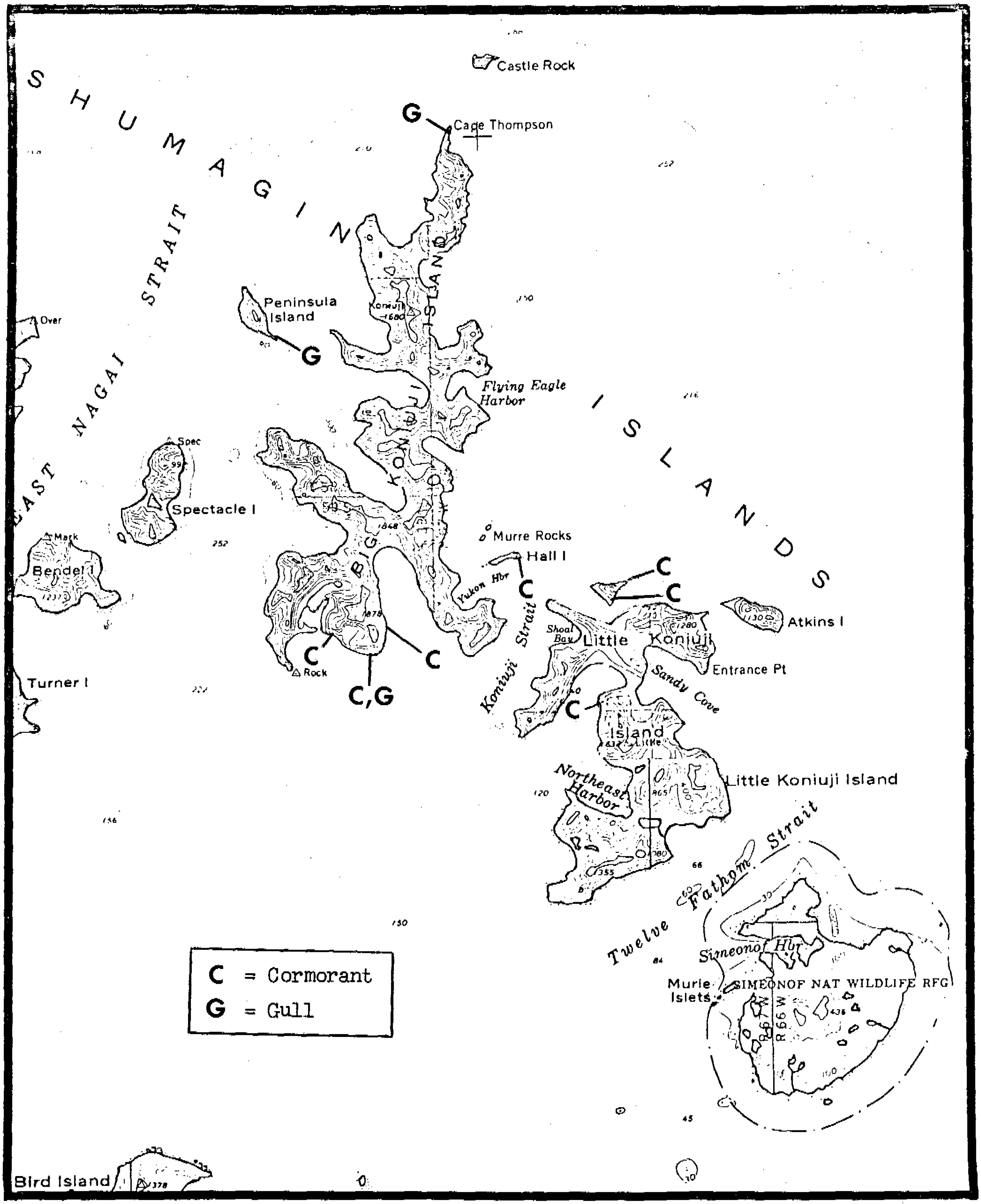

Figure 10. Distribution of cormorant and Glaucous-winged Gull roosting areas in the Koniuji Group.

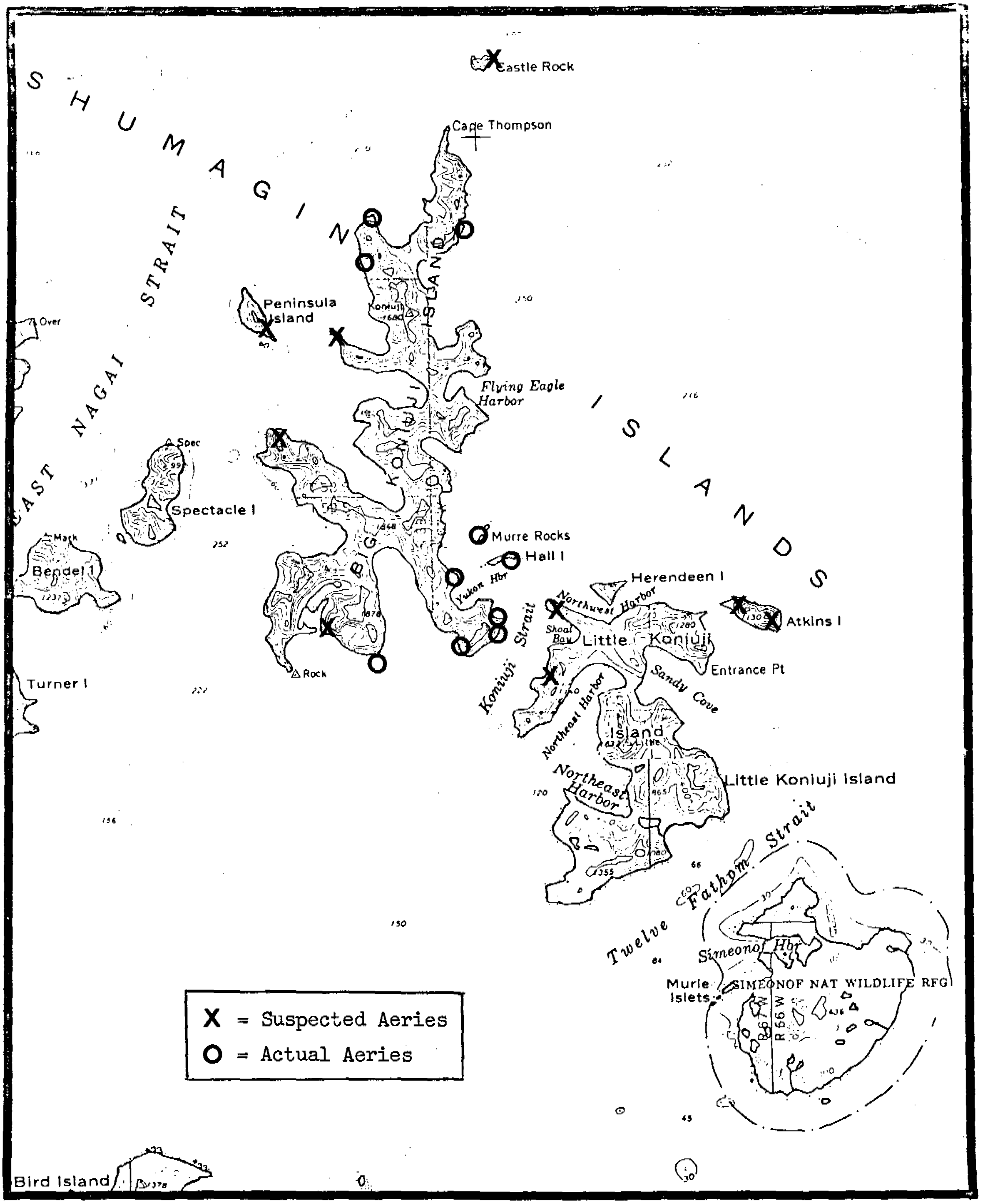

Figure 11. Locations of Bald Eagle aeries in the Koniuji Group, 1976. The locations of the two on Atkins Island are approximate.

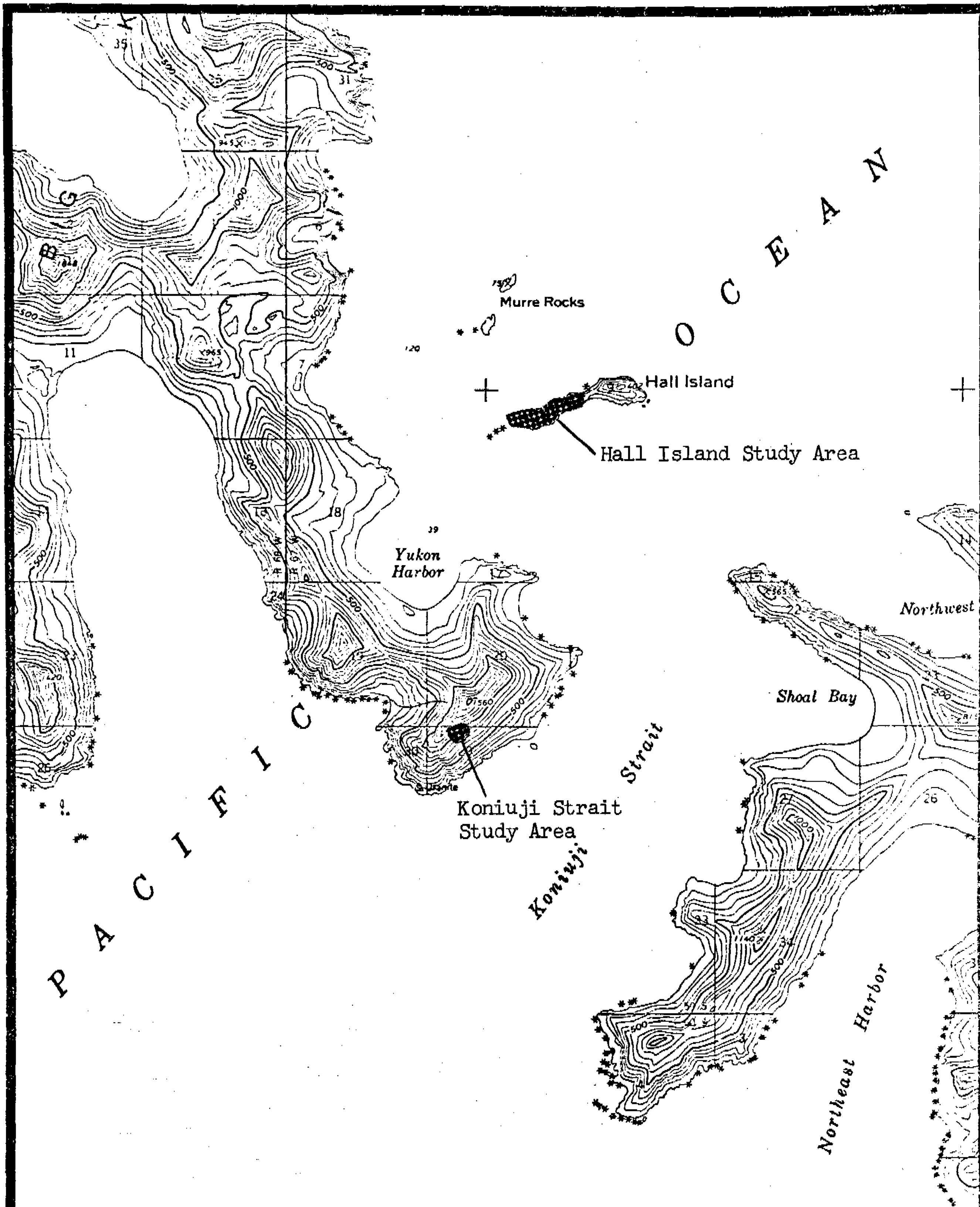

Figure 12. Location of the Hall Island and Koniuji Strait study areas.

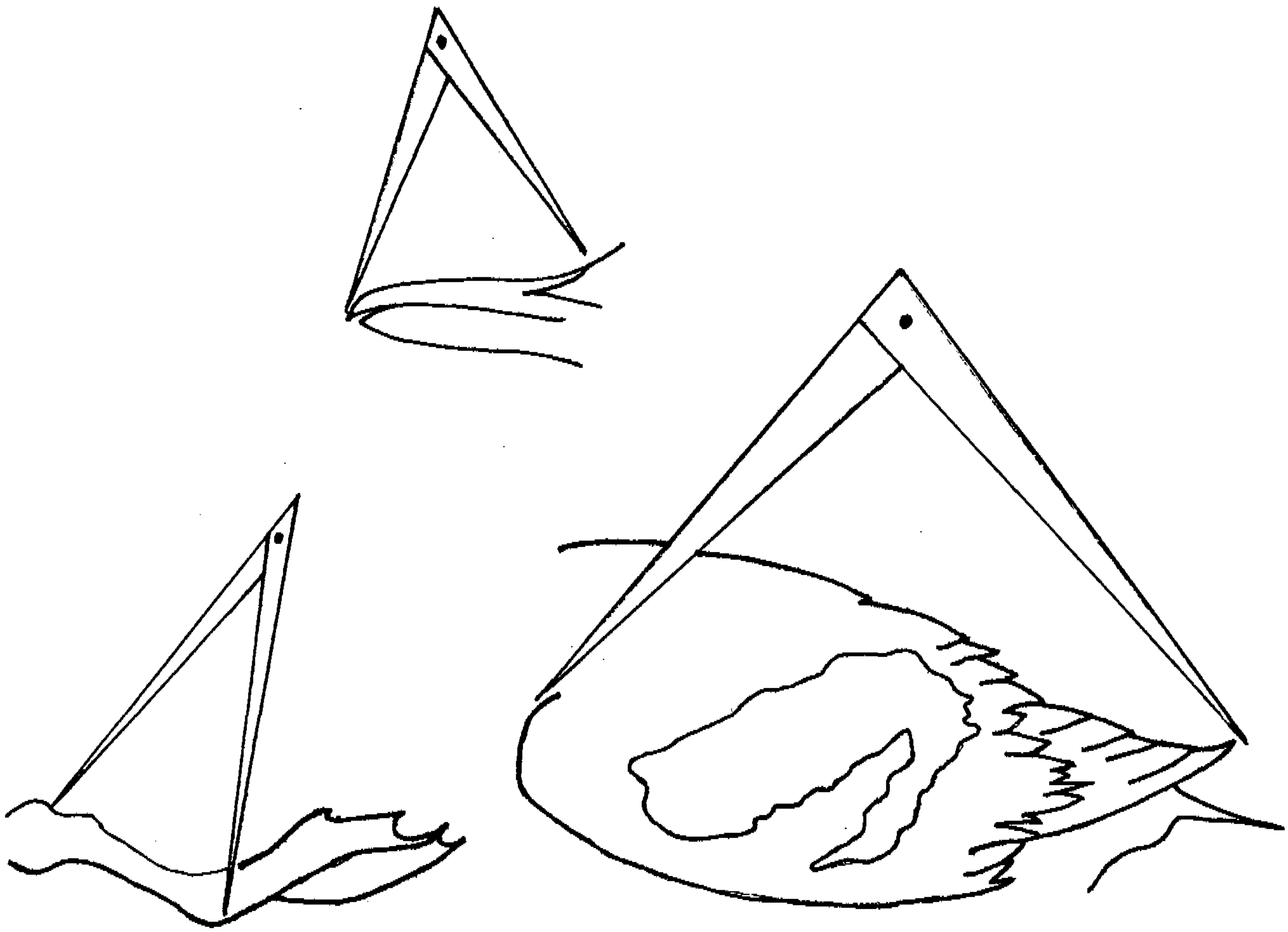

Figure 13. Method of taking wing cord, diagonal tarsus, and exposed culmen measurements (after Thorenson and Booth, 1958).

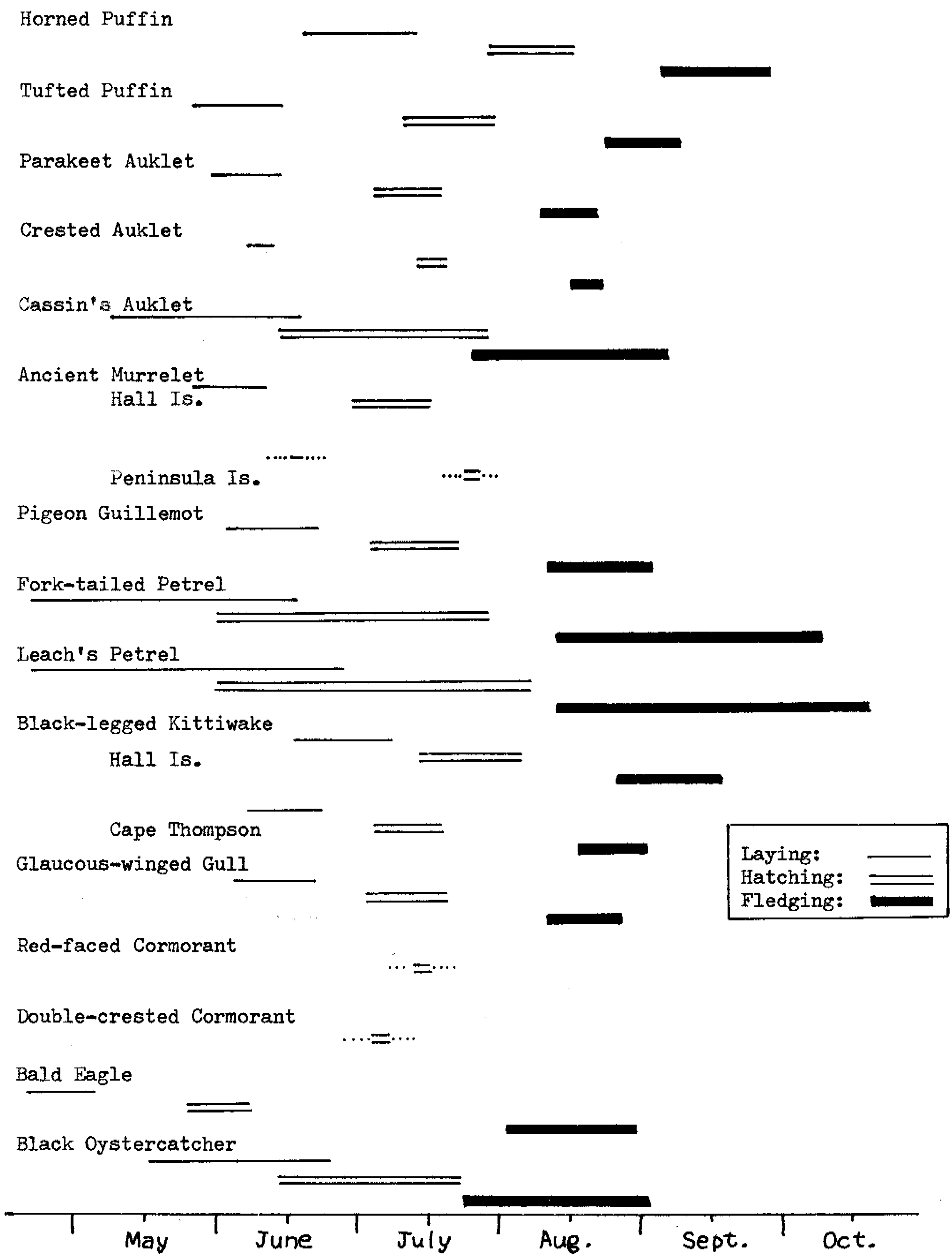

Figure 14. Breeding chronologies at the Koniuji Group during 1976.

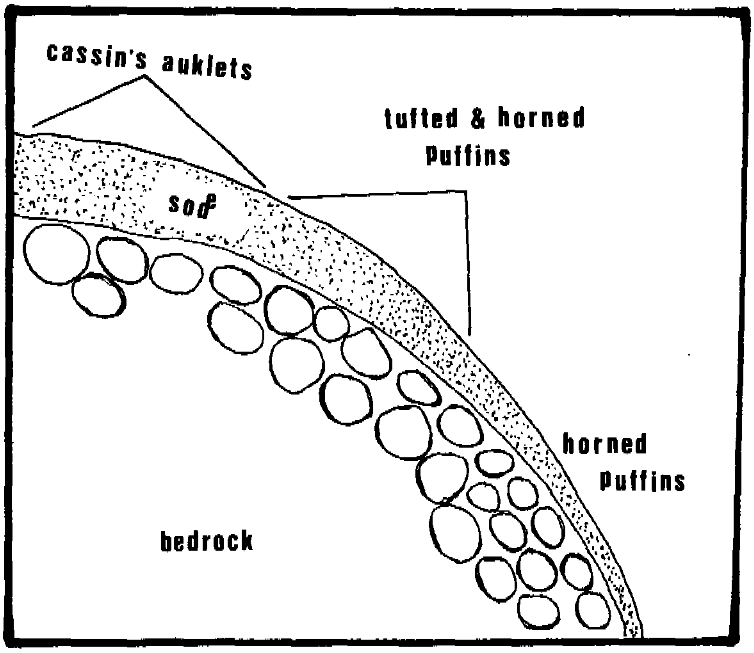

Figure 15. Nest site distribution between three species of alcids on the South side of Castle Rock.

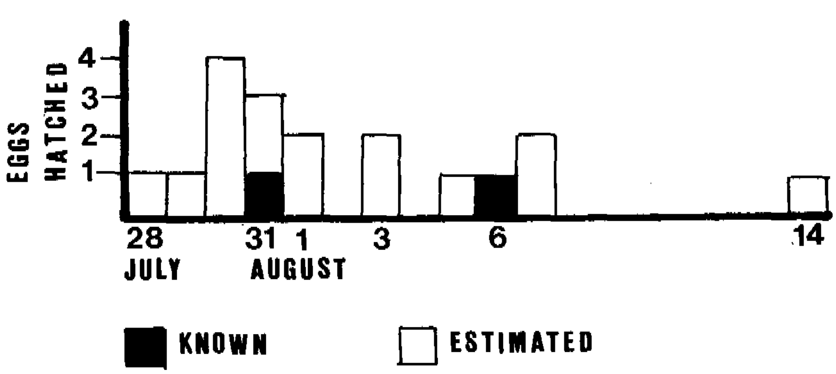

Figure 16. Hatching dates for 18 Horned Puffin chicks in the Koniuji Strait and Hall Island colonies, 1976.

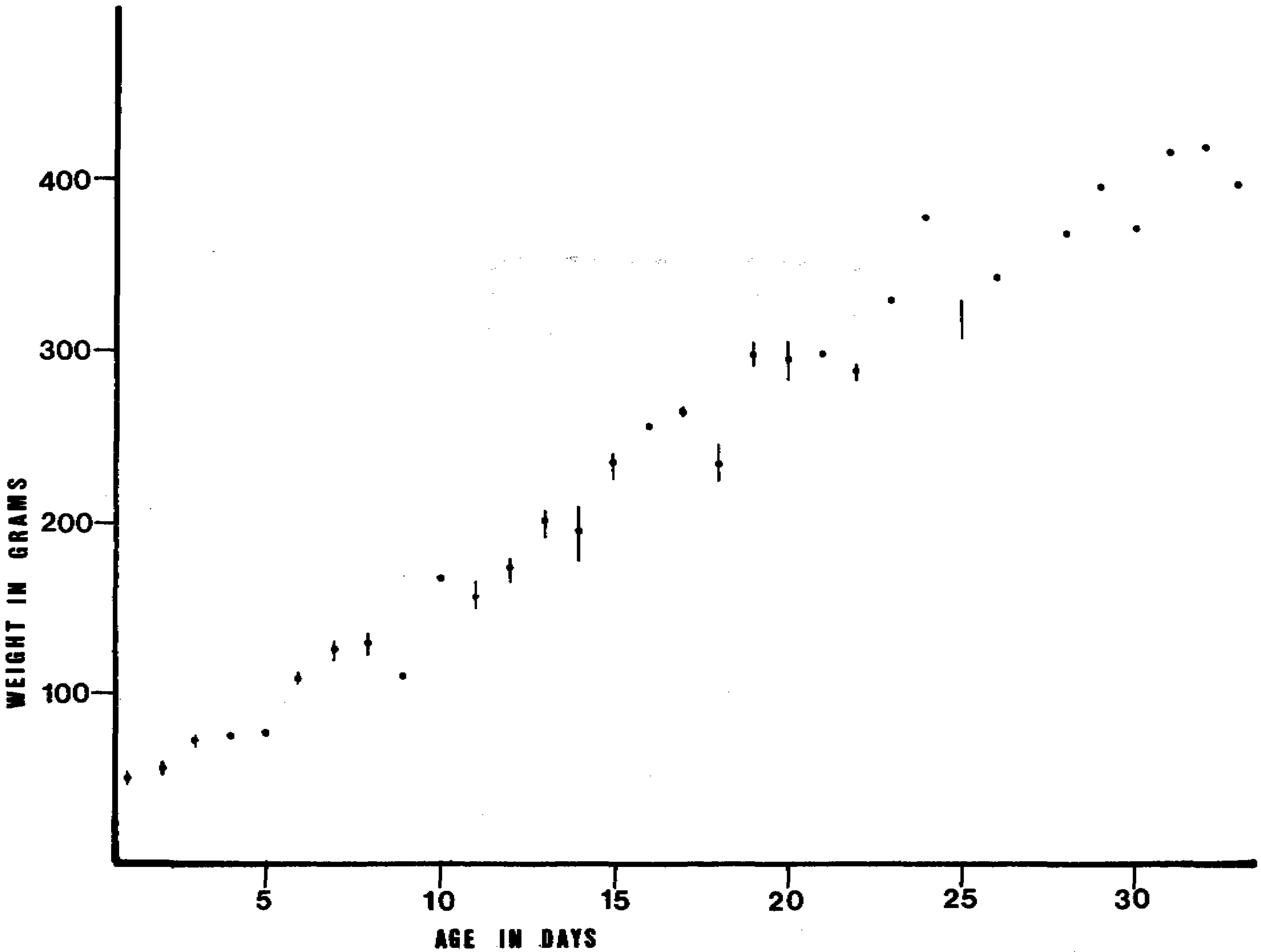

Figure 17. Weight increase in the Horned Puffin chicks of the Hall Island and Koniuji Strait colonies, 1976. Standard error is shown when the sample for a particular age was more than one.

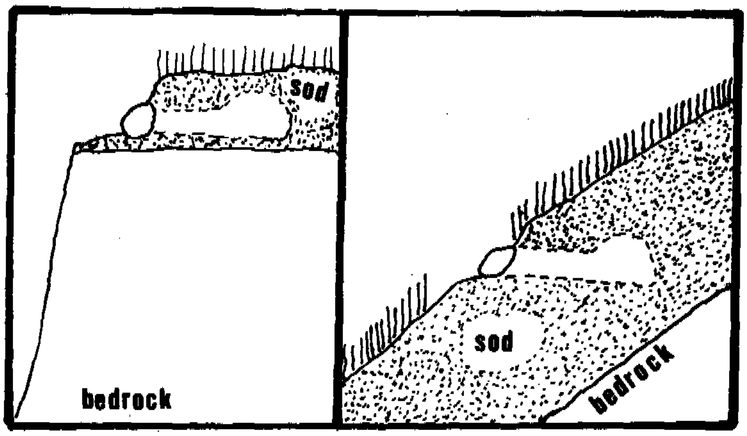

Figure 18. The two main types of Tufted Puffin burrows in the Koniuji Group.

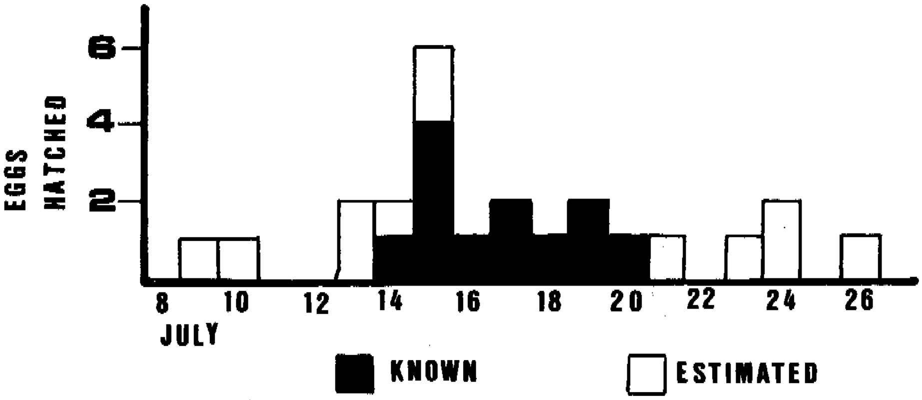

Figure 19. Hatching dates for 24 Tufted Puffin chicks in the Hall Island colony, 1976.

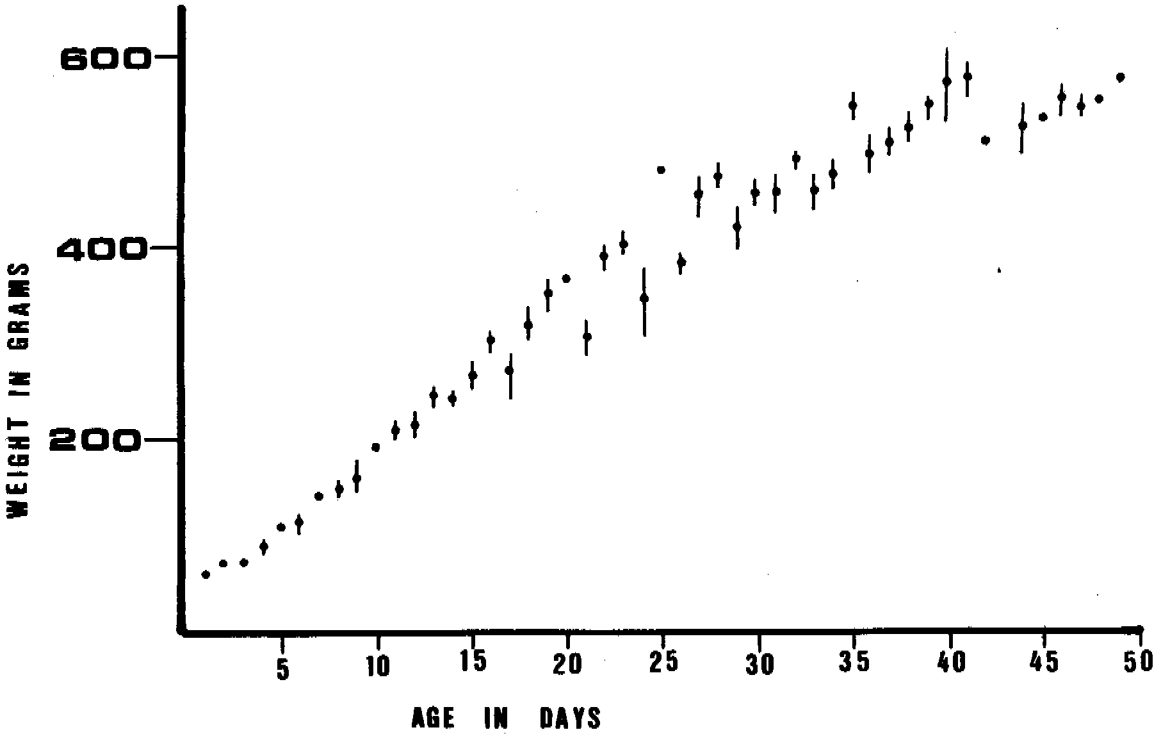

Figure 20. Weight increase in the Tufted Puffin chicks of Hall Island, 1976. Standard error is shown when the sample for a particular age was more than one.

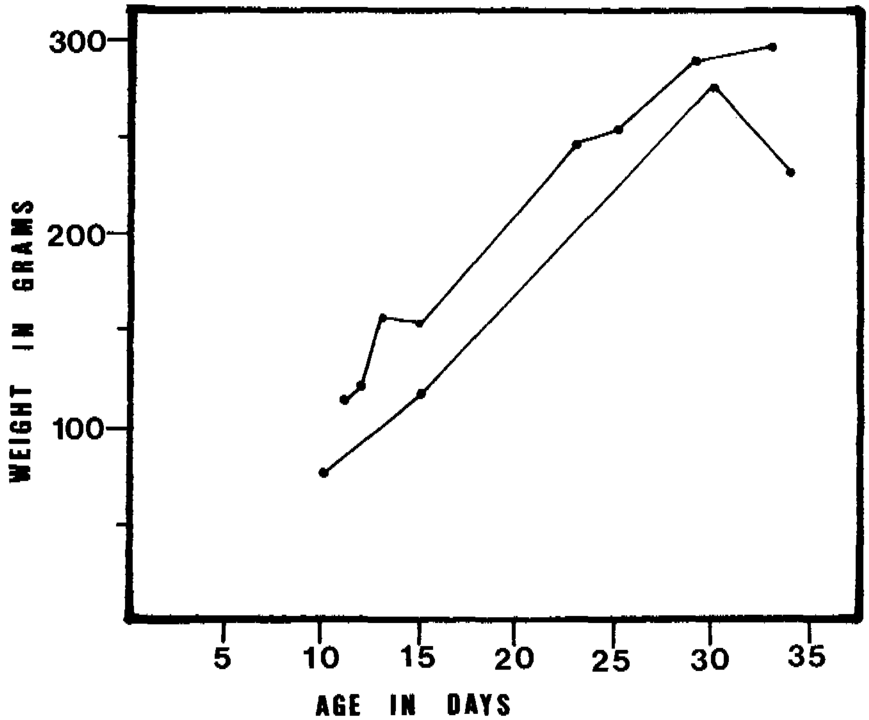

Figure 21. Weight increases in two Parakeet Auklet chicks on Hall Island, 1976.

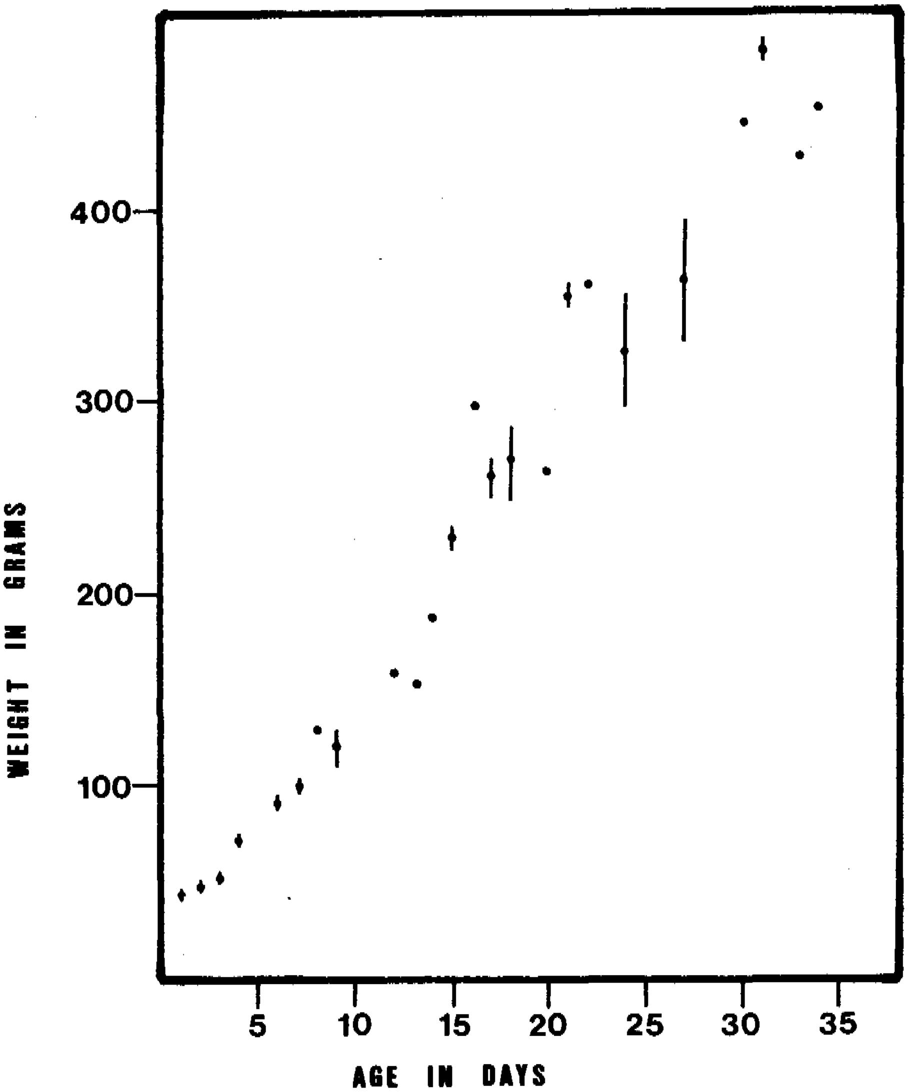

Figure 22. Weight increase in the Pigeon Guillemot chicks on Hall Island, 1976. Standard error is shown when the sample for a particular age was more than one.

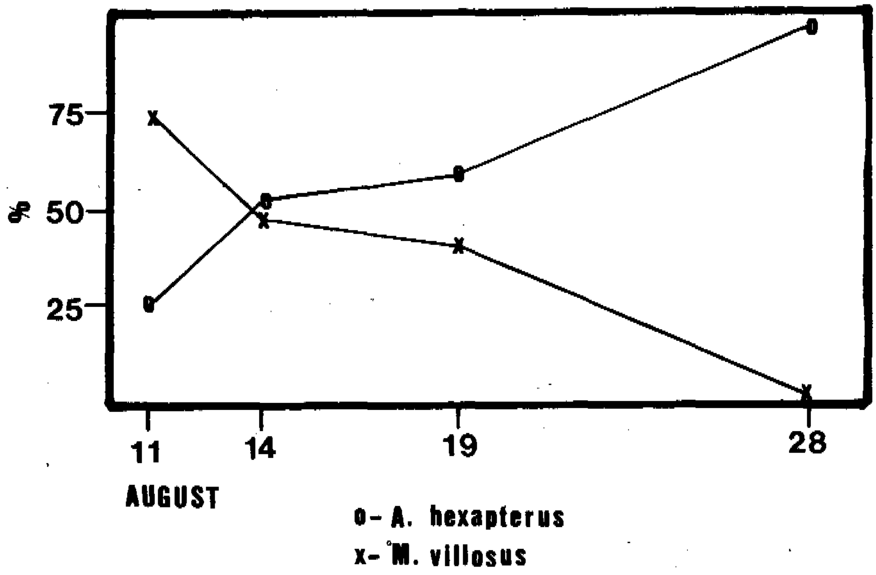

Figure 23. Relative importance of the two major food species of the Horned Puffin chicks at the Koniuji Strait colony, 1976.

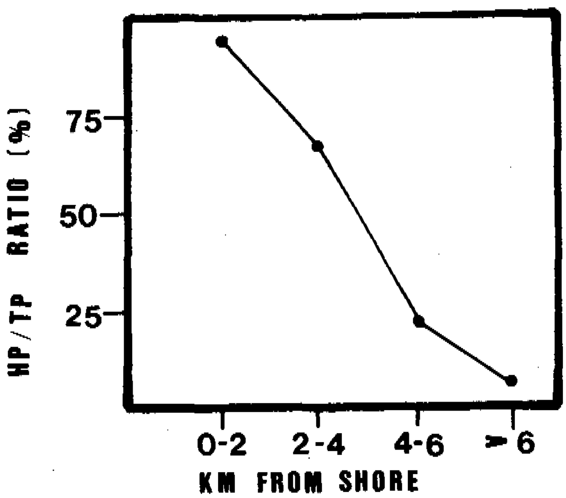

Figure 24. Relative abundance of the two species of Puffins with increasing distance from shore during a transect on 24 July, 1976, Big Koniuji Island.

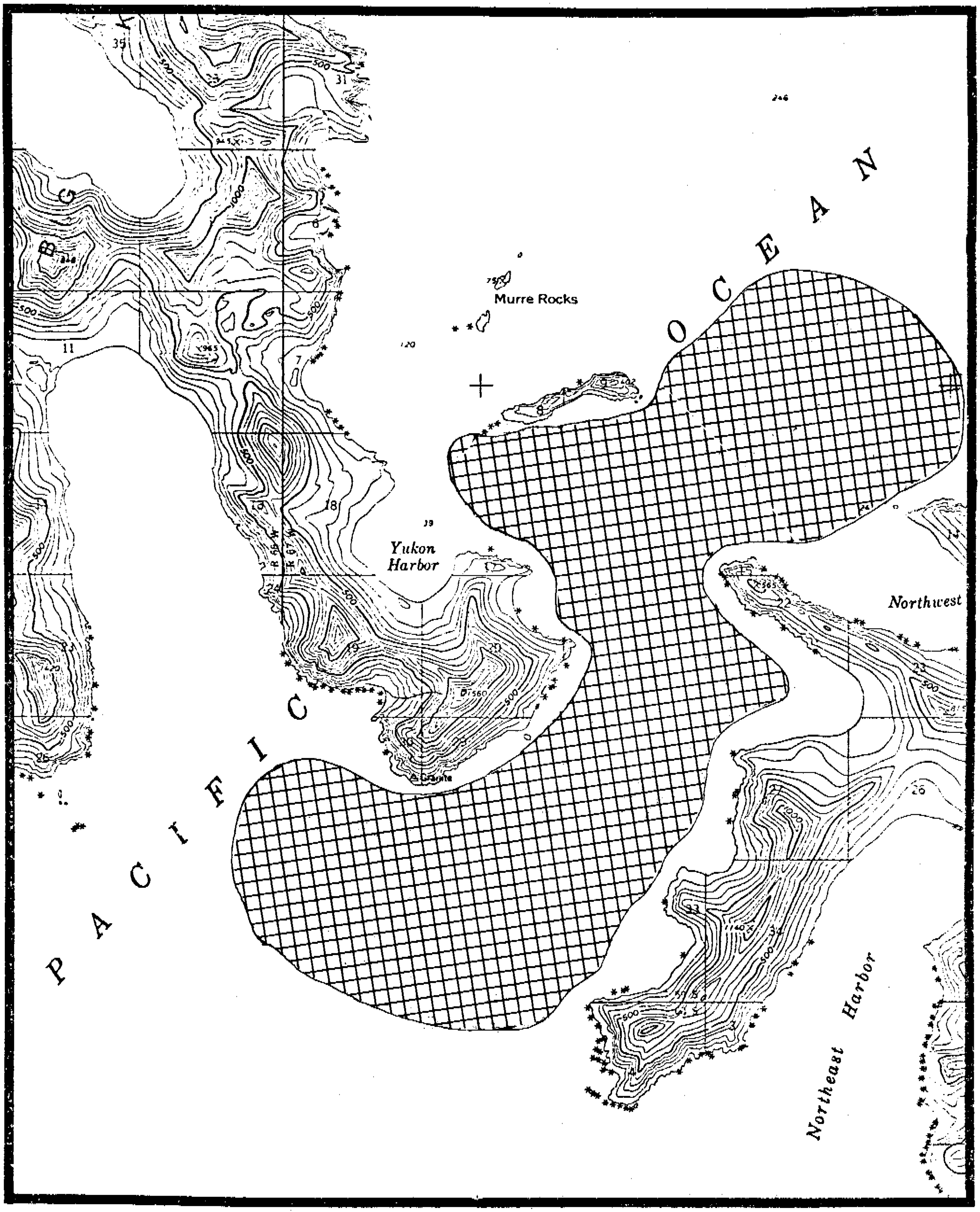

Figure 25. Feeding areas of Horned Puffins from the Koniuji Strait colony.

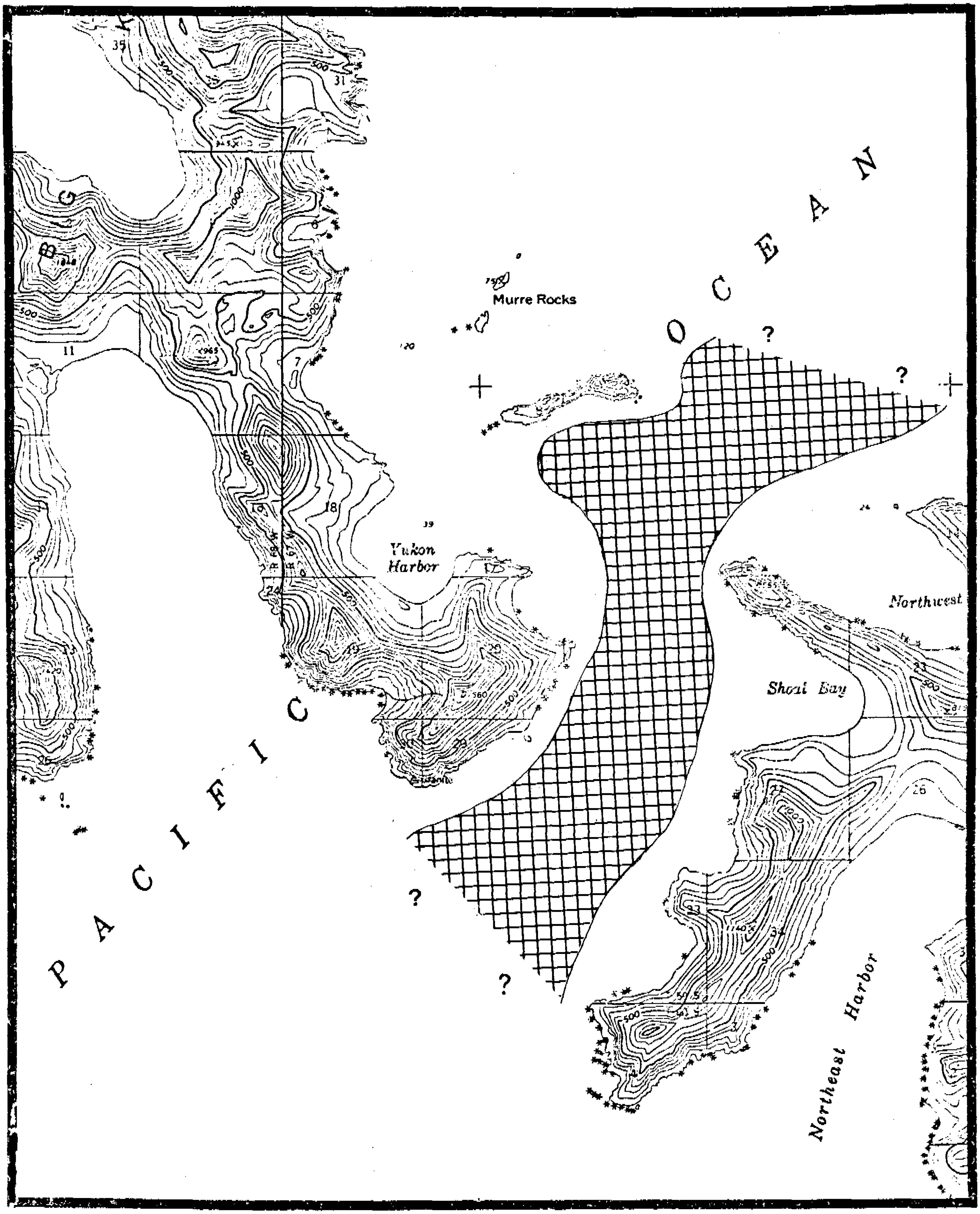

Figure 26. Feeding areas of the Yukon Harbor Crested Auklets.

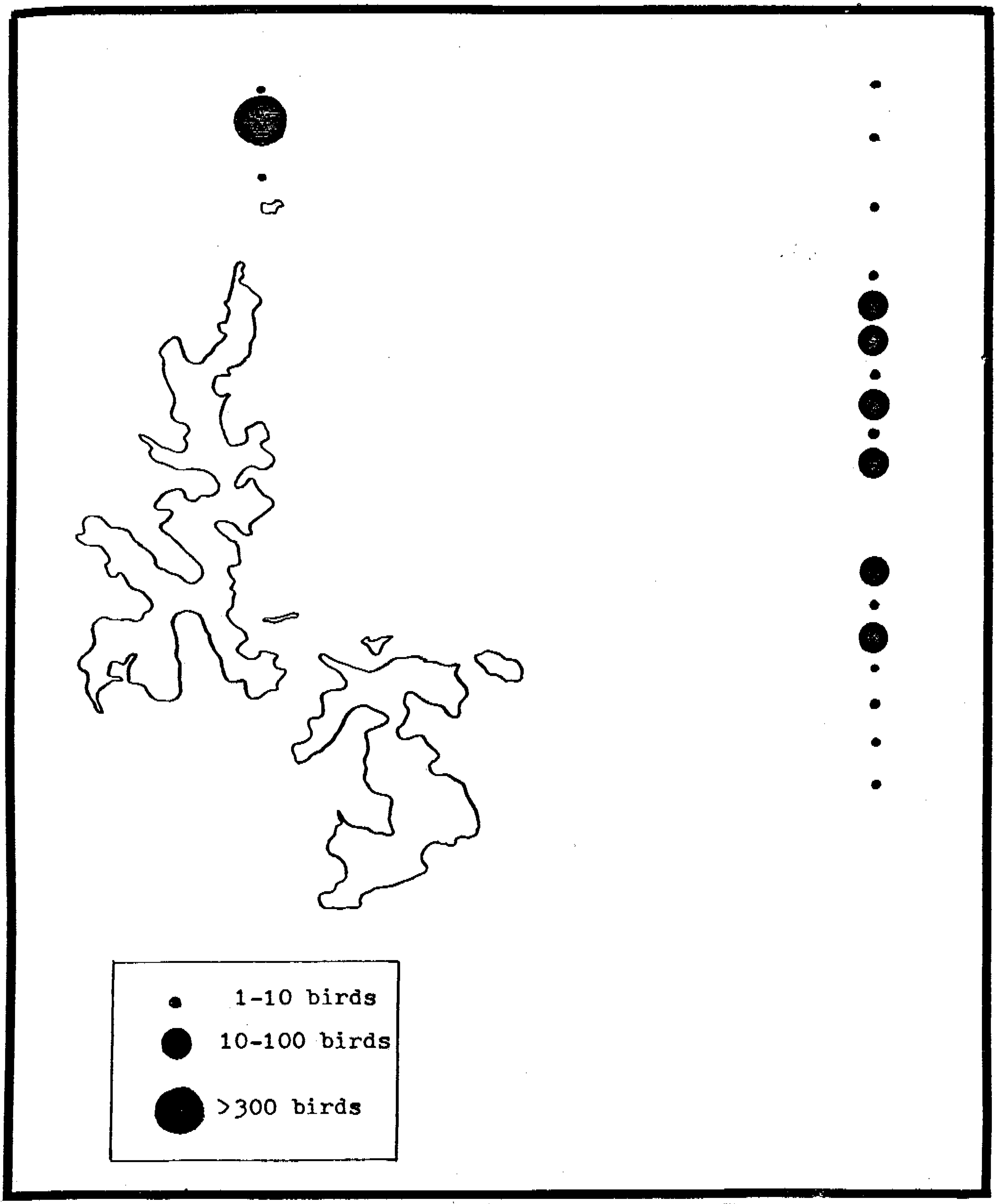

Figure 27. Distribution of "unidentified small alcids" during aerial transect at 1500 on 16 July, 1975.

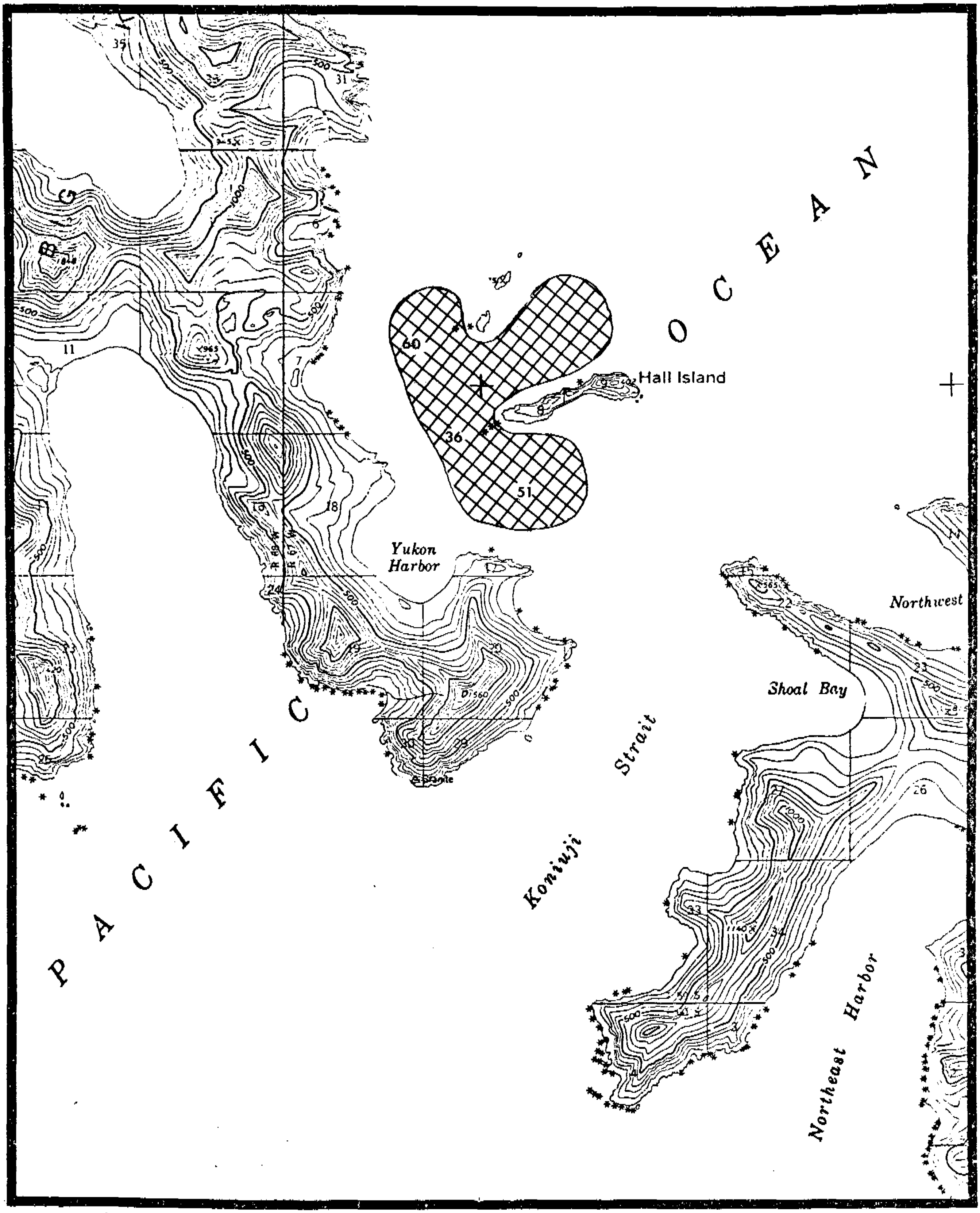

Figure 28. Feeding area of the Hall Island Ancient Murrelets. Depths are shown in meters.

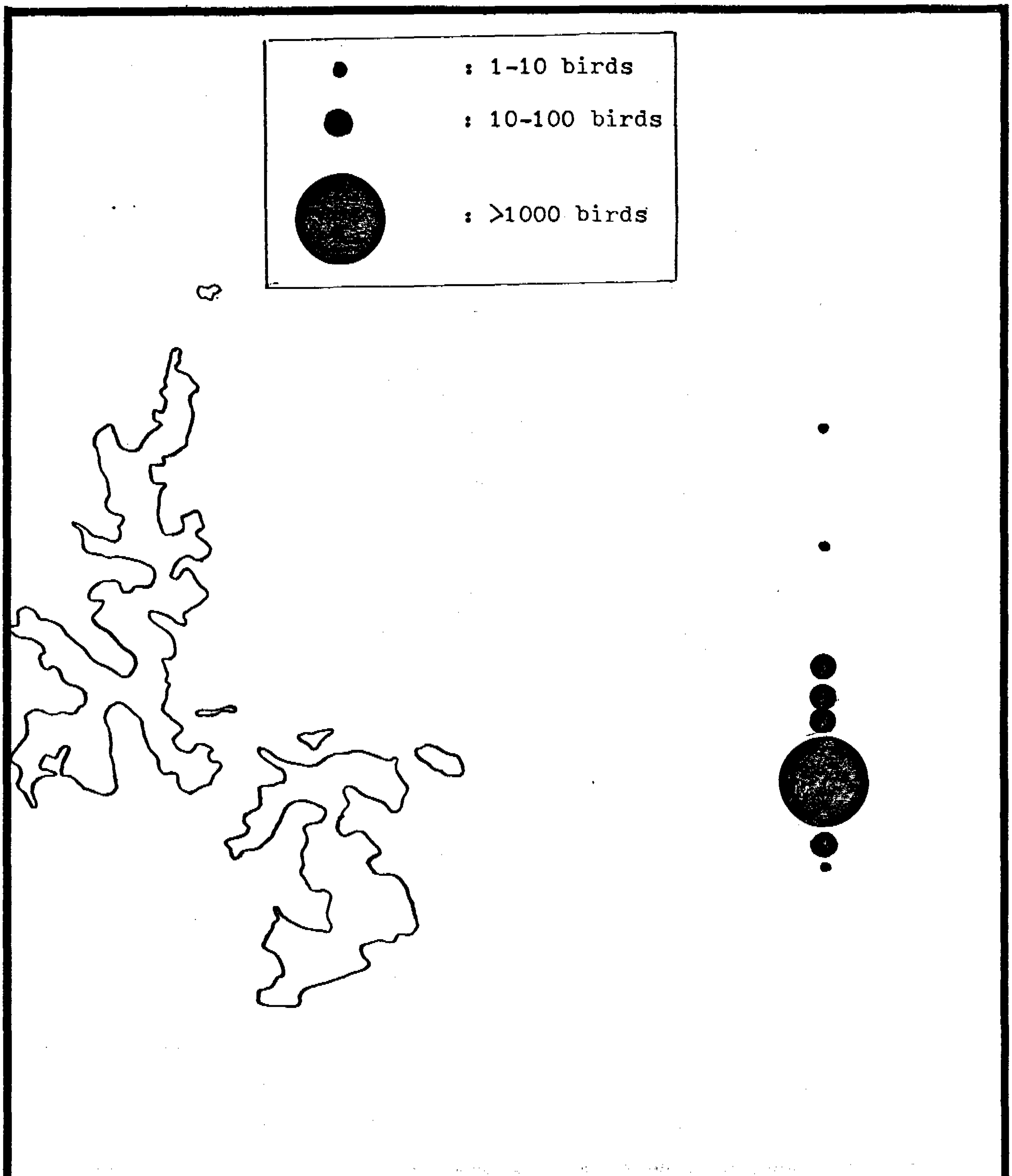

Figure 29. Distribution of Fork-tailed Storm Petrels during an aerial transect at 1600 on July 16, 1975.

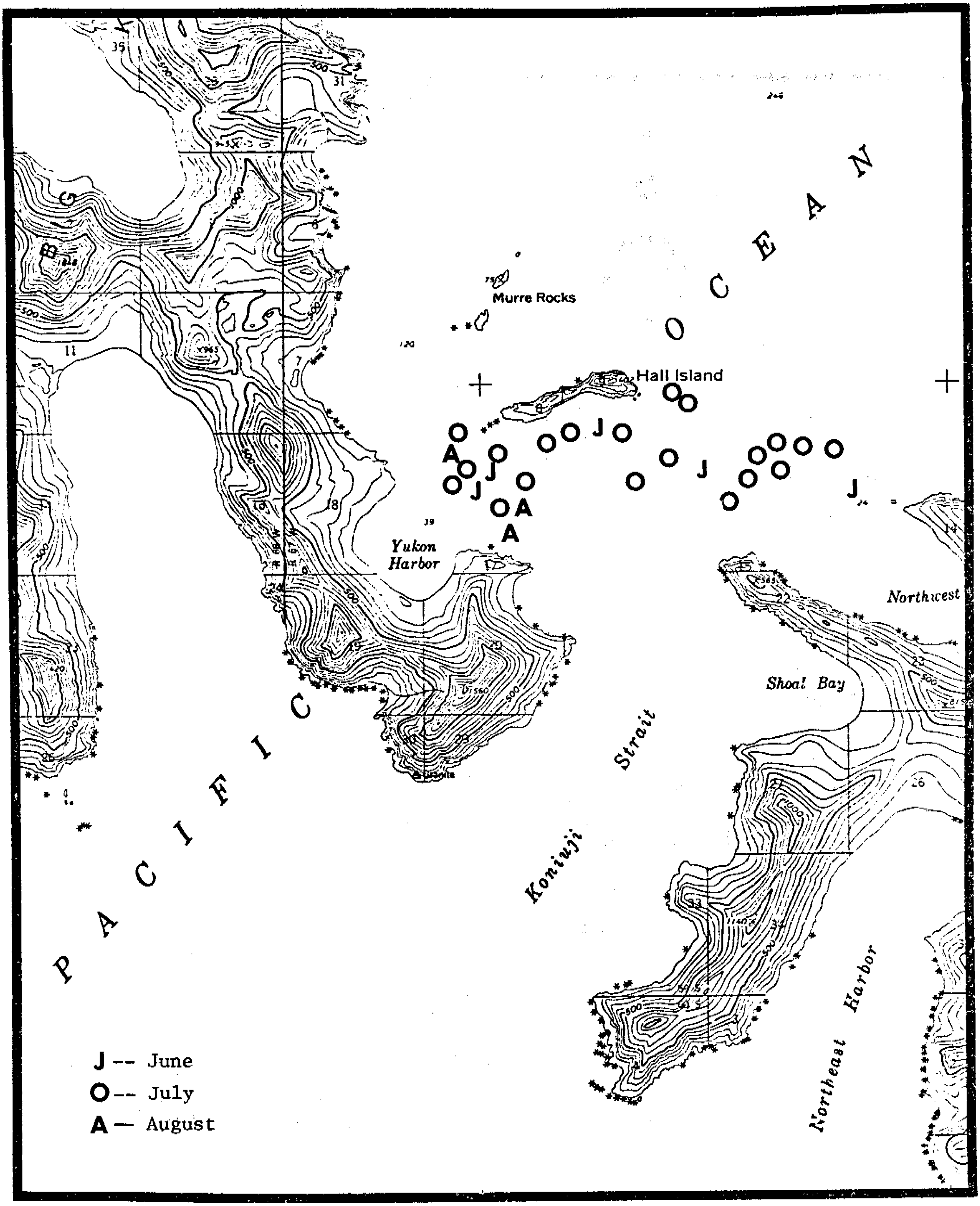

Figure 30. Location of the Minke Whale sightings in the Hall Island area, 1976

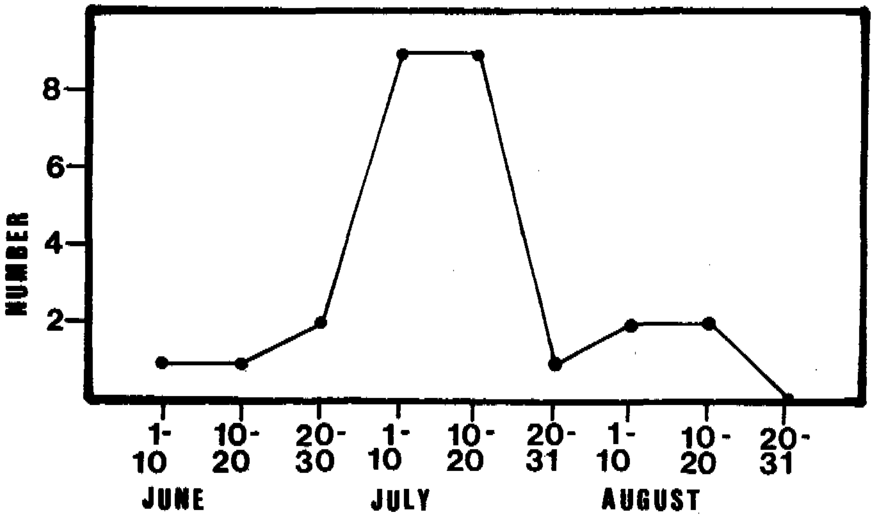

Figure 31. Numbers of Minke Whales seen in the Hall Island area, 1976.

ADDENDUM I

PLANTS COLLECTED IN THE BIG KONIUJI AREA OF THE SHUMAGIN ISLANDS
8 June - 29 August, 1976

(Unless otherwise noted, the plants were collected by R. Allen Moe, USFWS)

001. *Draba hyperborea.* 8 June, 1976
Big Koniuji Island, Yukon Head: beach cliff; cliff face

002. *Primula cuneifolia saxifragifolia.* 13 June, 1976
Big Koniuji Island, Otter Cove: granite crevice; cliff face

003. *Viola Langendorfii.* 13 June, 1976
Big Koniuji Island, Yukon Head: meadow; mixed meadow

004. *Androsace chamejasmine.* 13 June, 1976
Big Koniuji Island, Yukon Head: scree slope; neutral feldmark

005. *Draba borealis.* 14 June, 1976
Big Koniuji Island, Long Bay: scree slope and beach dune sand; dune

006. *Arctystaphylos alpina.* 15 June, 1976
Big Koniuji Island, Yukon Head: crowberry heath

007. *Rubus spectabilis.* 15 June, 1976
Big Koniuji Island, Yukon Harbor: alder slope

008. *Dactylorhiza aristata.* 15 June, 1976
Big Koniuji Island, Long Bay: meadow; mixed meadow

009. *Anemone Narcissiflora villosissima.* 22 June, 1976
Big Koniuji Island, Yukon Harbor: meadow; mixed meadow (2 sheets)

010. *Loiseleuria procumbens.* 22 June, 1976
Big Koniuji Island, Yukon Harbor: crowberry heath

011. *Saxifraga bracteata.* 24 June, 1976
Big Koniuji Island, Koniuji Head: wet, rocky cliffs; neutral feldmark

012. *Draba hyperborea.* 25 June, 1976
Hall Island: beach cliff

013. *Castilleja unalaschensis.* 4 July, 1976
Big Koniuji Island, Sandpiper Lagoon: meadow; mixed meadow (2 sheets)

014. *Cardamine praternsis angustifolia.* 4 July, 1976
Big Koniuji Island, Sandpiper Lagoon: meadow; mixed meadow

015. *Cochlearia officinialis oblongifolia.* 4 July, 1976
Big Koniuji Island, Sandpiper Lagoon: meadow; mixed meadow

016. *Arabis hirsuta Escholtziana.* 4 July, 1976
Big Koniuji Island, Sandpiper Lagoon: meadow; mixed meadow

017. *Saxifraga punctata insularis.* 5 July, 1976
Big Koniuji Island, Koniuji Head: wet talus crevice (elev. 1000 ft.), neutral feldmark

018. *Ranunculus Escholtzii.* 10 July, 1976
Big Koniuji Island, Koniuji Head: north-facing wet scree (elev. 1000 ft.), neutral feldmark

019. *Geum calthifolium.* 13 July, 1976
Big Koniuji Island, Yukon Harbor: crowberry heath

020. *Lagotis glauca glauca.* 13 July 1976
Big Koniuji Island, Yukon Harbor: crowberry heath (22 sheets)

021. *Cardamine umbellata.* 13 July, 1976
Big Koniuji Island, Yukon Head: wet scree; neutral feldmark

022. *Iris setosa setosa.* 22 July, 1976
Big Koniuji Island, Sandpiper Lagoon: wet meadow; mixed meadow

023. *Pinguicula vulgaris vulgaris.* 22 July, 1976
Big Koniuji Island, Sandpiper Lagoon: very wet areas near ponds

024. *Drosera rotundifolia.* 22 July, 1976 (not flowering)
Big Koniuji Island, Sandpiper Lagoon: very wet meadow

025. *Stellaria crassifolia.* 22 July, 1976
Big Koniuji Island, Sandpiper Lagoon: wet meadow - understory to dense stand of *Coeloglossium virede.* Mixed meadow

026. *Coeloglossium virede bracteatum.* 22 July, 1976
Big Koniuji Island, Sandpiper Lagoon: wet meadow; mixed meadow

027. *Sanguisorba stipulata.* 22 July, 1976
Big Koniuji Island, Sandpiper Lagoon: meadow; mixed meadow

028. *Achillea borealis.* 22 July, 1976
Big Koniuji Island, Sandpiper Lagoon: meadow; mixed meadow

029. *Aster sibiricus.* 22 July, 1976
Big Koniuji Island, Sandpiper Lagoon: meadow; mixed meadow

030. *Polygonum viviparum.* 22 July, 1976
Big Koniuji Island, Sandpiper Lagoon: meadow; mixed meadow

031. *Plantanthera dilatata.* 22 July, 1976
Big Koniuji Island, Sandpiper Lagoon: meadow; mixed meadow

032. *Plantago macrocarpa.* 22 July, 1976
Big Koniuji Island, Sandpiper Lagoon: meadow; mixed meadow

033. *Claytonia sibirica.* 23 July, 1976
Big Koniuji Island, Yukon Harbor: wet meadow; mixed meadow

034. *Barbarea orthoceras.* 23 July, 1976
Big Koniuji Island, Yukon Harbor: wet meadow; mixed meadow

035. *Juncus arcticus. sitchensis.* 22 July, 1976
Big Koniuji Island, Sandpiper Lagoon: streamside; mixed meadow

036. *Carex lyngbaei.* 22 July, 1976
Big Koniuji Island, Sandpiper Lagoon: streamside; mixed meadow

037. *Carex pluriflora.* 22 July, 1976
Big Koniuji Island, Sandpiper Lagoon: streamside; mixed meadow

038. *Plantago macrocarpa.* 24 July, 1976
Peninsula Island: flysch cliff

039. *Campanula latisepala.* 24 July, 1976
wet meadow; mixed meadow

040. *Mimulus guttatus.* 24 July, 1976
Peninsula Island: in dense mat on very wet cliff

041. *Polemonium acutiflorum.* 24 July, 1976
Big Koniuji Island, west side: meadow; mixed meadow

042. *Chrysanthemum arcticum arcticum.* 24 July, 1976
Peninsula Island: steep wet flysch slope; neutral feldmark

043. *Montia fontana.* 24 July, 1976
Peninsula Island: in dense mat with *Mimulus guttatus* on very wet flysch cliff; cliff face wet

044. *Romanzoffia unalaschensis.* 29 July, 1976
Big Koniuji Island, Koniuji Head: north-facing wet scree (elev. 1000 ft.); neutral feldmark

045. *Cerastium Beeringianum grandiflorum.* 29 July, 1976
Big Koniuji Island, Koniuji Head: north-facing wet meadow (elev. 1000 ft.); mixed meadow

046. *Campanula lasiocarpa laisocarpa.* 29 July, 1976
Big Koniuji Island, Koniuji Head: meadow (elev. 1000 ft.); neutral feldmark

047. *Heuchera glabra.* 29 July, 1976
Big Koniuji Island, Koniuji Head: meadow (elev. 1000 ft.); neutral feldmark

048. *Senecio resedifolius.* 29 July, 1976
Big Koniuji Island, Koniuji Head: meadow (elev. 1000 ft.); neutral feldmark

049. *Pedicularis kanei.* 29 July, 1976
Big Koniuji Island, Koniuji Head: north-facing wet meadow; neutral feldmark

050. *Rubus arcticus stellatus.* 29 July, 1976
Big Koniuji Island, Koniuji Head: meadow (elev. 1000 ft.);

051. *Antenaria monocephala monecephala.* 29 July, 1976
Big Koniuji Island, Koniuji Head: fell-field tundra; neutral feldmark

052. *Oxyria digna.* 29 July, 1976
Big Koniuji Island, Koniuji Head: north-facing wet scree (elev. 1000 ft.); neutral feldmark

053. *Veronica Stelleri.* 29 July, 1976
Big Koniuji Island, Koniuji Head: meadow (elev. 1000 ft.); mixed meadow

054. *Artemisia arctica arctica.* 29 July, 1976
Big Koniuji Island, Granite Pass: meadow (elev. 800 ft.); mixed meadow

055. *Ranunculus reptans.* 31 July, 1976
Little Koniuji Island, Northeast Harbor: warm, shallow fresh-water pond

056. *Ranunculus trichophllus hispidulus.* 31 July, 1976
Little Koniuji Island, Northeast Harbor: warm, shallow fresh-water pond

057. *Sparganium angustifolium.* 31 July, 1976
Little Koniuji Island, Northeast Harbor: warm, shallow fresh-water pond - in water 1½ ft. deep

058. *Potentilla palustris.* 31 July, 1976
Little Koniuji Island, Grosewold Marsh: wet meadow; mixed meadow

059. *Potentilla Egedii grandis.* 31 July, 1976
Little Koniuji Island, Grosewold Marsh: wet meadow and margin of fresh-water lake mixed meadow

060. *Swertia perennis.* 31 July, 1976
Little Koniuji Island, Grosewold Marsh: meadow; mixed meadow

061. *Geum calthifolium.* 31 July, 1976
Little Koniuji Island, Grosewold Marsh: meadow; mixed meadow

062. *Rhododendron camtschaticum camtschaticum.* 5 August, 1976
Big Koniuji Island, Yukon Harbor: alpine heath (elev. 500 ft.)

063. *Taraxacum trigonolobum.* 5 August, 1976
Big Koniuji Island, Granite Pass: alpine meadow (elev. 700 ft.); mixed meadow

064. *Gentiana algida.* 5 August, 1976
Big Koniuji Island, Granite Pass: north-facing meadow (elev. 600 ft.); neutral feldmark

065. *Dryas octopetala.* 5 August, 1976
Big Koniuji Island, Granite Pass: alpine heath (elev. 700 ft.)

066. *Potentilla villosa.* 5 August, 1976
Big Koniuji Island, Koniuji Head: moist rock crevice (elev. 700 ft.): cliff face

067. *Armeria maritima.* 5 August, 1976
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068. *Cornus suecica* (possibly hybrid with *C. canadensis* as stamens both longer as well as shorter than styles). 5 August, 1976
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069. *Antennaria monocephala monocephala.* 5 August, 1976
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NOTES ON THE WINTER SEABIRDS OF CHINIAK BAY, KODIAK ISLAND, ALASKA

by

Matthew Dick

Part XI
of

POPULATION DYNAMICS AND TROPHIC RELATIONSHIPS OF MARINE BIRDS IN THE GULF OF ALASKA AND SOUTHERN BERING SEA

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INTRODUCTION

Most efforts in the study of Alaska's marine bird resources have involved pelagic distribution/abundance and breeding distribution/behavior. We thus have little information on winter or bay and nearshore populations.

Published accounts of the avifauna of Kodiak Island and its surrounding waters are few and, for the most part, lacking in details. Gabrielson and Lincoln (1959) summarize all published information up to their publication date including accounts by Bretherton (1896), Freedmann (1935), Howell (1948), and Arnold (1948). A number of people have kept winter records on Kodiak in recent years. Rich MacIntosh has observed along the shores of Chiniak Bay and on the bay itself since about 1973. As he generally spends one or more summer months in the Bering Sea, he does much of his birding in the winter. MacIntosh has accumulated piecemeal data from many people including fisheries biologists, trappers and fishermen. Since 1973, William Donaldson (1974, 1975, 1976, 1977) has coordinated the Christmas bird count in Kodiak, and each year a team has covered the bay by skiff during the count. In December 1974, Gerry Atwell and the Kodiak National Wildlife Refuge staff censused seabirds around Kodiak Island from the M/V Aleutian Tern (Atwell 1975). In the winter of 1975-76, Paul Arneson of the Alaska Department of Fish and Game conducted an aerial census of seabirds around Kodiak Island (Arneson 1977).

METHODS

Most of my observations were made during day trips out of Kodiak in a 24 ft dory, although on two occasions I used a 16 ft Boston Whaler. Most of these surveys were conducted on weekends and holidays which coincided with good weather. Such restrictions allowed me to get out only several times a month. Trips were generally 3-6 hours in duration. Since I was primarily interested in collecting specimens for stomach content analysis, I did not travel any farther than Long Island or Viesoki Island (figure 1). Most trips were limited to the islands between Kodiak and Long Island, and south to Puffin Island. Sufficient numbers of the common and abundant winter seabirds could always be found in that area. Usually, I recorded notes into a cassette tape recorder and transcribed them after returning to Kodiak.

The Chiniak Bay road system provides an excellent means for observing seabirds. This was demonstrated on 23 January when Cal Lensink, Jim Bartonek and I drove to Cape Chiniak, stopping at suitable spots to glass the bay with binoculars and spotting scope. By the end of the day we felt we had a pretty good idea of what birds were in the three inner bays, and in what relative abundance. The next day, we complemented the road system trip with a 3.5 hour long boat trip to Dolgoi Lagoon. The day long road trip turned up five less species on the water than the shorter boat trip. Rich MacIntosh has been using the road system for years, and has a regular route that can be covered in half a day. Because of time and vehicular limitations, I did very little observing from the road system.

Another excellent avenue of observation is the docks in downtown Kodiak. From the Whitney Fidalgo cannery to Gibson Cove, there are nearly two miles of waterfront. Thousands of ducks and gulls are attracted to the canneries by the gurry they put out. Cannery row is an excellent place to look for marked gulls.

The Kodiak fishing fleet is a rich source of information. The King and Tanner crab fleet is reputed to shoot thousands of gulls every winter for crab bait. One such bait gull resulted in a band return from the Geese Islands last winter. Some fishermen are fairly reliable observers (e.g., Jeff Allen aboard the Point Omega) and can identify most of what they see. Mr. Allen, for one, keeps records of his observations. On occasion, large numbers of birds wreck aboard fishing boats. If the fishermen can be induced to bring some of these frozen, one can obtain feeding and distributional information.

I made fifteen trips on the water and one on the road system from 21 November to 3 May. I spent 10-11 November observing at Port Wakefield, and collected three Marbled Murrelets there. I kept a checklist of birds observed on each trip onto Chiniak Bay, and noted order of magnitude for each species. This gave a rough order of magnitude for Chiniak Bay. For instance, if a thousand Oldsquaw were noted in St. Paul Harbor and around the islands between Kodiak and Woody Island, then there were likely 'thousands' on Chiniak Bay, or somewhere betweeen one and five thousand. Having spent the two previous summers in the area, I was in a good position to compare bird usage of the bay in winter and summer. The winter of 1976-77 was exceptionally warm, with unusual winds and higher than normal surface water temperatures.

Specimens were collected with a 12 guage shotgun. Formalin was injected into the alimentary tract of each specimen immediately after collection to prevent further digestion. Specimens were either frozen for future analysis or, more often, opened up the same day in the laboratory of the Alaska Department of Fish and Game in Kodiak.

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The following Kodiak residents helped me one or more times each: Fred Ogden, John Putney, Irving Warner, Rich MacIntosh, Nell Terpening and Mary Ann Taranto. USFWS biologists Cal Lensink, Jim Bartonek, Margaret Petersen and John Trapp went out on one or more trips.

RESULTS

Following is an annotated list of seabirds observed in Chiniak Bay during the winter of 1976-77. I include my own observations and records that were given to me by local observers, mostly fishermen. Following the common name of each species, in parentheses, is the number of birds observed on the 1976 Christmas Bird Count (see Addendum I).

Loons. (CBC: Common Loon and Red-throated Loon observed during count period). Uncommon last winter, though MacIntosh has seen more other winters. One Arctic Loon was seen on 21 Nov., one Red-throated Loon on 22 Dec., and undentified loons on three occasions from November to January.

Red-necked Grebe. (CBC:5) Two were observed in Womens Bay on 23 Jan. and one in Dolgoi Lagoon on 27 Feb.

Horned Grebe. (CBC:12) This species was observed on 8 days from 12 Dec. to 17 Apr. It was found close to shore, anywhere in the bay. A few were present in Dolgoi Lagoon throughout January and February. Horned Grebes were also seen in Near Island Channel and between Kalsin Bay and Cape Chiniak.

Double-crested Cormorant. (CBC:27) The estimated winter density on the bay was 200-300. This species is uncommon in Chiniak Bay in summer, but does not breed there. It breeds sparsely around Spruce Island, Marmot Bay, and by the hundreds on southern Afognak Island. In winter, the Afognak birds, or some other population, move into Chiniak Bay. I saw them on 14 days from 21 Nov. to 3 May. They occupy loitering rocks with the other two cormorants. The most I saw at one time were about 25 on rocks at the base of the Nyman Peninsula on 21 Nov. Double-cresteds began to thin out in late March to early April. On 3 May I saw several on a grassy knoll at the SW tip of Zaimka Island. Although they looked as though they might breed, they were not present there later in May. Most of the wintering birds were adults, though a few subadults were present. Apparently this species feeds on large fish in winter. The individual collected on 5 Dec. contained sizeable fish remains. On 6 Mar. I watched a bird take a 25-30 cm long fish within 10 m of shore along Spruce Cape Peninsula.

Red-faced Cormorant. (CBC:8) This is quite a common breeder in Chiniak Bay, where there were at least 700 in the summer of 1975. There were fewer than 50 in the bay last winter. It is difficult to tell Red-faceds from Pelagics in winter. Some black-plumaged Red-faceds had tan bills; these may have been second winter immatures. Red-faceds occupied loitering rocks with the other two cormorants. They were first seen on the cliffs on 3 May.

Pelagic Cormorant. (CBC:167) An estimated 400-600 wintered on Chiniak Bay, making this species the most abundant cormorant. Both adults and subadults were present, though the former outnumbered the latter. Quite often, Pelagics were seen sitting on the floatplane docks near Kodiak Western Airlines, and on rocks along Near Island Channel. A few of them fed in Near Island Channel, and even in the small boat harbors on occasion. They loitered on rocks and buoys throughout the bay. They fed in shoal waters such as the area south of the Nyman Peninsula.

Emperor Goose. (CBC:108) As many as 300 may have wintered on the bay, though perhaps not all winter. I did not see any until 26 Dec., when there were at least 100 on rocks near Cliff Island. I noted fewer than ten on each of three days from January to March. From late March to early May, numbers increased. On 27 Mar. there were 8 adults and 10 juveniles on rocks near Gibson Cove. I noted a couple hundred on 3 May. Emperors generally used exposed rock piles, such as those around Cliff Island, between Cliff Point and Puffin Island, and the Discovery Rocks. They also stood on beaches in the inner bays and Dolgoi Lagoon.

Mallard. (CBC:261) An estimated 300-400, including adults of both sexes and juveniles, wintered around the bay. Many of these were on freshwater, though some occupied sheltered lagoons and bights.

Greater Scaup. (CBC:482) My records on this species are not good. I recorded it on the checklist on 6 days from 21 Nov. to 27 Feb., but I remember seeing scaup on many days along cannery row. Most of the winter, there were tens of scaup on Shahafka Cove Lagoon.

Common Goldeneye (CBC:615) This species was ubiquitously distributed on sheltered saltwater such as Dolgoi Lagoon, St. Paul Harbor, the mouth of Buskin River, Near Island Channel, Dog Bay, Womens Bay, and so forth. I noted it on 12 days from 21 Nov. to 27 Apr. There were 200-300 in Settlers Cove (Port Lions) on 10-11 Nov.; I noted such groups as 2M9F, 4M15F, 14M3F, 7M12F, around 200 mostly F (M=male; F=female or juvenile). The goldeneyes were diving with tens of Buffleheads in the shallows inside the Port Lions causeway. The two species often grouped together, as in Dolgoi Lagoon and Dog Bay, though the former outnumbered the latter. Probably 700-1,000 wintered on Chiniak Bay.

Bufflehead. (CBC:145) See notes under the above species. An estimated 200-300 wintered on and around Chiniak Bay. Buffleheads were noted on eight days from 21 Nov. to 27 Feb. The species was found close to shore in sheltered lagoons, open channels and the inner bays. In Settlers Cove on 10-11 Nov. there were at least a hundred; some groupings were 2F, 1 pair, 4 pair, 3F, 20 (M and F). Similar small flocks were observed on Chiniak. We observed them in low numbers in all three major sub-bays on 23 Jan.

Oldsquaw. (CBC:2,321) This was the most abundant duck last winter, when 3,000-5,000 occupied Chiniak Bay. There were 60 in Settlers Cove on 10 Nov., and many thousands winter in the Kodiak Archipelago.

The Oldsquaw is not a sheltered water duck like the Common Goldeneye. In moderate weather singles, pairs and small flocks were distributed in shoal waters throughout the bay. Nonetheless, there were areas of intensive usage for loitering, as well as feeding. One of these was around Bird Island. Throughout the winter, from several hundred to over a thousand could be seen in dense aggregations over the reefs to the north and the south, or between Bird Island and Holiday Island. The harbor between cannery row and the Gull-Uski Island complex was used heavily. In bad weather, especially, one could count on seeing over a thousand there. On 25 Nov. a 15 minute transect between Zaimka Island and Gull Island (one which we commonly ran in summer) yielded 34 males, 22 female types, and 80 of unidentified age/sex. In summer, the transect never yielded more than 86 birds total. Winter Oldsquaw densities like the above were not uncommon inside the 10 f depth contour.

Seven of the Oldsquaws collected were shot over water 9 f or less in depth; two were from water of 7-13 f. The frequency of occurrence of food items in nine specimens is portrayed in Table 1.

Mysids were clearly the most important food of Oldsquaws last winter. In several cases, the stomach and crop of a specimen were jammed full of the tiny crustaceans. Not a single specimen had an emtpy stomach. Oldsquaws overlapped in their feeding with Marbled Murrelets and Crested Auklets. The ducks utilized different areas and more food species than the alcids. Oldsquaws fed by the hundreds along cannery row, quite close to the docks, though whether they took cannery gurry or organisms attracted to the gurry was not determined. Interestingly, Oldsquaws were observed on several occasions flapping their wings underwater as they descended, exactly as alcids do. Undoubtedly they did it all the time, but the water was rarely clear enough to see through.

Harlequin. (CBC:533) I estimate that 700-1,000 wintered in Chiniak Bay. This species' preferred habitat in winter, as in summer, was along rocky shoreline, very close to shore. My notes on the species are not good. It seemed to me that there were approximately as many present in winter as in summer. On our 23 Jan. road trip, we found Harlequins to be common in the inner bays. They are one of the most ubiquitous species in winter, being found wherever there is suitable habitat.

King Eider. (CBC:6) An estimated 20-25 wintered in Chiniak Bay. I saw the same three birds (1 ad M, 2 ad F) on four occasions from 26 Dec. to 27 Feb. at the mouth of Dolgoi Lagoon. The Christmas Bird Count turned up a few more. Jeff Allen saw 12 near town on 2 May. Apparently the species winters in greater numbers in other parts of the archipelago. Mr. Allen reported that 12-15 flew aboard his fishing vessel during each weekly nighttime passage through the Geese Islands in March and early April 1973. He reported them common in mixed flocks in Whale Passage and in Uyak Bay where he was crabbing during the third week of February 1977.

Common Eider. (CBC:110) Probably no more than 200 wintered in Chiniak Bay last winter. This species was fairly ubiquitous inside the 10 f contour. Small flocks were commonly seen near shore and around rock complexes like Discovery Rocks or those north of Cliff Island. Generally, somewhere on the bay, one could find at least one aggregation of 50-100 birds in addition to the scattered small flocks. By 27 Mar. there were many pairs evident in a flock of 60 near Zaimka Island, and there were small groups (2M1F, 3M2F, 1M3F) elsewhere.

Steller's Eider. (CBC:1,179) Next to the Oldsquaw, this was the most abundant duck in Chiniak Bay, where an estimated 1,500-2,000 wintered. The species preferred sheltered water along rocky shore, and in this respect differed from the Common Eider, which was seen around exposed reefs and islands in mid bay or sitting on gravel beaches of islands. Until January, female types greatly outnumbered adult males. Typical flocks were 41F4M on 21 Nov., 59F1M on 25 Nov., 40F and 100F on 12 Dec. In January, more males began to appear, and this trend continued until spring. On 1 Mar. some flocks of tens contained a F:M ratio of 10:1. In several flocks of hundreds, the F:M ratio was 2:1 or 3:1. On 27 March, some flock compositions were 60F18M, 30F2M, 4F1M, 150 with 30-40%M, 2F5M, 1F3M, 6 pairs, 20F4M. The birds were beginning to pair by 16 Feb. When large flocks flew, pairs were evident in the lines of birds. There were many pairs in flocks on 1 Mar.

Some typical haunts of Steller's Eiders were around Gull and Uski Islands, around the islands between Near Island and Woody Island, Dolgoi Lagoon, the northern bight of Long Island, and the SW bight of Woody Island. Over a hundred commonly fed along the east shore of Holiday Island. Two females collected there on 12 Dec. contained the greatest diversity of organisms I have ever seen in a stomach: five to ten (perhaps more) species of polychaete worm, Hiatella, the common intertidal holothuroid (Cucumaria?), one or more species of amphipod, and other intertidal or near subtidal invertebrates. A female collected on 27 Feb. contained polychaete and mollusk remains.

White-winged Scoter. (CBC:124) I estimate that 200-300 were on the bay last winter. Generally singles and flocks of less than 10 were encountered. A few could usually be found on Dolgoi Lagoon. On 27 Mar., there were 40-50 in a flock between Puffin and Zaimka Islands; this was the largest group I saw. I observed them on 16 days from 21 Nov. to 3 May.

Surf Scoter. (CBC:10) Less common than the White-winged, this species was observed on 7 days from 21 Nov. to 17 Apr. I estimate fewer than 50 wintered on the bay. From November through February, only groups of 1-5 males were seen, except for a pair on 27 Feb. The most noted on any day were around ten with a flock of White-winged and Black Scoters on 27 Mar.

Black Scoter. (CBC:487) Probably 1,000-1,500 wintered on the bay. I observed it every trip I made from 21 Nov. to 3 Mar., 16 days in all. Like Steller's Eider, the duck seemed to prefer sheltered waters such as Dog Bay, Near Island Channel, Dolgoi Lagoon, around Zaimka and Cliff Islands, Gibson Cove, Woody Island Channel, Etc. It was fairly common in all three inner bays on the 23 Jan. road trip. The preferred habitat was very close to rocky shore. Small flocks (fewer than ten to a few tens) composed of both sexes were the rule, though flocks of 100-200 were not uncommon.

Red-breasted Merganser. (CBC:24) Somewhat more abundant than the Common Merganser, this species was sighted on 7 days from 25 Nov. to 8 May. Probably only a few tens occupied Chiniak Bay last winter. A few could usually be found in Dolgoi Lagoon.

Bald Eagle. (CBC:111) 100-200 were present on the bay last winter, perhaps more. Many long-time residents, especially fishermen, remarked upon the unusual number of eagles along cannery row and over the small boat harbor, especially in January - February. Fishermen, eager for a show, would throw old herring bait out to attract eagles, and on occasion I saw 30-40 circling out from a boat, swooping down to pick up the food. Many of these were immatures. A foreman at Kodiak King Crab cannery counted 40 in trees on the slope above the cannery. I often saw 10-30 perched there. Bald Eagles were scattered on islands and along shore throughout the bay, however. No one seems to know why there were so many eagles around town last winter.

Golden Eagle. (CBC:1) There was one over the town of Kodiak on 2 Jan.

Peregrine Falcon. (CBC:1) Uncommon, but a few were present all winter. On 24 Mar. biologist Frank van Hulle watched a peregrine kill a crow in his yard near Rezanof St., Kodiak.

Black Oystercatcher. (CBC:36) Probably 100-150 occupied Chiniak Bay last winter. Often I covered a lot of area and saw none, but when flocks were observed, they tended to be sizeable, up to 70 strong. This indicates the few present tended to be gregarious, though occasional small groups were noted. I recorded oysercatchers on 10 days from 21 Nov. to 14 May. On 27 Feb., it seemed as though the birds may have been moving back onto territories, as a pair and two singles occupied shore around Bird Island. There was no more evidence of this until 3 May, when pairs were definitely on territories.

Rock Sandpiper. (CBC:86) This species did not appear to be abundant last winter. I saw a few on four days from 25 Nov. to 27 Apr.

Glaucous Gull. (CBC:2) Probably a few tens were present on the bay last winter. I noted them on four days from 21 Nov. to 26 Dec.

Herring Gull. (CBC:2) Probably a very few present all winter. MacIntosh and I saw one adult on 21 Nov. I did not note any after that.

Glaucous-winged Gull. (CBC:1,044) This was an abundant seabird, yet my notes on it are skimpy. There were so many around the docks all winter, and I spent so much time on the docks, that eventually I stopped counting them. Hundreds could be seen on cannery roofs where processing was going on. I noted 1-2 thousand on roofs at Gibson Cove during the last week in January. I estimate that 1-2 thousand were present around the town of Kodiak all winter, and 2-3 thousand on Chiniak Bay. The farther one went from town, the fewer gulls he encountered.

The existence of a heavy winter fishery around Kodiak Island has no doubt changed the winter gull distribution from former days. Hundreds follow fishing boats on the crab grounds and take throwback crabs and bottom invertebrates brought up with the pots. A crewmember on one of the highliners told me last April that at least 15 of the boats in the Kodiak Tanner fleet use gulls extensively for hanging bait. He estimated that 11,000 to 15,000 birds were shot annually and that single boats took up to 80 a day. Boats larger than 80' or so have trouble maneuvering after shooting gulls and do not take them. I saw pump shotguns on the deck of one crab boat, and know from remarks of the crew that they were used for shooting bait gulls.

Adults, immatures and juveniles were all present. Adults in winter have gray heads, and this leads the unfamiliar observer to call them immatures.

The Glacuous-winged Gulls which breed in Chiniak Bay seem to move south in winter, at least some juveniles do. Two chicks banded on Zaimka Island in 1975 turned up in Astoria, Oregon, and at the Tsakawis River mouth in British Columbia. A chick banded near Nelson Lagoon in July 1976 was recovered in January 1977 in the Geese Islands, indicating that at least some of the birds wintering around Kodiak came from westward and northward.

Gulls used the intertidal heavily for feeding. On a low tide, one could see hundreds picking food from among the algae on the shores of Gull, Uski and Near Islands, and they presumably fed this way in other areas.

Mew Gull. (CBC:1,111) Adults, immatures and juveniles were present along the waterfront by the hundreds. I estimate 1,000 to 2,000 wintered on Chiniak Bay. At times along cannery row, one could see more Mew than Glaucous-winged Gulls, probably because many of the latter had followed fishing boats out. Mews were scattered sparsely around the bay, but their concentration was near town. Mews also utilized the intertidal along with Glaucous-winged Gulls. On 16 Feb., I noted hundreds of gulls, MEGU outnumbering GWGU 2:1, feeding on the shores of Gull, Uski, Round and part of Near Islands. There must have been a total of 2,000 gulls in the intertidal around St. Paul Harbor on that occasion.

Black-legged Kittiwake. (CBC:2) This species was surprisingly common near the town of Kodiak, often coming close to the docks to scavenge gurry or feed on gurry-attracted organisms with the Mew Gulls. A few tens occupied the bay at any given time. I counted 1 adult and 10 sub-adults in Near Island Channel on 25 Nov. and more could have been found around the rest of cannery row. I noted them on 9 trips from 21 Nov. to 1 Mar. and saw them frequently as I was working on the docks. The arrival date for breeders was 1 Apr.; on that day I saw several hundred in a flock off the Gibson Cove colony. On 17 Apr. there were several thousand massed on the water off the Viesoki Island colony.

Common Murre. (CBC:105) Probably 100-300 were present on Chiniak Bay last winter. I noted them on 14 days from 21 Nov. to 3 May. Usually I saw 1-3 a day, but on 26 Dec. I recorded flocks of 10, 5 and 5 and many groups of from 1-3 birds, all totaling 63. On 7 days, birds were observed in St. Paul Harbor, Near Island Channel or along Cannery Row, where they came within 100' of the docks. This was not a sheltered water species; the open sea and channels around Woody Island seemed the best areas to look for them. A summer plumaged bird was seen on 25 Feb. All others from November to May were in winter plumage.

Thick-billed Murre. (CBC:0) A group of three between Popof Island and the southern tip of Woody Island on 5 Dec. was the only record all winter.

Pigeon Guillemot. (CBC:54) I estimate 150-300 wintered in Chiniak Bay. The species seemed to feed in a wide range of depths, from less than a fathom to 21 f or more. It was widely but sparsely distributed inside the 20 f contour. One could find a few almost anytime in Near Island Channel, Dog Bay, north of Woody Island, along Spruce Cape, in Woody and Long Island Channels, in St. Paul Harbor, in Womens Bay, and so forth. The largest group observed was a flock of 10 on 24 Jan.; all other observations involved 1-3 birds. On 8 Jan., I recorded 3,1,1,pair,pair, 2,1,pair along Spruce Cape Peninsula. The groupings were similar to those of the Marbled Murrelet in winter.

The molt to summer plumage seemed to begin by January, with black mottling appearing on the breast. By 27 Mar. most birds had molted to black, but retained white mottling on the head and upper breast. By 27 Apr. most birds had assumed full summer plumage, though some remained in winter plumage. A few of these light-plumaged birds are seen all summer, and probably represent an age class. On 27 Apr. Pigeon Guillemots were noted as "common, but not yet in nesting densities near shore." Of eight birds collected from 21 Nov. to 27 Feb., three contained only shrimp, four only fish, and one both fish and shrimp. Guillemots were not attracted to cannery gurry.

Marbled Murrelet. (CBC:115) I estimate 150-300 wintered in Chiniak Bay. One could find a few anywhere within the 21 f contour, but there were areas of marked concentration. One of these was the area within a mile NE of Woody Island, where small groups, generally fewer than five, could be seen. There were always some present over the ridge in Long Island Strait, where the depth decreases to 8-9 f. On 26 Dec. there were 90 there in groups of up to 8, while on 27 Feb., there were over 100 in groups of 1-7. From 11 Nov. to 17 Apr., I collected 21 Marbled Murrelets. Three were from Port Wakefield, the rest from Chiniak Bay. There seem to be several possible ways to age Marbled Murrelets in winter. These would bear checking in the future.

1) Bursa: Margaret Petersen, who looked at some of my birds, was able to divide bursal measurements into three categories, as is done in waterfowl work. No bursa indicates an adult; a 10-13 mm bursa indicates an immature; a 16-18mm bursa indicates a juvenile.

2) Secondary underwing coverts: In four adults, or birds lacking bursae, these were slate gray, as were the rest of the coverts and remiges. In one juvenile, these were white, while the rest of the underwing feathers were gray. Of four immatures, or birds with bursas of 10-13 mm in length, two had white and two gray undercoverts. If it turns out that adults always have gray and juveniles always white secondary undercoverts, then gray or white may be indicative of separate age classes within the immature (bursa 10-13 mm) category.

3) Triangular white face patch. In mid-winter, from December through February, adults seemed to have only pure white patches, while juveniles had patches mottled with fine grayish/blackish/brownish feathers. Immatures probably also had mottled face patches, though I am not sure, as the ones I looked at were taken in March, when the molt to alternate plumage could have had influence (figure 2a and 2b).

Unfortuantely, I did not have time to make skins, but I did make a number of drawings in the collection catalog. If the above characters prove reliable for aging in winter, then it may be possible, through combinations of them, to separate three or four age classes.

I recorded rough food notes from 19 Marbled Murrelets before preserving the stomach contents (Table 2). Sixty-nine percent of the time, Marbled Murrelets had been feeding on only a single food organism when collected. In several cases where murrelets contained both mysids and larval osmerids, there was a very distinct layering in the stomach. In specimen MHD-77-8, there was a thin layer of granular purple chyme at the intestinal end of the stomach, a very tight layer of intact mysids occupying nearly half the lower stomach, and a very tight layer of larval osmerids occupying nearly half the stomach at the esophageal end (figure 3). It is evident that this individual stopped feeding on a school of crustaceans and immediately began feeding on a school of larval fish, all after a period of little or no feeding.

Groups of 1, 2 and 3 Marbled Murrelets were often observed and the obvious question is whether or not the twos were breeding adults which remained together over the winter, and whether or not the threes were pairs with a juvenile. In two cases, I collected both of a group of two. One turned out to consist of two females with gray underwings and bursa measurements of 10 mm and 12 mm, indicating both were of similar age. The other consisted of an adult male (no bursa, gray underwings) and an immature or juvenile female (13 mm bursa and white underwings). Flocks of two cannot be considered sexual pairs in winter, unless collected and proven otherwise.

Last winter, I occasionally heard Marbled Murrelets calling over the spruce woods with the same cry they give in summer. On 16 Feb., I heard them at around 2300 hours coming in over the base of Spruce Cape Peninsula during a storm. I noted having heard them on other occasions during the first two weeks of February, only at night.

Kittlitz's Murrelet. (CBC:0) I looked hard but saw none on Chiniak Bay from November through April. On 8 May I collected a pair which turned out to be two adult males. Both had empty stomachs.

Ancient Murrelet. (CBC:0) Uncommon on Chiniak Bay last winter. I only saw two singles on 27 Feb. One was collected and contained larval osmerids, like the Marbled Murrelets collected the same day.

Crested Auklet. (CBC:0) This species did not appear in Chiniak Bay until January. At its peak abundance, probably 500-1,000 utilized the bay. I noted it on four days from 8 Jan. to 27 Feb. Fewer than ten were noted on all days except 24 Jan., when I noted 200-500 in scattered small flocks in Woody Island and Long Island Channels. Two collected in the SW bight of Woody Island contained only mysids. Interestingly, two Marbled Murrelets collected over approximately the same depth, 1 km away and 15 min. earlier, contained only larval osmerids and a single larger fish.

On 16 Jan. thousands of Crested Auklets wrecked aboard the F/V Lynda in Whale Passage, and tens of thousands must have been aggregated there. Crested Auklets are quite abundant in winter in the Kodiak Archipelago. A long-time resident of Larsen Bay told me that he remembered running through huge flocks of "sea quail" in Uyak Bay, citing the Alf Islands and Amook Passage as some of the areas where he found them.

Horned Puffin. (CBC:0) Rare in Chiniak Bay last winter. The only sightings were an immature in Dolgoi Lagoon on 8 Jan. and an individual near Zaimka Island on 1 Mar. Very few were present on the bay as of 14 May.

Tufted Puffin. (CBC:0) Unobserved on Chiniak Bay last winter. On 27 Mar. I saw one still in winter plumage on the bay. Several days previously, Nell Terpening had seen one in Izhut Bay, 2 mi. N. of Peril Cape. These observations indicated the birds were coming back toward land. By 3 May, there were hundreds on Chiniak Bay.

Common Raven. (CBC:254) A few ravens were seen on the bay itself in winter. I noted them on 13 trips from 21 Nov. to 27 Apr., twice on or near Puffin Island, the rest of the times near town. The Christmas Bird Count turned up 254 ravens and only 247 crows. I imagine the ravens were at the dump, for I never saw anything indicative of that abundance on the bay or near town.

DISCUSSION/CONLUSIONS

Table 3 shows very roughly the differences in the summer and winter avifauna of Chiniak Bay. The list is complete for neither summer nor winter, but it does include the major species. The winter numbers are estimates given in this report for the winter of 1976-1977. The summer figures are based on Summer, 1975 data revised in some instances by data gathered in 1976.

Overall winter density appears to be 1/3 to 1/2 as great as summer density. My impression of the bay in winter was that there were more birds present than in summer, but this may have been an effect of different dispersal. In summer, birds are concentrated at feeding areas, some of which are out of the bay, at the colonies, or at loitering areas. In winter, birds tend to be distributed more evenly over the bay, especially close to shore. The Gull Island to Zaimka Island transects illustrated the winter dispersal. Nine transects taken in 1975 and 1976 from June to early September gave totals of 32-89 birds (mean=45). The only winter transect, taken in late November 1976, yielded 176 birds.

In summer, Charadriiforms comprise the bulk of the overall density. The primary food of these is probably forage fish. In winter, Anseriforms comprise the bulk of the overall density. Significant numbers of them feed on mysids (Oldsquaw) and intertidal invertebrates (Steller's Eider). Generally, the winter food of Anseriforms is not forage fish.

It has been my experience that birds collected in summer, when not actually observed to be engaged in feeding, are often empty of food. Last winter, only a couple of the 54 birds I shot (12 came from other sources) were empty. Only one or two of the 21 Marbled Murrelets collected in winter were empty, while the first two Kittlitz's Murrelets I saw in spring, both probably returning breeders, were empty. In winter, the most important activity of birds is eating. In summer, reproductive activities take a sizeable portion of time and energy. When feeding chicks, birds take more prey than they would for themselves alone. Thus, overall food consumption by adults may be similar in summer and winter. In summer, the abundant forage fish probably form the most important food source, while in winter other categories are important, such as pelagic crustaceans and fish, bottom invertebrates, and intertidal organisms. Steller's Eiders take a great diversity and probably a significant biomass of intertidal organisms. Glaucous-winged and Mew Gulls feed extensively in the intertidal in winter, perhaps more so than in summer when schooling forage fish are present. Marbled Murrelets and other small alcids, which take larval fish, possibly have as great an impact on certain forage fish populations as some birds which take the adult fish in summer. In Chiniak Bay in winter, most feeding takes place within the 10 f depth contour, while in summer, a good deal of it takes place over deeper water.

There are rest periods in spring and fall on Chiniak Bay. The more pronounced is mid-September to mid-October, when the breeding charadriiforms have departed and the anseriforms have not yet arrived. Bird densities are as low as they get all year. In spring, there is a similar but not so pronounced rest period. Fair numbers of anseriforms are still present when the kittiwakes arrive in early April, but most of the ducks leave before the puffins arrive in late April-May.

It remains to be determined whether or not the populations of the so-called resident species are the same in winter as in summer. There is evidence that local Glaucous-winged Gulls migrate south in winter, while gulls from westward and northward winter in Kodiak. Double-crested Cormorants, probably from Afognak, occupy the bay in winter, while most Red-faced Cormorants move out. It is not unreasonable to assume that the local Pelagic Cormorants migrate out of the bay in winter, and that the winter population comes from westward and northward.

Feeding habitats seem to remain well defined for each species all winter, and the foods taken seem to remain constant. For instance, Marbled Murrelets could be found in the same areas taking the same prey from November to April. In May, they were no longer found in the same areas. I did not gather any food data then. Steller's Eiders utilized the same habitat all winter, and specimens taken in December and February contained prey items characteristic of that habitat.

One must be careful when using the term "winter density" for a seabird. Winter species arrive and depart at different times, and different species have different peaks of abundance. An example is the Crested Auklet, which was not observed in Chiniak Bay until January, and which had departed by March. It seemed to me that Common Murres moved in and out of the bay at various times during the winter, possibly with the weather, as sometimes they were noticeably more common than at others.

Outer Continental Shelf (OCS) studies to date in Alaska have not adequately assessed inshore winter bird distribution, abundance and trophic relationships. It would seem that the danger of an oil disaster inshore is greater in winter than in summer. If a disaster were to occur in winter, cleanup operations would likely be more difficult, and volatile components would not evaporate as fast. Oiled plumage might prove to be more quickly and more extensively fatal in winter, due to the freezing temperatures. The effects of a winter oil spill are less easily assessed, because the bird populations involved are mostly not local; they come from many areas. The damage would not only affect the spill area, but also breeding grounds northward, westward, and in the interior of Alaska. The effects of a winter spill, however, might not be as lasting as a summer spill which involved whole colonies of breeding birds. Winter field work is more difficult and more expensive than summer work, and winter is the time when biologists return to the cities to compile their summer data. OCS planners should consider launching more field crews for safe but intensive winter field work in certain areas. Inshore aerial surveys have been used in winter with success, and I recommend they be conducted periodically in certain areas such as Kodiak, perhaps coordinated with boat surveys for ground truth.

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Table 1. Frequency of occurrence of food items in nine Oldsquaw stomach samples.

FOOD	PERCENT
Mysids present	67
Only mysids	56
Fish	33
Amphipods	22
Polinices	11
Barnacle fragments?	11
Shrimp	11
Juvenile tanner crab	11

Table 2. Frequency of occurrence of food items in 19 Marbled Murrelet stomach samples.

FOOD	PERCENT
Mysids only	11
Mysids present	37
Larval osmerids only	58
Larval osmerids present	84
Mysids and larval osmerids	26
Adult fish and larval osmerids	5

Table 3. Comparison of winter and summer seabird densities in Chiniak Bay. See text for explanation. (-) indicates few or no birds present.

Species	Summer Density	Winter Density
Double-crested Cormorant	-	200-300
Red-faced Cormorant	600-700	-
Pelagic Cormorant	1,000	400-600
Shearwaters	0-2,000	-
Emperor Goose	-	200-300
Common Goldeneye	-	700-1,000
Greater Scaup	-	500-700
Bufflehead	-	200-300
Oldsquaw	-	3,000-5,000
Harlequin	500-1,000 (?)	800-1,000
Common Eider	150	200
Steller's Eider	-	1,500-2,000
White-winged Scoter		200-300
Surf Scoter	500 (+?)	-
Black Scoter		1,000-1,500
Bald Eagle	100	100-200
Black Oystercatcher	100-150	100-150
Glaucous-winged Gull	2,000-3,000	2,000-3,000
Mew Gull	700-1,000	1,000-2,000
Black-legged Kittiwake	14,500	-
Pigeon Guillemot	500-800	150-300
Common Murre	500	150-300
Kittlitz's Murrelet	100-200	-
Marbled Murrelet	150-300	150-300

Table 3 (con't)

Species	Summer Density	Winter Density
Crested Auklet	-	500-1,000
Horned Puffin	400	-
Tufted Puffin	16,700	-
Northwestern Crow	500	500
Arctic Tern	500	-
Aleutian Tern	300	-
Total	39,800-44,300	13,250-19,950

ADDENDUM I
SEABIRDS RECORDED ON
KODIAK, ALASKA, CHRISTMAS BIRD COUNTS

COMPILER: Bill Donaldson

	1973	1974	1975	1976	1977
			Number observed		
Common loon	-	-	-	C.P.a	
Red-throated loon	-	-	-	C.P.	
Arctic loon	-	-	1	-	
Loon sp.	C.P.	1	-	-	
Red necked grebe	1	2	5	5	
Horned grebe	15	3	4	12	
Double-crested cormorant	9	24	2	27	
Pelagic cormorant	36	279	46	167	
Red-faced cormorant	C.P.	3	3*	8	
Emperor goose	150	C.P.	142	108	
Mallard	45	139	84	261	
Gadwell	C.P.	5	10	11	
Pintail	5	-	-	1	
Green-winged teal	-	3*	-	-	
American wigeon	6	-	1	7	
Greater scaup	181	247	135	482	
Lesser scaup	-	-	-	2	
Common goldeneye	140	265	216	615	
Barrows goldeneye	84	23	2	16	
Bufflehead	93	68	134	145	
Oldsquaw	1489	1162	1014	2321	
Harlequin	549	447	156	533	

Addendum I (con't)

	1973	1974	1975	1976	1977
			Number observed		
Steller's Eider	111	842	473*	1179	
Common Eider	2	79	375	110	
King Eider	10	1	4	6	
Ring-necked duck	-	-	-	-	
Spectacled eider	C.P.	-	-	-	
White-winged Scoter	27	11	4	124	
Surf Scoter	6	28	12	10	
Black Scoter	320	277	693	487	
Common merganser	5	5	-	7	
Red-breasted merganser	18	24	15	24	
Golden Eagle A.	-	-	-	-	
Im.	-	-	2	1	
Bald Eagle A.	74	54	28	44	
Im.	50	48	47	54	
Unident.	7	2	-	13	
Peregrine falcon	-	2	2	1	
Black oystercatcher	91*	-	83*	36	
Surfbird	1	-	2	24	
Rock sandpiper	455	110	27	86	
Dunlin	-	14	-	51	
Black turnstone	9	5	13	14	
Glaucous gull	3	1	-	2	
Glaucous-winged gull	3425	1562	937	1044	

Addendum I (con't)

	1973	1974	1975	1976	1977
Mew gull	1439	507	277	1111	
Black-legged kittiwake	6	C.P.	-	2	
Common murre	4	104	10	105	
Pigeon guillemot	3	39	13	54	
Marbled murrelet	30	49	4	115	

a: C.P. = species observed during count period but not on count day.

SCALE: 5 KILOMETERS

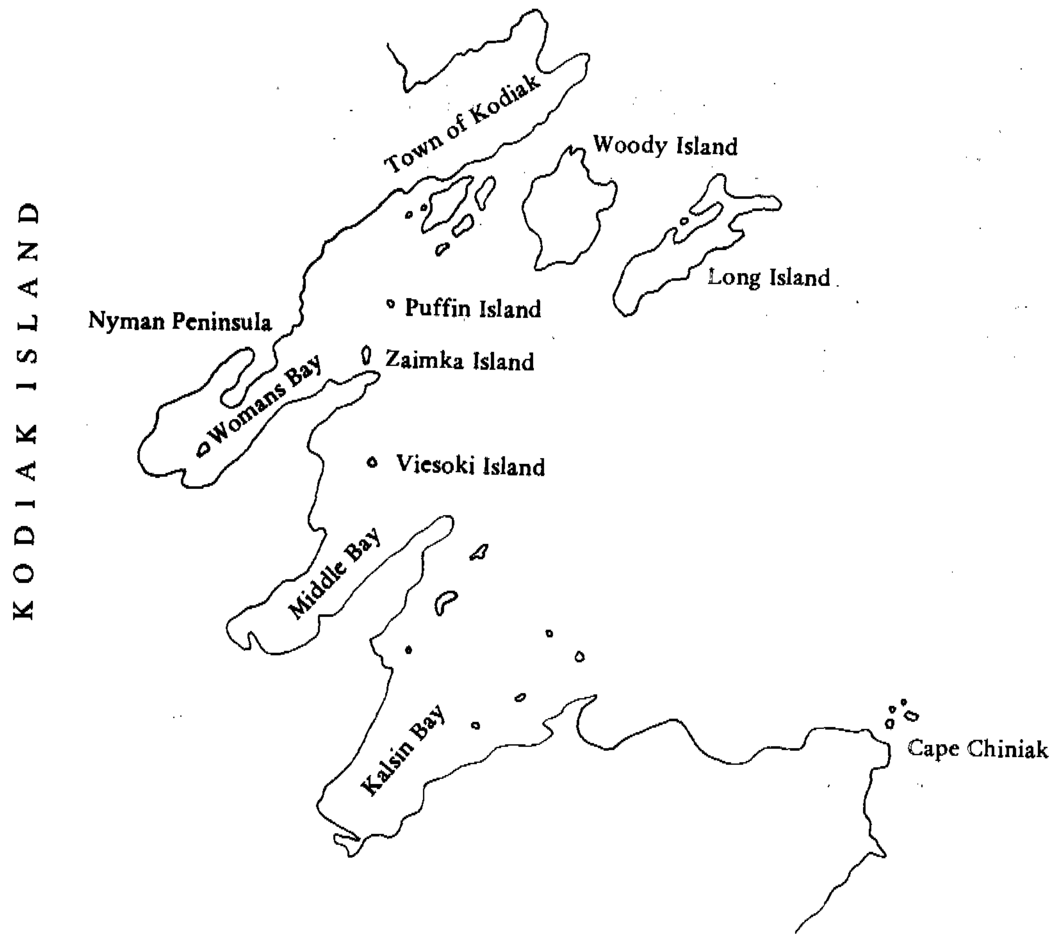

FIGURE 1. Study Area.

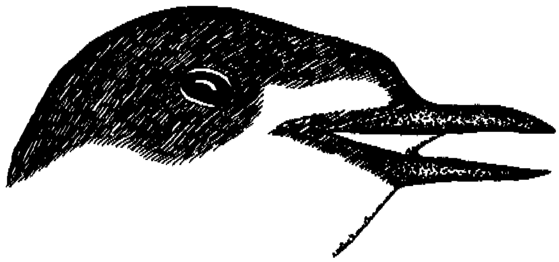

Figure 2a. Marbled Murrelet: Clear, white face patch possibly indicative of adult or near adult.

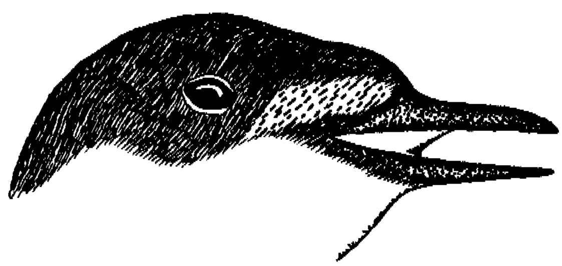

Figure 2b. Marbled Murrelet: Mottled face patch possibly indicative of juvenile (1st winter).

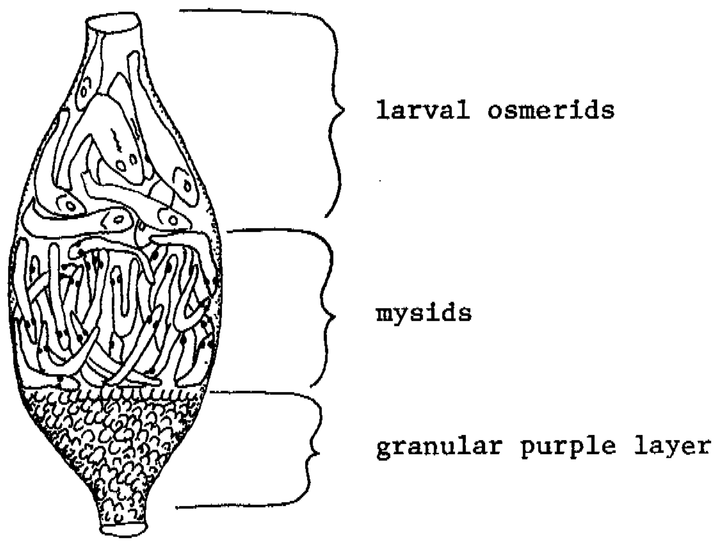

Figure 3. Marbled Murrelet: Drawing of stomach from specimen MHD-77-8, showing layering of food organisms.

ANNUAL REPORT

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ECOLOGICAL STUDIES OF COLONIAL SEABIRDS AT CAPE THOMPSON AND CAPE LISBURNE, ALASKA

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shearwaters	*Puffinus sp.*
Pelagic Cormorant	*Phalacrocorax pelagicus*
Common Eider	*Somateria mollissima*
King Eider	*Somateria spectabilis*
eiders	*Somateria sp.* and *Polysticta sp.*
Golden Eagle	*Aquila chrysaetos*
Gyrfalcon	*Falco rusticolus*
Glaucous Gull	*Larus hyperboreus*
Black-legged Kittiwake	*Rissa Tridactyla*
Common Murre	*Uria aalge*
Thick-billed Murre	*Uria lomvia*
guillemots	*Cepphus sp.*
Horned Puffin	*Fratercula corniculata*
Tufted Puffin	*Lunda cirrhata*
Crested Auklet	*Aethia cristatella*
Least Auklet	*Aethia pusilla*
Parakeet Auklet	*Cyclorrhynchus psittacula*
Arctic Cod	*Boreogadus saida*
Sandlaunce	*Ammodytes hexapterus*
sculpin	Cottidae
walrus	*Odobenus rosmarus*

I. SUMMARY OF OBJECTIVES, CONCLUSIONS AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

A. Objectives

The objective of this study is to provide current information on the ecology of seabirds nesting at Cape Thompson and at Cape Lisburne. The data obtained at Cape Thompson will be compared to recent historical studies in an attempt to describe "predevelopment" changes which may have occurred. Investigations at Cape Lisburne will further increase our understanding of seabird biology in the Chukchi Sea. By broadening the ecological data base, effects of resource development in this region may be more accurately measured.

B. Conclusions

The numbers of murres at Cape Thompson and Cape Lisburne appear to have changed little between 1976 and 1978. This short term stability is in contrast to observations at a colony in Norton Sound and can be explained, at least in part, by differences in the proportions of murre species at the different colonies and the implied breadth of the food bases which support them.

We have observed differences between Cape Thompson and Cape Lisburne in the amplitude of change and in the recovery rate of kittiwake reproductive success following 1976. The profiles of change at the two colonies have been the same and the differences referred to above are probably the result of different levels of food which have been available to each population.

The numbers of breeding Glaucous Gulls have been stable during the past three years and, at Cape Thompson, are similar to numbers reported during 1959-1961. Major seasonal and annual differences in numbers of subadult gulls, however, have made age structure and overall population size estimates difficult.

Ledyard Bay is the center of feeding activity of seabirds from Cape Lisburne and may also be utilized at times by birds from Cape Lewis and Cape Thompson. The birds distribute themselves over the bay in a manner which suggests resource allocation among different species. In late summer many birds feed to the north of Cape Lisburne, on the western edge of Ledyard Bay.

Seabirds at Cape Thompson appear to feed over a broad geographical area. During early-mid-summer they feed to the south and southeast of the colony and at distances of at least 100 km. In August and September murres may feed to the north of Cape Lisburne.

The regions in which the birds feed have been the same during the past three years. The seasonal changes in feeding areas of birds at both colonies imply seasonal differences in regions of marine productivity.

C. Implications with respect to OCS oil and gas development

The colonies at Cape Thompson, Cape Lewis and Cape Lisburne support most of the breeding seabirds in the eastern Chukchi Sea. The birds constitute a major component of the ecosystem in this region. Perturbations of the environment by resource development in the Hope Basin could threaten the health and stability of these populations.

II. INTRODUCTION

A. General nature and scope of study

The sea cliffs at Cape Thompson and Cape Lisburne provide nesting habitat for nine species of seabirds, three species of raptors and ravens. The colonies at these sites contain the largest concentrations of murres and kittiwakes in the eastern Chukchi Sea and are the northernmost colonies in western North America.

Prior to the present study the only formal investigation of seabirds nesting in this region was made at Cape Thompson during Project Chariot between 1959 and 1961. Information obtained by Swartz (1966; 1967) during the early 1960's at Cape Thompson has provided a sound base upon which we can build in an attempt to bridge gaps in our knowledge of seabird ecology within this region of Alaska.

B. Specific objectives

The specific objectives of this study are to:

1. Determine the numbers of cliff-nesting seabirds breeding at the Cape Thompson and Cape Lisburne colonies;

2. Determine the phenology of breeding activities and reproductive success of these birds;

3. Obtain data on food habits and foraging areas of the principal species in these colonies;

4. Describe factors critical to the success of the seabirds;

5. Expand the ecological data base of the Cape Thompson and Cape Lisburne region.

C. Relevance to problems of petroleum development

The Hope Basin is subject to lease sales which would allow oil and gas exploration and development. Within this part of the Chukchi Sea exist areas of critical habitat for as many as a half million breeding seabirds. These birds are not randomly distributed throughout the region but are concentrated at breeding colonies and at feeding areas, a distribution pattern which makes them particularly susceptible to oil pollution and habitat alteration.

Data we have acquired during the past three field seasons, together with those data obtained by Swartz during 1959-1961, have demonstrated that the success of seabirds nesting at colonies in the eastern Chukchi can vary dramatically between years. The causes appear to have been fluctuations in the birds' prey base, fluctuations which have probably been precipitated by one or a combination of environmental factors. These changes, however, appear to be short-lived, probably seldom longer than one season, and the "average" environment is one in which seabirds have prospered over the long run. If, however, environmental factors were coupled with perturbations to the system from developmental accidents or activities, the duration of periods of low reproductive output might be longer, the frequency might be greater and the long-term health and stability of seabird populations could be greatly compromised.

III. CURRENT STATE OF KNOWLEDGE

Seabird studies in the northern Bering Sea-Bering Strait region and Chukchi Sea during the past several years have demonstrated that seabird biology within the region as a whole may be dominated by a common set of environmental factors. The most recent, obvious expression of that relationship has been the synchronous highs and lows of kittiwake productivity at colonies on St. Lawrence Island and at Bluff in the south to Cape Lisburne in the north.

The fine tuning and balance of the system certainly depends upon a complex association of environmental and biological variables. Evidence exists, however, that the spring duration of sea ice together with current patterns and water mass transport from the northern Bering Sea north past Point Barrow in the Beaufort Sea may be major factors influencing the marine ecology of the entire region.

Circulation patterns in the northern Bering Sea are dominated by the north-setting current which moves water from the Gulf of Anadyr, north central Bering Sea and Norton Sound through Bering Strait and into the Chukchi Sea. Detailed discussions of current patterns, water masses and water transport can be found in Bloom (1964), Flemming and Heggarty (1966), Ingham and Rutland (1972), Hufford (1973) and Coachman et al. (1975). The currents and water transport are thought to be responsible for the continuity of biota between the Bering Sea and the Chukchi and Beaufort seas as described for zooplankton by Johnson (1956), Hand and Kahn (1961) and Cooney (1977) and for benthic invertebrates by Sparks and Pereyra (1966) and Stoker (1978).

The flow of water may also contribute to biological enrichment in other ways. Looking at generalized flow patterns in the region, one would expect that areas of upwelling should occur north and west of St. Lawrence Island and in Bering Strait (for a discussion of land influences on water movement and upwelling see LaFond and LaFond, 1971). Currents are relatively strong, in the order of 50 cm per second north through the Strait of Anadyr which lies between Cape Chukotsky and St. Lawrence Island. Both vertical and horizontal turbulence would be expected as the continuity of that flow is disrupted by bottom contours and by the presence of St. Lawrence Island. In Bering Strait currents are even stronger, velocities of up to 150 cm/sec are not uncommon and mean transport through the Strait is in the order of 1-2 Sv. Because of the high velocity and large volume of water pouring through Bering Strait, upwelling should be even greater than in the Strait of Anadyr.

If upwelling does in fact occur in the regions described, then one would expect those waters to be nutrient-rich and as a result highly productive. In contrast, Norton Sound is a cul-de-sac and probably does not benefit from open circulation and current effects. There, productivity should tend to be lower. Biological data which have been collected from the northern Bering Sea-Bering Strait region tend to support these conclusions.

Within Bering Strait, McRoy et al. (1972) measured rates of carbon fixation in excess of 4 g C $\cdot$ m^{-2} day^{-1}. This is an extremely high rate, higher than other regions in the Bering Sea and comparable to rates observed in the upwelling areas along the west coasts of Peru and Africa and in the Arabian Sea (Ryther et al. 1971, reported in McRoy and Goering 1976). Stoker (1978) has demonstrated that the standing stock distribution of benthic invertebrate macrofauna throughout the northern Bering and Chukchi Seas, when plotted against latitude, describes a bell-shaped curve with the mode in Bering Strait.

Of special interest to us are the tremendous populations of seabirds which nest on the islands in Bering Strait and on St. Lawrence Island. At Kongkok Bay on Southwest Cape, St. Lawrence Island, Bedard (1969) and Searing (1977) both reported that the majority of the birds in the large populations of alcids regularly fed to the north and west of Northwest Cape on St. Lawrence Island which would have placed them in the Strait of Anadyr. In the Bering Strait an indication of the high level of productivity is given by the overwhelming numbers of breeding and non-breeding seabirds which concentrate in the area. As would be expected, seabird populations in Norton Sound, on the other hand, are relatively impoverished (Drury in press).

A major component of the total flow through Bering Strait is Alaskan Coastal Water, a warm water mass of low salinity which originates in the northeast Bering Sea. North of Bering Strait, the flow of Alaskan Coastal Water tends to follow the 20-fathom contour interval which takes it eastward toward the Cape Thompson-Point Hope region, around Cape Lisburne and into the Beaufort Sea east of Point Barrow. A substantial portion of Alaskan Coastal Water derives from the discharge of the Yukon River south of Bering Strait and from the Kobuk and Noatak Rivers which flow into Kotzebue Sound. Alaskan coastal water which is relatively high in organic matter contributed from river input, is swept through Bering Strait and is undoubtedly enriched additionally with nutrients from the floor of Bering Strait and with plankton and benthic algae which grow on the floor and in the water column. All of this is injected into the Chukchi Sea and circulated through areas where, coincidentally, suitable nesting habitats for seabirds exist.

One major effect then of currents in the Chukchi Sea is probably to transport nutrient and plankton enriched waters into the area and, as in the embayment between Cape Lisburne and Point Lay (Ledyard Bay), to circulate this water in the large gyre which exists there. Additional enrichment in Ledyard Bay undoubtedly results from upwelling generated by the prevailing north winds which blow against the north-facing shoreline.

Another important effect which the currents may have is the amelioration of an otherwise colder, more extreme marine environment. Fleming and Heggarty (1966) have suggested that summer surface temperatures in the eastern Chukchi Sea are generally 10°C higher than what might be considered normal based on data from similar latitudes in the southern hemisphere.

That the warmer waters just north of Cape Lisburne and in Ledyard Bay are favorable for marine organisms is suggested by our observations of seabirds and by results of other marine biological studies made in these and adjacent waters. We have seen, as will be discussed in more detail in another section of this report, that seabirds at Cape Lisburne feed almost exclusively in Ledyard Bay or on the edge of the embayment north of Cape Lisburne, feeding patterns which are consistent with the meager oceanographic information we have. Birds from Cape Lewis appear to frequent these waters and, in some years, birds from Cape Thompson may also.

Data reported by Cooney (1977) on the distribution of zooplankton and micronekton in the Bering and Chukchi seas provide additional evidence of regional differences in the occurrence of marine organisms, differences which also could be the result of local currents. He reported that the most diverse assemblage of zooplankton and micronekton was in Bering Strait, the next most diverse was just north of St. Lawrence Island with somewhat fewer species in the Chukchi Sea west of Cape Thompson. By far the least diverse assemblages were observed in Kotzebue Sound and Norton Sound.

In response, we have developed a perhaps simple but interesting index to describe seabird diversity on a regional basis. Our definition of diversity can be described by the following example. Colony A and Colony B have the same number of seabird species and the same number of total birds. But because the numbers of each species in Colony A are approximately equal whereas the numbers of species in Colony B vary greatly between very low and very high numbers, Colony A is defined as the most diverse. This definition is not an arbitrary one and we are aware of many arguments which could be made against its validity. The index was developed as an application of the routine which describes the goodness of fit of mass spectra of unknown compounds to the library spectra of known compounds (W. Walker, pers. comm.).

Population estimates (Y_j) of the principal seabird species (Common and Thick-billed Murres; Least, Crested and Parakeet Auklets; and Black-legged Kittiwakes) at each colony were transformed to their square roots to minimize effects on the computation of very large numbers of single species, for example Least Auklets. The transformed values were normalized for each colony according to the formula

$$\frac{Y_j}{\max Y_j} \times 100 = Y_{j'}.$$

A theoretical colony was then described which had equal numbers of each species (X_i), which when normalized ($X_{j'}$) always equaled 100. The diversity of a colony was determined by comparing the proportions of species within the colony to those in the theoretical colony using the formula:

$$\text{Diversity index} = 1000 \cdot \frac{(\Sigma(X_{j'} Y_{j'}))^2}{\Sigma(X_{j'}^2) \cdot \Sigma(Y_{j'}^2)}$$

The computed diversity indices must fall between 0 and 1000, and colonies which exactly match the theoretical colony would have indices of 1000. The diversity indices we calculated are:

King Island - 865
Little Diomede Island - 551
St. Lawrence Island - 536
Cape Thompson-Cape Lisburne - 428
Bluff - 349

Using this formula, we determined that seabird diversity paralleled invertebrate diversity; diversity was greatest in the Bering Strait colonies of King Island and Diomede Island, next highest at St. Lawrence Island then Cape Thompson and lowest in Norton Sound. Whether this index is an accurate description of reality or not, it is apparent that the avifauna of the Bering Strait region is the most diverse within the area and that colonies within Norton Sound are the most impoverished. Colonies at Cape Lisburne and Cape Thompson lie between those extremes. Furthermore, the principal taxa in Norton Sound are all fish specialists, while at Cape Thompson and Cape Lisburne the fish specialists, Common Murres and kittiwakes, together occur in about equal numbers as do Thick-billed Murres, a species which consumes a much greater proportion of invertebrates. In the Bering Strait region and on St. Lawrence Island certainly the greatest number of different trophic positions are represented where, in addition to murres and kittiwakes, major populations of three auklets occur.

If currents do in fact play a major role in determining regional differences in productivity within the northern Bering Sea-Chukchi Sea region, those effects are certainly modified by the presence of sea ice which covers the entire area for a major portion of the year. The various effects that ice may have on productivity are undoubtedly complex.

McRoy and Goering (1974, 1976) have discussed the effects which sea ice has on the annual budget of primary production in the Bering Sea. The development of large standing stocks of micro-algae on the underside of sea ice, which begins in late February and reaches a peak just before breakup, significantly increases the total annual amount of carbon fixation. Horner (1976) has suggested that in the Beaufort Sea, ice algae may prolong the growing season by as much as two months and Schell (reported in English and Horner, 1977) has suggested that ice algae may act as a nutrient pump by concentrating nutrients and then releasing them into the water column when the cells disintegrate, thereby increasing the nutrient supply to benthic and planktonic microalgae which bloom following the dissipation of the ice cover.

The ice algae also appear to support grazing zooplankters which in turn support Arctic Cod populations. Arctic Cod is an important early season food source for murres and kittiwakes at Cape Thompson and Cape Lisburne and peak numbers of cod were taken, at least in 1977, coincident with ice breakup, a time when the fish would be especially susceptible to avian predators.

Although ice algae prolong the effective growing season in northern waters and markedly increase annual primary production, the presence of the ice still shades the water column where the greatest level of production occurs after breakup in the spring and early summer. Moreover, even though Coachman, Sharnell and Shumacher (RU 541/550) have recently demonstrated the continuity of northerly flow through Bering Strait under the ice during winter, the presence of the ice may influence the rate of advection of zooplankton north (Cooney 1977). Whether or not this would affect standing stocks of inverbetrates, fish and seabirds has, however, not yet been determined.

Another effect which sea ice probably has is modification of the thermal regime of the water, a factor which could be important, especially in the eastern Chukchi. Prolonged ice cover north of Bering Strait could reduce the warming effect of Alaskan Coastal Water and thereby modify the latitudinal distribution of potential food resources of seabirds, principally fish.

During the last several years we have seen rather striking differences in the rate at which the sea ice broke up and dissipated throughout the region. In the Cape Thompson area, southerly and westerly winds and ocean currents can cause a wide band of broken ice to be retained along the shoreline south of Point Hope well through the second week and often the third week of July. In 1959-1961, the ice was well broken up and moving out by 7 July (Swartz, pers. comm.). In 1976, ice in the embayment was not broken up well or dissipating until 20 July and was last observed as late as 29 July. Most of the ice in the region was gone by 10-12 July in 1977, however, and in 1978 the ice moved out by the end of June. If one were to rank the dates of ice departure from the Cape Thompson region and rank inter-year dates of breeding phenology, for example first seagoing of murre chicks for the same years, a perfect correlation would be demonstrated. A somewhat less intense but strong relationship exists between the dates of ice departure in the different years and the level of Black-legged Kittiwake reproductive success.

IV. STUDY AREA

Detailed descriptions of the study areas can be found in Wilimovsky and Wolfe (1966) and in our annual report of the 1977 field season.

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Our field work at Cape Thompson and Cape Lisburne this past summer was constrained by the relatively few days we were actually in the field, small field parties and by the predominance of stormy weather which resulted in many shore-bound days. As a result, we were unable to accomplish many of the activities which we had done in past years.

Work began on 4 July at Cape Thompson when a one-day visit was made to the site. On 5 July we went to Cape Lisburne, where we remained until 13 July. We collected birds at both sites and made general observations on colony-wide activity. A party of two people returned to Cape Lisburne on 22 July and stayed until 22 August and a second party of two people worked at Cape Thompson from 12 August to 24 August. A final one-day visit was made to Cape Thompson on 17 September.

Because of the time and personnel limitations mentioned above, we elected to concentrate our efforts on Black-legged Kittiwakes, the species which may be the single most sensitive indicator of changes in the marine environment. Partial counts of kittiwakes were made at both colonies; at Cape Lisburne 20 (27%) of 75 plots were counted and at Cape Thompson all of Colony 4 and two plots in Colony 2 were counted. The plots we counted at Cape Lisburne were selected from throughout the length of the colony; at Cape Thompson Colony 4 was selected because it had the longest history of complete counts. Productivity data on kittiwakes were collected at both sites and at Cape Lisburne kittiwake chick growth rates were measured.

We also counted murres at a small number of plots at Cape Lisburne, Horned Puffins at Colony 1, Cape Thompson, and at both Cape Lisburne and Cape Thompson cormorants were counted colony-wide and brood sizes were determined. As time and opportunity permitted, data on other species were also collected.

Murres and kittiwakes were collected at varying intervals during the summer at both Cape Thompson and Cape Lisburne. Data on brood patch development, condition of gonads and fat condition were obtained at the time of collection. Stomach contents were preserved in 70% ethanol and returned to Fairbanks, although those samples have not yet been analyzed.

In cooperation with Bill Drury and the Arctic Project Office, we flew aerial transects offshore at Cape Thompson and Cape Lisburne during the interval 25-29 July and again on 18 and 19 August. From those flights we hoped to improve our understanding of seabird foraging areas in the eastern Chukchi Sea. The flights were intended to coincide with the arrival of the vessel NATCHIK which was to sail from Barrow. Personnel onboard the NATCHIK were prepared to sample both physical and biological parameters within waters identified as feeding areas from the aerial transects. Other stations which showed lesser degrees of utilization by seabirds were also to be sampled. Although limited in scope and quantity, we hoped that data collected would provide insight into conditions which account for birds feeding in certain areas as opposed to others. Unfortunately, the NATCHIK encountered a series of difficulties at Wainwright and the remainder of the cruise, which was scheduled to include not only the Chukchi Sea but the Bering Strait region and the northern Bering Sea as well, had to be cancelled.

The aerial transects were flown in a Cessna 336 twin-engine aircraft chartered from Don Olson in Golovin. All flights were made between approximately 30 and 60 meters in altitude and at a ground speed of approximately 190 km per hour. Two or three observers, in addition to the pilot, were onboard during the surveys and observations were made from both sides of the aircraft.

Observations of birds on the water were summed during five-minute intervals. On all but one flight, birds in the air and their flight directions were also recorded. The positions of transects were determined from time and heading data and from radar fixes provided by radar operators at Cape Lisburne and Point Lay.

VI. RESULTS

Numbers

Murres were not counted at Cape Thompson this year and were counted on only six plots at Cape Lisburne. The numbers obtained from those counts, as well as counts of the plots in other years, are presented in Table 1 and suggest that no major change in the murre population has occurred at Cape Lisburne between 1976 and 1978.

The results of our kittiwake counts at Colony 4, Cape Thompson, are presented in Table 2 and are compared to previous counts at that colony in Figure 1. The two plots in Colony 2, which were counted on 20 August between 1420 hours and 1520 hours, contained 1029 birds (Plot U) and 414 birds (Plot V). Those numbers are compared to counts of the same plots in other years in Figure 2. Both Figures 1 and 2 indicate that the kittiwake population at Cape Thompson has continued to increase following the poor reproductive season documented in 1976.

Approximately 25% of the 75 plots at Cape Lisburne were counted for kittiwakes in 1978. The results of those counts are presented in Table 3 and are compared to counts obtained in 1978 at

Table 1. Murre counts at Cape Lisburne, 1976-1978.

	Uncompensated			Time Compensated*		
Plot	25 Aug. 1976	25-26 July 1977	3 Aug. 1978	25 Aug. 1976	25-26 July 1977	3 Aug. 1978
11	750	928	780	1190	1345	1039
12	1300	1545	1310	2063	2414	1658
25	825	1085	1015	1178	1391	1449
26	600	1225	1275	628	1612	1655
30	4250	3585	3150		5121	4437
32	2200	1738	1995		2896	3166
Total:	9925	10,106	9525		14,779	13,404

*Scores for all years compensated on the basis of the 1977 compensation counts.

Table 2. Black-legged Kittiwake census of Colony 4, Cape Thompson on 14 August 1978.

	Plot	Time	Number of birds
	A	1410	249
	B	1420	284
	C	1430	383
	D	1448	22
	E	1450	479
	F	1508	175
	G	1520	380
	H	1535	177
	I	1550	324
	J	1605	101
	K	1610	105
	L	1625	198
	M	1640	125
	N	1630	174
	O	1620	28
	P	1646	80
	Q	1650	4
	R	1652	2
Total			3290

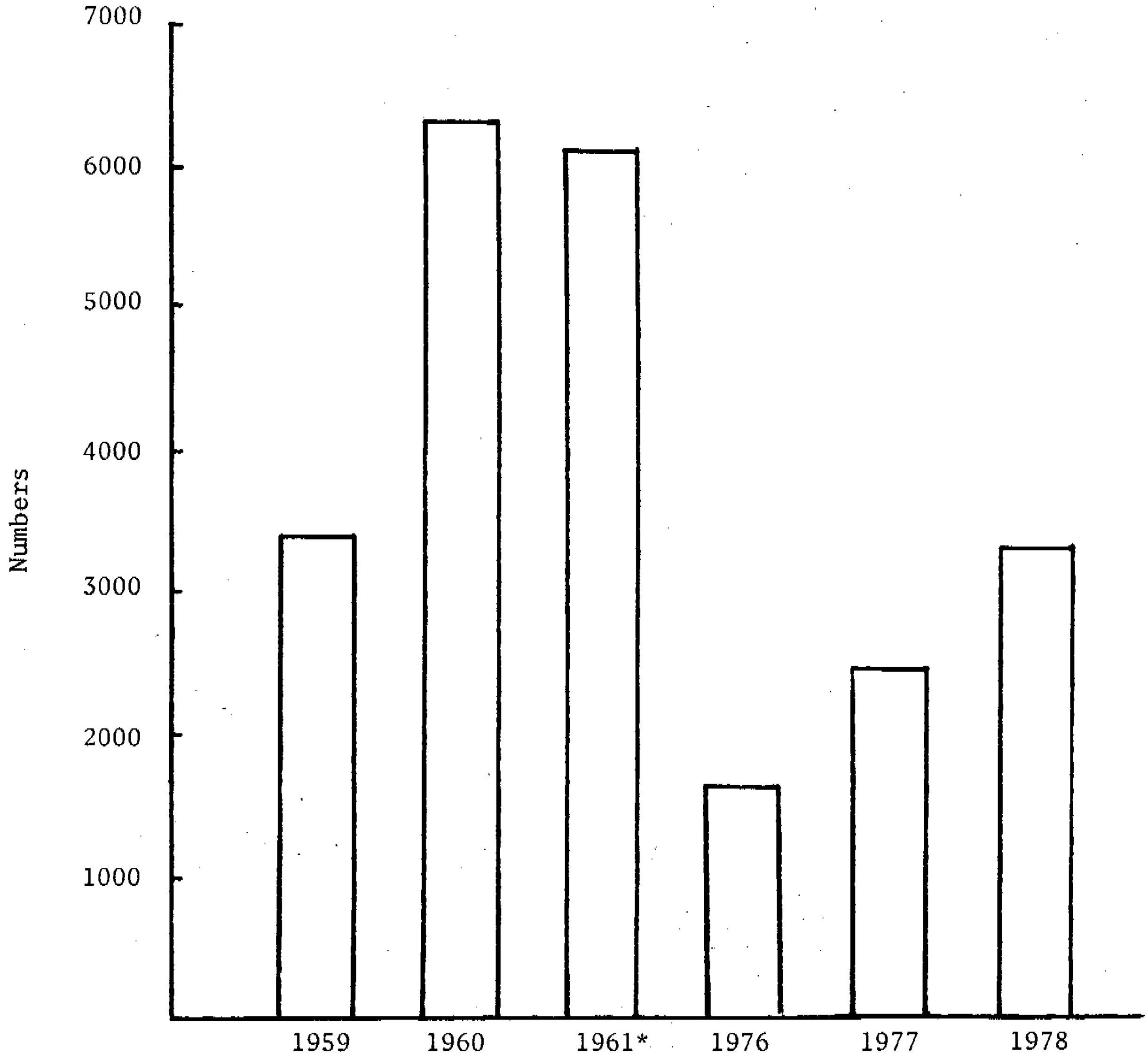

Figure 1. Counts of Black-legged Kittiwakes at Colony 4, Cape Thompson.

*Estimate based on partial count

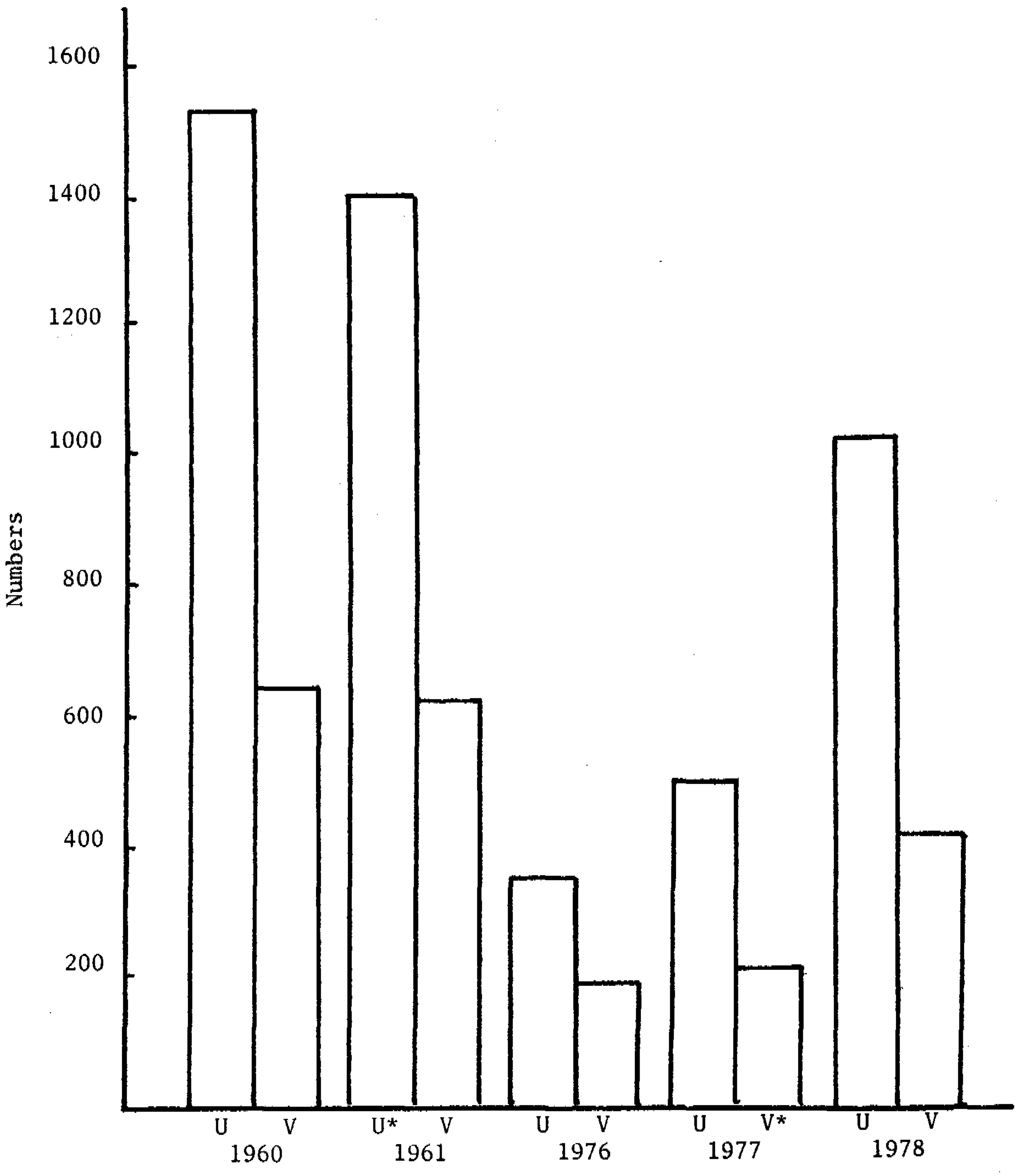

Figure 2. Counts of Black-legged Kittiwakes on two plots in Colony 2, Cape Thompson.

*Estimate

Table 3. Counts of Black-legged Kittiwakes at Cape Lisburne.

		1978			
		Observer			
Plot	Time	C	G	$\bar{X}$	1977
11	1330	192	192	192	114
26	1430	310	299	305	265
28	1500	374	400	387	228
36	1630	376	350	363	377
39	1650	140	136	138	144
48	1710	287	245	256	302
53	1725	168	160	164	153
61	1400	388	379	384	205
62	1425	360	-	360	293
63	1445	516	-	516	878
64	1500	508	-	508	571
65	1510	346	333	340	247
66	1515	50	44	47	50
67	1755	251	264	258	141
68	1520	118	-	118	182
69	1550	34	20	27	28
70	1600	274	330	302	296
71	1610	344	340	342	177
72	1620	188	190	189	274
73	1905	356	357	357	349
Total:				5553	5274

these same plots. The totals for the two years differ by only 5% and we are reluctant to suggest that the slightly larger number in 1978 implies an increase in the total population.

We cannot say how many kittiwakes nested at Cape Lewis in 1978, although we are certain there were many more than last year. We counted approximately 65% to 75% of the colony this year and the average of two observers' scores was 2845 birds. Foul weather prevented us from counting the remainder of the birds. Unfortunately, the photographs of Cape Lewis we had taken in 1977 were inadvertently left in Fairbanks and were destroyed by fire before we realized that they had been left. The number of birds we counted in 1977 colony-wide was only 81% as many as those we counted this year in only part of the colony. We estimate that there could have been as many as 30-50% more birds present than there were when we counted the entire colony in 1977.

Breeding Glaucous Gulls were not counted at either Cape Thompson or Cape Lisburne this summer but our impressions are that numbers were comparable to those observed in 1977 and in 1976. We did obtain data, however, on numbers of non-breeding adult and subadult gulls, which are common along the coast near both sites.

We saw only two subadult gulls at Cape Lisburne in early July, although we did not travel east of the base where they were usually first seen. Subadults were present at Cape Lisburne when we arrived on 22 July, which was about 2-3 weeks earlier than their arrival in 1977.

The earliest counts of Glaucous Gulls near Cape Lisburne were made on 25 July during the first of the aerial survey flights. On that date three flocks of about 75 gulls each, about 10% of which were subadult birds, were seen along the lagoons approximately 9-16 km east of Cape Lisburne. Two days later, on 27 July, gulls were counted along the coast from a point about 35 km south of Point Lay to Wainwright. Along that stretch of coast 1150 gulls were counted. Of the total, 767 were classified as either adult or subadult and 168 (22%) were subadult birds. The relationship between adult and subadult gulls, however, was not uniform along the entire section of coast surveyed on that day. From the starting point south of Point Lay to Icy Cape, 487 gulls were classified and 9% of them were subadult birds. However, between Icy Cape and Wainwright a dramatic change in the proportions of subadult birds occurred; 280 gulls were classified, 44% of which were subadults. The remainder of the birds seen in both survey sections, but which were unclassified as to age, appeared to consist of adult and subadult birds in about the same ratios as were those which were classified.

Gulls were also counted from our raft on 29 July between Cape Lisburne and Corwin Bluff, about 35 km to the east. The ratio of subadult to adult gulls which we saw on that trip (10-15% of approximately 200 gulls were subadults) was consistent with observations we made from the air south of Icy Cape.

Our next trip east by boat was not until 15 August, by which date major changes in the numbers of gulls and in the proportion of adult to subadult birds had occurred. We traveled only 20 km east of the base but saw at least six flocks of gulls which numbered between 100-350 each, for a total of about 1,000 birds. Estimating the actual number of birds in the flocks, as well as aging the birds, was difficult because the gulls were often mixed with kittiwakes, flocks which were as large as 750-1000 total birds. Our best estimate of the ratio of adult to subadult gulls on 15 August, however, was that approximately 90% of the birds were subadult.

The only data we have on numbers of non-breeding gulls in the vicinity of Cape Thompson this past summer are from flights made on 29 July and 17 September. During the July flight between Point Hope and Cape Thompson, we counted approximately 250 gulls along the shoreline, about 25% of which were subadults. The majority of birds were feeding on the numerous walrus carcasses which had washed up during the summer. In September we flew from Cape Thompson south nearly to Krusenstern Lagoon, a distance of approximately 80 km. On that flight we counted 92 (43%) adult, 92 (43%) subadult and 32 (14%) juvenile gulls. In addition to those birds, we saw about 75 more of which 50-75% were estimated to be subadult and about 10% juvenile.

Horned Puffins were counted at Colony 1 at Cape Thompson but no counts were made at Cape Lisburne. The number of birds counted at Colony 1 was 218 and was slightly lower than numbers counted there in other years. However, only one count was made this year while in 1976 and 1977 the numbers we reported were the highest counts obtained during several trials. Had we been able to count the colony several more times during 1978, we might well have obtained a somewhat higher value. Counts of all years are presented in Table 4.

The number of Tufted Puffins we counted (10) at Colony 1, Cape Thompson, was also the result of only one count. In 1977 the highest of several counts was 13, while in 1976 our highest count was 24.

Fewer Pelagic Cormorants nested at Cape Lisburne this year than in 1977, 25 pairs compared to 36 pairs. Fewer cormorants also were found at Cape Thompson this year; only 11 pairs were present, fewer than in any other year except 1959. Those data are listed in Table 5.

No raptors were seen in the vicinity of Cape Lisburne in 1978. The only ones present at Cape Thompson were a pair of Golden Eagles which occupied the same stick nest on Colony 2 which has been used for the past two years, and a single Gyrfalcon that occupied Crowbill Point where a pair had successfully nested in 1976 and 1977. The pair of Golden Eagles, likely the same one which was there in 1976 and 1977, had two young in the nest on 11 August. The chicks, which appeared fully grown and feathered on that date, both fledged successfully by 20 August.

Table 4. Horned Puffin counts at Colony 1, Cape Thompson.

	16 Aug. 1978				
Plot	Time	Number of birds	1977	1976	1960
A	2005	33	32	26	17
B					147
C	2000	55	82	65	40
D	1955	21	16	12	23
E	1950	52	65	72	87
F	1945	4	13	11	0
G	1945	13	5	19	25
H	1935	38	40	35	50
I	1935	2	12	1	28
Total:		218	265	241	417

Table 5. Nests of Pelagic Cormorants at Cape Thompson.

Year	Colony 1	2	3	4	5	Total
1959	1	1	0	4	0	6
1960	3	18	0	1	1	23
1961	4	18	0	1	0	23
1976	7	2	0	5	0	14
1977	16	0	0	2	0	18
1978	7	0	0	4	0	11

Phenology

Hatching dates of murres at Cape Lisburne suggest that the breeding season in 1978 was about one week earlier than in 1977. Eggs were just beginning to hatch on our first visit to nest ledges, 24 July, and the size of the largest chicks we saw indicated that they had hatched during the previous 1-2 days. Based on hatching dates, egg laying probably began as early as 15-18 June. The first chick we saw in 1977 was about 3-4 days old on 5 August.

Perhaps one of the best indicators of laying dates in murres is the time when chicks first begin to go to sea. During the sea-going, chicks are very conspicuous and are forced to occupy common ground with the observers. Dates of first sea-going of murre chicks this year were also indicative of an early breeding season. At both Cape Lisburne and Cape Thompson murres were seen leaving the cliffs 9-10 days earlier than in 1977. Dates of first sea-going for all years are presented in Table 6.

Table 6. First dates of murre chick sea-going. All dates are in August.

	Year 1959	1960	1961	1976	1977	1978
Cape Thompson	25	18	19	>25	22	13
Cape Lisburne				27	20	11

Observations made on our flight of 17 September past the Cape Thompson colonies were consistent with other observations of the timing of the breeding season. On 17 September of this year, no adult murres or chicks were seen on the cliffs at Cape Thompson or on the waters or flying anywhere in the vicinity of the colonies. Swartz (1966) reported that in 1960 the last chicks at Cape Thompson were seen on 17 September but adults of both species were observed as late as 23 September and he thought it probable that those birds were tending chicks until that date. Swartz also reported that counts of murres on the cliffs indicated that some chicks were still present on 17 September 1961.

The breeding season of Black-legged Kittiwakes appears to have occurred about the same time at Cape Thompson this year as it did in 1977, although it was much earlier at Cape Lisburne this year than last year. The dates presented in Table 7 give an indication of the size of that difference at Cape Lisburne between years.

Table 7. Hatching dates of Black-legged Kittiwake chicks at Cape Lisburne.

Year	Numbers of observed hatches		
	Before 2 Aug.	2-15 Aug.	15-20 Aug.
1977	1	12	5
1978	18	22	1

By the time we arrived at Cape Thompson on 12 August, nearly all of the kittiwake eggs had hatched so we have no good data on hatching dates at that site. The chick weights presented in Table 8, however, suggest that the phenology of the kittiwake breeding effort at Cape Thompson was similar between 1977 and 1978 and was also similar to that at Cape Lisburne in 1978. The data in Table 8 also help illustrate the difference in timing at Cape Lisburne between 1977 and 1978. These data nevertheless should be evaluated judiciously; sample sizes for Cape Thompson for both years were small, standard deviations were high, and differences in average chick growth rates between colonies would definitely affect the averages.

Reproductive success

Although the number of kittiwakes at Cape Lisburne did not appear to be much higher this year than last, nor was the apparent number of kittiwake nests (75 nests were counted on 3 plots in 1978

Table 8. Average weights of Black-legged Kittiwake chicks in late August of 1977 and 1978.

Location	Date	n	Average weight
Cape Thompson	21 Aug. 77	5	314 ± 97
Cape Thompson	17 Aug. 78	6	317 ± 104
Cape Lisburne	19-20 Aug. 77	18	145 ± 99
Cape Lisburne	19 Aug. 78	39	328 ± 127

compared to 71 nests on those plots in 1977), the reproductive output of the birds at Cape Lisburne was undoubtedly higher in 1978 than during the past two years. An indication of the size of that difference can be seen in Table 9, which shows kittiwake nest contents at Cape Lisburne, 1976-1978. The apparent success of the reproductive effort by kittiwakes at Cape Lisburne was high, as indicated by the data presented in Table 10, and was similar to the high level of success (hatching success of 95% and estimated fledging success of 89%) achieved by kittiwakes nesting at Cape Lisburne in 1977.

Table 9. Black-legged Kittiwake nest contents at Cape Lisburne, 1976-1978.

Date	Total nests	Empty	1 egg or chick	2 eggs or chicks or 1 egg and 1 chick	Brood/ clutch size
27 Aug. 76	132	118 (89%)	14 (11%)	0	1.00
24 July-6 Aug. 77	144	61 (42%)	71 (49%)	12 (8.3%)	1.14
25 July 78	151	48 (32%)	78 (52%)	25 (16%)	1.24

A somewhat smaller change in the reproductive output of kittiwakes at Cape Thompson between 1977 and 1978 is suggested by the data presented in Table 11. The numbers for 1978 are compared to similar values obtained at other colonies in the eastern Chukchi Sea during 1978 in Table 12, data which together suggest that kittiwake

Table 10. Black-legged Kittiwake nest contents at Cape Lisburne in 1978.

Date	Total nests	Empty	1 egg or chick	2 eggs or chicks or 1 egg and 1 chick	Brood/ clutch size
25 July	151	48 (32%)	78 (52%)	25 (16%)	1.24
19 Aug.	131	33 (29%)	65 (58%)	15 (13%)	1.19

Table 11. Black-legged Kittiwake nest contents at Cape Thompson, 1976-1978.

Date	Total nests	Empty	1 egg or chick	2 eggs or or chicks or 1 egg and 1 chick	Brood/ clutch size
10-20 Aug. 76	200 ±	>95%	<5%	0	1.00
23 Aug. 77	238	104 (44%)	129 (54%)	5 (2%)	1.04
12-17 Aug. 78	220	123 (56%)	89 (40%)	8 (4%)	1.08

Table 12. Black-legged Kittiwake nest contents at three colonies in the eastern Chukchi Sea in 1978.

Location	Date	Total nests	Empty	1 egg or chick	1 egg and 1 chick or 2 eggs or chicks	Brood/ clutch size
Cape Thompson	12-17 Aug.	220	123 (56%)	89 (40%)	8 (3.6%)	1.08
Cape Lewis	18 Aug.	109	43 (39%)	63 (58%)	2 (2%)	1.02
Cape Lisburne	19 Aug.	113	33 (29%)	65 (58%)	15 (13%)	1.19

pairs at Cape Lisburne enjoyed a higher level of output than did those which nested at either Cape Lewis or Cape Thompson.

Although the number of cormorants which nested at Cape Lisburne this year was lower than in 1977, productivity was much higher. The average brood size of 25 nests examined on 17 August 1978 was 2.56 chicks per nest. On 20 August 1977, 36 nests contained an average of only 2.0 chicks each.

Cormorants also reproduced well at Cape Thompson this year, eleven pairs averaged 2.3 young in late August. Only two nests were examined in 1977 and the average brood size of 2.5 chicks might not have been representative of all nesting pairs. Productivity this year, however, was only slightly higher than in 1976 when 10 active pairs produced 2.2 chicks each. Together these data suggest that cormorant productivity at Cape Thompson has been relatively stable during the past three seasons.

Growth Rates

We were able to acquire growth rate data for only one species at one colony this year, Black-legged Kittiwakes at Cape Lisburne. Date were obtained on 40 chicks at irregular intervals between 24 July and 19 August.

The overall growth rate of chicks in 1978 was 20 ± 5.9 grams per day (N=39). That average included only those chicks which were less than 23 days old and weighed less than 400 grams on the last day so as to exclude from the calculations birds which had attained a growth plateau. Although the average daily weight gain was the same in 1978 as in 1977 (20.1 ± 2.5 grams/day), much greater variation was seen in growth rates between individual chicks this year than last. Many chicks grew relatively slowly, 11-15 grams/day; however, 24 chicks had an average daily weight gain of at least 20 grams/day during one or more weighing intervals, eight chicks gained at least 25 grams/day, one chick gained 30 grams/day during the last three-day weighing interval, and another gained 33 grams/day during the same interval. These growth rates are considerably greater than any recorded in the Chukchi Sea during 1977 and are also greater than any recorded by other investigators for other colonies.

Food Habits

We have not yet analyzed the stomach contents from birds collected at Cape Thompson and Cape Lisburne in 1978. Casual inspections of the contents, however, at the time they were collected provided some indication of differences and similarities in food habits between 1977 and 1978.

Arctic Cod, sculpins and Sandlaunce were the principal food fish of murres at both colonies as they were in 1977. Perhaps the most noticeable difference was the early occurrence of Sandlaunce, which murres were utilizing in quantity at Cape Lisburne by early July. Murres at Cape Lisburne also took Arctic Cod during early July and were observed carrying them back to the colonies between 5-13 July, several weeks earlier than birds were noted carrying fish in 1977.

Kittiwakes appeared to feed almost exclusively on Sandlaunce although Arctic Cod also were taken with some frequency earlier in the season at Cape Lisburne. In early July at Cape Thompson, nereid polychaetes appeared to be an important food item. Several hundred kittiwakes were seen "dip-feeding" just offshore between Cape Seppings and the Telavirak Hills on 4 July, and returning birds collected at Chariot on that date had been feeding heavily on polychaetes. In 1977 polychaetes were also common in kittiwakes collected in early July at both colonies but were never encountered in birds collected later in the season.

At Cape Thompson murres and kittiwakes took herring during August, a group of fish which has been essentially absent from previous years' collections. Specimens recovered from murre bill loads appear to be small Pacific Herring (Clupea harengus), a species which is restricted to warmer water, and which occurred in small numbers as far north as Simpson Lagoon in the Beaufort Sea during 1978 (P. Craig, pers. comm.).

Invertebrate prey appeared to have been abundant this year and was taken in large quantities by murres especially at Cape Lisburne. During the storm which occurred the last week of July, murres began feeding heavily on euphausids, amphipods and on smaller numbers of shrimp. Many of the birds collected during that interval, both from flocks returning to the colony and which were feeding on the waters just east of the colonies, were gorged with those crustaceans. The degree to which this new food source was utilized was reflected in the color of the cliffs which became stained a reddish purple throughout the entire length of the colonies. Murres continued to feed heavily on crustaceans for the next two-three weeks, by which time the cliffs were beginning to return to the normal whitish color.

Feeding Areas

Ground-based observations of murre feeding flights at Cape Thompson on 4 July and between 11-24 August are illustrated in Figure 3. Observations from the beach at Chariot on 4 July indicated that most of the murre population was flying to and from the south and southwest, a pattern which was the same as that observed by late July 1977. No observations upcoast of the colonies were made, and we do not know whether or not murres were flying in any numbers to and from the northwest at that time.

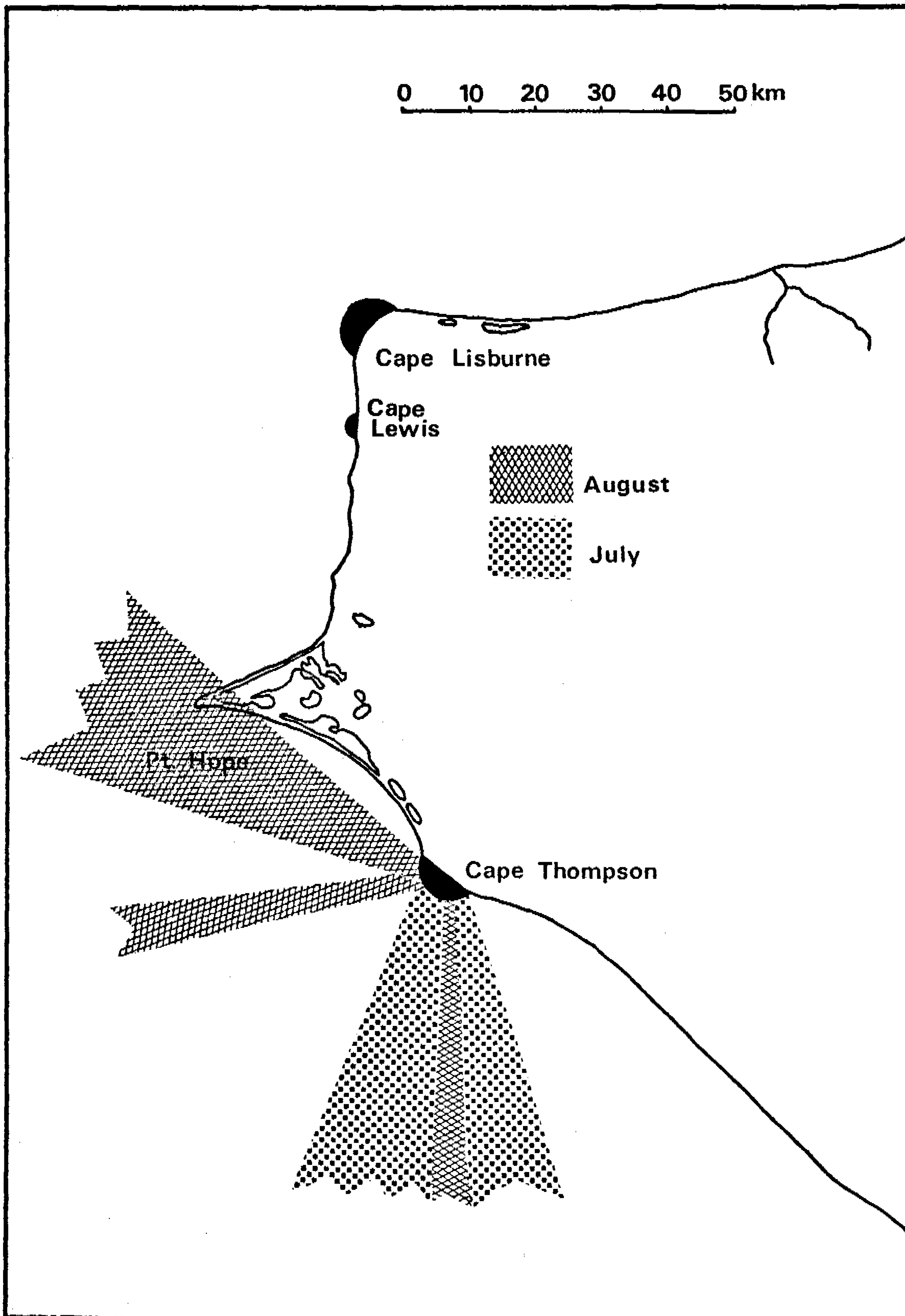

Figure 3. General murre feeding flight directions observed from shore at Cape Thompson, July - August 1978.

Small groups of kittiwakes were commonly seen flying in both directions south of Cape Thompson along the shoreline at Cape Seppings during 16-23 June (P.Bente and W. Tilton, pers. comm.). On 4 July kittiwakes were scattered along the coast between Chariot and the Singoalik River, and many more were flying to and from that region. Several large concentrations of kittiwakes were seen sitting on the water and appeared to be feeding (dipping) just northwest of Kisimilok Mountain.

On August 11, large numbers of feeding murres were observed on the water for several kilometers offshore and northwest of Colonies 3, 4 and 5. Most murres returning to the colonies were flying from the northwest and only a few flocks were observed returning from the south and southwest. Throughout the remainder of the 11-24 August period at Cape Thompson, some murres flew to and from the south and west, but it appeared that the majority of the birds were flying to and returning from the northwest as they had during August 1977.

Kittiwakes were foraging along the coast northwest of Colony 5 almost exclusively during the 11-24 August period. A few melees of 30-400 individuals were seen in front of the colonies and towards Point Hope. The birds were catching Sandlaunce which they were feeding to their chicks. Melees were less common at Cape Thompson this year than they were in 1977.

Generalized ground observations of murre flight directions at Cape Lisburne are illustrated in Figure 4. Between 5-13 July nearly all of the murres were flying to and from the east and northeast and they continued to follow that pattern until early August. By mid-August, however, the greatest number of murres were flying to the colony from waters lying in an arc between about 330° and 10° True from Cape Lisburne. Small numbers of birds flew more to the west and a few others continued to fly northeast. This basic pattern of early season activity to the northeast and late season activity more to the north was the same as that observed in 1977.

Kittiwakes at Cape Lisburne were observed to fly almost exclusively to and from the east during July, but by mid-August larger numbers were flying offshore to the north. Large melees were common throughout the season east of the colony and just offshore of the Cape Lisburne Air Force Base. The predominant food appeared to be Sandlaunce.

The July storm blew out of the south and caused particularly rough seas to the west of the Cape and offshore to the north. Surface water was very rough and considerable mixing occurred between surface and bottom water for a distance of several hundred meters offshore. This mixed zone was especially turbid from the input of bottom sediments into the water column. During the storm, which began on 25 July, feeding melees of kittiwakes along the coast near Cape Lisburne decreased in frequency and none were seen on 1 August. The majority of the kittiwake population appeared to be feeding then to the east of the Cape. Large numbers of murres, however, fed in the waters in front of the colonies and at a distance of about 100-1000 m.

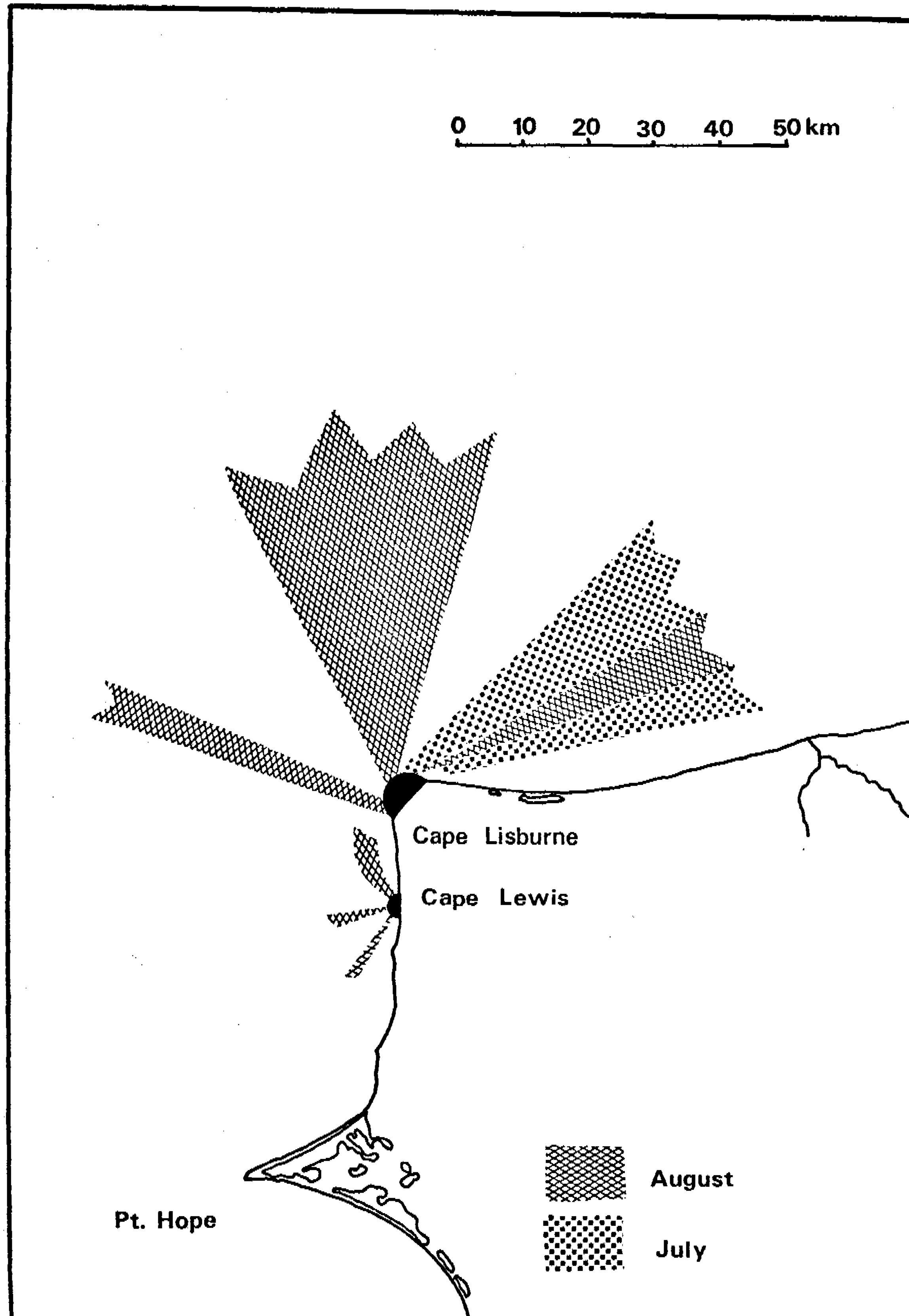

Figure 4. General murre feeding flight directions observed from shore at Cape Lisburne, July - August 1978.

offshore.

Some observations of murres and kittiwakes at Cape Lewis during August indicated that most of them were flying to and from the north, although a few were seen flying to and from the west and southwest. Feeding melees of kittiwakes were common along the coast between Cape Lewis and Cape Lisburne but murres were apparently feeding north of Cape Lisburne.

Data recorded during our aerial transects are illustrated in Figures 5-17. With the exception of our flight on 25 July for which we show eider distribution, we have included only numbers of murres and kittiwakes which were observed, although other species -- puffins, auklets, shearwaters and guillemots -- were seen in small numbers during most of our flights. We have not attempted to make estimates of absolute density, but use these data only to demonstrate areas of different realtive abundance.

Stormy weather prevailed during the week in July when our transects were flown and, as a result, somewhat less information was obtained in the vicinity of Cape Thompson than was at Cape Lisburne. Patterns of murre and kittiwake distribution near Cape Thompson were not clear except that few birds were feeding nearshore south of the site. Murres were seen on the water and flying west of Cape Thompson, however, our observations suggest that most of them were feeding at a considerable distance south of the colony. The same general pattern was apparent for kittiwakes also; a few birds were seen west of Cape Thompson, however, larger numbers were observed flying and sitting on offshore waters to the south.

At Cape Lisburne kittiwakes were encountered in large numbers on the July transects flown nearest the coast and were feeding in large melees just offshore. They were noticeably absent in deeper water farther from shore. Murres were also common nearshore and in deeper water northeast of the Cape. Observations from our raft suggested that most of the murres near the coast were Common Murres and that they were feeding on Sandlaunce. We do not know the species composition of the murres we saw offshore.

The transect we flew on 25 July between 1308 hours and 1340 hours seemed to lie on one edge of a sharply defined wedge within which birds flew to and from Cape Lisburne and feeding areas. Between this wedge and the coastal region of murre and kittiwake activity were seen large flocks of eiders. Estimating the numbers of birds present was difficult. One observer counted 35 flocks varying in size from 100 to 400, or approximately 12,000 total and a second observer estimated that he saw 15,000-20,000 birds on the water.

Unfortunately, the August window in which we intended to fly also was beset by stormy weather and flights were not made very far offshore of Cape Thompson. All observations, however, suggested that many murres were still feeding to the south and west of Cape Thompson and still in waters many kilometers distant.

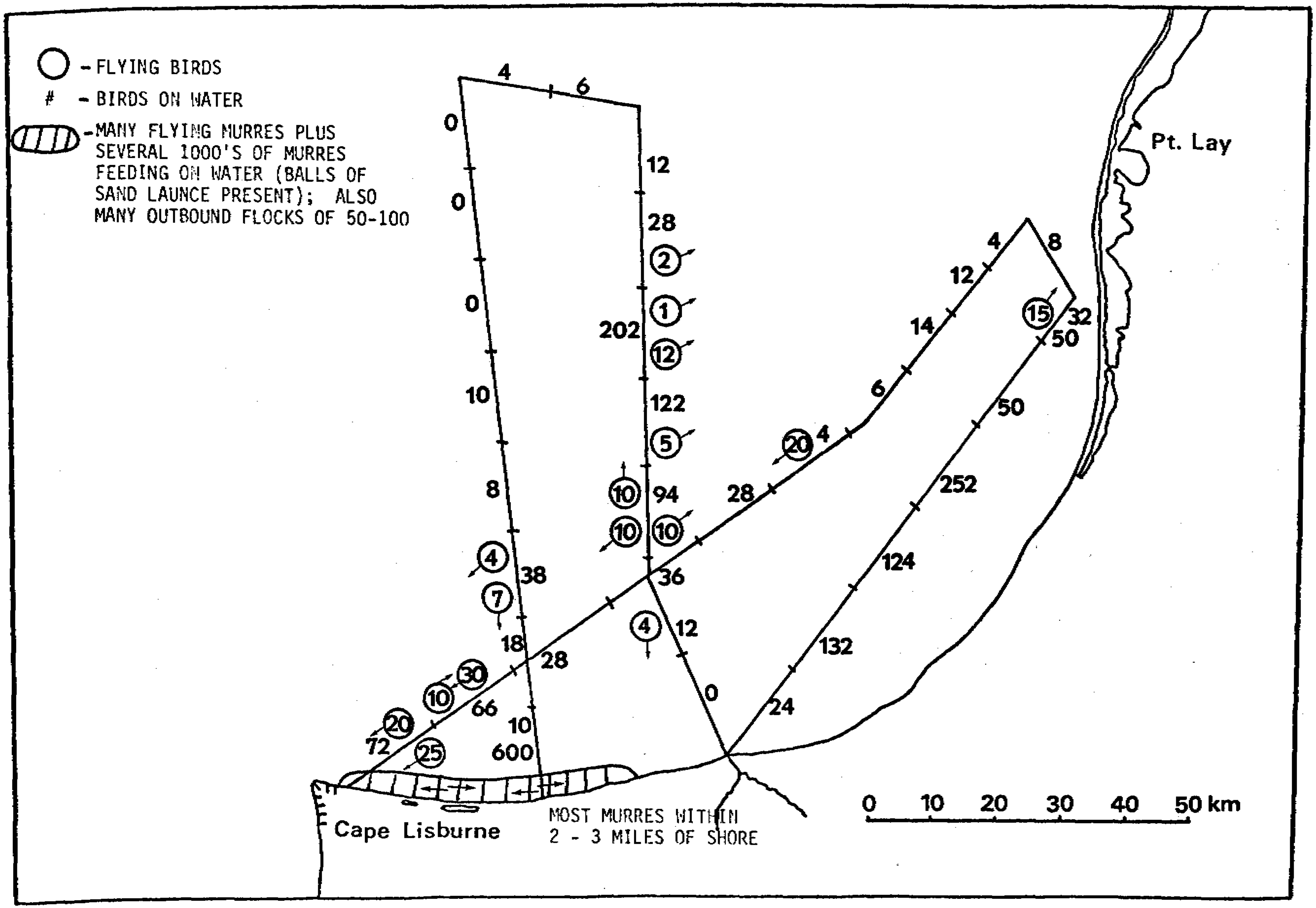

Figure 5. Observations of murres on transects flown 25 July 1978, 1208 - 1500 hrs. Bering Standard Time.

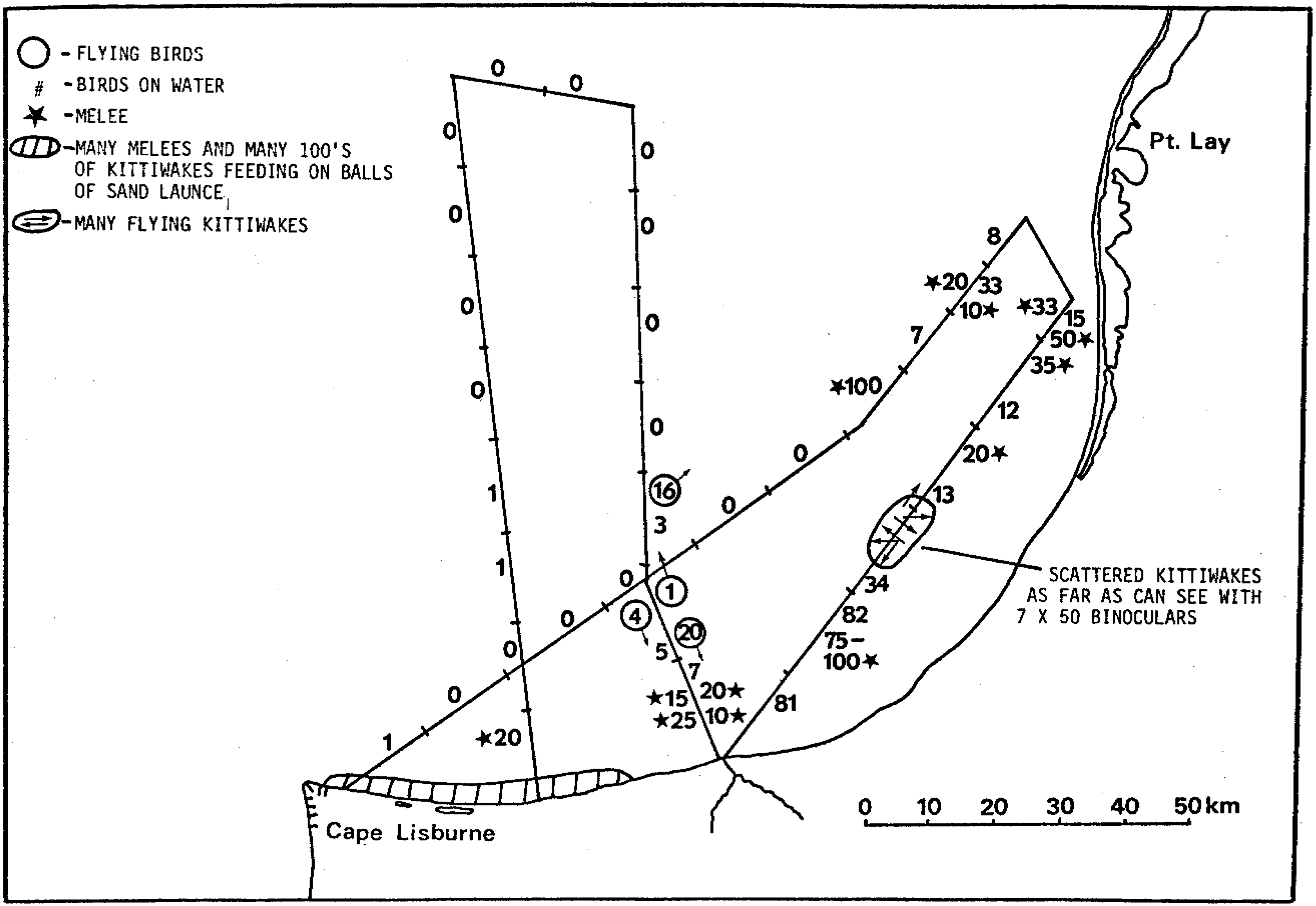

Figure 6. Observations of Black-legged Kittiwakes on transects flown 25 July 1978, 1208 - 1500 hrs. Bering Standard Time.

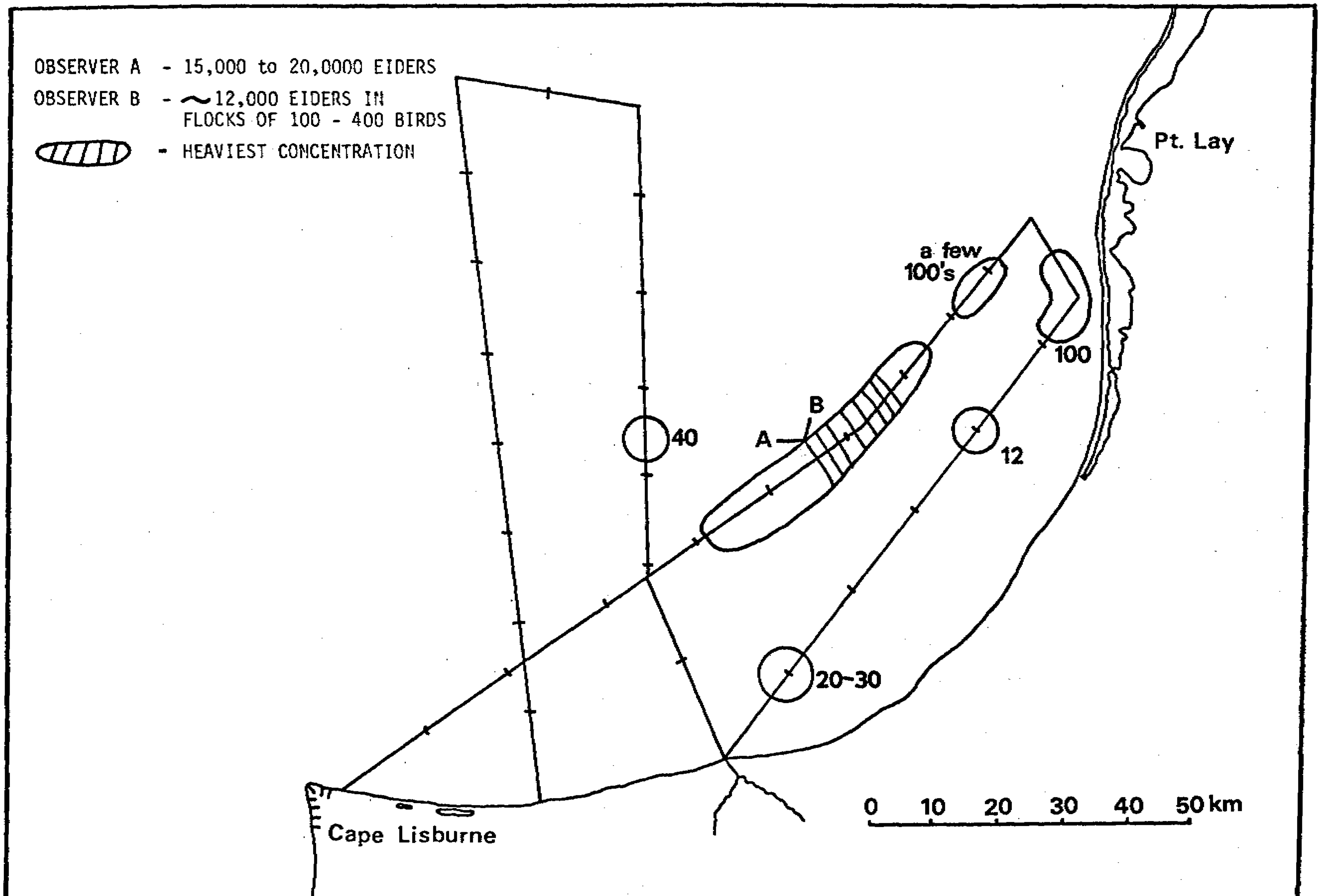

Figure 7. Observations of eiders on transects flown 25 July 1978, 1208 - 1500 hrs. Bering Standard Time.

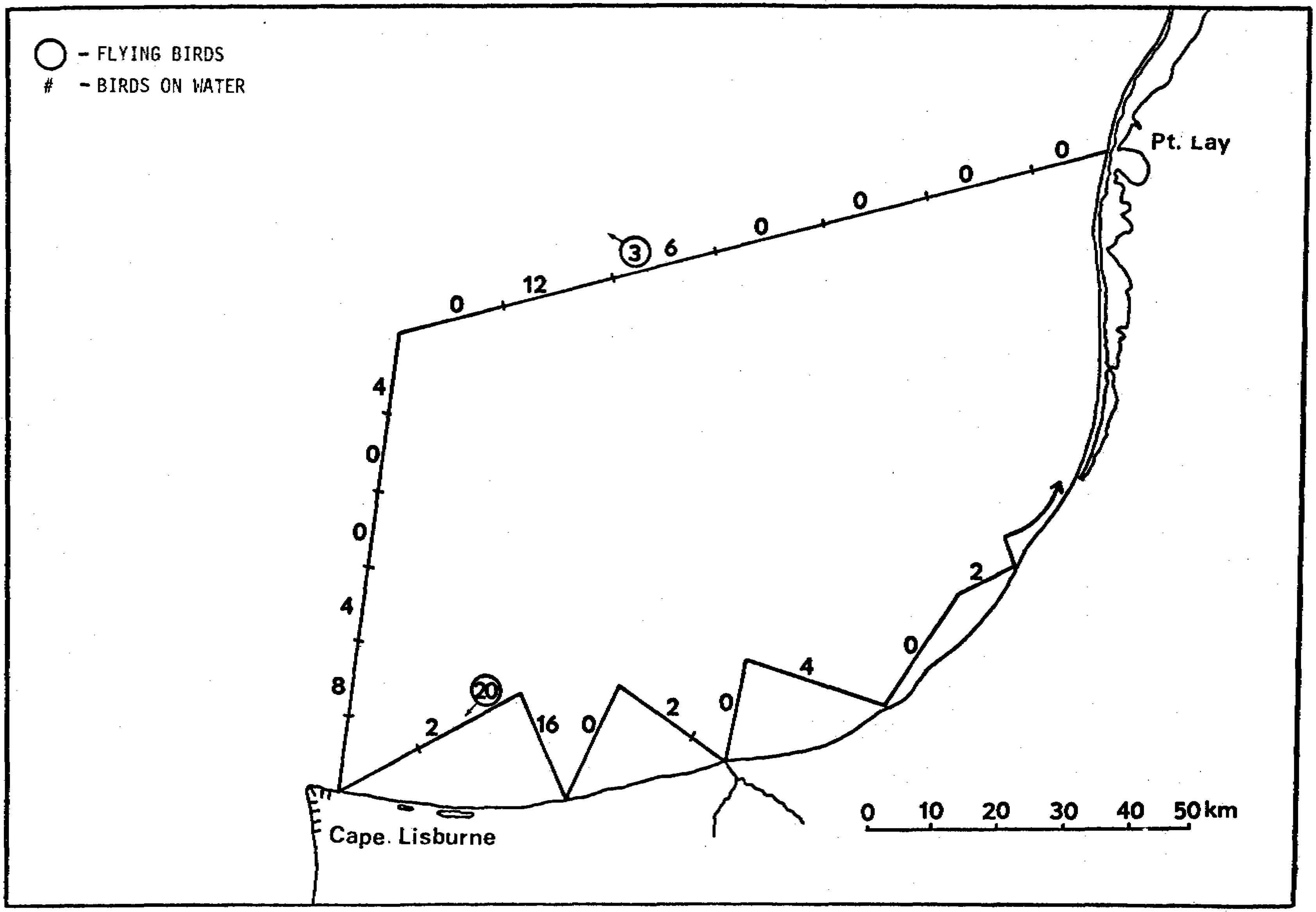

Figure 8. Observations of murres on transects flown 27 July 1978, 1000 - 1620 hrs. Bering Standard Time.

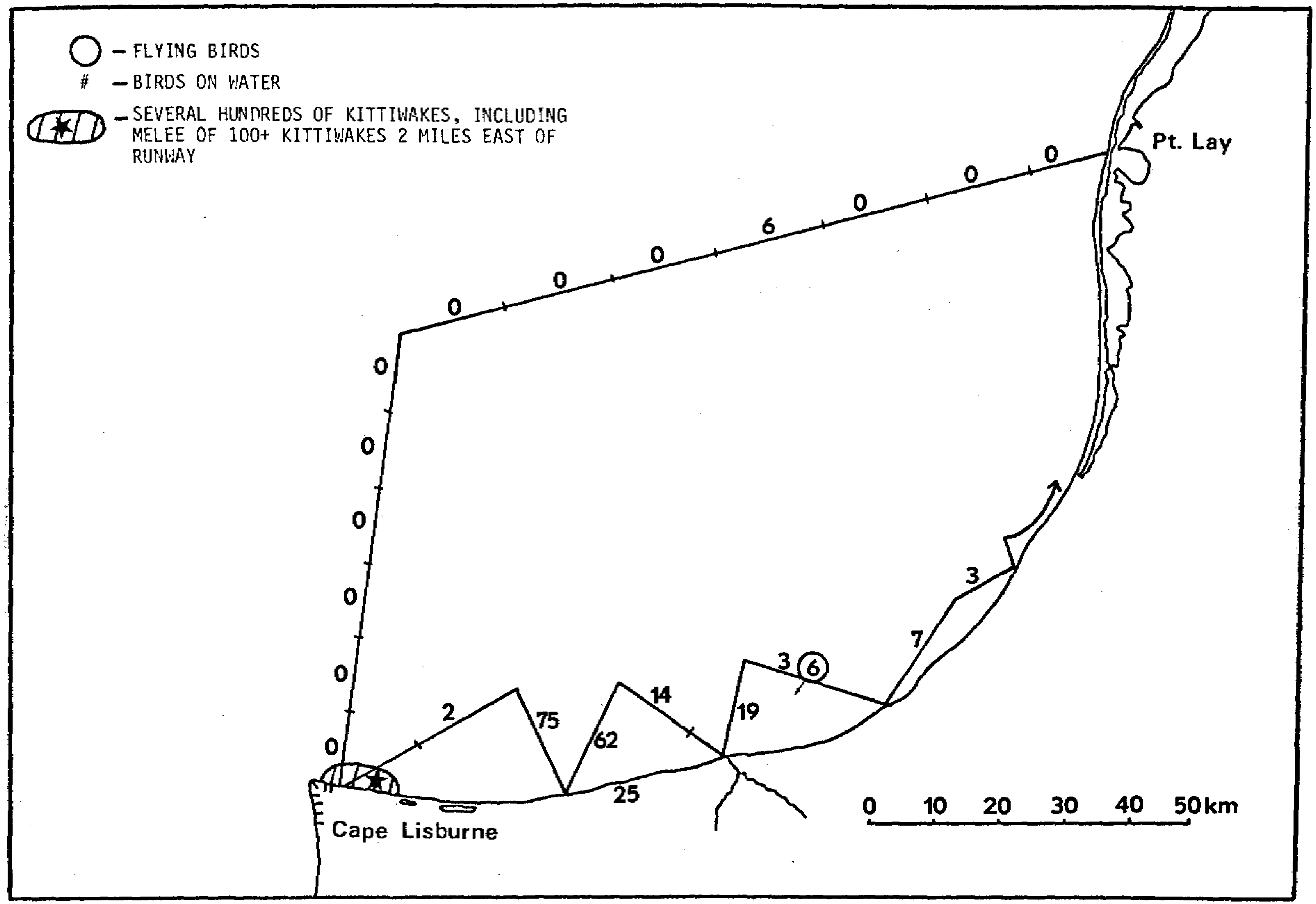

Figure 9. Observations of Black-legged Kittiwakes on transects flown 27 July 1978, 1000 - 1620 hrs. Bering Standard Time.

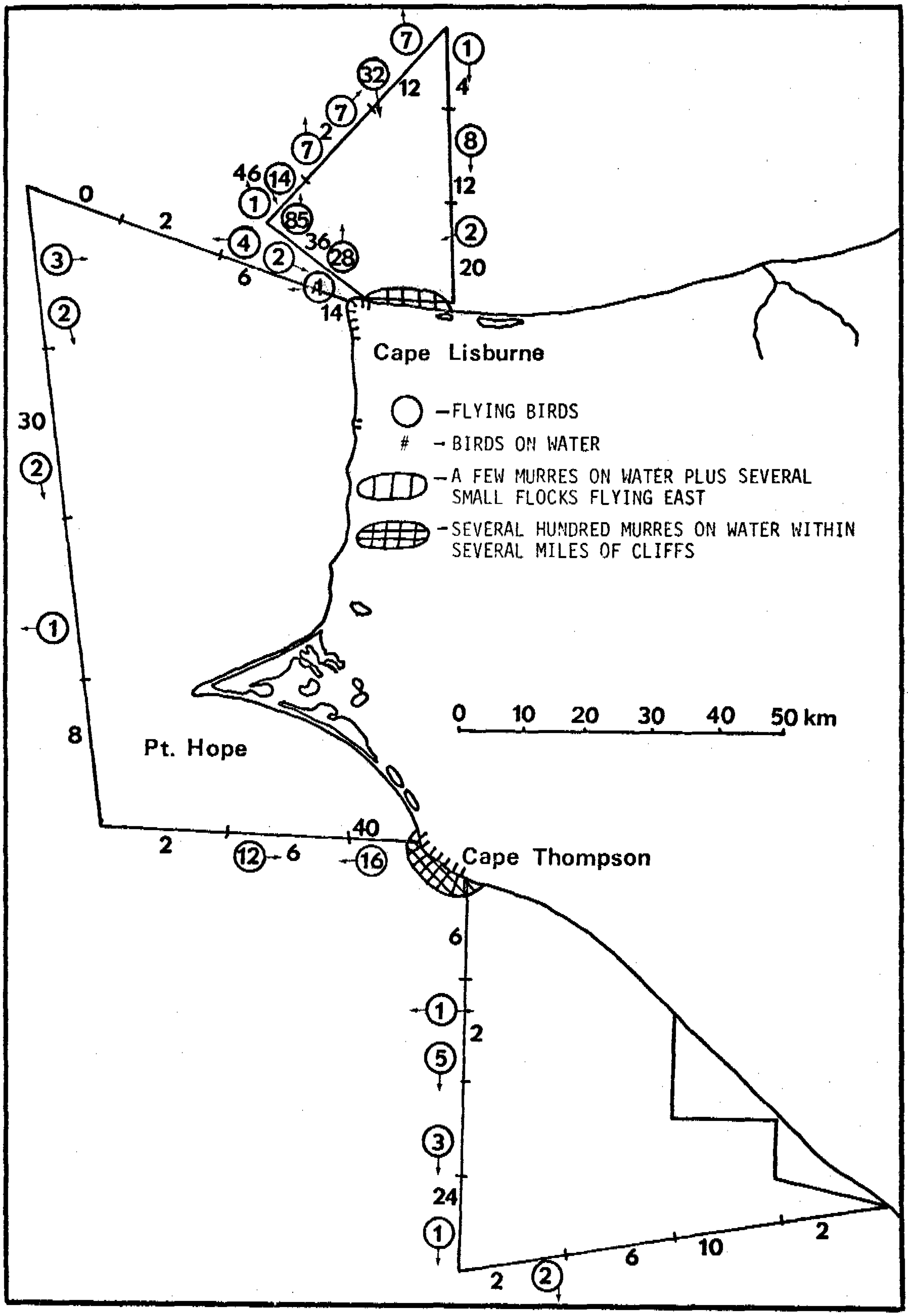

Figure 10. Observations of murres on transects flown 29 July 1978, 1032 - 1310 hrs. Bering Standard Time.

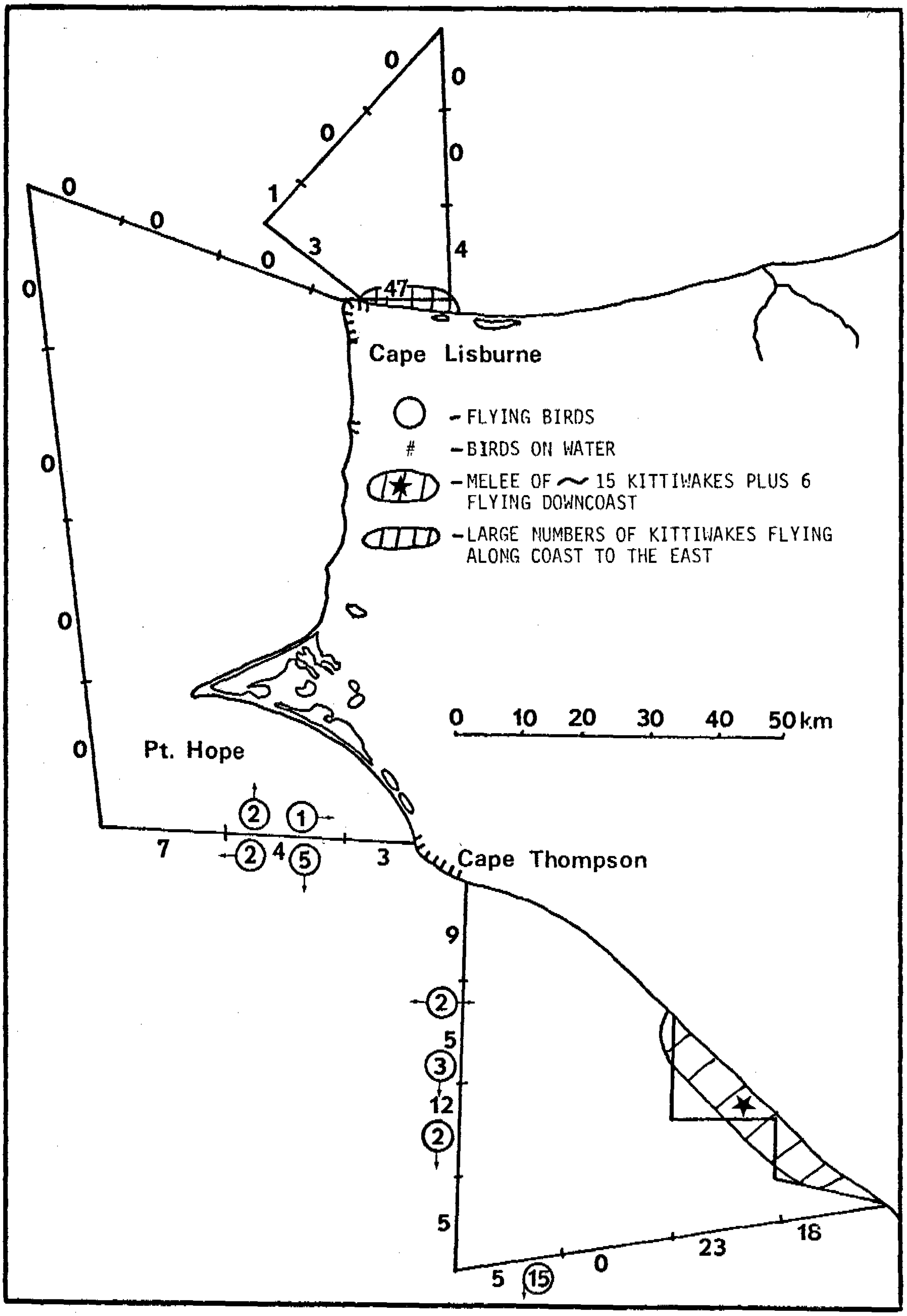

Figure 11. Observations of Black-legged Kittiwakes on transects flown 29 July 1978, 1032 - 1310 hrs. Bering Standard Time.

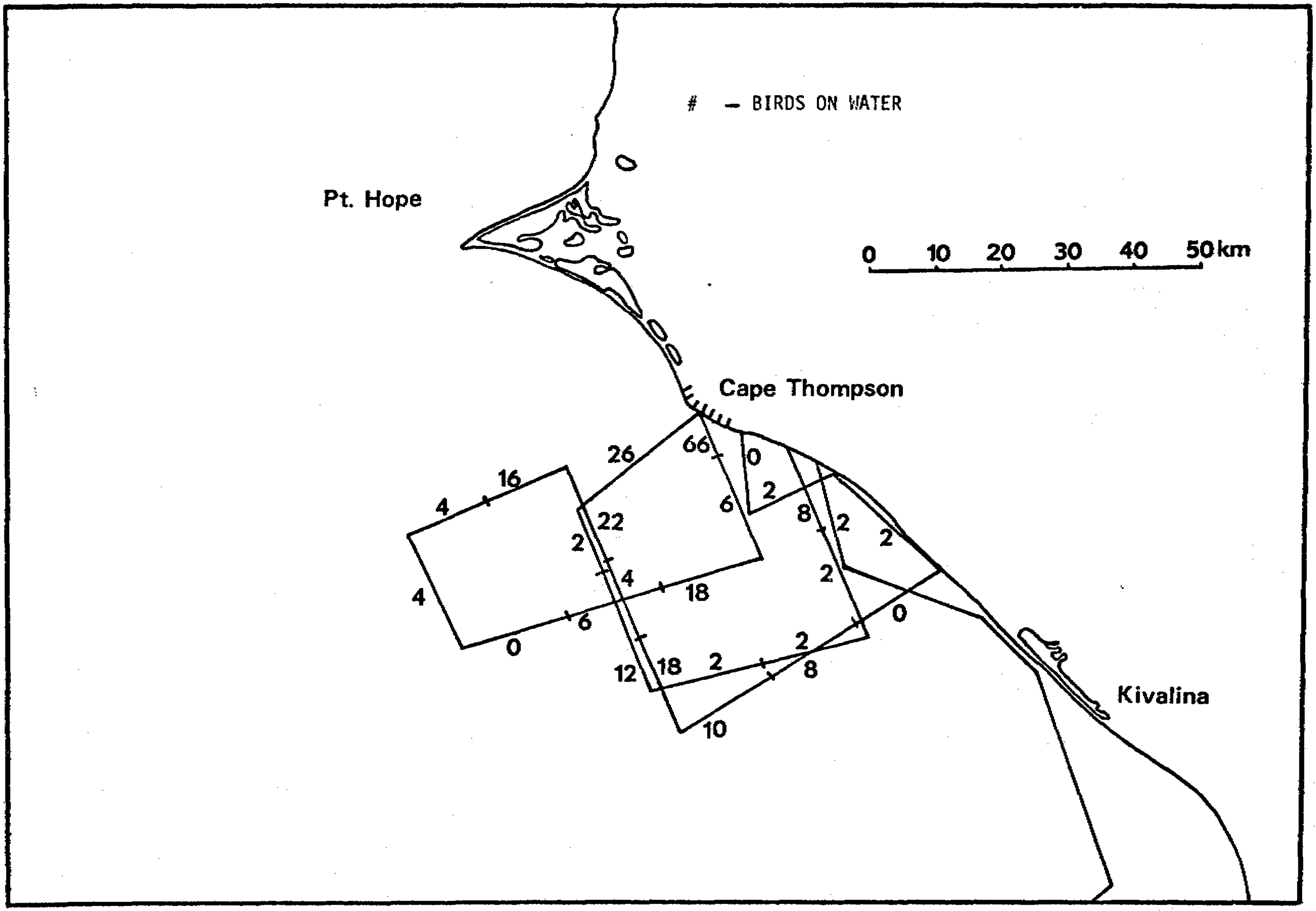

Figure 12. Observations of murres on transects flown 18 August 1978, 1055 - 1440 hrs. Bering Standard Time.

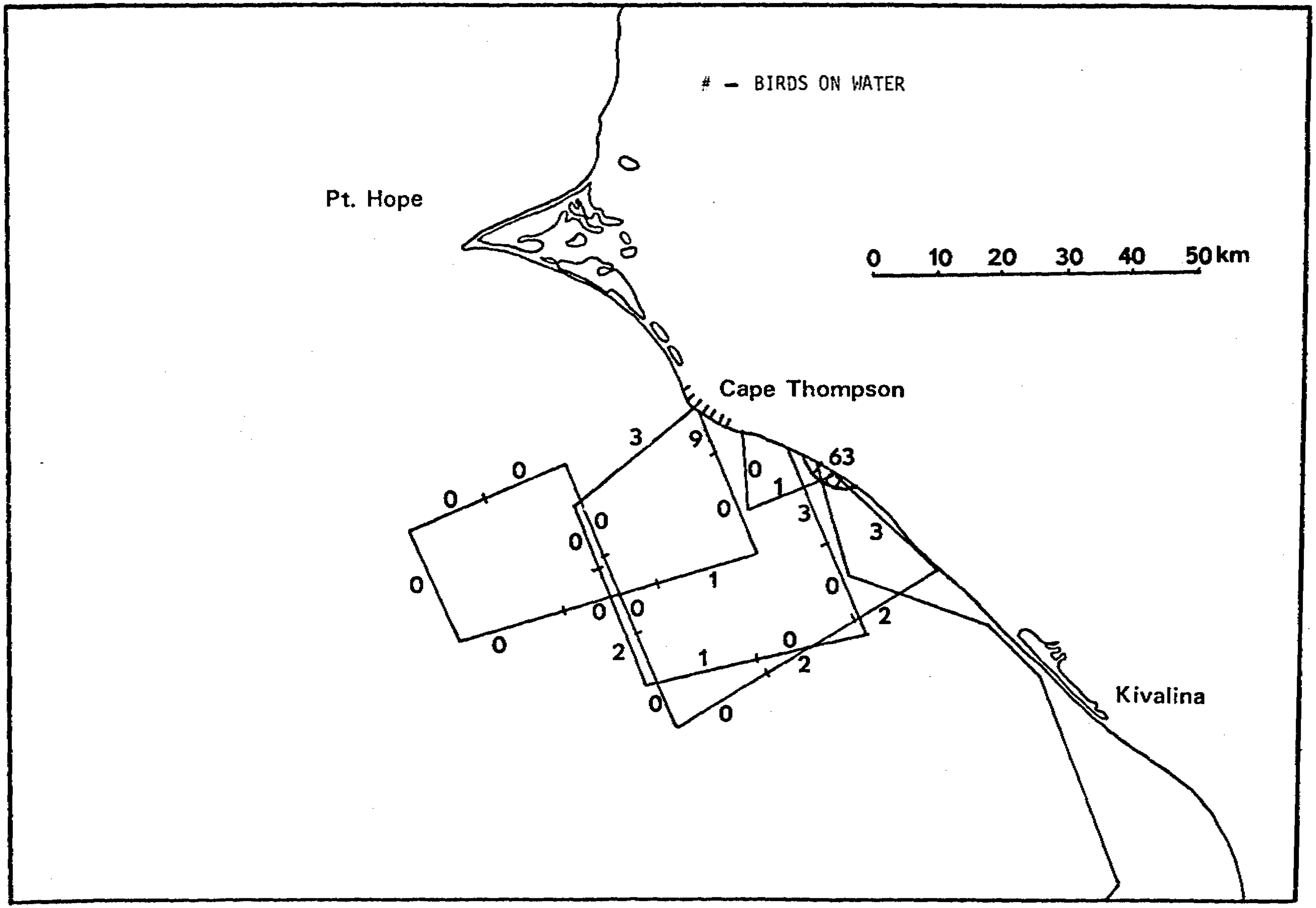

Figure 13. Observations of Black-legged Kittiwakes on transects flown 18 August 1978, 1055 - 1440 hrs. Bering Standard Time.

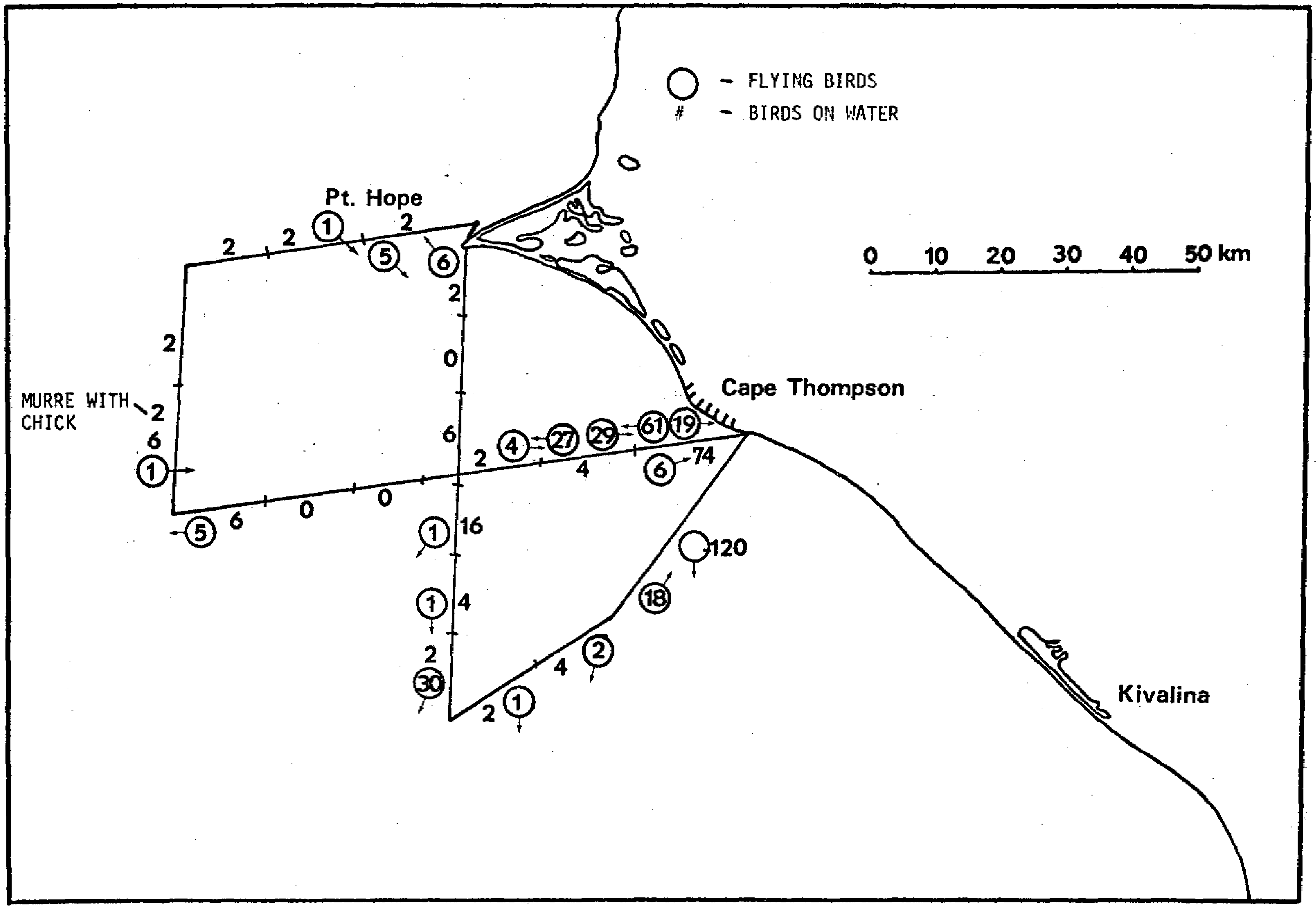

Figure 14. Observations of murres on transects flown 18 August 1978, 1930 - 2115 hrs. Bering Standard Time.

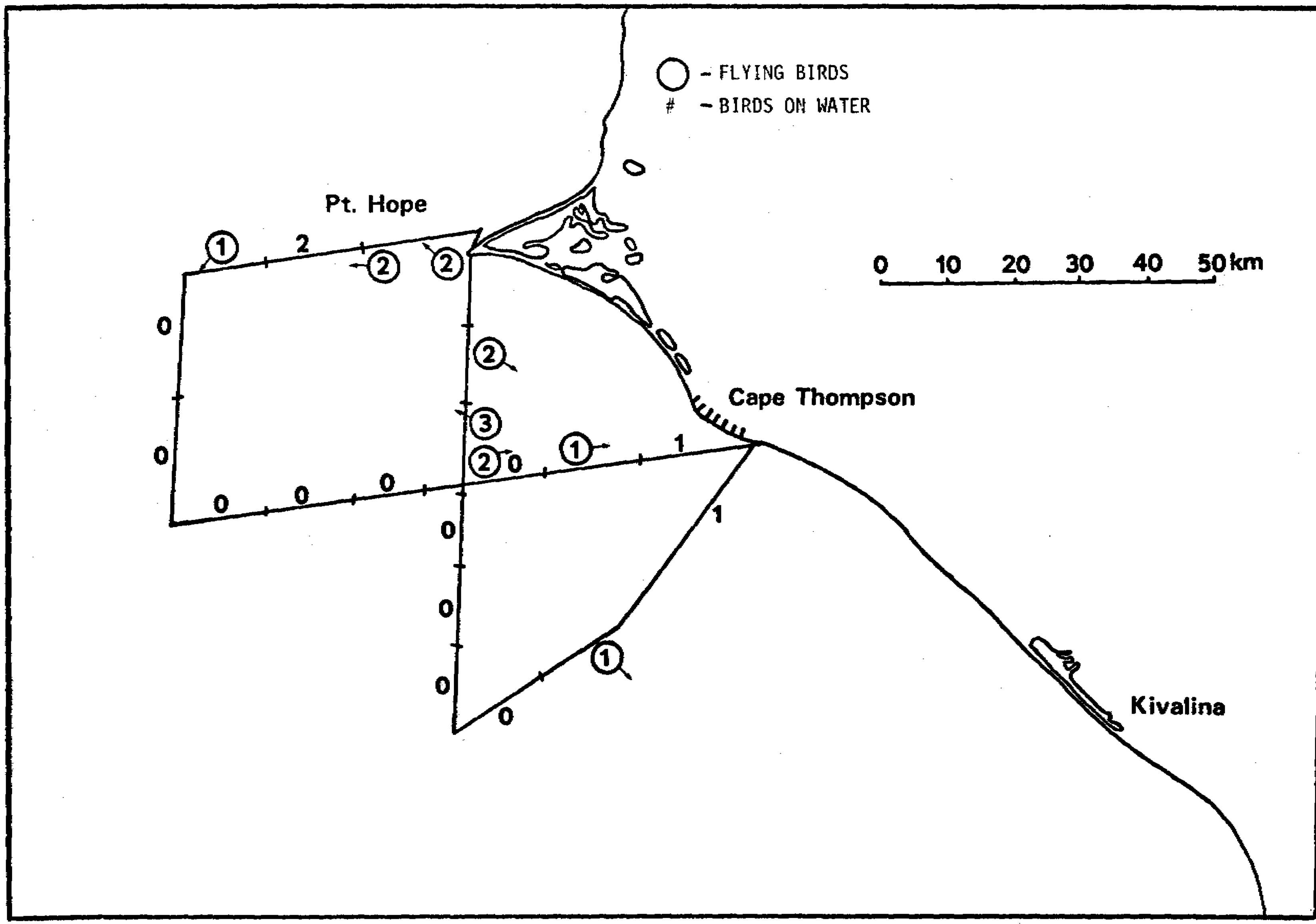

Figure 15. Observations of Black-legged Kittiwakes on transects flown 18 August 1978, 1930 - 2115 hrs. Bering Standard Time.

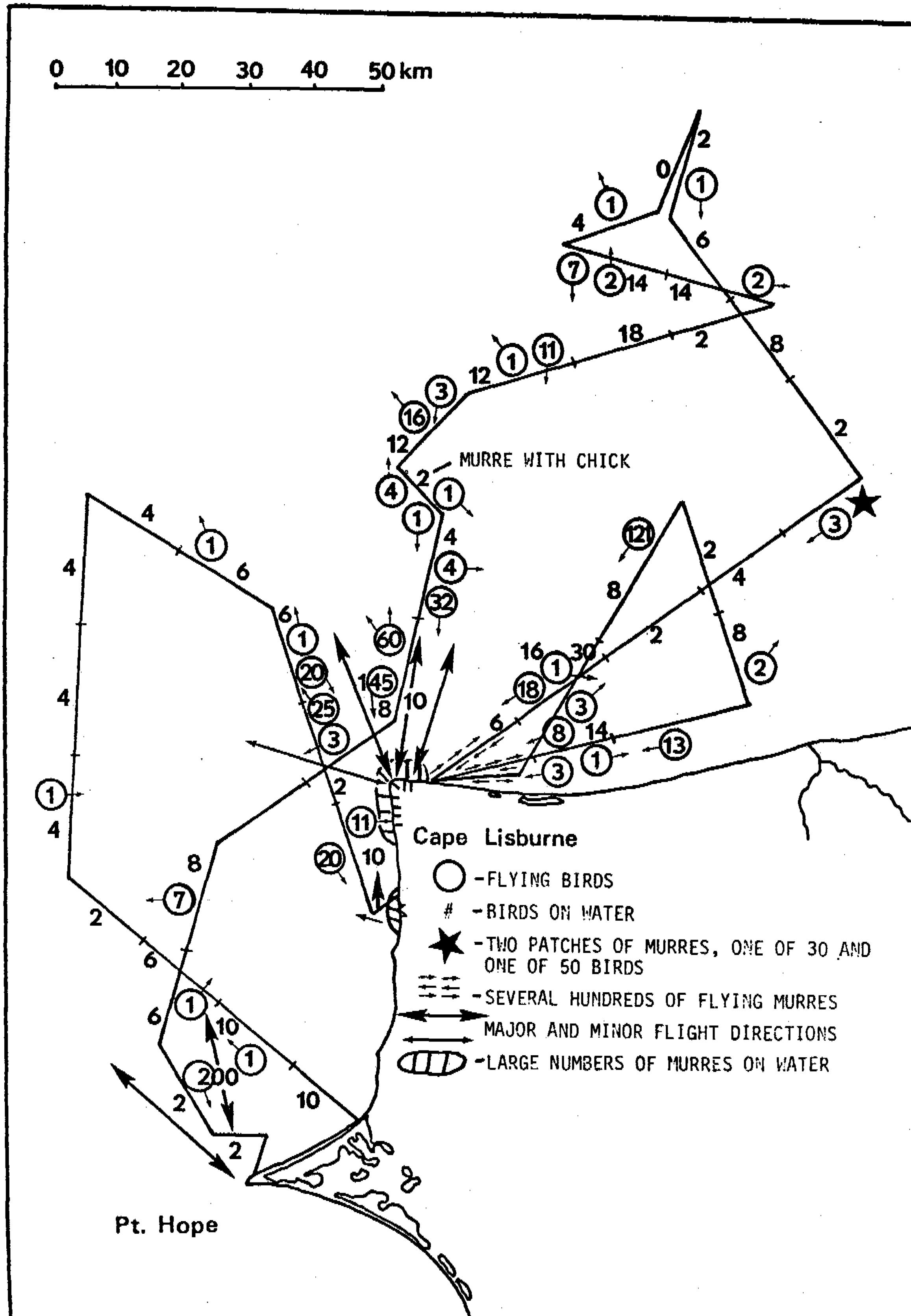

Figure 16. Observations of murres on transects flown 19 August 1978, 1304 - 1510 hrs. Bering Standard Time.

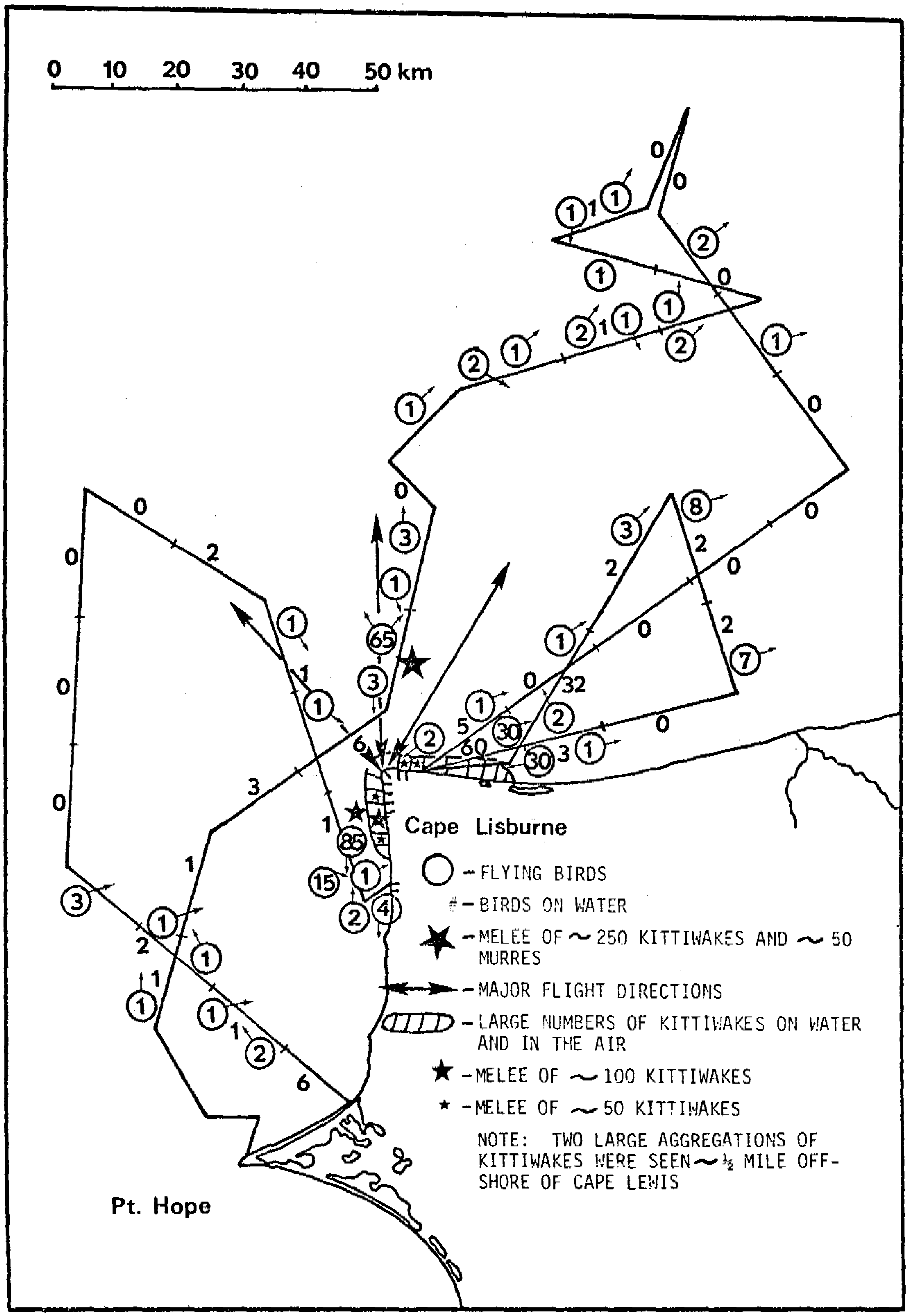

Figure 17. Observations of Black-legged Kittiwakes on transects flown 19 August 1978, 1304 - 1510 hrs. Bering Standard Time.

We also saw large numbers of murres flying north-south, apparently to and from Cape Thompson, past Point Hope. Birds were observed from the air in this region and were also seen flying across the end of the Point Hope spit while the aircraft was on the ground refueling. We saw few murres on the water west of Cape Thompson, nor did we see many birds on the water between Cape Thompson and Cape Lisburne. We believe that the murres which were observed flying past Point Hope may have been feeding with the birds from Cape Lisburne and Cape Lewis in waters north of Cape Lisburne.

During our flights off Cape Thompson we never encountered many kittiwakes, although several small groups totaling 63 individuals were seen on shore approximately 30 km south of Ogotoruk Creek. Our observations suggest that kittiwakes were feeding over a broad area and the majority may have been between Cape Thompson and Point Hope or north of our transects.

The northward shift in feeding grounds at Cape Lisburne, which was suggested by flight directions of birds seen from land, was confirmed during our transects on 19 August. Murres and kittiwakes were seen east of the colony but were much more numerous to the north than they had been in July. Birds were still uncommon offshore to the west of Cape Lisburne except for the ones which appeared to be commuting from Cape Lewis and Cape Thompson. Kittiwakes occurred in moderate numbers along the coast between Cape Lewis and Cape Lisburne and several melees were probably feeding on Sandlaunce.

Uncommon Observations

This past summer was the first season in which we observed either murres or kittiwakes in plumages other than those of adult breeding birds. We observed Thick-billed Murres in a mottled dark grey plumage, especially on the head and neck, on 10 occasions at Cape Lisburne and Cape Lewis during late July and August. Those birds were all on the water near the colonies but were not together in groups, and we collected two on 2 August. Both birds were small, one weighed 931 grams and the other weighed 910 grams, and neither bird showed evidence of reproductive development.

We also saw three kittiwakes during August which had grey hoods instead of clean white heads. Two of those birds were in a large flock of kittiwakes east of the Air Force base about 10 miles from Cape Lisburne - a flock of about 300 individuals, including both non-breeders and breeders. We collected four birds from that flock, one of which was a female grey-hooded bird which showed no signs of reproductive development. A single grey-hooded bird also was observed at Colony 4, Cape Thompson.

VII and VIII. DISCUSSION AND CONCLUSIONS

Our limited census work this summer leads us to believe that if the numbers of murres which have occupied the cliffs of Cape Thompson in recent years are in fact lower than they were in 1960 and 1961, the numbers now represent a stable decrease rather than a temporary response to a change in one or several environmental variables. Although we did not count murres at Cape Thompson this year, parallels between the many aspects of seabird biology at Cape Thompson and Cape Lisburne prompt us to speculate on the population of murres at Cape Thompson based on our limited counts at Cape Lisburne.

There was no indication that a major change in the number of murres had occurred at Cape Lisburne between 1976 and 1978. We believe that if, at Cape Thompson, a significant increase of murres had occurred between 1977 and 1978, we would have seen the same phenomenon this year at Cape Lisburne. Had an increase at Cape Thompson occurred, it would undoubtedly have been in response to some other change in the ecosystem, a change which would almost certainly have been felt at Cape Lisburne also.

At Bluff, on the other hand, Bill Drury has reported that the number of murres there has changed dramatically between 1975 and 1978; the population plummeted during 1976 and has tended to recover since then. That a similar change at Cape Thompson and Cape Lisburne has not been observed during our work is probably the result of two factors. The first is that a real problem does exist in being able to assess the significance of differences observed between years in numbers of murres in very large colonies. At Bluff, the murre population has varied between roughly 20,000 and 70,000, while at Cape Thompson and Cape Lisburne we are faced with populations numbering in excess of 200,000 birds at each colony. We feel confident, nevertheless, that if changes in the populations at Cape Thompson or at Cape Lisburne had occurred to the same degree as those reported at Bluff that we would have been able to detect them. This problem of accurately and precisely measuring numbers of birds in large colonies will be dealt with intensively at Cape Thompson during the coming field season.

The second factor, and the one which we believe is probably the definitive explanation, has to do with the composition of murre species between the two areas and the implied differences in prey abundance and diversity. At bluff, 99% of all murres are Common Murres while at Cape Thompson and Cape Lisburne Common Murres are outnumbered by Thick-billed Murres, approximately 60:40. During years when fish stocks are low, as we believe was the case in 1976, Common Murres will undoubtedly suffer more than Thick-billed Murres in any region. Moreover, in a region of low diversity such as Norton Sound, Common Murres have a much smaller buffer upon which they can depend to see them through lows of their preferred food. We saw, in 1976, that Common Murres at Cape Thompson took a greater percentage of invertebrate prey than they did in 1960 or 1977. The presence of relatively higher numbers of alternate prey for Common Murres at Cape Thompson compared to Bluff may well have moderated the effect of low fish stocks on Common Murres in the northern colonies.

Because of the substantially different trophic position which Thick-billed Murres occupy, the effect upon their population in years of low fish abundance would be even less than on Common Murres. Thick-billed Murres, at least at Cape Thompson and at Cape Lisburne, always take a much greater percentage of invertebrates than do Common Murres and in fact took apparently more invertebrates than fish in 1976. The greater diversity of marine fauna in the Cape Thompson-Cape Lisburne region, which probably determines in large measure the local seabird diversity, therefore, may also contribute to the stability of avian populations.

The data we have presented on kittiwake numbers at Colony 4, Cape Thompson, more nearly describe the numbers of kittiwake pairs which defended sites than the total number of kittiwakes which were present at the colony. We can support this conclusion on the basis of the following observations. During the time of the censuses of Colony 4 in each of the last three years, most of the kittiwakes were sitting singly on what appeared to be nest sites even though all of the sites were obviously not successful. Approximately 5%-10% of all occupied sites held pairs rather than single birds. That proportion of singles and pairs occupying sites was noticeably constant in 1977 and 1978 whenever counts were made, but was not always true in 1976. On 9 August 1976, the date on which our Colony 4 census occurred, the total of three plots, A, B, and C, within that colony was 467 birds. The total of those three plots on 14 August, however, was only 75 while on 15 August the total was 734. All of the counts on those days were made between 1750 and 1845 hours. On 14 August, obviously most of the birds were away from the colony and on 15 August we observed that many more sites were occupied by pairs than had been on 9 August or on 14 August.

If 10% of the kittiwake sites were occupied by pairs during the census of Colony 4 in 1976, 1977 and 1978, extrapolating numbers of total kittiwakes represented results in estimates of numbers which are in much closer agreement with data reported by Swartz for kittiwake numbers at Cape Thompson during 1959-1961. The totals which Swartz (1966) reported were based upon counts of "nests" which may well correspond to our definition of sites. However, judging from average clutch size information, conditions in 1960 were more favorable for kittiwake breeding than in recent years and many more birds may in fact have constructed nests. We have compared in Figure 18 our extrapolated Colony 4 totals to estimated totals based on nest counts which Swartz reported.

As we suggested in our 1976 annual report, the erratic behavior of kittiwakes during that summer prevented us from obtaining good estimates of either the total number of kittiwakes present at the colonies or the number of nests or sites defended by pairs. That the total kittiwakes counted at Cape Thompson at colonies 2-5 in 1977 was in fact somewhat lower than the same total for 1976, therefore, is possibly explained by the erratic nature of site occupation in 1976.

A larger fluctuation in numbers of kittiwakes appears to have occurred at Cape Thompson in the last three years than has at Cape

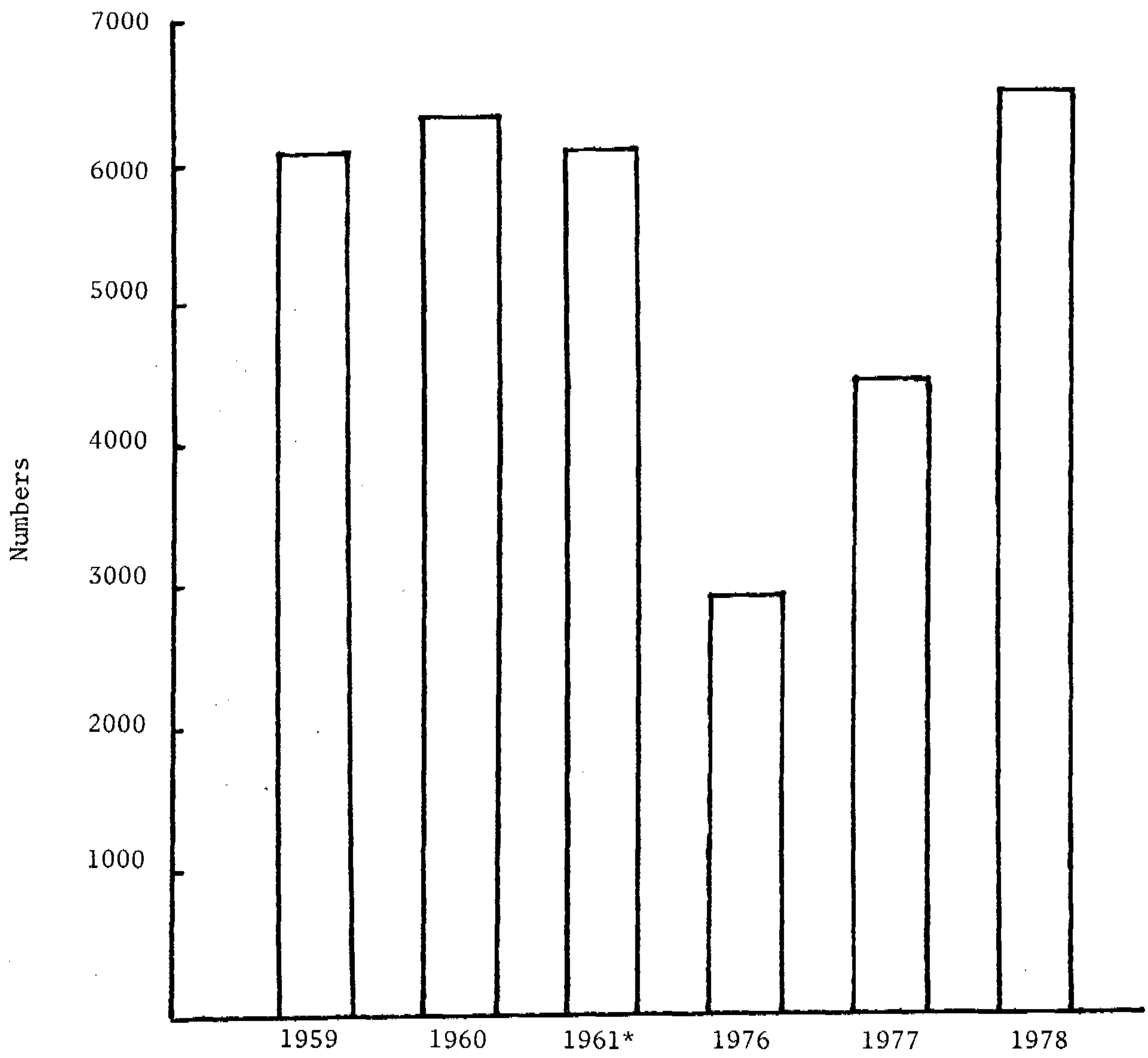

Figure 16. Estimated kittiwake totals in Colony 4, Cape Thompson. Numbers for 1959 and 1976-1978 extrapolated from total bird counts. Numbers for 1960 and 1961 are 2 x the number of nests counted.

*Estimate based on partial count

Lisburne. Unfortunately, we do not have data on kittiwake numbers at Cape Lisburne in 1976; however, there seems to have been less change between 1977 and 1978 at Cape Lisburne than there was at Cape Thompson. That difference is consistent with differences in other components of kittiwake biology between the two colonies which we have observed.

Kittiwakes at Cape Lisburne appear to have been somewhat less affected than birds at Cape Thompson by the factors which resulted in the kittiwake breeding failure of 1976. Although reproductive success at Cape Lisburne was poor, many more birds at that colony constructed nests, laid eggs and hatched chicks than did the birds which nested at Cape Thompson.

The recovery of kittiwake productivity at Cape Lisburne also appears to have been more rapid than at Cape Thompson. Because changes in numbers of breeding birds undoubtedly have been related to the reproductive success of the population, it follows therefore that the number of breeding kittiwakes at Cape Lisburne may not have fallen as drastically in 1976 as it did at Cape Thompson. Moreover, a much higher proportional recovery in numbers may have occurred at Cape Lisburne between 1976 and 1977. The census work we have planned for the coming summer should help clarify this issue.

Concern seems to be growing among other investigators over the proportions of adult and subadult Glaucous Gulls which have been observed in northwestern Alaska during recent years. The suspicion is that the Glaucous Gull population may be exploding since relatively larger and larger numbers of subadult gulls have been seen, especially during 1977 and 1978.

The changes in the total number of gulls which we have seen in our study areas have been due primarily to changes in the subadult population. At Cape Thompson we have not observed an increase in the numbers of breeding adult gulls since 1960, in fact the numbers are now very nearly the same as they were then. During the past three years in the Cape Lisburne region, the numbers of adult gulls have also remained stable, in the order of 200-250 birds. The numbers of subadult gulls, however, have increased during the years. Moreover, in 1978 subadult gulls were first observed near the colonies much earlier than in previous years.

We believe, however, that these data should be used carefully in forming conclusions regarding changes in the size or the age structure of the gull population. Widely different results will be obtained, depending upon the date during the summer when gulls are censused. No subadult gulls were seen at Cape Thompson in June of 1976 or in July of 1976 and 1977. Subadult gulls were not seen at Cape Lisburne during July of 1977, either. Not until August of 1976 and 1977, and somewhat earlier this year, have subadult gulls been seen near either Cape Thompson or Cape Lisburne, after which time they have increased in numbers and constituted progressively greater and greater proportions of the population. For example, had an age structure been developed on observations recorded at Cape Lisburne in

July of this year, it would have been determined that 10-15% of all gulls within the region were subadults. By late August, however, not only did subadult gulls account for 90% of all gulls but the total population size was approximately 10 times greater than it had been in July.

We question whether the major changes in numbers of subadult gulls represent either recent (during the past 3-4 years) changes in gull productivity, or major changes in gull survivorship curves. A flock of subadult gulls could be composed of birds one, two and three years old, and many of the birds in the flocks we saw at Cape Lisburne this summer were certainly alive and living well enough in some other region in 1977 and some also in 1976. We believe the reason they occurred in such large numbers this summer in the vicinity of Cape Lisburne is almost certainly the result of early, bountiful supplies of food fish, particularly Sandlaunce. Except for a few breeding birds at the colonies, all of the gulls were found east of the cliffs and were feeding perhaps exclusively on fish. Although detailed observations were not made at either the Cape Thompson or Cape Lisburne colony, our impressions were that predation by adult gulls on murre eggs and chicks was relatively lower this summer than in 1977 or 1976.

The changes we have seen in the Glaucous Gull population at Cape Thompson and Cape Lisburne are consistent with changes we have observed in other species of seabirds. We believe the causative factors underlying those changes are the same, that the prey base upon which the seabirds depend has been recovering steadily since a low in 1976. This is not to say that food subsidies for gulls, particularly at garbage dumps, may not in fact be responsible for an increase in the population. We stress, however, that conclusions of that nature need to be made carefully, keeping in mind parallel changes in other elements of the ecosystem.

All of our Horned Puffin totals at Colony 1, Cape Thompson, are much lower than those obtained in 1960 by Swartz (unpublished notes). The major source of the difference lies in the number of birds he counted on Plot B, a plot which we have been unable to relocate, but which may have been a gull plot above the cliff tops. Photographs taken in 1960 do not show major changes in the cliff structure or beach composition when compared to present conditions, changes which might have reduced the extent of nesting habitat. If the number of birds counted on Plot B in 1960 is excluded from that year's total for Colony 1, the resulting number of 270 is much closer to the totals we have gotten during the past three years. However, we cannot yet explain this difference to our satisfaction.

The apparent recovery of the size of the kittiwake population has been matched by progressively larger clutch and brood sizes and by earlier laying dates of kittiwakes and murres. We believe these changes undoubtedly describe the profile of energy available to the birds during these years, but we are not prepared to explain the factors and their relationships which result in yearly and seasonal differences in elements of the energy structure upon which seabirds depend. We believe that currents and sea ice are very important but the "how's" and "why's" are anything but clear.

The presence of Sandlaunce in the eastern Chukchi Sea during the summer months is undoubtedly important to the success of kittiwake and, perhaps, to a lesser extent murre reproductive success. Sandlaunce are probably the easiest prey for kittiwakes to catch because they school in dense shoals which are often just beneath the surface. For any diving birds these masses of Sandlaunce provide an easy opportunity to optimize the energy expense/energy income ratio. During years when Sandlaunce are abundant in the region of Cape Thompson and Cape Lisburne we have seen that kittiwakes reproduce much more successfully than during years when Sandlaunce appear to be unavailable.

We are intrigued by the way in which seabirds distribute themselves over Ledyard Bay. The pattern suggests that the birds are possibly exploiting food resources which have different regional levels of abundance, thereby reducing interspecific competition and optimizing the return on their respective investments in feeding activity.

Although Thick-billed Murres were commonly seen along the coast east of Cape Lisburne, Common Murres predominated. Similar observations of Common and Thick-billed Murre segregation have been made by Swartz (1967). That Common Murres would be found in the same area as kittiwakes is not surprising since both are highly piscivorous species and were feeding on Sandlaunce which were abundant along the coast throughout the length of Ledyard Bay. Thick-billed Murres, which also took large numbers of Sandlaunce, nevertheless consumed much greater relative numbers of invertebrates, mainly crustaceans, than did Common Murres or kittiwakes, a food resource which might have been more plentiful in deeper waters of the bay.

We doubt that the eiders occupied intermediate water because of racial considerations. However, we know little about eiders in the region; we do not know how long they had been in the area, how long they remained or what they were eating. We commonly see large flocks flying west past Cape Lisburne in later summer, flocks which number in the order of 300-500 birds. Their trajectory apparently carries them well offshore before they turn south, because eiders are seldom seen at Cape Thompson. These flocks appear to be composed primarily of King Eiders and Common Eiders.

It is clear from the aerial transect data and from our land-based observations of flight directions that the majority of seabirds at Cape Lisburne utilize Ledyard Bay throughout June and July. In contrast to this are the observations we have made both from the air and again from the land in August of a major northward shift in the waters utilized by murres and kittiwakes.

Very little information exists concerning regional distribution and abundance patterns of fish and invertebrates, and much less regarding seasonal differences in those patterns. Reports by Alverson and Wilimovsky (1966) and Wing (1974) suggest that cod and shrimp are most numerous northeast of Cape Lisburne during July and that copepods are most diverse and most dense north and northwest of Cape Lisburne in October. Presumably similar patterns would be evident in the respective predators and prey of those organisms. Patterns in the areal distribution of seabirds are certainly related to food availability and are consistent with the above observations.

To the south, between Cape Lisburne and Point Hope, prey stocks used by seabirds appear to be small. We saw very few birds on the water although we did see somewhat surprising numbers flying through the area en route to and from Cape Lewis and apparently Cape Thompson. In the Cape Thompson vicinity we do not have as clear a picture of foraging areas except that, besides the birds which apparently flew north, perhaps the majority fed at some distance to the southwest.

Ours are not the first observations of murres flying north from Cape Thompson. R. M. Gilmore (unpublished field notes) recorded watching "...endless flocks of Pallas Murres fly by" as he sat at Point Hope on 4 August 1931. His conclusion was that the birds were on their southward migration because their directional orientation was from north to south. We suggest that he was seeing flocks returning to Cape Thompson from feeding grounds which were likely north or northeast of Cape Lisburne.

Growth rates of kittiwake chicks are perhaps the single best indicator of energy available to the kittiwake population in mid to late summer. The differences in chick growth rates between Cape Thompson and Cape Lisburne which we reported last year, and the phenomenally high growth rates attained by chicks at Cape Lisburne this summer strengthen our belief that the waters of Ledyard Bay are unusually productive compared to other regions of the Chukchi Sea.

Because of heavy utilization of the whole of Ledyard Bay as a feeding ground of major populations of seabirds, resource development within these waters could not be recommended. The area appears to be central to the success of birds at Cape Lisburne, Cape Lewis and, in some years, Cape Thompson. Although few birds appear to frequent the region between Cape Lewis and Point Hope, we could not recommend development there either. The currents which circulate through Ledyard Bay, and which may be important to its productivity, of course arrive from the south, and the effects of accidents to the south of Cape Lisburne would almost certainly be felt in Ledyard Bay. We have seen that the ecosystem is not particularly stable, and it should be clear that chronic or acute disturbance resulting from developmental accidents or activities could have a serious impact on seabird populations throughout the eastern Chukchi Sea.

IX. NEEDS FOR FURTHER STUDY

Feeding grounds of seabirds at Cape Thompson are still poorly defined. Kittiwakes utilize nearshore waters both north and south of the colonies in years when Sandlaunce are plentiful. During much of the summer, murres appear to feed over a broad area which might be farther to the south and southwest than has previously been thought. The value of aerial transect observations was demonstrated at Cape Lisburne the past season and we believe that additional, more extensive flights should be made at both colonies but particularly at Cape Thompson. One factor which will certainly be of great importance to the long-term success of seabirds is the maintenance of unaltered regions in the Chukchi Sea which support the food base upon which the birds depend.

One of the most critical elements of kittiwake biology in the region appears to be Sandlaunce. In certain years the fish school in dense shoals in shallow, nearshore waters and are easy prey for most seabirds, especially kittiwakes which are restricted to feeding in waters less than about one meter in depth. Sandlaunce have been seen to fluctuate in their abundance and in the time when they arrive near the bird colonies, fluctuations which have coincided with major changes in kittiwake reproductive success. Therefore, we believe that studies should be undertaken which would address questions concerning the natural history of Sandlaunce. If Sandlaunce populations were jeopardized by effects of resource development, the results might be disastrous to kittiwake populations in the eastern Chukchi Sea.

Sandlaunce, however, are not the only food resources upon which seabirds depend. Murre food habits data suggest that other fish -- cod and sculpins -- and invertebrates are also important to the population. Our data also suggest that different food groups may be more abundant at some times during the summer than others. The success of the murre population, therefore, may depend upon a well-timed sequence of events which assures that adequate food of some type will be available to the birds throughout the summer. Loss of any component could threaten the population.

Studies should be developed then which would examine in detail the physical and biological oceanography of a region which supports large seabird populations. Ideally the study area would be relatively small and well defined. It would be highly productive, would support large numbers of birds of different trophic positions and would be used by the majority of the seabirds throughout most of the breeding season. A strong body of data would exist concerning seasonal and yearly food habits of the birds using the area and the recent biological history of the seabird populations would be known. Information obtained from the study should be applicable to other areas which support populations of similar avian species. We believe that such a study could and should be made in Ledyard Bay.

X. SUMMARY OF JANUARY-MARCH QUARTER

The only time devoted to RU 460 during this quarter was report preparation.

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